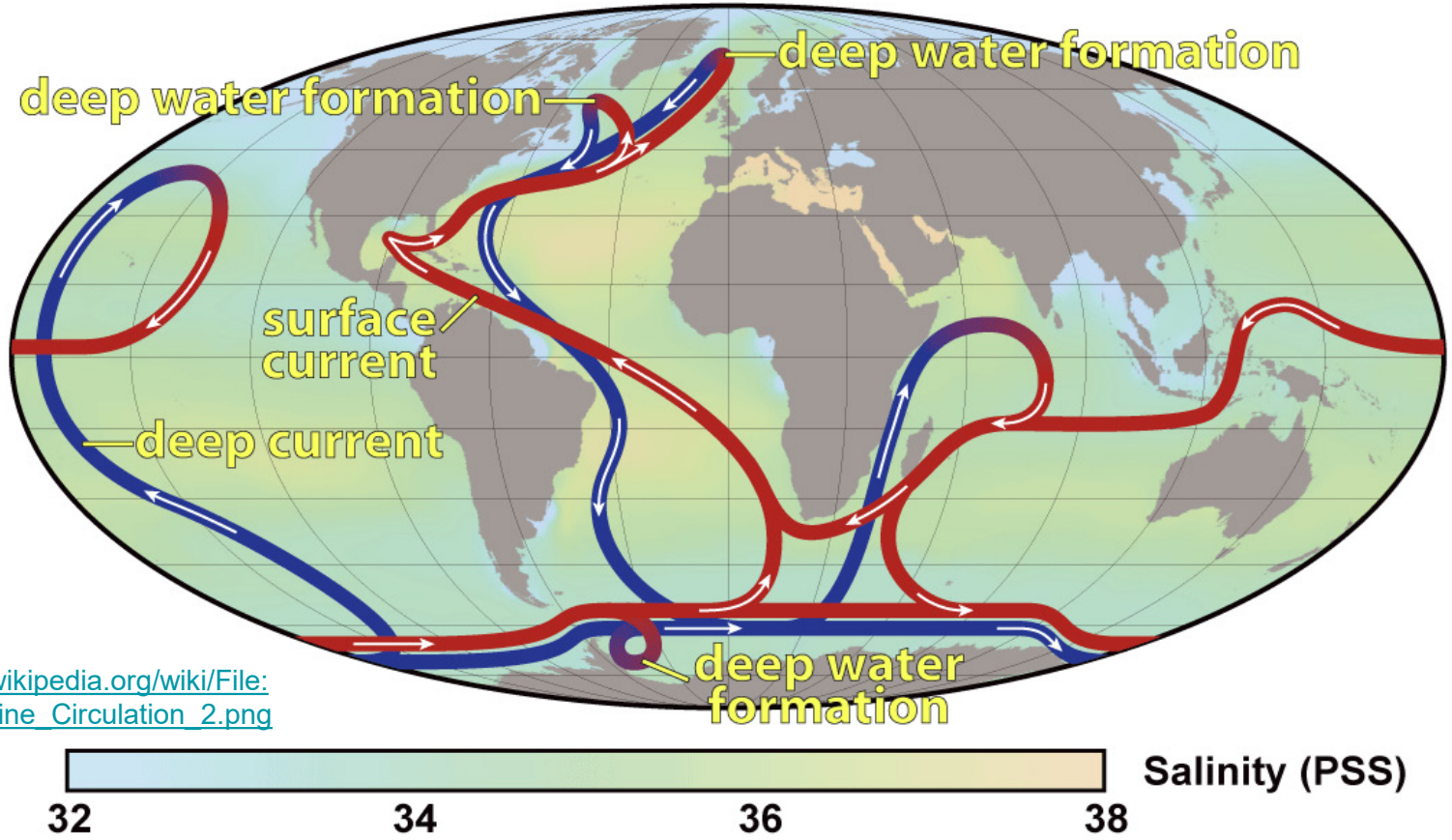
The Ocean’s Overall Role in Climate

Kenny Crager

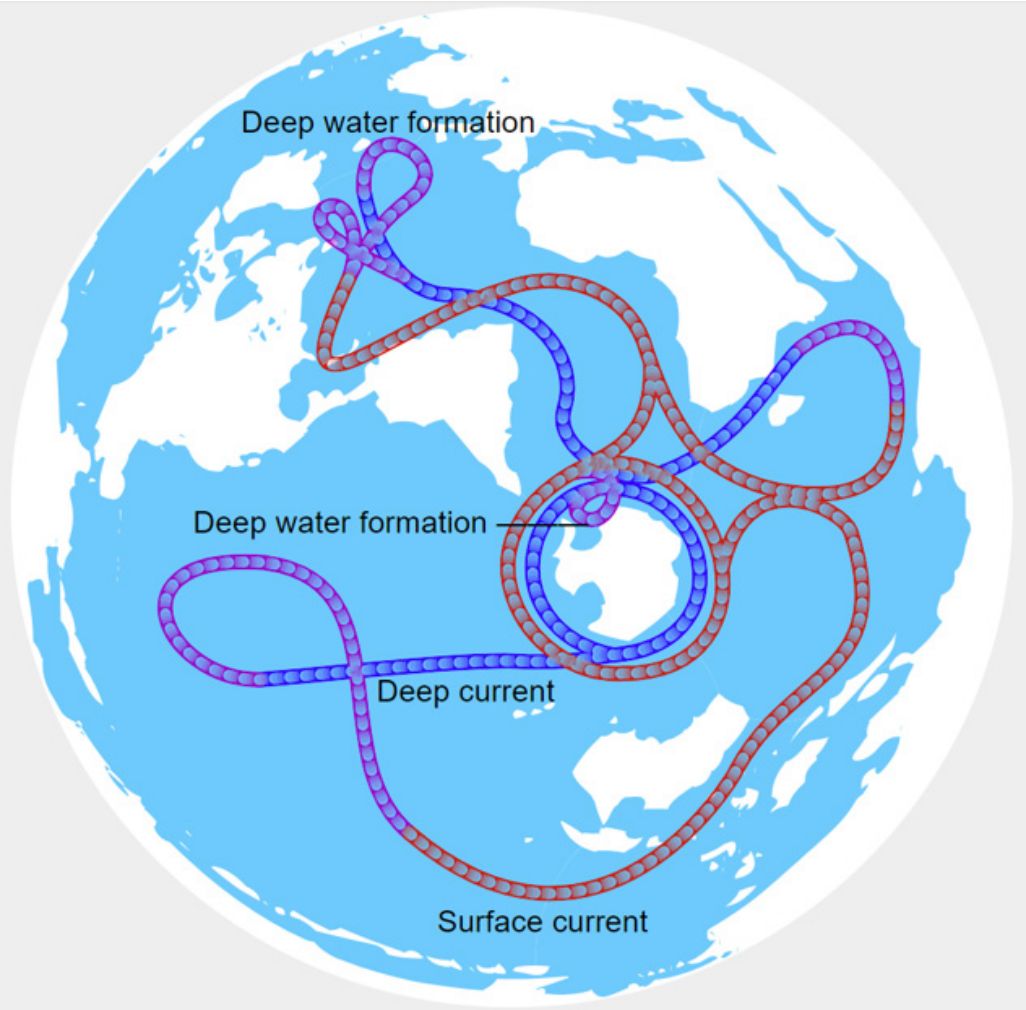
Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Thermohaline Circulation



https://en.wikipedia.org/wiki/File:Thermohaline_Circulation_2.png

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)



https://upload.wikimedia.org/wikipedia/commons/a/ab/Thermohaline_circulation.svg

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

- What do the thermohaline circulation graphics tell you about:
  - Heat transport?
  - Water mass formation?
  - Water mass modification?

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

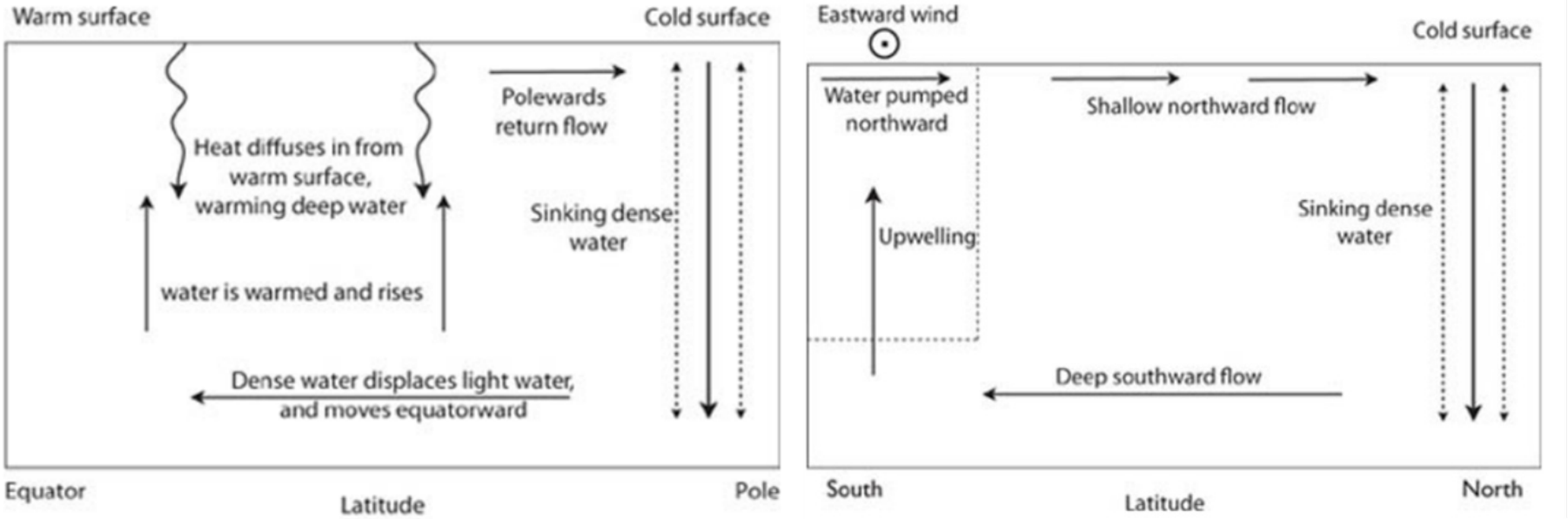


Figure 4.6. Schema of the two main components of the MOC. Top: The mixing-maintained circulation. Dense water at high latitudes sinks and moves equatorward, displacing warmer, lighter water. The cold, deep water is slowly warmed by diffusive heat transfer (mixing) from the surface in mid- and low latitudes, enabling it to rise and maintain a circulation. Bottom: Winds over the Antarctic Circumpolar Current (outlined by dashed lines) pump water northward, and this pumping enables deep water to rise and maintain the circulation. In the absence of both wind and mixing, the abyss would fill up with the densest available water and the circulation would cease.

Questions

- What geophysical feature did Vallis omit in his simplified cartoon?

- How might this feature affect the overall circulation?

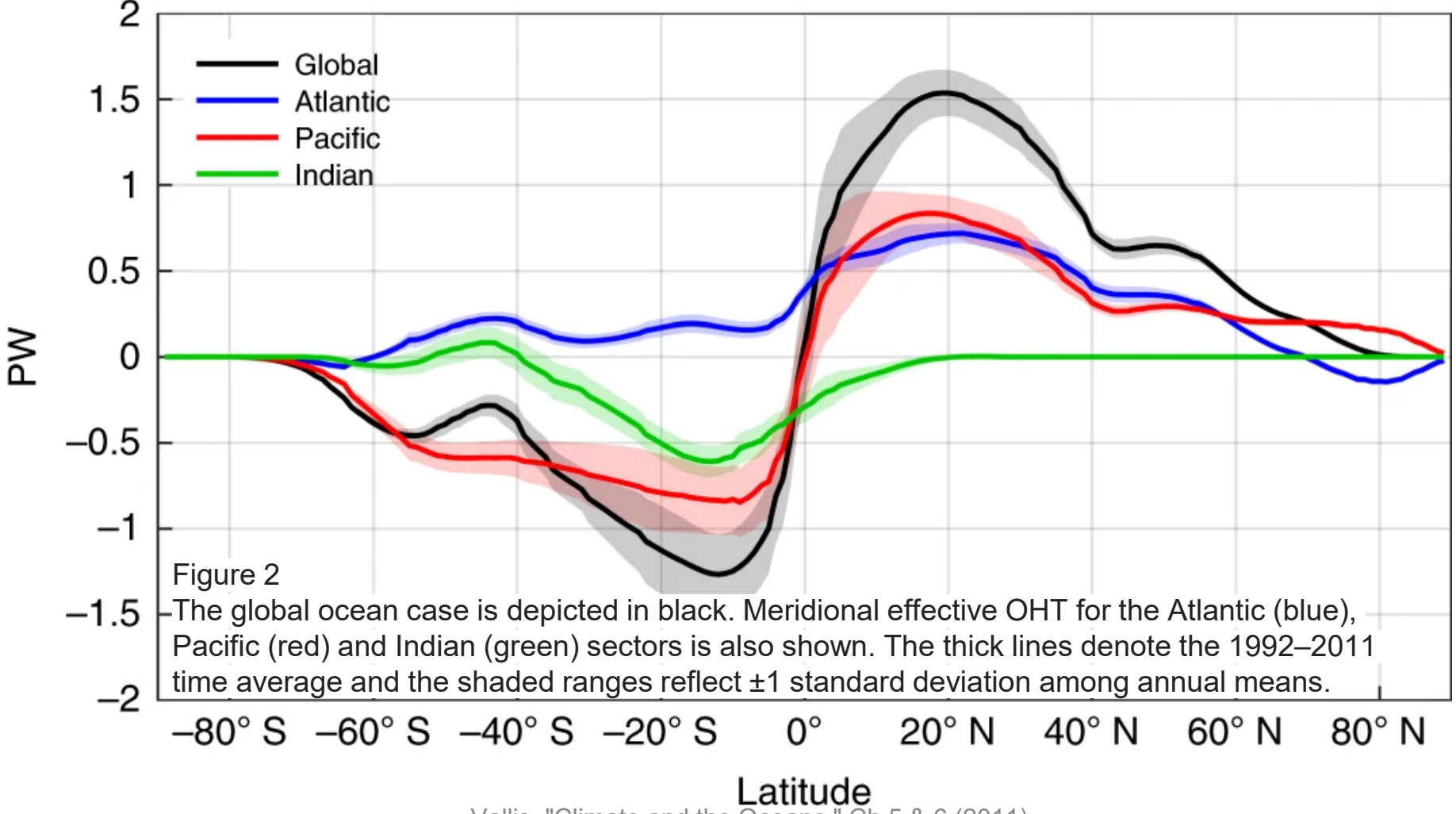


Figure 2
The global ocean case is depicted in black. Meridional effective OHT for the Atlantic (blue), Pacific (red) and Indian (green) sectors is also shown. The thick lines denote the 1992–2011 time average and the shaded ranges reflect ±1 standard deviation among annual means.

Forget, G., Ferreira, D. Global ocean heat transport dominated by heat export from the tropical Pacific. *Nat. Geosci.* 12, 351–354 (2019). https://doi.org/10.1038/s41561-019-0333-7

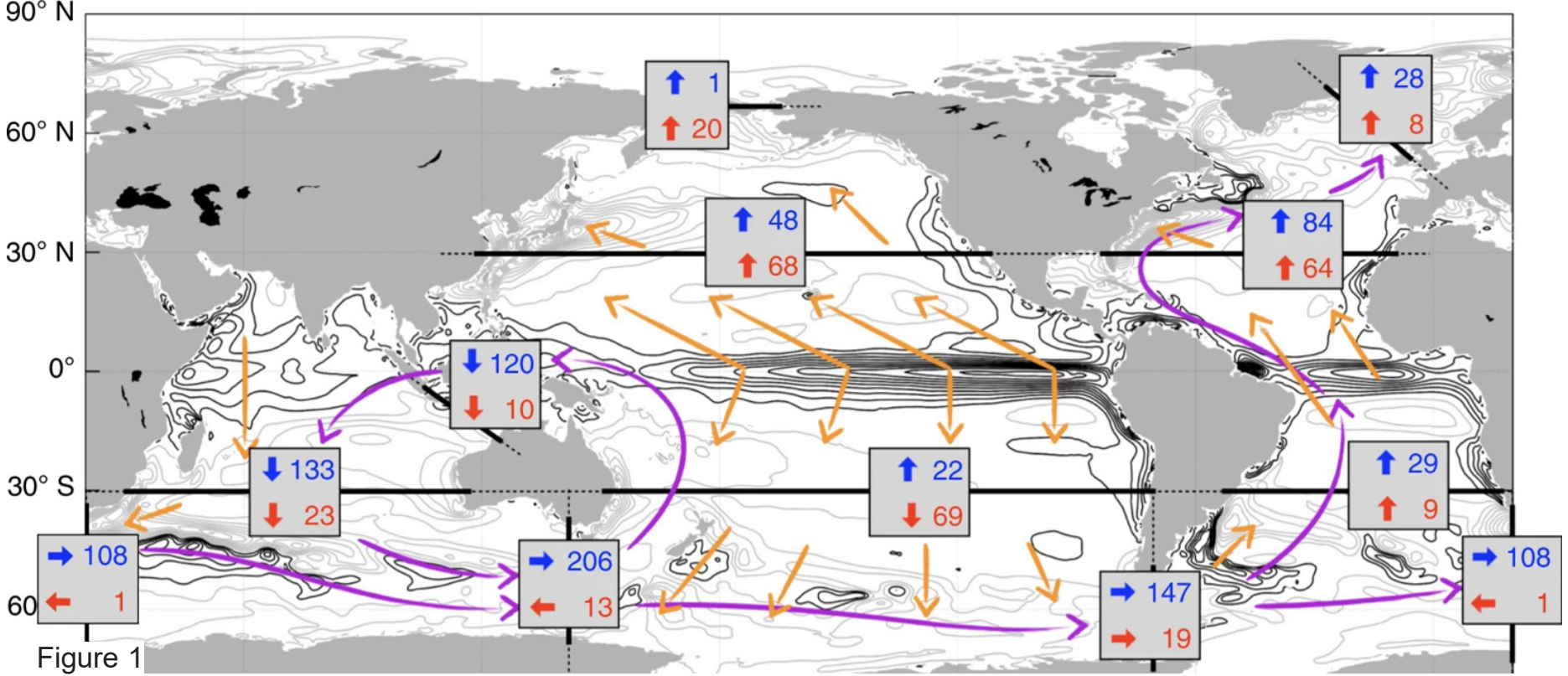


Figure 1

Values (in 0.01 PW=1013 Watts) of plain OHT (rotational + divergent components; OHT0) and effective OHT (divergent component alone; OHT∇) are charted in blue and in red, respectively. The thin lines with arrowheads are a schematic of internal ocean heat loops (purple) and effective OHT patterns (orange). The black contours (respectively, grey contours) represent the rate of OHT divergence (respectively, convergence), which corresponds to heat uptake from (respectively, heat release to) the atmosphere. These rates are contoured every 15 W m−2 starting from ±5 W m−2.

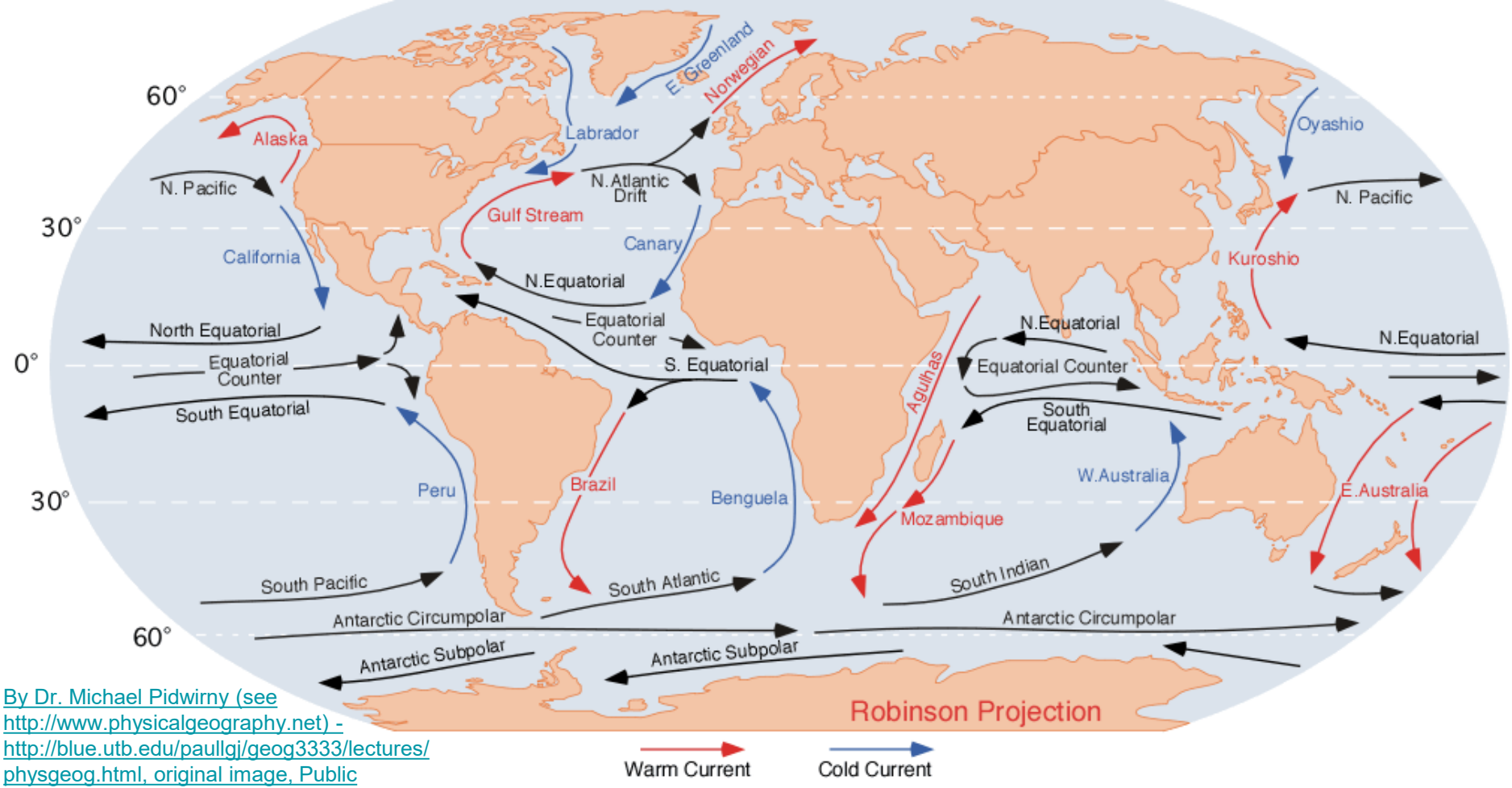
Forget, G., Ferreira, D. Global ocean heat transport dominated by heat export from the tropical Pacific. *Nat. Geosci.* 12, 351–354 (2019). https://doi.org/10.1038/s41561-019-0333-7

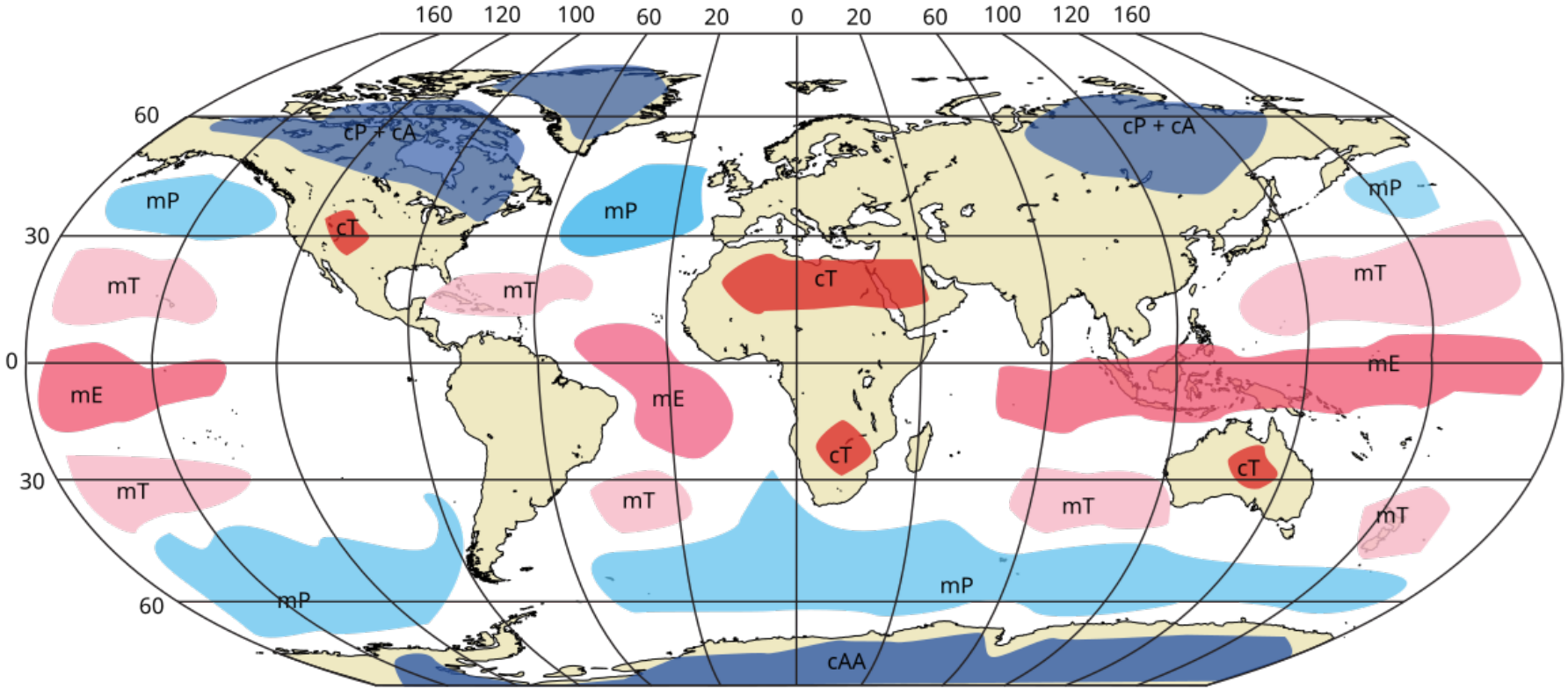
Questions

- What part of the oceans absorbs the most heat?

- What part of the oceans discharges the most heat?

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)





cP: **Continental Polar**
cA: **Continental Arctic**
cT: **Continental Tropical**
mP: **Maritime Polar**
mT: **Maritime Tropical**
mE: **Maritime Equatorial**

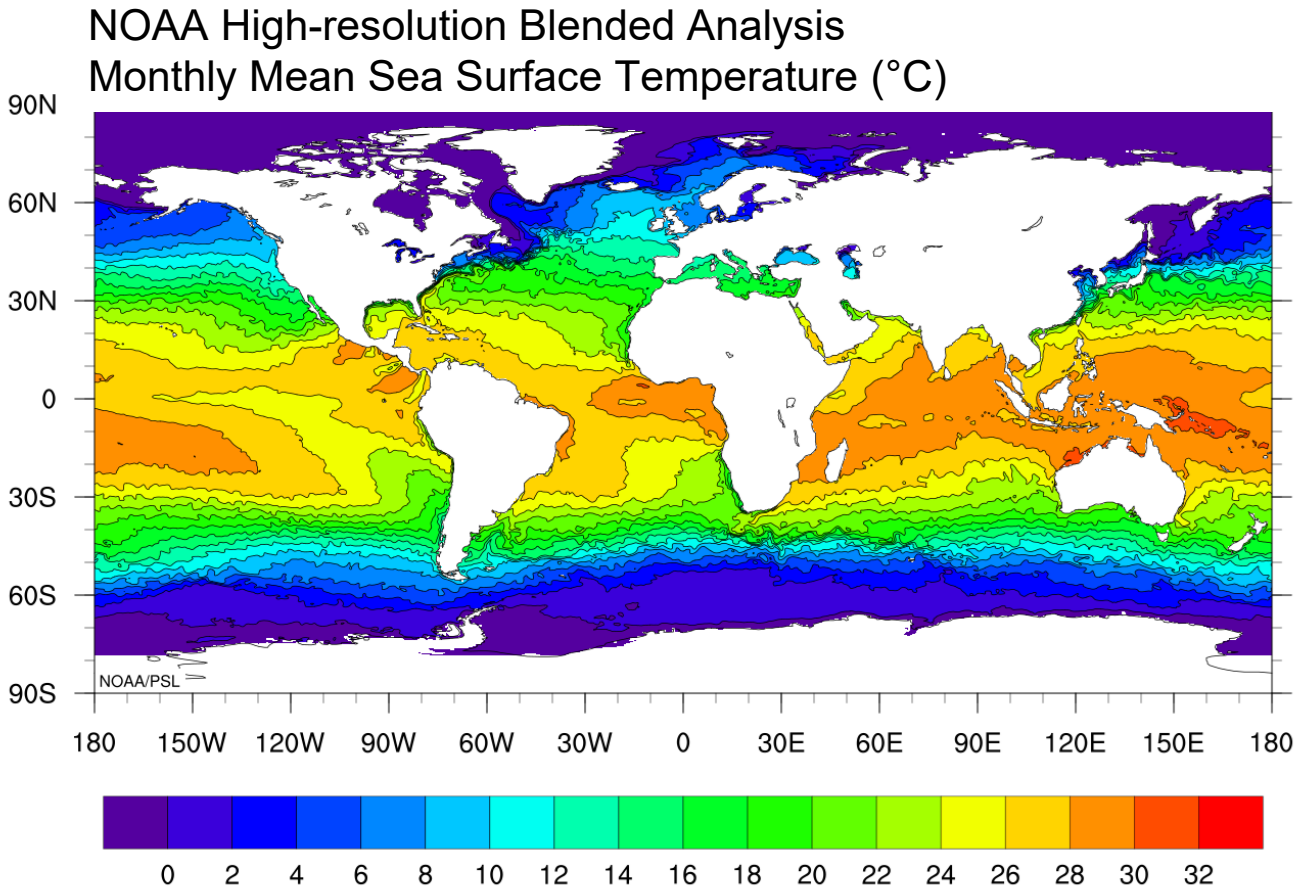
https://en.wikipedia.org/wiki/File:Air_masses.svg

Questions

- How do the oceans influence air masses?

- How does this affect local climate regimes?

FEB 2023



https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.highres.html

Huang, B., C. Liu, V. Banzon, E. Freeman, G. Graham, B. Hankins, T. Smith, and H.-M. Zhang, 2021: Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1, Journal of Climate, 34, 2923-2939. doi: 10.1175/JCLI-D-20-0166.1

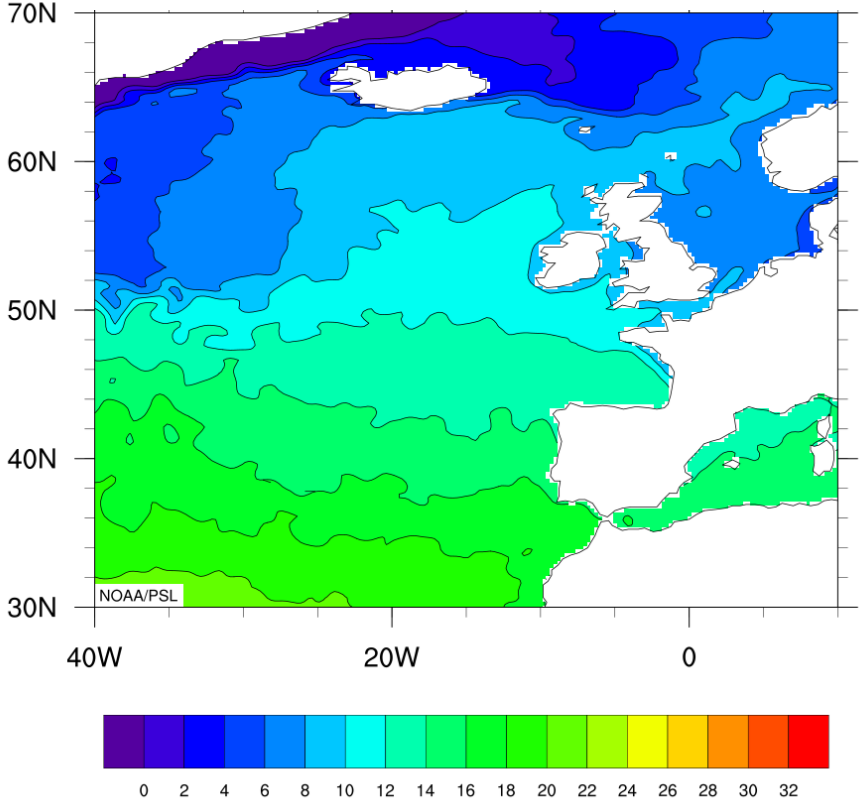
Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

- Based on the February 2023 mean sea surface temperatures, what kinds of conditions would you expect to find in various areas?

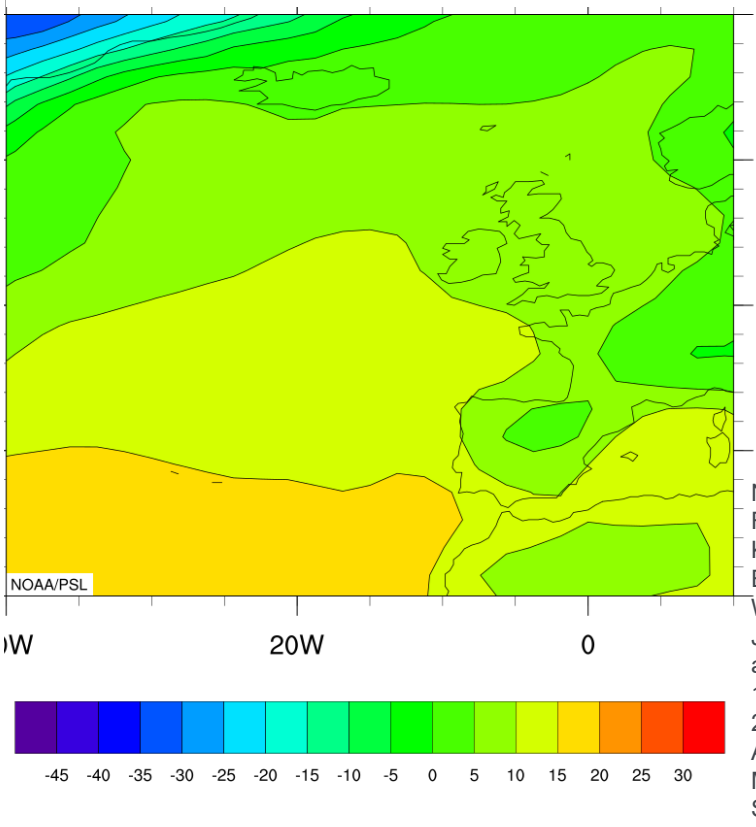
FEB 2023

NOAA High-resolution Blended Analysis
Monthly Mean SST (°C)



FEB 2023

NCEP/DOE AMIP-II Reanalysis
Monthly Mean 2.0 m Air Temperature (°C)

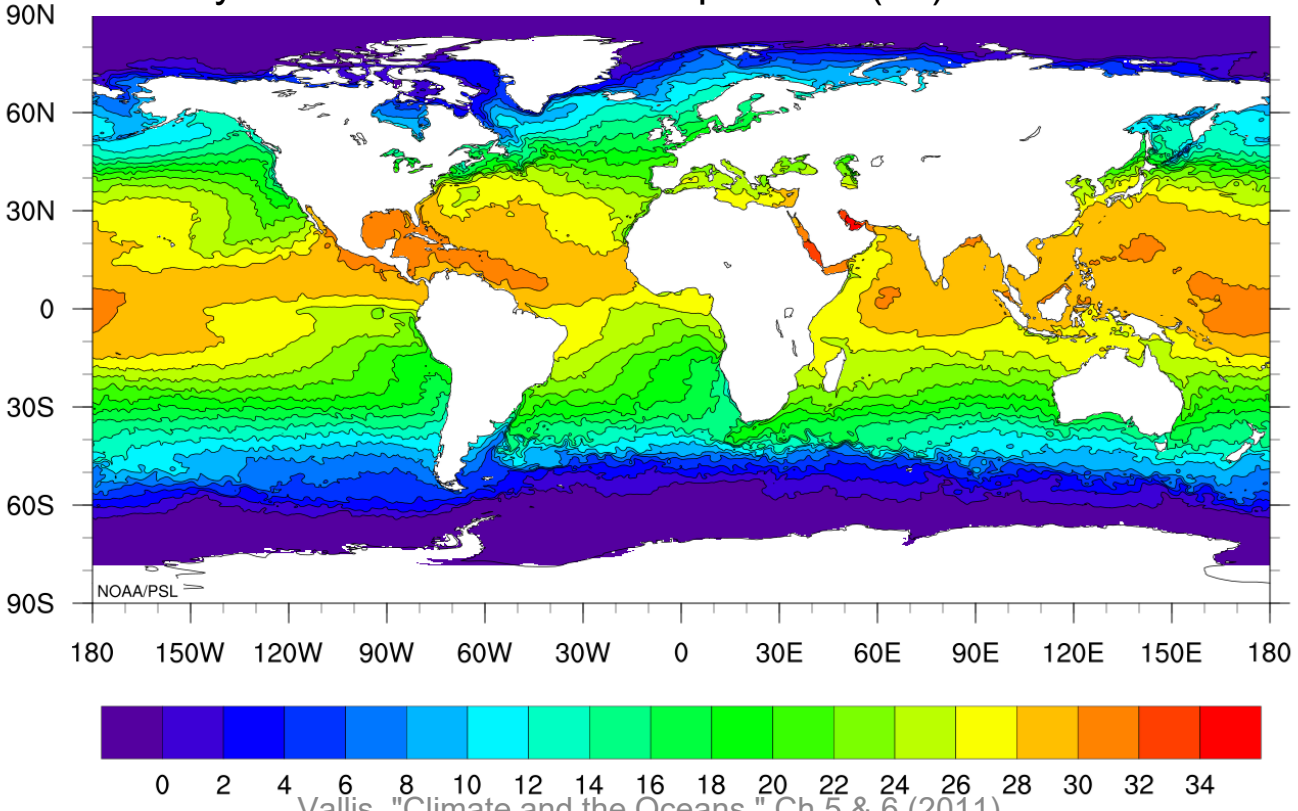


https://psl.noaa.gov/data/gridded/data.ncep.reanalysis2.html

NCEP-DOE AMIP-II Reanalysis (R-2): M. Kanamitsu, W. Ebisuzaki, J. Woollen, S-K Yang, J.J. Hnilo, M. Fiorino, and G. L. Potter. 1631-1643, Nov 2002, Bulletin of the American Meteorological Society.

SEP 2023

NOAA High-resolution Blended Analysis
Monthly Mean Sea Surface Temperature (°C)



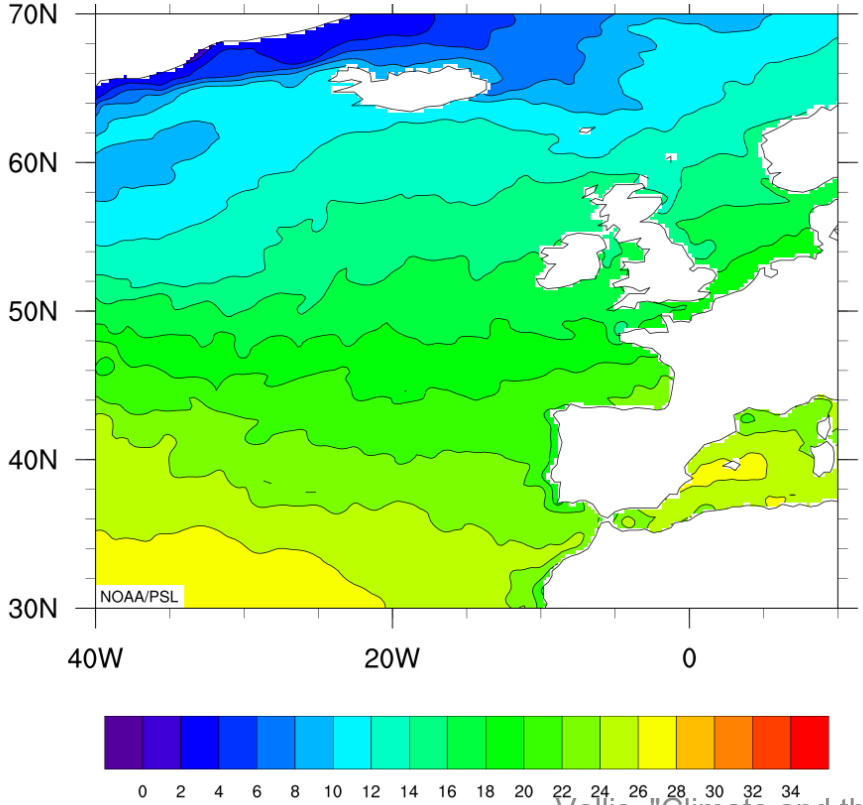
Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

- Based on the September 2023 mean sea surface temperatures, what kinds of conditions would you expect to find in various areas?

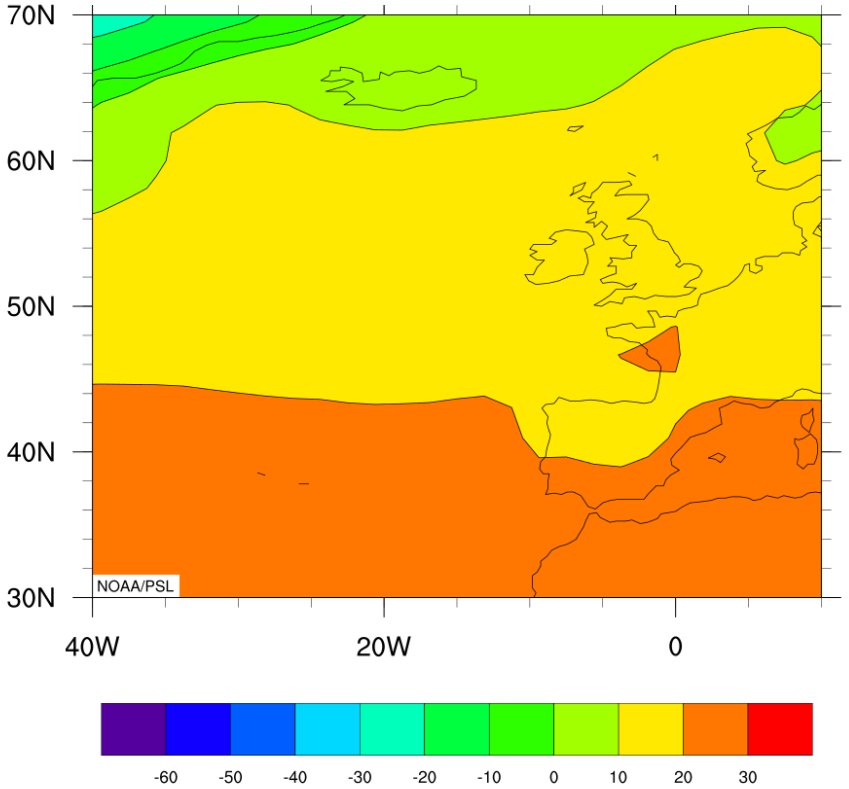
SEP 2023

NOAA High-resolution Blended Analysis
Monthly Mean SST (°C)



SEP 2023

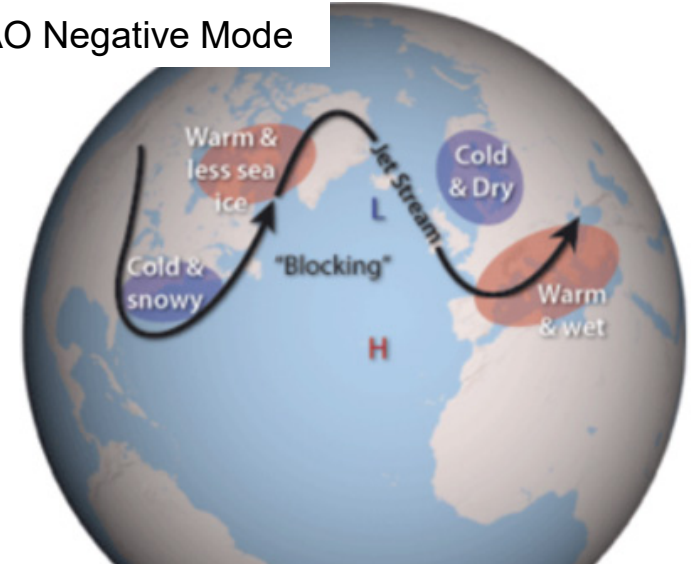
NCEP/DOE AMIP-II Reanalysis
Monthly Mean 2.0 m Air Temperature (°C)



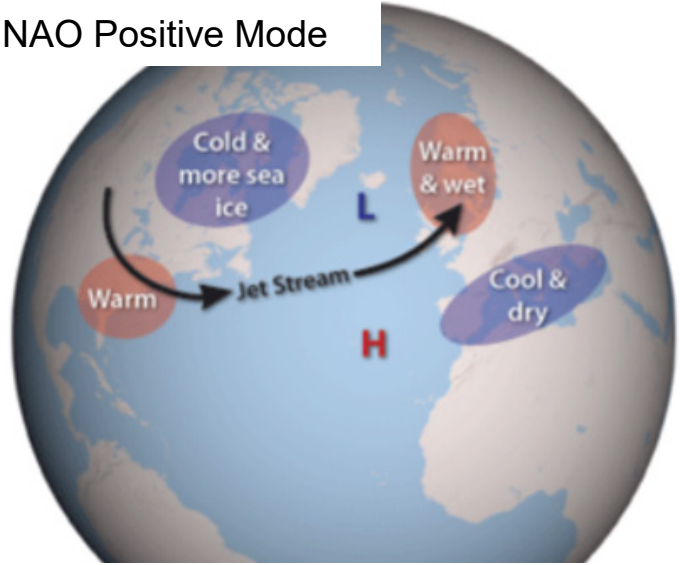
Climate Variability from Weeks to Years

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

NAO Negative Mode



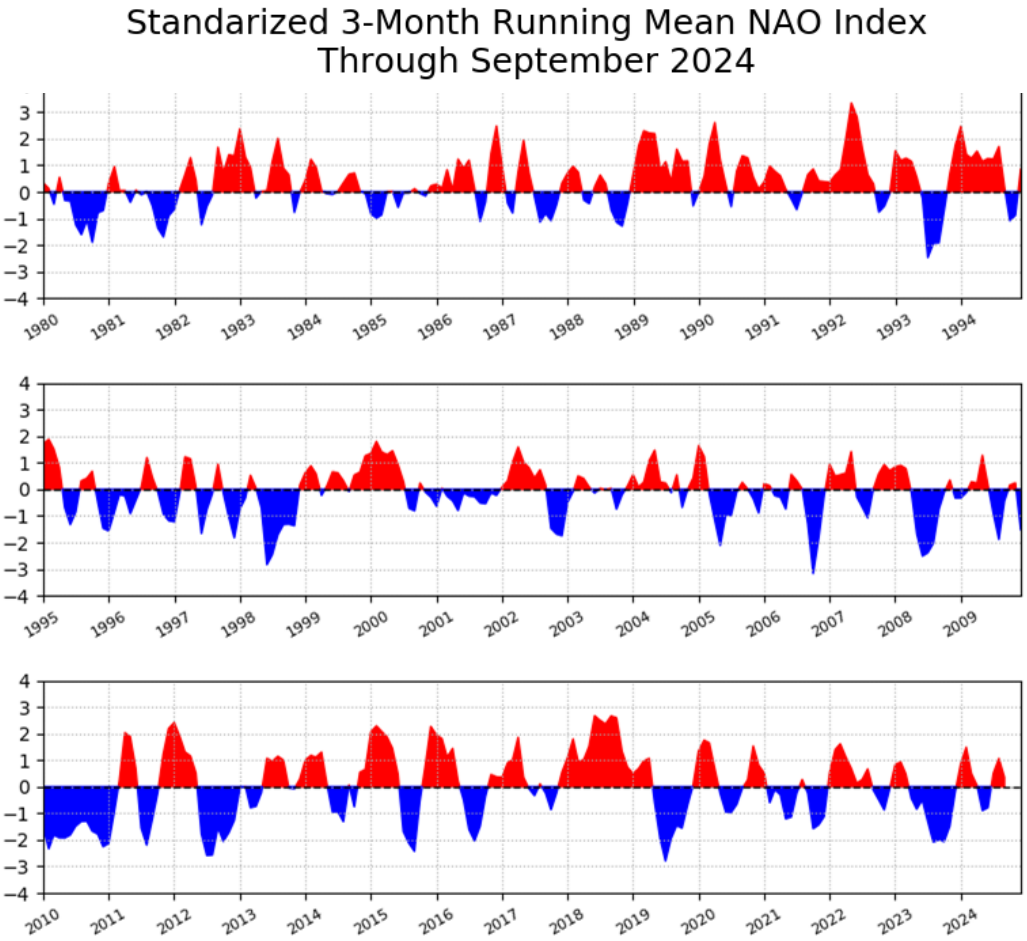
NAO Positive Mode



On average, the surface pressure near Iceland is relatively low (L), while the pressure near the Azores Islands is relatively high (H). During a negative phase (left), this pressure difference weakens. During a positive phase (right), the difference becomes stronger than usual. The variation in pressure patterns influences the strength and location of the jet stream and the path of storms across the North Atlantic. Schematic adapted from AIRMAP by Ned Gardiner and David Herring, NOAA.

https://www.climate.gov/news-features/understanding-climate/climate-variability-north-atlantic-oscillation

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)



https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/month_nao_index.shtml

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

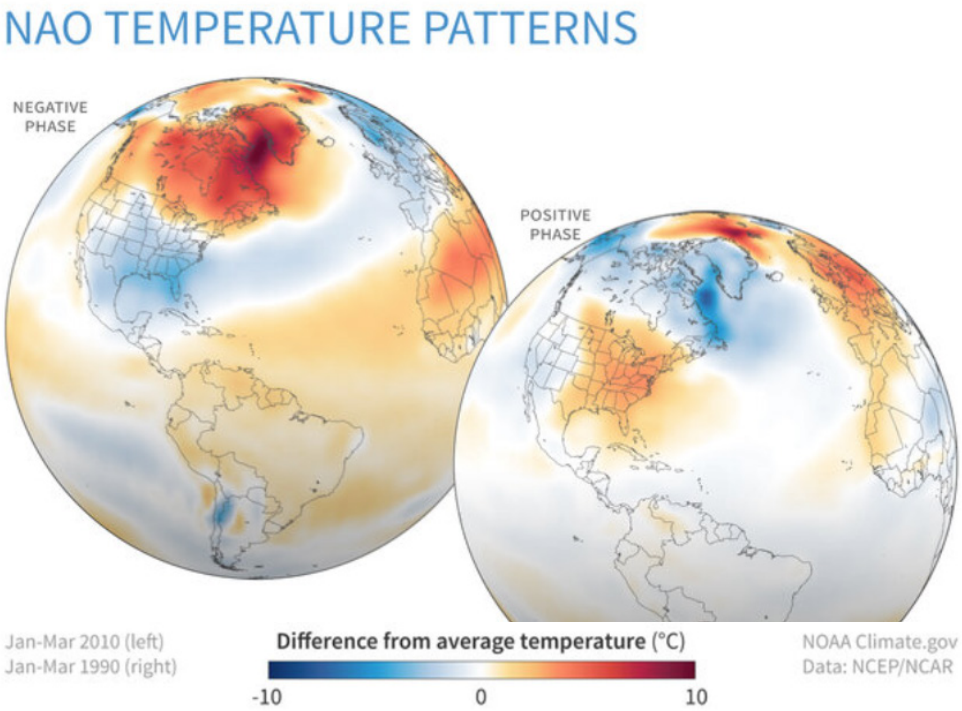
- What is the North Atlantic Oscillation, or NAO, and what are the phases?

- How might the phases of the NAO influence climate regimes?

- How might the ocean influence the phase of the NAO?

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

https://www.climate.gov/news-features/understanding-climate/climate-variability-north-atlantic-oscillation



Late winter temperatures compared to the 1981 – 2010 average when the NAO was strongly negative (top, Jan – Mar 2010) and when it was strongly positive (bottom, Jan – Mar 1990). Winters are often cooler than average across the mid-latitudes when the NAO is negative, and warmer than average when it is positive. NOAA Climate.gov image, based on data from the Physical Sciences Lab.

Questions

- What atmospheric conditions, corresponding the NAO phases, cause those temperature anomalies?

- How might the phases of the NAO influence ocean conditions?

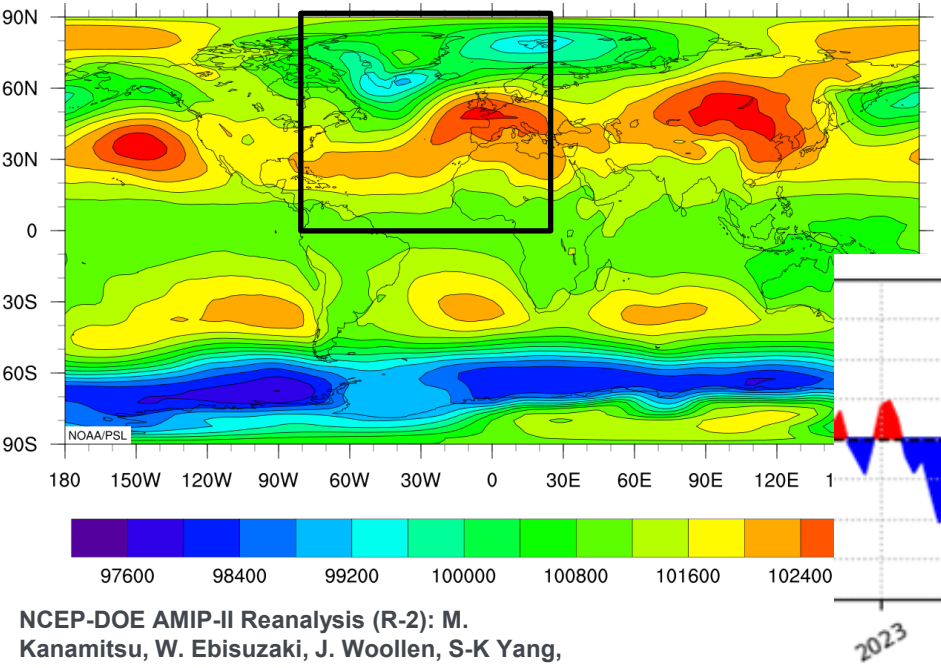
- How might ocean conditions influence the phase of the NAO?

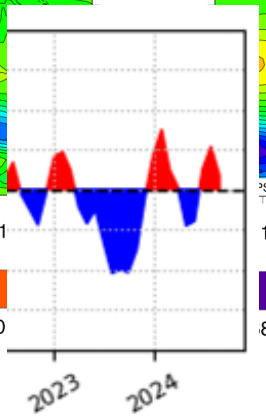
Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

https://psl.noaa.gov/data/gridded/data.ncep.reanalysis2.html

FEBRUARY 2023

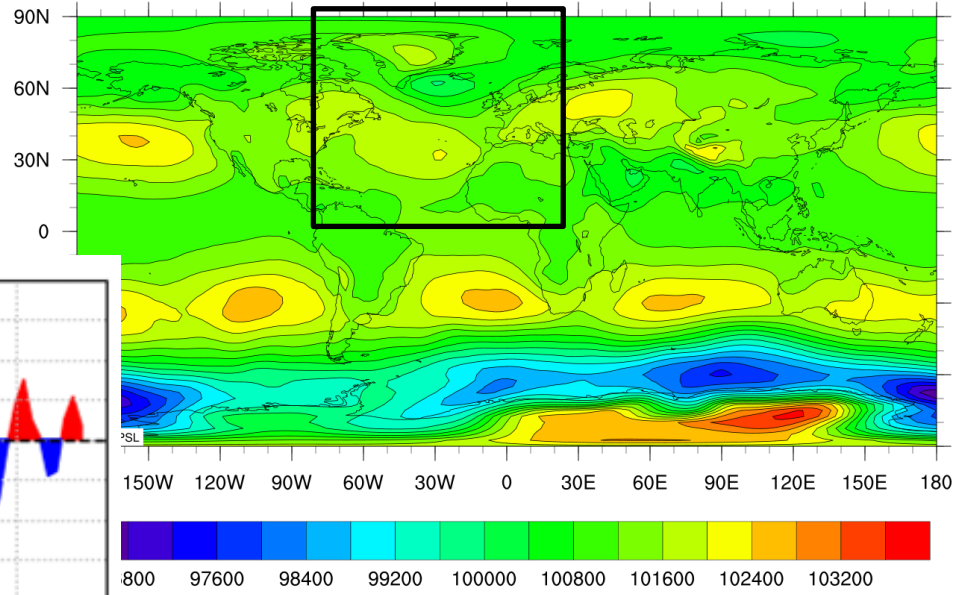
NCEP/DOE AMIP-II Reanalysis
Monthly Mean Sea Level Pressure (Pa)





SEPTEMBER 2023

NCEP/DOE AMIP-II Reanalysis
Monthly Mean Sea Level Pressure (Pa)



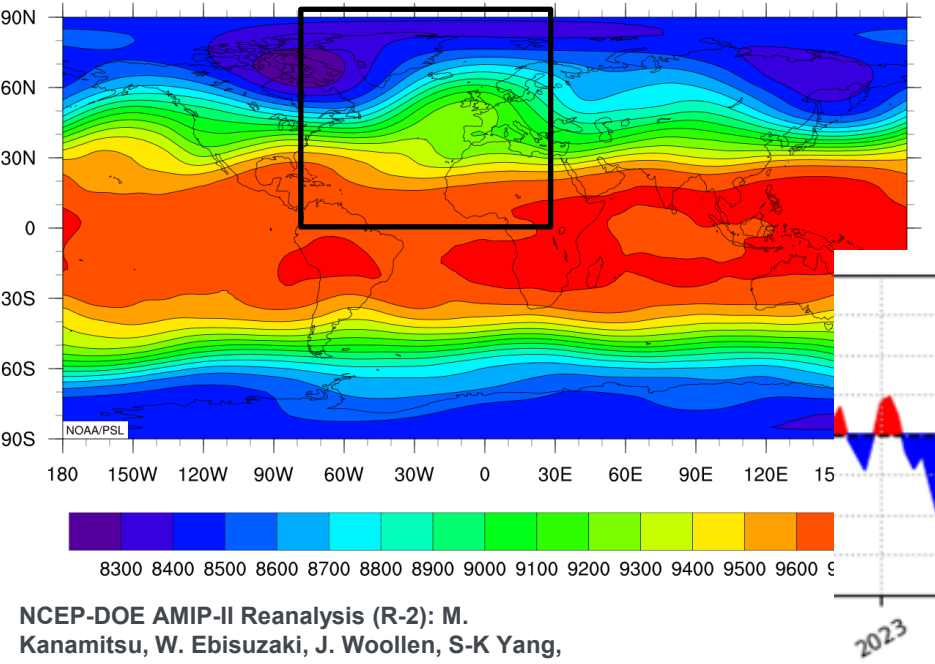
NCEP-DOE AMIP-II Reanalysis (R-2): M. Kanamitsu, W. Ebisuzaki, J. Woollen, S-K Yang, J.J. Hnilo, M. Fiorino, and G. L. Potter. 1631-1643, Nov 2002, Bulletin of the American Meteorological Society.

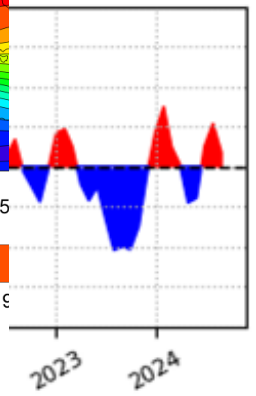
https://psl.noaa.gov/data/gridded/data.ncep.reanalysis2.html

FEBRUARY 2023

NCEP/DOE AMIP-II Reanalysis

Monthly Mean Geopotential Height (m)

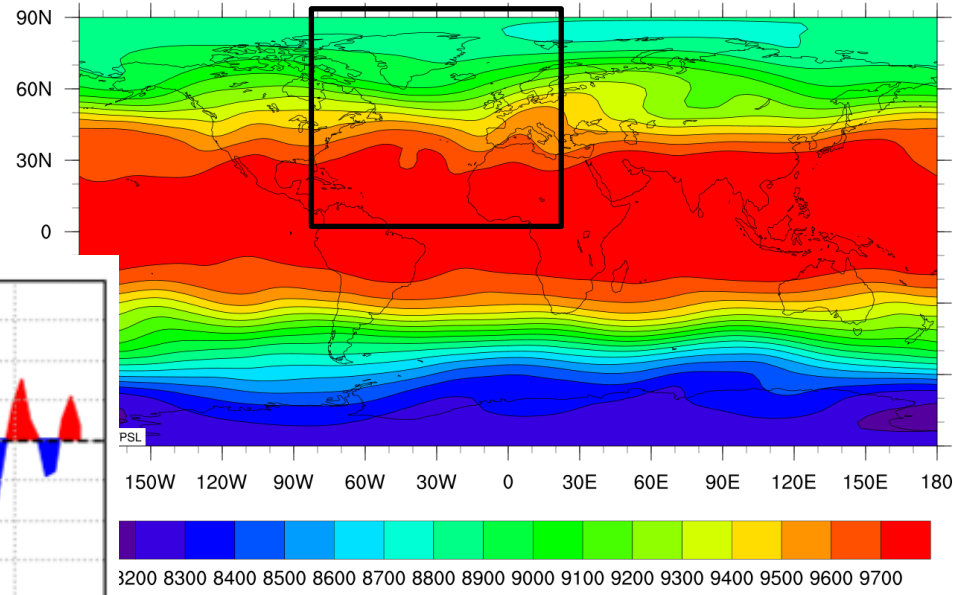




SEPTEMBER 2023

NCEP/DOE AMIP-II Reanalysis

Monthly Mean Geopotential Height (m)



NCEP-DOE AMIP-II Reanalysis (R-2): M. Kanamitsu, W. Ebisuzaki, J. Woollen, S-K Yang, J.J. Hnilo, M. Fiorino, and G. L. Potter. 1631-1643, Nov 2002, Bulletin of the American Meteorological Society.

Questions

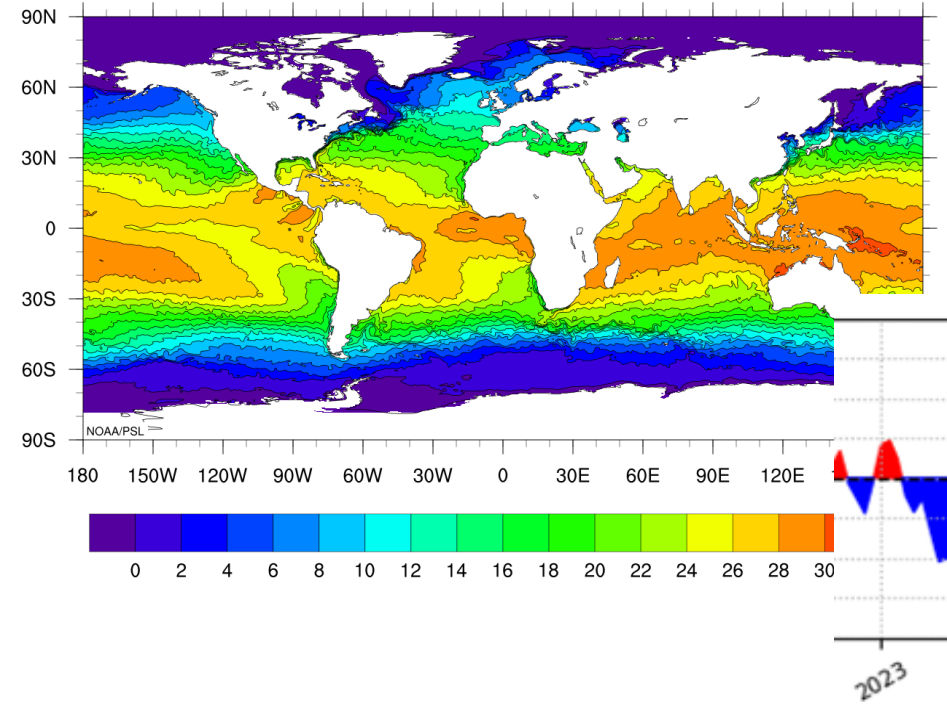
- Does anything stand out to you from the charts?

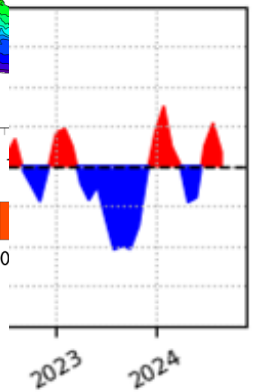
- What would you expect in terms of sea surface temperatures?

https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.highres.html

FEB 2023

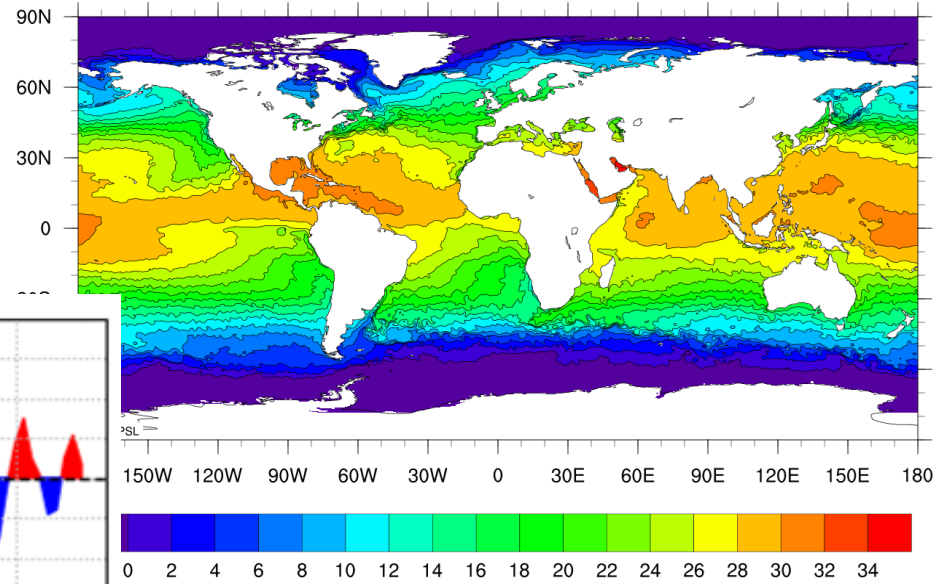
NOAA High-resolution Blended Analysis
Monthly Mean Sea Surface Temperature (°C)





SEP 2023

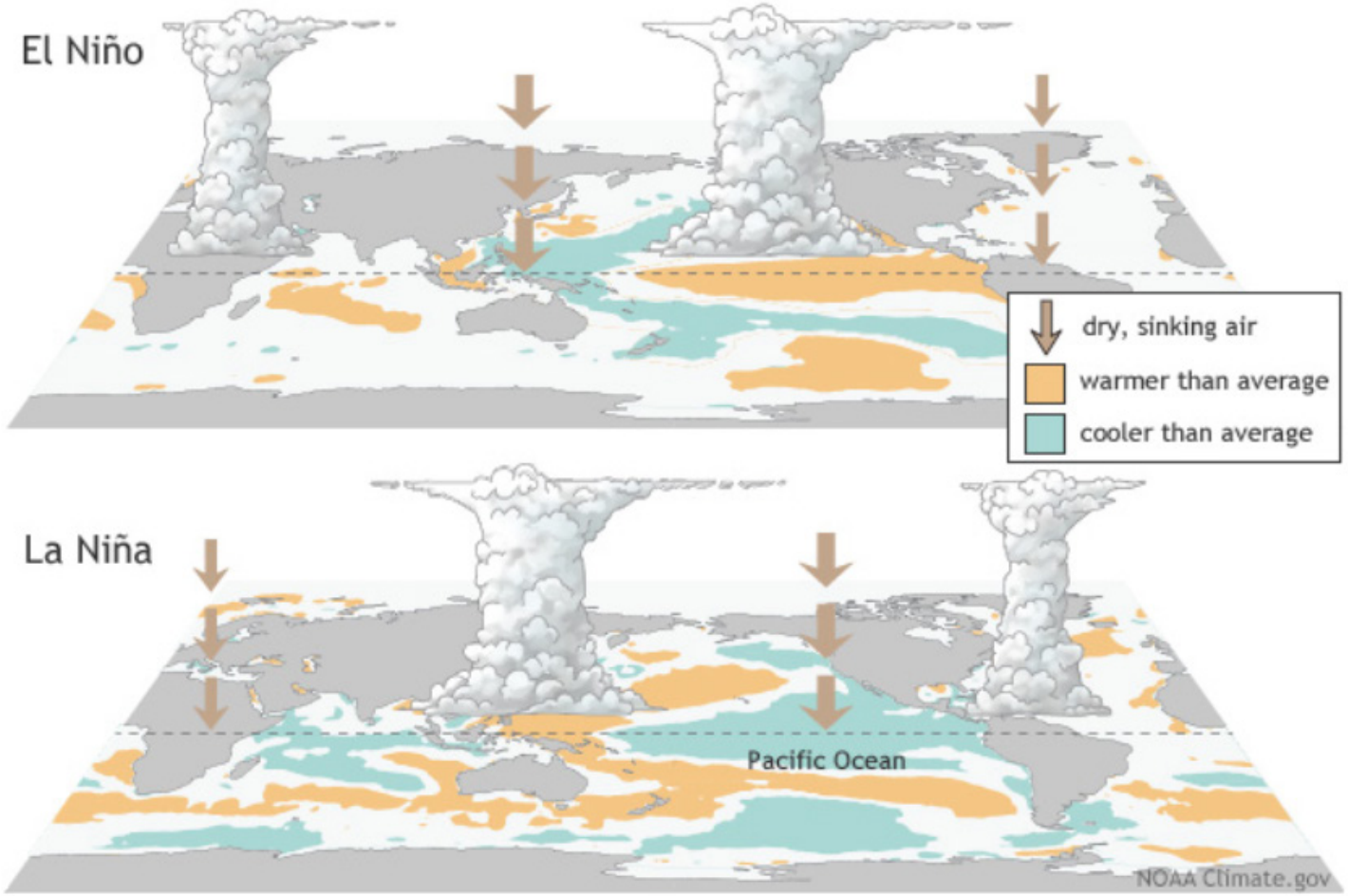
NOAA High-resolution Blended Analysis
Monthly Mean Sea Surface Temperature (°C)



Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

- How did your assumptions regarding the ocean-atmosphere coupling compare?



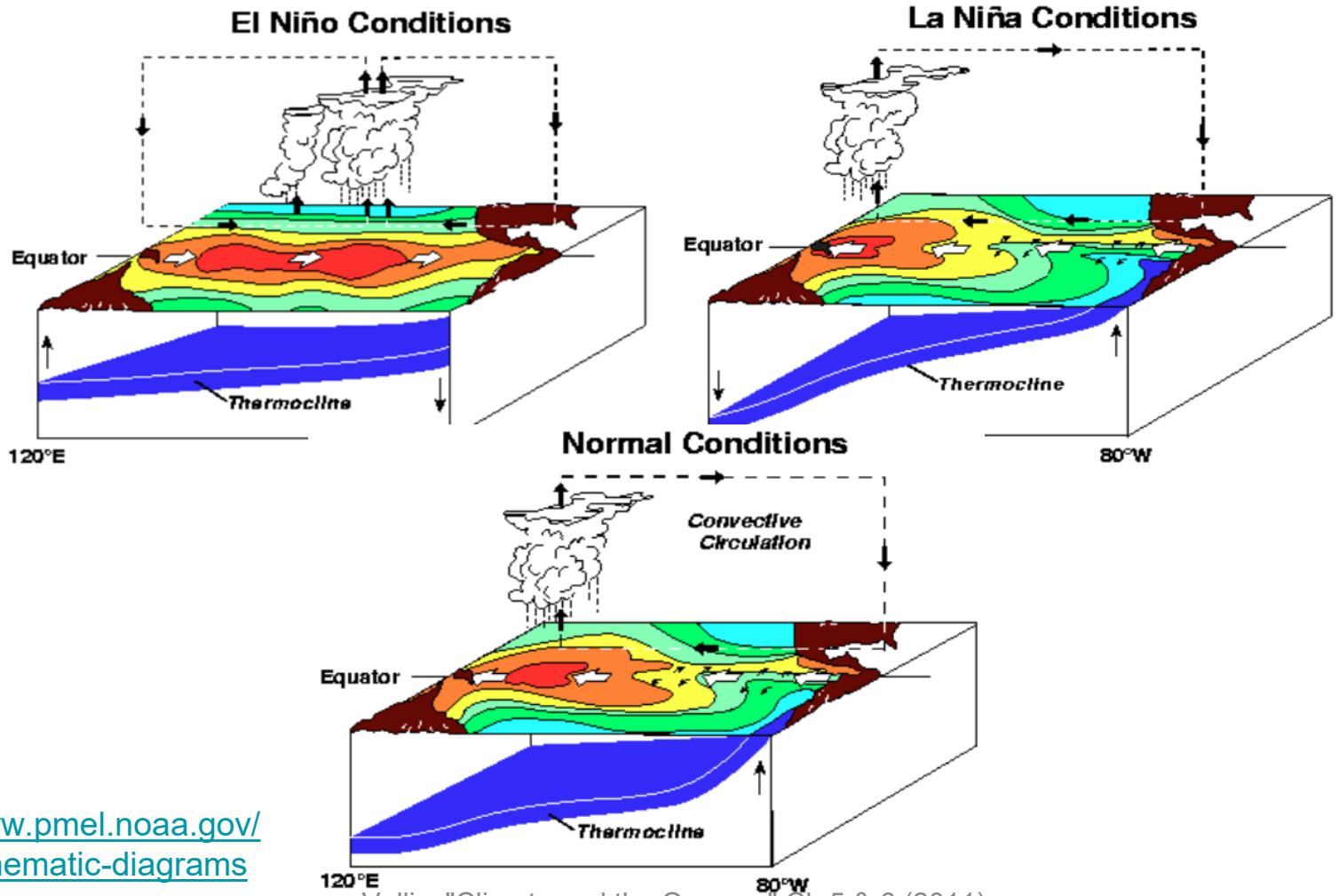
https://www.climate.gov/enso

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

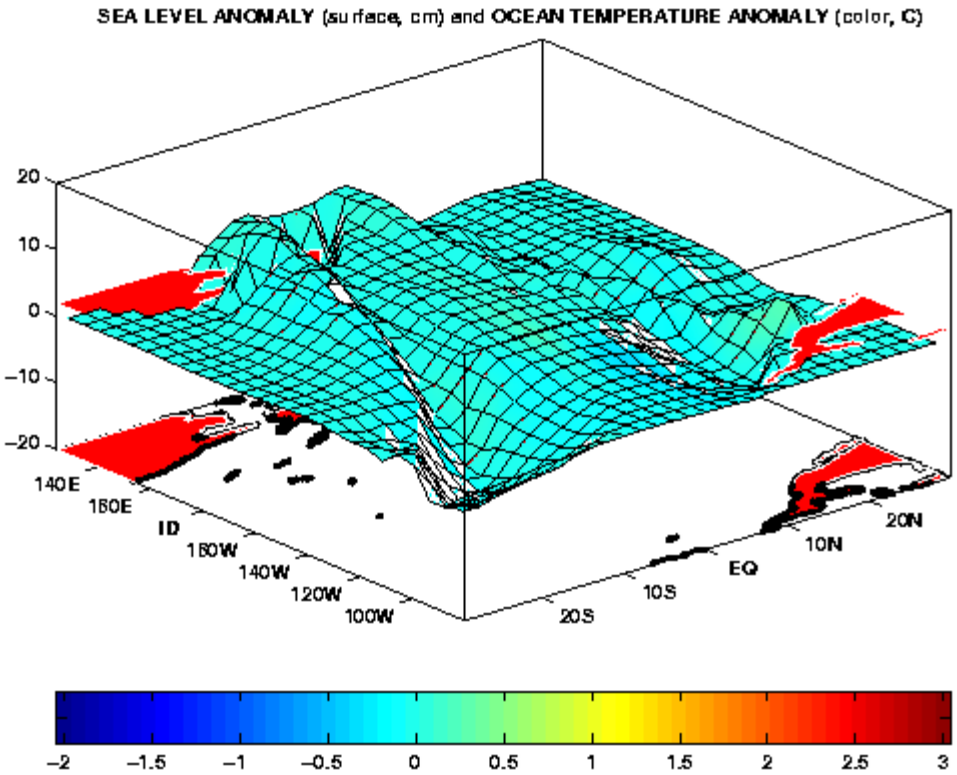
- How do the ocean and atmosphere interact with each other through the two phases of ENSO?

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)



https://www.pmel.noaa.gov/elnino/schematic-diagrams

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)



https://www.psl.noaa.gov/enso/enso.description.html

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

- How does the physical structure of the ocean change throughout ENSO?

- How does this influence climate patterns?

Notice: This page is updated automatically on the first Thursday of each month. Because of the high frequency filter applied to the ERSSTv5 data (Huang et al. 2017, J.Climate), ONI values may change up to two months after the initial "real time" value is posted. Therefore, the most recent ONI values should be considered an estimate.

DESCRIPTION: Warm (red) and cold (blue) periods based on a threshold of +/- 0.5°C for the Oceanic Niño Index (ONI) [3 month running mean of ERSST.v5 SST anomalies in the Niño 3.4 region (5°N-5°S, 120°-170°W)], based on centered 30-year base periods updated every 5 years.

For historical purposes, periods of below and above normal SSTs are colored in blue and red when the threshold is met for a minimum of 5 consecutive overlapping seasons. The ONI is one measure of the El Niño-Southern Oscillation, and other indices can confirm whether features consistent with a coupled ocean-atmosphere phenomenon accompanied these periods.

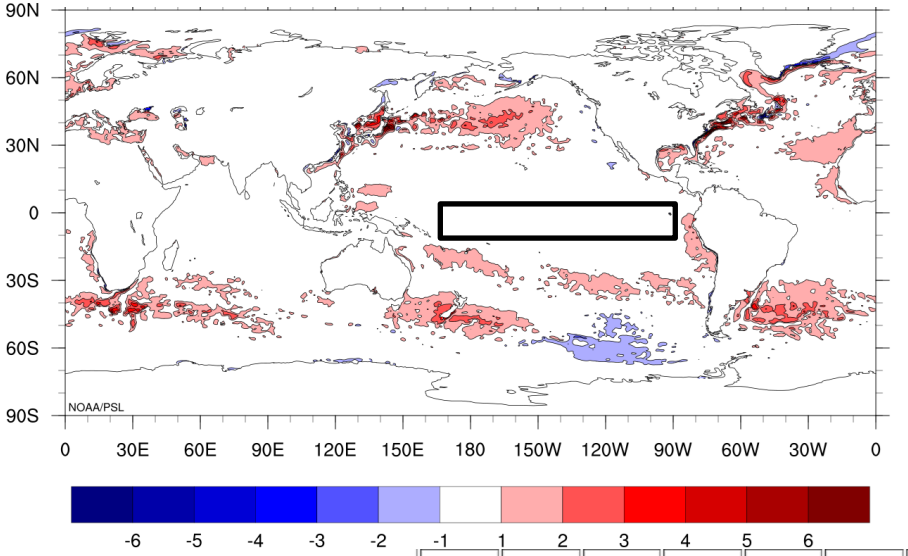
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.7	-1.4	-1.1	-0.8	-0.7	-0.6	-0.6	-0.5	-0.5	-0.6	-0.7	-0.7
2001	-0.7	-0.5	-0.4	-0.3	-0.3	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.3
2002	-0.1	0.0	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.2	1.3	1.1
2003	0.9	0.6	0.4	0.0	-0.3	-0.2	0.1	0.2	0.3	0.3	0.4	0.4
2004	0.4	0.3	0.2	0.2	0.2	0.3	0.5	0.6	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.4	0.4	0.3	0.1	-0.1	-0.1	-0.1	-0.3	-0.6	-0.8
2006	-0.9	-0.8	-0.6	-0.4	-0.1	0.0	0.1	0.3	0.5	0.8	0.9	0.9
2007	0.7	0.2	-0.1	-0.3	-0.4	-0.5	-0.6	-0.8	-1.1	-1.3	-1.5	-1.6
2008	-1.6	-1.5	-1.3	-1.0	-0.8	-0.6	-0.4	-0.2	-0.2	-0.4	-0.6	-0.7
2009	-0.8	-0.8	-0.6	-0.3	0.0	0.3	0.5	0.6	0.7	1.0	1.4	1.6
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2010	1.5	1.2	0.8	0.4	-0.2	-0.7	-1.0	-1.3	-1.6	-1.6	-1.6	-1.6
2011	-1.4	-1.2	-0.9	-0.7	-0.6	-0.4	-0.5	-0.6	-0.8	-1.0	-1.1	-1.0
2012	-0.9	-0.7	-0.6	-0.5	-0.3	0.0	0.2	0.4	0.4	0.3	0.1	-0.2
2013	-0.4	-0.4	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3	-0.2	-0.2	-0.3
2014	-0.4	-0.5	-0.3	0.0	0.2	0.2	0.0	0.1	0.2	0.5	0.6	0.7
2015	0.5	0.5	0.5	0.7	0.9	1.2	1.5	1.9	2.2	2.4	2.6	2.6
2016	2.5	2.1	1.6	0.9	0.4	-0.1	-0.4	-0.5	-0.6	-0.7	-0.7	-0.6
2017	-0.3	-0.2	0.1	0.2	0.3	0.3	0.1	-0.1	-0.4	-0.7	-0.8	-1.0
2018	-0.9	-0.9	-0.7	-0.5	-0.2	0.0	0.1	0.2	0.5	0.8	0.9	0.8
2019	0.7	0.7	0.7	0.7	0.5	0.5	0.3	0.1	0.2	0.3	0.5	0.5
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2020	0.5	0.5	0.4	0.2	-0.1	-0.3	-0.4	-0.6	-0.9	-1.2	-1.3	-1.2
2021	-1.0	-0.9	-0.8	-0.7	-0.5	-0.4	-0.4	-0.5	-0.7	-0.8	-1.0	-1.0
2022	-1.0	-0.9	-1.0	-1.1	-1.0	-0.9	-0.8	-0.9	-1.0	-1.0	-0.9	-0.8
2023	-0.7	-0.4	-0.1	0.2	0.5	0.8	1.1	1.3	1.6	1.8	1.9	2.0
2024	1.8	1.5	1.1	0.7	0.4	0.2	0.0	-0.1				

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.highres.html

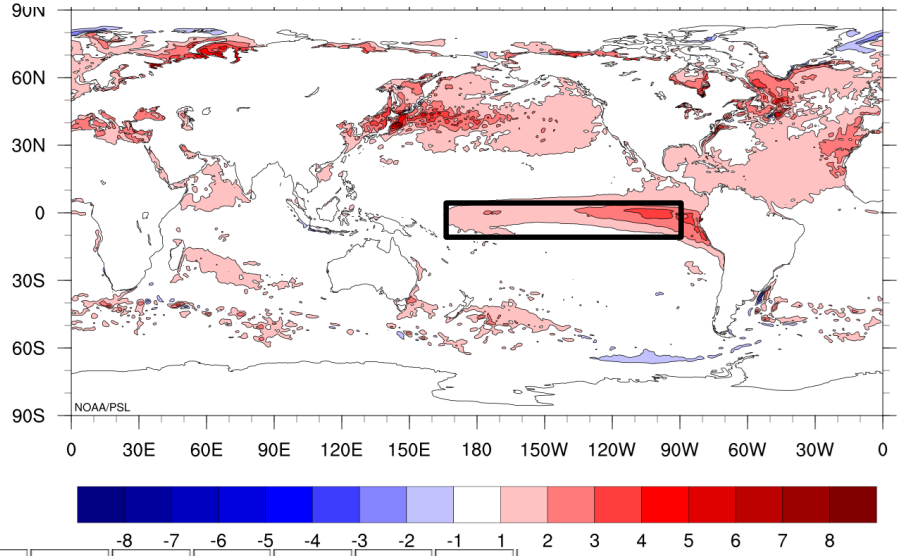
01 DEC 2022 – 30 APR 2023

NOAA High-resolution Blended Analysis
Daily Anomaly SST (°C)



01 JUL 2023 – 30 NOV 2023

NOAA High-resolution Blended Analysis
Daily Anomaly SST (°C)



Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2020	0.5	0.5	0.4	0.2	-0.1	-0.3	-0.4	-0.6	-0.9	-1.2	-1.3	-1.2
2021	-1.0	-0.9	-0.8	-0.7	-0.5	-0.4	-0.4	-0.5	-0.7	-0.8	-1.0	-1.0
2022	-1.0	-0.9	-1.0	-1.1	-1.0	-0.9	-0.8	-0.9	-1.0	-1.0	-0.9	-0.8
2023	-0.7	-0.4	-0.1	0.2	0.5	0.8	1.1	1.3	1.6	1.8	1.9	2.0
2024	1.8	1.5	1.1	0.7	0.4	0.2	0.0	-0.1				

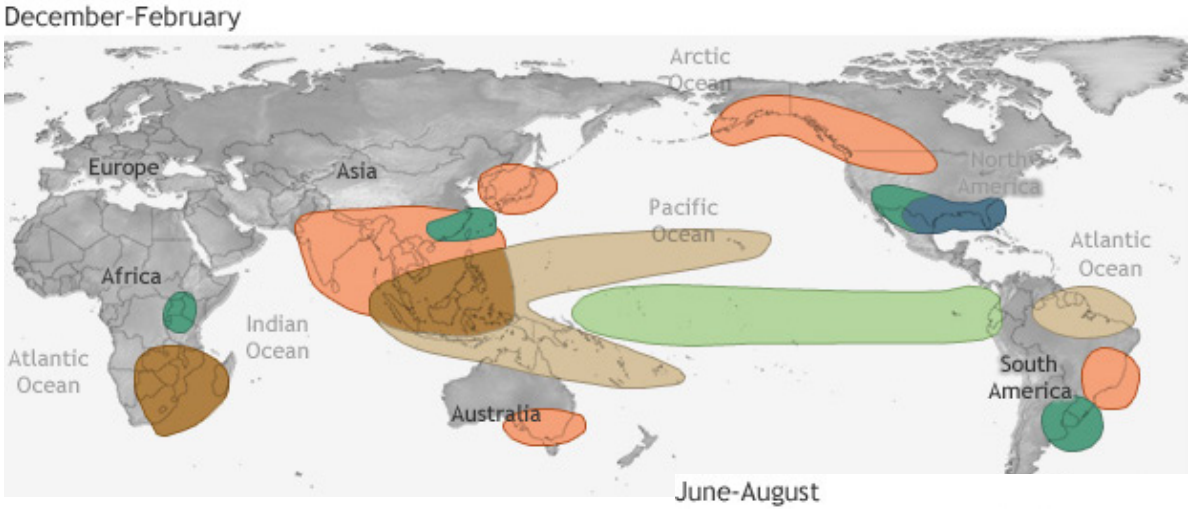
Huang, B., C. Liu, V. Banzon, E. Freeman, G. Graham, B. Hankins, T. Smith, and H.-M. Zhang, 2021: Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1, Journal of Climate, 34, 2923-2939. doi: 10.1175/JCLI-D-20-0166.1

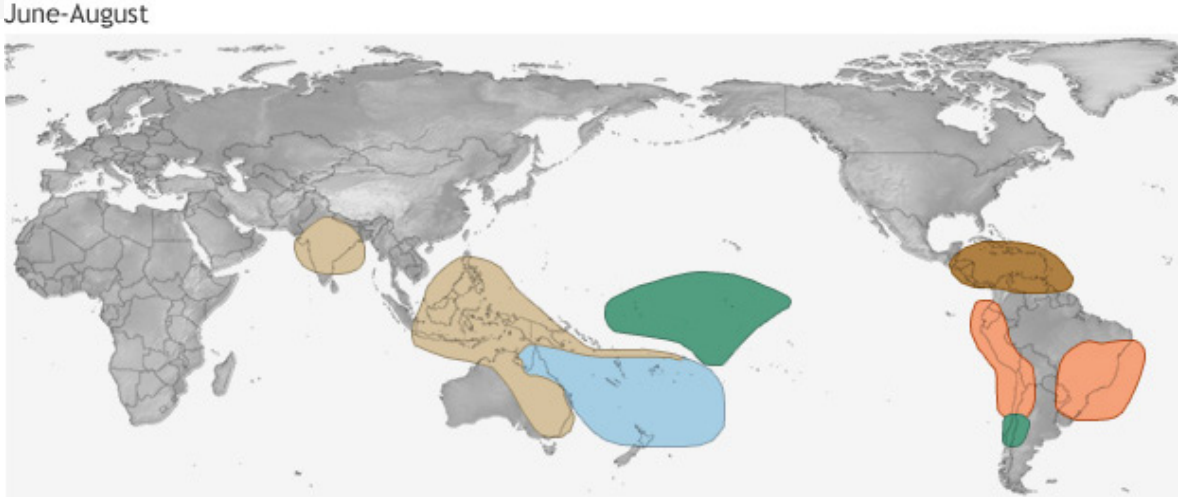
Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

- How does the ONI index compare to the SST anomalies?

El Niño
Climate Impacts





Cool
Warm
Wet
Dry
Cool and dry
Warm and dry
Cool and Wet
Warm and wet

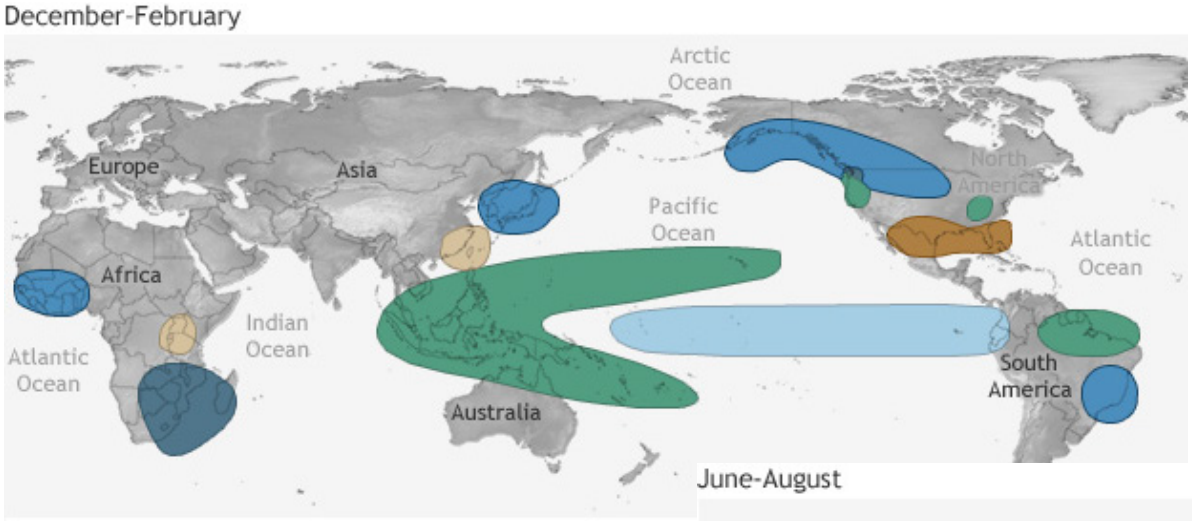
https://www.climate.gov/news-features/featured-images/global-impacts-el-niño-and-la-niña

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Questions

- How does a warm episode influence the global climate patterns?

La Niña
Climate Impacts



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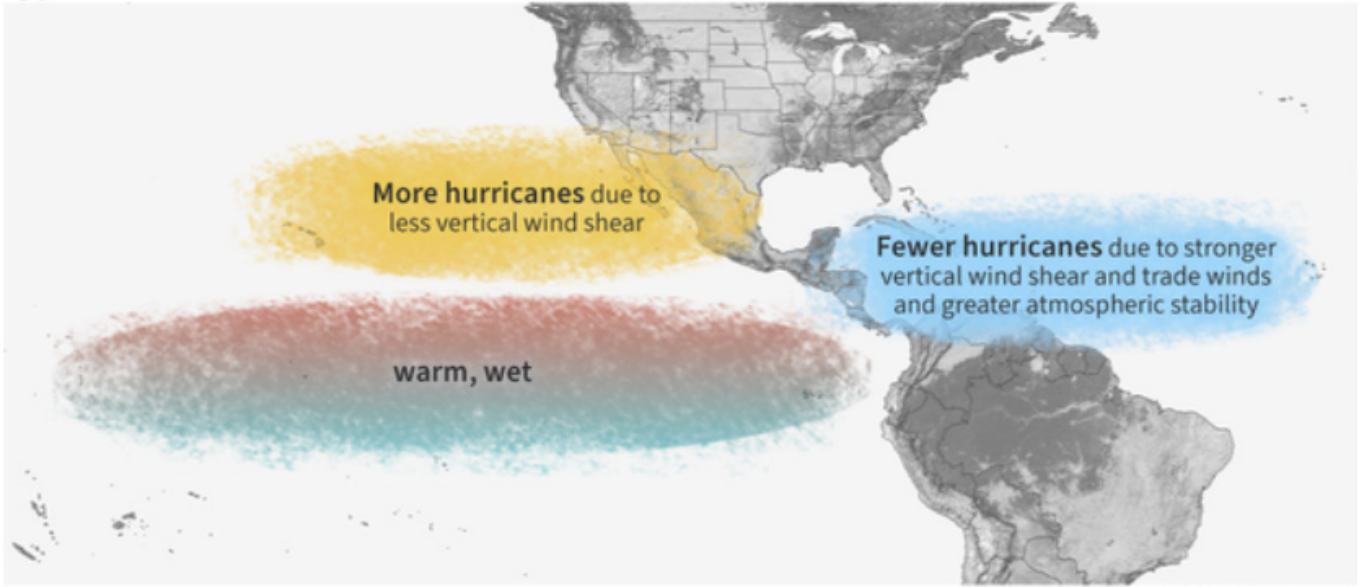
- How does a cold episode influence the global climate patterns?

Typical El Niño influence



https://www.climate.gov/news-features/blogs/enso/impacts-el-nino-and-la-nina-hurricane-season

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)

Recipe for a Hurricane

Whipping up a hurricane calls for a number of ingredients readily available in tropical areas:

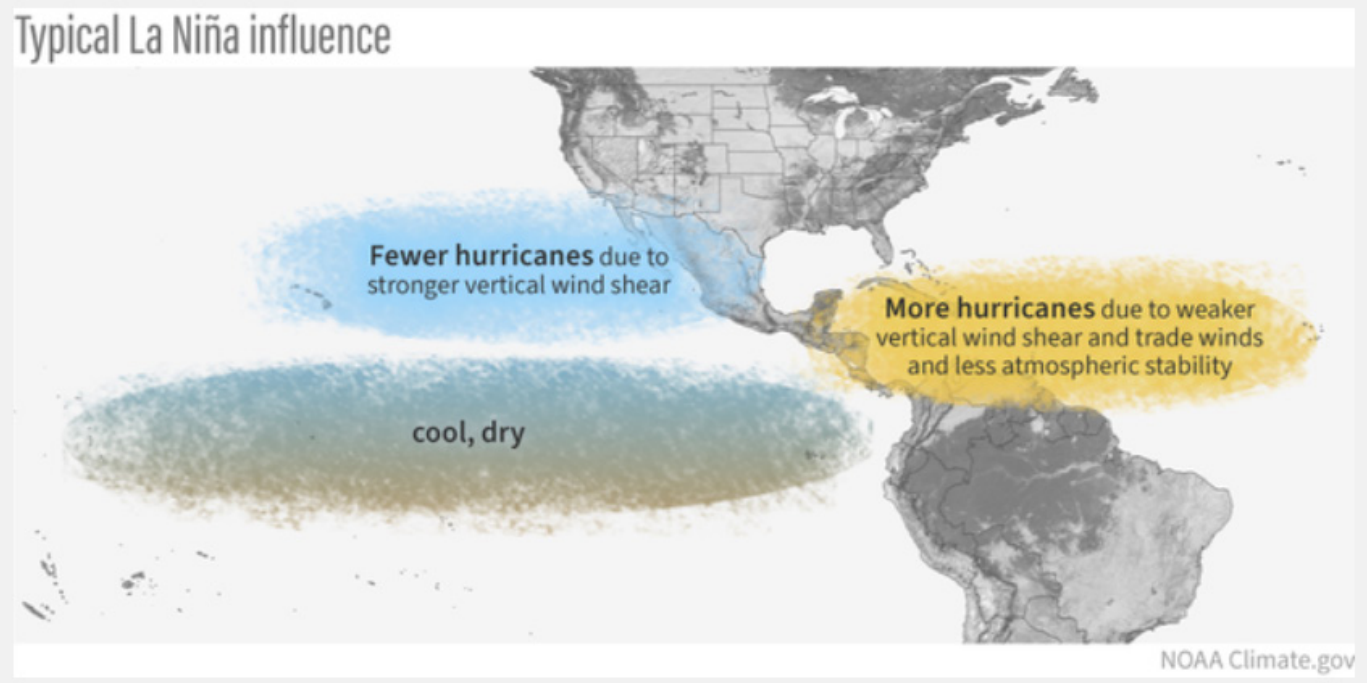
- **A pre-existing weather disturbance**: A hurricane often starts out as a tropical wave.
- **Warm water**: Water at least **26.5 degrees Celsius** over a depth of **50 meters** powers the storm.
- **Thunderstorm activity**: Thunderstorms turn ocean heat into hurricane fuel.
- **Low wind shear**: A large difference in wind speed and direction around or near the storm can weaken it.

Mix it all together, and you've got a hurricane—maybe. Even when all these factors come together, a hurricane doesn't always develop.

https://oceanservice.noaa.gov/facts/how-hurricanes-form.html

Questions

- How does a warm episode influence tropical cyclone development?



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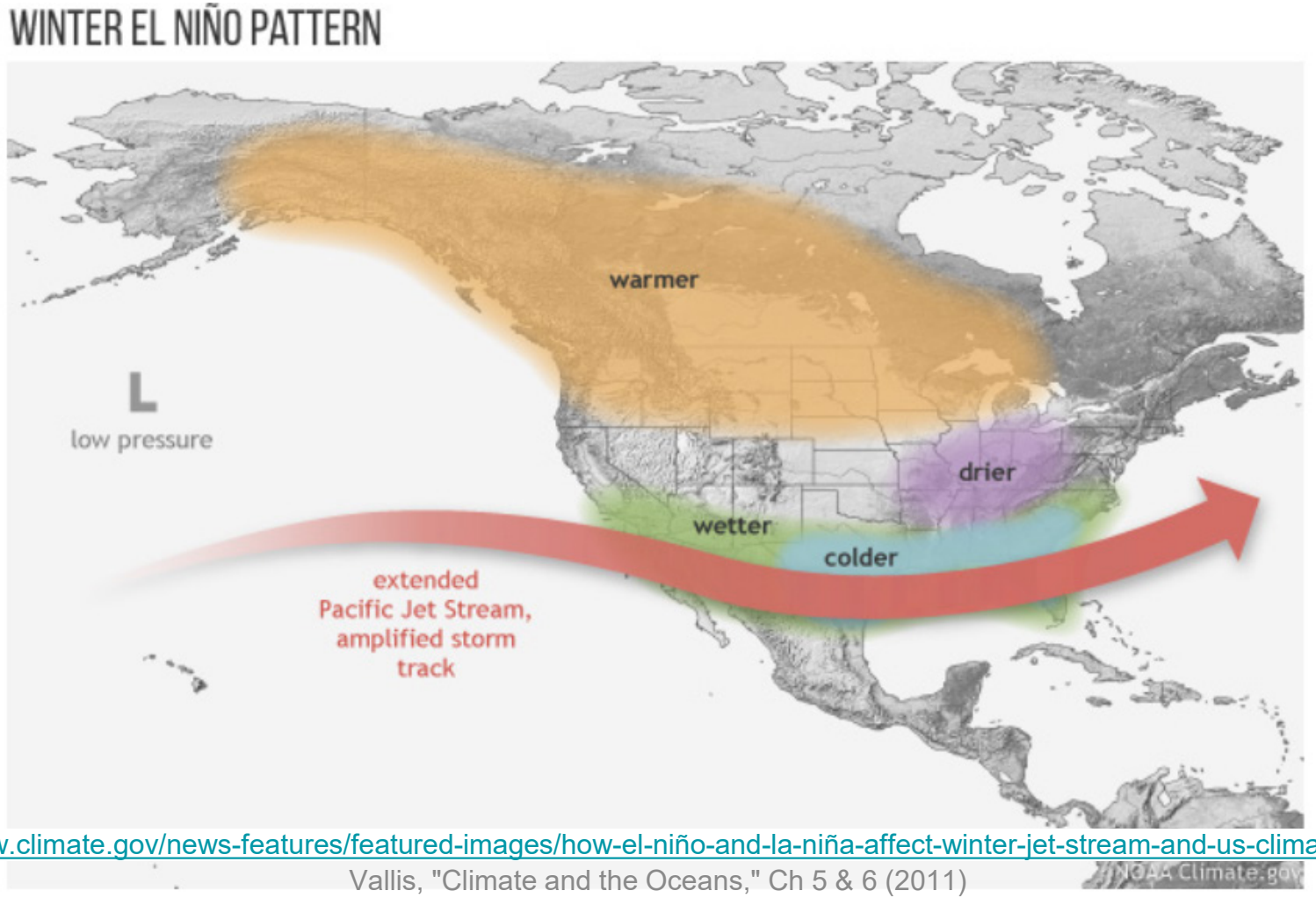

https://www.climate.gov/news-features/featured-images/how-el-niño-and-la-niña-affect-winter-jet-stream-and-us-climate

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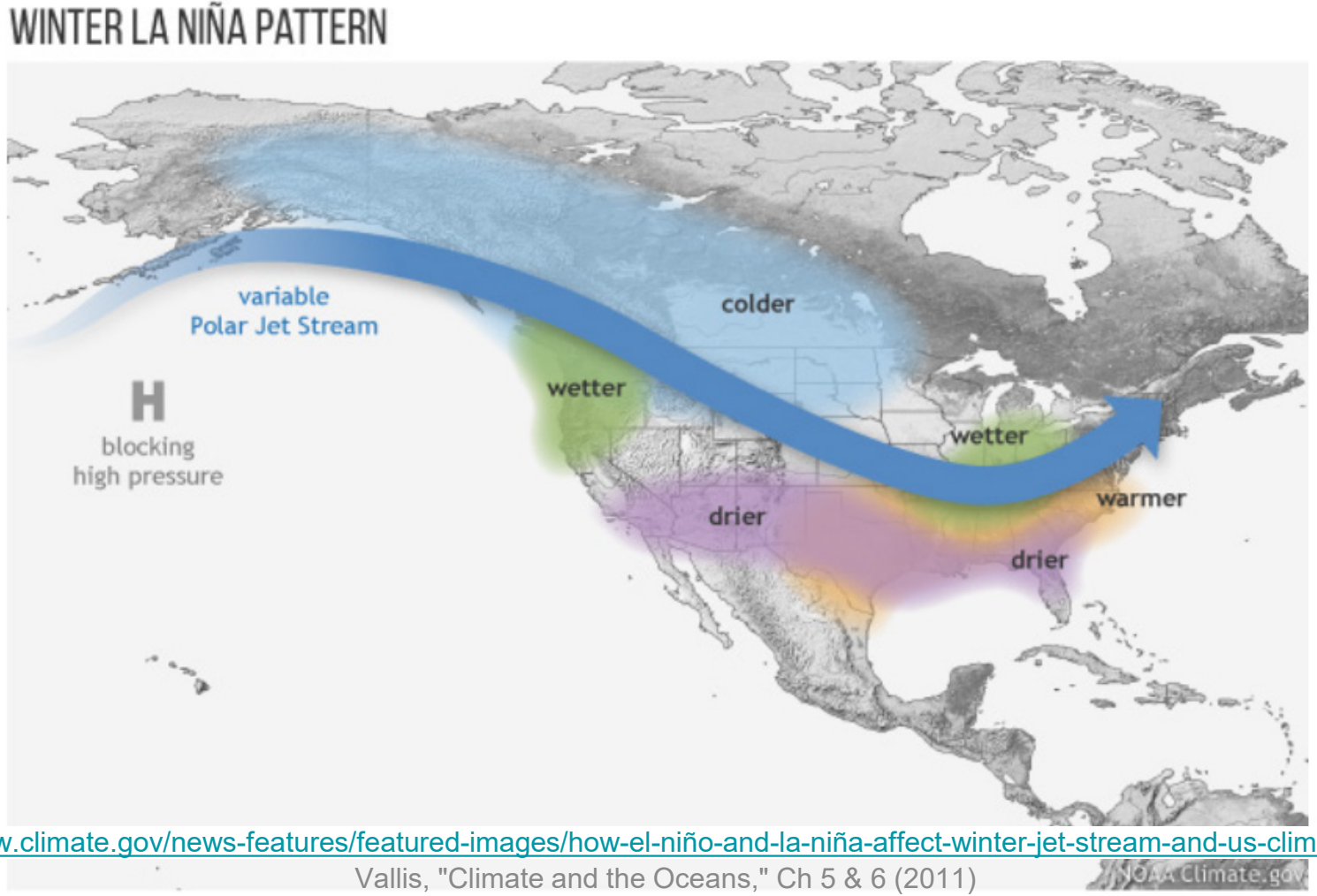
Questions

- How does a warm episode influence North American winters?



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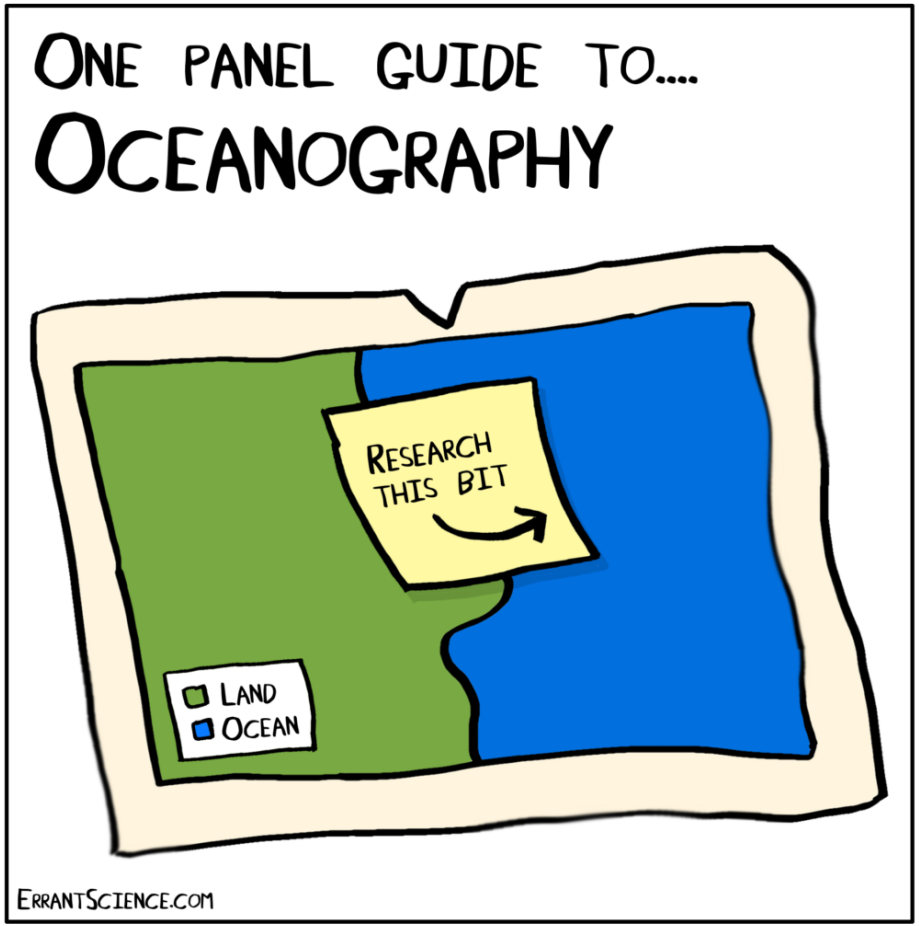

Vallis, "Climate and the Oceans," Ch 5 & 6 (2011)