

Meteorology – Lecture 13

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Important notes

- These slides show some figures and videos prepared by Robert G. Fovell (RGF) for his “Meteorology” course, published by The Great Courses (TGC). Unless otherwise identified, they were created by RGF.
- In some cases, the figures employed in the course video are different from what I present here, but these were the figures I provided to TGC at the time the course was taped.
- These figures are intended to supplement the videos, in order to facilitate understanding of the concepts discussed in the course. *These slide shows cannot, and are not intended to, replace the course itself and are not expected to be understandable in isolation.*
- Accordingly, these presentations do not represent a summary of each lecture, and neither do they contain each lecture’s full content.

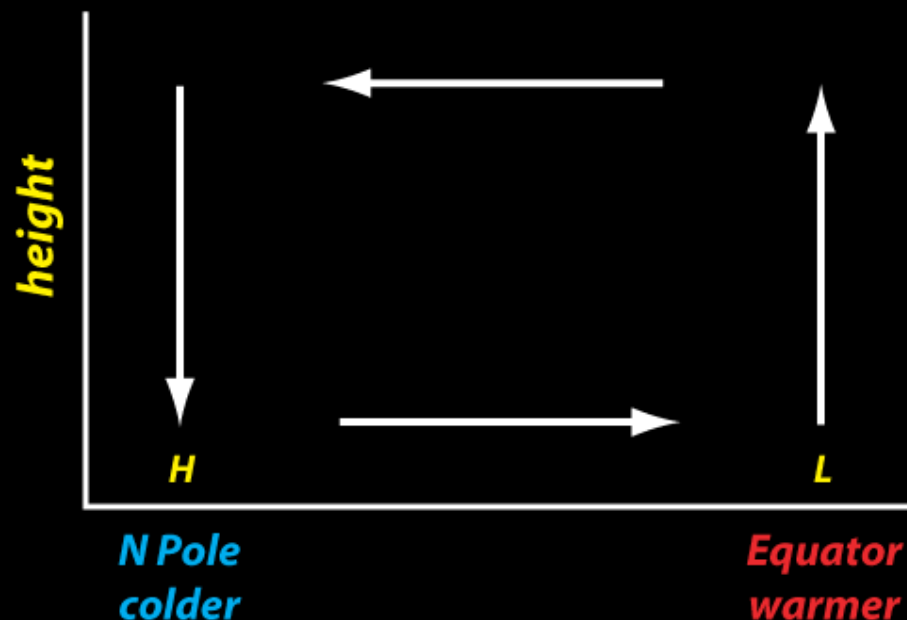
The sea-breeze model applied
to an entire hemisphere

Sea/land breeze idea were applied to the entire hemisphere looks like this.

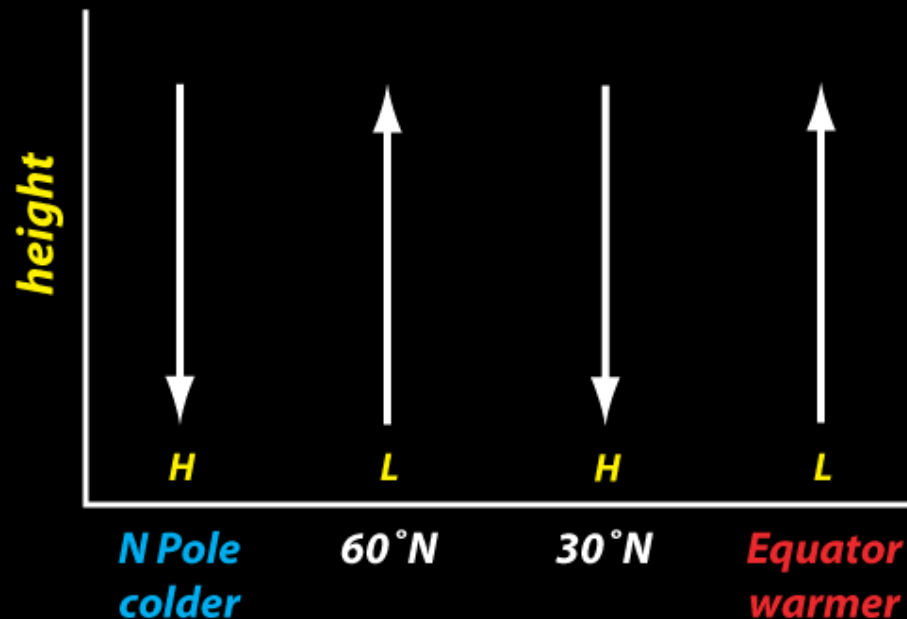
Sinking air at the colder N pole above surface H pressure.
Rising air at the warmer equator above surface L pressure.

Surface wind directed from the polar H to the equatorial L.

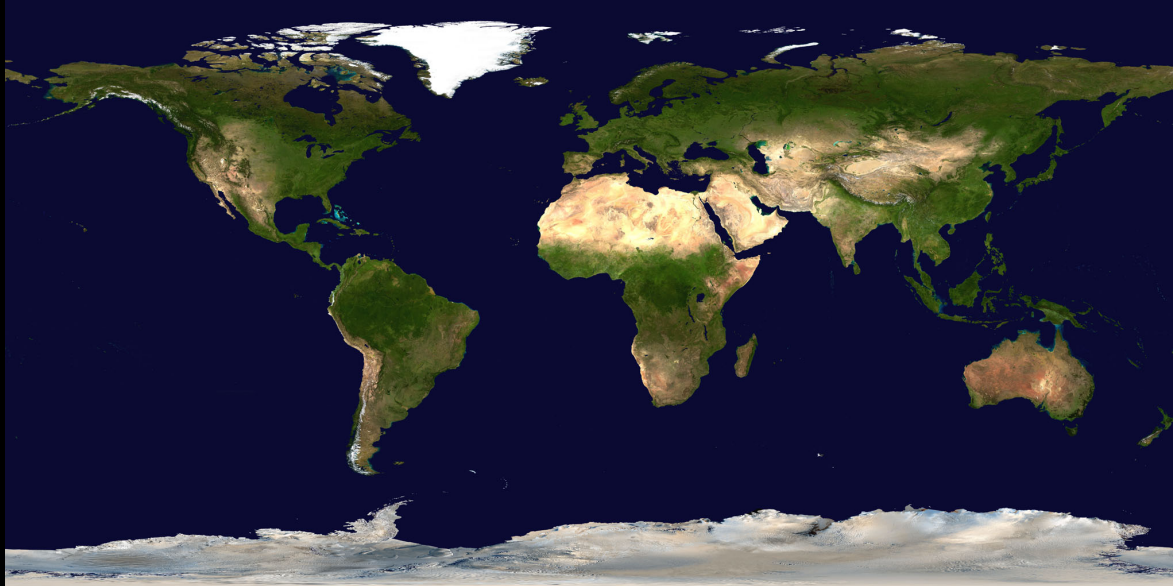
This is the **one-cell** model.



Coriolis (i.e., Earth rotation) does two things to the simple, once-cell thermally direct model. First, it splits the circulation into *three* cells. The middle cell (“Ferrel cell”) is thermally indirect. Note sinking motion at 30° and ascent at 60° .

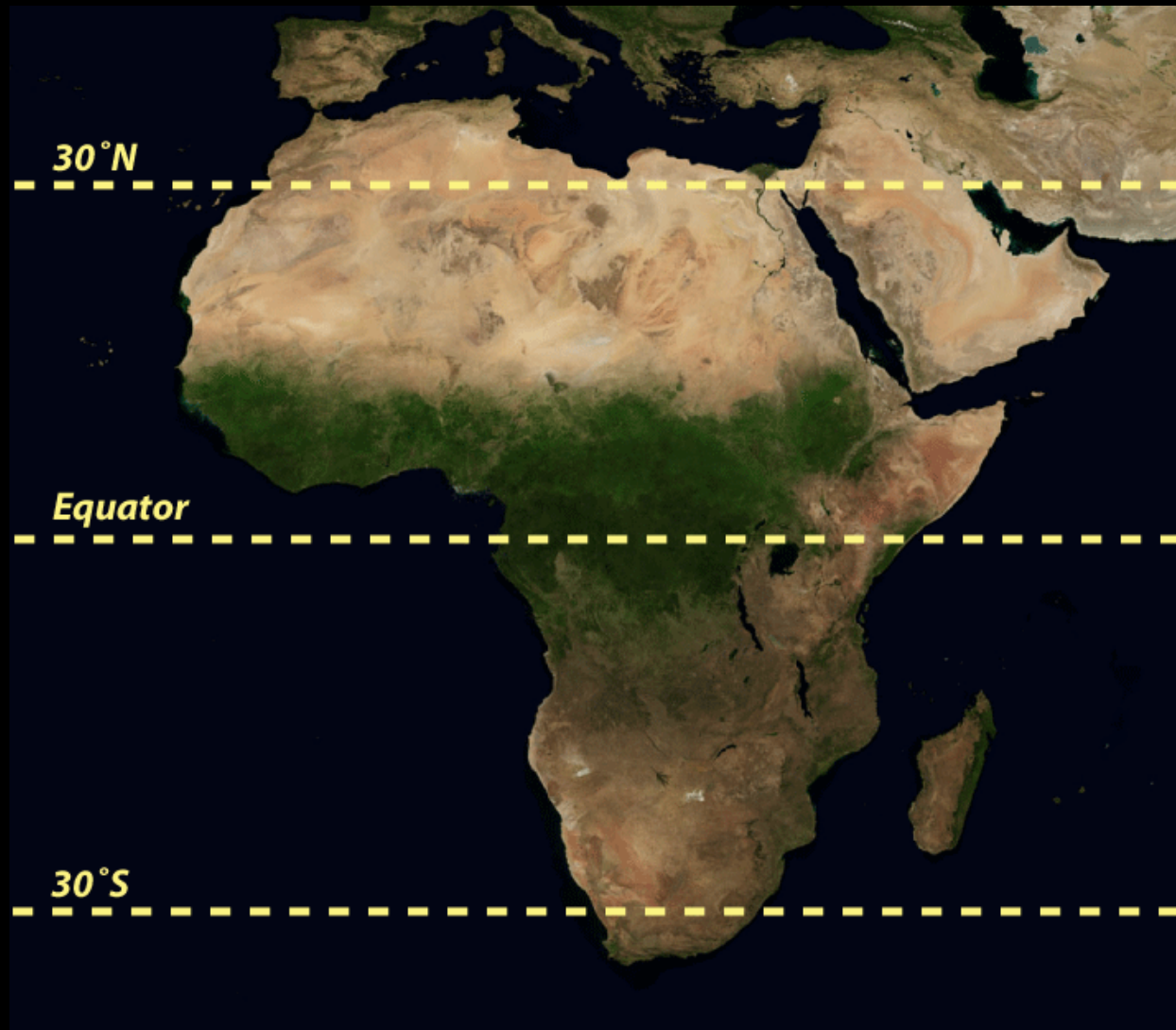


The three-cell model predicts deserts at roughly 30N and 30S -- where precipitation is suppressed by subsidence. The deserts appear bright, owing to the absence of green vegetation.

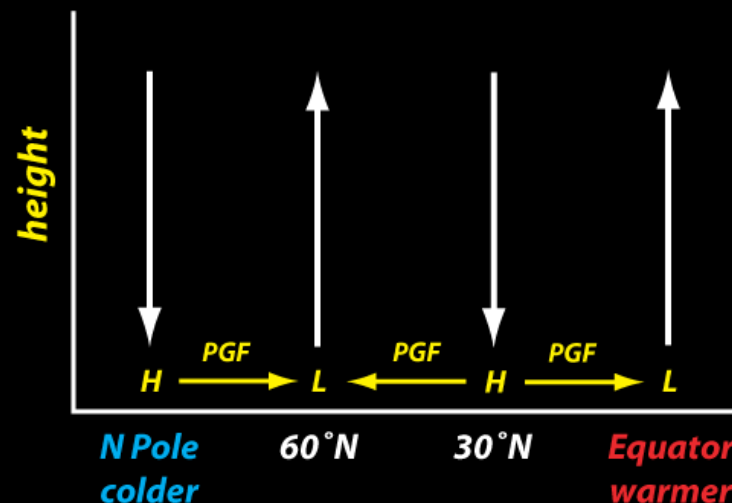


http://earthobservatory.nasa.gov/Features/BlueMarble/BlueMarble_monthlies.php

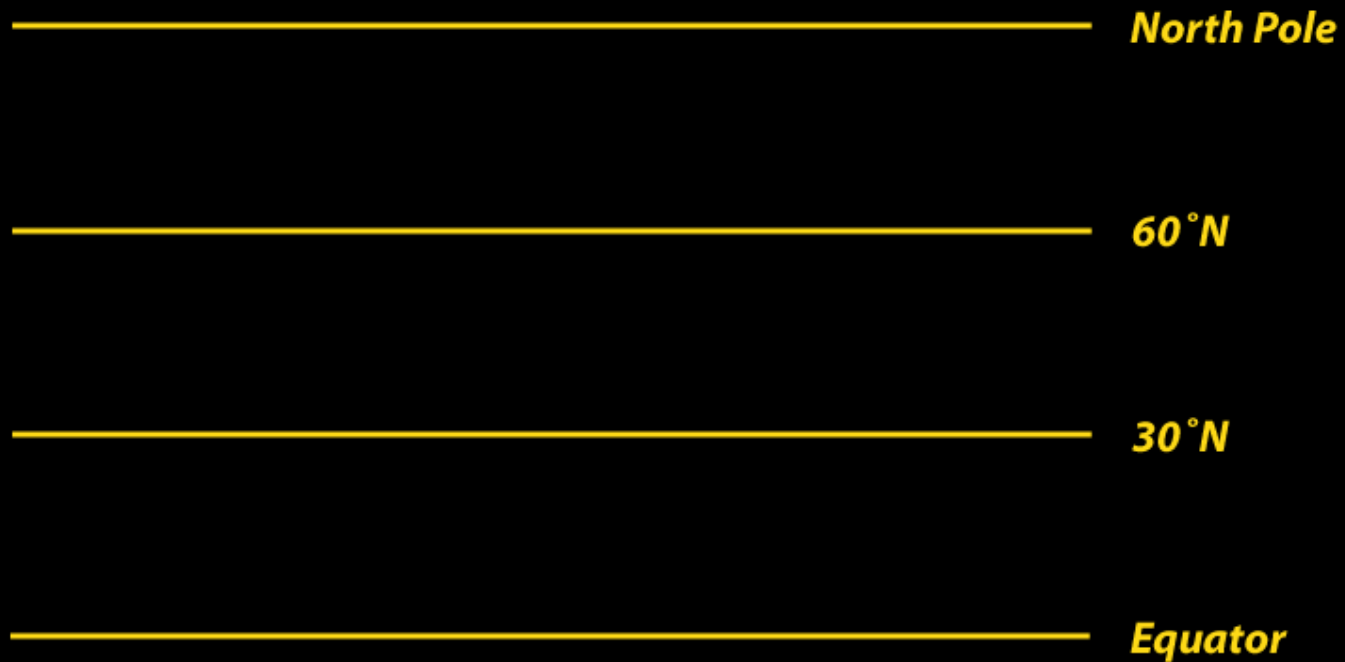
We see the Sahara and Arabian deserts at about 30°N, and also evidence of dry conditions near 30°S. The prevailing ascent near the Equator makes for lush, green conditions there. But the 3-cell picture is far from perfect. Land-sea contrasts, warm and cool seas, elevation and topography also influence where, when and how much precipitation falls.



Now examine the surface pressure gradients.
These are not the winds because other forces are acting,
notably Coriolis.



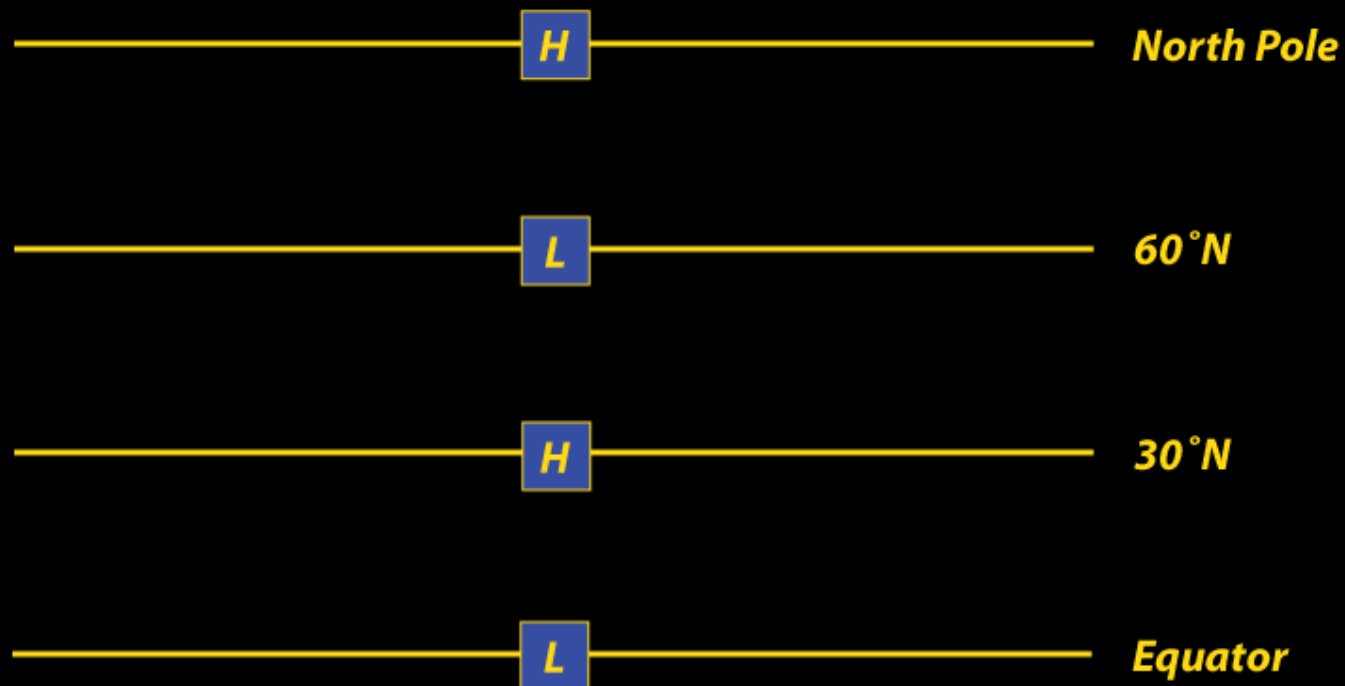
Now consider the surface winds, neglecting friction.
We're looking down on Earth from above.



The three-cell model predicts surface Ls at 60N and the Equator, and surface Hs at the pole and 30N.

What would the geostrophic winds be?

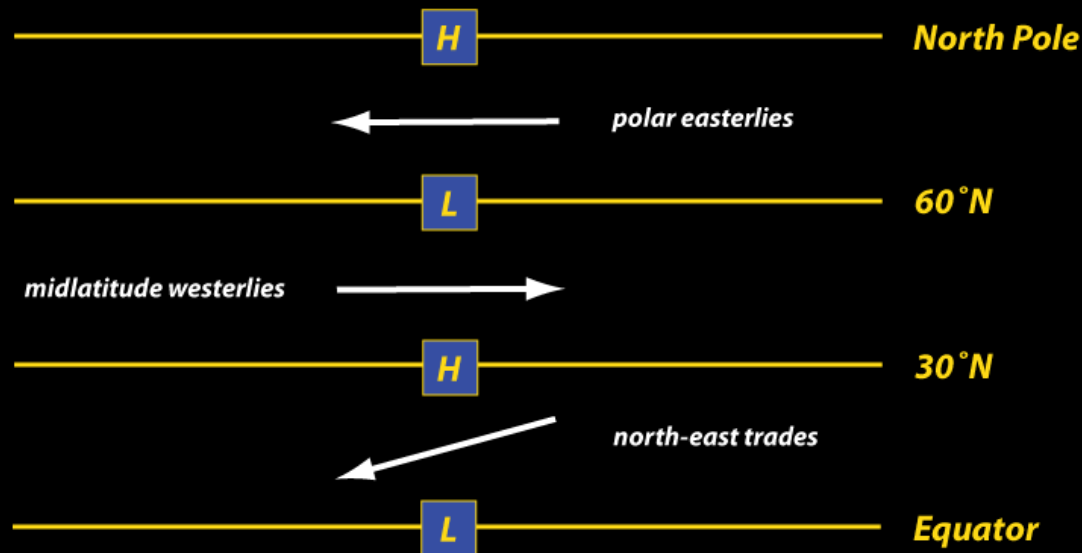
Keep Buys-Ballot's law in mind. We're in the NH, so with the wind at our backs, lower pressure is to the left.



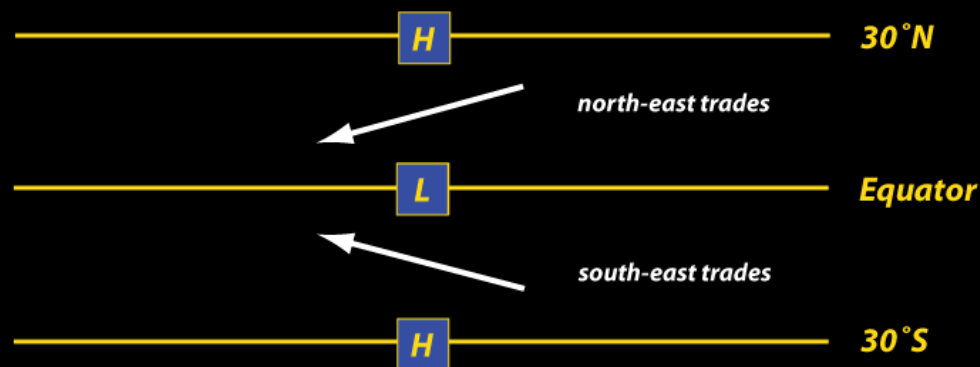
Therefore, geostrophic balance yields a *westerly* wind, directed from west to east, between 30-60N. We call these winds the **prevailing midlatitude westerlies**. Closer to the pole, the winds are easterly - the **polar easterlies**.

These are geostrophic winds, neglecting friction. Friction would let the winds turn a little towards lower pressure.

At the equator, Coriolis vanishes, permitting some component towards L pressure: the **north-east trades**.

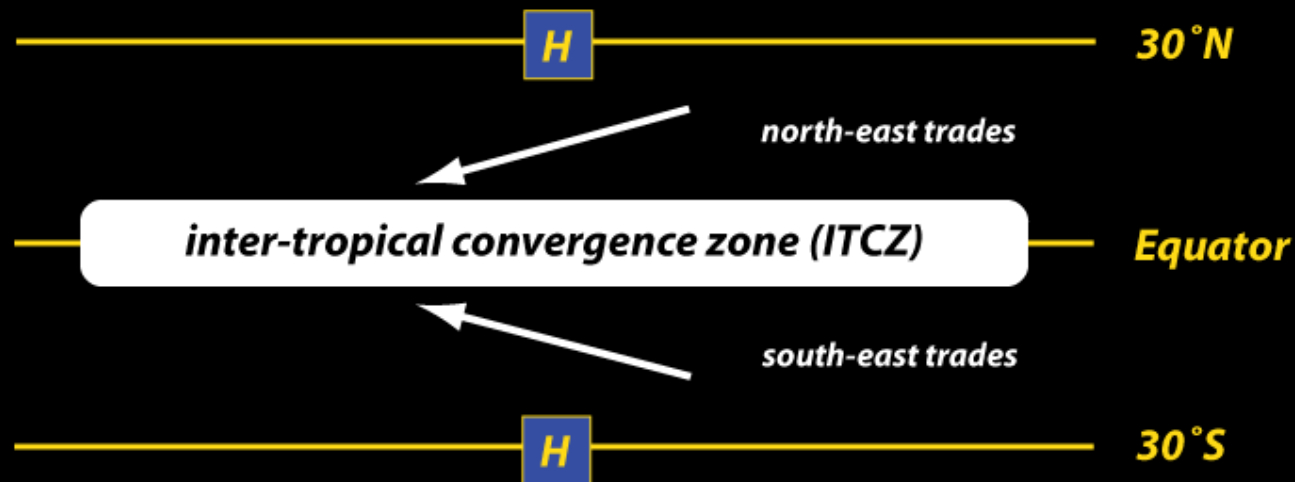


Expand into the S Hemisphere tropics. Coriolis acts to the **left** following the motion there. So the large-scale wind blows with lower pressure to the **right**. With the weaker Coriolis near the equator, we get south-east trade winds between Eq and 30S, also with a component directed towards the equator.



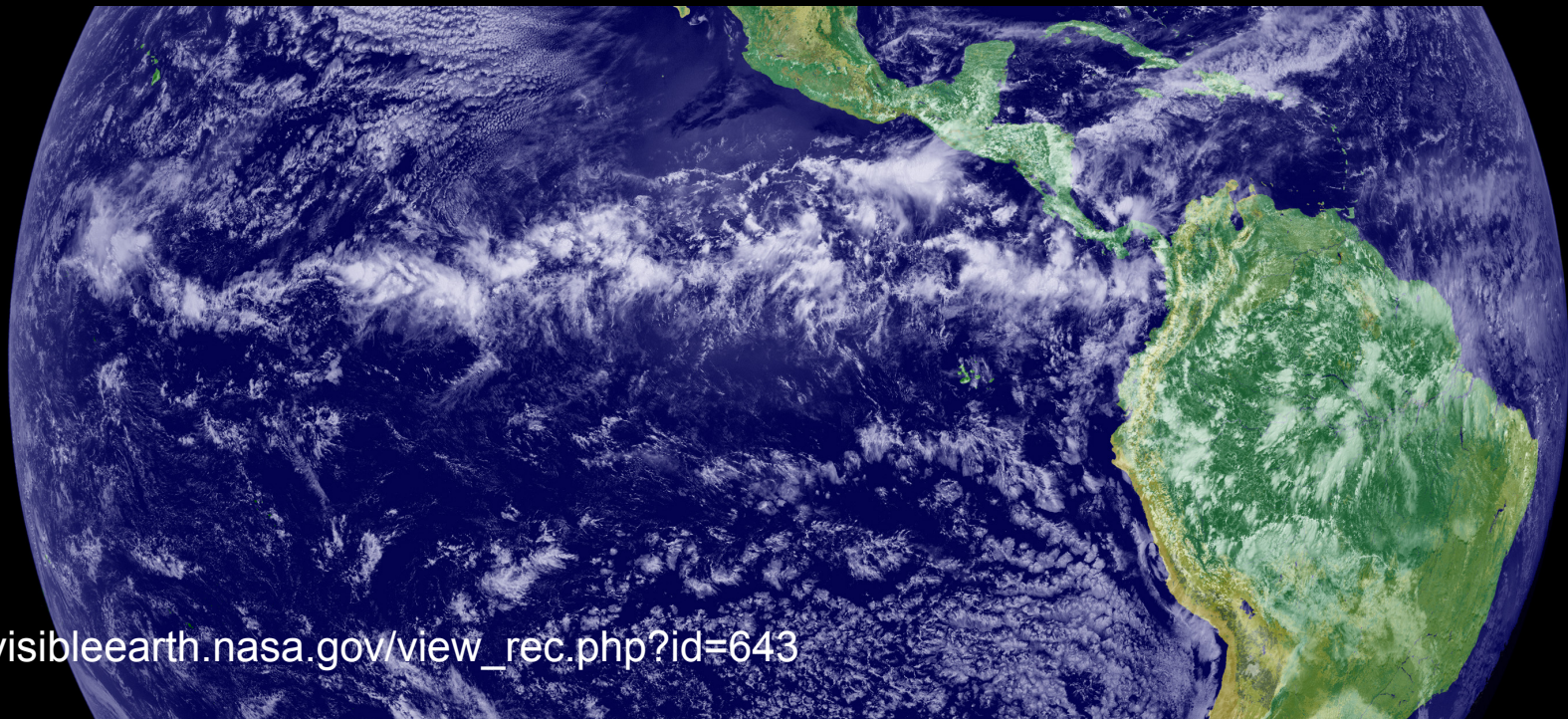
As a result there is a **CONVERGENCE** of surface air at the equator from both hemispheres. This forces sustained rising motion at what we call the **ITCZ**, the **inter-tropical convergence zone**.

A ring of deep convective storms around the planet, where NH and SH air meet.

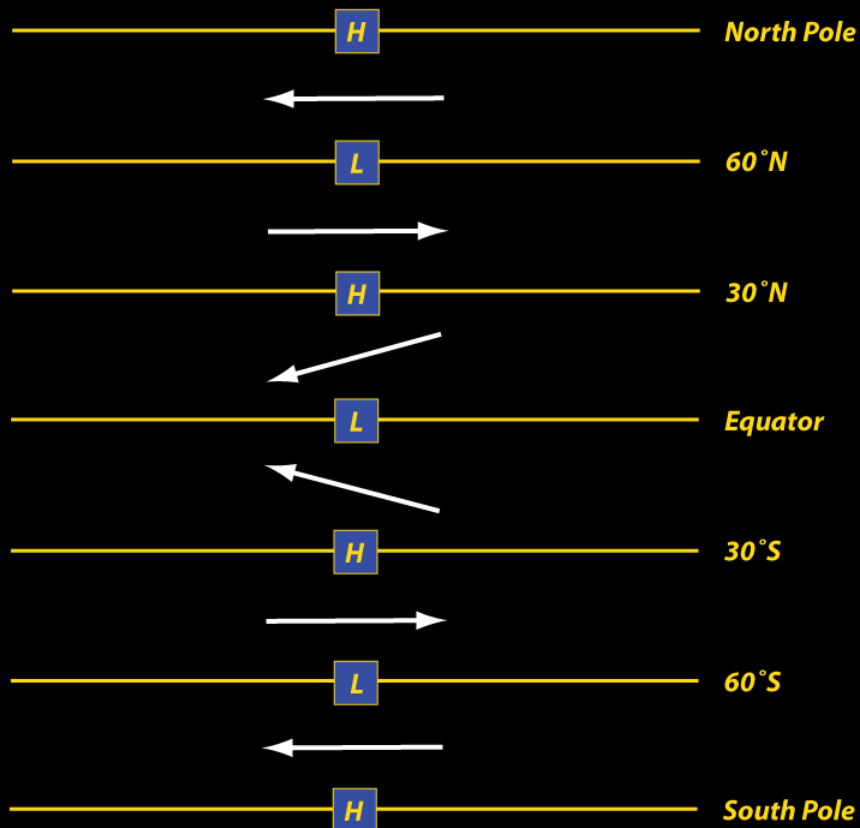


The ITCZ isn't a continuous band of storms, and it isn't usually located exactly ON the Equator either.

Take a look at this beautiful view from space, also courtesy of NASA. We see the ITCZ is pushed a few degrees of latitude N of the Equator. Its precise location actually varies with the seasons.

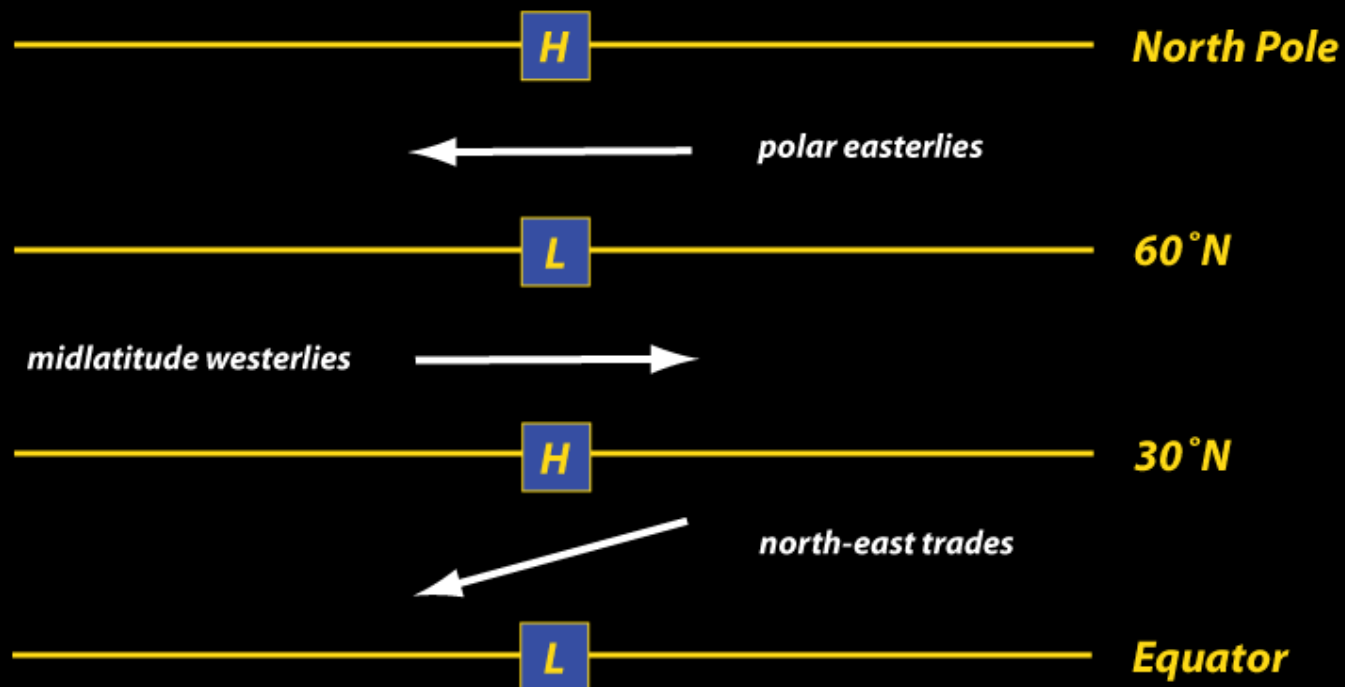


http://visibleearth.nasa.gov/view_rec.php?id=643

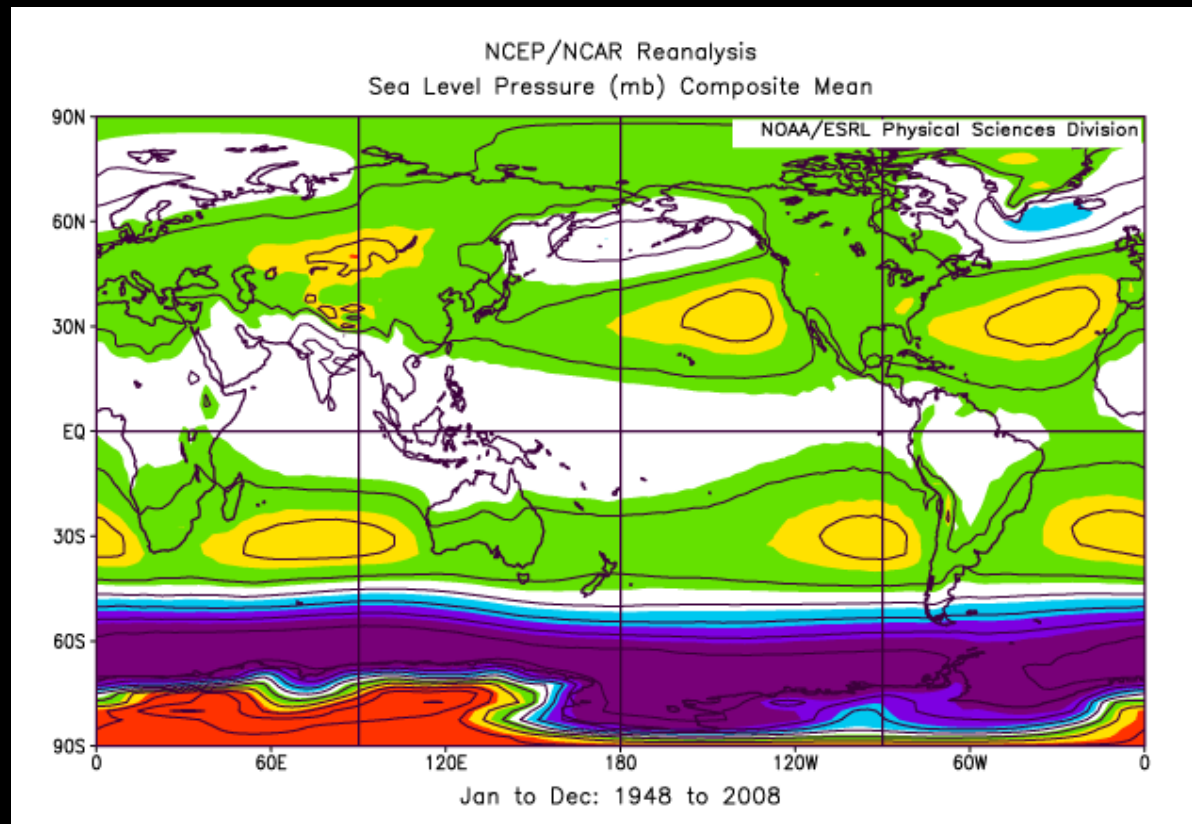


- Finally, look at both hemispheres simultaneously.
- We see both have westerly winds in midlatitudes and easterlies near the poles.
- The only real difference is the tropics, where the atmosphere is pushing air towards the equator from BOTH sides.

This is a very idealized model, presuming no complications such as land surfaces and topography.
How well does this hold up in reality?

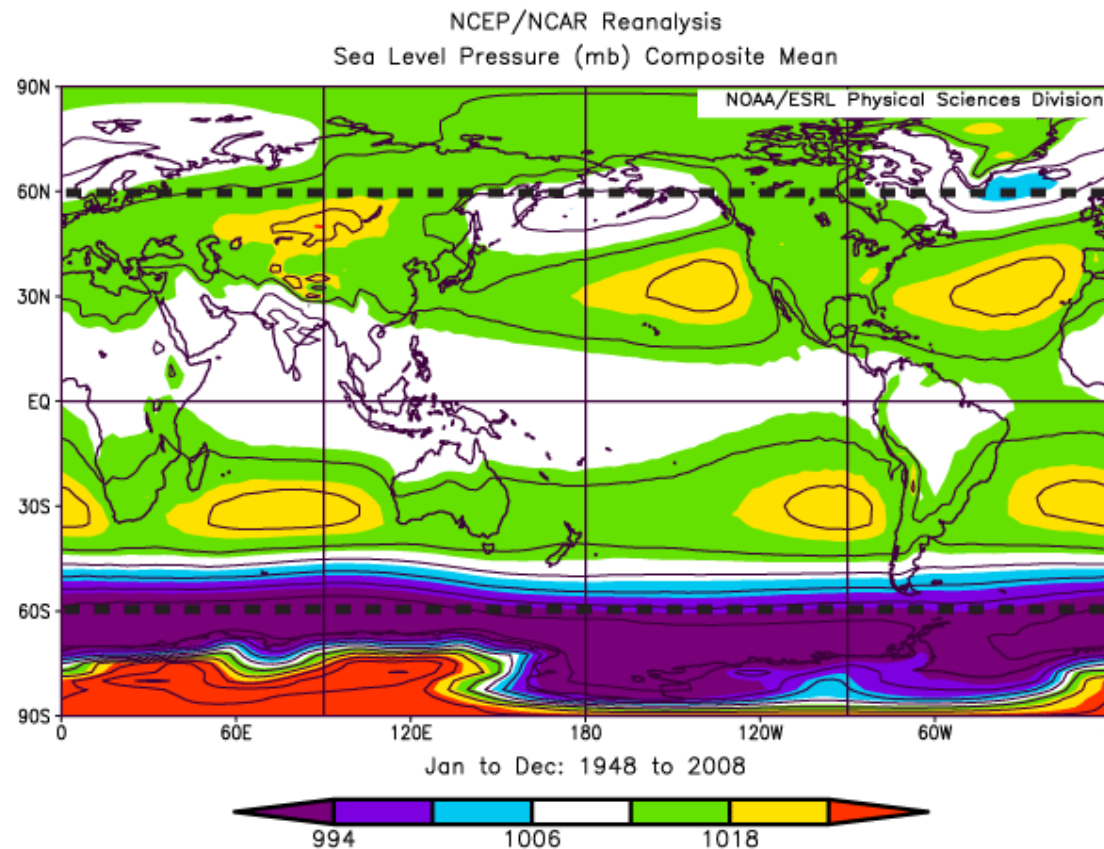


This is a map of long-term annual average SLP.
Warmer colors from green to red indicate areas of progressively higher pressure. Cooler colors from white to purple indicate lower pressure.



<http://www.cdc.noaa.gov/cgi-bin/data/composites/printpage.pl>

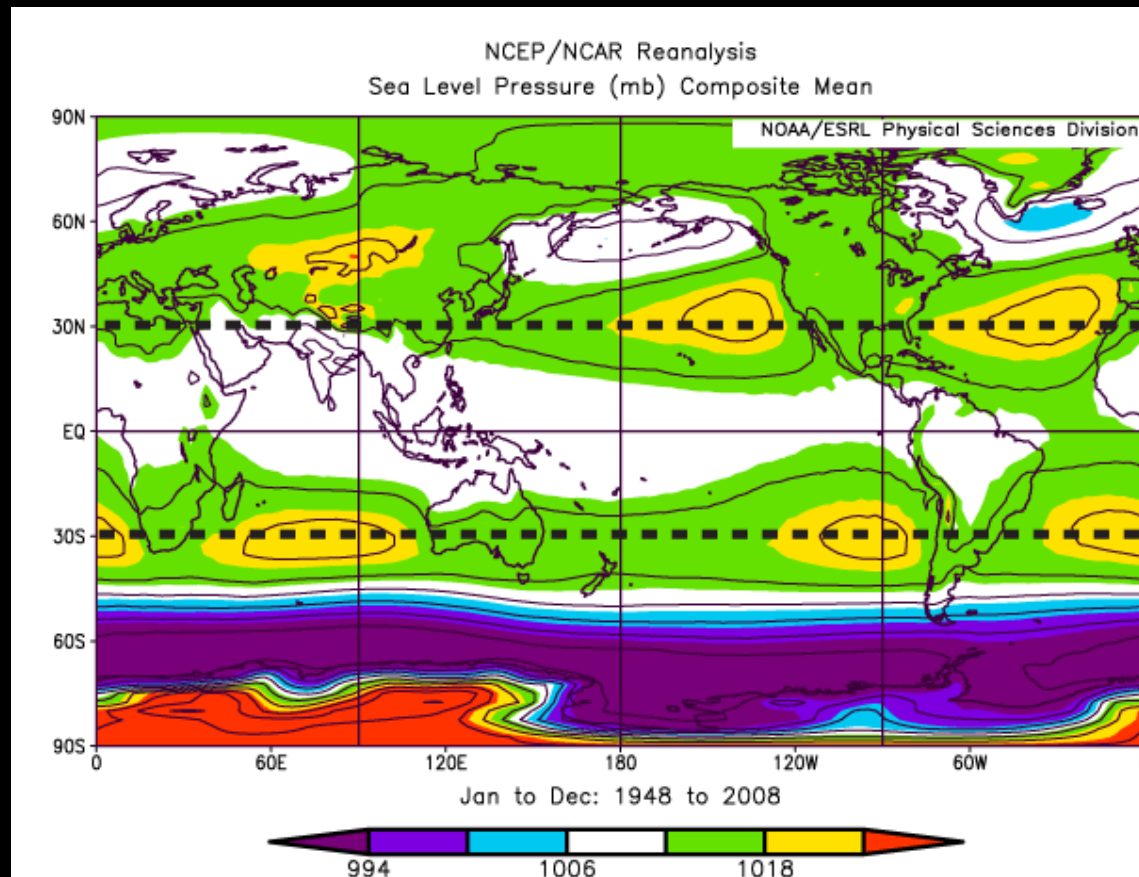
We expect to see L SLP at the equator and 60N/S.
This shows up VERY WELL in the SH, where there is a lot less land to complicate the picture... ESPECIALLY at 60S, which lies over the Southern Ocean ringing the Antarctic continent.
The equator L belt -- that white swath across the middle -- is less prominent, and at 60N the lows are crowded into the relatively narrow ocean areas at that latitude.



We also expect high pressure at 30N and S and also at the poles.
And pressure IS higher at 30deg, but it's also COMPLICATED by land/sea arrangements. Over the eastern Pacific and Atlantic oceans are our

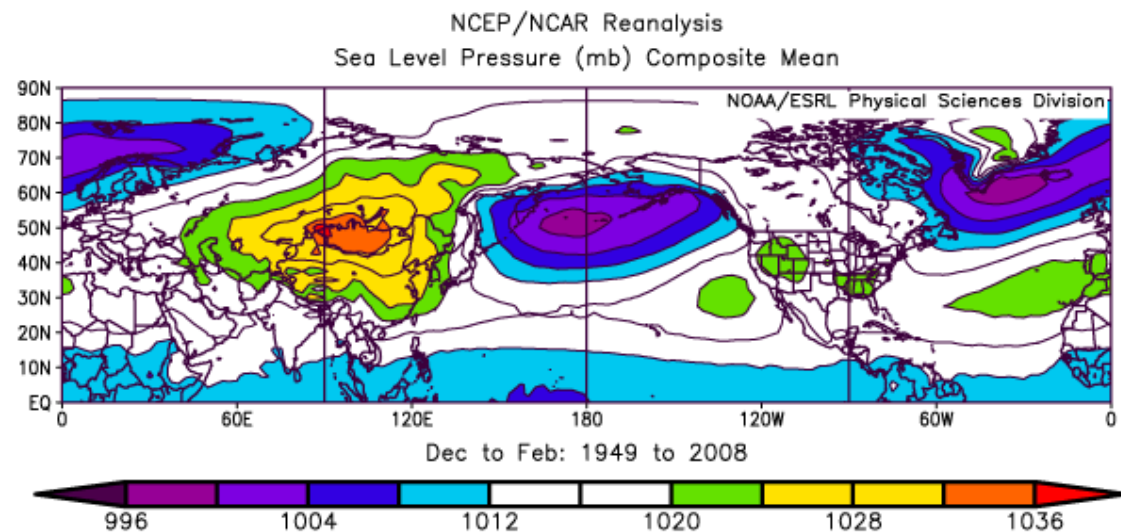
SUBTROPICAL HIGHS: the Pacific H and the Bermuda H.

Note there is also high pressure over Asia, but it's shifted well northward from the 30th parallel. While local H pressure at the NP is hard to see the south polar H is VERY prominent, aided by the extreme COLD of the Antarctic continent.



In NH winter, we see that our L pressure areas at 60N over the N Pacific and Atlantic Oceans are now very prominent.
These are the **Aleutian and Icelandic Lows**.

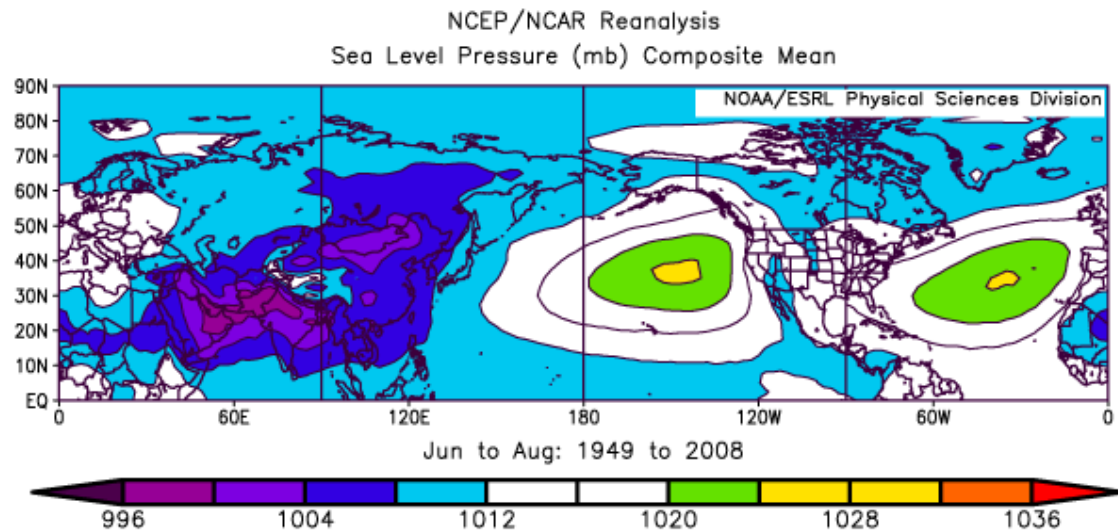
In winter, the subtropical highs at 30N are weak.
The highest pressure by far is over interior Asia,
which is very cold.

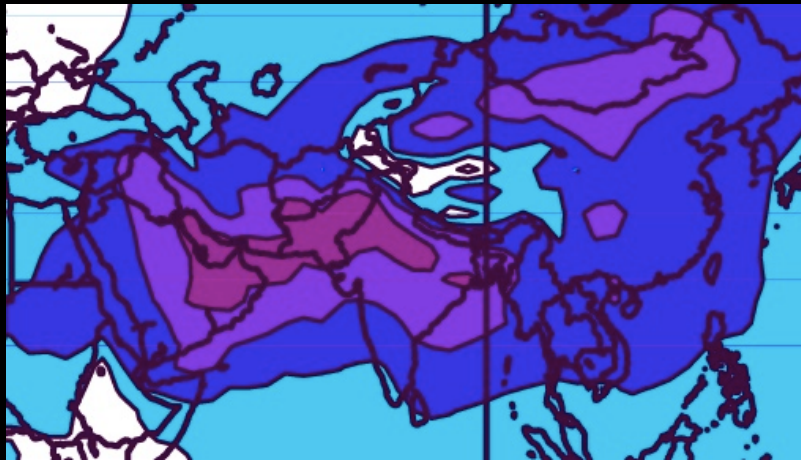


In NH summer, the Aleutian and Icelandic lows are absent and our subtropical Pacific and Bermuda Hs are prominent -- and dominant.

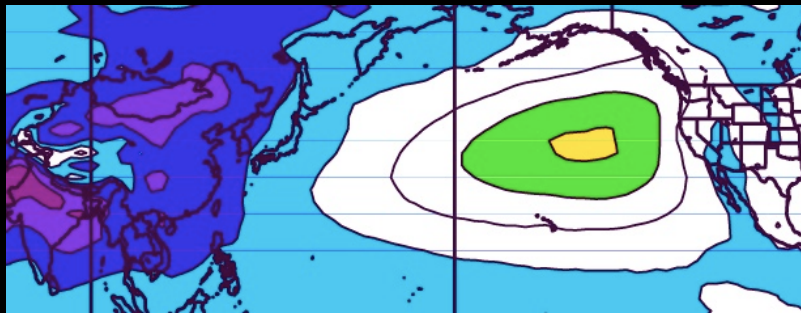
Notice the lowest pressures are over the LAND areas.

This reflects warm season heating of the land as in the sea-breeze circulation.

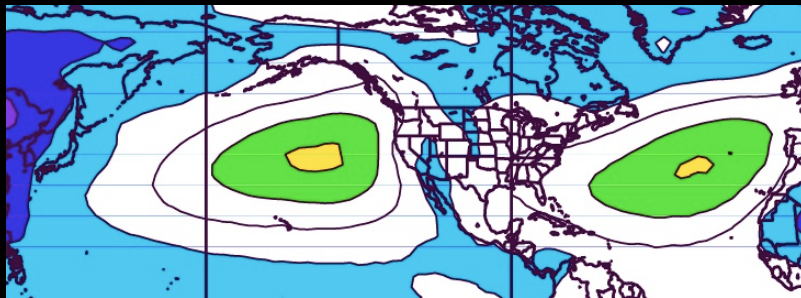




- Zoom in on Southern Asia, where the SLP is particularly low over a wide area.
- We're seeing an important element of the MONSOON here.
- Despite the complications of Coriolis, this deep low pressure over land is pulling warm, extremely moist air from the Indian Ocean onshore... leading to terrific rains, especially when and where aided by topographic lifting

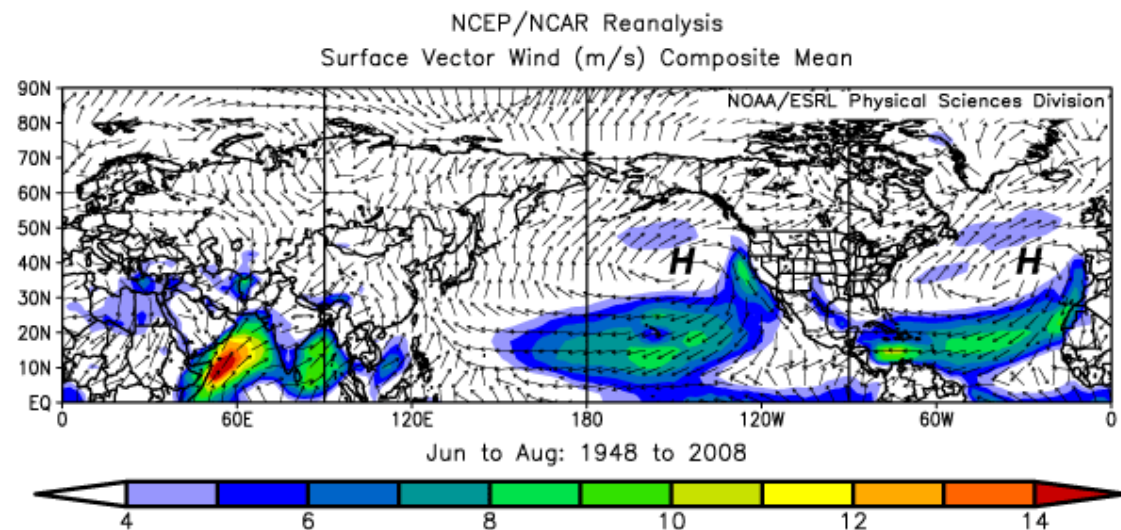


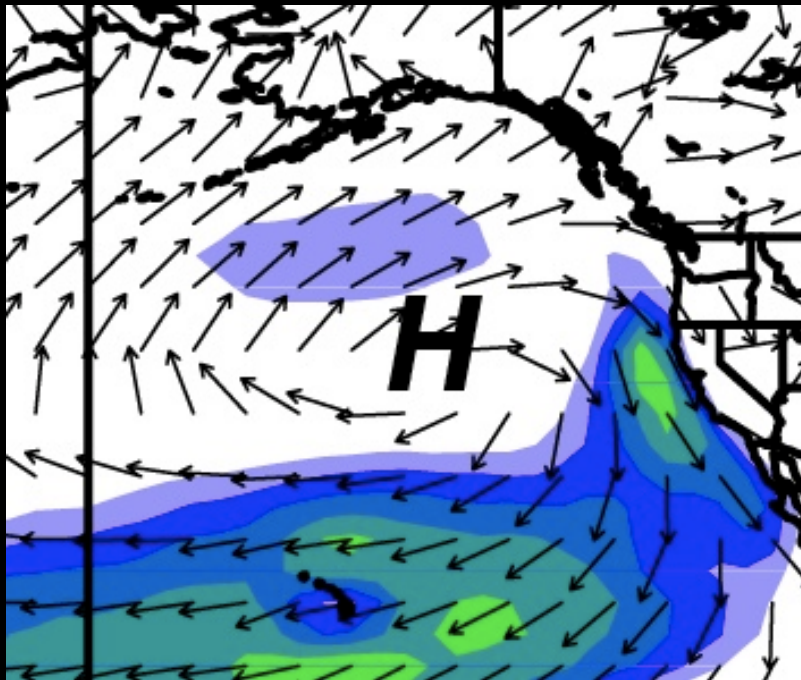
- Turn eastward, to the Pacific
- According to the 3 cell model, the primary sea-level pressure gradient is N-S, from the 30N H to the equatorial L
- And there IS a N-S gradient like this... in the E Pacific anyway
- But the W-E gradient -- between the Asian L and the Pacific H -- looks so much more substantial.
- And it's important, in part because it exists.. And in part because it VARIES in time.



- Now consider our two powerful subtropical H's.
- These are NH anticyclones, so they have CW flow
- The strong summertime CW flow around the BERMUDA high carried Columbus' ships from Spain to the Caribbean
- Columbus left in August, and arrived in the Bahamas in October.
- The Bermuda and Pacific Highs carry other things across the ocean as well... hurricanes.

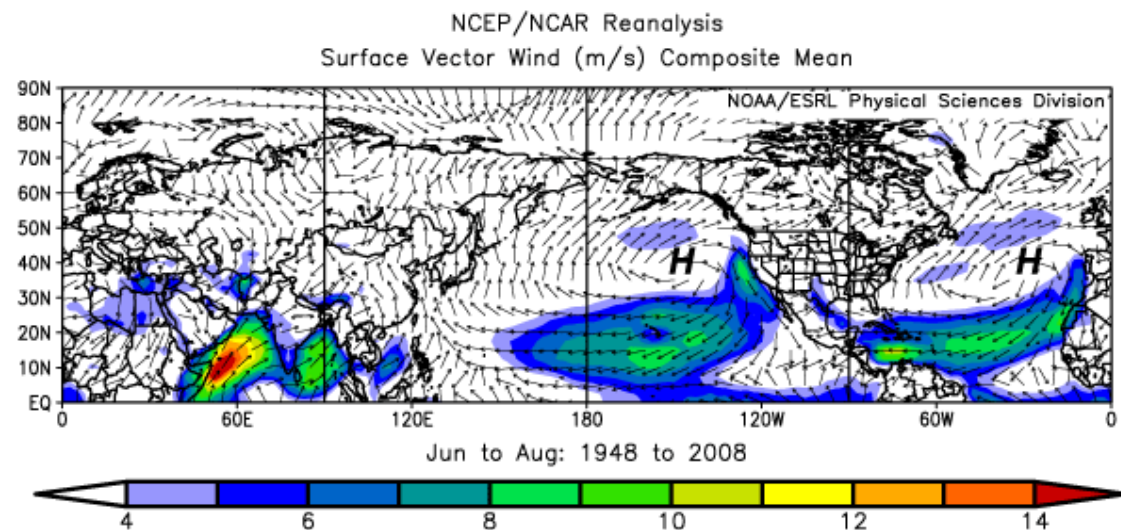
These vectors depict summer surface winds.
Recall gradient wind balance is the result of three forces:
PGF, Coriolis and centripetal/centrifugal.
We expected to see CW flow around the Pacific and
Bermuda Highs, and we do.
Let's zoom in on the east Pacific.





- Since these are SURFACE WINDS, we could also expect to see DIVERGING winds out of these Highs.
- And we do see this... though maybe not as much as we might have expected.
- Note the Pacific and Bermuda highs are over water.
- The ocean surface generally exerts less drag on the wind than a typical land surface.
- I'd expect even more surface divergence out of land-based anticyclones

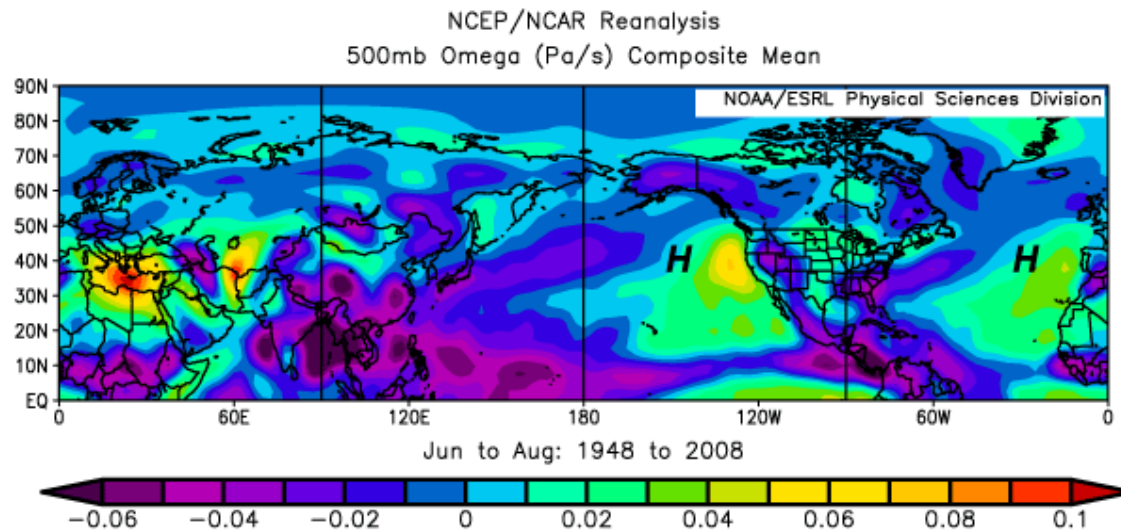
The colored areas on this figure indicate wind speed, from calm (white) to strong (green and red). We see strong winds south of BOTH subtropical highs heading southwestward towards the equator. Those are the northeast trades.



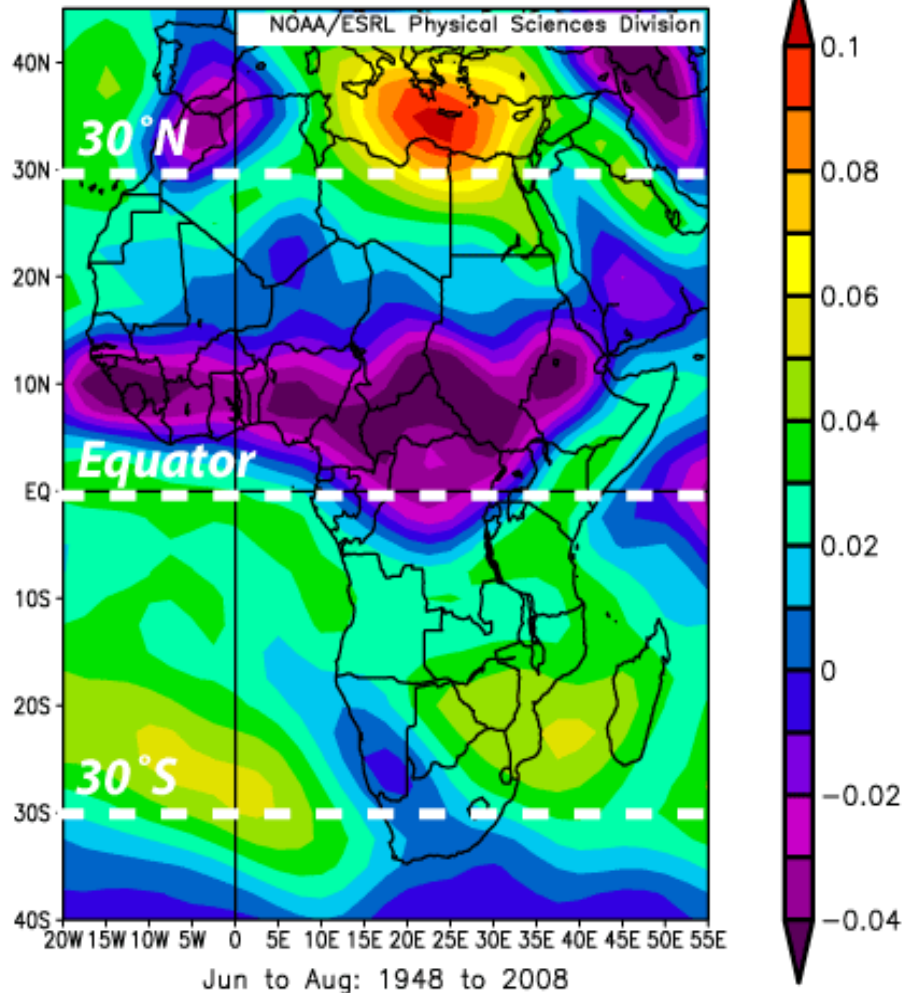
What else do we expect to see with high pressure?

From both the one-cell sea-breeze model or the three cells forced by Earth rotation, we associate high pressure areas with DESCENDING MOTION.

This plot shows where air is sinking in the NH at the 500 MB LEVEL.
Remember that's roughly 5.5 km or 3.5 mi above sea-level.
Warm colors are descent, the redder the stronger.

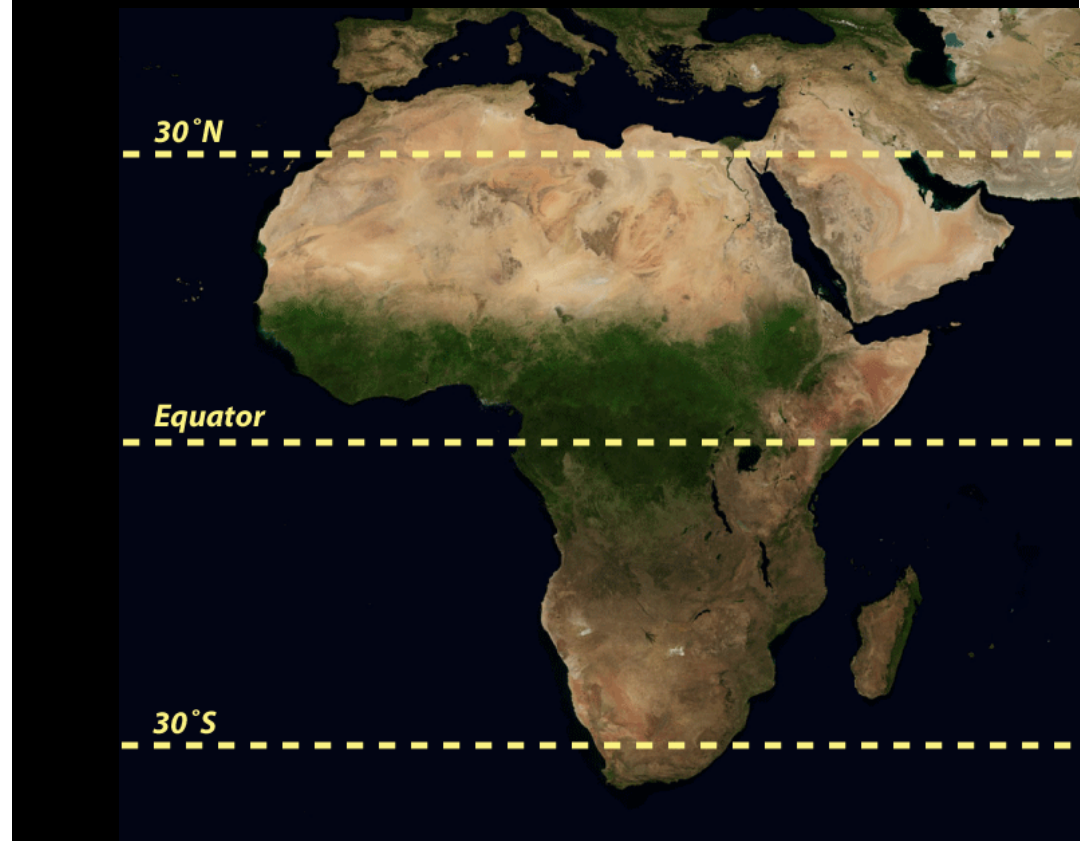
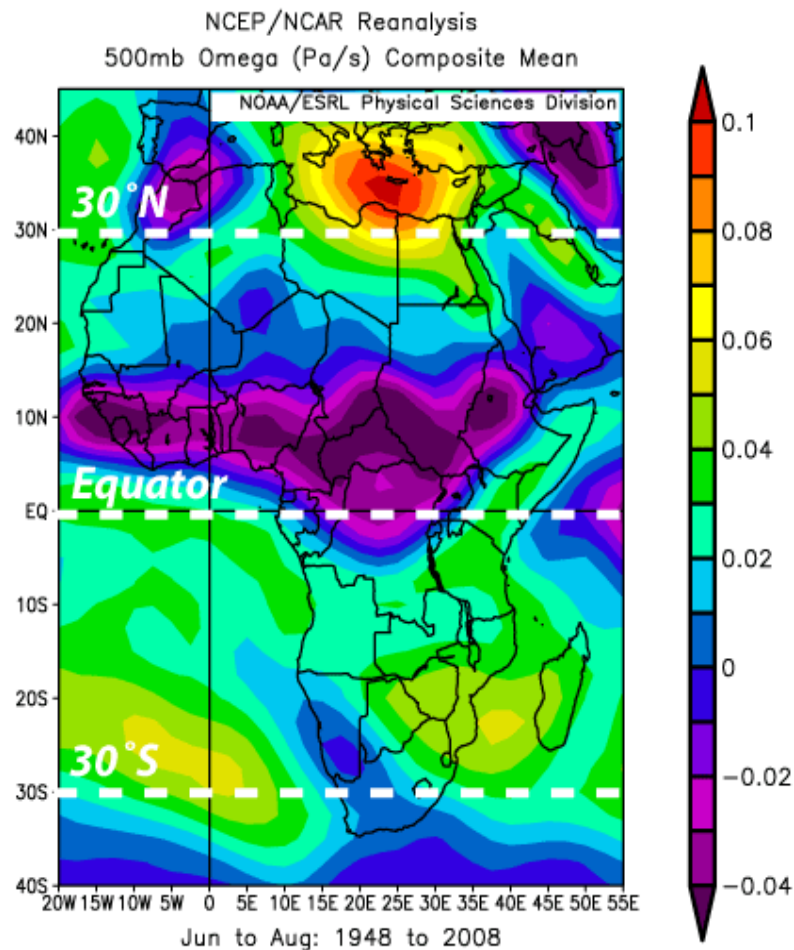


NCEP/NCAR Reanalysis
500mb Omega (Pa/s) Composite Mean

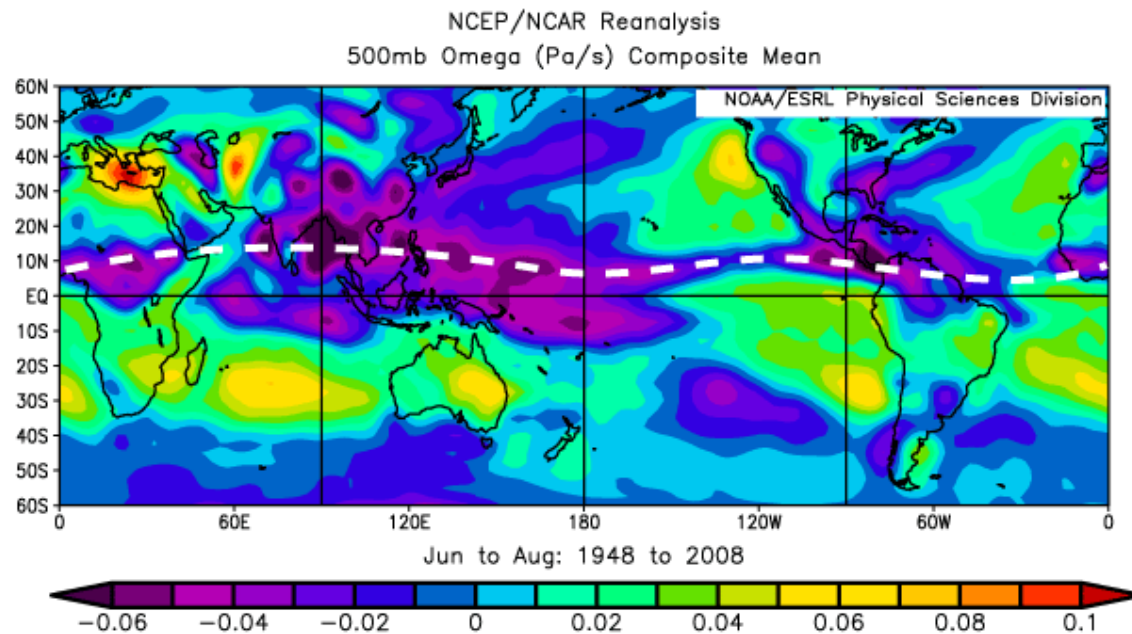


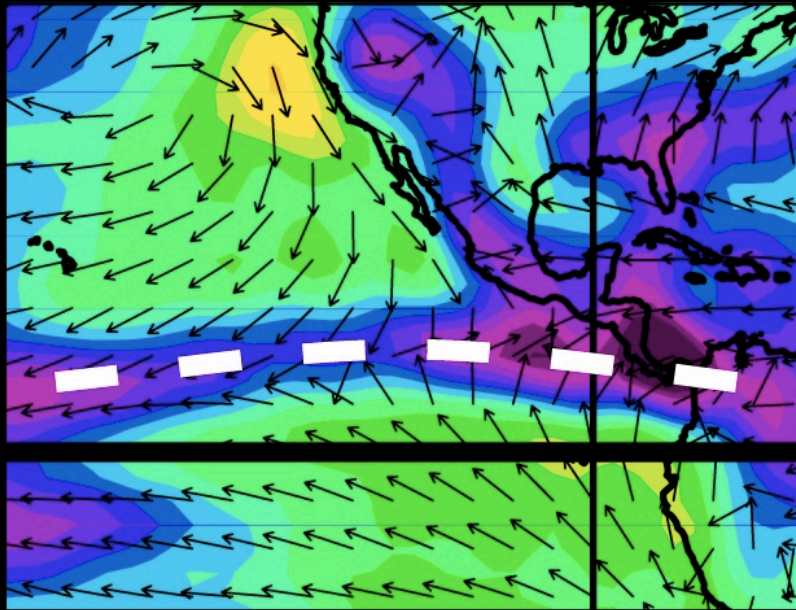
- The bullseye of strongest descent is over the Mediterranean, near Crete.
- That's 30N, so the latitude's right, but something EXTRA has to be going on there.
- And note the purple regions of ascent to the west, over the Straits of Gibraltar, and to the east... ascending air **DESPITE** being at the latitude of general subsidence.
- Something's complicating this picture. We'll see what it is soon.

We can compare Africa's vegetation with our regions of ascent and descent. The regions of purple ascent and green land -- and also red descent and bright, dry land -- match very well. There is widespread downward motion over South Africa... and also over Somalia. Subsidence has robbed the Horn of Africa of the equatorial lushness we see farther west on the continent at the same latitude.

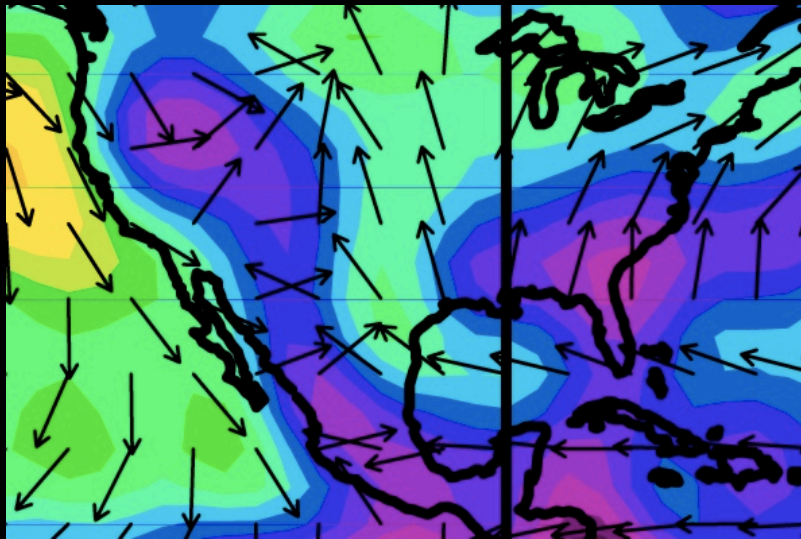


Highlighting the ITCZ, how it looks during NH summer.
Note that it resides up to 10 deg N of the equator.

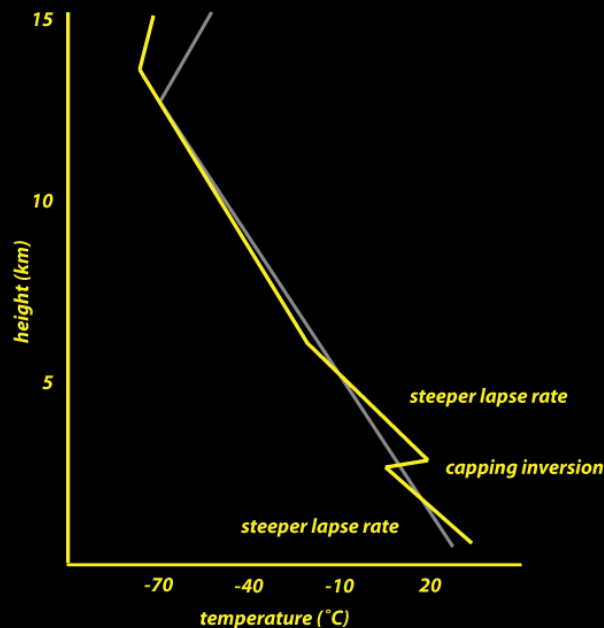




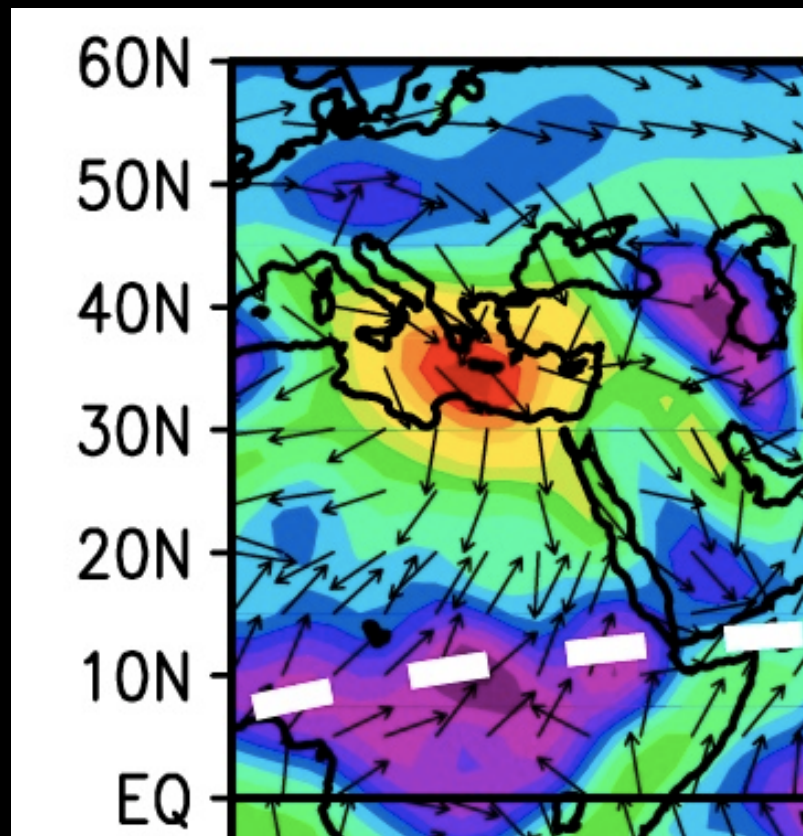
- Now focus on the E Pacific, N of the equator
- Note how THIN the line of ascent is there.
- This is air managing to rise despite being squeezed in between the two large subtropical highs.
- The ITCZ might not look like much in this region, but it's still very important for tropical cyclone development.



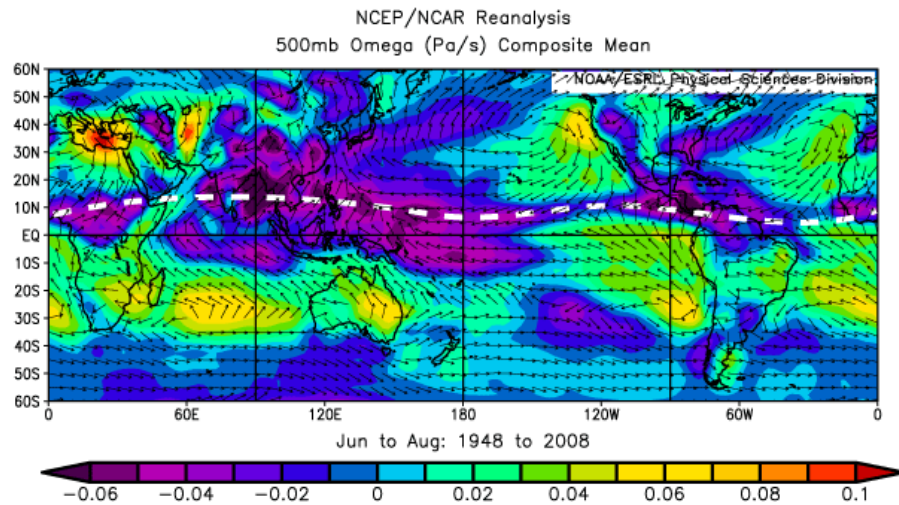
- Surface midlatitude westerlies largely absent in the US Great Plains, thanks in large part to the Rocky Mountains
- Instead, warm and moist air from the Gulf
- Above that air, subsidence is present owing to the Rockies.
- This is **tornado alley**



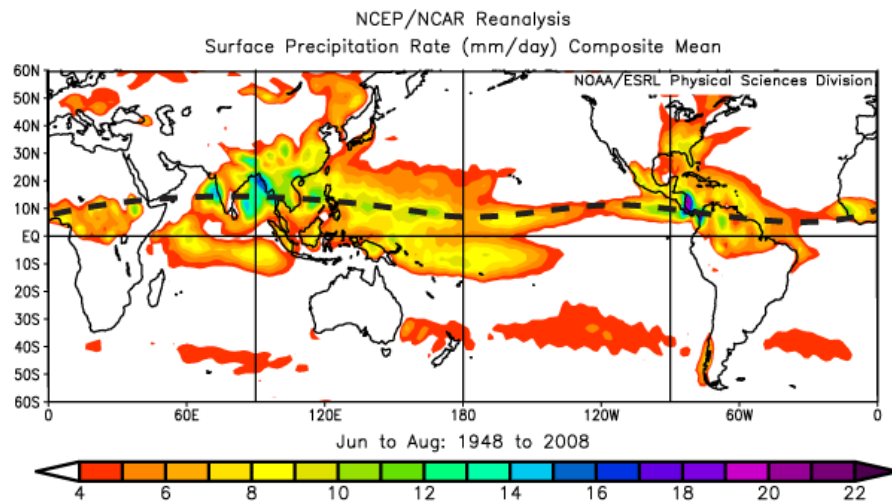
- That subsidence creates and maintains the **CAPPING INVERSION** I mentioned in Lecture 9
- This inversion is keeping the lid on surface air, preventing it from rising and becoming positively buoyant
- But, in many ways, it's like a pressure cooker, heating up during the day... until surface parcels can get LFCs
- We call this the **loaded gun sounding**

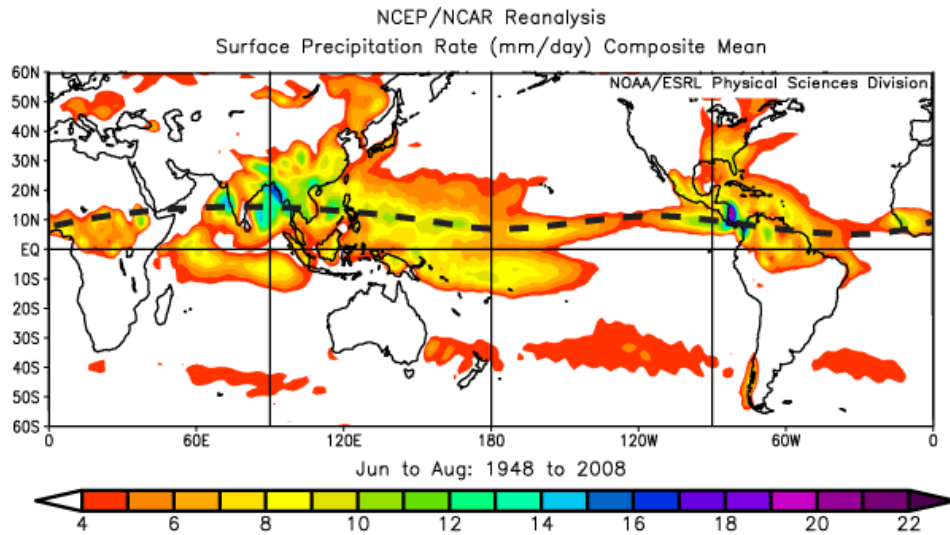


- That Mediterranean hotspot is also due to mountain-induced subsidence, by the Alps
- And both land and topography conspire again to complicate our simple 3 cell view of the world.



- Where there is convergence and ascent, there can be rain. There is a good correlation between the purples of ascent and the regions of heavy precipitation (colored orange, yellow and green).

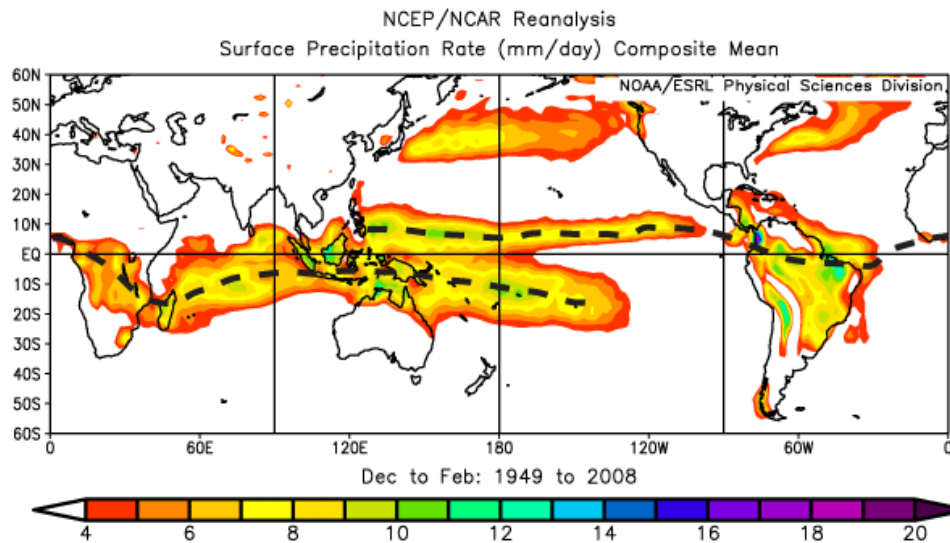




We can compare precip for the
NH summer w/ NH winter,
which is SH summer

The largest difference in the NH
is in the northern Pacific and
Atlantic for WINTER, where
we now see the STORM
TRACKS associated with the
Aleutian and Icelandic lows.

The precip is not confined to the
latitude of 60N. It's more
complex than that.



[end]