Weather and Climate

Jim Keller & Paul Belanger

Classroom assistant: Fritz Ihrig

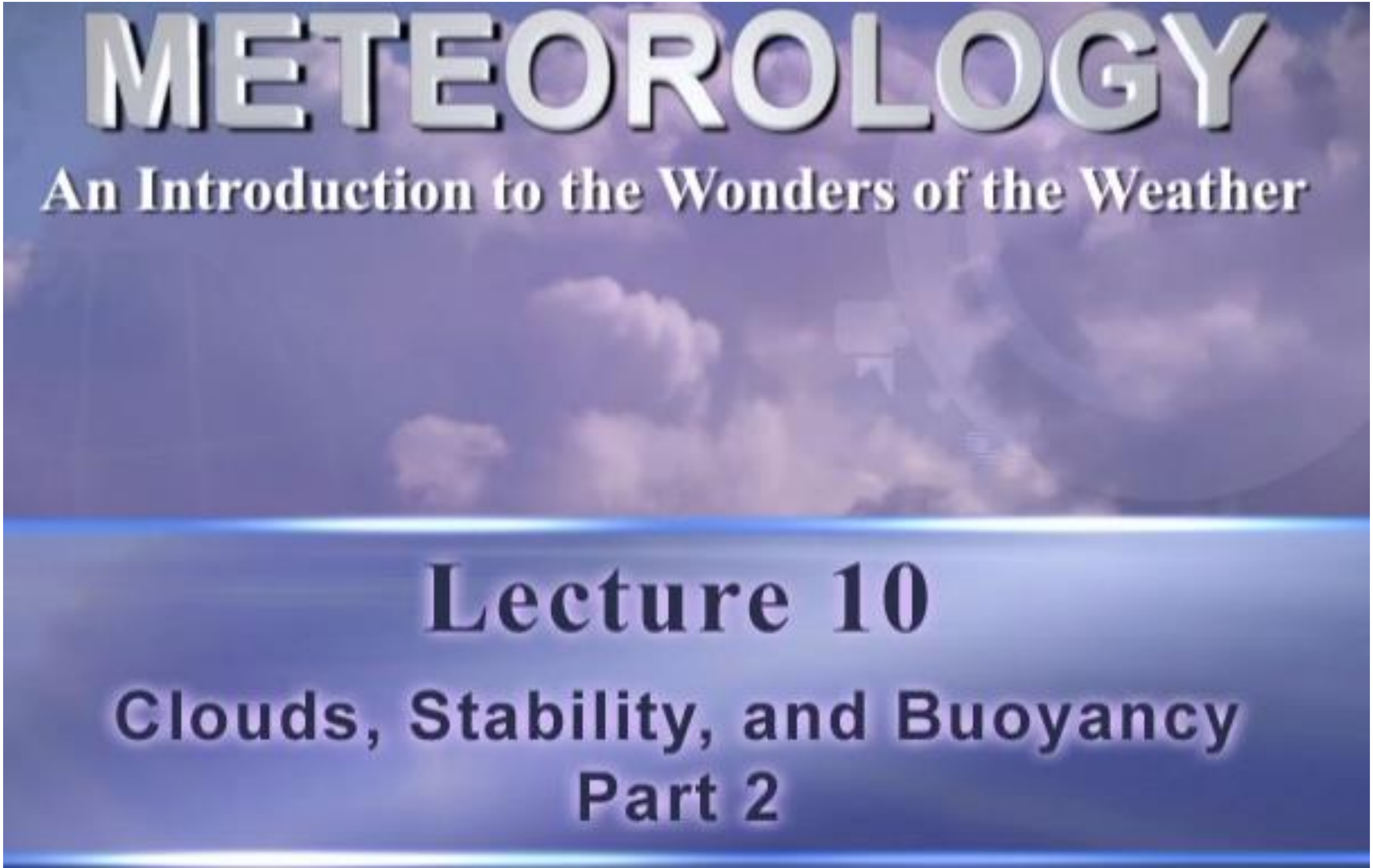
Week 4: February 5th , 2019

The Great Courses

Lecture Chapters

About the Professor

Meteorology: An Introduction to the Wonders of the...


METEOROLOGY
An Introduction to the Wonders of the Weather
Lecture 10
Clouds, Stability, and Buoyancy
Part 2

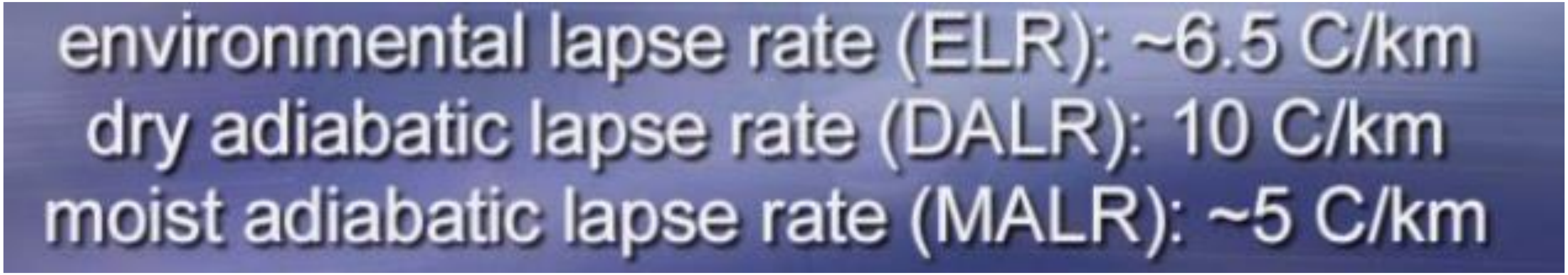
White board terms / definitions

- Lapse Rates C/km: ELR Environmental – lapse rate of the atmosphere

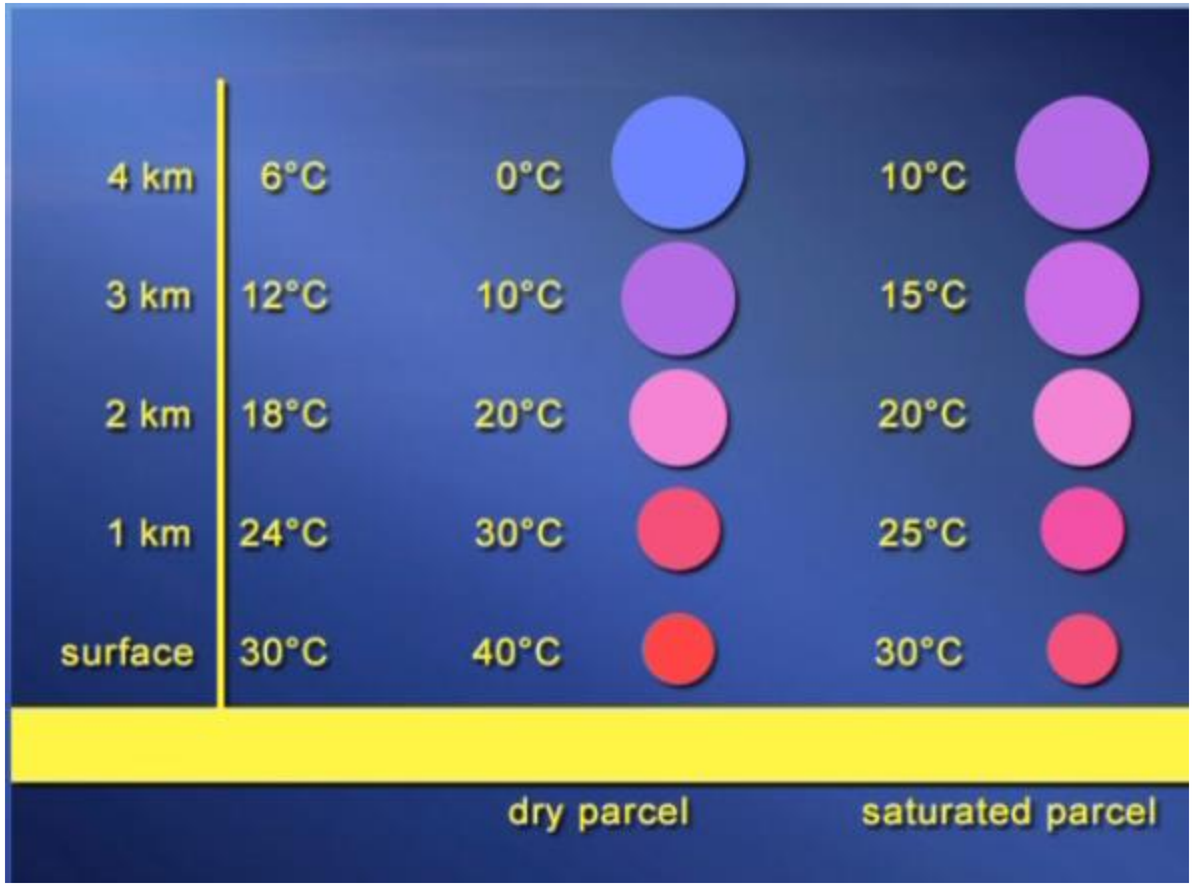
  Parcel lapse rates – DALR – Dry Adiabatic Lapse Rate; MALR – Moist Adiabatic Lapse Rate; DPLR - Dew Point Lapse Rate.
- LCL Lifting Condensation Level: – altitude where a cloud starts to form and parcel then rises @ MALR – Moist Adiabatic Lapse Rate
- Latent Heat: heat required to effect a phase change: melting or freezing of ice (80 Cal/gm); evaporation or condensation of liquid water (~ 540 Cal/gm)

Air Parcel

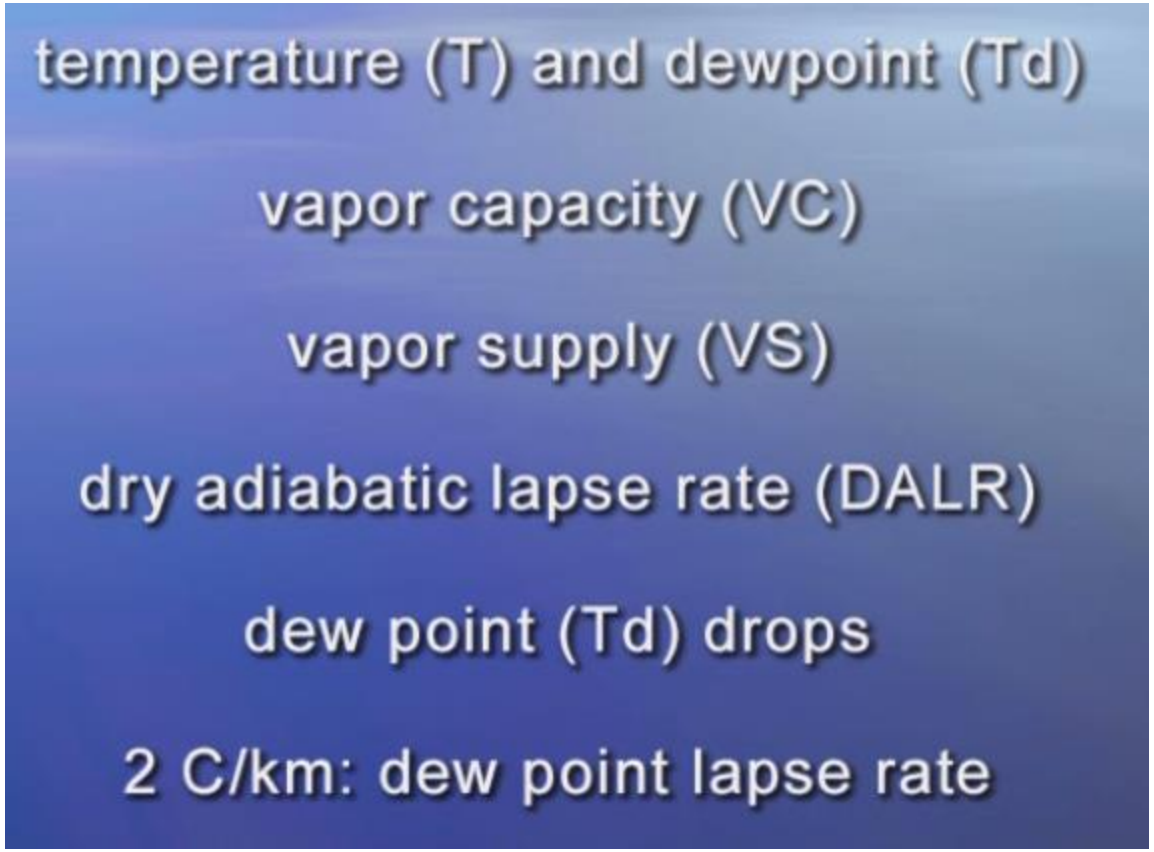
- ELR – Environmental lapse rate ~6.5C/km
- DALR – dry adiabatic: ~10C/km
- MALR – Moist adiabatic: variable but ~5C/km



- Dry hot air rises quickly but won't rise very far – won't stay hot – cools rapidly at the DALR rate of ~10C/km
- Saturated hot air on other hand rises quickly but cools at MALR rate of ~5C/km BECAUSE water condenses (a cloud forms) it releases heat and thus cools at a lower rate than if it were dry (i.e. at the DALR rate of ~10C/km)
- Leads to **conditional instability** – where the air becomes warmer & less dense than its surroundings and tends to rise.

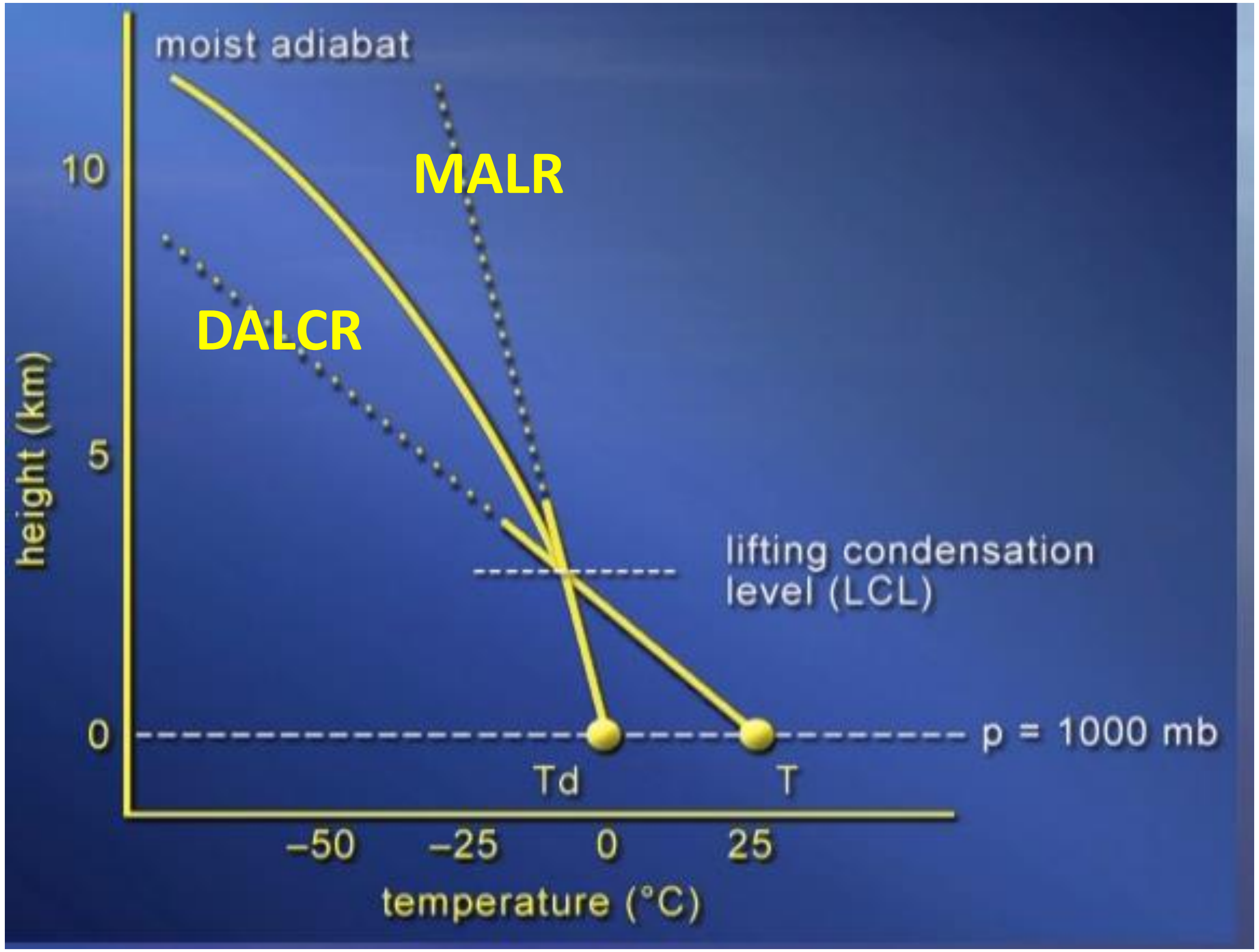


- So why doesn't the atmosphere turn over all the time?
  - Because we don't find saturated air parcels very often
- Raise a sub-saturated air parcel – it has a T and Td (dew point) with a certain vapor capacity VC and vapor supply VC. We lift it:
  - Starts at DALR, expands and cools @ ~10C/km. Dew point drops at the dew point lapse rate ~2C/km
  - When parcel reaches dew point, cloud forms (condensation) and parcel cools at moist adiabatic lapse rate, MALR ~5C/km

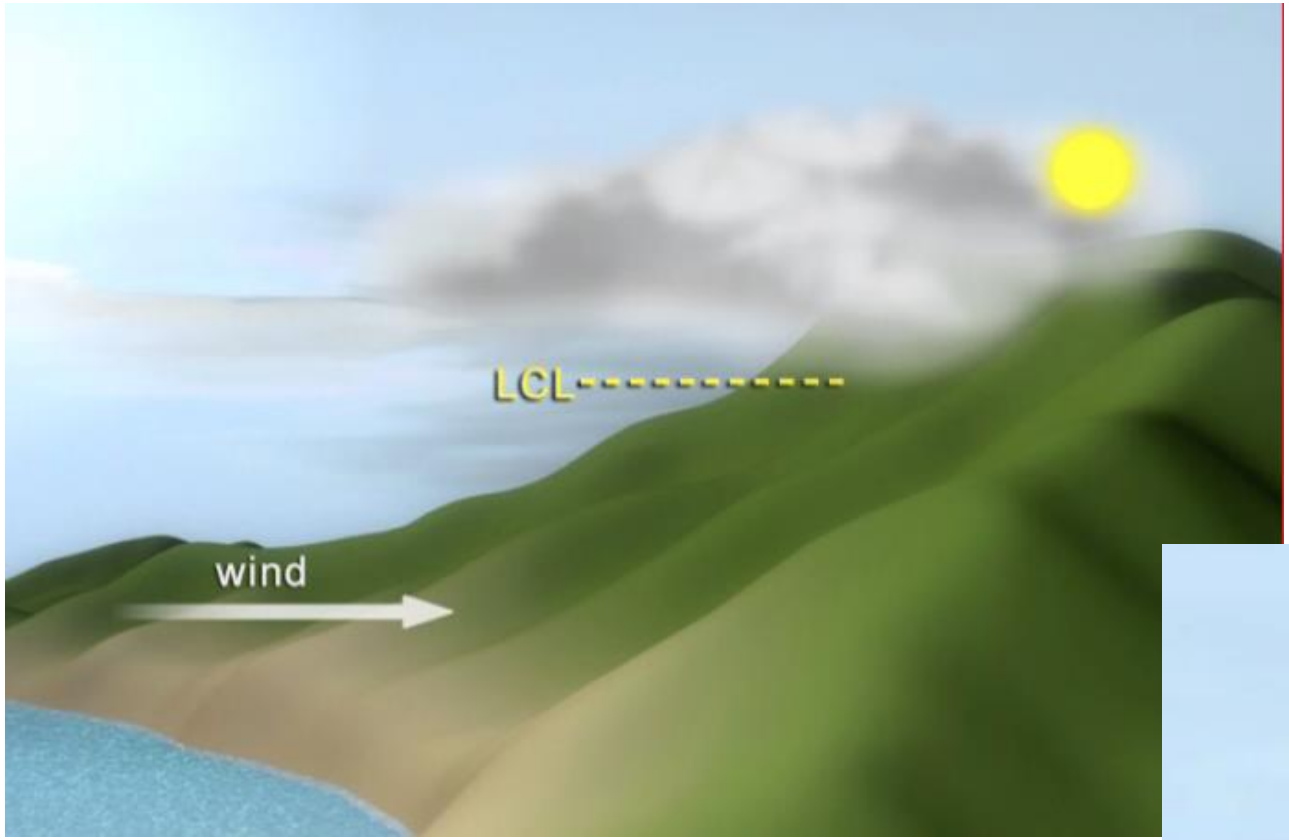


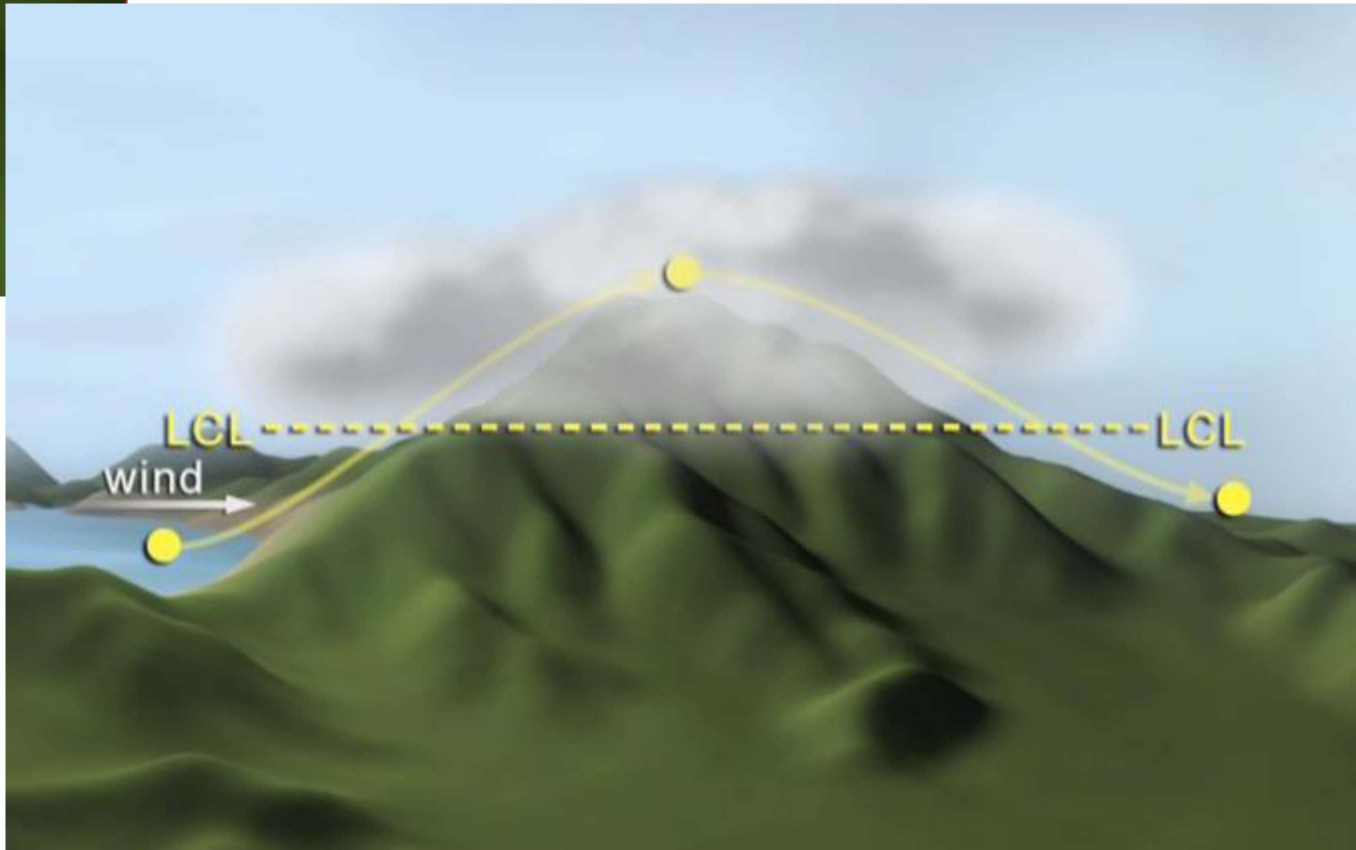
Summary - example

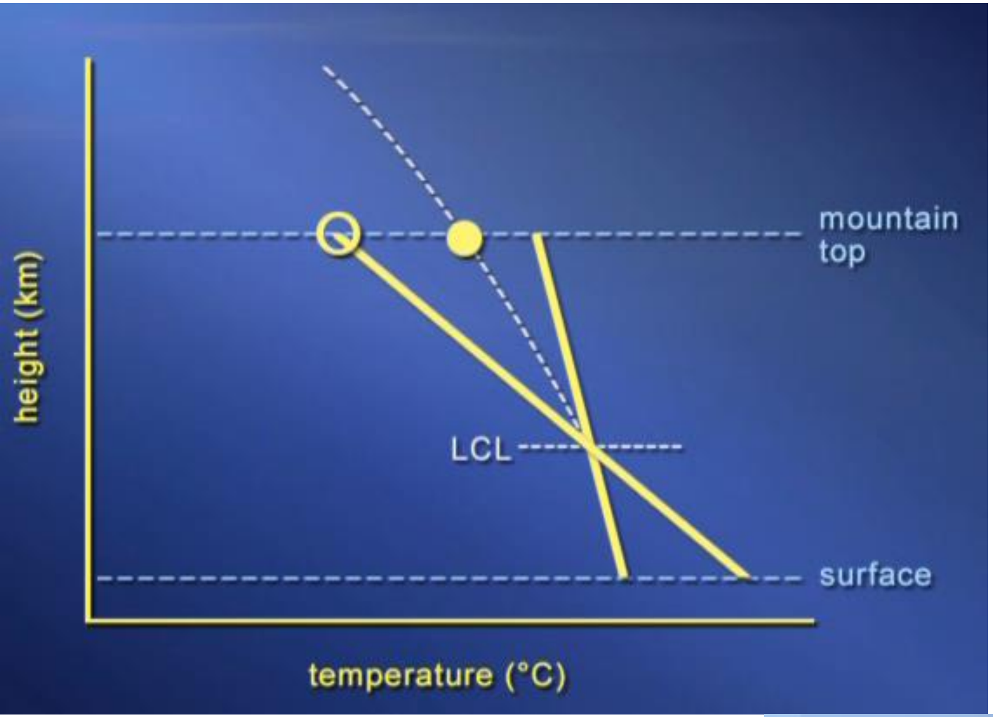
- Parcel starts @ DALR (Dry adiabatic Lapse Rate) ~ 10C/km, and DPLR (Dew Point Lapse rate) ~ 2 C/km
- Proceeds upwards until they cross – called the LCL (Lifting Condensation Level) – LCL – i.e. the CLOUD BASE
- Parcel then continues upward at the somewhat variable MALR ~ 5C/km

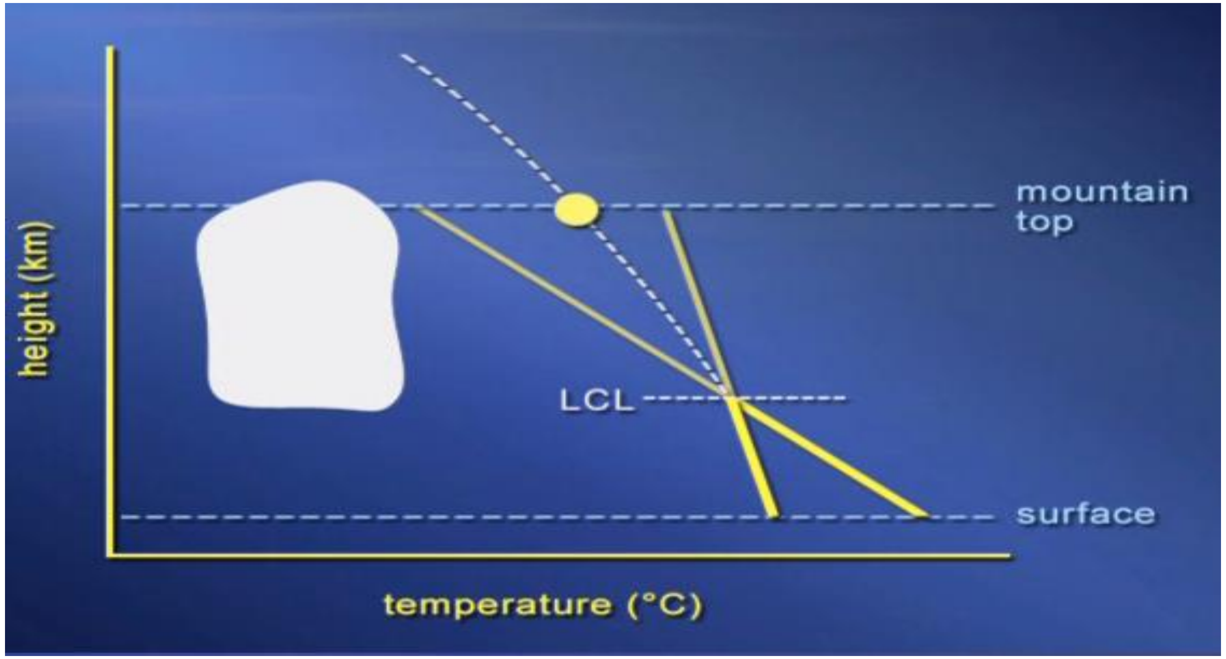


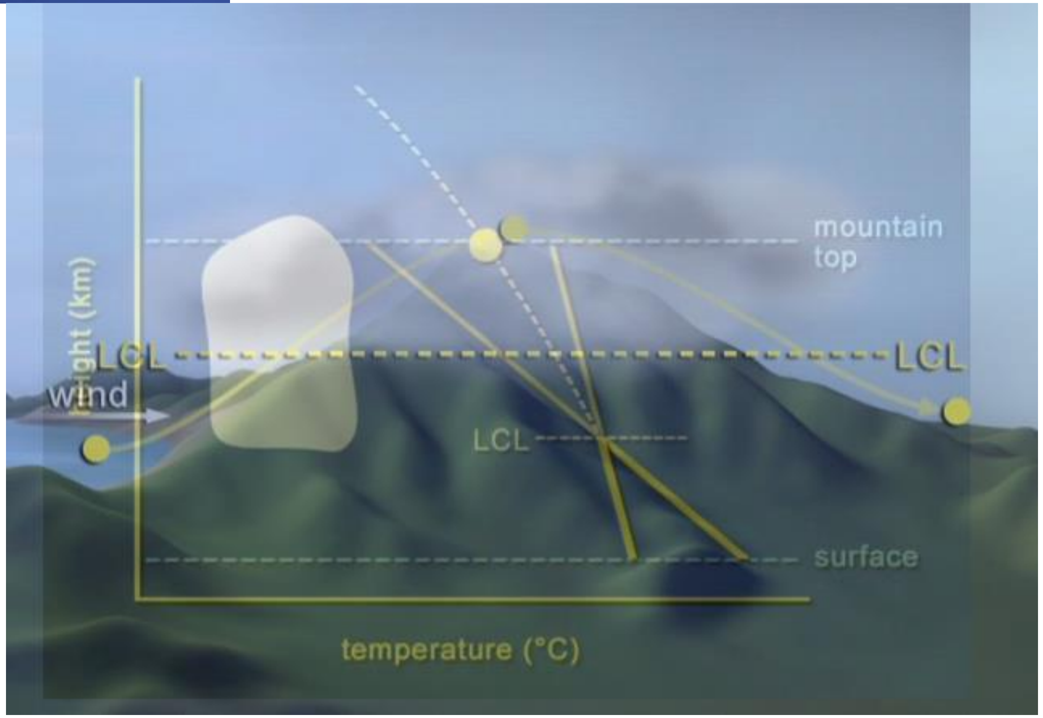
Parcel rises on windward side, becomes saturated, descends on lee side, cloud evaporates





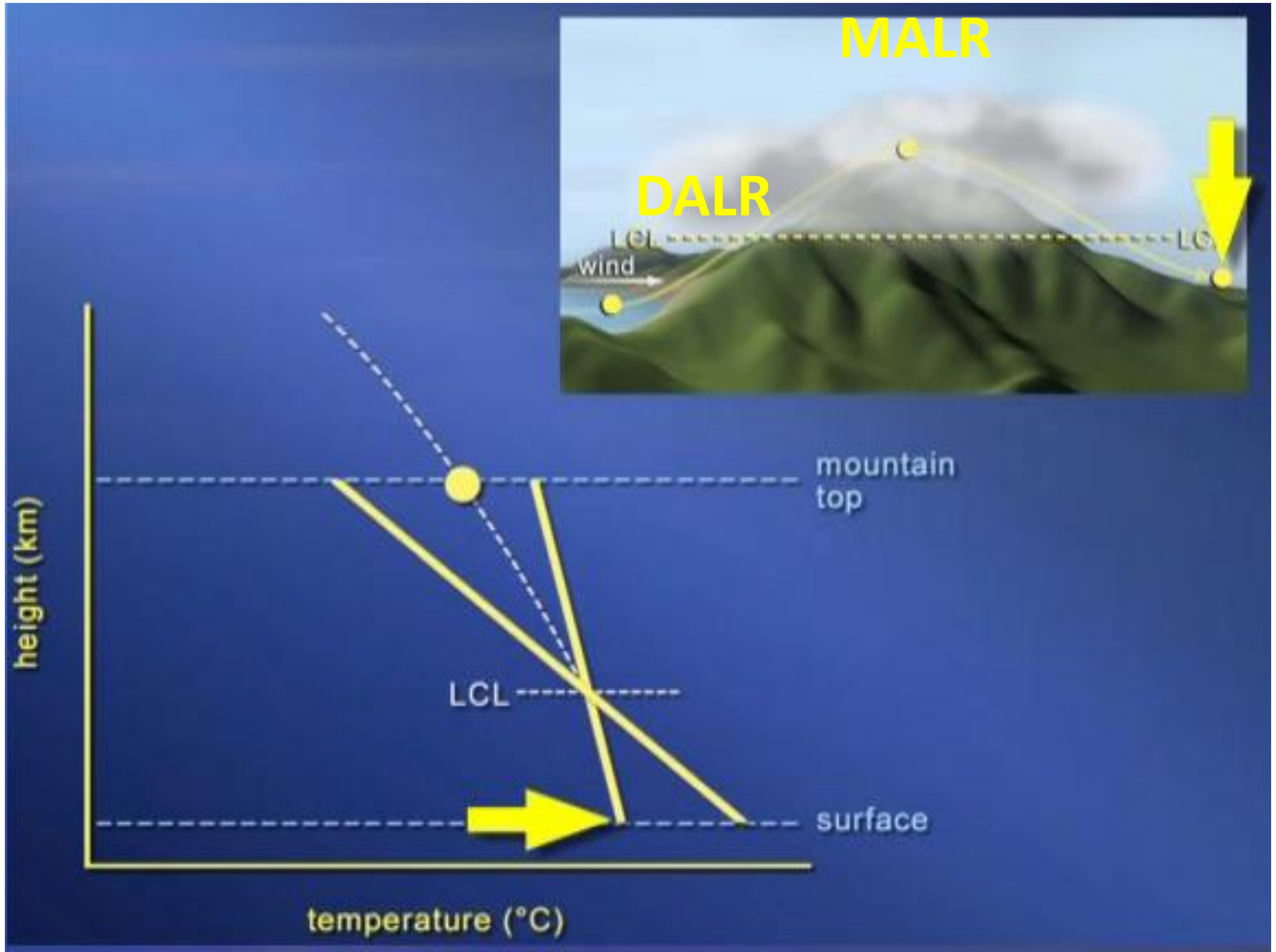

mountain top
LCL
surface
height (km)
temperature (°C)


mountain top
LCL
surface
height (km)
temperature (°C)


mountain top
LCL
LCL
LCL
wind
surface
height (km)
temperature (°C)

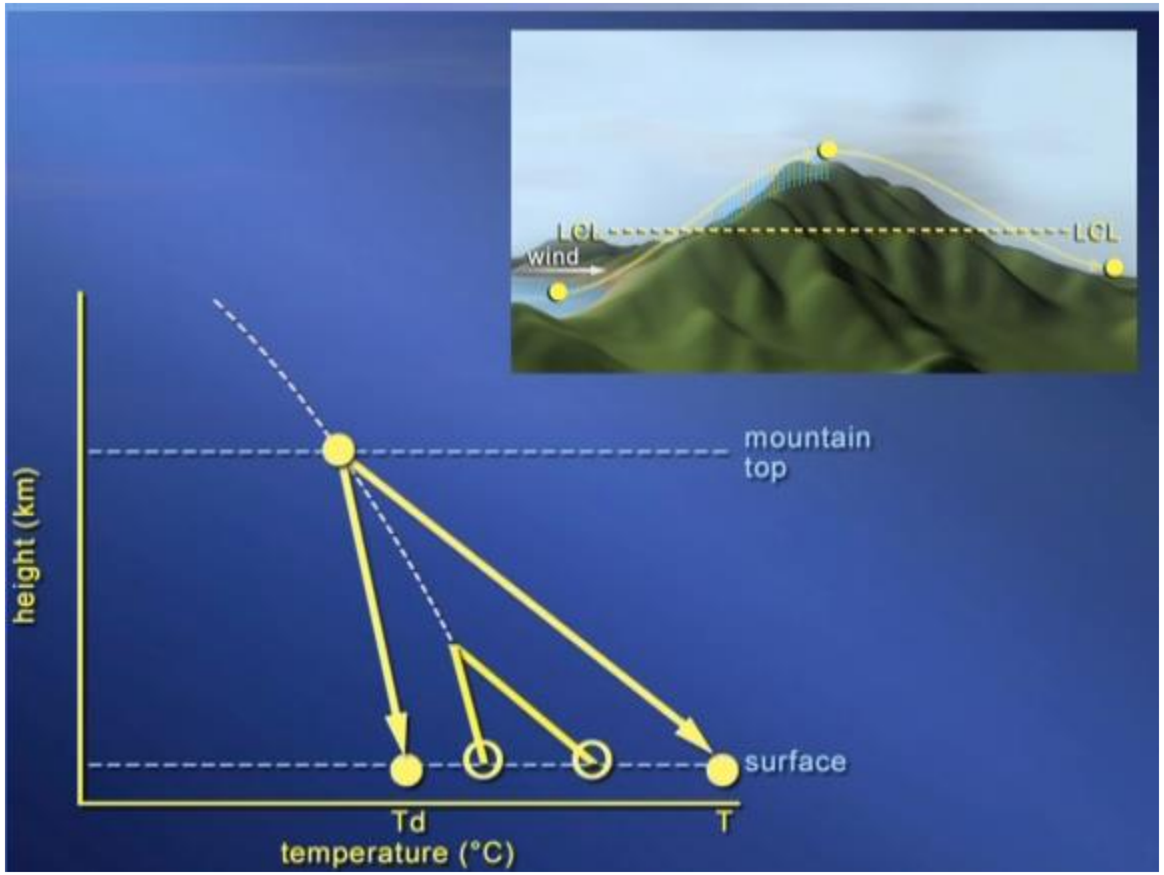
Did it precipitate or not?
1.All cloud no rain

- If it loses no precip – goes down the same path as it went up



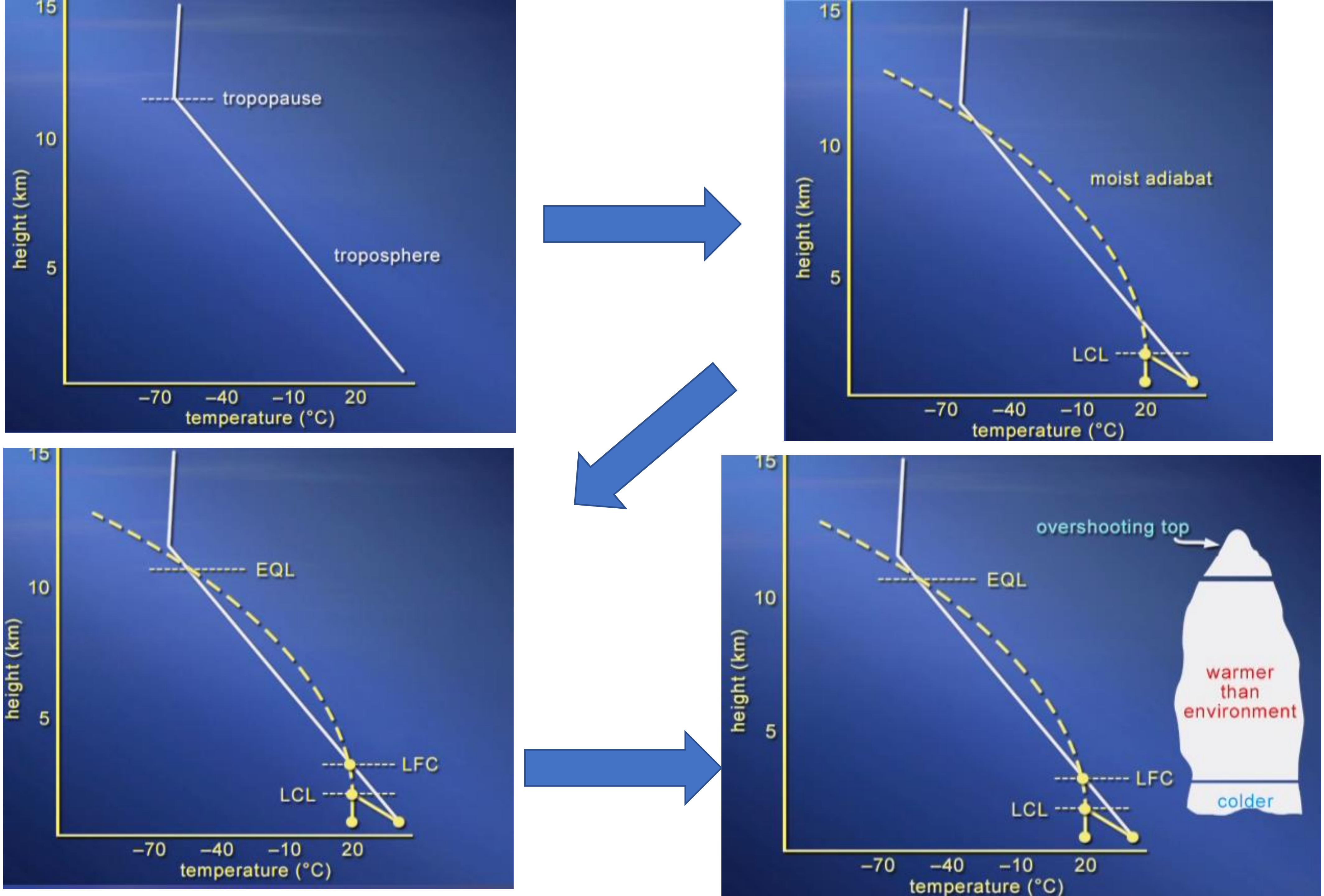
All rain and no cloud

- What if parcel lost the moisture
- Then it descends at DALR and gets a LOT warmer – Santa Ana/Chinook winds
- And lower dew point as well, due to loss of moisture

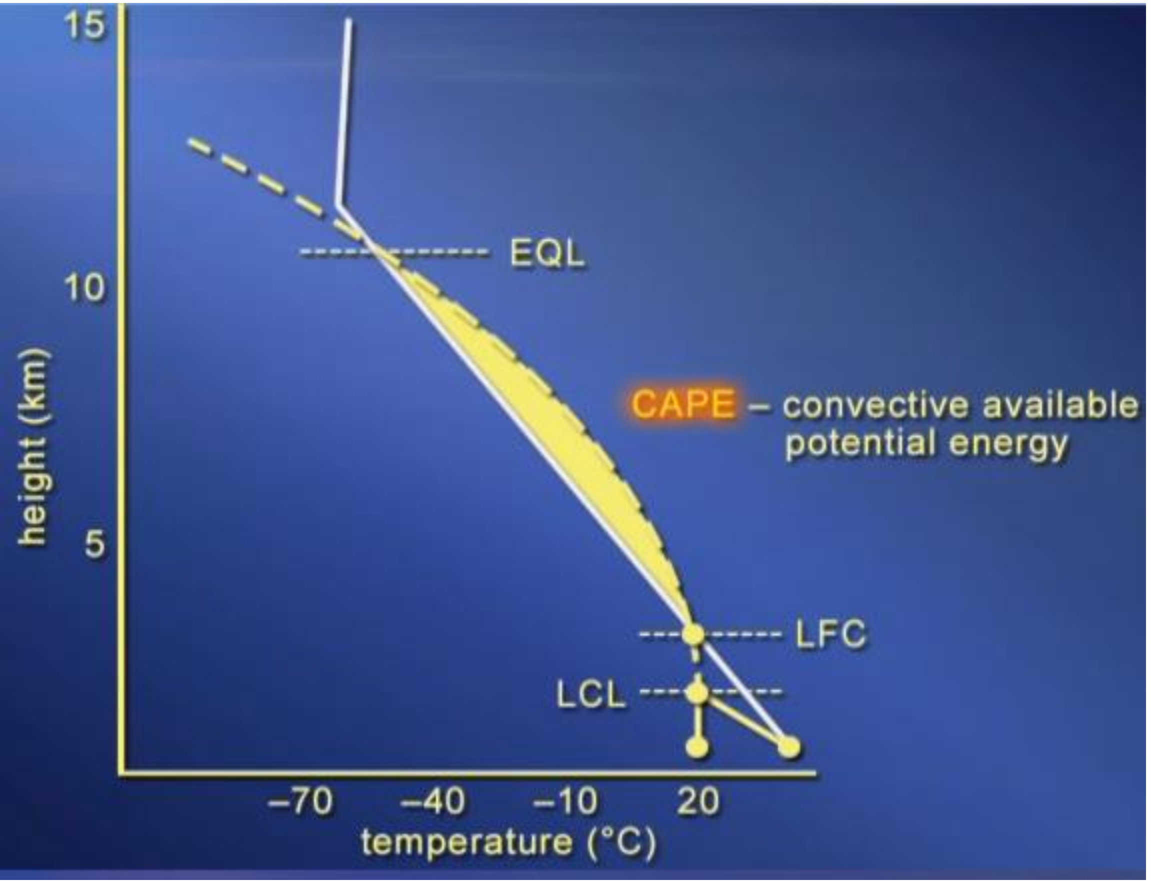


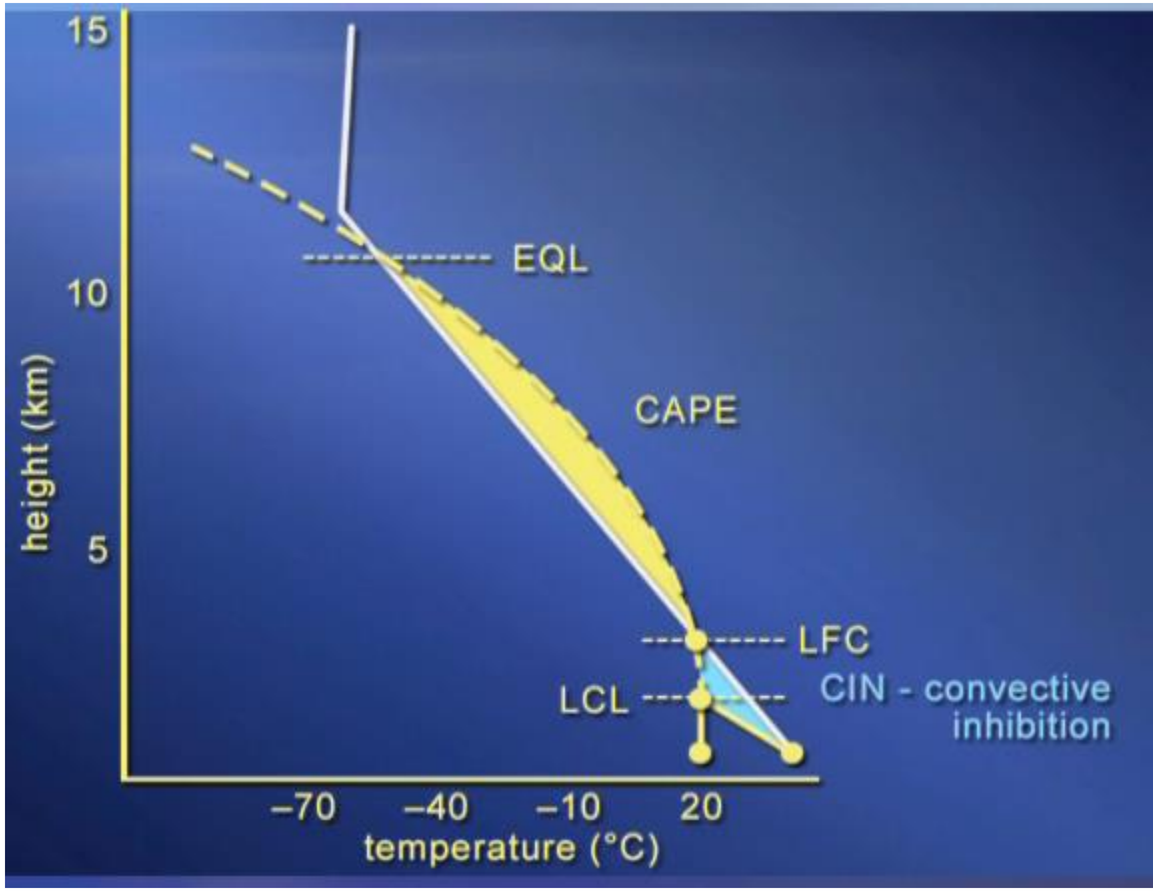
See net sequence of images:

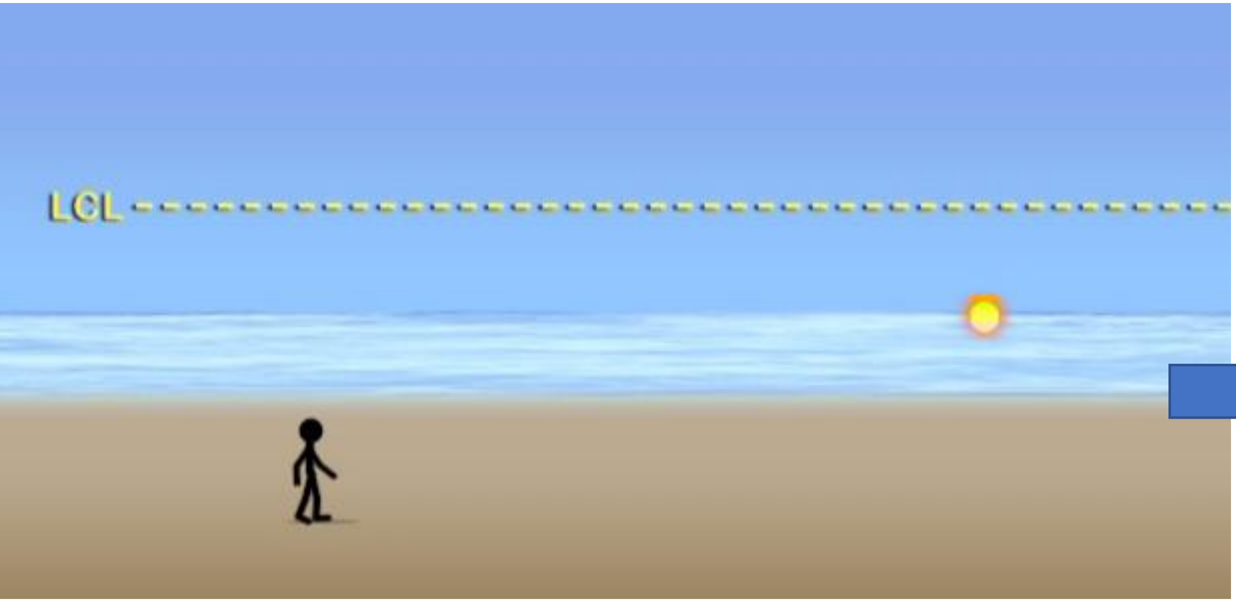
- At point of LFC it does not need to be pushed anymore – it’s more buoyant and rises on it’s own
- EQL it stops = CLOUD TOP but momentum may cause overshoot
- LFC = Level of free convection
- EQL = listen for it in the video
- CAPE = Convective Available Potential Energy – energy available to cause parcel to rise.

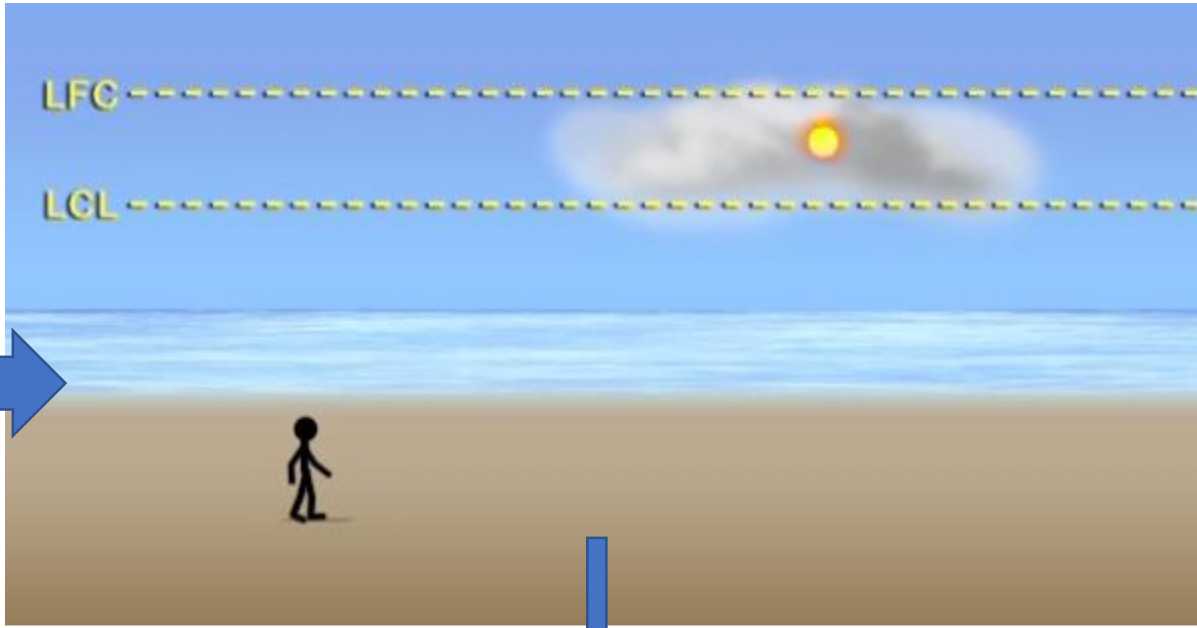

15
10
5
height (km)
tropopause
troposphere
−70 −40 −10 20
temperature (°C)
15
10
5
height (km)
moist adiabat
LCL
−70 −40 −10 20
temperature (°C)
15
10
5
height (km)
EQL
LFC
LCL
−70 −40 −10 20
temperature (°C)
15
10
5
height (km)
overshooting top
EQL
warmer
than
environment
LFC
LCL
colder
−70 −40 −10 20
temperature (°C)

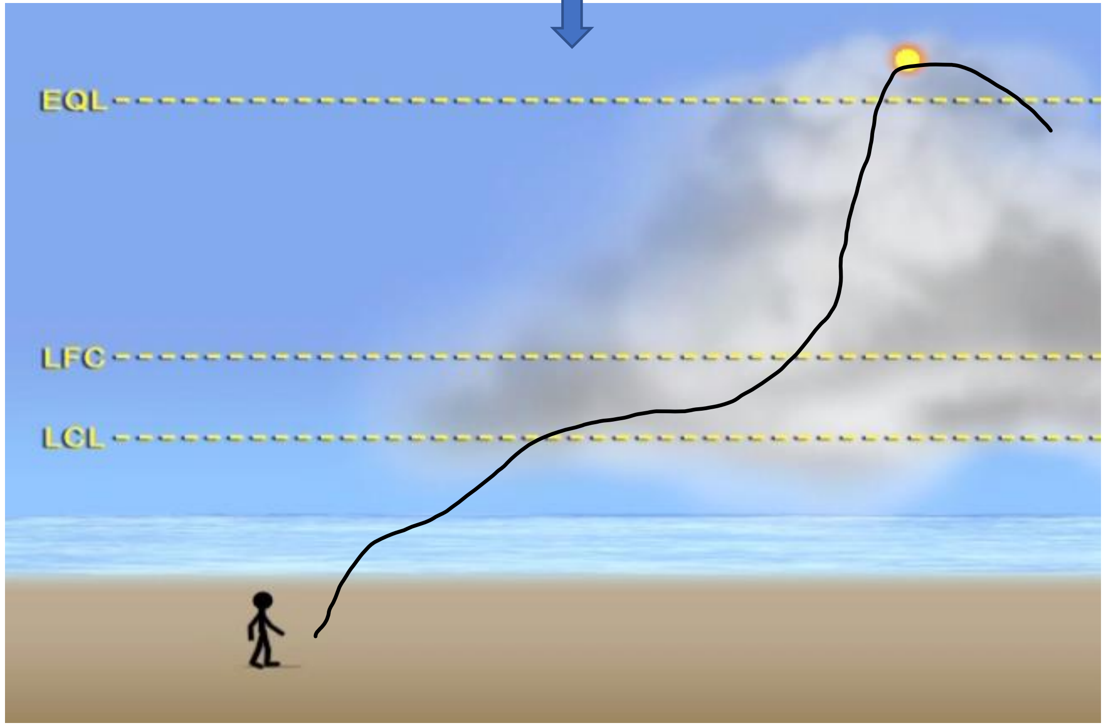
CAPE


15
10
5
height (km)
EQL
CAPE – convective available potential energy
LFC
LCL
–70
–40
–10
20
temperature (°C)

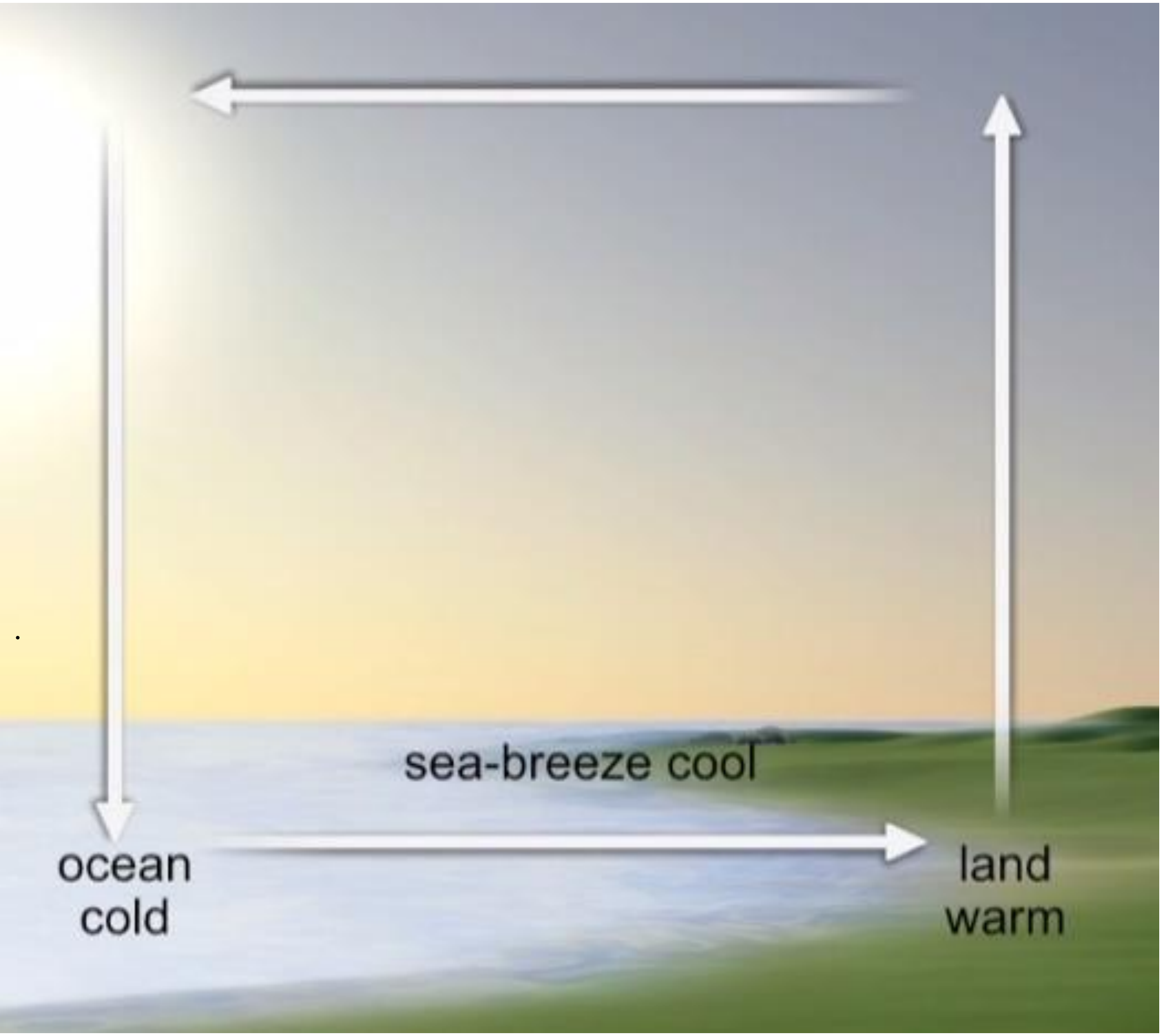

15
10
5
height (km)
EQL
CAPE
LFC
LCL
CIN - convective inhibition
–70
–40
–10
20
temperature (°C)

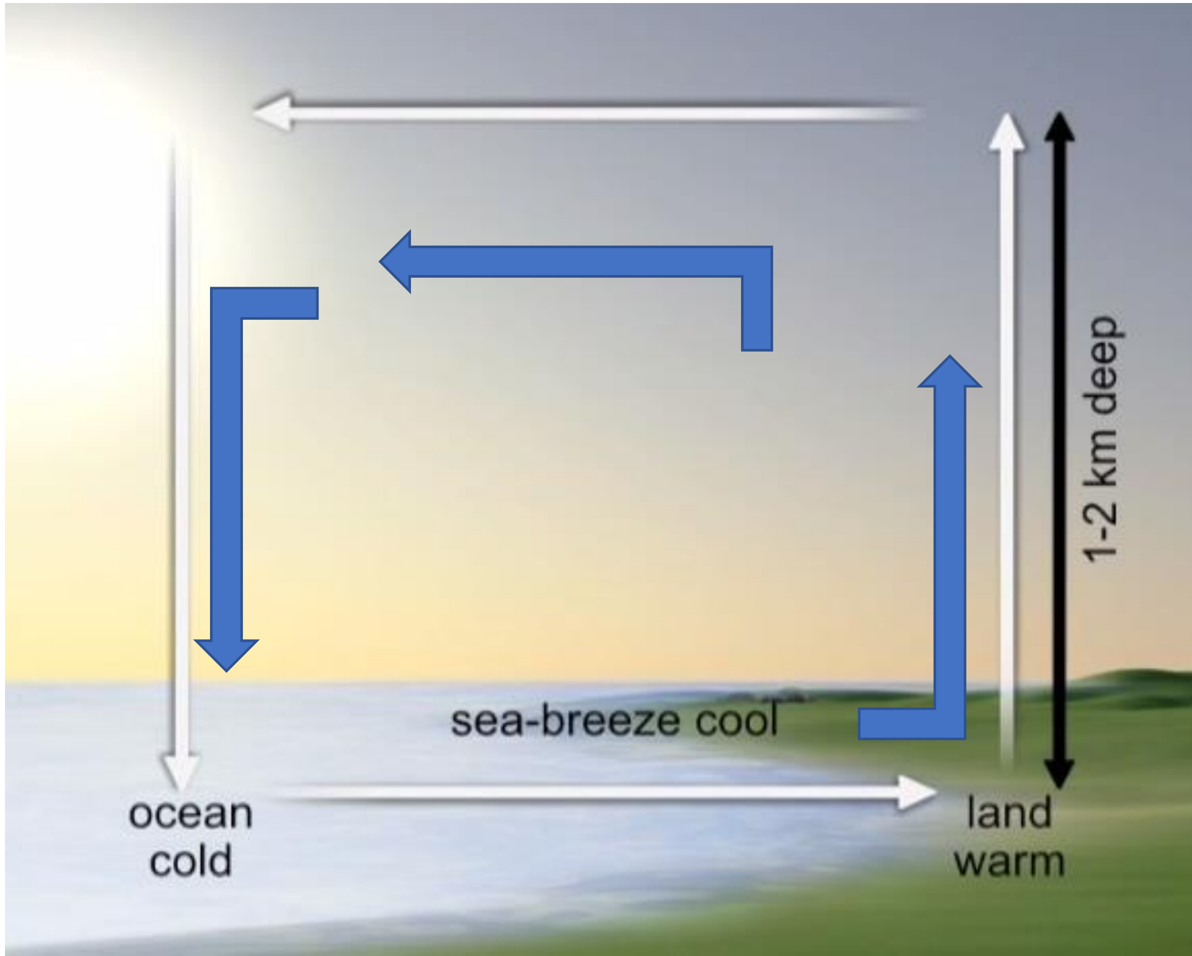






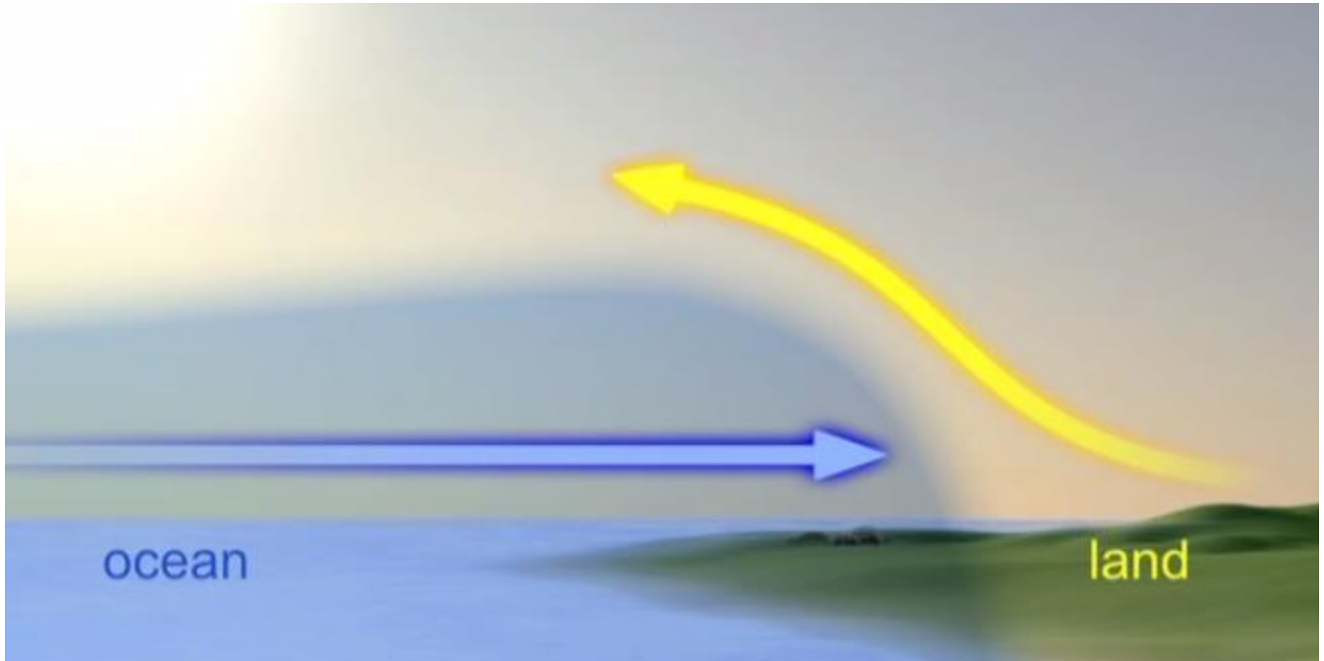
- 1. KICKS air parcel but doesn't reach LCL
- 2. kicks above LCL but not enough = it forms a cloud but no drizzle
- 3. super kicks above EQL level causes precipitation

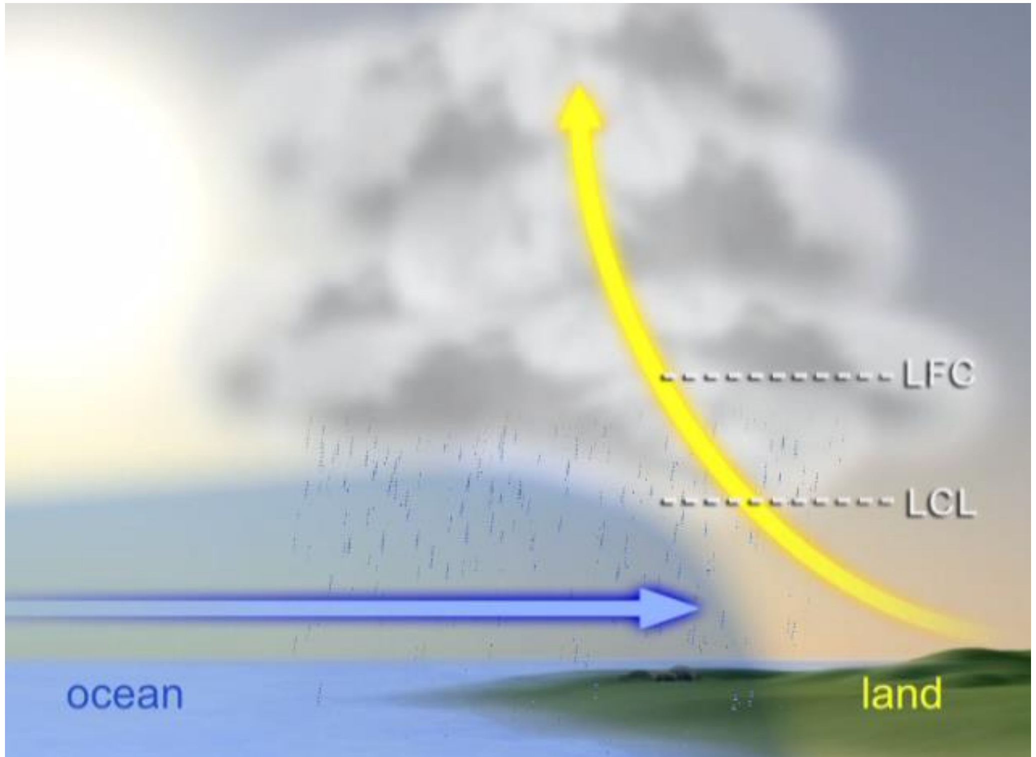

sea-breeze cool
ocean
cold
land
warm

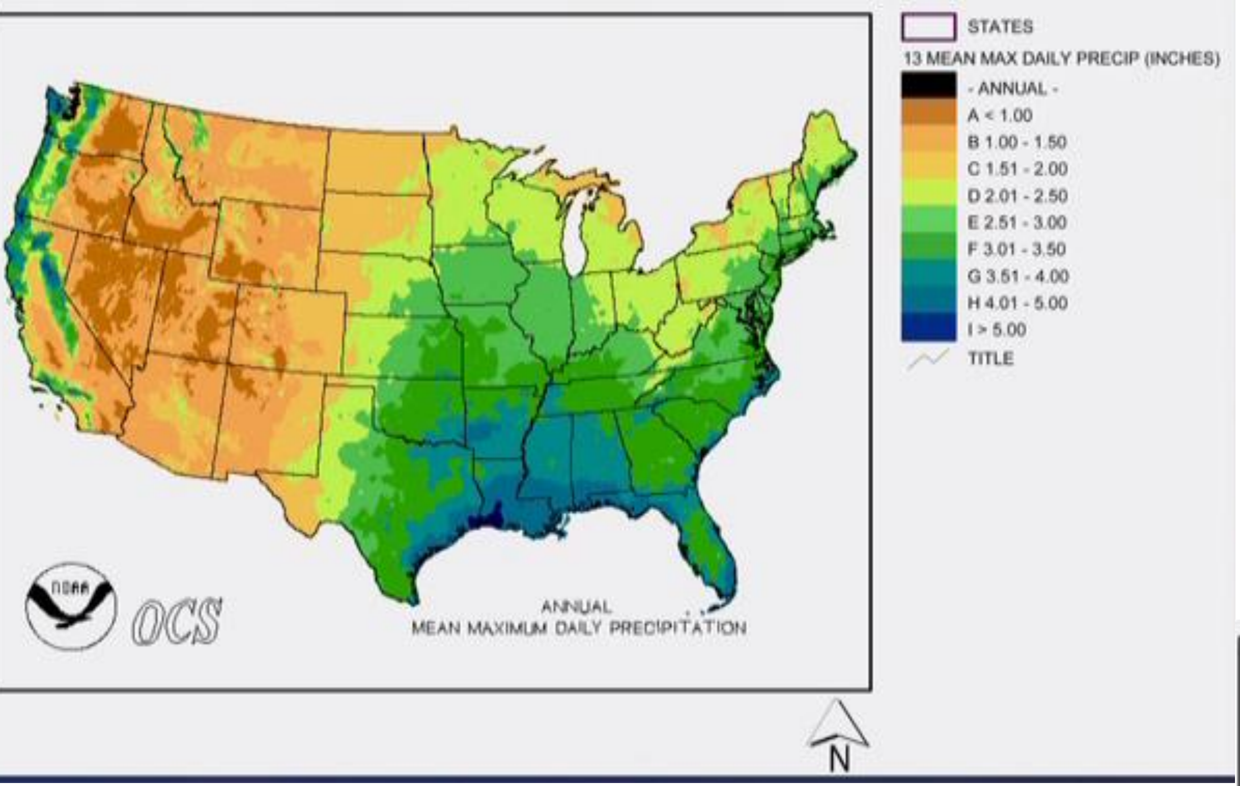

1-2 km deep
sea-breeze cool
ocean
cold
land
warm

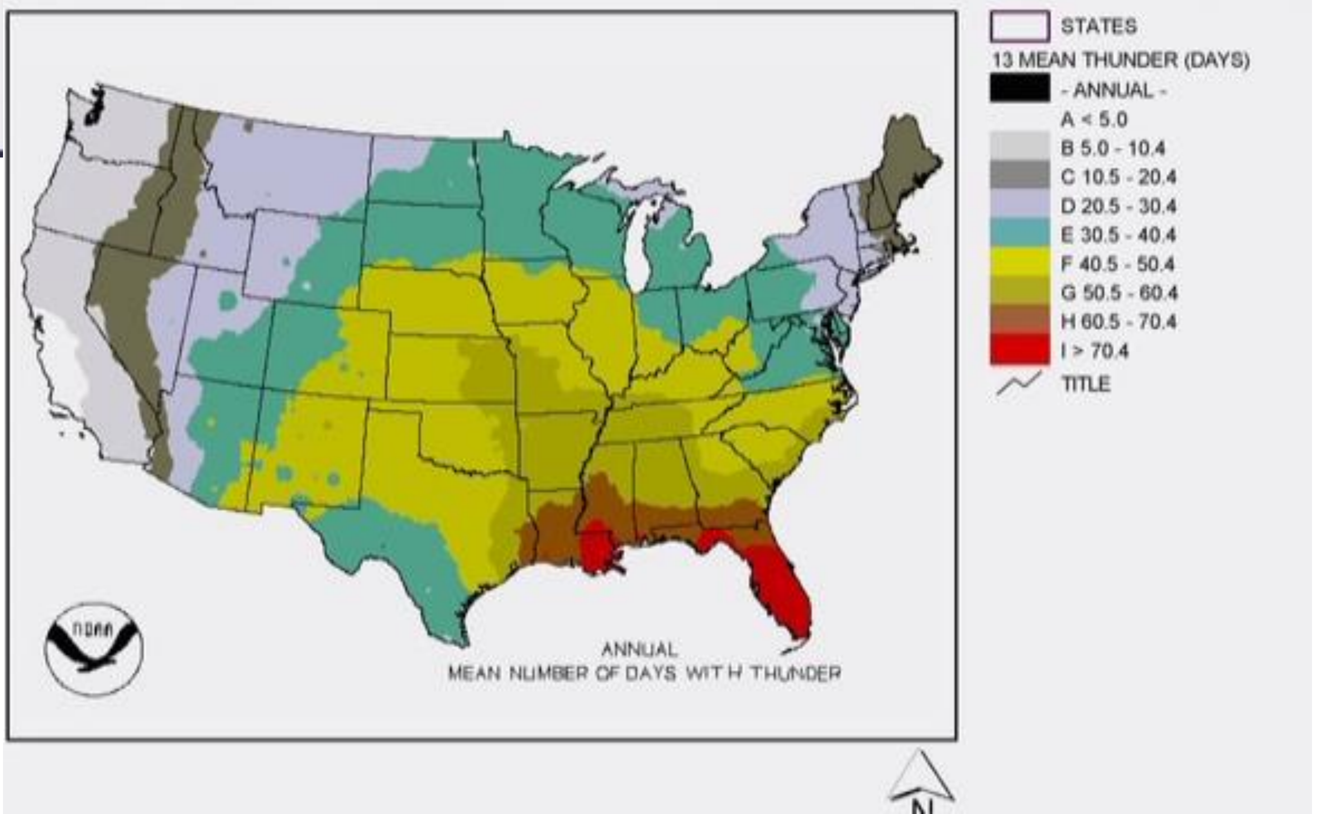
Fronts:

- Sea breeze fronts
- Cold fronts
- Warm fronts
- Occluded fronts

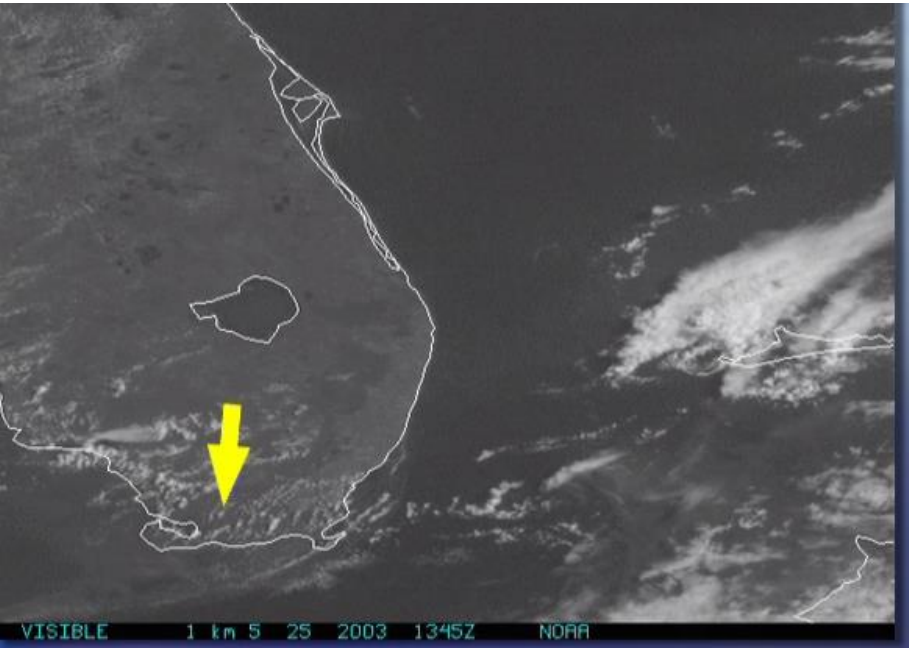





STATES
13 MEAN MAX DAILY PRECIP (INCHES)
- ANNUAL -
A < 1.00
B 1.00 - 1.50
C 1.51 - 2.00
D 2.01 - 2.50
E 2.51 - 3.00
F 3.01 - 3.50
G 3.51 - 4.00
H 4.01 - 5.00
I > 5.00
TITLE
NOAA
OCS
ANNUAL
MEAN MAXIMUM DAILY PRECIPITATION
N

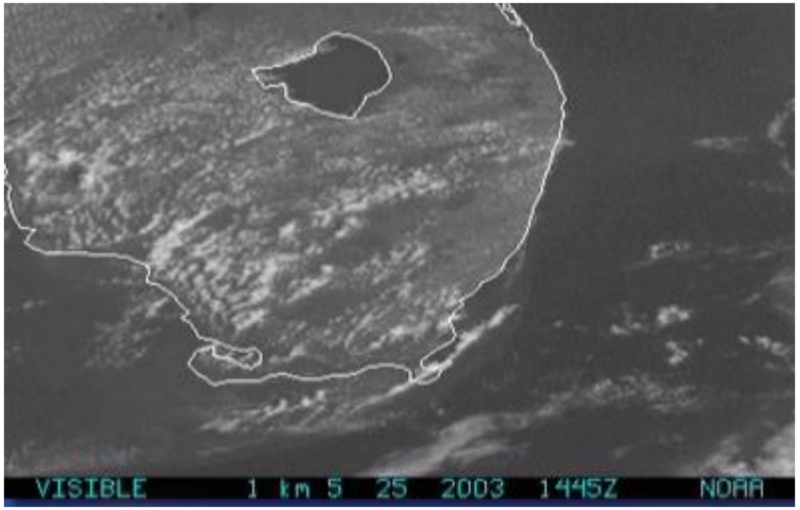

STATES
13 MEAN THUNDER (DAYS)
- ANNUAL -
A < 5.0
B 5.0 - 10.4
C 10.5 - 20.4
D 20.5 - 30.4
E 30.5 - 40.4
F 40.5 - 50.4
G 50.5 - 60.4
H 60.5 - 70.4
I > 70.4
TITLE
NOAA
ANNUAL
MEAN NUMBER OF DAYS WITH THUNDER
N

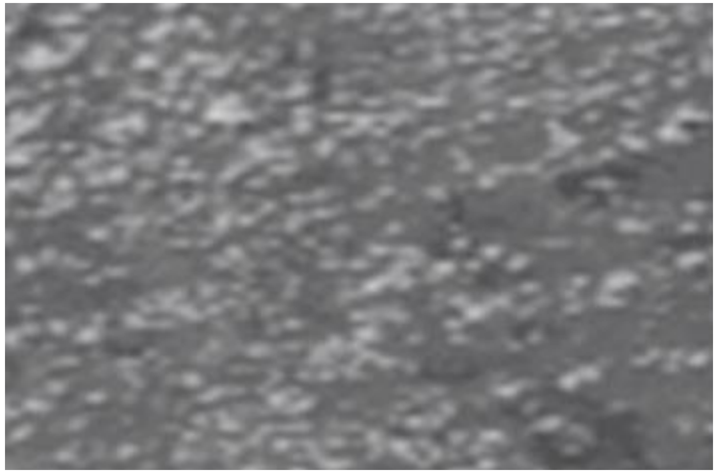
• 9:45 EST/1345Z

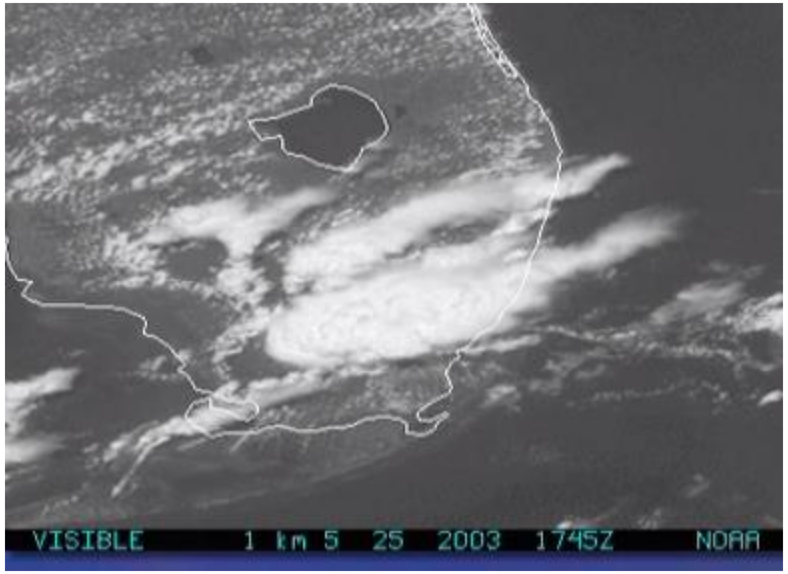


• Then 4 hours later: 13:45 EST/1745Z

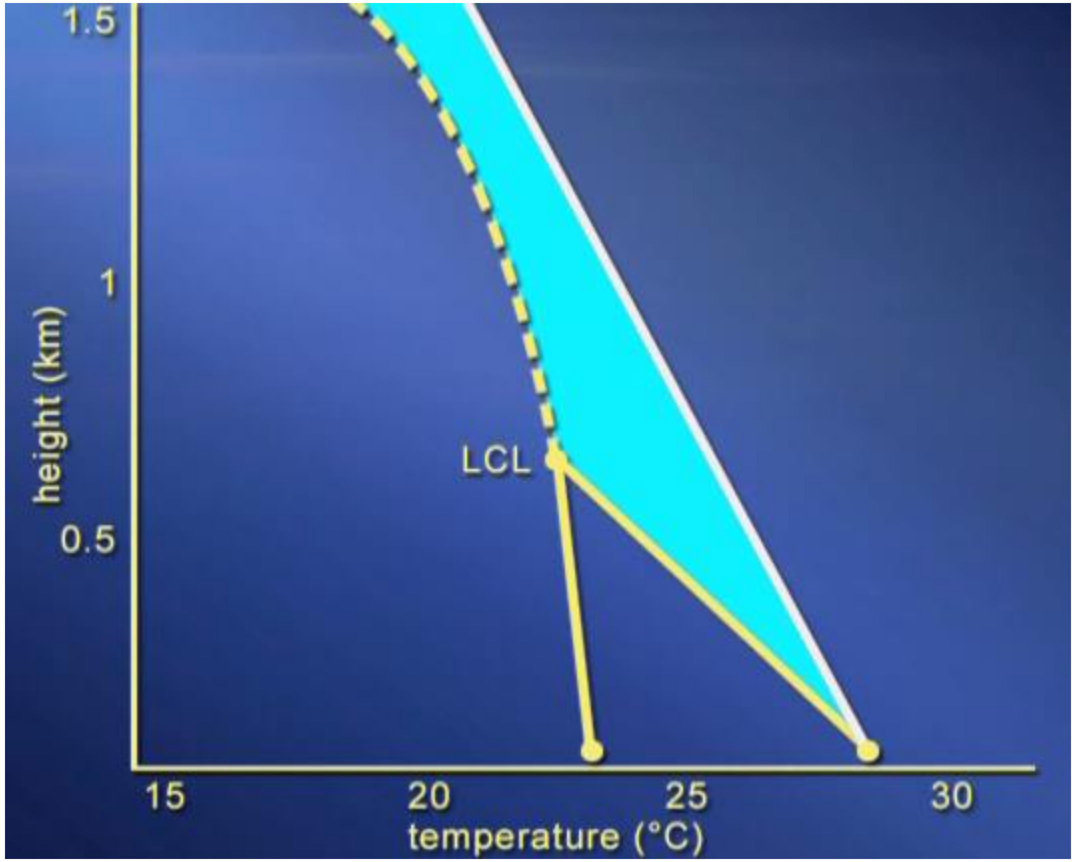
• 1 hour later: 10:45 EST/1445Z with closeup view

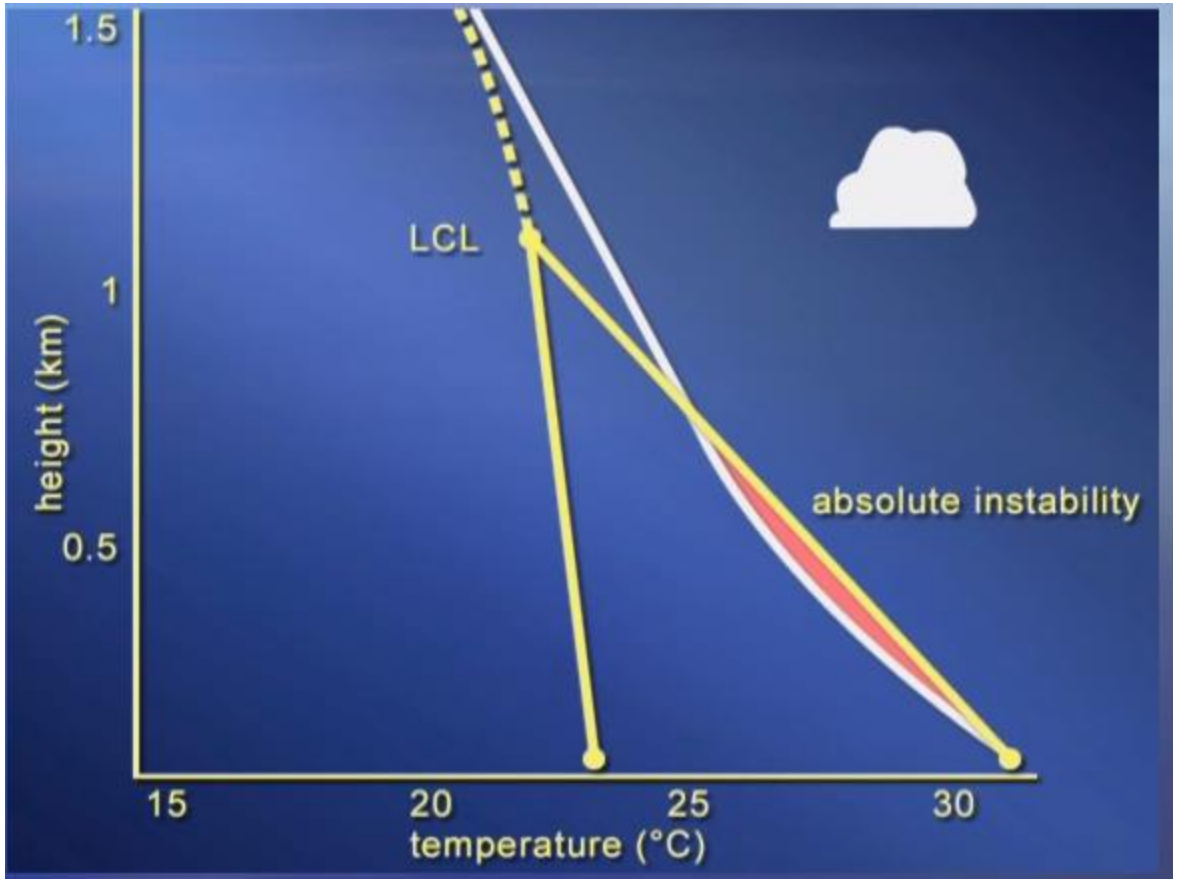


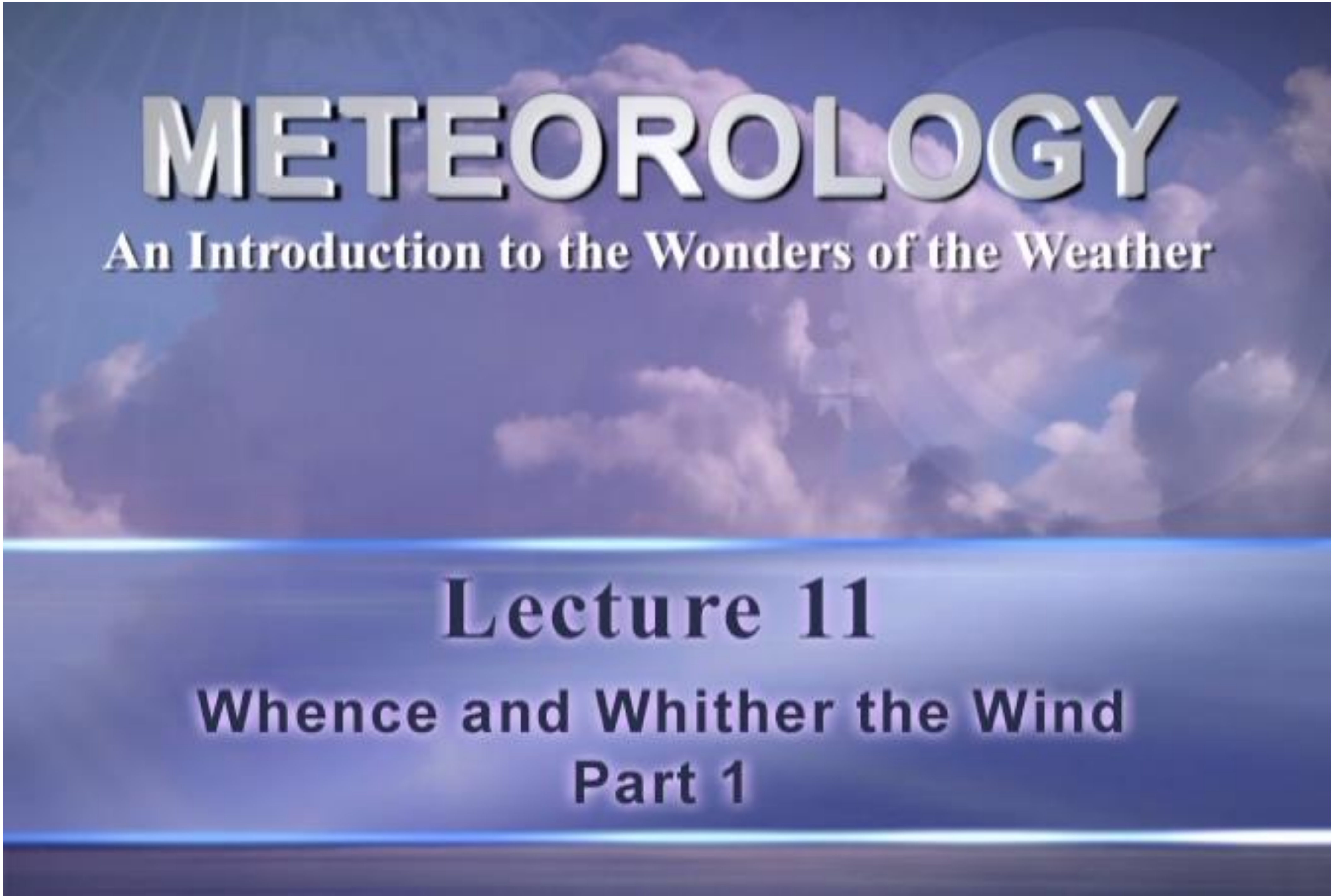




- Earlier to later – more heating






METEOROLOGY
An Introduction to the Wonders of the Weather
Lecture 11
Whence and Whither the Wind
Part 1

Horizontal wind – our back to the wind

- Nature air from high to low pressure (IMPORTANT ROLE OF MOISTURE)
- NATURE NORTH TO SOUTH
- A 5th – a curvature due to earth sphericity – important with rockets

thermally direct circulations

In the absence of other forces, nature will push mass from high to low pressure.

The four principal forces that determine when, where, and how quickly the horizontal winds blow:

- real
  Pressure gradient force (PGF)
- apparent
  Coriolis force (Earth's rotation)
- real
  frictional force
- Some of both
  centripetal/centrifugal force

PGF – Pressure Gradient Force

- Determines wind speed
- 10% of sea level pressure - 100 mb
- Distance important to determine gradient – pressure difference/ distance - the longer the distance the less the gradient:

  100 mb/100km little gradient, little force

  100mb/5km large gradient, large force

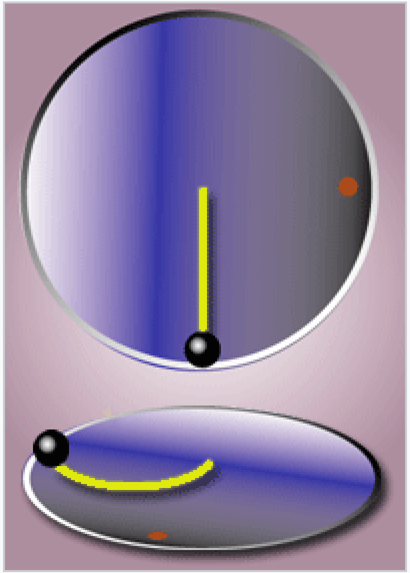
Coriolis Force – an apparent force phenomena is real, the explanation is self-serving

- Right in Northern hemisphere
- Left in Southern hemisphere
- Newton's 2nd Law

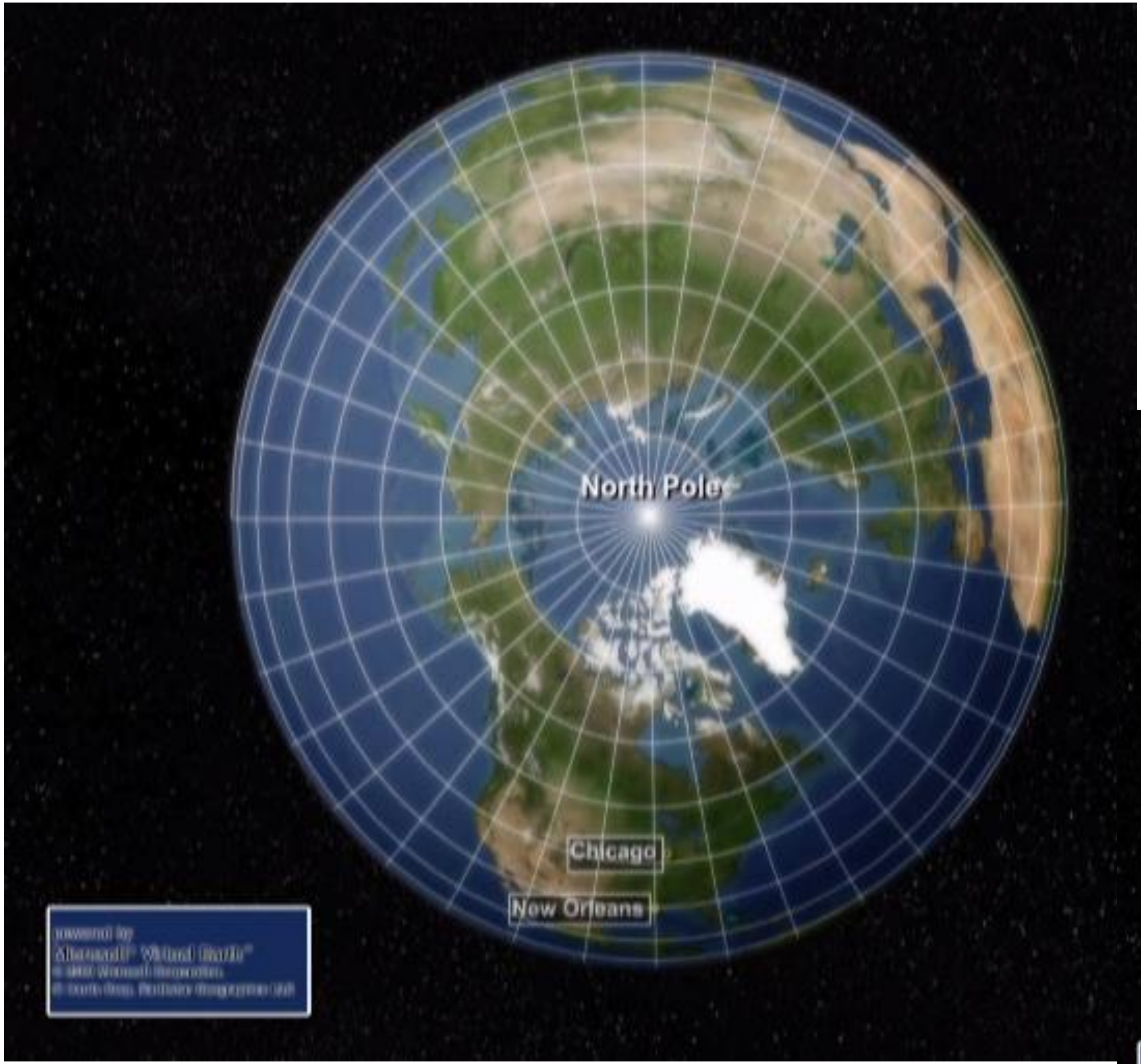
https://en.wikipedia.org/wiki/Coriolis_force

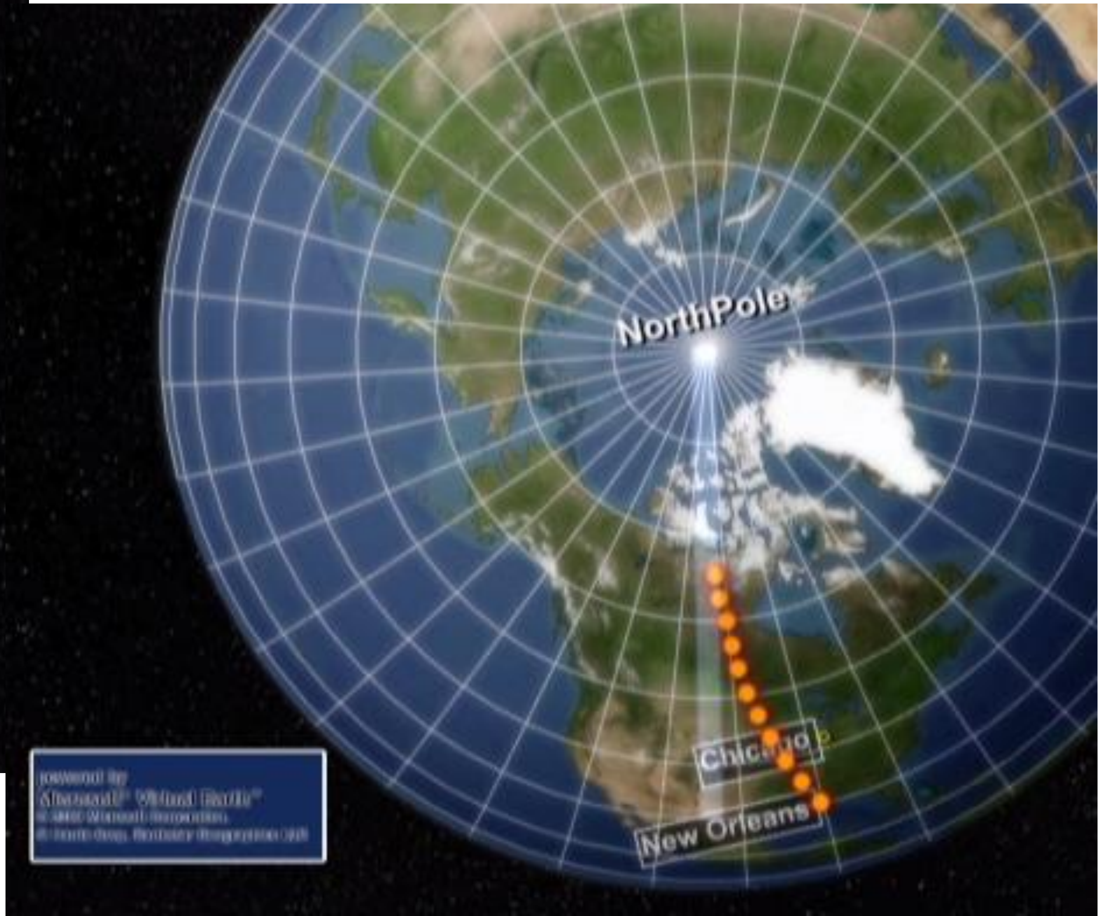
https://www.google.com/search?q=coriolis+force+northern+hemisphere&oq=coriolis+force&aqs=chrome.4.69i57j0l5.11239j0j9&sourceid=chrome&ie=UTF-8

Gaspard-Gustave de Coriolis
1792 – 1843



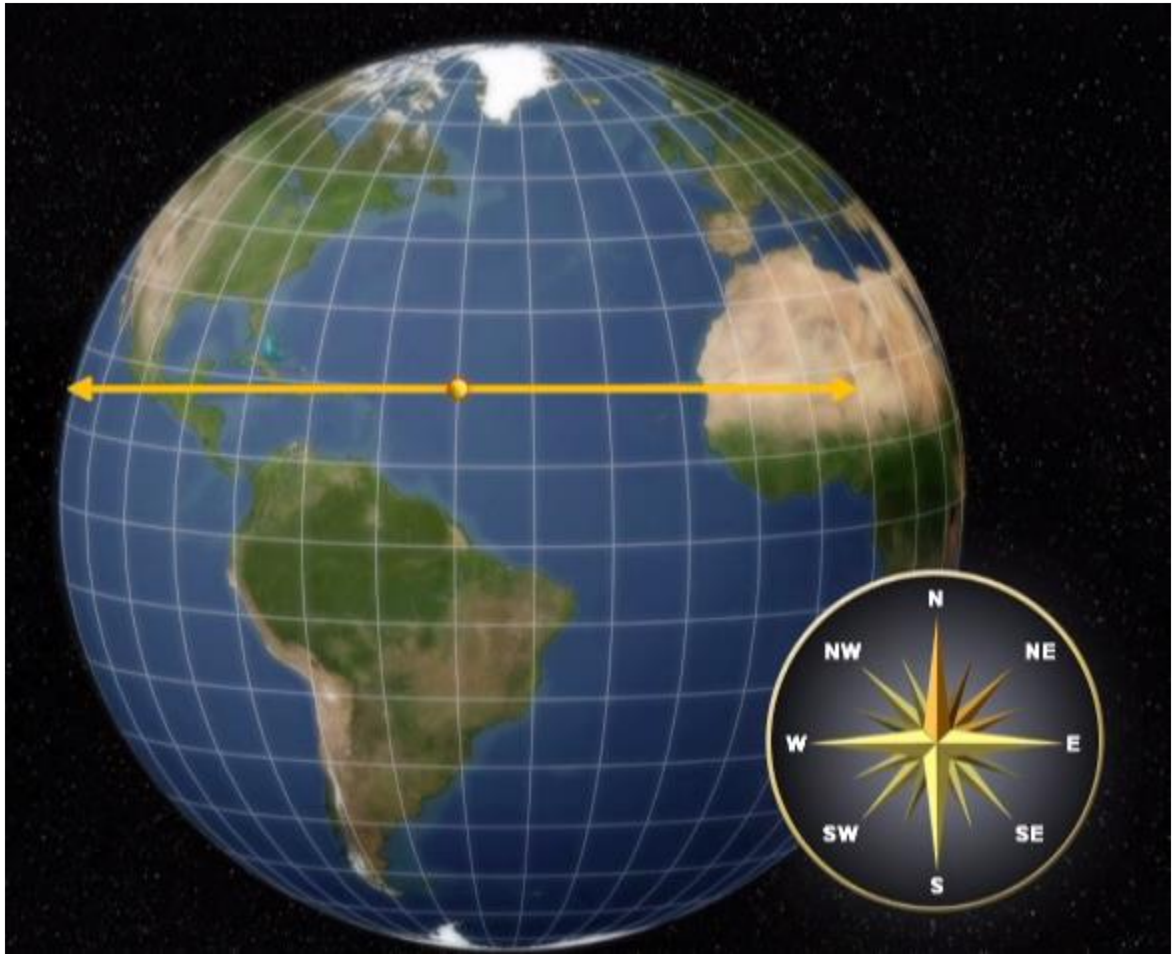
In the inertial frame of reference (upper part of the picture), the black ball moves in a straight line. However, the observer (brown dot) who is standing in the rotating/non-inertial frame of reference (lower part of the picture) sees the object as following a curved path due to the Coriolis and centrifugal forces present in this frame.


North Pole
Chicago
New Orleans


NorthPole
Chicago
New Orleans

Curvature effect

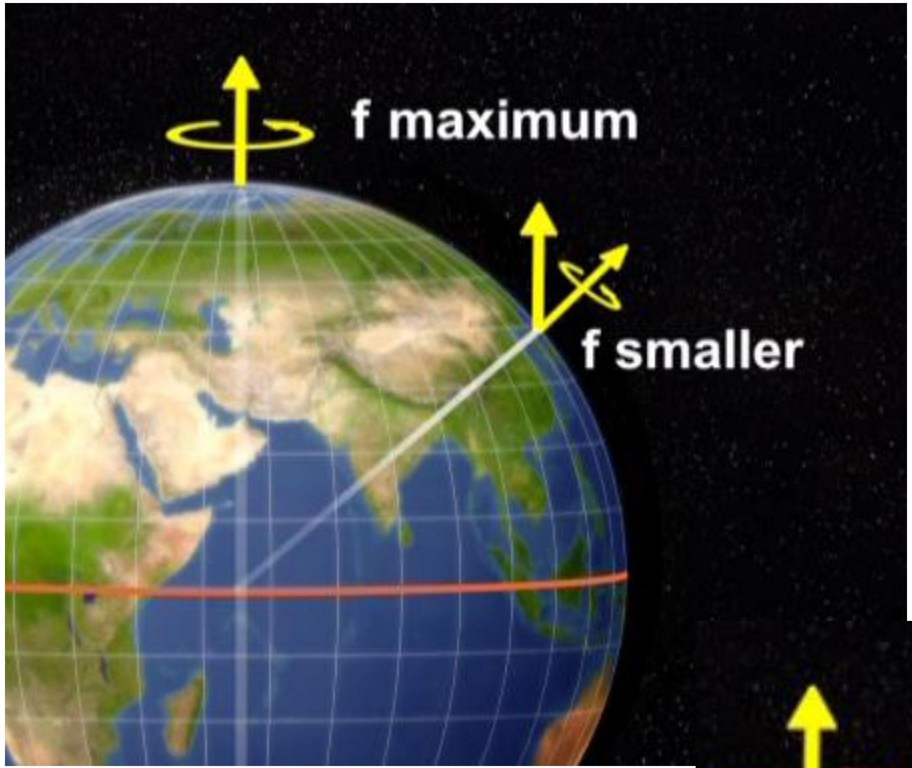
- Important for high accuracy rockets & airplane routes

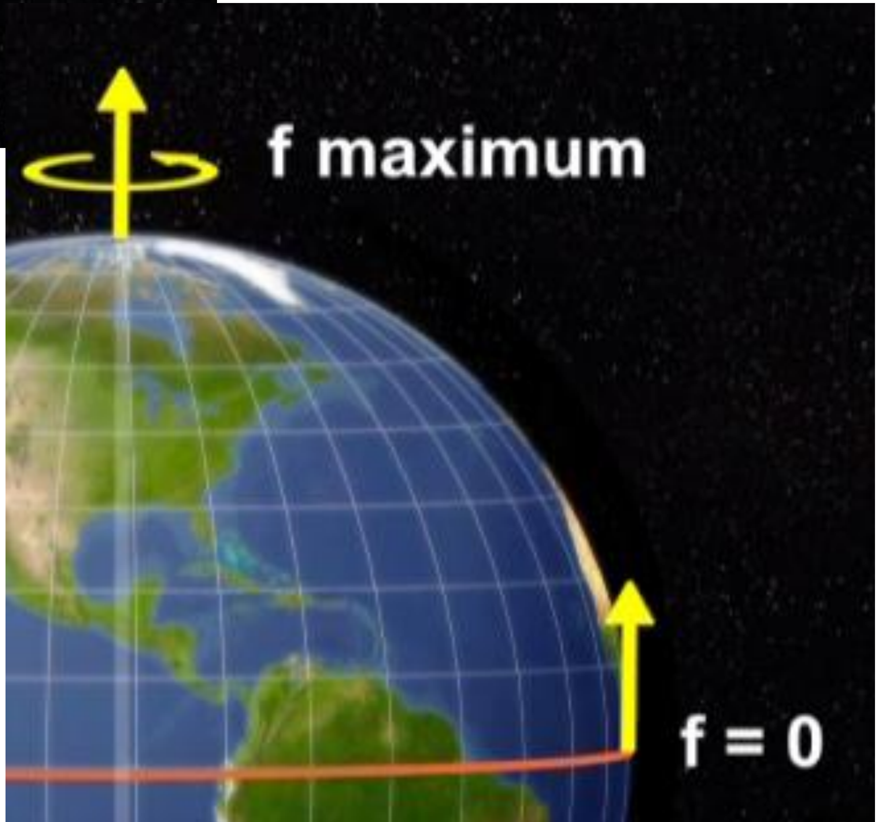


Coriolis force

- Vanishes at the equator –
  - Need vectors to explain
  - Spherical – right hand rule
- Right to North, Left to South
- Easiest way to understand: rocket or parcel at equator is moving east@ 25,000miles/day = 1040 miles/hour. It retains this eastern velocity when moving north. See:

https://www.nationalgeographic.org/encyclopedia/coriolis-effect/





Large scale wind - distance

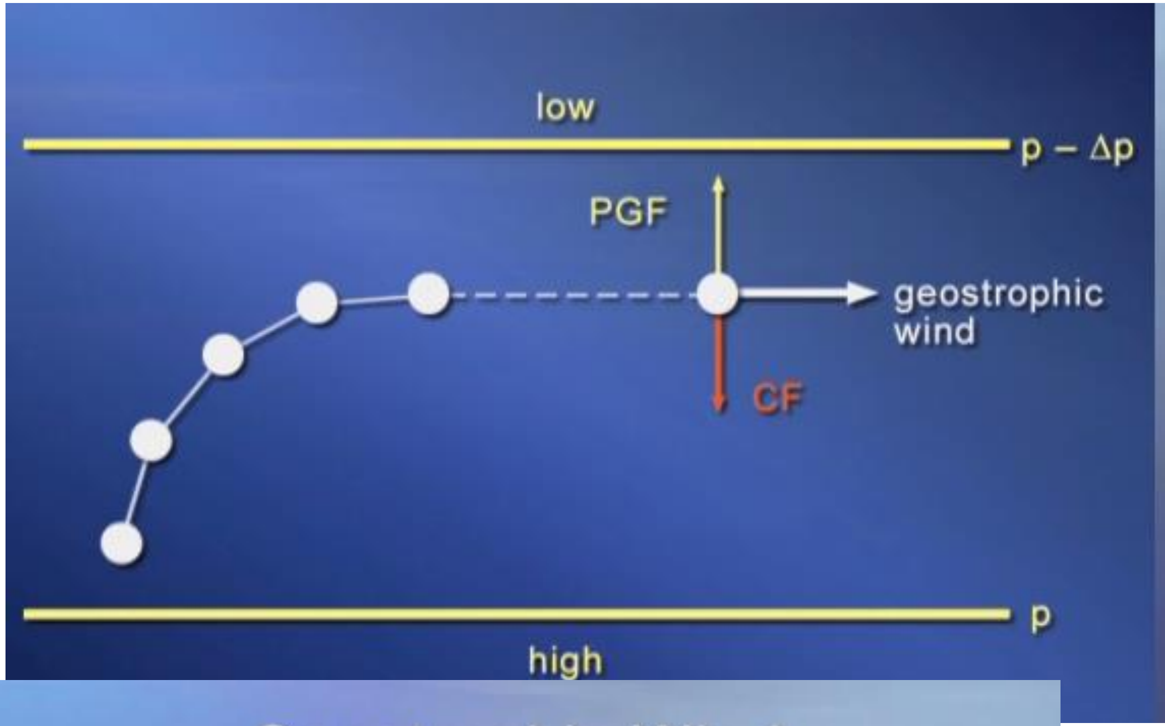
- 1. Pressure Gradient Force – driving force of horizontal wind
- 2. CORIOLIS – IMPORTANT WITH:
  - Velocity
  - Length and
  - Timescale
- 3. Centripetal /Centrifugal Force
- 4. Friction

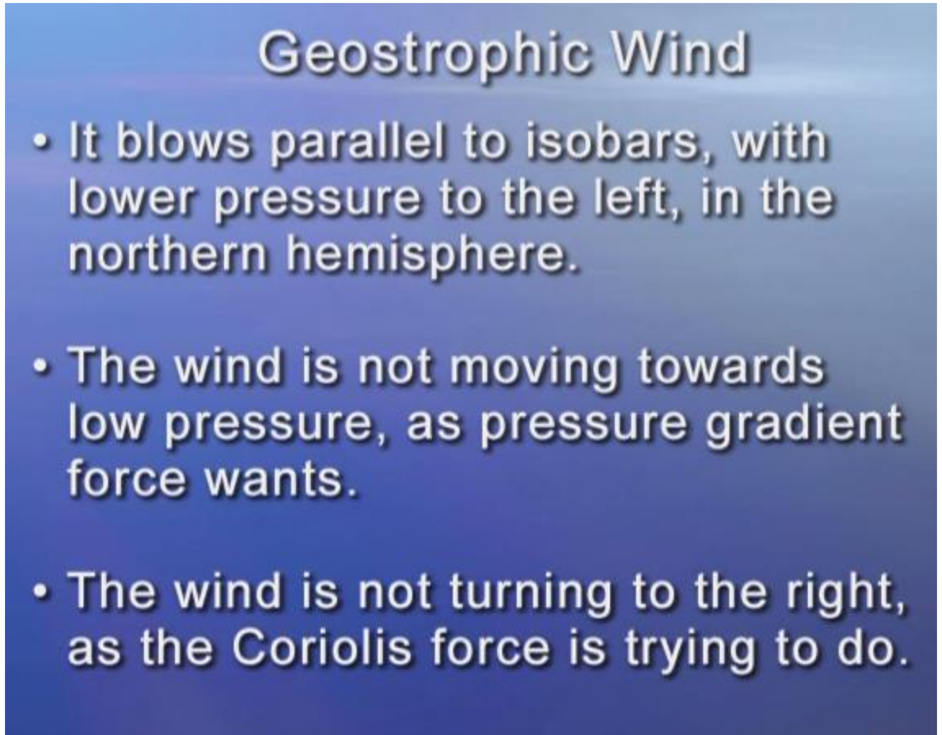
Geostrophic wind

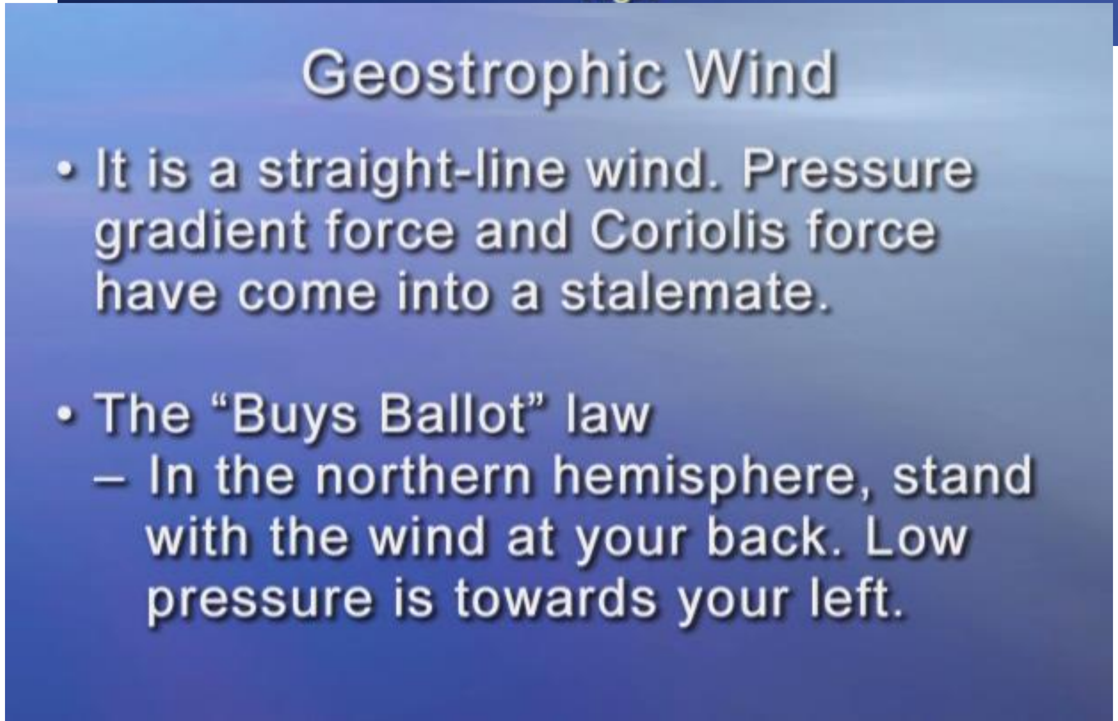
https://en.wikipedia.org/wiki/Geostrophic_wind

Links:

- https://en.wikipedia.org/wiki/Geostrophic_wind
- https://www.google.com/search?q=geostrophic+wind&oq=geostrophi&aqs=chrome.0.0j69i57j0l4.3802j0j7&sourceid=chrome&ie=UTF-8

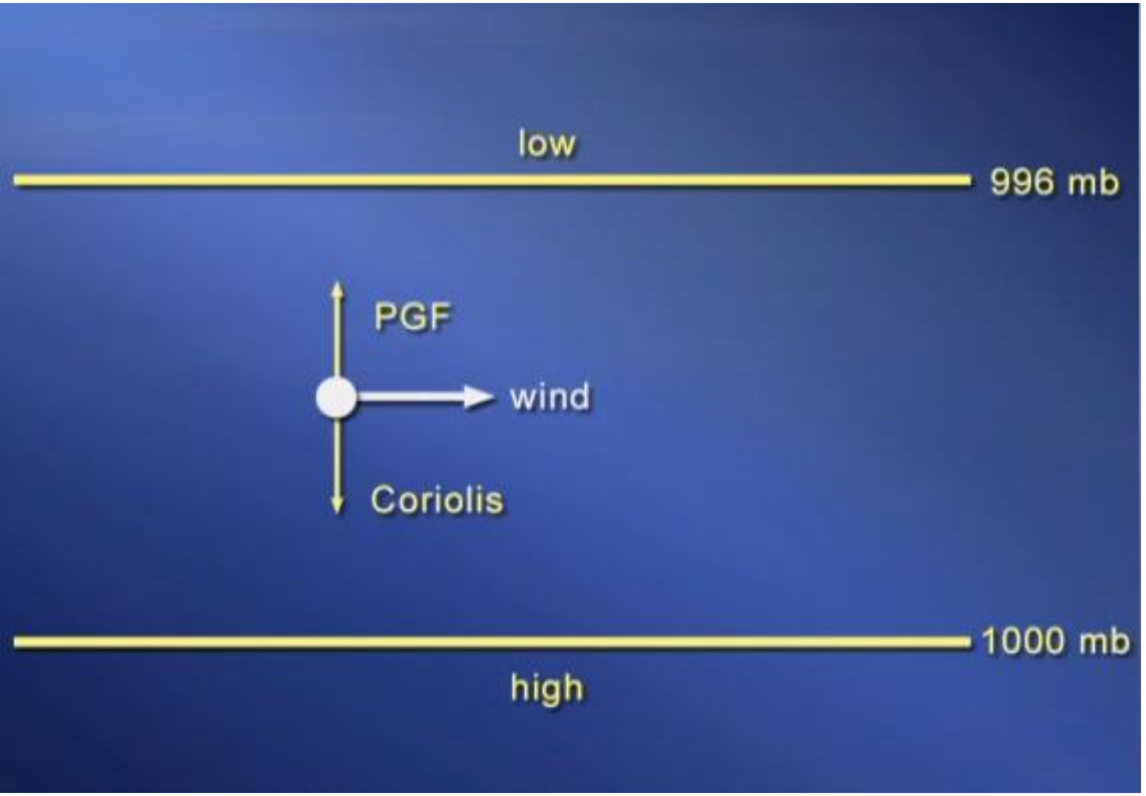


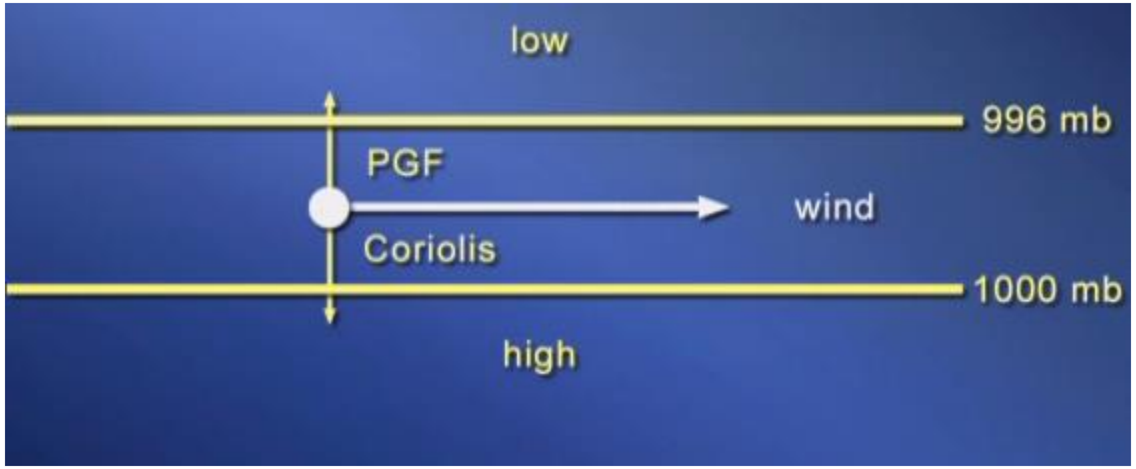




Coriolis force

- Coriolis Force - Proportional to wind speed



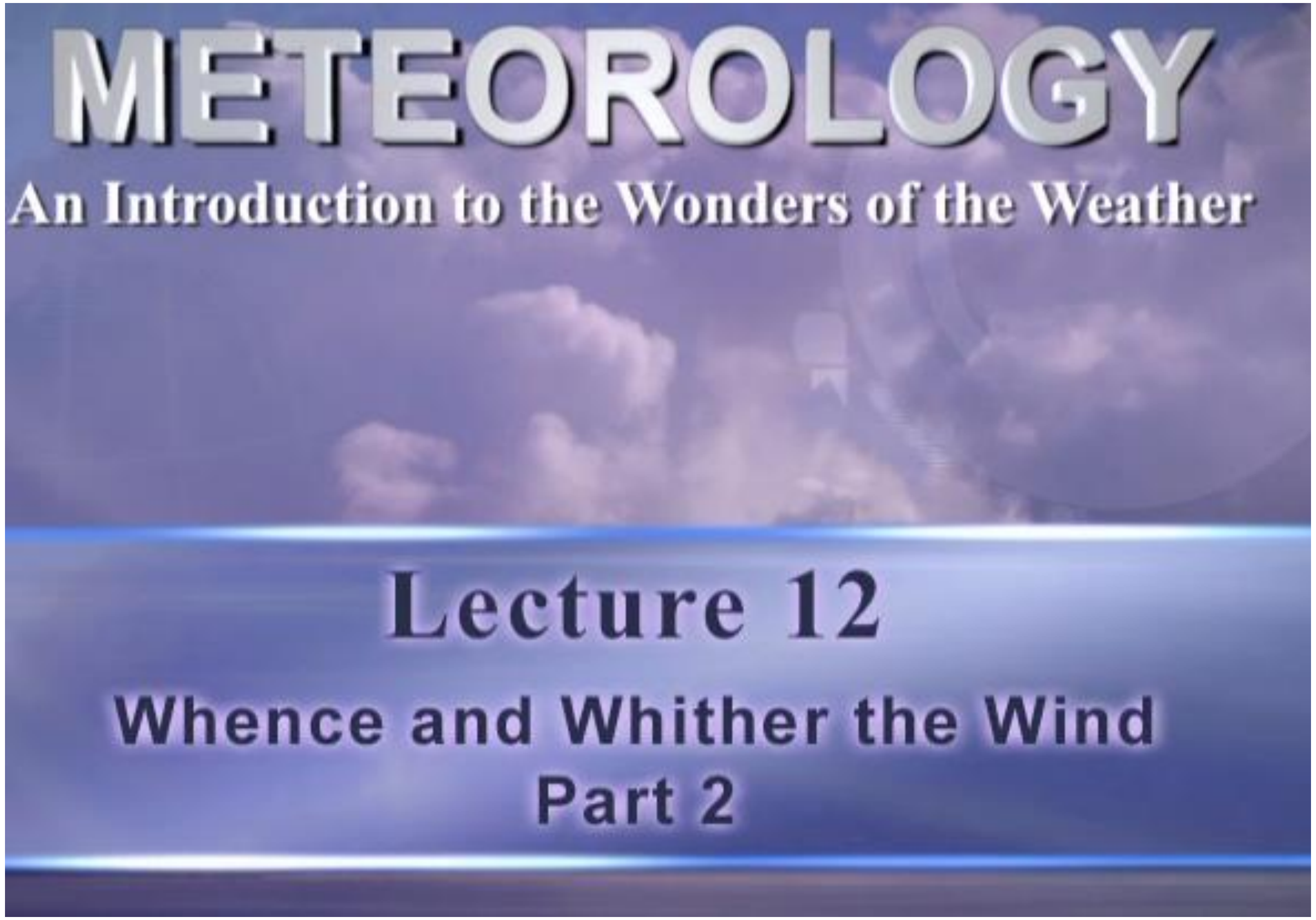


Summary

- PGF: Pressure Gradient Force
- CORIOLIS – a spoiler, prevents straight flow along gradient, across isobars to lower pressure.
- Friction helps somewhat to reduce Coriolis effect, to enable some flow across isobars from higher pressure to lower pressure

Chapter 12 – wind part 2 - skipping

- Notes follow:



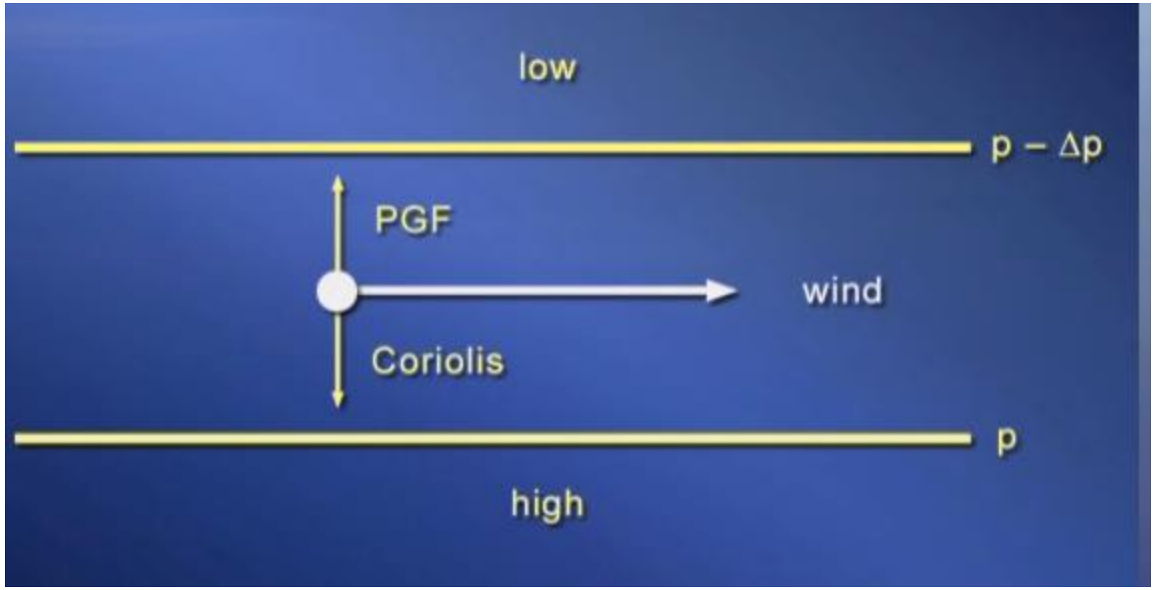
Horizontal winds – 4 forces

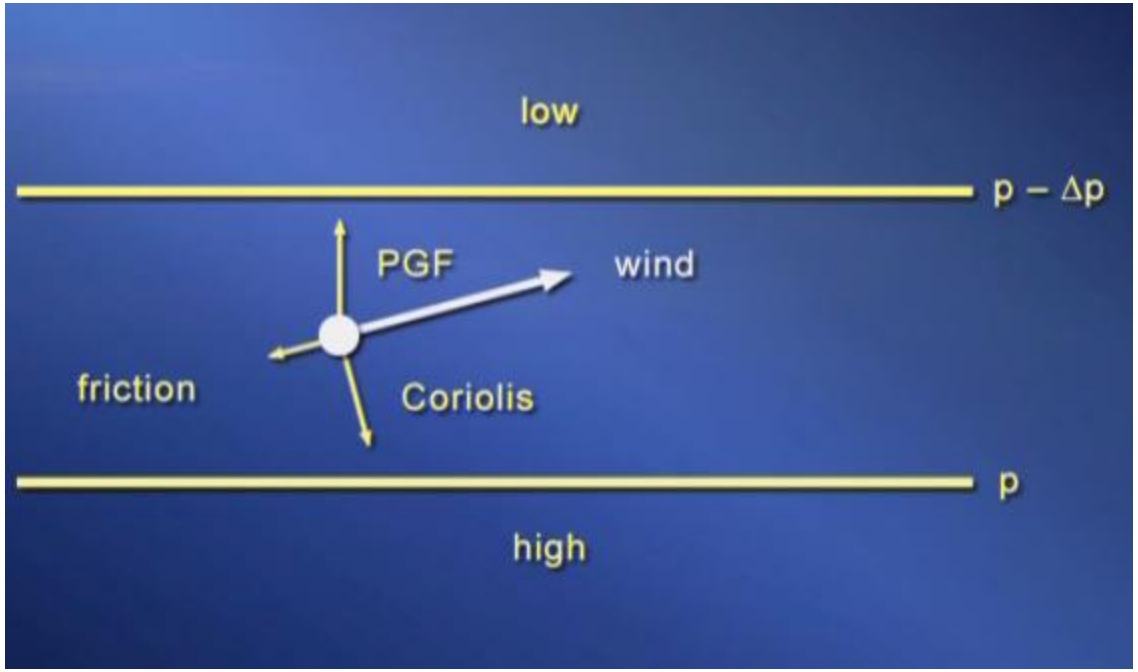
- PGF - Pressure Gradient Force
- CORIOLIS
- TOGETHER – GEOSTROPHIC WIND - http://ww2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/fw/geos.rxml

- LARGE SCALE WIND VS. LOCAL
- OTHER
  - FRICTION – LARGE SCALE TO LOW P
  - Centripetal force

Friction force can cause winds to cross isobars

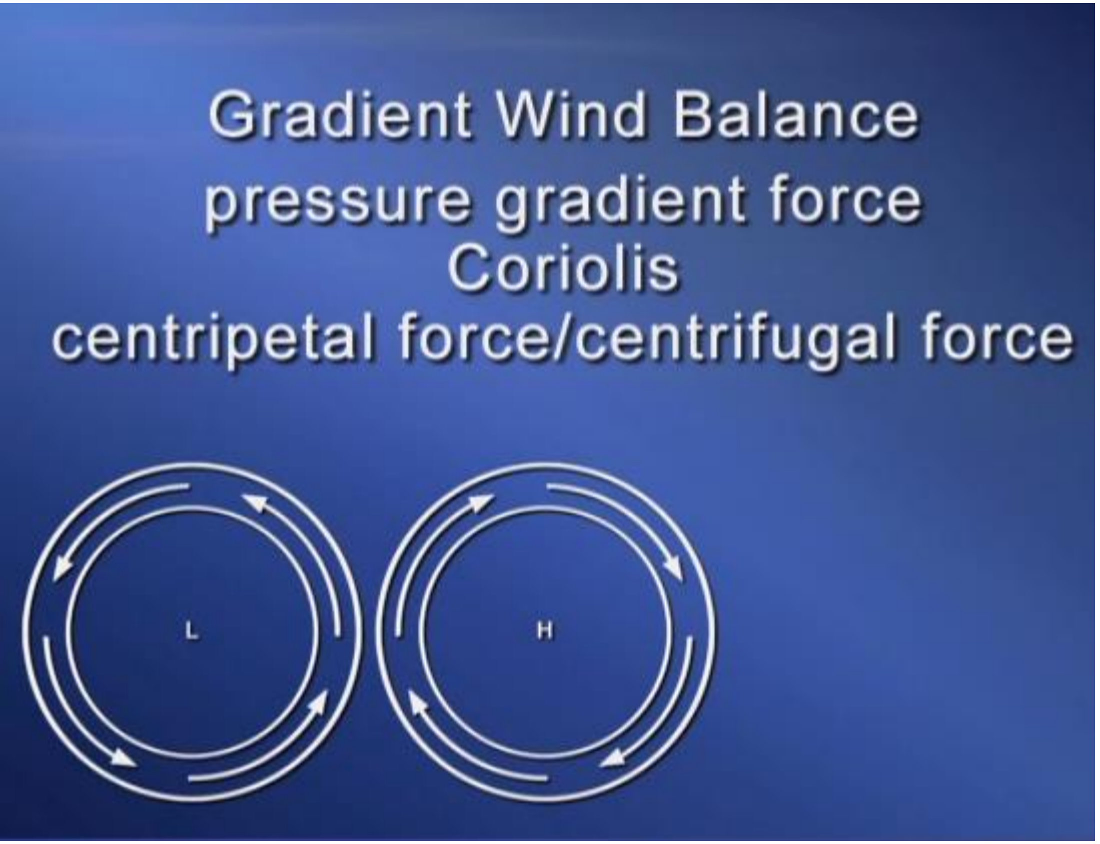
- Acts near surface
- Weakens Coriolis Force

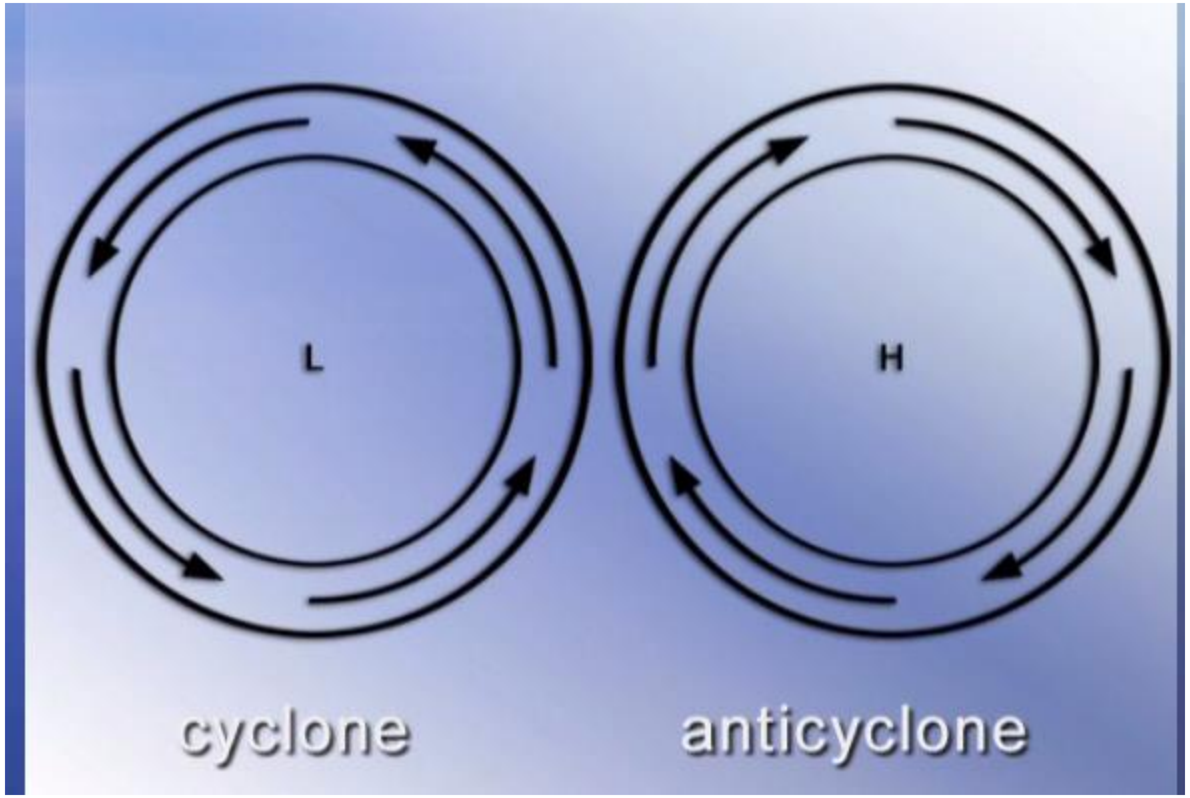




Cyclones and Anticyclone

- https://en.wikipedia.org/wiki/Cyclone





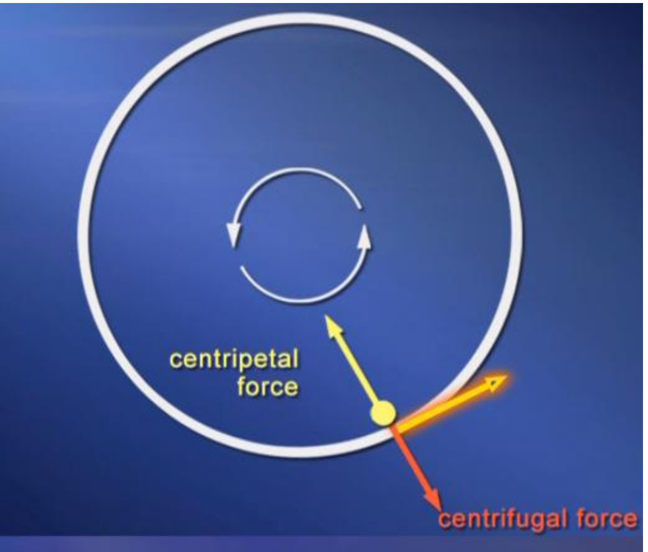
Centrifugal and Centripetal Forces

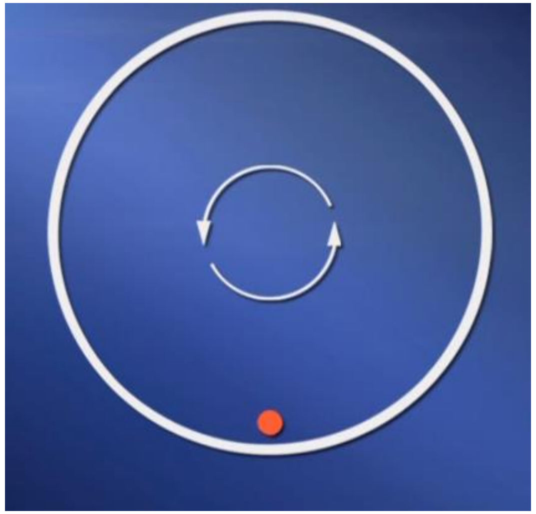
- Centrifugal – flee the center
- Centripetal – to seek the center

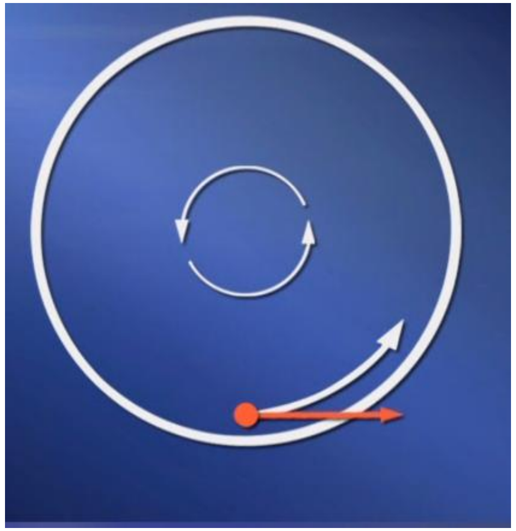
https://www.livescience.com/52488-centrifugal-centripetal-forces.html

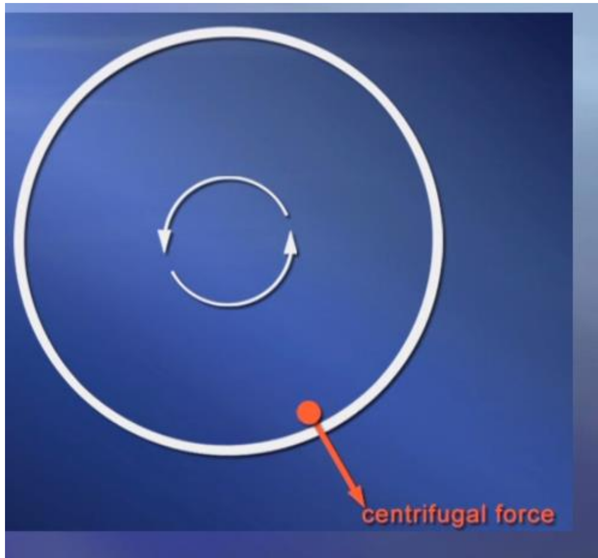
https://www.youtube.com/watch?v=9s1IRJbL2Co

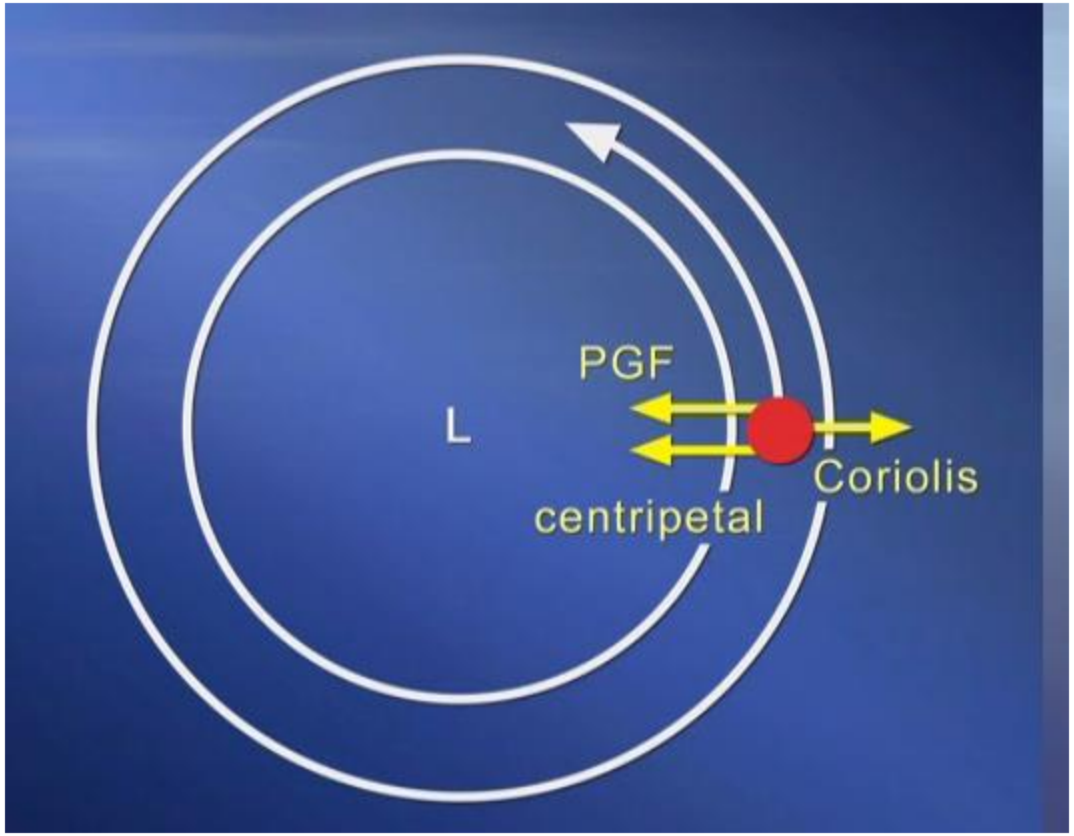
Centrifugal Force – flee the center:

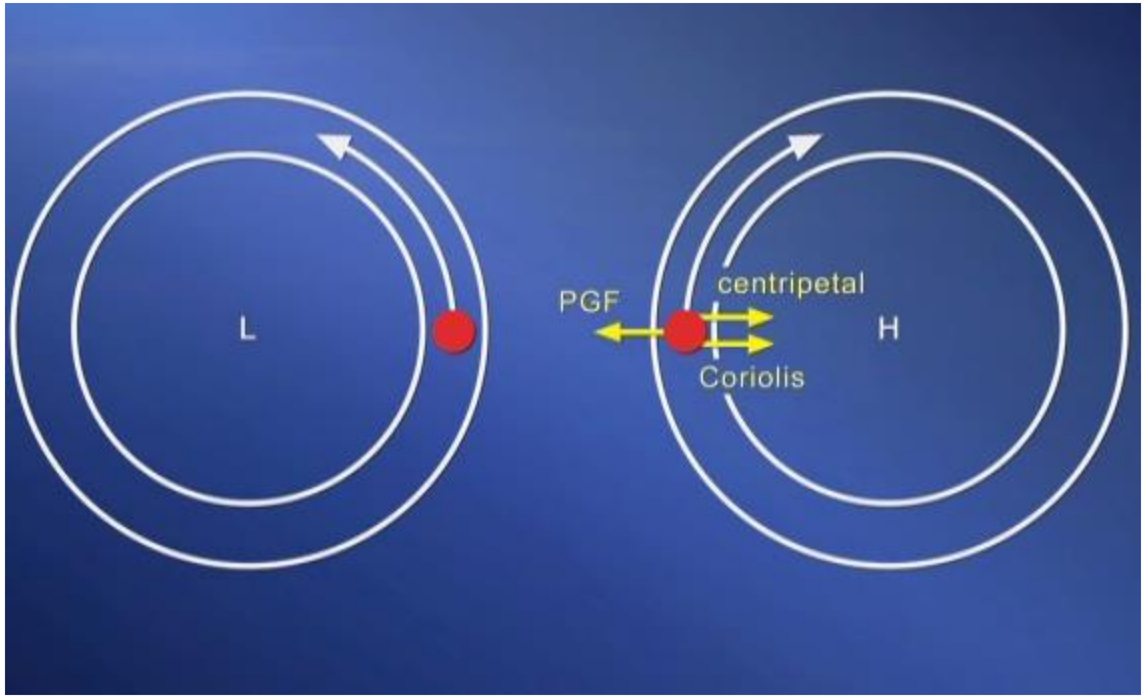




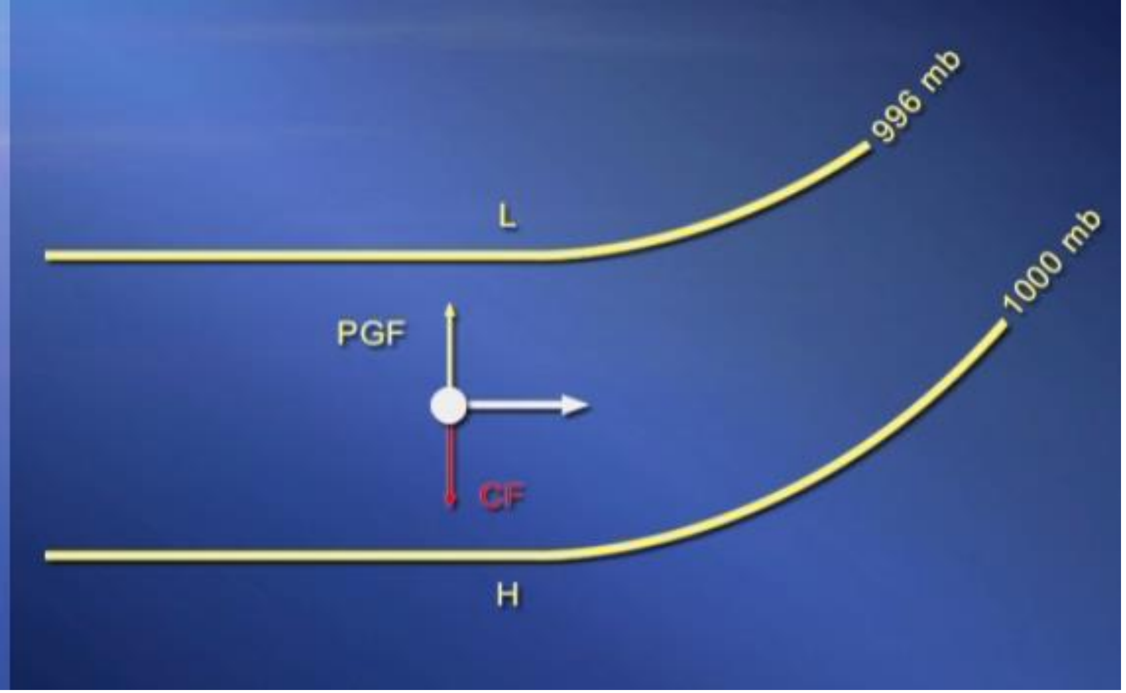


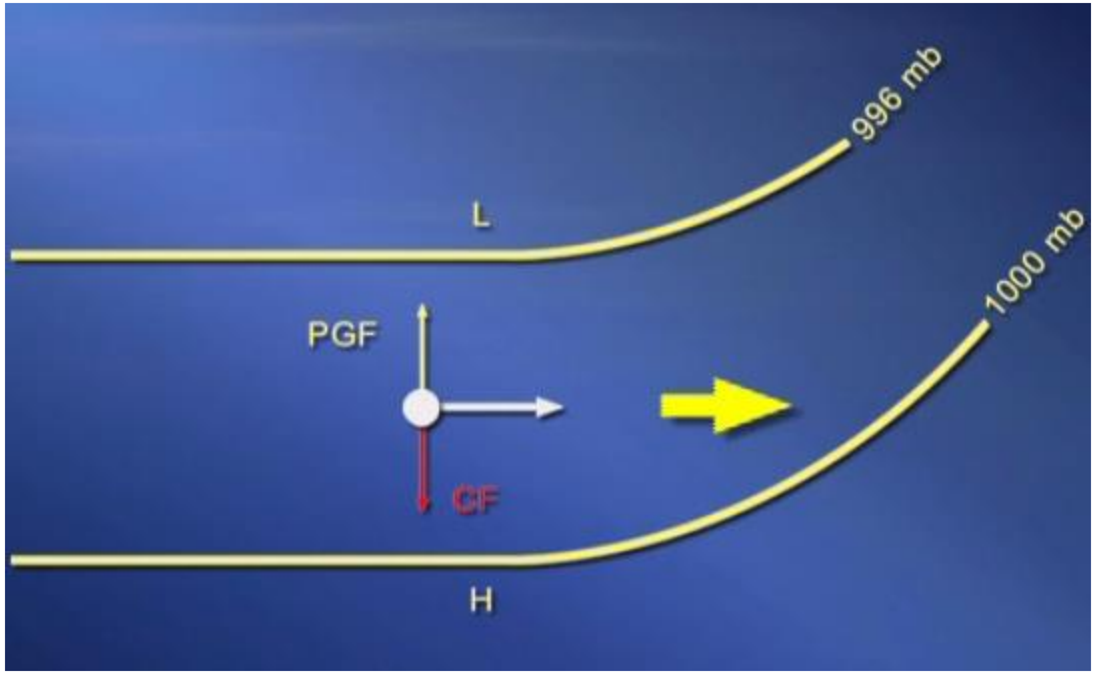



PGF
L
Coriolis
centripetal

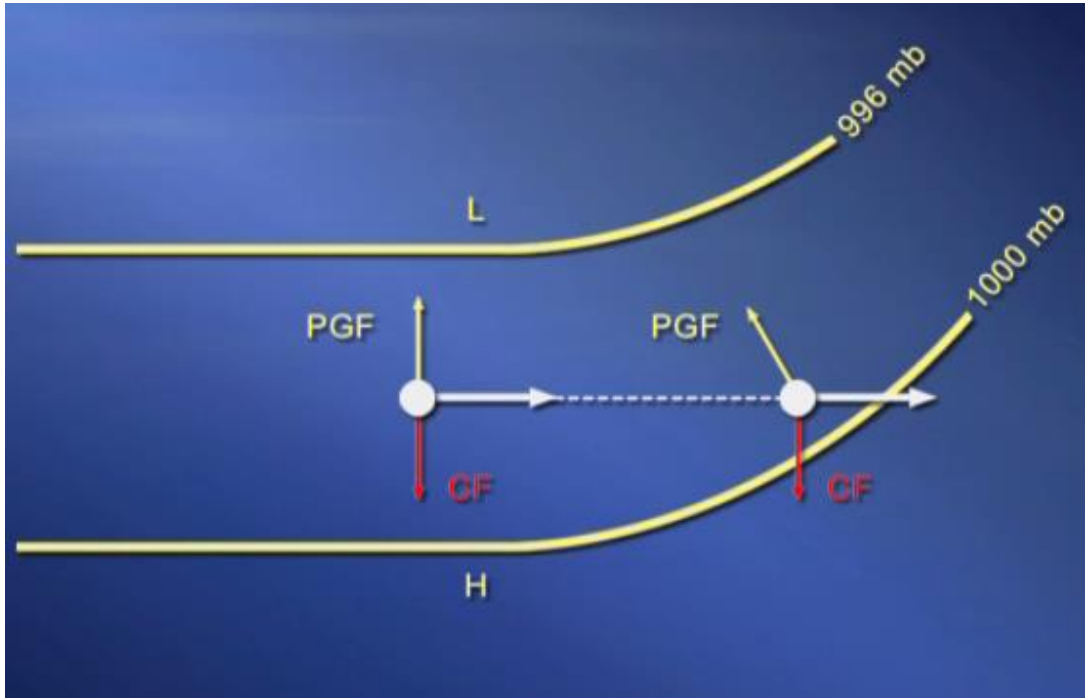

L
PGF
centripetal
H
Coriolis

- Partly cloudy
- Partly sunny

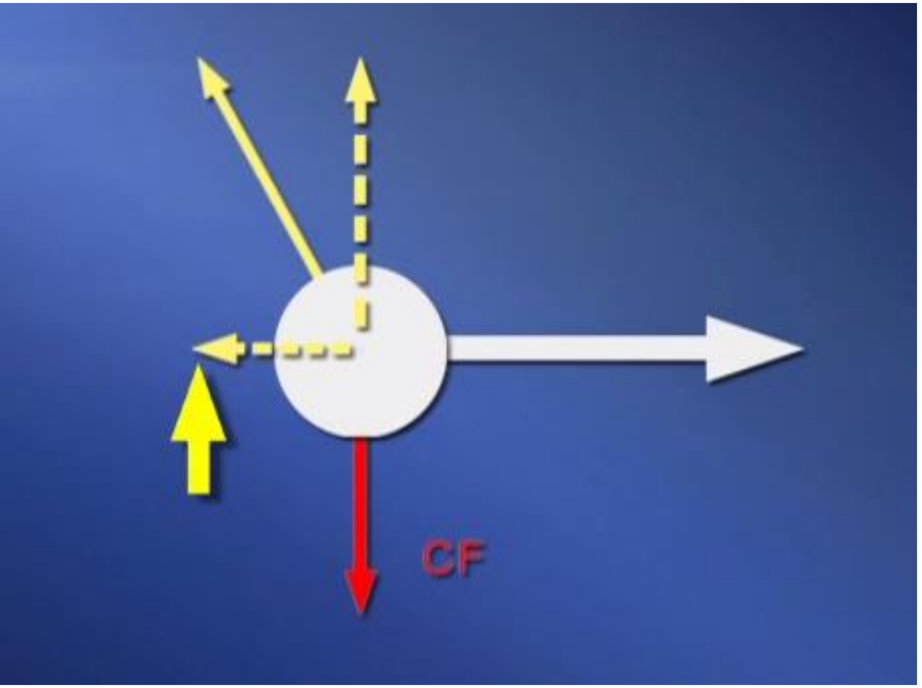

996 mb
L
1000 mb
PGF
CF
H

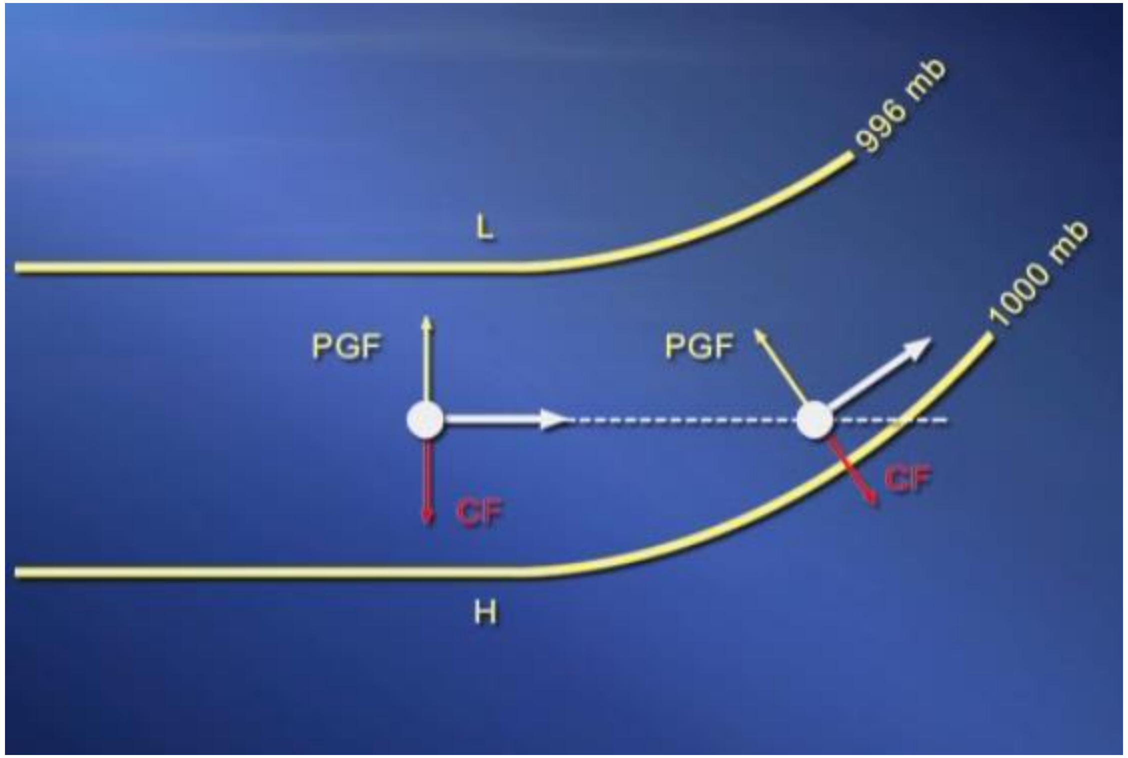

996 mb
L
1000 mb
PGF
CF
H

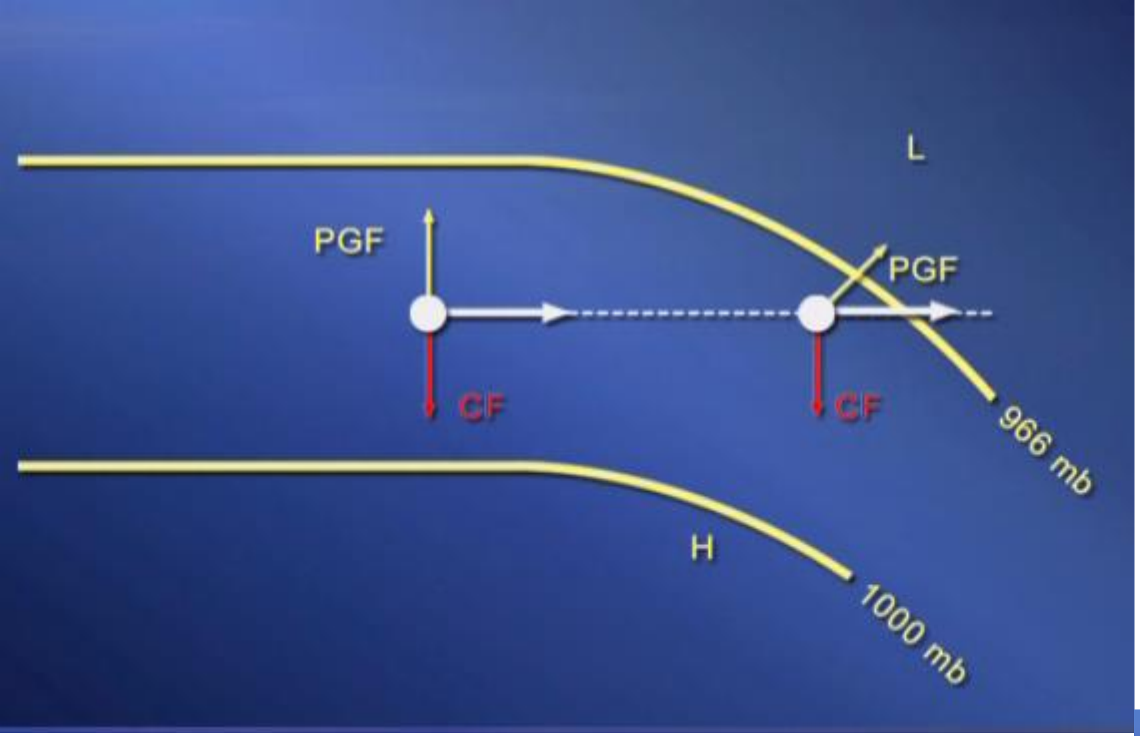

CF

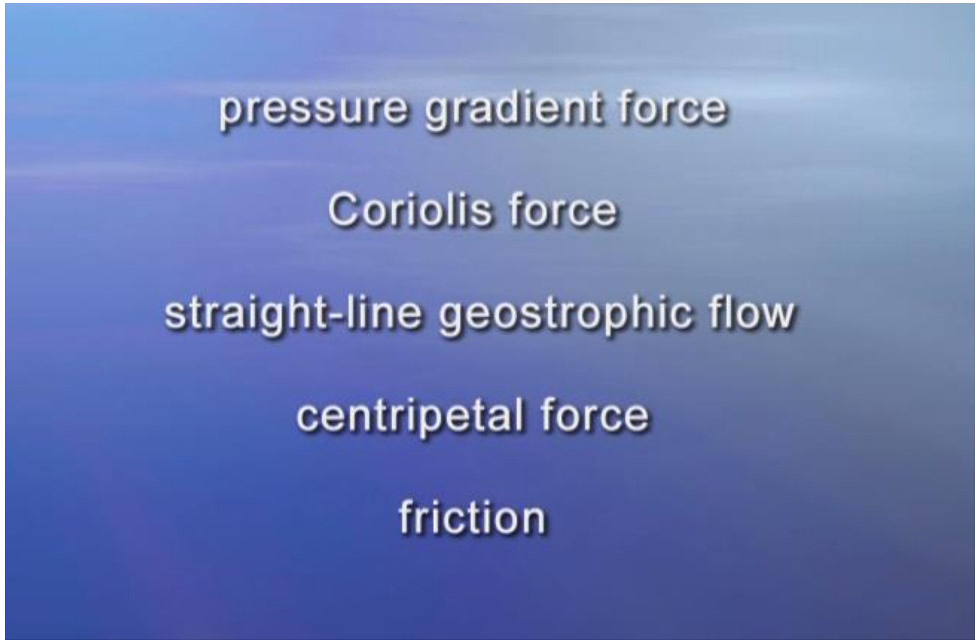

996 mb
L
1000 mb
PGF
PGF
CF
CF
H

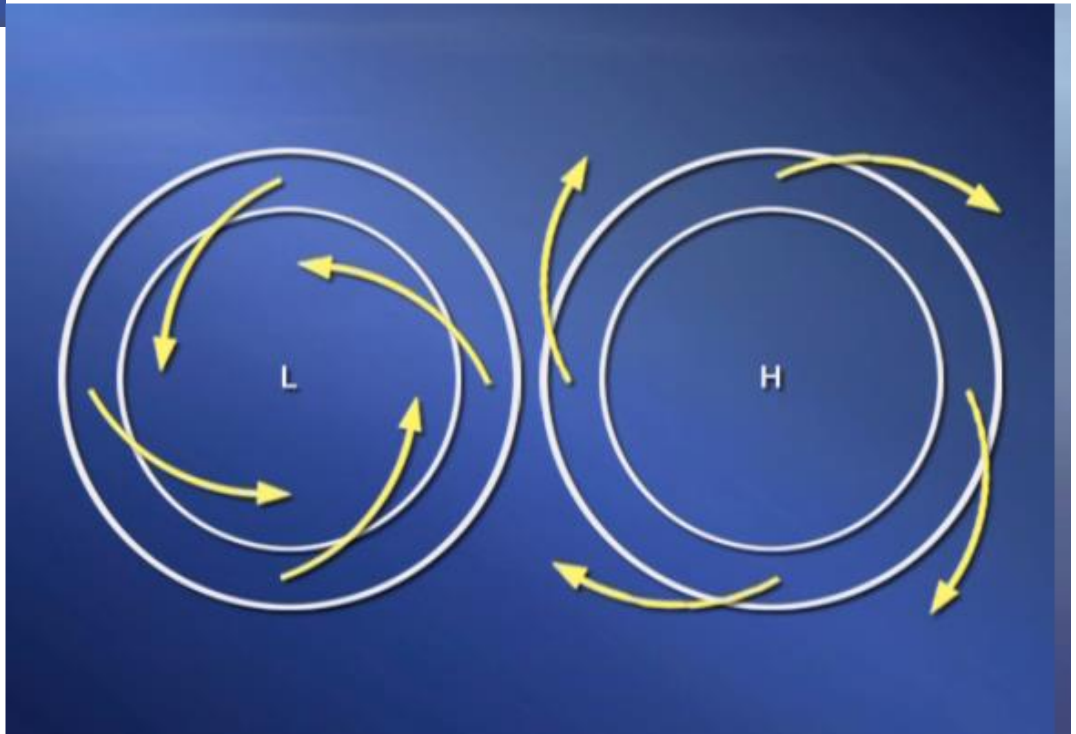
- Brakes – CF decreases and PGF gains upper hand

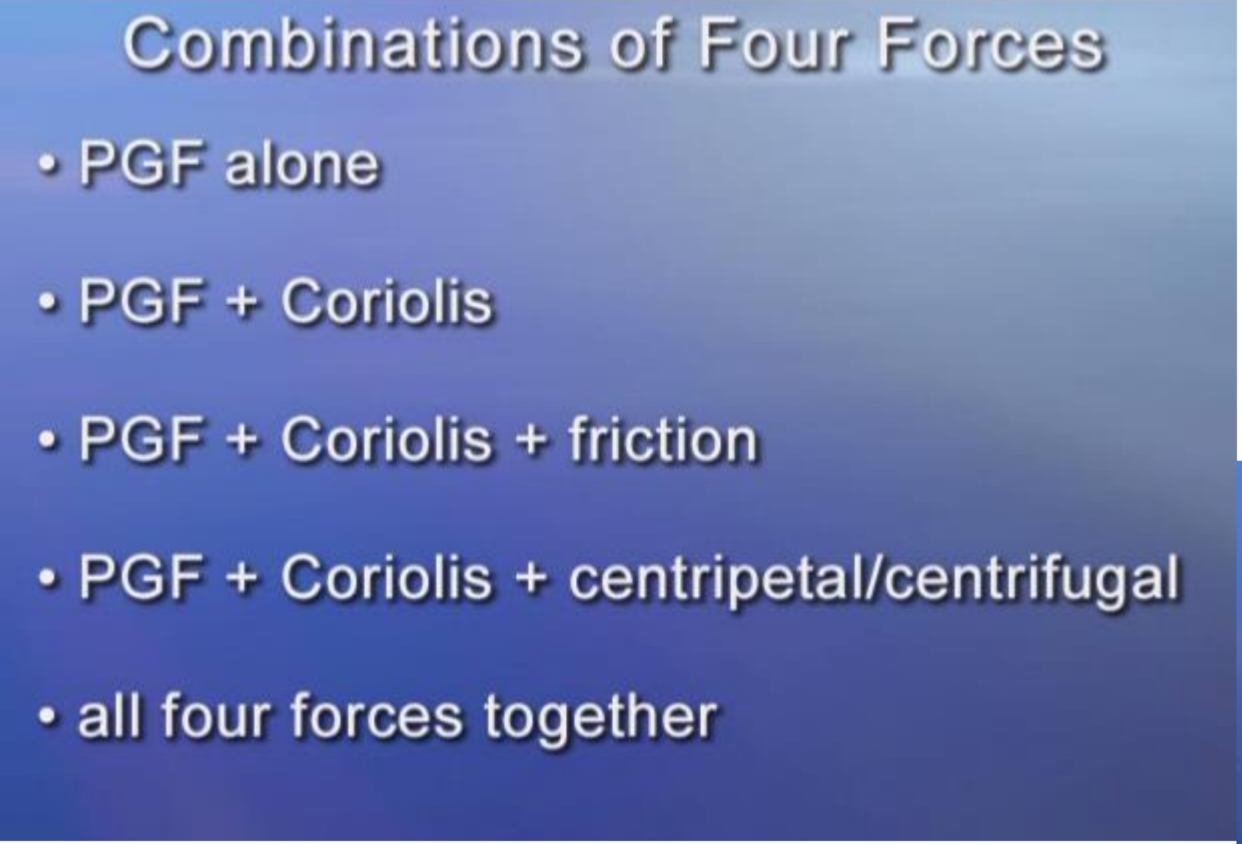


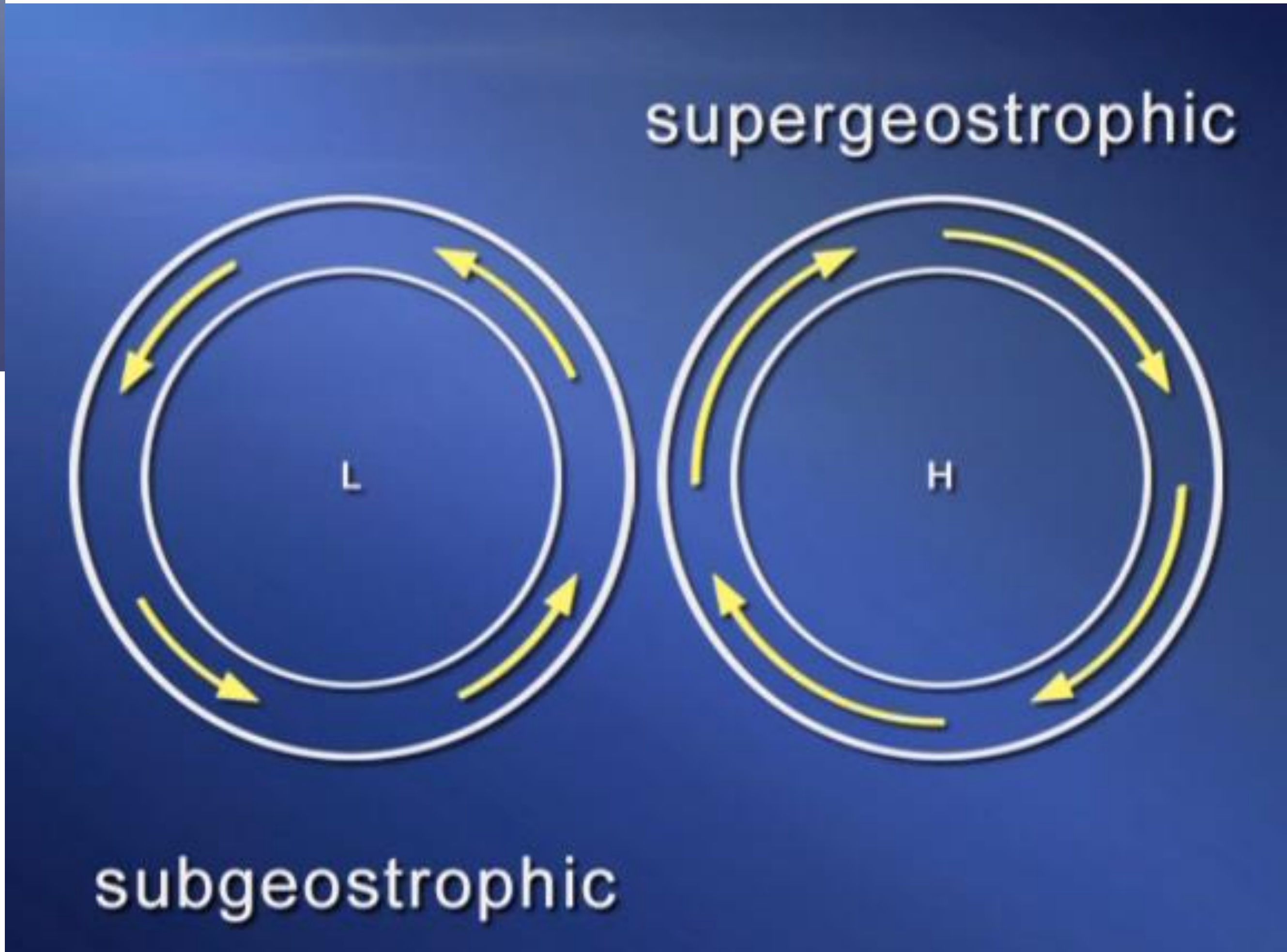



L
PGF
PGF
CF
CF
966 mb
H
1000 mb

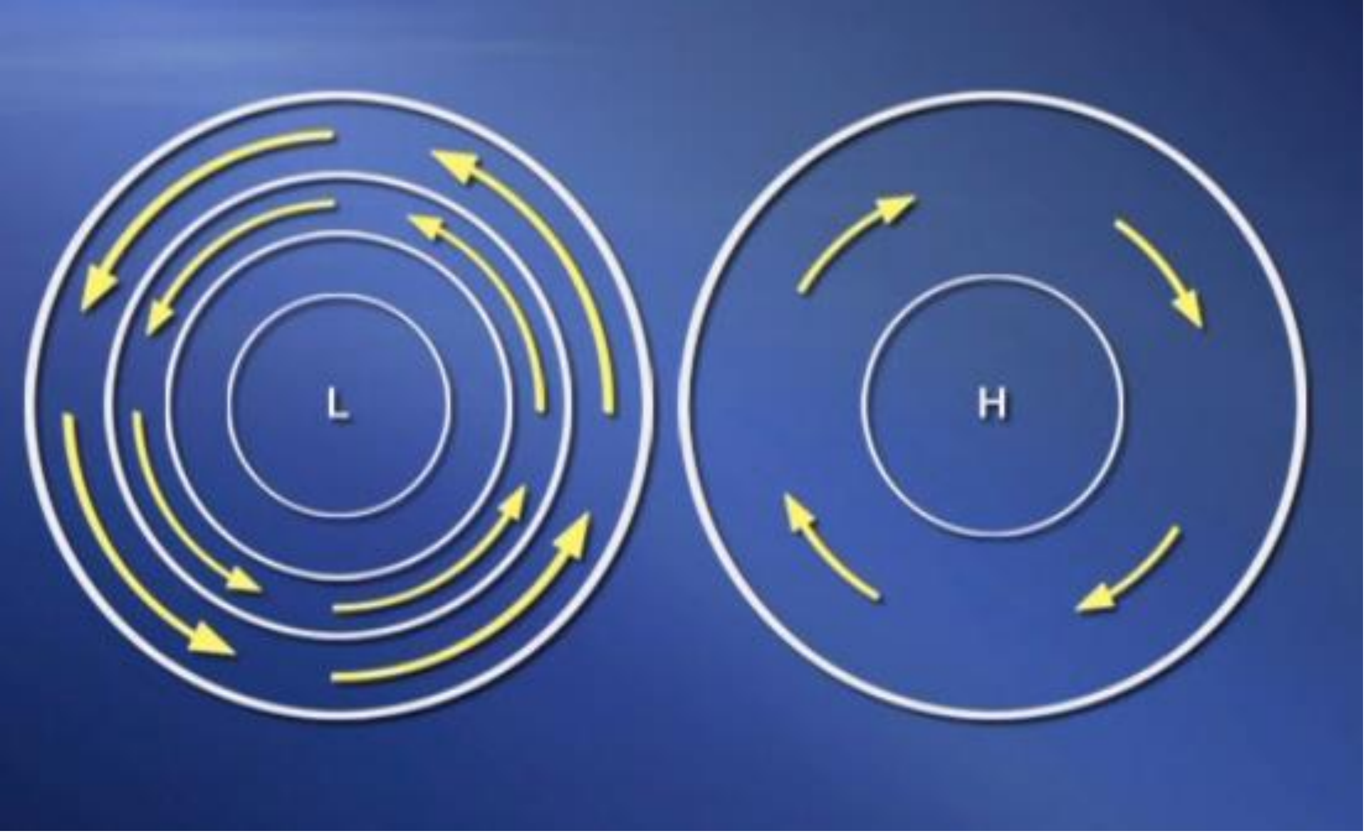

pressure gradient force
Coriolis force
straight-line geostrophic flow
centripetal force
friction


L
H



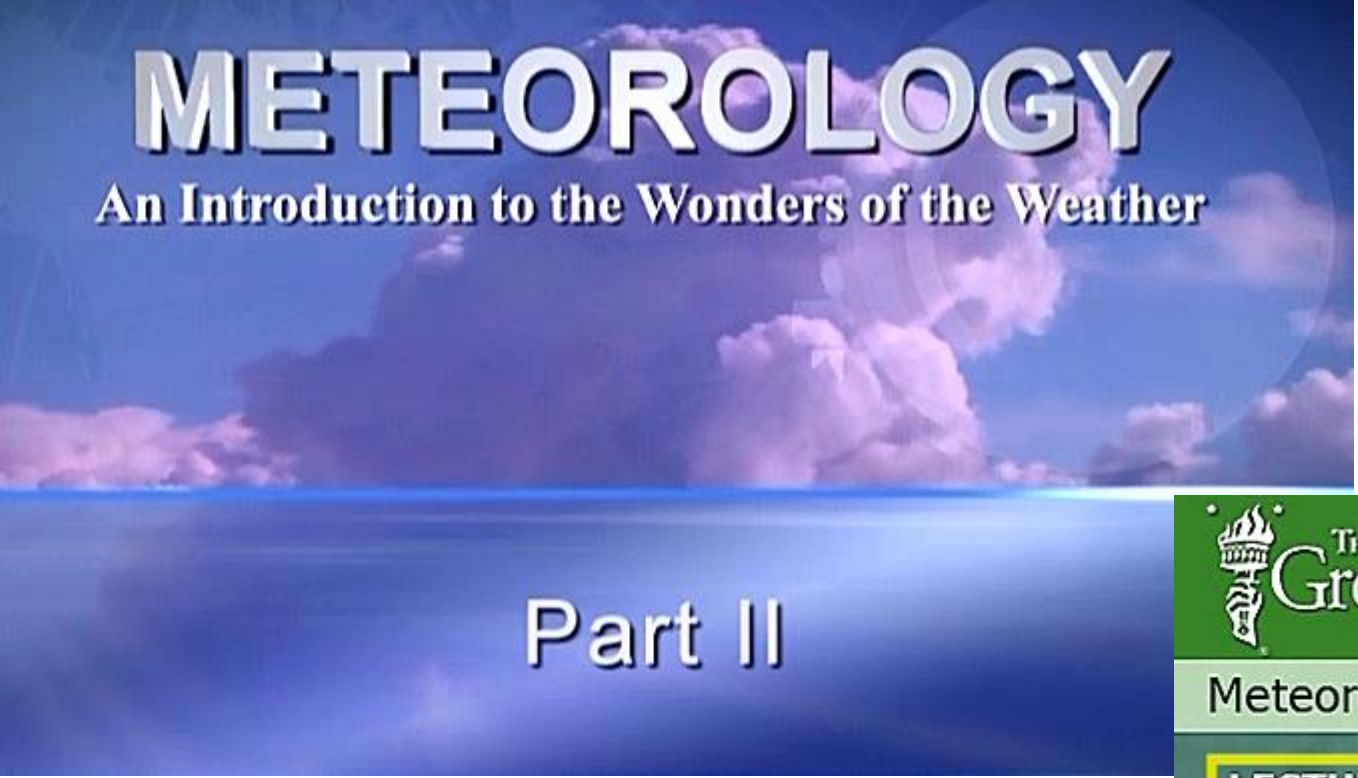


https://www.quora.com/Why-do-low-pressure-systems-rotate-counterclockwise-and-high-pressure-systems-rotate-clockwise



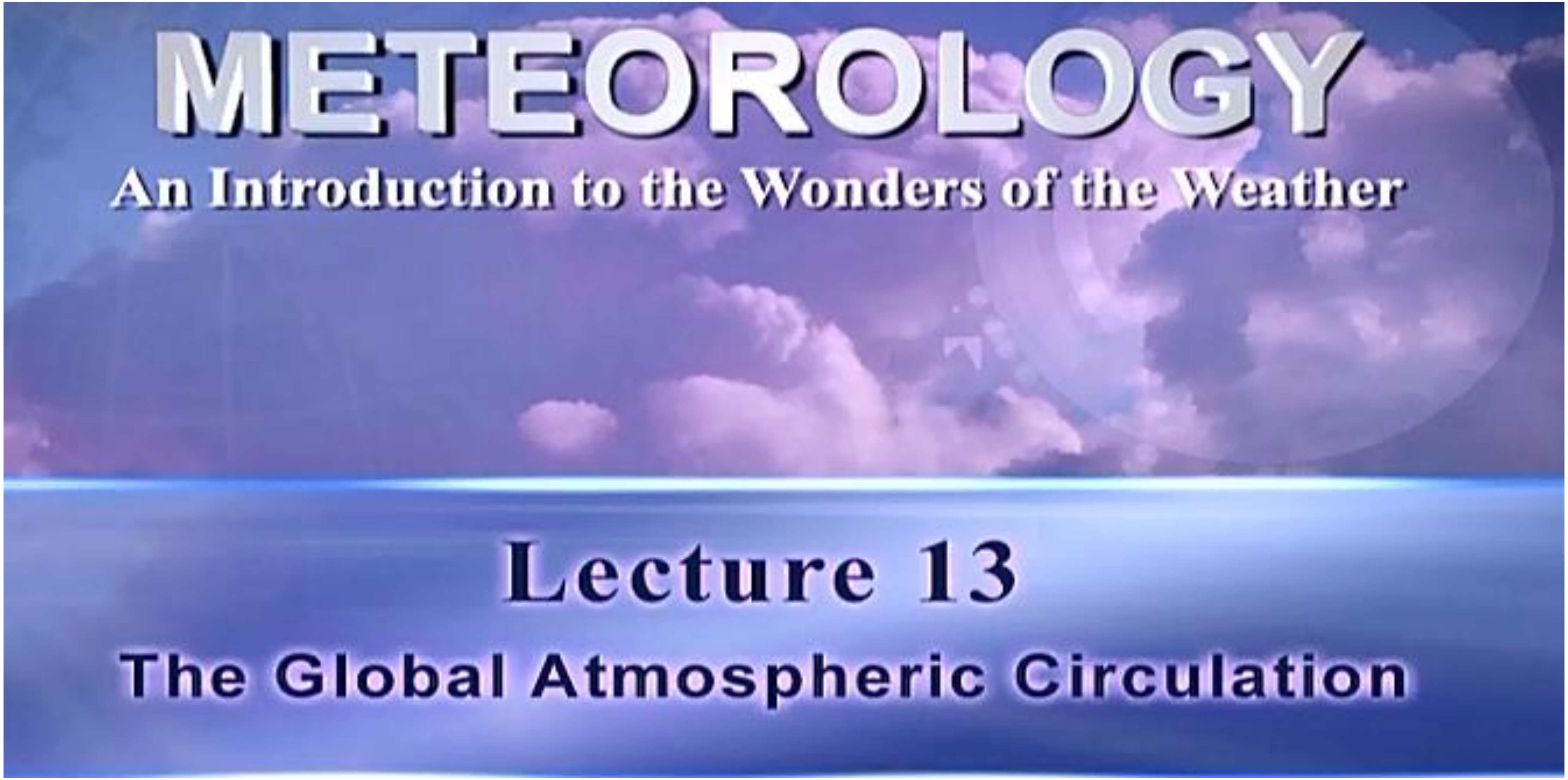
pressure gradient force + centrifugal force = cyclostrophic balance

Spin creates low pressure.


METEOROLOGY
An Introduction to the Wonders of the Weather
Part II


The Great Courses
Lecture Chapters
About the Professor
Meteorology: An Introduction to the Wonders of the...
LECTURE 13 The Global Atmospheric Circulation
LECTURE 14 Fronts and Extratropical Cyclones
LECTURE 15 Middle Troposphere—Troughs and Ridges
LECTURE 16 Wind Shear—Horizontal and Vertical
LECTURE 17 Mountain Influences on the Atmosphere
LECTURE 18 Thunderstorms, Squall Lines, and Radar
THE TEACHING COMPANY

GLOBAL ATMOSPHERIC CIRCULATION

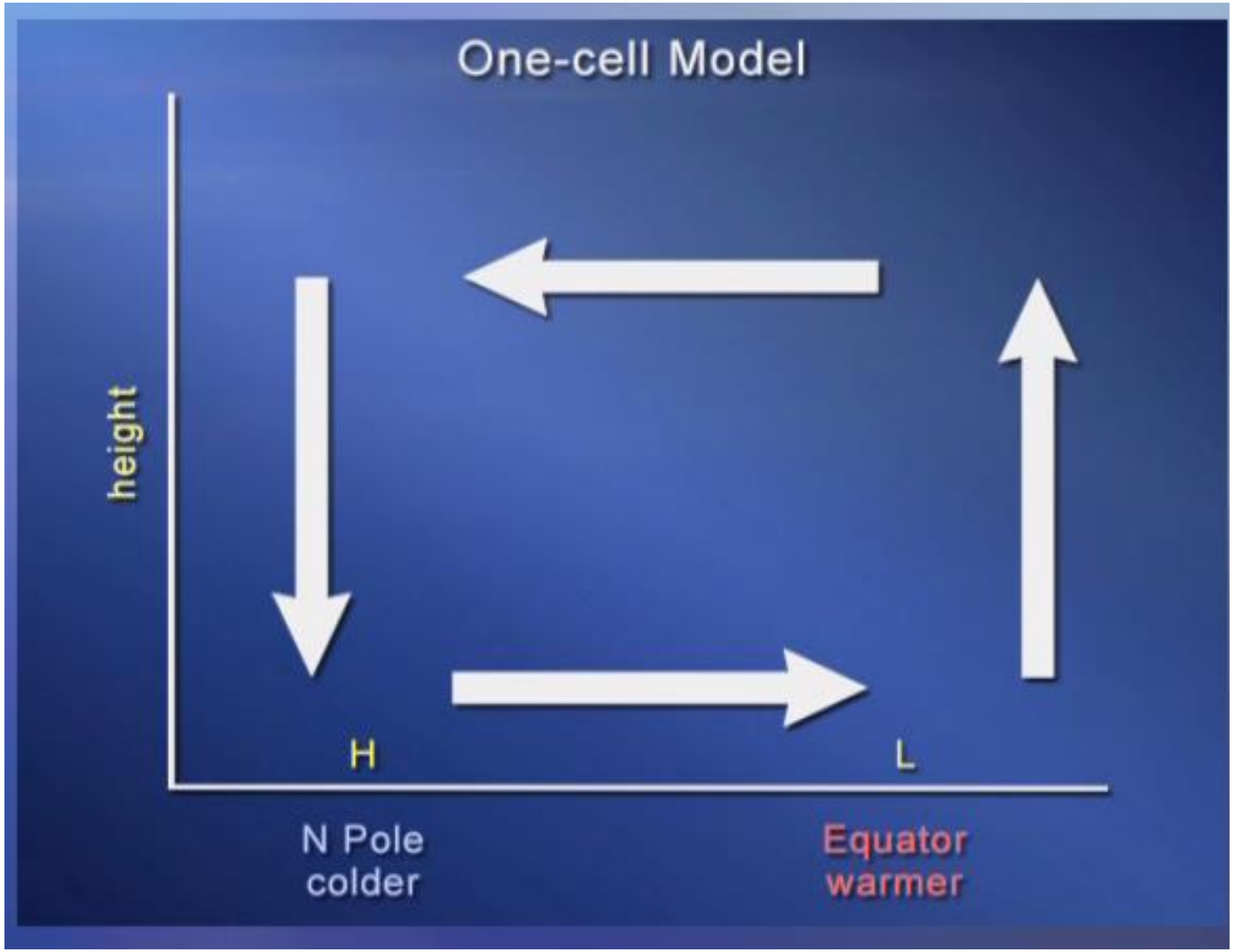


4 fundamental forces – Horizontal/large scale wind

- Pressure Gradient Force
- Coriolis Force
- Friction
- Centripetal/centrifugal forces with Earth’s curvature

- Coriolis plus pressure gradient = geostrophic wind
- Adding Centripetal/centrifugal – get cyclonic and anti-cyclonic winds

SIMPLE SEA-BREEZE MODEL inadequate for hemisphere

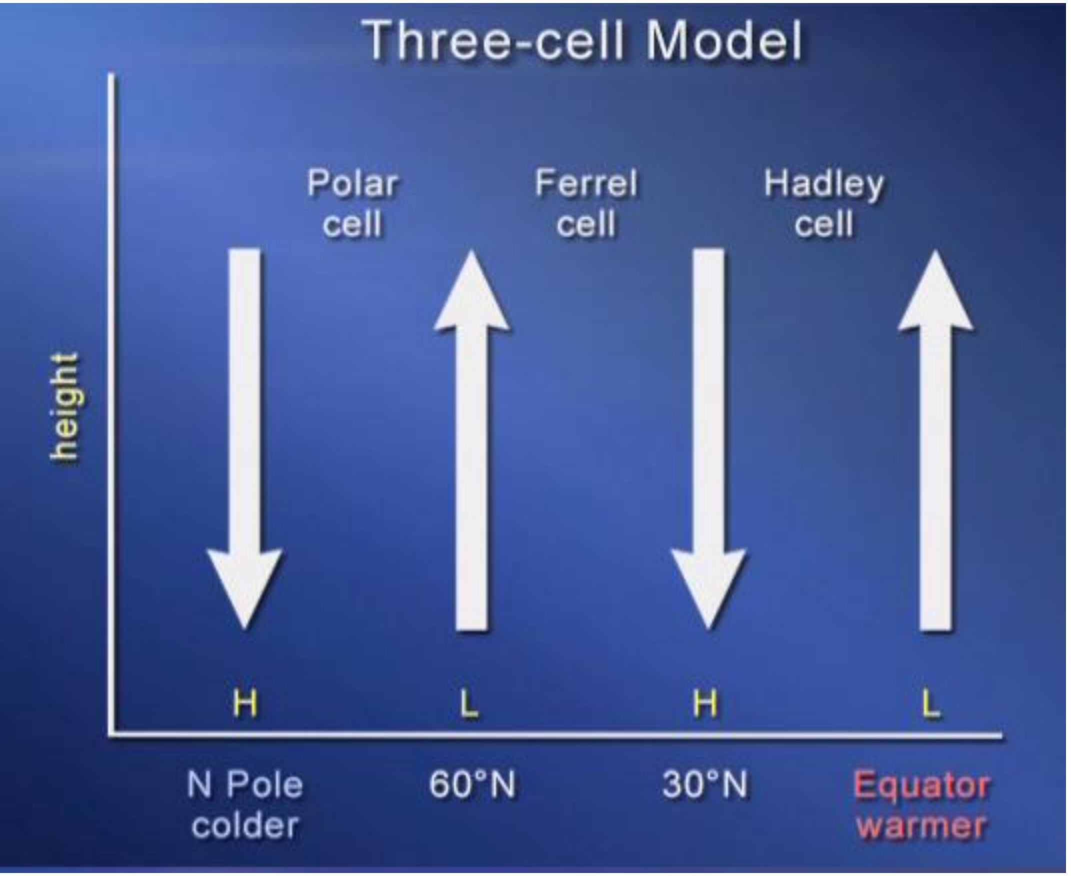


One-cell model – driven by temperature

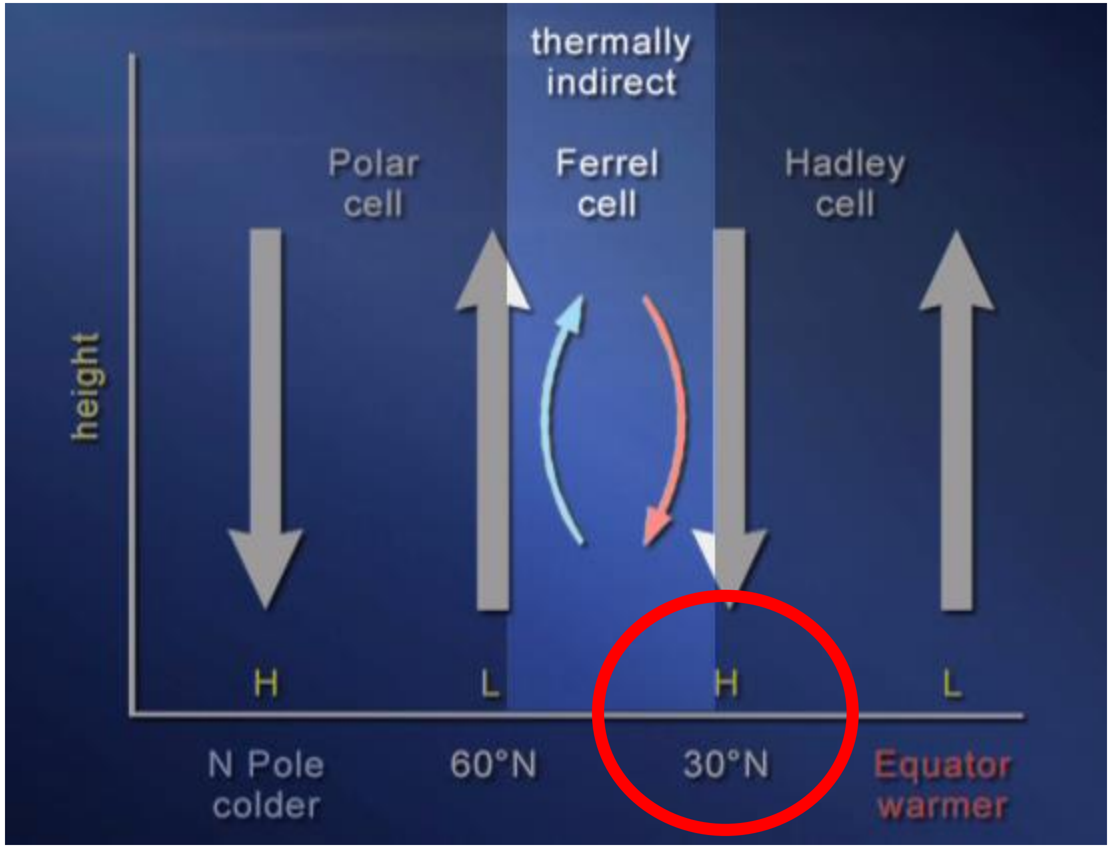
- Poles to equator – temperature difference causes pressure gradient

- But one-cell simple and okay for local area – but not for global circulation

3 cell model

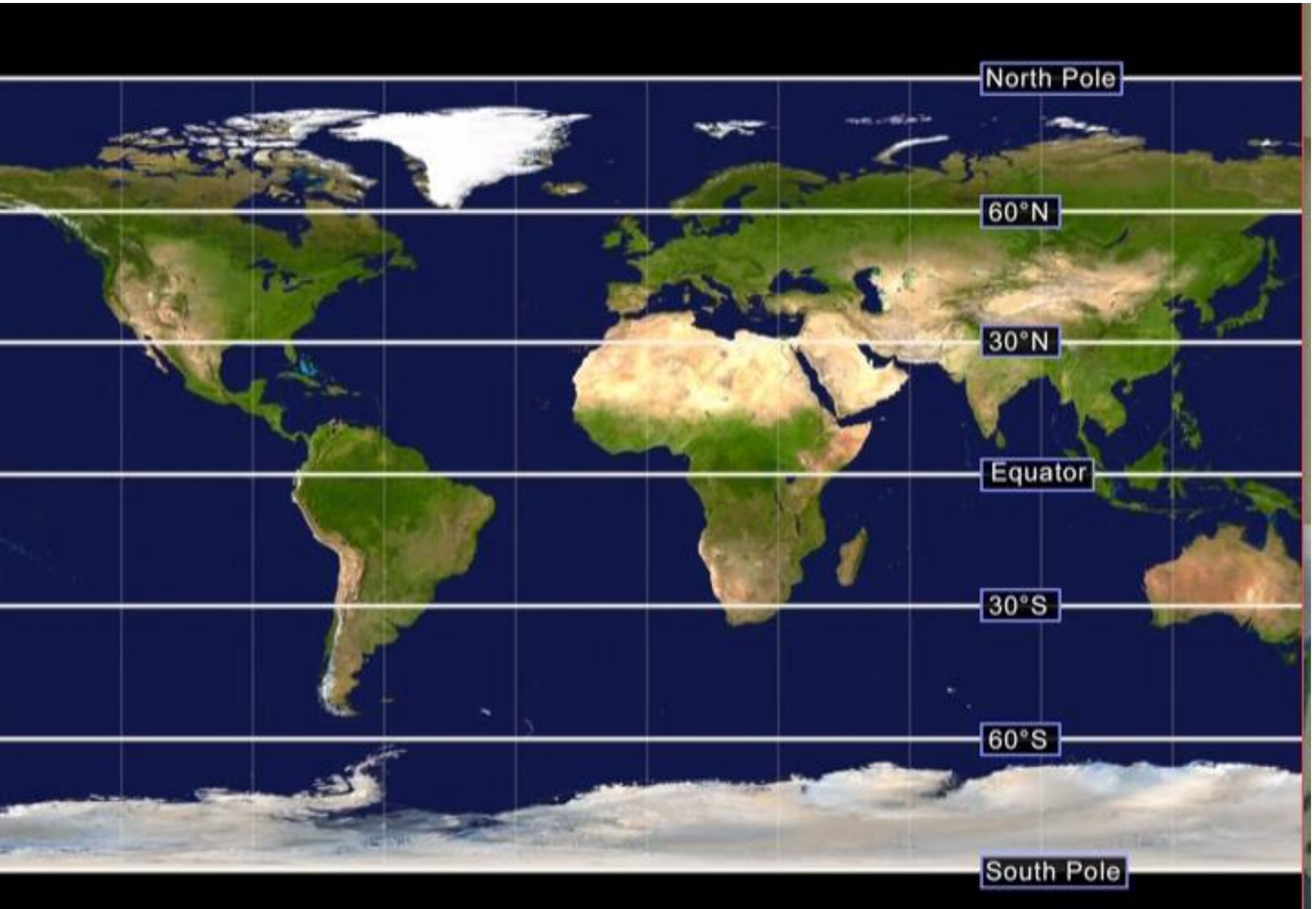


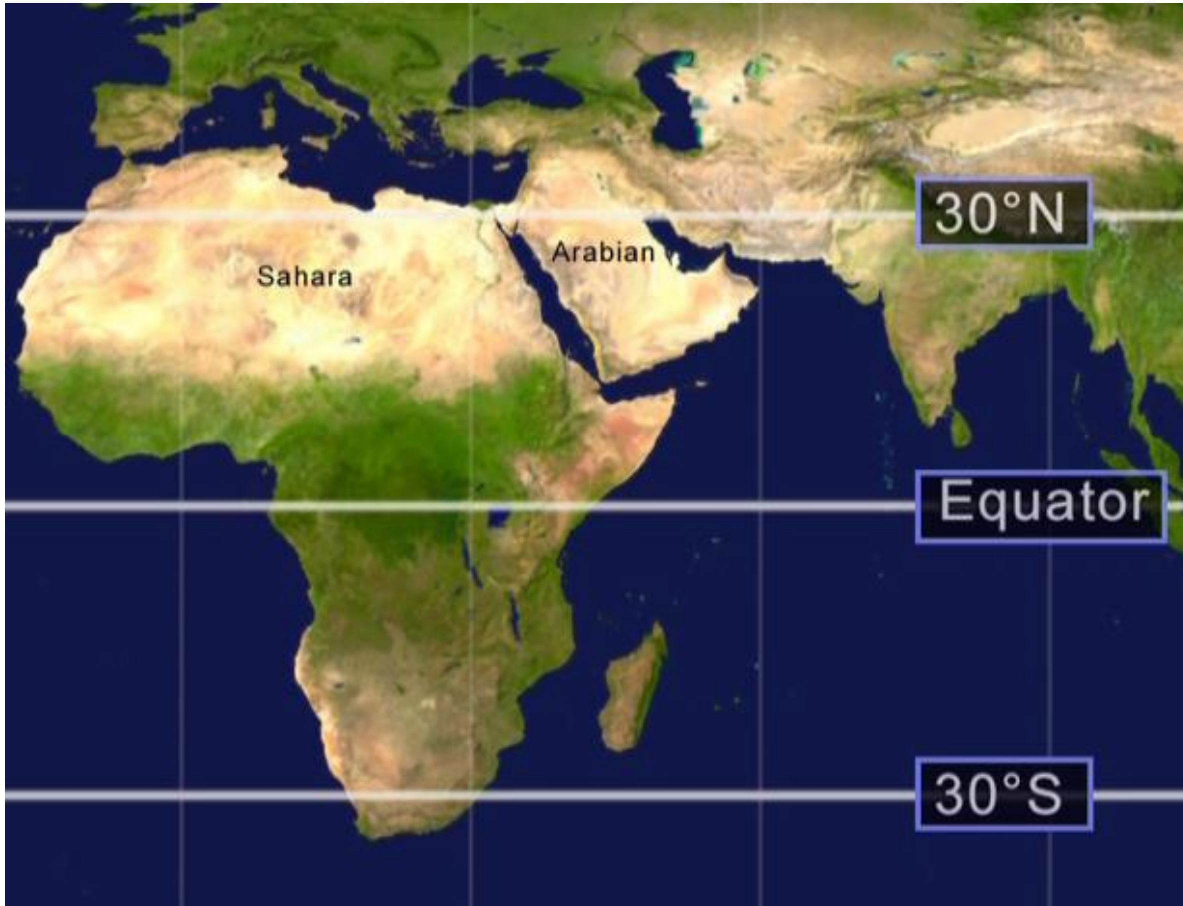
The middle gear



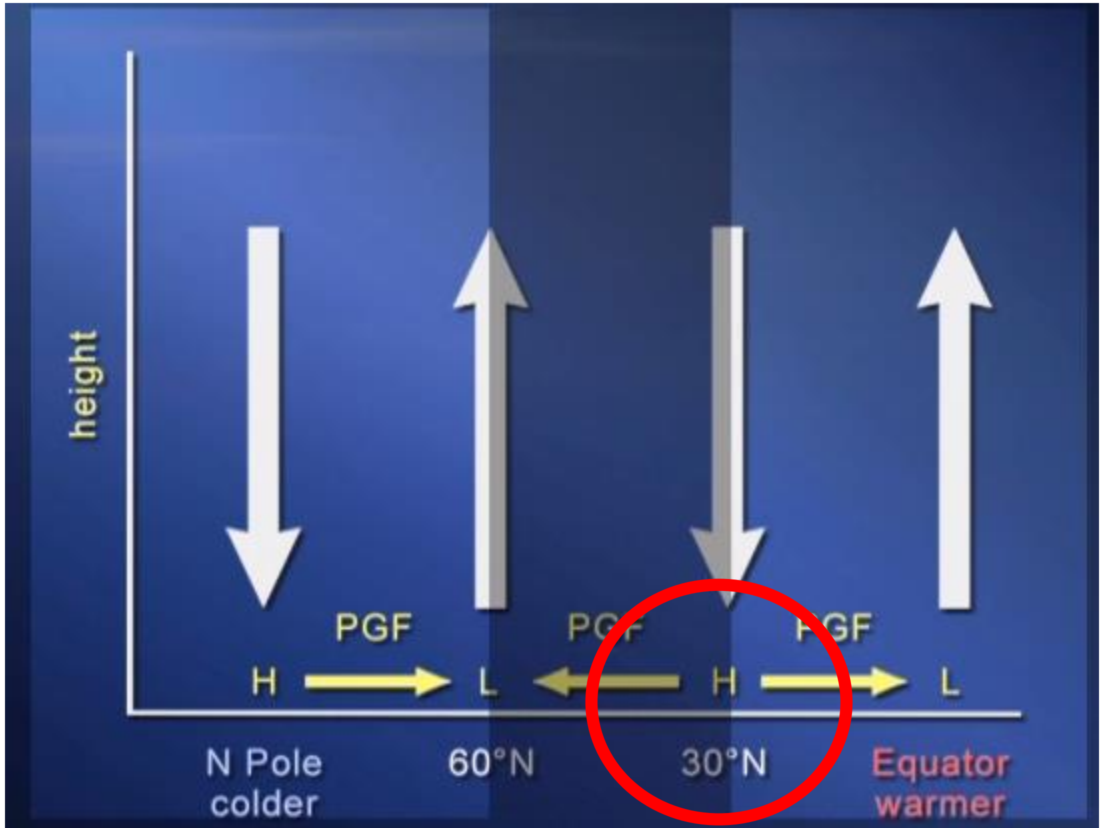
World Map

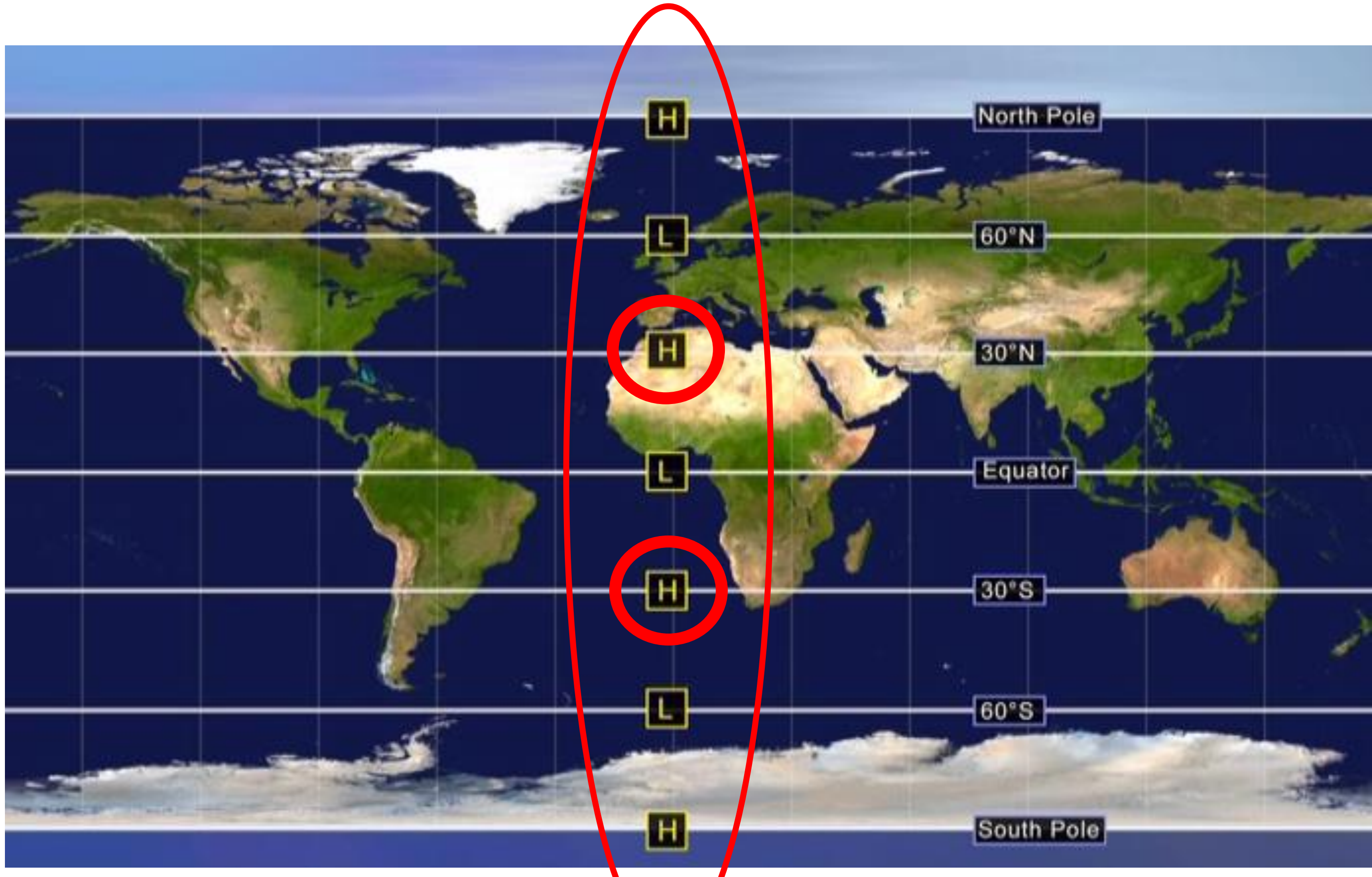
- Why the 30 degree belt is a desert belt: descending air – dry and getting warmer

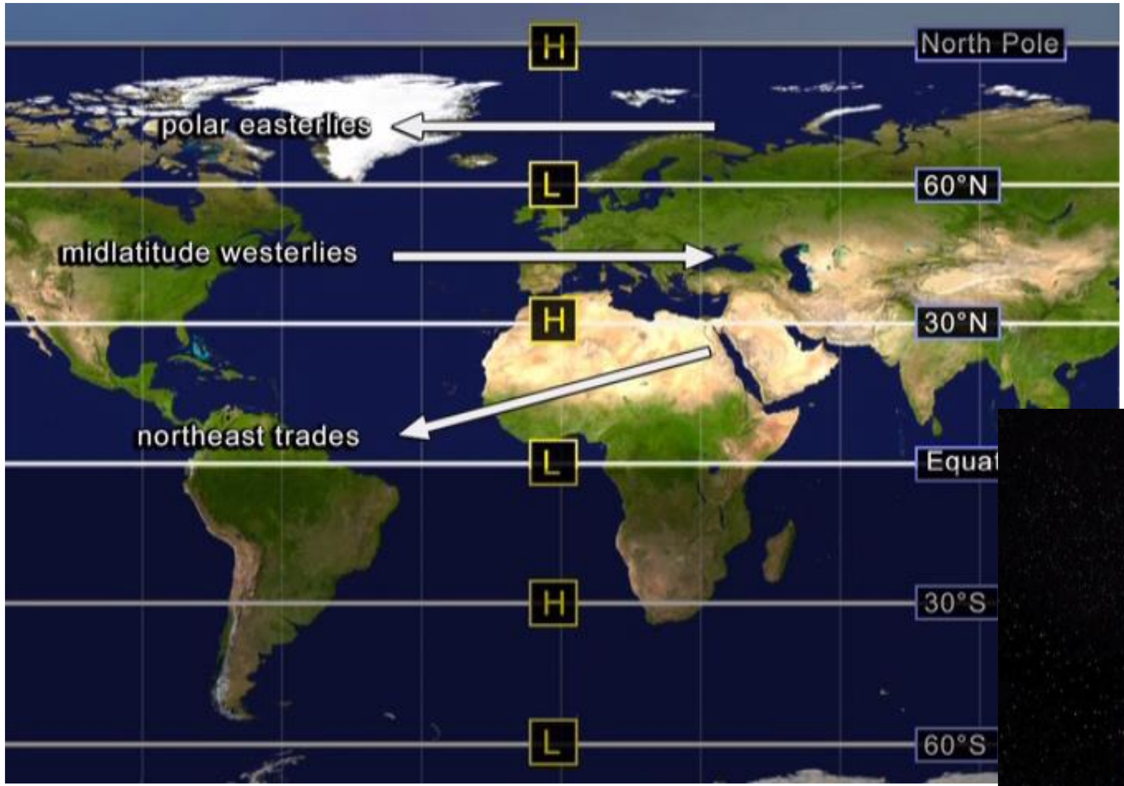
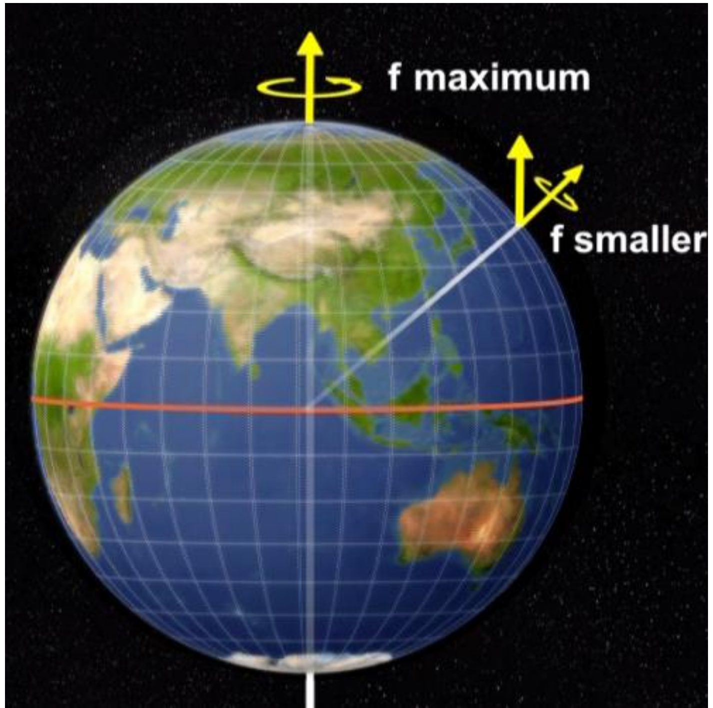
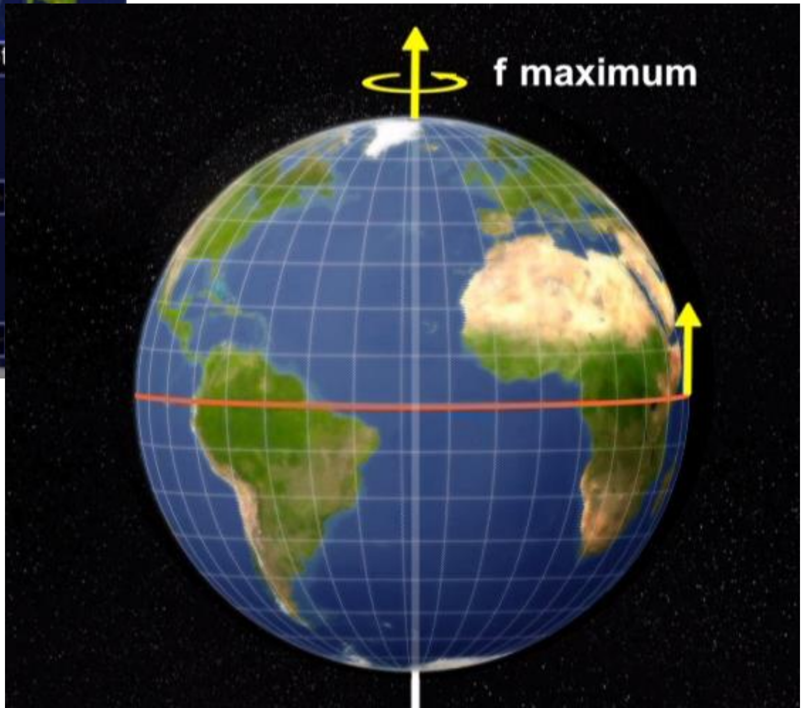




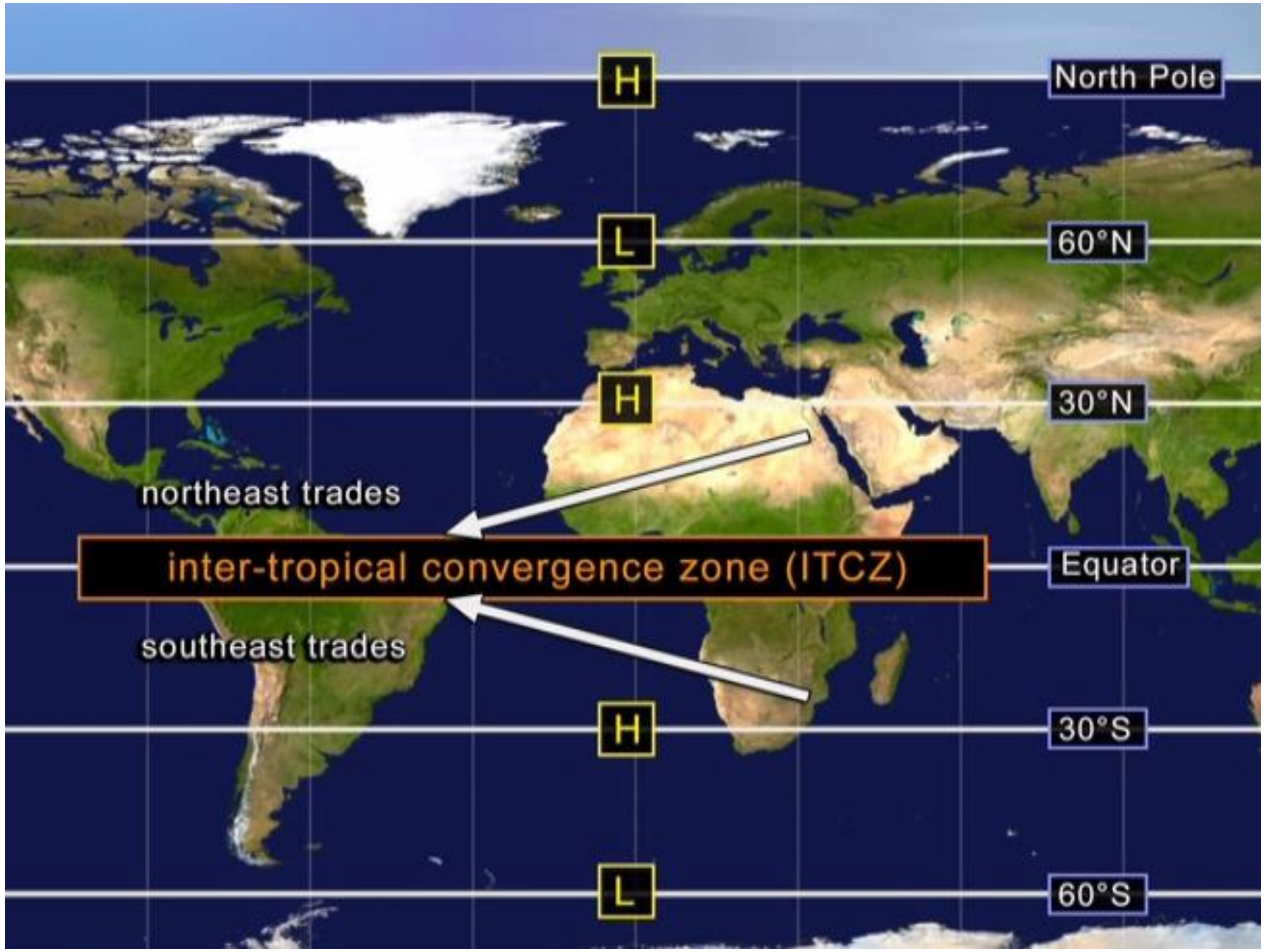
Descending air compresses, warms and thus is drier and associated with High pressure zones

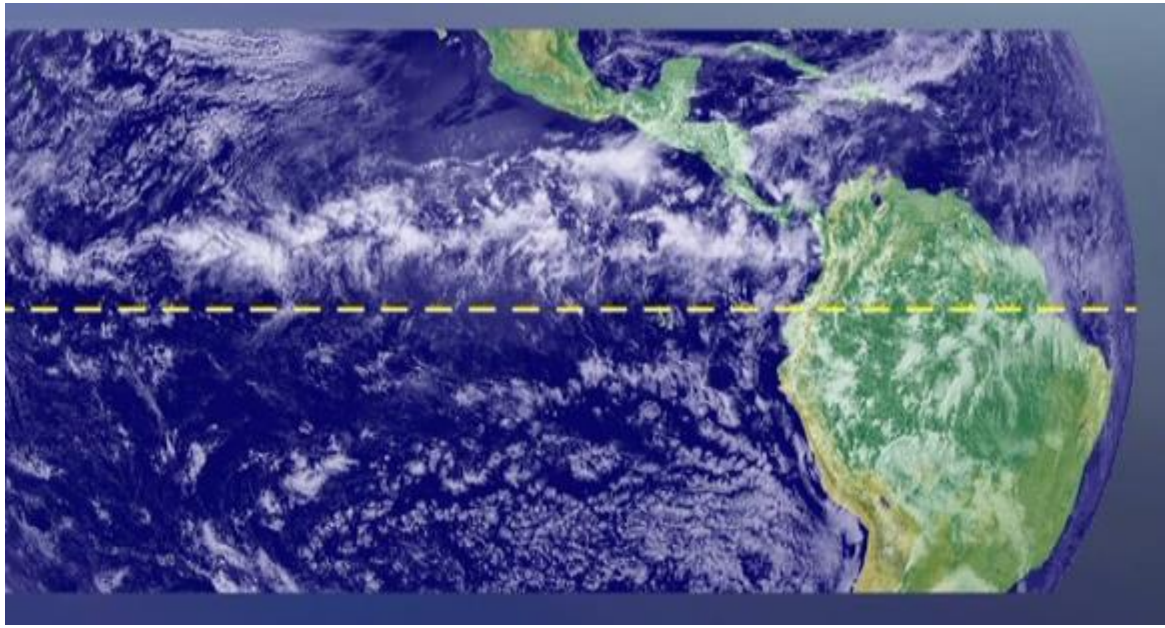


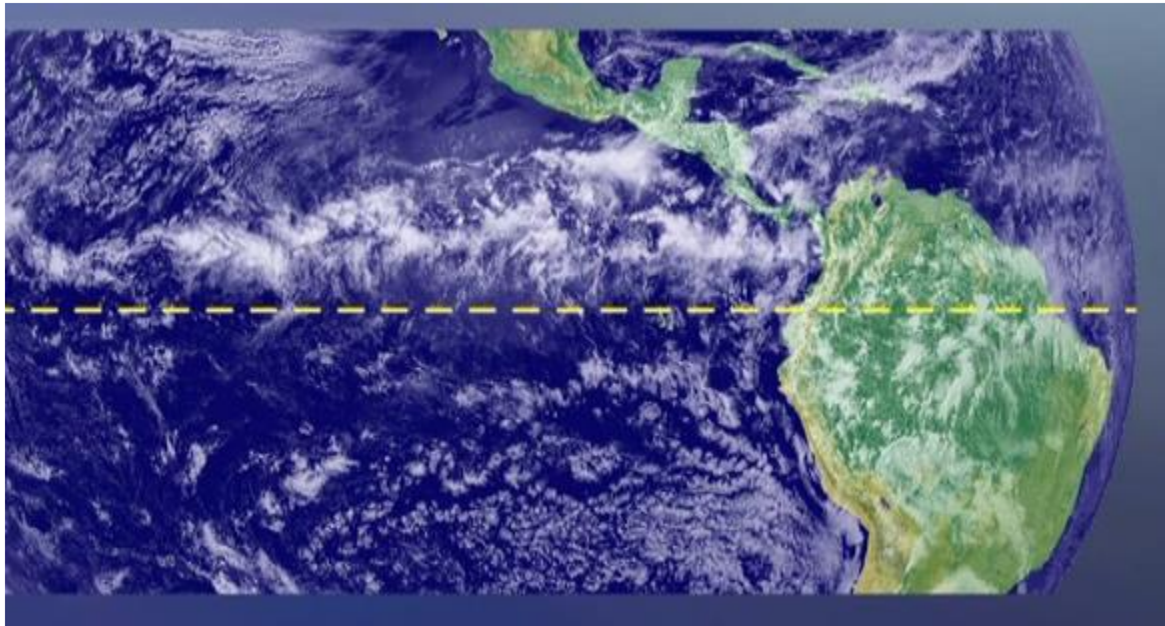


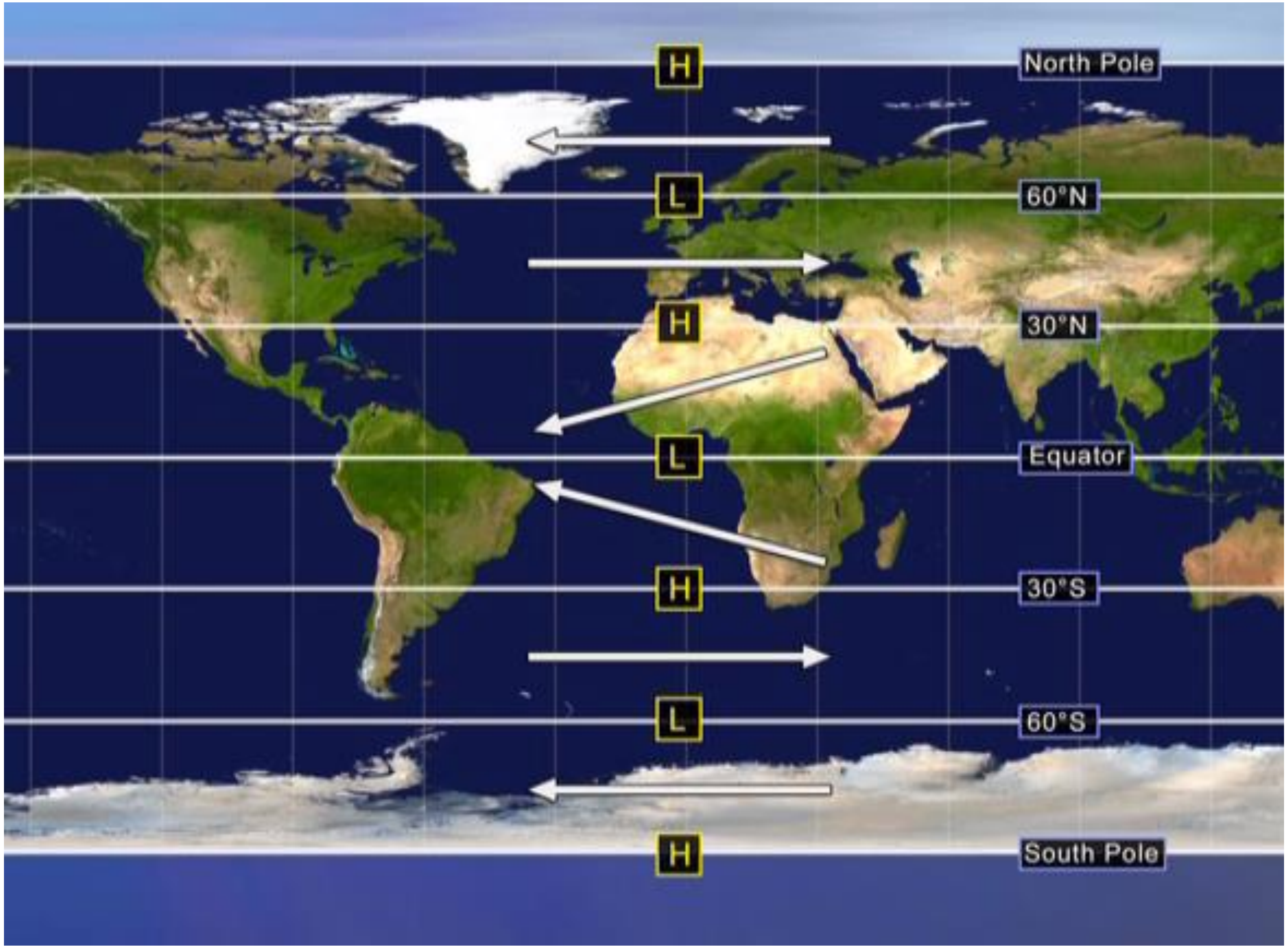

North Pole
polar easterlies
60°N
midlatitude westerlies
30°N
northeast trades
Equat
30°S
60°S
H
L
H
L
H
L

f maximum
f smaller

f maximum

The ITCZ

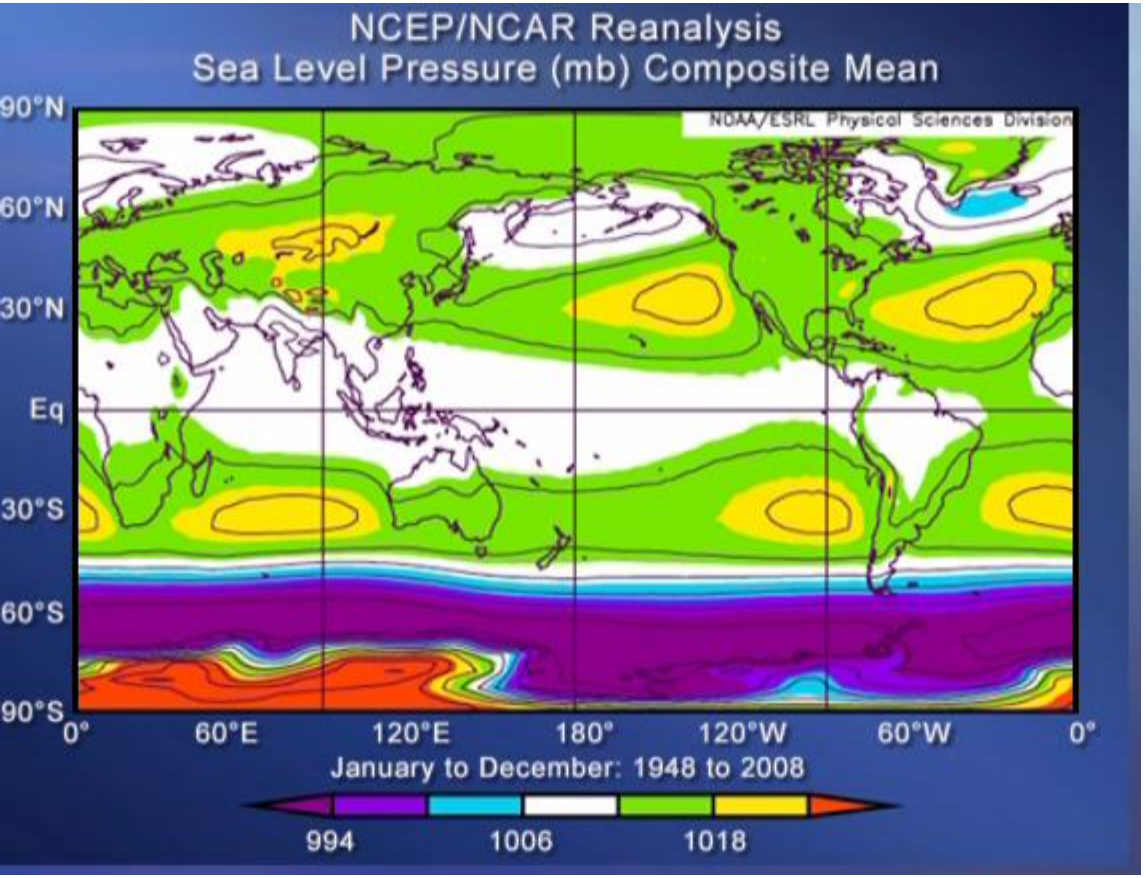

H
North Pole
L
60°N
H
30°N
northeast trades
inter-tropical convergence zone (ITCZ)
Equator
southeast trades
H
30°S
L
60°S

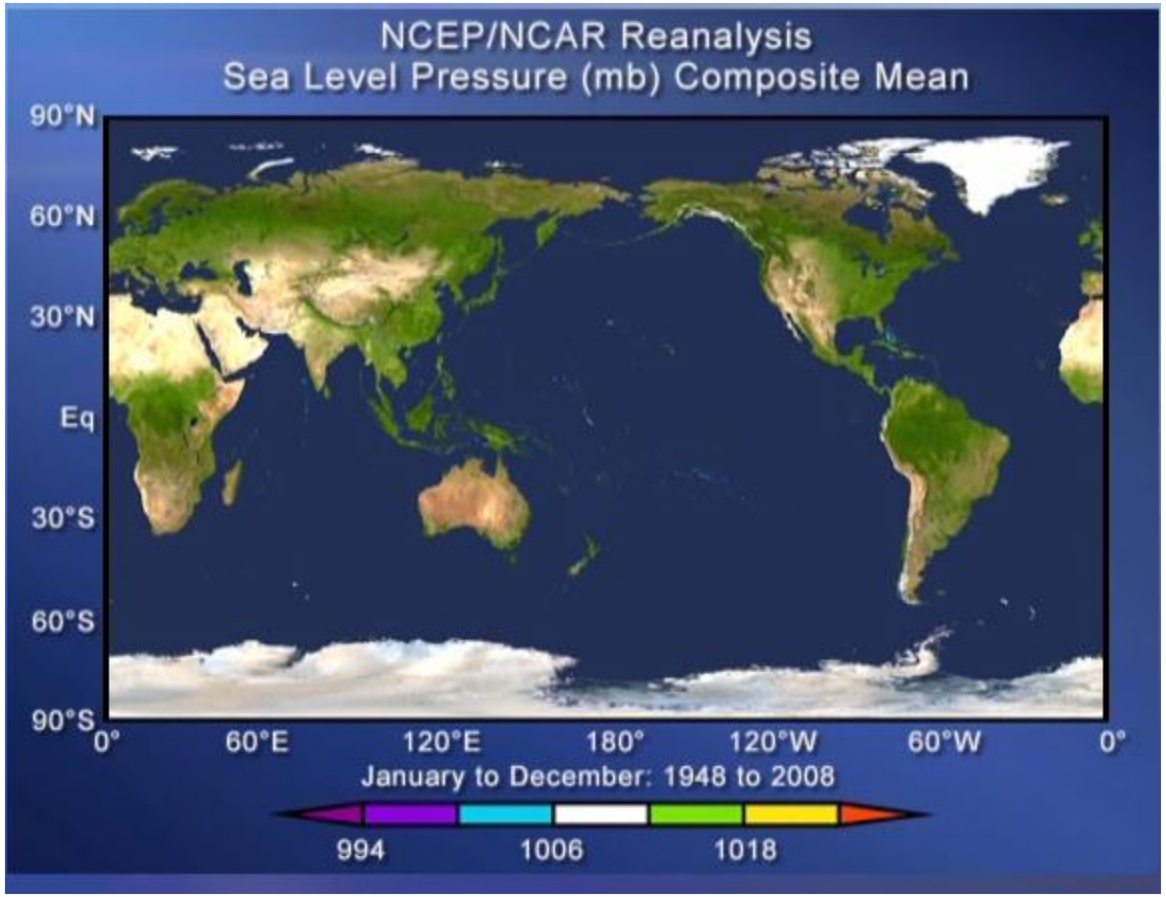


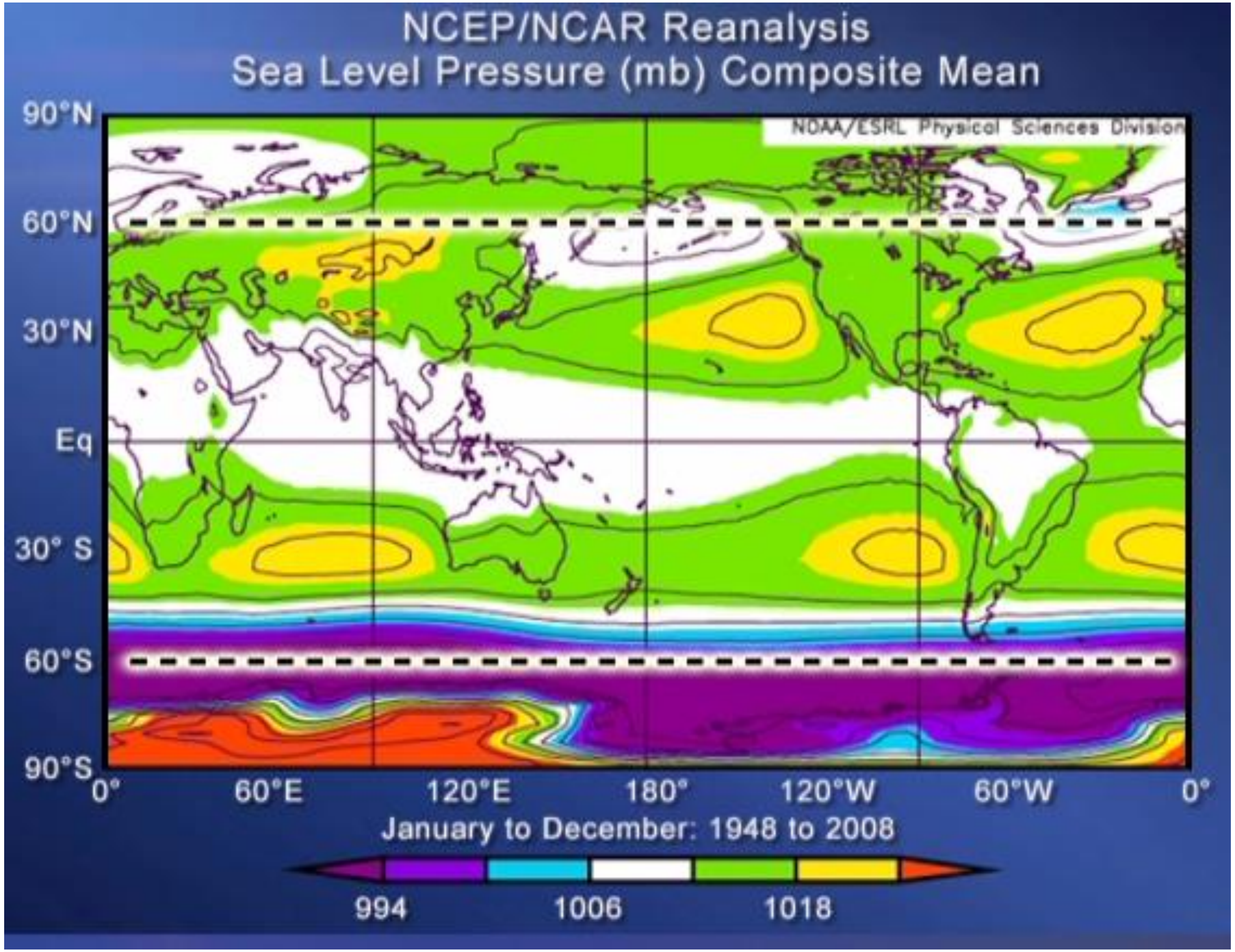



H
North Pole
L
60°N
H
30°N
L
Equator
H
30°S
L
60°S
H
South Pole

Vs.

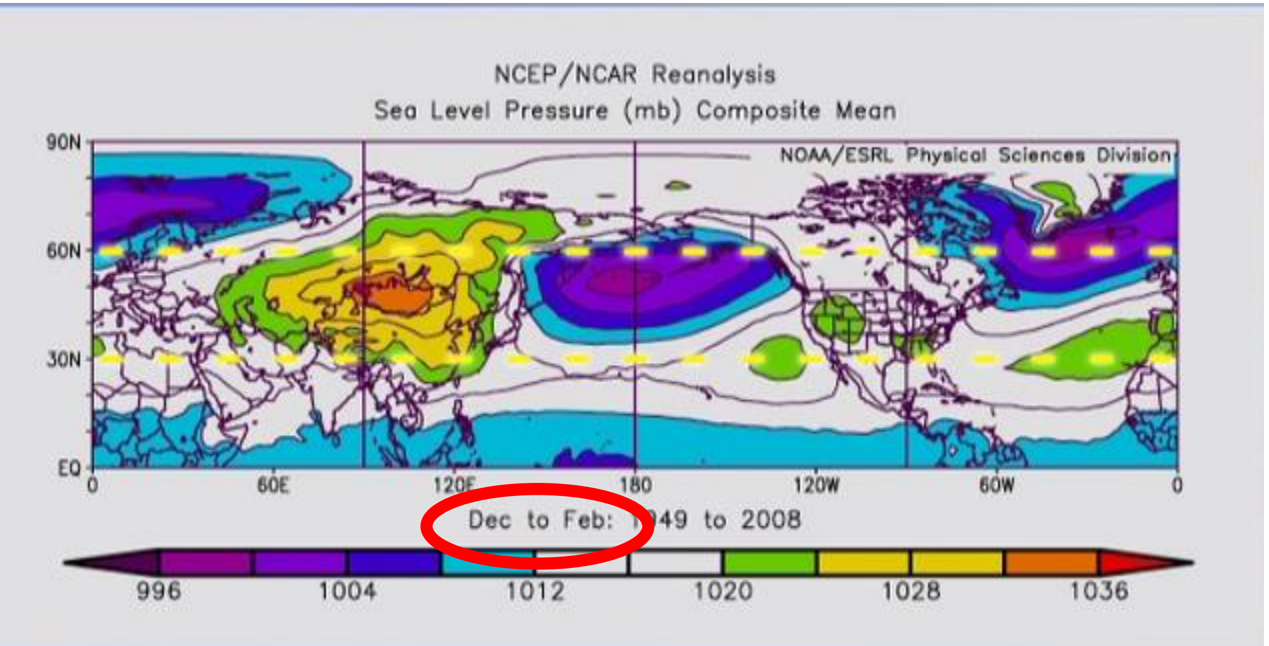

NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
NOAA/ESRL Physical Sciences Division
90°N
60°N
30°N
Eq
30°S
60°S
90°S
0°
60°E
120°E
180°
120°W
60°W
0°
January to December: 1948 to 2008
994
1006
1018

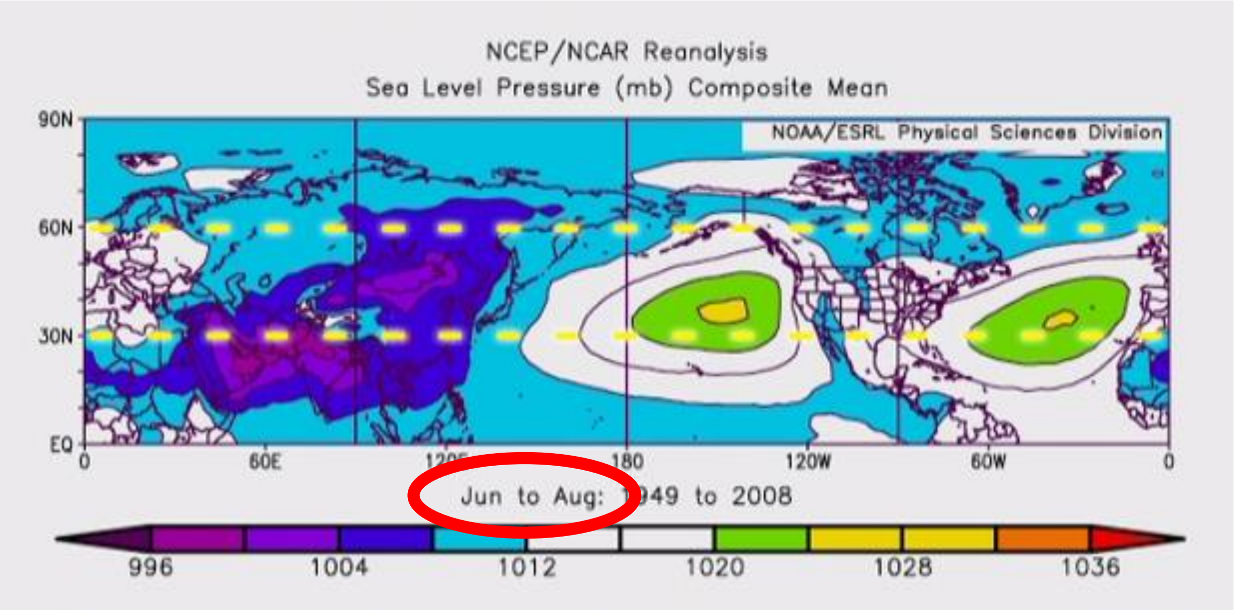

NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
90°N
60°N
30°N
Eq
30°S
60°S
90°S
0°
60°E
120°E
180°
120°W
60°W
0°
January to December: 1948 to 2008
994
1006
1018

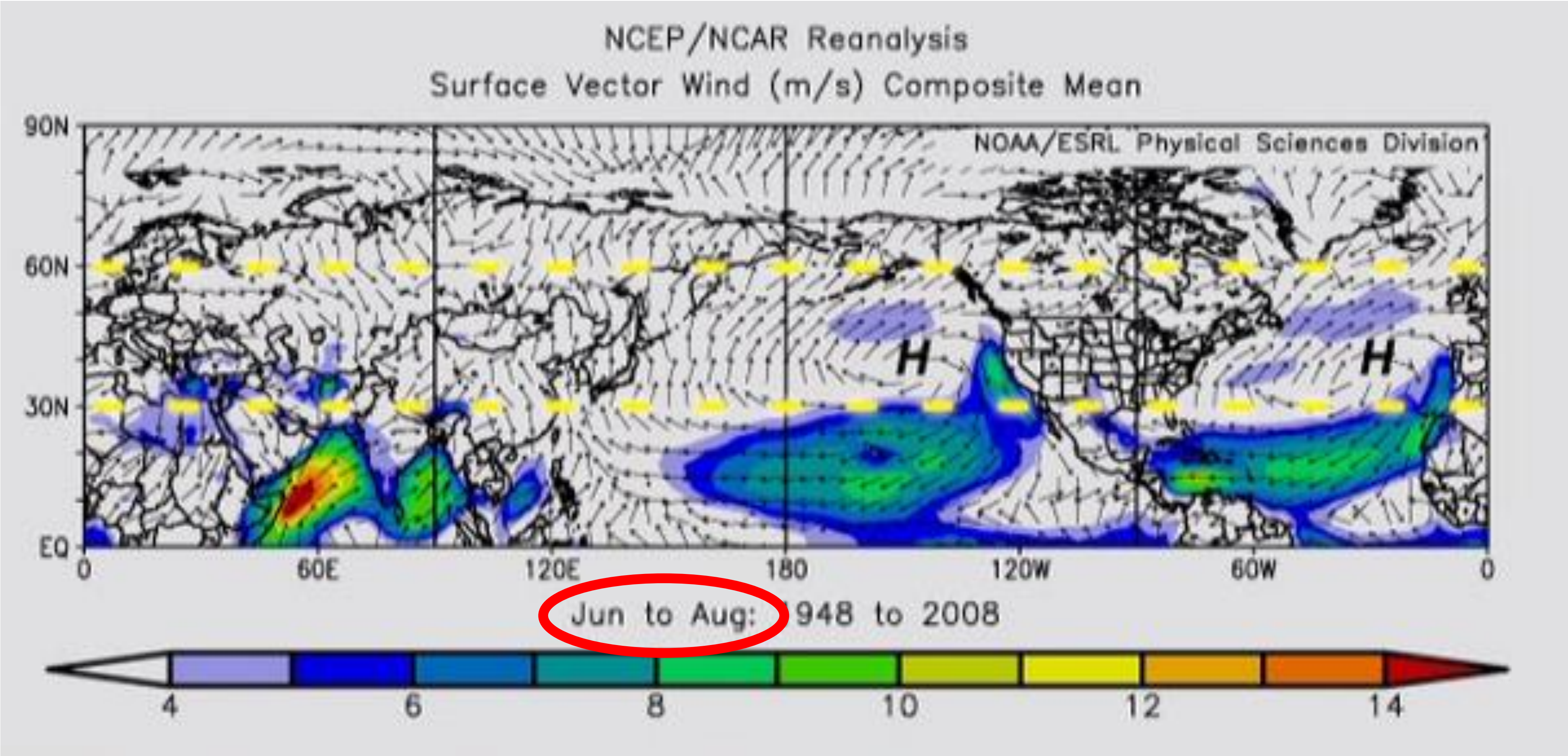


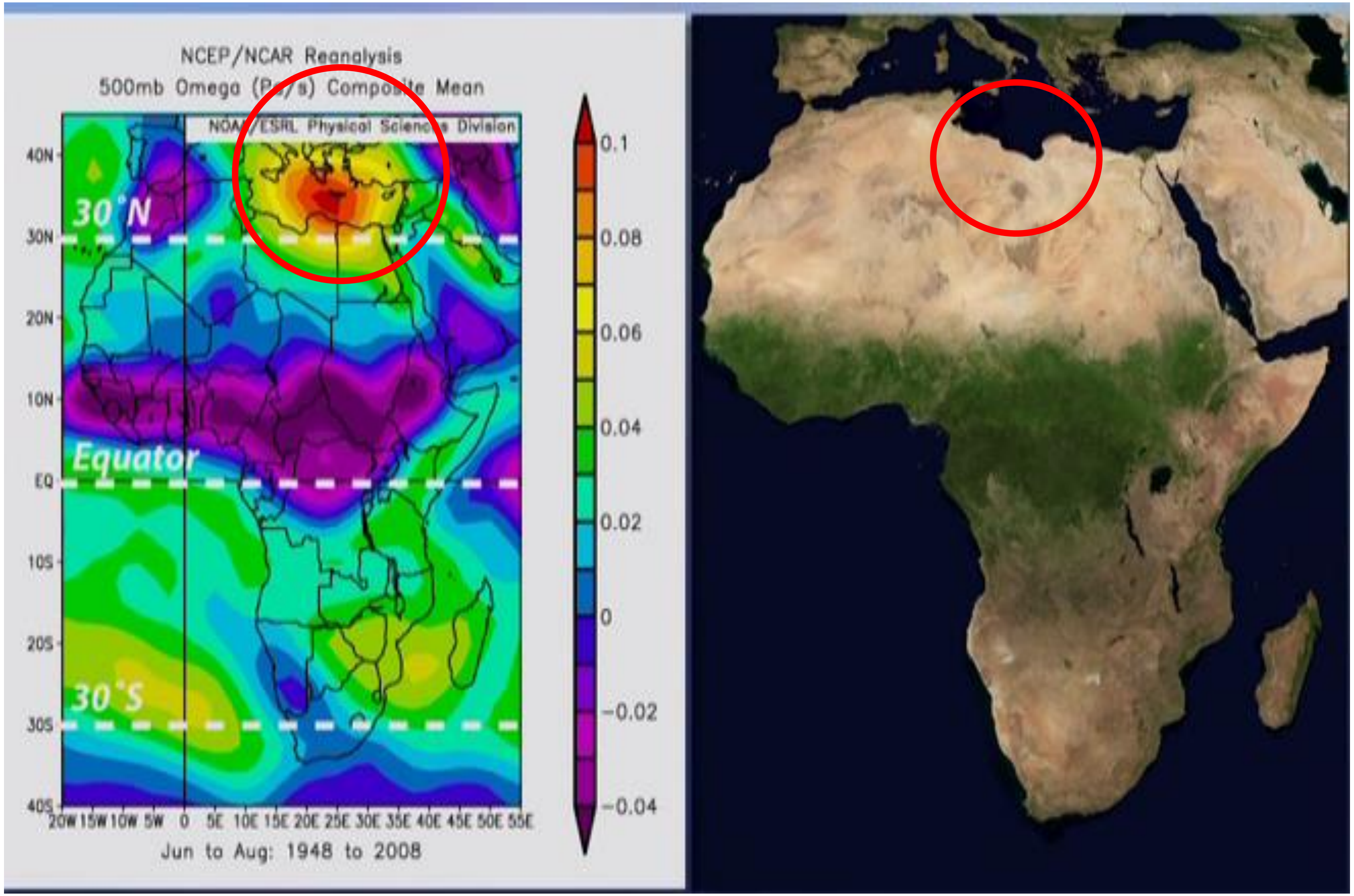
NCEP/NCAR Reanalysis
Sea Level Pressure (mb) Composite Mean
NOAA/ESRL Physical Sciences Division
90°N
60°N
30°N
Eq
30° S
60°S
90°S
0°
60°E
120°E
180°
120°W
60°W
0°
January to December: 1948 to 2008
994
1006
1018

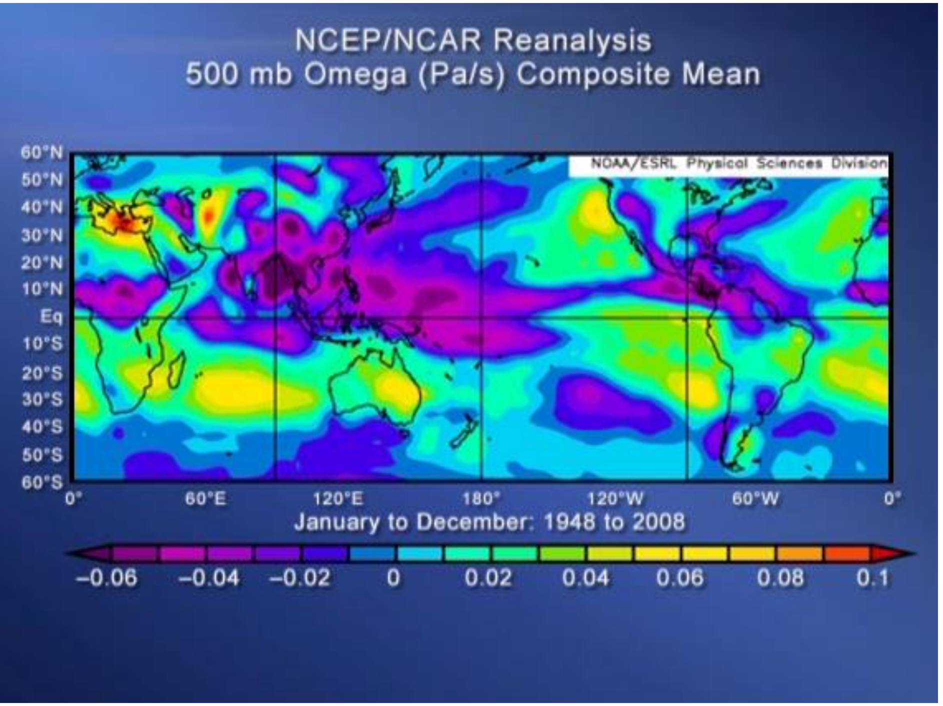
Winter vs. Summer

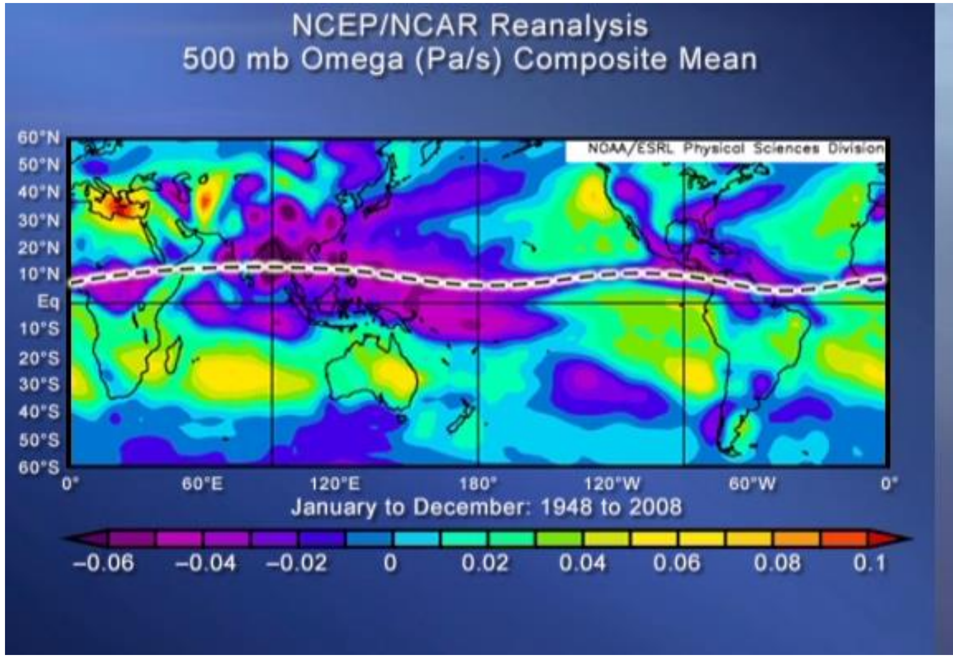


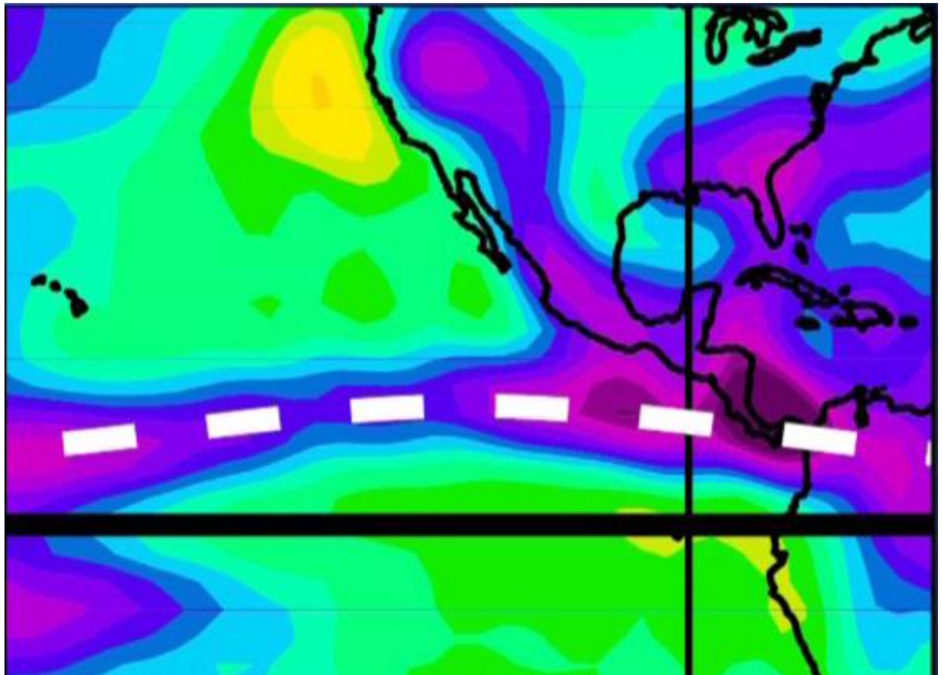


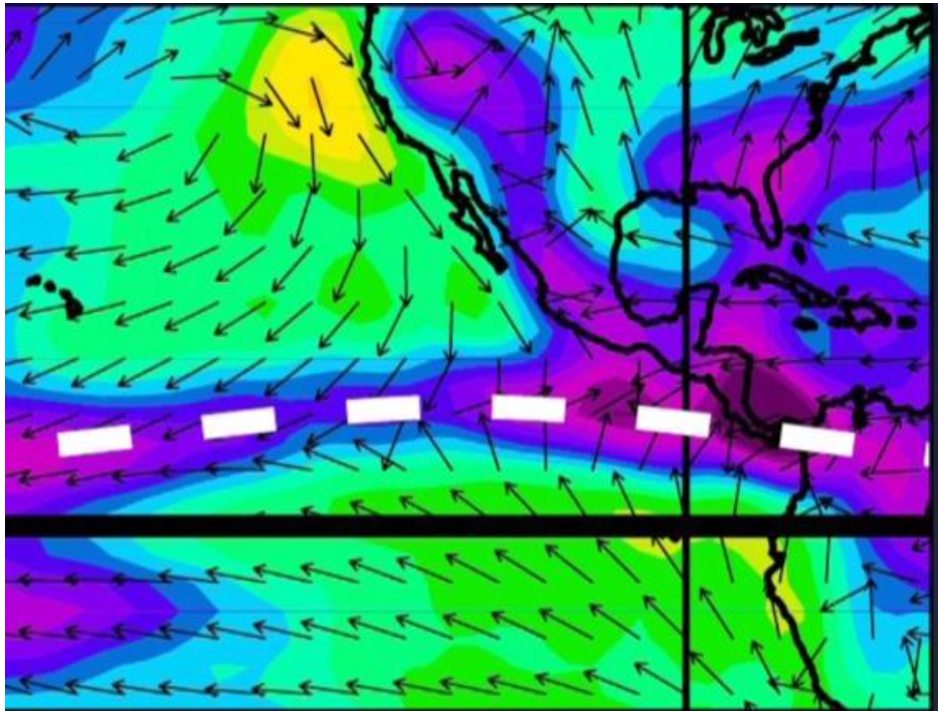

NCEP/NCAR Reanalysis
Surface Vector Wind (m/s) Composite Mean
NOAA/ESRL Physical Sciences Division
90N
60N
30N
EQ
0
60E
120E
180
120W
60W
0
H
H
Jun to Aug: 1948 to 2008
4
6
8
10
12
14

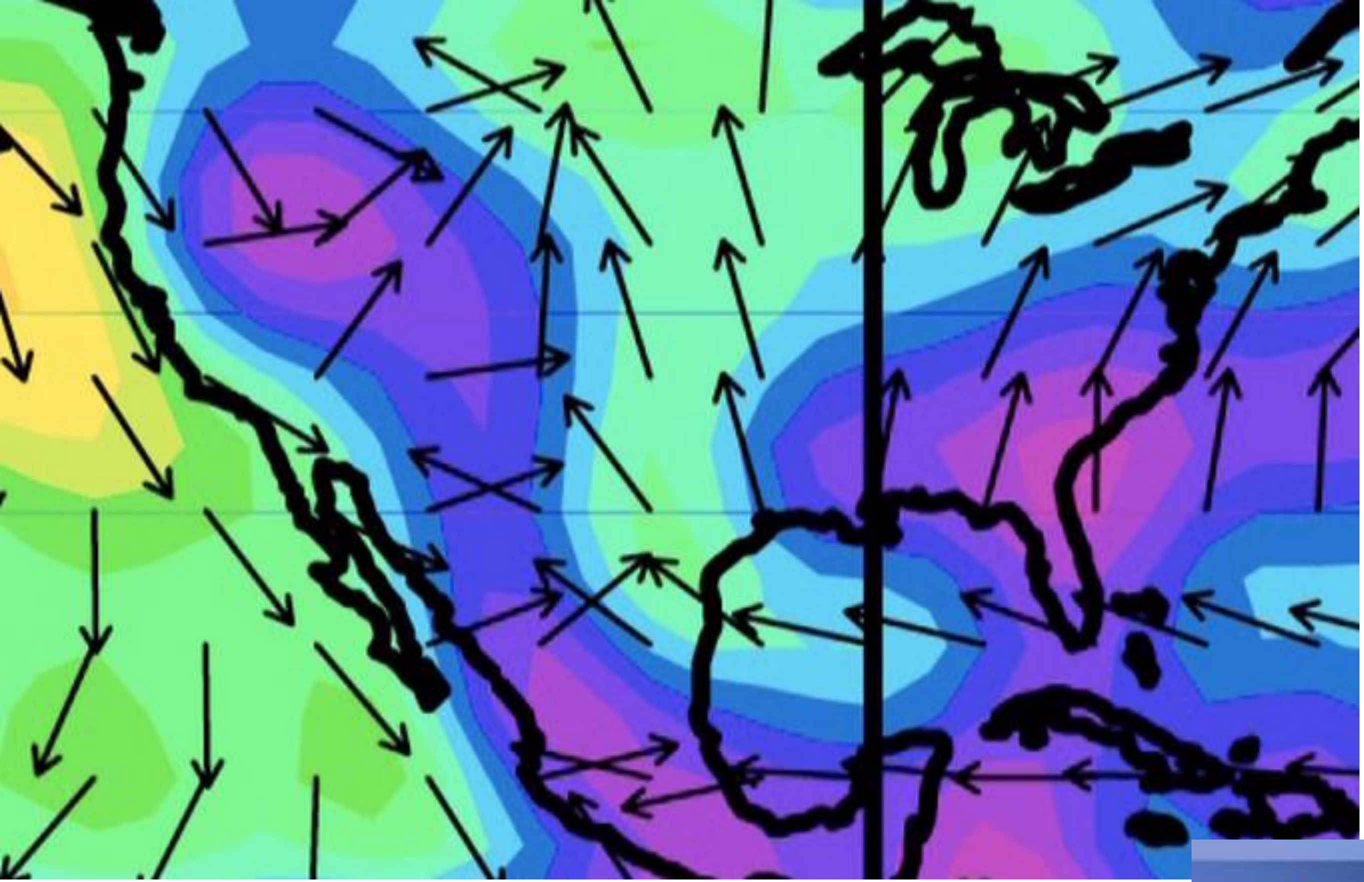

NCEP/NCAR Reanalysis
500mb Omega (Pa/s) Composite Mean
NOAA/ESRL Physical Sciences Division
30°N
Equator
30°S
40N
30N
20N
10N
EQ
10S
20S
30S
40S
20W 15W 10W 5W 0 5E 10E 15E 20E 25E 30E 35E 40E 45E 50E 55E
Jun to Aug: 1948 to 2008
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04

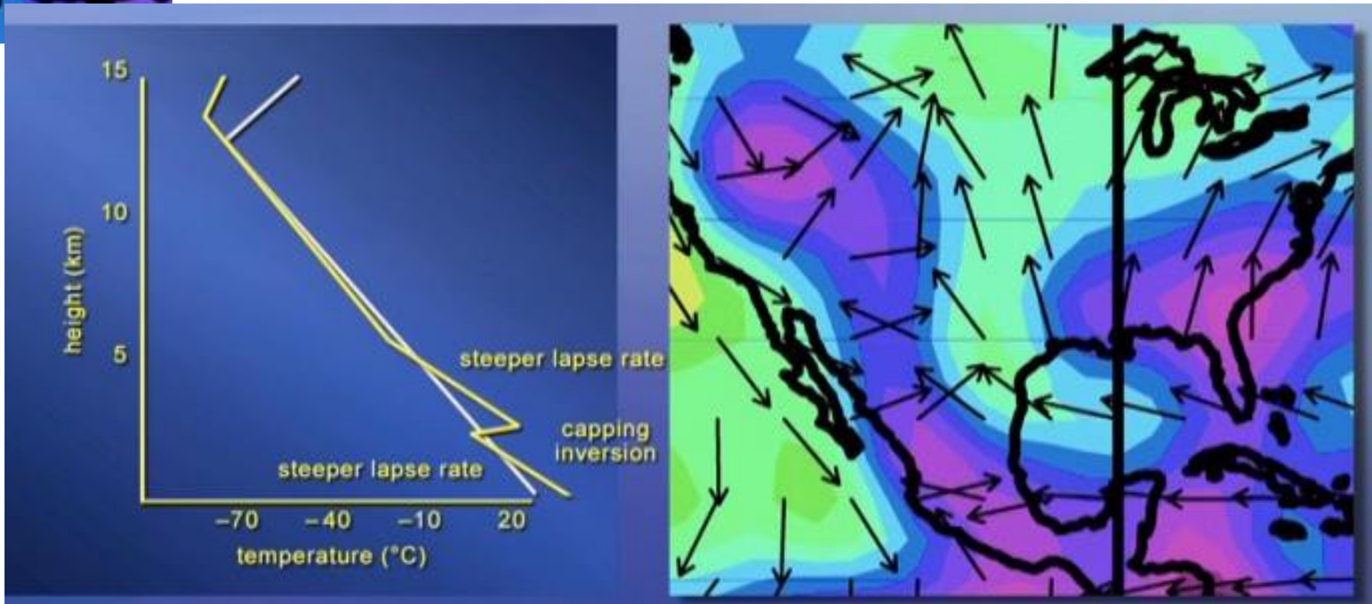

NCEP/NCAR Reanalysis
500 mb Omega (Pa/s) Composite Mean
NOAA/ESRL Physical Sciences Division
60°N
50°N
40°N
30°N
20°N
10°N
Eq
10°S
20°S
30°S
40°S
50°S
60°S
0° 60°E 120°E 180° 120°W 60°W 0°
January to December: 1948 to 2008
−0.06 −0.04 −0.02 0 0.02 0.04 0.06 0.08 0.1


NCEP/NCAR Reanalysis
500 mb Omega (Pa/s) Composite Mean
NOAA/ESRL Physical Sciences Division
60°N
50°N
40°N
30°N
20°N
10°N
Eq
10°S
20°S
30°S
40°S
50°S
60°S
0° 60°E 120°E 180° 120°W 60°W 0°
January to December: 1948 to 2008
−0.06 −0.04 −0.02 0 0.02 0.04 0.06 0.08 0.1

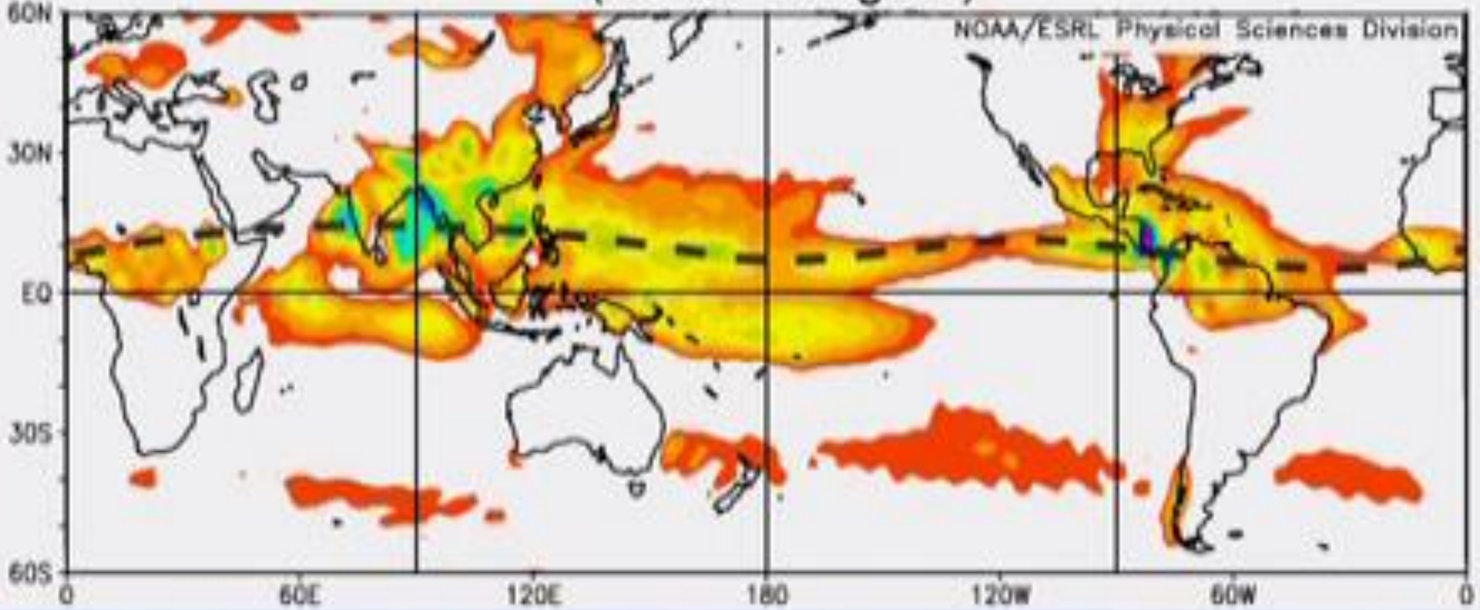




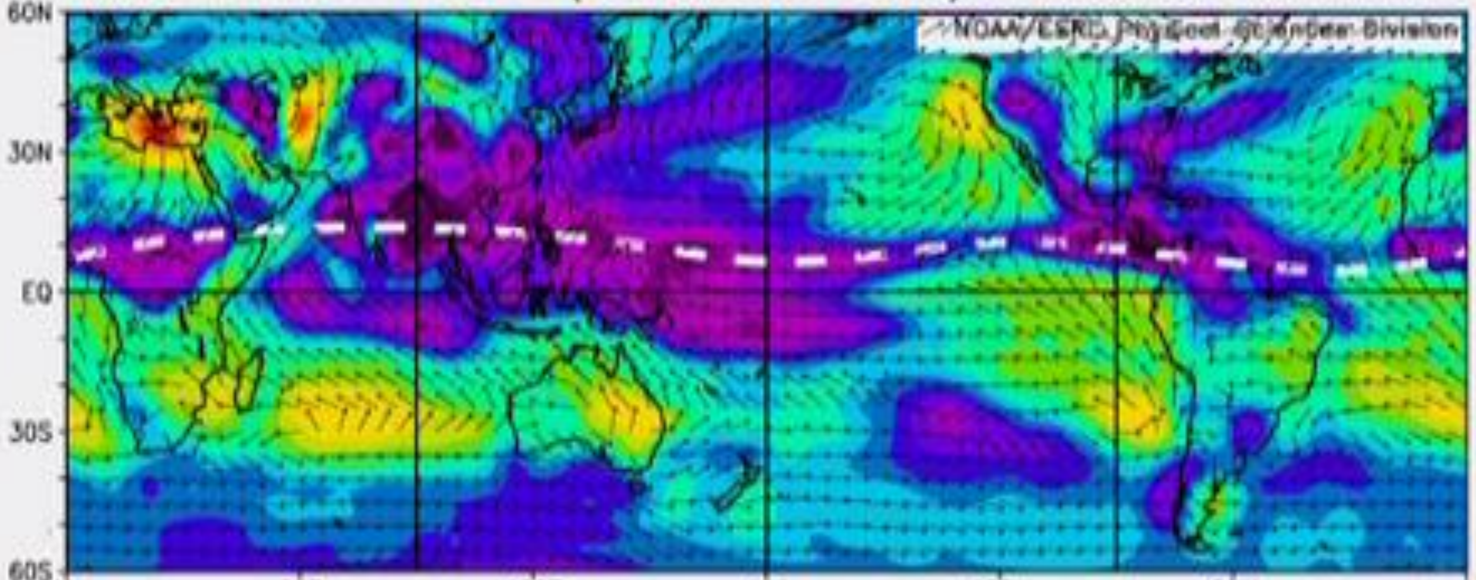



15
10
5
height (km)
steeper lapse rate
capping inversion
steeper lapse rate
−70
−40
−10
20
temperature (°C)

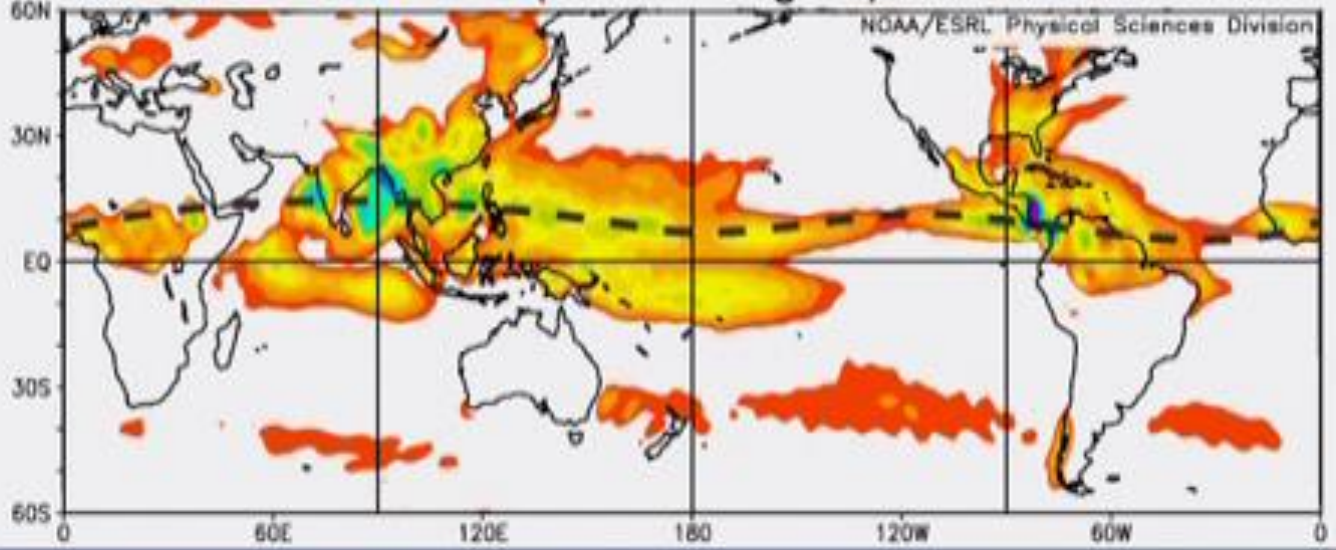
Surface Precipitation
(June – August)



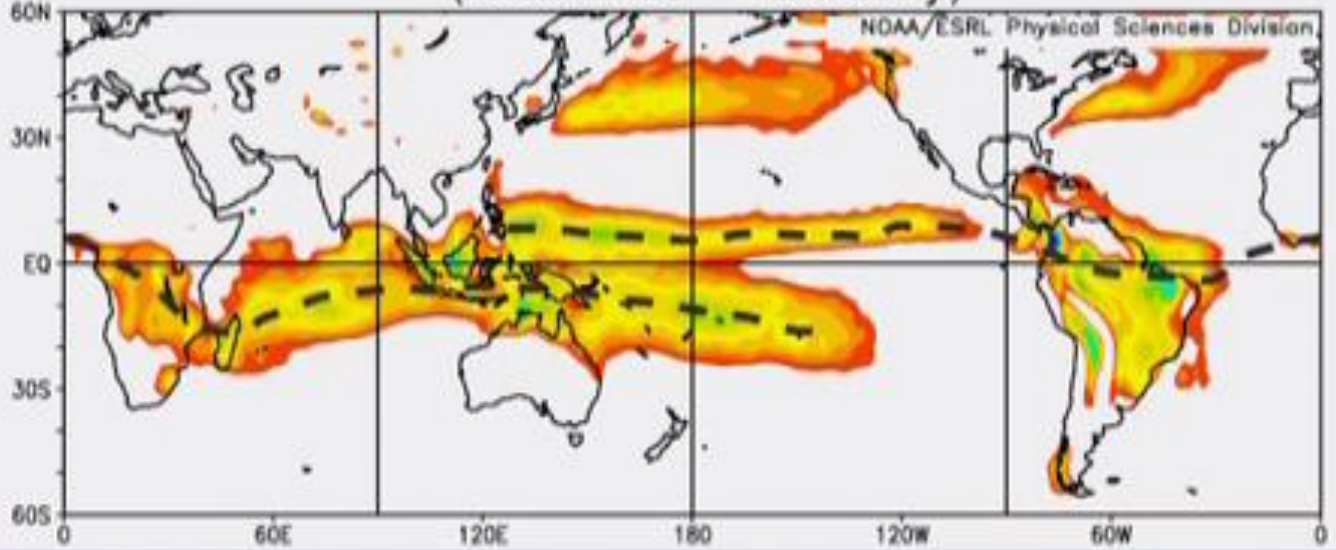
500mb Height
(vertical motion)



Surface Precipitation
(June – August)

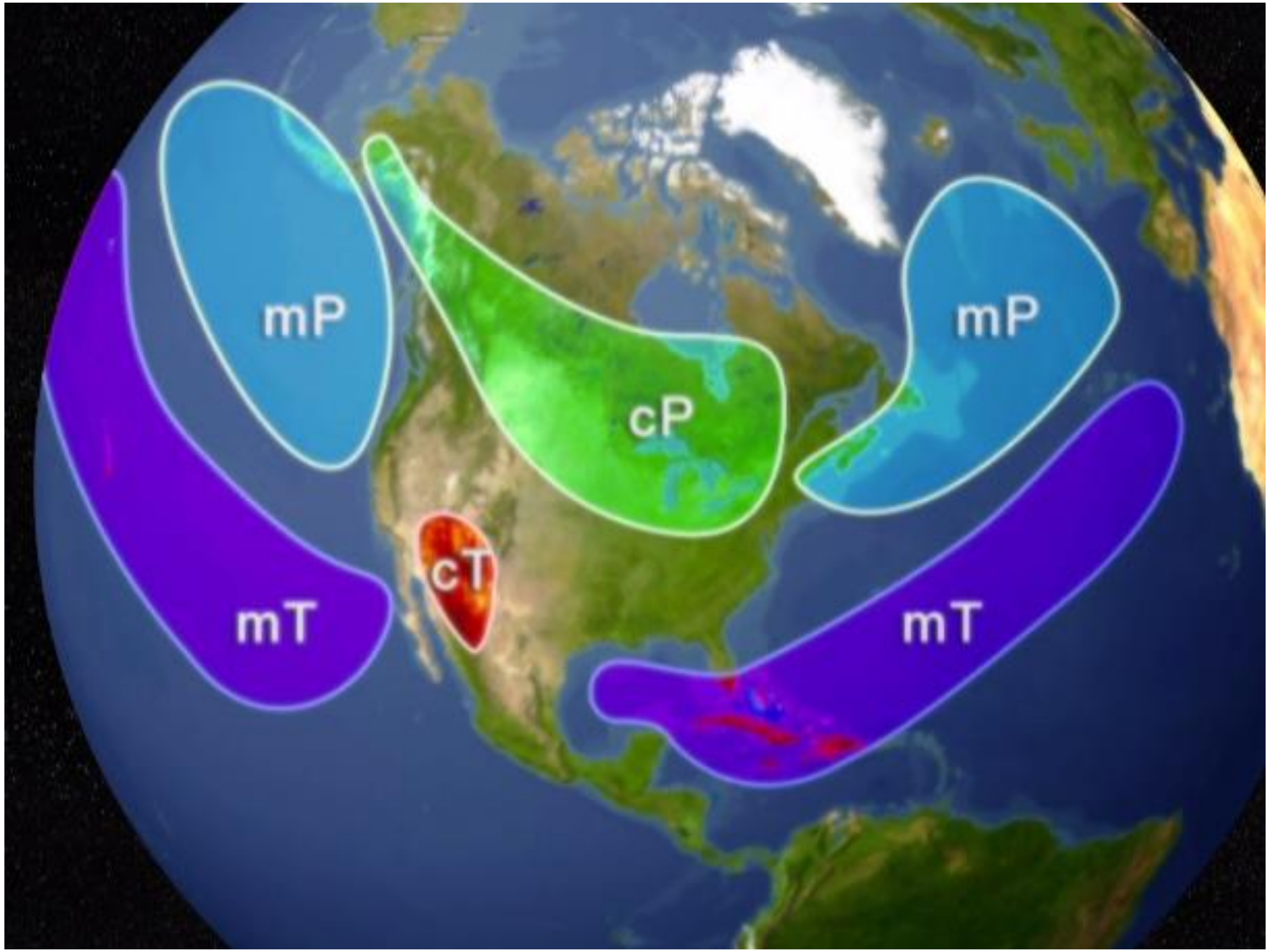


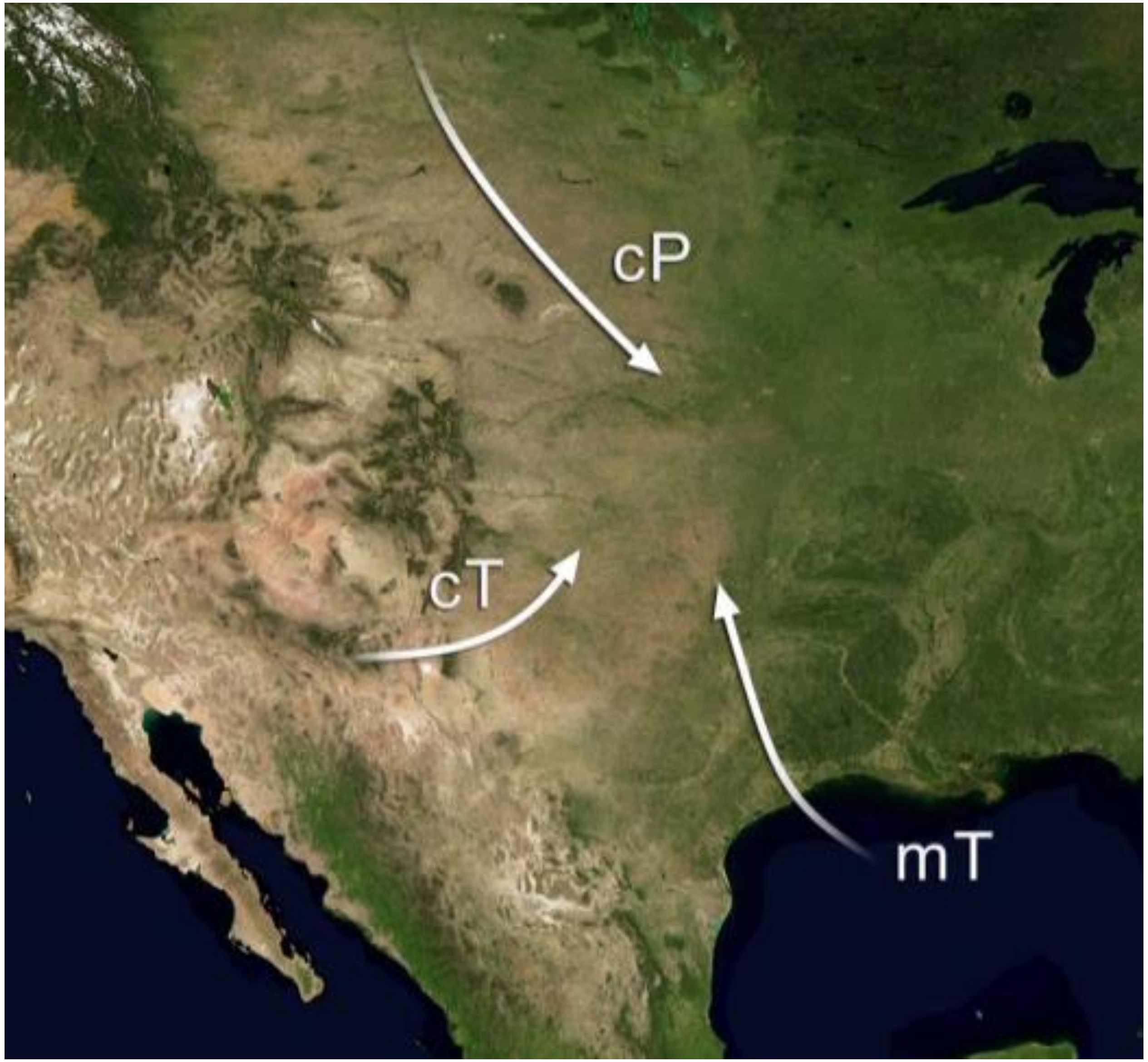
Surface Precipitation
(December – February)



Air Mass


Air Masses
continental
maritime
Source Regions
polar
tropical
continental polar (cP)
continental tropical (cT)
maritime polar (mP)
maritime tropical (mT)


mP
cP
mP
cT
mT
mT


cP
cT
mT

End of week 4