The El Nino Southern Oscillation
ENSO

A global coupled atmosphere-ocean phenomenon
seated in the tropics, with variability at 3-7 years

Ocean: warm/cold waters off the coast of Peru (El Nino/La Nina)

Atmosphere: pressure and wind variations (Southern Oscillation)

https://www.cpc.ncep.noaa.gov/ (click on ENSO in left menu)

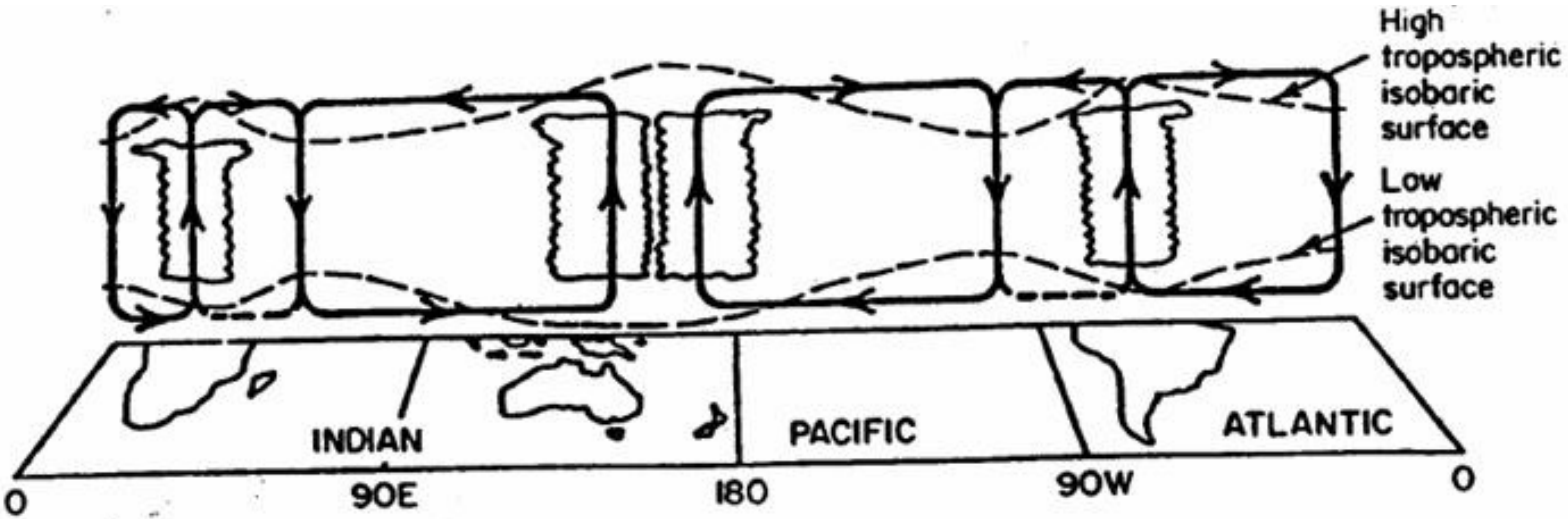


Figure 3.8 Schematic view of the east-west Walker circulation along the equator indicating low-level convergence in regions of convection where mean upward motion occurs. [From Webster (1983).]

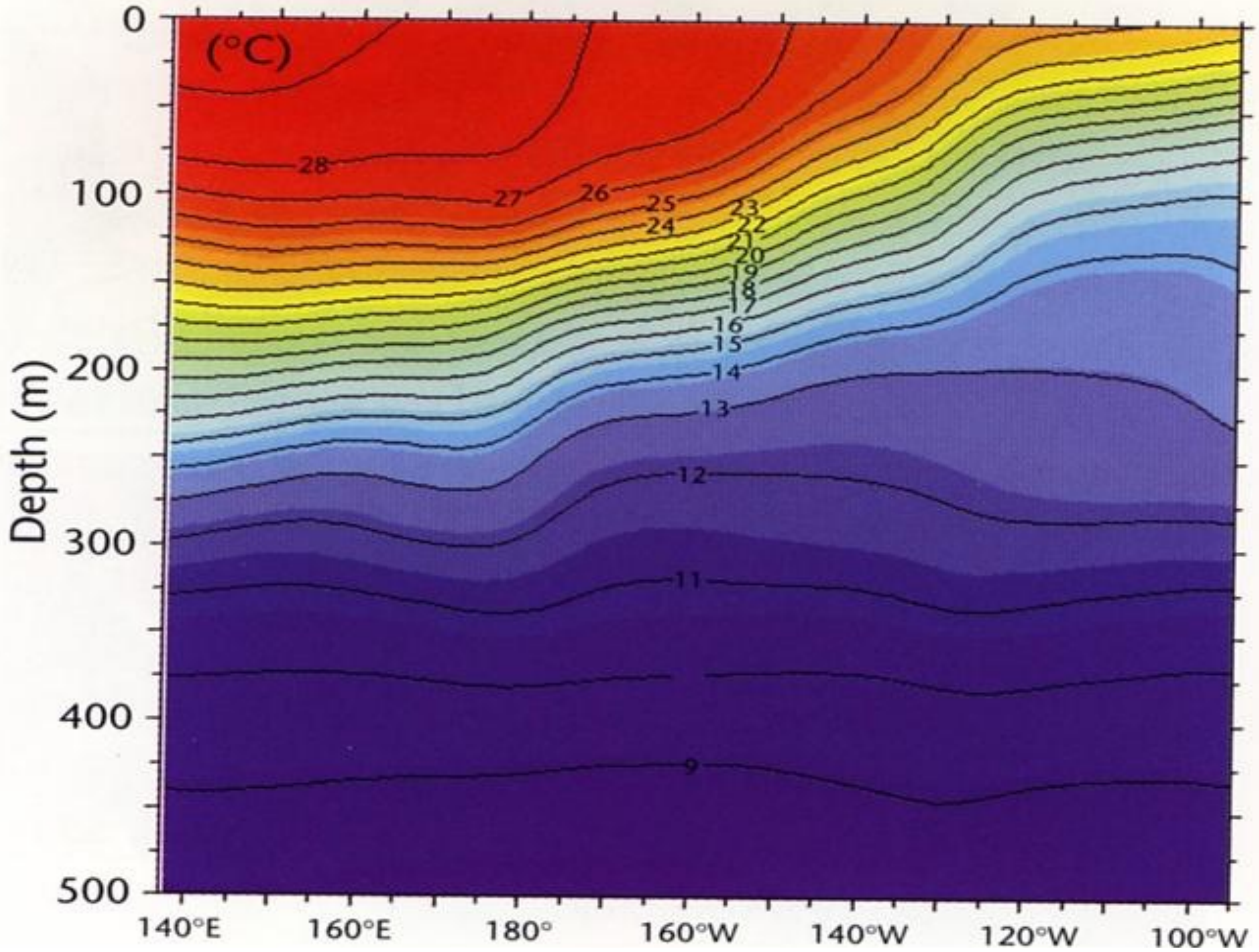
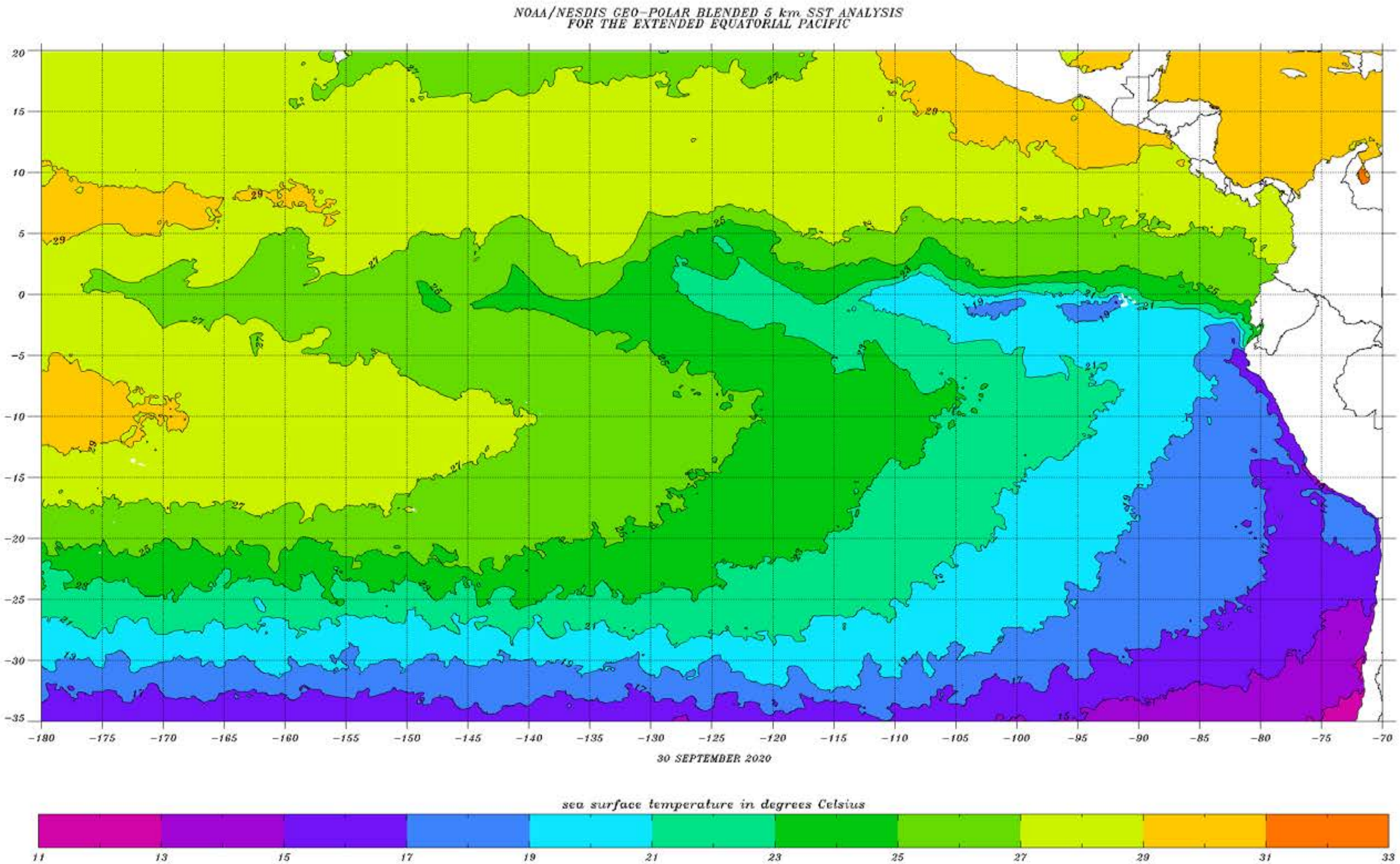
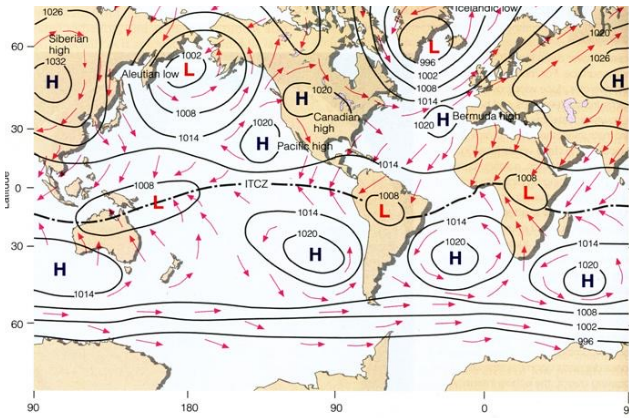


Figure 3.13. Vertical section along the equatorial Pacific showing the sloping thermocline, contour interval 1 K [www.cpc.noaa.gov].

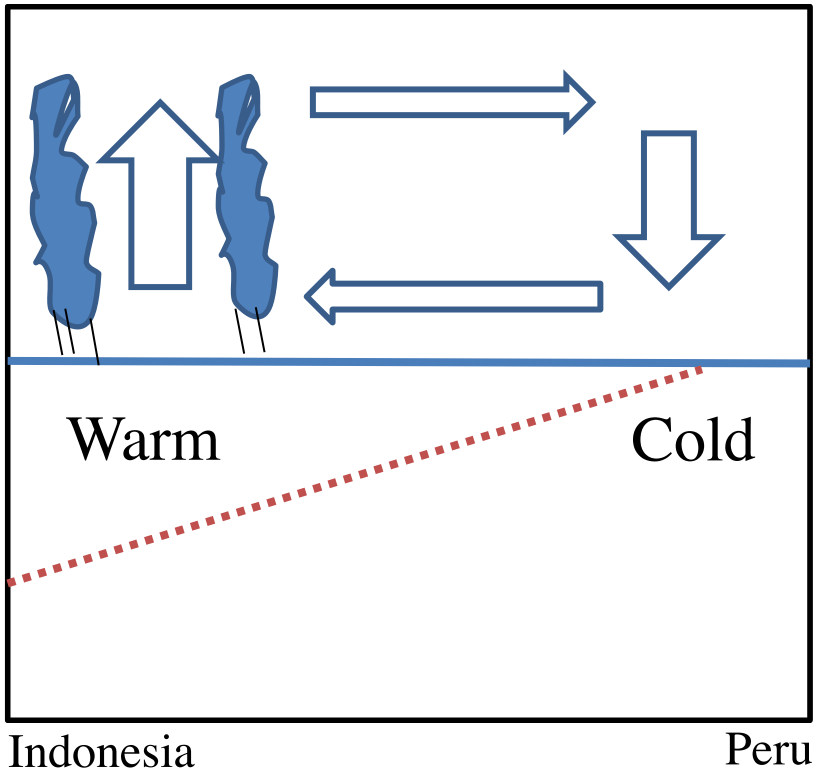


Northward winds along the coast drive offshore flow and upwelling.



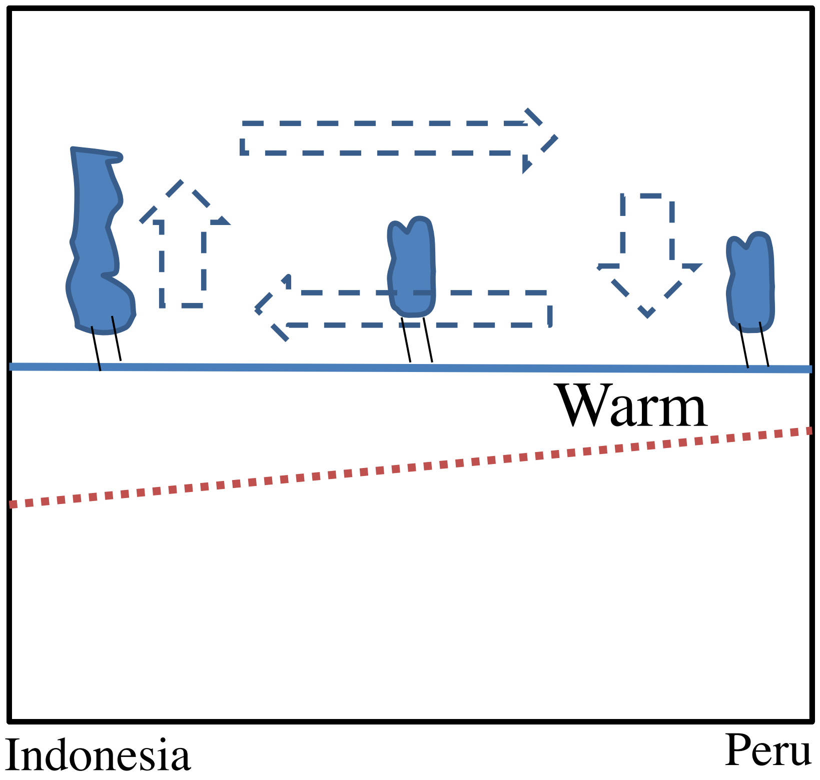
January

La Niña

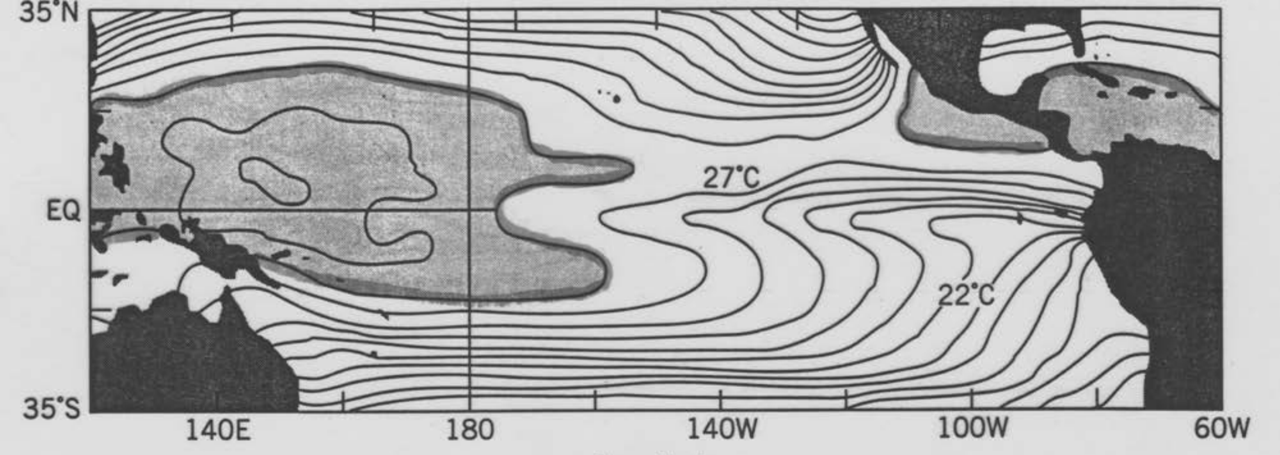


Strong Walker Circulation
Steeply-sloping thermocline
Cold SST/dry near Peru
Wet near Indonesia
Large Tahiti-Darwin SLP diff.

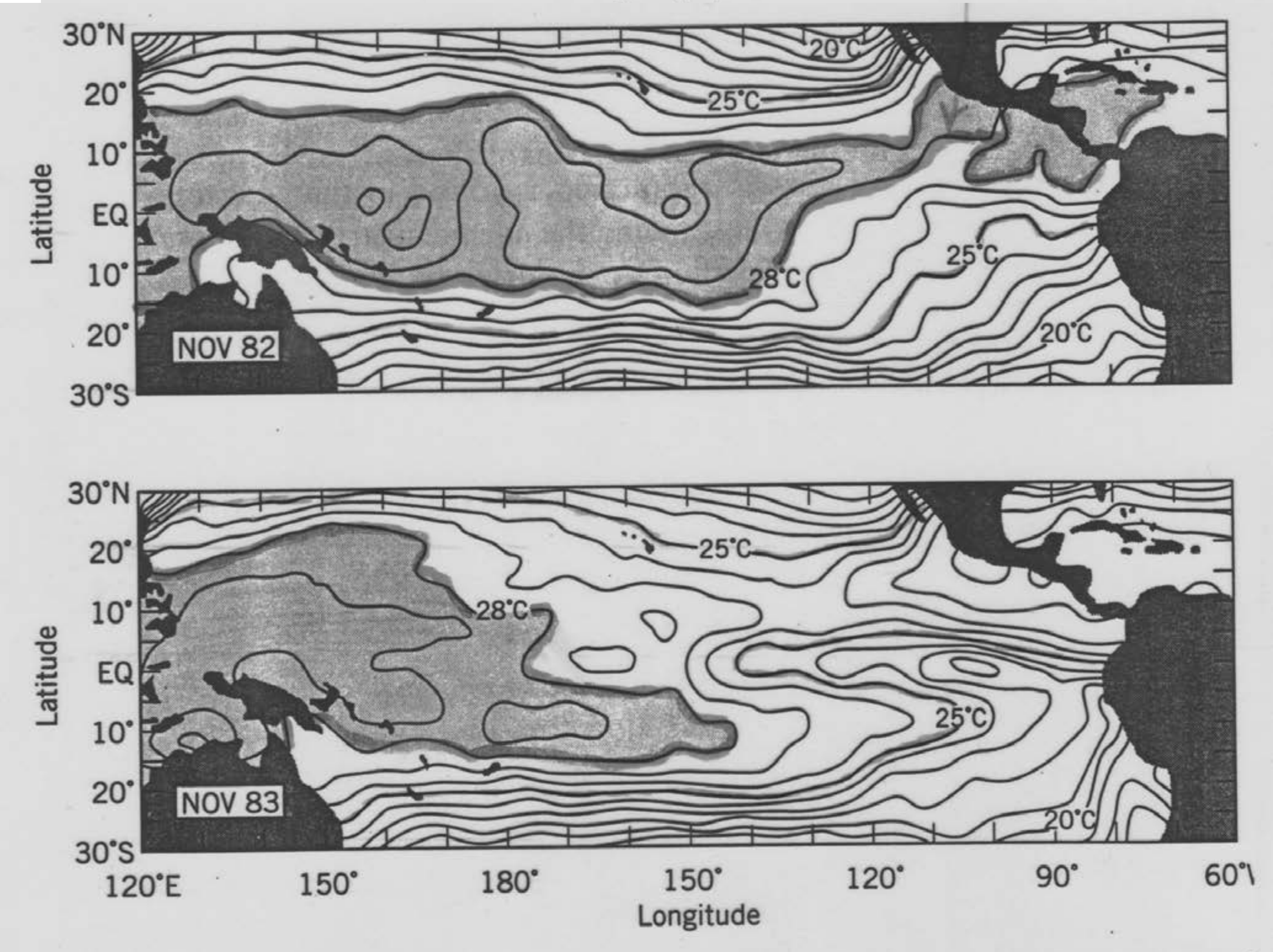
El Niño



Weak Walker Circulation
Flat thermocline
Warm SST/wet near Peru
Dry near Indonesia
Small Tahiti-Darwin SLP diff.

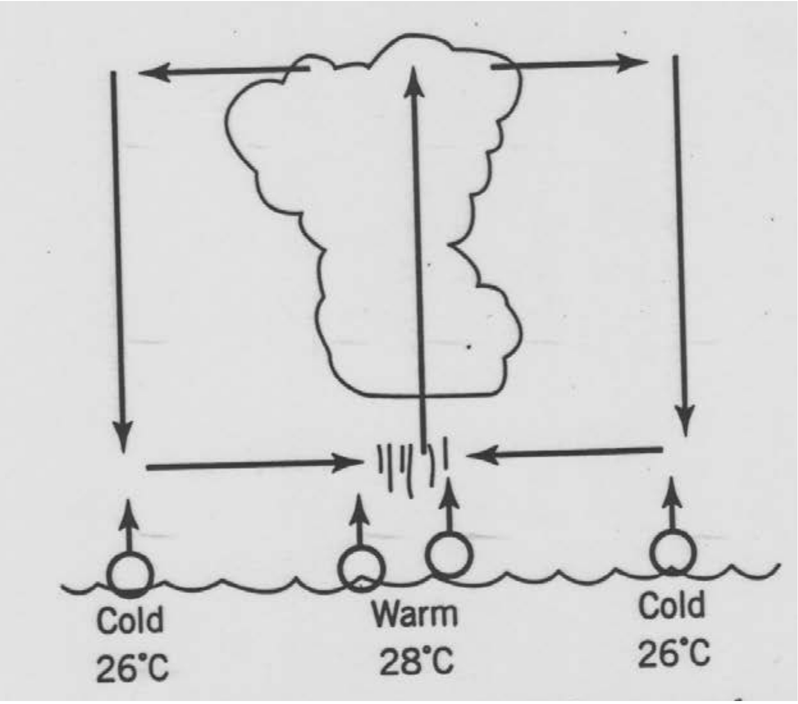


Time Mean SSTs
(for October)

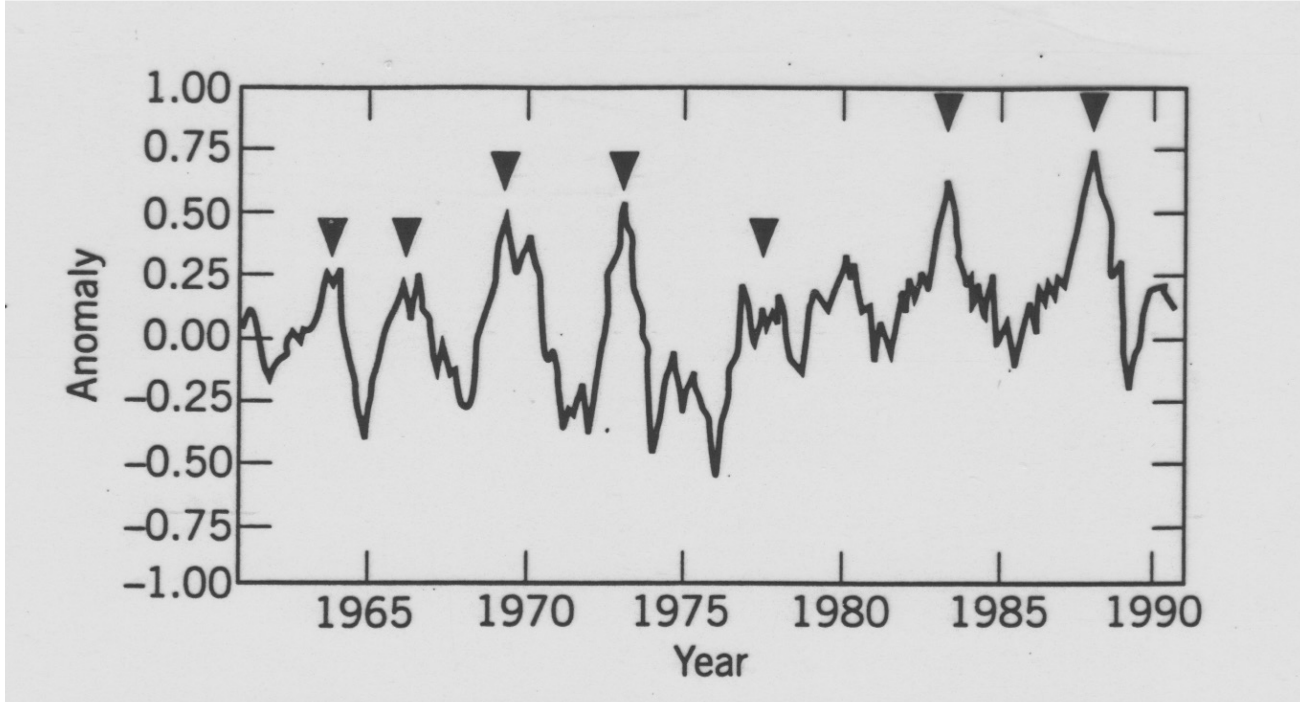


El Nino
Nov 1982

La Nina
Nov 1983



During El Nino, warm SSTs near the Date Line encourage thunderstorms to grow.



El Nino causes the global average temperature to be warmer.

ENSO modulates tropical deep convection, which affects the long-wave pattern in the extratropics.

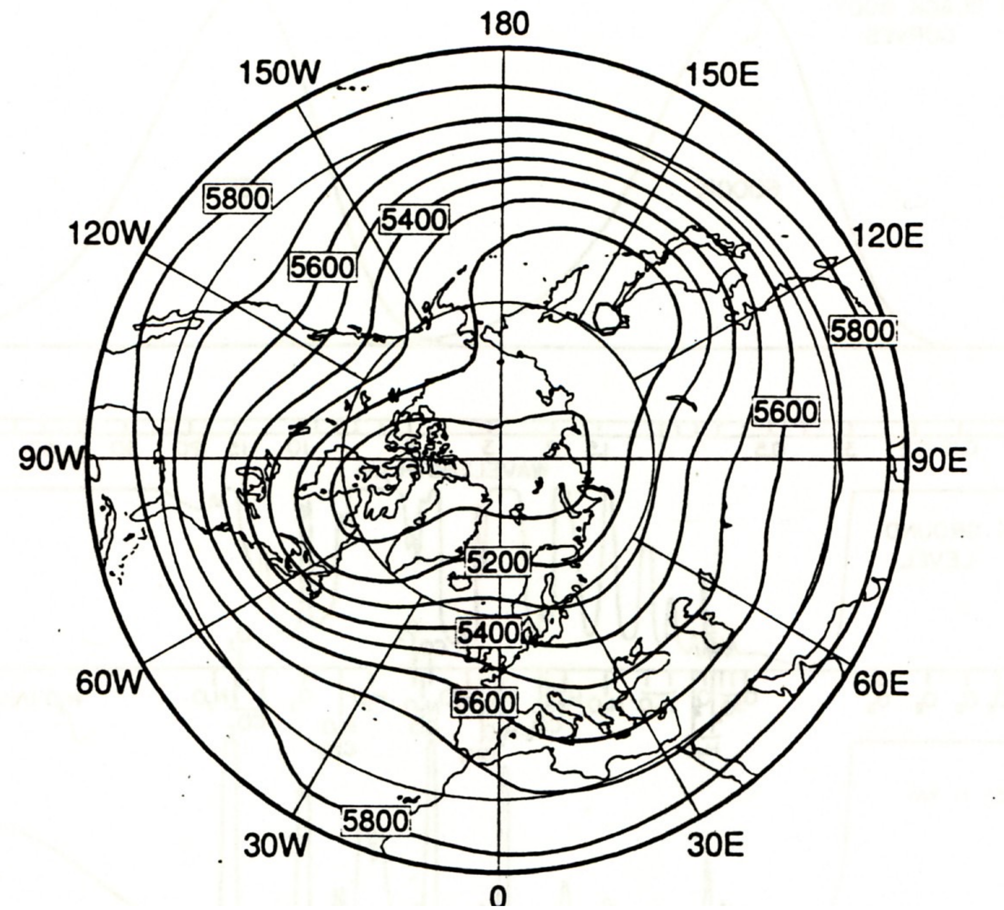


Figure 2.7. A Northern Hemisphere polar stereographic chart of 500 hPa geopotential height averaged for DJF, contour interval 100 m.

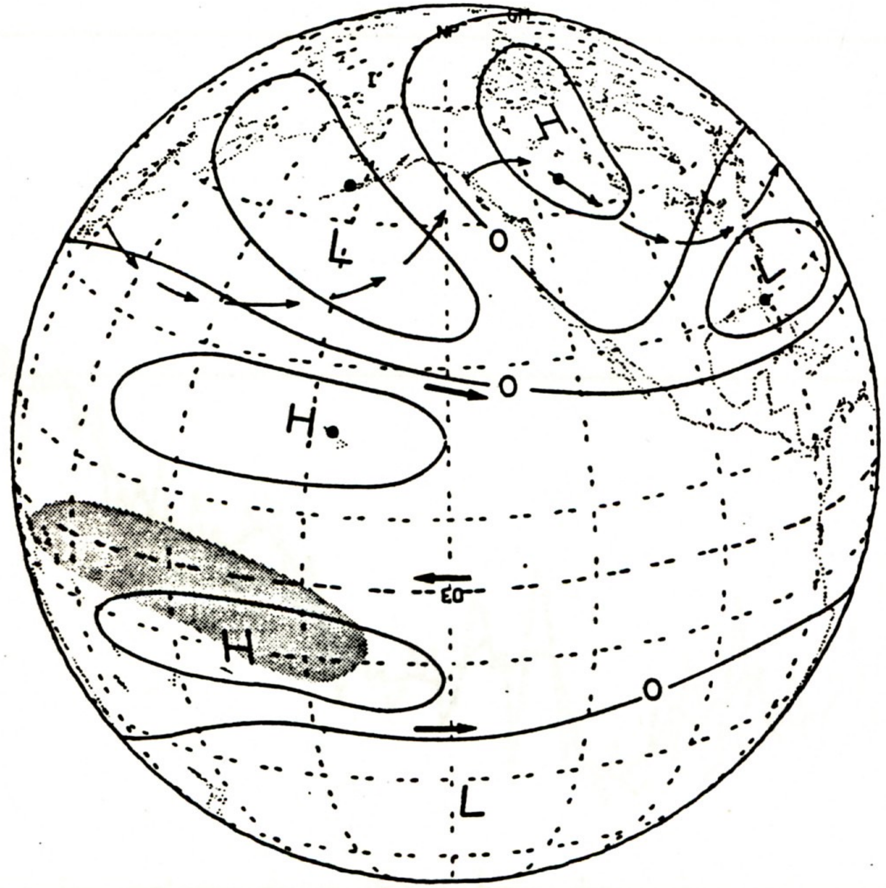
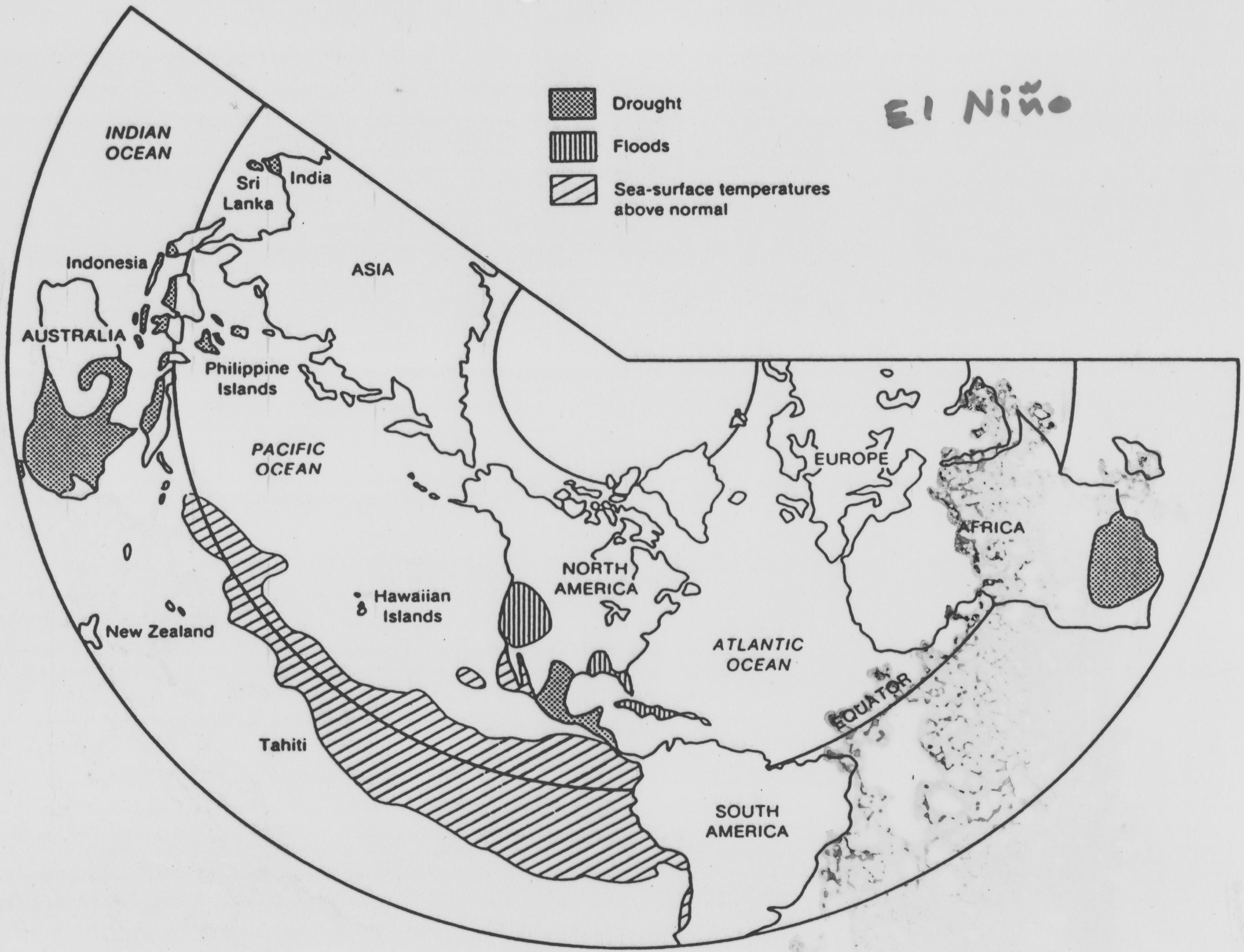


Figure 2.8. Upper tropospheric height anomaly pattern excited by El Nino [Horel and Wallace 1978].



<u>ENSO influences</u>

Droughts – fire, famine

Deluges – tropical disease

Crops

Fisheries

Table 8.8

Major ENSO Events Since 1780

El Niño	Strength	Regions Affected by Drought/Famine
1782–83	s	China, India
1790–93	vs	India
1803–04	s+	India, South Africa
1824–25	m+	China, India, South Africa
1828	vs	South Africa
1837	m+	China, India
1844–46	s	China, Brazil
1867–70	m+	China, India
1873–74	m	India
1876–78	vs	China, India, South Africa, Egypt, Java, Brazil
1887–89	m+	China, Ethiopia, Sudan, Sahel
1891	vs	China, India, Brazil
1896–97	m+	India, Brazil
1899–1900	vs	China, India, South Africa
1901–02	m+	China, South Africa
1911–13	s	China, India, Brazil
1917–19	s	China, India, Brazil, Morocco
1925–26	vs	China (floods), India
1957–58	s	China, Brazil
1965–66	s	China, India
1972–73	s	China, India, Ethiopia, Sahel, Brazil
1982–83	vs	China, India, Indonesia, South Africa
1991–95	s	South Africa, East Africa, Mexico
1997–98	vs	China (+ floods), Indonesia, Brazil

Key: m=moderate; s=strong; vs=very strong.

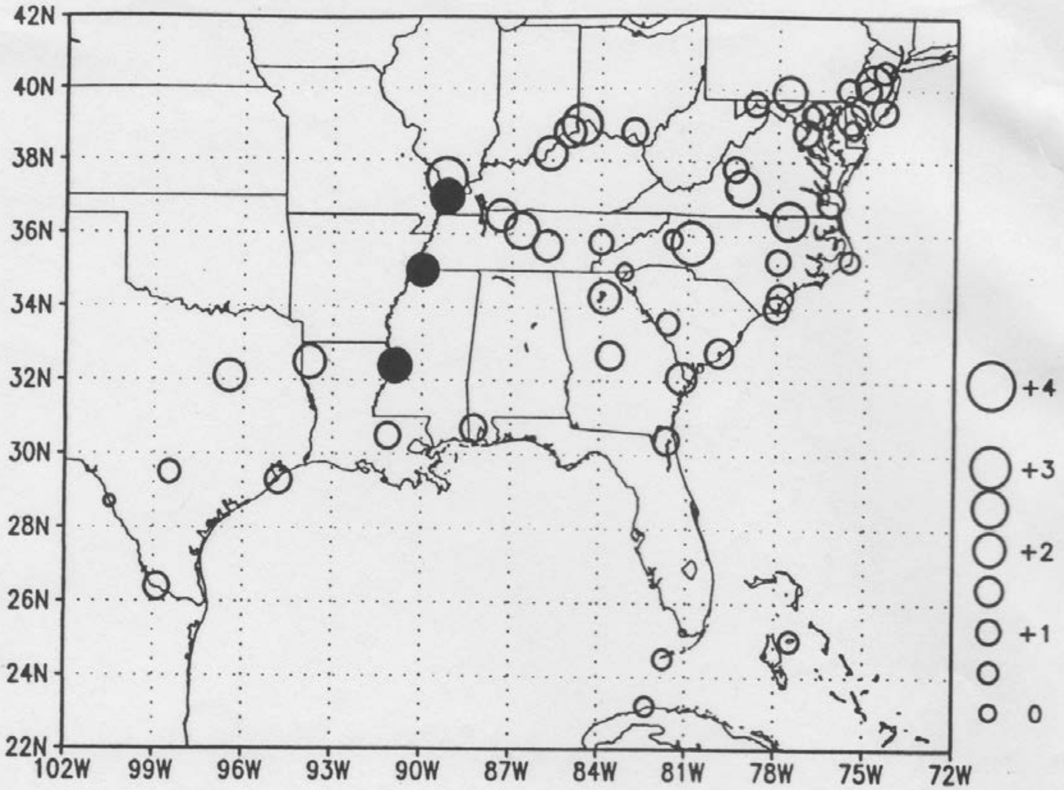


FIG. 3. Map showing temperature departures (°C) from record mean for stations in the southeast United States for the months of February–April of 1878. Magnitude of anomalies is proportional to the size of the circles. Solid dots identify the locations of Cairo, IL, Memphis, TN, and Vicksburg, MS.

TABLE 1. Years with major (> 1000 deaths) yellow fever epidemics, 1793–1905, in the United States. Data taken from Patterson (1993). El Niño years taken from Quinn (1992) and Quinn and Neal (1992).

Year	Deaths	Main location(s)	El Niño event
1793	ca. 5000	Philadelphia	Yes
1797	> 1300	Philadelphia	Yes
1802–03	> 1000	Charleston to New York	Yes
1817	> 1000	Charleston, New Orleans	Yes
1837–39	> 1500	Galveston to Charleston	Yes
1847–49	> 4000	mostly in New Orleans	No
1852–55	> 15 000	Galveston to Charleston*	Yes
1876	1200	Savannah	No
1878	ca. 20 000	Memphis, New Orleans	Yes

*Greatest death toll occurred in New Orleans with about 15 000 deaths reported.

Increased rainfall and tropical diseases in the southeastern U.S. are more likely during El Nino.

Bushfire burning in Victoria. The energy of all the fires on Black Saturday was the equivalent of fifteen hundred Hiroshimas.

El Nino

February 7, 2009

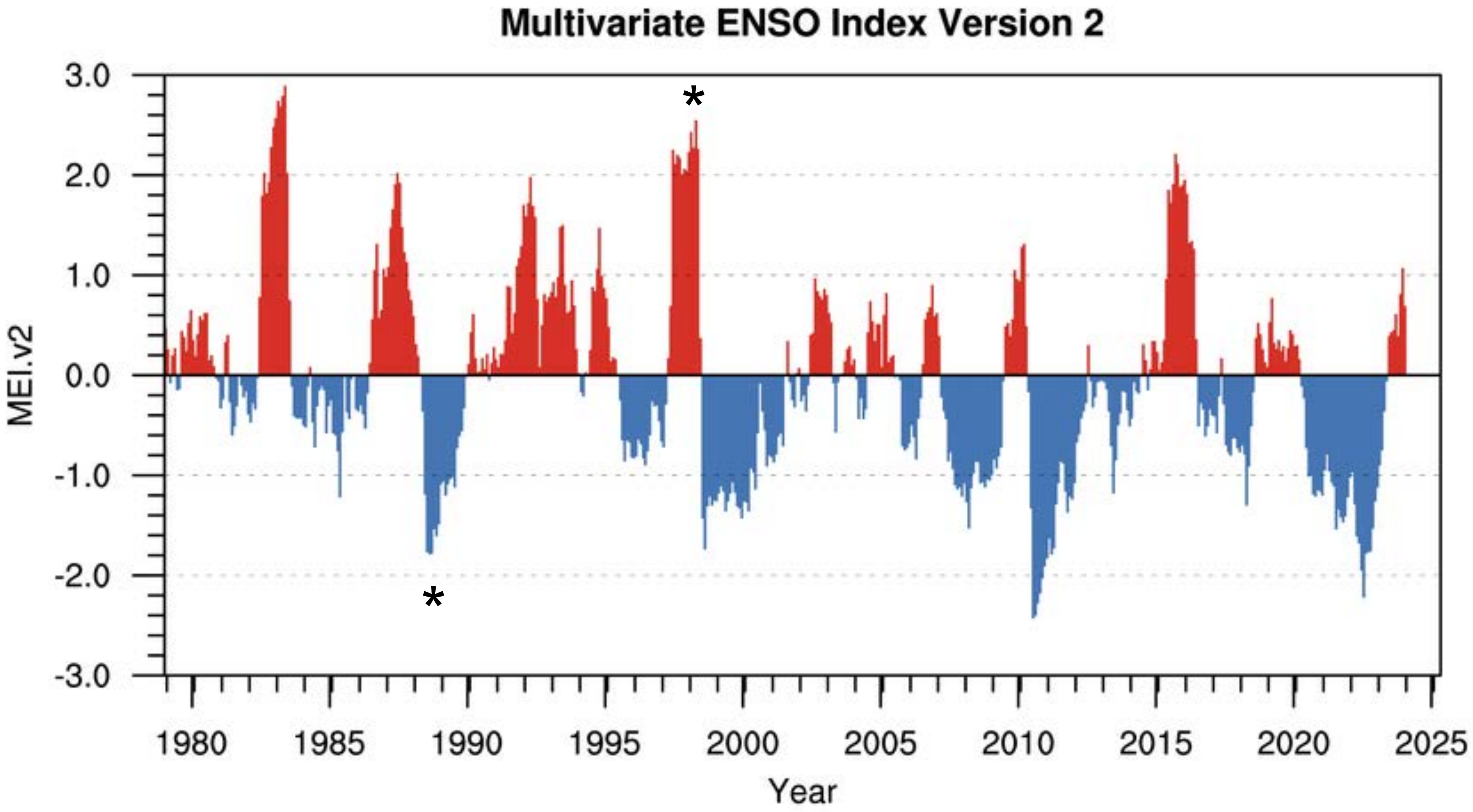
"Black Saturday"
fire near
Melbourne
Australia

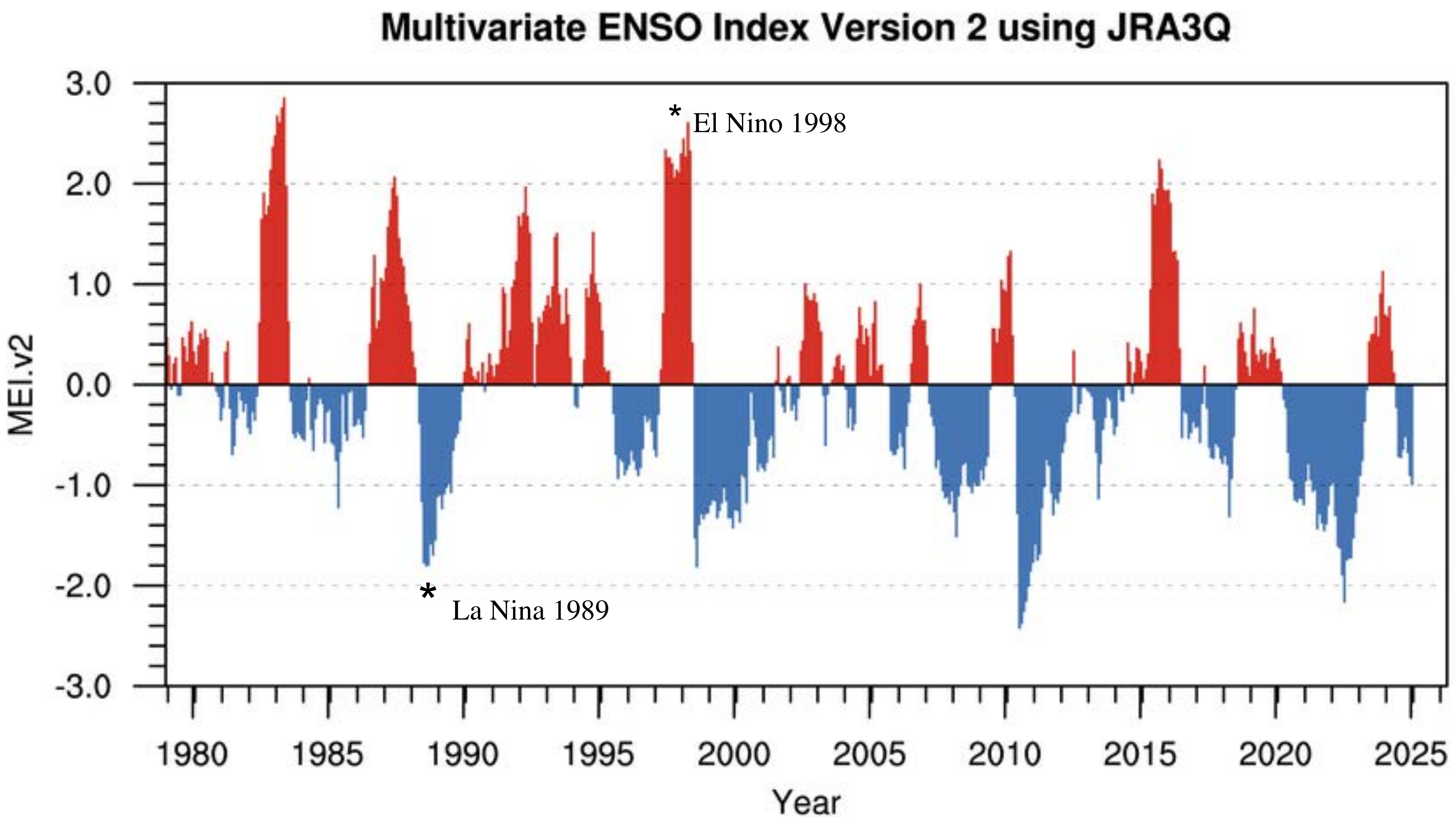
Figure 7.4

Key Stages in the Development of ENSO Theory

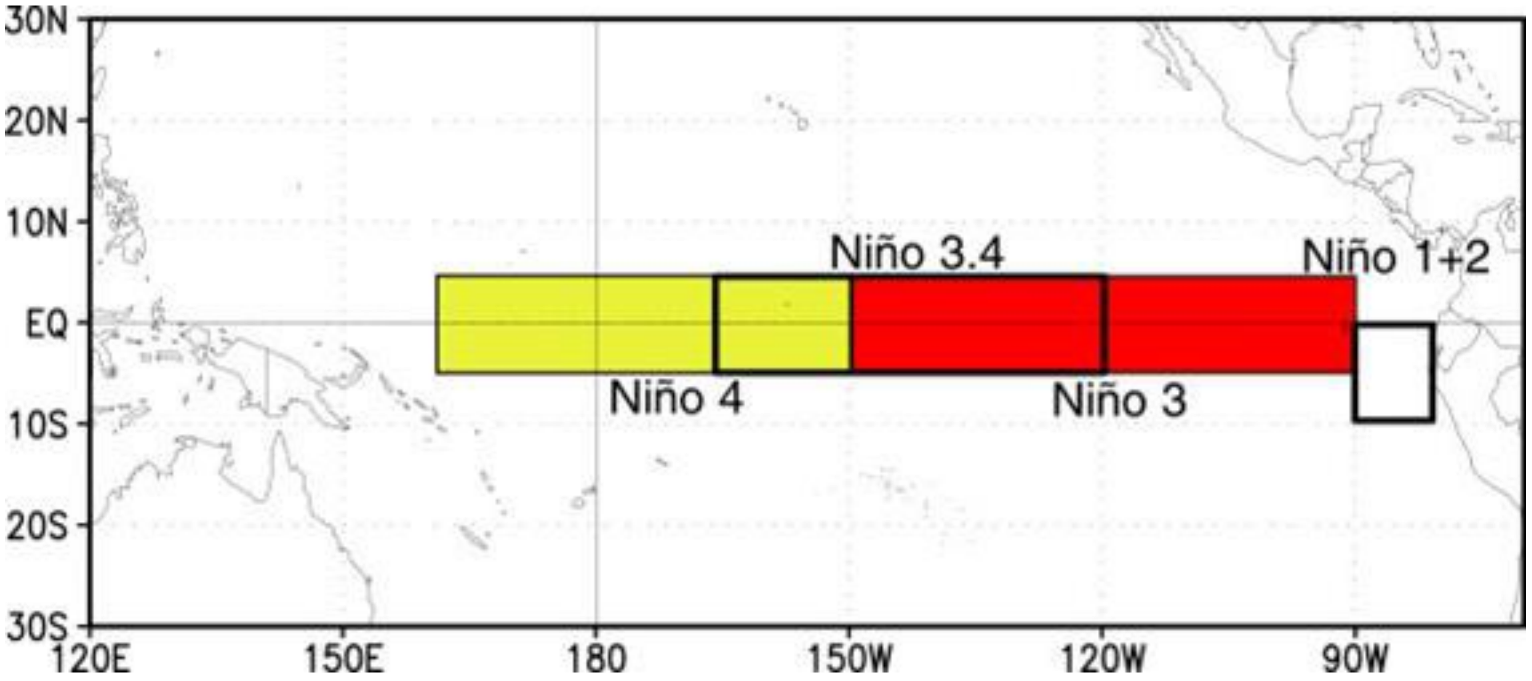
1. Recognizing global, synchronized drought	Roxburgh: 1790s Blanford: 1880
2. Linking drought to interhemispheric atmosphere "see-saw"	Blanford: 1880 Lockyer and Lockyer: 1900
3. Identifying the Southern Oscillation (SO)	Hildebrandsson: 1899 Walker: 1920s
4. Unifying the SO and El Niño in a single model	Bjerknes: 1960s
5. Recognizing La Niña (ENSO cold phase)	Philander: 1980s
6. Mechanism for the phase transition	Wyrtki: 1980s
7. Successful predictive model	Cane and Zebiak: 1986
8. Nature of interdecadal fluctuations	??

MEI = Weighted spatial patterns of 6 variables (SLP, SST, U, V, T, clouds)
monthly averages + = warm phase (El Nino) – = cold phase (La Nina)





Multivariate ENSO Index Version 2 using JRA3Q
MEI.v2
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
* El Nino 1998
* La Nina 1989
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year



30N
20N
10N
EQ
10S
20S
30S
120E
150E
180
150W
120W
90W
Niño 3.4
Niño 1+2
Niño 4
Niño 3

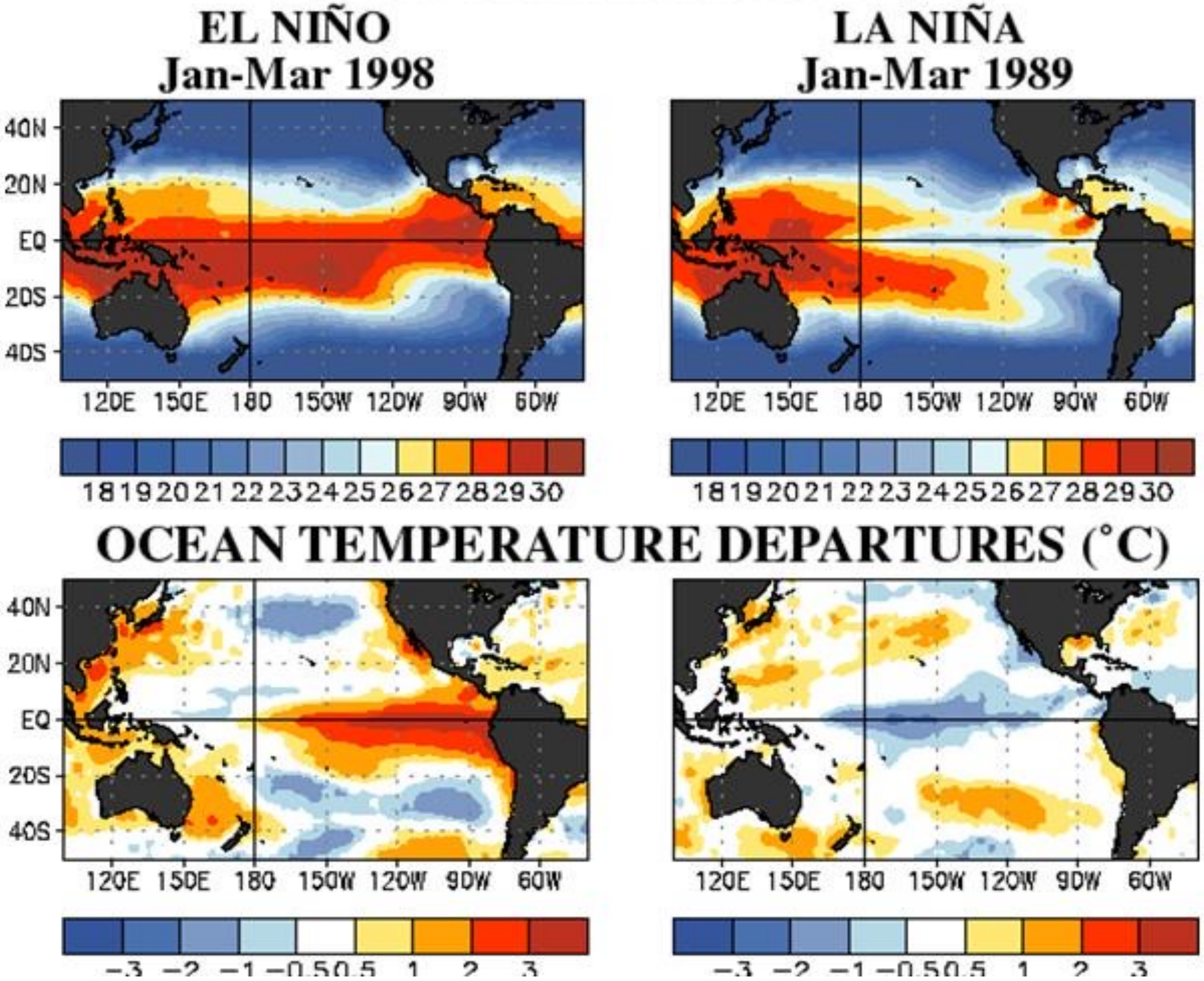


Figure 3.19. Sea surface temperature and anomaly for the 1998 El Nino and the 1989 La Nina [www.cpc.noaa.gov].

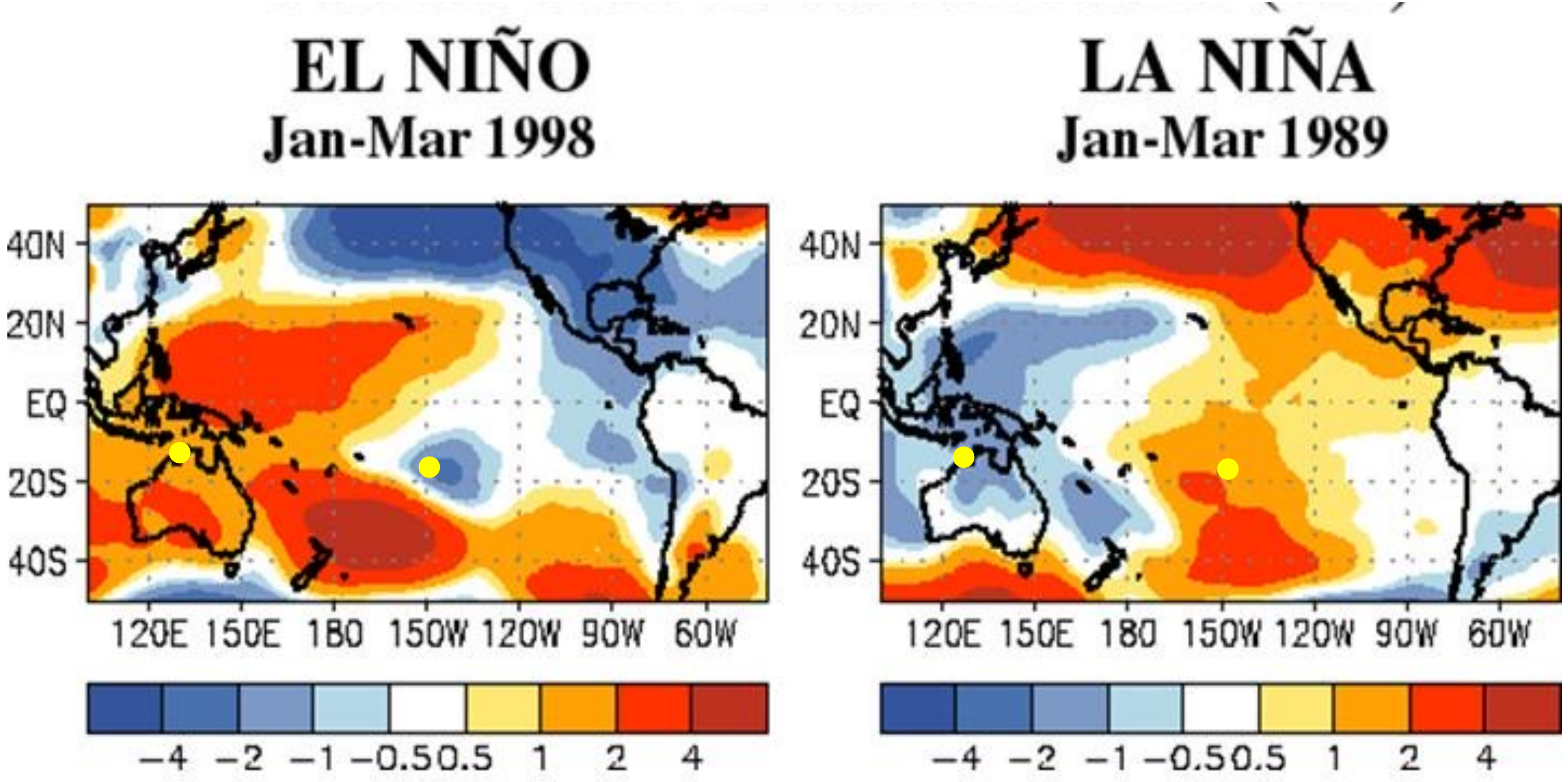


Figure 3.20. Sea level pressure anomalies for the 1998 El Nino and the 1989 La Nina [www.cpc.noaa.gov]. Yellow dots indicate the locations of Darwin (12.5°S, 130.8°E) and Tahiti (17.6°S, 149.4°W).

El Nino

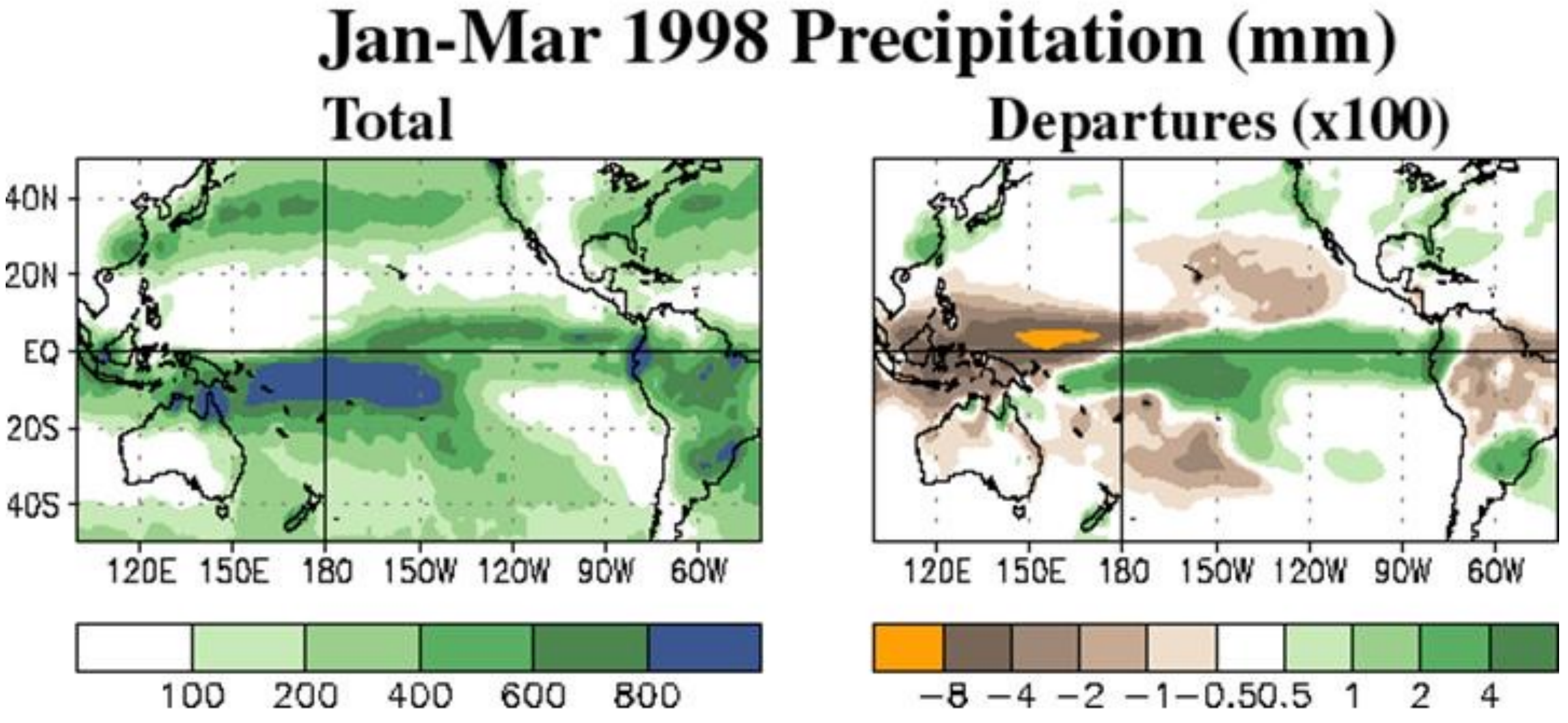


Figure 3.22a. January-March rainfall and rainfall anomaly during the 1998 El Nino.

La Nina

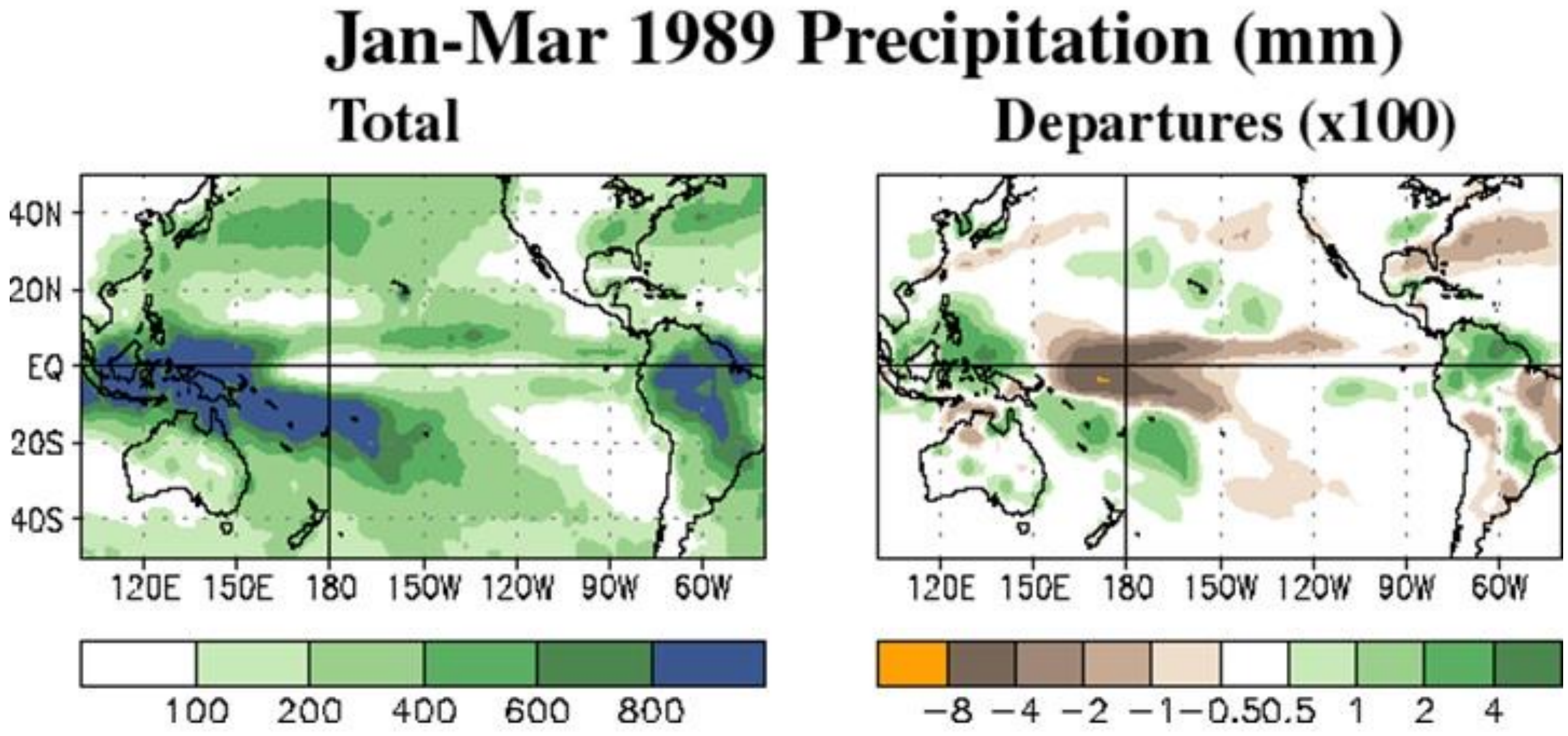
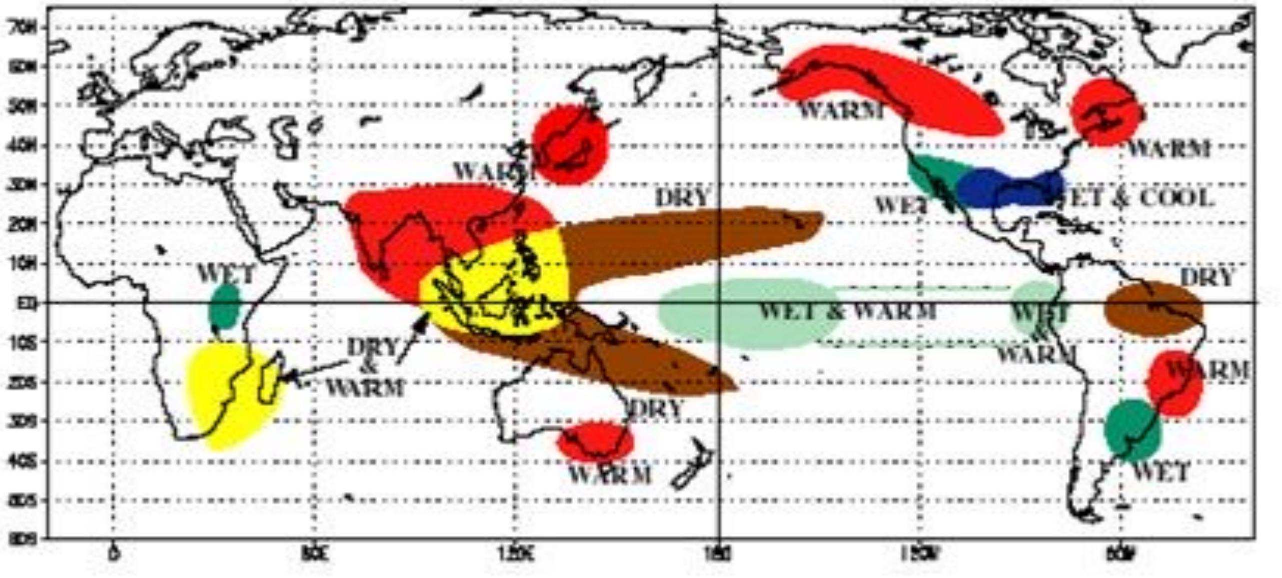
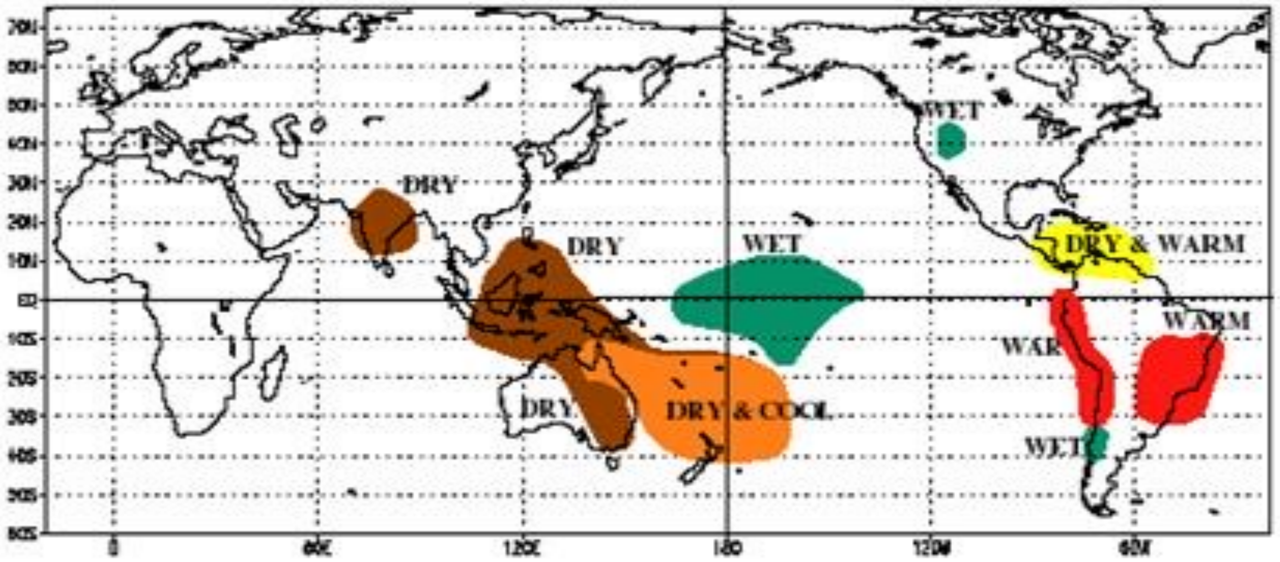


Figure 3.22b. January-March rainfall and anomaly during the 1989 La Nina.

WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

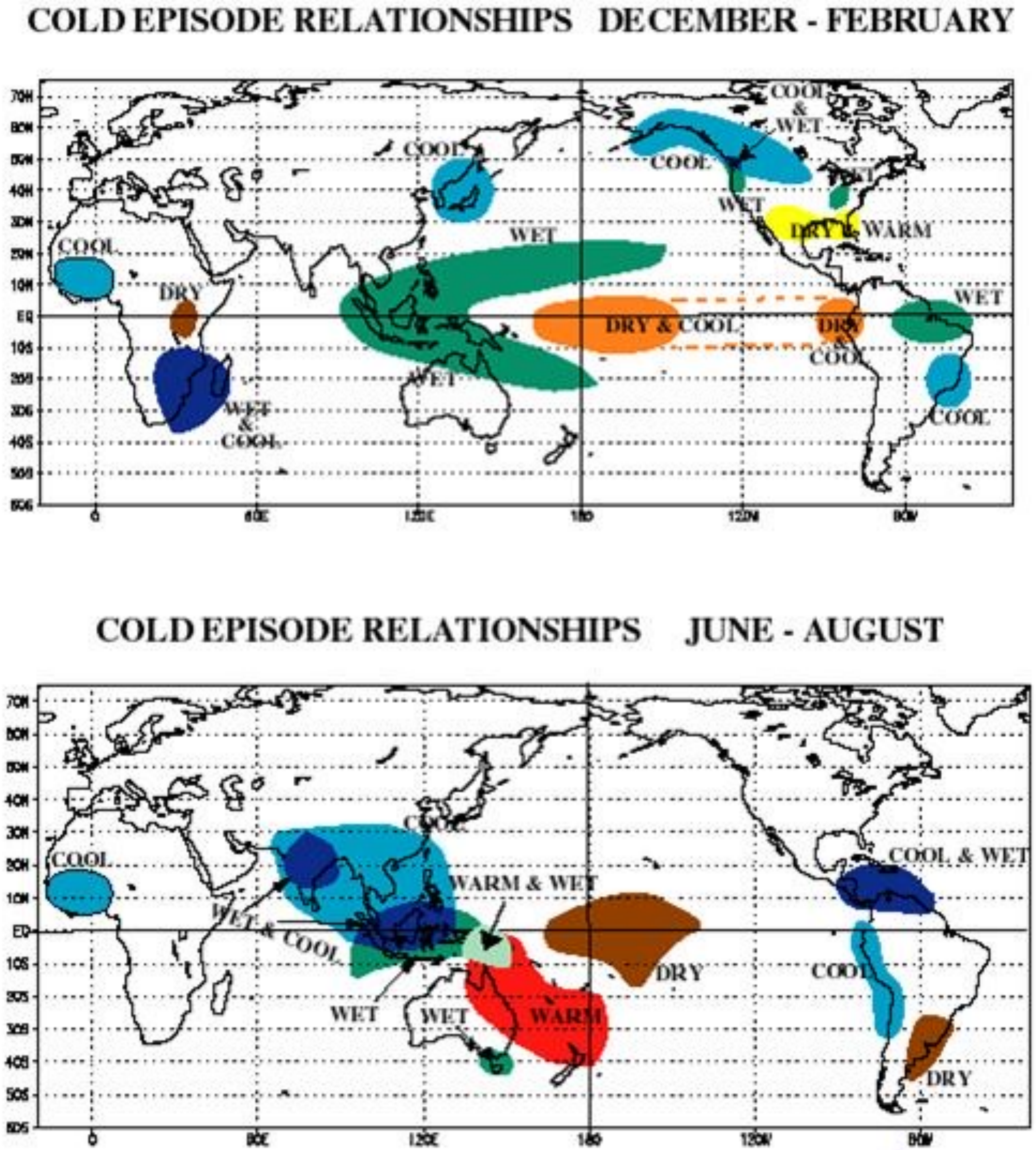


WARM EPISODE RELATIONSHIPS JUNE - AUGUST



El Nino

Figure 3.23a. Global weather relationships for DJF and JJA which tend to occur during El Nino [www.cpc.noaa.gov].



Chaco Canyon 1120

La Nina

Figure 3.23b. Global weather relationships for DJF and JJA which tend to occur during La Nina [www.cpc.noaa.gov].

What’s been happening with ENSO lately?

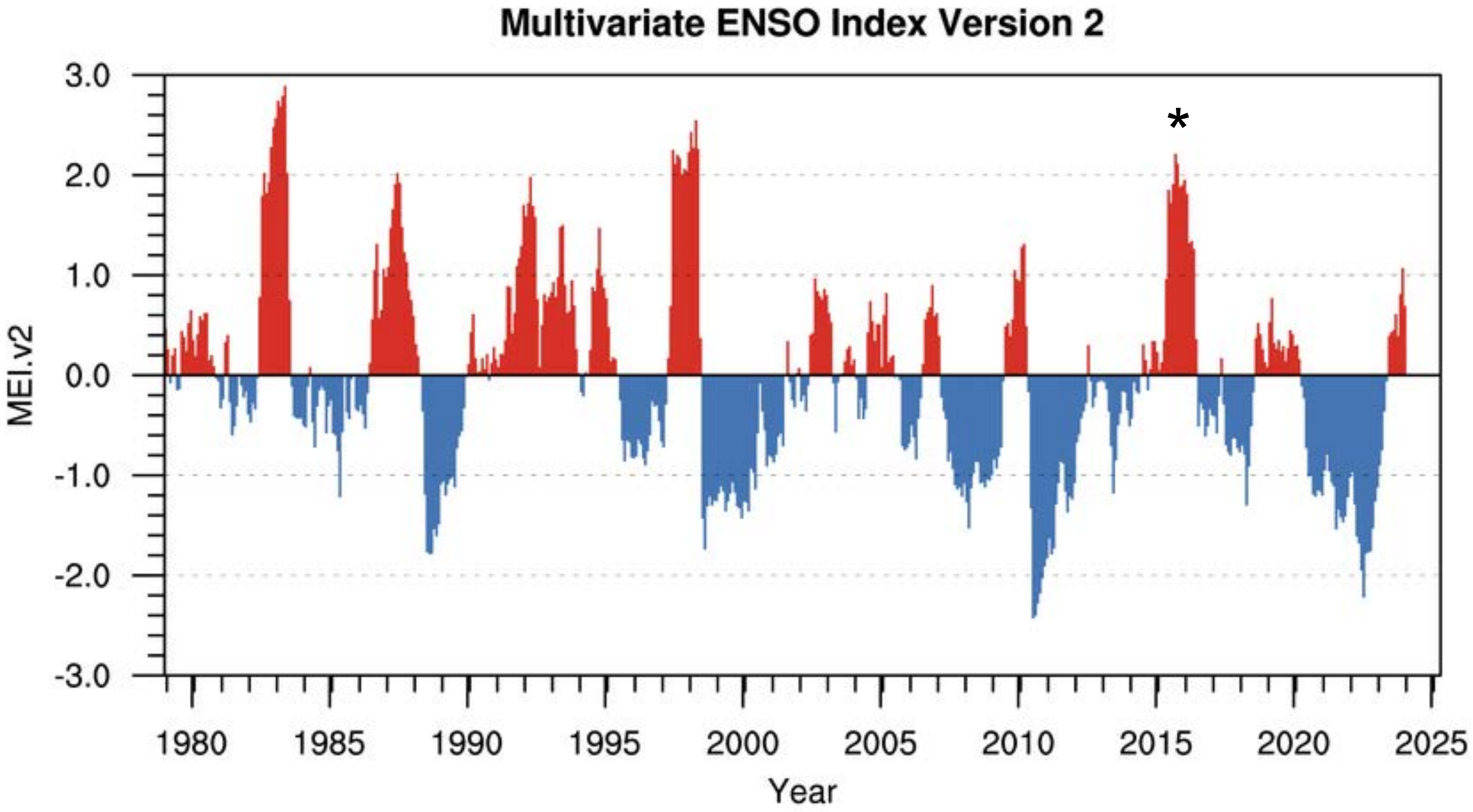
1. “The Blob” 2013-2018
   El Nino / Modoki 2015-2016

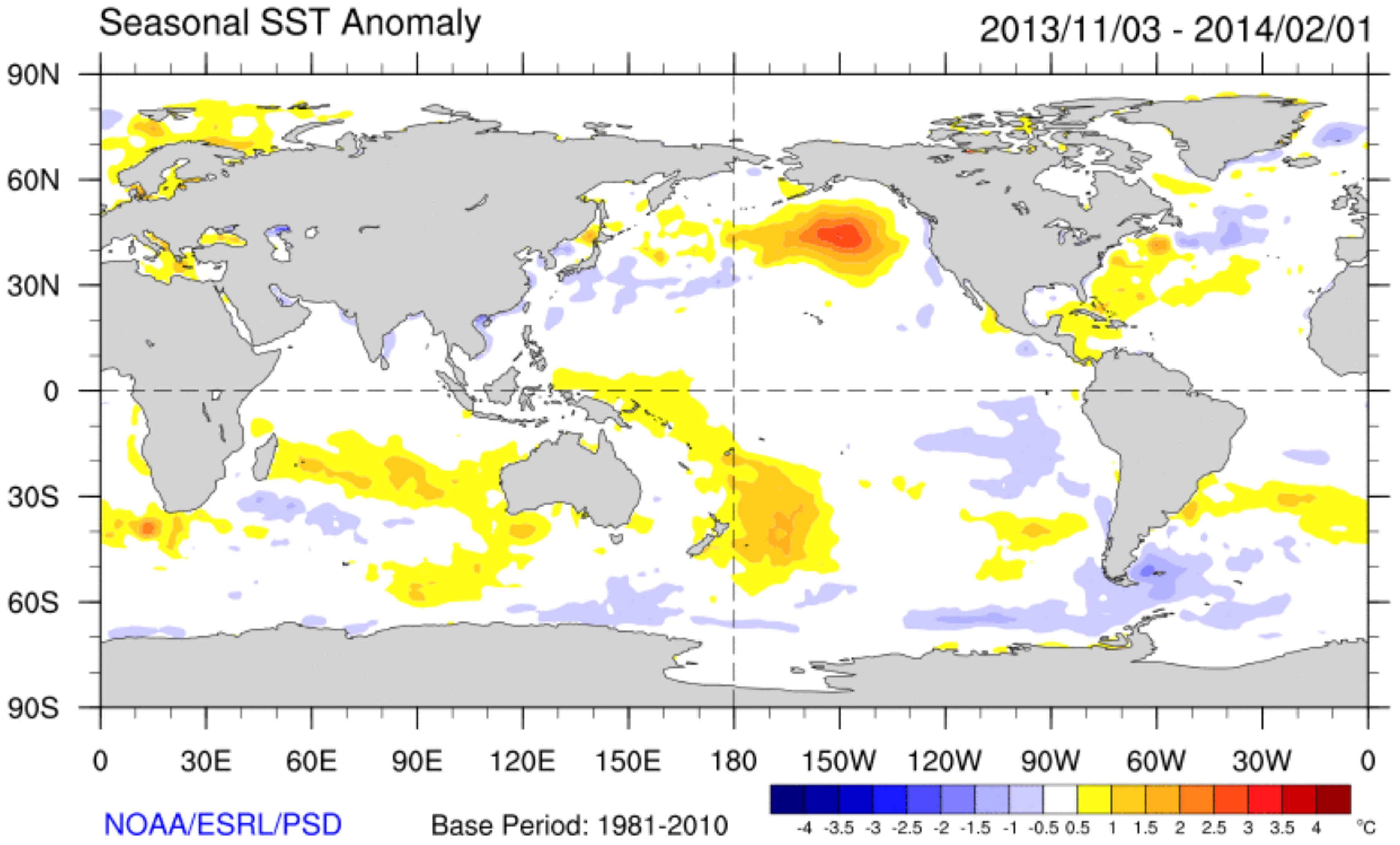
2. La Nina 2020 – 2023

3. El Nino 2023 – 2024

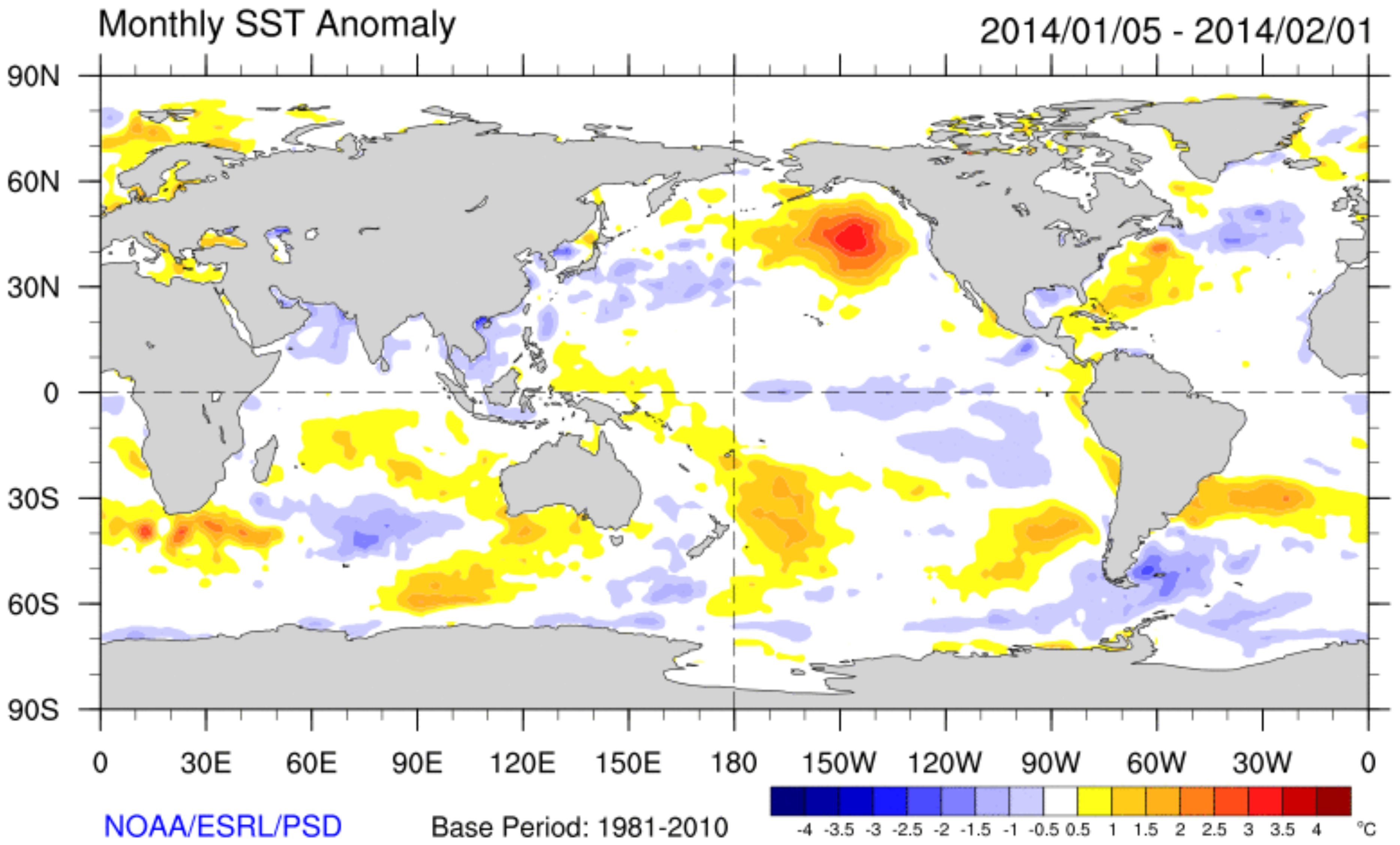
4. La Nina 2025

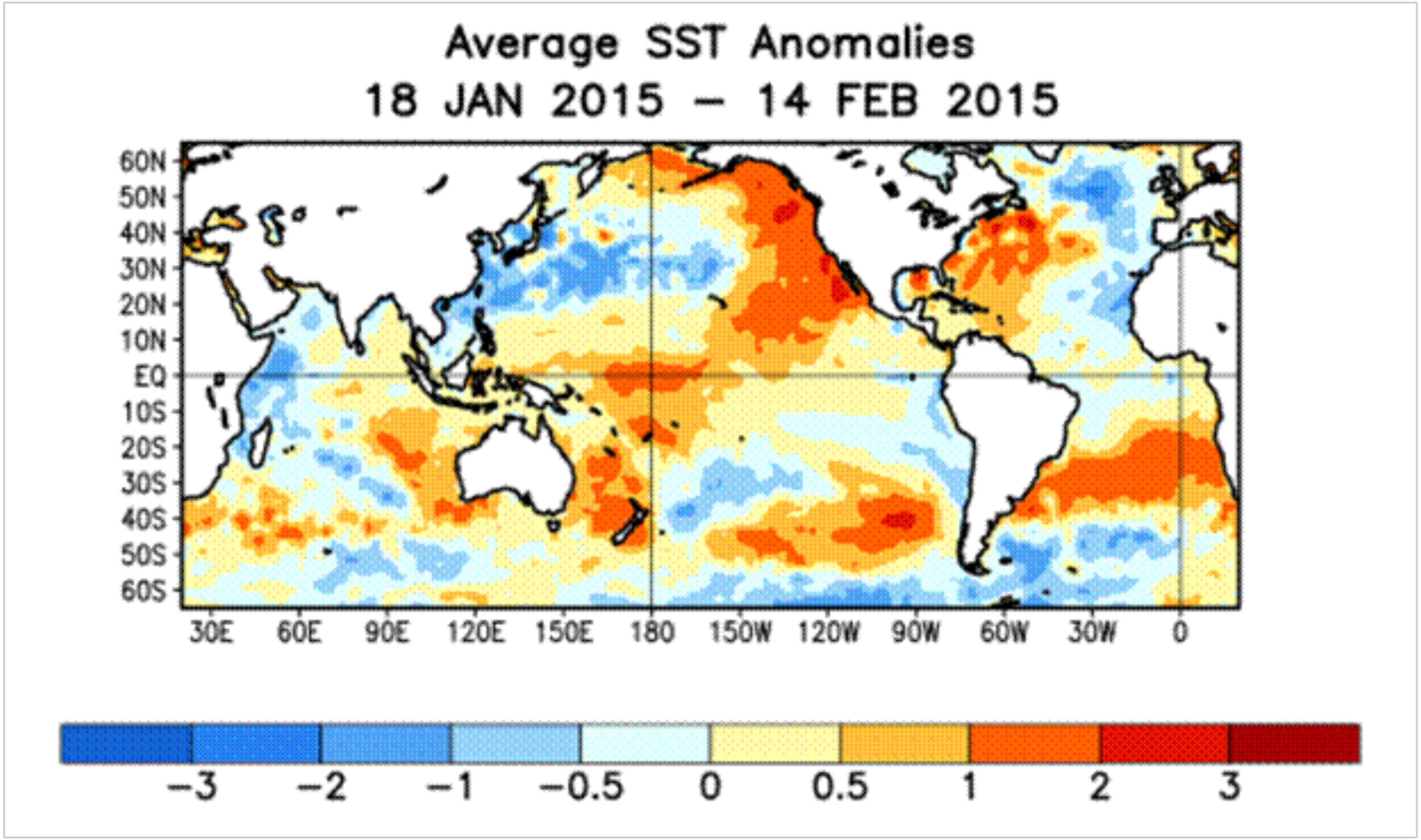
MEI = Weighted spatial patterns of 6 variables (SLP, SST, U, V, T, clouds)
monthly averages + = warm phase (El Nino) – = cold phase (La Nina)




Seasonal SST Anomaly
2013/11/03 - 2014/02/01
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
NOAA/ESRL/PSD
Base Period: 1981-2010
-4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0.5 1 1.5 2 2.5 3 3.5 4
°C

“The Blob” helped create an extension of the polar vortex over North America





Average SST Anomalies
18 JAN 2015 – 14 FEB 2015
60N
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
60S
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
−3
−2
−1
−0.5
0
0.5
1
2
3

“Modoki”

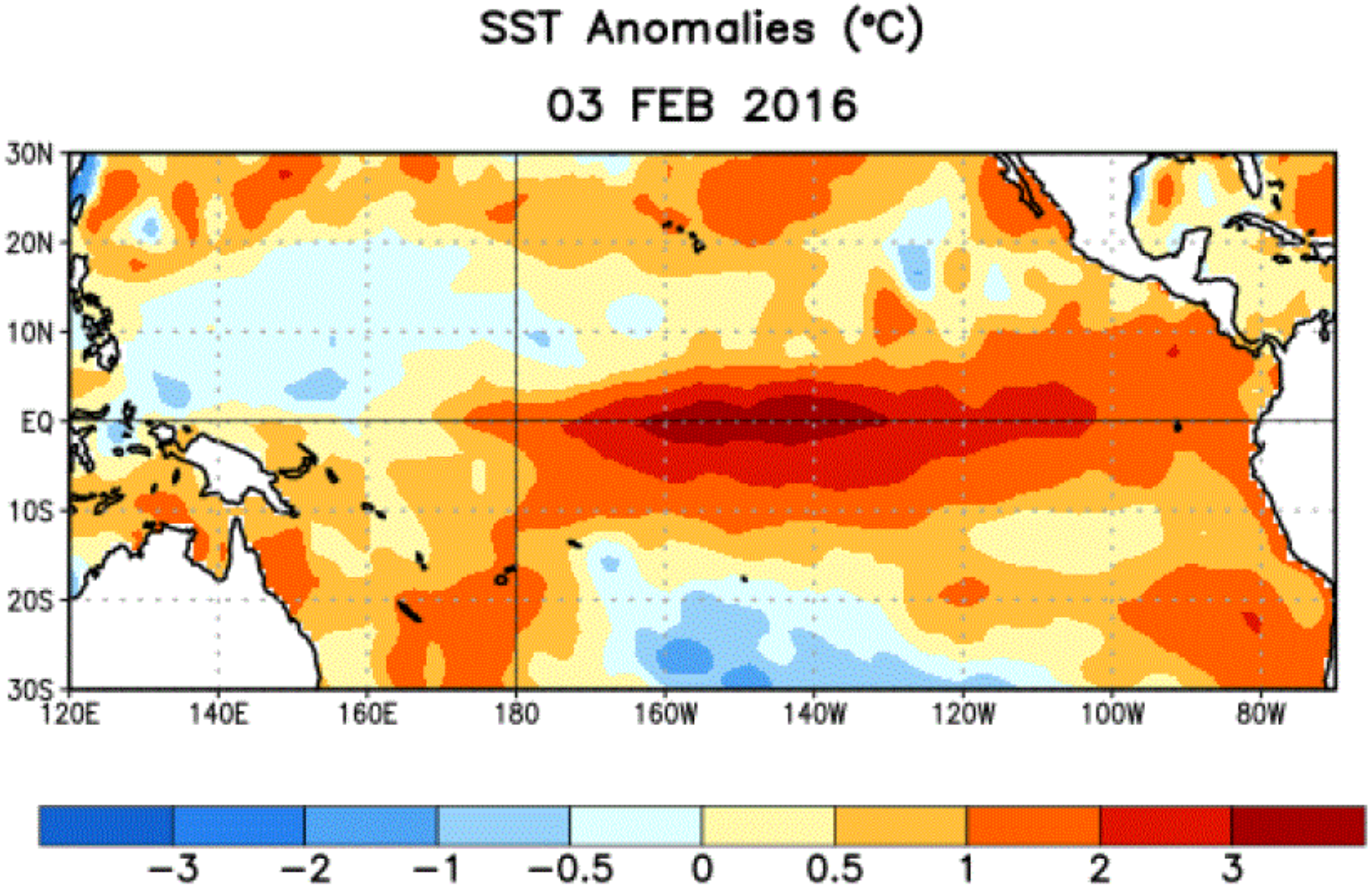


Figure 1. Average sea surface temperature (SST) anomalies (°C) for the week centered on 3 February 2016. Anomalies are computed with respect to the 1981-2010 base period weekly means.

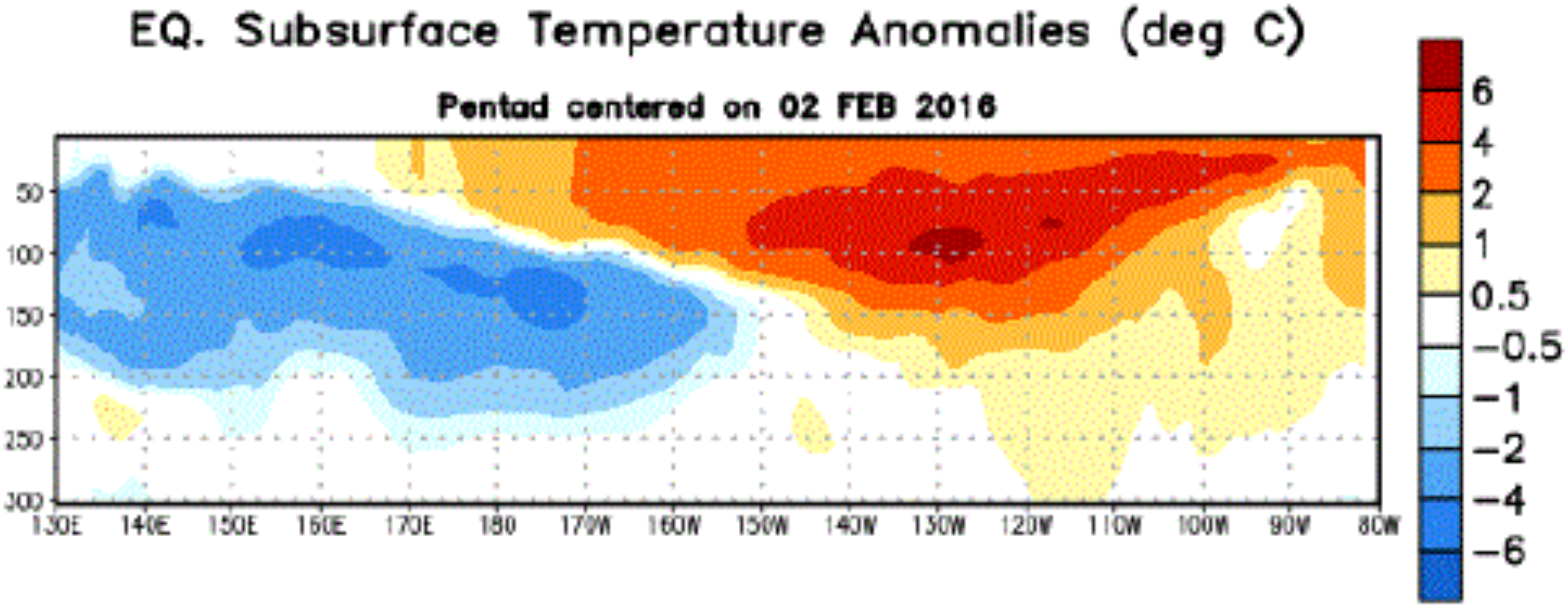


Figure 4. Depth-longitude section of equatorial Pacific upper-ocean (0-300m) temperature anomalies (°C) centered on the pentad of 2 February 2016. The anomalies are averaged between 5°N-5°S. Anomalies are departures from the 1981-2010 base period pentad means.

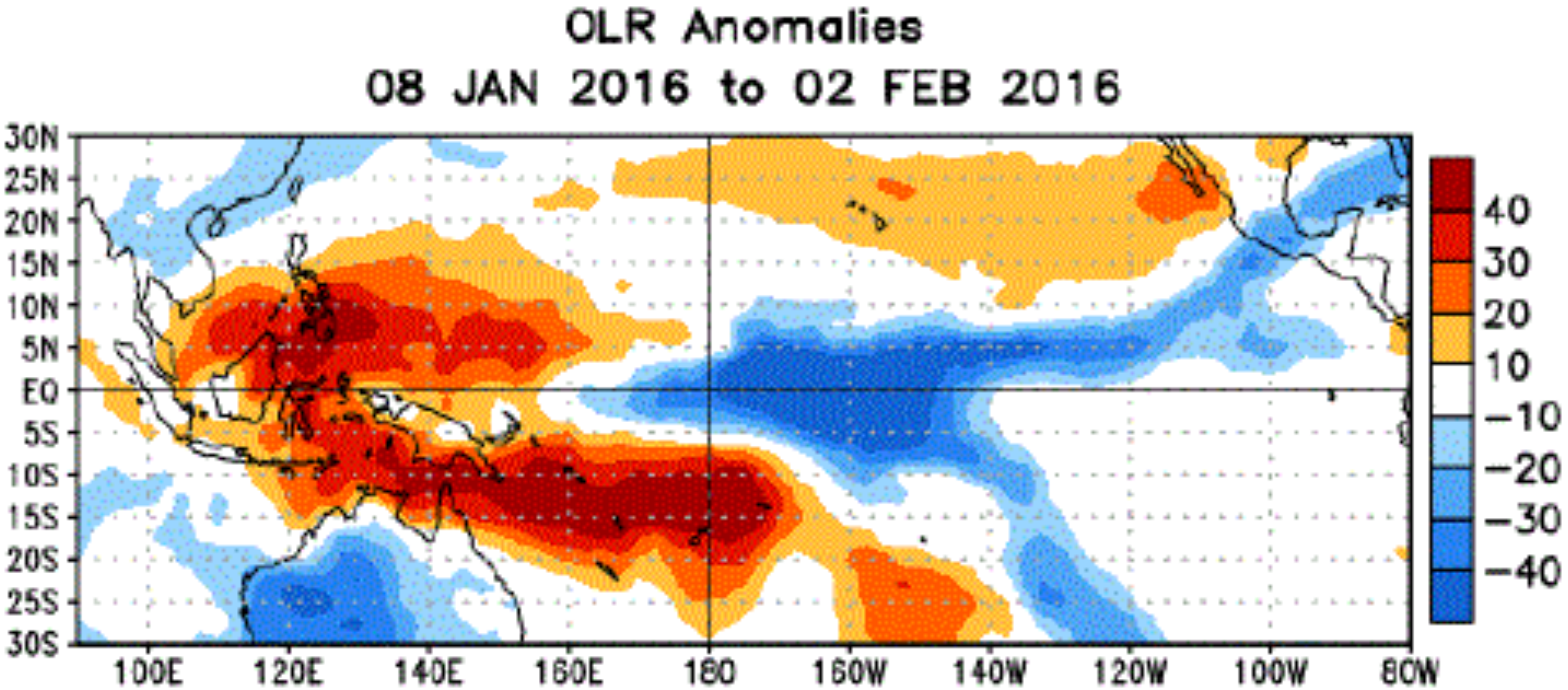
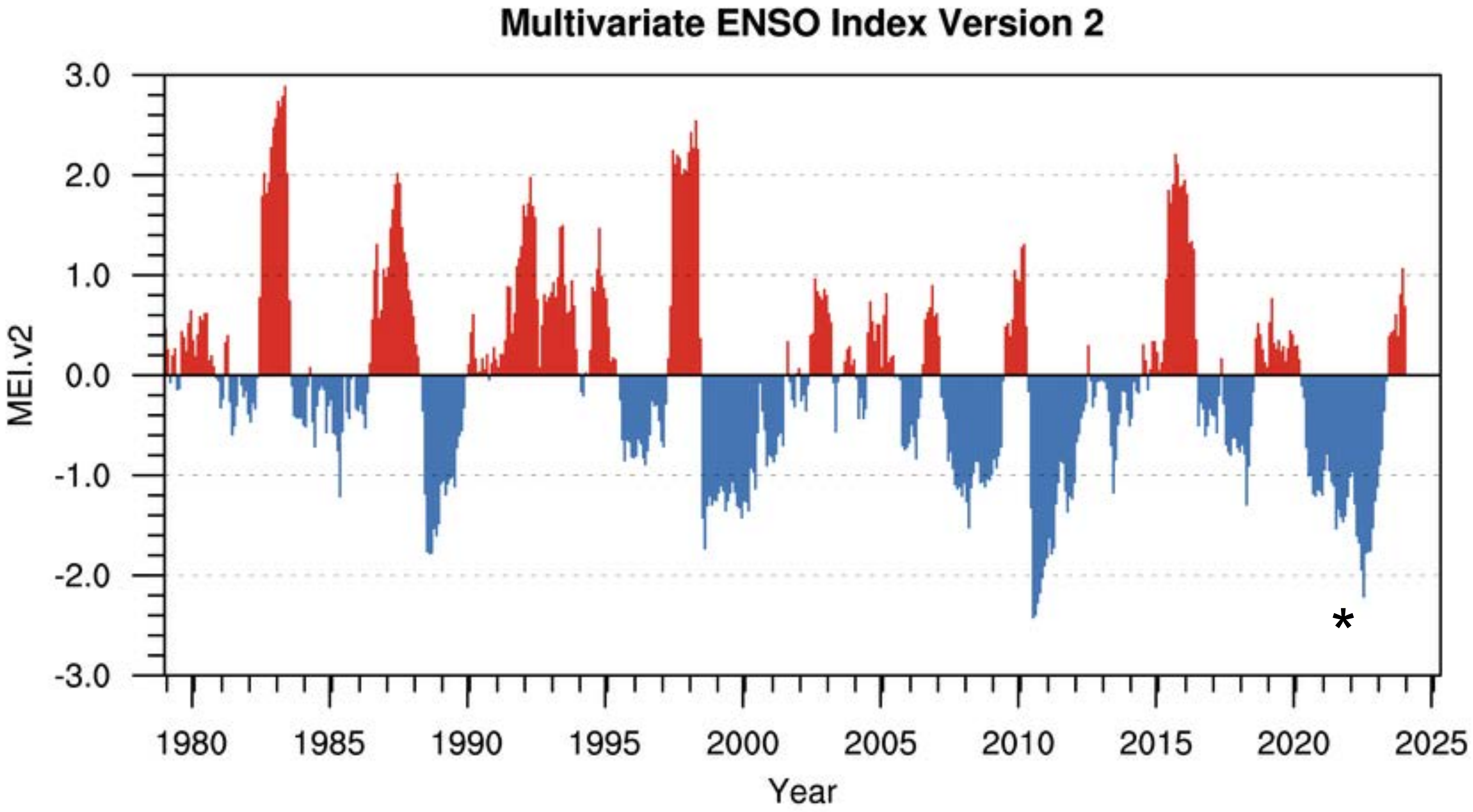
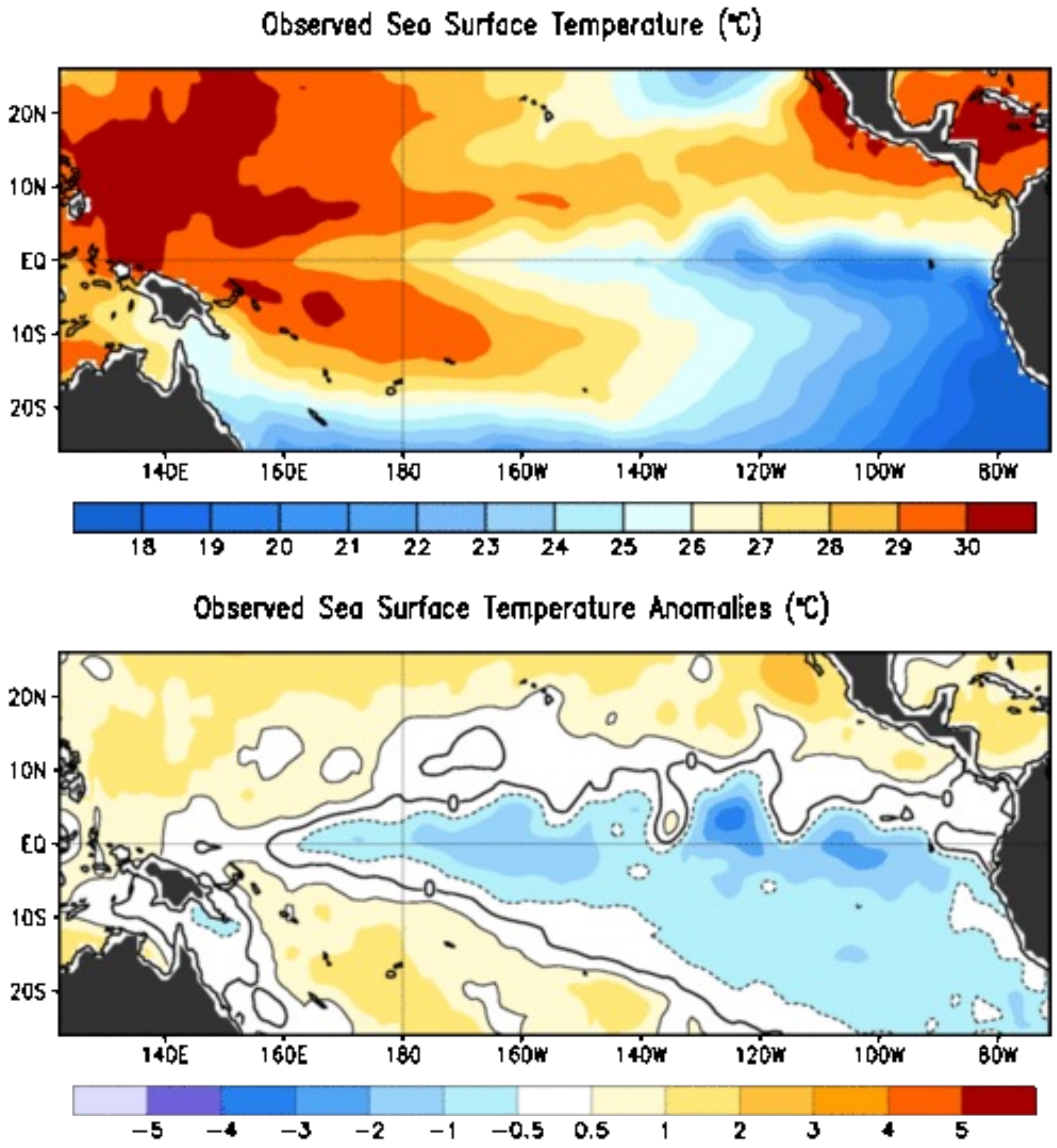


Figure 5. Average outgoing longwave radiation (OLR) anomalies (W/m^2) for the period 8 January – 2 February 2016. OLR anomalies are computed as departures from the 1979-1995 base period pentad means.

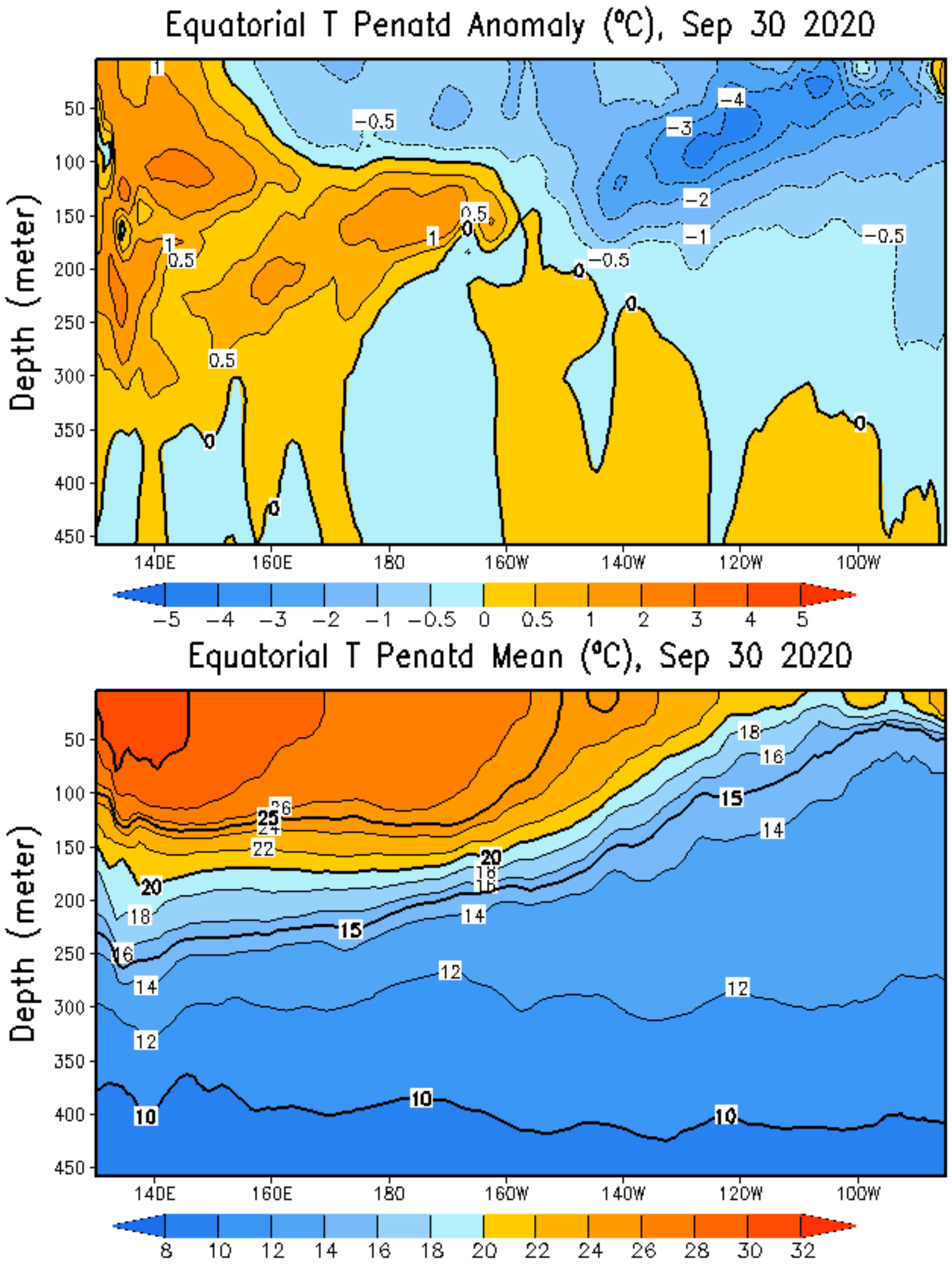
MEI = Weighted spatial patterns of 6 variables (SLP, SST, U, V, T, clouds)
monthly averages + = warm phase (El Nino) – = cold phase (La Nina)

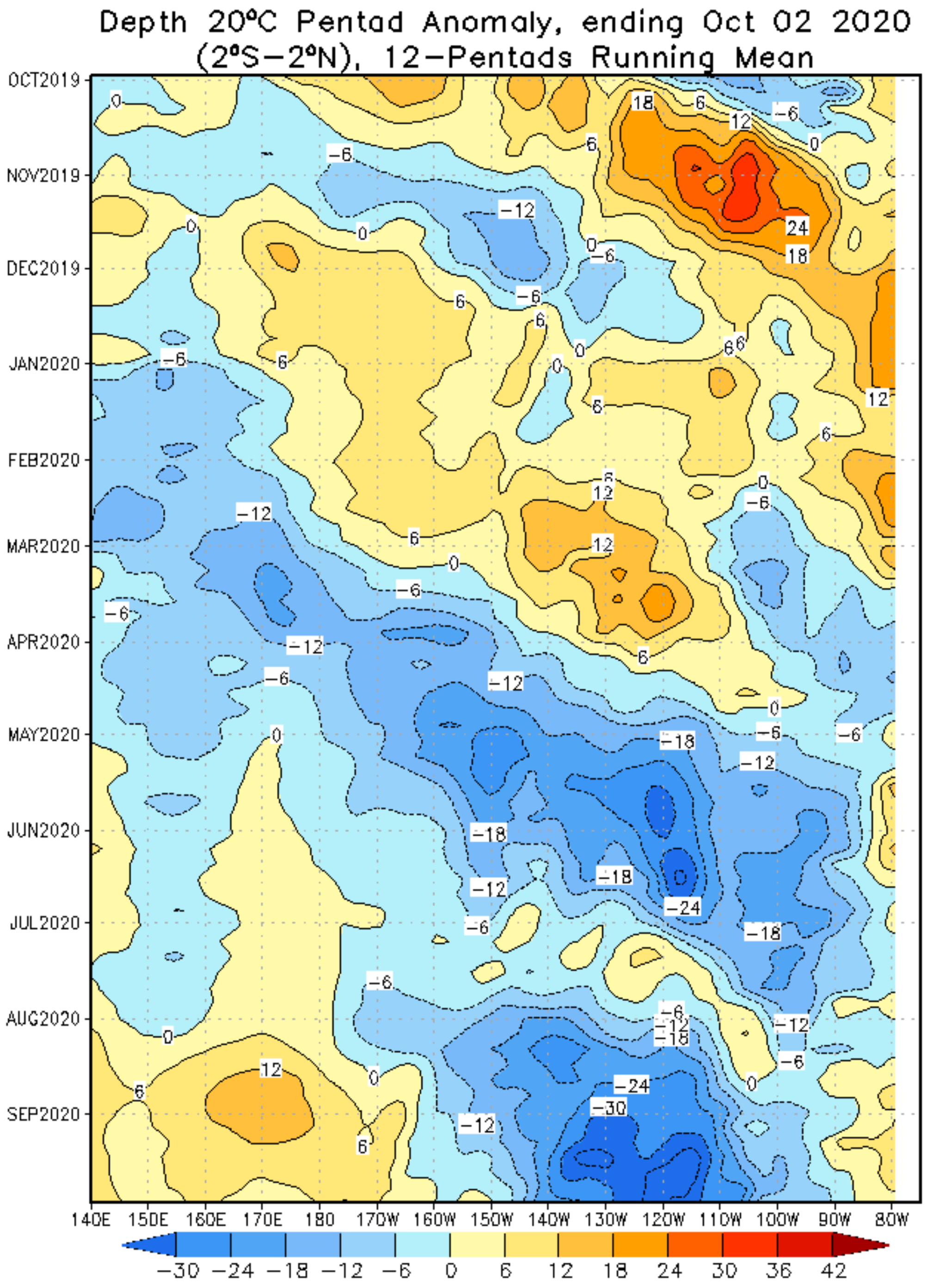




7-day Average Centered on 30 September 2020

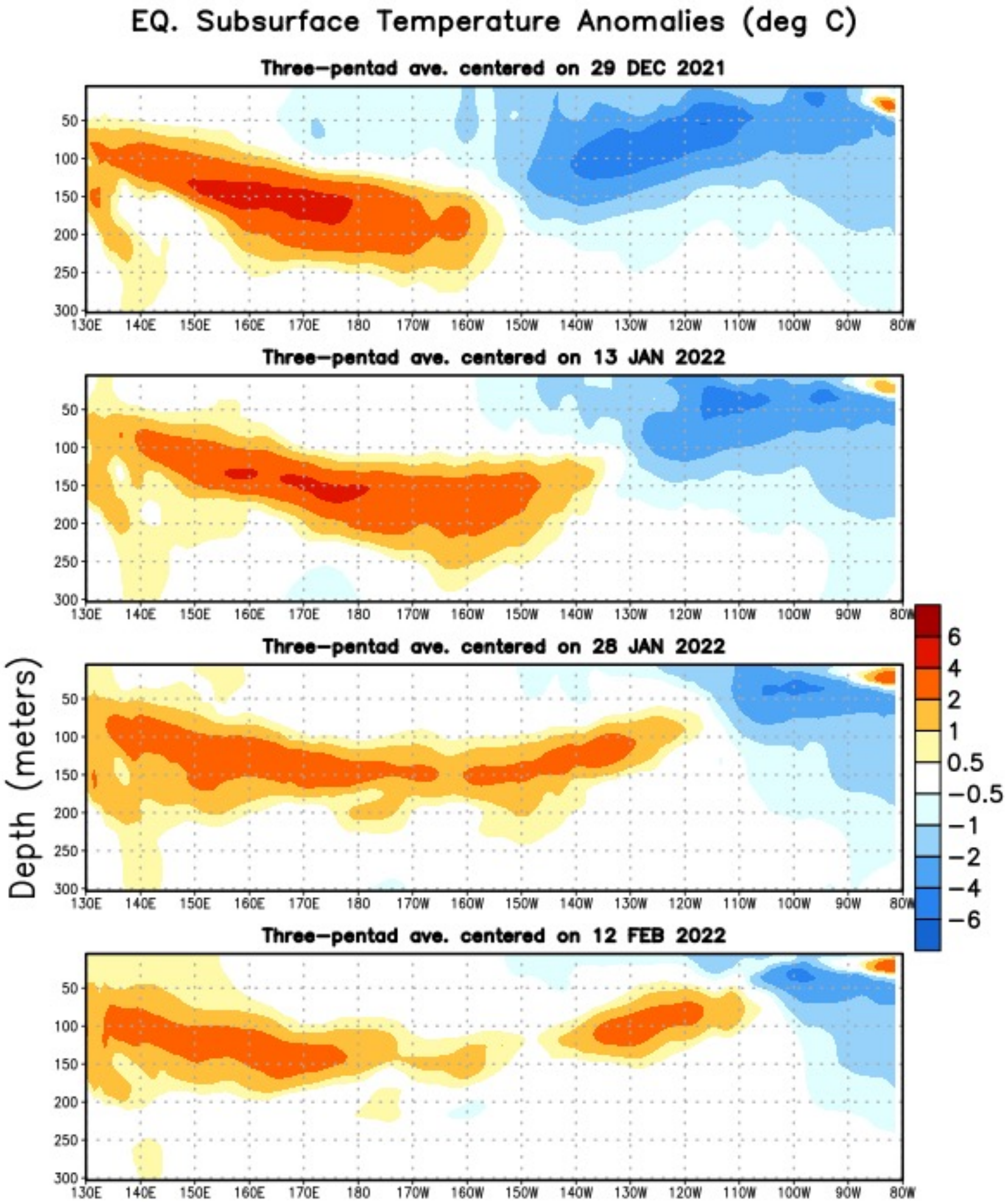
https://www.cpc.ncep.noaa.gov/


Equatorial T Penatd Anomaly (°C), Sep 30 2020
Depth (meter)
50
100
150
200
250
300
350
400
450
140E
160E
180
160W
140W
120W
100W
-5
-4
-3
-2
-1
-0.5
0
0.5
1
2
3
4
5
Equatorial T Penatd Mean (°C), Sep 30 2020
Depth (meter)
140E
160E
180
160W
140W
120W
100W
8
10
12
14
16
18
20
22
24
26
28
30
32

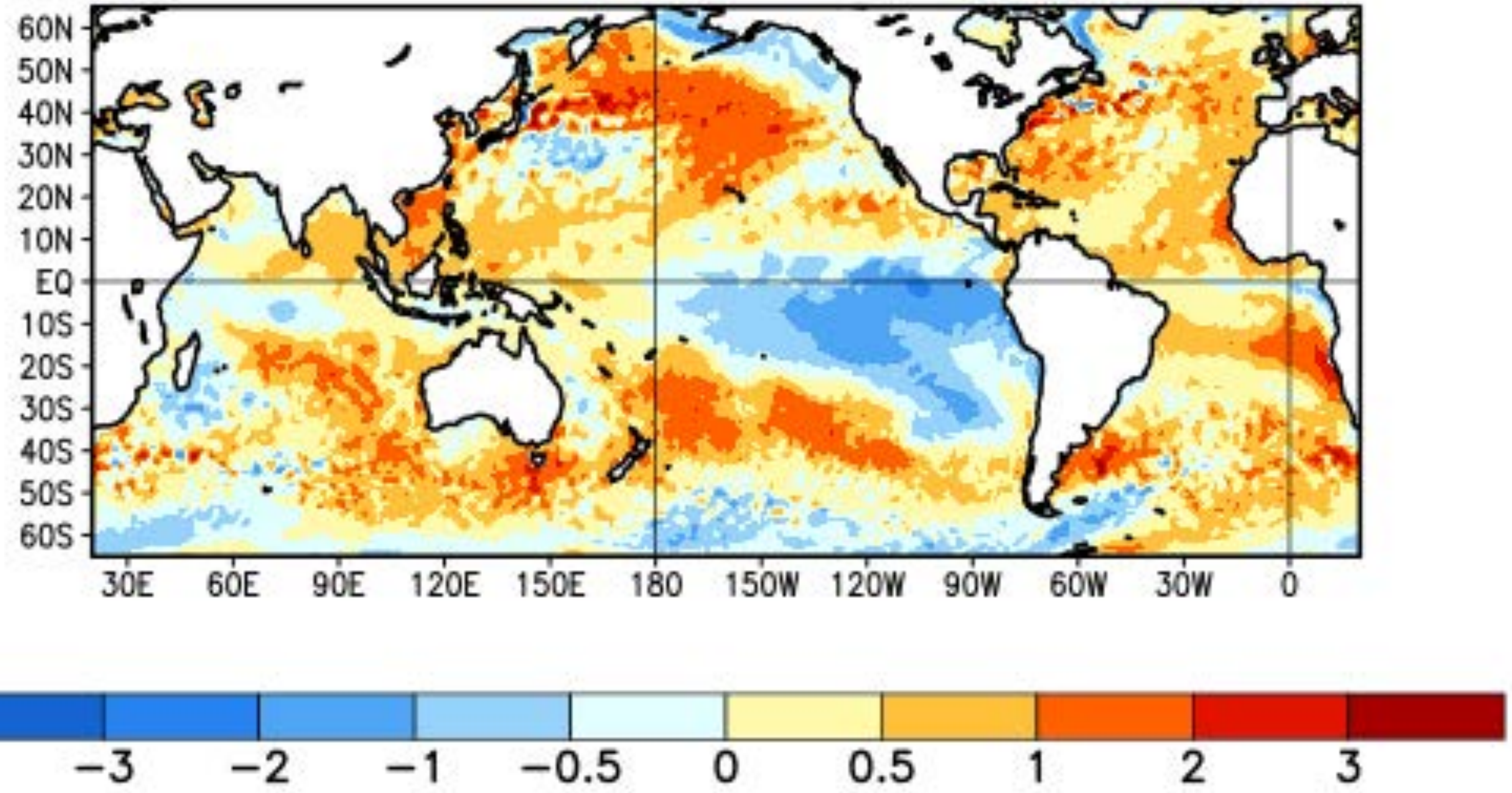


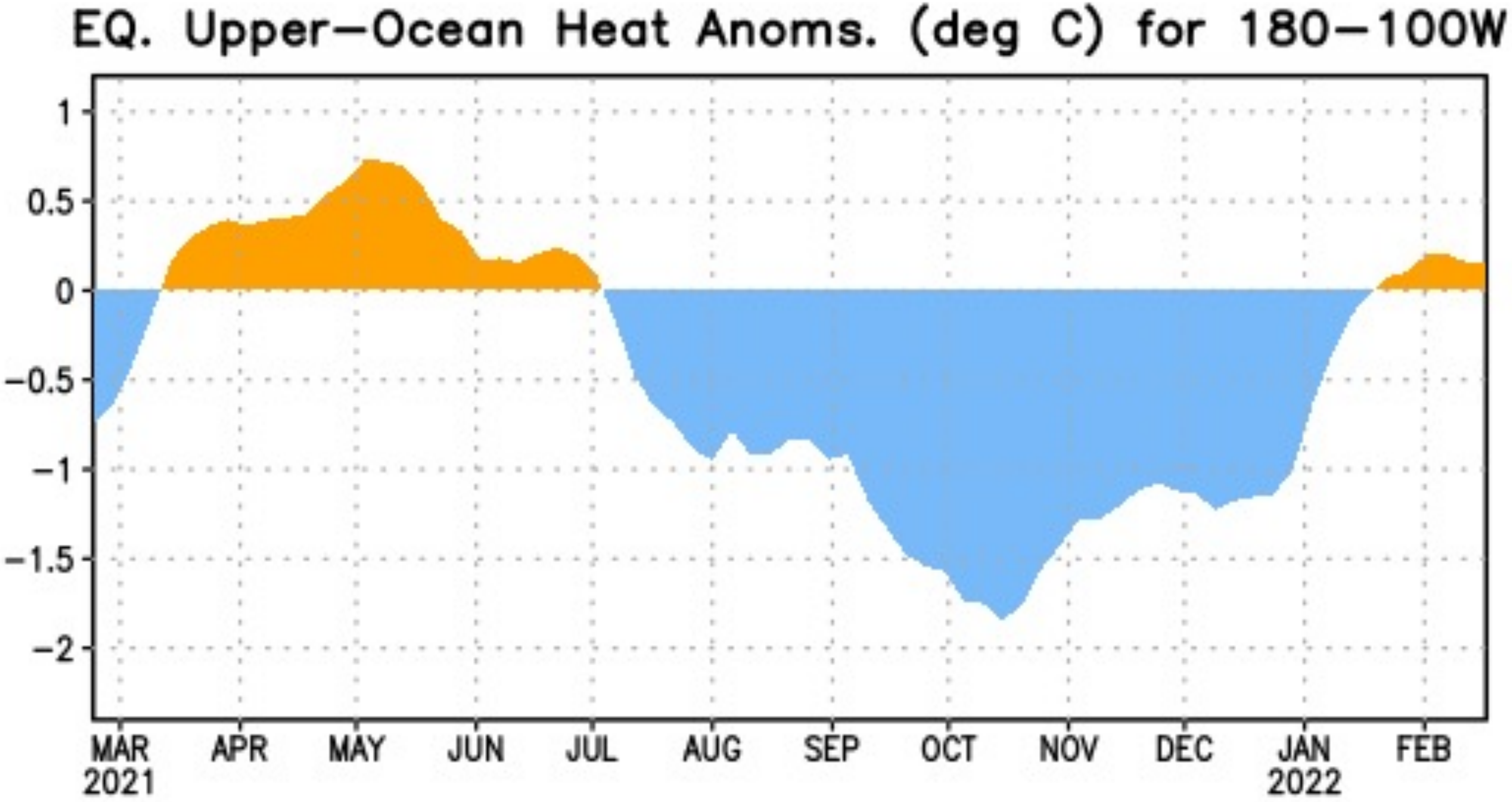
Warm and cold anomalies travel eastward

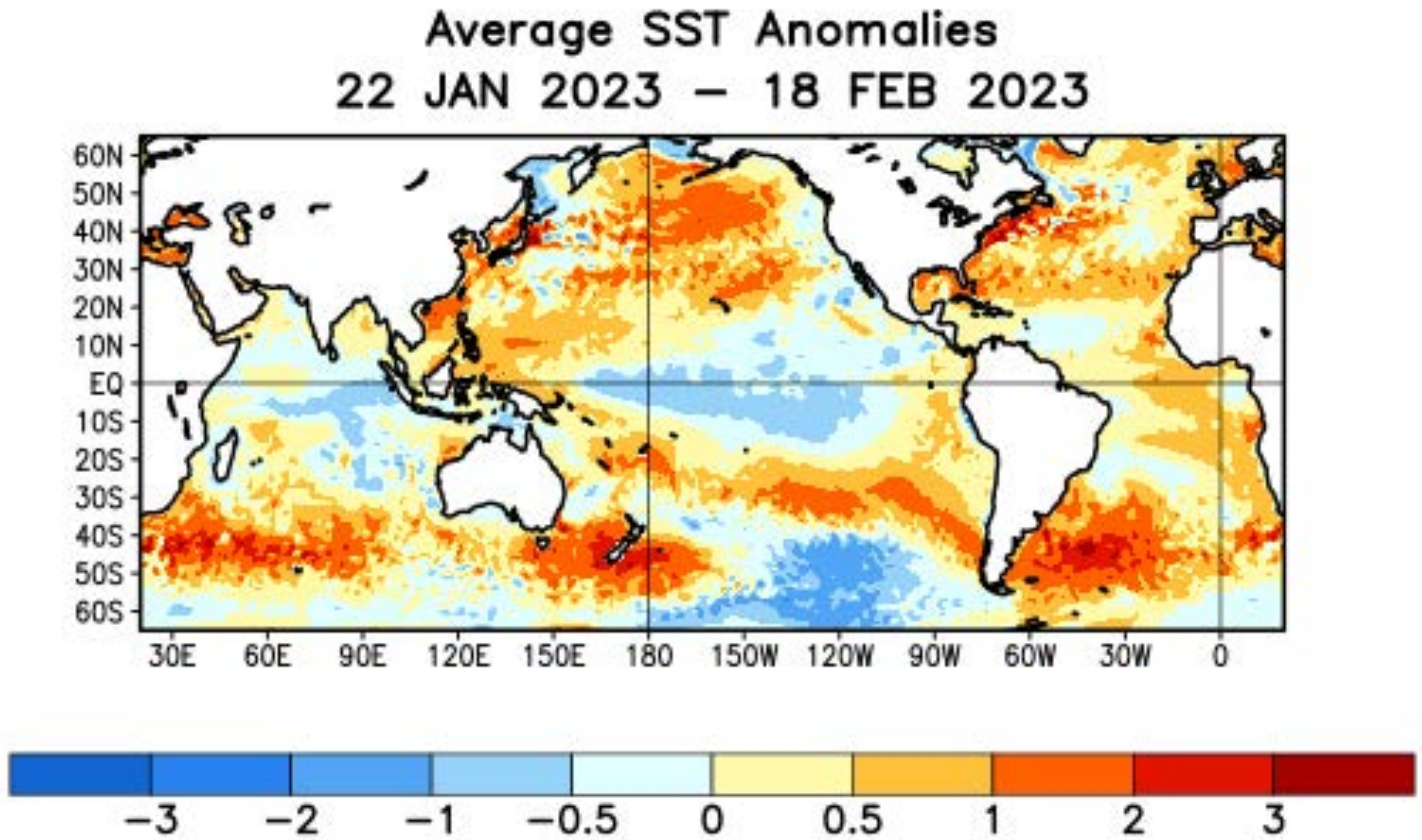
at the speed of an oceanic Kelvin wave


EQ. Subsurface Temperature Anomalies (deg C)
Three-pentad ave. centered on 29 DEC 2021
Three-pentad ave. centered on 13 JAN 2022
Three-pentad ave. centered on 28 JAN 2022
Three-pentad ave. centered on 12 FEB 2022
Depth (meters)
50
100
150
200
250
300
130E 140E 150E 160E 170E 180 170W 160W 150W 140W 130W 120W 110W 100W 90W 80W
6
4
2
1
0.5
−0.5
−1
−2
−4
−6

Average SST Anomalies
23 JAN 2022 – 19 FEB 2022

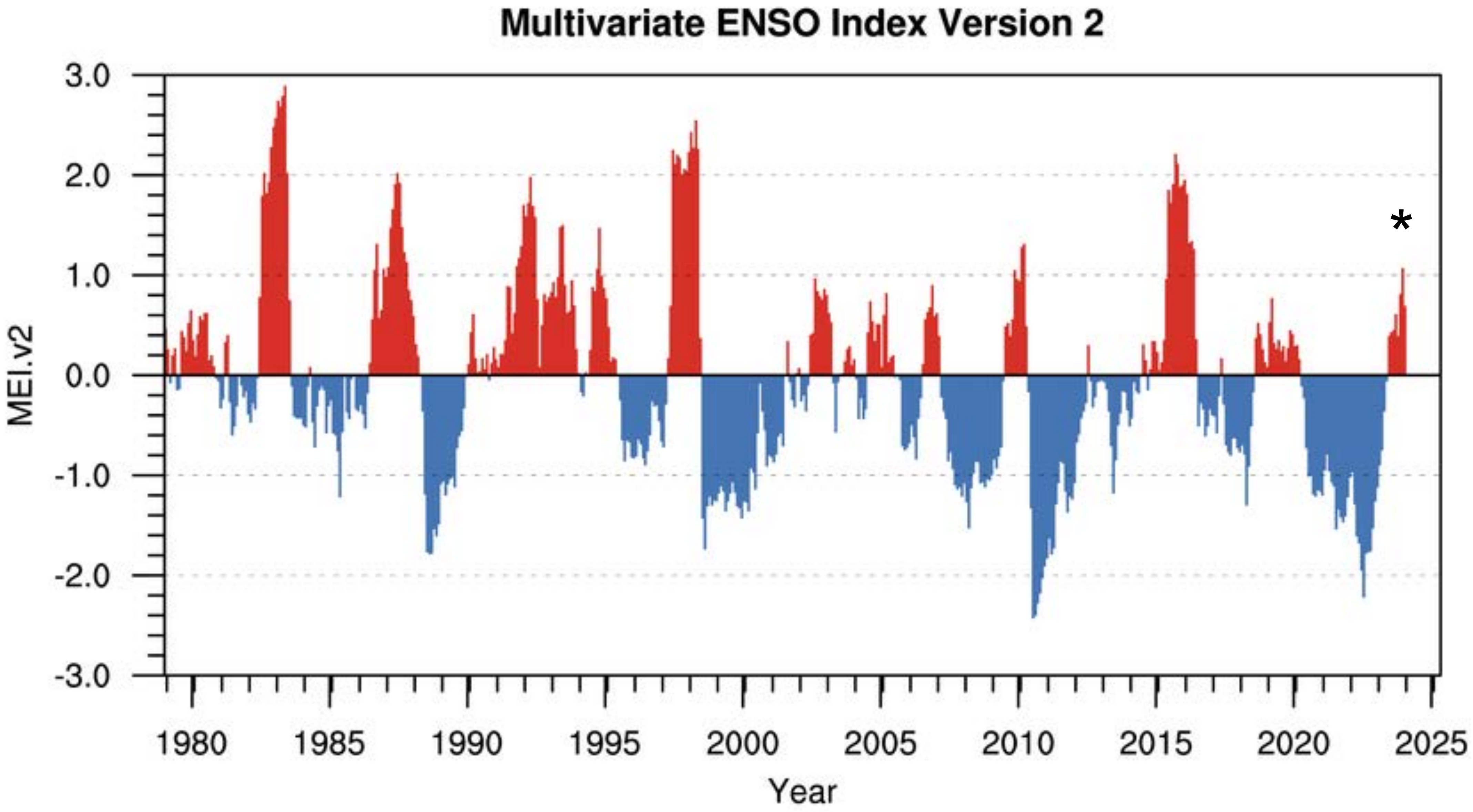


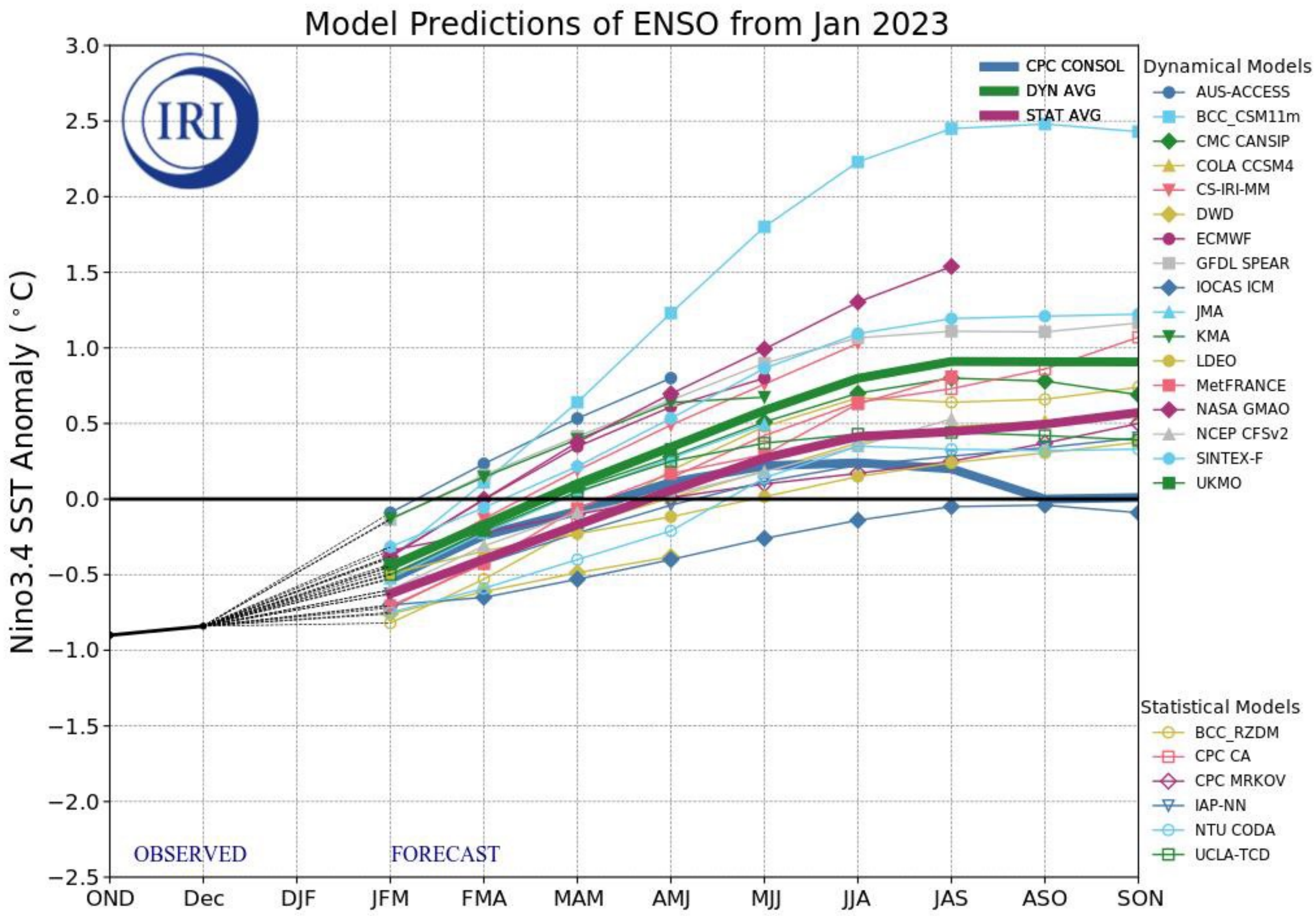

EQ. Upper-Ocean Heat Anoms. (deg C) for 180–100W
1
0.5
0
–0.5
–1
–1.5
–2
MAR
2021
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
2022
FEB



Average SST Anomalies
22 JAN 2023 – 18 FEB 2023
60N
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
60S
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
−3
−2
−1
−0.5
0
0.5
1
2
3

MEI = Weighted spatial patterns of 6 variables (SLP, SST, U, V, T, clouds)
monthly averages + = warm phase (El Nino) – = cold phase (La Nina)





Model Predictions of ENSO from Jan 2023
IRI
Nino3.4 SST Anomaly (°C)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
OND
Dec
DJF
JFM
FMA
MAM
AMJ
MJJ
JJA
JAS
ASO
SON
OBSERVED
FORECAST
CPC CONSOL
DYN AVG
STAT AVG
Dynamical Models
AUS-ACCESS
BCC_CSM11m
CMC CANSIP
COLA CCSM4
CS-IRI-MM
DWD
ECMWF
GFDL SPEAR
IOCAS ICM
JMA
KMA
LDEO
MetFRANCE
NASA GMAO
NCEP CFSv2
SINTEX-F
UKMO
Statistical Models
BCC_RZDM
CPC CA
CPC MRKOV
IAP-NN
NTU CODA
UCLA-TCD

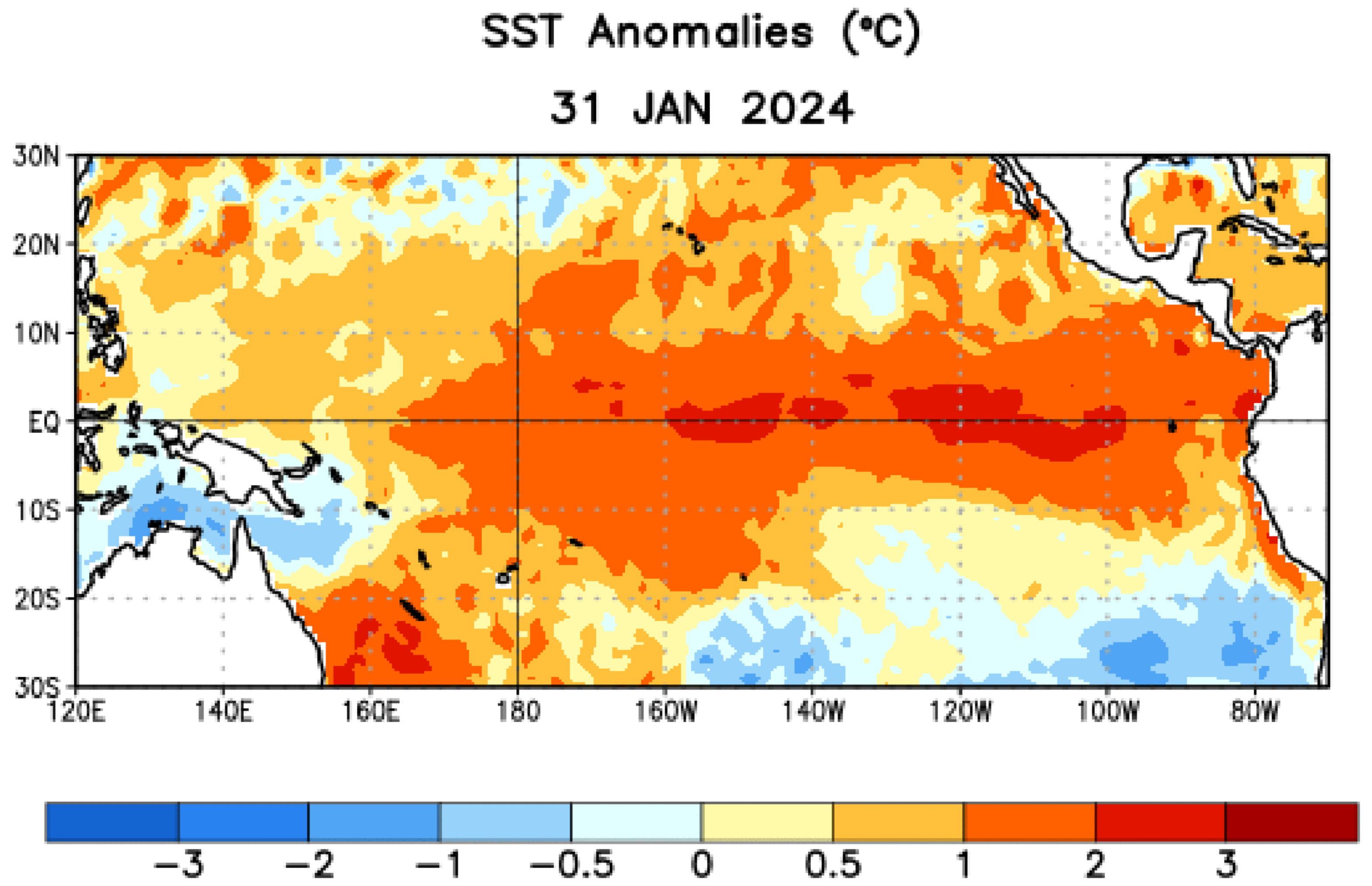


Figure 1. Average sea surface temperature (SST) anomalies (°C) for the week centered on 31 January 2024. Anomalies are computed with respect to the 1991-2020 base period weekly means.

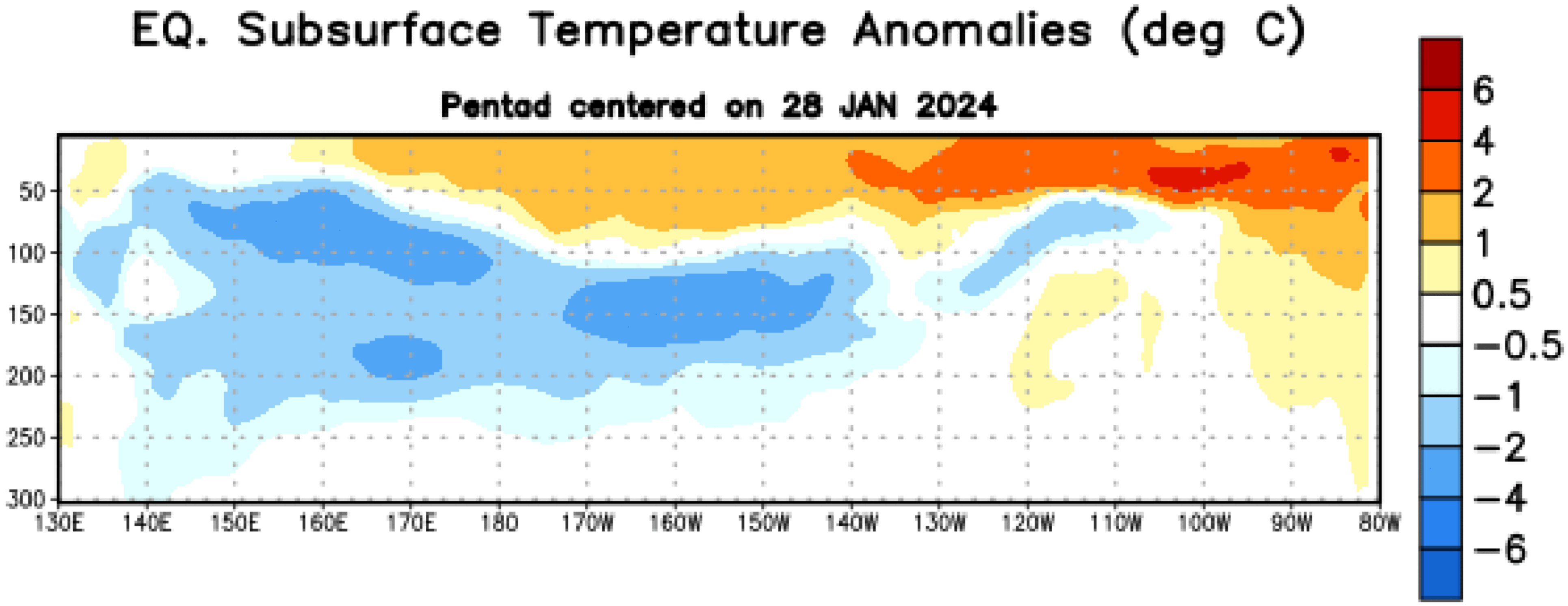


Figure 4. Depth-longitude section of equatorial Pacific upper-ocean (0-300m) temperature anomalies (°C) centered on the pentad of 28 January 2024. Anomalies are departures from the 1991-2020 base period pentad means.

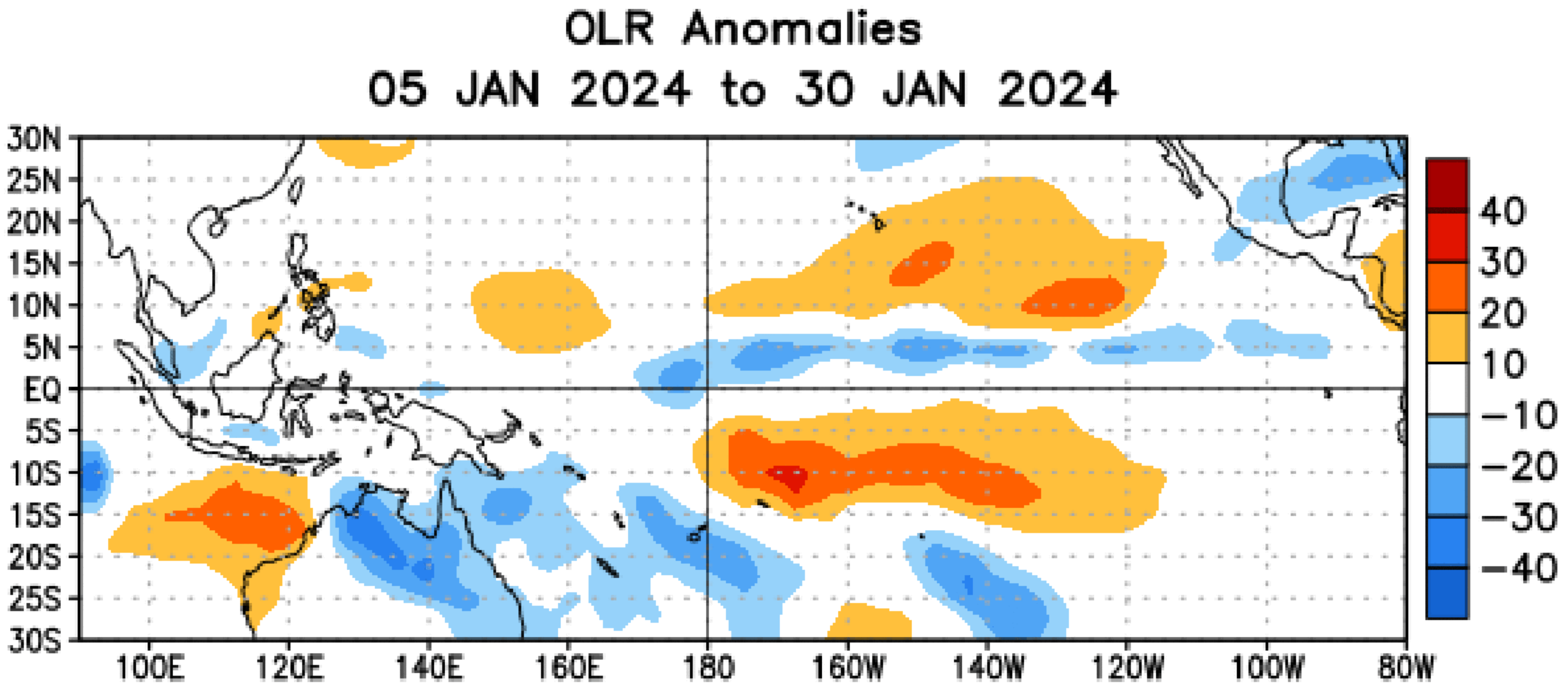


Figure 5. Average outgoing longwave radiation (OLR) anomalies (W/m^2) for the period 5 – 30 January 2024. OLR anomalies are computed as departures from the 1991-2020 base period pentad means.

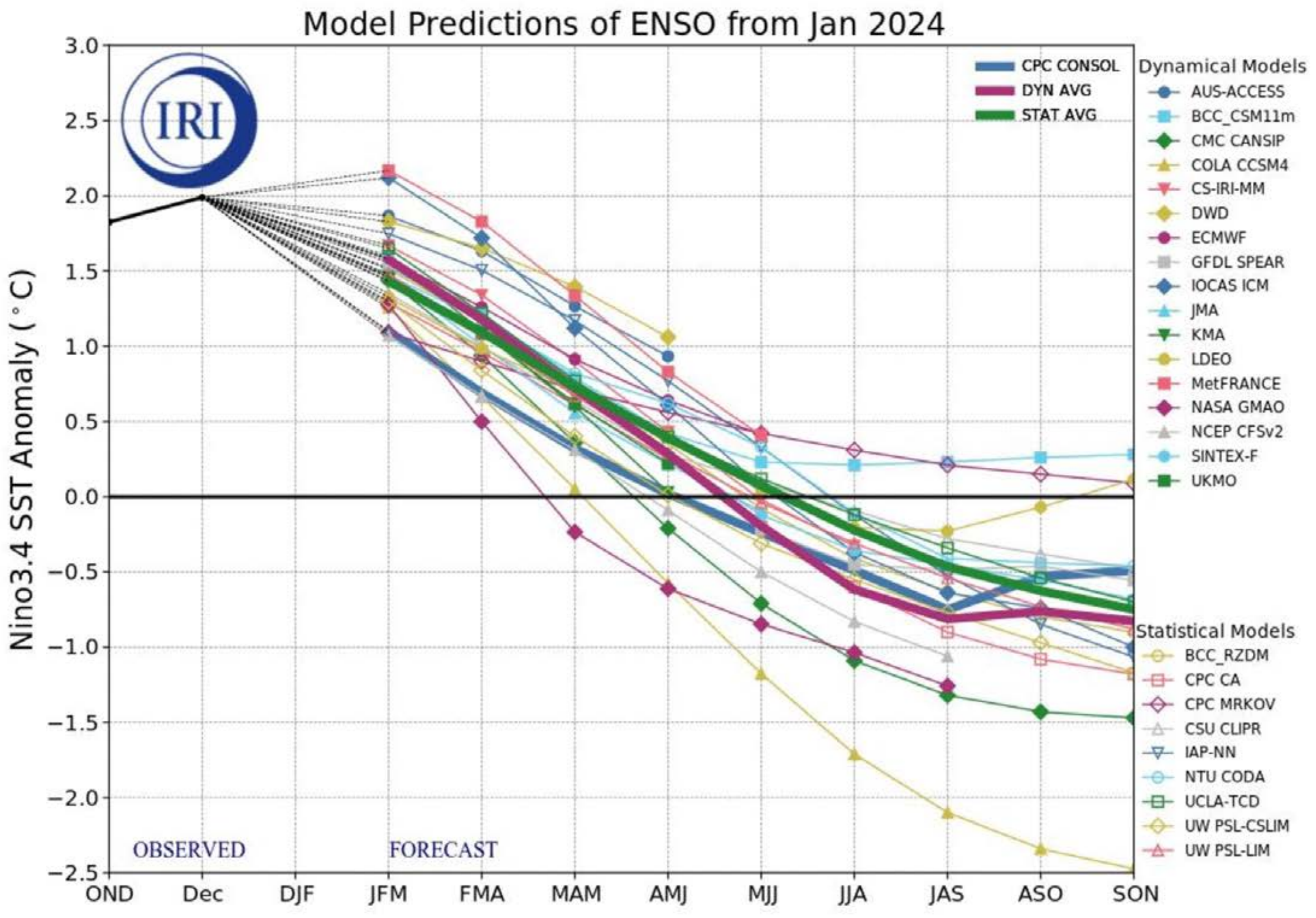


Figure 6. Forecasts of sea surface temperature (SST) anomalies for the Niño 3.4 region (5°N-5°S, 120°W-170°W). Figure updated 19 January 2024 by the International Research Institute (IRI) for Climate and Society.

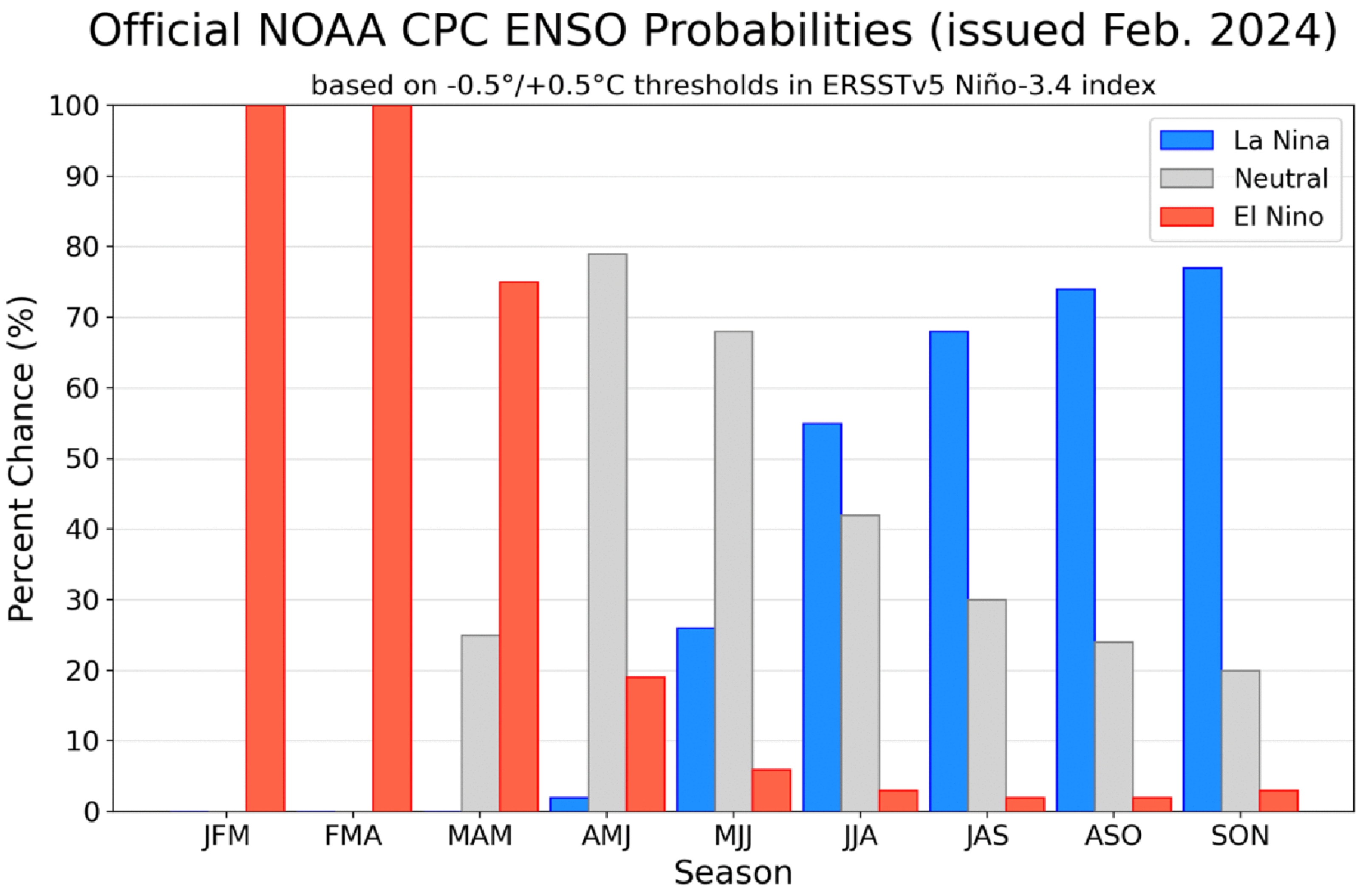
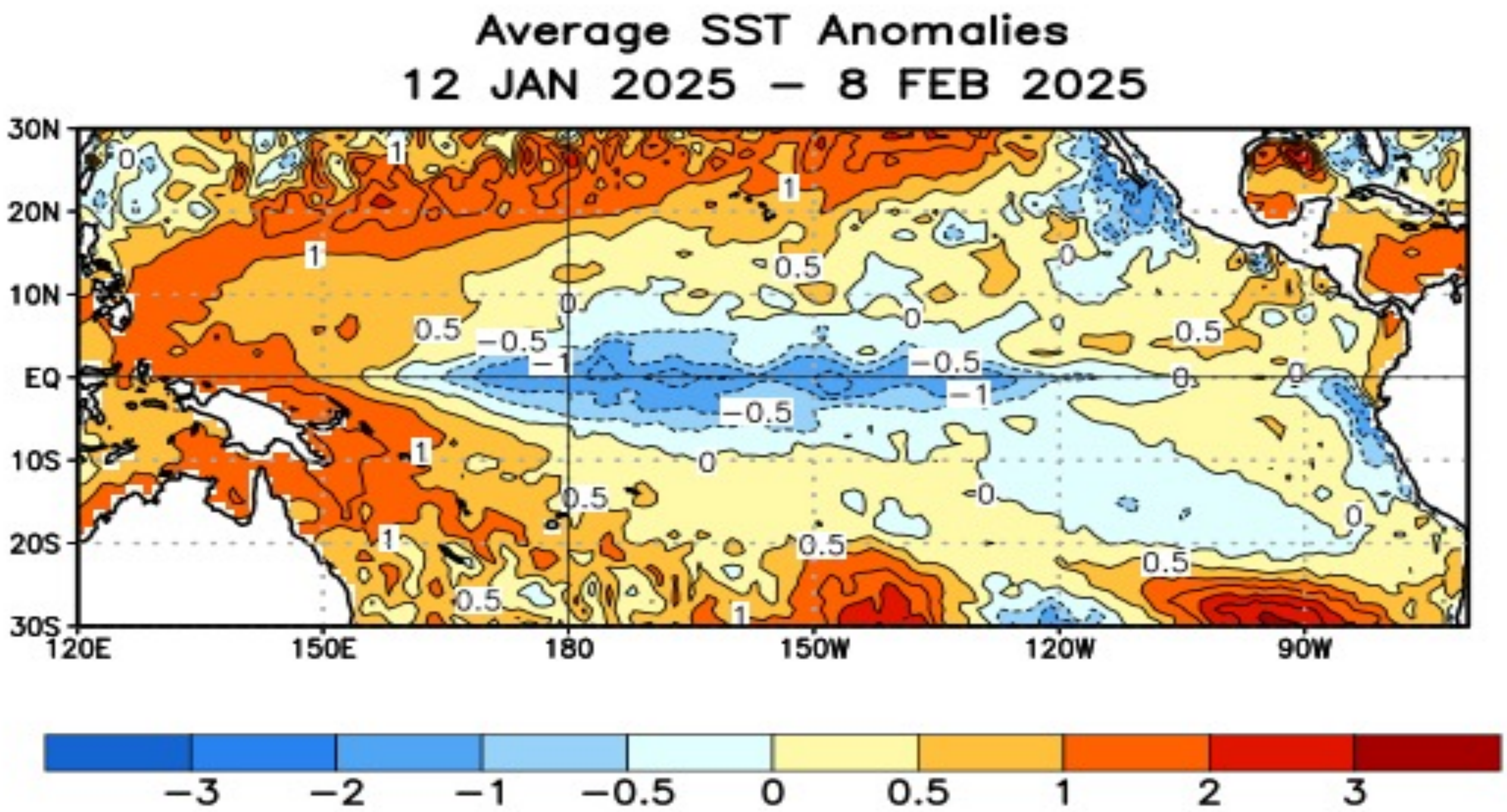
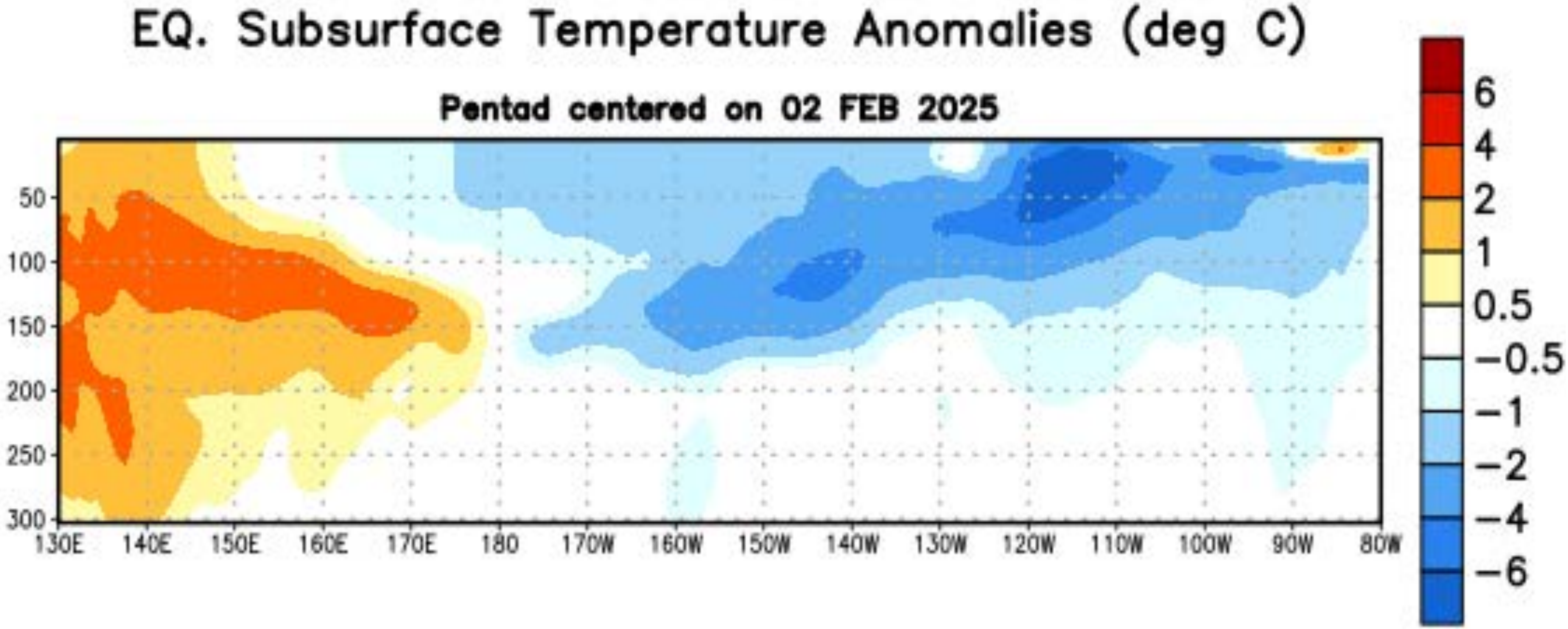


Figure 7. Official ENSO probabilities for the Niño 3.4 sea surface temperature index (5°N-5°S, 120°W-170°W). Figure updated 8 February 2024.



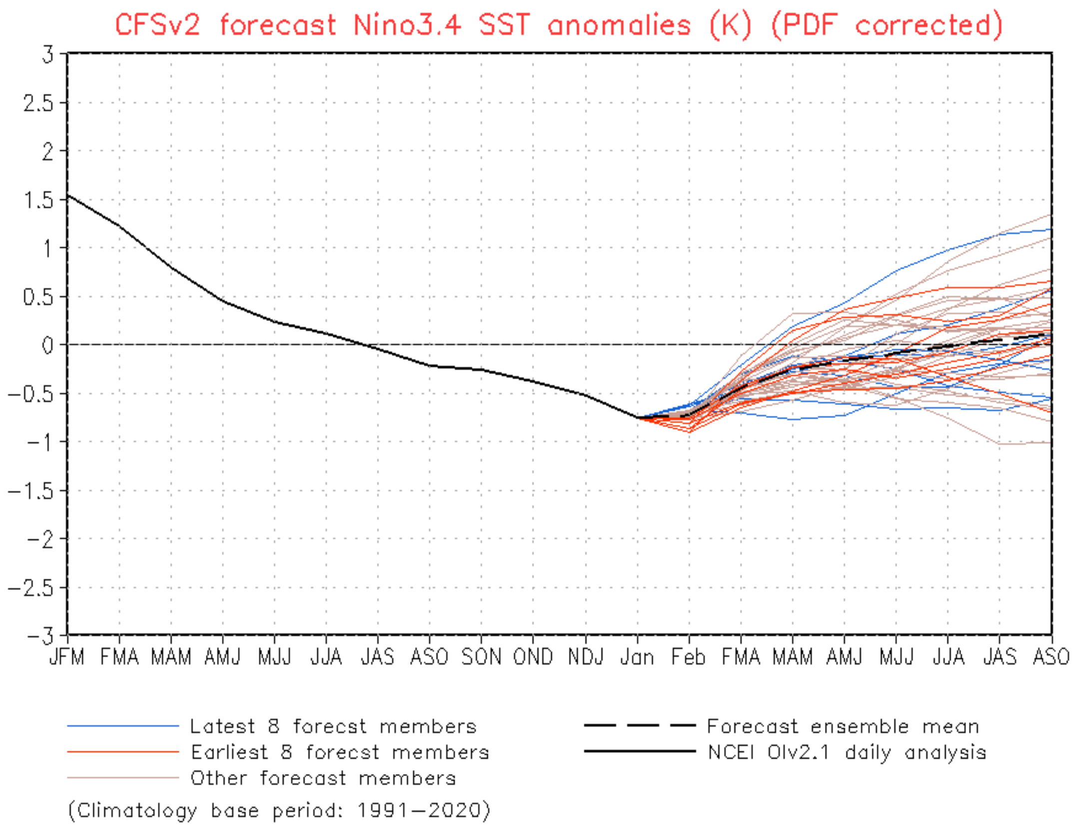
Average SST Anomalies
12 JAN 2025 – 8 FEB 2025
30N
20N
10N
EQ
10S
20S
30S
120E
150E
180
150W
120W
90W
−3
−2
−1
−0.5
0
0.5
1
2
3

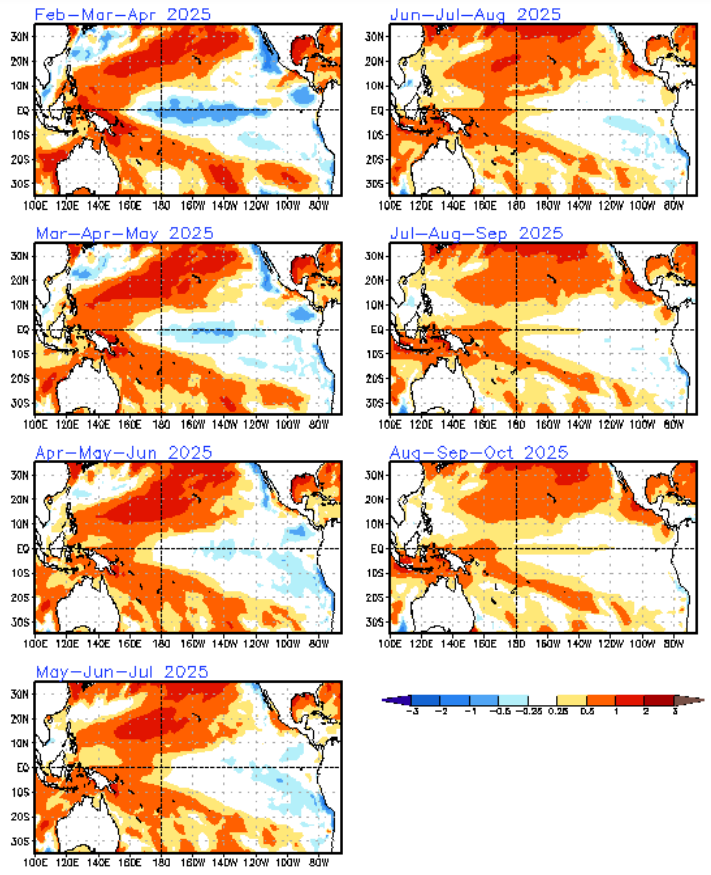

EQ. Subsurface Temperature Anomalies (deg C)
Pentad centered on 02 FEB 2025
50
100
150
200
250
300
130E
140E
150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
90W
80W
6
4
2
1
0.5
−0.5
−1
−2
−4
−6

SST Outlook: NCEP CFS.v2 Forecast (PDF corrected)

Issued: 9 February 2025

The CFS.v2 ensemble mean (black dashed line) indicates La Niña conditions are expected to persist through February-April 2025.



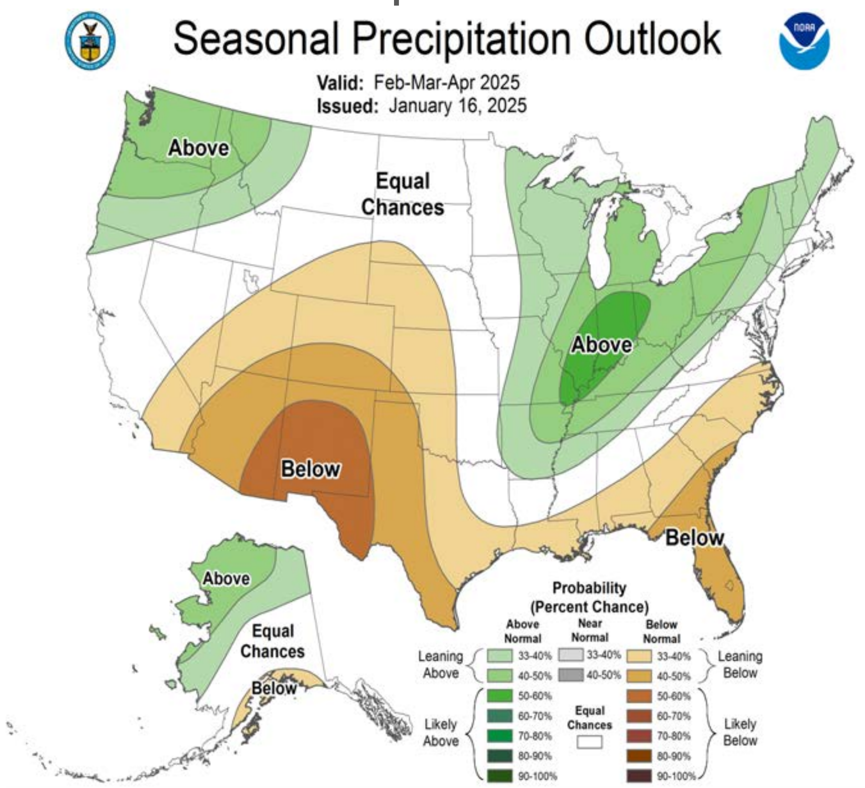


U. S. Seasonal Outlooks

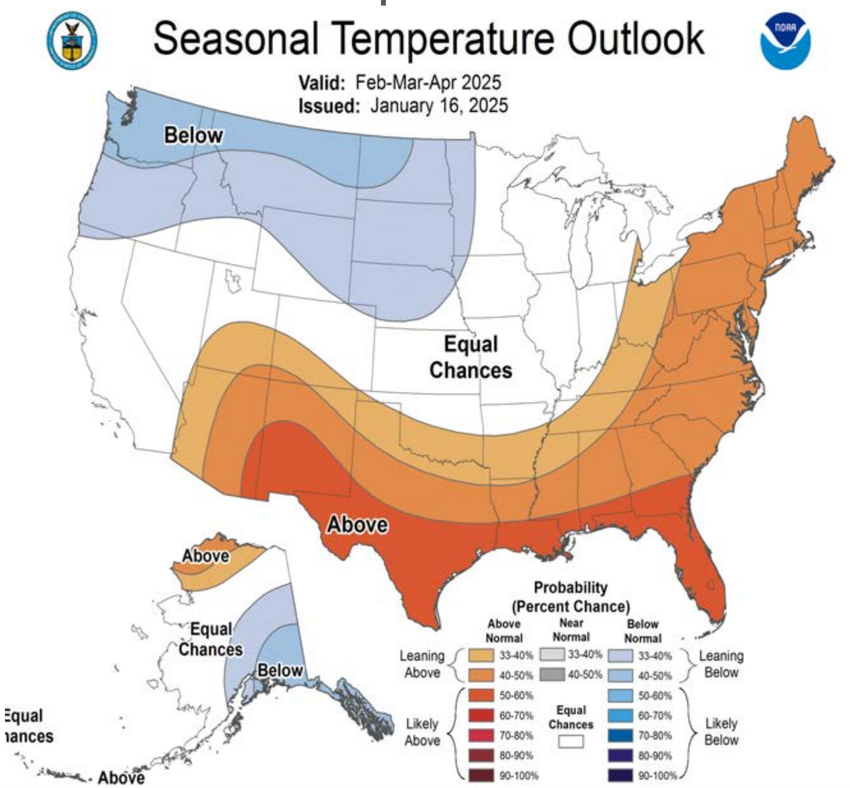
February – April 2025

The seasonal outlooks combine the effects of long-term trends, soil moisture, and, when appropriate, ENSO.

Precipitation



Temperature



Summary

ENSO Alert System Status: La Niña Advisory

La Niña conditions are present.*

Equatorial sea surface temperatures (SSTs) are below average in the central and east-central Pacific Ocean.

La Niña conditions are expected to persist through February-April 2025 (59% chance), with a transition to ENSO-neutral likely during March-May 2025 (60% chance).

* Note: These statements are updated once a month (2nd Thursday of each month) in association with the ENSO Diagnostics Discussion, which can be found by clicking here.

Ensō (円相 , circle)
Zen Buddhism

Symbolizes absolute enlightenment, strength, elegance, the universe, and mu (the void).

13. ENSO study guide questions

What is El Nino?

What is the Southern Oscillation?

What are the main characteristics of the tropical atmosphere and the ocean during the cold phase of ENSO (La Nina)?

During the warm phase (El Nino)?

What are some practical reasons for trying to understand and predict ENSO?

nullschool.net - check out today's patterns of winds and SSTs over the globe