More Hurricanes and Blizzards in NYC? - Teacher Materials

Unit 5	Earth and Space Science

The Curriculum and Instruction Department at New Visions for Public Schools develops free, full-course materials for all areas of high school science, math, ELA, and social studies, for use across our network of 80 New York City schools and beyond.

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Unit 5 More Hurricanes and Blizzards in NYC?

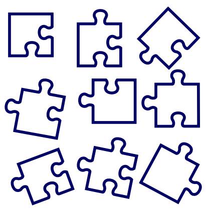
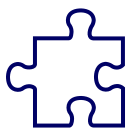
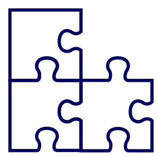
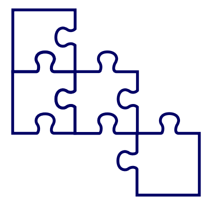
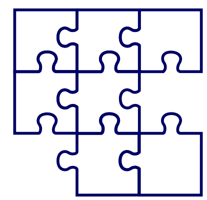
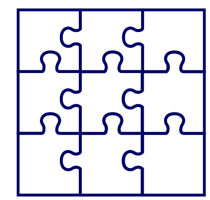
Weather

Performance Expectations
HS-ESS3-5, HS-ESS1-7, HS-ESS2-8, HS-ESS2-5

Time
26-41 days

Will there be more frequent and more intense severe storms in the future?

In this unit, students figure out the processes that cause weather phenomena, and they make qualitative claims about how climate change can affect storm frequency and intensity. To do this, they use a variety of physical and computer models related to these weather phenomena to explore the cause and effect relationships among variables such as temperature, water vapor, and air pressure; analyze and interpret national and global weather and climate data to find spatial and temporal patterns; construct explanations about what causes these types of storms; and engage in argument based on evidence from models and the data about what might happen in the future

Unit Opening	Moon Phases Optional 3E (Optional)	Blizzards 5E	The Paths of Severe Storms 5E	Hurricanes 5E	Unit Closing
Anchor Phenomenon →		**5E Lessons connect learning to the performance task** →			**Performance Task**
					
Will there be more frequent and more intense severe storms in the future?	*How does the moon contribute to storm severity?*	*How do severe winter storms form? What causes wind and precipitation? Can we make predictions about these weather phenomena?*	*How do severe winter storms form? What causes wind and precipitation?*	*How do hurricanes form? Why do hurricanes exhibit patterns in the time of year they occur?*	*Will there be more frequent and more intense severe storms in the future?*

Unit Introduction

How do we make science education meaningful and relevant to our students? High school earth and space science courses are traditionally filled with lectures and cookbook labs, memorizing vocabulary, and an occasional research report. New science education standards (NGSS/NYSSLS) require a more engaging, accessible vision of science teaching and learning to help *all* students learn about the natural world and become scientifically literate citizens.

The three-dimensional, phenomenon-driven materials in this unit support students in engaging in the authentic practices of science. Students construct meaning about the natural world through modeling, investigations, labs and experiments. As students have opportunities to manipulate the physical tools of science, they also engage in productive struggle that can be resolved through creating models from evidence and engaging in consensus building discussions. The materials support teachers in becoming skillful facilitators of student sense-making and deepen teachers' understanding of how to teach science in an interactive way that is driven by students' questions and ideas.

This unit was intentionally designed to build on the fourth unit of this course, Climate Change, in which students analyze data to construct explanations. In More Hurricanes and Blizzards in NYC?, students continue to engage with data to construct communications about future climate impacts. The common embedded group learning routines and curriculum structures introduced in the first unit are revisited, providing students and teachers multiple opportunities to engage in a culture of collaborative sensemaking around a phenomenon. In this unit, students are encouraged to explain how their cities may be impacted by climate change by increasing the frequency or intensity of storms.

The embedded group learning routines and formative assessments found in each of the Earth and Space Science units support teachers in learning about their students, both academically and personally. Whether students had strong science programs prior in prior courses, or if three-dimensional teaching and learning is brand new to them (or the teacher!), this unit is designed to reinforce and further build on students' earlier experiences with three-dimensional learning.

Unit Coherence

In Unit 5, the overall question about the potential increase in frequency and intensity of storms is intended to motivate student engagement across the unit. From the students' perspective, there should be a clear and explicit unit storyline that guides the sequence of activities. Rather than one long continuous unit, we have chosen to use an instructional model to develop four coherent sequences of lessons within Unit 5. Each sequence is based on students' questions and builds towards figuring out something that contributes to the overall unit-level question about how we know that humans are causing climate change and how that matters. This in turn allows students to construct a communication from data analysis explaining how storms may change in the future. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 5.

Phenomenon-Driven Instruction

Phenomena are a key part of instruction in A Framework for K-12 Science Education and the NGSS. As in the work of scientists, students should be encouraged to move from observable phenomena to generalizable explanations of the natural world. Too often, traditional science instruction has started with generalizable principles, sidelining the lived experience and intuitions that all young people bring to school. In this unit (and all New Visions units) there are two kinds of phenomena: anchor phenomena and investigative phenomena.

Anchor Phenomenon	Investigative Phenomena
• One per unit; drives the learning of the unit • Attention-grabbing and relevant • Does not have to be phenomenal	• One per 5E sequence (three in this unit) • Presented in the Engage phase of each 5E

Anchor Phenomenon

To support coherence, students are prompted to figure out one overarching, real-world question over the course of the unit. The anchor phenomenon question is revisited across the unit, and this question motivates the investigations conducted in each of the 5E instructional sequences. A good anchor phenomenon should be attention-grabbing and relevant to students but also thought-provoking, comprehensible, and connected to the science learning goals. It needs to be observable to students through firsthand experiences or through someone else's experiences, such as through a video or secondary data. If a teacher feels the anchor phenomenon will not be familiar or accessible to all students, we suggest relating it to similar, more familiar phenomena. It is important to notice that the phenomenon question anchoring the unit is different from the more generalized and abstracted science question for the unit. This difference is part of what helps make the unit more student-centered, rather than teacher-centered.

Investigative Phenomena

Based on the Anchor Phenomenon and three-dimensional learning goals for students for the unit, each 5E instructional sequence has a related investigative phenomenon, typically presented in the Engage phase. This phenomenon brings students together around a shared puzzle or experience that frames the learning for that 5E sequence. Similar to the anchor phenomenon question, the questions about the investigative phenomena are intended to be specific and contextualized, rather than the traditional content questions teachers use as their lesson aims. They present what is being figured out; therefore, the scientific concepts that are in the learning goal cannot be part of the wording of the question!

Storyline and Pacing Guide

Unit Opening

Will there be more frequent and more intense severe storms in the future?

Performance Expectations
HS-ESS3-5

Anchor Phenomenon
It has felt like storms are getting worse. Does the data support that feeling, and will it continue?

Time
1-2 days

Student Questions	What Students Do	Student Ideas
These questions motivate the unit storyline. *What are some similarities and differences between hurricanes and blizzards?* *Why was the 2020 hurricane season so intense and why were there more hurricanes?* *Why was the 2019-2020 winter storm season so intense?* *Will there be more frequent and/or more intense hurricanes and blizzards?* *How likely is a storm going to occur where we live sometime soon or in the future?* *Have hurricanes and blizzards become more frequent and intense over the last few decades, not just recent years?*	Students observe two years of blizzard and hurricane data in order to consider how weather patterns might be changing. Throughout the unit, they will understand what impacts the strength of storms through moon cycles and investigations into how temperatures affect storm strength and frequency.	*These ideas are revisited throughout the unit storyline.* • Characteristics of a hurricane include heavy rain and extremely strong wind. • Characteristics of a blizzard include heavy snow and very strong wind. • Both types of storms can cause a great deal of disruption, damage to property, and harm human life. • Hurricanes and blizzards only happen during certain months of the year and tend to occur and move in specific places on Earth. • In order to make predictions about the future, we need to investigate: • what causes hurricanes and blizzards • past and current patterns of hurricane and blizzard frequency and intensity • To prepare for storms - we need to determine the trajectory of storms, and when storms might occur during the year

After students consider how these two storm seasons have been different, students will dive into an investigation about how moon phases impact storm severity. After that, they will look at how climate factors like temperature affect storm frequency and intensity.

Moon Phases Optional 3E (Optional)

How does the moon contribute to storm severity?

Performance Expectations
HS-ESS1-7

Investigative Phenomenon
Hurricane Sandy created historic flooding in New York City on a high spring tide.

Time
7 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • *What are some reasons that some storms are worse than others?*	Students are tasked with explaining why hurricane Sandy was so damaging. First, they model moon phases to understand how the relative positions of the moon, Earth, and sun cause cyclic patterns of moon phases. Then they observe correlations between the moon phases and tides to explain the presence of spring tides, and how it affects storm surges. Finally students look at the causes of eclipses.	*Students figure out these ideas in this 5E sequence.* • Moon cycles drive tides, which influence storm flooding

Once students understand how cyclic conditions can impact storm severity, they are ready to consider how climate change scenarios exacerbate those conditions.

Blizzards 5E	How do severe winter storms form? What causes wind and precipitation? Can we make predictions about these weather phenomena?	**Performance Expectations** HS-ESS2-8	**Investigative Phenomenon** Winter storm Jonas produced strong enough winds and enough snow to cause significant disruptions to society, damage to property, and harm to human life.	**Time** 7-13 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • *What causes high-speed winds?* • *What causes rain to fall?* • *What causes thunderstorms?* • *What causes snow storms?*	Students create models of blizzard formation to determine how factors like temperature and density affect storm occurrence. They apply their understanding of storm factors to identify winter storms on maps using weather symbols and analysis. Finally, they use data from historical storm frequencies and intensities to argue how one of those two factors will change as temperatures continue to ruse.	*Students figure out these ideas in this 5E sequence.* • Wind is caused by uneven heating of Earth's surface, leading to differences in pressure. Air moves from high to low-pressure areas across Earth's surface; we call this wind. • When two air masses of different temperatures collide with each other, the colder, more dense air mass forces the warmer, less dense air mass up. As the warmer air mass rises, it loses high amounts of energy to the cold air at higher elevations and condenses. When the warm air contains enough water vapor, the water vapor condenses to form clouds and sometimes precipitation. • We can represent different kinds of air masses and fronts on maps with symbols. • Maps help us to identify weather systems and communicate this information to others. • Both wind and precipitation occur at fronts over the US and other places. • Mid-latitude cyclones become blizzards in the northern part of the US, mostly the midwest and northeast, as well as other places in the northern hemisphere where warm moist air masses meet cold dry air masses and it's cold enough. • Global climate models predict that temperatures and moisture in the atmosphere will increase in the future. This may have implications for severe storms in the future. • The precision and reliability of these models is strengthened by using multiple data sets that are consistent.

Revisit the **Unit Performance Task and Driving Question Board**. Are there questions that have been addressed in this 5E plan (what have we figured out)? Have students use the Student Scaffold to add information. Students should be able to develop a model and write an argument about the future of blizzards where they live based on multiple pieces of evidence. Ask, "*What additional questions do we have now?"* At this point in the unit, students may understand more about winter storms in general, but they don't know where winter storms come from and can't explain their trajectory patterns yet

The Paths of Severe Storms 5E	How do severe winter storms form? What causes wind and precipitation?	**Performance Expectations** HS-ESS2-8	**Investigative Phenomenon** Maps from 2018-2020 show that blizzards and hurricanes exhibit clear patterns in where they start and the direction in which they travel.	**Time** 6-11 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • *Why do severe winter storms form in the northeast?*	Students analyze global wind patterns and cyclone formation in order to determine why winter storms travel in the patterns that they do. Then they read a text about how global wind patterns may change with warming temperatures and construct an argument about how their regions will be affected by storms as global temperatures rise.	*Students figure out these ideas in this 5E sequence.* • The Earth is heated unevenly by the Sun due to its spherical shape. The area near the equator is the most intensely heated part of the Earth, while the poles are the least heated part of the Earth. • Air mass properties depend on where they were formed. Cold dry air masses form over land in the northern US and further north, while warm moist air masses form over water south and south west of the US. • Global winds drive these air masses toward each other over the US. These winds are driven by convection on a global scale due to the uneven heating of Earth's surface by the Sun. • Patterns of high precipitation and low precipitation at certain latitudes are explained by the sinking and rising of cold dry air and warm moist air at those latitudes. • Global winds cause the patterns we see in the trajectory of winter storms and hurricanes. • Models based on evidence about changes in global winds when the Earth went from a glacial period to a warm period 3 degrees celsius warmer than today suggest global wind and precipitation bands will shift north as temperatures continue to increase. This may have implications for severe storms in the future. • The reliability of these models is limited because they assume that what happened in the past will happen again in the future.

Revisit the **Unit Driving Question Board** - *are there questions that have been addressed in this 5E plan*? Add to performance task scaffold: students should be able to begin to address why and how winter storms form in specific areas, and explain that they follow the global wind patterns. Students can revise their initial argument about the future of winter storms where they live based on what they know about what models suggest regarding shifts in global wind and precipitation patterns in the future. Ask - *have new questions been brought to the forefront*? Students don't know how hurricanes form and don't know why hurricanes exhibit patterns in the time of year and location where they form.

Hurricanes 5E	How do hurricanes form? Why do hurricanes exhibit patterns in the time of year they occur?	**Performance Expectations** HS-ESS2-5	**Investigative Phenomenon** In 2005, hurricanes occurred in the North Atlantic Ocean between June and November 30, just like the 2018 and 2020.	**Time** 5-6 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • *Have hurricanes and blizzards become more frequent and intense over the last few decades, not just recent years?* • *How do the patterns we have seen over the past couple of years compare to data from the more distant past?*		*Students figure out these ideas in this 5E sequence.* • Hurricanes develop over warm waters. • Ocean temperature changes as seasons change. • Hurricanes get their energy from warm water. When warm water is heated enough, it evaporates and rises, then cools and condenses, releasing the energy into the heat energy. • This explains why we see hurricanes along the equator in the northern hemisphere during the northern hemisphere summer and southern hemisphere during the northern hemisphere winter. • Global climate models predict that temperatures and moisture in the atmosphere will increase in the future. This may have implications for hurricanes in the future. • The precision and reliability of these models is strengthened by using multiple data sets that are consistent. These models may include multiple scenarios to account for variation of different factors that can affect outcomes they predict.

Revisit the **Unit Performance Task and Driving Question Board**. Are there questions that have been addressed in this 5E plan (what have we figured out)? Have students use the Student Scaffold to add information. Students should be able to develop a model and write an argument about the future of hurricanes where they live based on multiple pieces of evidence from the Hurricanes and Paths of Severe Storms 5E investigations.

Unit Closing	Will there be more frequent and more intense severe storms in the future?	**Performance Expectations** HS-ESS3-5	**Anchor Phenomenon** It has felt like storms are getting worse. Does the data support that feeling, and will it continue?	**Time** 0-2 days

Student Questions	What Students Do	Student Ideas
These questions are addressed in the performance task.	Students construct oral arguments about the changes in storm patterns they expect to see in their region in the future.	*These ideas were developed throughout the unit storyline.*

Now that students have context about tides, climate change, and hurricane and blizzard formation, students are able to answer the question about if storms really are getting worse. They should also be able to combine their knowledge with what they learned in Unit 4, Climate Change, to understand that sea levels are rising, which will make moon phase driven high tides even higher, and result in more damaging storms.

Unit Standards

This unit is designed to meet Next Generation Science Standards Performance Expectations. Since this unit is part of a full-year Biology course, the design includes intentional foregrounding of a limited number of Crosscutting Concepts (CCCs) and Science and Engineering Practices (SEPs). Further, since an aspect of NGSS design is connections to Common Core Math and ELA standards, these connections are highlighted in this section.

Performance Expectations

HS-ESS3-5 **Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.**
Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).
Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.

In NYS the clarification statement has been edited as follows: Examples of evidence could include both data and climate model outputs that are used to describe climate changes...

HS-ESS1-7 Clarification Statement:
Assessment Boundary:

This PE, added by NYS, is not in the NGSS: Construct an explanation using evidence to support the claim that the phases of the moon, eclipses, tides and seasons change cyclically. [Clarification Statement: Emphasis of the explanation should include how the relative positions of the moon in its orbit, Earth, and the Sun cause different phases, types of eclipses or strength of tides. Examples of evidence could include various representations of relative positions of the Sun, Earth and moon.] [Assessment Boundary: Assessment does not include mathematical computations to support explanations but rather relies on conceptual modeling using diagrams to show how celestial bodies interact to create these cyclical changes.]

HS-ESS2-8 Clarification Statement:
Assessment Boundary:

This PE, added by NYS, is not in the NGSS: Evaluate data and communicate information to explain how the movement and interactions of air masses result in changes in weather conditions. [Clarification Statement: Examples of evidence sources could include station models, surface weather maps, satellite images, radar, and accepted forecast models. Emphasis should focus on communicating how the uneven heating of Earth's surface and prevailing global winds drive the movement of air masses and their corresponding circulation patterns, the interaction of different air masses at frontal boundaries, and resulting weather phenomena.] [Assessment Boundary: Analysis is limited to surface weather maps and general weather patterns associated with high and low pressure systems.]

HS-ESS2-5 **Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.**
Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations could include stream transportation (erosion) and deposition using a stream table, infiltration and runoff by measuring permeability and porosity of different materials, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations could include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).

Three-Dimensional Learning Goals in This Unit

Given the breadth of three-dimensional standards for high school Earth and Space Science, Unit 5 focuses primarily on ideas related to Earth's weather. This unit also engages students' use of the SEP of Thinking Mathematically and has a secondary focus on the SEP of Constructing Explanations and Designing Solutions. That is not to say that students will not engage in other SEPs throughout the lessons; however, it is important to foreground and be explicit about a limited number of practices with enough duration to see how students develop their understanding and ability to use this practice. This is important for both student and teacher learning! Similarly, the foregrounded CCC for this unit is *Patterns*, which fits well with our selected SEP and the understanding that patterns in Earth's processes and systems allows scientists to determine the structure and composition of Earth. Two secondary CCCs for the unit, Energy and Matter and Stability and Change are also useful to students as they use these ideas in two ways: (1) examining the changes to Earth's surface as a result of tectonic activity and; (2) developing explanations for how energy and matter move together during tectonic activity. The design of instruction across the unit supports students' three-dimensional learning and shifts classrooms to become more NGSS-aligned spaces.

Three Dimensions Foregrounded in Unit 5

This chart is a high-level summary of the foregrounded standards. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models	ESS1.B Earth and the Solar System	Patterns
Analyzing and Interpreting Data	ESS2.D Weather and Climate	Cause and Effect
Constructing Explanations and Designing Solutions	ESS3.D Global Climate Change	Systems and Systems Models
Obtaining, Evaluating, and Communicating Information	PS3.A Definitions of Energy	Stability and Change

Building on Middle School

High school science teaching necessarily builds on student learning from middle school. It is helpful to consider the middle school standards in order to enact a unit that builds on students' prior experiences. As we are in the middle of a multi-year transition, however, it is also critical to keep in mind that not all students will have experienced an NGSS-designed unit when they come to high school, so the process of building on middle school learning may be particularly complex for years to come. The following sections detail the ways in which this unit builds on middle school standards across the three dimensions.

Disciplinary Core Ideas from Middle School

ESS2.A Earth Materials and Systems

- In middle school, students learn that all Earth's processes are a result of energy flowing and matter cycling within and between Earth's systems over different scales. In this unit, students build upon that understanding by considering how energy drives the motion of matter during tectonic activity.

ESS2.B Plate Tectonics and Large-Scale System Interactions

- Students in middle school learn that Earth's plates have moved. This unit builds on that basic idea by adding complexity to the mechanisms of that motion, including how Earth's structure contributes to that motion and how energy from radioactive decay in Earth's mantle drives the movement.

ESS1.C The History of Planet Earth

- In middle school, students learn foundational concepts about tectonic activity slowly generating the seafloor and ocean ridges. In this unit, students expand upon that understanding by relating it to the rates of change that construct Earth's surface features and connect it to plate tectonic theory.

Crosscutting Concepts from Middle School

Stability and Change

This unit builds on the following aspects of Stability and Change in middle school:

- Middle school students learn that changes in one part of a system can impact other parts, and that change can happen quickly or over a long period of time. This unit builds on that background as students examine changes that happened gradually over Earth's history and disruptions that caused more rapid changes over shorter scales.

Patterns

This unit builds on the following aspects of Patterns in middle school:

- Middle school students learn that patterns in rates of change can provide information about natural systems. This unit builds on that background by using patterns at different scales to gain information about Earth's structure and plate tectonic theory.

Energy and Matter

This unit builds on the following aspects of Energy and Matter in middle school:

- Middle school students learn that matter is conserved and that the transfer of energy drives the movement of matter. This unit builds on that background as students examine the sources and movement of energy driving the movement of matter during tectonic activity.

Science and Engineering Practices from Middle School

Constructing Explanations and Designing Solutions

- Students in middle school have experience constructing explanations using multiple lines of evidence. In this unit, students build upon that practice by adding student-generated sources of evidence from investigations in order to make a claim about the relationship between different variables.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 5 targets a bundle of three PEs taken from high school Earth and Space Science; those standards are HS-ESS1-7 (NYSED), HS-ESS2-8 (NYSED), and HS-ESS3-5. This PE bundle informs the types of three-dimensional tasks in which students engage across the unit. Each sequence of lessons within the unit targets elements from one or more of the performance expectations for the unit, and the teacher has opportunities to collect evidence of student learning around these elements within that learning sequence. The unit-level Performance Task only targets a subset of three-dimensional learning goals informed by the bundled PEs for the unit. All other evidence of learning related the other dimensions/elements in the PEs can be found within the instructional sequences. The **Teacher Materials** for each sequence of lessons includes a matrix that lists which student artifacts can provide evidence of student learning for each of three-dimensional learning goals from that sequence.

This unit was designed to support teachers in tracking student progress across the three dimensions, not for mastery within individual lessons. The targeted disciplinary core ideas (DCIs) listed below will be developed throughout the unit. While all of the science and engineering practices (SEPs) may be utilized across the unit, the three target SEPs for the unit are listed below. Similarly, many crosscutting concepts (CCCs) may be useful in making sense of the phenomena in this unit, however the foregrounded, targeted CCCs are listed below.

The following Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts are assessed throughout the unit:

	Moon Phases Optional 3E (Optional)	Blizzards 5E	The Paths of Severe Storms 5E	Hurricanes 5E
Developing and Using Models		✔	✔	✔
Analyzing and Interpreting Data			✔	✔
Constructing Explanations and Designing Solutions	✔	✔		✔
ESS1.B Earth and the Solar System	✔			
ESS2.D Weather and Climate		✔		
ESS3.D Global Climate Change		✔		✔
PS3.A Definitions of Energy		✔	✔	✔
Patterns	✔			
Cause and Effect		✔	✔	✔
Systems and Systems Models		✔	✔	✔

At the end of Unit 5, teachers will have evidence in student work (tasks) related to the elements listed in this table and can therefore make claims at the end of this unit related to student proficiency for all three performance expectations.

To support assessment throughout the unit, rubrics have been included in the **Student Materials** to support the Evaluate phase in every 5E instructional sequence. Teachers should customize these rubrics to support their schools' grading systems. Rubrics address both individual reflection, peer review, and the teacher's feedback. The Unit 5 Performance Task also includes a rubric, and the task can be considered a final summative assessment for the unit - we have not included a traditional "unit test" in our materials. Teachers may opt to create their final exam using their states' previous exam questions, however we believe that the formative assessment tasks embedded in the materials (such as the Looks and Listen For notes, the Explore phase summaries, and the modeling done in the Evaluate phases), along with the Performance Task can serve as sufficient evidence of what students know and can do.

Common Core State Standards (ELA/Literacy)

Reading Standards for Literacy in Science and Technical Subjects

RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Implementing Unit 5

This unit is designed to be the fifth unit of the Earth and Space Science course. We do not recommend spending more than two months on this unit, as our field testing showed that six to eight weeks is the maximum amount of time students can stay engaged with the unit-level anchor phenomenon.

Within the unit, we also suggest spending no more than two weeks on each 5E instructional sequence. It is important to trust that ideas will build over time. Part of learning to teach NGSS-designed curriculum is getting comfortable with moving on, even if not every student "gets it," with the knowledge that there are additional opportunities to revisit particular standards. See the Assessment section below for guidance on providing multiple opportunities for assessment throughout the unit.

The first time enacting any unit with students may take longer than anticipated, particularly if the pedagogical approach is significantly different from what a teacher is used to. A teacher may want to skip entire lessons or activities, or revert to more traditional approaches when it seems like time is running out. We often ask teachers to think about the best way to modify recipes. Just like when using a recipe for the first time, it's a good idea to stay as true to the materials as possible before making modifications or substitutions! As teachers become more familiar and comfortable with the instructional model, the embedded routines, and three-dimensional teaching overall, the desire to skip things will dissipate. Teachers using our curriculum over time have noticed that they are able to move a bit quicker through this and other NGSS-designed units each year.

Routines

The table below summarizes the routines embedded in this unit. The number indicates the number of times a given routine appears in a lesson.

	Unit Opening	**Moon Phases Optional 3E (Optional)**	**Blizzards 5E**	**The Paths of Severe Storms 5E**	**Hurricanes 5E**	**Unit Closing**
Class Consensus Discussion			1	1		
Class consensus Discussion			1			
Domino Discover		1			1	
Driving Question Board	1					
Elbow Exchange + Domino Discover			2	2		
Elbow Share + Domino Discover		1			1	
Idea Carousel			1	1		
Random Reporter					1	
Read-Generate-Sort Solve		1				
Rumors		1	1	1	1	
Tell the Story	1					

	Unit Opening	Moon Phases Optional 3E (Optional)	Blizzards 5E	The Paths of Severe Storms 5E	Hurricanes 5E	Unit Closing
Think-Talk-Open Exchange		2	1			
Think-Talk-Open-Exchange					1	

Literacy Strategies

The table below summarizes the literacy strategies embedded in this unit. The number indicates the number of times a given strategy appears in a lesson.

	Unit Opening	Moon Phases Optional 3E (Optional)	Blizzards 5E	The Paths of Severe Storms 5E	Hurricanes 5E	Unit Closing

Simulations in this Unit

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
Blizzards 5E	Weather Fronts Simulator	https://learn.weatherstem.com/courses/wxstem_meteorology_01/module-01/03/09.html	NA	NA
Blizzards 5E	States of Matter Simulator	https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html	NA	NA

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
Blizzards 5E	IPCC WGI Interactive Atlas	https://interactive-atlas.ipcc.ch/regional-information#eyJ0eXBlIjoiQVRMQVMiLCJjb21tb25zIjp7Imxhd CI6OTc3MiwibG5nIjo0MDA2OTIsInpvb20iOjQsInByb2oiOiJFUFNHOjU0MDMwIiwibW9kZSI6ImNvbXBsZXRlX2F0bGFzIn0sInByaW1hcnkiOnsic2NlbmFyaW8iOiJzc3A1ODUiLCJwZXJpb2QiOiIyIiwic2Vhc29uIjoieWVhciIsImRhdGFzZXQiOiJDTUlQNiIsInZhcmlhYmxlIjoidGFzIiwidmFsdWVUeXBlIjoiQU5PTUFMWSIsImhhdGNoaW5nIjoiU0lNUExFIiwicmVnaW9uU2V0IjoiYXI2IiwiYmFzZWxpbmUiOiJwcmVJbmR1c3RyaWFsIiwicmVnaW9uc1NlbGVjdGVkIjpbXX0sInBsb3QiOnsiYWN0aXZlVGFiIjoicGx1bWUiLCJtYXNrIjoibm9uZSIsInNjYXR0ZXJZTWFnIjpudWxsLCJzY2F0dGVyWVZhciI6bnVsbCwic2hvd2luZyI6ZmFsc2V9fQ==	NA	NA
The Paths of Severe Storms 5E	Explore the Effect of the Angle of Incidence on Sun's Energy	https://profhorn.aos.wisc.edu/wxwise/radiation/sunangle.html	NA	NA

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Unit Opening	Island of Puerto Rico destroyed by Hurricane Maria	https://www.youtube.com/watch?v=zNFnVIlE6cA&t=1s	NA	NA
Unit Opening	A Deadly Winter Storm Heads to the East Coast	https://www.youtube.com/watch?v=dKk5CvbvrXk	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Moon Phases Optional 3E (Optional)	Watching the Tides	https://www.youtube.com/watch?v=QcbN9SVkqYU	NA	NA
Blizzards 5E	The Water Cycle	https://www.youtube.com/watch?v=77ENELQUIf4	NA	NA
Blizzards 5E	Video: How to Draw Isolines #1	https://www.youtube.com/watch?v=iYon-S6wCBw	NA	NA
Blizzards 5E	Video: How to Draw Isolines #2	https://www.youtube.com/watch?v=gSYje6UbPZU	NA	NA
Blizzards 5E	Mid-Latitude Cyclone Clip	https://www.youtube.com/watch?v=n4rJX4IIRaU	NA	NA
Blizzards 5E	Mid-Latitude Cyclones Explained	https://www.youtube.com/watch?v=RAqZpjIaoKM	NA	NA
Blizzards 5E	NOAA Site with Complete Guidelines for Analyzing Weather observation Maps	https://www.noaa.gov/jetstream/wxmaps-max/learning-lesson-drawing-conclusions	NA	NA
The Paths of Severe Storms 5E	Global Winds Animation	https://www.youtube.com/watch?v=4t5xeipHJ2A	NA	NA
The Paths of Severe Storms 5E	The coriolis effect and winds (0:32-2:20)	https://www.youtube.com/watch?v=PDEcAxfSYaI	NA	NA
The Paths of Severe Storms 5E	Coriolis Carousel (0:00-5:28)	https://www.youtube.com/watch?v=78Yymgk6qrM	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
The Paths of Severe Storms 5E	Visualizing pressure and water vapor in Winter Storm Jonas	https://globalcryospherewatch.org/interesting/archive/us-snowstorm_jan2016/	NA	NA
The Paths of Severe Storms 5E	News Report: Anticipating Winter Storm Jonas	https://www.youtube.com/watch?v=m5cAUT-L2HQ	NA	NA
Hurricanes 5E	How Do Hurricanes Happen (0-1:17)	https://www.nytimes.com/video/science/100000002555638/the-future-of-storms.html	NA	NA
Hurricanes 5E	More than 100 dead in devastation and flooding after Hurricane Helene (0-1:50)	https://www.youtube.com/watch?v=pKccCbQo1-I	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
The Paths of Severe Storms 5E	Global Movement of Air Investigation Lab minutes: 40 minutes	❏ 1 Balloon ❏ 3 permanent markers of different colors

Other Materials in this Unit

Lesson	Materials needed
Unit Opening	❏ Chart paper ❏ Post-it notes ❏ Optional: Teacher-provided questions for sorting; teacher could distribute ❏ and ask more advanced students to come up with their own questions.

Lesson	Materials needed
Moon Phases Optional 3E (Optional)	❑ Post-its ❑ Chart Paper ❑ Lunar Phases ❑ High and Low Tide Pictures ❑ New York (The Battery), NY - Local Tide Times, Tide Chart | US Harbors ❑ Tides ❑ Eclipses
Blizzards 5E	❑ Post-Its ❑ States of Matter Simulator ❑ Diffusion Simulator ❑ Chart paper ❑ Slides for Elbow Exchange + Domino Share ❑ Post-Its ❑ Chart paper ❑ Colored pencils ❑ Permanent markers ❑ *Weather Maps* ❑ Computers
The Paths of Severe Storms 5E	❑ Post-its ❑ Computers ❑ Post-its ❑ Chart Paper ❑ Sticky notes ❑ *Connect to the Performance Task: Paths of Severe Storms 5E*
Hurricanes 5E	❑ Post-its ❑ Ensure that there is enough space for students to circulate around the room and talk to each other ❑ Rumors Directions ❑ Colored pencils ❑ Monthly Sea Surface Temperature ❑ Poster paper and markers ❑ Slide: Hurricane Formation Diagram ❑ IPCC WGI Interactive Atlas ❑ *Connect to the Performance Task: Hurricanes 5E*
Unit Closing	❑ Driving Question Board

Teacher Materials for Unit 5

# Unit Opening	Will there be more frequent and more intense severe storms in the future?	**Performance Expectations** HS-ESS3-5	**Anchor Phenomenon** It has felt like storms are getting worse. Does the data support that feeling, and will it continue?	**Time** 1-2 days

In this unit, students figure out the processes that cause weather phenomena, and they make qualitative claims about how climate change can affect storm frequency and intensity. To do this, they use a variety of physical and computer models related to these weather phenomena to explore the cause and effect relationships among variables such as temperature, water vapor, and air pressure; analyze and interpret national and global weather and climate data to find spatial and temporal patterns; construct explanations about what causes these types of storms; and engage in argument based on evidence from models and the data about what might happen in the future.

ANCHOR PHENOMENON	It felt like hurricanes and blizzards were really bad this past year. What does the data show? Will this continue?	**Students use observations from videos and analyses of maps that show data about recent winter storms and tropical cyclones to look for patterns.**
PERFORMANCE TASK	Will there be more frequent and more intense severe storms in the future?	**Students develop initial predictions about storms.**
DRIVING QUESTION BOARD	Will there be more frequent and more intense severe storms in the future?	**Students ask questions that would help investigate these weather phenomena to improve their predictions.**

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

It felt like hurricanes and blizzards were really bad this past year. What does the data show? Will this continue?

Students use observations from videos and analyses of maps that show data about recent winter storms and tropical cyclones to look for patterns.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Groups of 3-4 students	❏ Tell the Story	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Tell the Story: Blizzards ❏ Tell the Story: Tropical Storms	None	❏ Chart paper ❏ Island of Puerto Rico destroyed by Hurricane Maria ❏ A Deadly Winter Storm Heads to the East Coast

[assessment-matrix]		
Dimension	Element Code	Assessment Opportunities
DCI	ESS3.D(1)	Tell the Story: Blizzards, Tell the Story: Tropical Storms
CCC	CCC7(2)	Tell the Story: Blizzards, Tell the Story: Tropical Storms
CCC	CCC1(1)	Tell the Story: Blizzards, Tell the Story: Tropical Storms

Introduce the Phenomenon

1. Show at least one video clip about **hurricanes** and **blizzards**. Students record observations and discuss the characteristics as a class (wind, visibility, snow, rain, flooding).

Analyze Visuals

1. Provide each student in each group with a visual about either hurricanes or blizzards. Have students complete the visual text analysis independently, then discuss in “expert” groups or pairs.

Share Analysis

1. In small groups, students share analyses of Visual Texts #1 and #2 and take notes on one another’s points. Students should describe the phenomenon: *Ex. over the past two years, the trend shows that while there are more tropical storms/hurricanes, there has not been an increase in the number of winter storms, however the winter storms did have a lot more snow.*

2. Make a CHART - list what the class comes up with to describe what they are seeing. This chart will be the summary of the anchor phenomena, and can be referred back to during the Performance Task Launch and throughout the Unit.

Performance Task

Will there be more frequent and more intense severe storms in the future?

Students develop initial predictions about storms.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Introduction to the Performance Task and Initial Ideas	None	

Introduce the Performance Task

1. Provide students with the handout Introduction to the Performance Task and Initial Ideas. Introduce the task by asking students to read the **student task.** Since the final task is an argument in which students are making predictions based on evidence and their modeling, it may be beneficial to discuss with students how predictions are different from but related to explanations, and/or how arguments are different from explanations.

Initial Predictions

Ask students to individually brainstorm ideas and predictions in response to the prompts

- Will hurricanes happen more often in the future?
- Will hurricanes be more intense in the future?
- Will blizzards happen more often in the future?
- Will blizzards be more intense in the future?

Allow them to exchange their best ideas, prompting them to discuss what they are basing their prediction on.

Driving Question Board

Will there be more frequent and more intense severe storms in the future?

Students ask questions that would help investigate these weather phenomena to improve their predictions.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ None	❏ Driving Question Board	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❏ Post-it notes ❏ Optional: Teacher-provided questions for sorting; teacher could distribute ❏ and ask more advanced students to come up with their own questions.

Ask Questions

1. Prompt students to think like scientists to generate HOW or WHY questions that would help them be able to make *better* predictions about weather and the anchor phenomenon (see chart from anchor phenomena launch). Ask, *What do you need to know more about, to better understand the phenomenon? What variables do you want to investigate? What might be affecting the weather?* Students should individually generate at least 3 questions on post-its. If you have a crosscutting concept chart in the classroom, prompt students to try to use various concepts to help them generate questions if they are stuck.

Develop a Driving Question Board

1. Invite students to share out their questions, one at a time. Create clusters of questions that are similar or related. Facilitate a discussion about the categories that emerge across students' questions (for example, one category might be ***weather variables,*** based on questions such as *why are the winds so strong*? Another category might be ***location and path of storms***, based on questions such as *where do these storms come from and why do they hit the Caribbean*?). In an ideal situation, students would bring up global warming as a potential cause for the anchor phenomenon, however it is not necessary that they do so.

Standards in Unit Opening

Performance Expectations

HS-ESS3-5 **Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.**
Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).
Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.

In NYS the clarification statement has been edited as follows: Examples of evidence could include both data and climate model outputs that are used to describe climate changes...

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	ESS3.D Global Climate Change • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. ESS3.D(1)	Stability and Change • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. CCC7(2)

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task
ESS3.D Global Climate Change	Introduction to the Performance Task and Initial Ideas		
Stability and Change	Introduction to the Performance Task and Initial Ideas		

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task
Mathematics			
ELA/Literacy			

Moon Phases Optional 3E (Optional)

How does the moon contribute to storm severity?

Performance Expectations
HS-ESS1-7

Investigative Phenomenon
Hurricane Sandy created historic flooding in New York City on a high spring tide.

Time
7 days

When students are considering what conditions might make storms worse in the future, it is important that they know what types of differences can influence storm severity with or without climate change. In this sequence, students investigate the relationship between moon phases and tides to understand how spring high tides created additional flooding during Hurricane Sandy.

ENGAGE	What do students know about why we see moon phases from Earth?	The teacher learns what students know and care about related to the **phases of the moon** by having them observe and **look for patterns** in **moon phase** images, then use their initial ideas to create a **diagram model** that **explains** the patterns they observed.
EXPLORE 1	Students observe models of moon phases	Students explore **phases of the moon** by **making observations of a 3-D moon phases model** and a **moon phase simulator** to **look for patterns that might provide evidence for causality** of the **moon phases**. The teacher's role is to confer with students around their learning, but not offer formal explanations yet.
EXPLAIN 1	Students explain phases of the moon	Students demonstrate their initial understanding of the moon phases by creating a **diagram model** of the **Earth-Sun-Moon system** that **explains** the **patterns observed** from the **moon phases** models. Students then read a text and watch a video about **moon phases** in order to **evaluate and refine** their initial diagram models.
EXPLORE 2	Students graph daily tides and look for connections to phases of the moon	Students learn about the **moon phases and tides** by **graphing** **daily tides** and **looking for patterns** in the graph that can be connected to **patterns observed** in **phases of the moon**. The teacher's role is to confer with students around their learning, but not offer formal explanations yet.
EXPLAIN 2	Students identify and explain the relationship between phases of the moon and tides	Students read a text and watch a video about **moon phase and tides** in order to **create a diagram model that explains** the connection between **patterns observed** in the **moon phases** and **patterns observed** in the **tides**.
ELABORATE	Students apply their learning about phases of the moon to eclipses	Students **test out their explanations** of **patterns observed** in the **phases of the moon** by applying their thinking to a new problem about **solar and lunar eclipses**. This task connects to prior learning and extends students' thinking.
EVALUATE	This 3E has no Evaluate	

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

What do students know about why we see moon phases from Earth?

The teacher learns what students know and care about related to the **phases of the moon** by having them observe and **look for patterns** in **moon phase** images, then use their initial ideas to create a **diagram model** that **explains** the patterns they observed.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Independent ❏ Table Groups	❏ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Why does the moon look different over the course of the month?	None	❏ Post-its ❏ Chart Paper

Instructional Sequence

1. Provide students with the handout *Why does the moon look different over the course of the month?*.
2. Have students individually respond to the prompt on the page.
3. Use the Group learning routine Rumors to share the patterns they notice.

Explore 1

Students observe models of moon phases

Students explore **phases of the moon** by **making observations of a 3-D moon phases model** and a **moon phase simulator** to **look for patterns that might provide evidence for causality** of the **moon phases**. The teacher's role is to confer with students around their learning, but not offer formal explanations yet.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs	❏ Elbow Share + Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ How Do We Use Modeling to Explain Patterns in Observations of the Moon?	❏ Ball on stick with one side marked ❏ Lamp ❏ Someone other than the person holding the moon	

Instructional Sequence

1. Launch students into how the moon changes over time by providing them with the handout *How Do We Use Modeling to Explain Patterns in Observations of the Moon?* and their investigation supplies.
2. Support students as they enact their models. It works best if the room is as dark as possible.
3. Confer with students around their learning as they work in collaborative groups, but be sure to avoid offering formal explanations at this point.
4. After students have individually completed the See-Think-Wonder, use Elbow Exchange to help students articulate their ideas so far. Facilitate a whole-class share with Domino Share + Random Reporter.

Explain 1

Students explain phases of the moon

Students demonstrate their initial understanding of the moon phases by creating a **diagram model** of the **Earth-Sun-Moon system** that **explains** the **patterns observed** from the **moon phases** models. Students then read a text and watch a video about **moon phases** in order to **evaluate and refine** their initial diagram models.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs ❏ Groups of 3 for Think-Talk-Open Exchange	❏ Think-Talk-Open Exchange	None

Materials

Handouts	Lab Supplies	Other Resources
❏ What is Your Explanation for Patterns in Observations of the Moon?	None	❏ Lunar Phases

Instructional Sequence

1. Launch students into moon phases by providing them with the handout *What is Your Explanation for Patterns in Observations of the Moon?*. Have students use the text Lunar Phases to gain ideas.
2. Confer with students around their learning as they work in collaborative groups to explain moon phases.
3. After students have individually completed the See-Think-Wonder, use Elbow Exchange to help students articulate their ideas so far. Facilitate a whole-class share with Domino Share + Random Reporter.

Explore 2

Students graph daily tides and look for connections to phases of the moon

Students learn about the **moon phases and tides** by **graphing** **daily tides** and **looking for patterns** in the graph that can be connected to **patterns observed** in **phases of the moon**. The teacher's role is to confer with students around their learning, but not offer formal explanations yet.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs	❏ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ High Tides and Moon Phases	None	❏ High and Low Tide Pictures ❏ New York (The Battery), NY - Local Tide Times, Tide Chart | US Harbors

Instructional Sequence

5. Launch students into how the tides change over time by showing them the High and Low Tide Pictures .
6. Providing students with the handout *High Tides and Moon Phases* and have them work in tables to review the data.
7. Support students as they use data from lNew York (The Battery), NY - Local Tide Times, Tide Chart | US Harbors to record high tides over a two week period
8. Confer with students around their learning as they work in collaborative groups, but be sure to avoid offering formal explanations at this point.
9. After students have completed the graph and analysis questions, have students discuss their findings in groups. Facilitate a whole-class share with Domino Discover.

Explain 2

Students identify and explain the relationship between phases of the moon and tides

Students read a text and watch a video about **moon phase and tides** in order to **create a diagram model that explains** the connection between **patterns observed** in the **moon phases** and **patterns observed** in the **tides**.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Triads	❏ Think-Talk-Open Exchange	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Why was Hurricane Sandy so Bad	None	❏ Tides ❏ Watching the Tides

Instructional Sequence

4. Remind students that we are trying to figure out why Hurricane Sandy was so damaging. Provide students with the handout *Why was Hurricane Sandy so Bad*.
5. Show students the Watching the Tides .
6. Have students use the text Tides to gain information around the prompt: why was hurricane Sandy, which hit on a spring tide, so damaging?
7. Facilitate the group learning routine Think-Talk-Open Exchange to help students share their ideas. Have students revise their responses after discussion.

Elaborate

Students apply their learning about phases of the moon to eclipses

Students **test out their explanations** of **patterns observed** in the **phases of the moon** by applying their thinking to a new problem about **solar and lunar eclipses**. This task connects to prior learning and extends students' thinking.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Read-Generate-Sort Solve	None

Materials

Handouts	Lab Supplies	Other Resources
❑ What Causes Lunar and Solar Eclipses?	None	❑ Eclipses

Instructional Sequence

1. Tell students that there is one final component of moon phases that is really cool, called eclipses.
2. Provide students with the handout *What Causes Lunar and Solar Eclipses?* and the text Eclipses .
3. Facilitate the group learning routine Read-Generate-Sort-Solve for students to understand what causes solar and lunar eclipses.

Evaluate

This 3E has no Evaluate

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Standards in Moon Phases Optional 3E (Optional)

Performance Expectations

HS-ESS1-7 Clarification Statement:
Assessment Boundary:

This PE, added by NYS, is not in the NGSS: Construct an explanation using evidence to support the claim that the phases of the moon, eclipses, tides and seasons change cyclically. [Clarification Statement: Emphasis of the explanation should include how the relative positions of the moon in its orbit, Earth, and the Sun cause different phases, types of eclipses or strength of tides. Examples of evidence could include various representations of relative positions of the Sun, Earth and moon.] [Assessment Boundary: Assessment does not include mathematical computations to support explanations but rather relies on conceptual modeling using diagrams to show how celestial bodies interact to create these cyclical changes.]

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2)	ESS1.B Earth and the Solar System • Earth and celestial phenomena can be described by principles of relative motion and perspective. ESS1.B(3)NYS	Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Constructing Explanations and Designing Solutions	*Why does the moon look different over the course of the month?*	*How Do We Use Modeling to Explain Patterns in Observations of the Moon?* *What is Your Explanation for Patterns in Observations of the Moon?*	*High Tides and Moon Phases* *Why was Hurricane Sandy so Bad*	*What Causes Lunar and Solar Eclipses?*	
ESS1.B Earth and the Solar System	*Why does the moon look different over the course of the month?*	*How Do We Use Modeling to Explain Patterns in Observations of the Moon?* *What is Your Explanation for Patterns in Observations of the Moon?*	*High Tides and Moon Phases* *Why was Hurricane Sandy so Bad*	*What Causes Lunar and Solar Eclipses?*	
Patterns	*Why does the moon look different over the course of the month?*	*How Do We Use Modeling to Explain Patterns in Observations of the Moon?* *What is Your Explanation for Patterns in Observations of the Moon?*	*High Tides and Moon Phases* *Why was Hurricane Sandy so Bad*	*What Causes Lunar and Solar Eclipses?*	

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP.2 MP.4	MP.2 MP.4		
ELA/Literacy		RST.9-10.1 RST.9-10.7	RST.9-10.1 RST.9-10.7		

Blizzards 5E

How do severe winter storms form? What causes wind and precipitation? Can we make predictions about these weather phenomena?

Performance Expectations
HS-ESS2-8

Investigative Phenomenon
Winter storm Jonas produced strong enough winds and enough snow to cause significant disruptions to society, damage to property, and harm to human life.

Time
7-13 days

In this 5E, students begin to determine the factors critical to producing winter storms in order to understand how increases in temperature may affect the formation of winter storms in the future, both in storm frequency and intensity.

ENGAGE	What do students know about wind, rain, and snow, and how they occur?	The teacher reminds students that in order to understand hurricanes and blizzards, we need to understand wind and precipitation. Students share initial **explanations** about what **causes** **wind, rain, and snow**.
EXPLORE 1	Students investigate wind formation through a variety of models.	Students **use models** of **wind formation** **to generate data** in order to establish **cause and effect** relationships between **temperature, pressure, density, and buoyancy**.
EXPLAIN 1	Students develop explanations for how wind from blizzards like Winter Storm Jonas occurs.	Students **develop a model based on evidence to illustrate** **cause and effect** **relationships** between **temperature, pressure, density, and buoyancy** during **wind formation**.
EXPLORE 2	Students investigate precipitation formation through models.	Students **use models** of **cloud formation and frontal boundaries** in order **to generate data** in order to establish **causality** for **precipitation at frontal boundaries**.
EXPLAIN 2	Students develop explanations for how snow from blizzards like Winter Storm Jonas occurs.	Students **develop a model based on evidence to illustrate** **cause and effect** **relationships** between **temperature of water and its phase** during **cloud and rain formation**.
ELABORATE	Students analyze weather maps to identify weather systems and develop a model to explain their formation.	Students **analyze data** (draw **isotherms** and **isobars** on a map) in order to identify **cold and warm air masses**, as well as **high and low-pressure systems**, including Winter Storm Jonas, then **develop a model** to explain the formation of **a mid-latitude cyclone**.
EVALUATE	Students connect their learning to the Performance Task	Students **develop a model based on evidence to illustrate** **cause and effect** **relationships** during blizzard formation, in order to make predictions about how **global temperature increase will affect the frequency and intensity of blizzards**.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

What do students know about wind, rain, and snow, and how they occur?

The teacher reminds students that in order to understand hurricanes and blizzards, we need to understand wind and precipitation. Students share initial **explanations** about what **causes wind, rain, and snow**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Independent	❑ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❑ Post-Its ❑ Video: Winter Storm Jonas in NYC

Instructional Sequence

1. Begin this 5E by bringing their attention to the Driving Question Board -- and highlight that during the Unit Opening they asked questions about *what causes severe winter storms*, which are also referred to as blizzards. They also asked questions about the characteristics of the storms - such as *what is causing the strong winds and precipitation* like rain and snow. Tell students that in order to better understand severe winter storms in general, we're going to investigate one specific severe winter storm, and then generalize what we learn from it. Show students the video, Winter Storm Jonas in NYC, which illustrates the disruption caused by extremely strong winds and heavy snowfall produced by Winter Storm Jonas.

Tell students that they will have an opportunity to investigate both of these key characteristics of a severe winter storm, but that the class will start by focusing on wind. Have students independently brainstorm ideas in response to the prompt, "What do you think is causing all the wind during Winter Storm Jonas?"

2. Ask each student to individually decide which idea they feel most confident about. Students write their name on the post-it as well.
3. Set up the group learning routine **RUMORS** to elicit student ideas. Students use this group learning routine to voice and exchange their ideas about what causes wind.

Look & Listen For

Possible student ideas that can be used to transition to the next phase(s):

- Wind is when air moves from one place to another fast
- I think wind is somehow caused by temperature changes
- I've heard on the news it has to do with pressure
- I think it has to do with the Earth spinning

4. Students may not surface all the ideas above and that's ok at this point. Let them know that they will have a chance to test their ideas and change or refine them as they carry out an investigation about wind using various models.
5. Reflect on student ideas and plan accordingly based on student understandings, incomplete ideas, and misconceptions. As you go through the 5E, either check ideas that the class thinks are more correct or cross off ideas they don't think are true anymore.

Explore 1

Students investigate wind formation through a variety of models.

Students **use models** of **wind formation to generate data** in order to establish **cause and effect** relationships between **temperature, pressure, density, and buoyancy**.

Preparation

Student Grouping	Routines	Literacy Strategies
None	❏ Elbow Exchange + Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Wind Formation Investigation	❏ Two 1 liter bottles ❏ Tubing ❏ Incense ❏ Hot and cold water	❏ States of Matter Simulator ❏ Diffusion Simulator ❏ Teacher resource: Wind Model Video

Instructional Sequence

1. Remind students or highlight their ideas about the role of wind in Winter Storm Jonas from the Engage phase. Use those ideas about wind being air that moves from one place to another and / or being caused by temperature to transition to investigating more about the movement of air, specifically why air moves from one place to another as wind.
2. Launch students into working on *Wind Formation Investigation*.
3. Confer with students as they work in collaborative groups.

Conferring Prompts

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

Model 1

- What did you notice was happening to the air in the bottle where the air was being heated by 'warm land'?
- What did you notice was happening to the air in the bottle where the air was being cooled by 'cool land'?
- Which direction was the air flowing horizontally across the 'Earth's surface'?

Model 2

- What did you notice was happening to the air molecules in the atmosphere as you cool and heat them?
- What happened to the density of the air molecules at 'Earth's surface' as you heated and cooled them?
- What happened to the pressure the air molecules were applying at 'Earth's surface' as you heated and cooled them?

Model 3

- In model 1, were there more air molecules in the bottle with air molecules over "cool land: or the bottle with air molecules over "warm land"? What observations from model 1 make you think that?
- How can you reflect the number of particles and the temperature of particles in model 1 with the simulator?
- Which side of the container in the simulation has more air pressure?
- In which direction do most of the molecules flow?
- Why do you think most air molecules flowed in that direction?

4. Have each student complete a See-Think-Wonder on *Wind Formation Investigation* to help them articulate their ideas so far. Elicit student ideas through the group learning routine, Elbow Exchange + Domino Share with Random Reporter.

Look & Listen For

These student observations and ideas are critical to students' success during the Explain phase:

Model 1

- Air over the 'cool land' is sinking.
- Air over the 'warm land' is rising.
- I noticed that the air moves from the side with 'cool land' to the side with 'warm land'.

Model 2

- When you cool air molecules they come closer together so are more dense
- When you warm air molecules they move further apart so are less dense
- When air molecules were warmed and spread apart and rose up there was less pressure on 'Earth's surface'
- When air molecules were cooled and came closer together at 'Earth's surface' there was more pressure on 'Earth's surface'

Models 3

- Most of the molecules flowed from the cooler denser side to the warmer less dense side.
- I think this is because there were more molecules / more pressure on the cooler denser side, so they were more easily able to flow to the other side with less molecules / less pressure.

5. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Explain 1

Students develop explanations for how wind from blizzards like Winter Storm Jonas occurs.

Students **develop a model based on evidence to illustrate cause and effect relationships** between **temperature, pressure, density, and buoyancy** during **wind formation**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Individual or pairs ❑ Groups of 3 for Think-Talk-Open Exchange	❑ Think-Talk-Open Exchange ❑ Class consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Explaining Wind Formation ❑ Summary Task	None	❑ Chart paper

Instructional Sequence

1. Remind students about their questions regarding how wind, like the strong winds they observed from Winter Storm Jonas, is formed. Let students know that they will now have a chance to apply all the ideas they surfaced during the previous investigation to developing an explanatory model for wind they observed from Winter Storm Jonas, and that they will start by first explaining the movement of air in Model 1. In pairs, have students complete all except the last two pages of *Explaining Wind Formation.*
2. Use Think-Talk-Open Exchange to help students articulate their ideas so far.

Think-Talk-Open Exchange guiding prompts:

- *What caused air to rise in model 1? How do you know?*
- *What caused air to sink in model 1? How do you know?*
- *What caused air to move from one bottle to another in model 1? How do you know?*

Be sure to highlight important vocabulary at this point, while making connections to the Explore phase.

3. On the last two pages of *Explaining Wind Formation*, have students work in pairs to complete their initial explanatory models of how wind from Winter Storm Jonas was formed and answer the questions that follow. They can draft their models independently in the handout, but group models should be completed on chart paper.
4. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:

Access for All Learners

Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context, which may be particularly helpful for **transitioning** language learners, who already have some mastery of language.

"We have a lot of different ideas circulating in the room right now. It is really important for us to get to some agreement on how we represent what we know about how wind from Winter Storm Jonas was formed, so that we have a shared understanding to build upon as we move ahead. In order to do this, we are going to do something called a **Class Consensus Discussion**. First, I will select a few different groups to share their ideas. Then, we will let each group share their claim and discuss what we can agree to as a class."

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to an agreement.

Classroom Supports

Post the steps to the Class Consensus Discussion in the room as a reference you can return to in future lessons.

Implementation Tip

We recommend you do NOT just let students talk about their explanatory models aloud. Some classmates will need to see/read the claim to be able to follow up.
**A discussion with no visual component may exclude a number of students.

You may decide to walk students through the entire poster or take them through the steps as you facilitate it.

Select two or three groups' work to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how wind from Winter Storm Jonas was formed. The decision about which groups' ideas to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence.

Ask the first group to share their explanation of how wind is formed. You can do this by:

- Projecting using a document camera; OR
- Copying the explanatory models to be shared and passing them out to the class; OR
- Taking a picture of each explanatory model and projecting them as slides.

Proceed through the steps in the Consensus Discussion Steps.

Implementation Tip

The prompts student groups confer about after groups present their work, are meant to make **CCC # 2 Cause & Effect** and **CCC # 4 Systems & Systems Models** more explicit for them, specifically ideas using molecular scale mechanisms in order to develop a causal mechanism for phenomena at an observable scale and using models to illustrate energy and matter flows within and between systems at different scales.

Before table groups confer, prompt them to consider how examining mechanisms at a molecular scale was helpful in figuring out a causal mechanism for the formation of wind. Some prompts you might provide are:

- How did examining what happens to air at the molecular level when heated and cooled help us better understand what causes wind to form?
- How did examining what happens to air at the molecular level when there are differences in pressure help us better understand what causes wind to form?
- In what ways do the models show the interaction of energy and matter at different scales?

During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following **key points**:

- High pressure regions of air at Earth's surface are located where cold air contracts and is more dense, so it sinks.
- Low-pressure regions of air at Earth's surface are located where warm air expands and is less dense, so it rises because air converges here due to a pressure gradient and is forced up.
- Air moves horizontally across Earth's surface due to differences in air pressure.
- It moves from high to low pressure because there is more space for air molecules to flow to in areas of low pressure.
- This is how the wind we observed from Winter Storm Jonas must have formed and how wind from other storms like it form.

Display the categories of ideas about how wind forms that students generated during the Engage phase. Ask students if there are ideas on the class list that can be:

a. eliminated based on our investigation of wind;
b. changed based on our investigation of wind;
c. added based on our investigation of wind.

Modify the list of student ideas about how wind forms based on student responses.

Return to student questions from the unit launch and Engage phase, and highlight the fact that the class still hasn't explained how snow from Winter Storm Jonas occurs. Let them know that they will have an opportunity to do that in the next investigation.

5. Have students complete the *Summary Task*.

Explore 2

Students investigate precipitation formation through models.

Students **use models** of **cloud formation and frontal boundaries** in order **to generate data** in order to establish **causality** for **precipitation at frontal boundaries**.

Preparation

Student Grouping	Routines	Literacy Strategies
None	❏ Elbow Exchange + Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Precipitation Formation Investigation	❏ 3 wide clear plastic cups per group ❏ 3 taller clear plastic cups per group ❏ Hot tap water ❏ Warm tap water ❏ Cold tap water ❏ Magnifying glass ❏ Ice	❏ Slides for Elbow Exchange + Domino Share ❏ Weather Fronts Simulator

Instructional Sequence

1. Remind students about the tremendous amount of snow produced by Winter Storm Jonas from the Engage phase. Let students know that they will now have an opportunity to investigate how precipitation occurs so they can apply their learning to explaining how the snow they observed from Winter Storm Jonas occurred.
2. Ask students to think about a really muggy/humid day that they have experienced. With an elbow partner, ask them to discuss how they know that day was muggy/humid, and be ready to share specific things they might feel on a muggy/humid day.
3. Tell students they will be conducting an investigation that will help them understand how water moves through the atmosphere, with a focus on how rain occurs and how it is connected to wind.
4. Launch students into working on *Precipitation Formation Investigation*. Be sure that students understand what the different components from the Weather Fronts simulator represent. Consider doing this through either a screenshot of one of the front simulations or by showing the cold front simulation and having students identify what the different components represent.
5. Confer with students as they work in collaborative groups.

Conferring Prompts

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

Model 1

- *What pattern do you observe from the warm moist air in the fronts simulation?*
- *What pattern do you observe from the dry cold air in the fronts simulation?*
- *What patterns do you observe about where precipitation occurs?*
- *Why do you think warm moist air was rising?*
- *Why do you think the cool dry air stays near the surface?*

Model 2

- *Why do you think warm moist air was rising?*
- *What happens when it reaches the top of the container? Why?*
- *How did temperatures of water and air change your observations?*
- *How do you think this is similar to what you observed in the front simulator?*
- *Think about your experience feeling the air where you live. Do you think all air contains the same level of moisture?*

6. Have each student complete a See-Think-Wonder on *Precipitation Formation Investigation* to help them articulate their ideas so far. Elicit student ideas through the group learning routine Elbow Exchange + Domino Share.

Look & Listen For

These student observations and ideas are critical to their success during the Explain phase:

Model 1

- Warm moist air rises at three out of the four fronts
- Cool dry air stays near the Earth's surface at all fronts
- Precipitation occurs when the two air masses meet and warm moist air rises at three out of the four fronts
- I think the warm moist air is rising because warmer air has a lower density than cooler air

Model 2

- When the warm air reaches the top of the container where it is cooler, water droplets form
- I think this is because the moisture / water in the air condenses into liquid again when it is cooled
- When the water is warmer, more water evaporates. Maybe warmer waters cause more rain in the atmosphere.

When the air is cooler, the water vapor turns to liquid.

These possible student questions or similar questions can be used to transition to the next phase(s):

- How does this explain the snow from Winter Storm Jonas?
- How do storms like Winter Storm Jonas produce rain / snow and wind at the same time?

7. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in

making those observations before moving on, as they will be key to success in the Explain phase that follows.

Explain 2

Students develop explanations for how snow from blizzards like Winter Storm Jonas occurs.

Students **develop a model based on evidence to illustrate cause and effect relationships** between **temperature of water and its phase** during **cloud and rain formation**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Individual or pairs ❑ Groups of 4 for Idea Carousel	❑ Idea Carousel ❑ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Explaining Precipitation Formation ❑ Summary Task	None	❑ Post-Its ❑ Chart paper ❑ The Water Cycle ❑ States of Matter Simulator

Instructional Sequence

1. Remind students about their questions regarding how Winter Storm Jonas produces so much snow. Let students know that they will now have a chance to apply all the ideas they surfaced during the previous investigation to developing an explanatory model for rain and snow they observed in the fronts simulation and from Winter Storm Jonas.

Use the States of Matter Simulator to review how water behaves (changes phases) as it is heated and cooled.

Tell students that they will use their understanding of how relatively cold air interacts with relatively warm air, as well as their understanding of how water behaves at a molecular scale as its temperature changes, to explain the weather patterns they observe at the boundaries between air masses of different properties.

Implementation Tip

Be sure to reference the Explain 1 phase and how students used what they learned about air at the molecular level to figure out a cause and effect mechanism for wind formation. Encourage students to use what they understand about water's behavior at the molecular level to develop a cause and effect mechanism for how clouds form and precipitation occurs. This will support students in using this lens for **CCC #2 - Cause and Effect** when making sense of other phenomena in the future.

Classroom Supports

Post the steps to the Class Consensus Discussion in the room, as a reference you can return to in future lessons.

2. Have students complete part 1 of *Explaining Precipitation Formation* in pairs.
3. Point out to students that the maps that provide data of average air surface temperature during the northern hemisphere winter and summer, come from a computational model that is based on over 100 data sets from reputable research institutions around the globe and that only data that was in agreement across all models was used to create the computational model. Ask students to turn and talk to each other why this can make them feel more confident about the data. Use the **Domino Discover** routine to share out student ideas.

Implementation Tip

The discussion here is meant to make **CCC #4 Systems and Systems Models** more explicit for students, specifically that models have limited reliability, but this reliability can be improved by the use of numerous data sets from different sources that are in agreement with each other, an important element of **CCC #4 Systems and Systems Models** at the high school level.

4. Have students complete part 2 of *Explaining Precipitation Formation* in pairs. Part 2 focuses on where, when, and why mid-latitude storm systems become winter storms and sometimes blizzards.
5. Have each student pair team up with another student pair to collaboratively create a poster of their cause and effect model of cloud formation and precipitation at a front. They should also illustrate why precipitation falls in the form of snow in some front systems.
6. Use Idea Carousel to facilitate student sharing and critiquing of cause and effect models on posters.
7. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:

"We have a lot of different ideas circulating in the room right now. It is really important for us to get to some agreement on how we represent what we know about how snow from Winter Storm Jonas was formed, so that we have a shared understanding to build upon as we move ahead. In order to do this we are going to do something called a **Class Consensus Discussion**. First, I will select a few different groups to share their ideas. Then, we will let each group share their claim and discuss what we can agree to as a class."

You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to an agreement.

Implementation Tip

We recommend you do NOT just let students talk about their models aloud. Some classmates will need to see/read the claim to be able to follow up. A discussion with no visual component may exclude a number of students.

Select two or three groups' work to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how snow from Winter Storm Jonas was formed. The decision about which groups' ideas to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence.

Ask the first group to share their explanation of how wind is formed. You can do this by:

- Projecting using a document camera; OR
- Copying the explanatory models to be shared and passing them out to the class; OR
- Taking a picture of each explanatory model and projecting them as slides.

Proceed through the steps in the Consensus Discussion Steps.

Before table groups confer, prompt them to consider how examining mechanisms at a molecular scale was helpful in figuring out a causal mechanism for cloud formation and the occurrence of precipitation. Some prompts you might provide are:

- How did examining what happens to air at the molecular level when heated and cooled help us better understand the causal mechanism for cloud formation and the occurrence of precipitation?
- How did examining what happens to water at the molecular level when heated and cooled help us better understand the causal mechanism for cloud formation and the occurrence of precipitation?
- In what ways do the models show the interaction of energy and matter at different scales?

Implementation Tip

The prompts student groups confer about after groups present their work, are meant to make **CCC # 2 Cause & Effect** and **CCC # 4 Systems & Systems Models** more explicit for them, specifically ideas using molecular scale mechanisms in order to develop a causal mechanism for phenomena at an observable scale and using models to illustrate energy and matter flows within and between systems at different scales.

During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following **key points**:

- When warm moist air interacts with cool dry air, the warm moist air rises because it is less dense.
- Because temperature is lower as you move higher into the atmosphere, warm moist air cools as it rises, causing the water molecules to condense and form clouds.
- When the water is heavy enough, it drips down as rain.
- Warm water results in more evaporation than cold water so when it's warm there is more water in the atmosphere that can form clouds and cause precipitation.
- Snow happens when the air temperature is cold enough to freeze water, this is why blizzards occur during the winter at higher latitudes.
-

8. Have students complete *Summary Task*.

Elaborate

Students analyze weather maps to identify weather systems and develop a model to explain their formation.

Students **analyze data** (draw **isotherms** and **isobars** on a map) in order to identify **cold and warm air masses**, as well as **high and low-pressure systems**, including Winter Storm Jonas, then **develop a model** to explain the formation of **a mid-latitude cyclone**.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Independent or pairs	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Identifying Winter Storm Jonas on a Map	❏ Laptops	❏ Colored pencils ❏ Permanent markers ❏ *Weather Maps* ❏ Video: How to Draw Isolines #1 ❏ Video: How to Draw Isolines #2 ❏ Mid-Latitude Cyclone Clip ❏ Mid-Latitude Cyclones Explained ❏ NOAA Site with Complete Guidelines for Analyzing Weather observation Maps

Instructional Sequence

1. Tell students that they will now learn how to represent weather variables on a map in order to analyze them, and identify the location of Winter Storm Jonas on a map.
2. Show students the video Mid-Latitude Cyclone Clip so they have context around identifying these types of storms.

Differentiation Point

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□↔○

- Drawing of isolines can be modeled by the teacher
- Videos for drawing isolines can be used by students for further support
- The teacher can work with small groups of students to model and use probing questions to support drawing of isolines and analysis

3. Provide students with the instructions on the handout *Identifying Winter Storm Jonas on a Map*. Use the directions for mapping surface air pressure to demonstrate how to draw a few isolines. Have students

work in pairs to complete the isolines (isobars) on the surface air pressure map in *Weather Maps*.

4. Have students complete an analysis of the surface air pressure map and share out their findings.
5. Support students in completing isolines for temp, dewpoint, and pressure change maps and in completion of analyses for these maps. For some students, these activities may be largely self-guided, using the check-your-work images for support. Other students may need additional modeling, to work in smaller chunks, and have many checkpoints throughout.
6. Have students share out their analysis of each map (pressure, temp, dewpoint, and pressure change). Use probing questions to support students in refining their analysis of the individual maps.
7. Have students use their previous maps and a key of weather symbols to analyze Complete Surface Observation map and construct warm and cold front lines. For New York State teachers, the key to weather symbols images come from page 18 of the ESSRT.
8. Have students use the Winter Storm Jonas: Jan 21, 15 UTC - Surface Analysis Map with station models data around the country to try to locate the formation of a low pressure system that might indicate storm activity. Students may need support; they are looking for an area of low pressure that shows winds changing directions in a cyclone shape, and where temperatures vary widely across a small space. They should identify that there is a cyclone containing a warm and cold front over the low pressure area in Texas.
9. Have students synthesize their learning from this 5E by completing part 2 of *Identifying Winter Storm Jonas on a Map*.
10. Show the video Mid-Latitude Cyclones Explained to help students refine their ideas about how all concepts learned through this 5E help to explain the occurrence of wind and precipitation.

Evaluate

Students connect their learning to the Performance Task

Students **develop a model based on evidence to illustrate cause and effect relationships** during blizzard formation, in order to make predictions about how **global temperature increase will affect the frequency and intensity of blizzards**.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Independent	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ What is the Future of Winter Storms? ❏ Blizzards 5E Arguing from Evidence Rubric ❏ Connect to the Performance Task: Hurricanes 5E	None	❏ Computers ❏ IPCC WGI Interactive Atlas

Instructional Sequence

1. Have students work on the handout *What is the Future of Winter Storms?* to gather evidence about how storms will change based on climate change predictions. Assist students with using the IPCC WGI Interactive Atlas . Their instructions direct them to view different variables for winter in the northern hemisphere; advanced students may choose to explore different modeling scenarios or datasets as well.
2. Have students work on the *Connect to the Performance Task: Hurricanes 5E* based on what they have learned from this 5E.

In the Evaluate phase, at the end of this 5E, students will use historical data regarding the frequency and intensity of winter storms, as well as future climate models to develop models and make an argument regarding predictions of Blizzard frequency and intensity where they live in the future. They should connect these explanations to think about their DQB, and how this information can help them revise their initial predictions AND what more they need to learn about (ex. The trajectory of severe storms and how and why hurricanes form).

Note: for most students, responding to the prompt about intensity may be more accessible, because the data throughout the 5E aligns to give a clear picture of how intensity should change in the future. Data about frequency is inconsistent, and different pieces of evidence indicate changes in different directions; students taking on this prompt must be able to weigh competing evidence and reach the conclusion that they cannot know what will happen to the frequency of storms in the future.

Provide students with the *Blizzards 5E Arguing from Evidence Rubric*, so that they can peer or self assess.

Implementation Tip

The performance task is another opportunity to assess **CCC # 2 Cause & Effect** and **CCC # 4 Systems & Systems Models**, specifically ideas using molecular scale mechanisms in order to develop a causal mechanism for phenomena at an observable scale and using models to illustrate energy and matter flows within and between systems at different scales.

Additionally, students are again asked to reflect on how the use of multiple data sets to develop computational models can give us more confidence in the precision of that data and therefore their predictions, another important element of **CCC # 4 Systems & Systems Models**.

Performance Expectations

HS-ESS2-8 Clarification Statement:
Assessment Boundary:

This PE, added by NYS, is not in the NGSS: Evaluate data and communicate information to explain how the movement and interactions of air masses result in changes in weather conditions. [Clarification Statement: Examples of evidence sources could include station models, surface weather maps, satellite images, radar, and accepted forecast models. Emphasis should focus on communicating how the uneven heating of Earth's surface and prevailing global winds drive the movement of air masses and their corresponding circulation patterns, the interaction of different air masses at frontal boundaries, and resulting weather phenomena.] [Assessment Boundary: Analysis is limited to surface weather maps and general weather patterns associated with high and low pressure systems.]

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3) Constructing Explanations and Designing Solutions • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. SEP6(1)	ESS2.D Weather and Climate • Concepts of density and heat energy can be used to explain observations of weather patterns ESS2.D(5)NYS ESS3.D Global Climate Change • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. ESS3.D(1) PS3.A Definitions of Energy • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. PS3.A(2) • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. PS3.A(4)	Cause and Effect • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. CCC2(2) Systems and Systems Models • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. CCC4(3) • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. CCC4(4)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Developing and Using Models		Movement of Air Molecules Investigation: See-Think-Wonder Making Connections to Earth's Troposphere Class Consensus Discussion Summary Task	Movement of Water in the Atmosphere: See-Think-Wonder Cause & Effect Model Class Consensus Discussion	*Identifying Winter Storm Jonas on a Map*	Unit Performance Task
Constructing Explanations and Designing Solutions		Summary Task			
ESS2.D Weather and Climate				*Identifying Winter Storm Jonas on a Map*	
ESS3.D Global Climate Change					Unit Performance Task
PS3.A Definitions of Energy		Making Connections to Earth's Troposphere Class Consensus Discussion	Cause & Effect Model Class Consensus Discussion		Unit Performance Task
Cause and Effect		Movement of Air Molecules Investigation: See-Think-Wonder Making Connections to Earth's Troposphere Summary Task	Cause & Effect Model Class Consensus Model Summary Task	*Identifying Winter Storm Jonas on a Map*	Unit Performance Task
Systems and Systems Models		Movement of Air Molecules Investigation: See-Think-Wonder Making Connections to Earth's Troposphere Summary Task	Movement of Water in the Atmosphere: See-Think-Wonder	*Identifying Winter Storm Jonas on a Map*	Unit Performance Task

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP.2	MP.2	MP.2	MP.2
ELA/Literacy		RST.9-10.7	RST.9-10.7	RST.9-10.7	RST.9-10.7

Student Work for Blizzards 5E

New Visions for Public Schools

Connect to the Performance Task: Blizzards 5E

Choose one of the two tasks below and apply what you figured out from the Blizzards 5E to complete the task. Each task involves the following:

- identifying the independent and dependent variable in the task prompt
- developing a model for how climate change will impact winter storms in your region in the future based on evidence from the investigation
- writing an argument based on evidence for how climate change will impact winter storms in your region in the future based on evidence from the investigation

Task 1 Prompt

Will the frequency of winter storms per year where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable: Global Temperatures Dependent variable: Frequency of Winter Storms

Part 2:

1. Gather evidence for what will happen to the independent variable you indicated above and note it in the table below.

What is the evidence?	Which resource did the evidence come from?
Historical data shows storms increasing in the high latitudes in recent decades compared to 1950, but staying approximately the same in mid-latitudes.	The evaluate text has graphs showing storm frequency by decade
Globally, temperatures are increasing and are expected to increase further, and warm air can hold more water, making it more likely to precipitate	• IPCC atlas shows temperatures increasing • The activity with 2 cups in Explaining precipitation formation showed that warm air holds more water
Air needs to be cold (below 32°F) to form snow/blizzards	Part 2 of "Explaining precipitation formation" shows that winter storms need temperatures below 32°F

2. Review your model for how a winter storm forms from the investigation, then develop a model that illustrates what you think will happen to the frequency of winter storms per year where you live based on evidence regarding the independent variable. Be sure to include:
   - how and why energy and matter flow within the storm system and relevant surrounding systems
   - small scale mechanisms that explain what you are representing at the macro scale

Modeling Frequency of Winter Storm in the Future

Temperatures will increase, especially in mid-latitudes like NYC

→

More air will decrease in density, causing it to rise

heat → rises

air molecules

lower density

→

warm air holds more water than cold air, so the rising warm air will be wetter

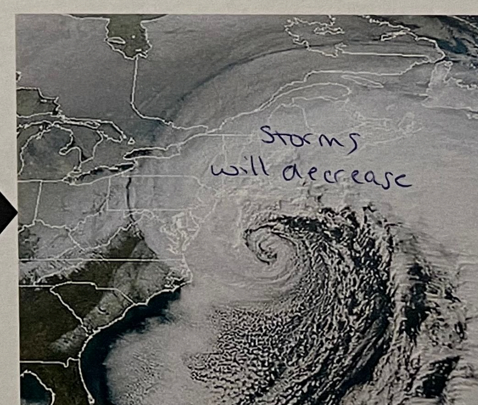
→

Storms form where warm wet air meets dry cold air

→

In mid-latitudes, less cold air is present because temperatures are increasing, so storms likely won't form as much

→



New Visions for Public Schools

Part 3: Engage in an argument from evidence regarding whether the frequency of winter storms per year where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. Consider the following:

- historical winter storm frequency data
- the conditions necessary for a winter storm to form
- relevant data from global climate models, such as projections of future temperatures
- how your prediction has limited precision and reliability due to the assumptions and approximations inherent in global climate models you used

In New York city, where I live, winter storms will likely decrease (or stay the same) as global temperatures increase. This decrease is because winter storms form when temperatures are lower than 32° F, and when warm, wet air meets cold, dry air. Rising temperatures will result in those cold conditions existing less often.

Although the temperature increasing means that air will be warmer and therefore better able to both hold water and rise, it is less likely to encounter the cold air needed for storms to form.

Historical data supports this prediction, showing no consistent change in storms ~~are~~ frequency since 1950.

However, these projections are based on small amounts of data. If other global systems change, for example bringing more cold air from the Northern latitudes, then there may be more storms as the warmer, wetter air reaches cold air.

Task 2 Prompt

Will the intensity of winter storms where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable: Global Temperatures Dependent variable: Intensity of Winter storms

Part 2:

1. Gather evidence for what will happen to the independent variable you indicated above and note it in the table below.

What is the evidence?	Which resource did the evidence come from?
Historical data shows the intensity of storms increasing in mid- and high-latitudes in recent decades compared to 1950.	The evaluate text has graphs showing storm ~~frequency~~ intensity by decade
Globally, temperatures are rising and are expected to rise further, and warm air can hold more water, making it more likely to precipitate into big storms	• IPCC atlas shows temperatures increasing • The activity with 2 cups in Explaining precipitation formation showed warm ~~air~~ holds more water
As air warms, it becomes less dense and rises, creating low pressure areas for winds to be created	The wind formation bottle investigation showed that wind forms when air moves into low pressure zones left by warm air rising

1. Review your model for how a winter storm forms from the investigation, then develop a model that illustrates what you think will happen to the intensity of winter storms where you live based on evidence regarding the independent variable. Be sure to include:
   - how and why energy and matter flow within the storm system and relevant surrounding systems
   - small scale mechanisms that explain what you are representing at the macro scale

Modeling Intensity of Winter Storms in the Future

Temperatures will increase, especially in mid-latitudes like NYC

→

More air will decrease in density, causing it to rise

air molecules — heat → lower density — air rises

→

As warm air rises, low pressure areas form, creating wind as lower air rushes to fill in the space.

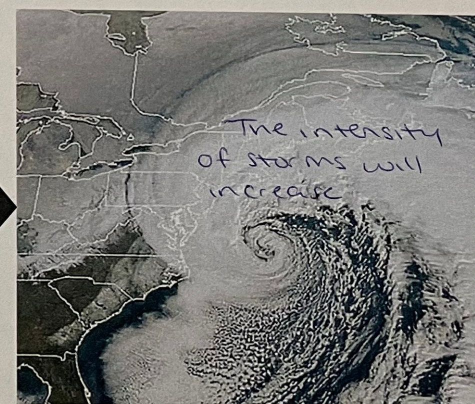
→

warm air holds more water than cold air, so the rising warm air will be wetter

→

conditions will be created with high amounts of water to precipitate and high winds

→



New Visions for Public Schools

Part 3: Engage in an argument from evidence regarding whether the intensity of winter storms where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. Consider the following:

- historical winter storm intensity data
- the conditions necessary for a winter storm to to produce intense snowfall
- relevant data from global climate models, such as projections of future temperatures
- the precision and accuracy of the global climate models you used

In New York City, where I live, winter storms will likely become more intense as global temperatures increase.

Though storms may happen less often, when they do occur, the will be the result of very warm, moist air meeting cold air. The fact that this air has more energy means it will rise quickly, causing strong winds to flow into the resulting low pressure zones, and it will hold more water. When precipitation forms, there will be high levels of snowfall.

Historical data supports this prediction, showing an increare in storm intensity in both mid- and high-latitudes since 1950.

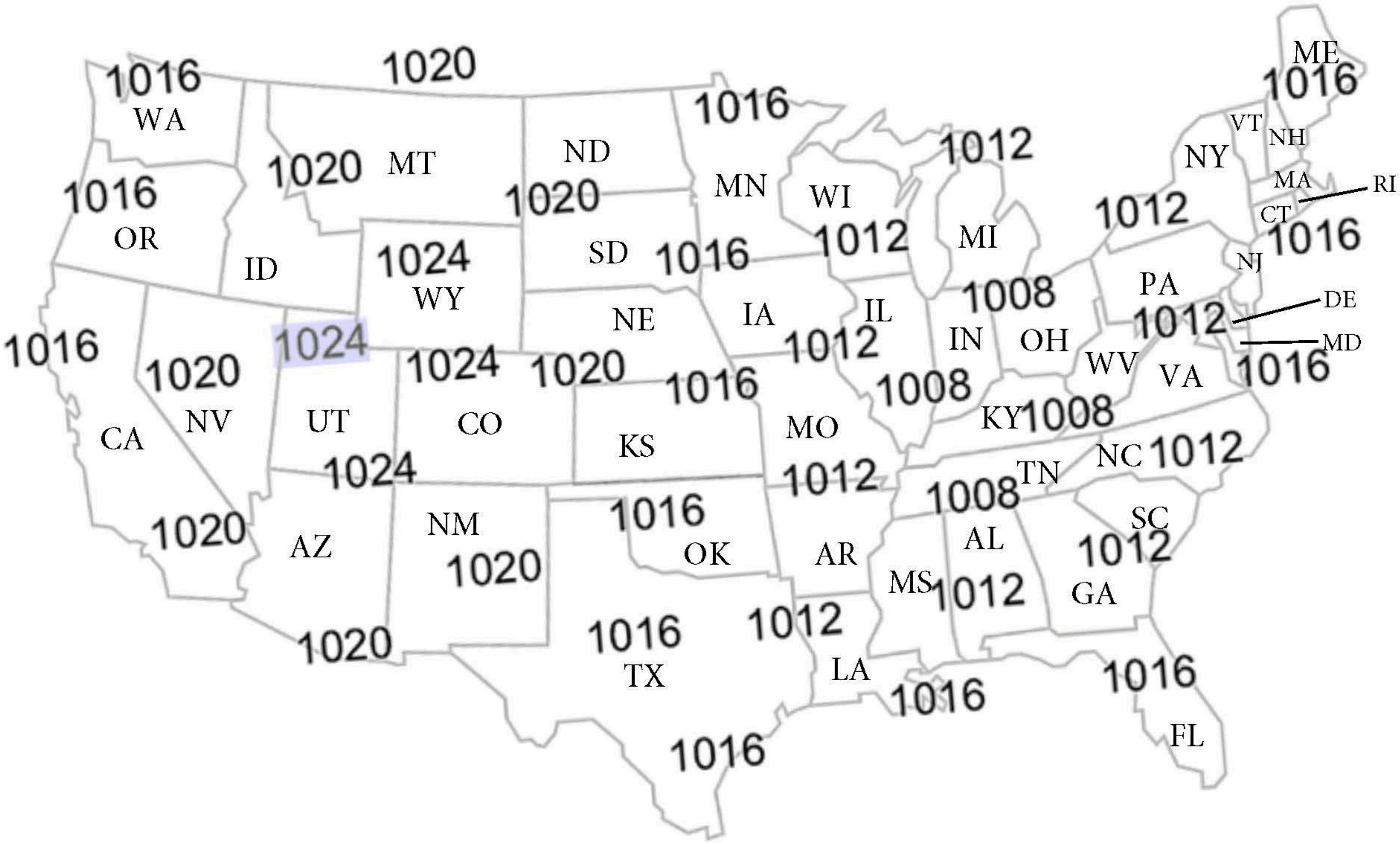
However, these projections are made from limited data, and other changes in global systems could result in other outcomes.

Classroom Resources for Blizzards 5E

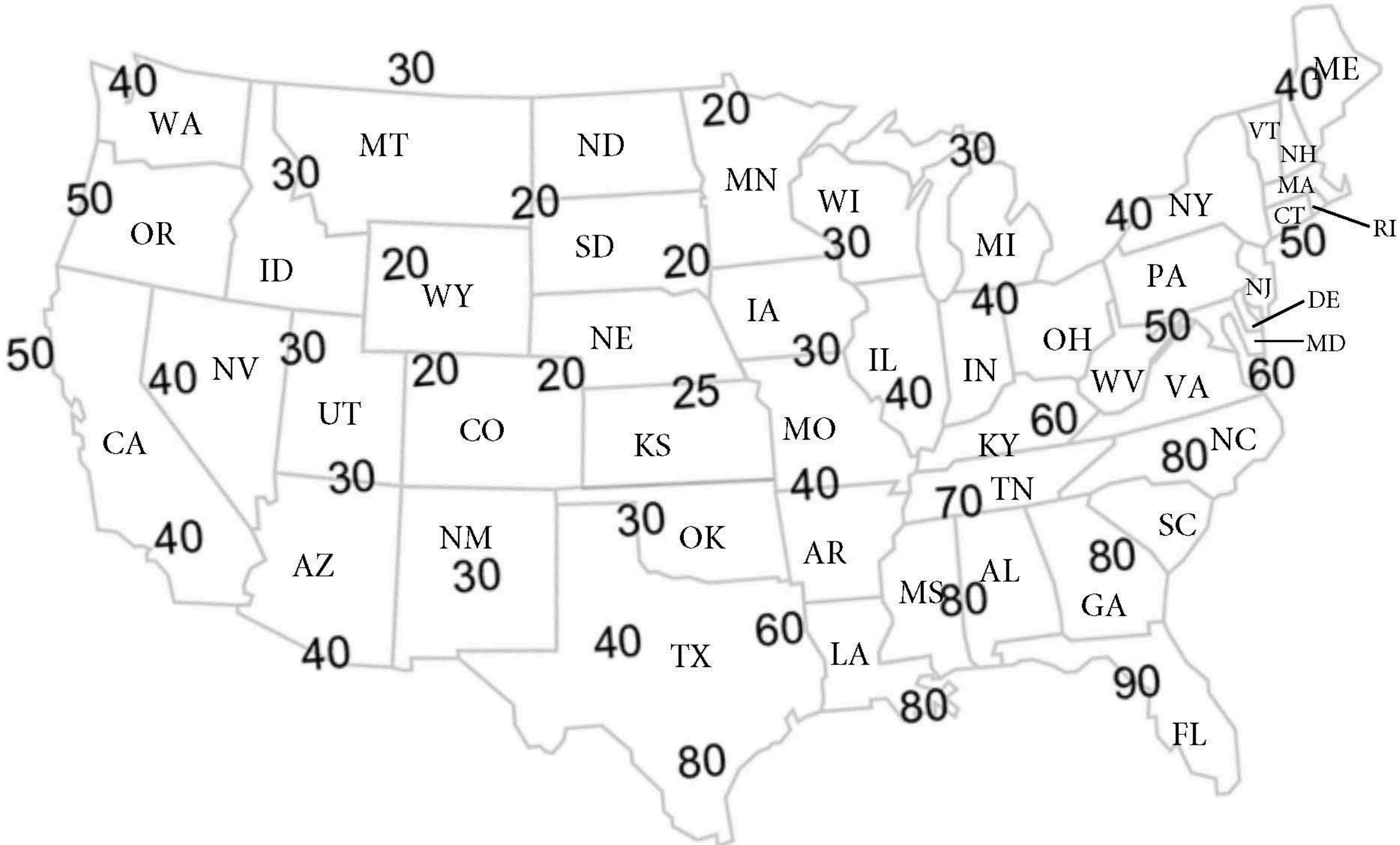
Weather Maps

Weather Maps

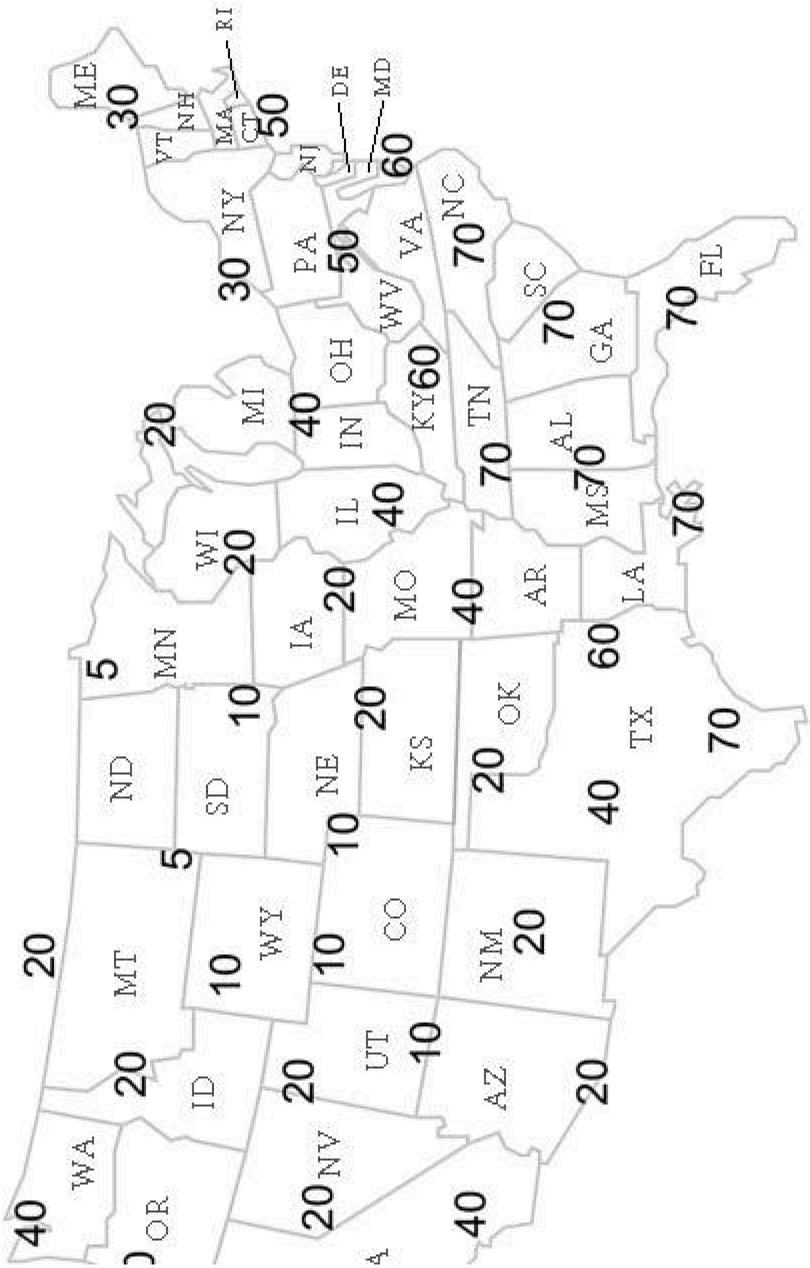
1. Air Pressure Map

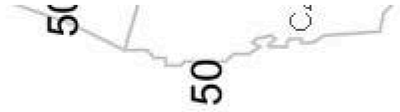


2. Temperature Map

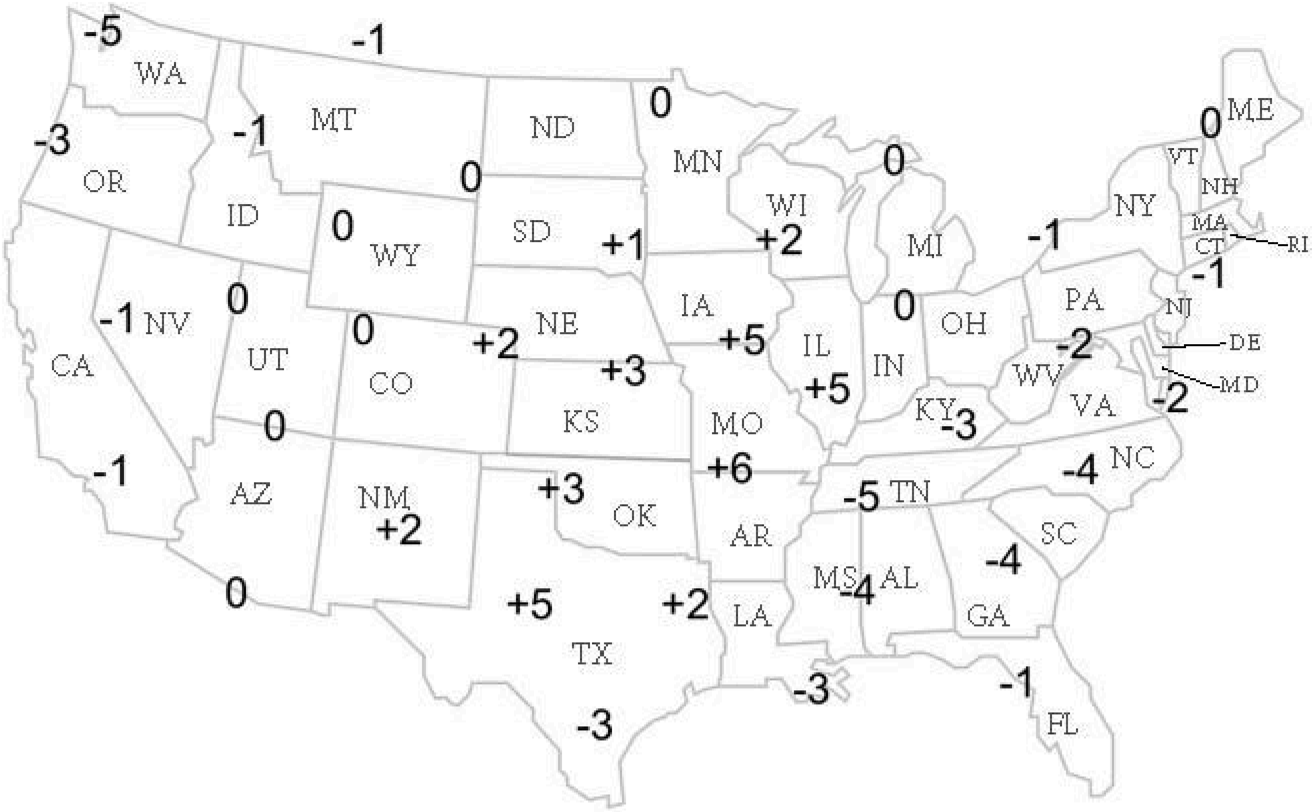


3. Dew Point Map

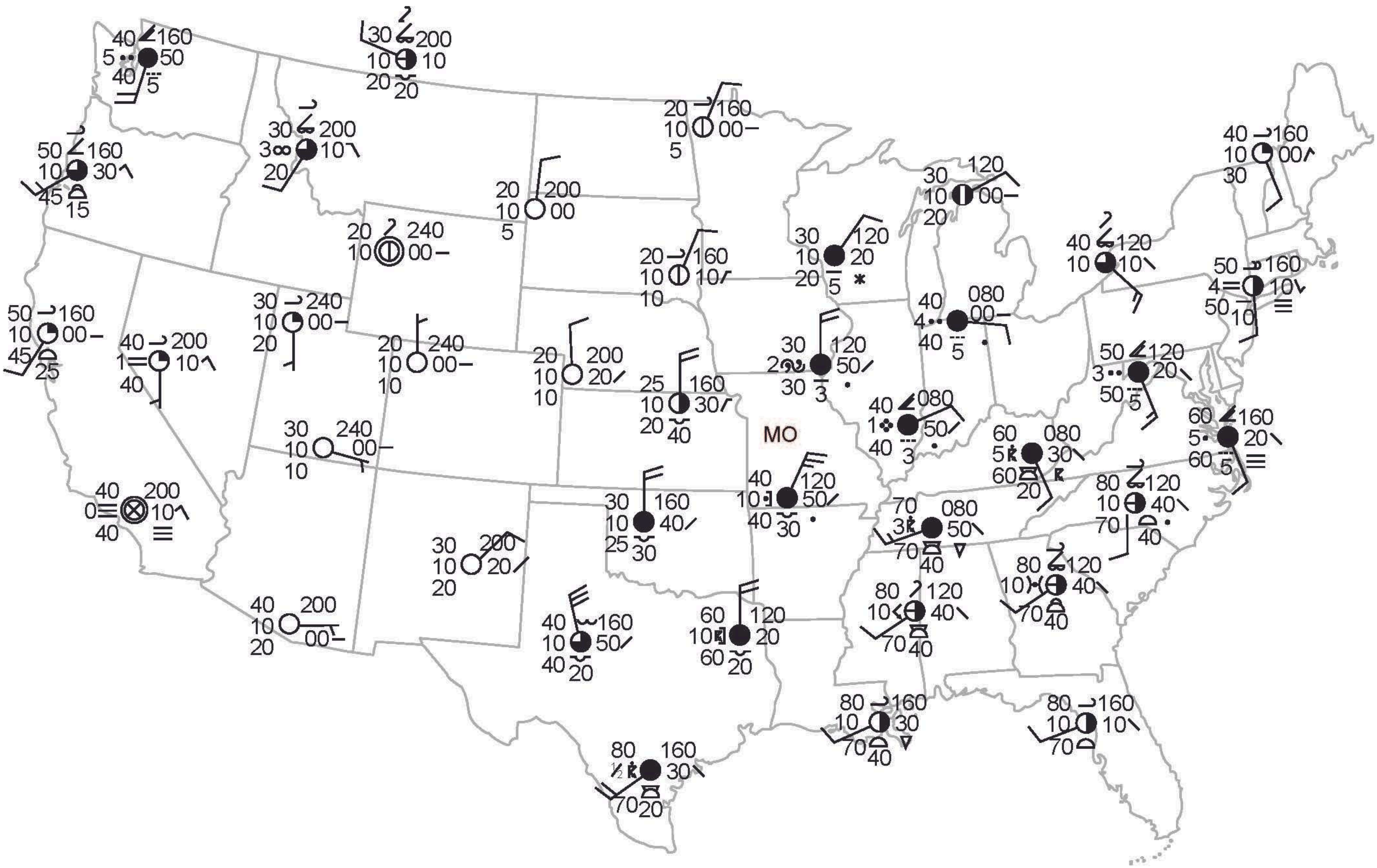



50

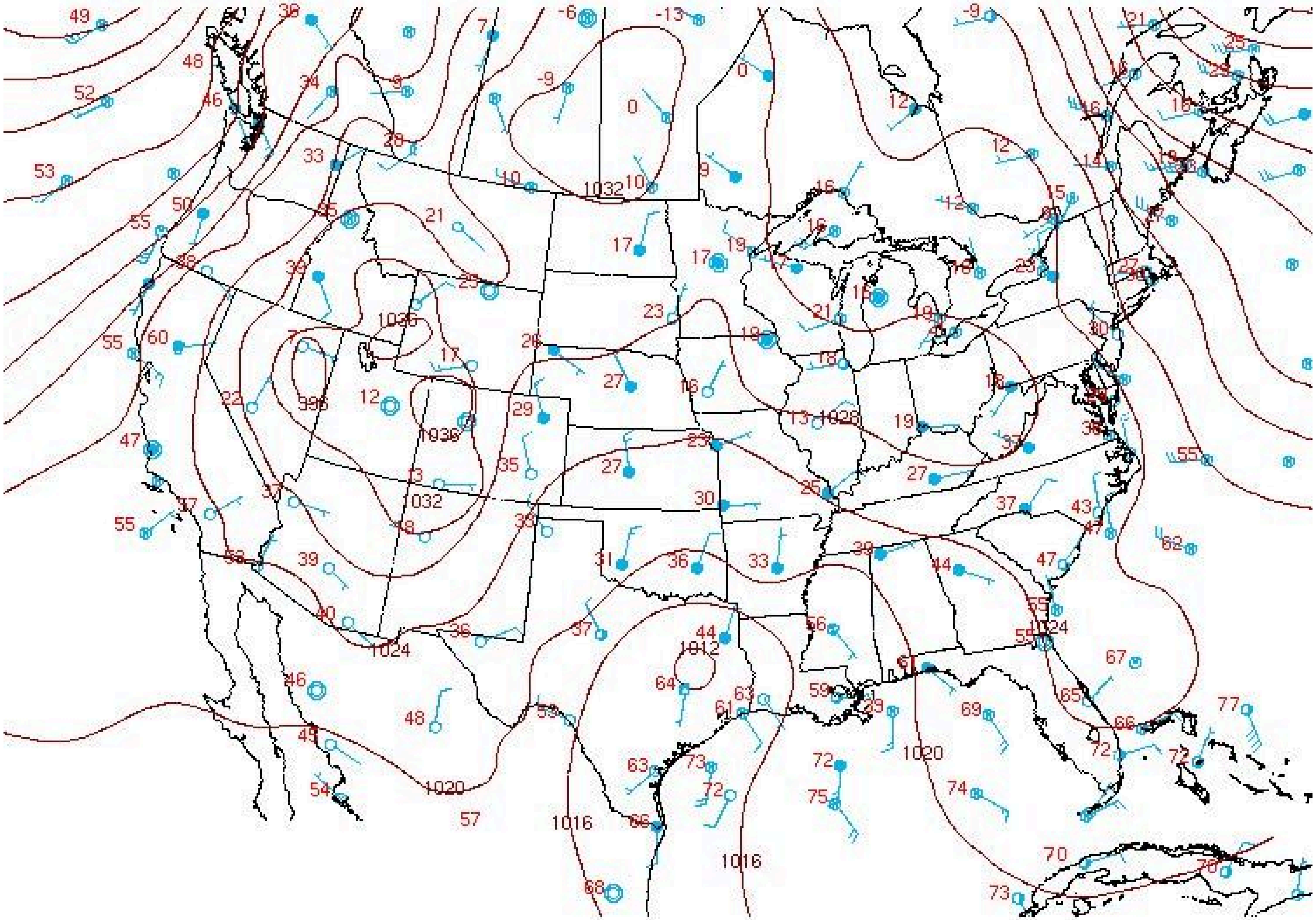
4. Air Pressure Change Map



5. Surface Observation Map



Winter Storm Jonas: Jan 21, 05 UTC - Surface Analysis Map



# The Paths of Severe Storms 5E	How do severe winter storms form? What causes wind and precipitation?	**Performance Expectations** HS-ESS2-8	**Investigative Phenomenon** Maps from 2018-2020 show that blizzards and hurricanes exhibit clear patterns in where they start and the direction in which they travel.	**Time** 6-11 days

Where storms land has a big impact on how much damage they do, and may change as global temperatures rise. By determining how global wind patterns influence storm paths, students are able to construct arguments about how the frequency of winter storms will change in their regions as global temperatures rise.

ENGAGE	What do students know about why we see patterns in the location blizzards and hurricanes form and in their trajectories?	The teacher has students revisit the **blizzard** and **hurricane** trajectory maps from the anchor phenomenon launch and asks students to share their initial ideas about what might explain the **patterns** in the location and trajectories for each type of storm.
EXPLORE 1	Students explore air surface temperature and intensity of solar insolation	Students **use empirical evidence** from **models** to identify the relationship between **patterns** of **global surface air temperature averages** and **intensity of insolation**.
EXPLAIN 1	Students identify and explain where different air masses originate	Students use patterns of **global surface air temperature averages, intensity of insolation**, and **underlying physical science concepts** to **construct explanations** for what **causes properties of air masses** that form in different regions.
EXPLORE 2	Students investigate global movement of air	Students **use empirical evidence** from **global winds models** to identify relationships between **patterns** of **air movement, air pressure**, and **precipitation**.
EXPLAIN 2	Students explain patterns of global wind and precipitation	Students use patterns of **atmospheric movement** and underlying physical science concepts to **develop a model** for what **causes global wind and precipitation** patterns.
ELABORATE	Students apply their learning about global winds to explain and make predictions about storm trajectory	Students **construct an explanation** for what causes **air masses** to move and meet each other over the US so often and what causes **patterns in blizzard and hurricane trajectories** using their understanding of **global wind** patterns. Students then **make predictions** about the trajectory of Winter Storm Jonas (2016).
EVALUATE	How does this connect to the Performance Task?	Students **develop a model based on evidence to illustrate cause and effect relationships** during blizzard formation, in order to make predictions about how **global temperature increase will affect the frequency and intensity of blizzards**.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

What do students know about why we see patterns in the location blizzards and hurricanes form and in their trajectories?

The teacher has students revisit the **blizzard** and **hurricane** trajectory maps from the anchor phenomenon launch and asks students to share their initial ideas about what might explain the **patterns** in the location and trajectories for each type of storm.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Independent	❏ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Blizzard and hurricane trajectory maps from the anchor phenomenon launch	None	❏ Post-its

Instructional Sequence

1. Revisit the 2018-2020 blizzard and hurricane trajectory maps from the Anchor Phenomenon launch during the Unit Opening and questions students had about why the storms exhibit a pattern of starting in a particular region and having a similar trajectory.
2. Ask students to consider what they have learned about how severe winter storms form and independently brainstorm their initial ideas about what might explain the patterns in the location and trajectories for blizzards and hurricanes. Then have each student decide which one idea they feel most confident about and write it on a post-it.
3. Set up the group learning routine **RUMORS** to elicit student ideas. Students use this group learning routine to voice and exchange their ideas about what causes the patterns we saw in blizzard and hurricane origin and trajectory.

Look & Listen For

Possible student ideas that can be used to transition to the next phase(s):

- I think that where storms start is where warm moist air masses and cold dry air masses exist and meet
- I think where the storms take place has something to do with temperature
- I think where the storms take place has something to do with geography
- I think their trajectory has something to do with differences in pressure
- I think their trajectory has something to do with global winds

4. Students may not surface all the ideas above and that’s ok at this point. Let them know that they will have a chance to test their ideas and change or refine them as they carry out an investigation about blizzard and hurricane origin and trajectory.
5. Reflect on student ideas and plan accordingly based on student understandings, incomplete ideas, and misconceptions. As you go through the 5E, either check ideas that the class thinks are more correct or cross off ideas they don't think are true anymore.

Explore 1

Students explore air surface temperature and intensity of solar insolation

Students **use** **empirical evidence** from **models** to identify the relationship between **patterns** of **global surface air temperature averages** and **intensity of insolation**.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs	❏ Elbow Exchange + Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Air Masses Investigation	None	❏ Computers ❏ Explore the Effect of the Angle of Incidence on Sun's Energy

Instructional Sequence

1. Begin by pointing to students' ideas that surfaced in the Engage Rumors activity related to warm moist air masses meeting cold dry air masses meeting over the US and North Atlantic. Tell students they will be conducting an investigation about what the air is like around the US and North Atlantic that could help us explain why we see so many blizzards here so they can refine their initial thinking from the Engage phase. And that later they will have an opportunity to conduct a more in depth investigation specifically about hurricanes.
2. Launch students into working on *Air Masses Investigation* using the simulation Explore the Effect of the Angle of Incidence on Sun's Energy .
3. Confer with students as they work in collaborative groups.

Conferring Prompts

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

- What patterns do you see in the temperature and latitude data?
- What patterns do you notice in the 'Energy from the Sun' data and the 'Energy on Earth' data?
- What patterns do you notice in the way the sunlight hits the Earth at different latitudes? What patterns do you notice in the spread (or concentration) of the sunlight hitting the Earth?
- Do you see any connections between the patterns in the spread of sunlight and the data that you recorded about 'Energy on Earth' in the table above?

4. Have each student complete a See-Think-Wonder to help them articulate their ideas so far. Elicit student ideas through the group learning routine, Domino Discover.

Look & Listen For

These student observations and ideas are critical to students' success during the Explain phase:

- There is a pattern of temperatures being highest at the equator and decreasing as you move away from the equator in either direction.
- There is a pattern of the amount of energy reaching the Earth at various latitudes being highest at the equator and decreasing as you move away from the equator in either direction.
- There is a relationship between the amount of energy reaching Earth at and the temperature at each latitude.

These possible student questions or similar questions can be used to transition to the next phase(s):

- Why do we see both cold and warm air masses at fronts if they meet at one particular latitude?
- What makes some air masses warm and moist and some cold and dry?
- Where do the different types of air masses come from?

5. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Explain 1

Students identify and explain where different air masses originate

Students use patterns of **global surface air temperature averages, intensity of insolation**, and **underlying physical science concepts** to **construct explanations** for what **causes properties of air masses** that form in different regions.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Individual or pairs ❑ Groups of 3 for Think-Talk-Open-Exchange	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Explaining Air Mass Origins	None	❑ Post-its

Instructional Sequence

1. Remind students about their questions regarding the characteristics of different air masses and where they come from. Let students know that they will now have a chance to apply all the ideas they surfaced during the previous investigation to explain how different air masses get their characteristics and where they come from.
2. Provide students with the handout, *Explaining Air Mass Origins.*

Have students read the Defining Air Masses section and summarize what they read on the handout, then have several students share what they learned from the reading.

Tell students that they will now be trying to explain why interactions between cool, dry air masses and warm, moist air masses tend to happen so much in the US, starting with explanations for the types of locations where the different types of air masses are formed.

3. Have students complete *Explaining Air Mass Origins.*

Access for All Learners

Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context, which may be particularly helpful for **transitioning** language learners, who already have some mastery of language.

Implementation Tip

Be sure to ask students to reflect briefly on their experience when developing a causal mechanism for wind, clouds, and rain formation. Ask students to share what they might consider when making claims about the formation of air masses with different properties. Listen for students to say they will consider what is happening at the molecular level and the interaction between energy and matter. This will support students in using these important elements of **CCC # 2 Cause & Effect** and **CCC # 4 Systems & Systems Models** when making sense of the origin of different types of air masses and other phenomena they investigate in the future.

4. Facilitate the Group Leaning Routine, Think-Talk-Open Exchange. Students should discuss the prompts below based on their claims in the *Claims About the Origin of Air Masses* table.
   - Where does each of the four types of air masses form? Why?
   - How might this help us explain why blizzards tend to form so much in the US?
   - What remaining questions do you have about what explains the patterns in the location and trajectories of these storms in the US?

Look & Listen For

These student ideas are critical to students' success during the next phase(s):

- Air masses take on the characteristics of the region where they form
- Cool moist air masses form in the northern latitudes over large bodies of water.
- Cool dry air masses form in the northern latitudes over land.
- Warm moist air masses form in the southern latitudes over large bodies of water.
- Warm moist air masses form in the southern latitudes over land.
- Cool dry air masses from the north and warm moist air masses from the south must somehow be moving toward the US and colliding there.

These possible student questions or similar questions can be used to transition to the next phase(s):

- What is causing these air masses to meet over the US? Why are they moving there?
- What is causing the blizzards to move in the patterns we see?
- What is causing the patterns we see in the location of hurricane formation and trajectory we see in the North Atlantic?

5. If students don't surface any of the important ideas named in the Look and Listen For, direct students back to appropriate data maps and use conferring questions to support them in surfacing these ideas before moving on, as they will be key to success in the phases that follow.

Explore 2

Students investigate global movement of air

Students **use empirical evidence** from **global winds models** to identify relationships between **patterns** of **air movement, air pressure**, and **precipitation**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	❑ Elbow Exchange + Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Global Movement of Air Investigation	❑ 1 Balloon ❑ 3 permanent markers of different colors	❑ Global Winds Animation

Instructional Sequence

1. Remind students about their questions regarding what is causing air masses to move and meet over the US and NA and what is causing storms they observed in the storm trajectory maps. Tell students they will be conducting an investigation that will help them further understand what causes air masses to move and meet each other over the US so often and why we see patterns in the trajectories of storms.
2. Launch students into working on *Global Movement of Air Investigation, Part 1.*
3. Confer with students as they work in collaborative groups.

Integrating Three Dimensions

The *Reliability of the Model Questions* are intended to make **CCC #4 Systems and Systems Models** more explicit for students, specifically that models inherently make assumptions and approximations, an important element of **CCC #4 Systems and Systems Models** at the high school level. This idea will be important as they consider the reliability of the global climate models they use to make predictions about the future of severe storms.

Conferring Prompts

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

Video: 'Idealized Hadley Cell Circulation'

- What do you notice about the air at the equator? What have you learned previously that might explain this?
- What do you notice about the air at 30° N and 30° S? What have you learned previously that might explain this?

Video: 'Develop Tropical and Midlatitude Components' and 'Develop High Latitude Components'

- Which latitudes does air moving across Earth's surface move away from? What have you learned previously that might explain this?
- Which latitudes does air moving across Earth's surface move toward? What have you learned previously that might explain this?
- What else (curves right in the northern hemisphere and left in the southern hemisphere) do you notice about the movement of air moving across Earth's surface? What have you learned previously that might explain this?

Table 3:

- Have students use their observations from the video, their completed diagrams of global wind circulation based on the video, and the cross-section model of Earth's lower atmosphere (for New York teachers, this diagram is from the ESSRT page 19) to complete the table

After filling out Table 3

- What patterns do you see in relationships between variables in the table? What do you think explains these patterns?

4. Ensure students have completed their See-Think-Wonders to help them articulate their ideas so far. Elicit student ideas through the group learning routine, Domino Discover

Look & Listen For

Look and Listen For
These student observations and ideas are critical to students' success during the Explain phase:

- Air rises at the equator
- I think air rises at the equator because it receives the most energy from the sun and that causes the density to decrease, so they air rises
- Air sinks at 30° N and 30° S
- I think air sinks at 30° N and 30° S because at that point it is at a high altitude which is lower temperature, so its density decreases and that causes the air to sink to Earth's surface again
- The air at Earth's surface moves away from latitudes that are higher pressure and toward latitudes that are lower pressure
- I think the air moves from higher pressure to lower pressure because the air particles at high pressure are denser and can more easily move through the less dense particles at low pressure
- The air wind curves to the left in the northern hemisphere and to the right in the southern hemisphere
- I think this might be because the Earth is spinning

These possible student questions or similar questions can be used to transition to the next phase(s):

- What explains these overall global patterns of air flow and precipitation?
- Do these wind patterns affect the movement of air masses?
- Does this explain why warm moist air masses and cool dry air masses meet over the US and NA?
- Is this why blizzards and hurricane paths curve?

5. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.
6. Distribute the balloons and markers, and direct students to turn to *Part 2. Why does air curve as it moves north and south?* In pairs, students follow the procedure and complete the analysis questions.
7. Ask a few groups to share their claims and predictions about the spin of tropical cyclones based on their responses to the *Analysis of Observations Questions*.

8. Finally, ask a few groups to share their ideas about the reliability of the model based on their responses to the *Reliability of the Model Questions*.

Explain 2

Students explain patterns of global wind and precipitation

Students use patterns of **atmospheric movement** and underlying physical science concepts to **develop a model** for what **causes global wind and precipitation** patterns.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Individual or pairs ❏ Groups of 3-4 for Idea Carousel	❏ Idea Carousel ❏ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Explaining Global Wind Patterns ❏ Summary Task	None	❏ Chart Paper ❏ Sticky notes ❏ The coriolis effect and winds (0:32-2:20) ❏ Coriolis Carousel (0:00-5:28)

Instructional Sequence

1. Remind students about their questions regarding what explains the patterns of global air movement and precipitation, and patterns of wind movement explains why air masses meet to form blizzards over the US and NA, and why we see a pattern in the trajectory of both blizzards and hurricanes.
2. Tell students that they will now refine their understanding of the patterns they observed during the Explore 2 phase, as a first step in answering their remaining questions about what causes air masses to move and meet each other over the US so often and why we see patterns in the trajectories of storms.
3. Have students complete *Explaining Global Wind Patterns*, parts 1 and 2

Classroom Supports

Post the steps to the Class Consensus Discussion in the room as a reference you can return to in future lessons.

Implementation Tip

This is an opportunity to assess whether students will consider what they know about molecular scale mechanisms and the interaction between energy and matter in order to develop a causal mechanism for phenomena at an observable scale and include these ideas in their models. If groups are not incorporating these concepts, prompt them to do so by referencing prior experiences in this unit. This will support students in using this lens for **CCC # 2 Cause & Effect** and **CCC # 4 Systems & Systems Models** when making sense of the phenomenon of global wind and precipitation patterns and other phenomena they investigate in the future.

4. After students have described the bending pattern to global winds in Part 2, pause the class for a classwide discussion of the Coriolis effect. Tell students that the bending they observed in the balloon experiment and in the global winds model is due to a force called the Coriolis force, which causes moving objects and winds to appear to bend as they move around a rotating surface. You may choose to show videos to assist with that explanation. The video The coriolis effect and winds shows how the coriolis effect impacts global winds (don't show past 2:20; the video goes on to explain how the coriolis effect impacts storms, but students will explain that for themselves in the next part), and the video Coriolis Carousel helps students conceptualize the force at smaller scales.

It is important that students leave the conversation understanding:

- The coriolis effect causes wind to bend towards the right in the northern hemisphere
- The coriolis effect causes wind to bend towards the left in the southern hemisphere
- The force is due to objects moving at different speeds relative to each other on a rotating globe

5. Have students complete *Explaining Global Wind Patterns,* parts 3 and 4
6. Have students work in groups of 3-4 complete a poster diagram (model) that includes causal mechanisms for the patterns they saw in the movement of air during the Explore 2 phase. This should include causal mechanisms for:
   - Why air rises at the equator and sinks at the 30° N and 30° S
   - The patterns they saw in wind direction and curvature
   - Why air sinks at the poles
   - Global precipitation patterns

Facilitate the group learning routine, Idea Carousel, to help students articulate their ideas and collaboratively complete their cause and effect models.

7. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:

"We have a lot of different ideas circulating in the room right now. It is really important for us to come to some agreement on how we represent what we know about the causal mechanism for global wind patterns so that we have a shared understanding to build upon as we move ahead. In order to do this, we are going to do something called a **Class Consensus Discussion**. First, I will select a few different groups to share their ideas. Then, we will let each group share their claim and discuss what we can agree to as a class."

You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to an agreement.

Implementation Tip

We recommend you do NOT just let students talk about their models aloud. Some classmates will need to see/read the claim to be able to follow up. A discussion with no visual component can exclude a number of students.

Select two or three groups' work to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of the causal mechanism for global wind patterns. The decision about which groups will share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence.

Ask the first group to share their explanation of how wind is formed. You can do this by:

- Projecting using a document camera; OR
- Copying the explanatory models to be shared and passing them out to the class; OR
- Taking a picture of each explanatory model and projecting them as slides.

Proceed through the steps in the Consensus Discussion Steps.

Before table groups confer, prompt them to consider how examining mechanisms at a molecular scale was helpful in figuring out a causal mechanism for global wind and precipitation patterns. Some prompts you might provide are:

- Where do our models illustrate what happens to air at the molecular level when heated and cooled? Are these ideas clear in our models?
- Where do our models illustrate what happens to water at the molecular level when heated and cooled? Are these ideas clear in our models?

During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.
Display the categories of ideas about what we know about the causal mechanism for global wind patterns that students generated during the Engage phase. Ask students if there are ideas on the class list that can be:

a. eliminated based on our investigation of the causal mechanism for global wind patterns;
b. changed based on our investigation of the causal mechanism for global wind patterns;

c. added based on our investigation of the causal mechanism for global wind patterns.
Modify the list of student ideas about the causal mechanism for global wind patterns based on student responses.

Implementation Tip

The prompts student groups confer about after groups present their work, are meant to make **CCC # 2 Cause & Effect** and **CCC # 4 Systems & Systems Models** more explicit for them, specifically ideas using molecular scale mechanisms in order to develop a causal mechanism for phenomena at an observable scale and using models to illustrate energy and matter flows within and between systems at different scales.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following **key points**:

- The region at and near the equator receives the most direct sunlight, warming air particles there, causing air to expand and become less dense, creating a pressure gradient which causes air to converge and be forced upward.
- As moisture in warm air rises it cools, causing it to condense and form clouds. This is where rain often occurs.
- The cool air reaches a natural (semi) barrier at the top of the troposphere and moves outward, then continues to cool and become denser, causing it to sink at 30° N and 30° S.
- Air reaches the poles at high altitudes and continues to cool and become denser, causing it to sink.
- The spin of the Earth as air moves across its surface causes the wind to bend towards the right in the northern hemisphere and towards the left in the southern hemisphere.

Return to student questions from the start of the 5E (the Engage), in order to bring up lingering issues not yet resolved, and new issues that have come up.

8. Have students complete the *Summary Task*.

Elaborate

Students apply their learning about global winds to explain and make predictions about storm trajectory

Students **construct an explanation** for what causes **air masses** to move and meet each other over the US so often and what causes **patterns in blizzard and hurricane trajectories** using their understanding of **global wind** patterns. Students then **make predictions** about the trajectory of Winter Storm Jonas (2016).

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Independent ❏ Groups of 3 for Read-Generate-Sort-Solve	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Elaborate Part 1: Explaining Patterns of Storm Origin and Trajectories ❏ Elaborate Part 2: Making Predictions about the Trajectory of Winter Storm Jonas ❏ Jan 23 3 UTC ❏ Jan 23 9 UTC ❏ Jan 23 15 UTC	None	❏ Visualizing pressure and water vapor in Winter Storm Jonas ❏ News Report: Anticipating Winter Storm Jonas

Instructional Sequence

1. Let students know that they will now apply their understanding of global wind patterns to explain what causes air masses to move and meet each other over the US so often and why we see patterns in the trajectories of storms. Launch students into working on *Elaborate Part 1: Explaining Patterns of Storm Origin and Trajectories*.

For New York State teachers, take time with the Model of Generalized Planetary Wind Belts in the Troposphere, found in question 3 of Part 1. This diagram is from the ESSRT, page 19, and shows a more nuanced model of global planetary winds. Help students compare this diagram to note similarities and differences between it and the global winds models they have seen before, and then use it to map paths of Atlantic tropical storms.

2. After students have completed *Elaborate Part 1: Explaining Patterns of Storm Origin and Trajectories*, surface student ideas using the group learning routine, **Domino Discover**.

Look & Listen For

Possible student ideas:

- Cold dry air that forms over land in the arctic is driven down to the US by global winds that move south west
- Warm moist air that forms over the ocean around 30°N is driven up to the US by global winds that move north east
- These two types of air masses tend to meet and form storms near the northwest region of the US
- Global winds that move north west drive the storms across the US with a curved path that moves north east
- Those same global winds that move north east from 30°N drive hurricanes to move northeast in a curved trajectory

3. Show the video, *News Report: Anticipating Winter Storm Jonas*. Ask students why they think it's important that we are able to understand storm formation to make predictions about the trajectory. Students are likely to say that it helps us know how and when to prepare for storms. If they do not, reference the video and ask probing questions that will help them reach that conclusion.
4. Have students revisit the Winter Storm Jonas: Jan 21, 2016 15 UTC - Surface Analysis Map from the Elaborate phase of the Blizzards 5E. Tell them that they will use what they have learned so far to make predictions about the trajectory of Winter Storm Jonas between Jan 21, 2016, and Jan 23, 2016.
5. Launch students into working on*Elaborate Part 2: Making Predictions about the Trajectory of Winter Storm Jonas*.
6. Show the video Satellite Video of Winter Storm Jonas Moving Across US (2:01-2:19), so that students can see the actual trajectory of Jonas through satellite video.

Evaluate

How does this connect to the Performance Task?

Students **develop a model based on evidence to illustrate cause and effect relationships** during blizzard formation, in order to make predictions about how **global temperature increase will affect the frequency and intensity of blizzards**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs/groups ❑ Independent	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ How will global wind patterns be affected by rising global temperatures? ❑ The Paths of Severe Storms 5E Arguing from Evidence Rubric ❑ Connect to the Performance Task: Paths of Severe Storms 5E	None	❑ *Connect to the Performance Task: Paths of Severe Storms 5E*

Instructional Sequence

1. At this point, students should be able to explain why mid-latitude cyclones become winter storms in the midwest / northeast. They should explain that winter storms frequently form over North America due to the southern moving polar air masses from Canada colliding with the warmer air masses in the mid-latitudes, and that they tend to move from Southwest to Northeast due to global wind patterns.
2. Provide students with the handout *How will global wind patterns be affected by rising global temperatures?* Have students work in pairs or groups of three to read the text, answer the questions, and then analyze the storm tracks maps below.
3. After students have completed the handout, engage them in a discussion about the patterns they saw in storm tracks and how those patterns would change if the westerlies move 5 degrees north.

Ask students: based on the overall patterns of which latitude bands would receive more or less storms, how would you expect storm frequency to change in your area? Then, prompt students to consider if the pattern for the band as a whole holds true for their area. As a class, count the number of storms passing through your area in each map, and then look in the band 5 degrees below to count how many storms would pass through if the westerlies moved 5 degrees north. Discuss if your specific area would see changes that reflect the expected changes across the whole country.

Note: it is okay if this activity does not produce perfectly clear answers. The answers may vary depending on which year's storm tracks students are looking at, interpreting this data by counting storms with precision is challenging, and the results may not be consistent. Prompt students to consider that this is a small sample size with no additional data. Engage students in a discussion about the fact that sometimes, we cannot get simple answers to questions, and unclear answers tell us that we would need to look for more information.

4. Independently, have students fill in the *Connect to the Performance Task: Paths of Severe Storms 5E* based on what they have learned from this 5E.

Provide students *The Paths of Severe Storms 5E Arguing from Evidence Rubric* so that they can use it to peer or self assess their response.

5. Revisit the driving question board in light of what they have just learned. They should use their explanations to think about how this information can help them revise their initial predictions AND what more they need to learn about (ex. they did NOT learn what specifically causes a hurricane).

Standards in The Paths of Severe Storms 5E

Performance Expectations

HS-ESS2-8 Clarification Statement:
Assessment Boundary:

This PE, added by NYS, is not in the NGSS: Evaluate data and communicate information to explain how the movement and interactions of air masses result in changes in weather conditions. [Clarification Statement: Examples of evidence sources could include station models, surface weather maps, satellite images, radar, and accepted forecast models. Emphasis should focus on communicating how the uneven heating of Earth's surface and prevailing global winds drive the movement of air masses and their corresponding circulation patterns, the interaction of different air masses at frontal boundaries, and resulting weather phenomena.] [Assessment Boundary: Analysis is limited to surface weather maps and general weather patterns associated with high and low pressure systems.]

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3) Analyzing and Interpreting Data • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. SEP4(1)	PS3.A Definitions of Energy • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. PS3.A(4)	Cause and Effect • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. CCC2(2) Systems and Systems Models • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. CCC4(3)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Developing and Using Models		See-Think-Wonder Claims About the Origin of Air Masses	See-Think-Wonder Patterns of Wind Flow and Precipitation on a Global Level Poster Diagram Summary Task	Making Predictions	Unit Performance Task
Analyzing and Interpreting Data		See-Think-Wonder			
PS3.A Definitions of Energy			Patterns of Wind Flow and Precipitation on a Global Level Poster Diagram Class Consensus Discussion		
Cause and Effect		See-Think-Wonder Claims About the Origin of Air Masses TTOE Discussion	See-Think-Wonder Patterns of Wind Flow and Precipitation on a Global Level Poster Diagram Class Consensus Discussion	Explaining Patterns of Storm Origin and Trajectories	Unit Performance Task
Systems and Systems Models		See-Think-Wonder Claims About the Origin of Air Masses	See-Think-Wonder Patterns of Wind Flow and Precipitation on a Global Level Poster Diagram		

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP.2	MP.2	MP.2	MP.2
ELA/Literacy		RST.9-10.7	RST.9-10.7	RST.9-10.7	RST.9-10.7

Student Work for The Paths of Severe Storms 5E

New Visions for Public Schools

Connect to the Performance Task: Paths of Severe Storms 5E

Apply what you figured out from the Paths of Severe Storms 5E to respond to the prompt below.

Will the frequency of winter storms per year where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable: Global Temperatures   Dependent variable: Frequency of winter storms

Part 2:
Gather evidence from the investigation and note it below.

What is the evidence?	Which resource did the evidence come from?
Winds are predicted to shift north by approximately 5°	The article "Will global warming bring a change in the winds?"
On average, fewer storms occur in the 5° latitude band below NY than in the 5° latitude band that includes NY	Maps of winter storm tracks in the evaluate lesson
NY is at ~40°N, and at that latitude, global winds carry warm air from the south up towards the north	The global movement of air investigation and explaining global winds
There is a low precipitation band at 30°N	Explaining global precipitation diagram

Part 3: Engage in an argument from evidence regarding whether the frequency of winter storms where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. You may use pictures to help illustrate your claims and support your reasoning. Consider the following:

- historical winter storm frequency data
- the conditions necessary for a winter storm to form
- relevant data from global climate models, such as projections of future temperatures
- the reliability of the models used to make predictions

As global temperatures increase, the frequency of blizzards in New York will decrease.

New York is at approximately 40°N. ~~At~~ that latitude, warm air moves north from southern latitudes because of global wind patterns, so as global temperatures rise, the air moving north will be even warmer, and less able to form snowstorms.

Additionally, scientists predict that eastern-moving winds will shift 5° further north. Currently, there is a low precipitation band at 30°N, which could shift north 5°, pushing more dry air north towards New York, and reducing precipitation. This idea is corroborated by maps of historical winter storm tracks. On average, the latitude band containing New York has more winter storms than the 5° latitude band below it. If the winds shift north by 5°, more storms could all be shifted north, therefore putting NY in an area with fewer storms.

However, this prediction is based on one idea about how winds could change as a result of rising global temperatures. If rising temperatures cause air in the poles to disrupt other global wind patterns, the impacts on NY may be different.

Hurricanes 5E

Hurricanes 5E	How do hurricanes form? Why do hurricanes exhibit patterns in the time of year they occur?	**Performance Expectations** HS-ESS2-5	**Investigative Phenomenon** In 2005, hurricanes occurred in the North Atlantic Ocean between June and November 30, just like the 2018 and 2020.	**Time** 5-6 days

ENGAGE	What do students know about hurricanes?	The teacher asks students to share their initial **explanations** about what **causes hurricanes** to form and what makes them stronger.
EXPLORE	Students look for patterns in location and time of year of hurricane occurrence	Students **analyze hurricane** data to **identify patterns** in frequency of hurricanes in **different regions during different seasons**, then make connections to **patterns** in **sea surface temperature** in different regions during different seasons.
EXPLAIN	Students explain patterns of hurricane location and seasons	Students **explain** patterns of **hurricane location and seasons** using concepts from the **causal mechanism** for hurricanes.
ELABORATE	Students use text to describe changes in precipitation due to global temperatures.	Students **analyze a text to explain** how the changes in **global temperatures** cause precipitation levels to change during storm events.
EVALUATE	Students connect their learning to the Performance Task	Students **develop a model based on evidence to illustrate cause and effect relationships** during hurricane formation, in order to make predictions about how **global temperature increase will affect the frequency and intensity of hurricanes**.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

What do students know about hurricanes?

The teacher asks students to share their initial **explanations** about what **causes** **hurricanes** to form and what makes them stronger.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Independent for assessment probe ❑ Whole class for Rumors routing	❑ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❑ Post-its ❑ Ensure that there is enough space for students to circulate around the room and talk to each other ❑ Rumors Directions ❑ Video: 2005 Hurricane Season (1:42-3:45)

Instructional Sequence

1. Begin by reminding students that while they have learned a lot about severe winter storms, they still have open questions about hurricanes (point to DQB). Then explain that similar to what we did with Jonas where we looked at one specific winter storm to help us explain winter storms in general, we take a look at one specific hurricane season to help us think about hurricanes in general.

Show students the *2005 Hurricane Season* video (1:42-3:45), providing the following guiding questions:

- What patterns do you see in where hurricanes form?
    - For example, what time of year do hurricanes tend to form?
    - For example, what part of the world do hurricanes tend to form?
- What patterns do you see in where hurricanes tend to die?

Note: When watching the video, it is important that students are aware that the sea surface temperature is indicated with color; the warmest sea surface temperatures are red, and the coldest are blue.

2. Have students share their responses with a partner or small group. Tell each pair or group that each person should be ready to share with the rest of the class.
3. Ask students from several pairs or groups to share some of their responses.
4. Pose the question: *What caused the patterns of location and time of year we observed from the 2005 hurricane season over the North Atlantic Ocean?* Tell students to independently jot down all their ideas to

the question based on the patterns that were surfaced from the video and what they already know about hurricanes.

Students can use the following sentence starters if they are helpful:

- Hurricanes form near the equator and die after moving north as a result of… I think this because…
- Hurricanes form between June and November as a result of… I think this because…

5. Teacher sets up the group learning routine **RUMORS** to elicit student ideas. Students use this group learning routine to voice and exchange their ideas about what causes a hurricane to form and what makes it stronger.

Look & Listen For

Possible student ideas:

- I think they form near the equator because the water is warmer and die after moving north because the water is cooler. I think this because all hurricanes formed where the water was color coded red and started dying or died when it was yellow and blue.
- I think the hurricanes occurred between June and November because it is warmer and the water is warmer.

6. Students may not surface all the ideas above and that's ok at this point. Let them know that they will have a chance to test their ideas and change or refine them as they carry out an investigation about the location where and time of year of the 2005 hurricane season.
7. Reflect on student ideas and plan accordingly based on student understandings, incomplete ideas, and misconceptions.

Explore

Students look for patterns in location and time of year of hurricane occurrence

Students **analyze** **hurricane** data to **identify patterns** in frequency of hurricanes in **different regions during different seasons**, then make connections to **patterns** in **sea surface temperature** in different regions during different seasons.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Groups of 3-4	❑ Elbow Share + Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ What Patterns Do We See in Global Occurrence of Hurricanes?	None	❑ Colored pencils ❑ Monthly Sea Surface Temperature

Instructional Sequence

1. Begin by referring to the ideas surfaced in the Engage phase about the 2005 hurricane season - students should have noted things related to the location and time of year of the storms being connected to warmer water temperature. Let them know that they will have an opportunity to investigate further in order to either confirm, refine, or change their ideas about what

Launch students into the investigation of hurricanes and blizzards task, using pages 2-5 of *What Patterns Do We See in Global Occurrence of Hurricanes?* and the corresponding Climate and Seasonal Variation Maps.

Note: Have students look at both Summer and Winter sea surface temperature maps in order to complete page 5. They should use a red or orange pencil to color the parts of the ocean where the water is the warmest during the Northern Hemisphere's summer and winter.

2. Confer with students as they work in collaborative groups.

Integrating Three Dimensions

Let students know that the maps were generated by a computational model based on over 150 data sets, and only data that was consistent across all datasets was used for the maps. There is no need for further discussion here, as this idea will be revisited later in order to address **CCC #4 Systems and Systems Models**, specifically that models inherently make assumptions and approximations, an important element of **CCC #4 Systems and Systems Models** at the high school level.

Conferring Prompts

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

Tropical Cyclones

- What patterns do you see in the location of tropical cyclones?
- What patterns do you see in the time of year that tropical cyclones occur?
- What patterns do you see in sea surface temperature throughout any given year?
- What relationship do you see between occurrences of tropical cyclones and climate (air surface temperature and sea surface temperature)?

3. Have each student complete 2-3 rows of the See-Think-Wonder to help them articulate their ideas so far. Elicit student ideas through the Group Learning Routine, Domino Discover with Random Reporter.

Look & Listen For

These student observations and ideas are critical to students' success during the Explain phase:

- Tropical cyclones occur near the equator in both the southern and northern hemisphere.
- Tropical cyclones occur during the warmer months in each hemisphere.
- The sea temperature is related to the air temperature in each hemisphere.
- Tropical cyclones occur at locations and the time of year that air and sea temperature is warmest.

These possible student questions or similar questions can be used to transition to the next phase(s):

- Why do tropical cyclones occur when the air and sea temperature is warmer?
- Does heat give the tropical cyclones their energy?

1. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Explain

Students explain patterns of hurricane location and seasons

Students **explain** patterns of **hurricane location and seasons** using concepts from the **causal mechanism** for hurricanes.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs ❏ Groups of 3-4 for Idea Carousel	❏ Random Reporter ❏ Think-Talk-Open-Exchange	None

Materials

Handouts	Lab Supplies	Other Resources
❏ What Explains Patterns of Hurricane Occurrence? ❏ Summary Task	None	❏ Poster paper and markers ❏ Slide: Hurricane Formation Diagram ❏ How Do Hurricanes Happen (0-1:17)

Instructional Sequence

1. Remind students of their questions about why warm water would cause hurricanes to form, cool water would cause hurricanes to die, and how hurricanes form. Tell them that In order to understand this more, you are going to show them a video and a diagram that include models of hurricane formation. Show them the video, How Do Hurricanes Happen up to 1:17, then show them the *Hurricane Formation Diagram*. Have students observe both with the following guiding question:
   - What is required for a hurricane to form and gain strength?

Note: It is important that students do NOT view the rest of the video, as it begins to discuss whether or not hurricanes will occur more frequently in the future, which is a prediction they should make on their own during the Evaluate phase of this 5E and as part of the unit performance task.

2. Ask students to share their responses to the guiding question with a partner. Then ask several pairs to share their thoughts about what is required for a hurricane to form and gain strength.
3. Have students work in pairs to complete part 1 of the *What Explains Patterns of Hurricane Occurrence?* handout, where they will revise the hurricane formation model diagram by including what is happening to water at the molecular level.
4. After students have completed part 1, have them revisit the location and seasonal patterns they surfaced during the Explore phase and complete part 2, where they will write a scientific explanation in response to the prompt: *What caused hurricanes from the 2005 hurricane season to form near the equator and die after moving north? Why did they form between June 1-Nov 30?*

Implementation Tip

This is an opportunity to assess whether students will consider what they know about molecular scale mechanisms in order to develop a causal mechanism for phenomena at an observable scale and include these ideas in their explanations. This will support students in using this lens for **CCC # 2 - Cause and Effect** when making sense of other phenomena in the future.

5. Use the Group Learning Routine, Think-Talk-Open Exchange, to help students articulate and share their explanations.
6. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:
   - "We are going to use a **Class Consensus Discussion**, just like we did a few days ago, to learn about all the thinking in the room. This time we are going to come to some decisions about what explains why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator June 1-Nov 30, and why they die after moving north, so that we have a shared understanding to build upon as we move ahead."
7. You may decide to walk students through the entire poster again, or take them through the steps as you facilitate it.

Classroom Supports

Post the steps to the Class Consensus Discussion in the room, as a reference you can return to in future lessons.

Access for Multilingual Learners

Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context, which may be particularly helpful for **transitioning** language learners, who already have some mastery of language.

Class Consensus Discussion Steps

10. We select a few different groups' ideas.
11. The first group shares out their work.
12. One person repeats or reiterates what the first group shared.
13. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

14. Everyone confers in table groups.
15. Engage in whole-class discussion about the ideas that were shared, in order to come to an agreement.

1. Select two or three groups' claims to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of what explains why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1 to Nov 30, and why they die after moving north. The decision about which claims to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence.

2. Ask the first group to share their claim. You can do this by:
    - Projecting using a document camera; OR
    - Copying the claims to be shared and passing them out to the class; OR
    - Taking a picture of each model and projecting them as slides.

3. Proceed through the steps in the Consensus Discussion Steps.

Implementation Tip

The prompts student groups confer about after groups present their work, are meant to make **CCC # 2 Cause & Effect** and **CCC # 4 Systems & Systems Models** more explicit for them, specifically ideas using molecular scale mechanisms in order to develop a causal mechanism for phenomena at an observable scale and using models to illustrate energy and matter flows within and between systems at different scales.

4. Before table groups confer, prompt them to consider how examining mechanisms at a molecular scale was helpful in explaining why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1 to Nov 30, and why they die after moving north. Some prompts you might provide are:
    a. As you were trying to explain why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1 to Nov 30, and why they die after moving north, what information from the model (diagram) of hurricane formation was most useful? Why?
    b. How was considering what happens to air and water molecules when heated and cooled helpful in explaining why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1 to Nov 30, and why they die after moving north?

5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following **key points**:

- Sea surface water in the Northern Hemisphere is warmest at the equator from June 1-Nov 30.
- Hurricanes get their energy from rising moist air.
- Since sea surface water in the Northern Hemisphere and air above it is warmest at the equator from June 1-Nov 30, this causes water to evaporate more and rise up with warm, less dense air, providing sufficient energy for hurricanes to form and get stronger.
- When hurricanes move north to cooler water, they no longer have sufficient energy because not enough water is evaporating.

6. Display the categories of ideas that students generated during the Engage phase about why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1-Nov 30, and why they die after moving north. Ask students if there are ideas on the class list that can be:
   - eliminated based on our investigation of why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1-Nov 30, and why they die after moving north;
   - changed based on our investigation of why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1-Nov 30, and why they die after moving north;
   - added based on our investigation of why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1-Nov 30, and why they die after moving north.

7. Modify the list of student ideas about why the most frequent occurrence of hurricanes in the Northern Hemisphere is near the equator from June 1-Nov 30, and why they die after moving north, based on student responses.

8. Return to student questions from the start of the 5E (the Engage), in order to bring up lingering issues not yet resolved, and new issues that have come up.

9. Have students complete the *Summary Task*.

Elaborate

Students use text to describe changes in precipitation due to global temperatures.

Students **analyze a text to explain** how the changes in **global temperatures** cause precipitation levels to change during storm events.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ What is happening to precipitation as global temperatures rise?	None	❑ More than 100 dead in devastation and flooding after Hurricane Helene (0-1:50)

Instructional Sequence

1. Remind students that, so far, we have been discussing hurricane frequency and winds, but we haven't discussed precipitation from them. Ask students if they have experienced flooding or damage from big storms. Show students the *Video:* More than 100 dead in devastation and flooding after Hurricane Helene . Ask students what caused the damage during the hurricane.
2. Introduce the handout *What is happening to precipitation as global temperatures rise?* Have students work in pairs or individually to read the text, analyze the map, and answer the analysis questions.
3. Ask students to discuss the prompt in their groups: Why do we need to consider rainfall in addition to intensity when we discuss hurricane conditions, and how has it been changing?

Elicit student ideas through the Group Learning Routine, Domino Discover with Random Reporter.

Look & Listen For

Possible student ideas:

- Hurricane "intensity" only refers to wind speed
- Damage is also caused by rain
- Precipitation has increased during the biggest storms since 1958
- Increased precipitation during storms does not mean increased annual precipitation

Evaluate

Students connect their learning to the Performance Task

Students **develop a model based on evidence to illustrate cause and effect relationships** during hurricane formation, in order to make predictions about how **global temperature increase will affect the frequency and intensity of hurricanes**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Independent or pairs	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ What is the Future of Tropical Cyclones? ❑ Final Argument Rubric ❑ Connect to the Performance Task: Hurricanes 5E	None	❑ IPCC WGI Interactive Atlas ❑ *Connect to the Performance Task: Hurricanes 5E*

Instructional Sequence

1. Provide students with the handout *What is the Future of Tropical Cyclones?* Have them work in pairs to complete Part 1. Support students as they analyze the graphs to determine patterns surrounding frequency and intensity of hurricanes.
2. When students are done with Part 1, assist them to access the IPCC WGI Interactive Atlas and begin Part 2. The instructions direct them to select hurricane seasons and regions, and then explore different variables, including average sea surface temperature and precipitation. If students are stuck, suggest that they view maximum 1 day precipitation, total precipitation, and/or surface wind speed. Advanced students may choose to explore different modeling scenarios or datasets as well.

Implementation Tip

The performance task is another opportunity to assess **CCC # 2 Cause & Effect** and **CCC # 4 Systems & Systems Models**, specifically ideas using molecular scale mechanisms in order to develop a causal mechanism for phenomena at an observable scale and using models to illustrate energy and matter flows within and between systems at different scales.

Additionally, students are asked to reflect on how assumptions used to develop the global climate computational model may impact its reliability and therefore their predictions, another important element of **CCC # 4 Systems & Systems Models**.

3. Have students read the text *Reliability of Models Based on Assumptions* and answer the two questions.
4. Guide students to work on the *Connect to the Performance Task: Hurricanes 5E*. Students should use what they have learned about the trends in hurricane and winter storm frequency and intensity to inform their predictions about what will happen to hurricane and winter storm frequency and intensity in the future.

Encourage students to consider their explanations for patterns of hurricane location and seasons when developing their models and making predictions about hurricane frequency and intensity in the future.

Standards in Hurricanes 5E

Performance Expectations

HS-ESS2-5 **Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.**
Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations could include stream transportation (erosion) and deposition using a stream table, infiltration and runoff by measuring permeability and porosity of different materials, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations could include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3) Analyzing and Interpreting Data • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. SEP4(1) Constructing Explanations and Designing Solutions • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. SEP6(1)	ESS3.D Global Climate Change • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. ESS3.D(1) PS3.A Definitions of Energy • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. PS3.A(2) • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. PS3.A(4)	Cause and Effect • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. CCC2(2) Systems and Systems Models • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. CCC4(3) • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. CCC4(4)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models			What Explains Patterns of Occurrence? Summary Task	Why do Tropical Cyclones Spin?	Unit Performance Task
Analyzing and Interpreting Data		See-Think-Wonder			
Constructing Explanations and Designing Solutions	Rumors		What Explains Patterns of Occurrence?		
ESS3.D Global Climate Change					Unit Performance Task
PS3.A Definitions of Energy			What Explains Patterns of Occurrence? Class Consensus Discussion		Unit Performance Task
Cause and Effect			Class Consensus Discussion Summary Task		Unit Performance Task
Systems and Systems Models			What Explains Patterns of Occurrence?	Why do Tropical Cyclones Spin?	

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP.2 HSN.Q.A.1	MP.2	MP.2 HSN.Q.A.1	MP.2 HSN.Q.A.1
ELA/Literacy		RST.9-10.7	RST.9-10.7	RST.9-10.7	RST.9-10.7

Student Work for Hurricanes 5E

New Visions for Public Schools

Connect to the Performance Task: Hurricanes 5E

Choose one of the two tasks below and apply what you figured out from the Hurricanes 5E and the Paths of Severe Storms 5E to complete the task. Each task involves the following:

- identifying the independent and dependent variable in the task prompt
- developing a model for how climate change will impact hurricanes in your region in the future based on evidence from the investigation
- writing an argument based on evidence for how climate change will impact hurricanes in your region in the future based on evidence from the investigation

Task 1 Prompt
Will the frequency of hurricanes per year where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable: Global Temperatures   Dependent variable: Frequency of Hurricanes

Part 2:

1. Gather evidence for what will happen to the independent variable you indicated above and note it in the table below.

What is the evidence?	Which resource did the evidence come from?
Historical data shows an increase in hurricanes in the NY region	The observed change in frequency of tropical cyclones shows increasing hurricanes in the Atlantic basin
As global temperatures increase, water temperatures increase	The IPCC interactive shows that water temperatures are expected to increase
As water temperatures increase, more warm water evaporates, increasing potential precipitation	The explain hurricanes model shows that warm water is evaporating

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2. Review the model for how a hurricane forms from the investigation, then develop a model that illustrates what you think will happen to the frequency of hurricanes per year where you live based on evidence regarding the independent variable. Be sure to include:
   - how and why energy and matter flow within the storm system and relevant surrounding systems
   - small scale mechanisms that explain what you are representing at the macro scale

Modeling Frequency of Hurricanes in the Future

Global temperatures will increase, including in the NY area.

→

When temperatures rise, the water temperatures will increase as well, and have more energy

→

warm water evaporates more, and warm air holds more water

→

warm air rising creates low pressure zones, which creates wind cyclones of air filling the low pressure zone

→

wet air forms precipitation and the cyclone forms winds. Hurricane frequency increases.

→

Part 3: Engage in an argument from evidence regarding whether the frequency of hurricanes per year where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. Consider the following:

- historical hurricane frequency data
- the conditions necessary for a hurricane to form
- relevant data from global climate models, such as projections of future temperatures

In New York, where I live, hurricanes will likely increase in frequency as global temperatures ~~to~~ increase.

Hurricanes form when warm water evaporates, bringing high-energy molecules into the air, which fuel cyclones that form as air rushes in to fill the low-pressure zone that results; and the evaporated moisture forms precipitation.

Global temperatures are expected to rise, which will increase water temperatures, increasing water evaporation and the energy rising into the air. Therefore, hurricane frequency will increase. This prediction is corroborated by historical data, which shows an increase in tropical storms in the Atlantic basin over the past 40 years.

New Visions for Public Schools

Task 2 Prompt
Will the intensity of hurricanes where you live increase, decrease, or stay the same as global temperatures increase in the future?

Part 1: Identify the independent and dependent variable in the prompt above by writing them below.

Independent variable: Global Temperatures Dependent variable: Intensity of Hurricanes

Part 2:

1. Gather evidence for what will happen to the independent variable you indicated above and note it in the table below.

What is the evidence?	Which resource did the evidence come from?
Historical data shows an increase in category 4 and 5 storms since 1990; the number of category 4 and 5 storms went from 16 in 1975-1989 to 25 from 1990-2004 in the North Atlantic	The graph and data table of strong hurricanes from 1975-1989 and 1990-2004 and the graph from 1990-2020
Global temperatures are expected to rise, and as they rise, water temperatures will rise too	The IPCC interactive shows that water temperatures are expected to increase
warm water evaporation increases energy in the air, fuelling stronger wind intensity	The Explain hurricanes formation model shows that the energy that ~~comes from the~~ fuels hurricane winds comes from warm water

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New Visions for Public Schools

3 Review the model for how a hurricane forms from the investigation, then develop a model that illustrates what you think will happen to the intensity of hurricanes per year where you live based on evidence regarding the independent variable. Be sure to include:

- how and why energy and matter flow within the storm system and relevant surrounding systems
- small scale mechanisms that explain what you are representing at the macro scale

Modeling Intensity of Hurricanes in the Future

Global temperatures will increase, including in the New York area

→

When air temperatures rise, the water temperatures will rise too

→

When water evaporates, it carries energy into the atmosphere. Warmer water transfers more energy to the atmosphere

→

winds form as warm air rises and creates a low pressure zone, which air flows in to fill

→

With warmer, higher energy water evaporation, the resulting winds have more energy, ~~result~~ These winds are stronger, so the intensity is higher

→

Part 3: Engage in an argument from evidence regarding whether the intensity of hurricanes where you live will increase, decrease, or stay the same as global temperatures increase.

You must provide any evidence and scientific reasoning that supports your claim, and any evidence and scientific reasoning that supports a counterclaim. Consider the following:

- historical hurricane intensity data
- the conditions necessary for a hurricane energy to increase
- relevant data from global climate models, such as projections of future temperatures
- the reliability of the global climate model you used to make predictions

In New York, where I live, hurricane intensity will likely increase as global temperatures rise.

Hurricanes form when warm water evaporates, bringing high-energy molecules into the air. This energy fuels cyclones as air rushes in to fill the low-pressure zone caused by rising warm air. As temperatures rise, more energy is transferred to the air, causing stronger winds.

Global temperatures are expected to rise, which will increase water temperatures and cause the energy transfer to the air to increase. As a result, hurricane intensity will increase.

This prediction is corroborated by historical data, which shows the number of category 4 and 5 storms increasing from 1990-2020.

Unit Closing

Will there be more frequent and more intense severe storms in the future?

Performance Expectations
HS-ESS3-5

Anchor Phenomenon
It has felt like storms are getting worse. Does the data support that feeling, and will it continue?

Time
0-2 days

Now that students have investigated the factors that contribute to winter storm and hurricane formation, they are able to use information about warming temperatures to argue about how their regions will be impacted by climate change.

ANCHOR PHENOMENON	Will there be more frequent and more intense severe storms in the future?	Students generate more ideas about the potential frequency and intensity of severe storms in the future.
DRIVING QUESTION BOARD	Are there any questions we haven't answered?	Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.
PERFORMANCE TASK	How will storms change in our region as climate change continues?	Not every region will be impacted in the same ways, and not all types of storms will change in the same ways. What will happen in students' regions?

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

Will there be more frequent and more intense severe storms in the future?

Students generate more ideas about the potential frequency and intensity of severe storms in the future.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table Groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ None	None	

Generating Ideas about Anchor Phenomenon

1. Students return to the anchor phenomenon of increasing severe storms. They review their ideas about the causes of hurricanes and blizzards, past and present patterns in data, and what this data indicates about the potential for increasing frequency and severity of storms.

Driving Question Board

Are there any questions we haven't answered?

Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table Groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ None	None	❏ Driving Question Board

Revisit the Driving Question Board

Students return to the questions generated throughout the unit and reflect. What questions have been answered? Are there questions that we still need to investigate?

Note that not all of the students' questions will be answered at the end of the unit, and students may have generated entirely new questions. Depending on student interest and instructional time, prompt students to explore some of the unanswered questions independently.

Performance Task

How will storms change in our region as climate change continues?

Not every region will be impacted in the same ways, and not all types of storms will change in the same ways. What will happen in students' regions?

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table Groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ None	None	

Final Performance Task

1. Tell students that the future of storms is uncertain. Our data has suggested the trends in winter storms and hurricanes over time, but other factors may come into play that influence those trajectories.
2. Tell students that they will now prepare to conduct oral arguments about the future of storms in their regions.
3. Give table groups time to prepare their opinions about the future intensities and frequencies of hurricanes and winter storms in their region.
4. When students are ready, they can either present their arguments in groups or conduct a socratic seminar to debate the figure of storms in their regions.

Standards in Unit Closing

Performance Expectations

HS-ESS3-5 **Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.**
Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).
Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.

In NYS the clarification statement has been edited as follows: Examples of evidence could include both data and climate model outputs that are used to describe climate changes...

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). SEP8(5)	ESS3.D Global Climate Change • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. ESS3.D(1)	Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. CCC1(1) • Empirical evidence is needed to identify patterns. CCC1(5) Stability and Change • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. CCC7(2)

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Obtaining, Evaluating, and Communicating Information			Final Oral Argument	
ESS3.D Global Climate Change			Final Oral Argument	
Patterns			Final Oral Argument	
Stability and Change			Final Oral Argument	

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Mathematics				
ELA/Literacy				