

## Climate Science

# SYNOPTIC-SCALE ATMOSPHERIC CIRCULATION/WAVE CYCLONES AND STORM TRACKS

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## Linking Weather and Climate

### Background:

If we want to see what the current weather is like across the country or what weather that could be expected over the next day or two, we would consult the daily weather maps and the forecast charts. But what if we wanted to know about the atmospheric conditions during the just concluded winter or during this upcoming summer season? We soon realize that weather can be used to describe the atmospheric state not only at the current time, but also over relatively short intervals, say up to ten days out into the future. Description of atmospheric conditions for longer time spans, such as for a month or for a three-month season, typically falls into the realm of climate analysis or forecasting. For such time scales, individual storms or migratory high pressure systems become less relevant, as the general atmospheric circulation scheme begins to become more important in deciding multi-day temperature and precipitation patterns.

Weather forecasts for the next several days are based upon numerical prediction models, such as those run at NOAA's Weather Prediction Center. These models are predicated on sophisticated numerical weather prediction models that have a set of equations including those describing Newtonian motion, thermodynamics and mass conservation. Observational data from the surface and aloft describing current weather conditions are entered into these weather prediction models, and iterative calculations are made of the atmospheric state at computational small time-steps over the next several days. Output statistics are generated by these models for the next 60 hours (short-range forecasts) and the next 10 days (medium-range forecasts).

To determine what type of weather conditions that we could expect for the next month or the next season (typically a three-month span) would require consultation with the official climate outlook maps generated by NOAA's Climate Prediction Center (CPC). (A [chart](#) shows the types of outlook maps, graphs and tables produced by CPC). These maps show the probabilities of how the temperature, precipitation and sea surface temperatures (SSTs) will deviate from the long-term or normal state for the next month and three month periods, extending from one to thirteen months into the future. In addition to these one-month to three-month climate outlooks, CPC also issues 6-10 Day and 8-14 Day extended outlook maps. These maps also show the probabilities of temperature and precipitation departing from the long-term average or normal conditions. The long-lead forecasts that may range from two weeks to thirteen months are based upon a dynamical ocean-atmosphere model that incorporates oceanic and atmospheric data. Sophisticated statistical analysis predicts how the patterns of temperature and precipitation should evolve based upon recent patterns of temperature and precipitation across the national, along with global sea-surface temperatures and tropospheric flow patterns. Consideration is also made of the effects of trends associated with El Niño and La Niña effects (to be discussed next week).

## **STORMS & THEIR TRACKS**

When we look at surface weather maps, we would soon realize that tranquil weather is usually associated with areas of high pressure, while inclement weather typically accompanies low-pressure systems. Midlatitudes are characterized by migratory weather systems, such as storms, that are carried along by the general westerly winds in the troposphere. These storms develop in a process called *cyclogenesis* and evolve as they are carried eastward, finally dissipate in a process called *cyclolysis*. A series of weather maps can show the complete sequence of cyclogenesis, travel and cyclolysis of individual storms. By tracking all the storms that develop over an extended time interval, say for the last 10, 30 and 90 days, we can get some indication of how atmospheric patterns are evolving not just on the time scale that we call weather, but on monthly and seasonal time scales that can be considered climate.

For example, CPC has a series of graphics that show the locations of [cyclogenesis and cyclolysis](#) across a large section of the Northern Hemisphere extending from eastern Asia across North America to western Europe. The current series of 10, 30 and 90-day maps show an active pattern, which should be expected as the time intervals cover a sizable portion of the winter season for the Northern Hemisphere. The movement of storms can also be tracked, with the resulting maps called "storm track maps." These storm tracks are studied by CPC, along with several other important fields, such as lower tropospheric winds, associated [precipitation](#) patterns, significant [ocean wave height](#) and sea ice. On the individual maps, the intensity of the storm (or cyclone) is indicated by a color code that is based upon the minimum central pressure (in millibars). When the storm tracks are overlaid upon precipitation maps, one can see that widespread precipitation can be found along the storm tracks, especially over the subpolar North Pacific and North Atlantic and adjacent land areas on the eastern sides of Eurasia and North America. Significant wave heights are also linked to the storm tracks, extending outward across the North Pacific and North Atlantic.

So how do the storm tracks vary by season of the year? A climatology of storm tracks has been assembled to allow CPC forecasters to monitor recent storminess across both the Northern and Southern Hemispheres. This storm-track climatology was developed by determining the location of low-pressure systems on a daily basis, running from 1950 through 2002. A four-panel [map](#) shows the seasonal frequency of storms and the distribution of storm tracks across the section of the Northern Hemisphere extending from eastern Asia to western Europe. The top panel (a) is for boreal winter (December, January and February) and shows most of the storms during this season develop and spend much of their time in preferred regions of cyclogenesis. These cyclogenesis regions are over the western North Pacific Ocean off Japan and the eastern coast of Asia, as well as over the North Atlantic off the Canadian Maritime Provinces on the eastern coast of North America. Seven to eight storms typically form between December and February over these waters. Other areas with high numbers of storms are across the Great Lakes in North America, and along the eastern slopes of the Rocky Mountains from southwestern Canada southward to the Panhandles of Oklahoma and Texas. The next panel (b) for northern spring (March, April and May) shows fewer storms and a northward displacement of the regions of cyclogenesis. This trend in reduced storminess and more northerly track of the storms is also noted in the third panel (c) for the boreal summer season (June, July and August). Most of the storms develop and are found across eastern Canada, in a region that corresponds to the summer position of the Icelandic low pressure system in the planetary scale pressure patterns. Some storms also are found over the North Pacific off Russia's Kamchatka Peninsula and along the western Aleutian Island chain. The last map (d) for northern autumn (September, October and November) shows an intensification of the storms across the Gulf of Alaska, the western North Pacific and over the Great Lakes of North America.

# SYNOPTIC-SCALE ATMOSPHERIC CIRCULATION: HIGH AND LOW PRESSURE SYSTEMS

**Driving Question:** *What are the synoptic-scale features of climate? Where do these features form, what are their climate-impacting features, and where and when do they prevail?*

Educational Outcomes: To describe the origins and characteristics of the synoptic-scale high and low atmospheric pressure systems. To explain their impacts on local and regional weather and climate, and how these impacts vary over the year.

**Objectives:** After completing this investigation, you should be able to:

- Identify the synoptic-scale high and low pressure systems that play major roles in determining local and regional climates of middle and high latitudes.
- Describe short-term and seasonal changes in the weather patterns which imply boundary conditions of weather and climate at different times of the year.

## Synoptic-Scale Atmospheric Circulation

The atmospheric synoptic scale covers the range between planetary-scale (thousands of kilometers) and mesoscale (tens of kilometers). The features commonly appearing on national weather maps, including highs, lows and fronts, are synoptic in scale.

Weather and climate result from a combination of factors including (a) the directional receipt of solar energy, (b) Earth's rotation and revolution, (c) character of Earth's surface (e.g., topographical relief, land/water surfaces), and (d) atmospheric composition (e.g., clouds, greenhouse gases, aerosols).

The interplay of these factors produces the boundary conditions of weather and climate. While complex, the impacts of these factors can be detected by surveying the state of Earth's climate system at different times, and by observing changes over time.

### A. January Snapshot of Weather (and Climate) in the Northern Hemisphere Middle Latitudes:

For a view of typical winter weather, **Figure 1** displays general weather features for the coterminous U.S. and parts of Canada and Mexico at 7:00 a.m. EST on 12 January 2012.

1. The major features of surface weather maps are revealed by analysis of air pressure readings adjusted to the same altitude (i.e., "corrected" to sea level). The drawing of isobars (lines of constant pressure) show pressure patterns over the region covered by the map. These patterns provide information on horizontal forces (called pressure gradient forces) which act to put air into motion. In some places and at some times, isobars completely or partially surround areas of relatively high- and low-pressure and are marked on the map with **H** and **L** labels, respectively. On this **Figure 1** map, an expansive and elongated high-pressure area (with highest pressures encircled by 1036-mb isobars) stretched across much of the mountain west. A printed **L** appearing over western Lake Erie identified a broad low-pressure area surrounded by a 996-mb isobar. Other prominent **L**'s were plotted over lower Lake Michigan and northeastern Maryland.

The isobar interval (difference in pressure values between neighboring isobars) on the map is [(4)(8)(10)] mb. This is the isobar interval used for pressure analyses on most U.S. surface weather maps.

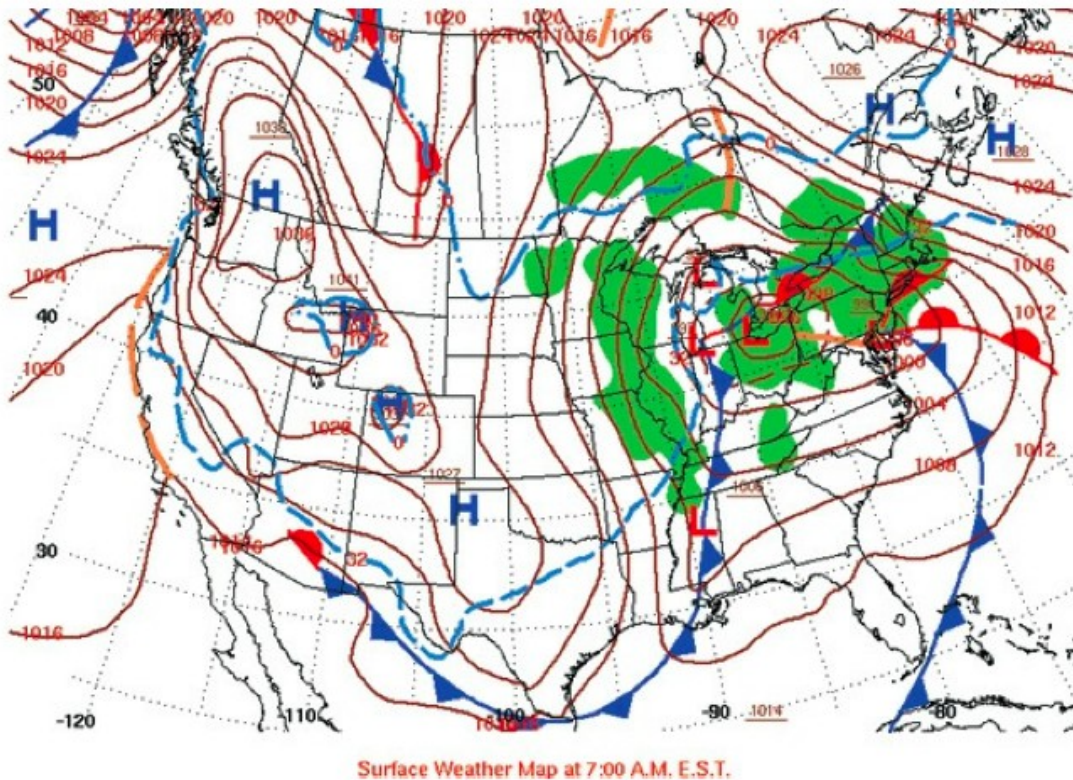


Figure 1.  
U.S. Daily Weather Map for 7:00 a.m. EST, 12 January 2012. [HPC/NOAA]

2. Green shading on the map delineates areas of precipitation. These precipitation areas are generally more closely associated with [(high-pressure)(low-pressure)] systems.
3. The blue dashed and dot/dashed lines on the map are the 32°F and 0°F isotherms, respectively. The isotherm pattern shows that much of the western half of the coterminous U.S. was subjected to freezing temperatures at map time, with sub-zero cold in parts of Idaho, Wyoming, Colorado, and [(Michigan)(Maine)(North Dakota)].

To retrieve more weather details for this same day, 12 January 2012, go to NOAA's Hydrometeorological Prediction Center's (HPC) Daily Weather Map website: <http://www.hpc.ncep.noaa.gov/dailywxmap/index.html>.

To the left under "Select Date," select "January," "12," and "2012," click on the lower "Get Map" button. The large map that appears is the same as Figure 1.

4. Click on the large map. The new map that appears is for the same time as Figure 1 and has detailed observational data plotted at individual locations. The plotted wind arrows at individual stations (each pointing in the direction towards which air was flowing) show that to the north of the



dashed blue 32° isotherm line, across the central Plains states (including Kansas and Nebraska), the winds are generally blowing from the **[(northwest)(northeast)(southeast)]**. This flow of cold air is an extension of the normal clockwise and outward spiral circulation (as seen from above) generally observed in high-pressure systems, and especially evident on this map in the expansive **H** centered in the northwestern states.

5. Extending out from the low-pressure centers are cold (blue), stationary (alternating red and blue) and warm (red) fronts. Fronts signify boundaries between neighboring air masses with different temperature and/or humidity characteristics. Movement of fronts is indicated by symbols and their positioning on the heavy lines showing the location of fronts. Blue triangles identify a cold front and point in the direction it is moving. Red semi-circles identify a warm front and are on the side of the front towards which it is moving. Alternating red semi-circles and blue triangles pointing in opposite directions label stationary fronts. The wind arrows in the eastern third of the country centered on the lowest-pressure center over western Lake Erie reveal a gigantic overall **[(clockwise)(counterclockwise)]** circulation pattern as seen from above. This is typical of atmospheric circulations around centers of surface low pressure in the Northern Hemisphere.

Return to the generalized map by clicking the “Back to Main Page” button above the map on screen or on your browser’s back button. Scroll down to the bottom two images.

6. Examine the map to the bottom right showing the total precipitation in the 24-hour period ending on 7 a.m., 12 January 2012. Compare the areas with and without precipitation across the country, especially noting locations of heaviest precipitation. The comparison confirms that the precipitation areas were more closely associated with the **[(high)(low)]** pressure areas seen on the 12 January 2012 daily weather map.

Now examine the map at the bottom left showing the upper-air 500-mb constant pressure surface at 7:00 a.m. EST on 12 January 2012. Then click on the 500-mb map for a more detailed view.

7. Comparison of this upper air map with the [Figure 1](#) surface map shows the general relationships between Rossby waves and surface weather features that you were introduced to in Investigation 6B. Surface storm systems (Lows) tend to be more closely related to the east side of upper air **[(ridges)(troughs)]**.

Now click on your browser’s back button or on “Back to Main Page” above the map to return to the main surface weather map. Starting with the 12 January 2012 map, follow the major weather features seen on the surface map as they progress and evolve over the next day. Do this by clicking on “Next Day” to the upper right. To replay the sequence, first click on the “Previous Day” button to return to the 12 January 2012 map.

8. Note that by the next morning (13 January 2012), the major low-pressure area centered over western Lake Erie moved **[(westward)(eastward)(southward)]**. In general terms, this is a common direction of movement for weather systems impacting the coterminous U.S.

### **B. July Snapshot of Weather (and Climate) in the Northern Hemisphere Middle Latitudes:**

Now set the HPC Daily Weather Map website to 14 July 2011 for a view of summer weather.

9. Compare the pressure pattern on the July map with that on the 12 January 2012 winter map in [Figure 1](#). The range of pressures and numbers of isobars on the July map are [*(less than)(about the same as)(more than)*] those on the January map.
10. The closer the spacing between isobars on the maps, the greater the change in air pressure horizontally per unit distance and the greater the horizontal force (called the pressure gradient force) acting on air. This, in turn, results in higher wind speeds. Consequently, it is likely that wind speeds over the map area in January are [*(weaker than)(about the same as)(stronger than)*] those in July. [Note: You can check this by looking at the detailed surface maps for the two dates.]
11. Now, compare the contour patterns on the 500-mb maps for the two dates. The closer the spacing between neighboring contour lines, the greater the horizontal pressure gradient forces putting air into motion. Consequently, it is likely that wind speeds on the 500-mb constant pressure surface over the map area in January are [*(weaker than)(about the same as)(stronger than)*] those in July. [Note: You can check this by looking at the detailed 500-mb maps for the two dates by clicking on the small maps to access detailed views showing wind speeds.]
12. Finally, compare the 24-hour precipitation record ending on 7 a.m. for the two dates by clicking on their respective small color-coded precipitation maps to go to enlarged maps showing precipitation areas and station amounts. Consider the overall patterns of precipitation and locations where amounts of 0.75 in. or greater liquid equivalence were observed. They reflect the common observation that greater precipitation amounts tend to be more widely distributed across the U.S. with [*(winter)(summer)*] storms. This arises partially because of different prevailing temperatures and the unique relationship between temperature and the “capacity” of air to hold water vapor, i.e., the higher the temperature, the higher the water vapor “capacity” of air.

**Summary:** Snapshots of winter and summer weather as examined in this investigation provide evidence of the dramatic seasonal swings in local and regional weather patterns forming the basis of climate that can be traced back to annual cyclical changes in boundary conditions. Observational data, including those provided to the public via the NOAA/HPC Daily Weather Map series, provide the empirical basis of weather. They also demonstrate the intricate connections confirming that weather and climate result from a combination of factors including (a) the directional receipt of solar energy, (b) Earth’s rotation and revolution, (c) character of Earth’s surface (e.g., topographical relief, land/water surfaces), and (d) atmospheric composition (e.g., clouds, greenhouse gases).

## WAVE CYCLONES AND STORM TRACKS

**Driving Questions:** *What are the major storm systems, known as wave or extratropical cyclones, of the middle and high latitudes? Where do they form? What are their climate-impacting features? Where and when do they prevail?*

**Educational Outcomes:** To describe the origins and characteristics of the synoptic-scale storm systems of the middle and high latitudes, called wave or extratropical cyclones. To explain where they occur and their impacts on local and regional weather and climate.

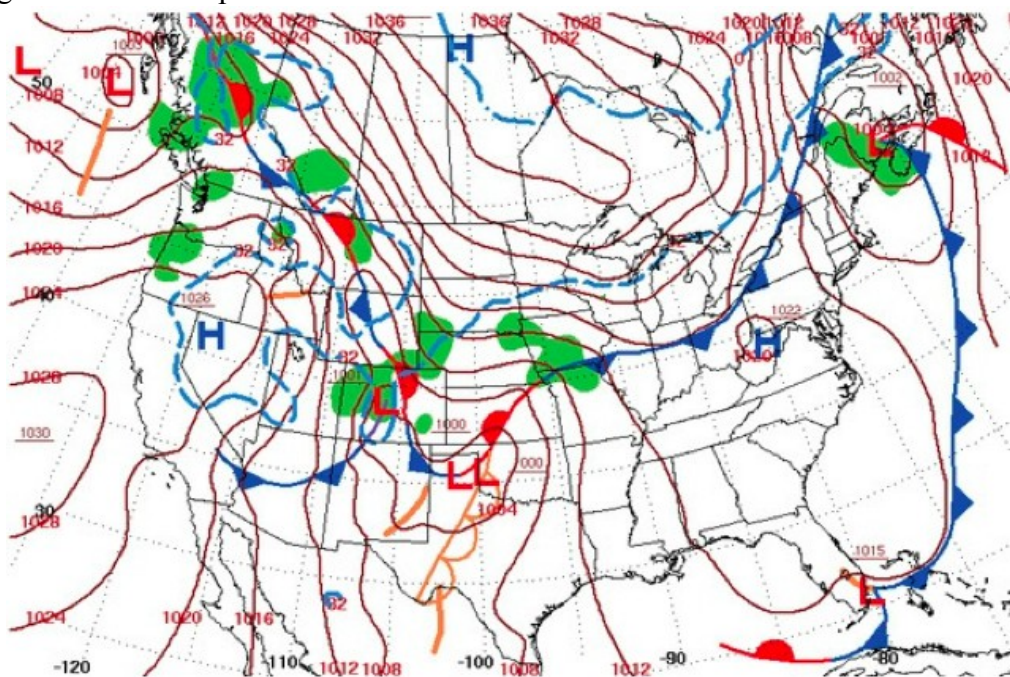
**Objectives:** After completing this investigation, you should be able to:

- Describe the synoptic-scale wave or extratropical cyclones that play major roles in determining local and regional climates in the middle and high latitudes.
- Provide an overview of the distribution of wave cyclone tracks.
- Describe short-term and seasonal changes in the atmosphere associated with wave cyclone occurrence which identify boundary conditions of weather and climate at different times of the year.

**Introduction:** The middle and higher latitudes exhibit considerable variability in weather because of poleward flows of energy as Earth's climate system strives to achieve radiational equilibrium with outer space. As described in earlier investigations, these latitudes are subjected to a combination of thermal and turbulent fluid flow, which result in local weather often alternating between fair and stormy episodes. This investigation examines the storm systems, called **wave** or **extratropical cyclones**, which play major roles in transporting heat energy to higher latitudes.

Air residing over uniform surfaces gradually acquires the physical characteristics of the underlying surfaces; be they cold or warm, dry or humid. As gigantic lobes of the conditioned air, called **air masses**, migrate across Earth's surface, they carry these characteristics with them. Where air masses of different character (which produce different air densities) come in contact, a persistent interface, or transition zone, marking the boundary between them and called a front, is formed. Along these fronts, synoptic-scale wave (or extratropical) cyclones can form. These are the migratory storm systems common in the middle and high latitudes.

**Wave Cyclones:** Wave cyclones form as part of the turbulent atmospheric flow in the middle and high latitudes. They exhibit cyclonic circulations around low-pressure centers, counterclockwise as seen from above in the Northern Hemisphere. They form along the boundaries, or fronts, between neighboring air masses and produce a wavelike deformation of the front.



Surface Weather Map at 7:00 A.M. E.S.T.

Figure 1.

U.S. Daily Weather Map for 7:00 a.m. EST, 14 April 2011. [NOAA/HPC]

1. **Figure 1** is the NOAA/HPC Daily Weather Map for 12Z (7:00 a.m. EST), Thursday, 14 April 2011. As shown in **Figure 1**, a frontal system designated by a heavy line stretched its way across the U.S. from north of Maine to Kansas separating a warm air mass to the south and east from a cold air mass to the north and west. A cold front is the leading edge of colder air. The short red portion of the line indicates a warm front across Kansas moving in the direction the symbol is pointing. The air mass boundary is designated a cold front if surface air is flowing so that colder air is replacing warmer air and a warm front if warmer surface air is replacing colder air. The cold front from Maine to Kansas is moving generally towards the **[(northeast)(southeast)]**.
2. Go to the NOAA/HPC Daily Weather Map website (<http://www.hpc.ncep.noaa.gov/dailywxmap/index.html>). At the left on the webpage, fill in the form for 14 April 2011 and click “Get Map”. The map that appears is the same as the **Figure 1** map. Now click on the map for a detailed version. Note reported wind directions at stations in the several states surrounding the Low center marked by two Ls in the panhandle of Texas. (For example, at Oklahoma City, OK, the southeast wind was flowing toward the northwest.) The wind directions exhibit a **[(clockwise)(counterclockwise)]** circulation as seen from above.
3. A short warm front extending from the Texas low-pressure center indicates relatively warm air was replacing retreating cold surface air in that area. This movement across Earth’s surface **[(is)(is not)]** consistent with the wind flow described in Item 2.

The orange line with open semicircles extending from west-central Oklahoma across Texas denotes a dry line, a non-frontal boundary separating warm, humid air to the east from warm, but dry air to the west. The dry air is flowing into the system from dry-land areas while the humid air has its origins over the waters of the Gulf of Mexico. This is a frequent feature in the Southwest in summer arising from differences in air density primarily due to variations in water vapor content (the lower the humidity, the greater the density). The resulting density differences often lead to clouds and thunderstorms. Orange dashed lines are extensions of lower pressure showing curvature in isobars, producing low-pressure troughs.

The surface weather map features (low-pressure center, cold and warm fronts, wind pattern) you have examined on the 14 April 2011 map clearly display the initial stage in the life cycle of a **wave cyclone**.

**Figure 2** shows the same system 24 hours later. From the NOAA/HPC Daily Weather Map website, fill in the form for 15 April 2011 and get map (or click on “Next Day” above the 14 April map). It is the Daily Weather Map for 7:00 a.m. EST, 15 April 2011, below.



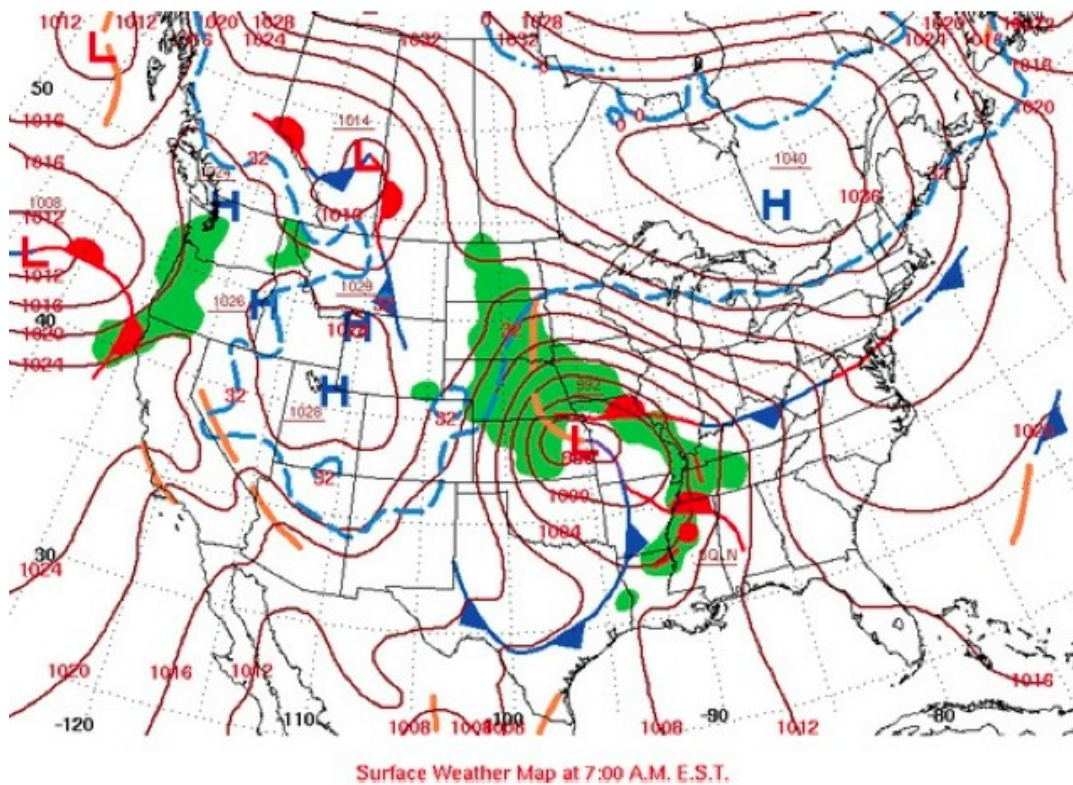


Figure 2.  
U.S. Daily Weather Map for 7:00 a.m. EST, 15 April 2011.

4. Comparisons of the maps in Figure 1 and 2 show that the low-pressure center moved northeastward. The central pressure value is given as a small underlined number near the L. The maps indicate the central pressure of the cyclone decreased [(4)(8)(11)] mb during the 24 hours between map times indicating intensification of the storm system.
5. Click on the 15 April 2011 surface weather map for the detailed version. Wave cyclones typically are divided by the cold and warm fronts into warm and cold sectors. Jackson, in central Mississippi, with a temperature of 72°F, was in the [(*cold*)(*warm*)] sector of this well-developed wave cyclone.
6. Temperature and dew point values reported at individual stations on the two sides of a wave cyclone's cold front often show the contrast between the two air masses in contact. Dewpoint, a humidity measure reported at the 8 o'clock position on map station models, increases as the amount of water vapor in the air increases. The dewpoint at Jackson was 66°F. Compare warm-sector dewpoints with dewpoints behind the cold front, such as at Dallas, TX. They indicate that compared to the warm-sector air mass, the cold air mass was [(*more*)(*less*)] humid. The water vapor being fed into the wave cyclone can be a major energy source that drives the storm system, thereby transporting energy from one place to another across Earth's surface.
7. Note the purple front drawn on the map from the Kansas low-pressure center southeastward. Its alternating triangular and semi-circle symbols face in the direction towards which the front is

moving. This is called an **occluded front**, which forms when the faster moving cold front catches up with the slower moving warm front. Its growing length over time is an indication of the eventual maturity and then demise of the wave cyclone. Assuming continued motion in the same northeast direction at about the same speed, it could be predicted that a day later, at 7:00 a.m. EST on 16 April, the low pressure center will be in the general area of [(*Cape Hatteras, NC*)(*the Great Lakes*)].

**Figure 3** is a composite of two visible satellite images provided by NCEP/NOAA showing cloud cover at 1815Z (1:15 p.m. EST) on 14 April 2011 (left) and 15 April 2011 (right). The left image is 6 hours after the [Figure 1](#) surface map while the right is 6 hours after the [Figure 2](#) map. An “L” superimposed on each shows the location of the surface low-pressure center at image time.

8. The position of the low-pressure center is marked with an “L” in each view. Note that the cloud patterns suggest the counter-clockwise and inward spiral of air flow surrounding the storm’s center. As is typical with wave cyclones, the change in location of cloudiness about the Low center and the position of the center itself indicate movement of the storm system across Earth’s surface generally toward the [(*west*)(*east*)].
9. The expansive cloud cover in the center of the U.S., particularly the view on the right, displays a comma (,) shape. This is a common cloud-cover configuration of mature wave cyclones. In the right view, the band of clouds curving from the Low center to the Texas Gulf Coast region would likely align with the [(*cold*)(*warm*)(*occluded*)] front as seen in [Figure 2](#).

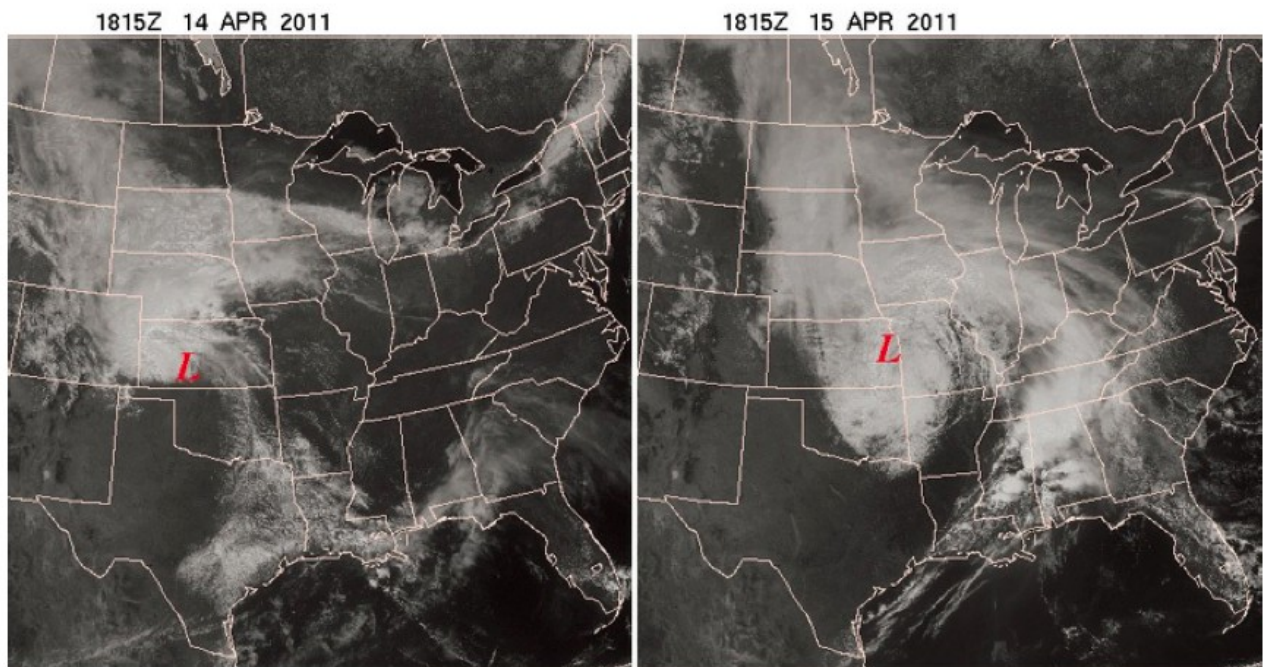


Figure 3.  
Composite visible satellite images at 1815Z on 14 April 2011 (left) and 15 April 2011 (right).



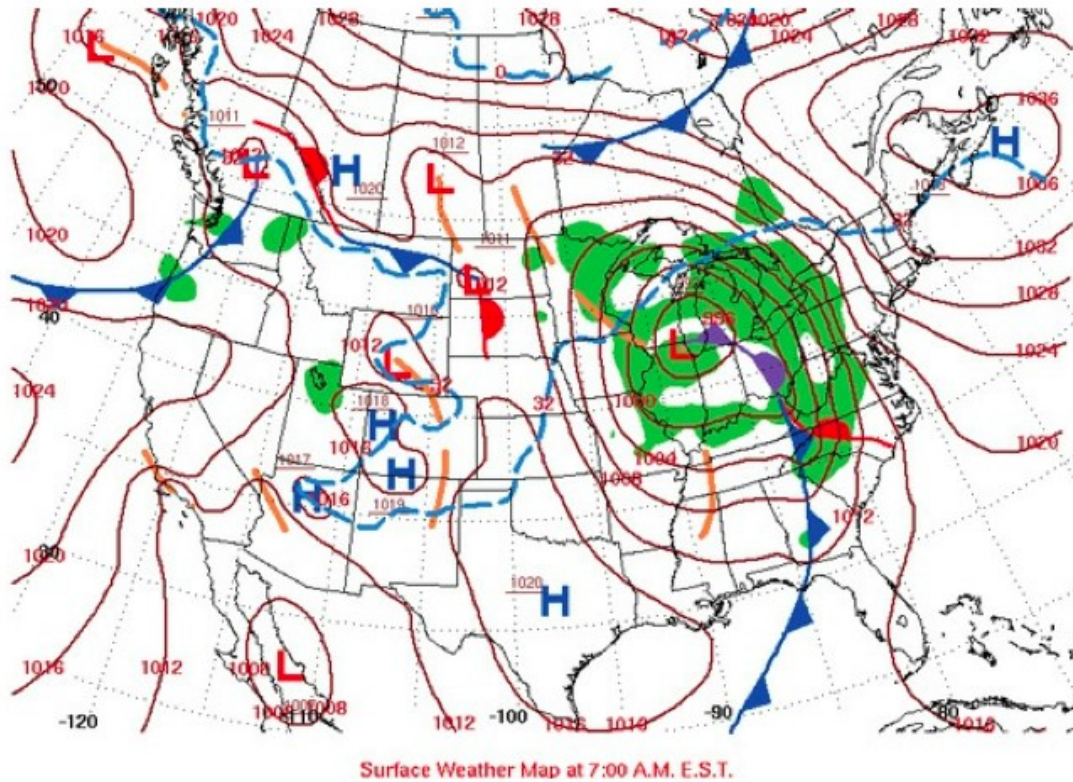


Figure 4.  
U.S. Daily Weather Map 7:00 a.m. EST, 16 April 2011.

Figure 4 shows the same weather system 24 hours after Figure 2. It is the Daily Weather Map for 7:00 a.m. EST, 16 April 2011.

10. Figure 4 shows the wave cyclone in a late stage of its life cycle. The location of the low-pressure center [(did)(did not)] track as expected in item 7.

Figure 5 shows the same weather system 24 hours after Figure 3, at 7:00 a.m. EST, 17 April 2011.

The low-pressure center was located north of the Great Lakes in Canada by 17 April with the occluded front beginning to dissipate (shown by the broken purple line). A new Low center had formed over New England and the system was moving rapidly to the northeast and out to sea. By 18 April, the storm remnants were passing the Canadian Maritime Provinces into the Atlantic.

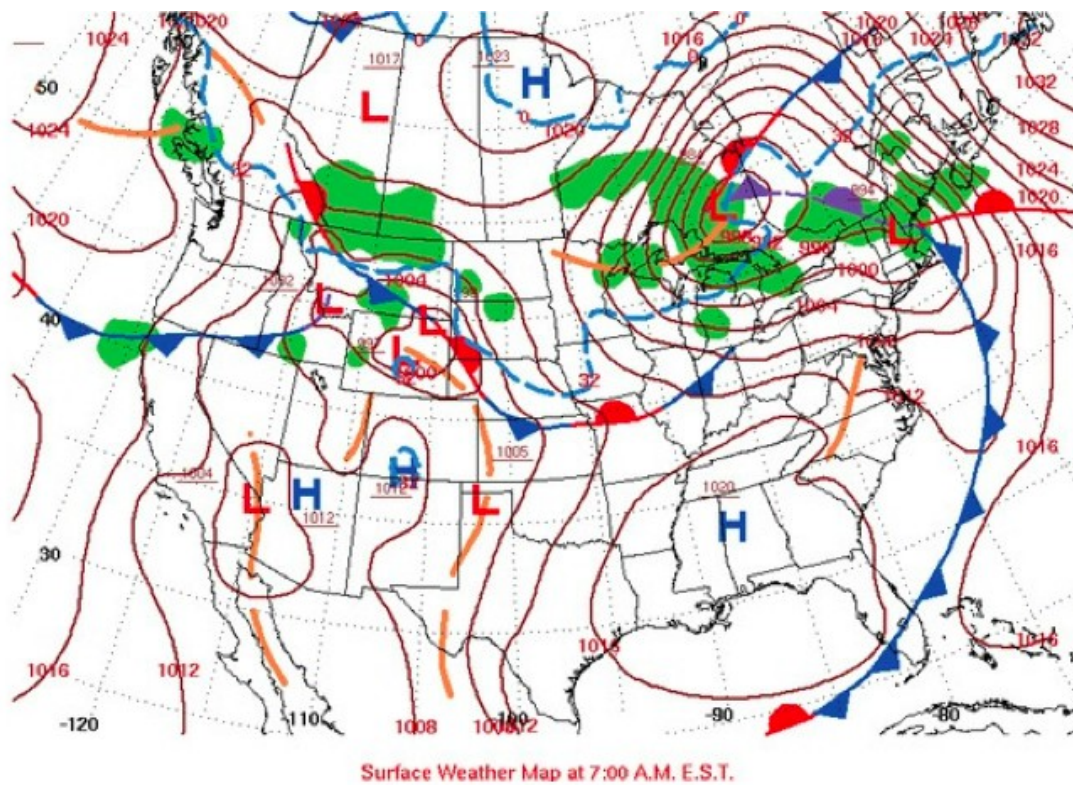


Figure 5.  
U.S. Daily Weather Map for 7:00 a.m. EST, 17 April 2011.

11. [Figure 5](#) shows the wave cyclone in a late stage of its life cycle. As is typical of most wave cyclones, its entire lifecycle was completed in a few [(hours)(days)(weeks)].

**Extratropical Storm Tracks:** As evident in the April 2011 wave cyclone, extratropical storm systems are integral components of the global atmospheric circulation. Although relatively short-lived, these migratory synoptic-scale systems can impact the weather and climate over vast areas. Over one-third of the coterminous U.S. directly experienced some combination of precipitation, temperature change, wind variations, pressure fluctuations, etc., as this April 2011 storm developed and evolved through its life cycle while tracking across Earth's surface.

Where do these storms form? What are their typical paths or tracks? Is their occurrence more frequent in some places than others? Do they play major roles in determining local and regional climate? Examining the tracks of extratropical storms can help us find answers to these questions while contributing to better weather forecasting and climate prediction.

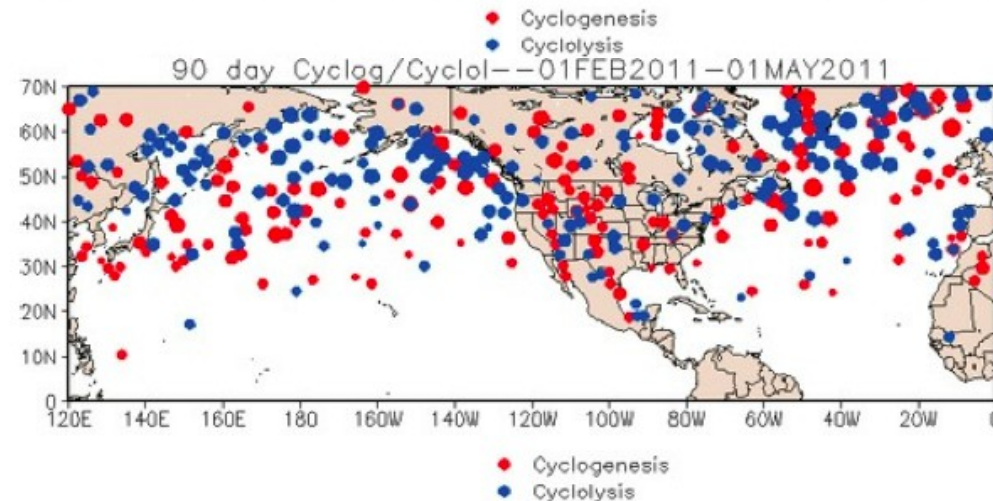
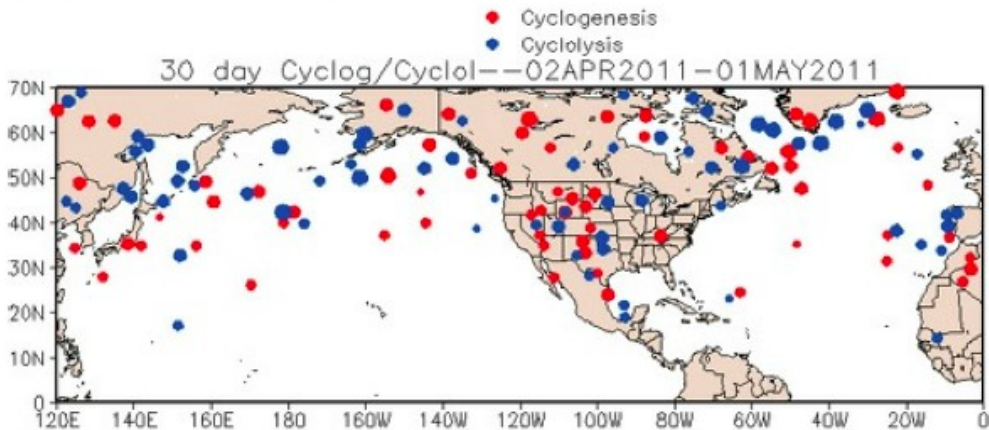
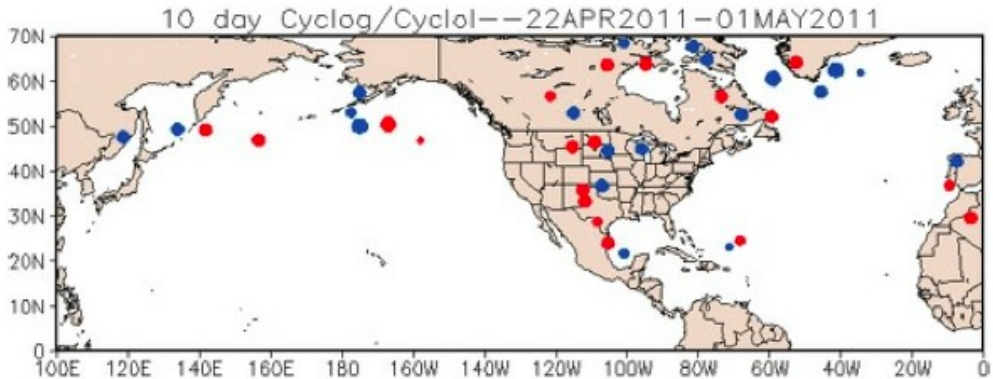
[Figure 6](#) displays imagery from CPC/NOAA in which air pressure analyses are employed to place red dots showing positions where extratropical storms formed (cyclogenesis) and blue dots where they lost cyclonic identity (cyclolysis). The maps show cyclogenesis and cyclolysis locations during the 10, 30 and 90 days prior to 1 May 2011.

12. The 90-day map essentially pinpoints where storm systems began and ended during the 2011



winter-spring seasonal transition. The distribution of red dots implies that cyclogenesis is not a random event, i.e., the pattern of dots shows some clustering that would not be expected if storm development occurred purely by chance. For example, during this 90-day sample it appears that late winter-early spring storms in the U.S. more frequently formed in the [(western)(eastern)] half of the country.

13. Although not marked on these maps, the storm systems moved so their tracks (paths) typically extended from red dots to blue dots somewhere further east. Now draw a straight line across the 90-day image at 45° N. Note which colored dots (red or blue) dominate south of 45° N and which dominate north of the 45° latitude line worldwide. This pattern implies that the storm systems tended to move toward [(lower latitudes)(due east)(higher latitudes)]. This is typical of extratropical cyclones.



**Figure 6.**

Maps showing cyclogenesis and cyclolysis during three time periods (10, 30 and 90 days) ending on 1 May 2011. [CPC/NOAA]

For the latest maps showing cyclogenesis and cyclolysis during the past 10, 30, and 90 days, go to: [http://www.cpc.noaa.gov/products/precip/CWlink/stormtracks/combined\\_cgl.gif](http://www.cpc.noaa.gov/products/precip/CWlink/stormtracks/combined_cgl.gif).

**Optional:** Detailed seasonal and monthly maps of extratropical storm tracks in both the Northern and Southern Hemispheres covering the time period 1961-1998 can be found at:

<http://data.giss.nasa.gov/stormtracks/>. We recommend that you visit this NASA site and explore the information provided. Look for overall seasonal patterns in the storm tracks [e.g., latitudinal differences between winter (December, January, February) and summer (June, July, August)].

**Summary:** Studies of storm tracks show how ubiquitous extratropical cyclones are in the middle and higher latitudes, but they also reveal that considerable variation exists concerning where they form, the paths they take, and where they terminate. These variations imply there are boundary conditions operating, including those related to differences in Earth's surface properties (e.g., ocean, land) and topographical barriers (mountains).