Meteorology – Lecture 20

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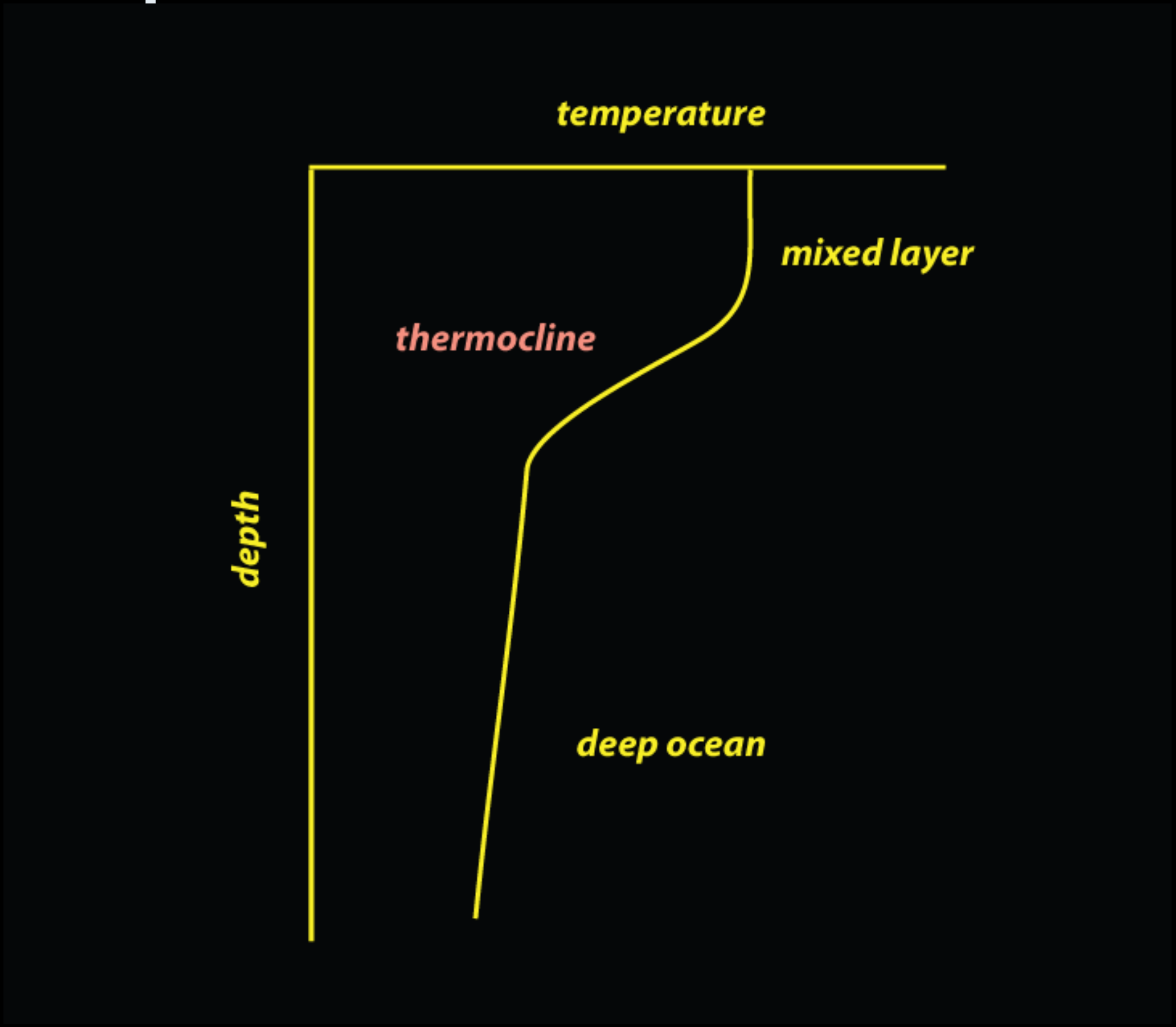
Important notes

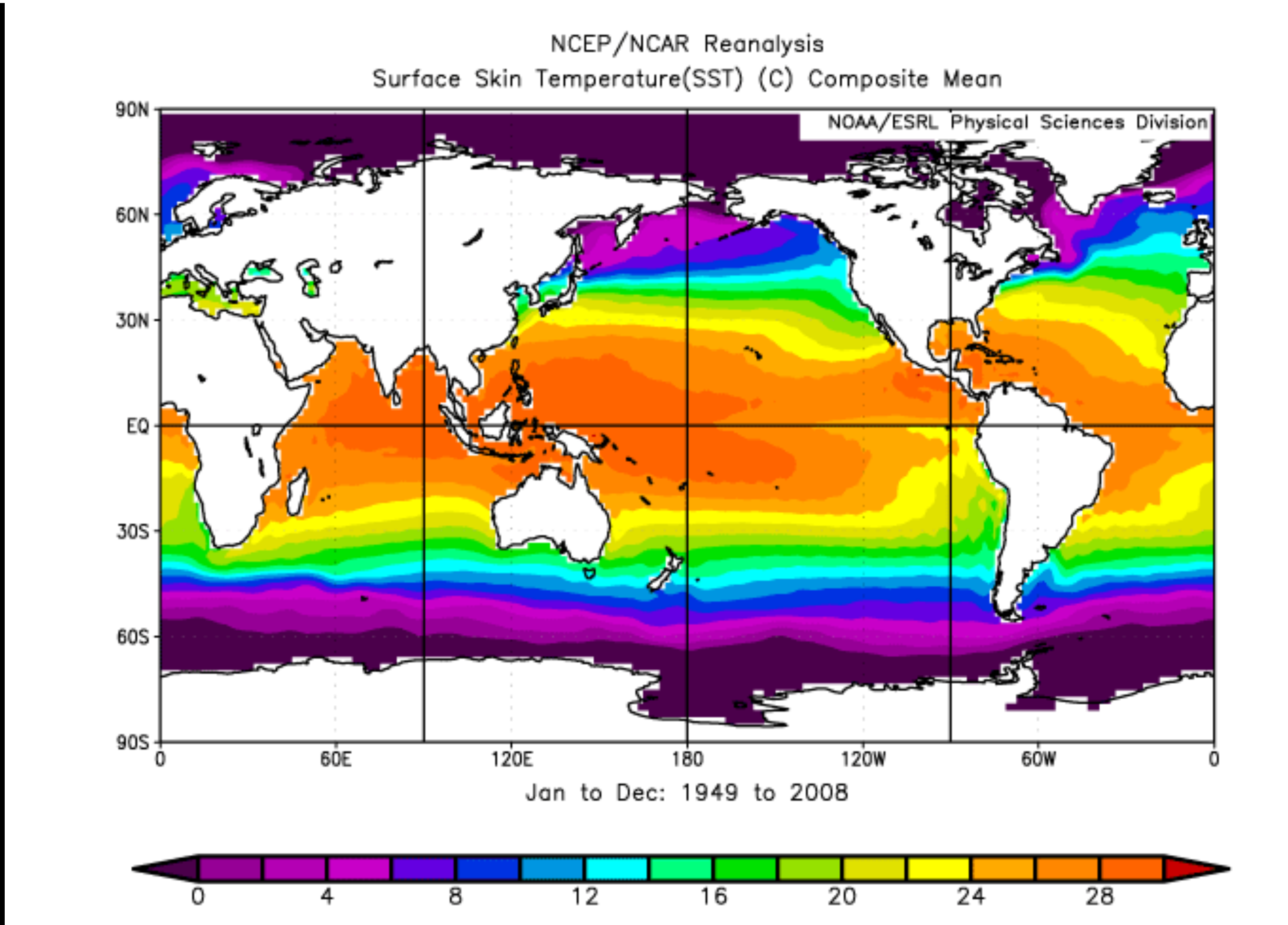
- These slides show some figures and videos prepared by Robert G. Fovell (RGF) for his “Meteorology” course, published by The Great Courses (TGC). Unless otherwise identified, they were created by RGF.
- In some cases, the figures employed in the course video are different from what I present here, but 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.

Animations linked in the PowerPoint version of these slides may also be found here:

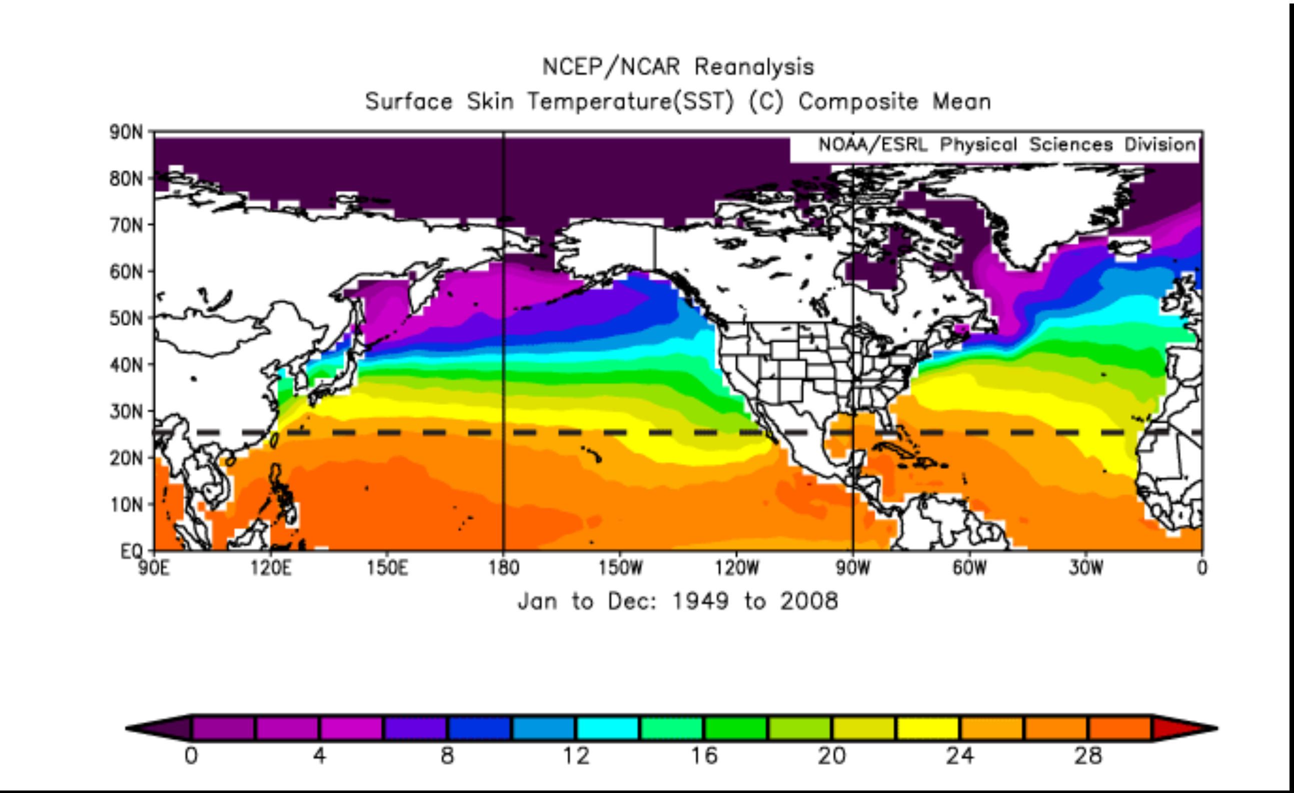
http://people.atmos.ucla.edu/fovell/meteo/

Vertical variation of temperature in the ocean

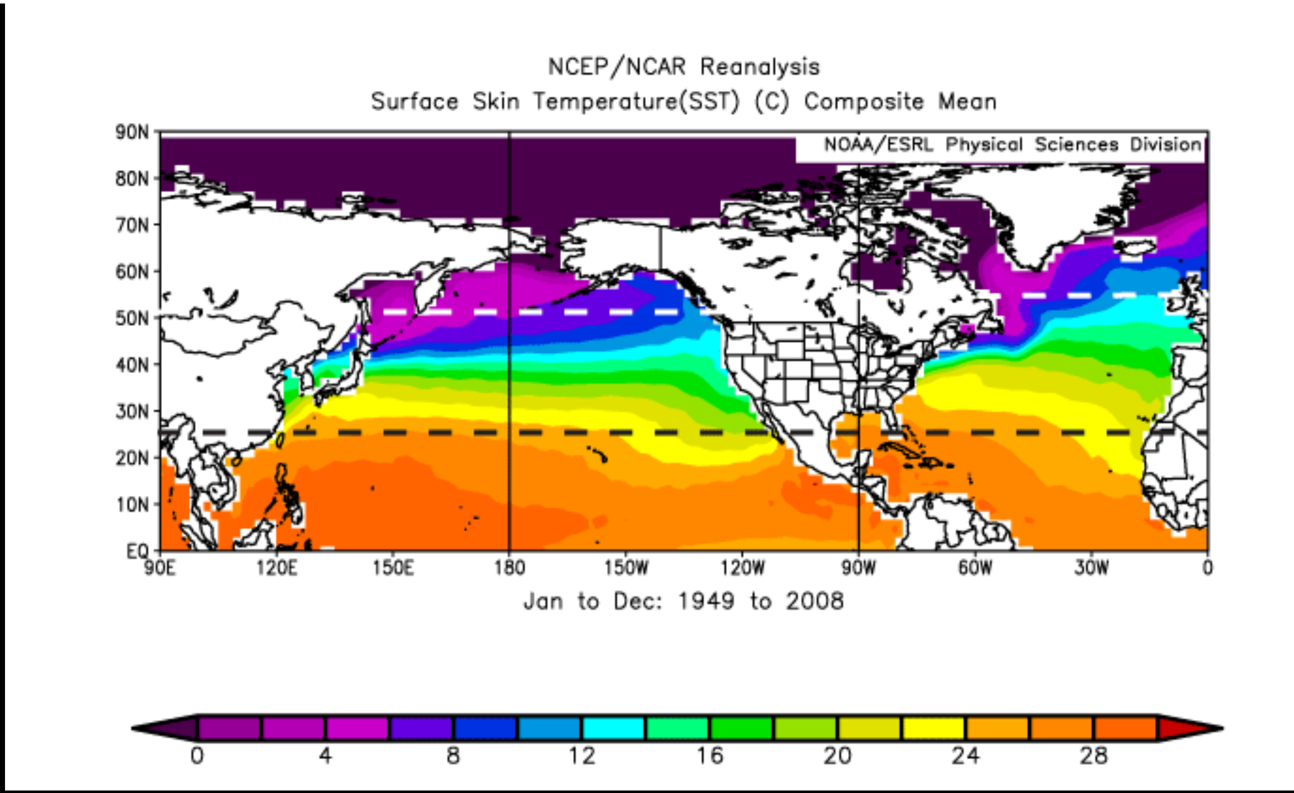




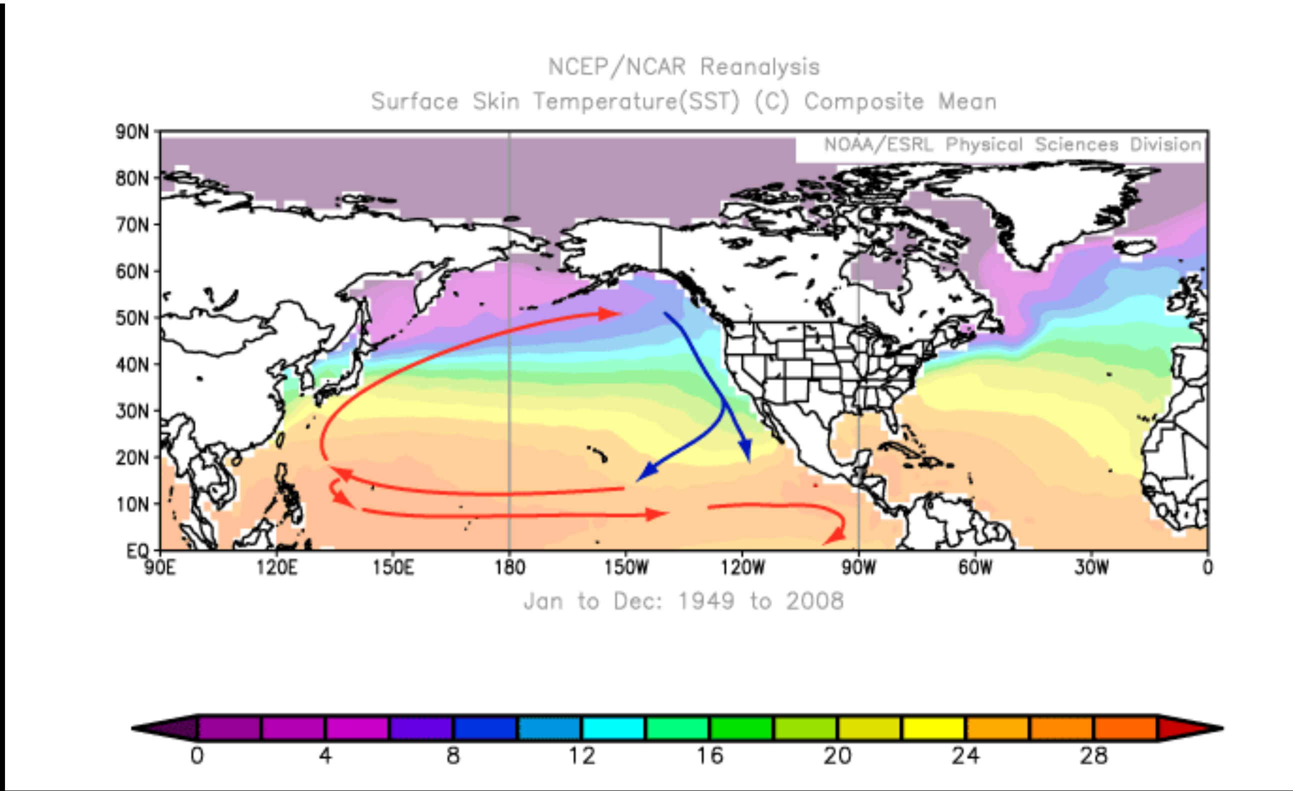
Here's a plot of annual average sea-surface temperature (SST). Latitude is a fairly good proxy for temperature. And yet there are very interesting departures from that simple picture.



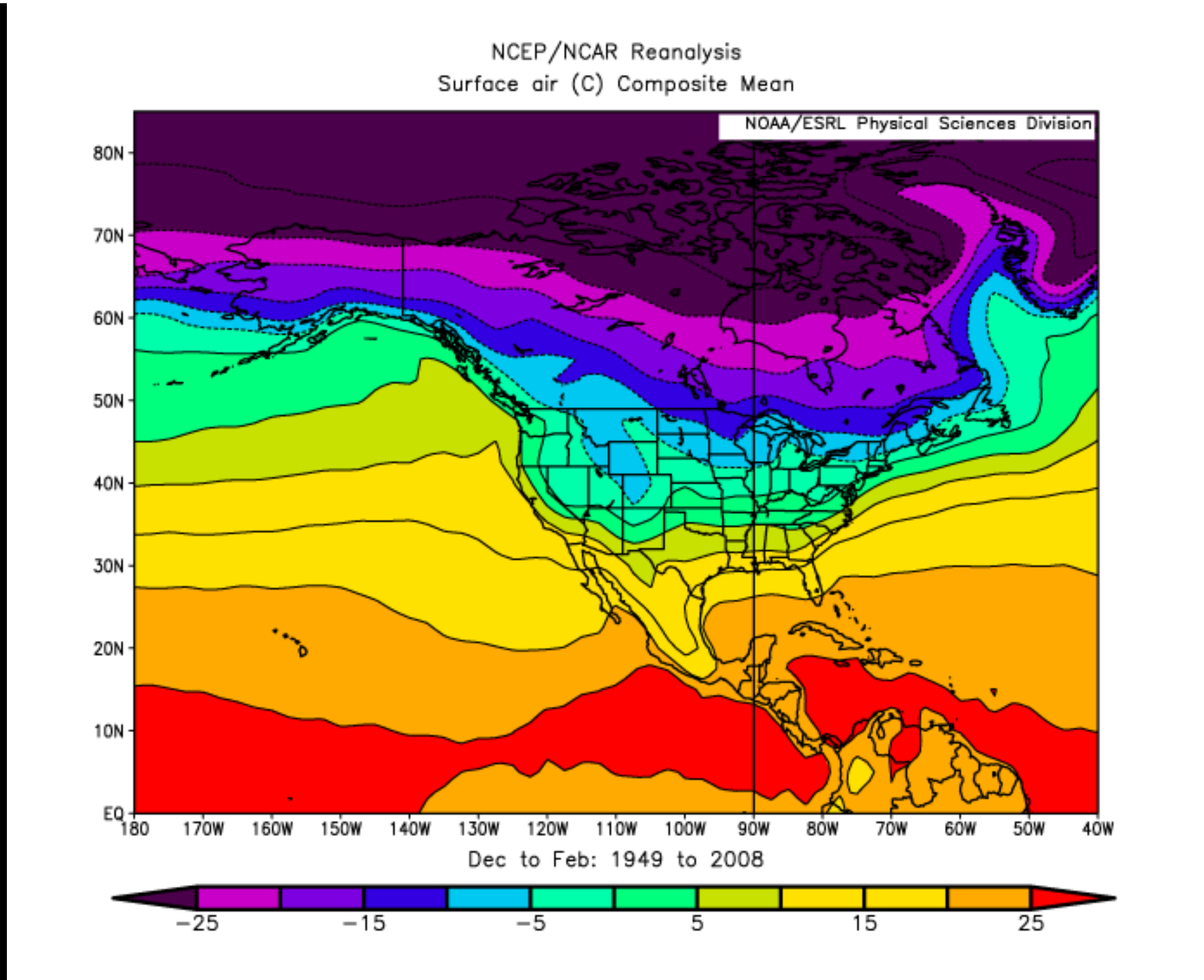
The guideline at 25˚N helps us see that, at this latitude, the oceans are cooler on their EAST sides.



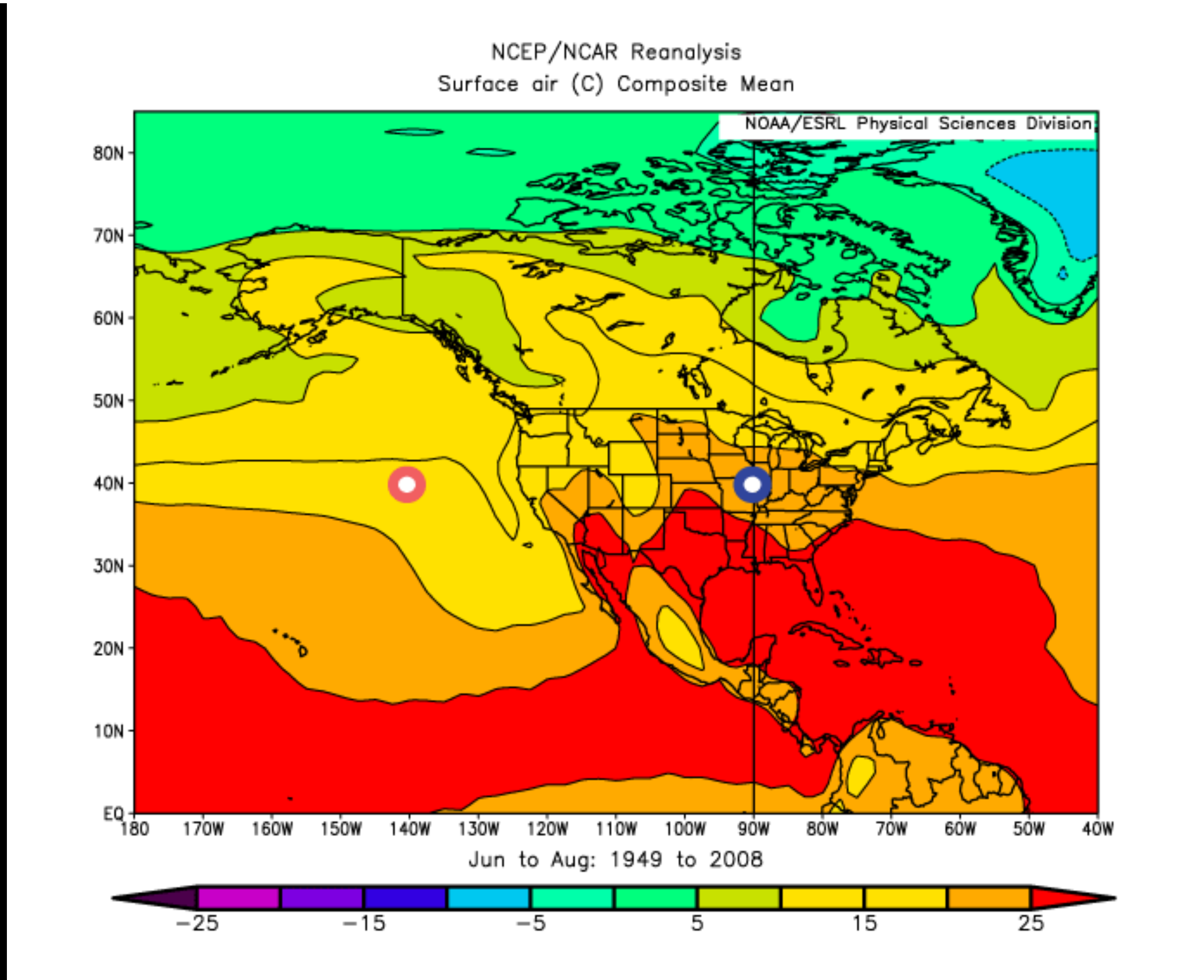
Two more lines mark two more northerly latitudes. Note now it is WARMER on the east sides of the two oceans. All of this reflects the ocean's circulation. Ocean currents accomplish substantial heat transport.



Principal surface ocean currents of the N Pacific.

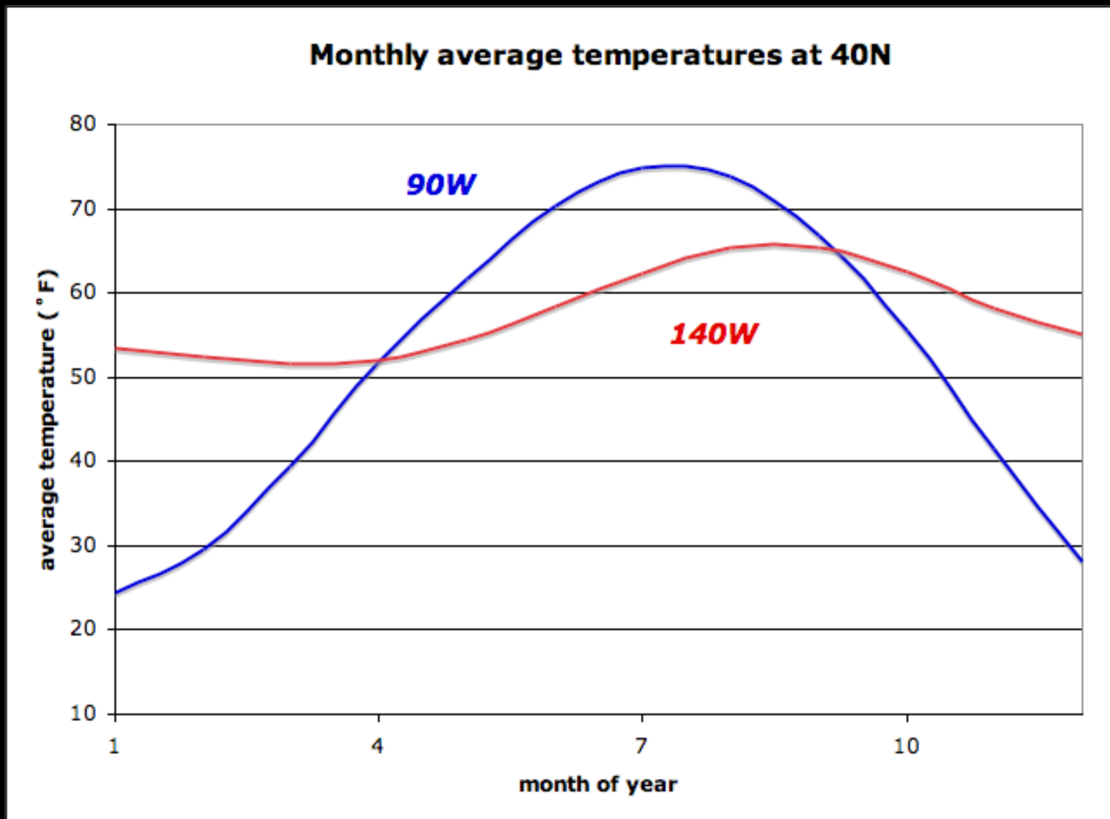


Average surface air temperature in the winter season for N America and the adjacent oceans.



Now for summer. To demonstrate ocean influence, I've selected two locations on this map located at 40˚N, one over the E Pacific, the other very near Springfield, IL

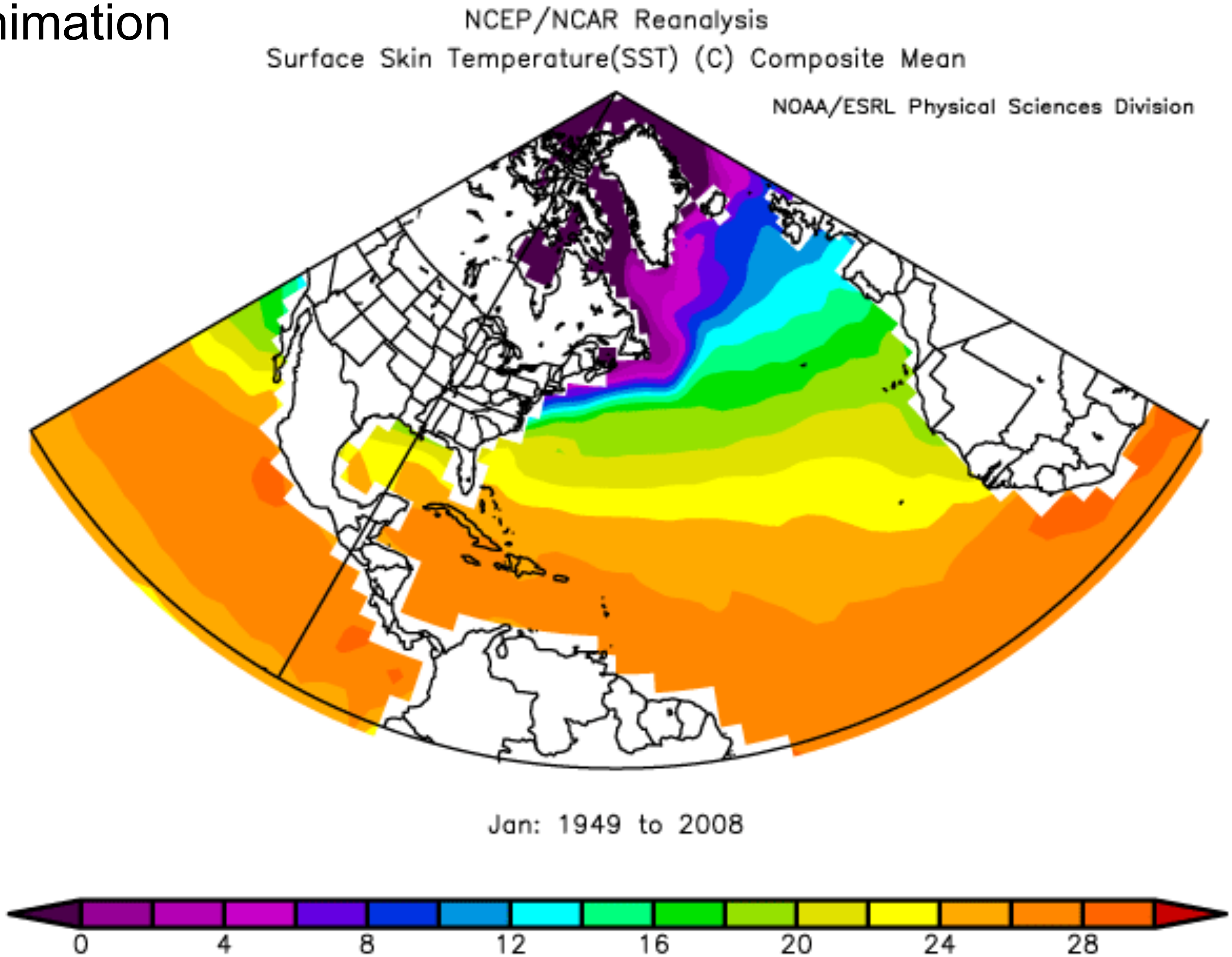
Variation of temperature at 40N



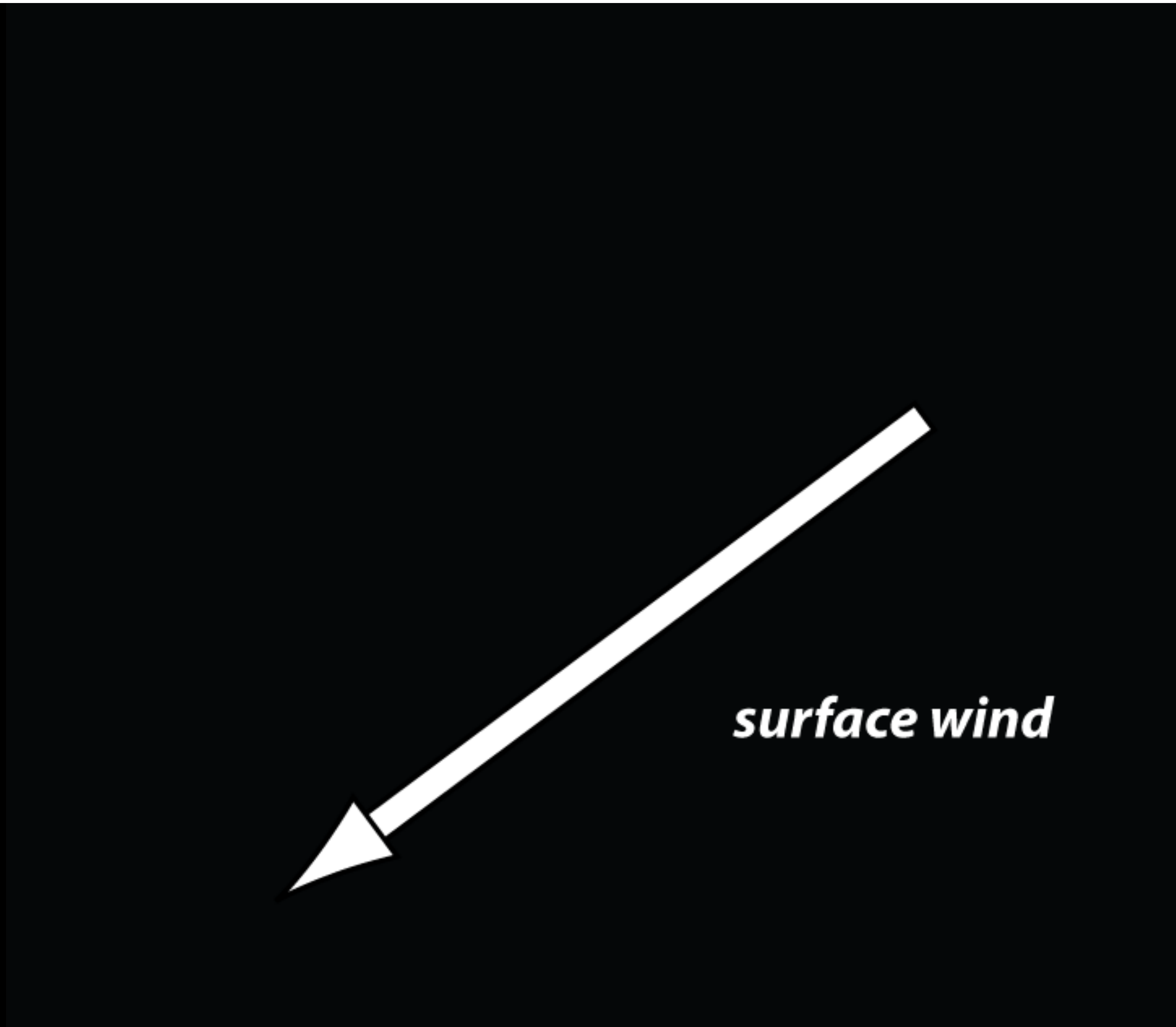
Blue = over land; red = over ocean

SST variation by month

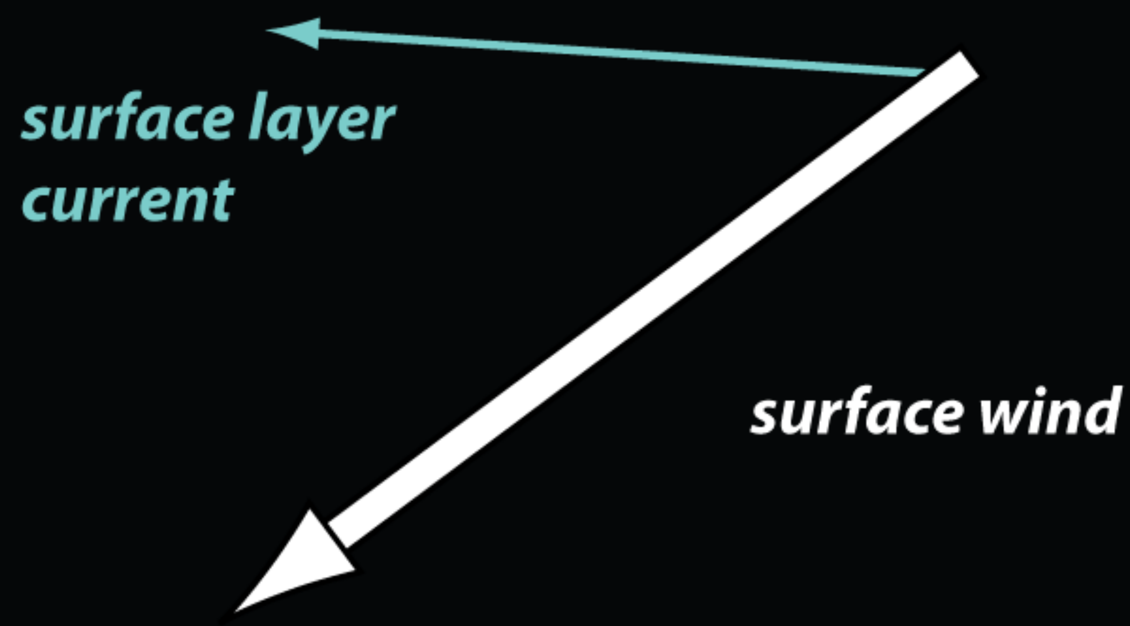
Animation


NCEP/NCAR Reanalysis
Surface Skin Temperature(SST) (C) Composite Mean
NOAA/ESRL Physical Sciences Division
Jan: 1949 to 2008
0
4
8
12
16
20
24
28

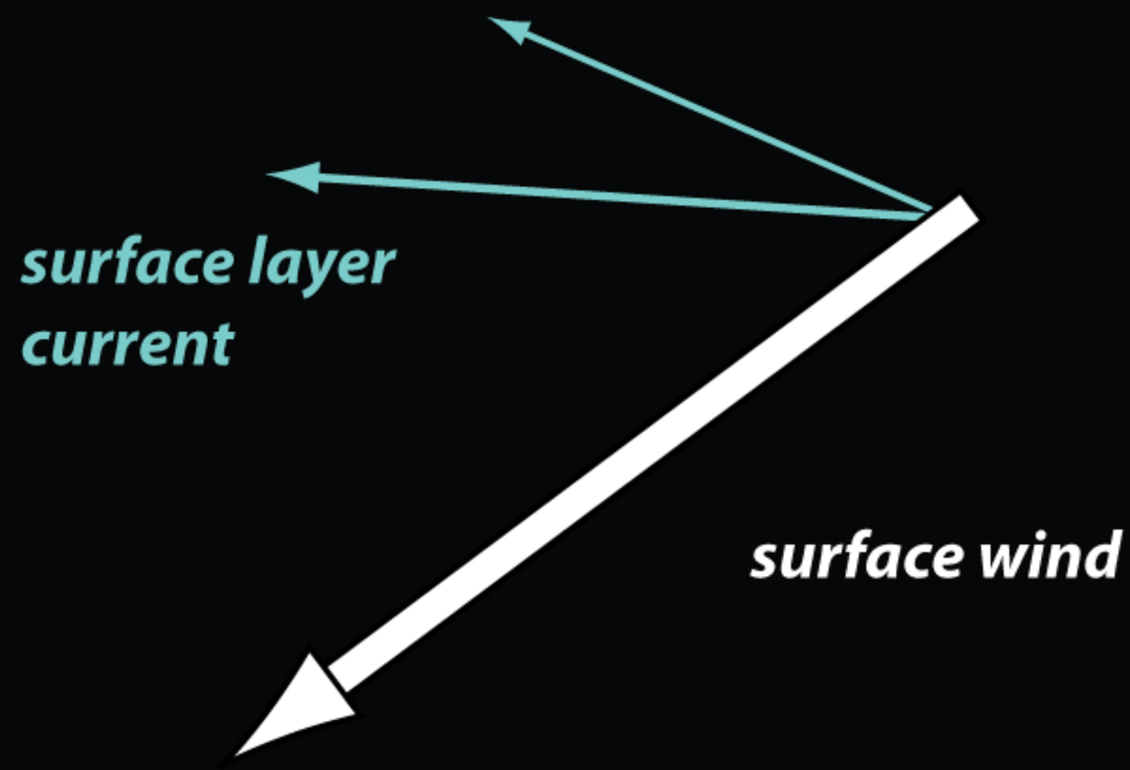
Surface winds vs. ocean currents



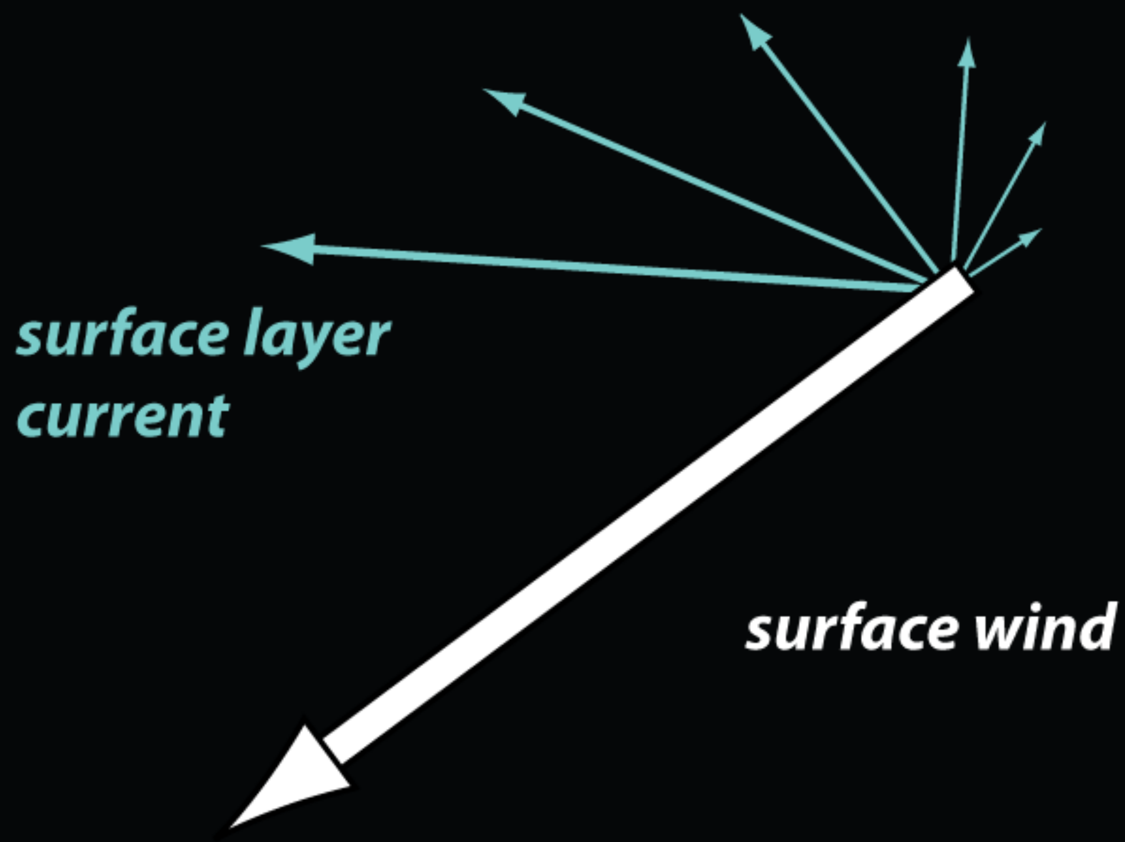
We start with a surface wind, such the NE trade winds of the tropical N Pacific.



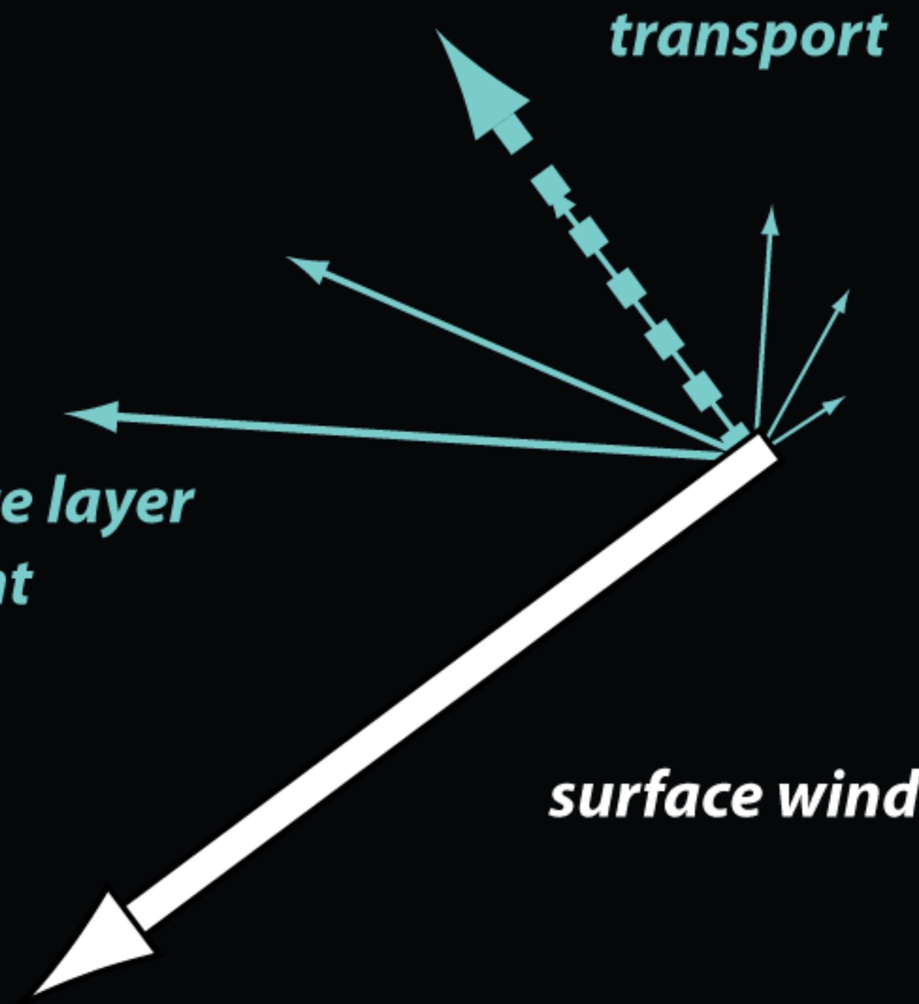
While the wind is pushing the water SW-ward, the ocean's surface layer current is moving both more slowly, and to the RIGHT of the wind, in the NH. This is because of the Coriolis force.



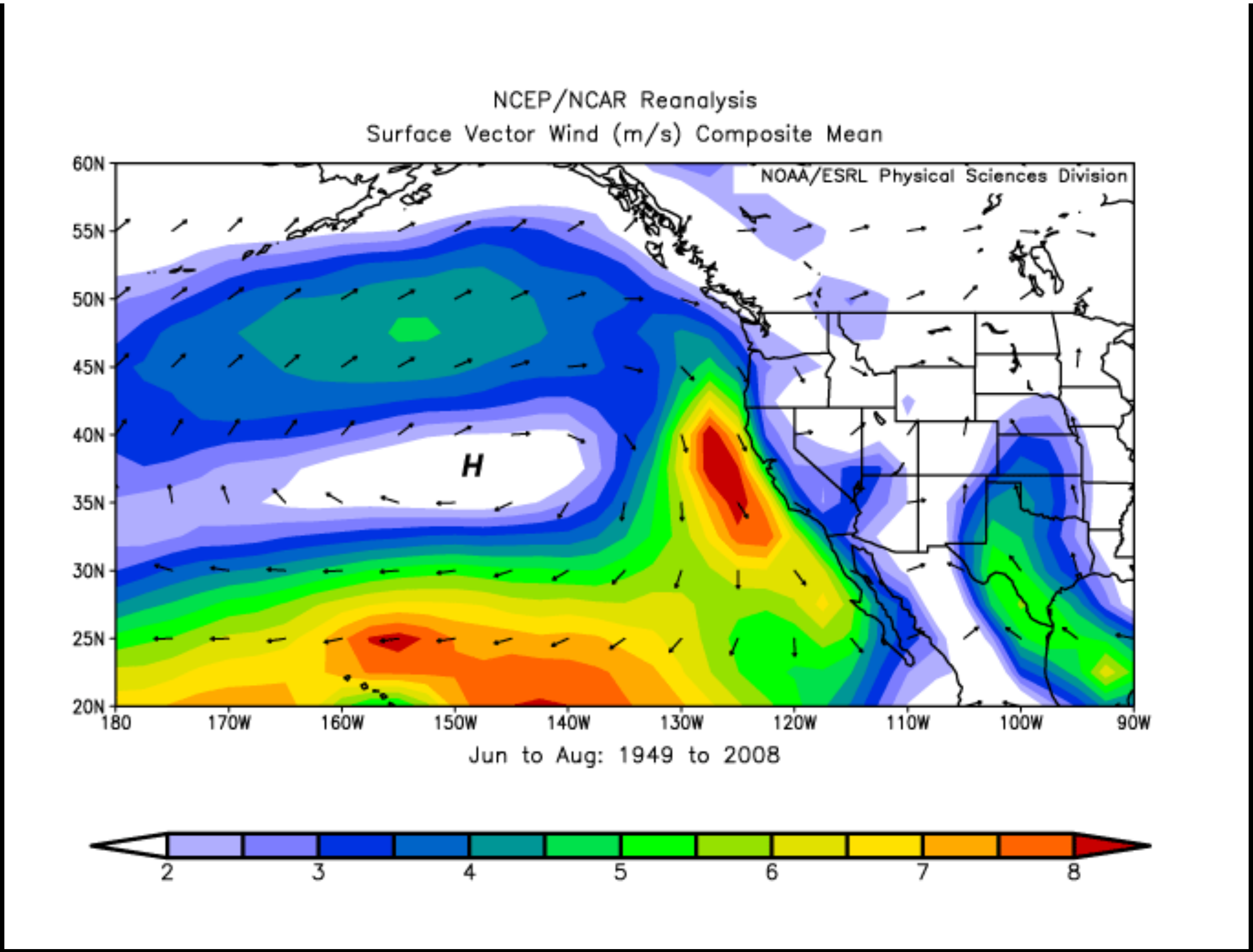
The surface layer current is dragging along water underneath, representing the primary forcing for the next layer down. But Coriolis also tries to make THAT water turn to the right of THIS forcing. So at this depth, the current is weaker, but even MORE turned rightward relative to the surface wind.



This keeps going, with the current both slowing and turning CW with increasing depth. By about 100 m down, 100 yards, the water is flowing in the OPPOSITE direction to the surface wind!
This is called an EKMAN SPIRAL.



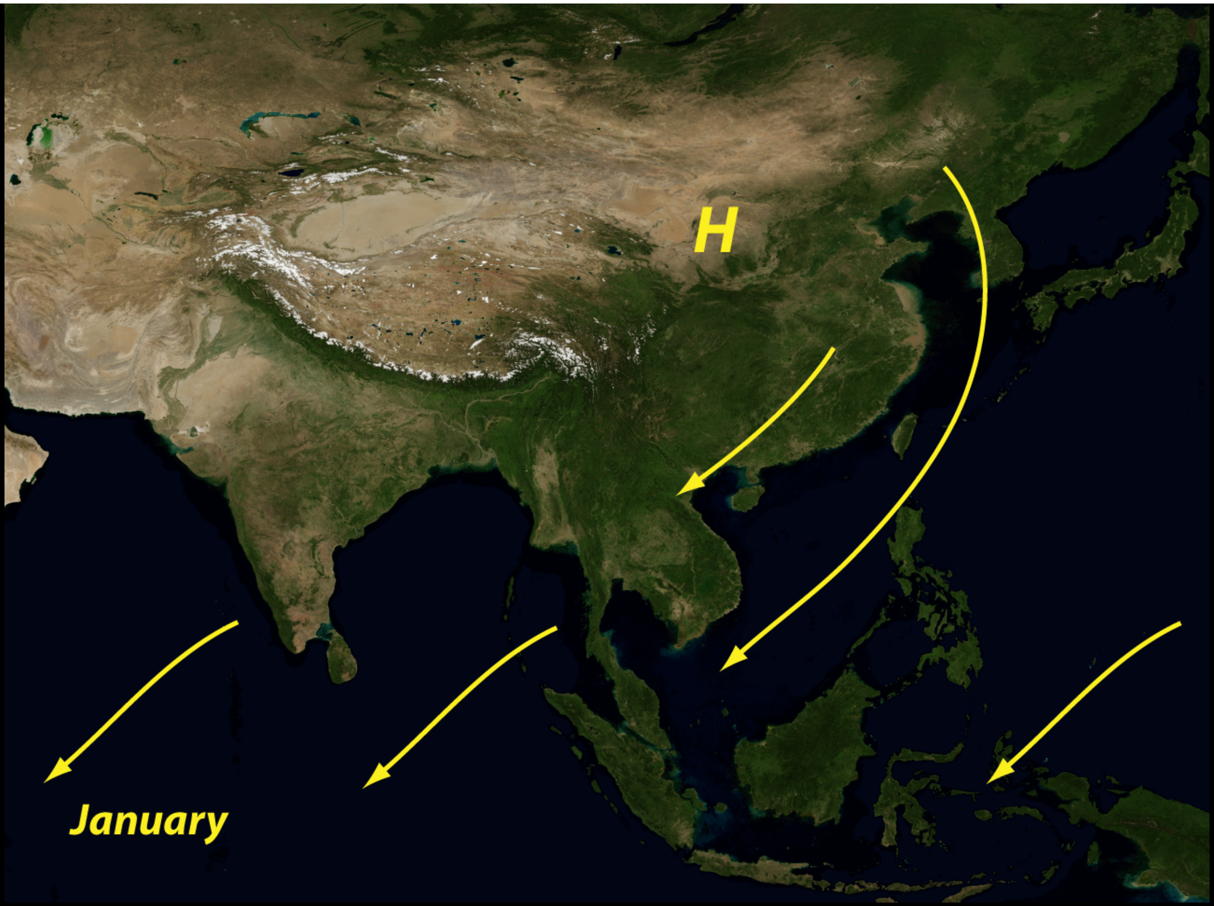
The Ekman spiral has an important consequence. The layers I've drawn here don't represent an equal amount of water, but if we were to AVERAGE the currents and mass transports in the vertical, we'd see that the MEAN DIRECTION is about 90 degrees to the RIGHT of the surface wind direction. In the mean, the ocean water is flowing to the RIGHT of the surface wind.
We'll call this mass motion the EKMAN TRANSPORT.



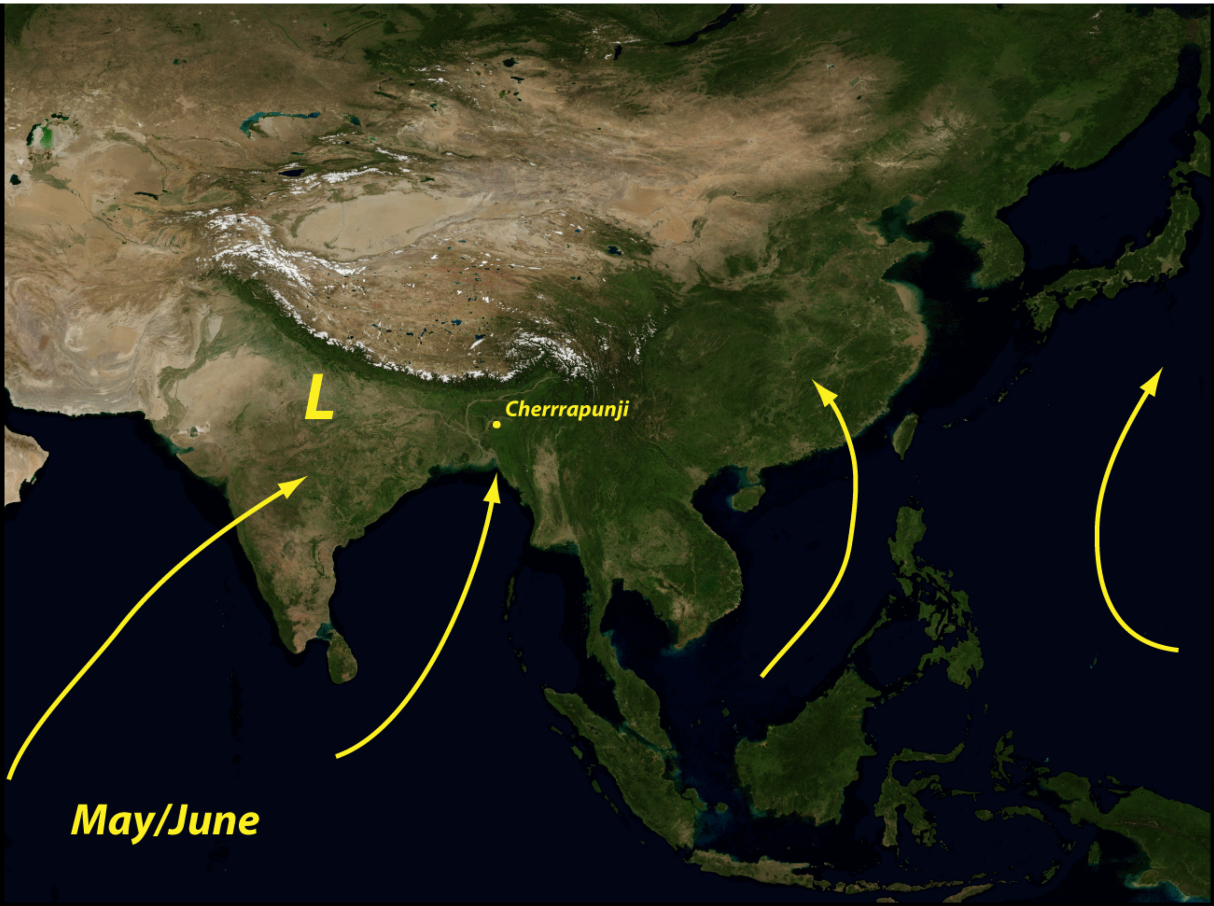
Map of average surface wind directions and speeds during the summertime. Note the winds are tending to blow southward, parallel to the CA coastline. If the flow is SOUTHWARD along the coast, the average movement of upper ocean water is WESTWARD, AWAY from shore.

As the surface layer Ekman transport pushes cool water away from the shoreline, even COLDER water from farther below is drawn up along the coast.
This UPWELLING of bottom water transports nutrients to the surface, and makes the SST lower than it otherwise would have been.

The monsoon

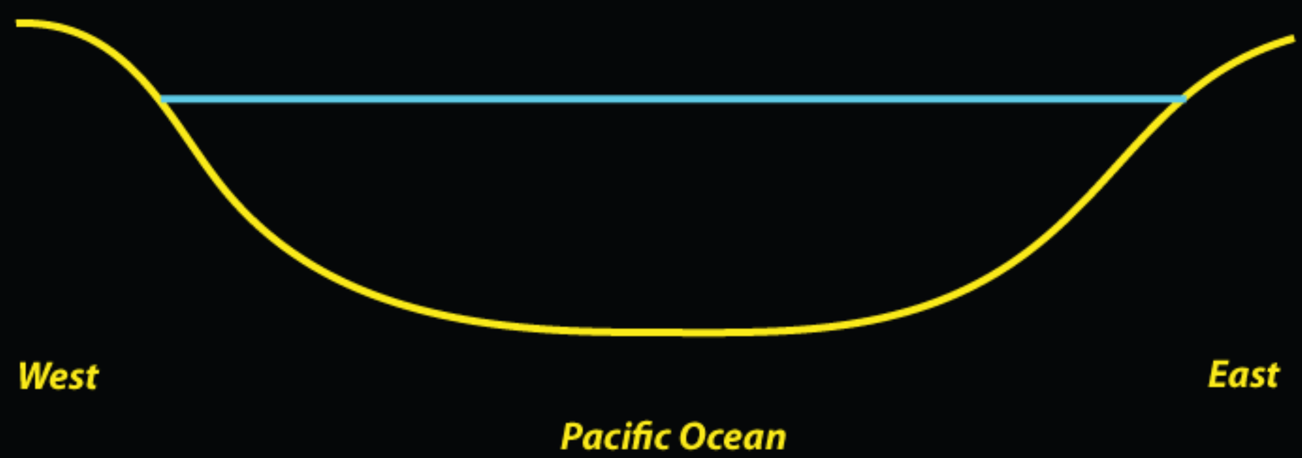


Consider January in Asia. There's high pressure over the very cold interior. CW flow around that H, along with the NE trades, mean that the winds over S Asia are generally directed from land to sea. The air also tends to be subsiding over India and SE Asia. This is the dry season.

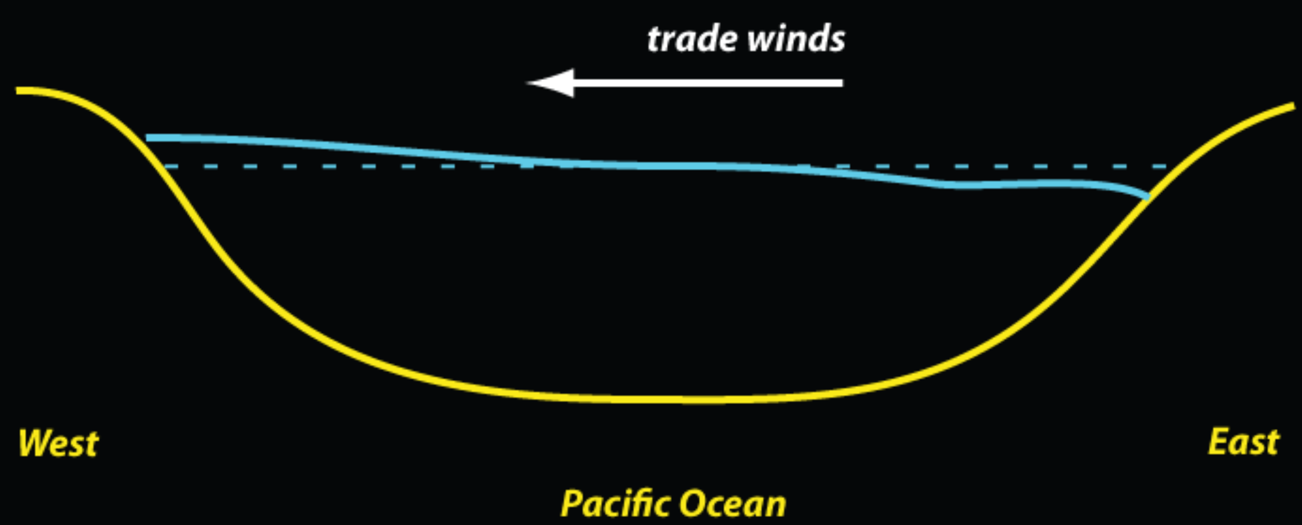


As the land warms up, air starts rising above it and the winds reverse, generally drawn towards a wide swath of thermally produced low pressure. The ocean at this time is also quite warm, pushing copious amounts of water vapor inland. This produces especially heavy rains where lifted by mountains.

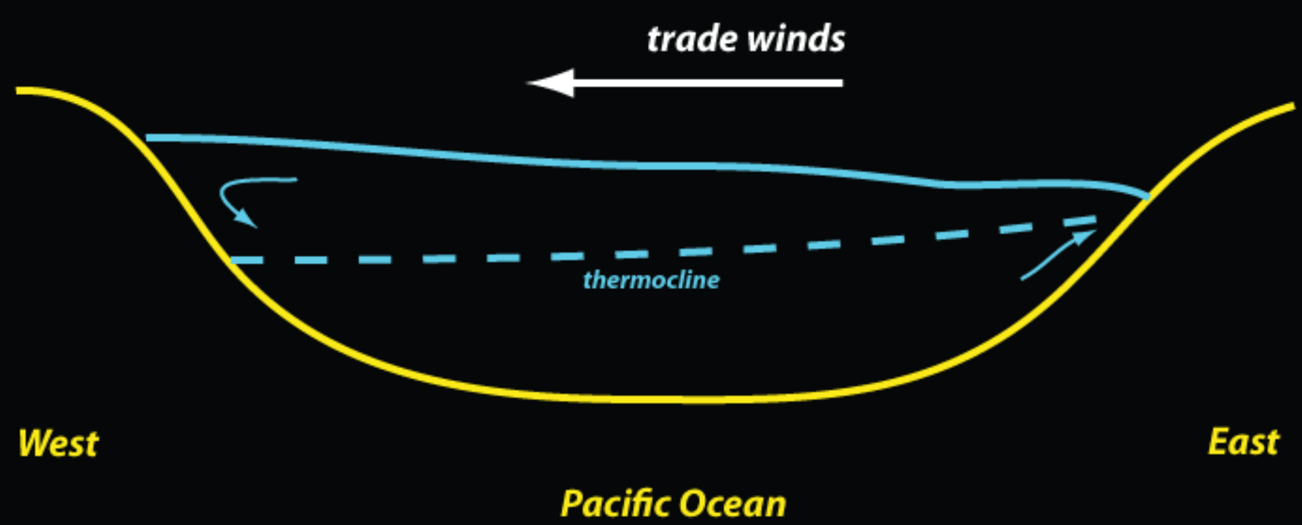
The Walker circulation and El Nino



This could be your bathtub, but instead it's a model of the Pacific Ocean, from W to E across the tropics.

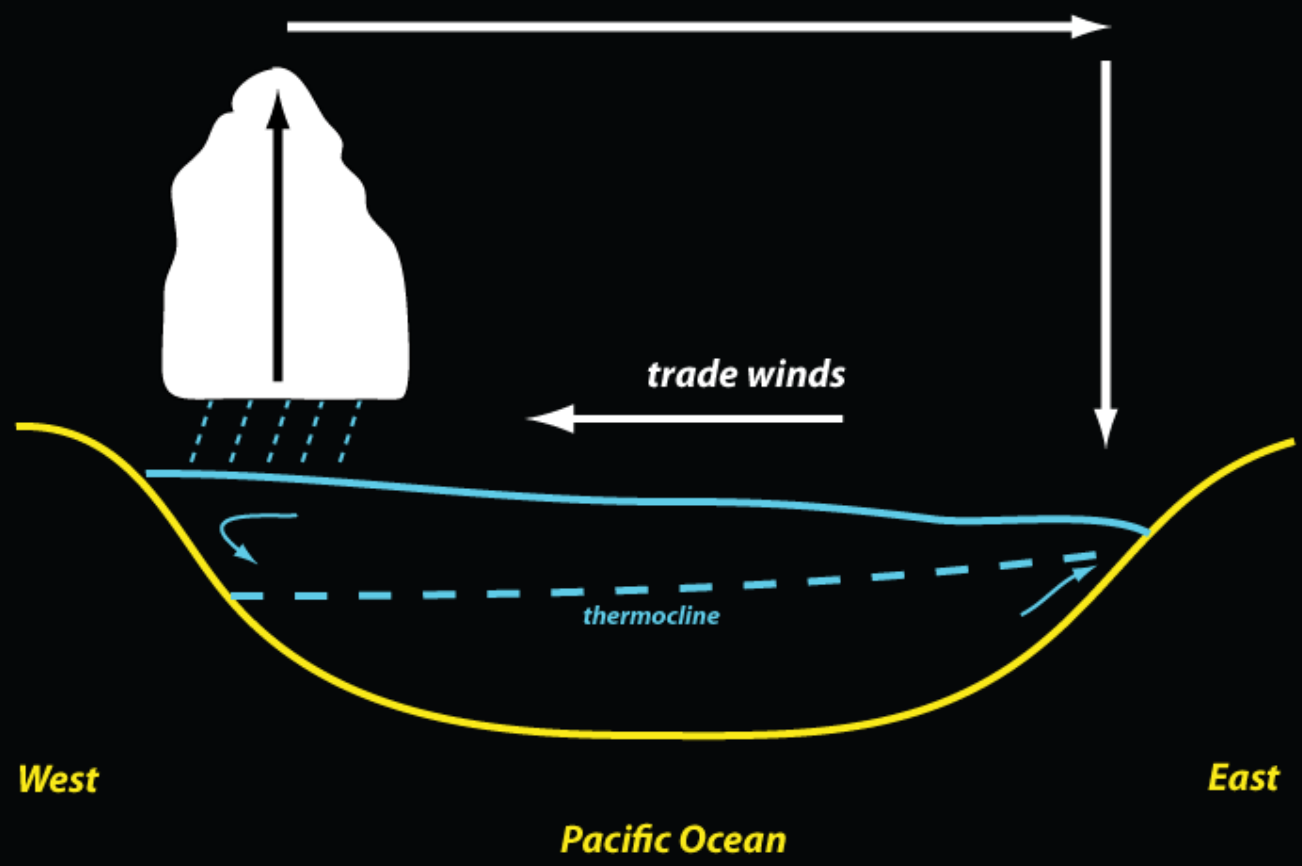


Unlike your bathtub, the tropical Pacific has persistent trade winds angling towards the equator. Considering the Ekman transport, this has the effect of pushing water mass generally WESTWARD across the Pacific. So it piles up in the west Pacific.

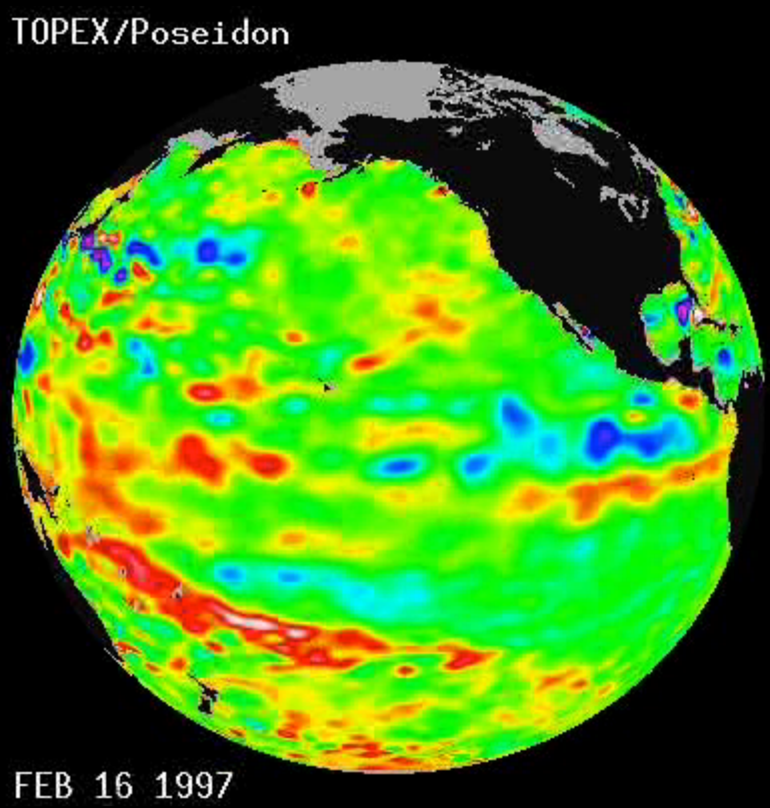


The flow of water away from the coastlines in the east Pacific creates upwelling, making SSTs there colder. That also brings the thermocline closer to the surface.

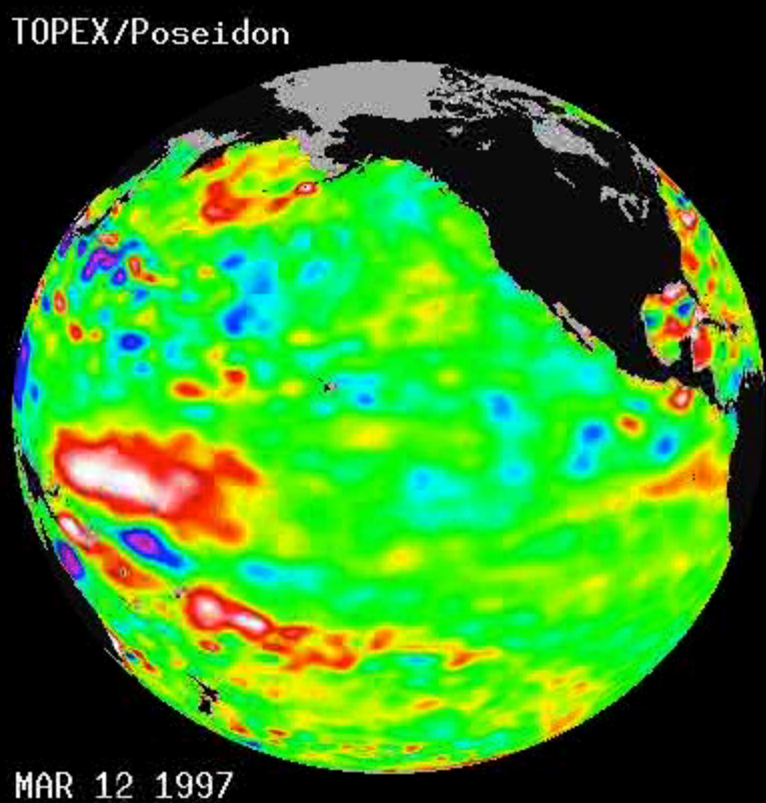
Meanwhile, the water being carried across the Pacific is being heated along the way by the sun.



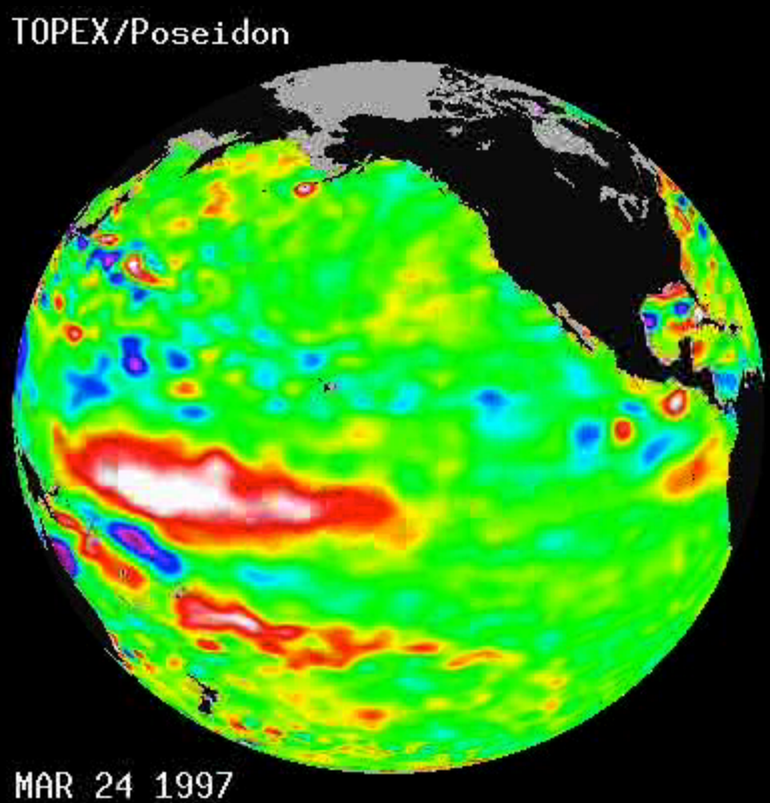
That deep layer of warm water provides a large reservoir of energy that drives deep convection and strong ascent. That causes the surface pressure to drop, making the naturally low surface pressure of equatorial region even lower in the W Pacific. The circulation is called the Walker cell. El Nino represents a periodic weakening of this Walker circulation.



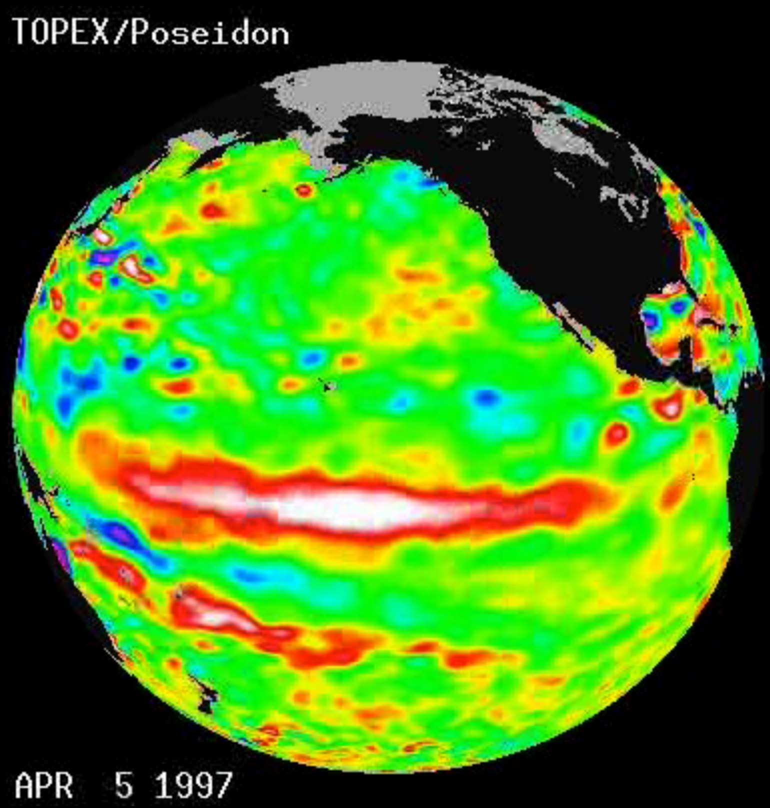
- Satellite image from the particularly strong and famous El Nino event, 1997-98. This image represents sea-surface height anomaly (departure from long-term mean).
- We start in February 1997, with sea-surface heights close to normal along the equator.



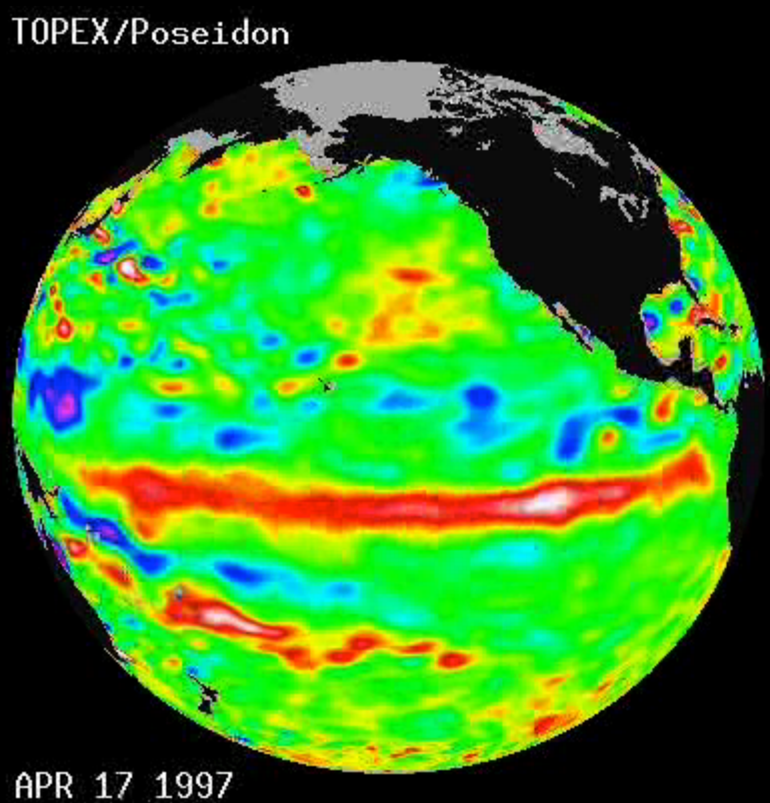
- Anomalously large heights have appeared in the west Pacific by March 12.
- The white areas have the largest positive anomalies.



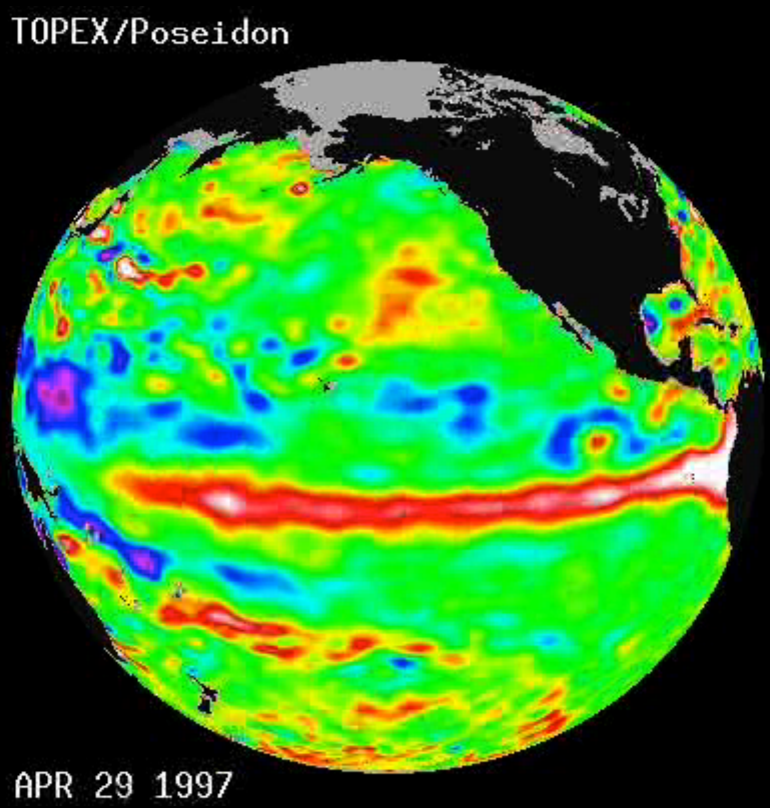
- By March 24, the high sea-level heights have started spreading towards the central and eastern Pacific



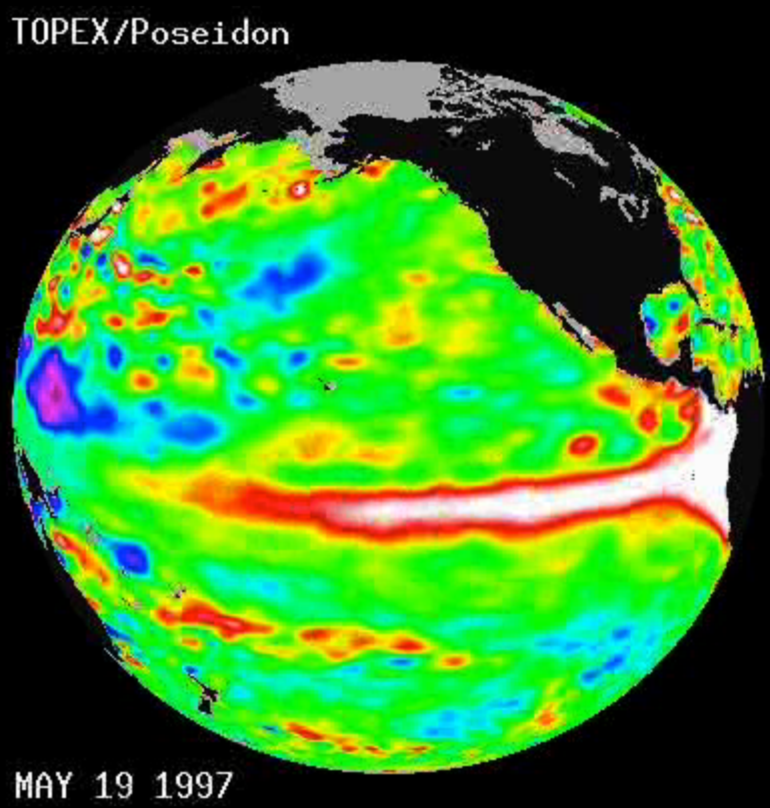
- By April 5th, the warm water and high sea-levels have progressed most of the way across the Pacific.
- The largest anomalies are in the central part of the ocean.



- By April 17, it looks like the feature is petering out, but note it’s now gotten very close to the end of its journey



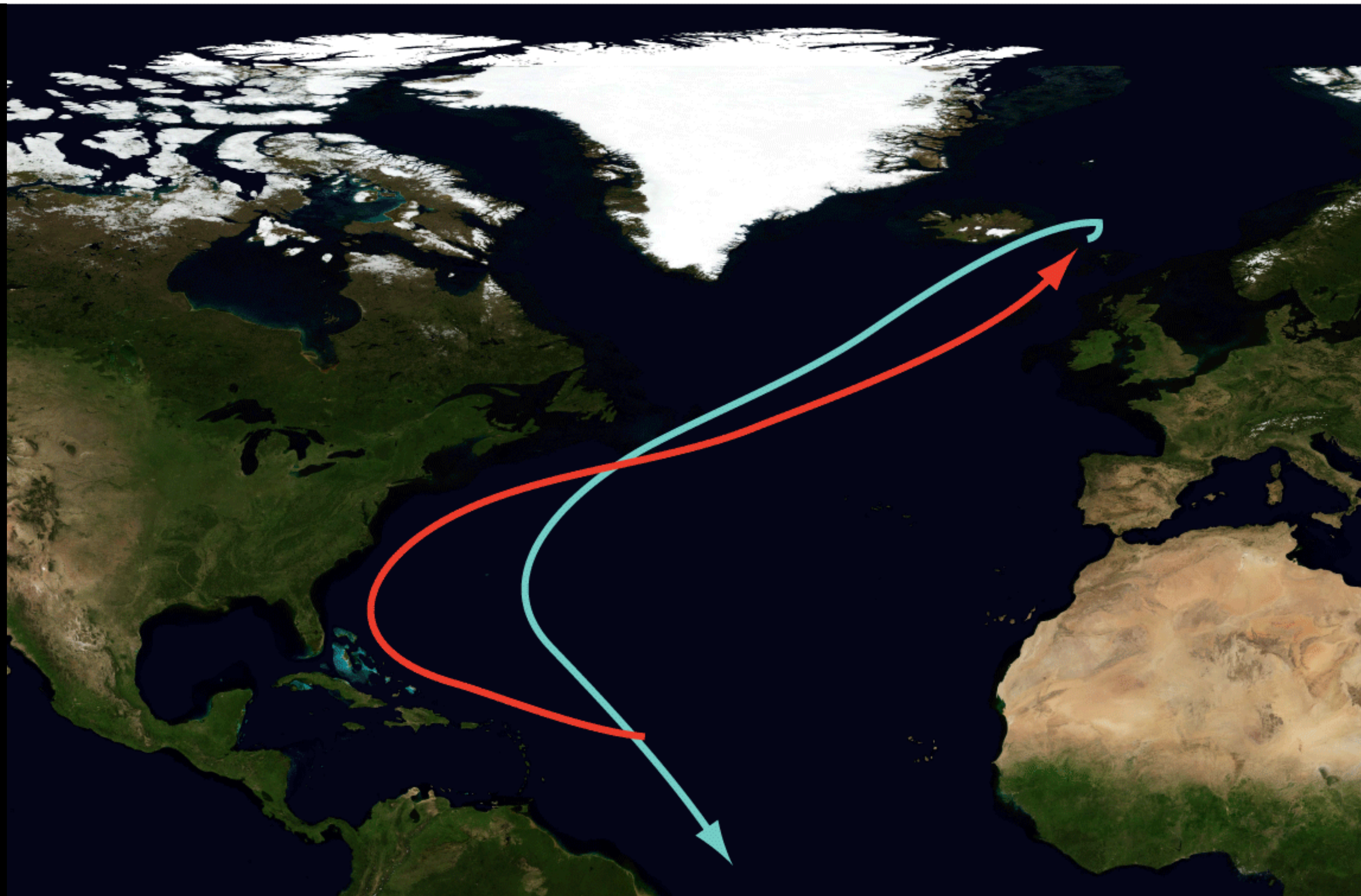
- It’s now late April and locally very high sea level heights are now seen at the coasts of Ecuador and Peru.



- Skipping ahead to late May, we see the high heights are now moving back *westward.*
- El Nino is in full swing.

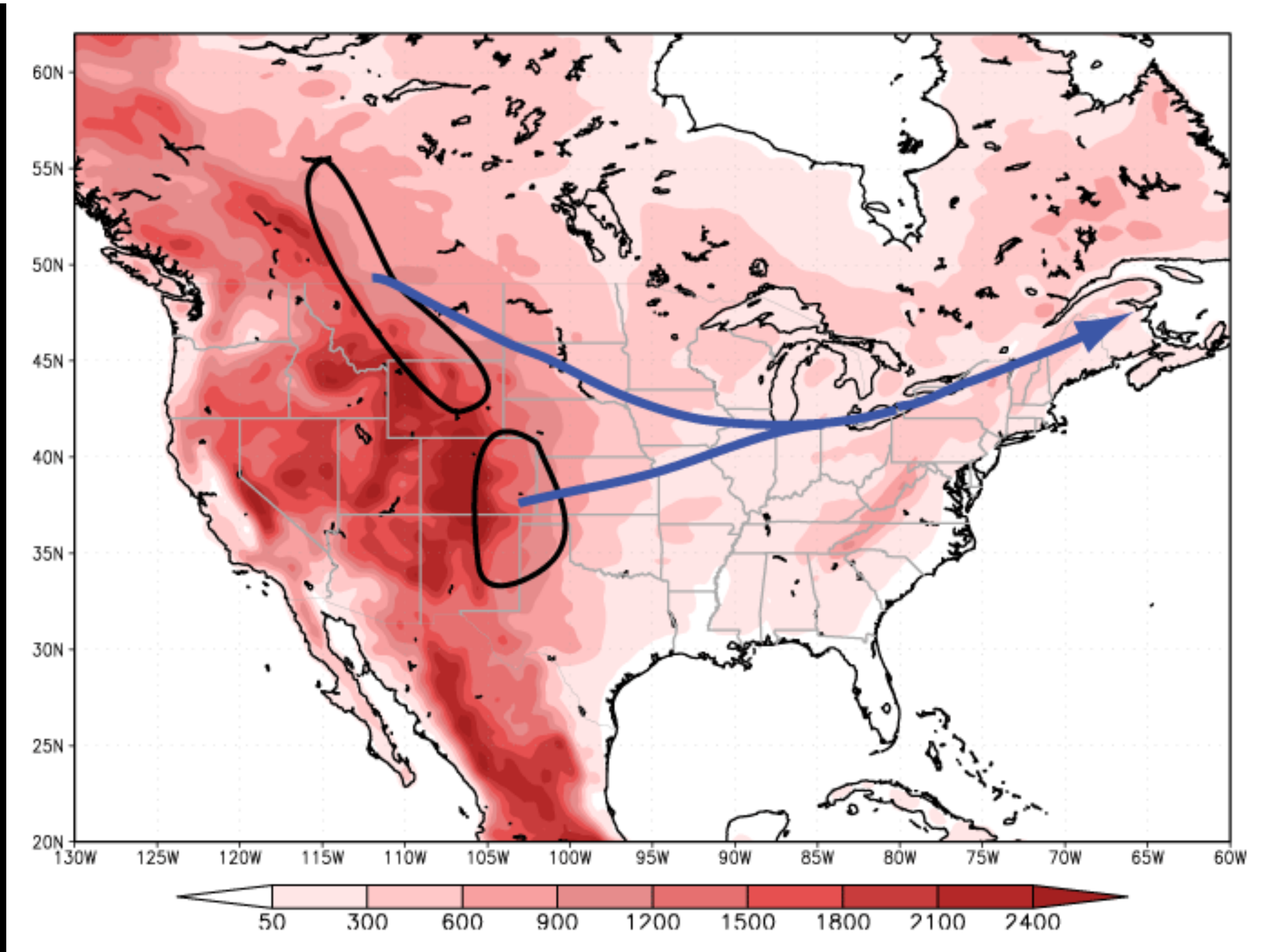
For updated animations: https://sealevel.jpl.nasa.gov

The deep ocean

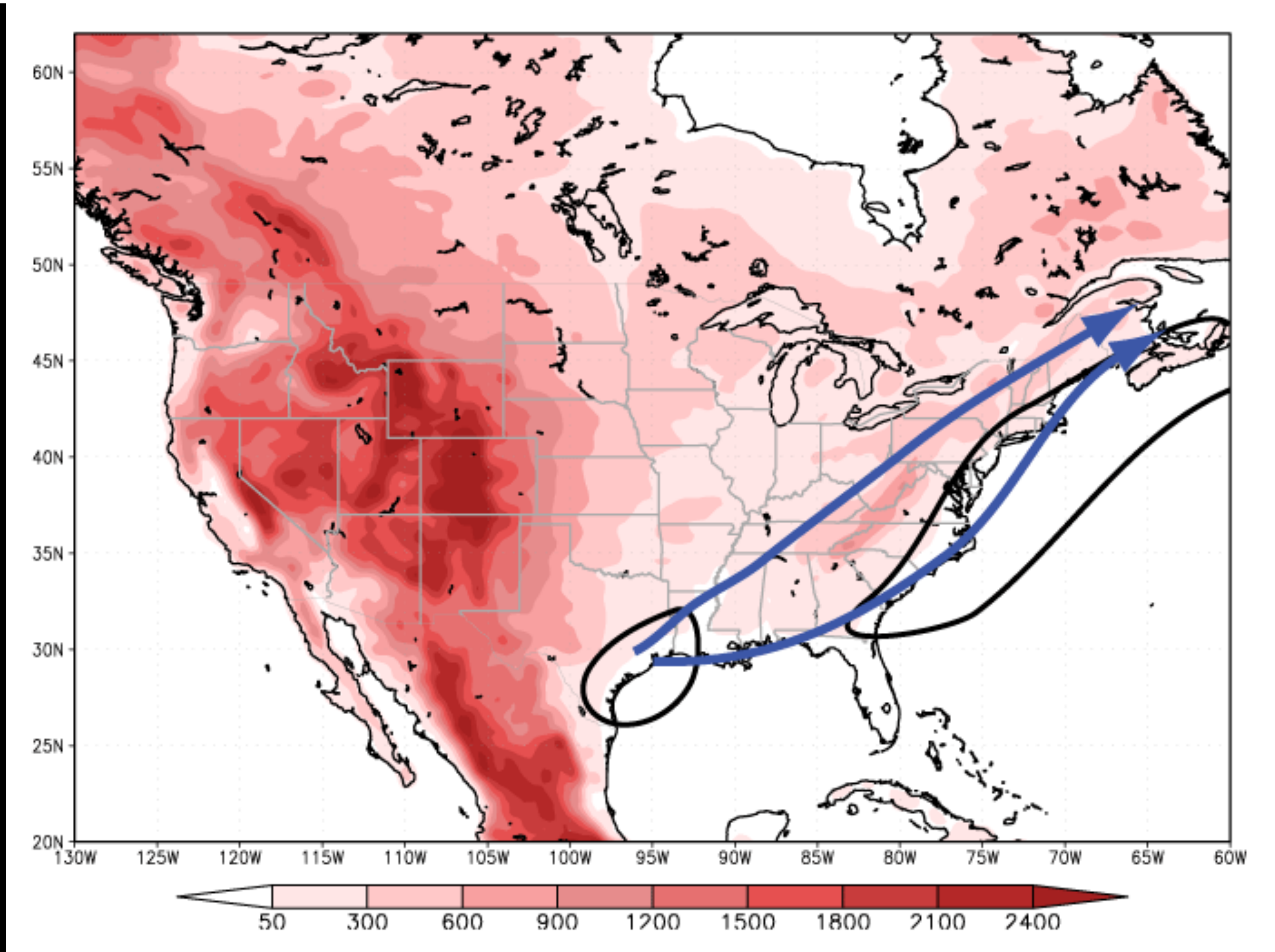


Thermohaline circulation in Atlantic

U.S. extratropical cyclone hotspots (extended)



Previously, we discussed why cyclones tend to form in these hotspots and then to move towards New England and the East Coast.



Two more "hotspots" are along the Texas coast and the Gulf Coast N of Florida, aided by the thermal contrast between the cold land and warm ocean.

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