Mountain Weather

Notes available at: http://www.rod-plasman.ca/wxcourse.pdf

Outline

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  - Hazardous weather
  - Units and Measurements
  - Seasons
  - Atmosphere
  - Radiation and Heat Transfer
  - Pressure
  - Global Circulation and Coriolis Force
  - Air Masses
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  - NOAA Main Site
  - SPOTWX
  - ECMWF

Weather Overview and Theory

Hazardous Weather

- Strong Wind
- Heavy Snow
- Heavy Rain
- White-outs
- Thunderstorms
- Tornados
- Temperature extremes
- Rapidly changing conditions
- ?

What do we observe?

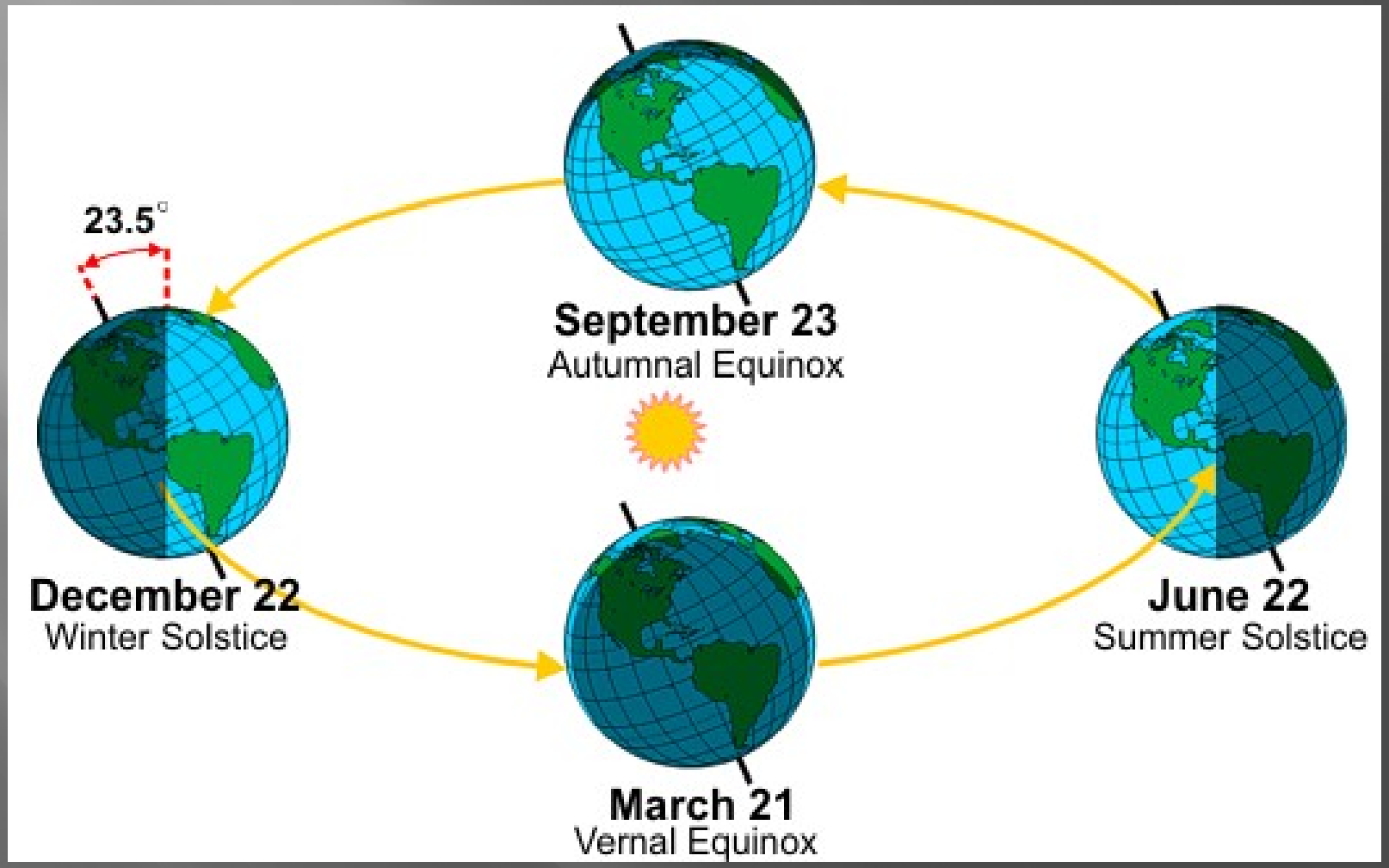
- Time - UTC
  - Most weather maps and charts use UTC as their standard time
  - Stands for *"Coordinated Universal Time"*
  - Can be considered the equivalent of Greenwich Mean Time (GMT)
  - To convert for the Mountain Time Zone:
    - Daylight savings: UTC – 6 hours
    - Standard: UTC – 7 hours
- Sky Clear – Overcast
  - Octals
- Precipitation
  - Type
  - Intensity
  - Amount
  - Liquid is measured in millimeters (mm) – Solid in centimeters (cm). Intensity is in mm per hour or cm per hour

What do we observe?
continued

- Temperature (Celsius)
  - Maximum
  - Minimum
  - Current
- Relative Humidity (%)
- Wind
  - Speed (kilometers per hour)
  - Direction (N, NE, E, SE, S, SW, W, NW)
- Pressure
  - Current (millibars (mb))
  - Trend (steady, rising slowly, rising rapidly, dropping slowly, dropping rapidly)

Seasons

- The Earth's axis is tilted at 23.5°



Atmosphere

- Composition
  - Nitrogen 78%
  - Oxygen 21%
  - Argon, CO_2, H_2O 1%

- Layers
  - Troposphere
    - Where weather occurs
    - Temperature decreases with height
    - Highest at the equator 17km – 8km at poles
  - Stratosphere
    - Temperature increases with height
    - Contains the ozone layer
    - No significant weather
  - Mesosphere and Thermosphere
    - No weather
    - Is where the aurora occurs

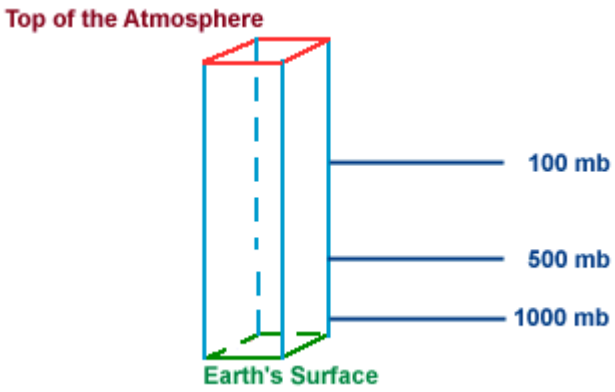
Heat Transfer

- Radiation
  - Short Wave
  - Long Wave
- Convection
- Conduction

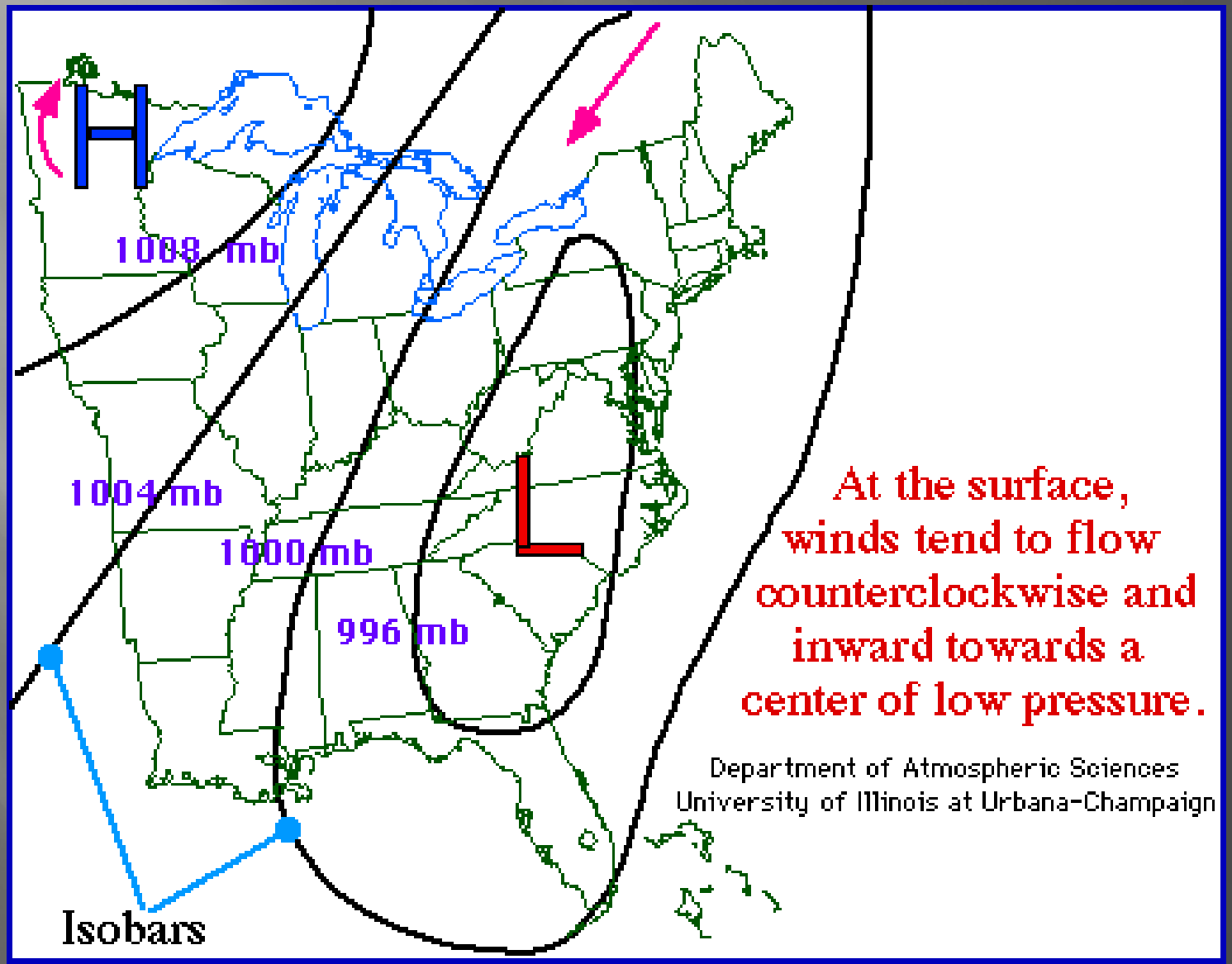
Air Pressure

Pressure	Approximate Height	Approximate Temperature
Sea Level	0 m 0 ft	15 C 59 F
1000mb	100 m 300 ft	15 C 59 F
850 mb	1500 m 5000 ft	05 C 41 F
700 mb	3000 m 10000 ft	-05 C 23 F
500 mb	5000 m 18000 ft	-20 C -04 F
300 mb	9000 m 30000 ft	-45 C -49 F
200 mb	12000 m 40000 ft	-55 C -67 F
100 mb	16000 m 53000 ft	-56 C -69F

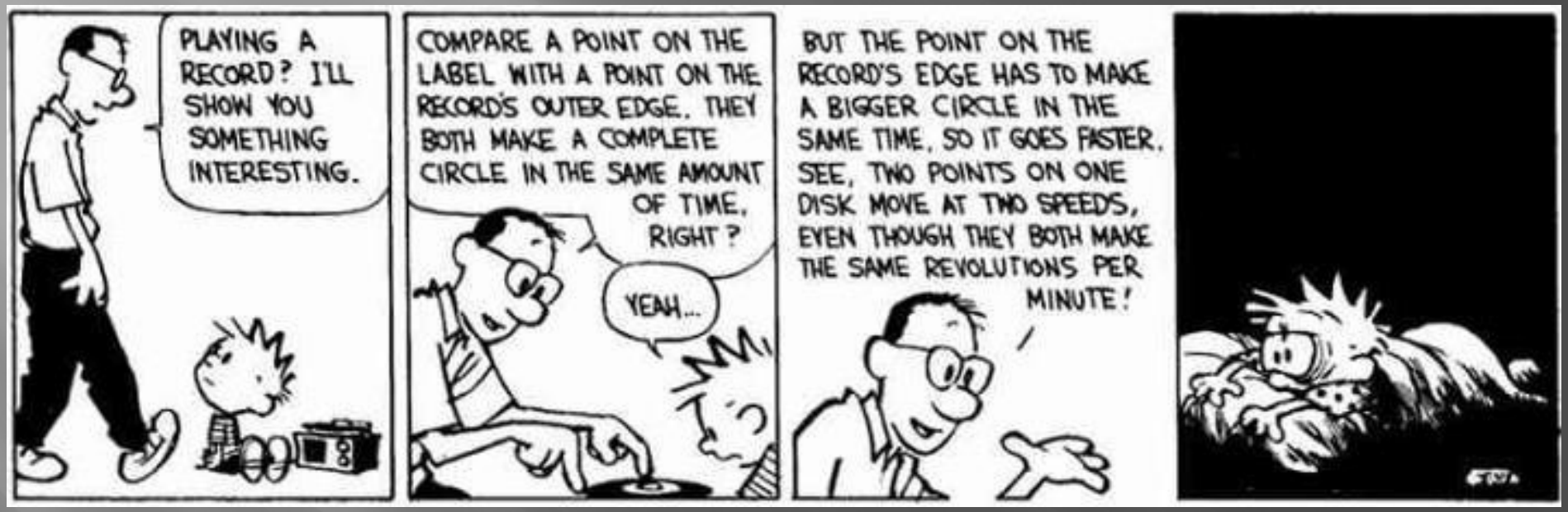
Chart from: WXP Purdue



Pressure Systems

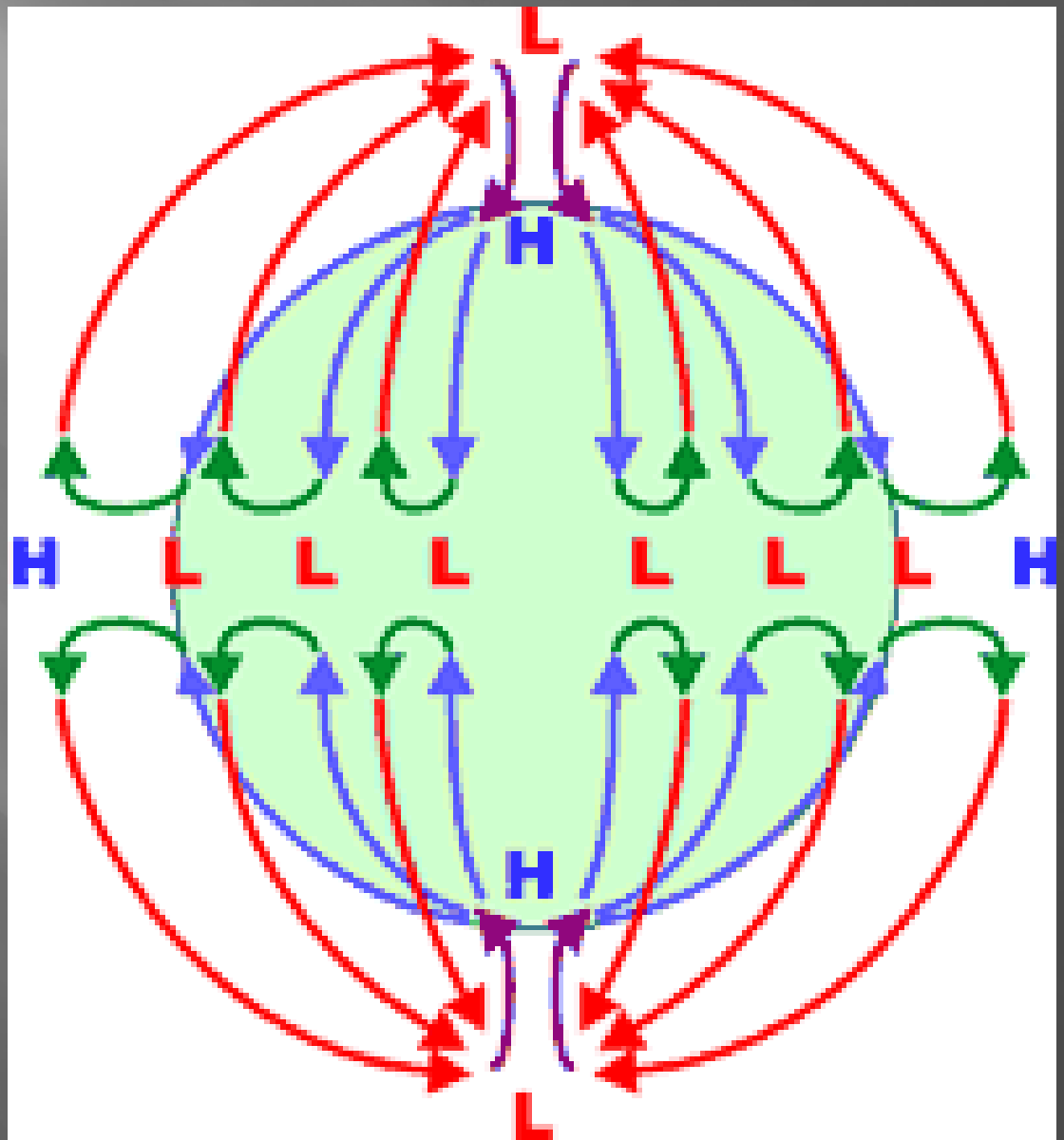


Coriolis Force

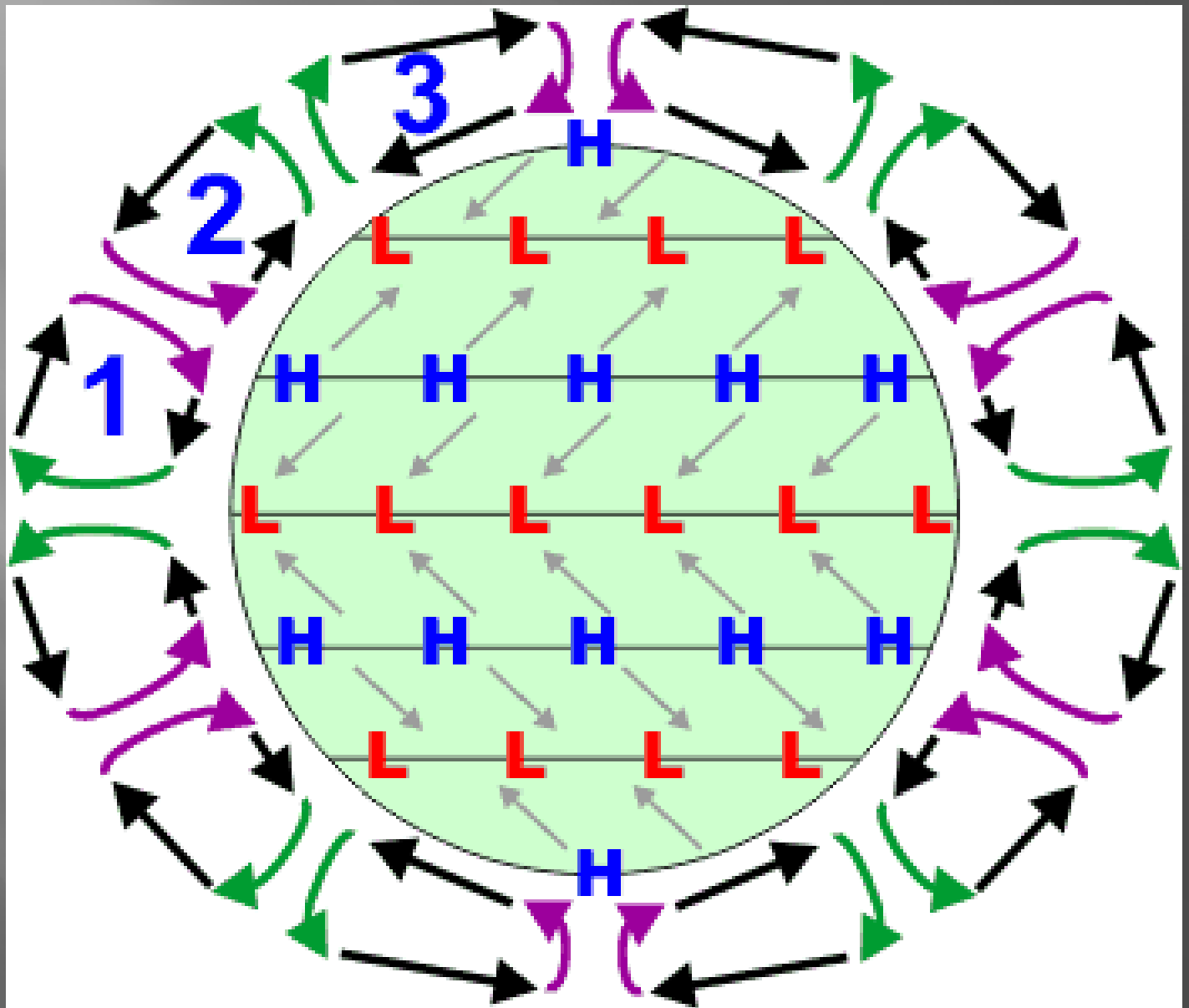


Coriolis Force

Coriolis Force



Global Circulation

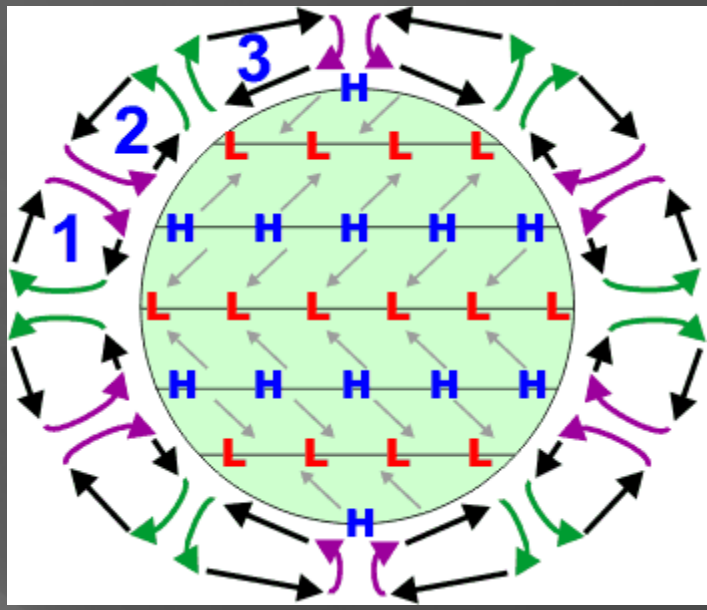


Global Circulation

1. Hadley cell - Low latitude air movement toward the equator that with heating, rises vertically, with poleward movement in the upper atmosphere and equatorward at the surface. This forms a convection cell that dominates tropical and sub-tropical climates.

2. Ferrel cell - A mid-latitude mean atmospheric circulation cell for weather named by Ferrel in the 19th century. In this cell the air flows poleward and eastward near the surface and equatorward and westward at higher levels.

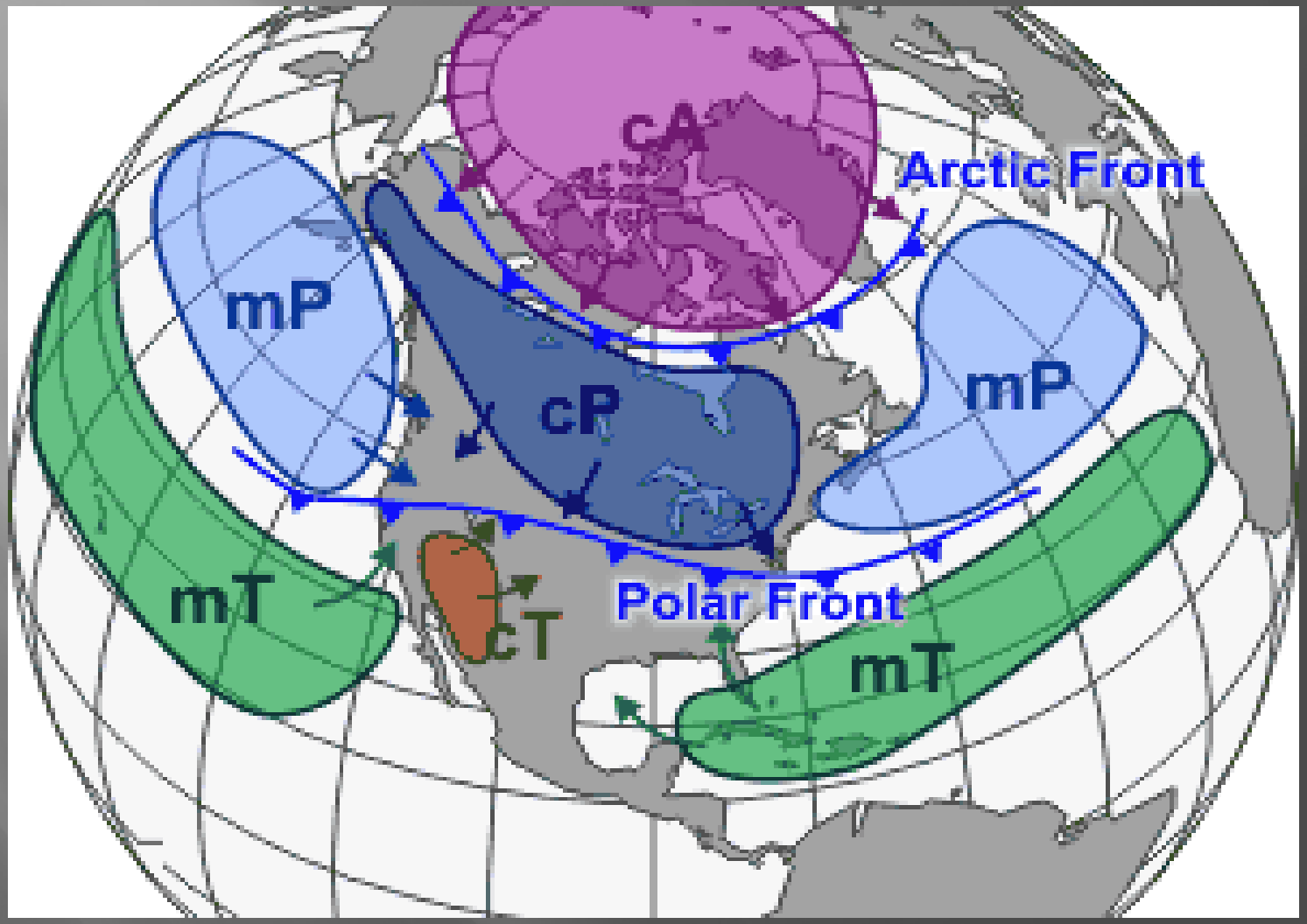
3. Polar cell - Air rises, diverges, and travels toward the poles. Once over the poles, the air sinks, forming the polar highs. At the surface, air diverges outward from the polar highs. Surface winds in the polar cell are easterly (polar easterlies).



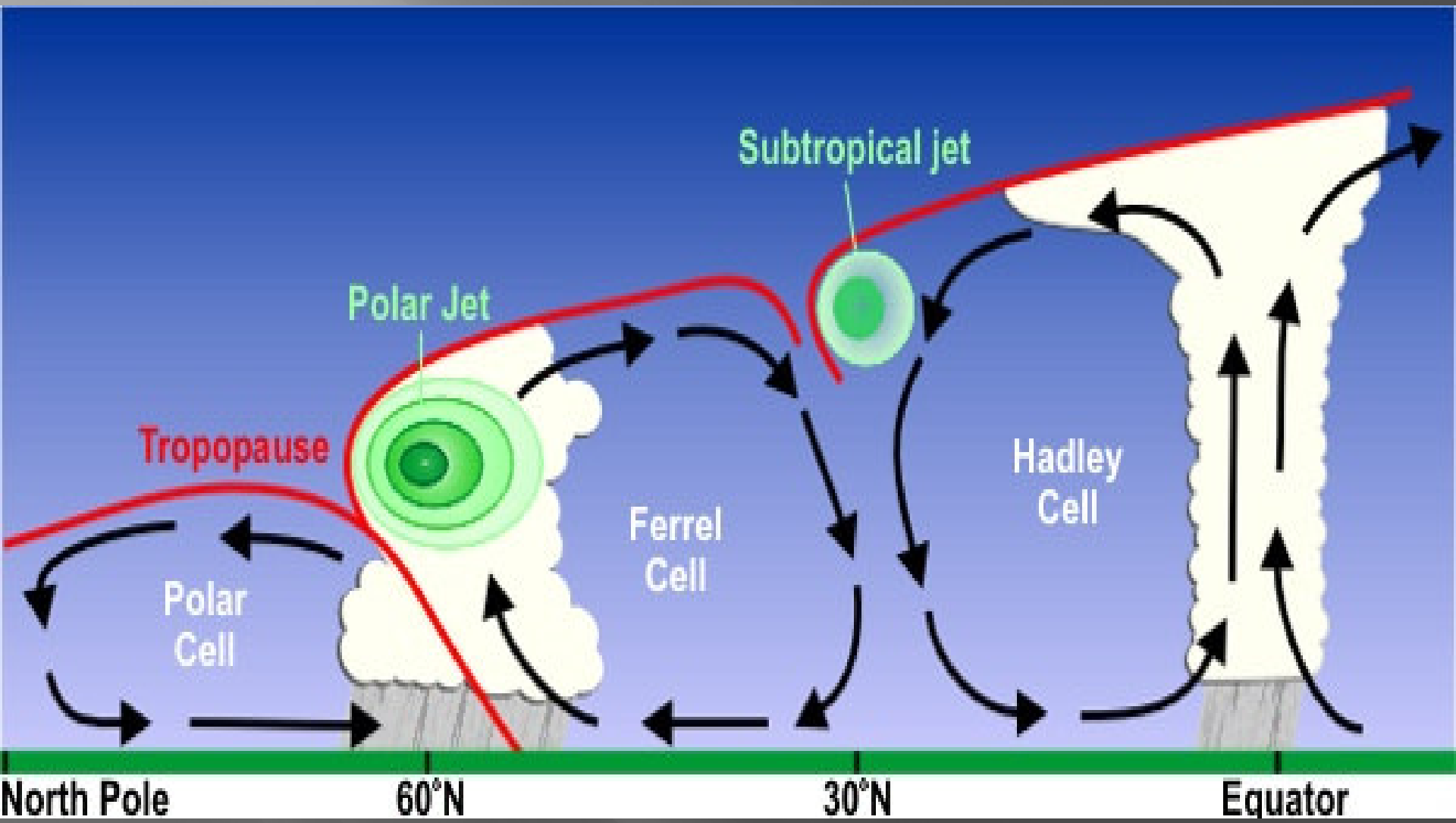
Between each of these circulation cells are bands of high and low pressure at the surface. The high pressure band is located about 30° N/S latitude and at each pole. Low pressure bands are found at the equator and 50°-60° N/S.

Usually, fair and dry weather is associated with high pressure, with rainy and stormy weather associated with low pressure. You can see the results of these circulations on a globe. Look at the number of deserts located along the 30°N/S latitude around the world. Now, look at the region between 50°-60° N/S latitude. These areas, especially the west coast of continents, tend to have more precipitation due to more storms moving around the earth at these latitudes.

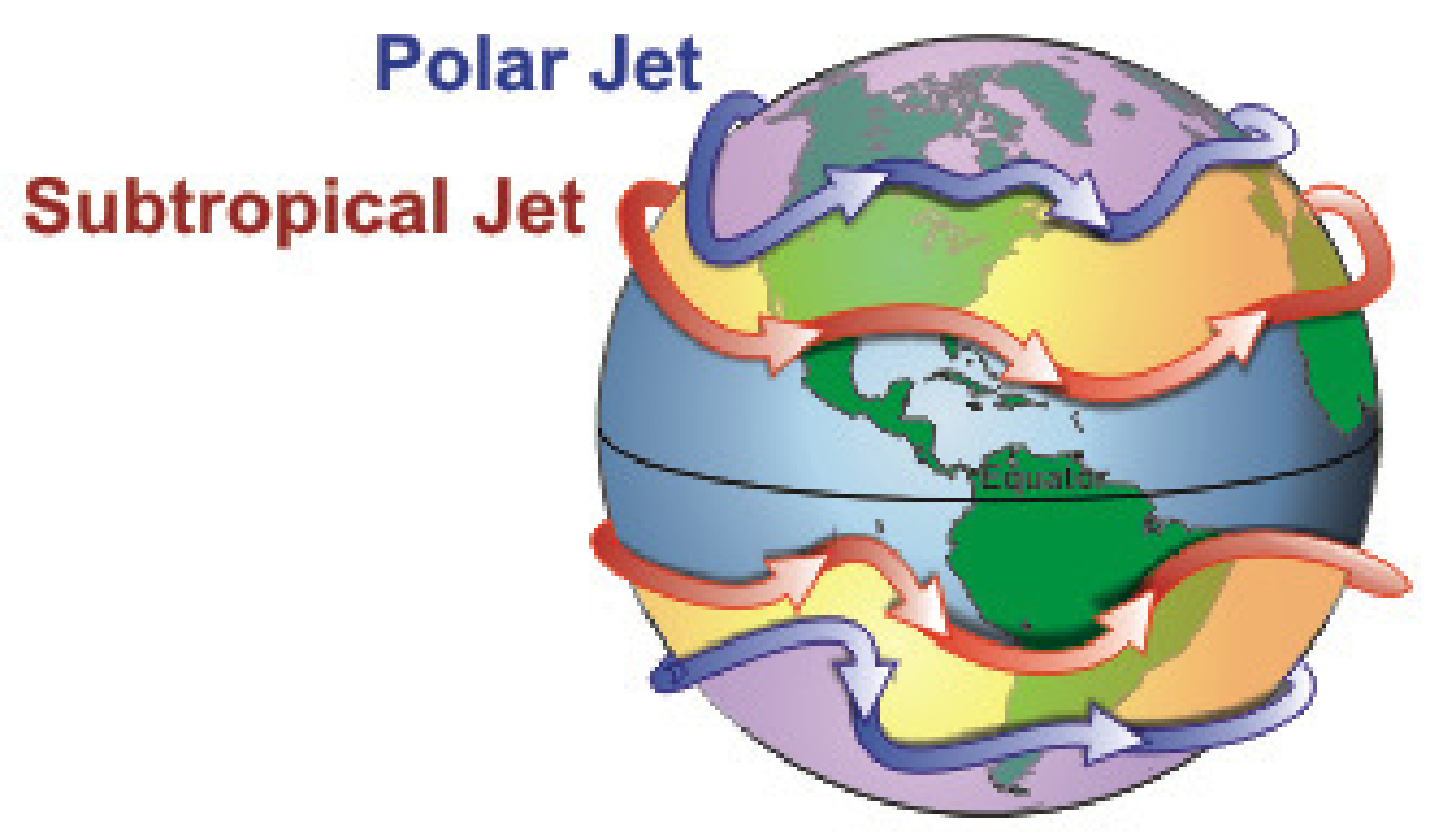
Air Masses



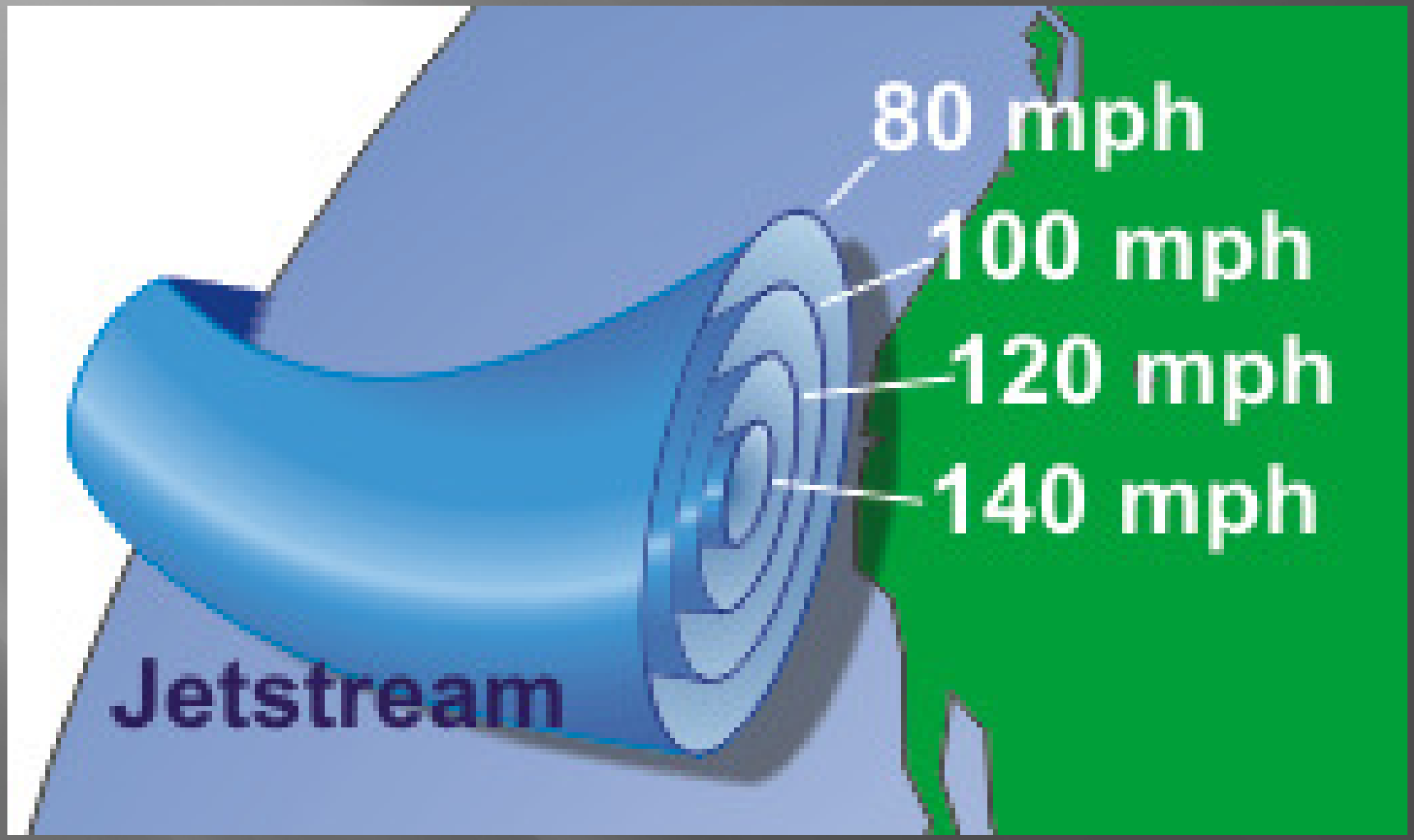
Jet Stream


Subtropical jet
Polar Jet
Tropopause
Hadley Cell
Ferrel Cell
Polar Cell
North Pole
60°N
30°N
Equator

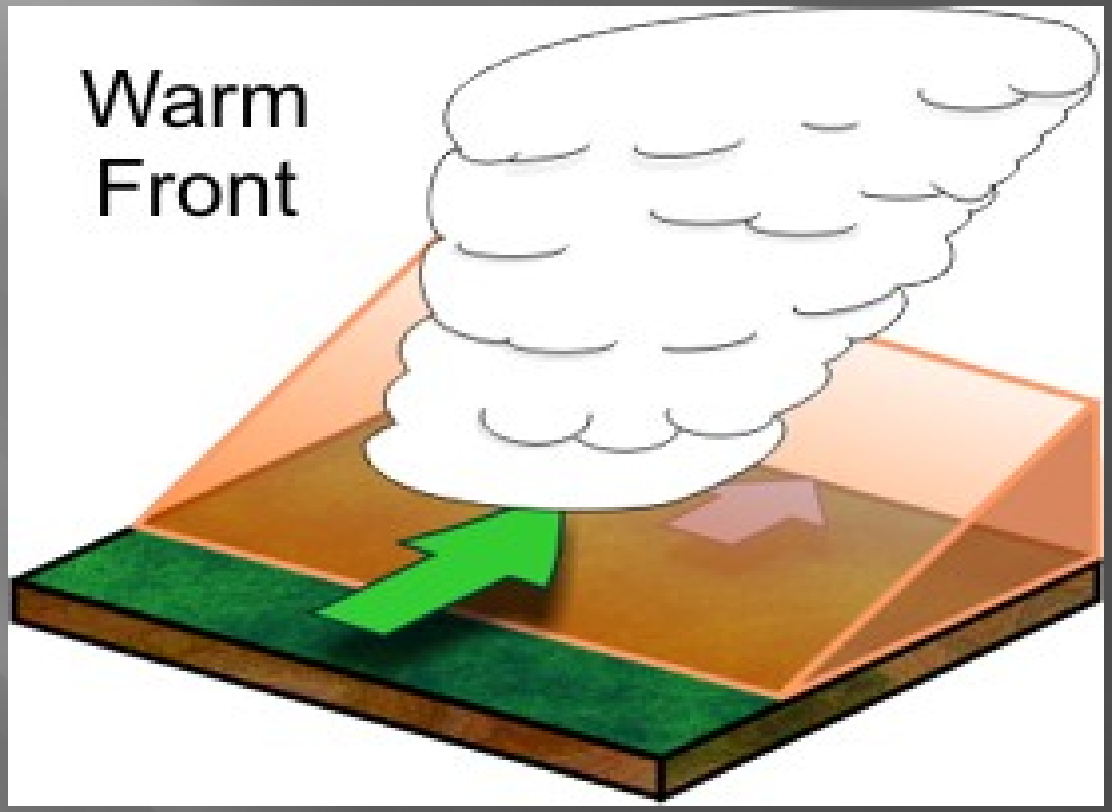
Jet Stream



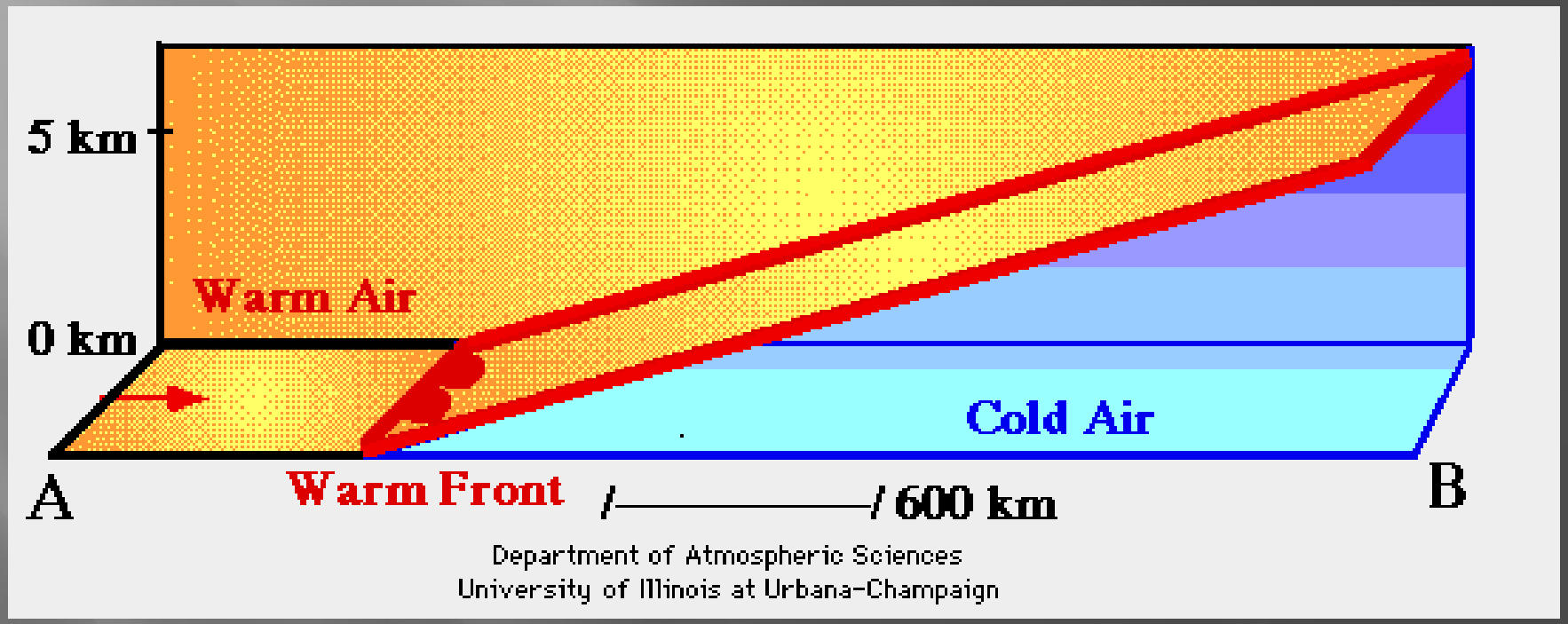
Jet Stream



Warm Front

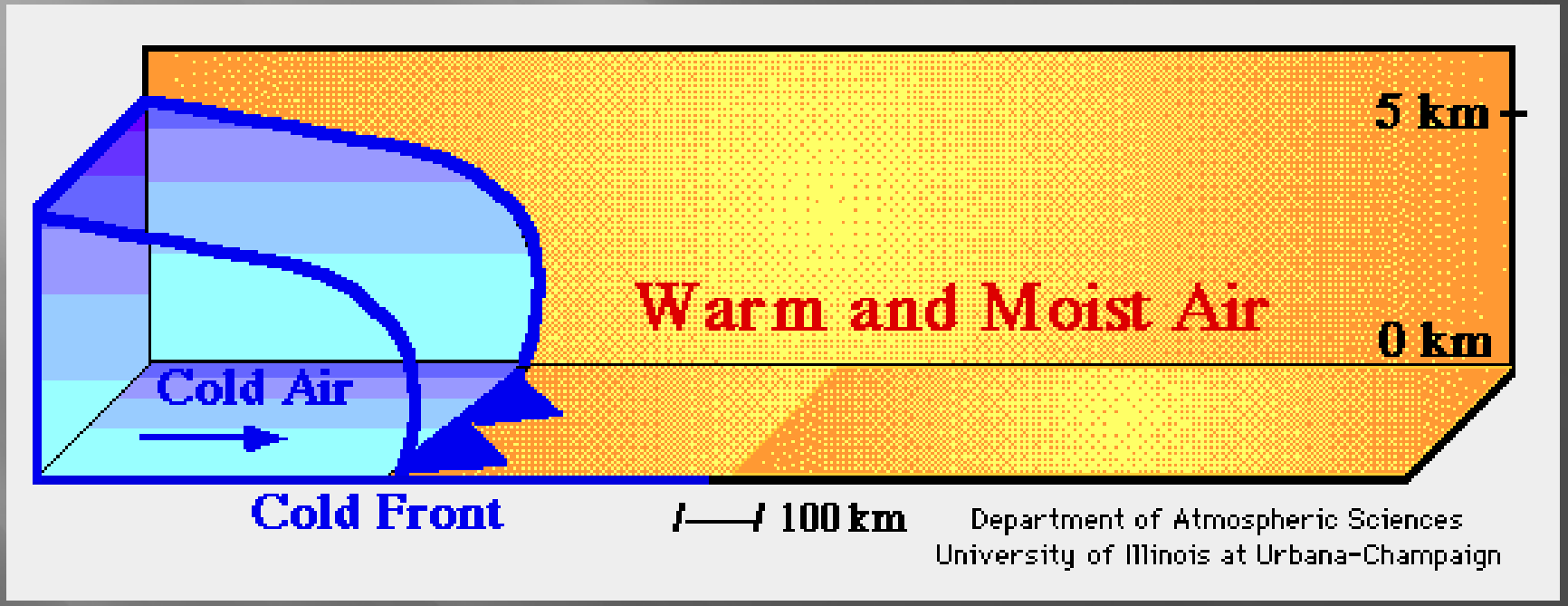


Warm Front


5 km
0 km
Warm Air
Cold Air
A
Warm Front
600 km
B
Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign

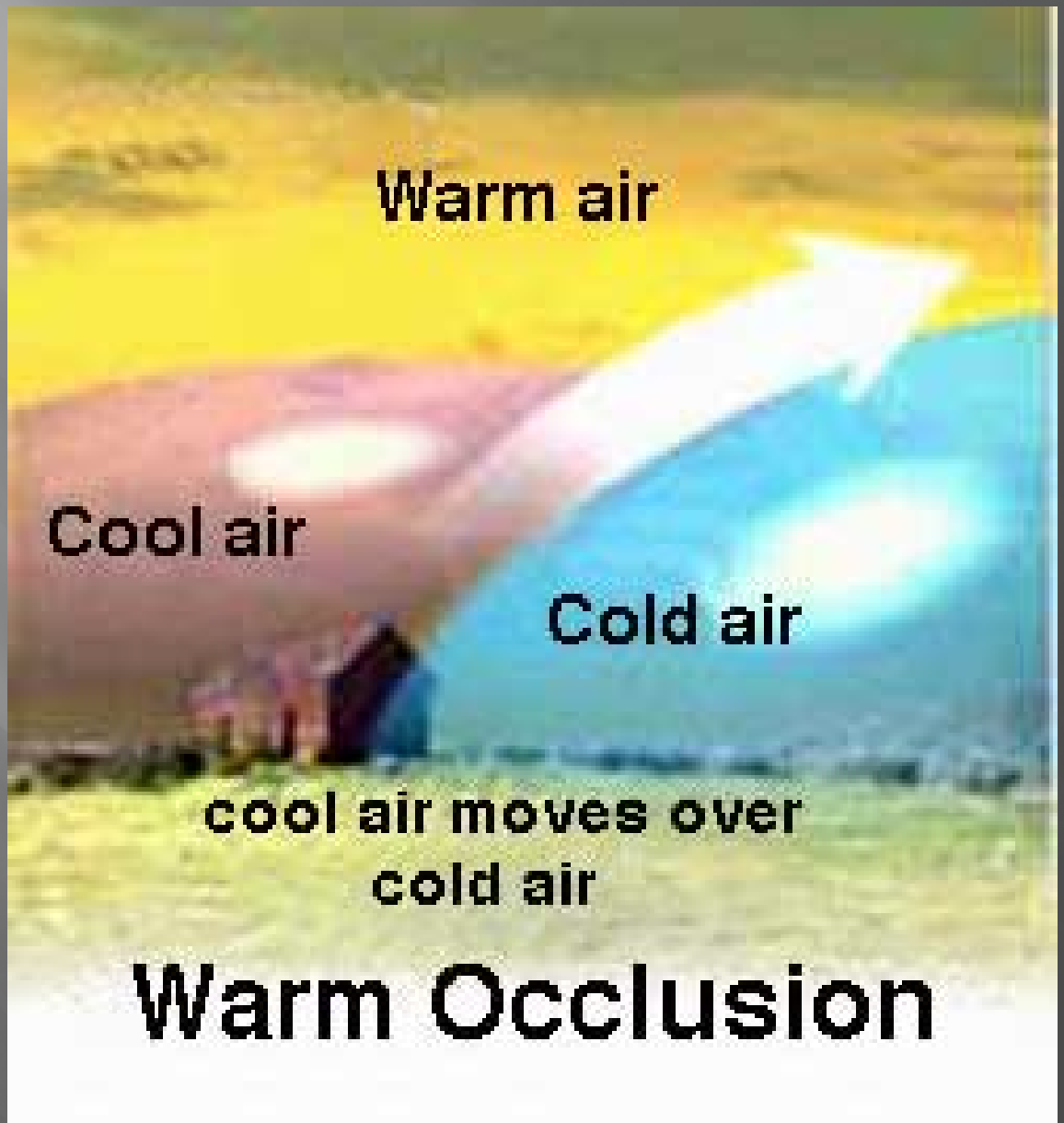
Cold Front

Cold Front

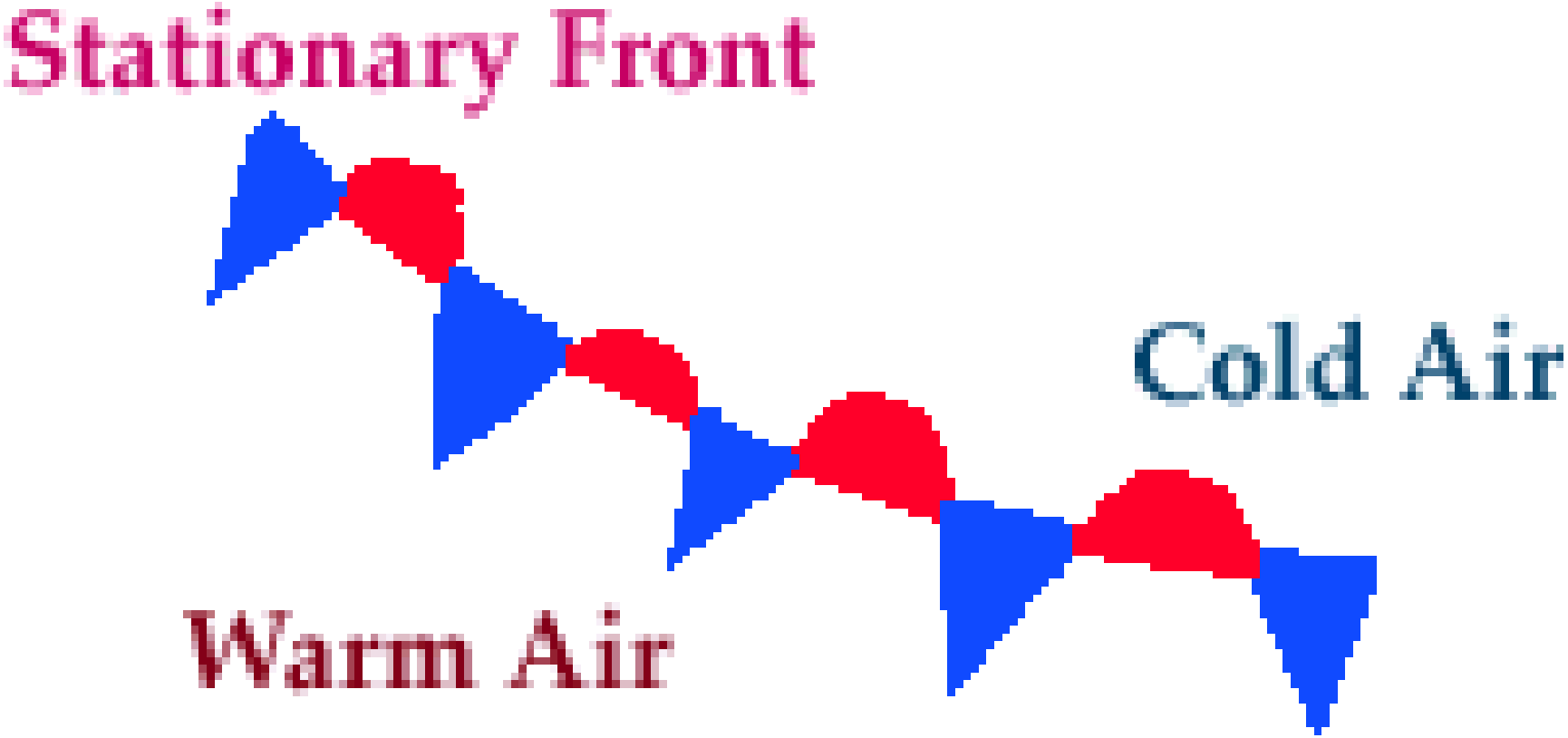

5 km
Warm and Moist Air
0 km
Cold Air
Cold Front
100 km
Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign

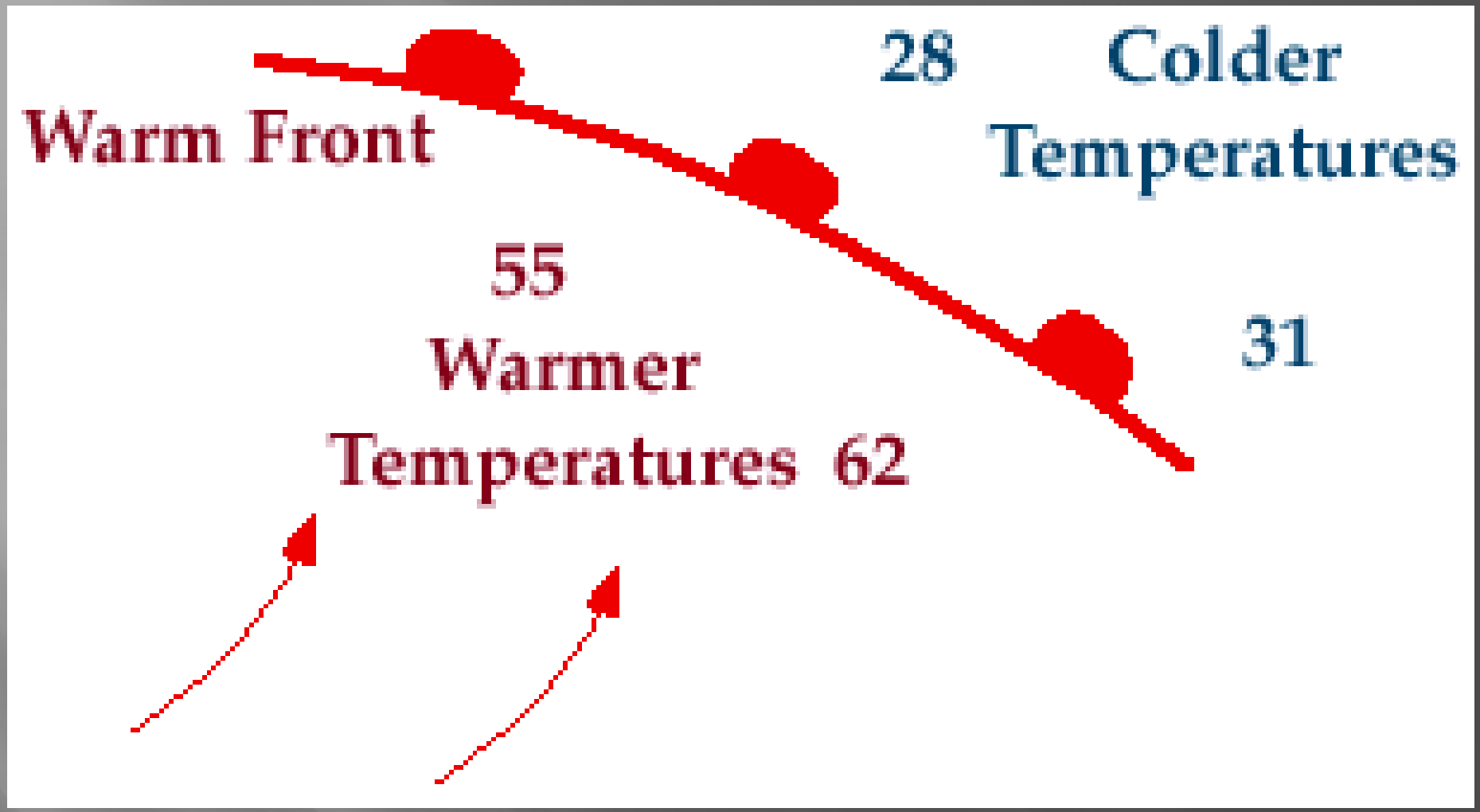
Occluded Front

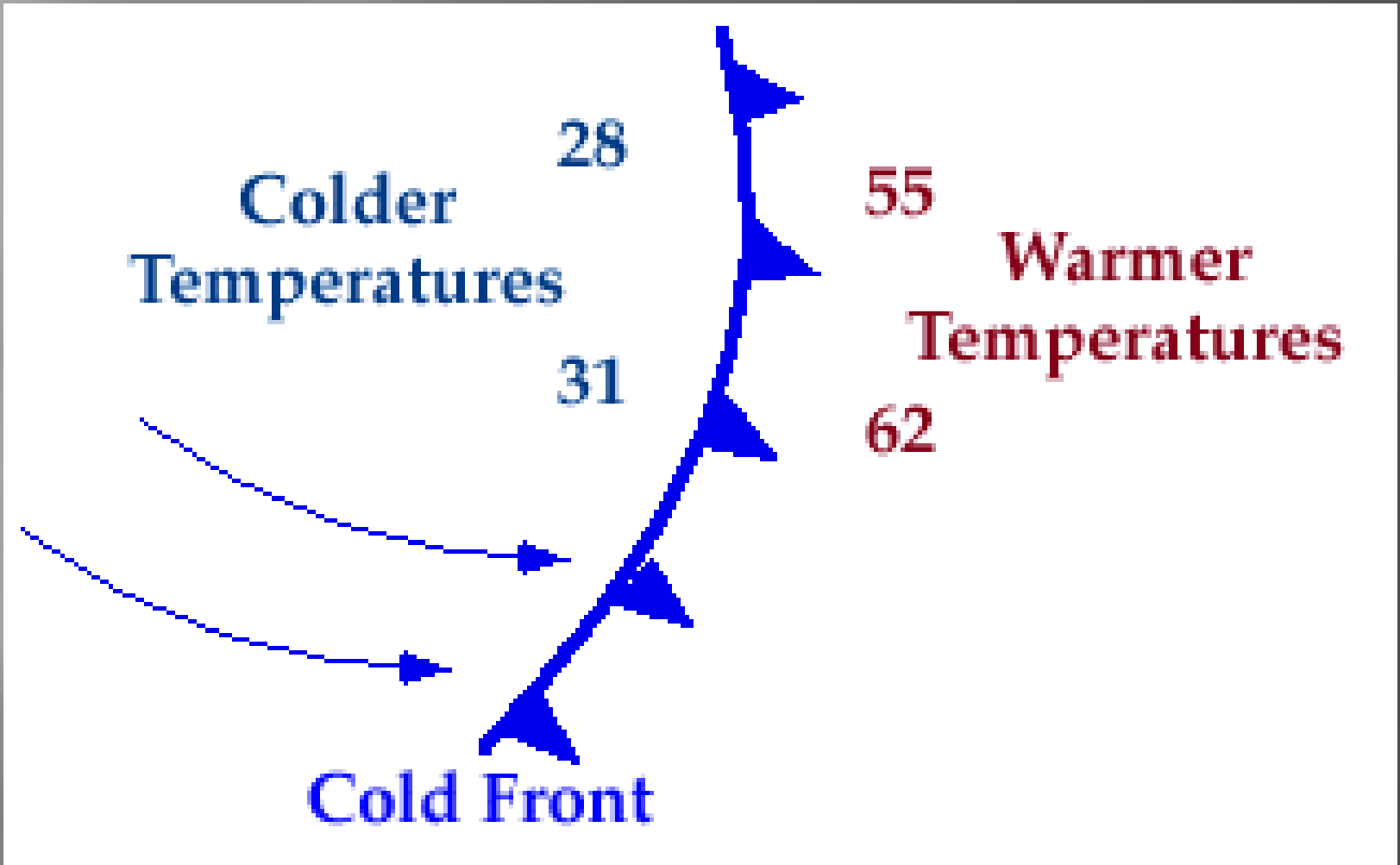
Occluded Front

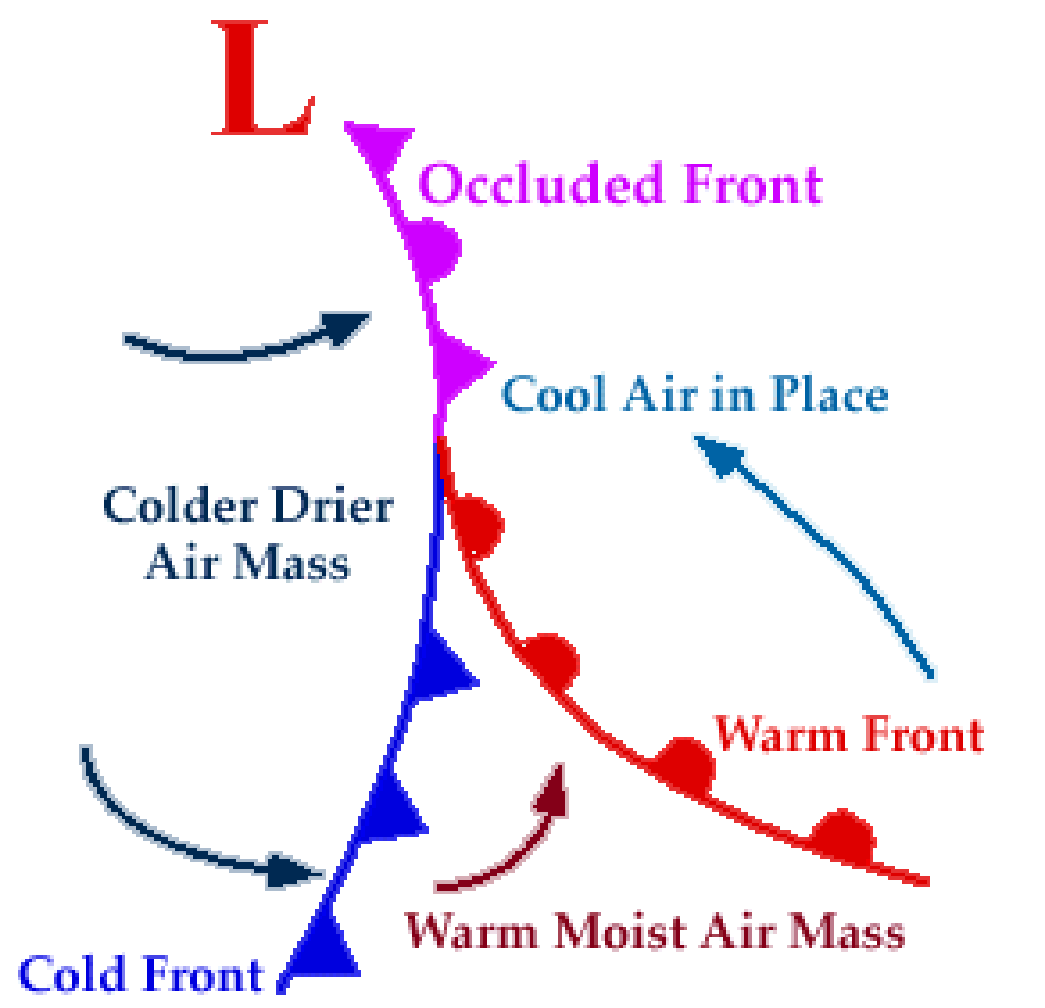


Fronts On Weather Maps

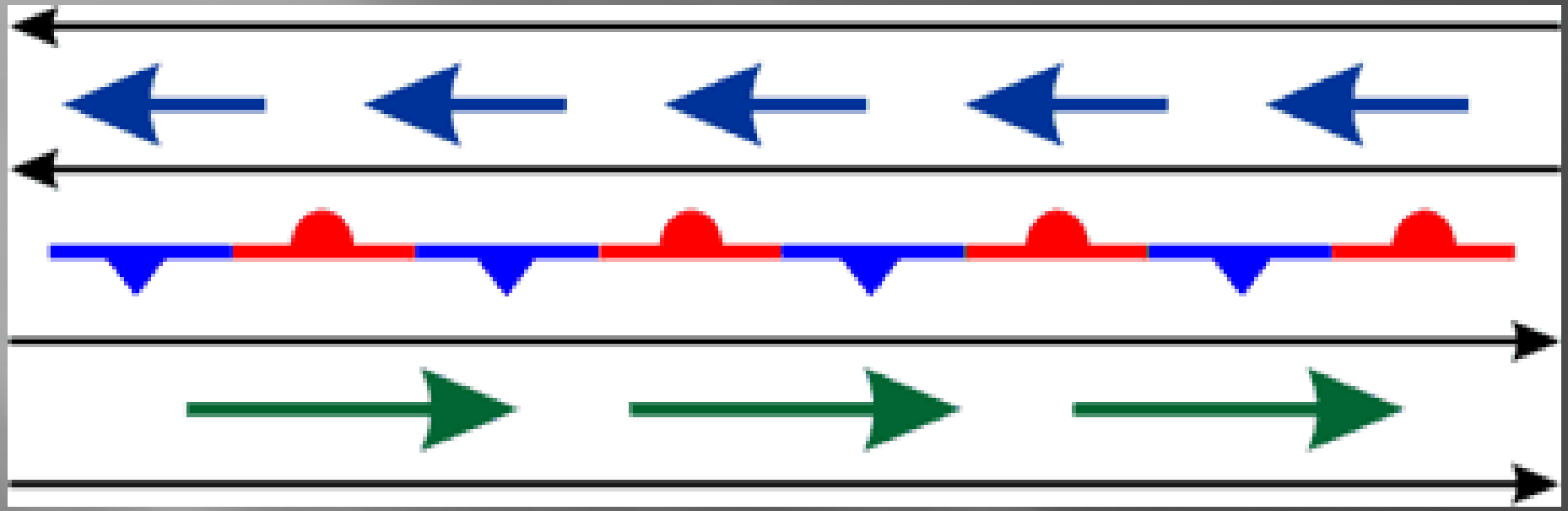



Warm Front
28
Colder
Temperatures
55
Warmer
Temperatures
62
31


28
Colder
Temperatures
31
55
Warmer
Temperatures
62
Cold Front

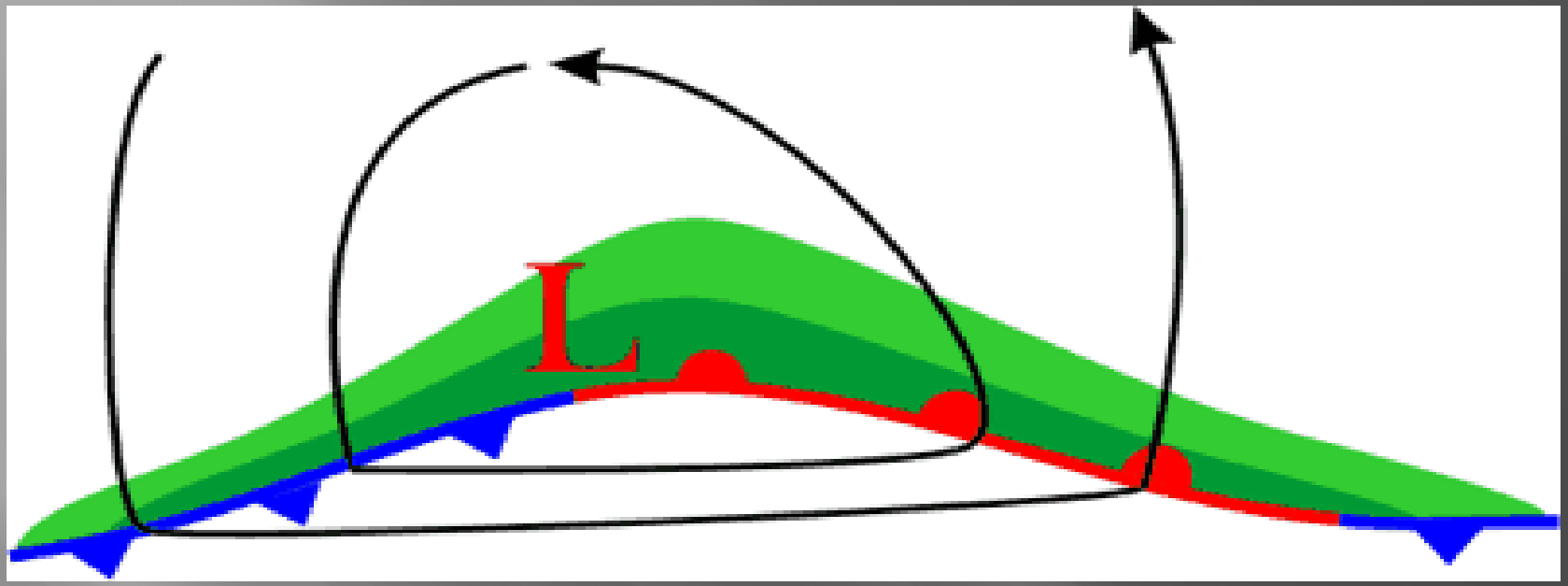

L
Occluded Front
Cool Air in Place
Colder Drier
Air Mass
Warm Front
Warm Moist Air Mass
Cold Front

Life Cycle of Fronts



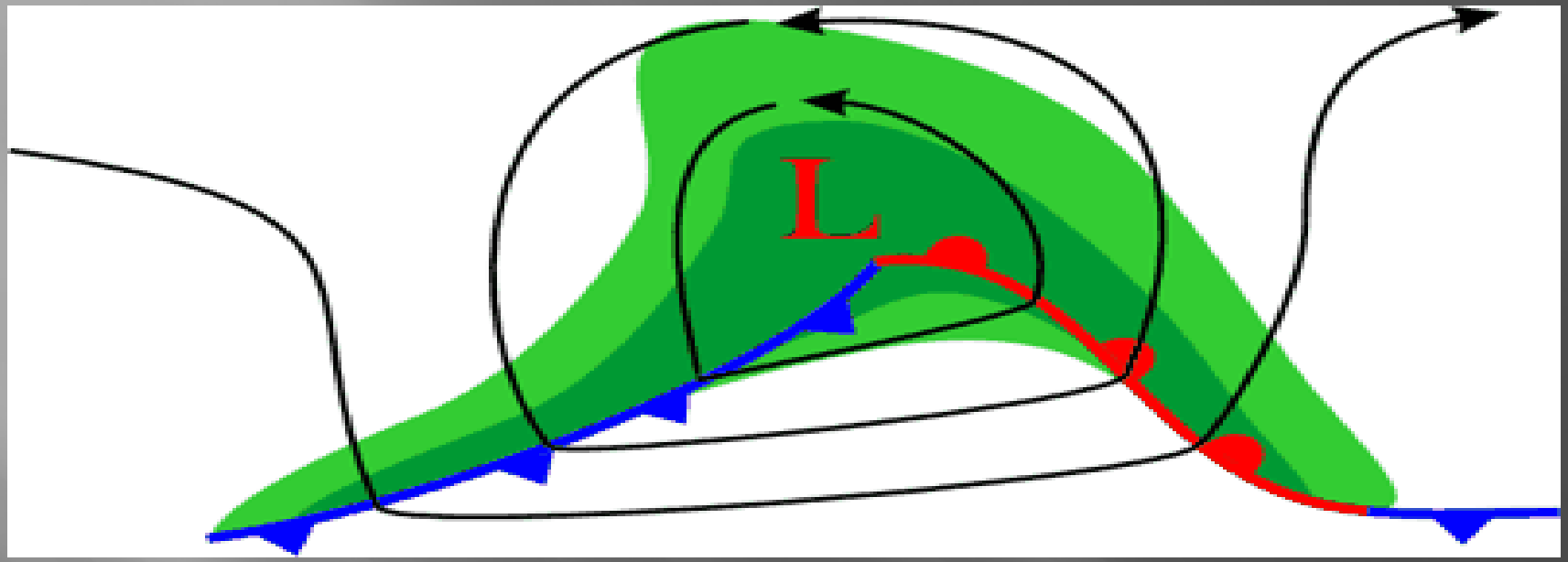
Initially be a boundary, or front separating warm air to the south from cold air to the north. The front is often stationary.

Life Cycle of Fronts



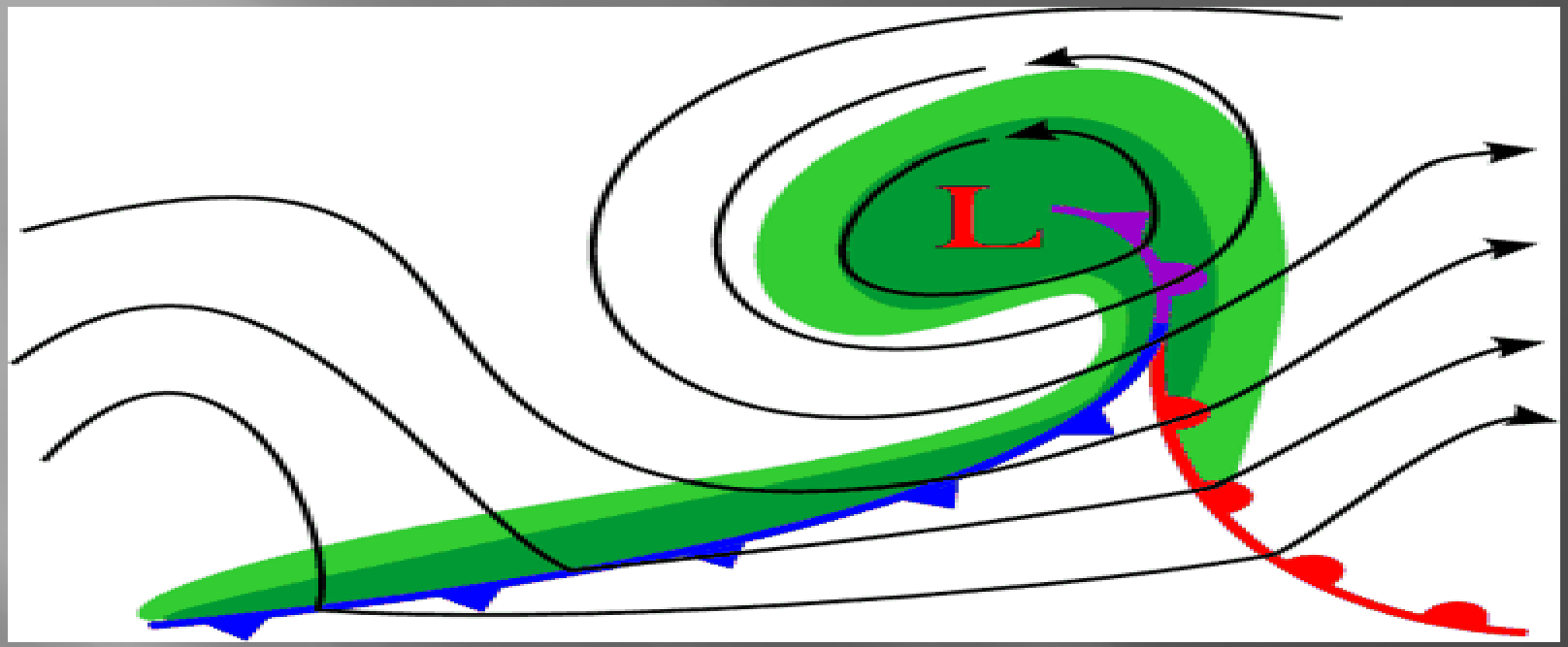
A wave on the front will form as an upper level disturbance embedded in the jet stream moves over the front. The front develops a “kink” where the wave is developing. Precipitation begins to develop with the heaviest occurrence along the front (dark green).

Life Cycle of Fronts



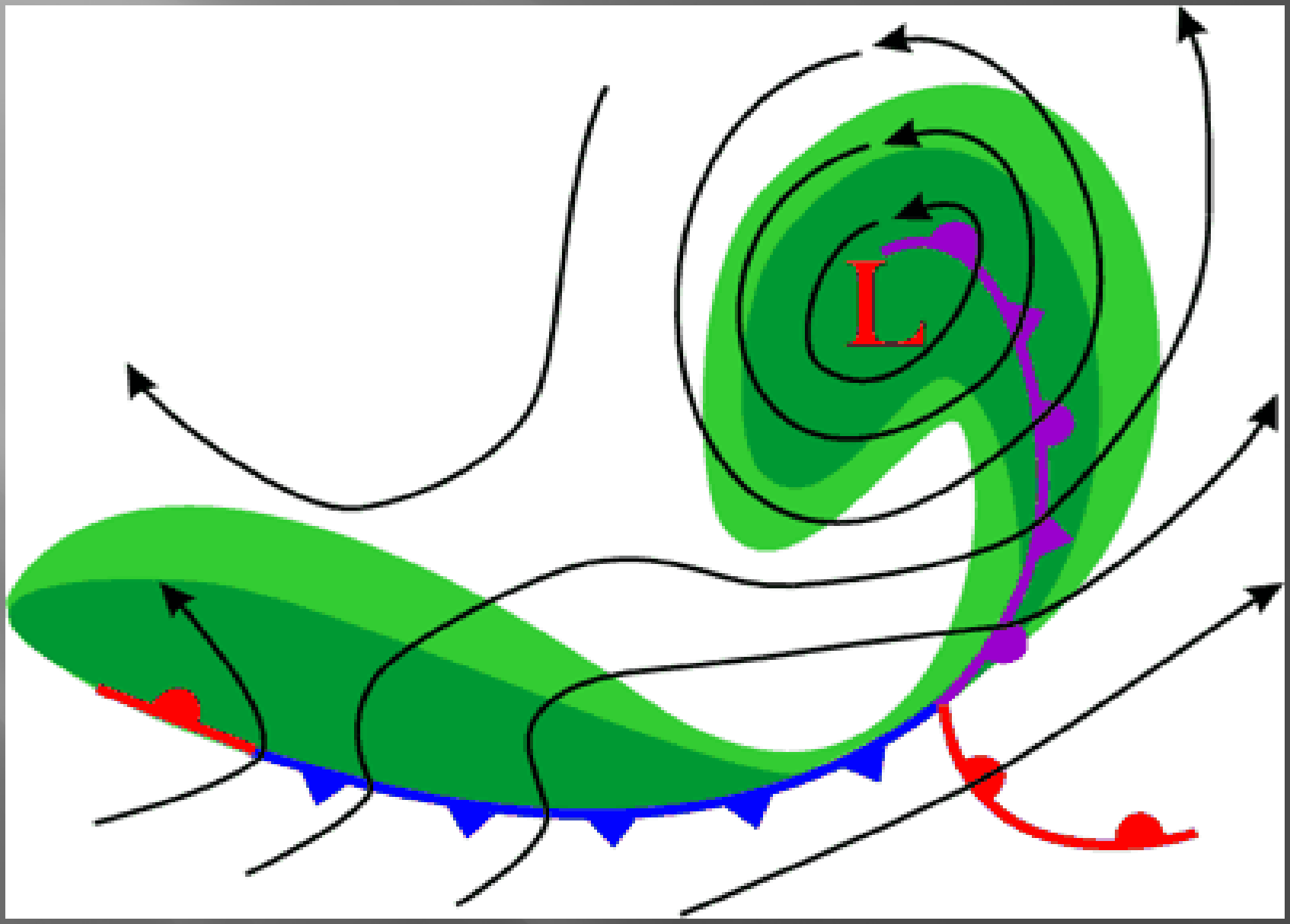
As the wave intensifies, both cold and warm fronts become better organized.

Life Cycle of Fronts

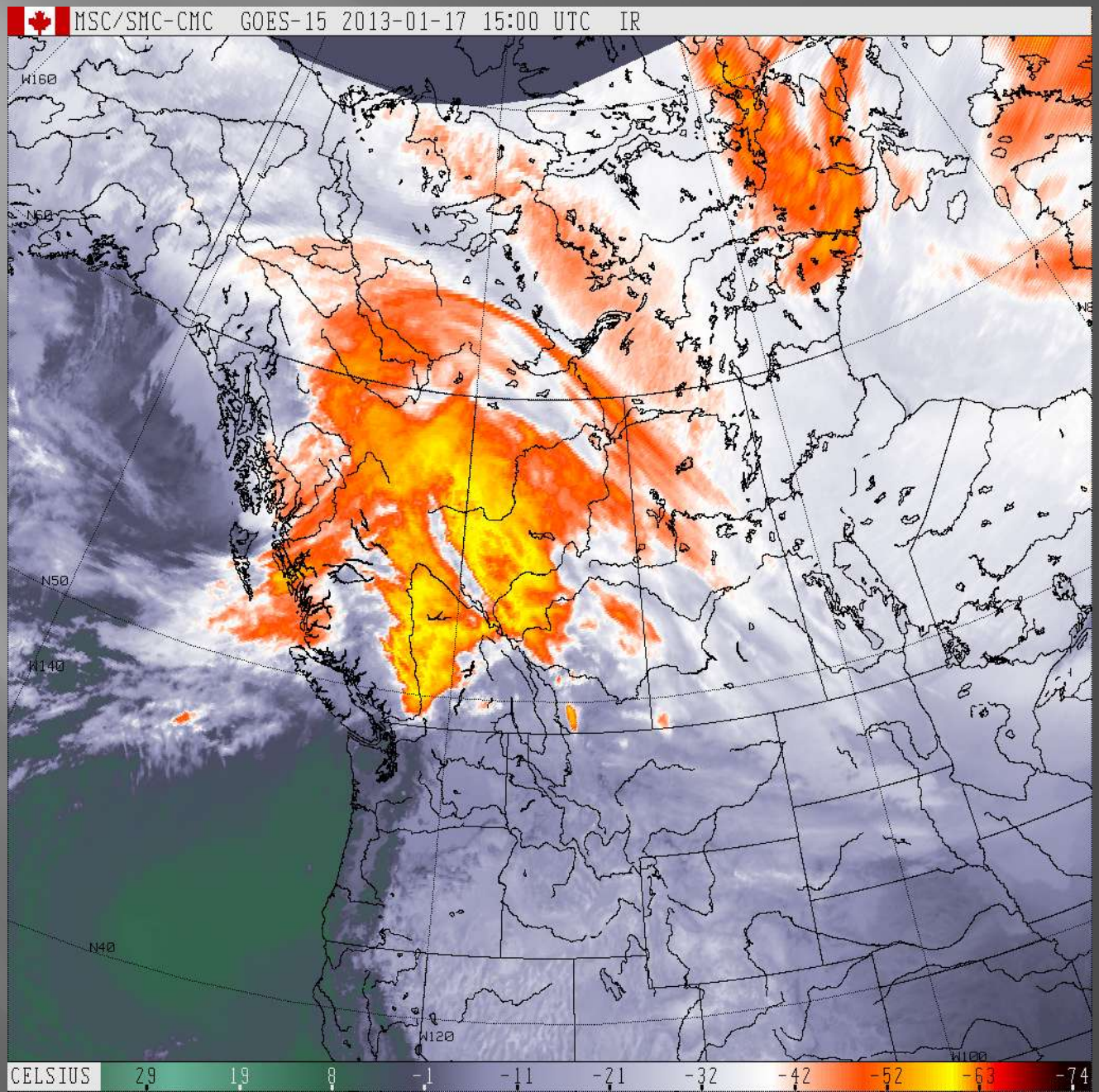


The wave becomes a mature low pressure system, while the cold front, moving faster than the warm front, “catches up” with the warm front. As the cold front overtakes the warm front, an occluded front forms.

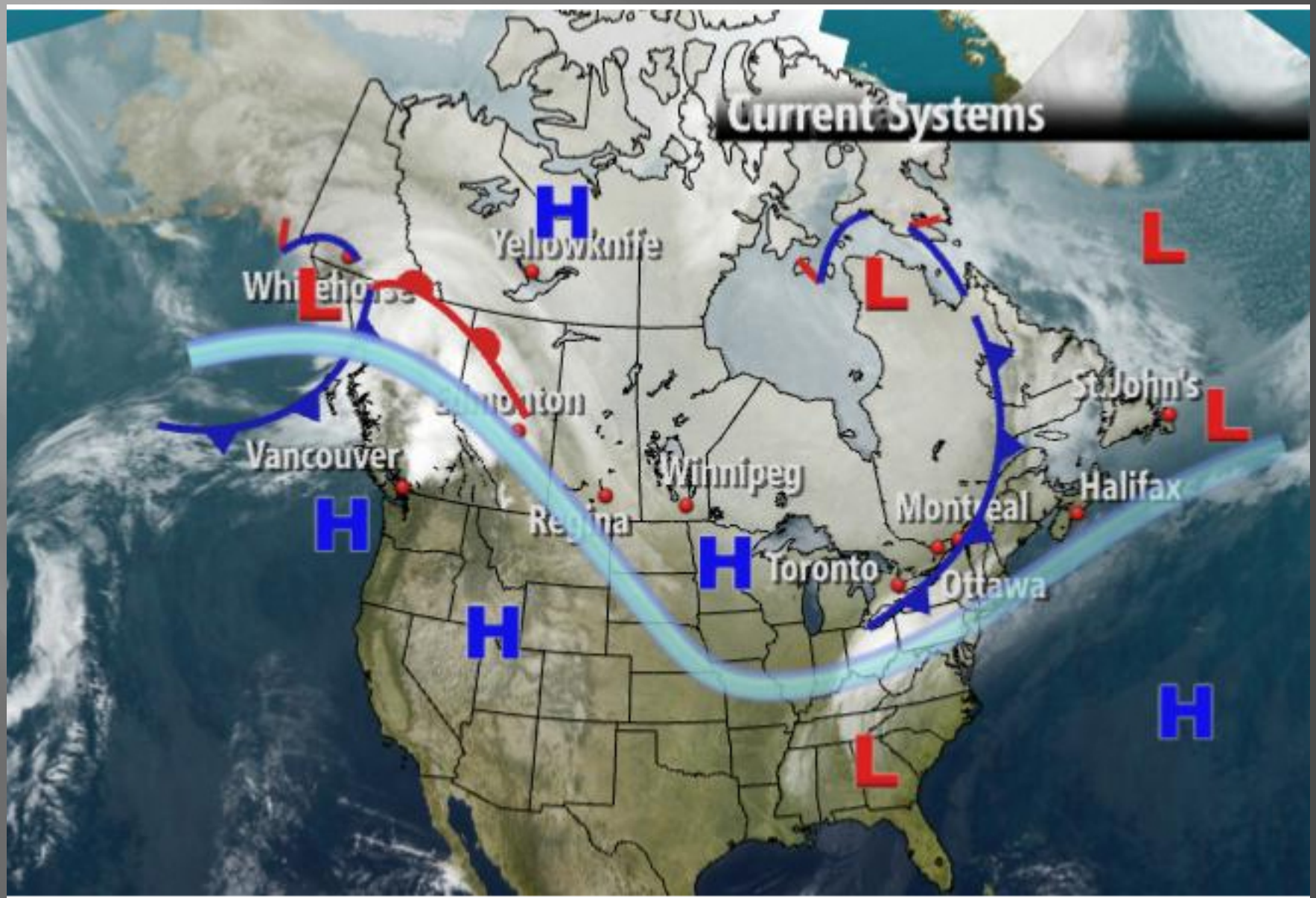
Life Cycle of Fronts



Warm Front


MSC/SMC-CMC GOES-15 2013-01-17 15:00 UTC IR
W160
N60
N50
W140
N40
W120
W100
CELSIUS 29 19 8 -1 -11 -21 -32 -42 -52 -63 -74

Warm Front


Current Systems
H
Yellowknife
L
L
L
L
Vancouver
Winnipeg
Halifax
H
H
H
H
L

Warm Front Weather

	Before Passing	While Passing	After Passing
Winds	East-southeast	Variable	South – southwest
Temperature	Cool-cold, slow warming	Steady rise	Warmer then steady
Pressure	Usually falling	Leveling off	Slight rise followed by a fall
Clouds	Ci, Cs As Ns Cb d fog; n summer	Stratus type	Clearing with scattered Sc; occasionally Cb in summer
Precipitation	Light-to-moderate rain, snow, sleet, or drizzle	Drizzle or none	Usually none, sometimes light rain or showers
Visibility	Poor	Poor but improving	Fair in haze
Dew Point	Steady rise	Steady	Rise then steady

Cold Front Weather

	Before Passing	While Passing	After Passing
Winds	South southwest	Gusty shifting	West – northwest
Temperature	Warm	Sudden drop	Steadily dropping
Pressure	Falling steadily	Minimum, then sharp rise	Rising steadily
Clouds	Increasing: Ci, Cs and Cb	Cb	Cu
Precipitation	Short period of showers	Heavy rains, sometimes with hail, thunder and lightning	Showers then clearing
Visibility	Fair to poor in haze	Poor, followed by improving	Good except in showers
Dew Point	High; remains steady	Sharp drop	Lowering

Occluded Front Weather

	Before Passing	While Passing	After Passing
Winds	east-southeast	Variable	West – northwest
Temperature Cold type	Cold – cool	Dropping	Colder
Warm type	Cold	Rising	Milder
Pressure	Usually falling	Low point	Usually rising
Clouds	Ci, Cs As Ns	Ns, sometimes Tcu and Cb	Ns, As or scattered Cu
Precipitation	Light, moderate or heavy	Light, moderate or heavy continuous precipitation or showers	Light-to-moderate precipitation followed by general clearing
Visibility	Poor	Poor in precipitation	Improving
Dew Point	Steady	Usually slight drop, especially if cold-occluded	Slight drop, although may rise a bit if warm-occluded

Atmospheric Moisture

- Humidity
  - Absolute
  - Relative
- Dewpoint
- Lifting condensation level

Atmospheric Moisture
Lifting Mechanisms

- Heating at the surface (convection)
- Air is forced over a topographic feature (orographic lift)
- Uplift over a frontal boundary
- Convergence

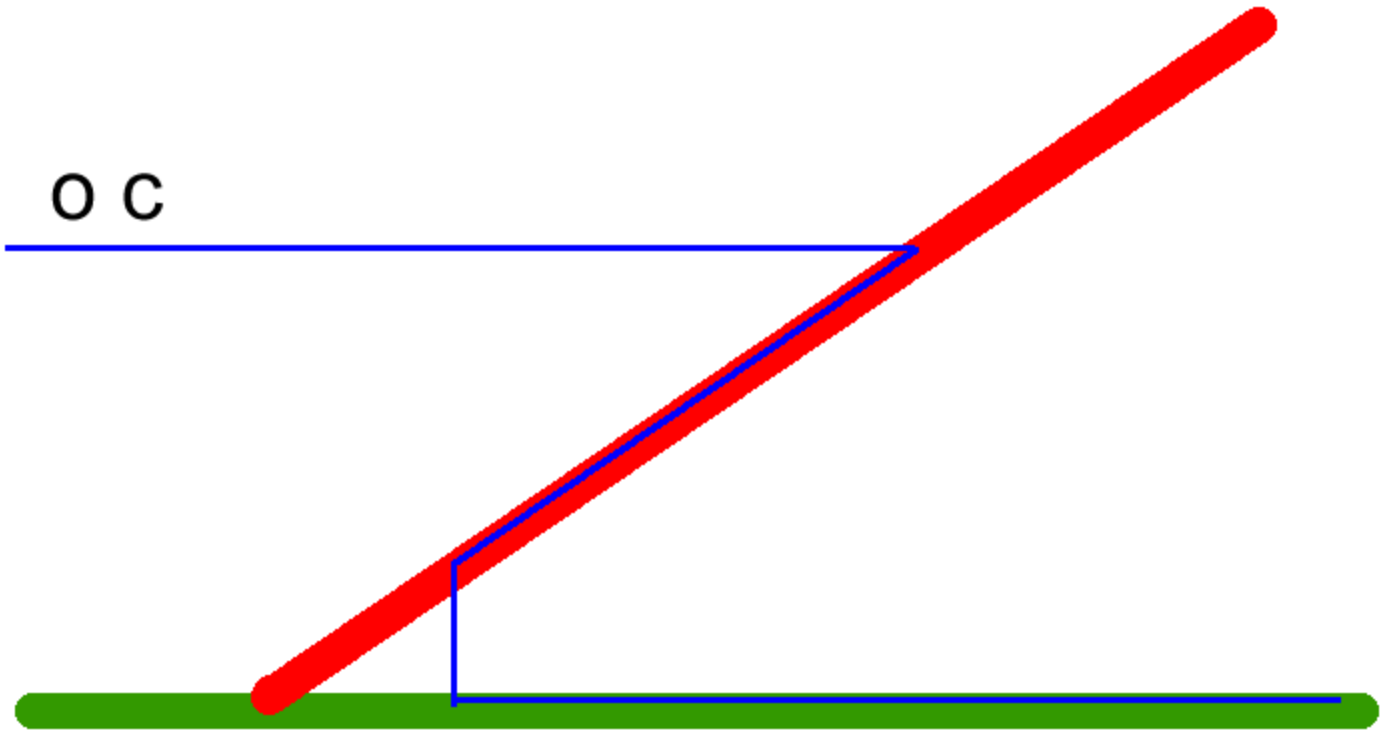
Atmospheric Stability

- Lapse Rates
  - Dry air lapse rate (DALR)
    - 1c / 100 m
  - Saturated air lapse rate (SALR)
    - .5c / 100 m
- Stable Air
- Unstable Air
- Temperature inversions

Precipitation

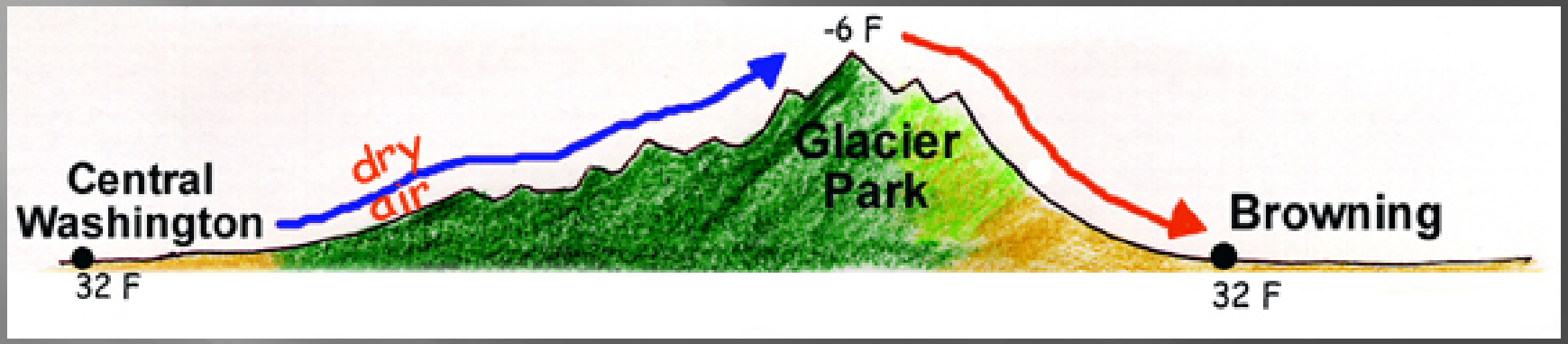
- Rain
- Snow
- Hail
- Freezing Rain
- Ice Pellets

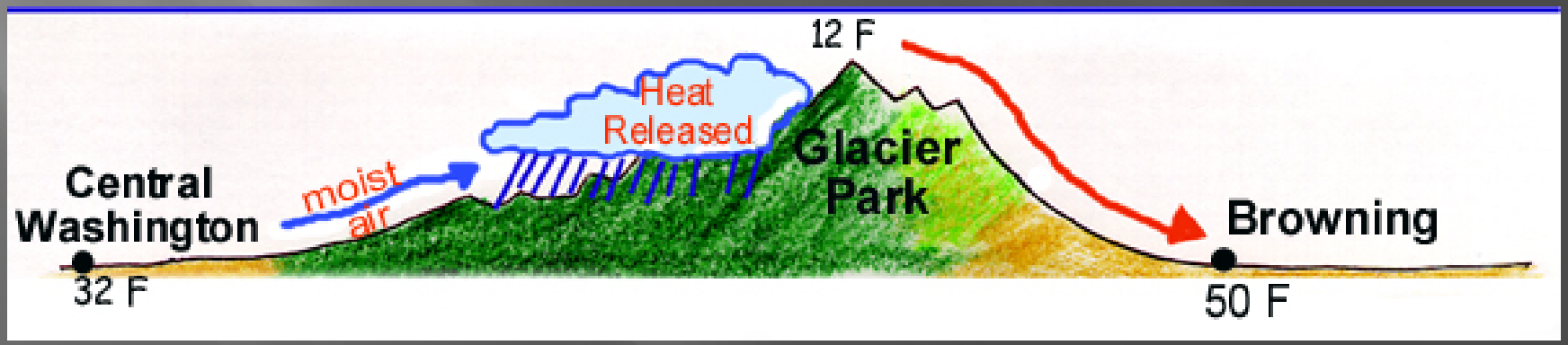
Snow / Ice Pellets / Freezing Rain



Chinooks

- Dry air lapse rate
  - 1c / 100 m
- Wet air lapse rate
  - .5c / 100 m





Weather On The Trail

Clouds

Clouds

- Stratiform
- Cumuloform
- Elevation

Clouds

Elevation

Level	Polar Region	Temperate Region	Tropical Region
High Clouds (cirro)	10,000-25,000 feet (3-8 km)	16,500-40,000 Feet (5-13 km)	20,000-60,000 feet (6-18 km)
Middle Clouds (alto)	6,500-13,000 feet (2-4 km)	6,500-23,000 feet (2-7 km)	6,500-25,000 feet (2-8 km)
Low Clouds	Surface-6,500 feet (0-2 km)	Surface-6,500 feet (0-2 km)	Surface-6,500 feet (0-2 km)

High Clouds

Cirrus (Ci)

High Clouds

Cirrus (Ci)

High Clouds

Cirro-Stratus (Cs)

High Clouds

Cirro-Cumulus (Cc)

High Clouds

Cirro-Cumulus (Cc)

Middle Clouds

Alto-Cumulus (Ac)

Middle Clouds

Alto-Cumulus (Ac)

Middle Clouds

Alto-Cumulus (lenticular) (Ac)

Middle Clouds

Alto-Stratus (As)

Middle Clouds

Alto-Stratus

Low Clouds

Stratus (st)

Low Clouds

Fog

Low Clouds

Nimbo-Stratus (Ns)

Low Clouds

Nimbo-Stratus (Ns)

Low Clouds

Strato-Cumulus (Sc)

Low Clouds

Strato-Cumulus (Sc)

Clouds With Vertical Development

Cumulus (Cu)

Clouds With Vertical Development

Cumulus (Cu)

Clouds With Vertical Development

Towering Cumulus (Tcu)

Clouds With Vertical Development

Towering Cumulus (Tcu)

Clouds With Vertical Development

Cumulo-Nimbus (Cb)

Clouds With Vertical Development

Cumulonimbus (Cb) with Pileus

Clouds With Vertical Development

Cumulo-Nimbus (Cb)

Clouds With Vertical Development

Pyro-Cumulus

Thunderstorms

Thunderstorms

- Are associated with cumulonimbus clouds
- Require unstable air
- Can be either frontal or air mass
- Cumulus clouds in the morning, growing vertically are a good sign that an afternoon storm is possible
- Thunderstorm safety

Lunch Break

Tornadoes

Tornadoes

- Are the most violent weather event in our part of the world
- Are associated with thunderstorms
- Require a *supercell* thunderstorm, the strongest most violent type of thunderstorm
- Do not form over mountainous terrain
- What do you do when a tornado threatens?

Local Weather Signs and Idiosyncrasies

- Clouds coming from the east > upslope developing
- Frost in July indicates a building high pressure
- Building cumulus clouds in the morning indicates potential afternoon thunderstorms
- Different cloud layers moving different directions indicates deteriorating weather
- Bluish tint where clouds meet hills or mountains indicates thin valley cloud
- Long jet trails indicate moisture aloft. Could mean deteriorating weather
- Heavy frost on a cold clear night quite often indicates warmer air higher up
- Heavy rainfall warning in Vancouver often indicates a chinook is iminent

Terrain and Wind

- Land / Sea Breeze
- Winds from surface heating / cooling
- Frost Hollows
- Passes and peaks
- Barriers
- Major valleys

Ways Of Taking Field Weather Observations

- Temperature
  - Use an analog snow thermometer on a string and twirl
- Pressure
  - Use an altimeter / barometer wristwatch
- Wind speed
  - Use a Brunton Sherpa
  - Drifting Snow

Pressure Drop

3 Hour Pressure Decrease	Altimeter Increase	Recommended Action
.6 – 1.2 millibars	6 – 12 meters	None except normal monitoring of weather conditions
1.2 – 1.8 millibars	12 – 18 meters	Watch sky for thickening and or lowering clouds. Watch for increasing shifting winds to east or southeast.
1.8 – 2.4 millibars	18 – 24 meters	Same as above. Consider aborting due to high winds and or severe storm.
2.4 millibars or more	24 meters or more	Run away!

Field Weather Signs

- The charts associated with fronts are a good indicator of frontal weather
- Rising altimeter bears watching
  - Always set your altimeter at the start of the day and at known elevations
- Increasing winds
- Increasing cloudiness
- Rapid changes

Scenario 1

- You are hiking in the Purcell's early July
- Temperature is warm and it is muggy
- Mosquitoes are ferocious
- The morning starts clear with cumulus clouds developing
- Wind is light westerly

Scenario 2

- It is late July and you are on the fourth day of the Brazeau Loop.
- The weather has been cool and showery (flurries above 2200 meters).
- Your altimeter shows that you are higher than you really are.
- The wind is picking up out of the Southeast.

Scenario 3

- You are crossing the Campbell Icefield, a featureless glacier.
- Tannis Dakin, owner of Sorcerer Lodge, has indicated that the forecast for the Rockies is for flurries.
- The wind is calm – light and variable.
- The altimeter has been very accurate all day.

Scenario 4

- It is early October.
- You are on Pigeon Mountain.
- Even though you are sitting and having a snack, the altimeter shows you are climbing rapidly.
- Wind is out of the east and the clouds are moving up valley towards Banff.
- It is quite cold.

Scenario 5

- You are on Grizzly Peak in July.
- There is a pleasant breeze from the west.
- The morning was clear.
- Cumulus and alto-cumulus clouds develop in the afternoon.
- The altimeter agrees with the map.

Scenario 6

- You are hiking in the Coast Mountains in late August.
- The last week has been hot, muggy and sunny.
- The morning started clear.
- The wind is out of the southwest and it is increasing.
- The altimeter is showing that you are higher than you actually are.

Scenario 7

- You are hiking on Heart Mountain in mid June.
- The morning started clear.
- The temperature is above average and it is humid.
- There is a light southwesterly wind.
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Scenario 7

- You are hiking on Heart Mountain in mid June.
- The morning started clear.
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- Sitting on the first summit, you notice towering cumulus developing west and east of where you are.

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- Looking at the cloud with binoculars, you notice a protuberence hanging beneath the southwest part of the cloud
- Just below tree line the storm from the west hits with rain, lightning and thunder and lasts 15 minutes
- In the valley, the storm that hit earlier has decided to turn around and hit you again

Scenario 8

- It is early May and you are going ski touring up the Icefields Parkway. It has been warm and unsettled for the last week. You are based at the Columbia Icefields and have not been able to get a current forecast. Your goal is to summit Mt Columbia and Mt North Twin.
- The day starts warm and overcast, the Icefields are socked in.
- At noon you notice some clear patches of sky developing.
- By late afternoon, the sky clears completely; the barometer has been rising all day.
- You get an early start.

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- You arrive at the spot where you remove your skis, there are some clouds floating about and the barometer is slowly dropping. Wind is light and variable.

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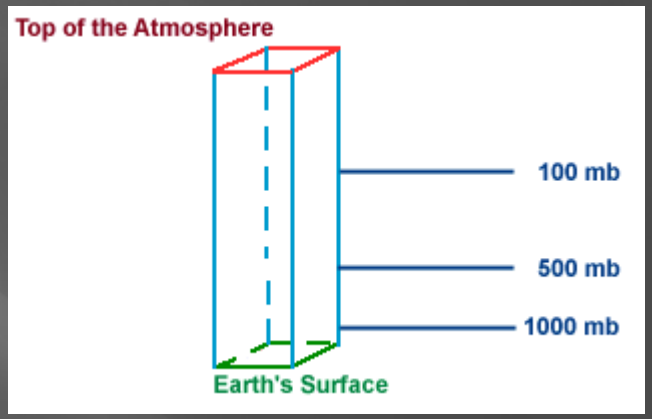
- You stay in camp, you have one day left and at noon the clouds lift above your level.

Planning and Forecasting

700 mb Chart

Pressure	Approximate Height		Approximate Temperature	
Sea Level	0 m	0 ft	15 C	59 F
1000mb	100 m	300 ft	15 C	59 F
850 mb	1500 m	5000 ft	05 C	41 F
700 mb	3000 m	10000 ft	-05 C	23 F
500 mb	5000 m	18000 ft	-20 C	-04 F
300 mb	9000 m	30000 ft	-45 C	-49 F
200 mb	12000 m	40000 ft	-55 C	-67 F
100 mb	16000 m	53000 ft	-56 C	-69F

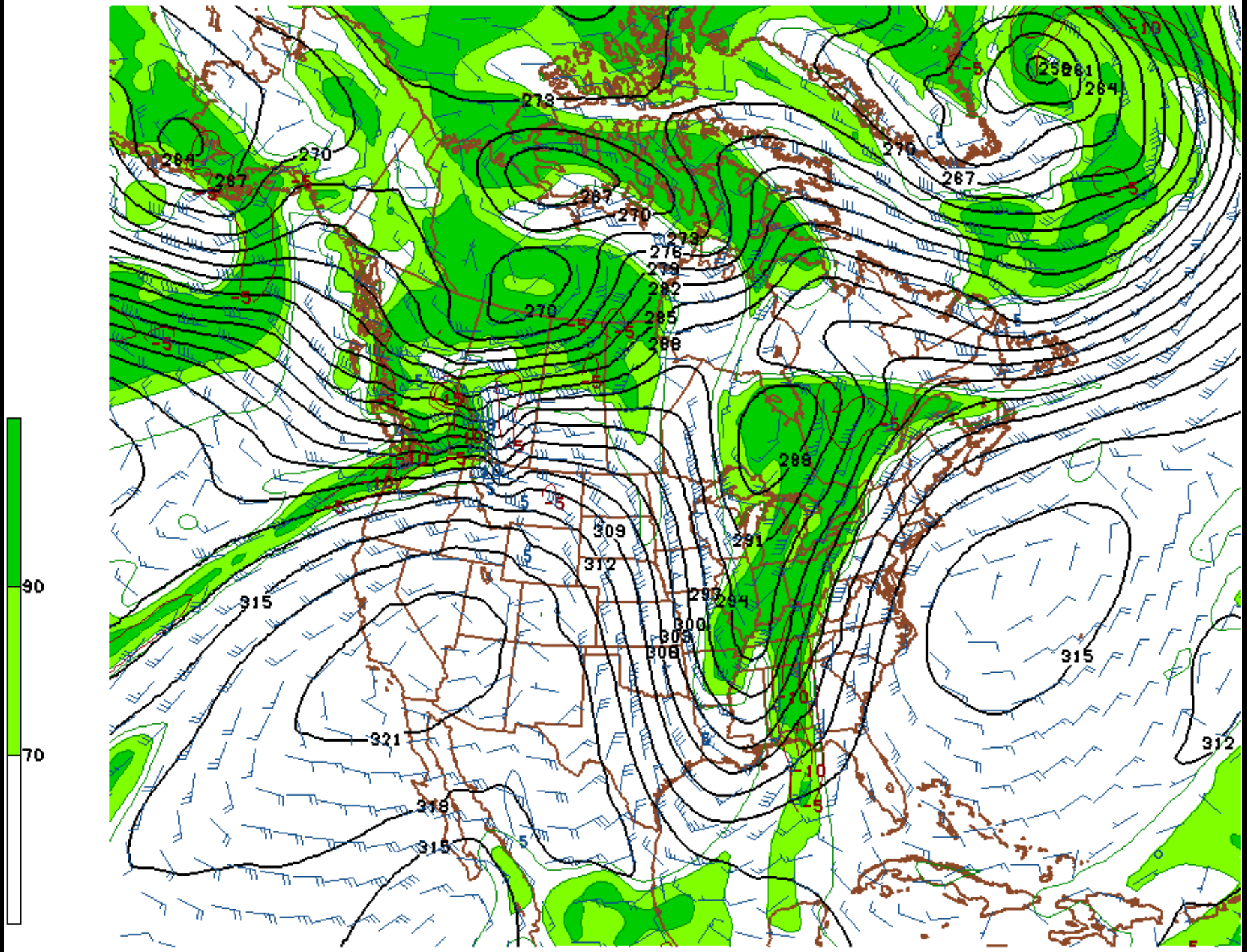
Chart from: WXP Purdue



Weather Associated With Upper Wind Direction

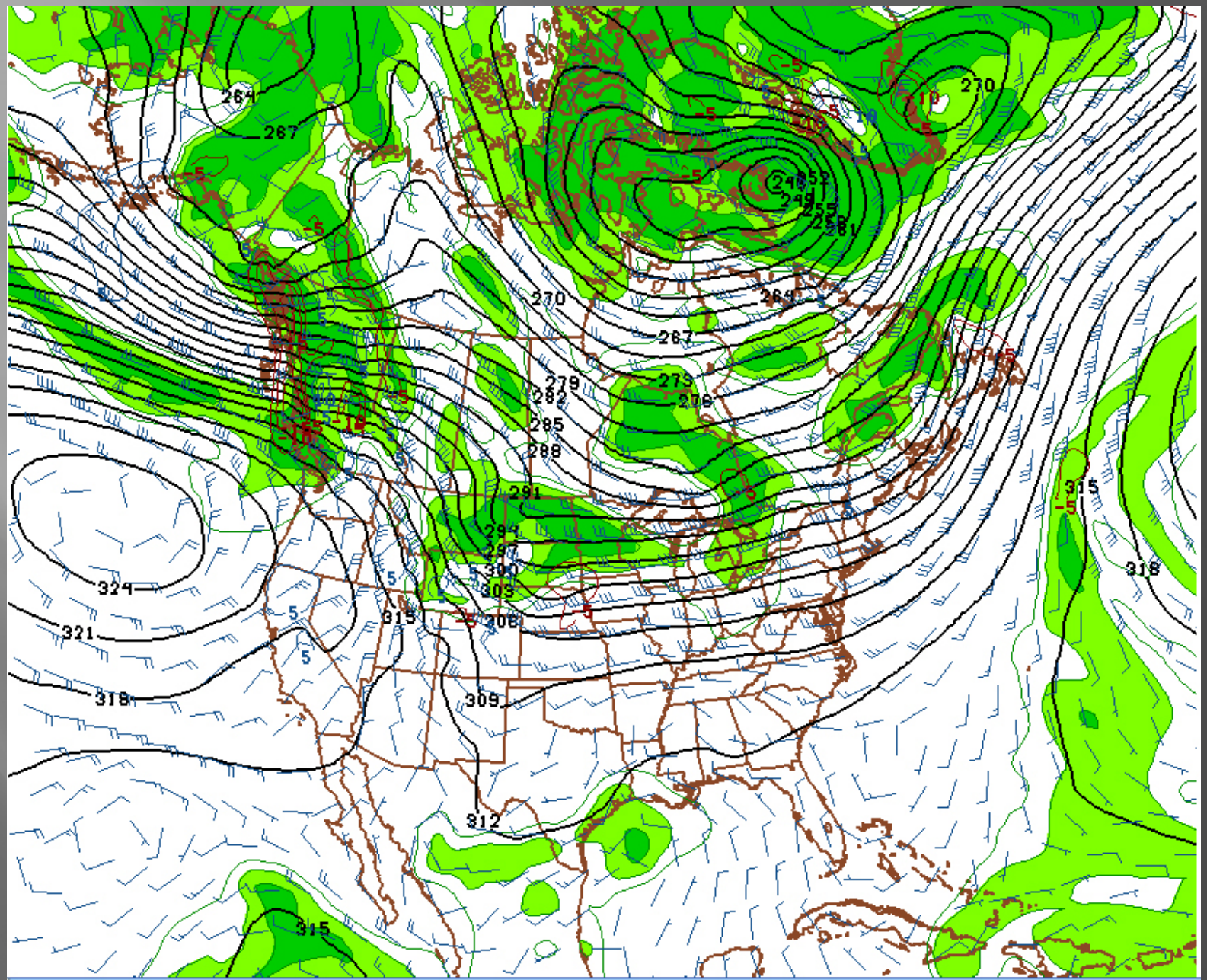
- Use the 700 mb chart to determine mountain top wind direction
- Shows elevation of where the pressure is 700mb
  - High elevation = high pressure
  - Low elevation = low pressure
- Shows wind direction and speed using barbs
- Shows relative humidity
- Is the flow upslope or downslope?

11/25/11 12UTC 054HR FCST VALID SUN 11/27/11 18UTC NCEP/NWS/NOAA



111127/1800V054 GFS 700MB HT, REL HUMIDITY AND OMEGA

Characteristics of Westerly Flow



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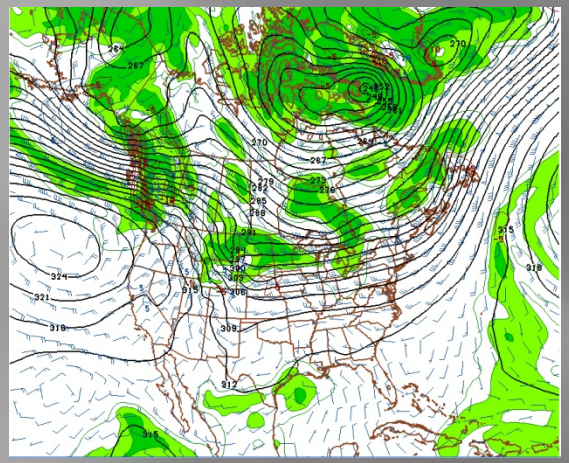
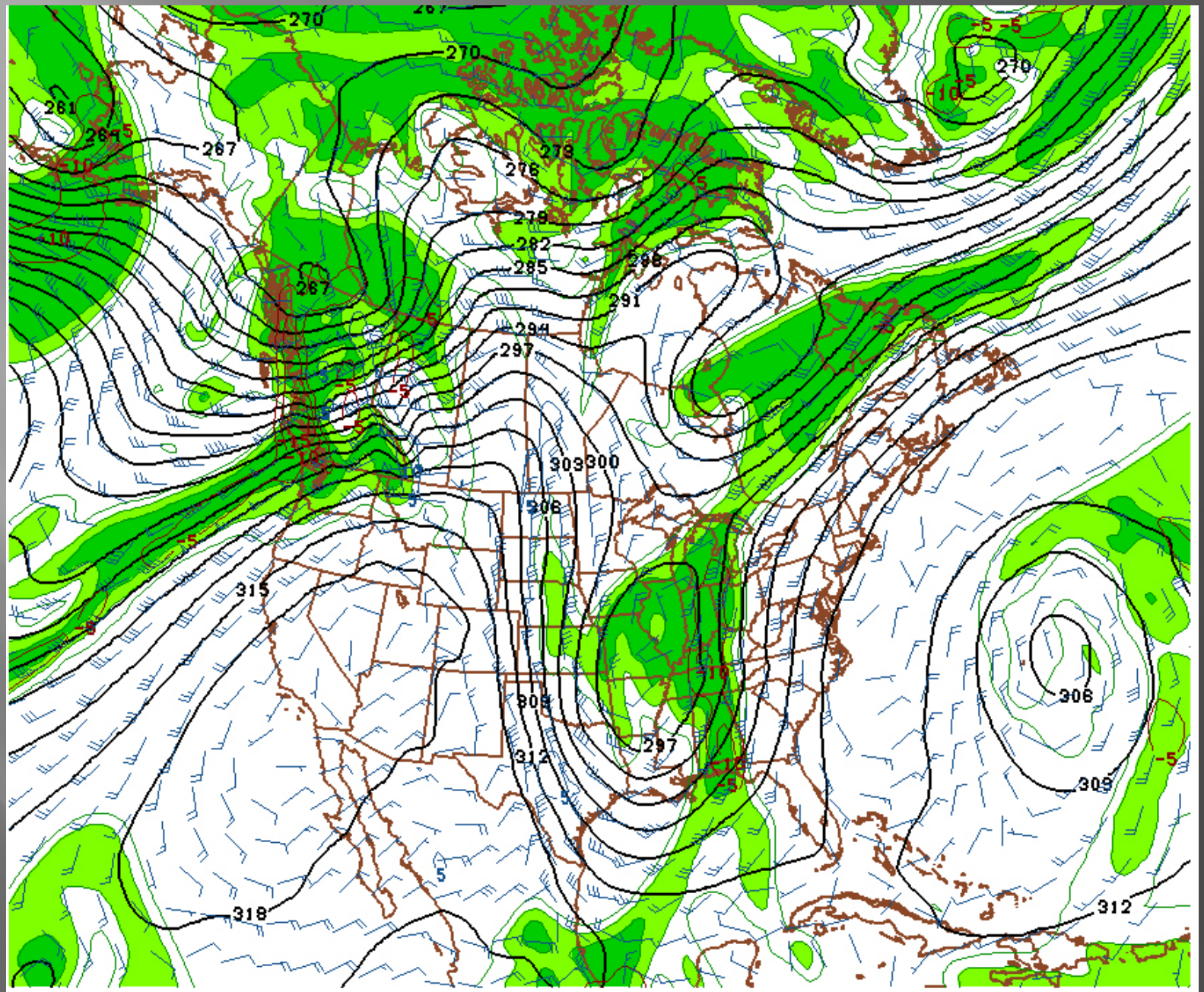


- Upslope flow and enhanced precipitation is greatest along north-south oriented ranges and especially at the convergent ends of west-east oriented valleys and inlets along the coast.
- Warm air cannot move northward in this flow so the freezing level remains relatively unchanged, rising only briefly with each approaching system before falling again on cold frontal passage. Warm 'noses' of air ahead of systems are sometimes pinched off entirely and slump southeastward, maintaining low freezing levels.
- Embedded storms are fast-moving and often followed by periods of rapid clearing that may last for a few hours but can persist for a full day. Timing of systems beyond day two is extremely difficult due to their rapid motion, so confidence in the forecast beyond day two is low. Satellite imagery shows smaller comma-shaped systems moving onshore followed by post-frontal cellular convective clouds (bright cauliflower shaped clouds that) form in the unstable air behind a cold front.

Characteristics of Southwesterly Flow



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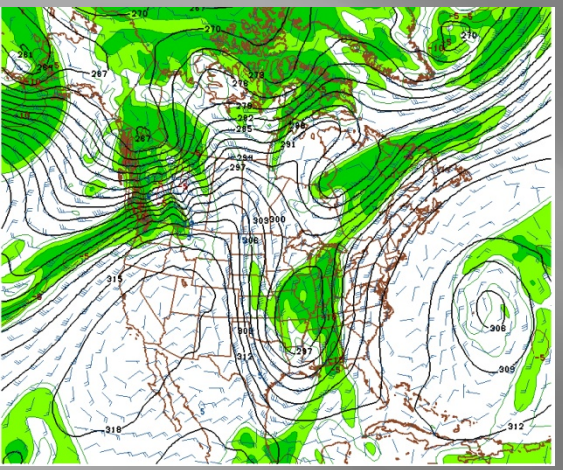
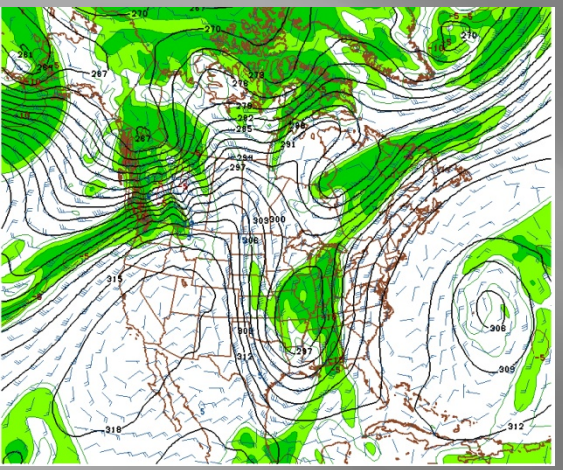


- Southwest flow is perpendicular to most mountain ranges, maximizing the upward forcing of the air and the precipitation on the upslope (windward) side of the range. Southwest flow correspondingly maximizes subsidence on the lee (downwind) side, especially over the Interior Plateau and the prairies. Heavy precipitation is guaranteed along the Coast Range, with extreme amounts in southwest to northeast oriented valleys and inlets. Heavy snow is likely across the west slopes of eastern ranges as the air is forced upward again by the towering Rocky Mountains. With rising freezing levels heavy wet snow persists only at the highest elevations while lee slopes/valleys remain bone-dry in subsidence breaks.

Characteristics of Southwesterly Flow



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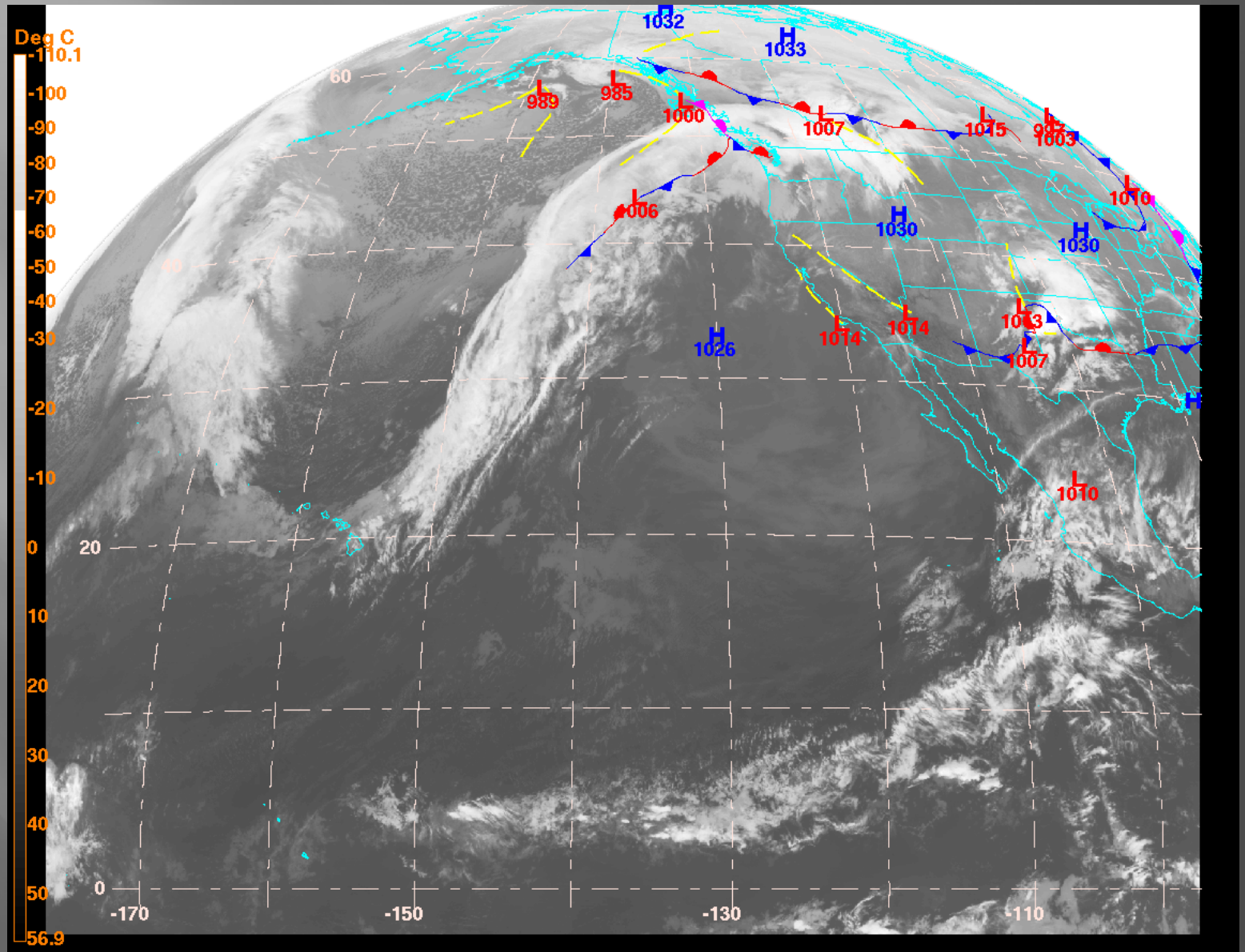
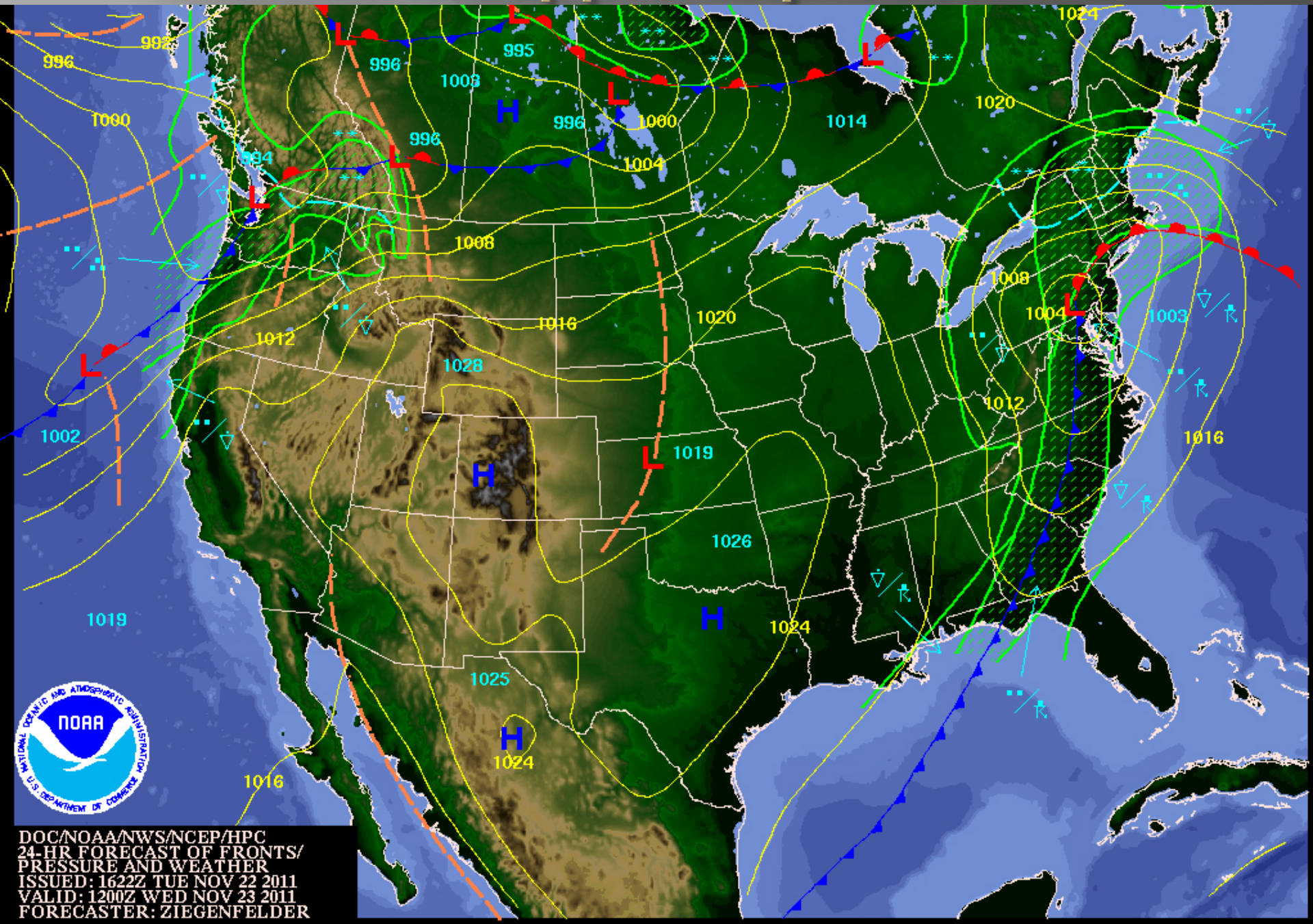
- Freezing level rises dramatically to sometimes over 3000 metres as a steady flow of warm stable air floods western Canada.
- Embedded storms can be fast-moving with very brief clearing (or none) between. If the offshore trough digs and a series of waves ripple along the frontal zone, a nearly stationary moisture-laden northeast to southwest-oriented cloud mass can linger for one to three days causing record rainfalls and flooding - the Pineapple Express - when air originates in the sub-tropics.
- Classic chinook flow. To see if a chinook is possible, analyze the 700mb chart looking for winds in excess of 25 knots and humidity greater than 70% (light green)

Pineapple Express

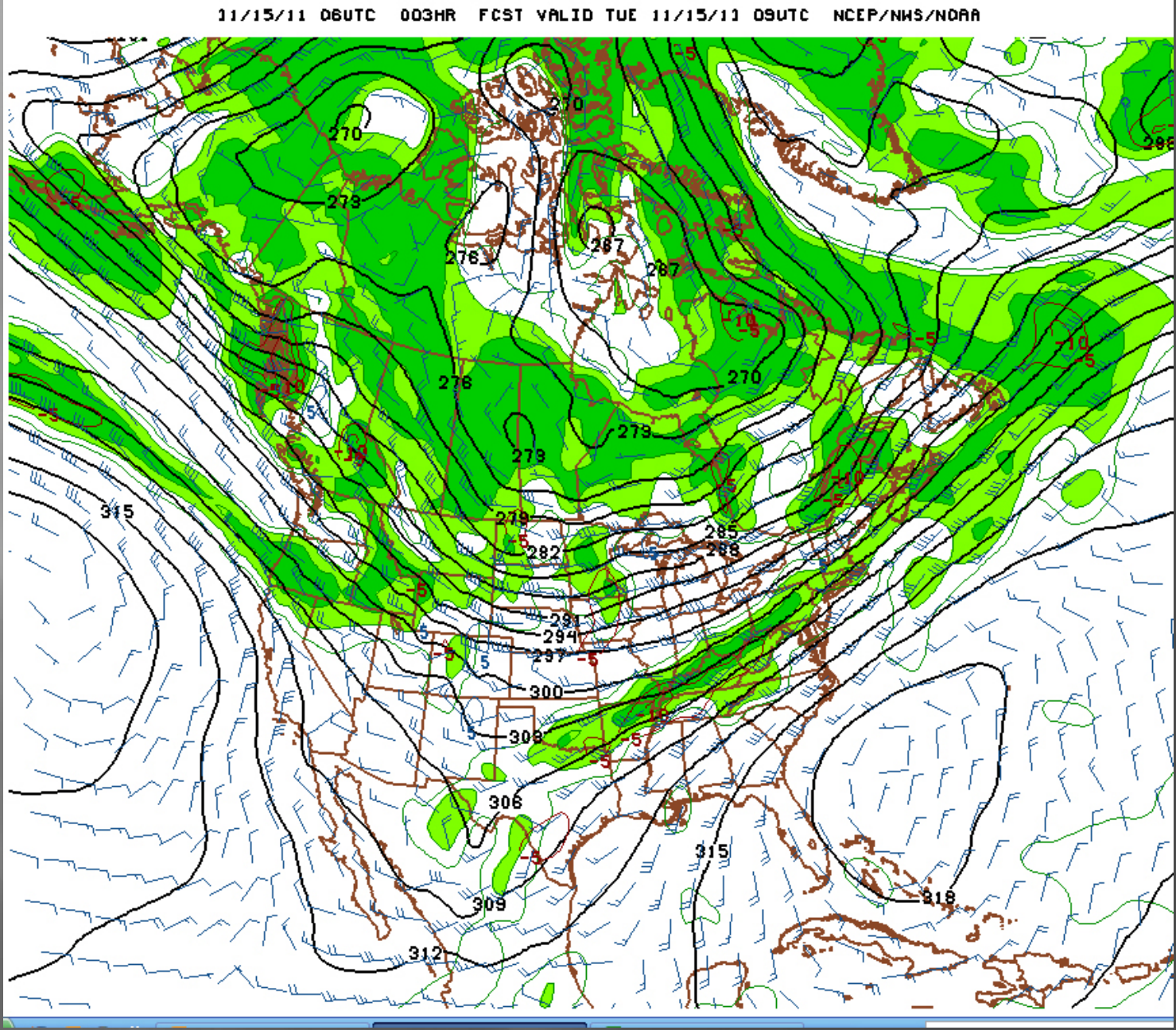


Pineapple Express

Pineapple Express



Characteristics of Northwesterly Flow



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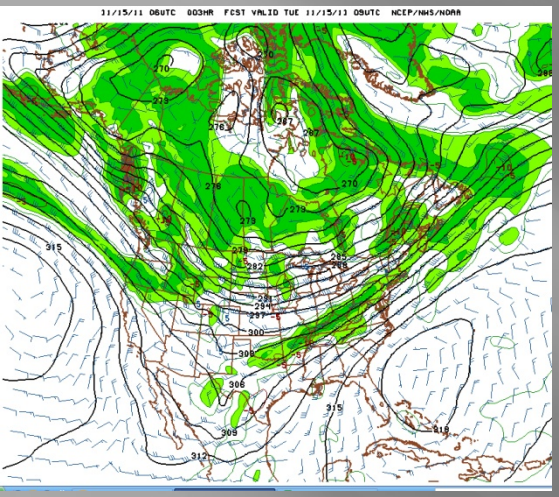
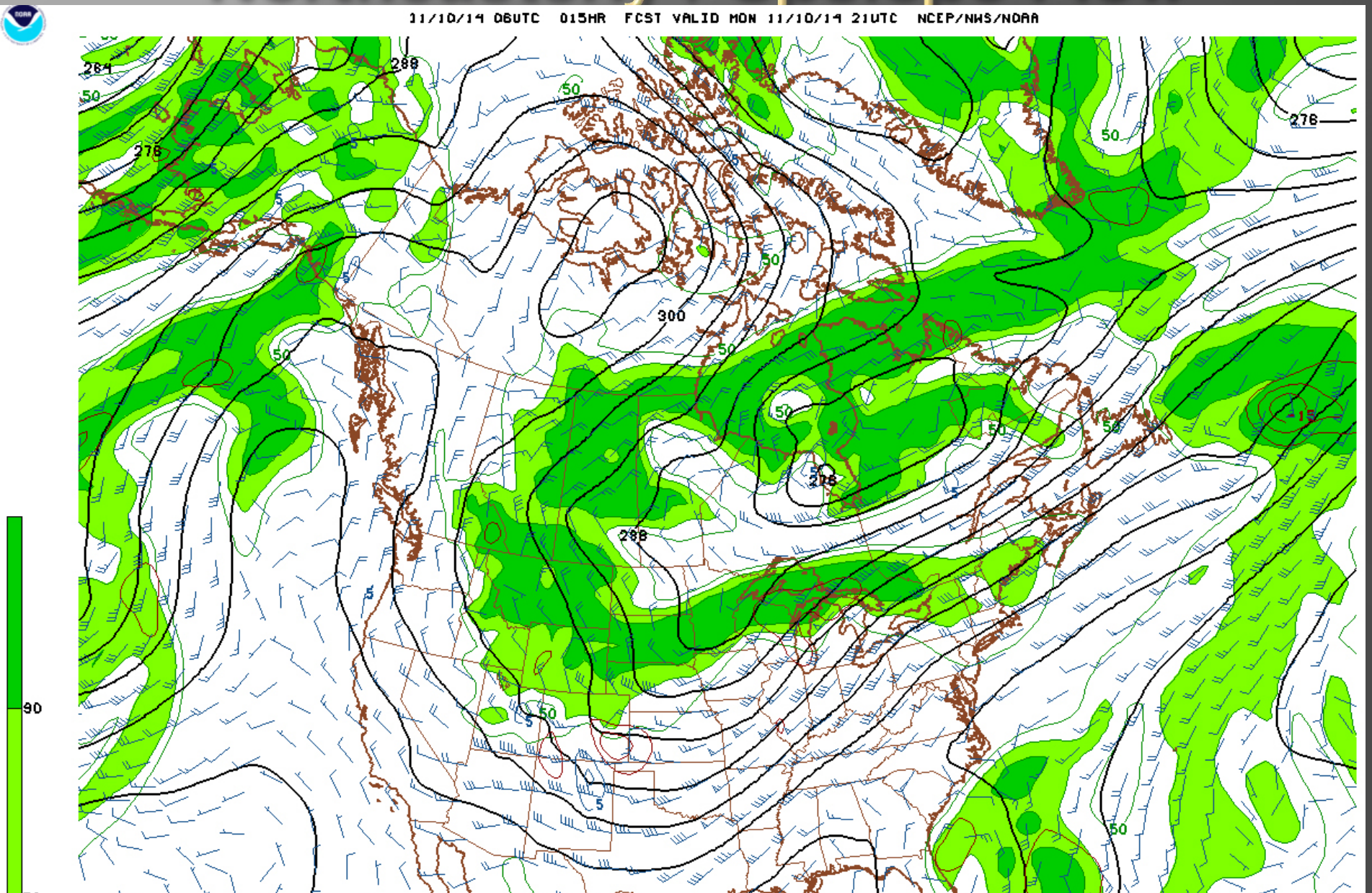


- The skier's flow. A cold airstream gathers moisture over the Gulf of Alaska, becomes increasing unstable, and moves onshore in the form of bubbling convective cells (bright cauliflower shaped clouds that form in unstable air) that give brief but locally heavy snowfalls from the tops of peaks to near valley bottoms.
- Freezing level usually drops to 500 metres or lower.
- Occasional embedded storms appear as swirling comma-shaped conglomerations of convective cells moving swiftly southeastward. The duration of snowfall is limited by the small scale and rapid motion of these storms but snowfall rates can be very high.
- Heaviest accumulations along the Coast Range but if the comma cloud crosses the Coast Range, dry powder snow can accumulate over the interior ranges.

Characteristics of Northerly / Northeasterly / Upslope Flow



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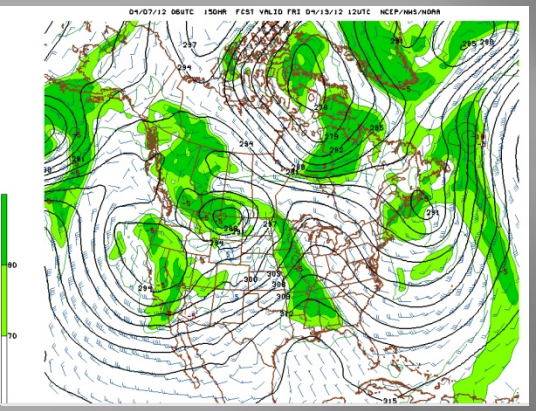
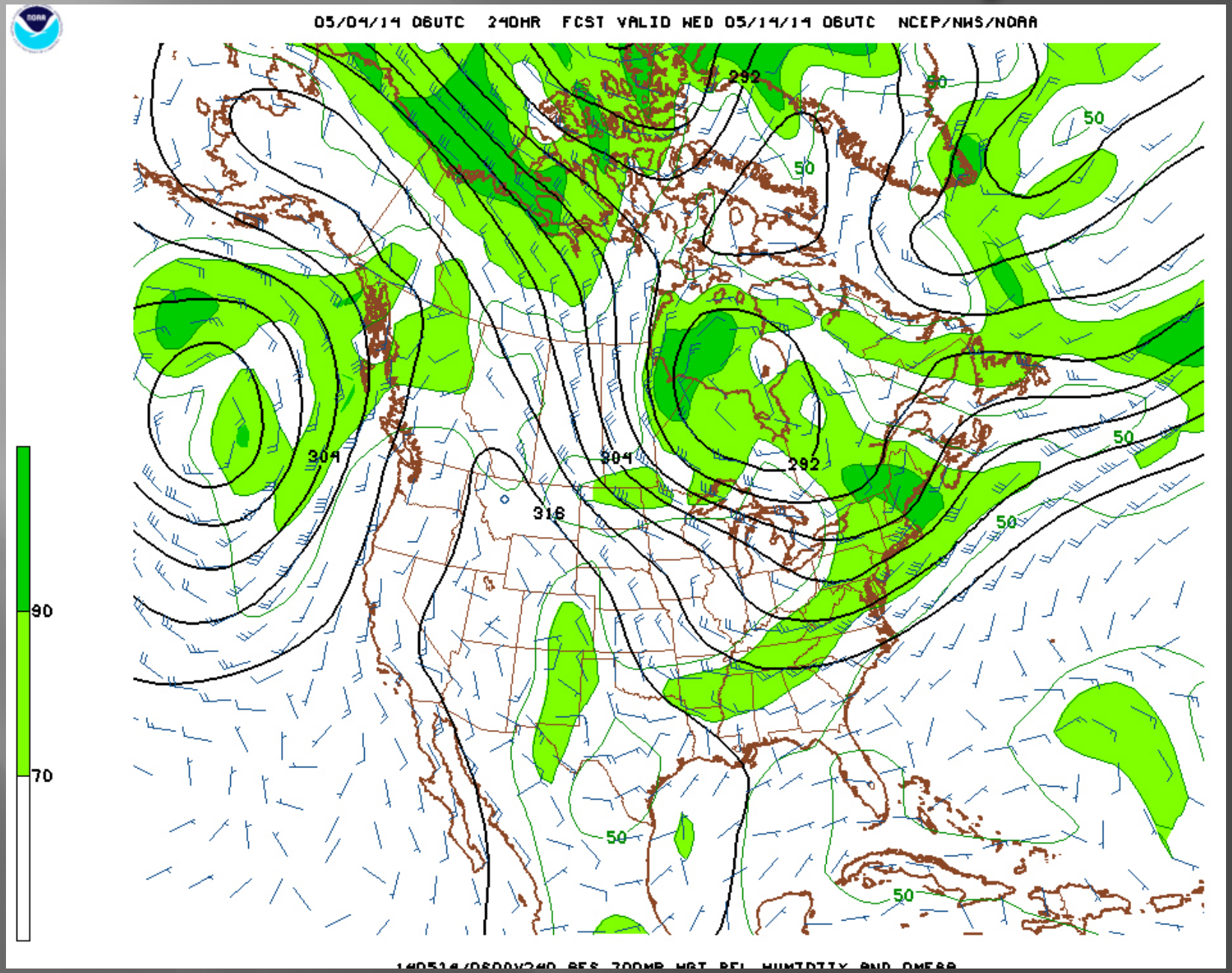
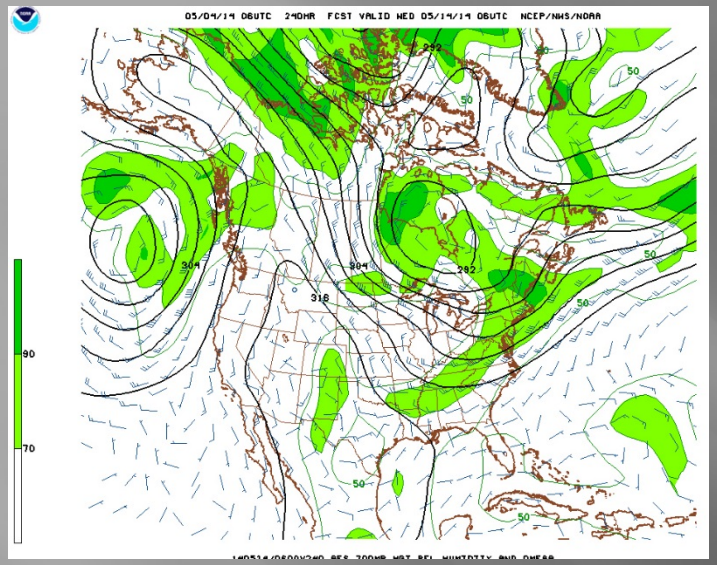


- Dreadfully cold flow of arctic air is aligned with the mountain ranges and valleys. Upslope flow now occurs off the Interior Plateau to the eastern slopes of the Coast Range and Rocky Mountains. Associated weather usually constrained to a few flurries as the arctic front moves southward followed by rapid clearing and bitter cold conditions that can persist for days or weeks. On rare occasions, an embedded system from the north brings light snowfalls (5 to 10cms) of exceptionally dry snow.
- Freezing level lowers to the surface everywhere.
- This pattern breaks down with a gradual shift to southwest flow and the arrival of maritime air resulting in heavy snowfalls to sea-level on the coast. Quickly followed by a rapid transition to milder Pacific air that spreads inland via the Fraser Canyon in developing southwest flow.
- Also known as the “Polar Vortex”

Characteristics of Southerly Flow

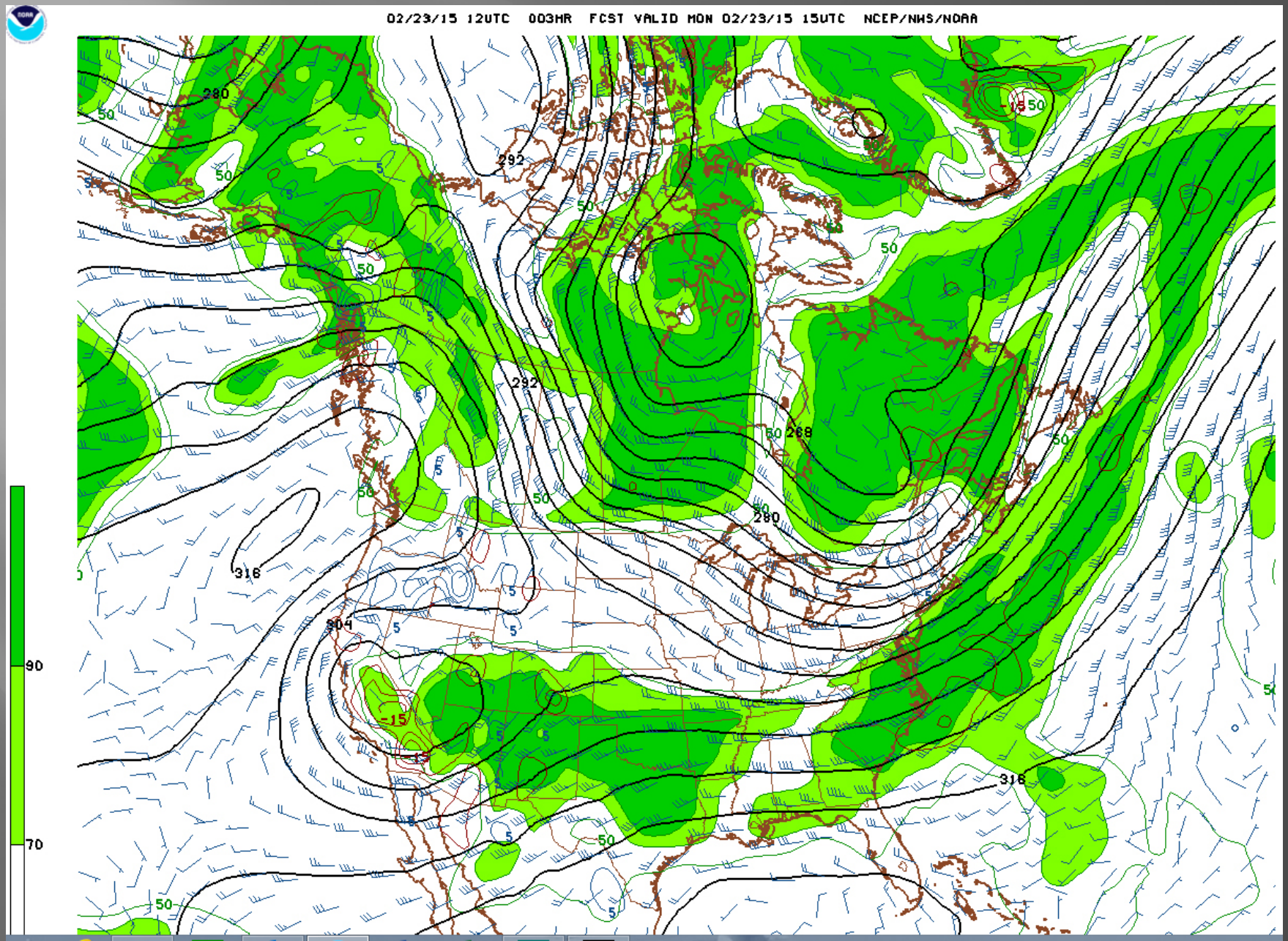


Characteristics of Southerly Flow



- Upslope flow occurs over the southern interior as air is forced upward from the Columbia Basin of Washington State. There is no significant subsidence.
- Extremely high (3500 metres) freezing levels as warm air spreads to northern BC.
- A nearly stationary north-south oriented front may linger for days across the North Coast Mountains. Storms rippling along the front maintaining wet, mild conditions.
- Warm southerly over-running of cold air in valleys east of the front creates persistent temperature inversions with little weather associated. Fog and low clouds clog interior valleys while the peaks of mountains remain relatively warm and sunny. Moist air flowing northward can give persistent low clouds and rainfall to the otherwise dry southern interior valleys. If arctic air is entrenched in those valleys then significant snowfall or freezing rain occur.
- Also known as the “Tropical Punch”

Characteristics of a Split Flow



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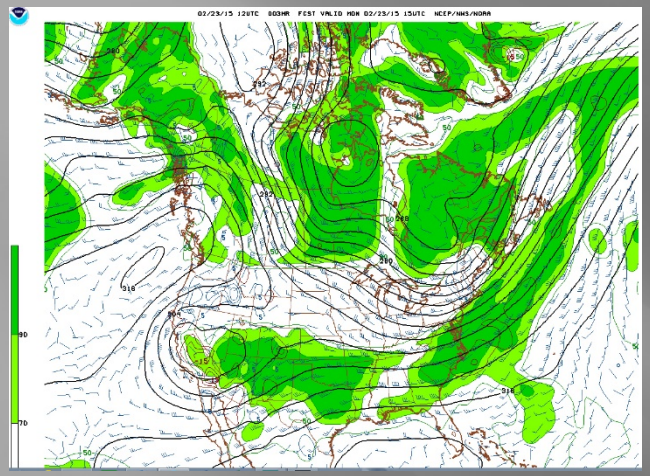
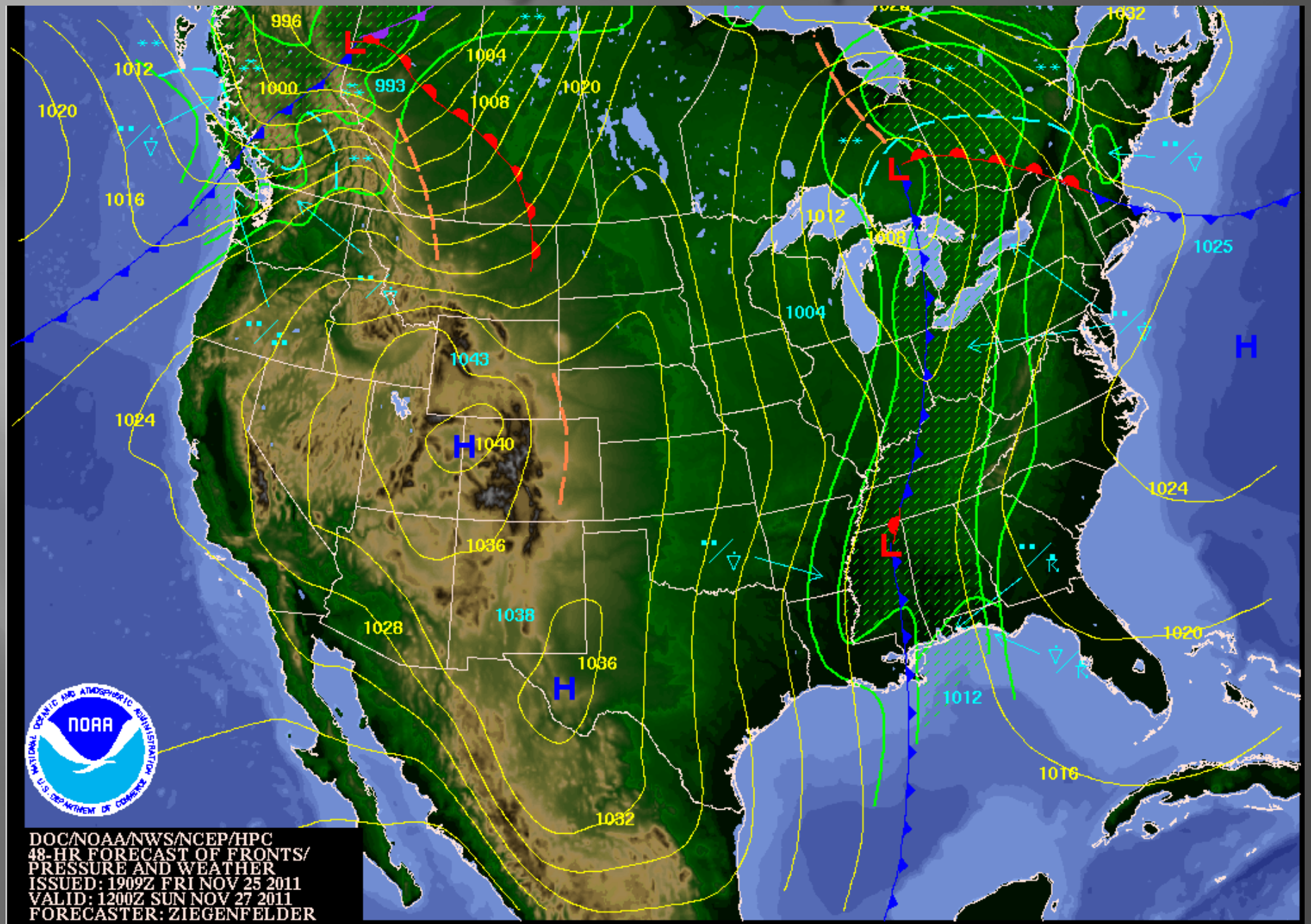


- Approaching storms are deceiving; they shear apart offshore
- Very little precipitation; more in the south
- Warmer than average all over western North America
- Pattern is persistent sometimes lasting an entire season eg. Winter 2015 and Winter 2016
- Common during el nino winters

Weather Maps and Charts

System Map


996
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DOC/NOAA/NWS/NCEP/HPC
48-HR FORECAST OF FRONTS/
PRESSURE AND WEATHER
ISSUED: 1909Z FRI NOV 25 2011
VALID: 1200Z SUN NOV 27 2011
FORECASTER: ZIEGENFELDER

Satellite and Radar Images

- Satellite
  - Visible light (measures brightness) only useful in the daytime
  - Infrared (measures temperature) applicable at all hours
  - Water vapour
- Radar
  - Shows precipitation
  - Largest precipitation event locally is Mt. Lougheed
  - Jasper is in a hole where there is poor radar coverage

Webcams

- Are near real time
- A great way to gauge sky conditions
- Sites are constantly changing
- Highway departments are getting more
  - Quite often include remote weather sensors
- Useless at night
- Webcams

Planning Your Trip

Generate Forecast

- Look out the window!
- Review Environment Canada Website forecasts and maps
- Review weather network forecasts
- Review satellite photos
- Review relevant webcams
- Review NOAA Forecast Discussion
- Analyze the 700mb chart Link
- Fill out worksheet (next slide)

Generate Weather Worksheet

Weather Analysis Sheet			
Planned Route / Description			
Date Prepared	Prepared by:		
Trip date:			
Weather Information Sources			
Watches /Warnings / Advisories			
Synopsis			
Observations			
Location			
Sky / Wx			
Temp			
Dewpoint			
Relative Humidity			
Wind			
Pressure			
Comments			
Winds Aloft			
Altitude	Direction	Speed	Temp
700mb			
500mb			
Area forecasts			
Date / Time			
Sky			
Weather			
Temps			
Extended Outlook			
Avalanche if relevant			
Notes			

Generate Forecast

Internet Weather Sites:

Environment Canada: https://weather.gc.ca/index_e.html

The Weather Network: http://www.theweathernetwork.com/

NOAA Discussion:
http://forecast.weather.gov/product.php?site=NWS&issuedby=TFX&product=AFD&format=CI&version=1&glossary=1

700 mb charts:
http://mag.ncep.noaa.gov/model-guidance-model-area.php

NOAA Main Site:
http://www.weather.gov/

SPOTWX
https://spotwx.com/

ECMWF
http://www.yr.no/place/Canada/Alberta/Canmore/

Questions

Mountain Weather

The End
Thank You

Notes available at: http://www.rod-plasman.ca/wxcourse.pdf