Observing Monsoon Weather Patterns with TRMM Data

Lesson Overview:
Students will think about how we determine weather, on the ground and from satellites, and then go into detail about how satellites measure precipitation. Students will look at data from the TRMM (Tropical Rainfall Measuring Mission) satellite and compare monthly rain patterns the Eastern U.S. to those in India to observe the seasonal monsoon weather pattern. Then they will examine surface temperature data for the same are to develop an explanation of why those seasonal patterns occur. Finally, students will write a description of the patterns they noticed, how satellite data can help us visualize the data, and an explanation about why India has the weather patterns it does.

Learning Objectives:
- Students will understand how a satellite (specifically TRMM) collects precipitation data.
- Students will observe satellite data and describe the monsoon weather pattern of Southeast Asia compared to the eastern United States.
- Students will observe the Earth's surface temperature and use that data and their knowledge of winds to explain why the monsoon weather pattern occurs.

National Standards:
ESS2.D: The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

MS-ESS2-6. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. [Clarification atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]

From the Next Generation Science Standards, available at http://www.nextgenscience.org/

Background Information:
"The term 'monsoon' is derived from the Arabic word 'mausim' which means season. Ancient traders sailing the Indian Ocean and Arabian Sea used it to describe a system of alternating winds that blow persistently from the northeast during the winter and from the opposite direction, the southwest, during the summer. It is now well understood that seasonal reversals of wind direction occur because of temperature differences between the land and sea across all of the Tropics. There are many features in common to these summer monsoon circulations, but the most recognizable are the seasonal changes in rainfall patterns, both increases and decreases.

Billions of people in the tropics and subtropics rely on the summer sun to draw rain clouds off the oceans and onto the continents. For centuries, people have sown and harvested crops, bred livestock, and planned outdoor activities such as construction projects or hunting expeditions

according to a relatively well-defined set of calendar dates based on the arrival and departure of the monsoon rains.

In many countries the arrival of the summer monsoon rainfall is good news since it replenishes the waterways and provides a critical supply of water for agriculture and other economic concerns. However, occasionally the rains are excessive and can cause serious and life-threatening floods. At other times a weak monsoon can cause a drought to develop, leaving fields and waterways parched and dry. Since extreme weather conditions associated with monsoons, like floods and drought, occasionally wreak havoc on a region's economy and people, monsoons throughout the world need to be accurately understood and predicted by weather and climate models, so that scientists can anticipate upswings and downswings in the monsoon and help societies plan accordingly."

Text excerpted from: http://www.cpc.ncep.noaa.gov/products/outreach/Report-to-the-Nation-Monsoon_aug04.pdf

Materials:
-   Projector and screen or TV to show PowerPoint and animations
-   Optional: Color printouts of data for reference as they write the descriptions (see end of document)
-   Optional: Computers with Internet access for extend activities, especially those using MY NASA DATA

Engage: Using the *GPM Monsoon Weather Patterns and TRMM – PowerPoint*, start a discussion with students about how rain is measured (*slide 3-4*). Questions to guide the discussion: (see notes in the PowerPoint for possible answers)
-   How do you determine if it's raining outside?
-   How do you know if it rained yesterday? If it will rain tomorrow?
-   What if we want to know if it has rained in other places in the world?
-   Where does weather data come from?

Explain: Show students that the focus of this lesson will be satellite data, specifically the TRMM satellite (*slides 5-6*). Next, show students how the TRMM satellite (and soon its successor GPM - the Global Precipitation Measurement mission), collects data about precipitation from space (*slides 7-11*). The slides contain the basic outline – for more details about TRMM in general and the specific instruments, see http://trmm.gsfc.nasa.gov/overview_dir/background.html.

Show the video "TRMM at 15: The Reign of Rain" to explain the far-reaching applications TRMM has enabled for precipitation science (*slide 12*). Video link: http://gpm.nasa.gov/education/videos/trmm-15-reign-rain. When the GPM core satellite launches in early 2014, it will increase the range and precision for precipitation measurements compared to TRMM (*slide 13*). The main GPM website is found at: http://ppm.nasa.goc/GPM For an animation of the satellites in the GPM constellation and how they work together to give a precipitation reading every three hours, go to: http://pmm.nasa.gov/video-gallery/global-precipitation-measurement-constellation

Explore:

Show students the visualizations of worldwide precipitation data (*slide 14*). Have them think about any patterns that they notice, and note them on the *GPM Monsoon Weather Patterns and TRMM Data – Student Capture Sheet* to discuss afterward.

Next show, students the animation of the precipitation data for just the Eastern United States (*slide 13*). Students may notice some minor seasonal differences, but for the most part there is no clear pattern, except for the mostly continuous belt of heavy rain off the east coast of the U.S.

Now that they have a baseline for comparison, students will look at an area of the globe with very distinct seasonal precipitation patterns: monsoons in India. Refresh their knowledge of the geography (*slide 16*), then show them the animation of TRMM data over India (*slide 17*). Students should be able to see quite clearly that India goes from very little rain over its land area, to very intense rain for a period of a few months, then back to little rain. The rain starts to come across the continent from the south in June, intensifying in July and August, and then beginning to retreat in September. The animation repeats the cycle several times, but it may be helpful to pause and point out the months, as the text may be hard to read from a distance.

Next, introduce the term monsoon (*slide 18*). On the slide, the image and word monsoon won't appear until you click, giving you a chance to elicit responses from students if they are familiar with the term. This is also an opportunity to ask students if they have any experience with monsoon rains in Southeast Asia or elsewhere. Click on the word monsoon for a link to a video of monsoon rains in Kerala, India, http://youtu.be/bETUbu7pXgs. Show students images of monsoon rain and the flooding it can cause (*slide 19-20*), followed by a map depicting the normal dates for the onset of the monsoon (*slide 21*), showing the progression of rain from the southeast toward the northwest which they should have observed in the animation.

Explain:

To understand what causes the monsoon, students will first need to review (or be taught) the cause of winds. Show them a short animation of air heating and cooling, changing the pressure, and images explaining how wind flows from high to low pressure (*slide 22*). For more information, see http://www.srh.noaa.gov/jetstream/synoptic/wind.htm.

Following the explanation of winds, students will look at animation of the Earth's surface temperature (*slide 23*). The animation plays through twice, both starting and ending with December monthly averages. Because of the way the images were created, during the first run-through, the scale adjusts slightly in each frame based on the range of temperatures depicted. This shows very clearly when the land is warmer than the ocean in summer months and cooler in the winter months, but gives a bit of a false impression of how much the sea surface temperature changes. The second time the animation plays through, the scale is consistent throughout, showing better that the ocean is not really changing temperature as quickly or as much as it appeared, but instead the land is warming and cooling much faster in comparison. This is a great opportunity to discuss the importance of paying attention to the scale or key when interpreting a graphical data display or map.

After a discussion of their observations of the data, you can follow up with a clip from NOVA: "Earth from Space" about monitoring Earth's water vapor (*slide 24*). The description from the PBS website, http://www.pbslearningmedia.org/resource/nves.sci.earth.vapor/monitoring-earths-water-vapor/: "In this video excerpt from NOVA: "Earth From Space," observe the global pattern of water vapor circulation and learn how it connects the Sun, oceans, atmosphere, and life. Animations show how satellites in geostationary orbit provide a global view of the movement of water vapor. As water vapor produced near the equator travels toward Earth's poles, it transports energy and creates weather. Variations in the topography of different regions result in different outcomes (for example, the Asian monsoon, an arid desert, or sweltering conditions)." The video's duration is 5:29 - the portion specifically dealing with monsoons runs from ~2:00 to 3:40.

Another video to support the discussion is from the BBC (*slide 25*), http://www.bbc.co.uk/learningzone/clips/monsoon-floods-in-pakistan-causes/10769.html: "Life in many parts of South Asia depends on the rains which arrive during the monsoon season. The monsoon of 2010, however, delivered exceptionally high rainfall across areas of northern Pakistan. This resulted in widespread flooding across the entire country in the days and weeks which followed. The report includes graphics and satellite images showing the size and development of the monsoon rains over the region. This clip was first published on BBC News Online on 2 August 2010. Please note this clip is only available in Flash." Duration 2:39

Finally, to bring it all together show a final diagram of the reason for monsoons (*slide 26*) and make sure students understand the concepts. An excellent summary can be found at http://www.nc-climate.ncsu.edu/edu/k12/.monsoons.

Evaluate:
Students will write a description of the patterns they saw in the TRMM data, and how that relates to the monsoon weather pattern (*slide 27*). The student directions from the PowerPoint are as follows:

- *Explain what you've learned about monsoons! Write a well-written paragraph or two describing why India has the weather pattern it does. Be sure to include:*
    - *What the weather pattern is called (monsoon!) and what the weather would be like if you lived there*
    - *Why a monsoon weather pattern occurs (hint: be sure you talk about seasons and changes in temperature of the land and ocean)*
    - *The patterns you saw in the satellite data for precipitation and surface temperature over India, and how that relates to the reason for monsoons*
    - *How a satellite (especially TRMM) collects data and how that helps us understand monsoons*

It may help students to be able to refer to the data from the animations. See the end of this document for several options to print out for their reference (could be laminated as reused as a class set), and a sample rubric to evaluate the final written description.

Elaborate/Extend:

- Use MY NASA DATA to retrieve TRMM data for specific years during El Niño and La Niña conditions, and compare the precipitation patterns in different regions. See the instructions later in this document about how to retrieve precipitation and surface temperature data maps using the Live Access Server. For more about El Niño and La Niña, see http://www.elnino.noaa.gov/. For a list of years with El Niño and La Niña effects, see http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml
- Read articles about the effect of monsoon timing and duration on the large number of people living in South Asia. One possibility: http://www.climate.gov/news-features/climate-current-events/late-monsoon-leads-drought-india
- Research done by a team at NOAA looked at whether aerosols and greenhouse gases released by humans into the air were responsible for an observed decrease in the South Asian summer monsoon. The abstract has some high-level vocabulary that students will need help with, but it's a good example of real, relevant scientific work being done. http://www.gfdl.noaa.gov/news-app/story.30
- Listen to an NPR news story about the effect of the monsoon weather pattern on the Southwestern U.S., http://www.npr.org/templates/story/story.php?storyId=12056315

Additional Resources:

- To learn more about the effects of the monsoon weather pattern in the southwestern U.S., see http://monsoonsafety.org/
- For an animation of the Asian-Australian monsoon with wind arrows and isobars, see http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/Asian_Monsoons.shtml

Directions to get maps of TRMM precipitation data using MY NASA DATA:

1. Go to https://mynasadata.larc.nasa.gov/live-access-server/ and click on the link for the Live Access Server (Advanced Edition).

2. Choose *Dataset > Atmosphere > Precipitation > Average Monthly Precipitation Climatology 1998-2010 (TRMM)*

   (If the window at right doesn't come up automatically, click the *Choose Dataset* button in the upper left.)
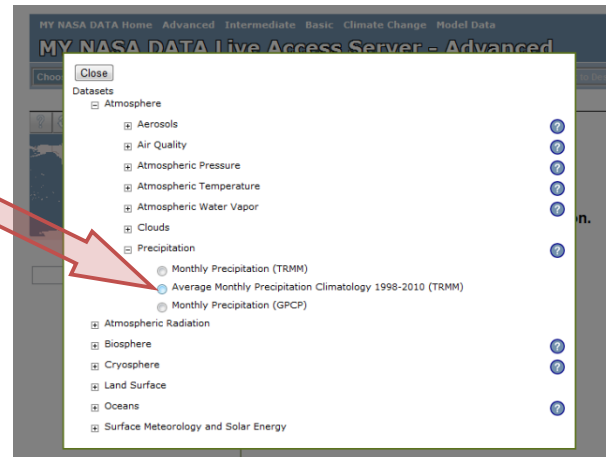
3. In the boxes by the compass, enter the latitude and longitude for the area for which you wish to see data (for example, the coordinates are for India). You should see a box appear at your location on the map. Choose *Latitude-Longitude* under *Maps*.
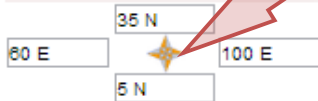
4. Click the *Update Plot* from the menu bar near the top, and your map should appear.
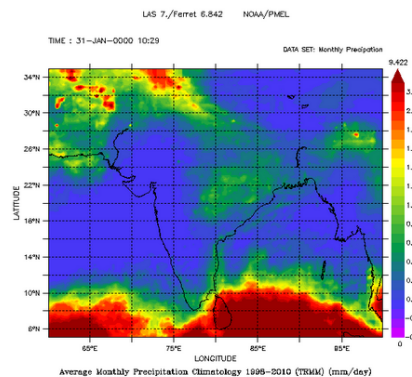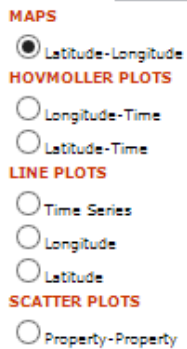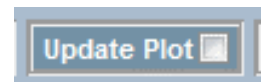
5. Change the drop-down box under *Data* to see data for other months (you'll need to click the *Update Plot* button each time, or check the box in the button for it to update automatically). You can also try to animate the yearly sequence, but the program is not always able to create the animation successfully.

Another useful data set:

→ In step 2, choose *Surface Meteorology and Solar Energy > Monthly Climatologies … > Monthly Climatology Earth Skin Temperature (SSE Release 6)*

Observing Monsoon Weather Patterns with TRMM Data

Look at the visualizations of precipitation data from different months below, collected by the Tropical Rainfall Measuring Mission satellite. Red and orange mean more precipitation, blue and purple mean less precipitation. What patterns do you notice in the data?
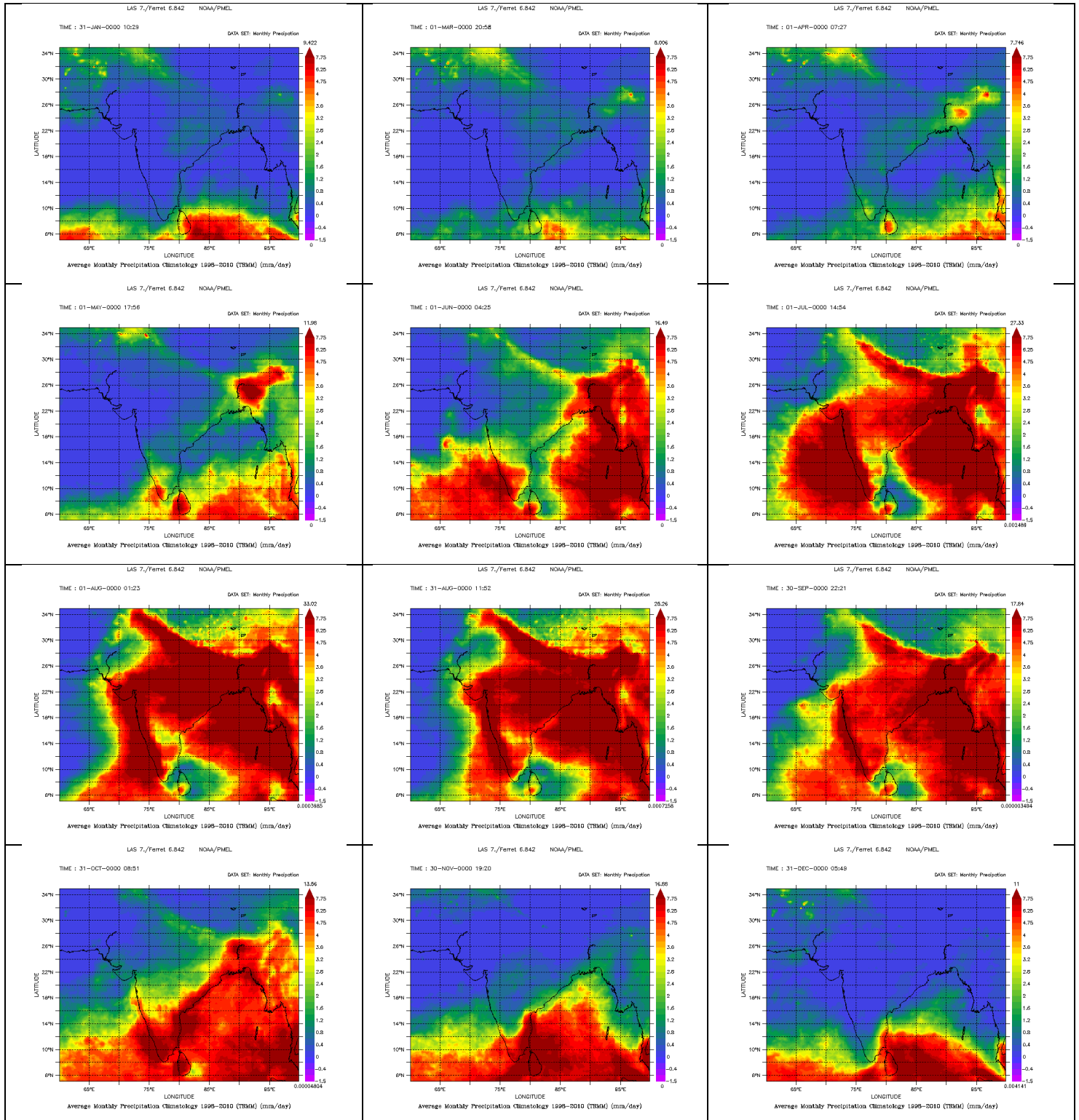

Data from the TRMM satellite, Average Monthly Climatology 1998 -2010
Retrieved from http://mynasadata.larc.nasa.gov/, Live Access Server (Advanced Edition)

Observing Monsoon Weather Patterns with TRMM Data

Use the visualizations of the Earth's skin surface temperature data from different months, plus your knowledge of winds and what creates them, to help develop your explanation for the monsoon weather pattern. Red and orange mean higher temperatures, blue and purple mean lower temperatures. What patterns do you notice in the data?
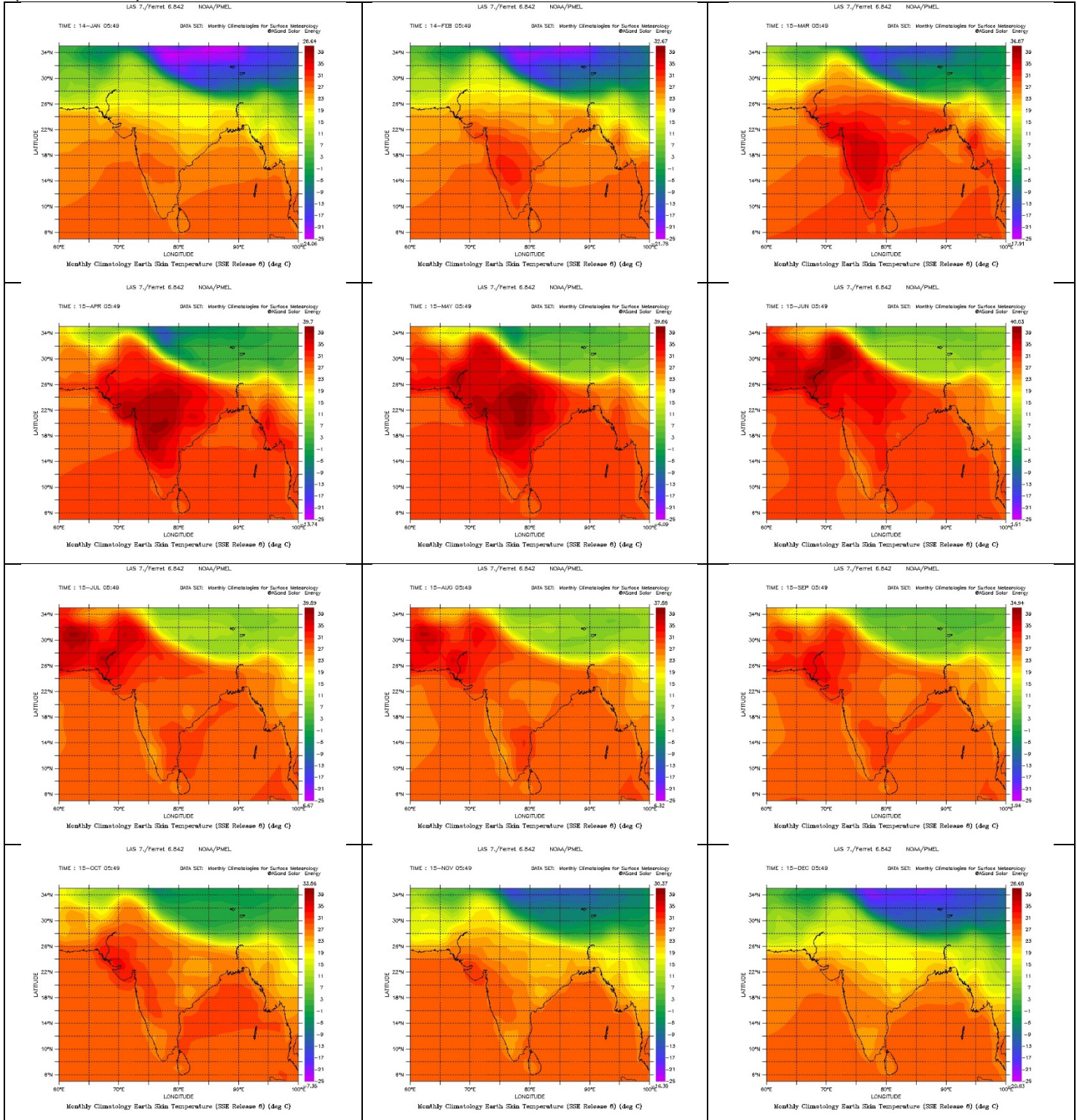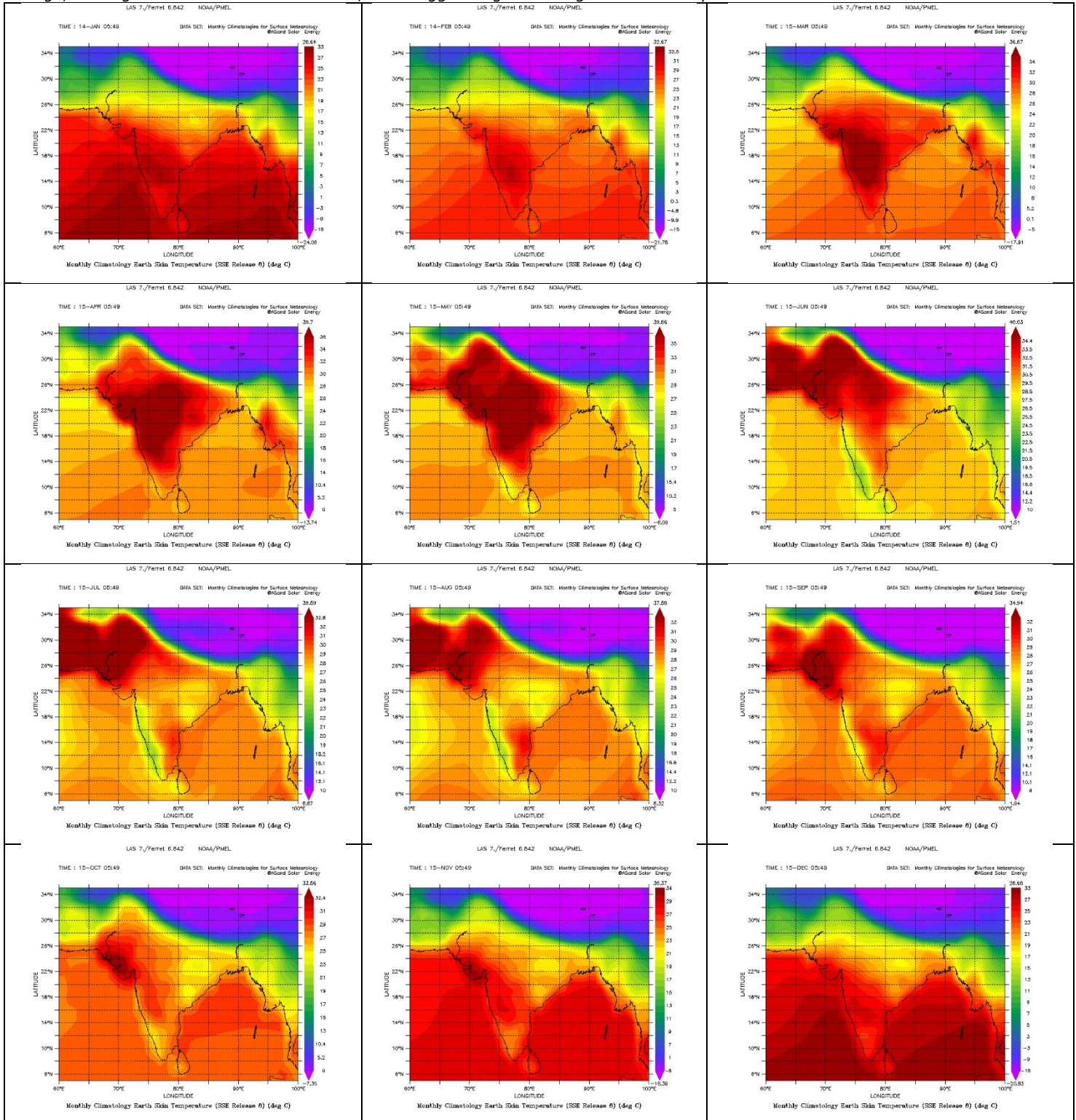

Data from the Monthly Climatology Earth Skin Temperatre (SSE Release 6)
Retrieved from http://mynasadata.larc.nasa.gov/, Live Access Server (Advanced Edition)

Observing Monsoon Weather Patterns with TRMM Data

Use the visualizations of the Earth's skin surface temperature data from different months, plus your knowledge of winds and what creates them, to help develop your explanation for the monsoon weather pattern. Red and orange mean higher temperatures, blue and purple mean lower temperatures. What patterns do you notice in the data? NOTE: The scale changes slightly based on the range of data in each particular data image, making the differences easier to see, but exaggerating the change in ocean temperature.

Data from the TRMM satellite, Average Monthly Climatology 1998 -2010
Retrieved from http://mynasadata.larc.nasa.gov/, Live Access Server (Advanced Edition)