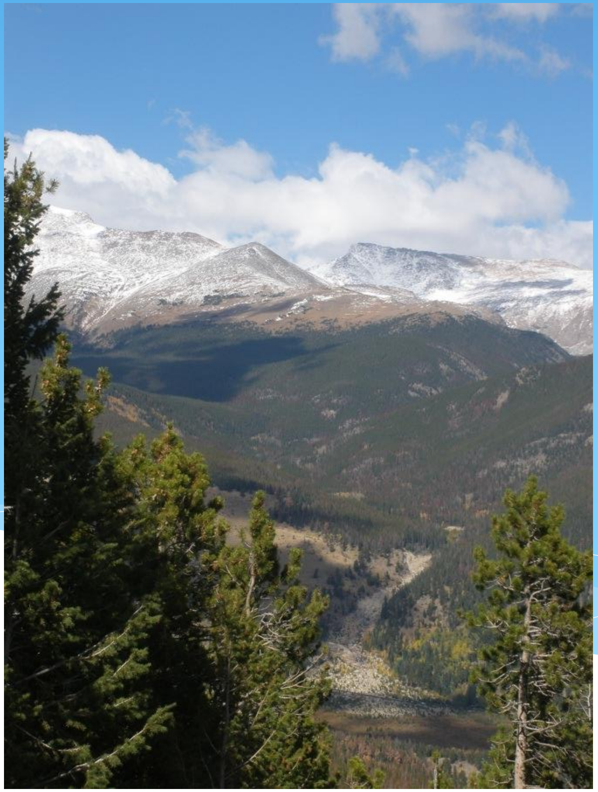
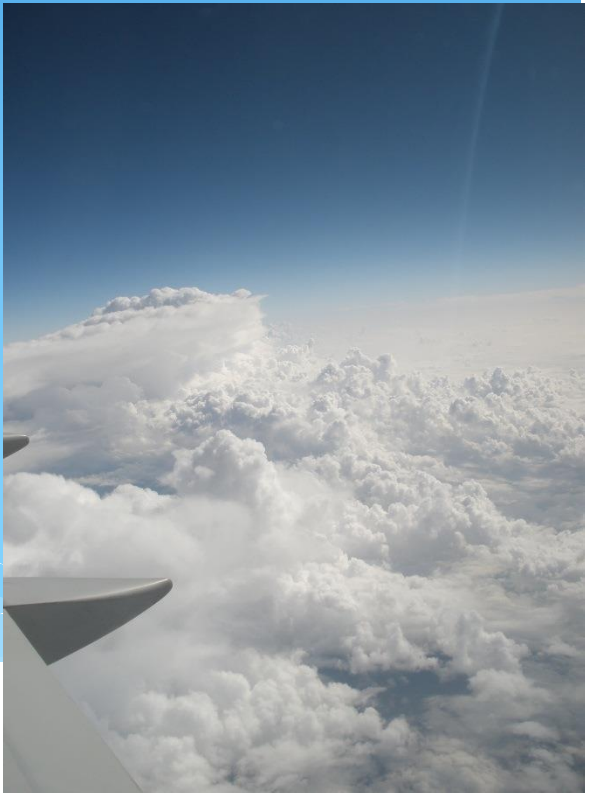
Atmosphere in 3-D

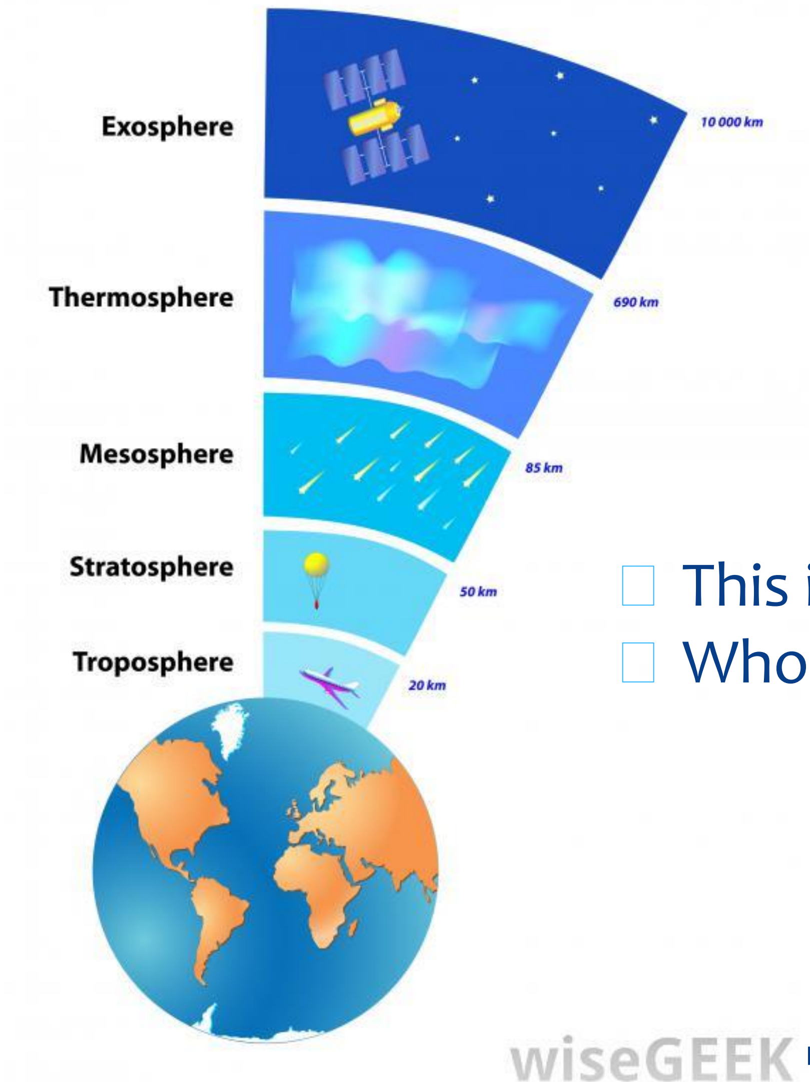




Why Study?

- The atmosphere that directly impacts our lives extends from the surface upwards for many kilometers.
- Connections exist between the surface weather and conditions aloft.
- Just by looking at the clouds you can see how things change with altitude
- For a more complete understanding, we must study the third dimension.

How thick is the atmosphere?



- This is what our students often see
- Who has issues with this?

Actual thickness of Atmosphere


"Atmosphere is thinner than the skin of an apple"

Dividing Up the Atmosphere

- **By composition**
  - Homosphere
  - Heterosphere
- **By particle type**
  - Ionosphere
  - Ozonosphere
- **By temperature**
  - Troposphere
  - Stratosphere
  - Mesosphere
  - Thermosphere
  - Exosphere

Dividing Up the Atmosphere

By Composition

- **Homosphere**
  - Up to about 80 km (50 mi)
  - Gases are well mixed
  - From surface up through most of the Mesosphere
- **Heterosphere**
  - Above 80 km
  - Gases are stratified

TABLE 2.1
Gases Composing Dry Air in the Lower Atmosphere (below 80 km)

Gas	% by Volume	Parts per Million
Nitrogen (N_2)	78.08	780,840.0
Oxygen (O_2)	20.95	209,460.0
Argon (Ar)	0.93	9,340.0
Carbon dioxide (CO_2)	0.03890	389.0
Neon (Ne)	0.00180	18.0
Helium (He)	0.00052	5.2
Methane (CH_4)	0.00014	1.4
Krypton (Kr)	0.00010	1.0
Nitrous oxide (N_2O)	0.00005	0.5
Hydrogen (H)	0.00005	0.5
Xenon (Xe)	0.000009	0.09
Ozone (O_3)	0.000007	0.07

- Note – this deals with dry air. Water vapor varies greatly, and is not included in the table.

Dividing Up the Atmosphere

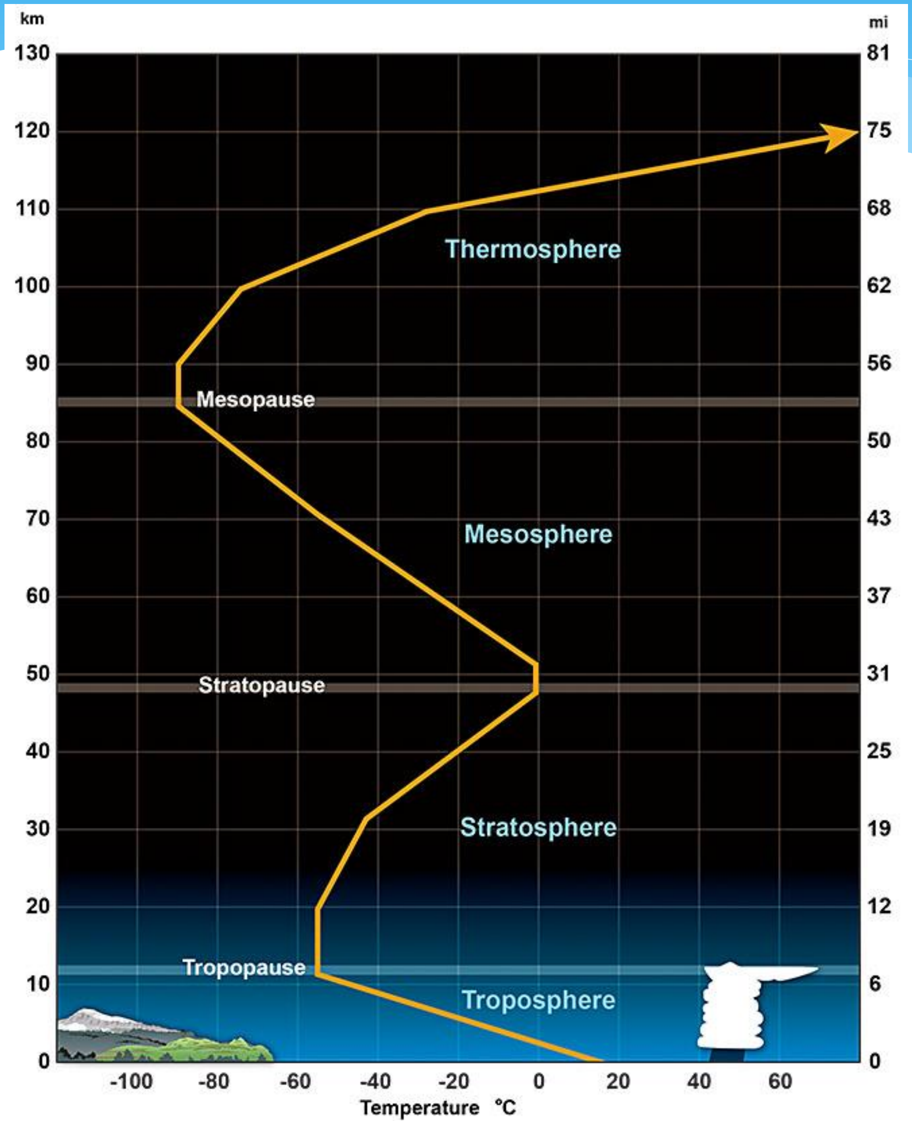
By Particle Type

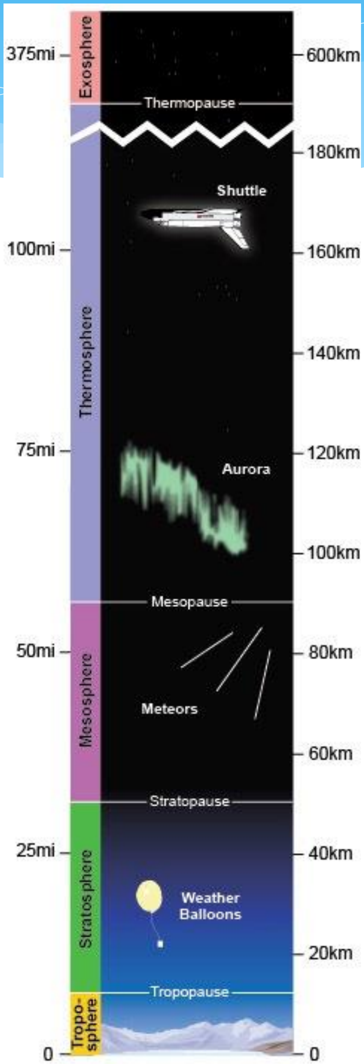
- **Ionosphere**
  - From 70-80 km (43 -50 mi) to an indefinite altitude
  - High concentration of ions and electrons – charged
    - Caused by solar energy stripping electrons from oxygen and nitrogen atoms and molecules, leaving a positive charge
  - Doesn't influence day-to-day weather but does reflect radio waves
  - Site of Aurora borealis/australis
  - Located mostly in the thermosphere
  - Space Weather!

- **Ozonosphere**
  - Lies roughly between 10-50 km with maximum ozone concentrations around 20-25 km
  - Contains an appreciable ozone concentration in which ozone plays an important part of the radiative balance of the atmosphere

Dividing Up the Atmosphere

By Temperature





Dividing Up the Atmosphere
By Temperature

- **Troposphere** (“Weather Layer”)
  - Lowest layer
  - Where almost all weather occurs. ***Why?***
  - From Earth’s surface to 6-20 km (4-12 mi)
    - ~ 6 km thick at the poles, ~20 km thick at the equator
  - Temperature decreases with altitude.
  - Generally, but with frequent exceptions (e.g., inversion, isothermal layer)
  - Average temperature drop is 6.5 °C/1000 m (3.5 °F/1000 ft) = *lapse rate*
  - Upper boundary/transition zone to next layer is called the **tropopause**.

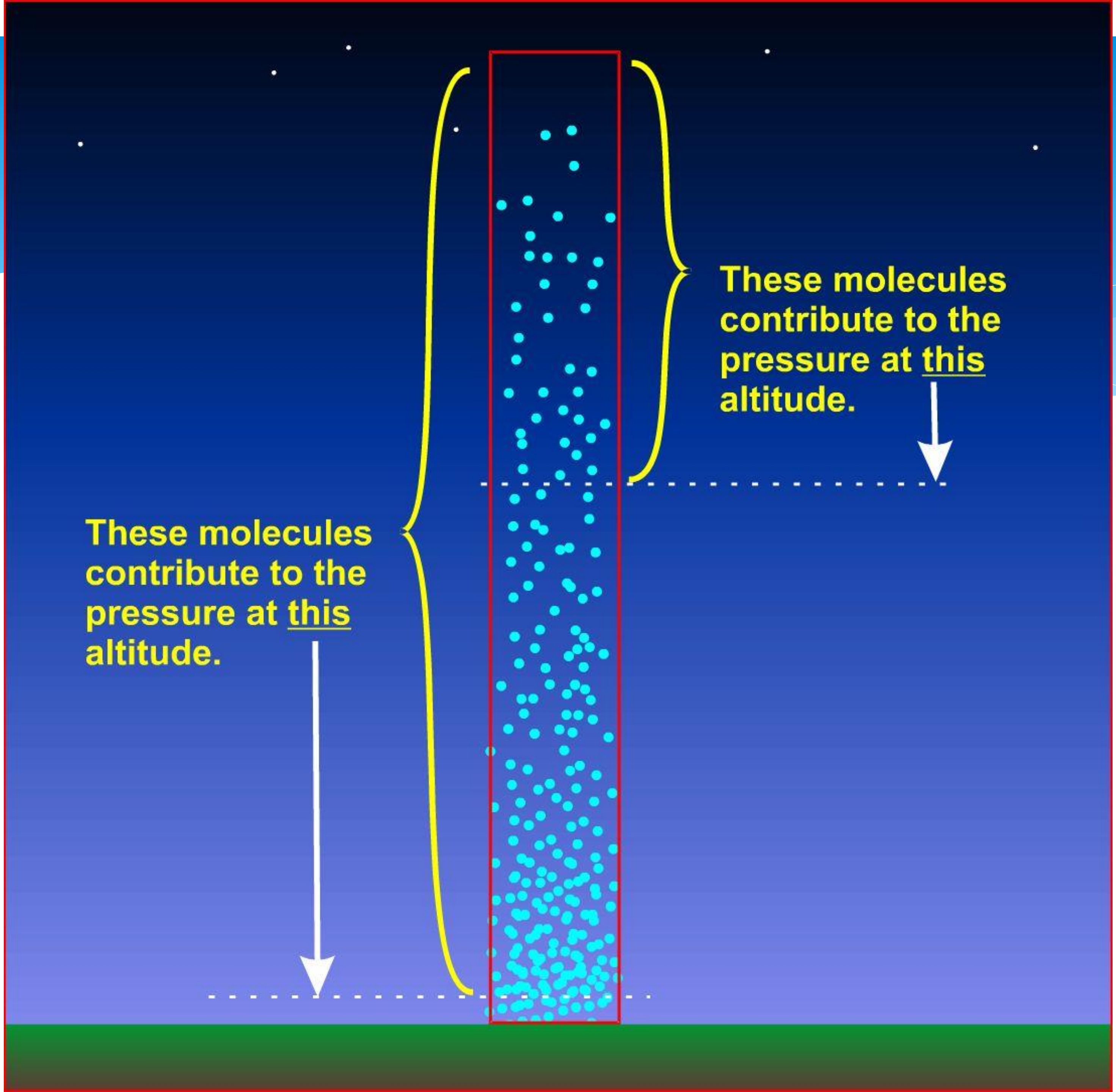
Temperature falls with increasing altitude so that it is generally colder on mountain peaks than in lowlands.

Dividing Up the Atmosphere
By Temperature

- **Stratosphere** ("Stable Layer")
  - Goes from tropopause up to ~ 50 km (30 mi)
  - In lower stratosphere, temperature is constant (isothermal).
  - Above 20 km (12 mi), temperature increases with increasing altitude (inversion).
    - Ozone is absorbing UV energy therefore warming this layer
  - Stable conditions are ideal for jet aircraft travel, but can cause trapping of pollutants (e.g. from volcanic eruptions) in lower stratosphere.
  - Upper boundary/transition zone to next layer is called the **stratopause**.

Dividing Up the Atmosphere
By Temperature

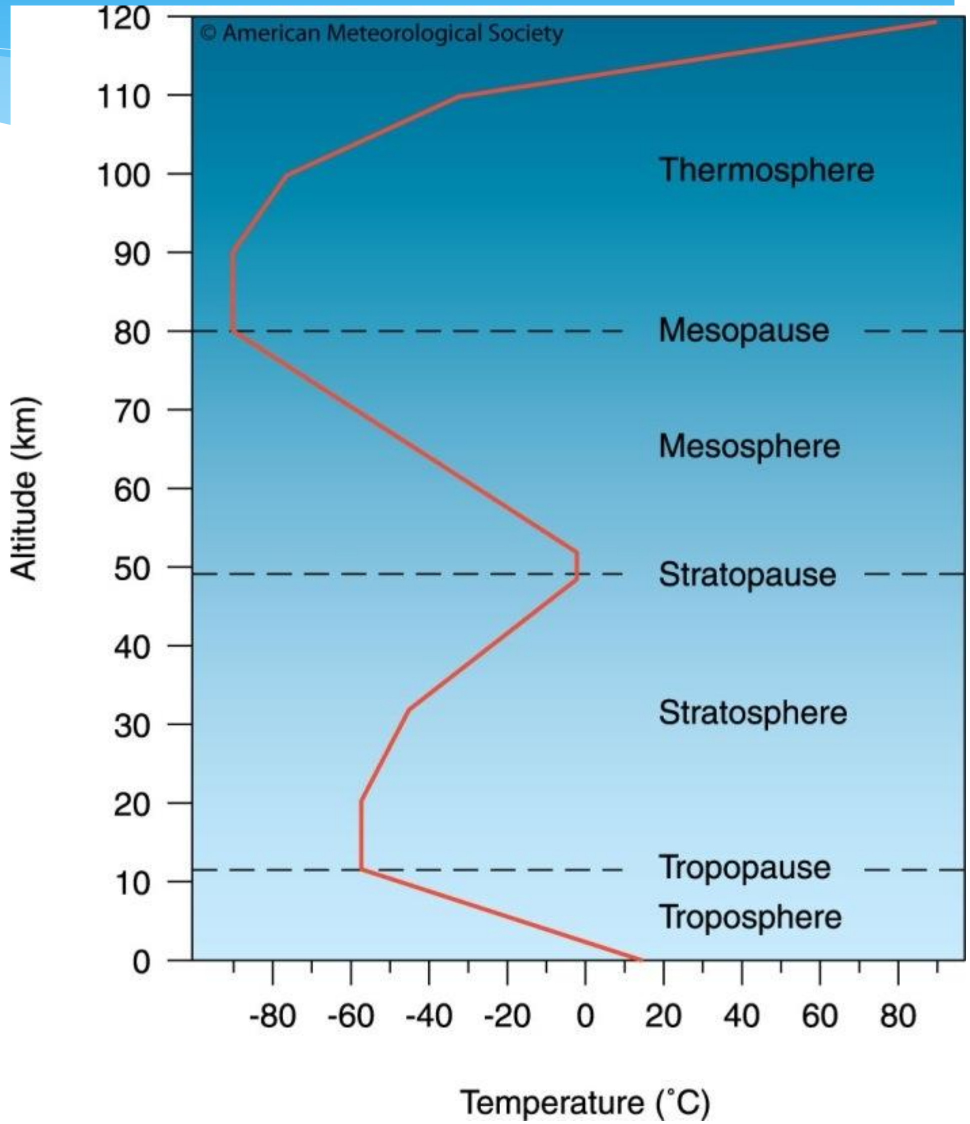
- **Mesosphere** ("Middle Layer")
  - Goes from stratopause up to about 80 km (50 mi) to the **mesopause**.
    - Lowest average temperature in atmosphere = -95°C (-139 °F)
  - Air is thin; pressure is low (~ 1 mb)
  - Temperature decreases with increasing altitude.
    - Little ozone in air to absorb solar radiation
- **Thermosphere**
  - Temperatures are isothermal in the lower thermosphere.
  - Temperatures rise rapidly above that.
  - Air temperature particularly sensitive to incoming solar radiation.
  - Temperature is more variable than in other regions.
  - Auroras occur in this region.
  - However, not much heat in this layer

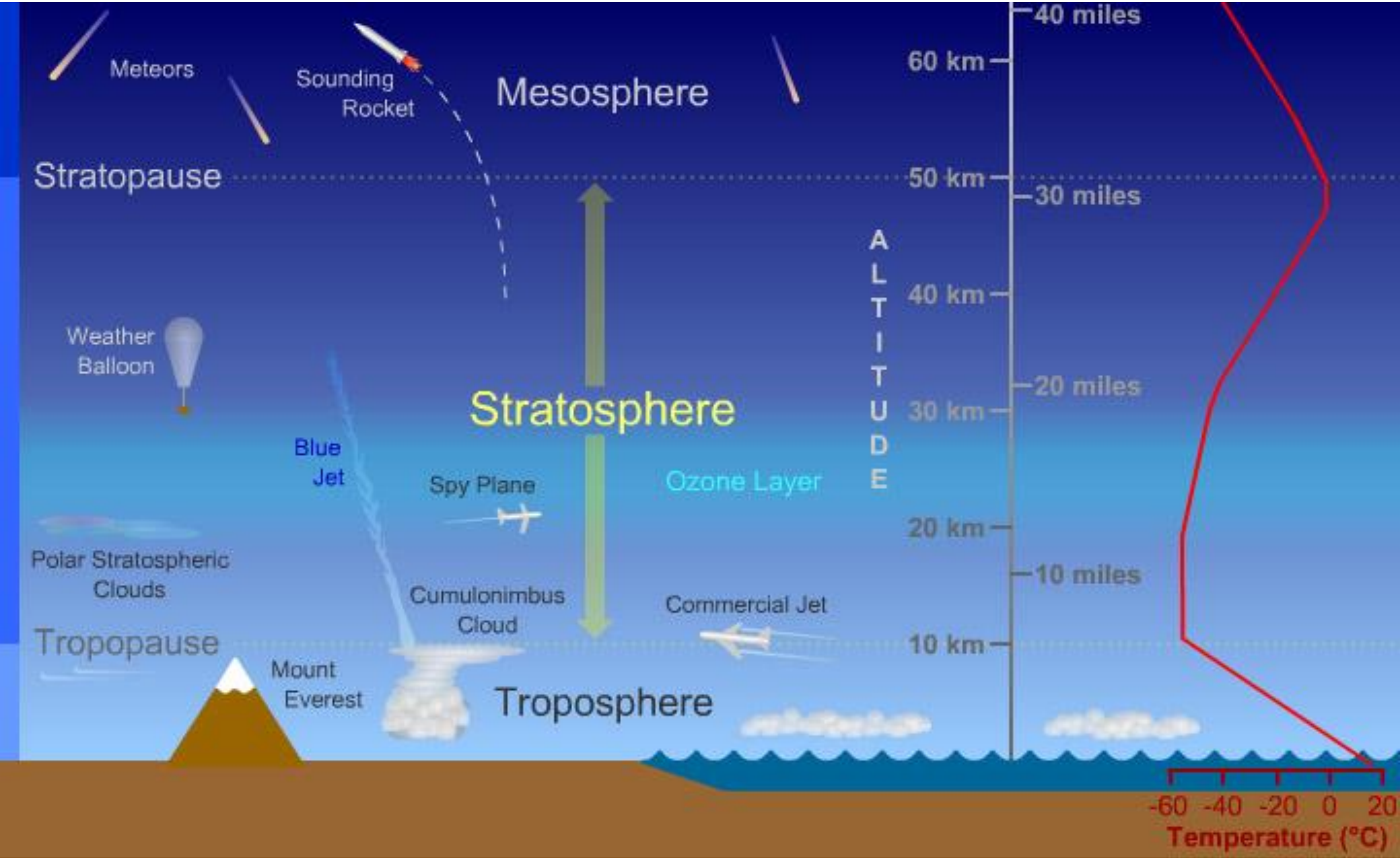

These molecules contribute to the pressure at this altitude.
These molecules contribute to the pressure at this altitude.

Dividing Up the Atmosphere

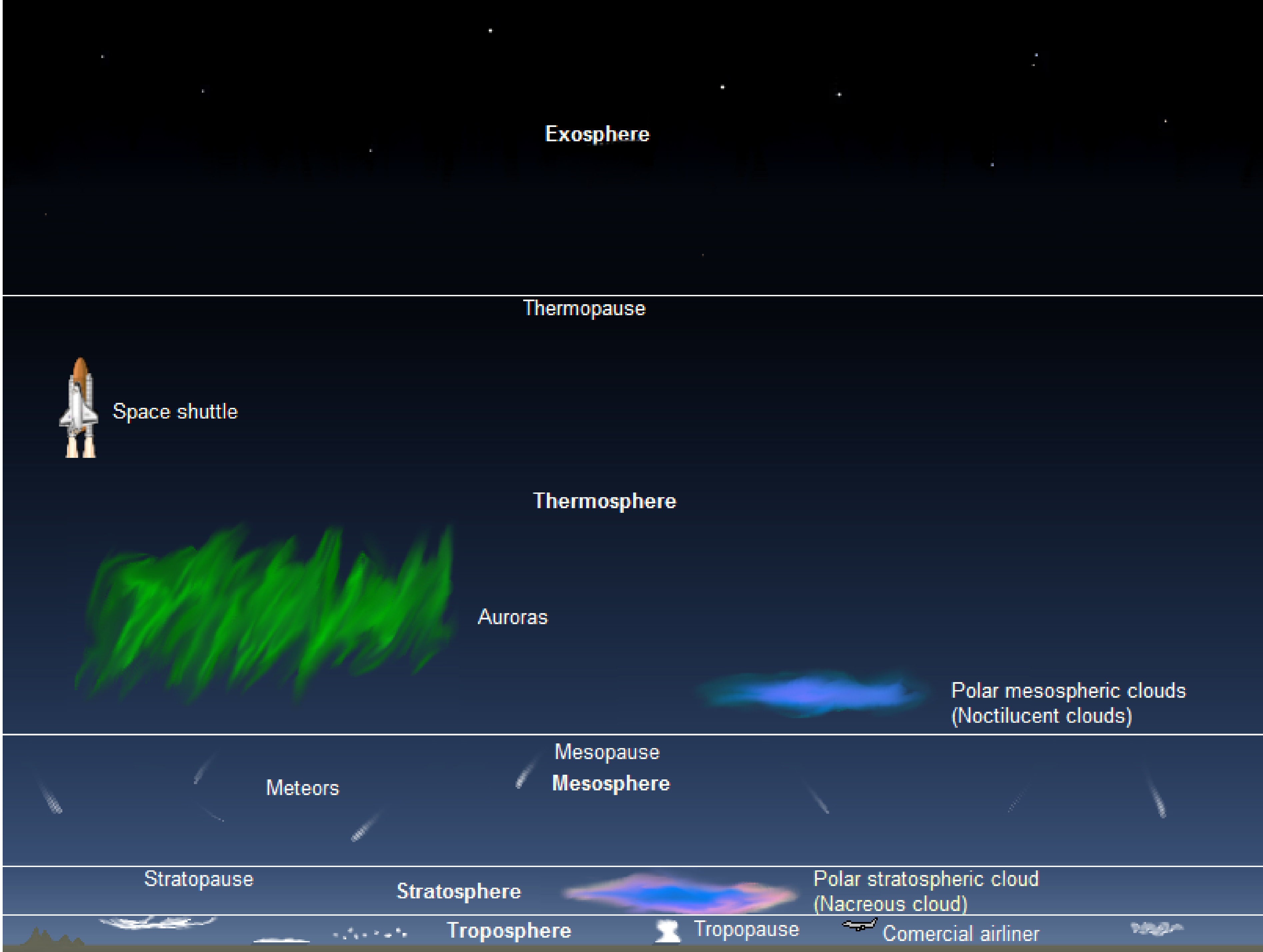
By Temperature

- **Exosphere** (“Escape layer”)
  - Upper limit of atmosphere
  - About 500 km (300 mi) above Earth’s surface
  - Many of the lighter, faster moving molecules escape Earth’s gravitational pull




Meteors
Sounding Rocket
Mesosphere
Stratopause
Weather Balloon
Stratosphere
Blue Jet
Spy Plane
Ozone Layer
Polar Stratospheric Clouds
Cumulonimbus Cloud
Commercial Jet
Tropopause
Mount Everest
Troposphere
ALTITUDE
60 km
50 km
40 km
30 km
20 km
10 km
40 miles
30 miles
20 miles
10 miles
-60 -40 -20 0 20
Temperature (°C)

UCAR


Exosphere
Thermopause
Space shuttle
Thermosphere
Auroras
Polar mesospheric clouds
(Noctilucent clouds)
Mesopause
Mesosphere
Meteors
Stratopause
Stratosphere
Polar stratospheric cloud
(Nacreous cloud)
Troposphere
Tropopause
Comercial airliner

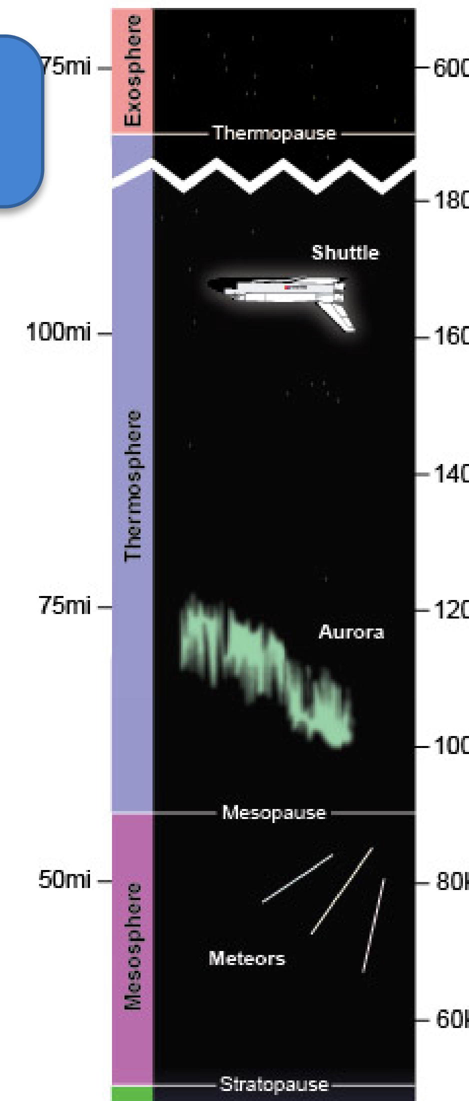
The Atmosphere
Introduction
Layers of the Atmosphere
Air Pressure
The Transfer of Heat Energy
Energy Balance
Hydrologic Cycle
Review Questions
ıtional Info:
son Plan Overview
ic Matrix
Stream News

Layers of the Atmosphere

The envelope of gas surrounding the Earth changes from the ground up. Five distinct layers have been identi...

http://www.srh.noaa.gov/jetstream/index.htm

Each of the layers are bounded by "pauses" where the greatest changes in thermal characteristics, chemical composition, movement, and density occur.



Exosphere

This is the outermost layer of the atmosphere. It extends from the top of the thermosphere to 6,200 miles (10,000 km) above the earth. In this layer, atoms and molecules escape into space and satellites orbit the earth. At the bottom of the exosphere is the thermopause located around 375 miles (600 km) above the earth.

Thermosphere

Between about 53 miles (85 km) and 375 miles (600 km) lies the thermosphere. This layer is known as the upper atmosphere.

While still extremely thin, the gases of the thermosphere become increasingly more dense as one descends toward the earth. As such, incoming high energy ultraviolet and x-ray radiation from the sun begins to be absorbed by the molecules in this layer and causes a large temperature increase.

Because of this absorption, the temperature increases with height. From as low as -184°F (-120°C) at the bottom of this layer, temperatures can reach as high as 3,600°F (2,000°C) near the top.

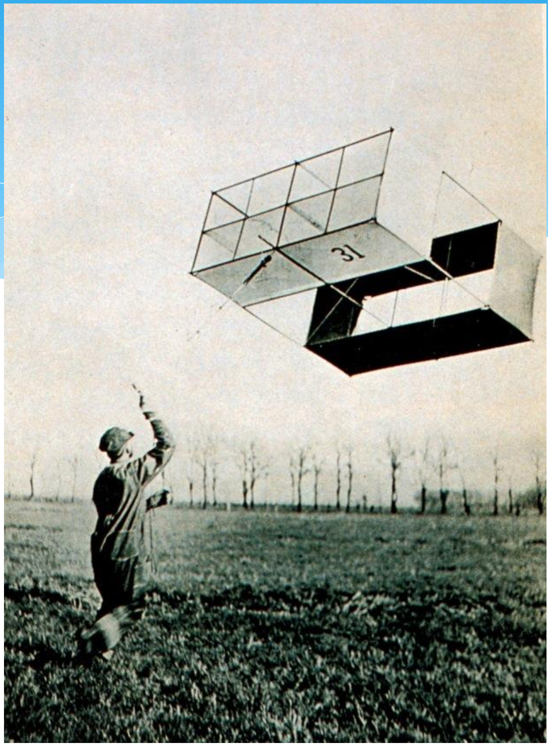
However, despite the high temperature, this layer of the atmosphere would still feel very cold to our skin due to the very thin atmosphere. The high temperature indicates the amount of the energy absorbed by the molecules but with so few in this layer, the total number of molecules is not enough to heat our skin.

Take It to the MAX! The Ionosphere

Mesosphere

This layer extends from around 31 miles (50 km) above the Earth's surface to 53 miles (85 km). The

History of Upper Air Observations



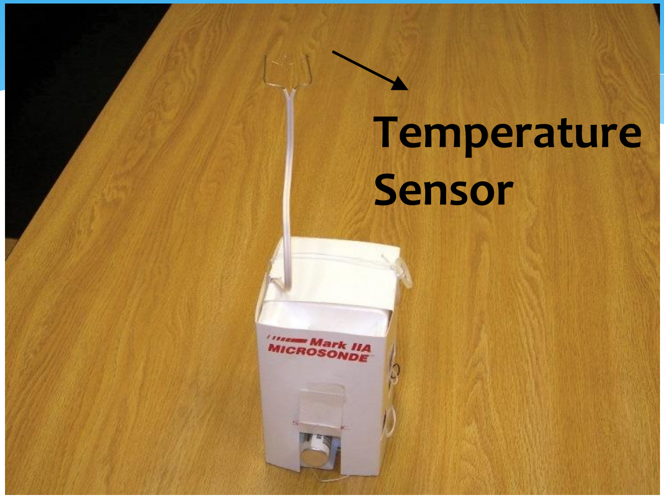
1. Kites
2. Manned balloons
   - 1804, Gay-Lussac & Biot
     - Measured temperature & humidity up to (23,000 ft)
   - 1862, Glaisher & Coxwell
     - Weather measurements to 9000 m (29,500 ft)
     - Nearly perished from cold and oxygen deprivation
3. Kites with a *thermograph* (1894)
   - Provided a vertical profile of air temperature up to 427 m (1400 ft)
4. Box kites with *meteorographs* (early 1900s)
   - Profiled altitude variations in air pressure, temperature, humidity, and wind speed
   - Measured up to 3000 m (10,000 ft)

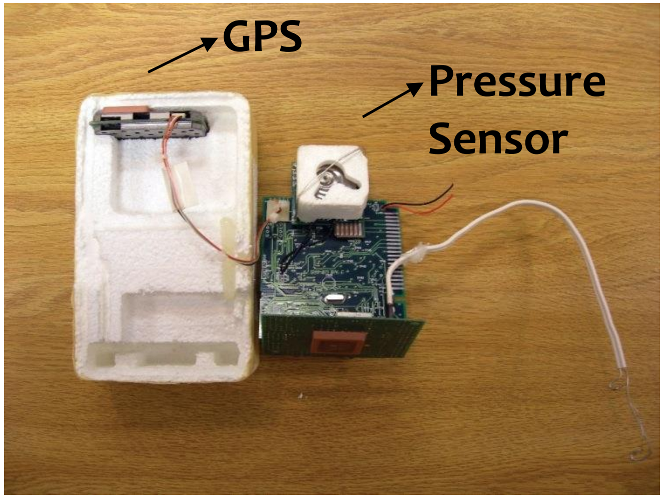
History of Upper Air Observations

5. Radiosonde (1920s)
   - Allowed for monitoring at higher altitudes
   - Small instrument package equipped with a radio transmitter carried aloft by a helium- or hydrogen-filled balloon.
   - Transmits altitude readings of temperature, air pressure, and dewpoint
   - First official U.S. Weather Bureau radiosonde was launched at East Boston, MA in 1937.

- A radiosonde tracked from the ground to measure variations in wind direction/speed with altitude is a *rawinsonde*.

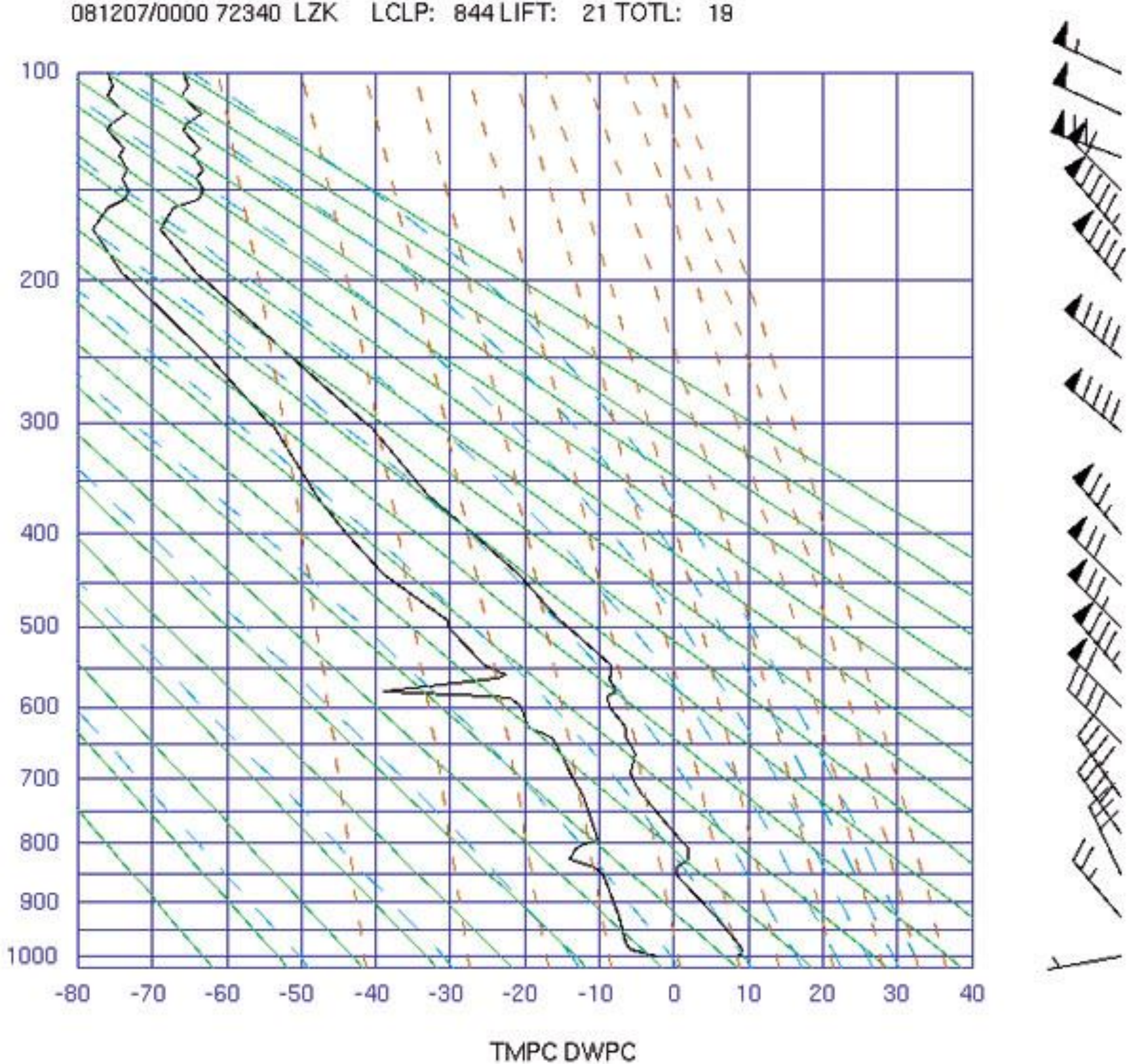
Upper Air Observations





Radiosonde

Launching a radiosonde



Data from radiosonde shown in a Stüve diagram

Temp curve on right

Dewpoint curve on left

Datastreme and the Upper Atmosphere

Additional Radar Links

Satellite

Infrared - Latest	Latest IR Animation	Infrared - 00Z	Infrared - 12Z
Visible - Latest		Visible - 18Z	
Water Vapor - Latest	Latest WV Animation		GOES Satellite Server

Additional Satellite Links

Upper Air

850 mb - Contours, Isotherms, & Data	00Z - 500 mb - Analysis
700 mb - Contours, Isotherms, & Data	12Z - 500 mb - Analysis
500 mb - Contours, Isotherms, & Data	500 mb - Data
300 mb - Contours, Isotachs (wind speed) & Data	300 mb - Data
Stüves for Selected Cities	Upper Air Data - Text
Available Upper Air Stations	

Additional Upper Air Links

Watches, Warnings, Advisories and Forecasts

Current NWS Weather Watches and Warnings	Weather-Ready Nation
NWS Short-Range Forecast Maps	Quantitative Precipitation Estimates

Additional Severe Weather/Forecast Links

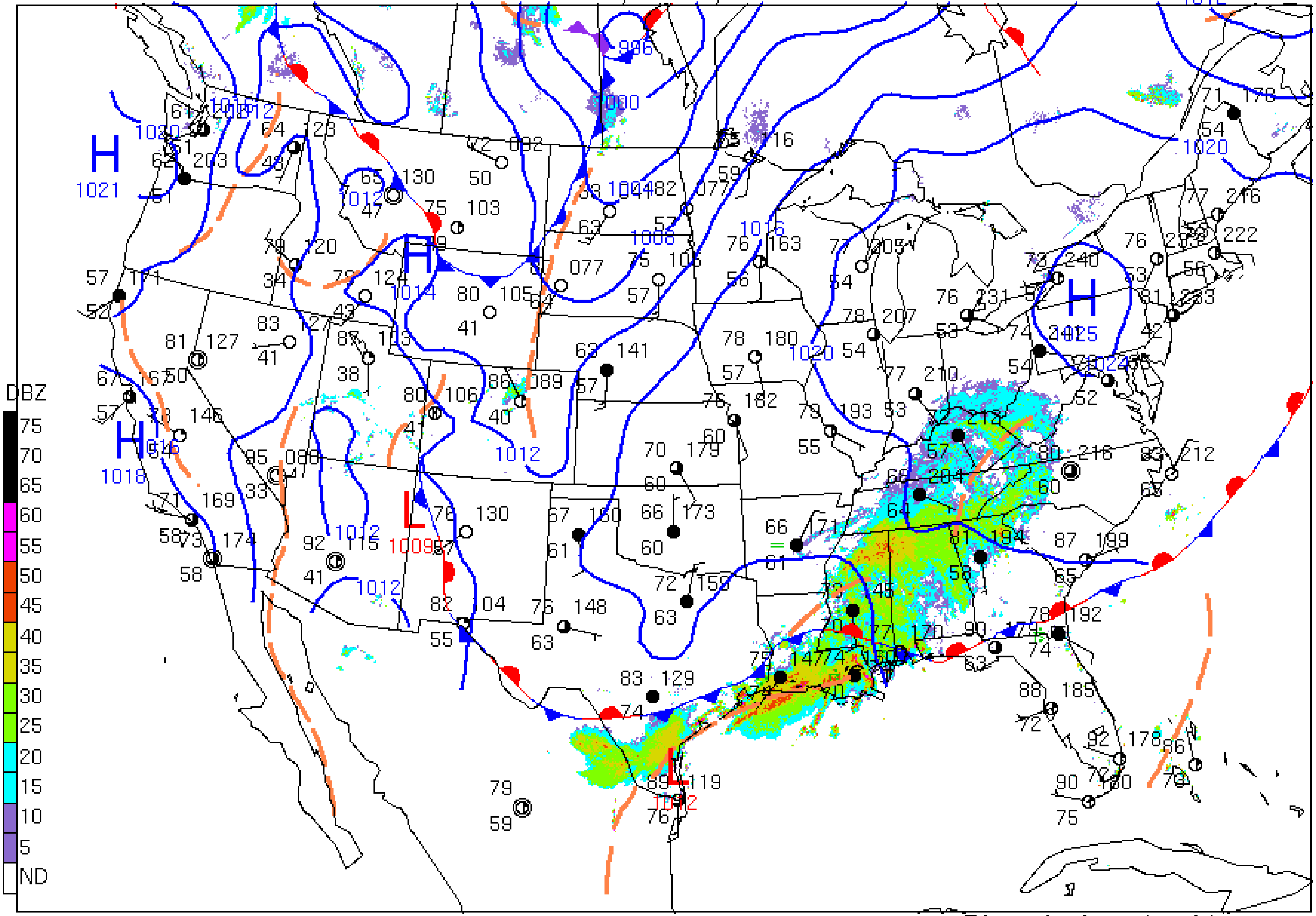
Alaska	**Hawaii and Pacific**	**Puerto Rico and Caribbean**

Additional International Links

Climate

National Temps/Precip.	NOAA Climate Services	U.S. Climatology
Local NWS Offices	NNDC Climate Data Online	Drought Monitor

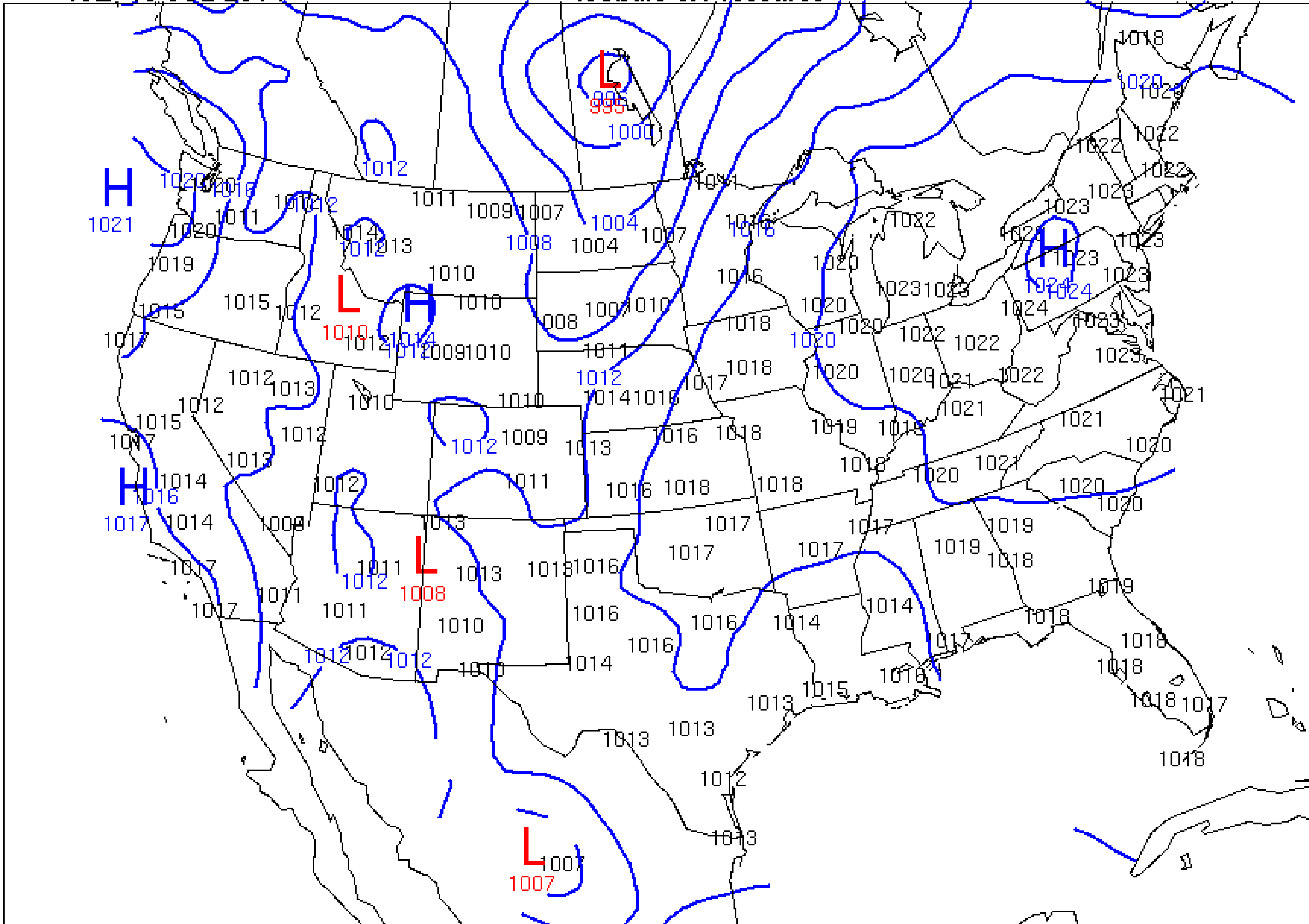
17Z 18 JUL 2014 Isobars, Fronts, Radar & Data Fronts at 15Z



NCEP/NWS/NOAA NATIONAL 2 KM BASE REFLECT 0.00 DEG **Blue - Isobars (4 mb)**

18Z 18 JUL 2014

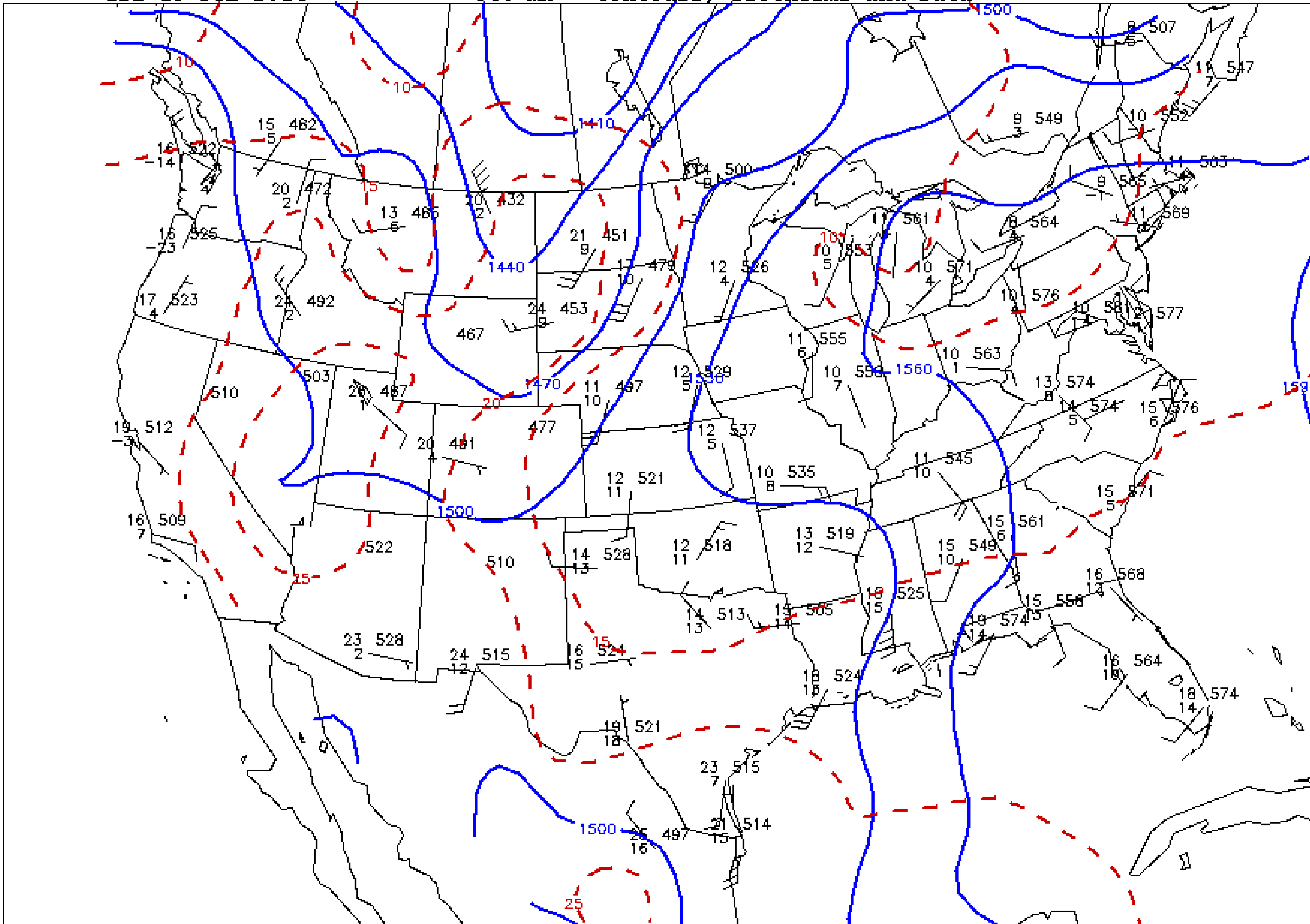
Isobars & Pressures



NCEP/NWS/NOAA

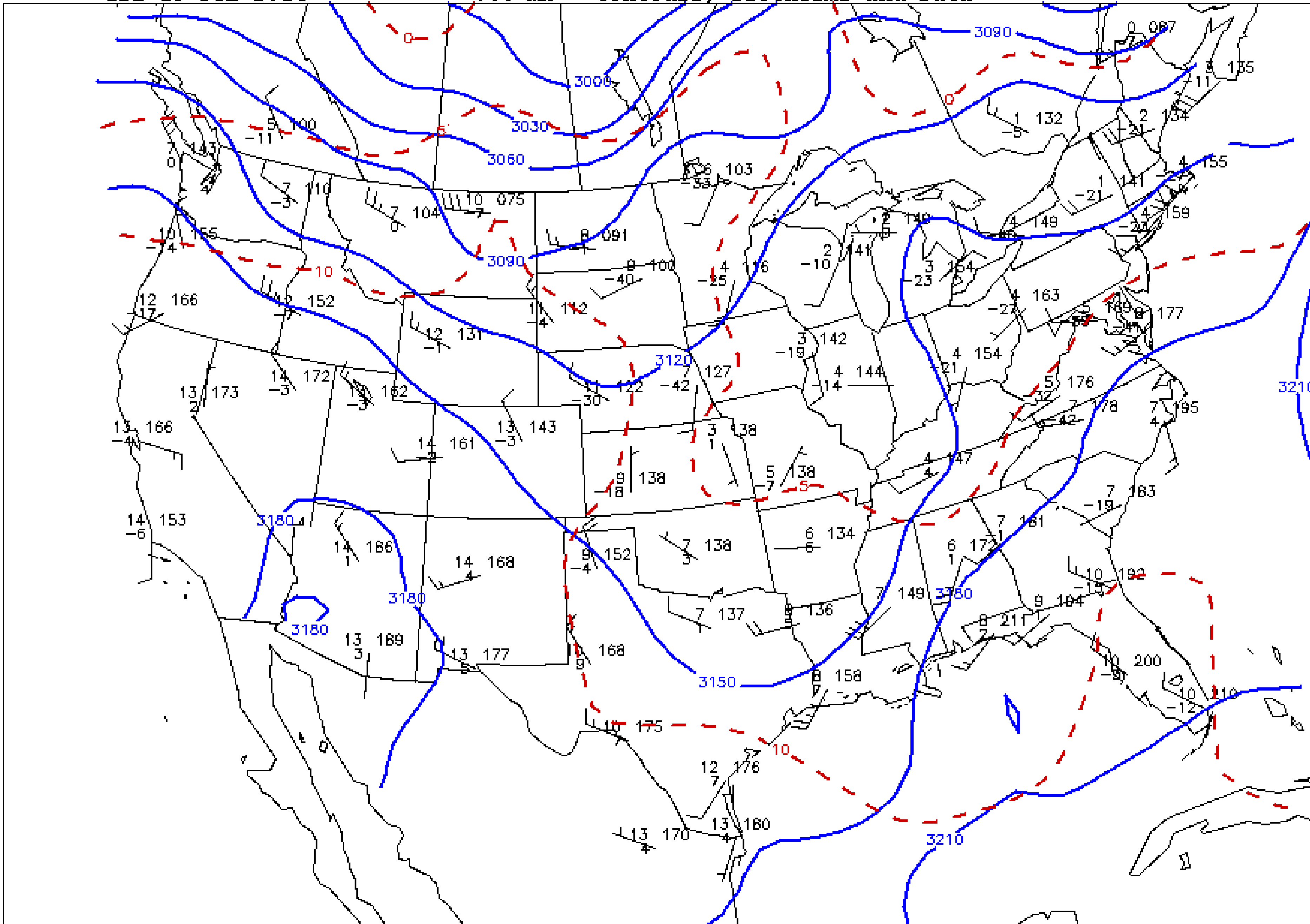
Blue - Isobars (4mb)

12Z 18 JUL 2014 850 mb - Contours, Isotherms and Data



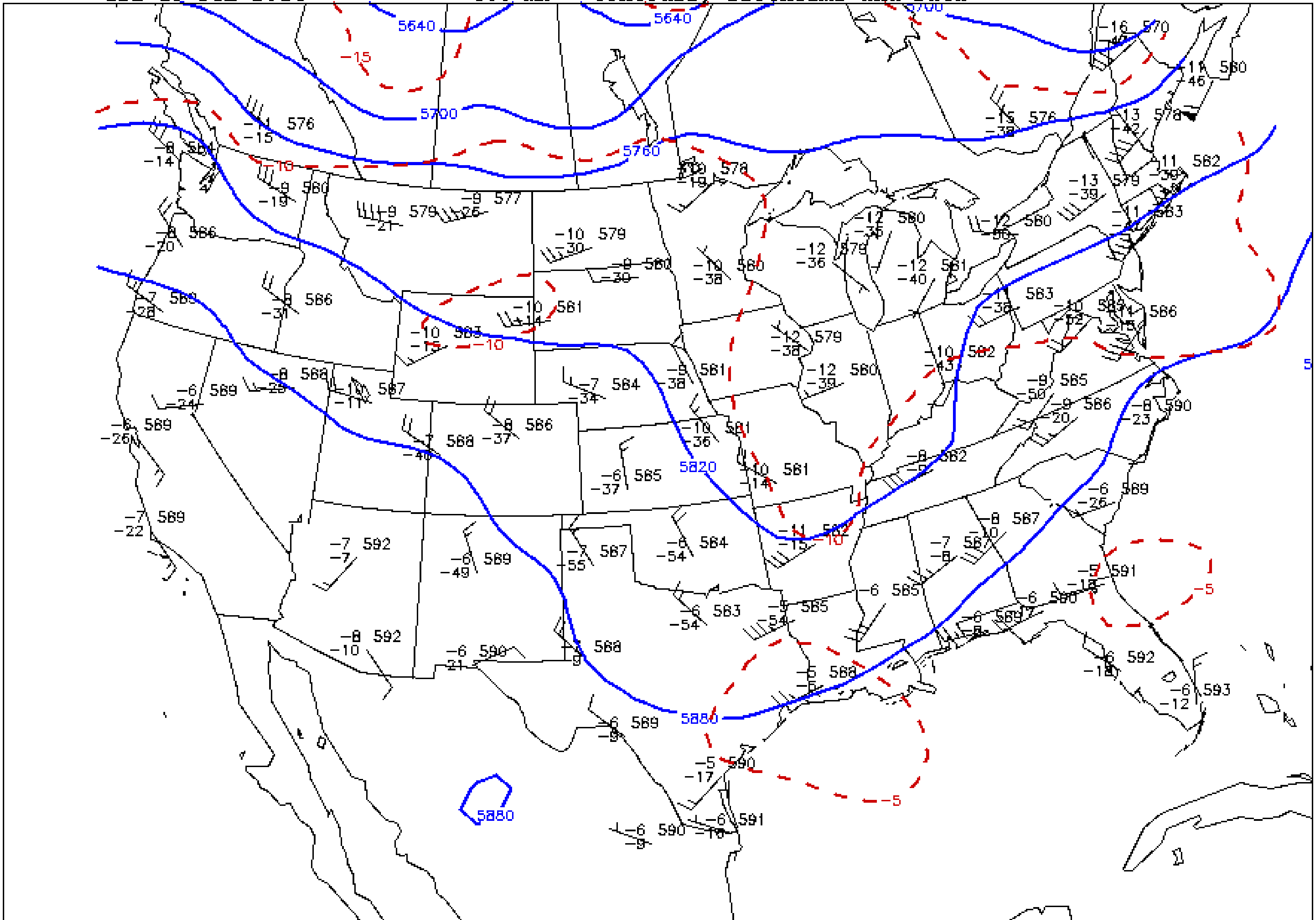
NCEP/NWS/NOAA Blue (Solid) - Contours of Height(30m) Red (Dash) - Isotherms (5C)

12Z 18 JUL 2014 700 mb - Contours, Isotherms and Data



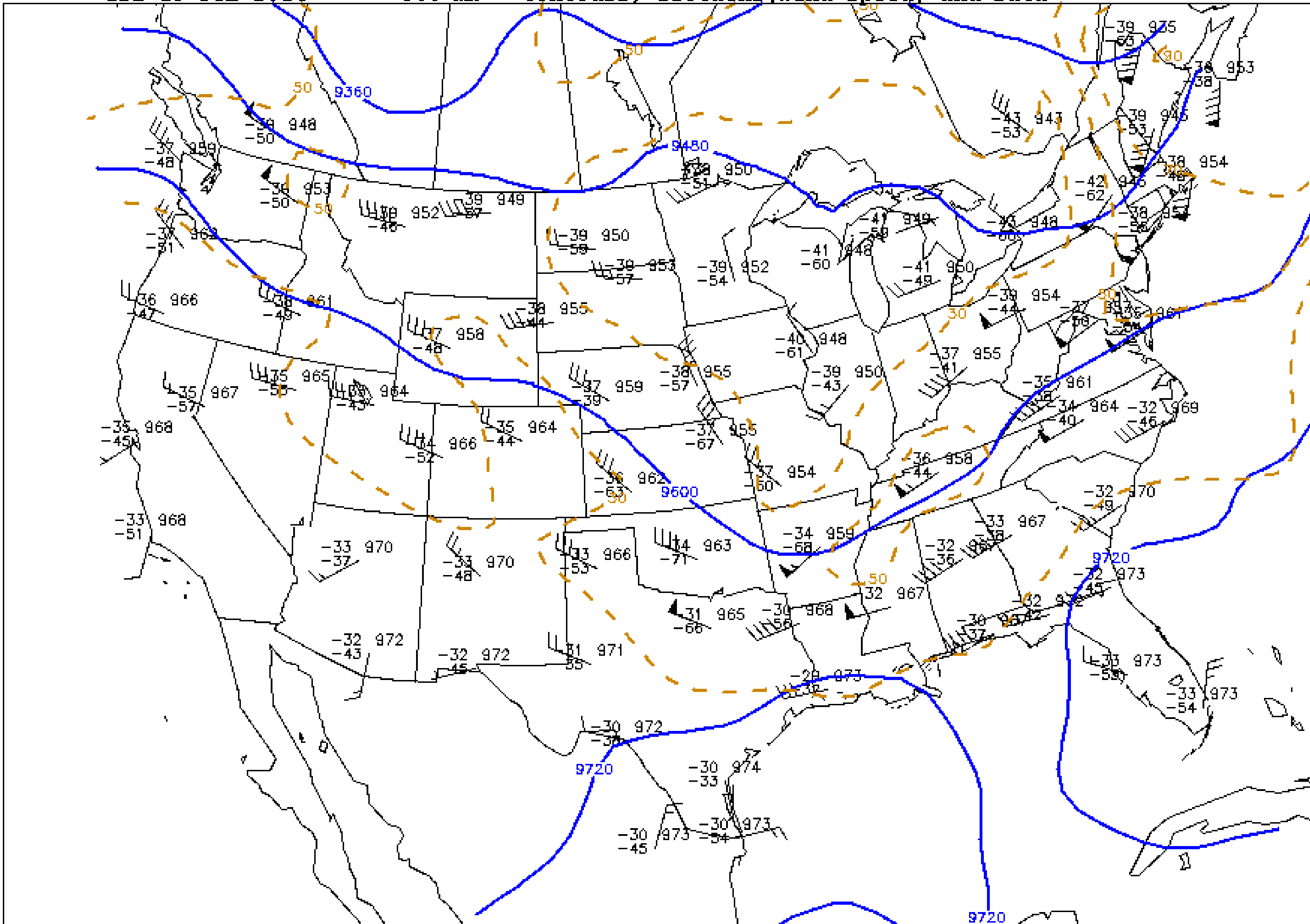
NCEP/NWS/NOAA Blue (Solid) - Contours of Height(30m) Red (Dash) - Isotherms (5C)

12Z 18 JUL 2014 500 mb - Contours, Isotherms and Data



NCEP/NWS/NOAA Blue (Solid) - Contours of Height(60m) Red (Dash) - Isotherms (5C)

12Z 18 JUL 2014 300 mb - Contours, Isotachs(wind speed) and Data



NCEP/NWS/NOAA Blue (Solid) - Contours of Height(120m) Brown(Dash) - Isotachs(20 kt)

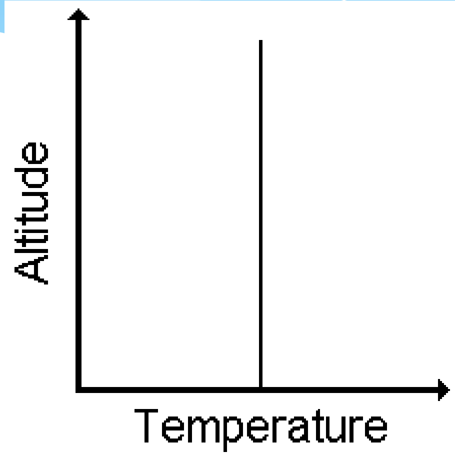
Stable vs. Unstable

- Based on the idea that warm air rises
- The temperature of a rising parcel is compared to the surrounding air temperature
- Radiosondes measure that air temperature
- Rising cools at the dry or moist adiabatic rate. Based on pressure change, not heat loss.

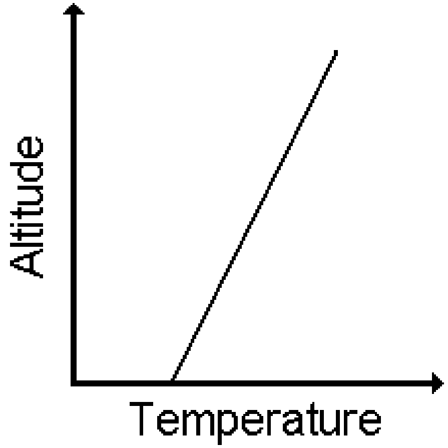
Stable vs. Unstable

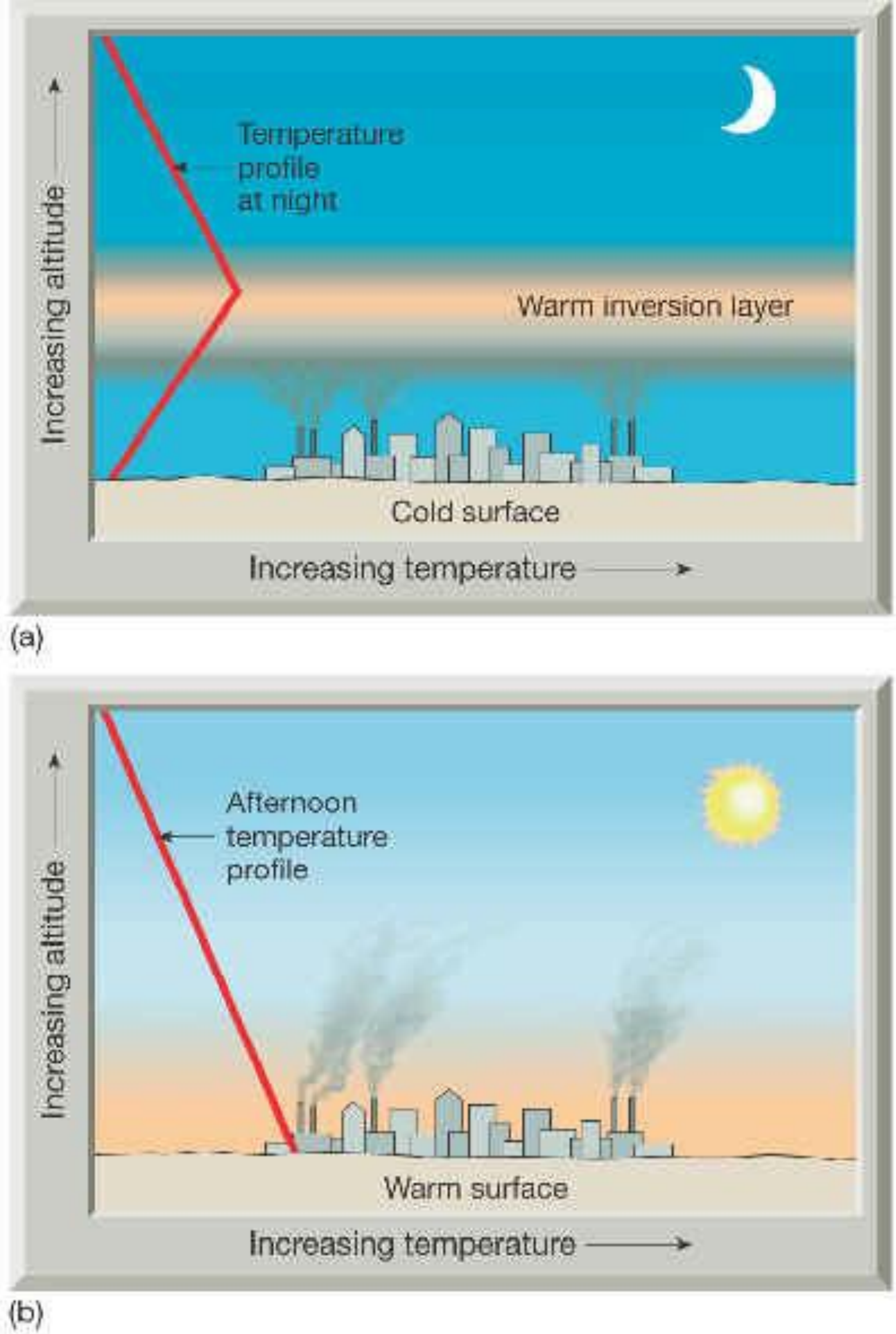
Types of Temperature Profiles

Isothermal – air temperature remains constant with height.



Inversion – air temperature increases with height.

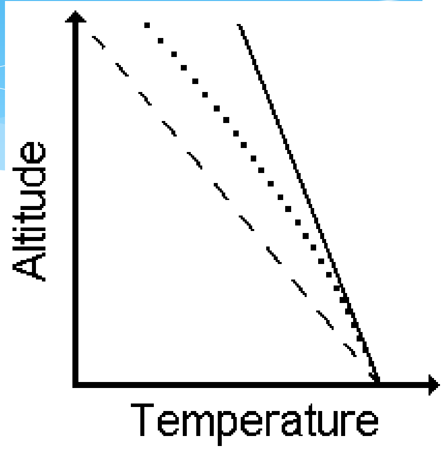



Temperature profile at night
Warm inversion layer
Cold surface
Increasing altitude
Increasing temperature
(a)
Afternoon temperature profile
Warm surface
Increasing altitude
Increasing temperature
(b)

Stability

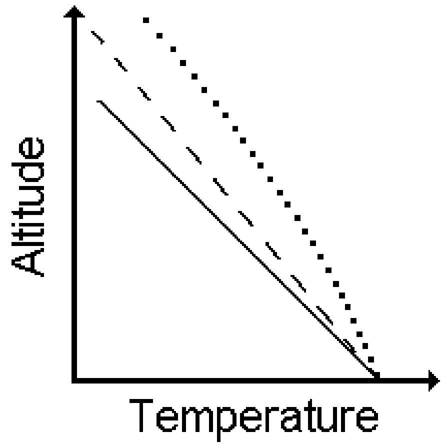
Absolute Stability

- Environmental lapse rate < moist adiabatic lapse rate (temp drops more slowly than the moist adiabatic lapse rate)
- Stable for saturated and unsaturated parcels
- Examples: isothermal layer, inversion



Absolute Instability

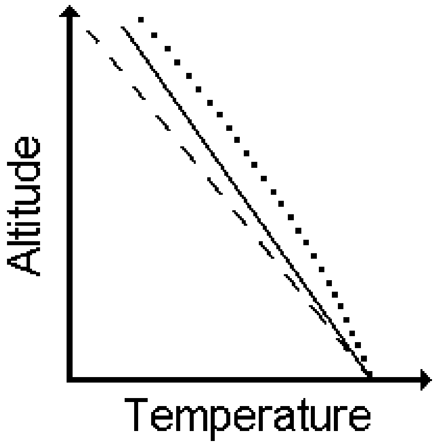
- Environmental lapse rate > than the dry adiabatic lapse rate (& of course the moist one too) (temperature drops more rapidly with altitude than the dry adiabatic lapse rate)
- Unstable for both saturated and unsaturated air parcels
- Once pushed, air parcels will continue to rise on their own b/c they're warmer/less dense than surrounding air.

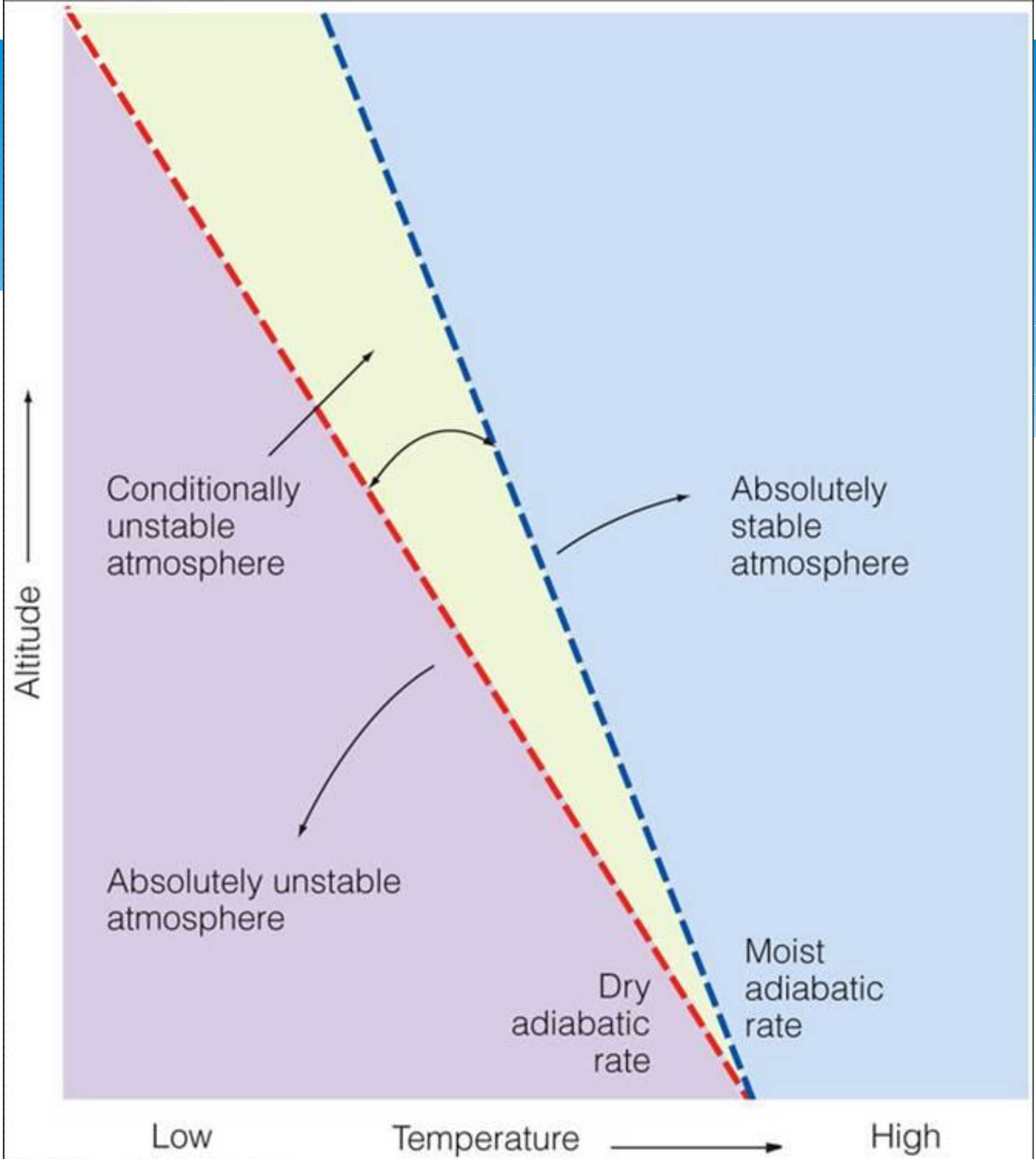


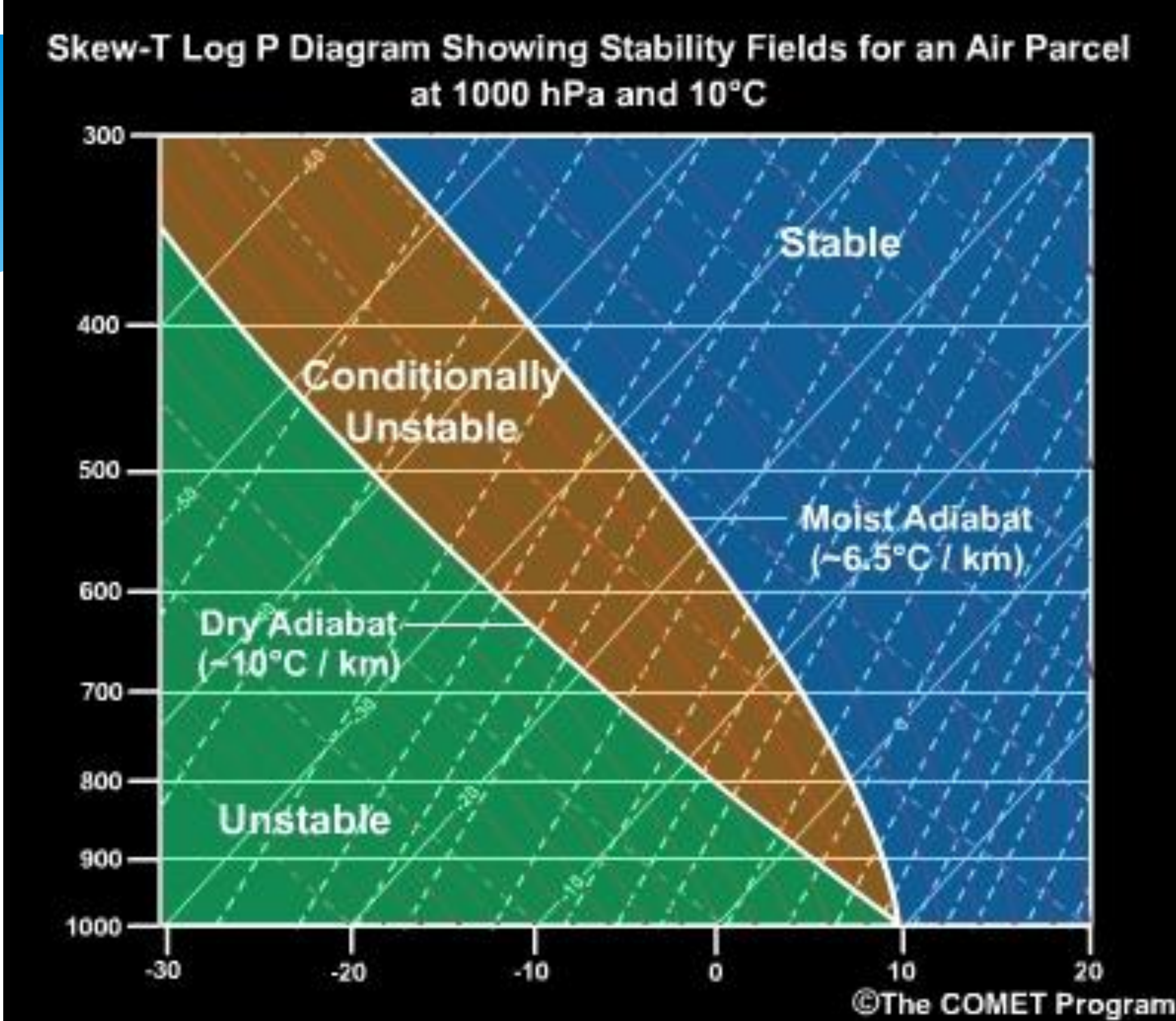
Stability

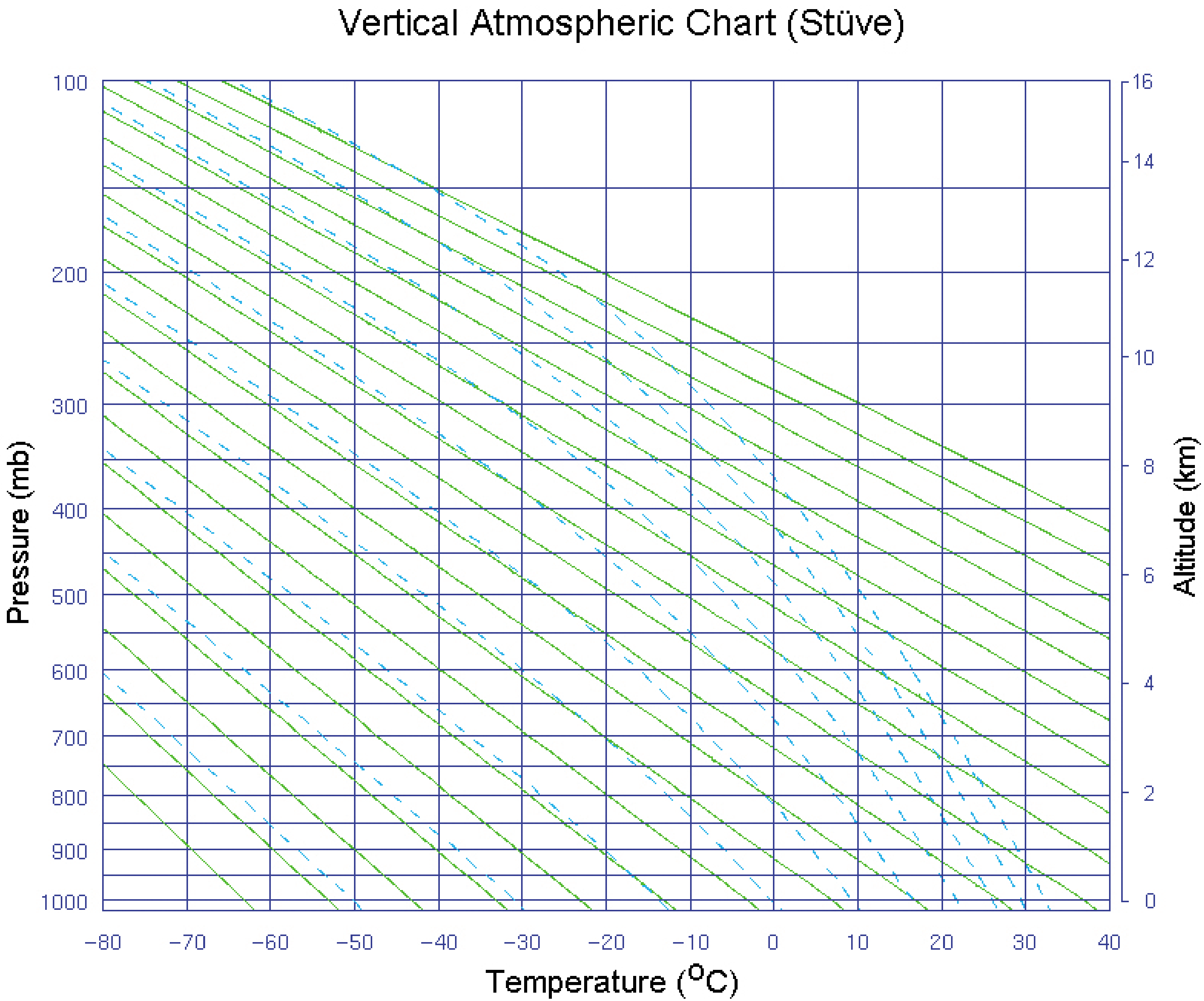
Conditional Stability

- Environmental lapse rate is between the moist and the dry adiabatic lapse rates.
- Stable for unsaturated air (parcel is cooler than environment)
- Unstable for saturated air (parcel is warmer than environment)
- Common situation
- If unsaturated air is lifted upwards and reaches saturation, instability would result.




Conditionally unstable atmosphere
Absolutely stable atmosphere
Absolutely unstable atmosphere
Dry adiabatic rate
Moist adiabatic rate
Altitude
Low
Temperature
High


Skew-T Log P Diagram Showing Stability Fields for an Air Parcel at 1000 hPa and 10°C
300
400
500
600
700
800
900
1000
-30
-20
-10
0
10
20
Stable
Conditionally Unstable
Moist Adiabat (~6.5°C / km)
Dry Adiabat (~10°C / km)
Unstable
©The COMET Program


Vertical Atmospheric Chart (Stüve)
Pressure (mb)
100
200
300
400
500
600
700
800
900
1000
Altitude (km)
16
14
12
10
8
6
4
2
0
−80
−70
−60
−50
−40
−30
−20
−10
0
10
20
30
40
Temperature (°C)