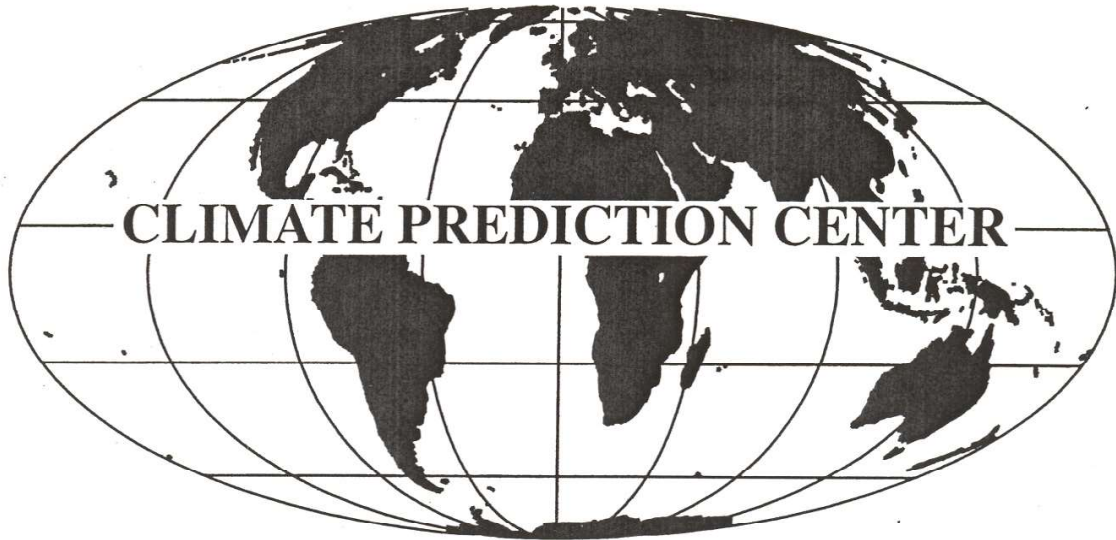


CLIMATE DIAGNOSTICS BULLETIN



JUNE 2023

NEAR REAL-TIME OCEAN / ATMOSPHERE

Monitoring, Assessments, and Prediction

**U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
National Centers for Environmental Prediction**

CLIMATE DIAGNOSTICS BULLETIN



CLIMATE PREDICTION CENTER
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5830 University Research Court
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Chief Editor: Wei Shi

Editors: Michelle L'Heureux and Emerson LaJoie

Bulletin Production: Wei Shi

External Collaborators:

Center for Ocean-Atmospheric Prediction Studies (COAPS)
Cooperative Institute for Research in the Atmosphere (CIRA)
Earth & Space Research
International Research Institute for Climate and Society (IRI)
Joint Institute for the Study of the Atmosphere and Ocean (JISAO)
Lamont-Doherty Earth Observatory (LDEO)
NOAA-CIRES, Climate Diagnostics Center
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If you have any problems accessing the bulletin, contact Dr. Wei Shi by E-mail:

Wei.Shi@noaa.gov

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Tropical Highlights - June 2023

During June 2023, sea surface temperatures (SSTs) were above-average in much of the equatorial Pacific (Fig. T18). The latest monthly Niño indices were +2.6°C for the Niño 1+2 region, +0.9°C for the Niño 3.4 region and +1.2°C for the Niño 3 region (Table T2). The depth of the oceanic thermocline (measured by the depth of the 20°C isotherm) was above-average across the equatorial Pacific (Figs. T15, T16). The corresponding sub-surface temperatures were 1-6°C above-average in the far eastern equatorial Pacific (Fig. T17).

Also during June, the lower-level and upper-level winds were near average over much of the equatorial Pacific (Table T1, Figs. T20, T21). Meanwhile, tropical convection was enhanced near the International Date Line and suppressed over far western equatorial Pacific and eastern tropical Indian Ocean (Fig. T25). Collectively, these oceanic and atmospheric anomalies were consistent with weak El Niño conditions.

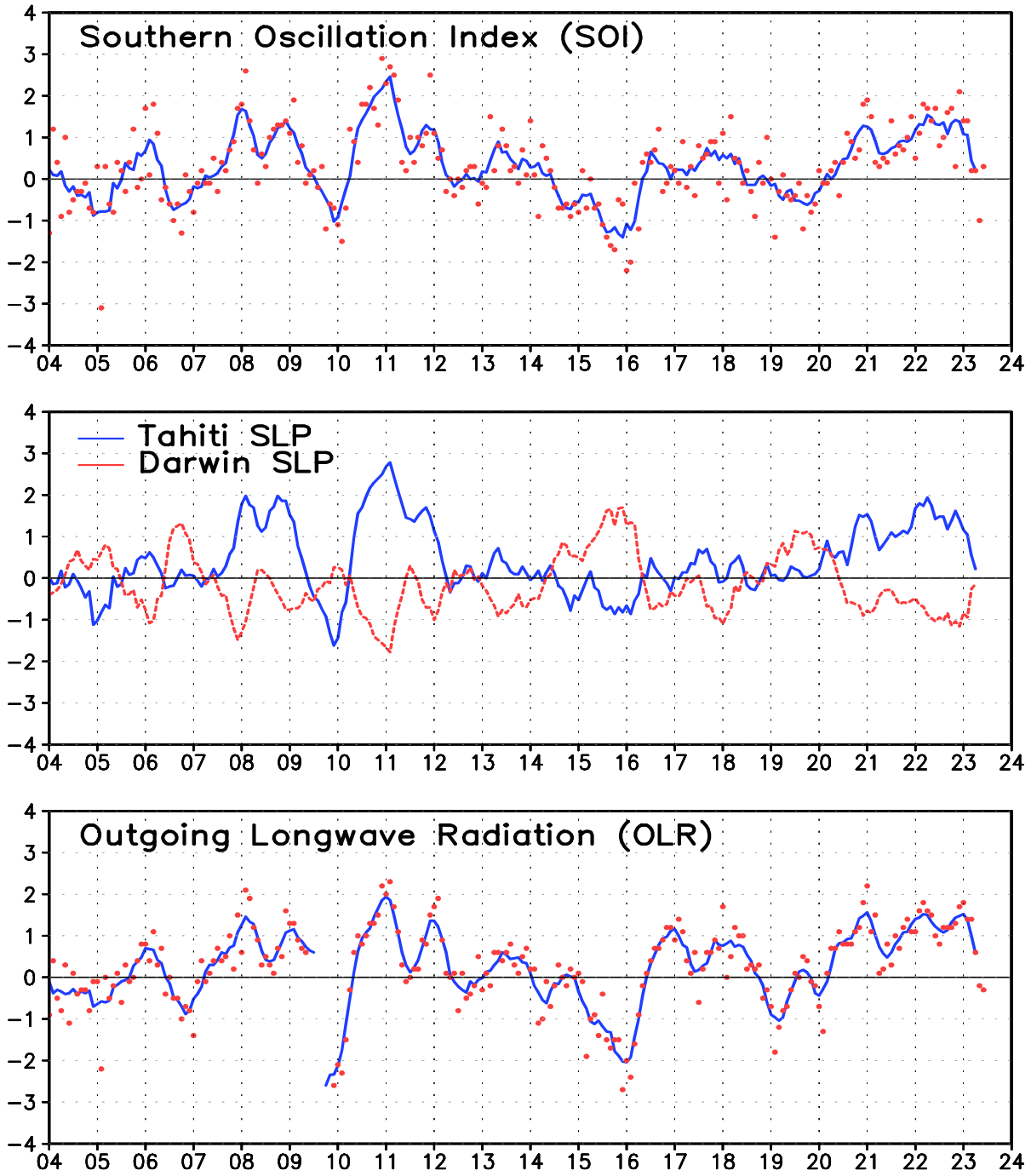
For the latest status of the ENSO cycle see the ENSO Diagnostic Discussion at:
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/index.html

Month	SLP Anomalies		Tahiti minus Darwin SOI	850-hPa Zonal Wind Index			200-hPa Wind Index	OLR Index
	Tahiti	Darwin		5N-5S 135E-180	5N-5S 175W-140W	5N-5S 135W-120W		
JUN 23	0.3	-0.1	0.3	0.4	0.1	0.4	-0.4	5N-5S 160E-160W
MAY 23	-0.3	1.6	-1.0	-0.4	0.4	0.6	1.3	5N-5S 165W-110W
APR 23	-0.3	-0.8	0.2	0.3	0.5	0.2	1.1	5N-5S 160E-160W
MAR 23	0.4	0.1	0.2	0.2	0.7	0.2	1.0	5N-5S 160E-160W
FEB 23	1.0	-1.5	1.4	0.7	1.5	1.1	2.9	5N-5S 160E-160W
JAN 23	1.9	-0.7	1.4	1.4	1.3	1.1	0.9	5N-5S 160E-160W
DEC 22	2.2	-1.8	2.1	1.8	1.8	1.8	2.3	5N-5S 160E-160W
NOV 22	0.3	-0.3	0.3	1.3	1.3	0.4	1.0	5N-5S 160E-160W
OCT 22	1.6	-1.5	1.7	1.6	1.9	1.3	1.5	5N-5S 160E-160W
SEP 22	2.1	-0.9	1.6	1.3	1.0	1.1	0.1	5N-5S 160E-160W
AUG 22	0.7	-1.2	1.0	1.3	1.3	0.9	0.6	5N-5S 160E-160W
JUL 22	1.2	-0.3	0.8	1.9	1.7	1.5	2.3	5N-5S 160E-160W
JUN 22	1.8	-1.2	1.7	1.1	0.4	0.0	0.8	5N-5S 160E-160W

TABLE T1 - Atmospheric index values for the most recent 12 months. Indices are standardized by the mean annual standard deviation, except for the Tahiti and Darwin SLP anomalies which are in units of hPa. Positive (negative) values of 200-hPa zonal wind index imply westerly (easterly) anomalies. Positive (negative) values of 850-hPa zonal wind indices imply easterly (westerly) anomalies. Anomalies are departures from the 1991-2020 base period means.

Month	PACIFIC SST				ATLANTIC SST		GLOBAL							
	Niño 1+2 0-10S 90W-80W	Niño 3 5N-5S 150W-90W	Niño 3.4 5N-5S 170W-120W	Niño 4 5N-5S 160E-150W	N.ATL 5N-20N 60W-30W	S. ATL 0-20S 30W-10E								
JUN 23	2.6	25.8	1.2	27.9	0.9	28.6	0.6	29.5	1.3	28.0	0.3	25.2	0.6	28.5
MAY 23	2.0	26.6	0.9	28.1	0.5	28.4	0.3	29.1	0.8	27.2	0.6	26.8	0.6	29.0
APR 23	2.5	28.2	0.4	28.0	0.2	28.0	0.3	28.8	0.5	26.4	0.3	27.2	0.5	29.0
MAR 23	1.5	28.1	0.4	27.5	-0.0	27.2	-0.1	28.1	0.4	26.0	0.2	27.3	0.2	28.4
FEB 23	0.7	26.8	-0.1	26.3	-0.4	26.3	-0.5	27.6	0.1	25.7	0.4	26.9	0.0	27.8
JAN 23	-0.2	24.3	-0.5	25.2	-0.7	25.9	-0.6	27.6	-0.1	25.9	0.7	26.3	0.0	27.6
DEC 22	-0.3	22.5	-0.8	24.5	-0.8	25.8	-0.7	27.7	-0.0	26.8	0.5	25.2	-0.1	27.5
NOV 22	-1.4	20.3	-0.9	24.3	-0.9	25.9	-0.9	27.8	-0.1	27.5	0.5	24.4	-0.1	27.5
OCT 22	-1.8	19.1	-0.9	24.2	-0.9	25.9	-1.1	27.6	0.3	28.4	0.4	23.7	-0.2	27.3
SEP 22	-1.1	19.5	-0.8	24.2	-0.9	25.8	-1.0	27.7	0.4	28.6	0.3	23.2	-0.1	27.1
AUG 22	-0.6	20.3	-0.5	24.7	-1.0	25.9	-0.9	27.8	0.4	28.1	0.2	23.3	-0.1	27.1
JUL 22	-1.2	20.7	-0.4	25.5	-0.6	26.7	-0.9	27.9	0.3	27.4	0.2	23.9	-0.1	27.3
JUN 22	-1.4	21.8	-0.6	26.0	-0.7	27.0	-0.6	28.3	0.4	27.1	0.5	25.4	0.0	27.9

TABLE T2. Mean and anomalous sea surface temperature (°C) for the most recent 12 months. Anomalies are departures from the 1991-2020 adjusted OI climatology (Smith and Reynolds 1998, *J. Climate*, **11**, 3320-3323).



Data updated through June 2023

FIGURE T1. Five-month running mean of the Southern Oscillation Index (SOI) (top), sea-level pressure anomaly (hPa) at Darwin and Tahiti (middle), and outgoing longwave radiation anomaly (OLR) averaged over the area 5N-5S, 160E-160W (bottom). Anomalies in the top and middle panels are departures from the 1991-2020 base period means and are normalized by the mean annual standard deviation. Anomalies in the bottom panel are departures from the 1991-2020 base period means. Individual monthly values are indicated by “x”s in the top and bottom panels. The x-axis labels are centered on July.

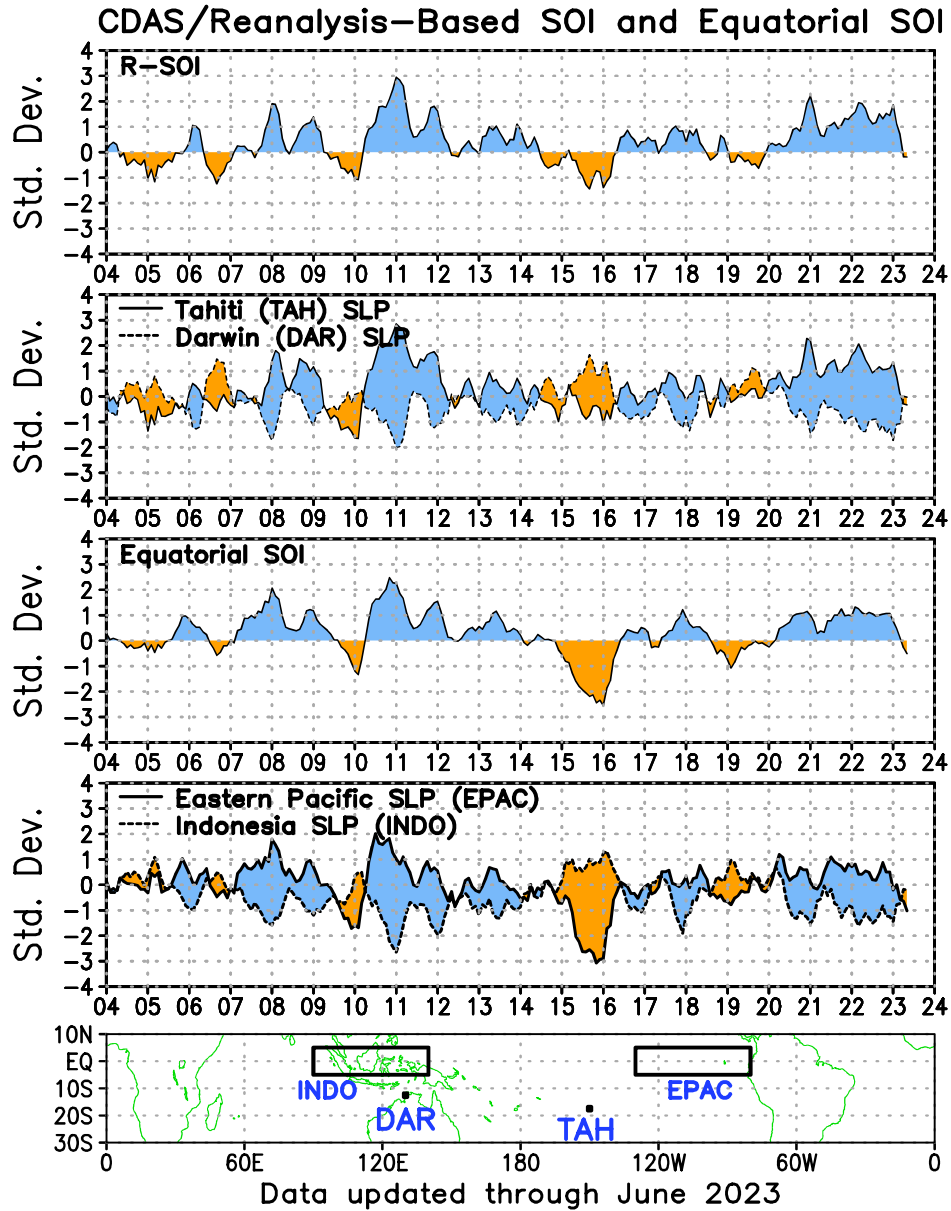


FIGURE T2. Three-month running mean of a CDAS/Reanalysis-derived (a) Southern Oscillation Index (RSOI), (b) standardized pressure anomalies near Tahiti (solid) and Darwin (dashed), (c) an equatorial SOI ([EPAC] - [INDO]), and (d) standardized equatorial pressure anomalies for (EPAC) (solid) and (INDO) (dashed). Anomalies are departures from the 1991-2020 base period means and are normalized by the mean annual standard deviation. The equatorial SOI is calculated as the normalized difference between the standardized anomalies averaged between 5°N–5°S, 80°W–130°W (EPAC) and 5°N–5°S, 90°E–140°E (INDO).

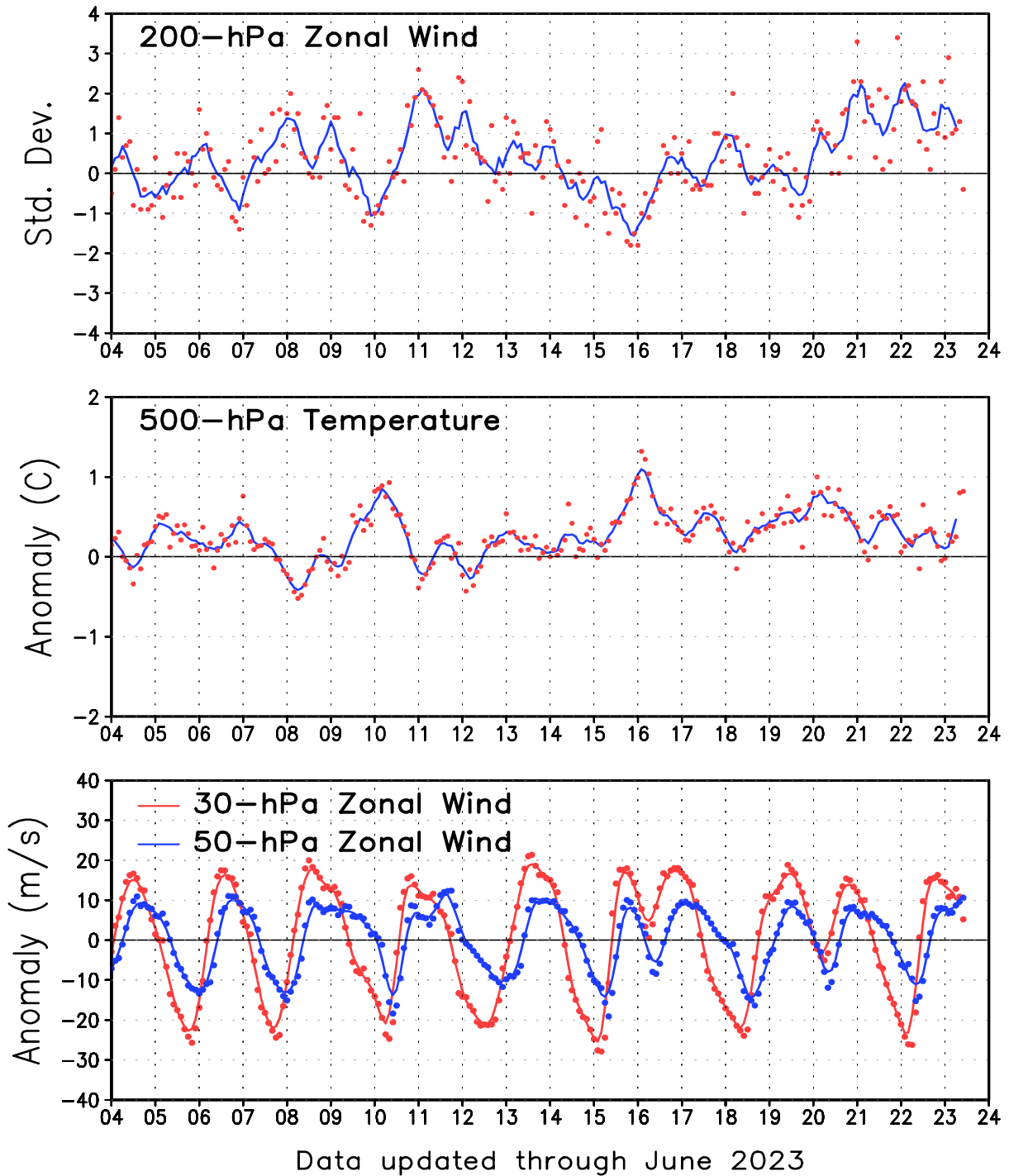


FIGURE T3. Five-month running mean (solid lines) and individual monthly mean (dots) of the 200-hPa zonal wind anomalies averaged over the area 5N-5S, 165W-110W (top), the 500-hPa virtual temperature anomalies averaged over the latitude band 20N-20S (middle), and the equatorial zonally-averaged zonal wind anomalies at 30-hPa (red) and 50-hPa (blue) (bottom). In the top panel, anomalies are normalized by the mean annual standard deviation. Anomalies are departures from the 1991-2020 base period means. The x-axis labels are centered on January.

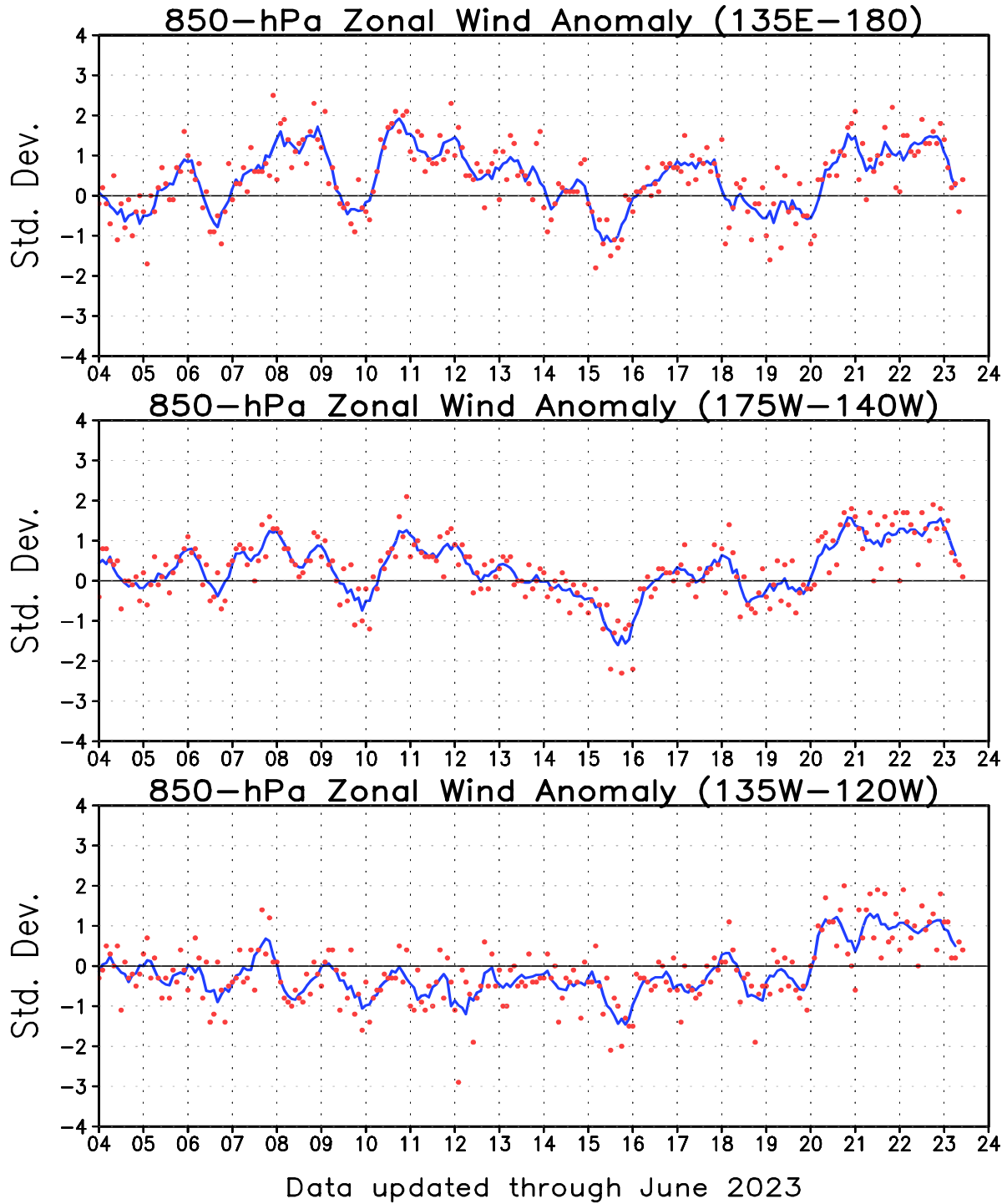


FIGURE T4. Five-month running mean (solid line) and individual monthly mean (dots) of the standardized 850-hPa zonal wind anomaly index in the latitude belt 5N-5S for 135E-180 (top), 175W-140W (middle) and 135W-120W (bottom). Anomalies are departures from the 1991-2020 base period means and are normalized by the mean annual standard deviation. The x-axis labels are centered on January. Positive (negative) values indicate easterly (westerly) anomalies.

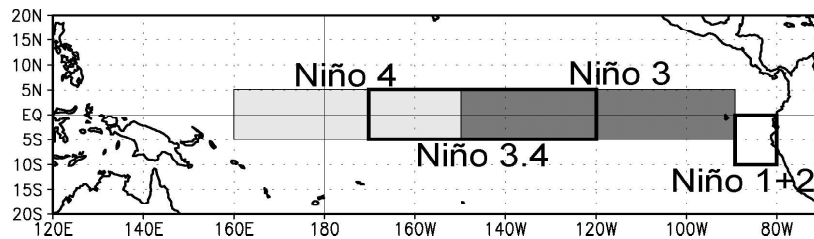
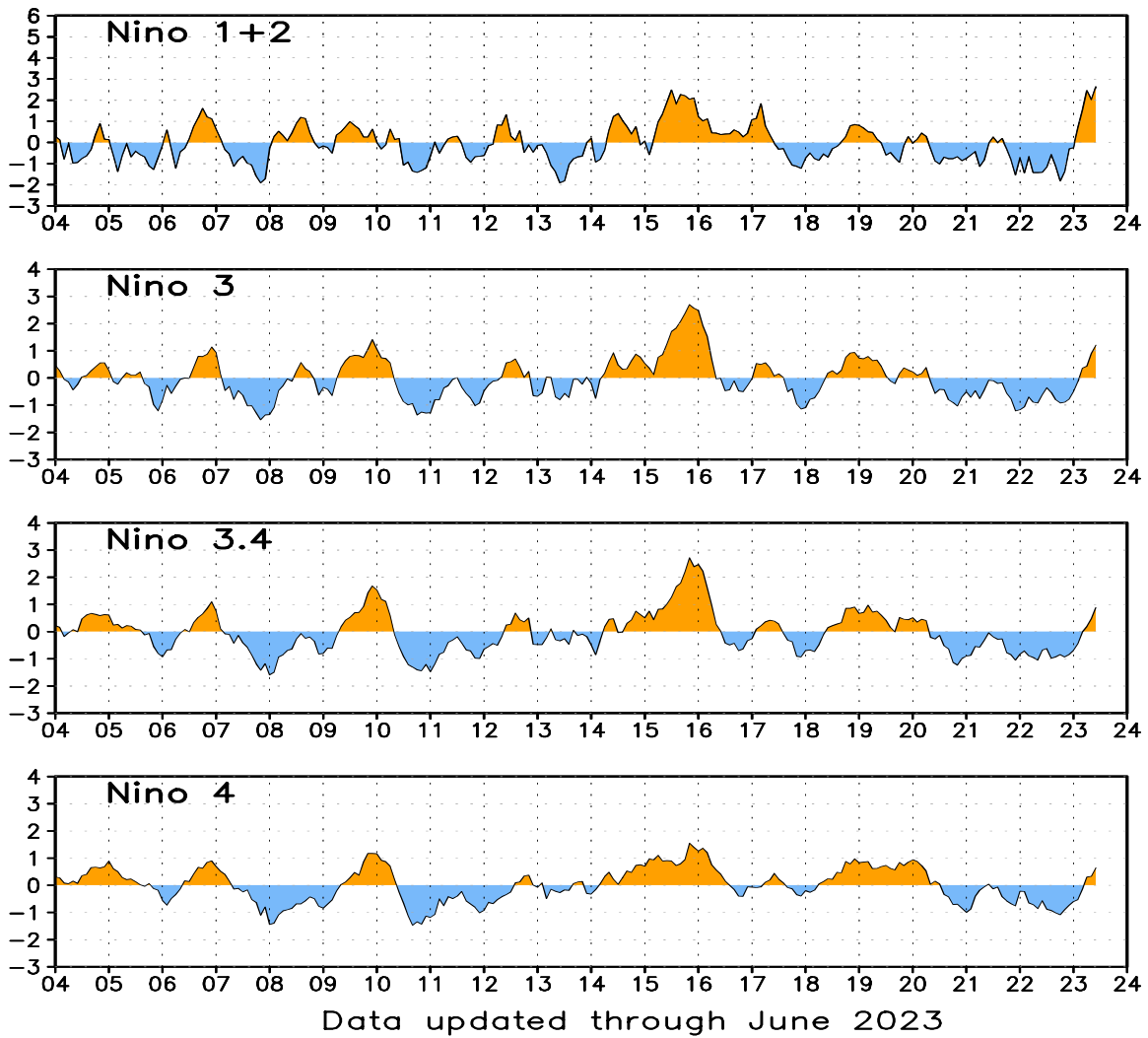


FIGURE T5. Niño region indices, calculated as the area-averaged sea surface temperature anomalies (C) for the specified region. The Niño 1+2 region (top) covers the extreme eastern equatorial Pacific between 0-10S, 90W-80W. The Niño-3 region (2nd from top) spans the eastern equatorial Pacific between 5N-5S, 150W-90W. The Niño 3.4 region (3rd from top) spans the east-central equatorial Pacific between 5N-5S, 170W-120W. The Niño 4 region (bottom) spans the date line and covers the area 5N-5S, 160E-150W. Anomalies are departures from the 1991-2020 base period monthly means (*Smith and Reynolds 1998, J. Climate, 11, 3320-3323*). Monthly values of each index are also displayed in [Table 2](#).

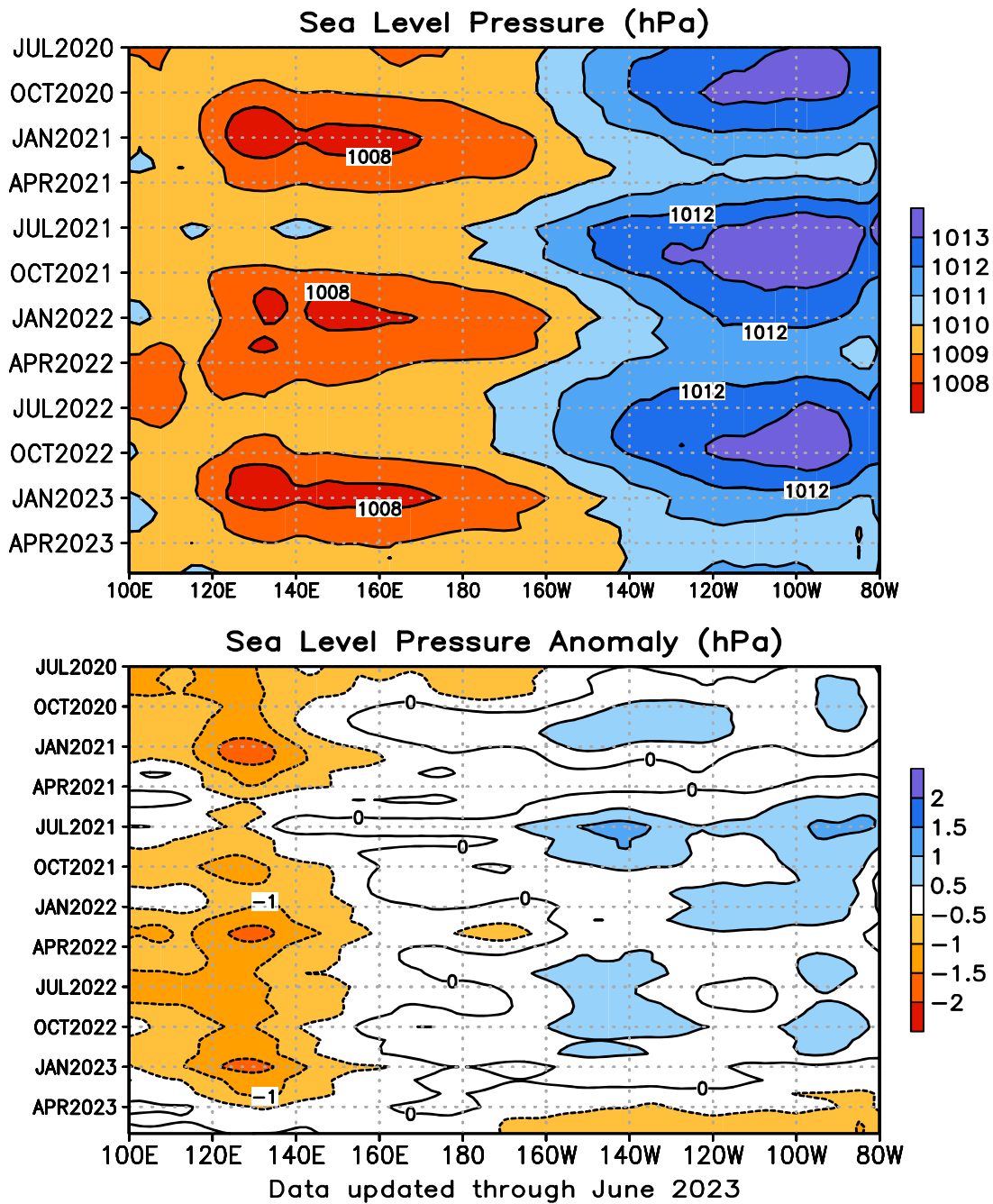


FIGURE T6. Time-longitude section of mean (top) and anomalous (bottom) sea level pressure (SLP) averaged between 5N-5S (CDAS/Reanalysis). Contour interval is 1.0 hPa (top) and 0.5 hPa (bottom). Dashed contours in bottom panel indicate negative anomalies. Anomalies are departures from the 1991-2020 base period monthly means. The data are smoothed temporally using a 3-month running average.

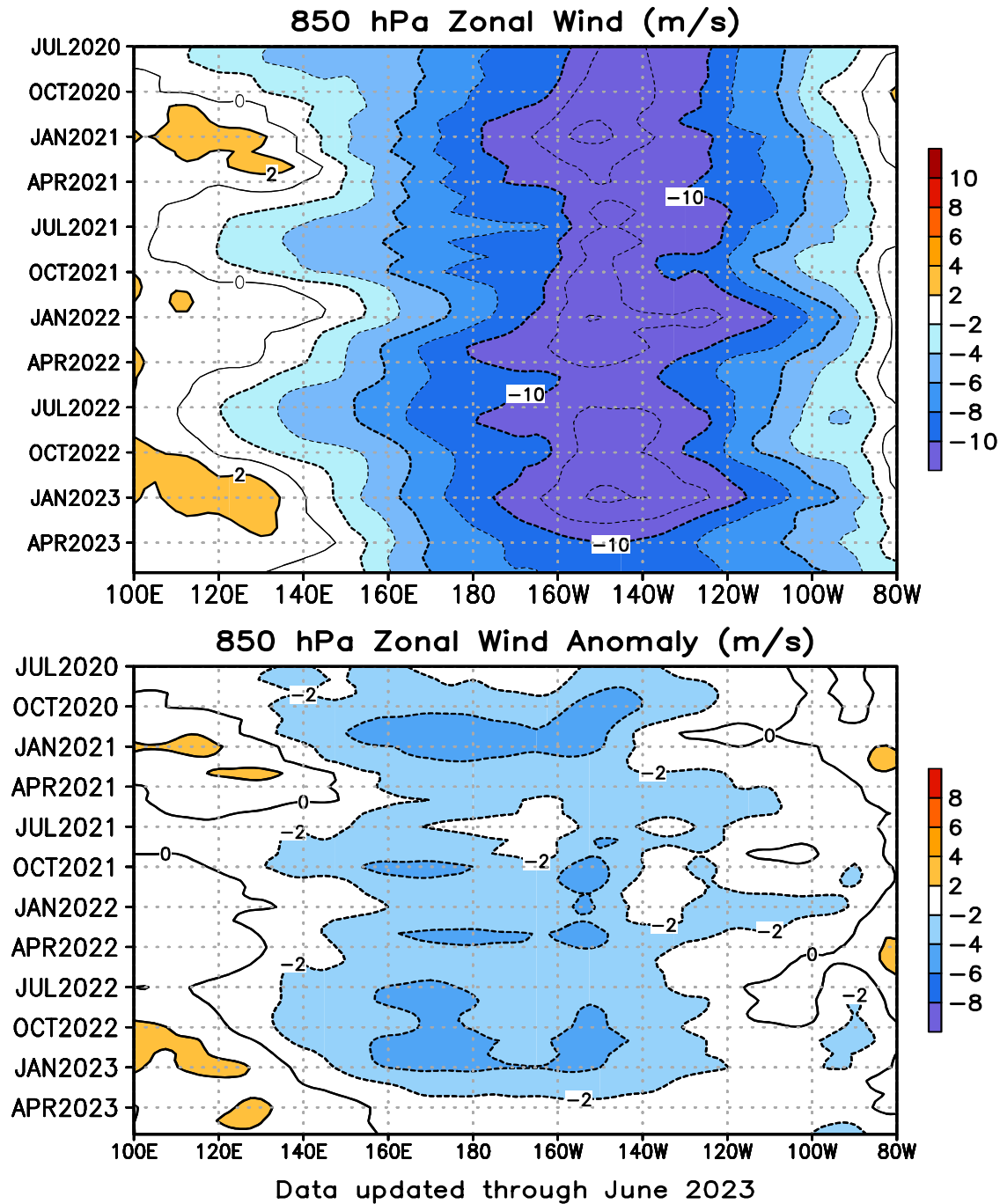


FIGURE T7. Time-longitude section of mean (top) and anomalous (bottom) 850-hPa zonal wind averaged between 5N-5S (CDAS/Reanalysis). Contour interval is 2 ms^{-1} . Blue shading and dashed contours indicate easterlies (top) and easterly anomalies (bottom). Anomalies are departures from the 1991-2020 base period monthly means. The data are smoothed temporally using a 3-month running average.

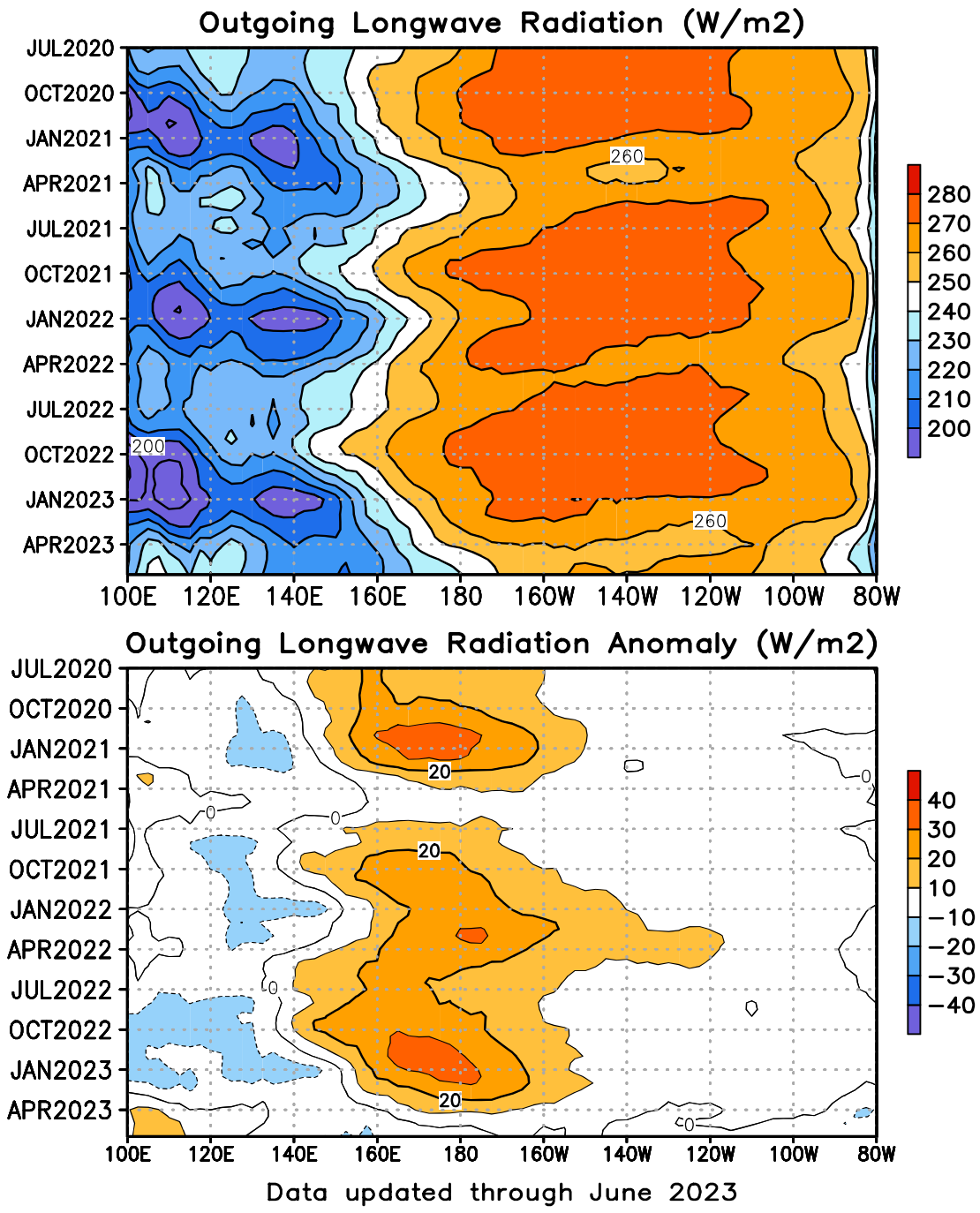


FIGURE T8. Time-longitude section of mean (top) and anomalous (bottom) outgoing longwave radiation (OLR) averaged between 5N-5S. Contour interval is 10 Wm⁻². Dashed contours in bottom panel indicate negative OLR anomalies. Anomalies are departures from the 1991-2020 base period monthly means. The data are smoothed temporally using a 3-month running average.

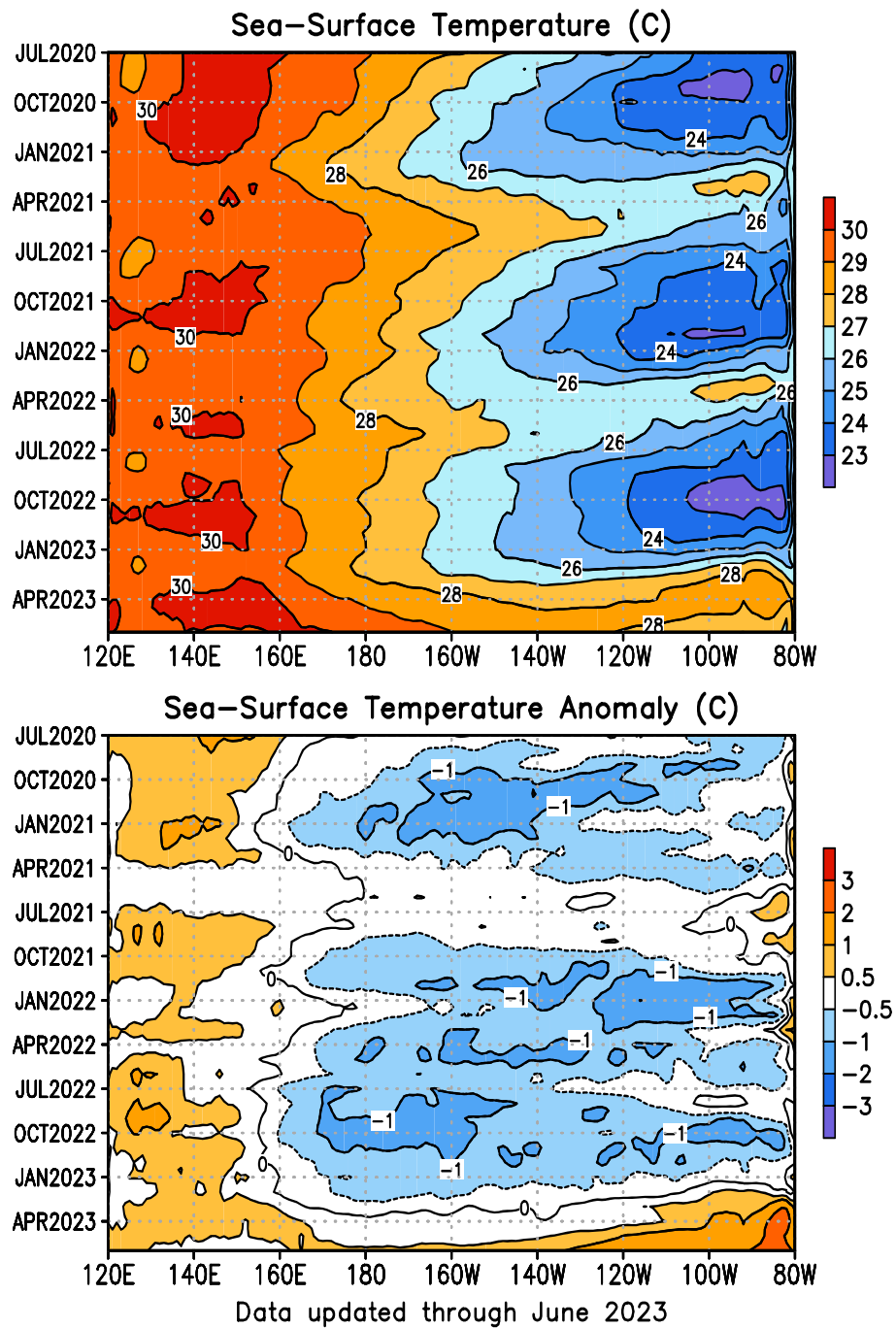


FIGURE T9. Time-longitude section of monthly mean (top) and anomalous (bottom) sea surface temperature (SST) averaged between 5N-5S. Contour interval is 1C (top) and 0.5C (bottom). Dashed contours in bottom panel indicate negative anomalies. Anomalies are departures from the 1991-2020 base period means (Smith and Reynolds 1998, *J. Climate*, **11**, 3320-3323).

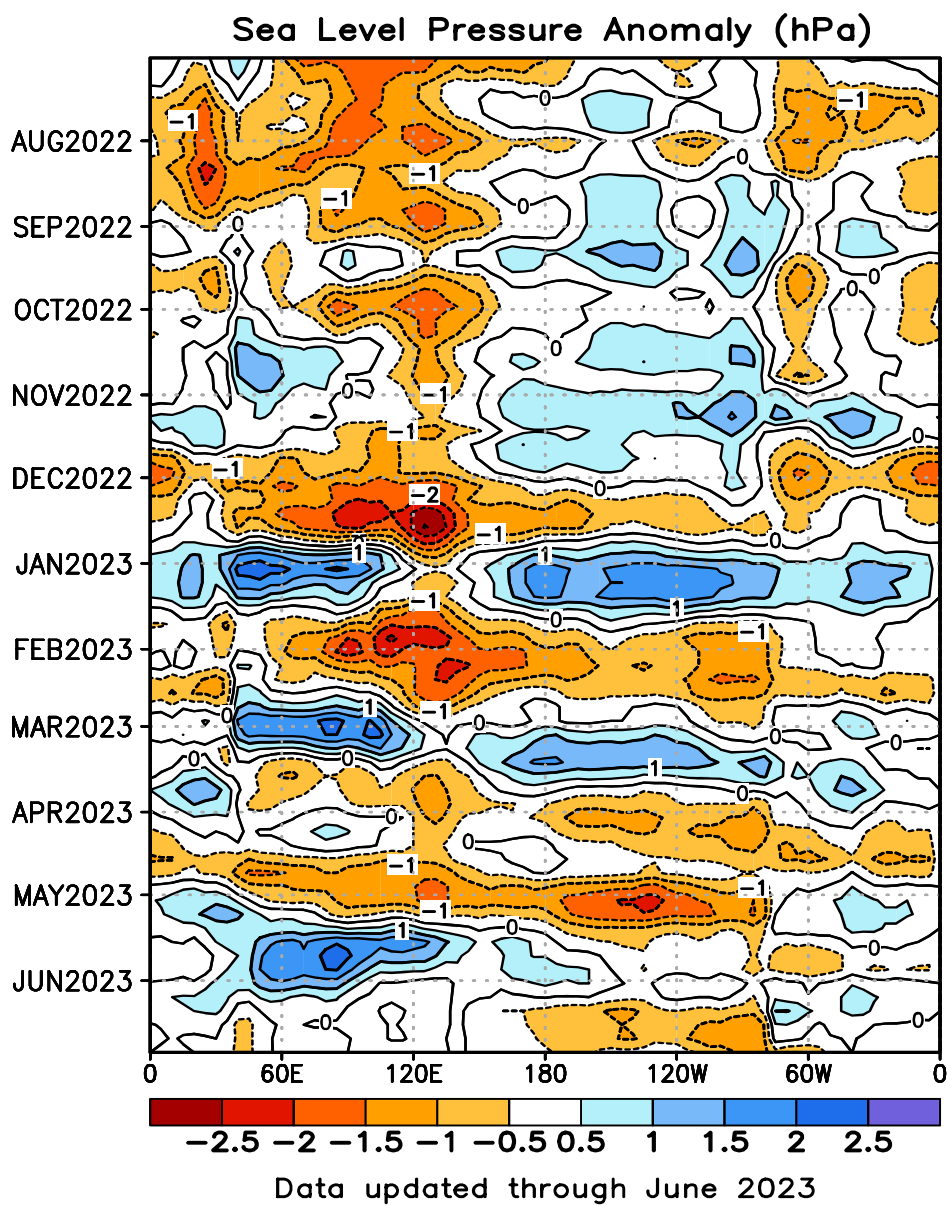


FIGURE T10. Time-longitude section of anomalous sea level pressure (hPa) averaged between 5N-5S (CDAS/Re-analysis). Contour interval is 1 hPa. Dashed contours indicate negative anomalies. Anomalies are departures from the 1991-2020 base period pentad means. The data are smoothed temporally using a 3-point running average.

Outgoing Longwave Radiation Anomaly (W/m^2)

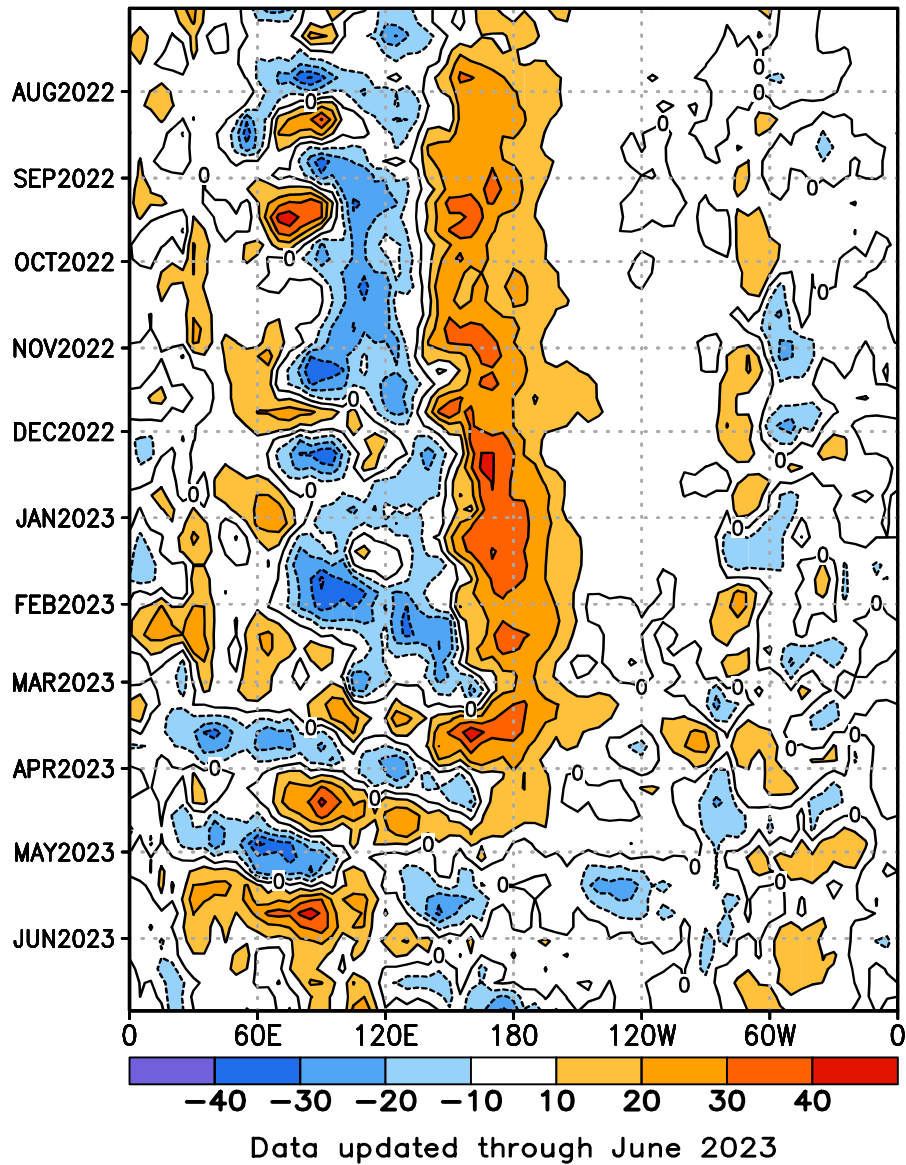


FIGURE T11. Time-longitude section of anomalous outgoing longwave radiation averaged between 5N-5S. Contour interval is $15 Wm^{-2}$. Dashed contours indicate negative anomalies. Anomalies are departures from the 1991-2020 base period pentad means. The data are smoothed temporally using a 3-point running average.

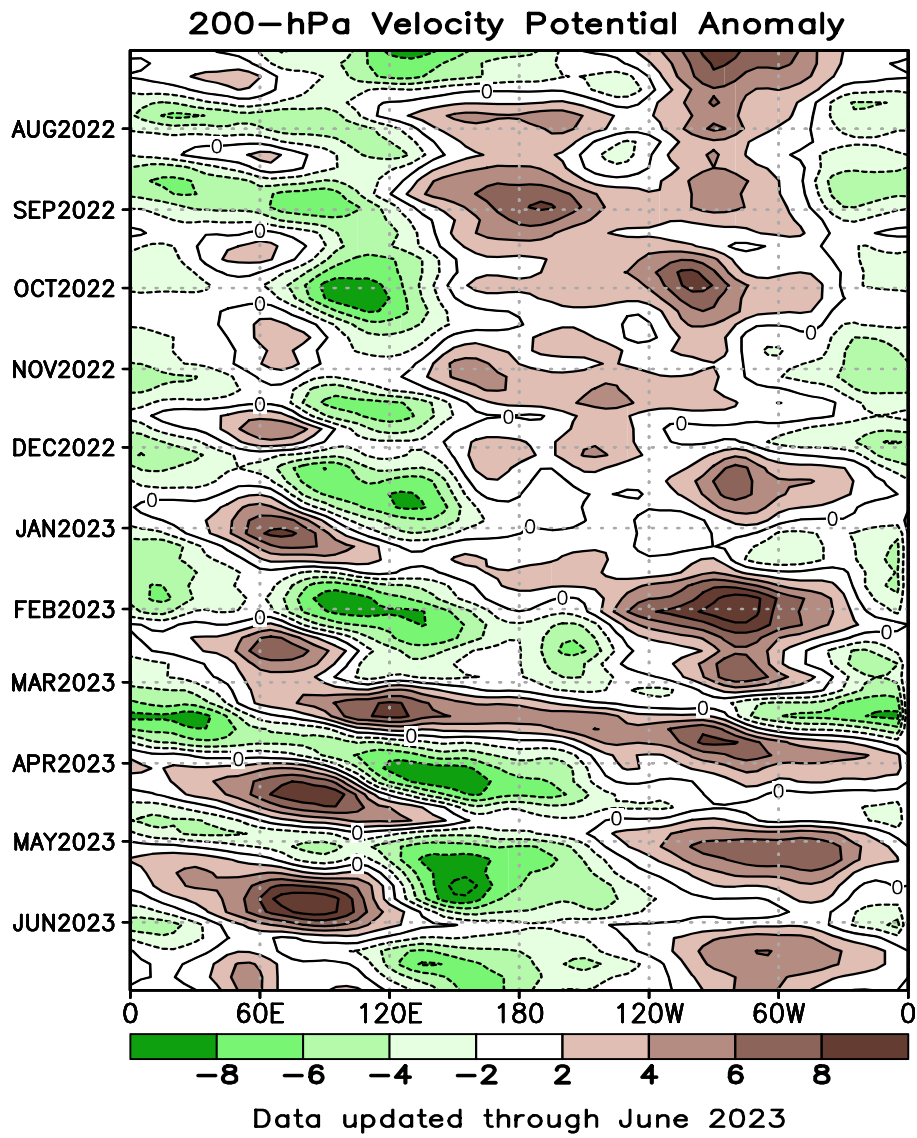


FIGURE T12. Time-longitude section of anomalous 200-hPa velocity potential averaged between 5N-5S (CDAS/Re-analysis). Contour interval is $3 \times 10^6 \text{ m}^2\text{s}^{-1}$. Dashed contours indicate negative anomalies. Anomalies are departures from the 1991-2020 base period pentad means. The data are smoothed temporally using a 3-point running average.

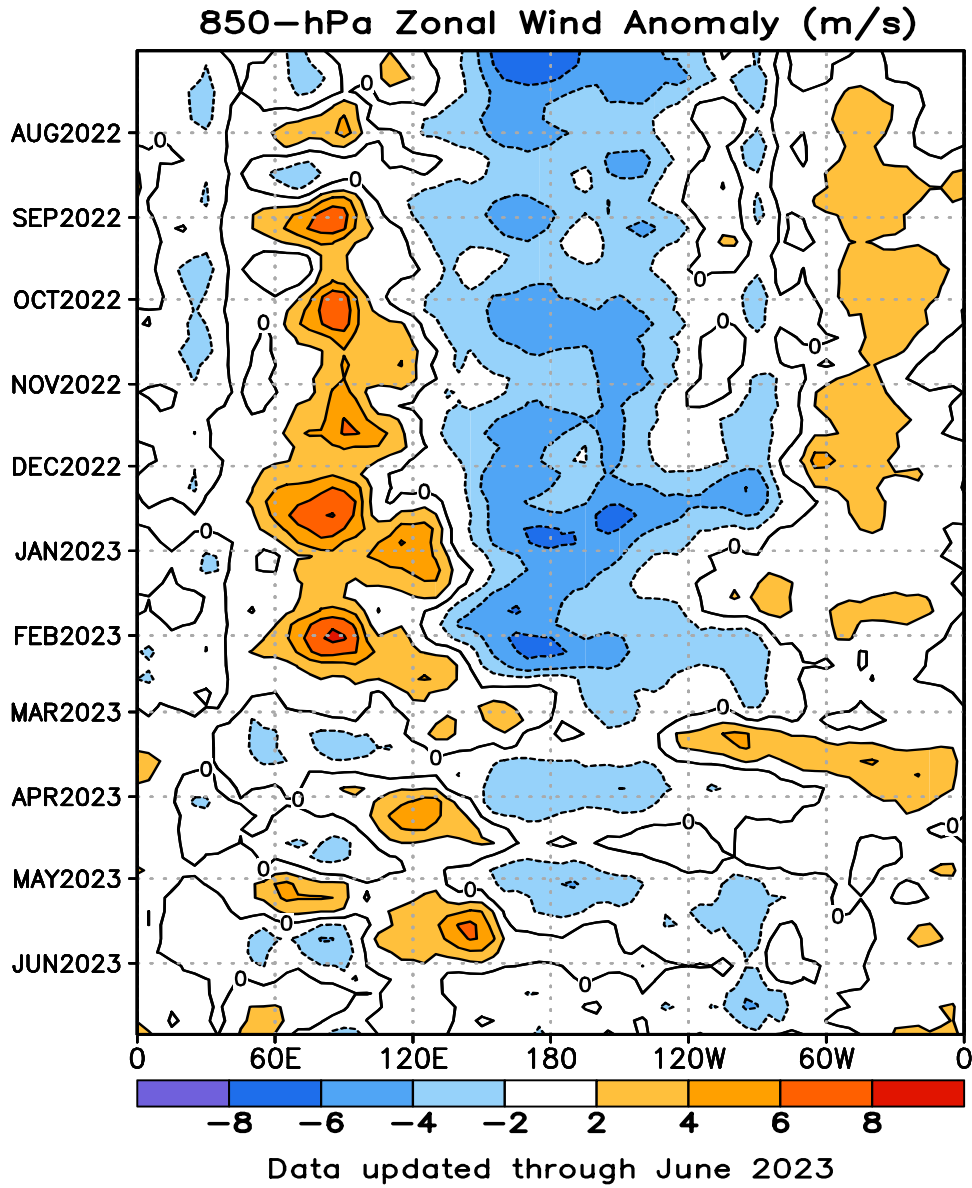


FIGURE T13. Time-longitude section of anomalous 850-hPa zonal wind averaged between 5N-5S (CDAS/Reanalysis). Contour interval is 2 ms^{-1} . Dashed contours indicate negative anomalies. Anomalies are departures from the 1991-2020 base period pentad means. The data are smoothed temporally by using a 3-point running average.

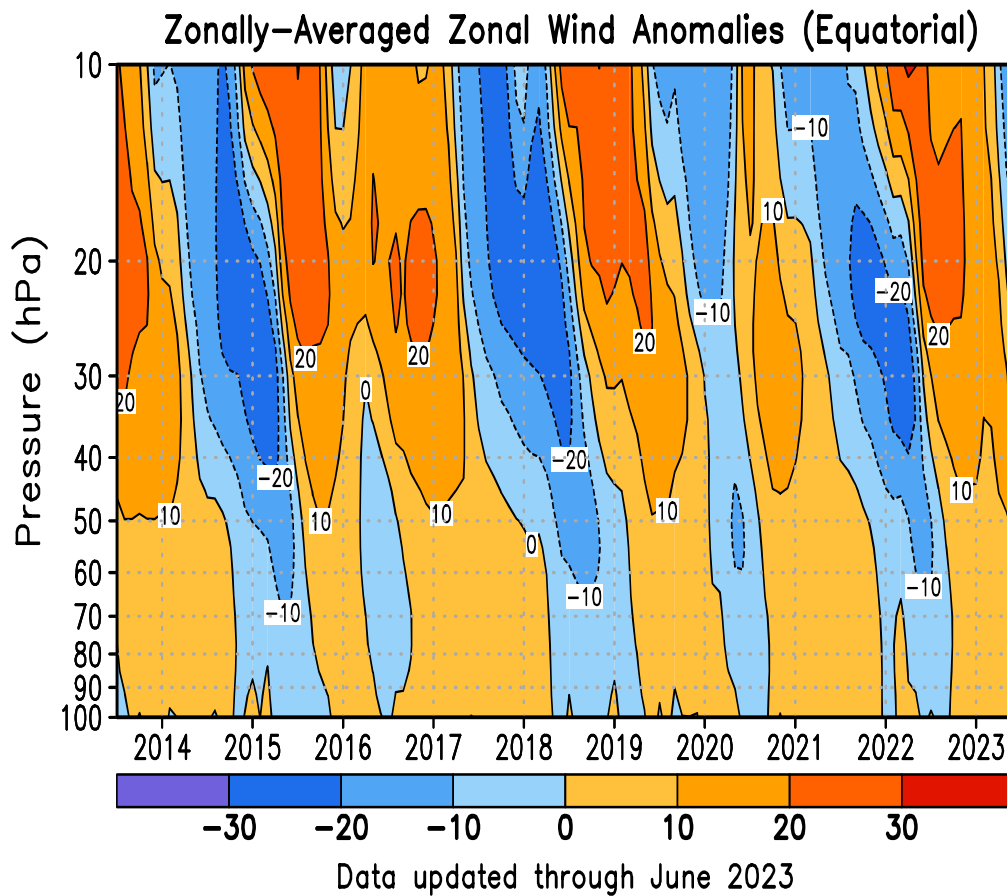


FIGURE T14. Equatorial time-height section of anomalous zonally-averaged zonal wind (m s^{-1}) (CDAS/Reanalysis). Contour interval is 10 m s^{-1} . Anomalies are departures from the 1991-2020 base period monthly means.

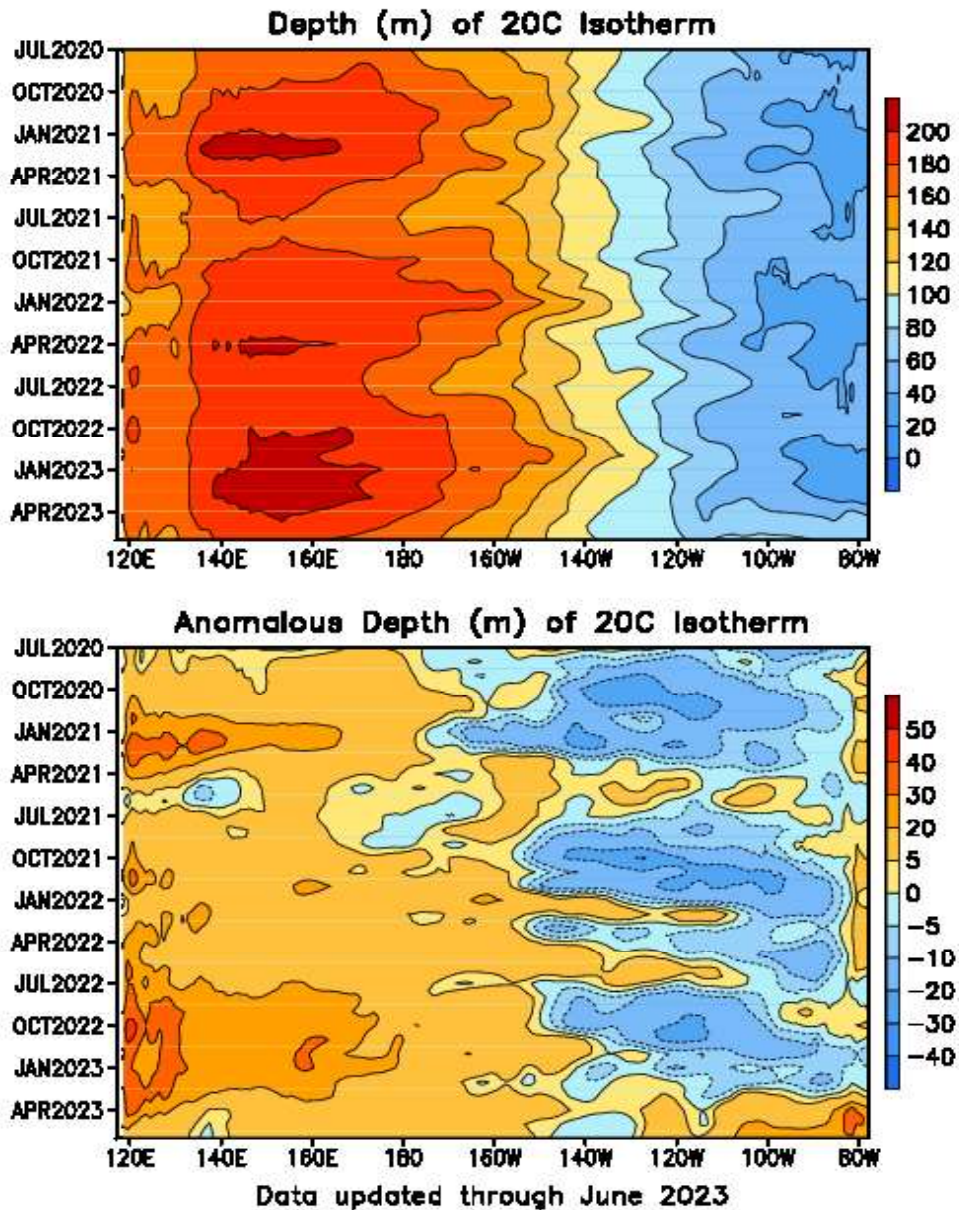


FIGURE T15. Mean (top) and anomalous (bottom) depth of the 20C isotherm averaged between 5N-5S in the Pacific Ocean. Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM (Behringer, D. W., and Y. Xue, 2004: Evaluation of the global ocean data assimilation system at NCEP: The Pacific Ocean. AMS 84th Annual Meeting, Seattle, Washington, 11-15). The contour interval is 10 m. Dashed contours in bottom panel indicate negative anomalies. Anomalies are departures from the 1991-2020 base period means.

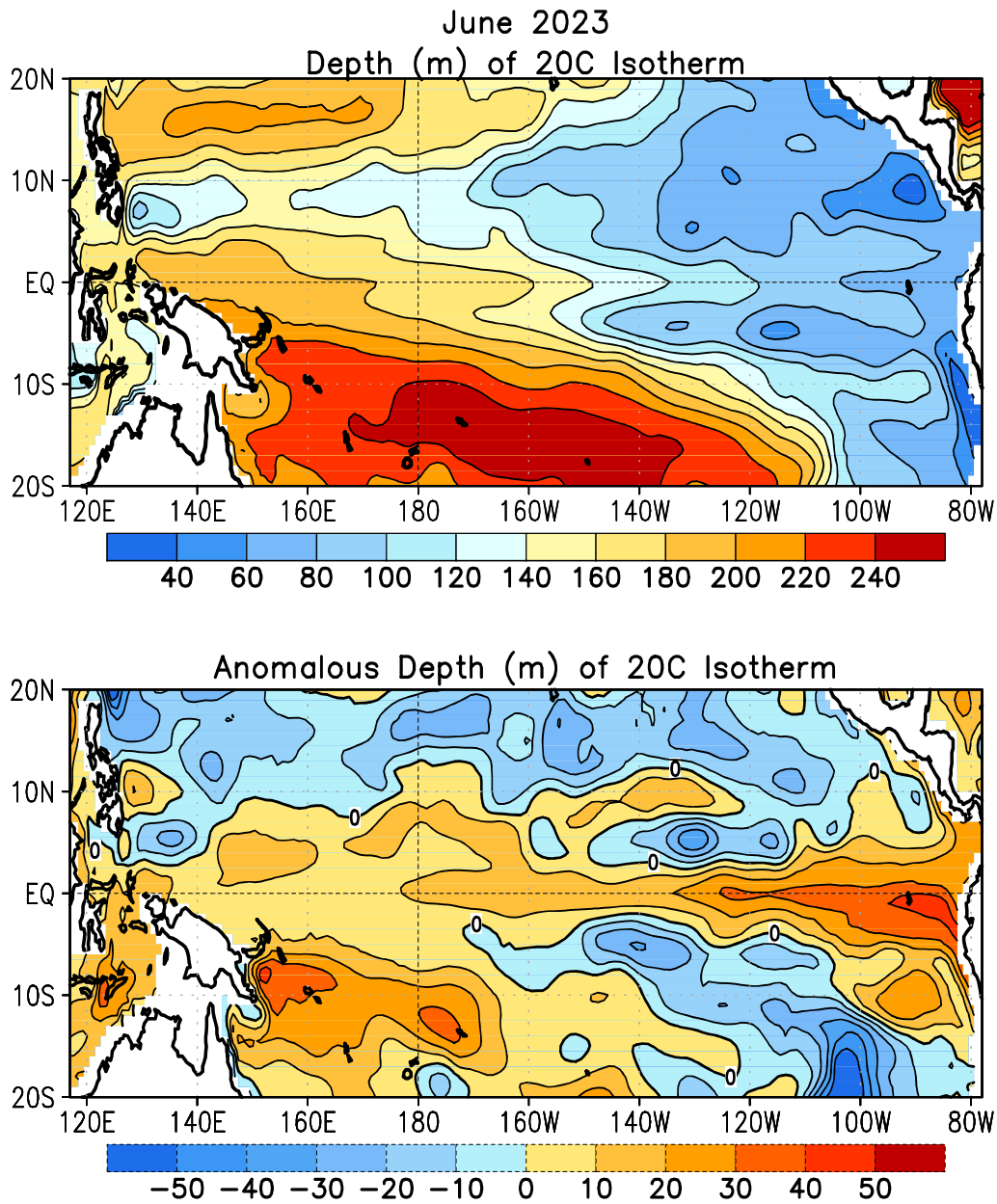


FIGURE T16. Mean (top) and anomalous (bottom) depth of the 20°C isotherm for JUN 2023. Contour interval is 40 m (top) and 10 m (bottom). Dashed contours in bottom panel indicate negative anomalies. Data are derived from the NCEP's global ocean data assimilation system version 2 which assimilates oceanic observations into an oceanic GCM (Xue, Y. and Behringer, D.W., 2006: Operational global ocean data assimilation system at NCEP, to be submitted to BAMS). Anomalies are departures from the 1991-2020 base period means.

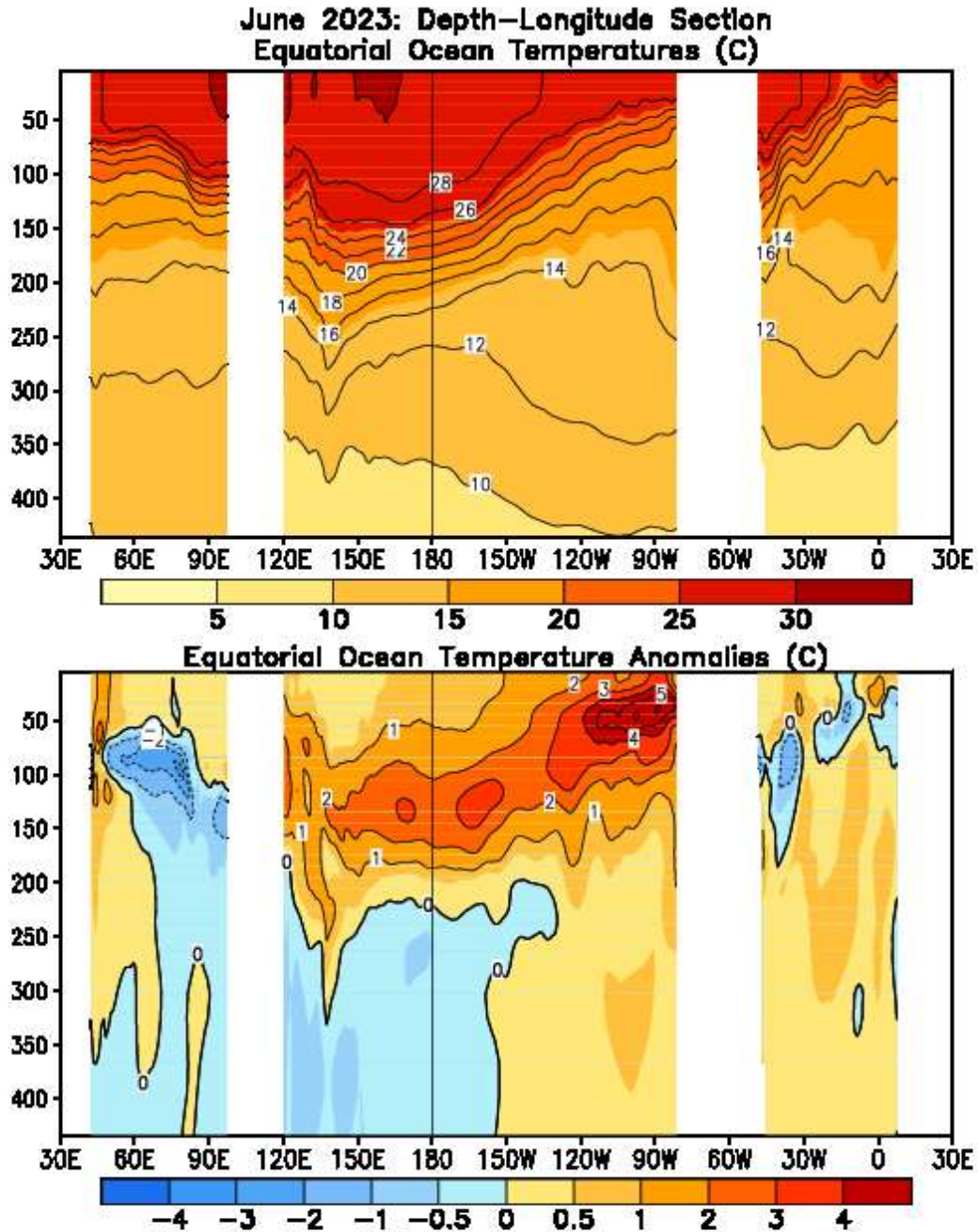


FIGURE T17. Equatorial depth–longitude section of ocean temperature (top) and ocean temperature anomalies (bottom) for JUN 2023. Contour interval is 1°C. Dashed contours in bottom panel indicate negative anomalies. Data are derived from the NCEP’s global ocean data assimilation system version 2 which assimilates oceanic observations into an oceanic GCM (Xue, Y. and Behringer, D.W., 2006: Operational global ocean data assimilation system at NCEP, to be submitted to BAMS). Anomalies are departures from the 1991-2020 base period means.

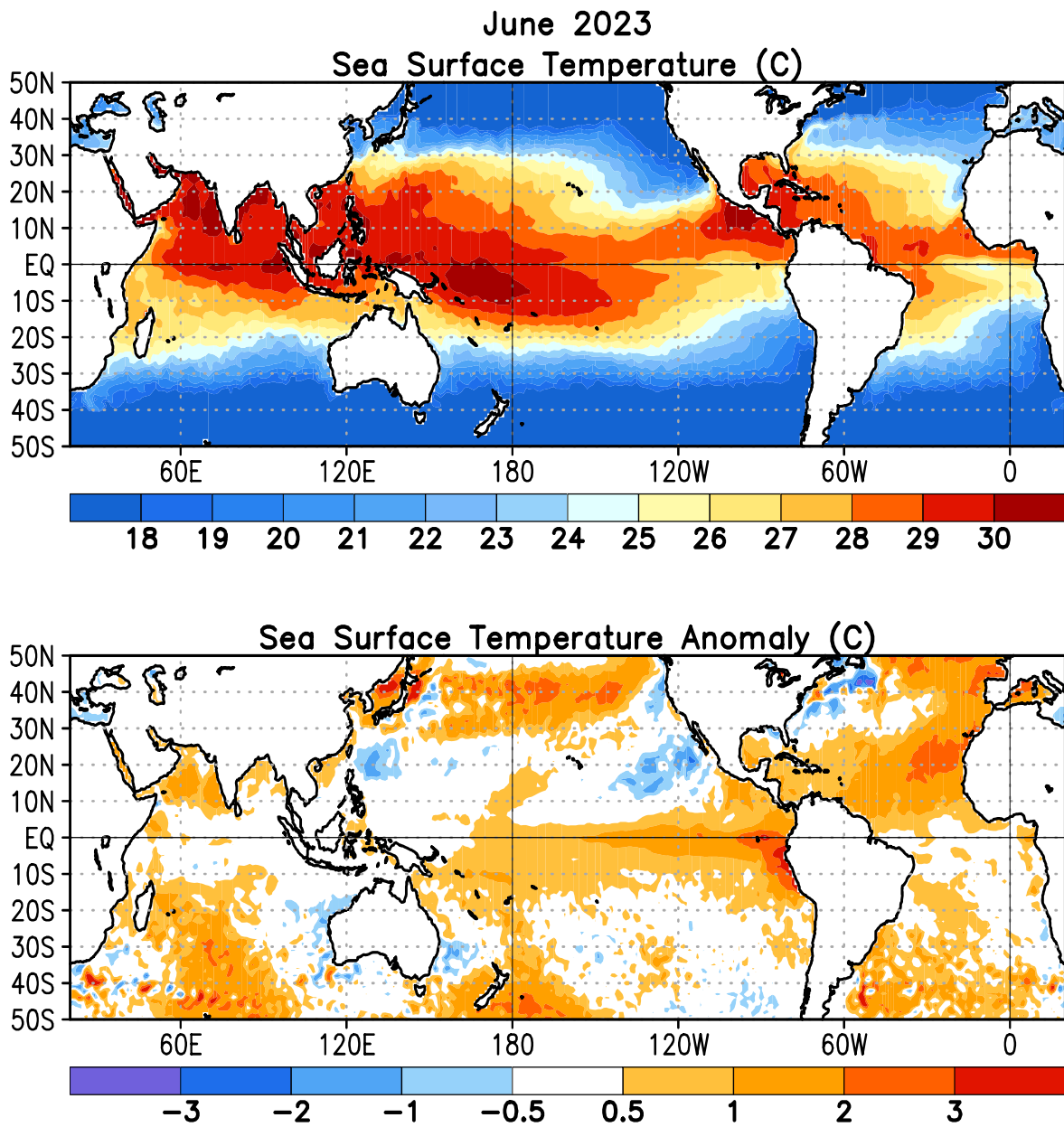


FIGURE T18. Mean (top) and anomalous (bottom) sea surface temperature (SST). Anomalies are departures from the 1991-2020 base period monthly means (Smith and Reynolds 1998, *J. Climate*, **11**, 3320-3323).

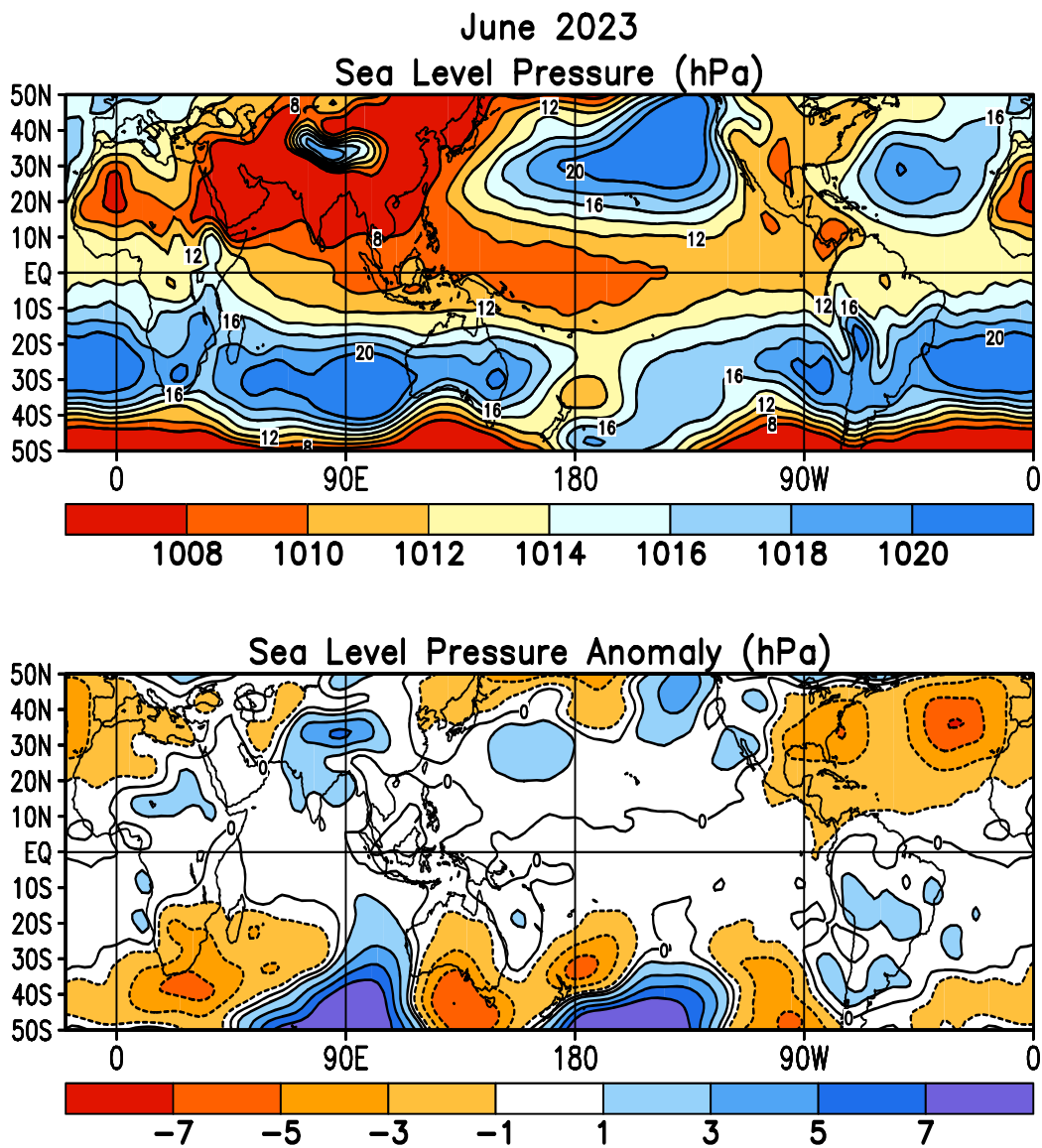


FIGURE T19. Mean (top) and anomalous (bottom) sea level pressure (SLP) (CDAS/Reanalysis). In top panel, 1000 hPa has been subtracted from contour labels, contour interval is 2 hPa, and values below 1000 hPa are indicated by dashed contours. In bottom panel, anomaly contour interval is 1 hPa and negative anomalies are indicated by dashed contours. Anomalies are departures from the 1991-2020 base period monthly means.

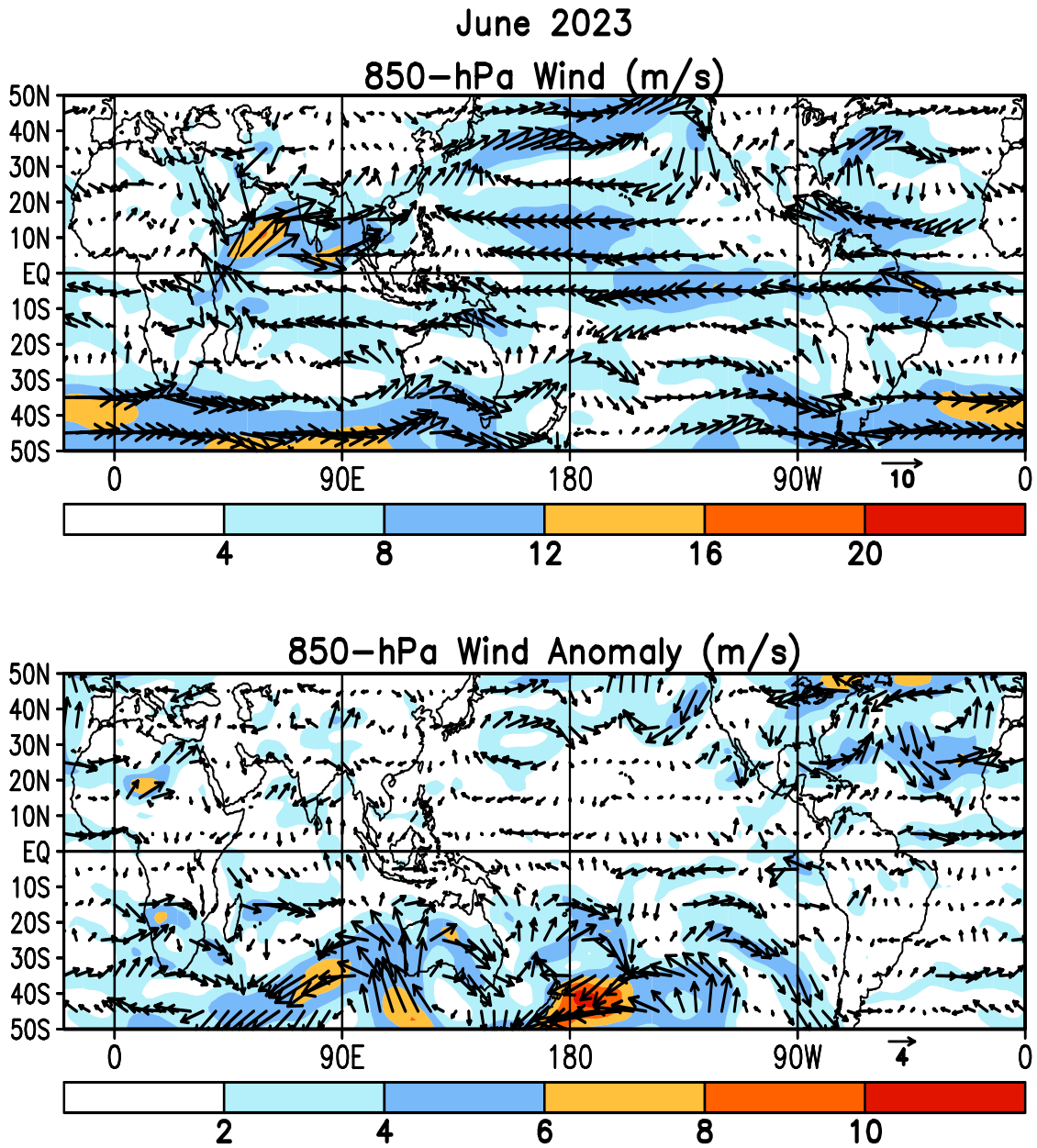


FIGURE T20. Mean (top) and anomalous (bottom) 850-hPa vector wind (CDAS/Reanalysis) for JUN 2023. Contour interval for isotachs is 4 ms^{-1} (top) and 2 ms^{-1} (bottom). Anomalies are departures from the 1991-2020 base period monthly means.

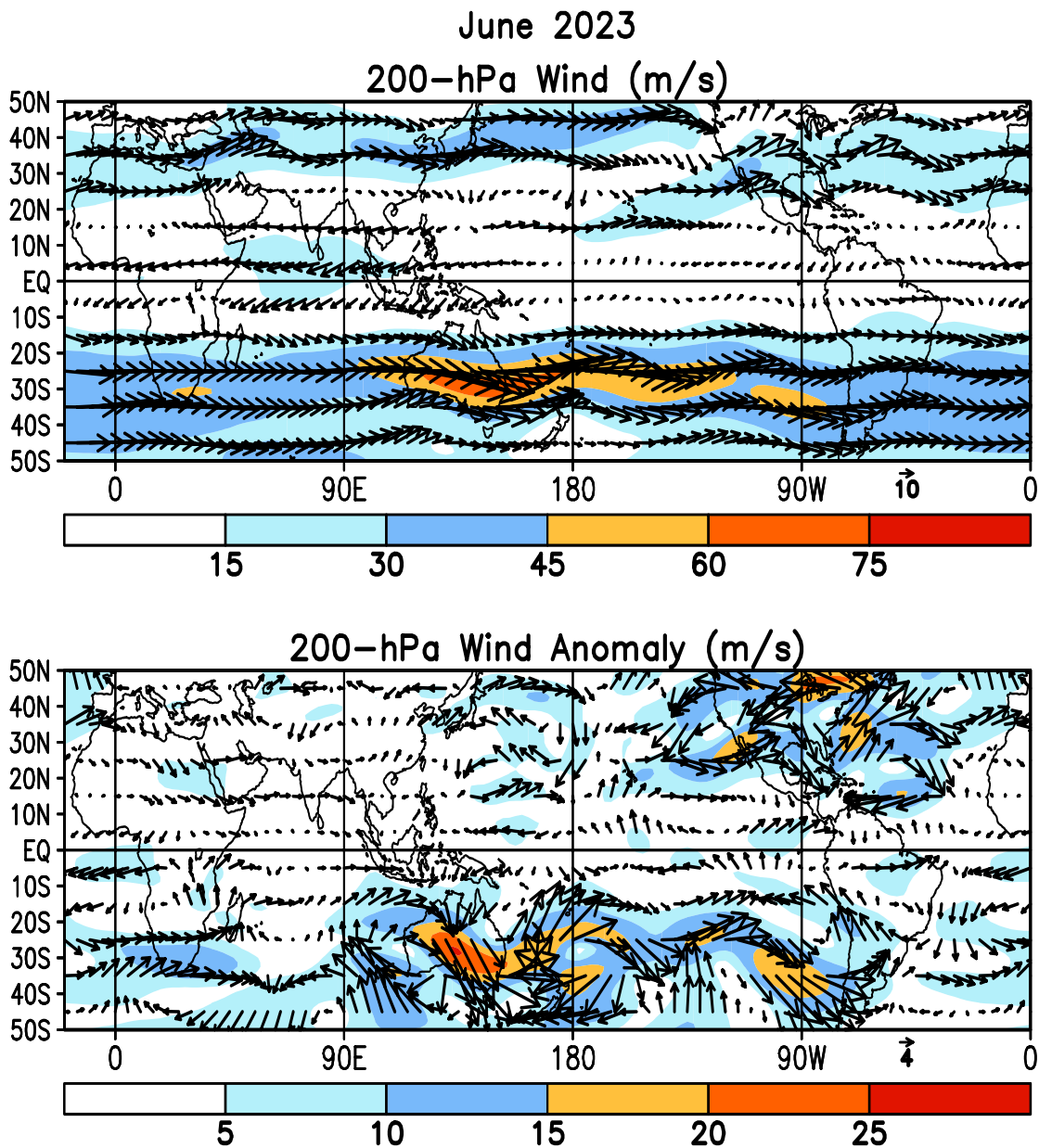


FIGURE T21. Mean (top) and anomalous (bottom) 200-hPa vector wind (CDAS/Reanalysis) for JUN 2023. Contour interval for isotachs is 15 ms^{-1} (top) and 5 ms^{-1} (bottom). Anomalies are departures from 1991-2020 base period monthly means.

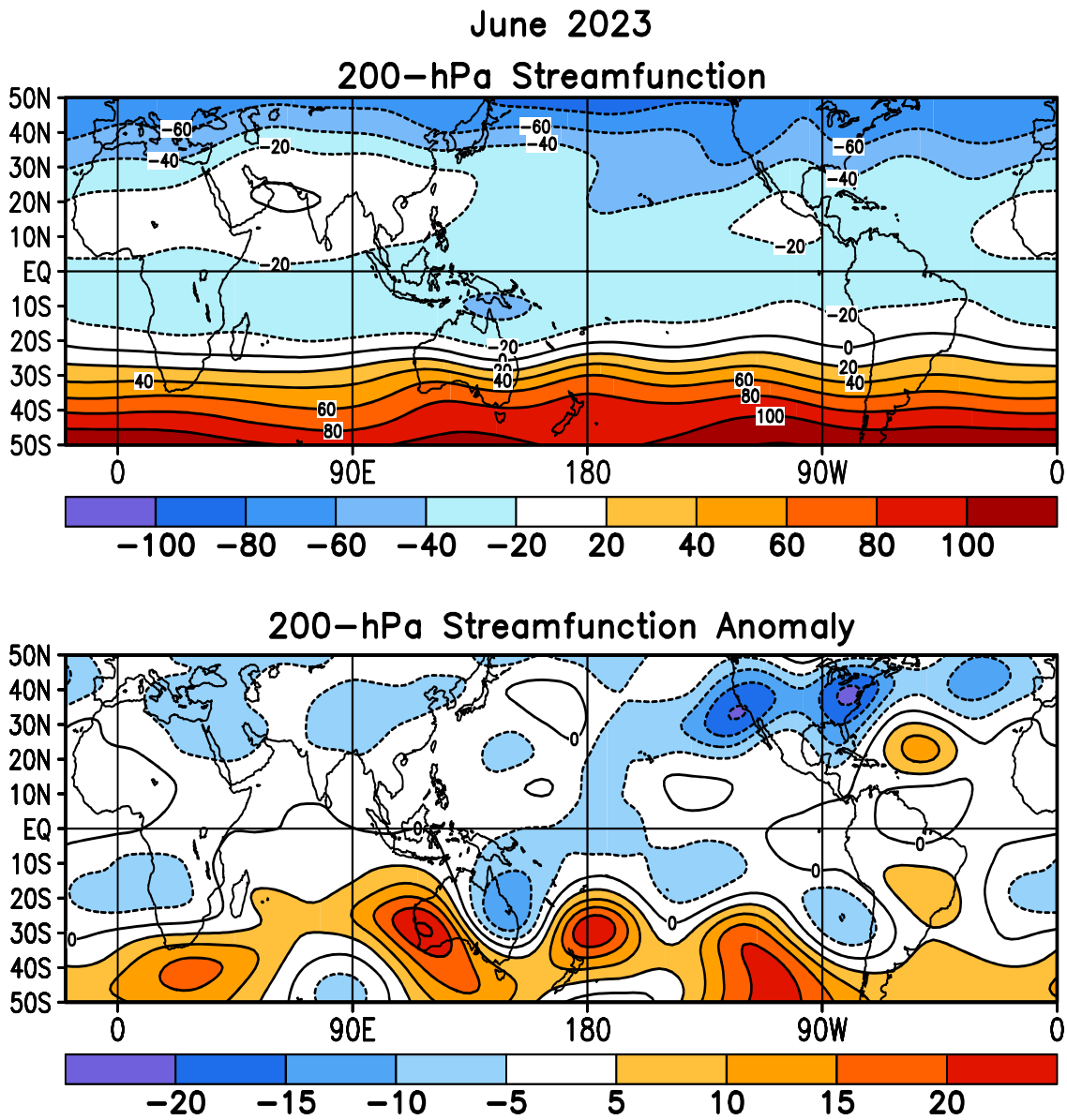


FIGURE T22. Mean (top) and anomalous (bottom) 200-hPa streamfunction (CDAS/Reanalysis). Contour interval is $20 \times 10^6 \text{ m}^2\text{s}^{-1}$ (top) and $5 \times 10^6 \text{ m}^2\text{s}^{-1}$ (bottom). Negative (positive) values are indicated by dashed (solid) lines. The non-divergent component of the flow is directed along the contours with speed proportional to the gradient. Thus, high (low) stream function corresponds to high (low) geopotential height in the Northern Hemisphere and to low (high) geopotential height in the Southern Hemisphere. Anomalies are departures from the 1991-2020 base period monthly means.

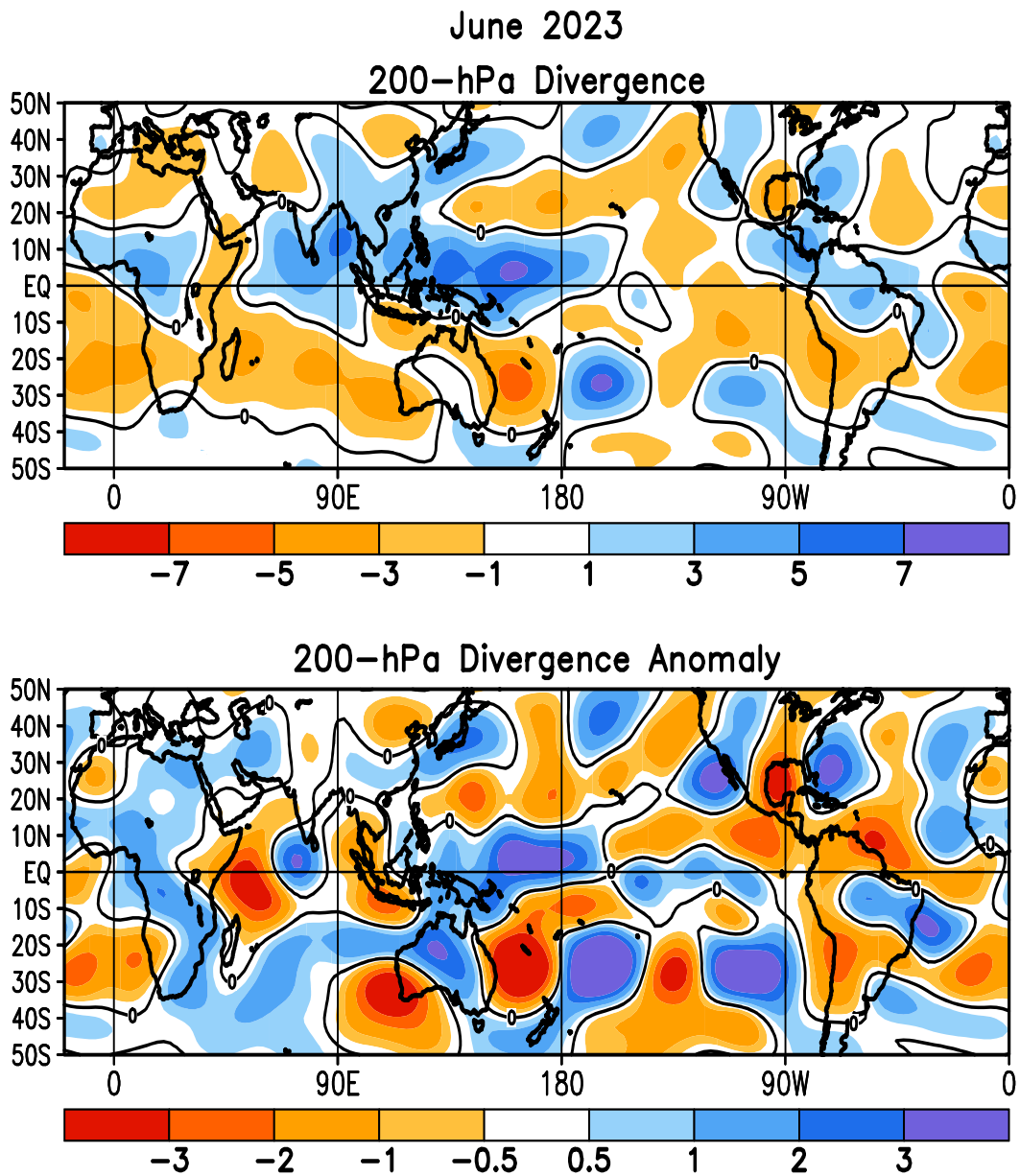


FIGURE T23. Mean (top) and anomalous (bottom) 200-hPa divergence (CDAS/Reanalysis). Divergence and anomalous divergence are shaded blue. Convergence and anomalous convergence are shaded orange. Anomalies are departures from the 1991-2020 base period monthly means.

June 2023

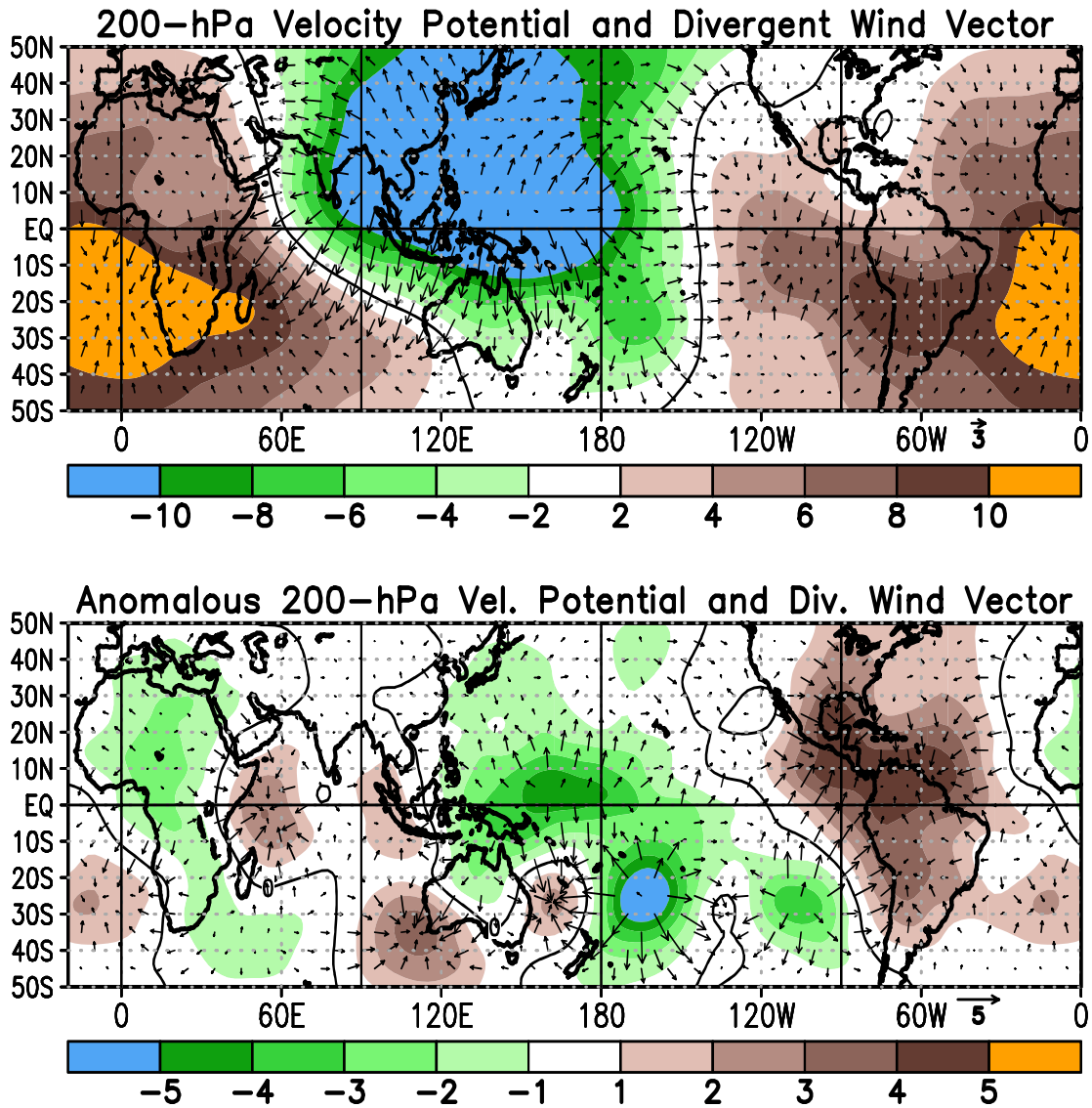


FIGURE T24. Mean (top) and anomalous (bottom) 200-hPa velocity potential ($10^6\text{m}^2\text{s}$) and divergent wind (CDAS/ Reanalysis). Anomalies are departures from the 1991-2020 base period monthly means.

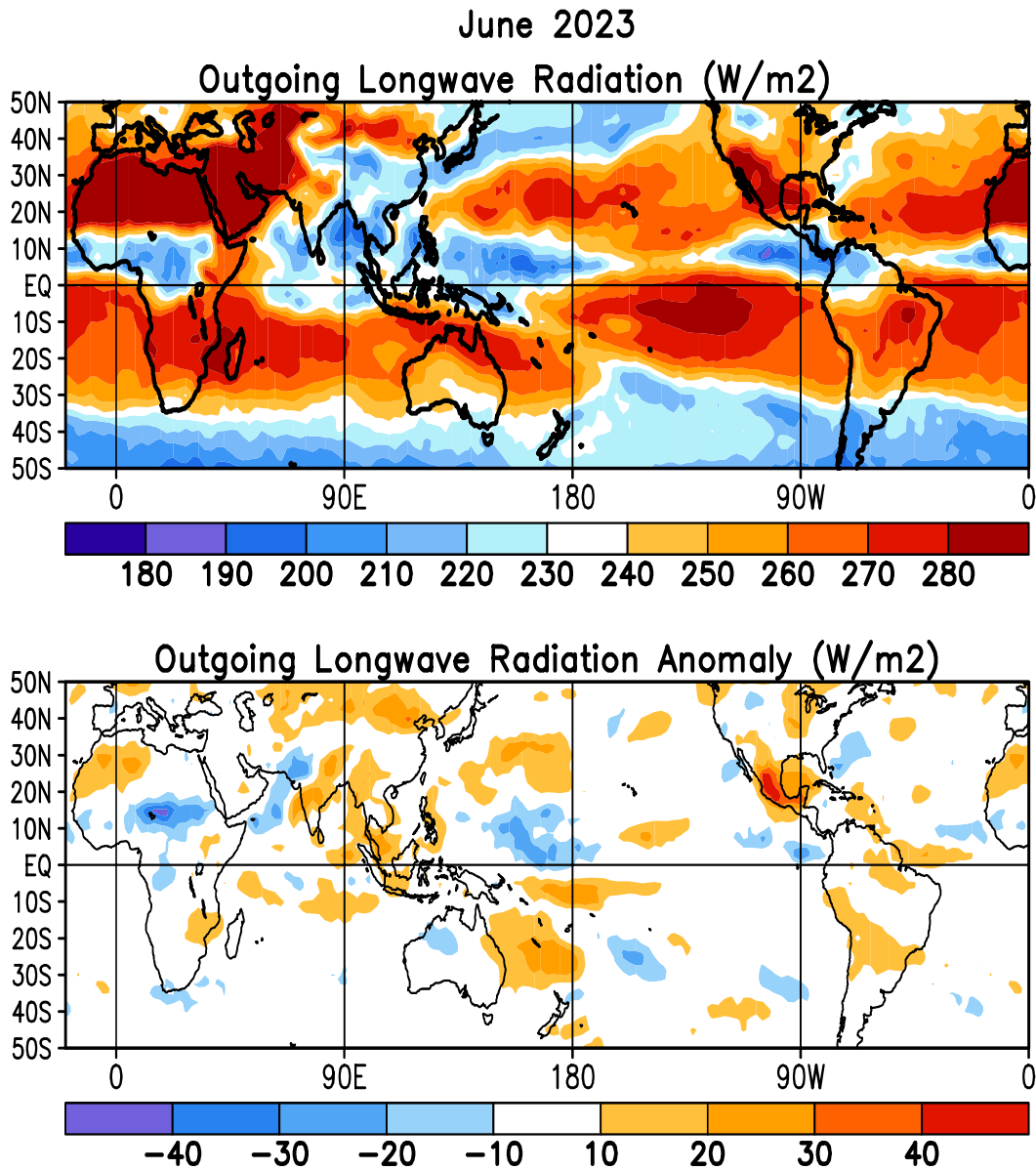
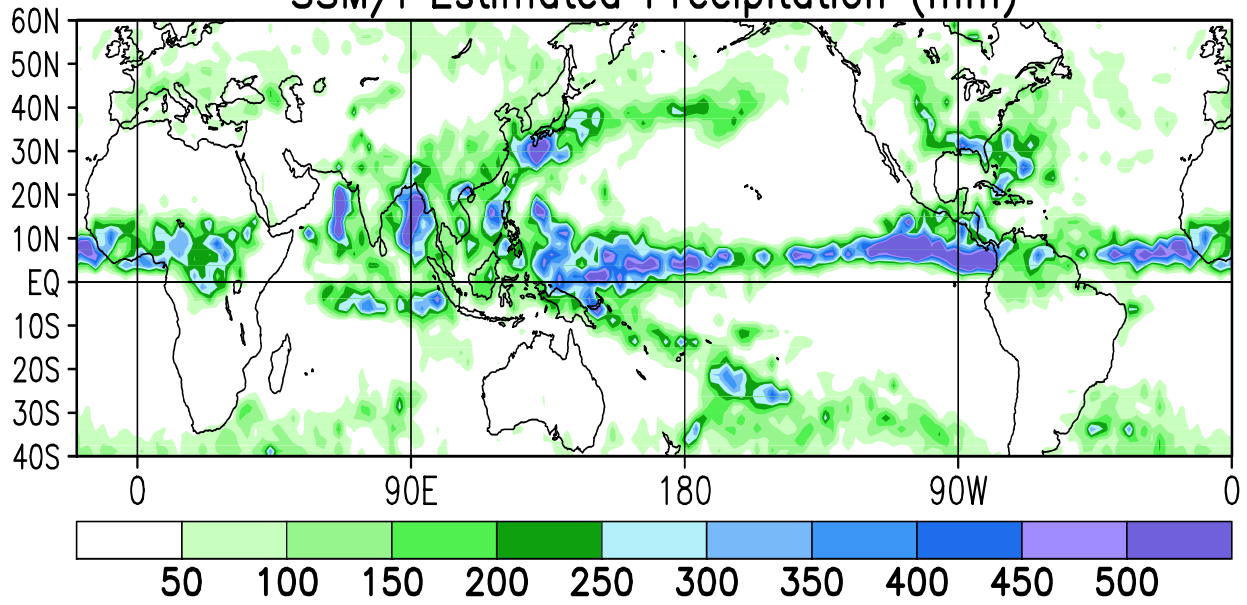


FIGURE T25. Mean (top) and anomalous (bottom) outgoing longwave radiation for JUN 2023 (NOAA 18 AVHRR IR window channel measurements by NESDIS/ORA). OLR contour interval is 20 Wm⁻² with values greater than 280 Wm⁻² indicated by dashed contours. Anomaly contour interval is 15 Wm⁻² with positive values indicated by dashed contours and light shading. Anomalies are departures from the 1991-2020 base period monthly means.

June 2023

SSM/I Estimated Precipitation (mm)



SSM/I Precipitation Anomalies (mm)

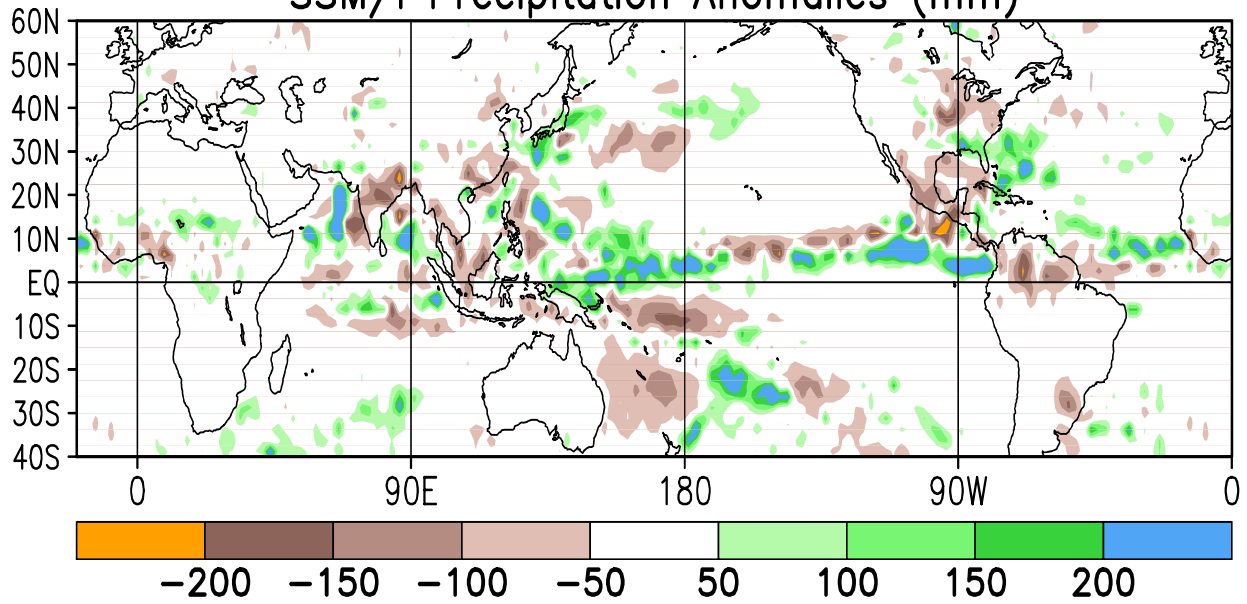
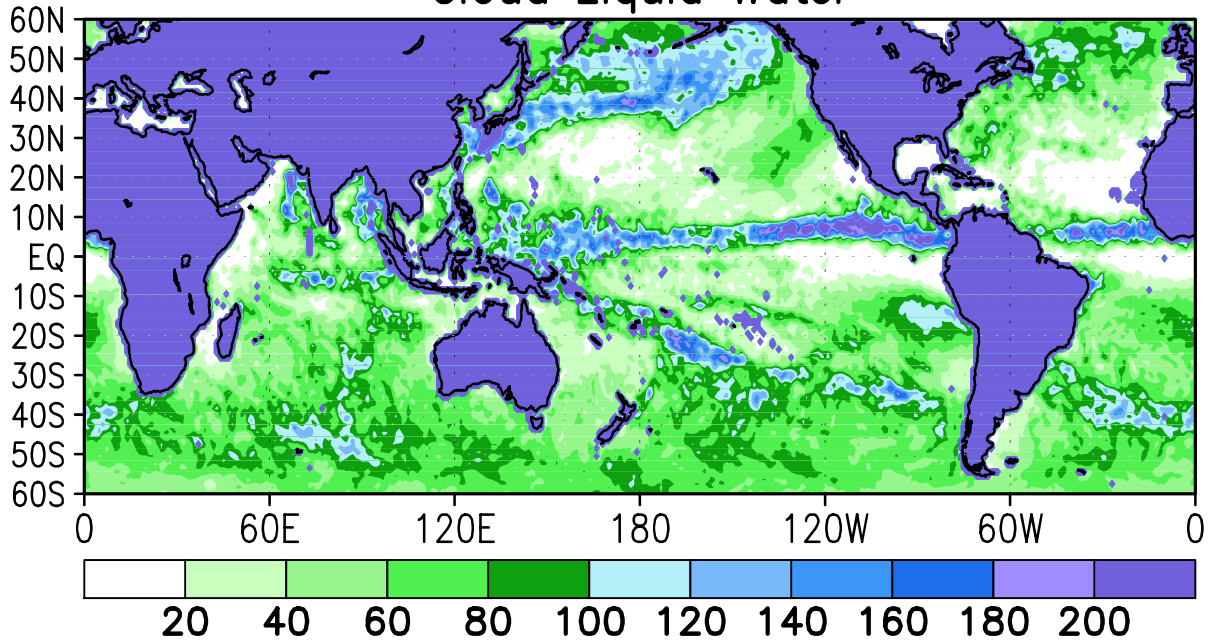


FIGURE T26. Estimated total (top) and anomalous (bottom) rainfall (mm) based on the Special Sensor Microwave/Imager (SSM/S) precipitation index (Ferraro 1997, *J. Geophys. Res.*, **102**, 16715-16735). Anomalies are computed from the SSM/I 1987-2010 base period monthly means. Anomalies have been smoothed for display purposes.

June 2023
Cloud Liquid Water



Cloud Liquid Water Anomaly

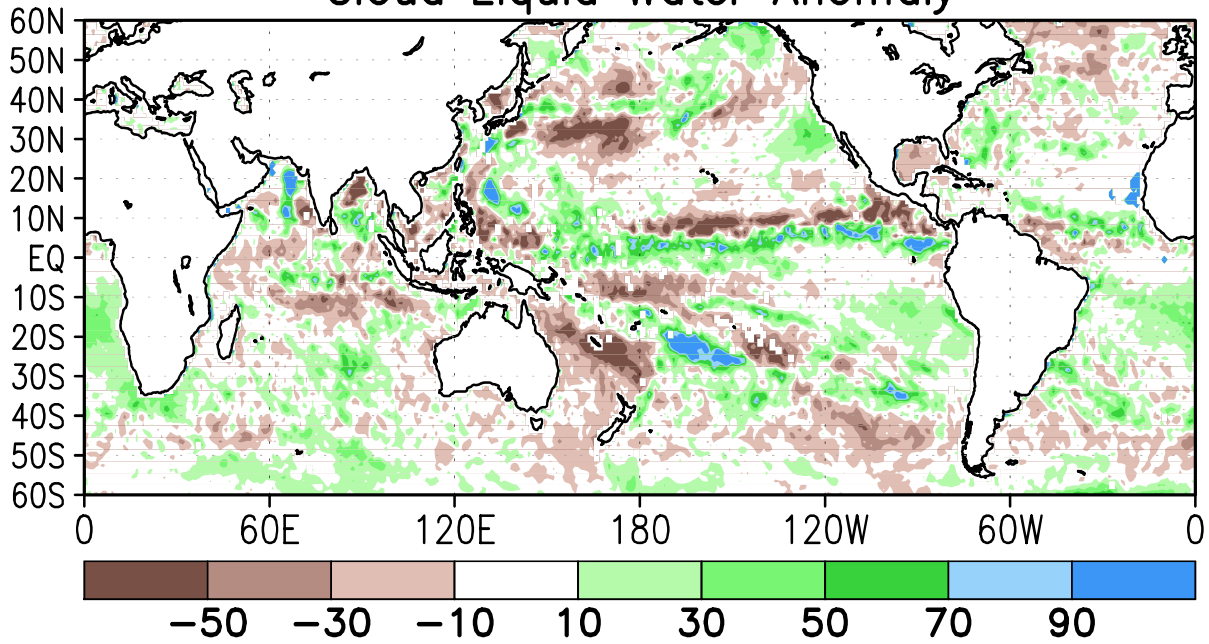


FIGURE T27. Mean (top) and anomalous (bottom) cloud liquid water (g m^{-2}) based on the Special Sensor Microwave/Imager (SSM/I) (Weng et al 1997: *J. Climate*, **10**, 1086-1098). Anomalies are calculated from the 1987-2010 base period means.

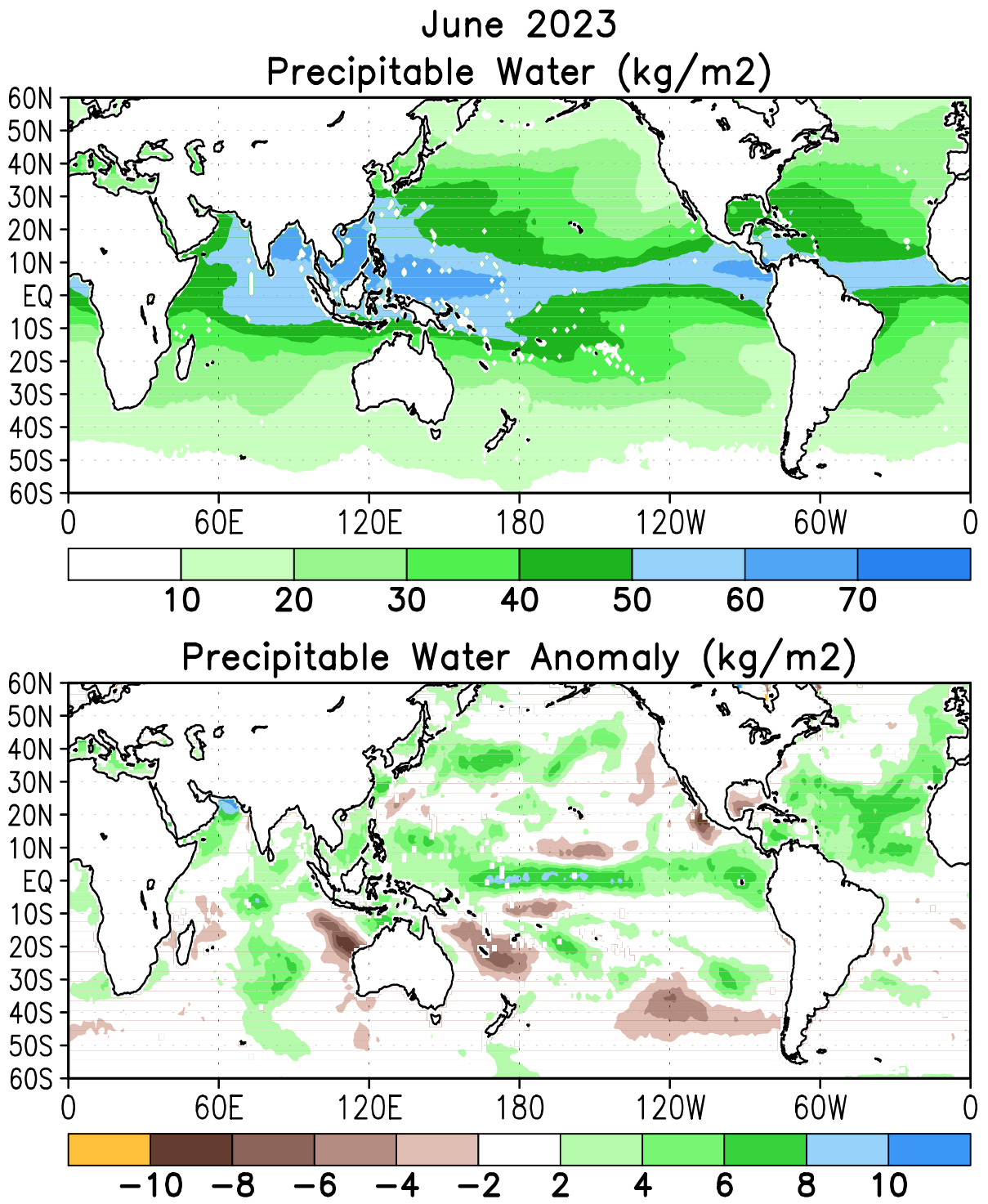


FIGURE T28. Mean (top) and anomalous (bottom) vertically integrated water vapor or precipitable water (kg m^{-2}) based on the Special Sensor Microwave/Imager (SSM/I) (Ferraro et. al, 1996: *Bull. Amer. Meteor. Soc.*, 77, 891-905). Anomalies are calculated from the 1987-2010 base period means.

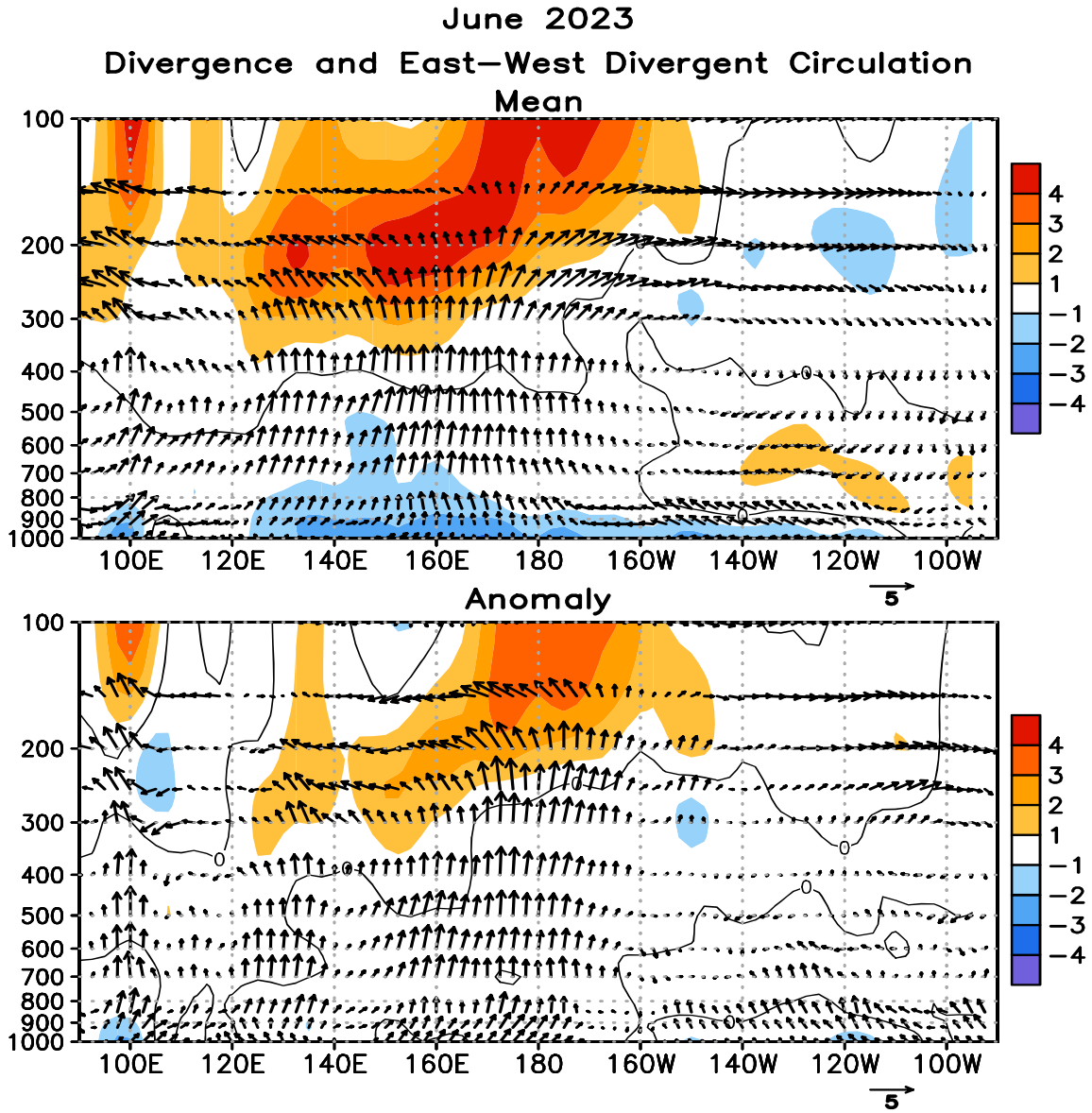


FIGURE T29. Pressure-longitude section (100E–80W) of the mean (top) and anomalous (bottom) divergence (contour interval is $1 \times 10^{-6} \text{ s}^{-1}$) and divergent circulation averaged between 5N–5S. The divergent circulation is represented by vectors of combined pressure vertical velocity and the divergent component of the zonal wind. Red shading and solid contours denote divergence (top) and anomalous divergence (bottom). Blue shading and dashed contours denote convergence (top) and anomalous convergence (bottom). Anomalies are departures from the 1991–2020 base period monthly means.

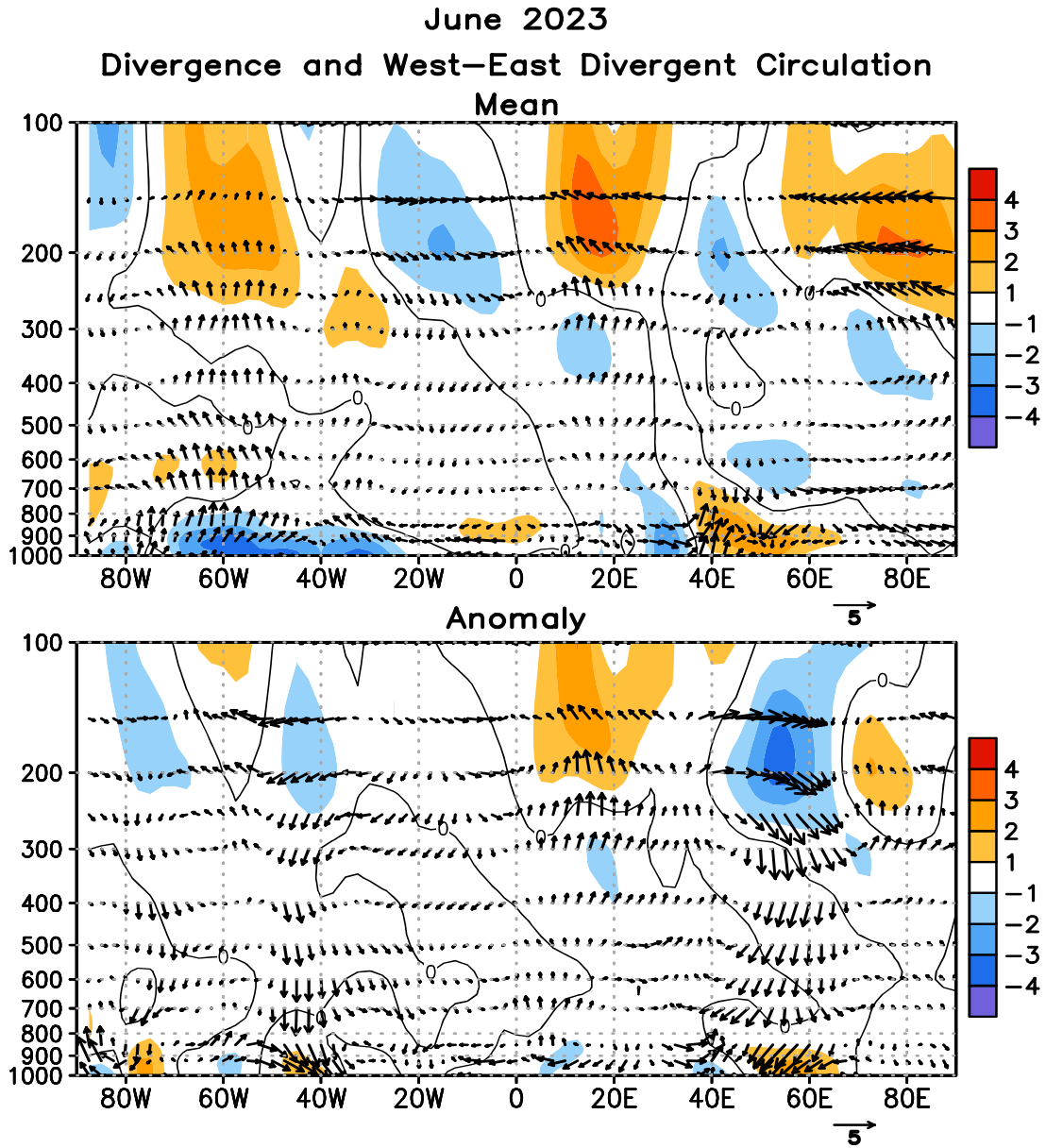


FIGURE T30. Pressure-longitude section (80W-100E) of the mean (top) and anomalous (bottom) divergence (contour interval is $1 \times 10^{-6} \text{ s}^{-1}$) and divergent circulation averaged between 5N-5S. The divergent circulation is represented by vectors of combined pressure vertical velocity and the divergent component of the zonal wind. Red shading and solid contours denote divergence (top) and anomalous divergence (bottom). Blue shading and dashed contours denote convergence (top) and anomalous convergence (bottom). Anomalies are departures from the 1991-2020 base period monthly means.

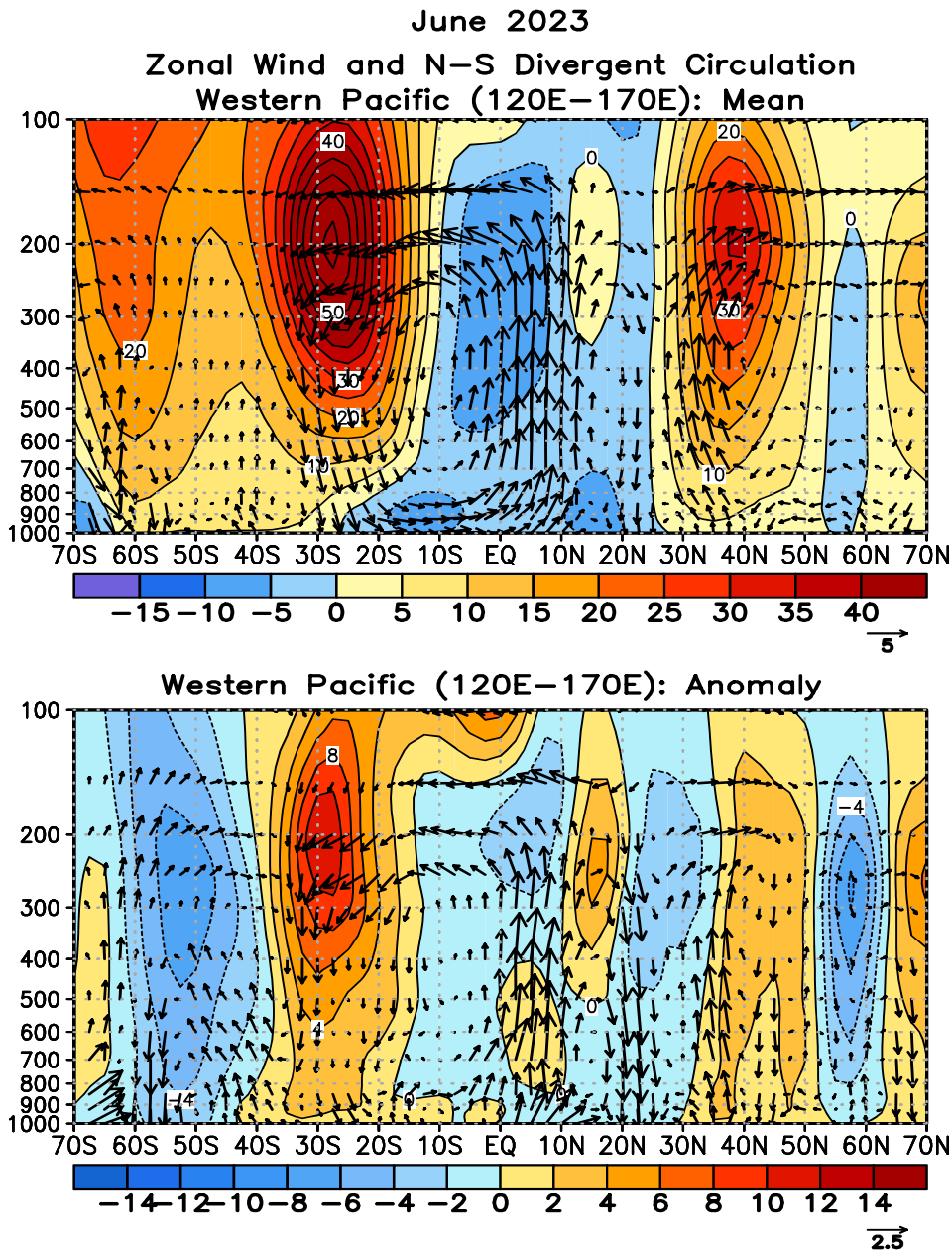


FIGURE T31. Pressure-latitude section of the mean (top) and anomalous (bottom) zonal wind (m s^{-1}) and divergent circulation averaged over the west Pacific sector (120E-170E). The divergent circulation is represented by vectors of combined pressure vertical velocity and the divergent component of the meridional wind. Red shading and solid contours denote a westerly (top) or anomalous westerly (bottom) zonal wind. Blue shading and dashed contours denote an easterly (top) or anomalous easterly (bottom) zonal wind. Anomalies are departures from the 1991-2020 base period monthly means.

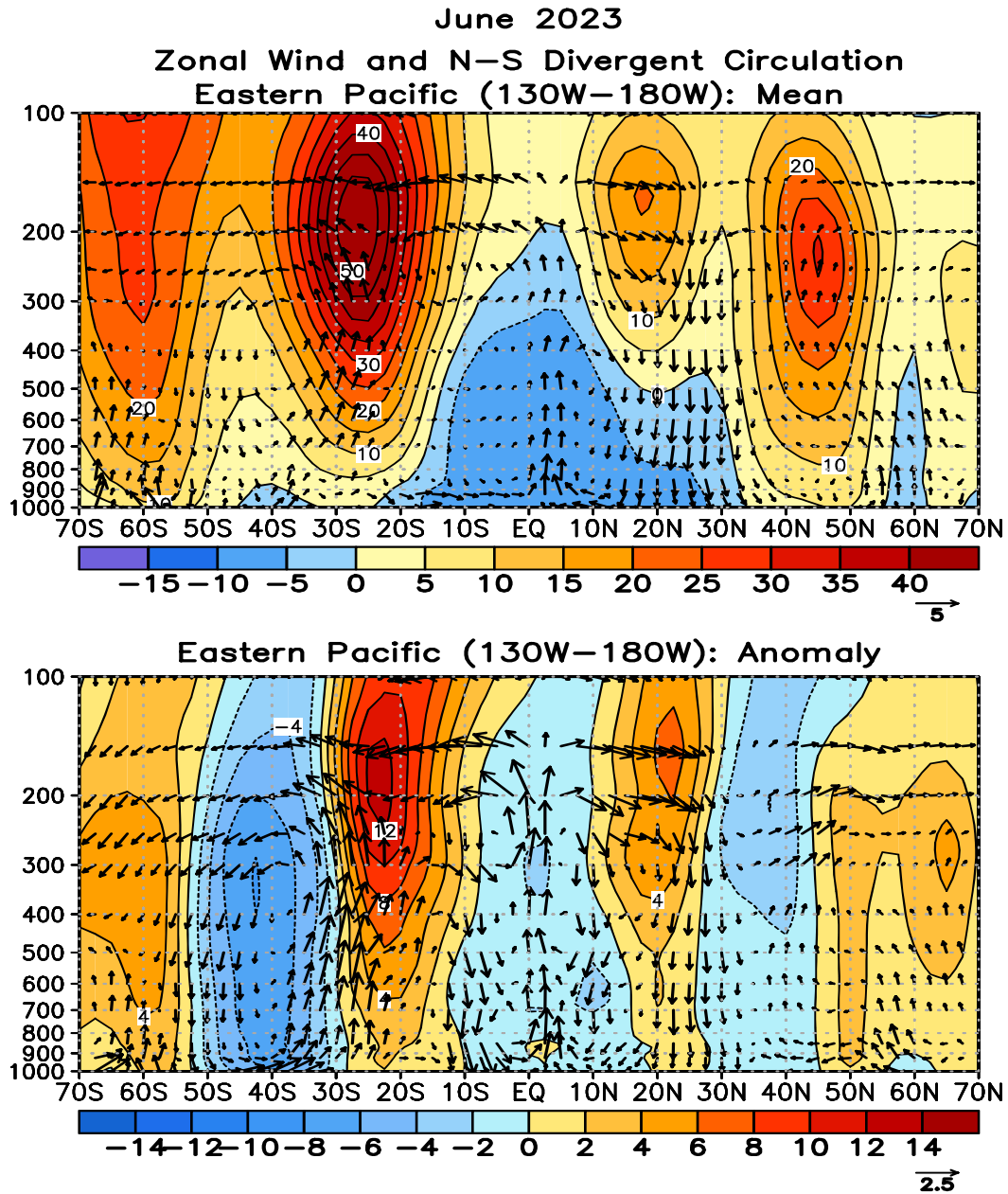


FIGURE T32. Pressure-latitude section of the mean (top) and anomalous (bottom) zonal wind (m s^{-1}) and divergent circulation averaged over the central Pacific sector (130W-180W). The divergent circulation is represented by vectors of combined pressure vertical velocity and the divergent component of the meridional wind. Red shading and solid contours denote a westerly (top) or anomalous westerly (bottom) zonal wind. Blue shading and dashed contours denote an easterly (top) or anomalous easterly (bottom) zonal wind. Anomalies are departures from the 1991-2020 base period monthly means.

During June 2023, 168 satellite-tracked surface drifting buoys were reporting from the tropical Pacific. A small number of drifters at 100W, ~5N measured eastward anomalies exceeding 70 cm/s, but it is unclear if this is associated with a broader pattern or with an instability wave. Drifters at 5-7N across the central basin exhibited westward anomalies of 40 cm/s, continuing the pattern that appeared in May.

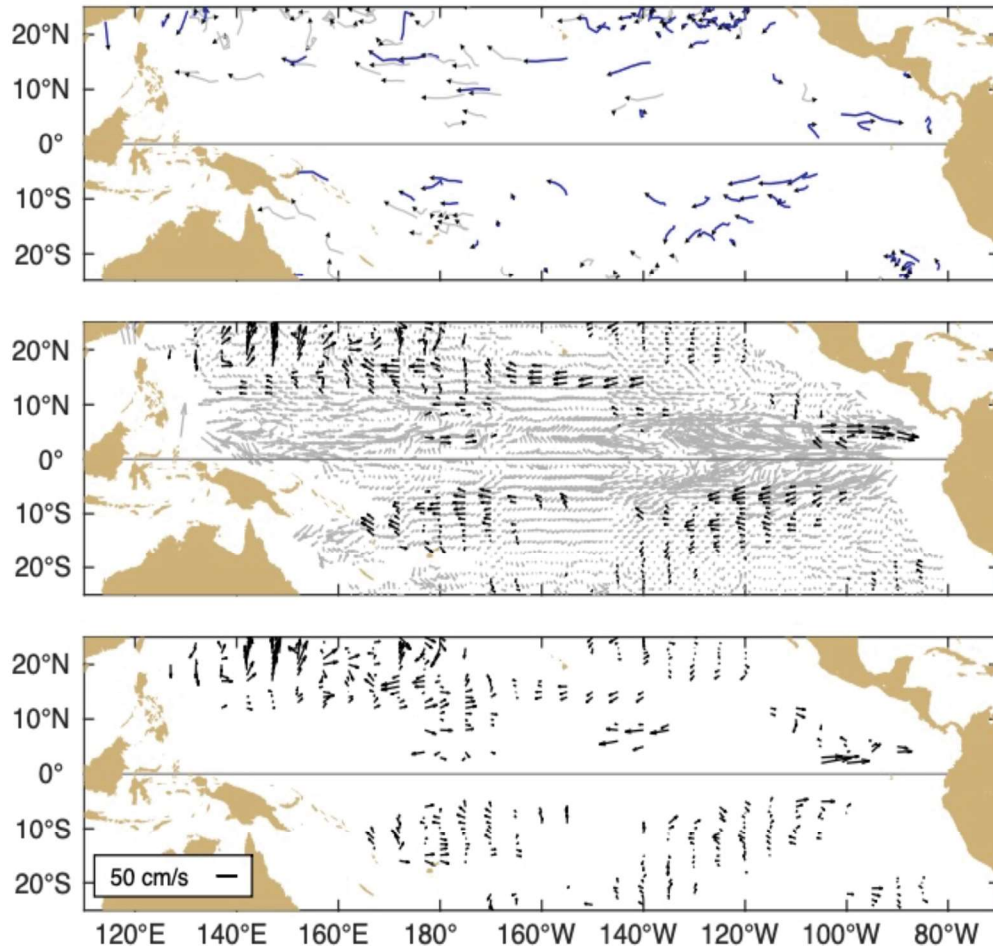


Figure A1.1 Top: Movements of drifting buoys in the tropical Pacific Ocean during June 2023. The linear segments of each trajectory represent a one week displacement. Trajectories of buoys which have lost their subsurface drogues are gray; those with drogues are black.

Middle: Monthly mean currents calculated from all buoys 1993-2002 (gray), and currents measured by the drogued buoys this month (black) smoothed by an optimal filter.

Bottom: Anomalies from the climatological monthly mean currents for this month.

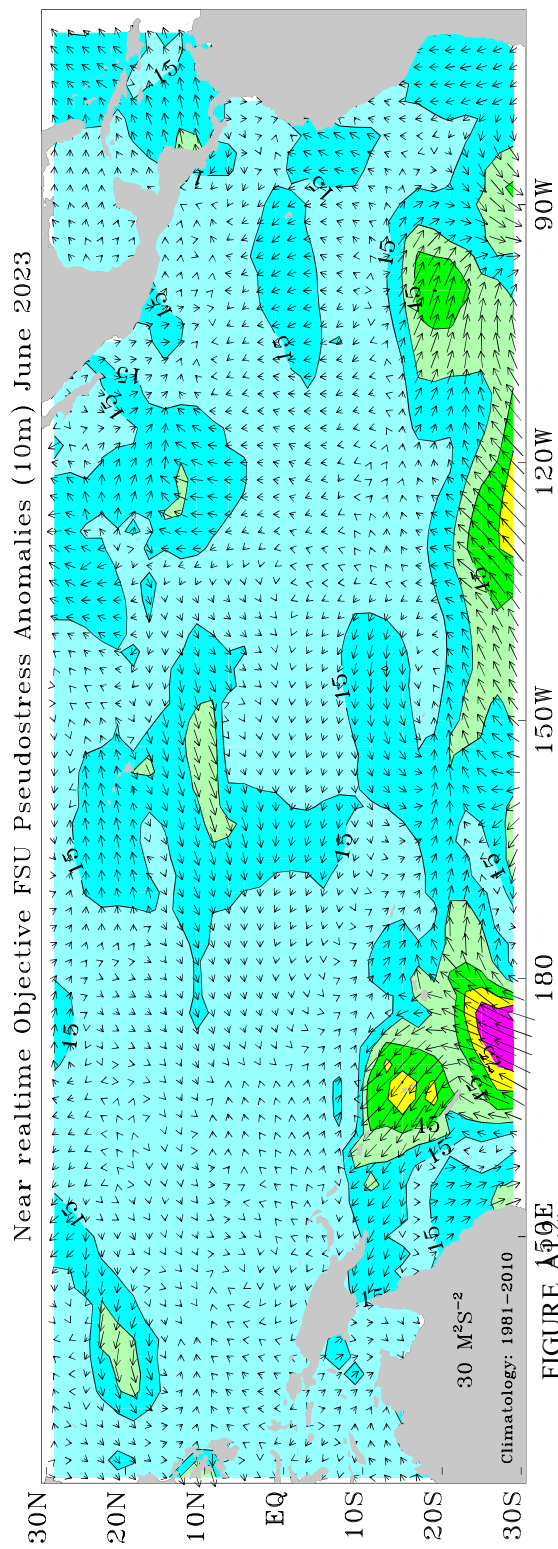
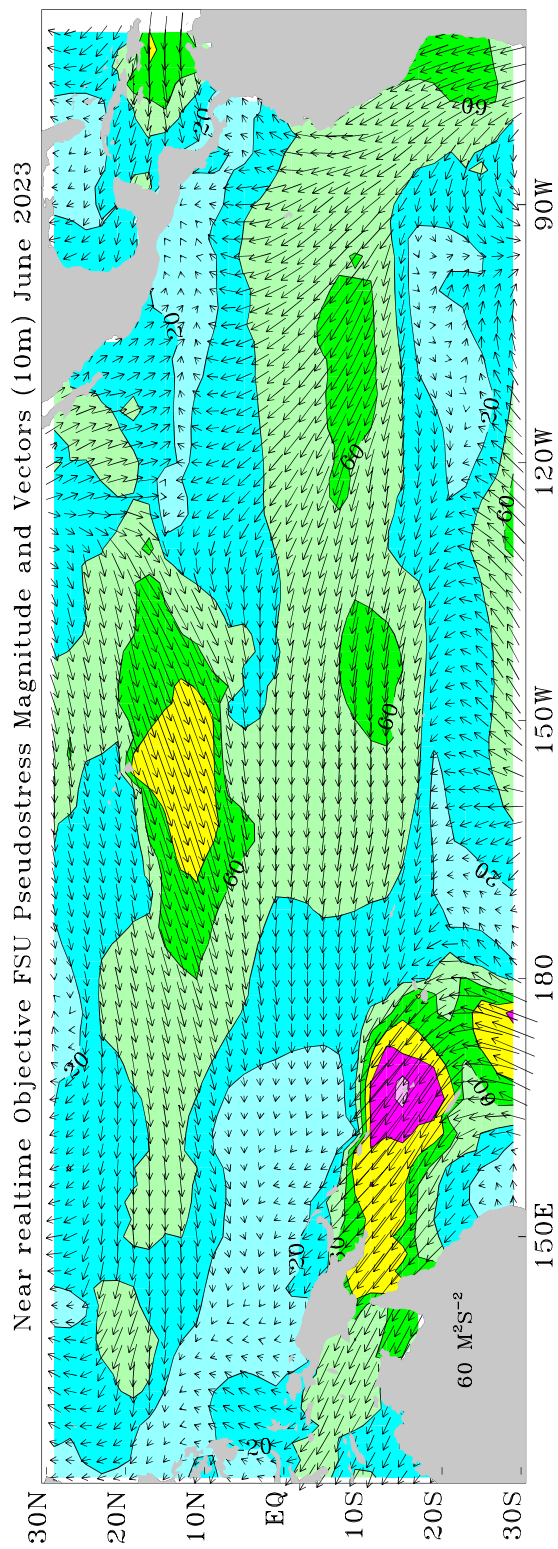


FIGURE A10E
 FSU SURFACE PSEUDO-STRESS VECTORS AND ANOMALIES: June 2023. Pseudo-stress vectors (top) are objectively analyzed from ship and buoy winds on a 2° grid. Ship and buoy data are independently weighted and the background field is created from the data. Contour interval of the vector magnitudes is $20 \text{ M}^2\text{S}^{-2}$. Anomalies (bottom) are departures from 1981–2010 mean. The contour interval is $15 \text{ M}^2\text{S}^{-2}$. For more information, please visit our web site at <http://www.coaps.fsu.edu/RVSMDC/html/winds.shtml>. Produced by Shawn R. Smith and Mark A. Bourassa, Center for Ocean–Atmospheric Prediction Studies, Florida State University, Tallahassee, FL 32306–2840, USA.

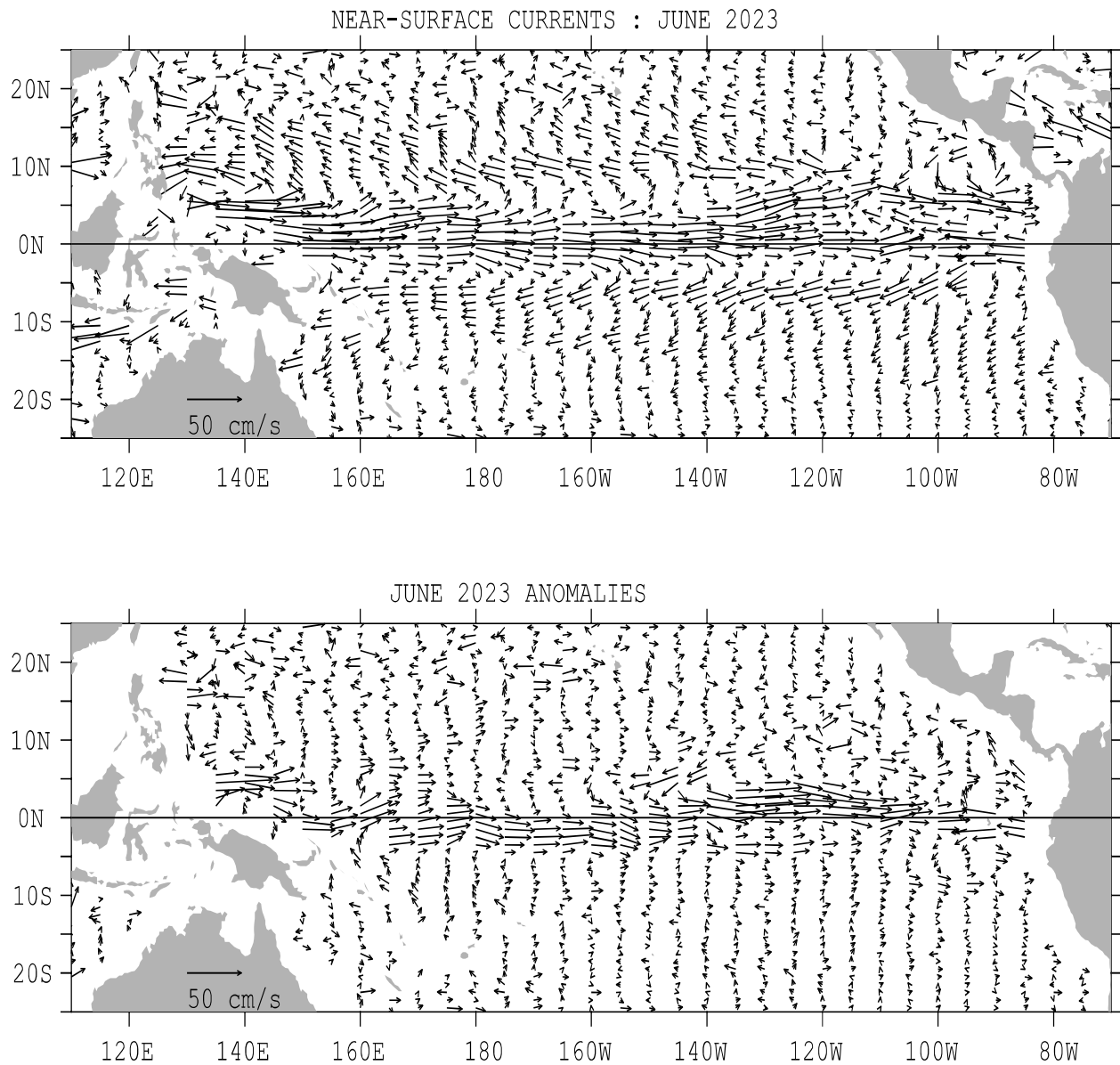


FIGURE A1.3. Ocean Surface Current Analysis-Real-time (OSCAR) for JUN 2023 (Bonjean and Lagerloef 2002, *J. Phys. Oceanogr.*, Vol. 32, No. 10, 2938-2954; Lagerloef et al. 1999, *JGR-Oceans*, 104, 23313-23326). (top) Total velocity. Surface currents are calculated from satellite data including Jason sea level anomalies and NCEP winds. (bottom) Velocity anomalies. The subtracted climatology was based on SSM/I and QuickScat winds and Topex/Poseidon and Jason from 1993-2003. See also <http://www.oscar.noaa.gov>.

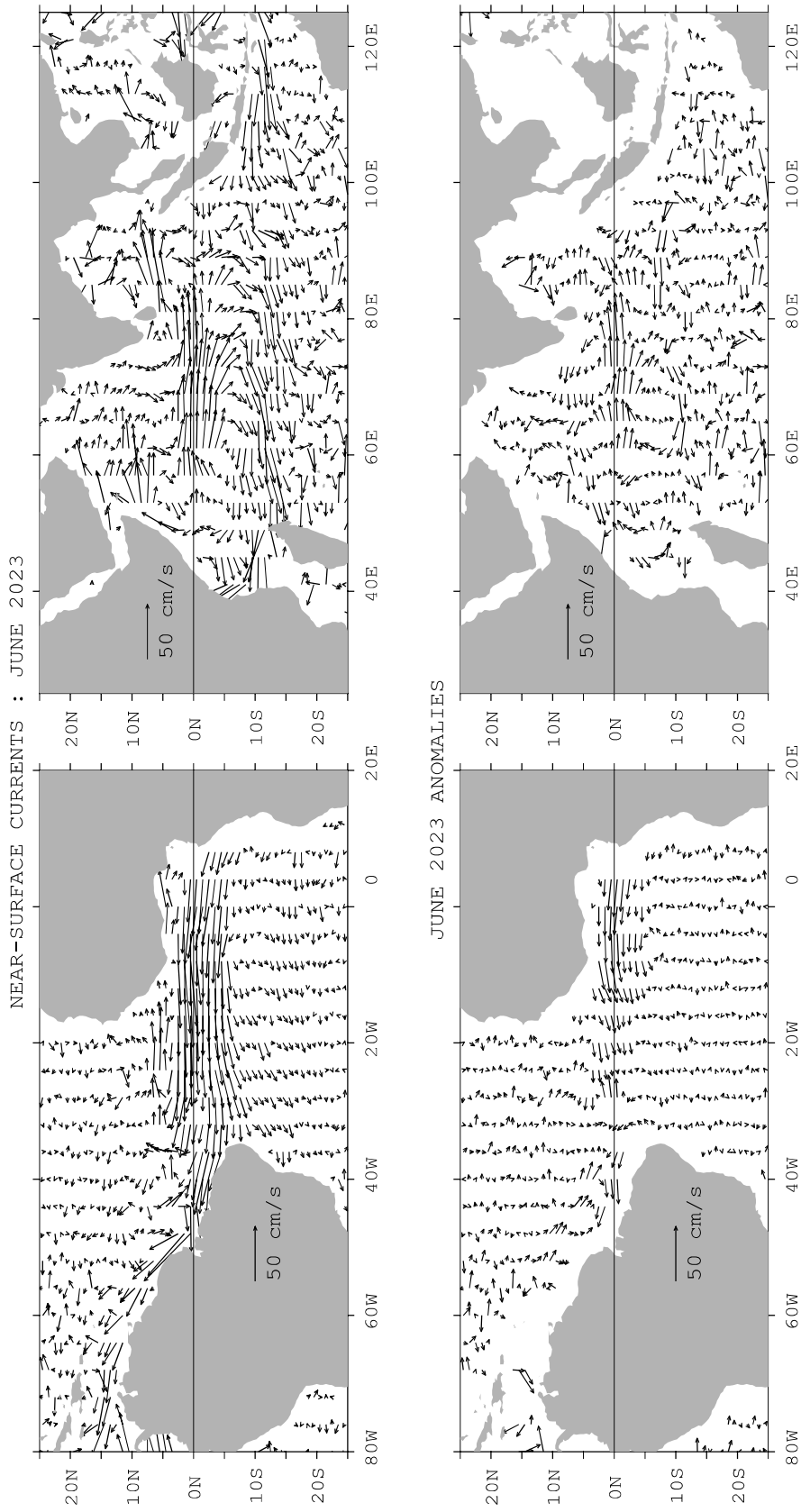


FIGURE A1.4. Ocean Surface Current Analysis-Real-time (OSCAR) for JUN 2023 (Bonjean and Lagerloef 2002, *J. Phys. Oceanogr.*, Vol. 32, No. 10, 2938-2954; Lagerloef et al. 1999, *JGR-Oceans*, 104, 23313-23326). (top) Total velocity. Surface currents are calculated from satellite data including Jason sea level anomalies and NCEP winds. (bottom) Velocity anomalies. The subtracted climatology was based on SSM/I and QuickScat winds and Topex/Poseidon and Jason from 1993-2003. See also <http://www.oscar.noaa.gov>.

Forecast Forum

The canonical correlation analysis (CCA) forecast of SST in the central Pacific (Barnett et al. 1988, *Science*, **241**, 192196; Barnston and Ropelewski 1992, *J. Climate*, **5**, 13161345), is shown in **Figs. F1 and F2**. This forecast is produced routinely by the Prediction Branch of the Climate Prediction Center. The predictions from the National Centers for Environmental Prediction (NCEP) Coupled Forecast System Model (CFS03) are presented in **Figs. F3 and F4a, F4b**. Predictions from the Markov model (Xue, et al. 2000: *J. Climate*, **13**, 849871) are shown in **Figs. F5 and F6**. Predictions from the latest version of the LDEO model (Chen et al. 2000: *Geophys. Res. Lett.*, **27**, 25852587) are shown in **Figs. F7 and F8**. Predictions from the ENSO CLIPER statistical model (Knaff and Landsea 1997, *Wea. Forecasting*, **12**, 633 652) are shown in **Fig. F9**. Niño 3.4 predictions are summarized in **Fig. F10**, provided by the Forecasting and Prediction Research Group of the IRI.

The CPC and the contributors to the **Forecast Forum** caution potential users of this predictive information that they can expect only modest skill.

ENSO Alert System Status: [El Niño Advisory](#)

Outlook

There is a greater than 90% chance that El Niño will continue through the Northern Hemisphere winter.

Discussion

In June, a weak El Niño was associated with above-average sea surface temperatures (SSTs) across the equatorial Pacific Ocean (Fig. T18). Nearly all of the monthly Niño indices were near or in excess of +1.0°C: Niño-3.4 was +0.9°C, Niño-3 was +1.2°C, and Niño1+2 was +2.6°C (Table T2). Area-averaged subsurface temperatures anomalies increased compared to May, with positive anomalies below the surface of the equatorial Pacific Ocean (Fig. T17). In contrast, the tropical atmospheric anomalies were weaker compared to the oceanic anomalies. For the June monthly average, low-level winds were near average over most of the equatorial Pacific (Fig. T20). Upper-level wind anomalies were easterly over the western Pacific and westerly over the eastern Pacific (Fig. T21). Convection and rainfall were enhanced around the International Date Line and were weakly suppressed in the vicinity of Indonesia (Fig. T25). The equatorial SOI remained negative (0.5 standard deviations below average), while the traditional, station-based SOI was near zero (Figs. T1 & T2). Collectively, the coupled ocean-atmosphere system reflected a weak El Niño.

The most recent IRI plume indicates El Niño will persist through the Northern Hemisphere winter 2023-24 (Figs. F1-F12). Forecasters favor continued growth of El Niño through the fall,

peaking this winter with moderate-to-strong intensity (81% chance of November-January Niño-3.4 $\geq 1.0\text{C}$). An event that becomes “historically strong” (seasonally averaged Niño-3.4 $\geq 2.0\text{C}$), rivaling the winters of 1997-98 or 2015-16, has an approximately 1 in 5 chance. In summary, there is a greater than 90% chance that El Niño will continue through the Northern Hemisphere winter.

Weekly updates of oceanic and atmospheric conditions are available on the Climate Prediction Center homepage ([El Niño/La Niña Current Conditions and Expert Discussions](#)).

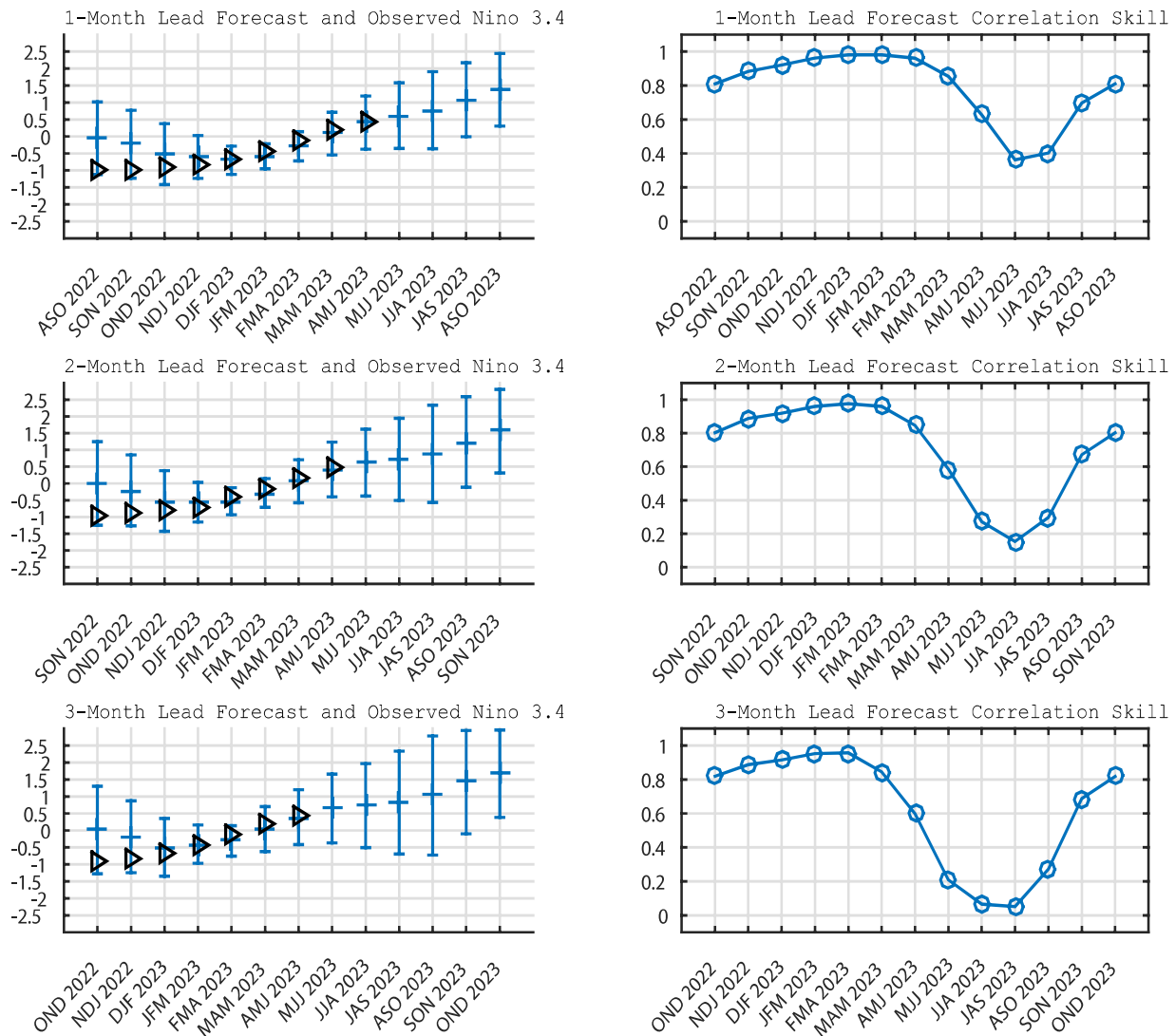


FIGURE F1. Canonical correlation analysis (CCA) sea surface temperature (SST) anomaly prediction for the central Pacific (5N to 5S, 120W to 170W (Barnston and Ropelewski, 1992, *J. Climate*, 5, 1316-1345)). The three plots on the left are, from top to bottom, the 1-month, 2-month, and 3-month lead seasonal forecasts from the past 12 months plus the current month. The triangles in each plot are the observed SST anomaly through the latest available season. The lines at the mid-points of the forecast error bars represent the real-time CCA predictions based on the anomalies of quasi-global sea level pressure, the anomalies of tropical Pacific SST, and heat content of the upper 300 meters of the near-equator tropical Pacific (10S to 10N). The vertical lines represent the two standard deviation error bars for the predictions based on past performance. The three plots on the right are skill values for the corresponding seasons, from the correlations of the predicted and observed SST in the prior 10 years of simulated real-time forecasts. Skill values show a clear annual cycle and are inversely proportional to the length of the error bars depicted in the forecast time series.

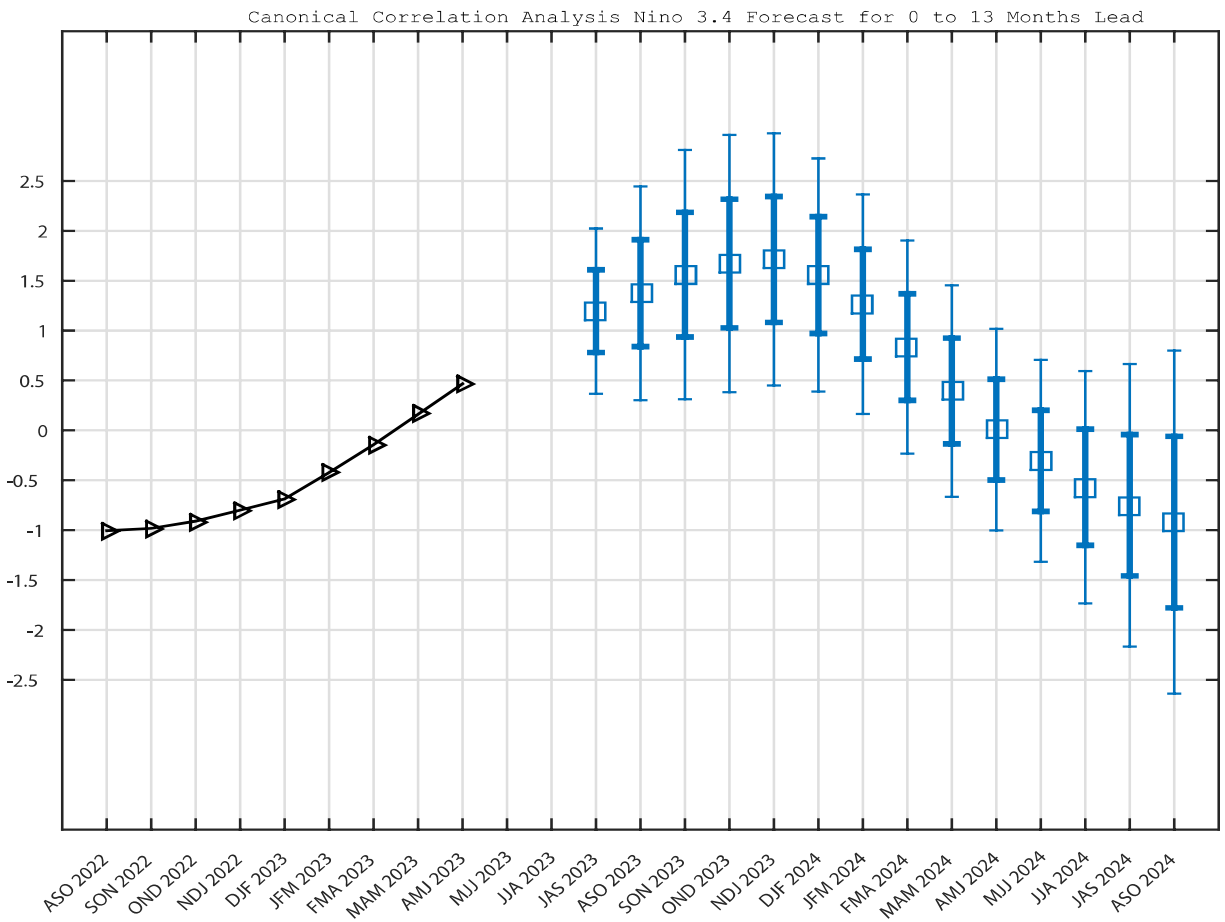


FIGURE F2. Canonical Correlation Analysis (CCA) forecast of sea-surface temperature anomalies for the Nino 3.4 region (5N-5S, 120W-170W) for the upcoming year of three-month overlapping periods. The CCA predictions are based on anomaly patterns of sea level pressure, tropical Pacific SST, and heat content of the upper 300 meters of the near-equator tropical Pacific (10S to 10N). Small squares at the midpoints of the vertical forecast bars represent the CCA predictions, and the bars show the one (thick) and two (thin) standard deviation errors. The triangles and line represent the observed three-month mean SST anomaly in the Nino 3.4 region up to the most recently available data.

Last update: Sun Jul 2 2023
Initial conditions: 22Jun2023-01Jul2023

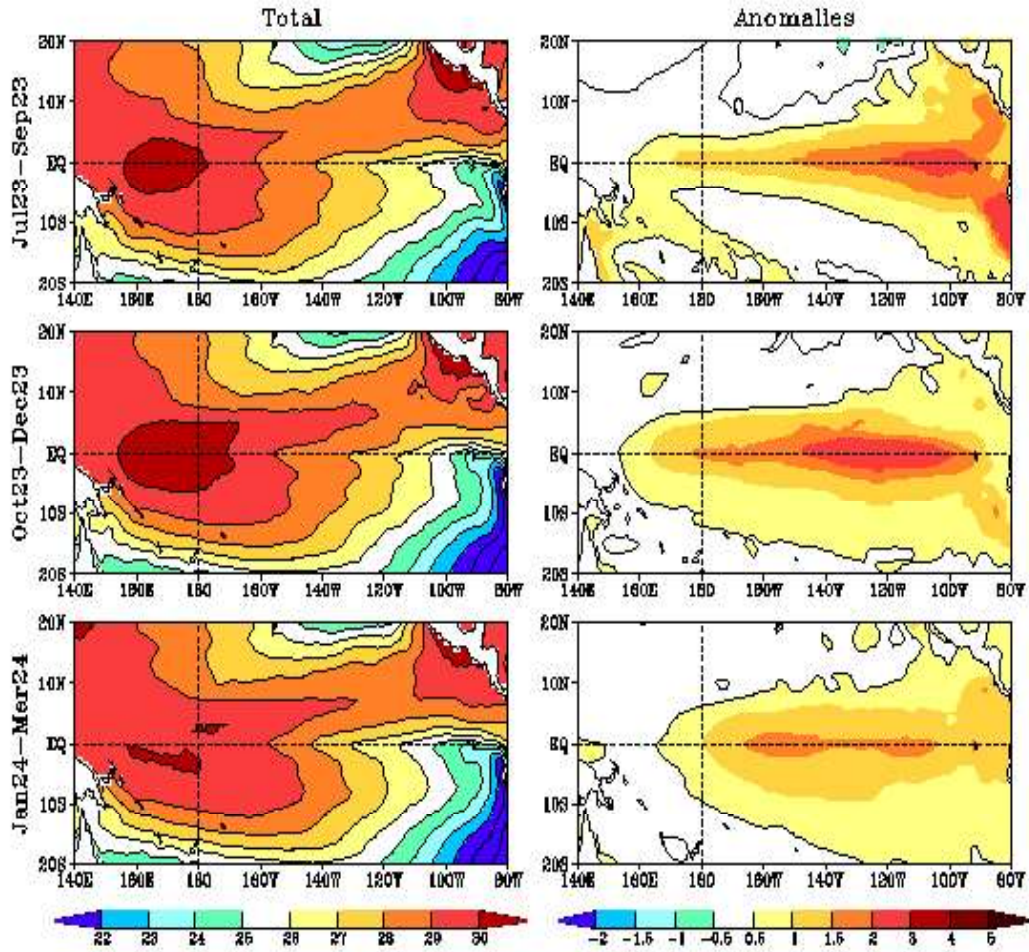


FIGURE F3. Predicted 3-month average sea surface temperature (left) and anomalies (right) from the NCEP Coupled Forecast System Model (CFS03). The forecasts consist of 40 forecast members. Contour interval is 1°C, with additional contours for 0.5°C and -0.5°C. Negative anomalies are indicated by dashed contours.

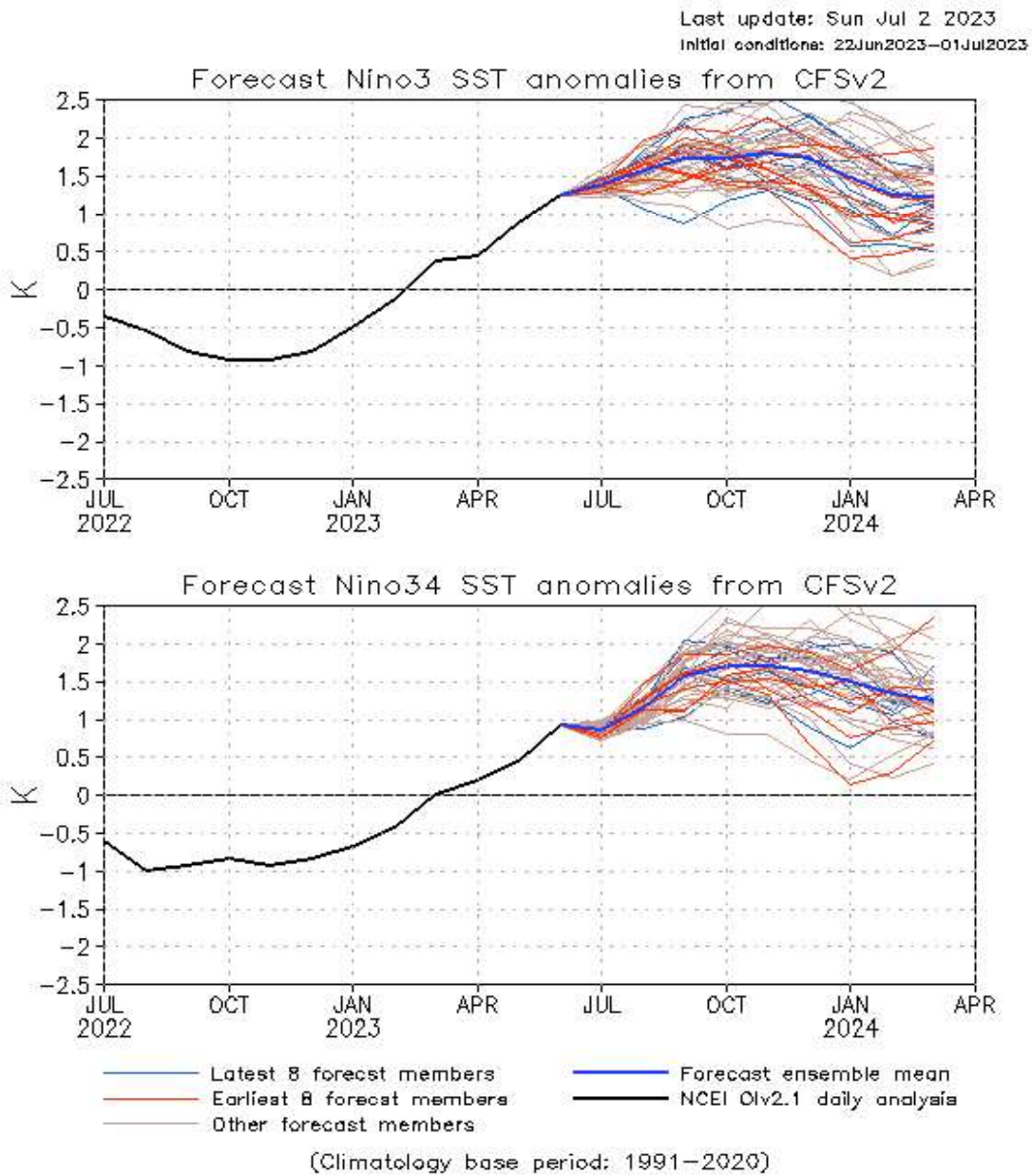


FIGURE F4. Predicted and observed sea surface temperature (SST) anomalies for the Nino 3 (top) and Nino 3.4 (bottom) regions from the NCEP Coupled Forecast System Model (CFS03). The forecasts consist of 40 forecast members. The ensemble mean of all 40 forecast members is shown by the blue line, individual members are shown by thin lines, and the observation is indicated by the black line. The Nino-3 region spans the eastern equatorial Pacific between 5N-5S, 150W-90W. The Nino 3.4 region spans the east-central equatorial Pacific between 5N-5S, 170W-120W.

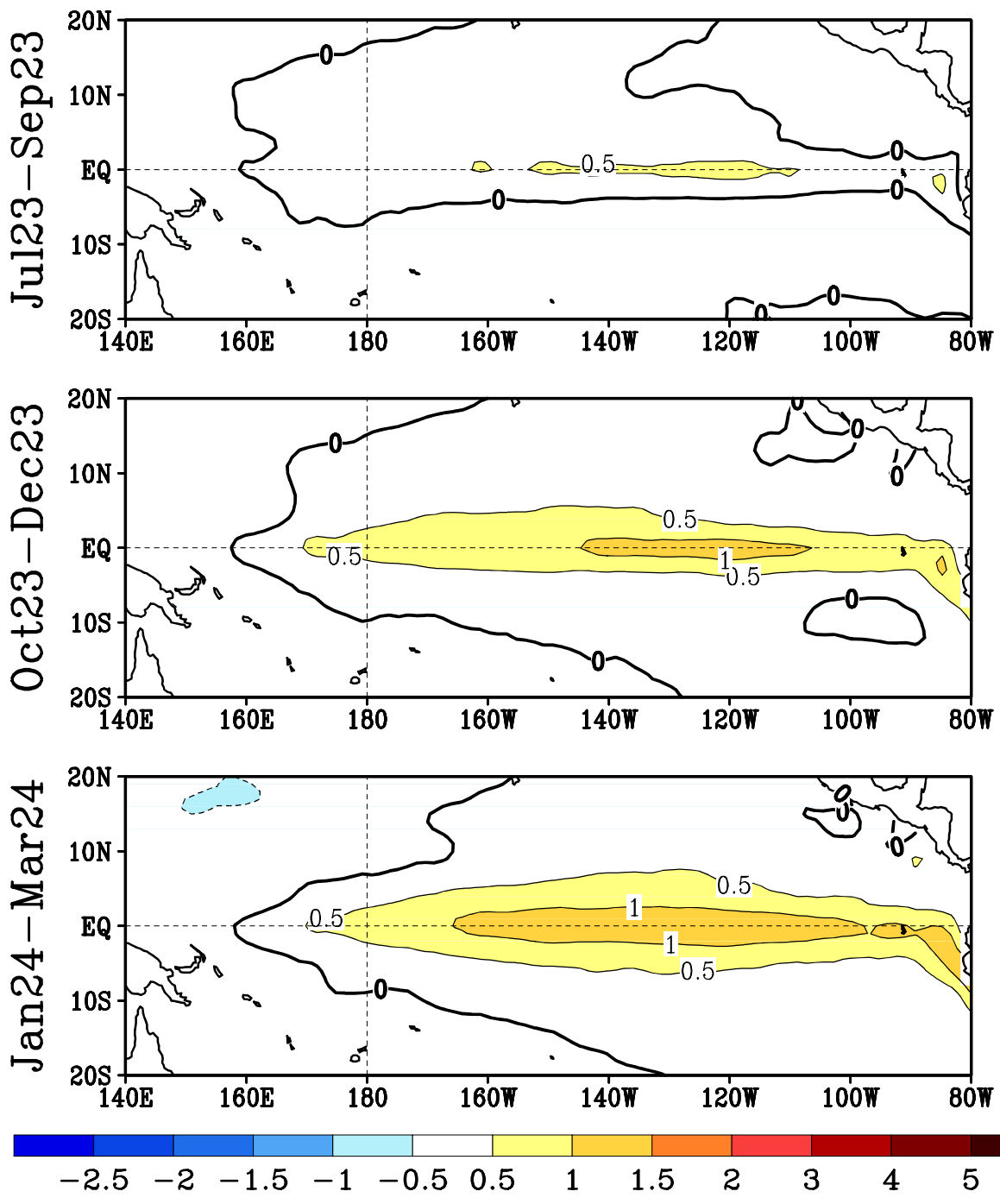


FIGURE F5. Predicted 3-month average sea surface temperature anomalies from the NCEP/CPC Markov model (Xue et al. 2000, *J. Climate*, **13**, 849-871). The forecast is initiated in JUN 2023 . Contour interval is 0.3C and negative anomalies are indicated by dashed contours. Anomalies are calculated relative to the 1971-2000 climatology.

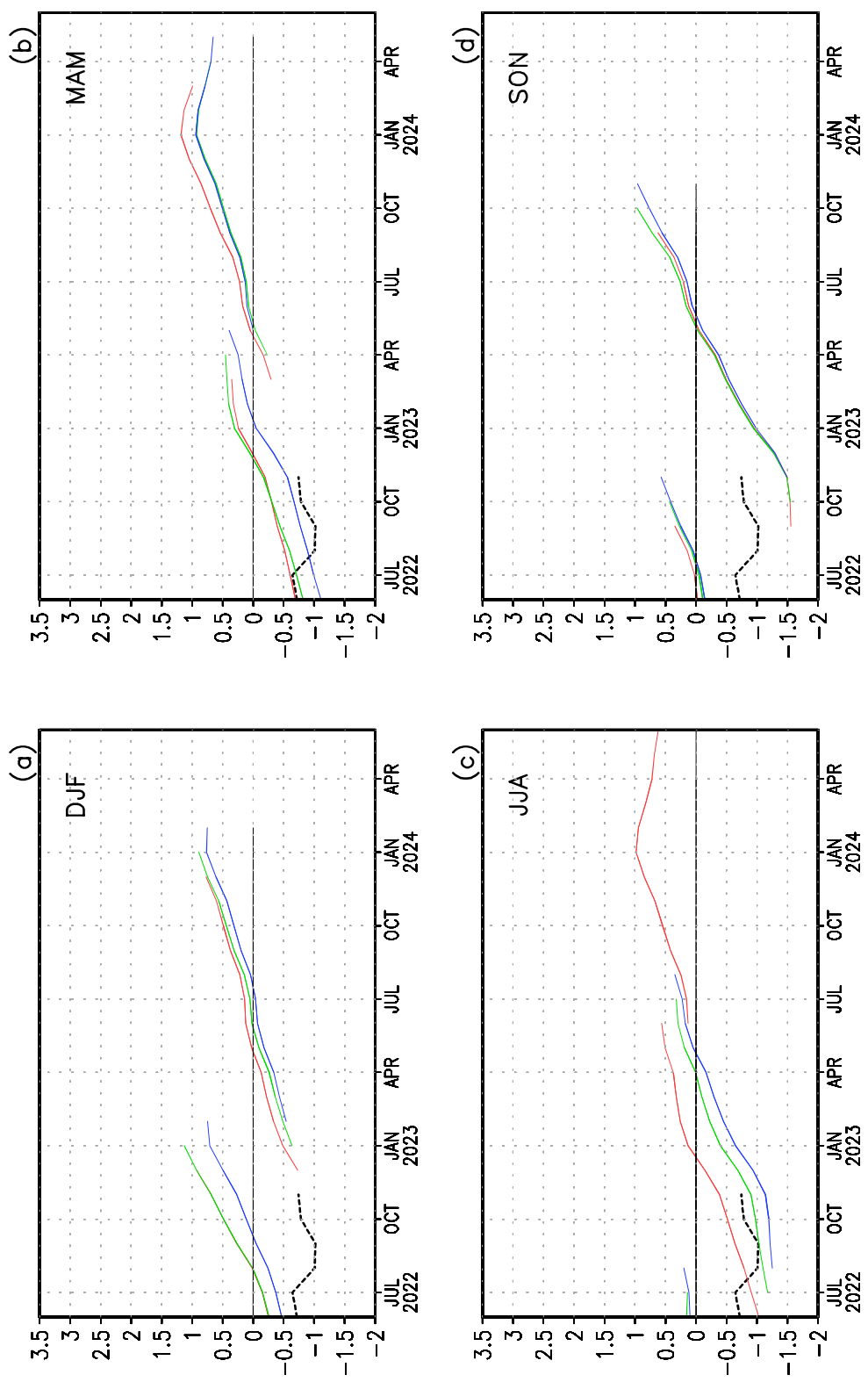


FIGURE F6. Time evolution of observed and predicted SST anomalies in the Niño 3.4 region (up to 12 lead months) by the NCEP/CPC Markov model (Xue et al. 2000, *J. Climate*, **13**, 849–871). Anomalies are calculated relative to the 1971–2000 climatology. Shown in each panel are the forecasts grouped by three consecutive starting months: (a) is for December, January, and February, (b) is for March, April, and May, (c) is for June, July, and August, and (d) is for September, October, and November. The observed Niño 3.4 SST anomalies are indicated by the black dashed lines. The Niño 3.4 region spans the east-central equatorial Pacific between 5N–5S, 170W–120W.

LDEO FORECASTS OF SST AND WIND STRESS ANOMALIES

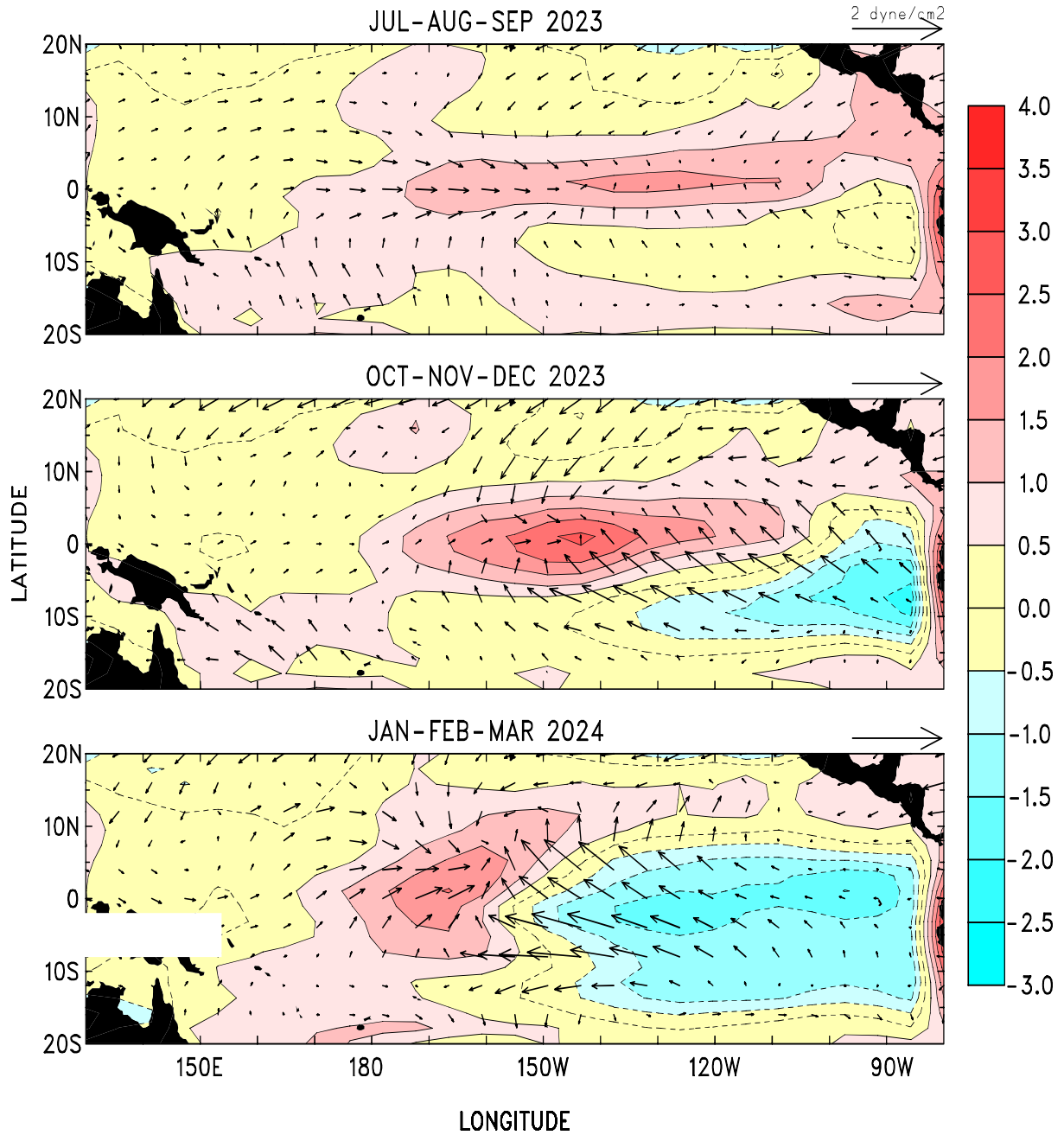


FIGURE F7. Forecasts of the tropical Pacific Predicted SST (shading) and vector wind anomalies for the next 3 seasons based on the LDEO model. Each forecast represents an ensemble average of 3 sets of predictions initialized during the last three consecutive months (see Figure F8).

LDEO FORECASTS OF NINO3

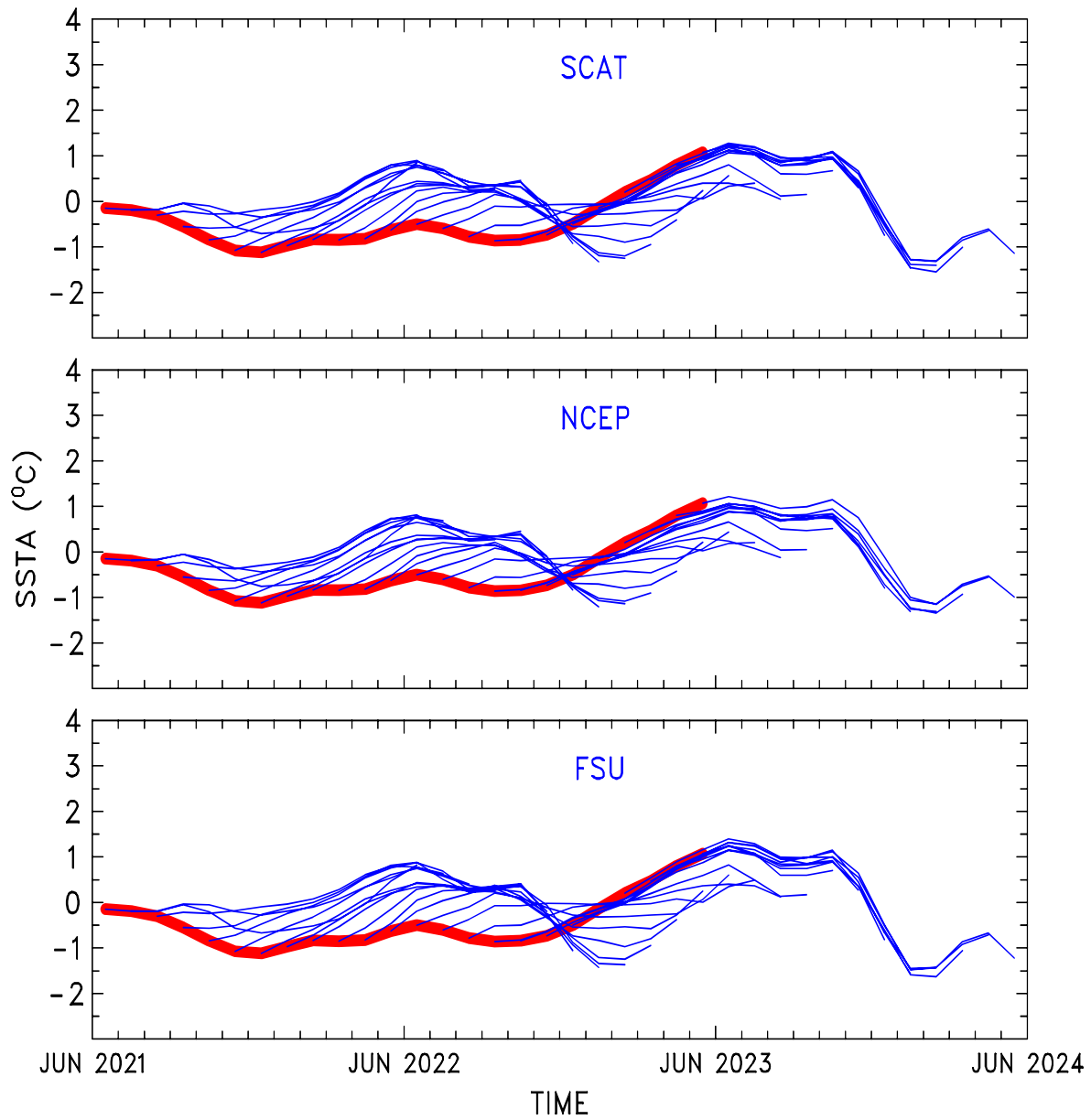


FIGURE F8. LDEO forecasts of SST anomalies for the Nino 3 region using wind stresses obtained from (top) QuikSCAT, (middle) NCEP, and (bottom) Florida State Univ. (FSU), along with SSTs (obtained from NCEP), and sea surface height data (obtained from TOPEX/POSEIDON) data. Each thin blue line represents a 12-month forecast, initialized one month apart for the past 24 months. Observed SST anomalies are indicated by the thick red line. The Nino-3 region spans the eastern equatorial Pacific between 5N-5S, 150W-90W.

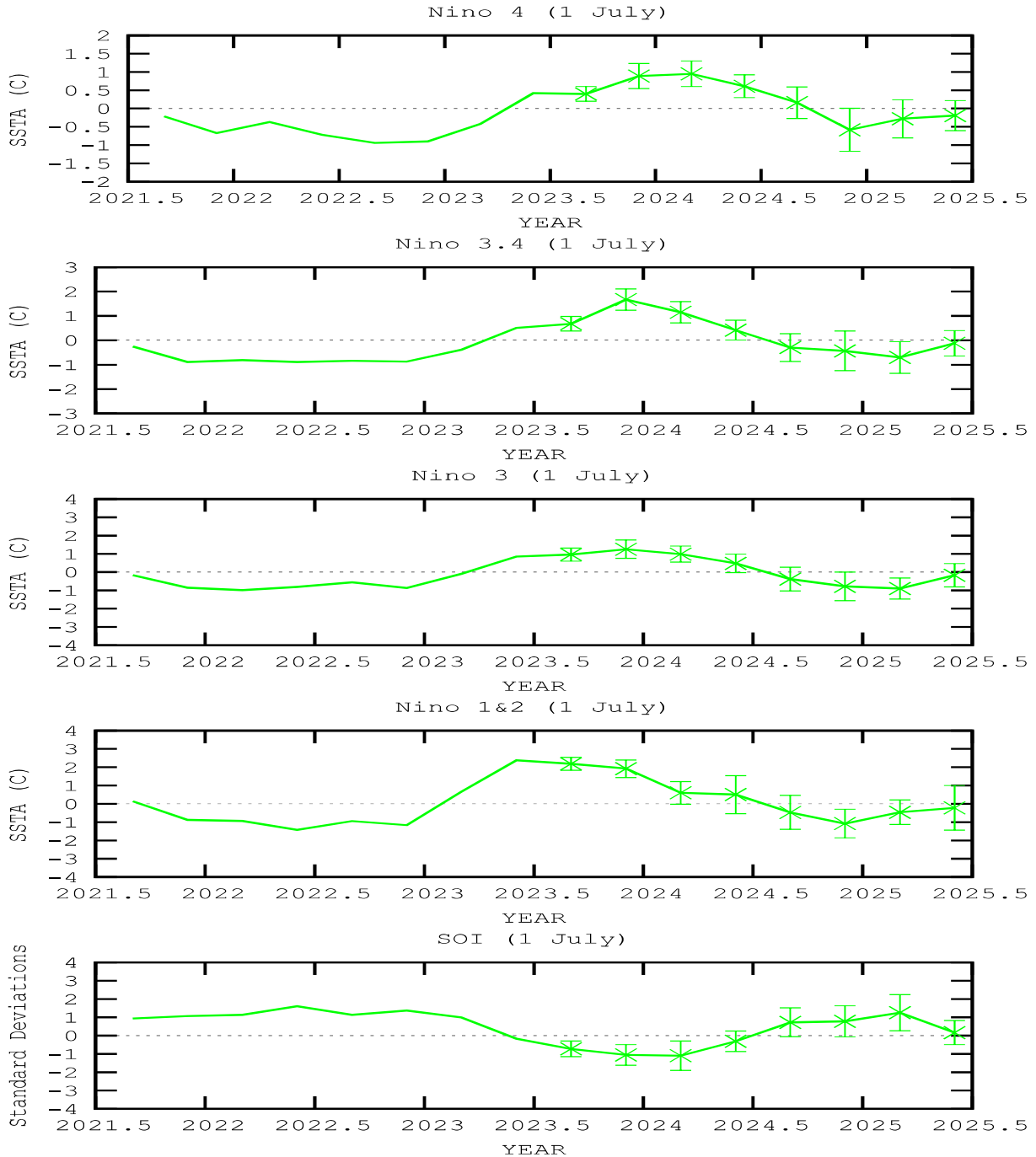


FIGURE F9. ENSO-CLIPER statistical model forecasts of three-month average sea surface temperature anomalies (green lines, deg. C) in (top panel) the Nino 4 region (5N-5S, 160E-150W), (second panel) the Nino 3.4 region (5N-5S, 170W-120W), (third panel) the Nino 3 region (5N-5S, 150W-90W), and (fourth panel) the Nino 1+2 region (0-10S, 90W-80W) (Knaff and Landsea 1997, *Wea. Forecasting*, **12**, 633-652). Bottom panel shows predictions of the three-month standardized Southern Oscillation Index (SOI, green line). Horizontal bars on green line indicate the adjusted root mean square error (RMSE). The Observed three-month average values are indicated by the thick blue line. SST anomalies are departures from the 1991-2020 base period means, and the SOI is calculated from the 1951-1980 base period means.

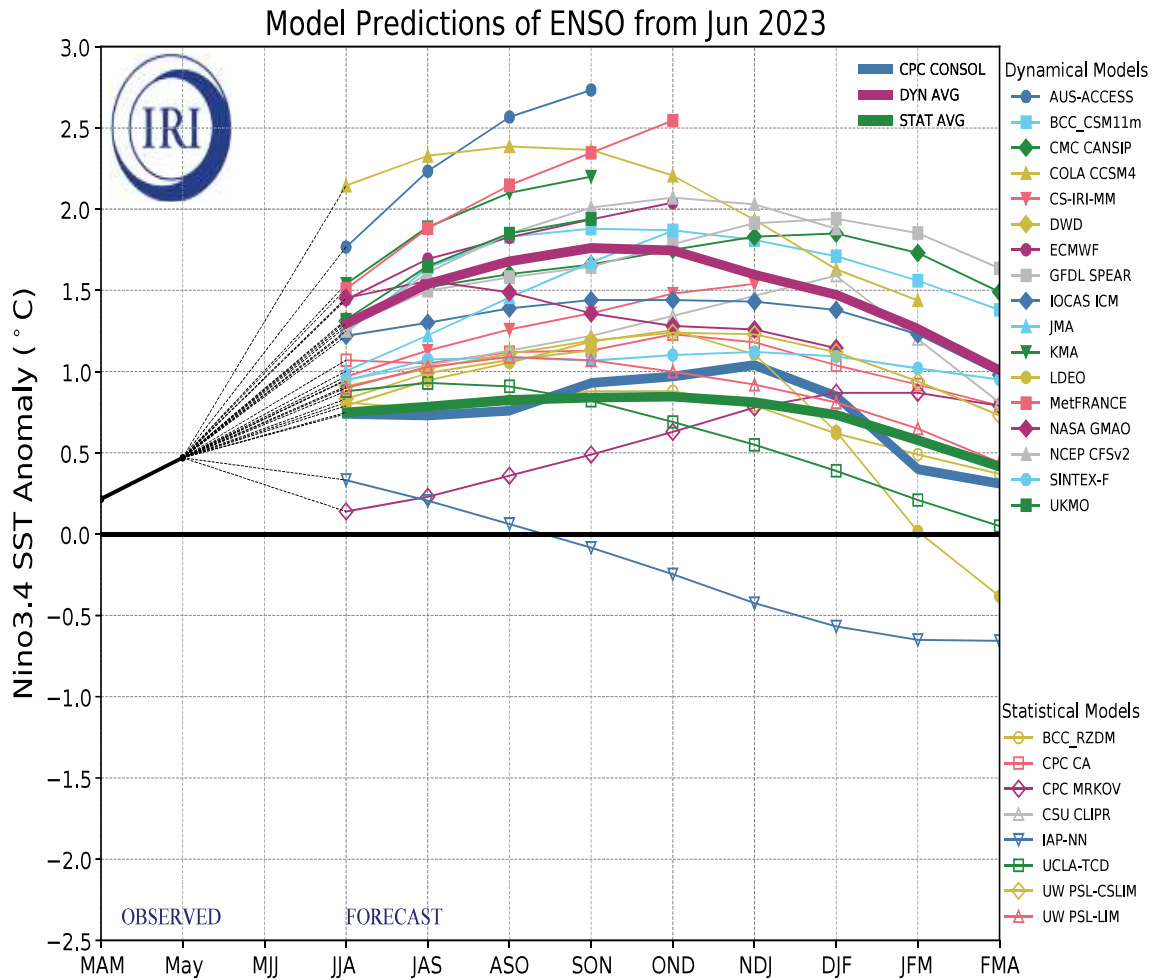


FIGURE F10. Time series of predicted sea surface temperature anomalies for the Nino 3.4 region (deg. C) from various dynamical and statistical models for nine overlapping 3-month periods. The Nino 3.4 region spans the east-central equatorial Pacific between 5N-5S, 170W-120W. Figure provided by the International Research Institute (IRI).

Extratropical Highlights – June 2023

1. Northern Hemisphere

The 500-hPa circulation during June featured a strong ridge over much of Canada and Scandinavia and moderate troughing over both U.S. coasts, western Alaska, and Siberia (Fig. E9). The main land-surface temperature signals during June were above-average temperatures across much of North America, Europe, Russia, and parts of Asia (Fig. E1). The main precipitation signals included drier than average conditions for most of Europe, Scandinavia, and parts of North America, and wetter than average conditions for parts of North America, and across southern Eurasia (Fig. E3).

a. North America

The 500-hPa circulation anomalies during June featured strongly above-average heights over much of Canada, and below-average heights over western Alaska, as well both the West and East Coasts of the U.S. (Fig. E9). The anomalous ridging pattern contributed to above-average temperatures for much of Canada with some regions recording temperatures in the 90th percentile of occurrences (Fig. E1). In some regions of the western and mid-Atlantic Seaboard of the U.S., temperatures for the month of June were below-average (Fig. E1). Above-average precipitation totals were recorded for parts of the central and southeast U.S., with the central region recording rainfall in the 90th percentile of occurrences (Fig. E3). Of note during June were the wildfires across Canada which, in combination with the ridging pattern that set up over eastern Canada, brought smoke and hazy conditions to the mid-Atlantic Seaboard on several occasions and significantly degraded air quality. June is the typical month for the yearly onset of the Southwestern Monsoon and this year the June precipitation totals associated with the monsoon were well below-average and recorded in the lowest 10th percentile of occurrences (Figs. E5, E6).

b. Eurasia

The 500-hPa height pattern featured above-average heights over Scandinavia, the North Sea, and northern Europe and below-average heights over central regions of Siberia (Fig. E9). The ridging pattern ushered in well-above average temperatures for Europe and below-average temperatures for northwestern Russia (Fig. E1). Across Europe, temperatures were recorded in the highest 90th percentile of occurrences (Fig. E1). Precipitation totals were below-average across northern Europe and Scandinavia and above-average along the north coast of the Mediterranean Sea and parts of Eurasia (Figs. E3, E4).

2. Southern Hemisphere

The 500-hPa circulation anomalies during June featured a wavetrain pattern with strongly above-average heights over the Indian Ocean and central South Pacific Ocean, as well as over Antarctica, and strongly below-average heights over the eastern portions of the South Pacific Ocean, south of South America and south of Australia (Fig. E15). Above-average temperatures were recorded across many regions in South America with regions near Bolivia recording temperatures in the highest 90th percentile of occurrences (Fig. E1). Temperatures in eastern Australia were also well above normal and in the 90th percentile of occurrences, while western Australia observed mildly below-average temperatures (Fig. E1). Precipitation totals were well below normal for much of the region north of central Brazil as well as in Patagonia (Figs. E1, E3). Precipitation totals were well above average in the Sahel of Africa as well as South Africa, where both regions recorded rainfall in the 90th percentile of occurrences (Figs. E1, E3).

TELECONNECTION INDICES

Month	North Atlantic			North Pacific				EURASIA		
	NAO	EA	WP	EP-NP	PNA	TNH	EATL/ WRUS	SCAND	POLEUR	
JUN 23	-0.3	-1.1	0.3	-1.9	0.8	---	0.4	0.8	0.2	
MAY 23	0.4	-0.1	1.0	-0.8	-0.7	---	-2.2	-1.1	1.9	
APR 23	-0.8	-0.2	-0.2	-0.7	-0.7	---	-0.2	1.3	-0.7	
MAR 23	-1.6	0.5	0.6	0.4	-1.9	---	2.0	-2.1	0.9	
FEB 23	0.6	-0.8	2.5	-0.5	-1.2	1.7	1.5	-0.7	-0.9	
JAN 23	0.9	-1.0	2.0	1.4	-0.4	-0.4	-0.6	0.7	-1.1	
DEC 22	-0.2	-0.0	-0.0	---	-1.0	-0.7	-1.2	0.9	-1.2	
NOV 22	0.6	1.2	0.3	0.4	-0.7	---	0.8	1.6	-0.3	
OCT 22	-0.3	0.2	1.0	-0.1	0.3	---	-0.7	-0.2	1.1	
SEP 22	-1.4	-1.2	1.8	-0.8	0.1	---	-1.1	0.5	-0.6	
AUG 22	1.8	1.4	-0.4	-1.1	0.8	---	-3.4	1.0	-0.3	
JUL 22	-0.1	1.4	-0.5	-1.6	2.0	---	-1.2	-0.5	0.0	
JUN 22	0.2	0.5	-1.7	-0.0	-0.2	---	-0.5	0.0	-1.3	

TABLE E1-Standardized amplitudes of selected Northern Hemisphere teleconnection patterns for the most recent thirteen months (computational procedures are described in Fig. E7). Pattern names and abbreviations are North Atlantic Oscillation (NAO); East Atlantic pattern (EA); West Pacific pattern (WP); East Pacific - North Pacific pattern (EP-NP); Pacific/North American pattern (PNA); Tropical/Northern Hemisphere pattern (TNH); East Atlantic/Western Russia pattern (EATL/WRUS)-called Eurasia-2 pattern by Barnston and Livezey, 1987, *Mon. Wea. Rev.*, **115**, 1083-1126); Scandinavia pattern (SCAND)-called Eurasia-1 pattern by Barnston and Livezey (1987); and Polar Eurasia pattern (POLEUR). No value is plotted for calendar months in which the pattern does not appear as a leading mode.

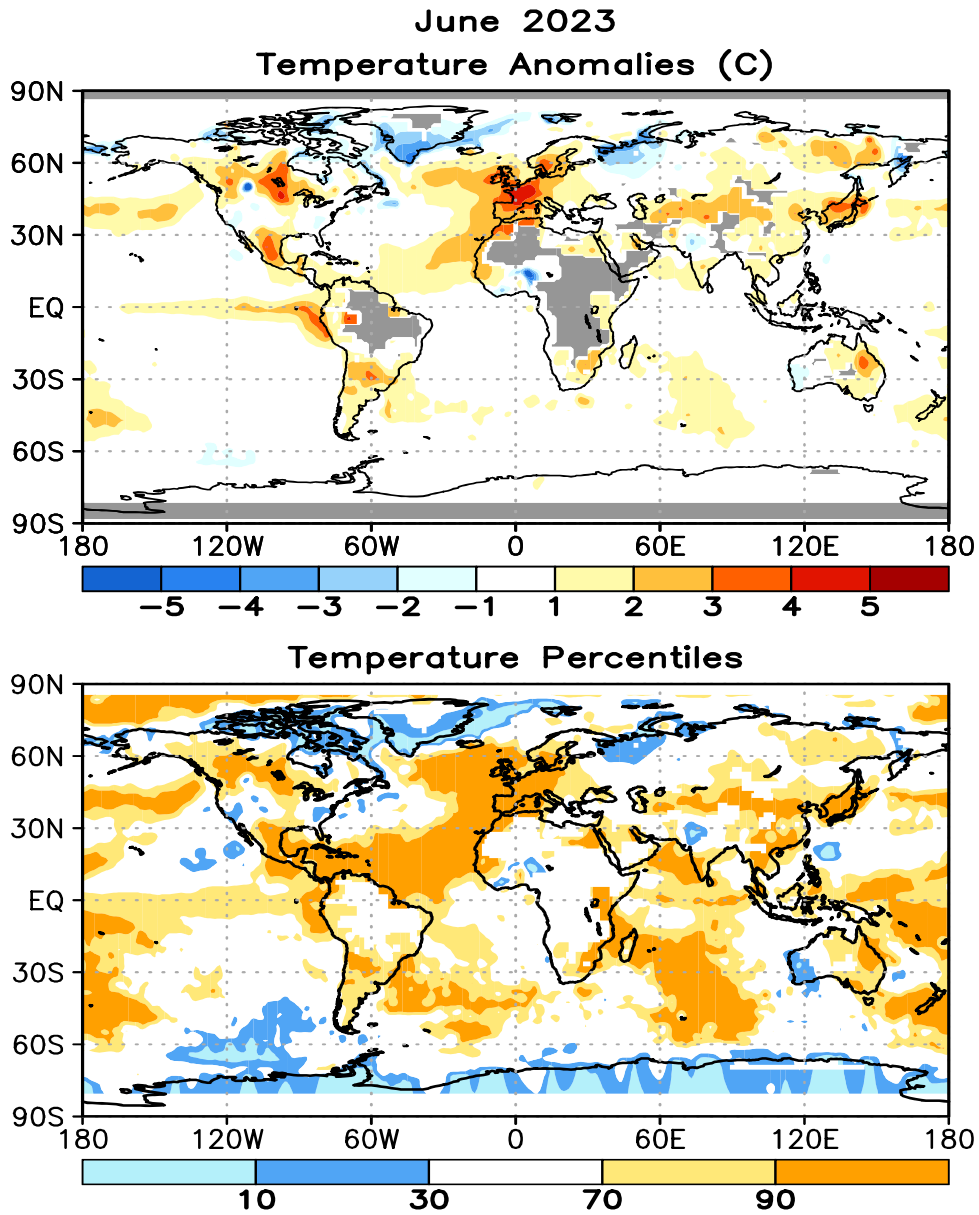


FIGURE E1. Surface temperature anomalies ($^{\circ}\text{C}$, top) and surface temperature expressed as percentiles of the normal (Gaussian) distribution fit to the 1991-2020 base period data (bottom) for JUN 2023. Analysis is based on station data over land and on SST data over the oceans (top). Anomalies for station data are departures from the 1991-2020 base period means, while SST anomalies are departures from the 1991-2020 adjusted OI climatology. (Smith and Reynolds 1998, *J. Climate*, **11**, 3320-3323). Regions with insufficient data for analysis in both figures are indicated by shading in the top figure only.

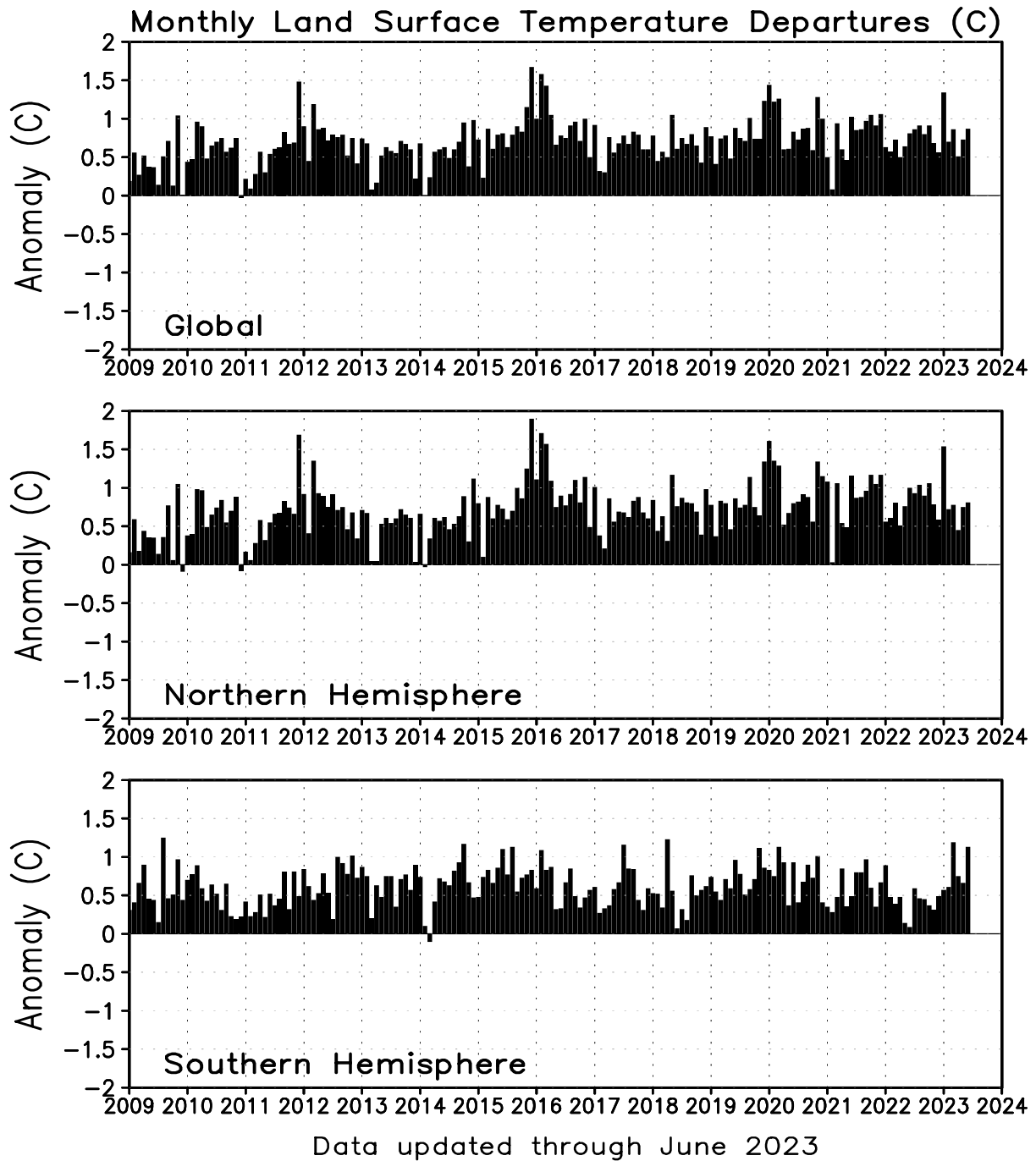


FIGURE E2. Monthly global (top), Northern Hemisphere (middle), and Southern Hemisphere (bottom) surface temperature anomalies (land only, °C) from January 1990 - present, computed as departures from the 1991-2020 base period means.

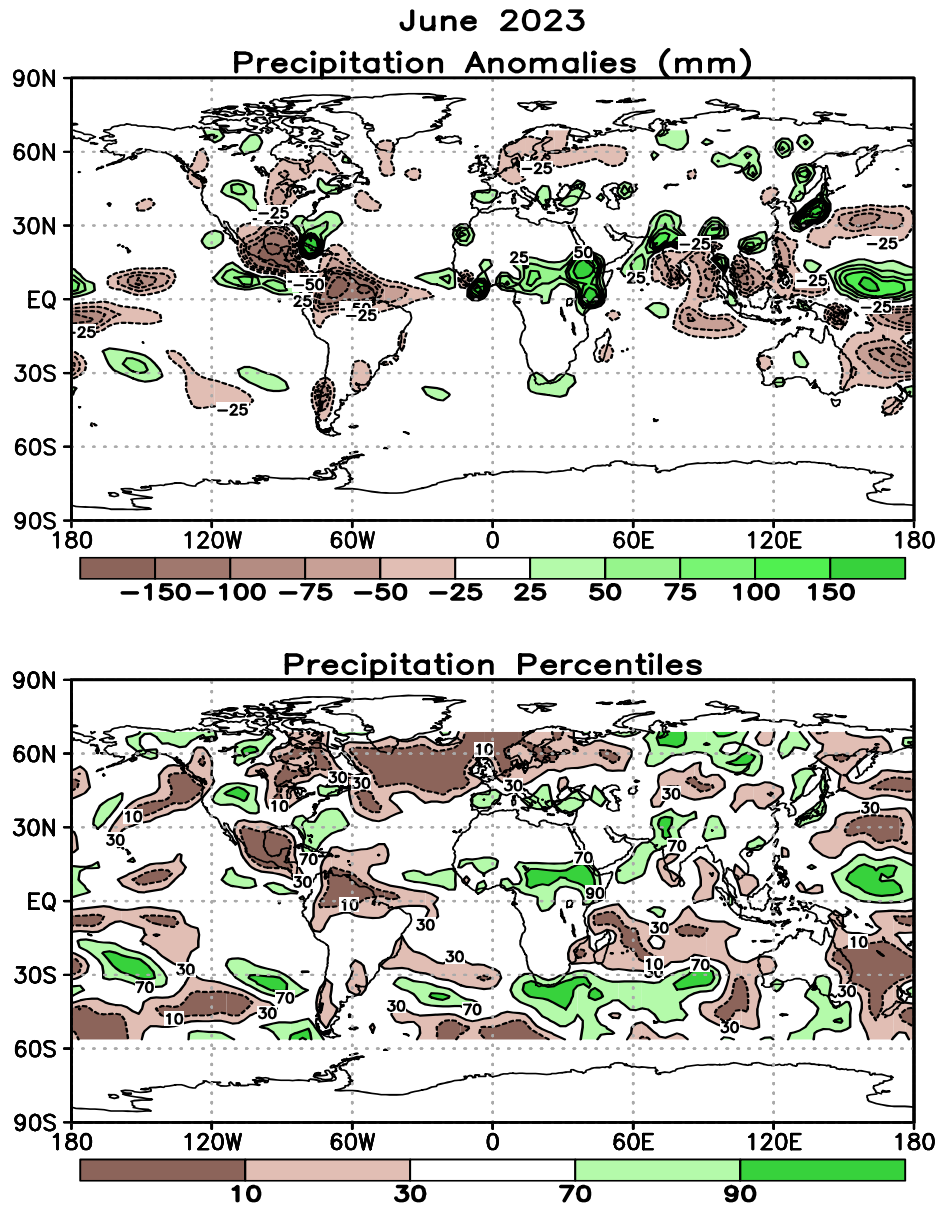


FIGURE E3. Anomalous precipitation (mm, top) and precipitation percentiles based on a Gamma distribution fit to the 1981-2010 base period data (bottom) for JUN 2023. Data are obtained from a merge of raingauge observations and satellite-derived precipitation estimates (Janowiak and Xie 1999, *J. Climate*, **12**, 3335–3342). Contours are drawn at 200, 100, 50, 25, -25, -50, -100, and -200 mm in top panel. Percentiles are not plotted in regions where mean monthly precipitation is <5mm/month.

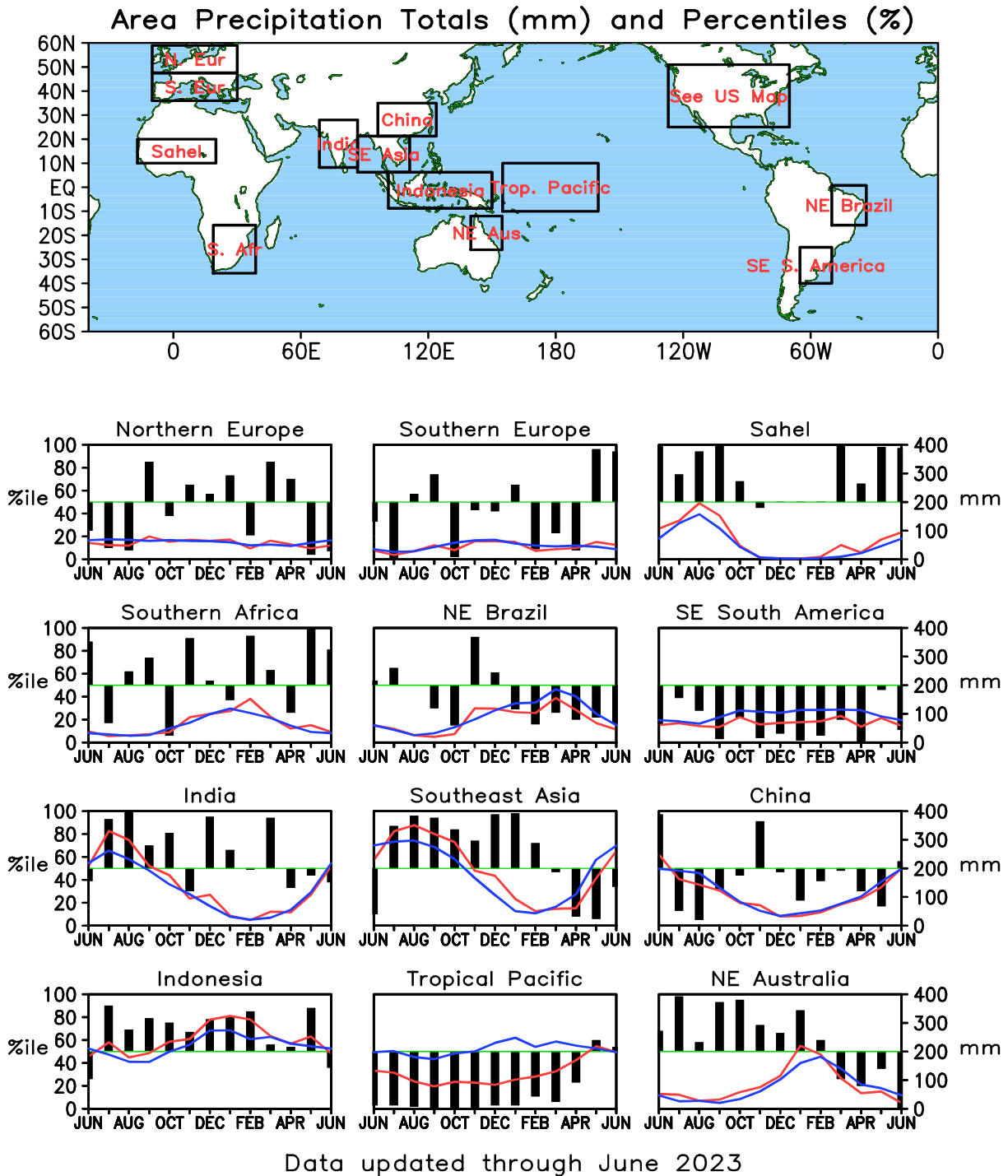


FIGURE E4. Areal estimates of monthly mean precipitation amounts (mm, solid lines) and precipitation percentiles (% bars) for the most recent 13 months obtained from a merge of raingauge observations and satellite-derived precipitation estimates (Janowiak and Xie 1999, *J. Climate*, **12**, 3335–3342). The monthly precipitation climatology (mm, dashed lines) is from the 1981-2010 base period monthly means. Monthly percentiles are not shown if the monthly mean is less than 5 mm.

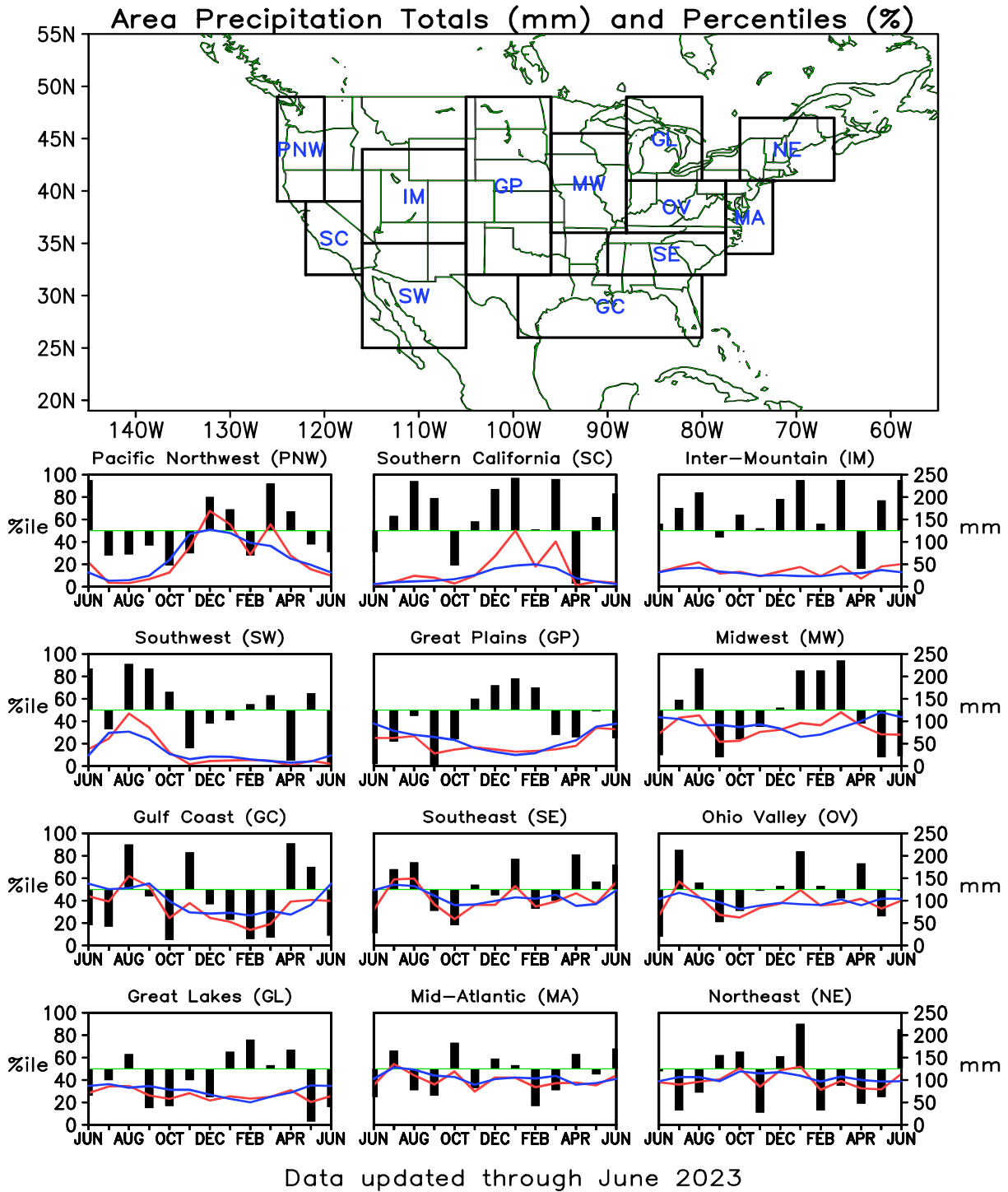


FIGURE E5. Areal estimates of monthly mean precipitation amounts (mm, solid lines) and precipitation percentiles (%) for the most recent 13 months obtained from a merge of raingauge observations and satellite-derived precipitation estimates (Janowiak and Xie 1999, *J. Climate*, 12, 3335–3342). The monthly precipitation climatology (mm, dashed lines) is from the 1981-2010 base period monthly means. Monthly percentiles are not shown if the monthly mean is less than 5 mm.

Monthly Accumulation -- June, 2023

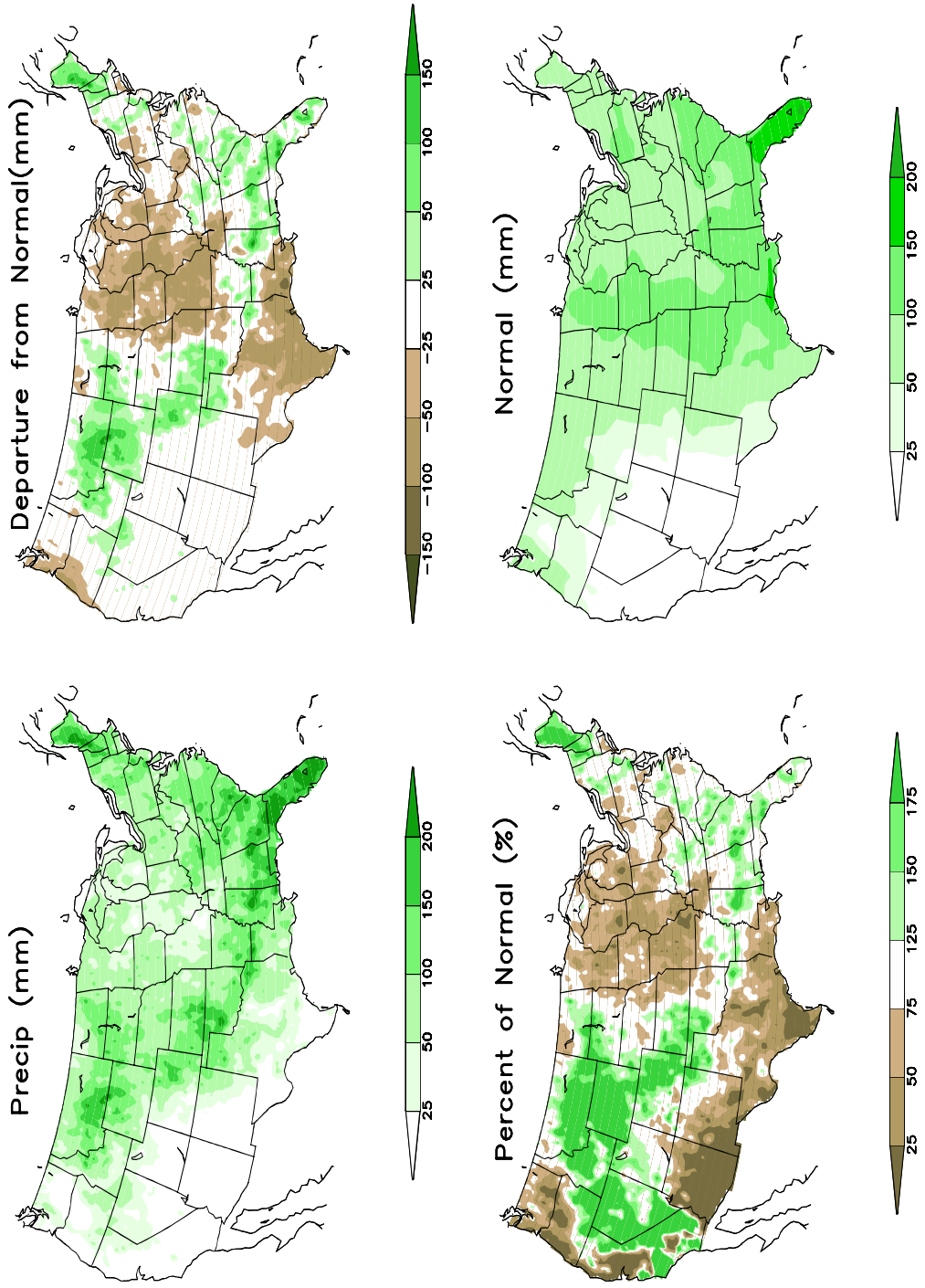


FIGURE E6. Observed precipitation (upper left), departure from average (upper right), percent of average (lower left), and average precipitation (lower right) for JUN 2023. The units are given on each panel. Base period for averages is 1991-2020. Results are based on CPC's U. S. daily precipitation analysis, which is available at <http://www.cpc.ncep.noaa.gov/products/precip/realtime>.

Monthly Teleconnection Indices Through June 2023

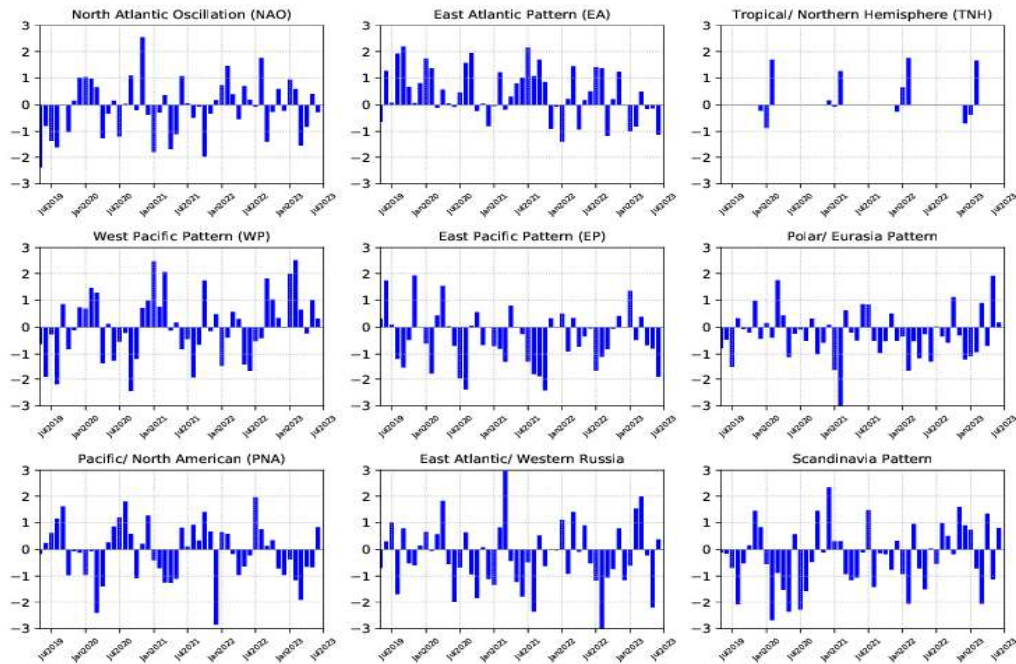


FIGURE E7. Standardized monthly Northern Hemisphere teleconnection indices. The teleconnection patterns are calculated from a Rotated Principal Component Analysis (RPCA) applied to monthly standardized 500-hPa height anomalies during the 1991-2020 base period. To obtain these patterns, ten leading un-rotated modes are first calculated for each calendar month by using the monthly height anomaly fields for the three-month period centered on that month: [i.e., The July modes are calculated from the June, July, and August standardized monthly anomalies]. A Varimax spatial rotation of the ten leading un-rotated modes for each calendar month results in 120 rotated modes (12 months x 10 modes per month) that yield ten primary teleconnection patterns. The teleconnection indices are calculated by first projecting the standardized monthly anomalies onto the teleconnection patterns corresponding to that month (eight or nine teleconnection patterns are seen in each calendar month). The indices are then solved for simultaneously using a Least-Squares approach. In this approach, the indices are the solution to the Least-Squares system of equations which explains the maximum spatial structure of the observed height anomaly field during the month. The indices are then standardized for each pattern and calendar month independently. No index value exists when the teleconnection pattern does not appear as one of the ten leading rotated EOF's valid for that month.

June 2023
Sea-Level Pressure and Anomaly

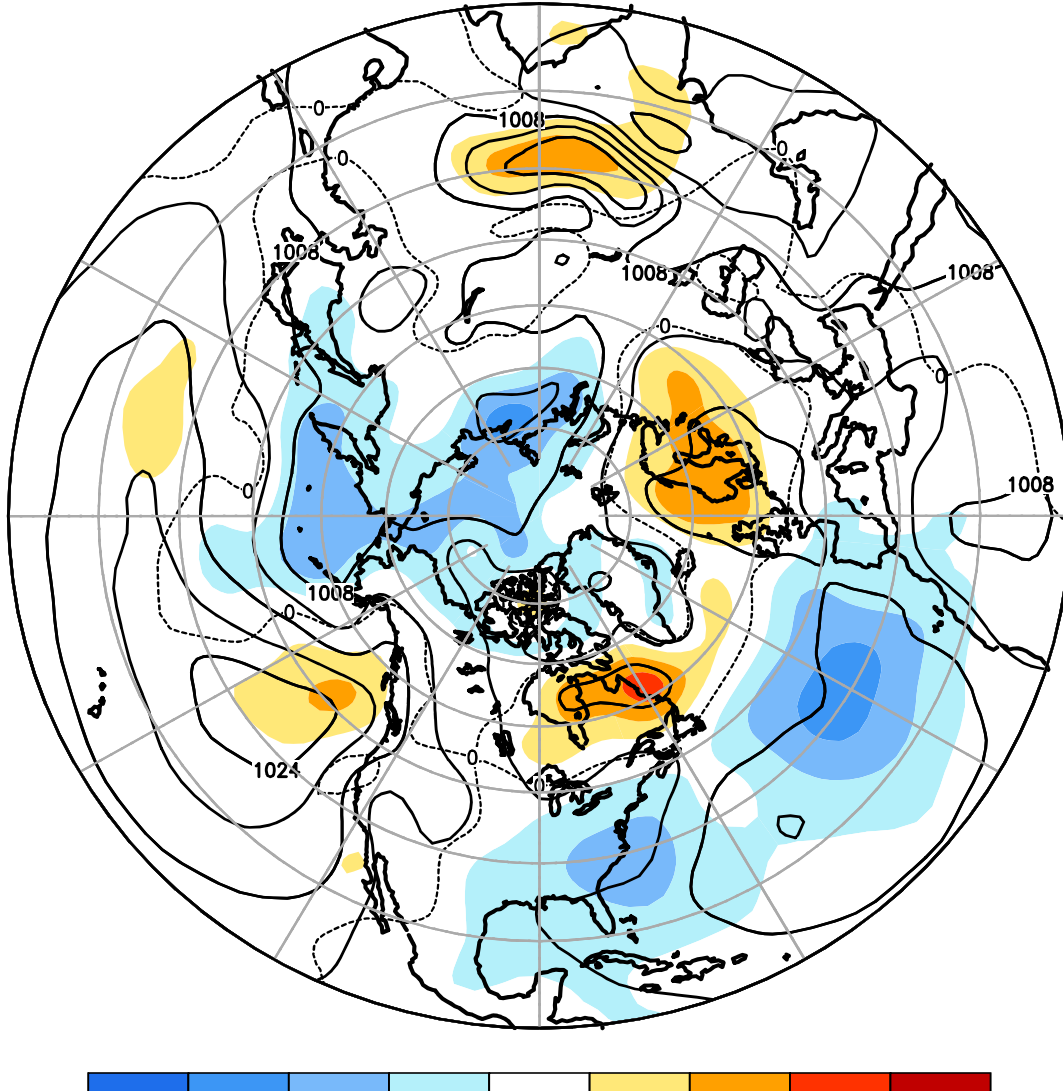


FIGURE E8. Northern Hemisphere mean and anomalous sea level pressure (CDAS/Reanalysis) for JUN 2023. Mean values are denoted by solid contours drawn at an interval of 4 hPa. Anomaly contour interval is 2 hPa with values less (greater) than -2 hPa (2 hPa) indicated by dark (light) shading. Anomalies are calculated as departures from the 1991-2020 base period monthly means.

June 2023
500-hPa Height and Anomaly

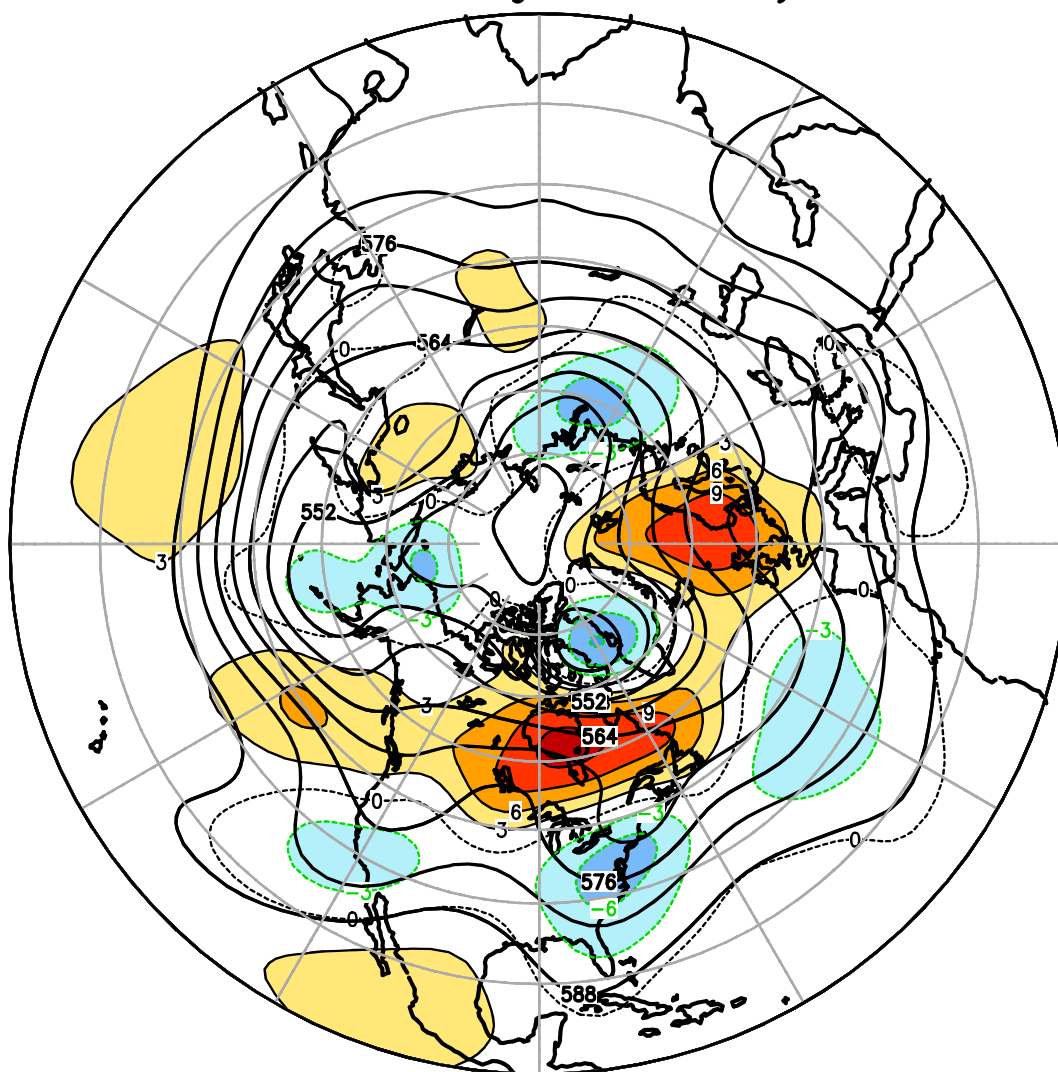


FIGURE E9. Northern Hemisphere mean and anomalous 500-hPa geopotential height (CDAS/Reanalysis) for JUN 2023. Mean heights are denoted by solid contours drawn at an interval of 6 dam. Anomaly contour interval is 3 dam with values less (greater) than -3 dam (3 dam) indicated by dark (light) shading. Anomalies are calculated as departures from the 1991-2020 base period monthly means.

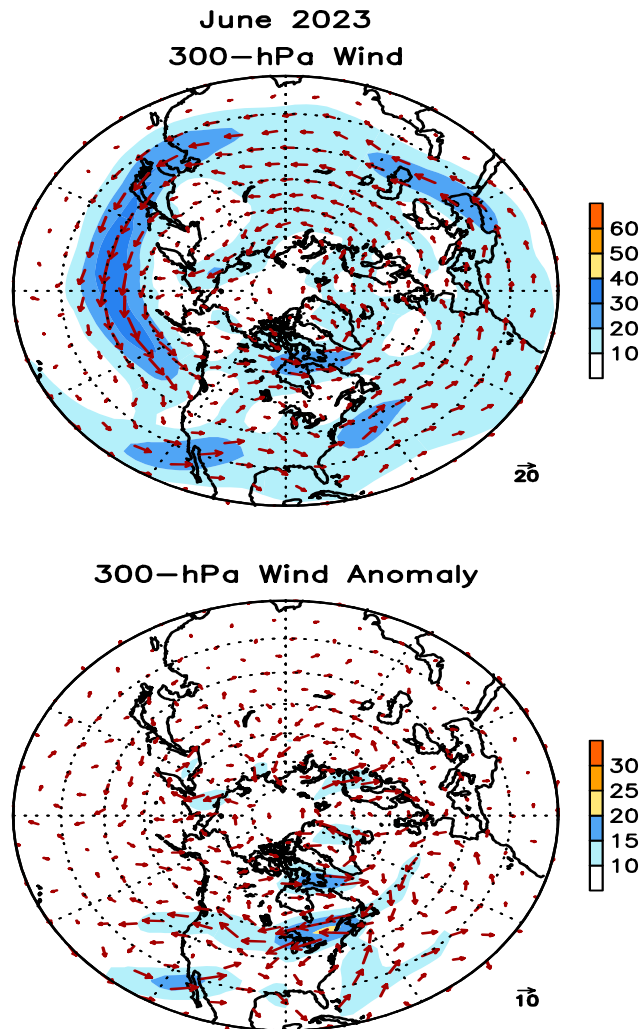


FIGURE E10. Northern Hemisphere mean (left) and anomalous (right) 300-hPa vector wind (CDAS/Reanalysis) for JUN 2023. Mean (anomaly) isotach contour interval is 10 (5) ms^{-1} . Values greater than 30 ms^{-1} (left) and 10 ms^{-1} (rights) are shaded. Anomalies are departures from the 1991-2020 base period monthly means.

June 2023
500-hPa: Percentage of Anomaly Days

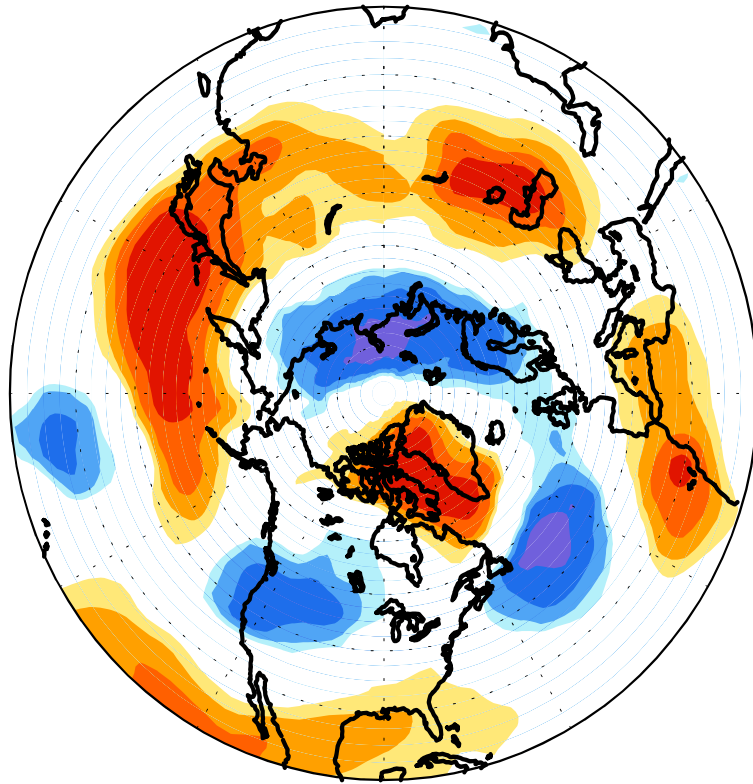


FIGURE E11. Northern Hemisphere percentage of days during JUN 2023 in which 500-hPa height anomalies greater than 15 m (red) and less than -15 m (blue) were observed. Values greater than 70% are shaded and contour in-

June 2023
500-hPa Height Anomalies: 40°N

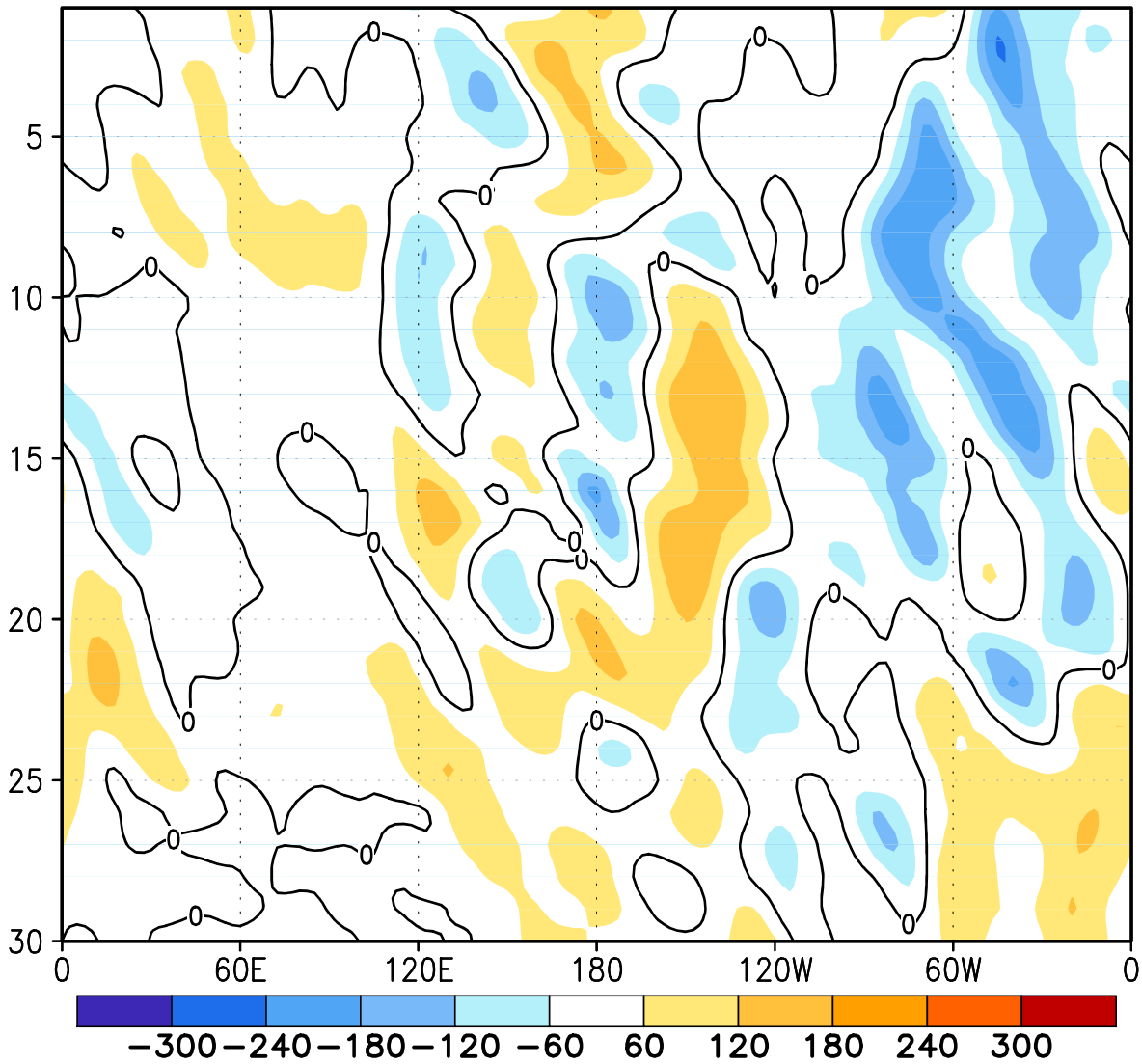
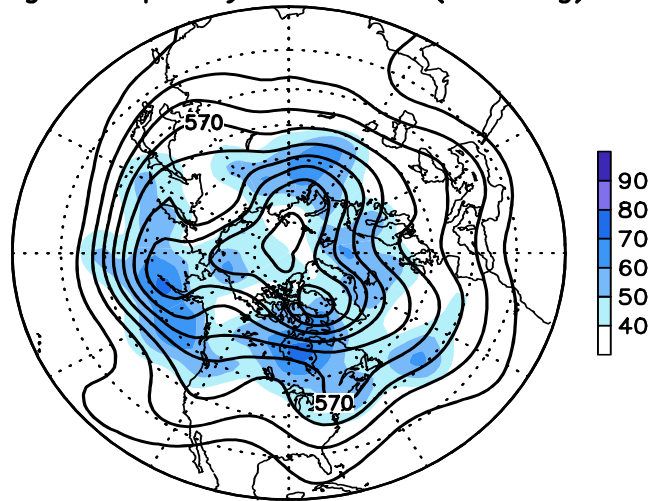


FIGURE E12. Northern Hemisphere: Daily 500-hPa height anomalies for JUN 2023 averaged over the 5° latitude band centered on 40°N. Positive values are indicated by solid contours and dark shading. Negative values are indicated by dashed contours and light shading. Contour interval is 60 m. Anomalies are departures from the 1991-2020 base period daily means.

June 2023
500-hPa Heights (Contours)
High Frequency Std. Dev. (Shading)



500-hPa Heights (Contours)
Normalized High Frequency Variance (Shading)

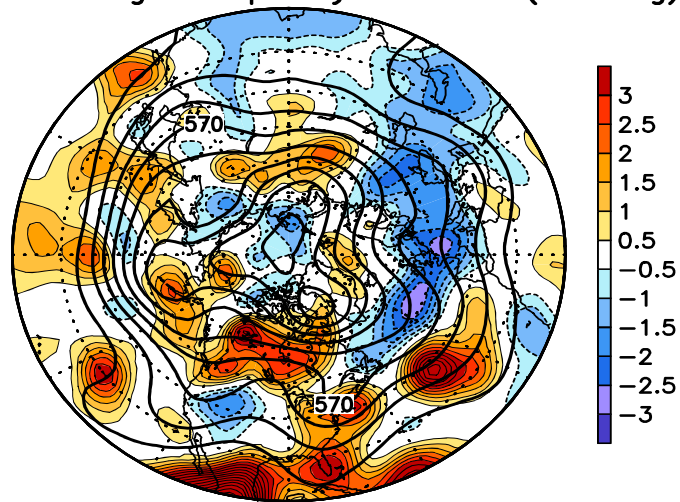


FIGURE E13. Northern Hemisphere 500-hPa heights (thick contours, interval is 6 dam) overlaid with (Top) Standard deviation of 10-day high-pass (HP) filtered height anomalies and (Bottom) Normalized anomalous variance of 10-day HP filtered height anomalies. A Lanczos filter is used to calculate the HP filtered anomalies. Anomalies are departures from the 1991-2020 daily means.

June 2023
Sea-Level Pressure and Anomaly

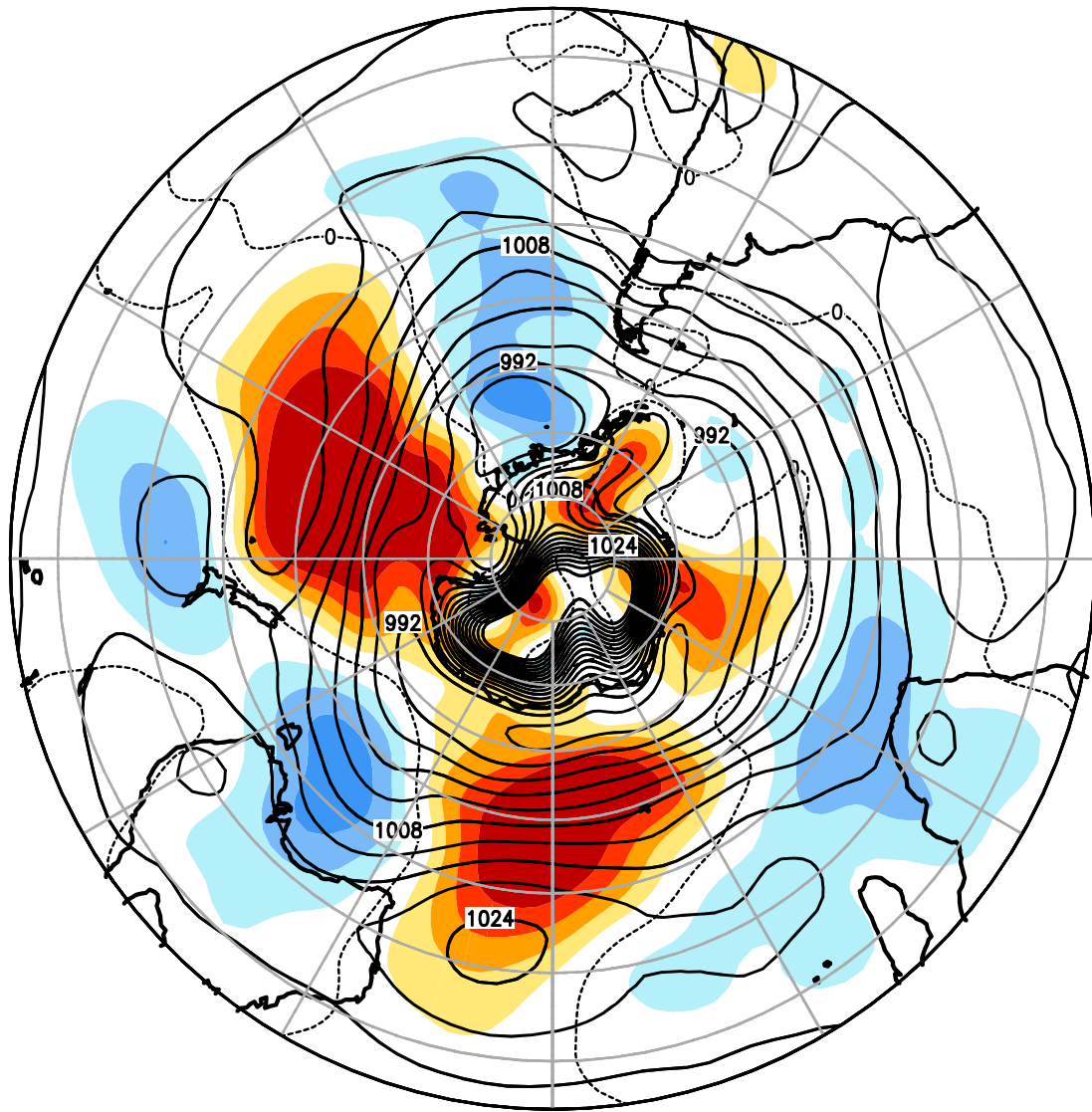


FIGURE E14. Southern Hemisphere mean and anomalous sea level pressure(CDAS/Reanalysis) for JUN 2023. Mean values are denoted by solid contours drawn at an interval of 4 hPa. Anomaly contour interval is 2 hPa with values less (greater) than -2 hPa (2 hPa) indicated by dark (light) shading. Anomalies are calculated as departures from the 1991-2020 base period monthly means.

June 2023
500-hPa Height and Anomaly

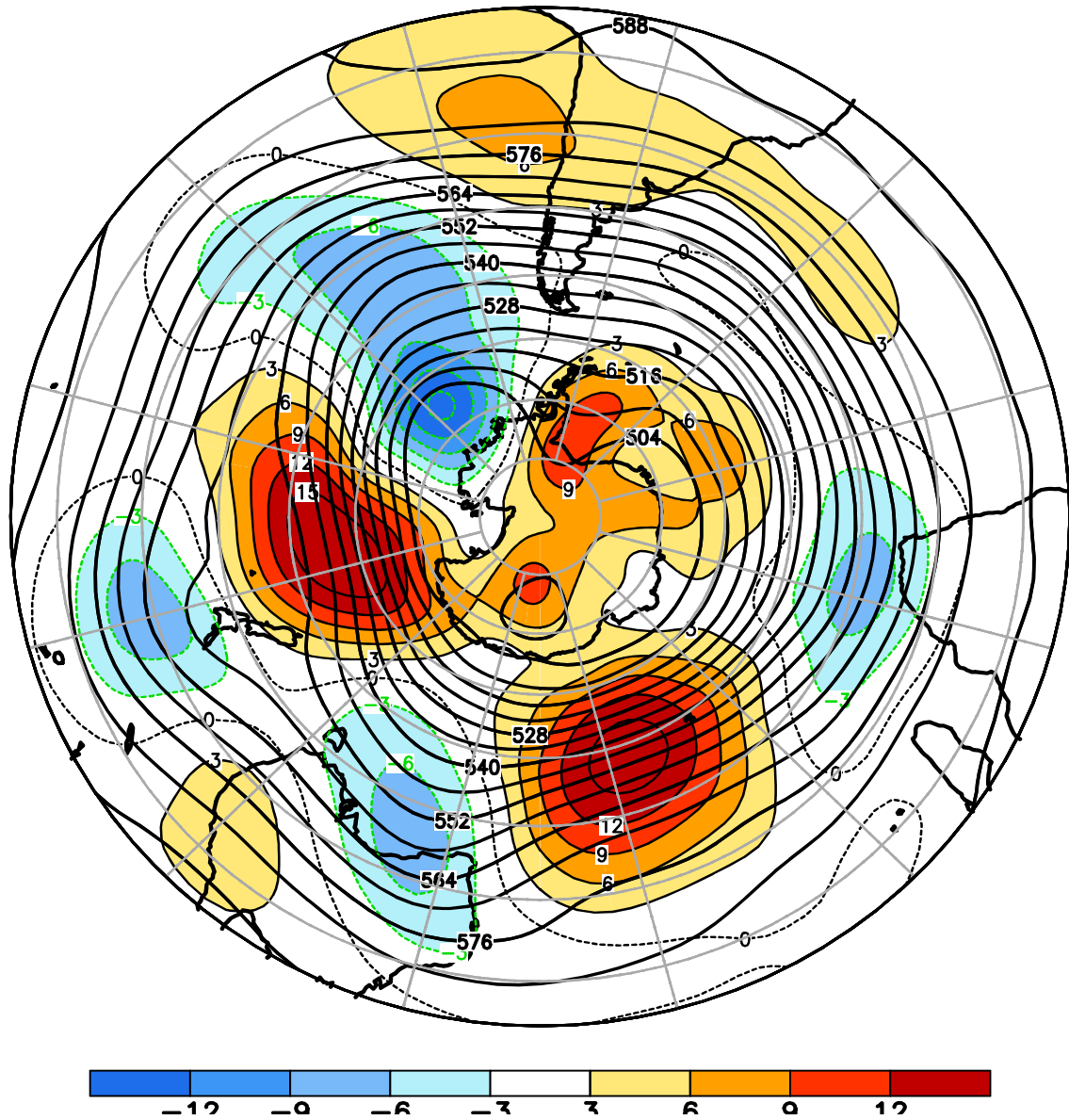


FIGURE E15. Southern Hemisphere mean and anomalous 500-hPa geopotential height (CDAS/Reanalysis) for JUN 2023. Mean heights are denoted by solid contours drawn at an interval of 6 dam. Anomaly contour interval is 3 dam with values less (greater) than -3 dam (3 dam) indicated by dark (light) shading. Anomalies are calculated as departures from the 1991-2020 base period monthly means.

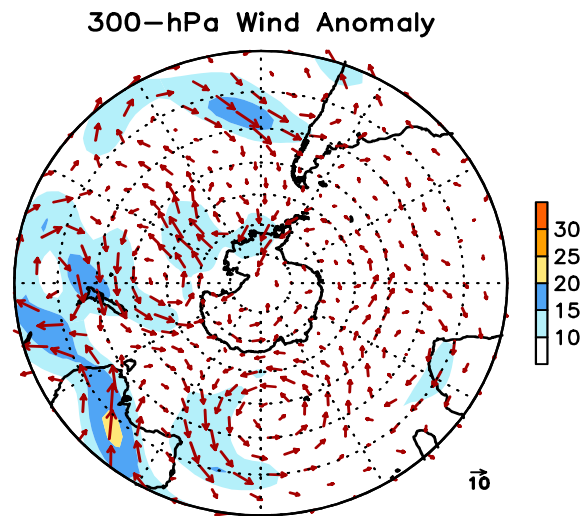
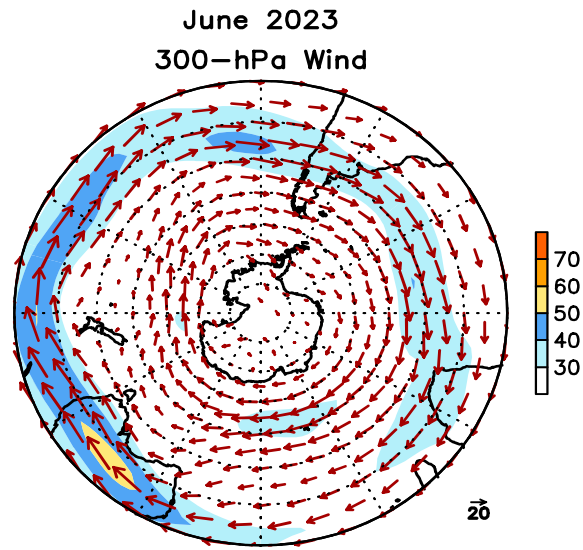


FIGURE E16. Southern Hemisphere mean (left) and anomalous (right) 300-hPa vector wind (CDAS/Reanalysis) for JUN 2023. Mean (anomaly) isotach contour interval is 10 (5) ms^{-1} . Values greater than 30 ms^{-1} (left) and 10 ms^{-1} (rights) are shaded. Anomalies are departures from the 1991-2020 base period monthly means.

June 2023

500-hPa: Percentage of Anomaly Days

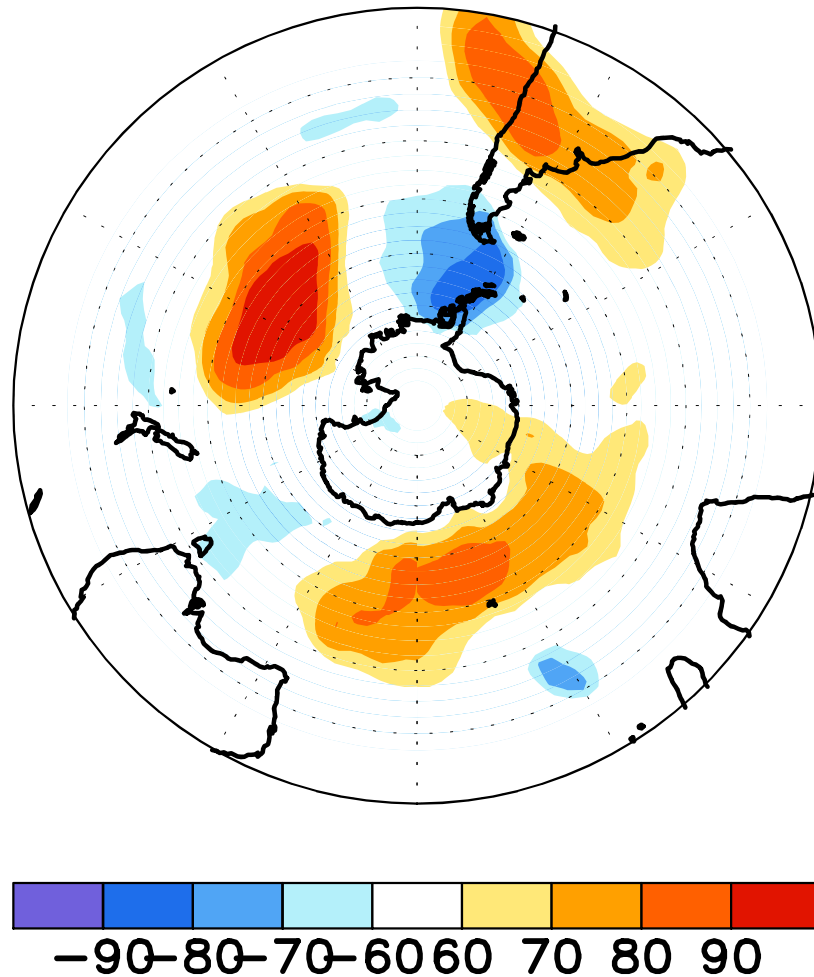


FIGURE E17. Southern Hemisphere percentage of days during JUN 2023 in which 500-hPa height anomalies greater than 15 m (red) and less than -15 m (blue) were observed. Values greater than 70% are shaded and contour in-

June 2023
500-hPa Height Anomalies: 40°S

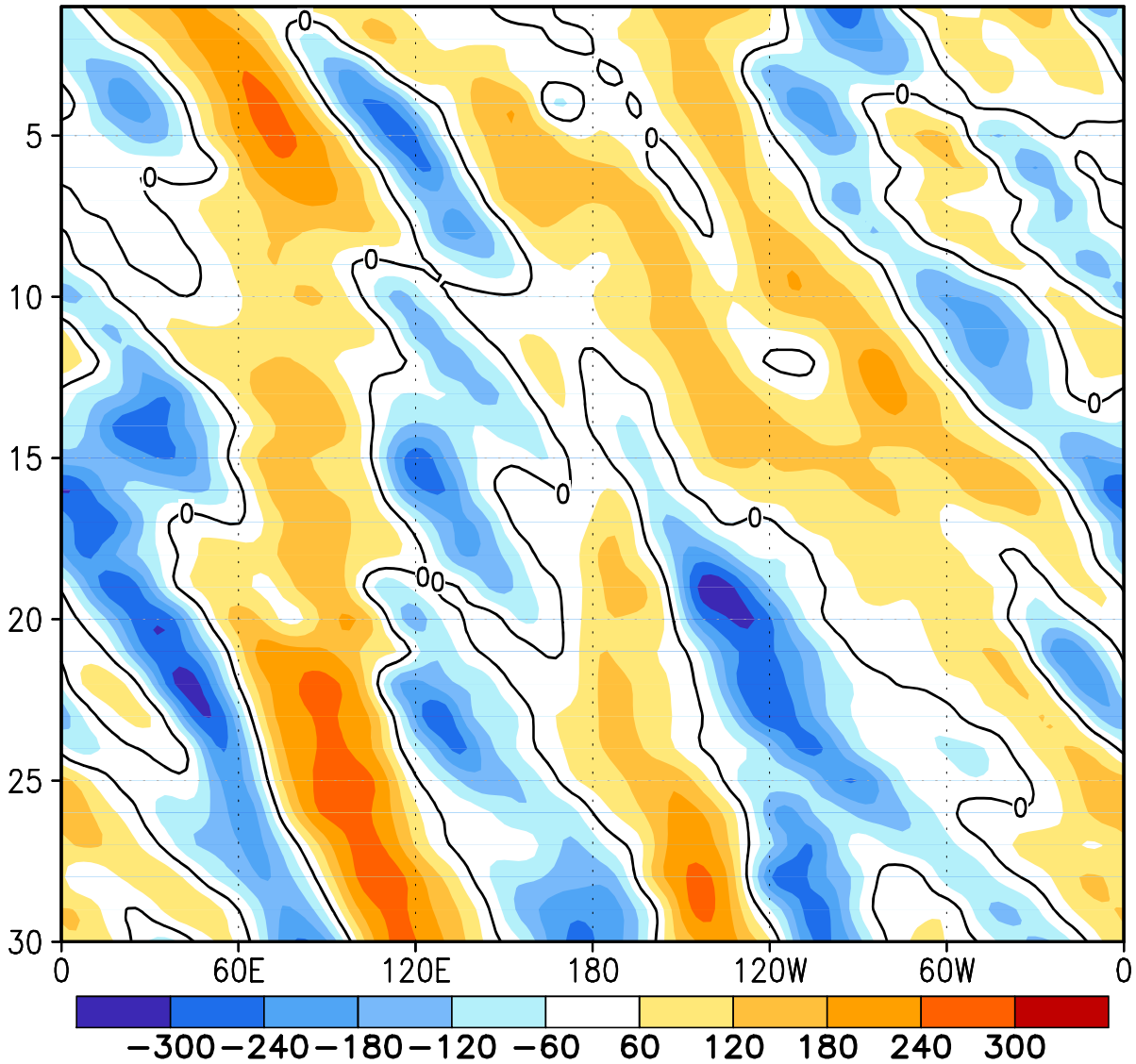


FIGURE E18. Southern Hemisphere: Daily 500-hPa height anomalies for JUN 2023 averaged over the 5° latitude band centered on 40°S. Positive values are indicated by solid contours and dark shading. Negative values are indicated by dashed contours and light shading. Contour interval is 60 m. Anomalies are departures from the 1991-2020 base period daily means.

June 2023
Height Anomalies

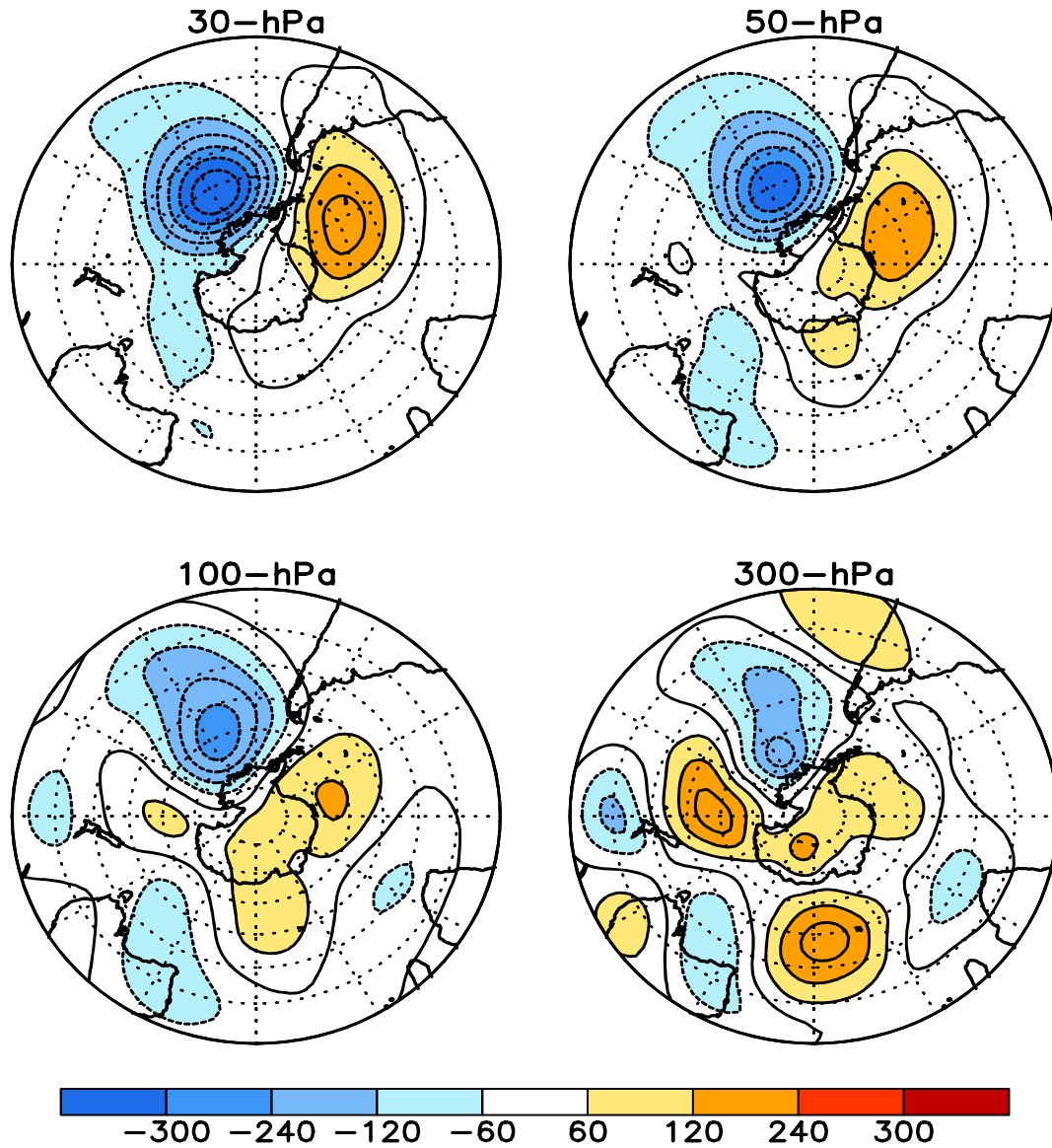


FIGURE S1. Stratospheric height anomalies (m) at selected levels for JUN 2023. Positive values are indicated by solid contours and dark shading. Negative values are indicated by dashed contours and light shading. Contour interval is 60 m. Anomalies are calculated from the 1991-2020 base period means. Winter Hemisphere is shown.

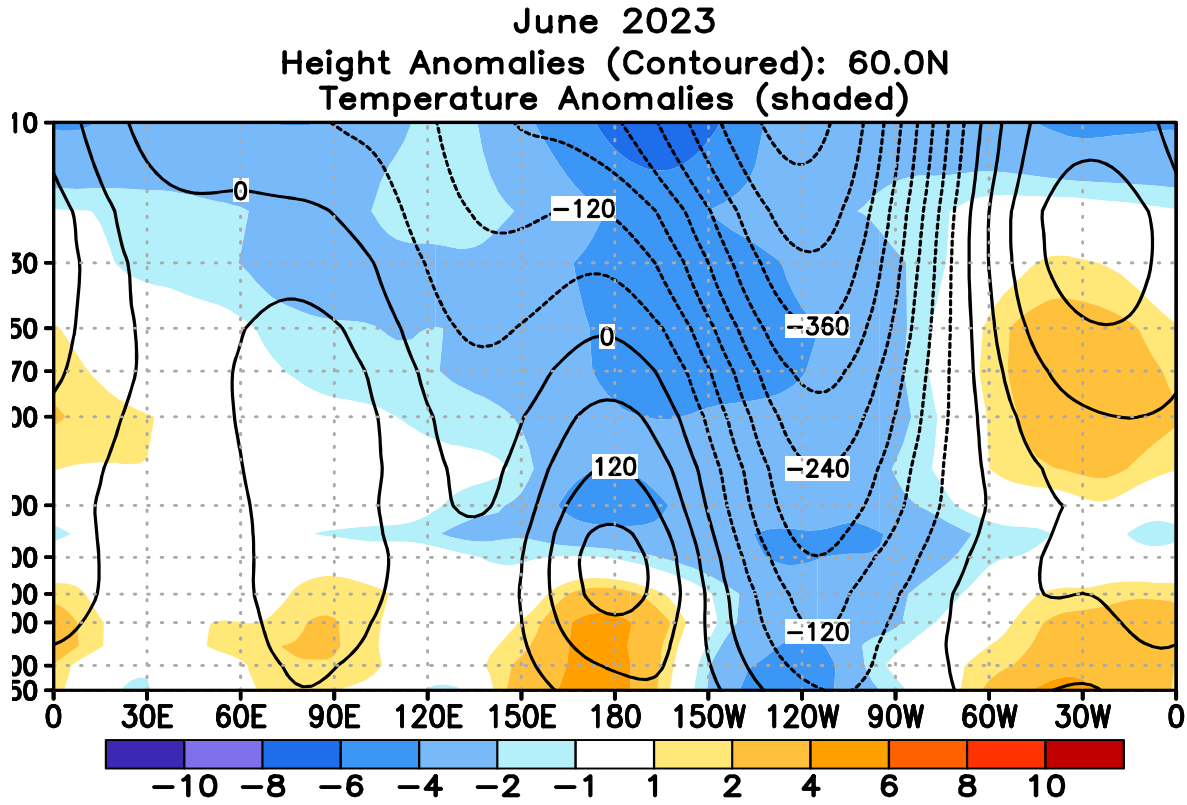


FIGURE S2. Height-longitude sections during JUN 2023 for height anomalies (contour) and temperature anomalies (shaded). In both panels, positive values are indicated by solid contours and dark shading, while negative anomalies are indicated by dashed contours and light shading. Contour interval for height anomalies is 60 m and for temperature anomalies is 2°C. Anomalies are calculated from the 1991-2020 base period monthly means. Winter Hemisphere is shown.

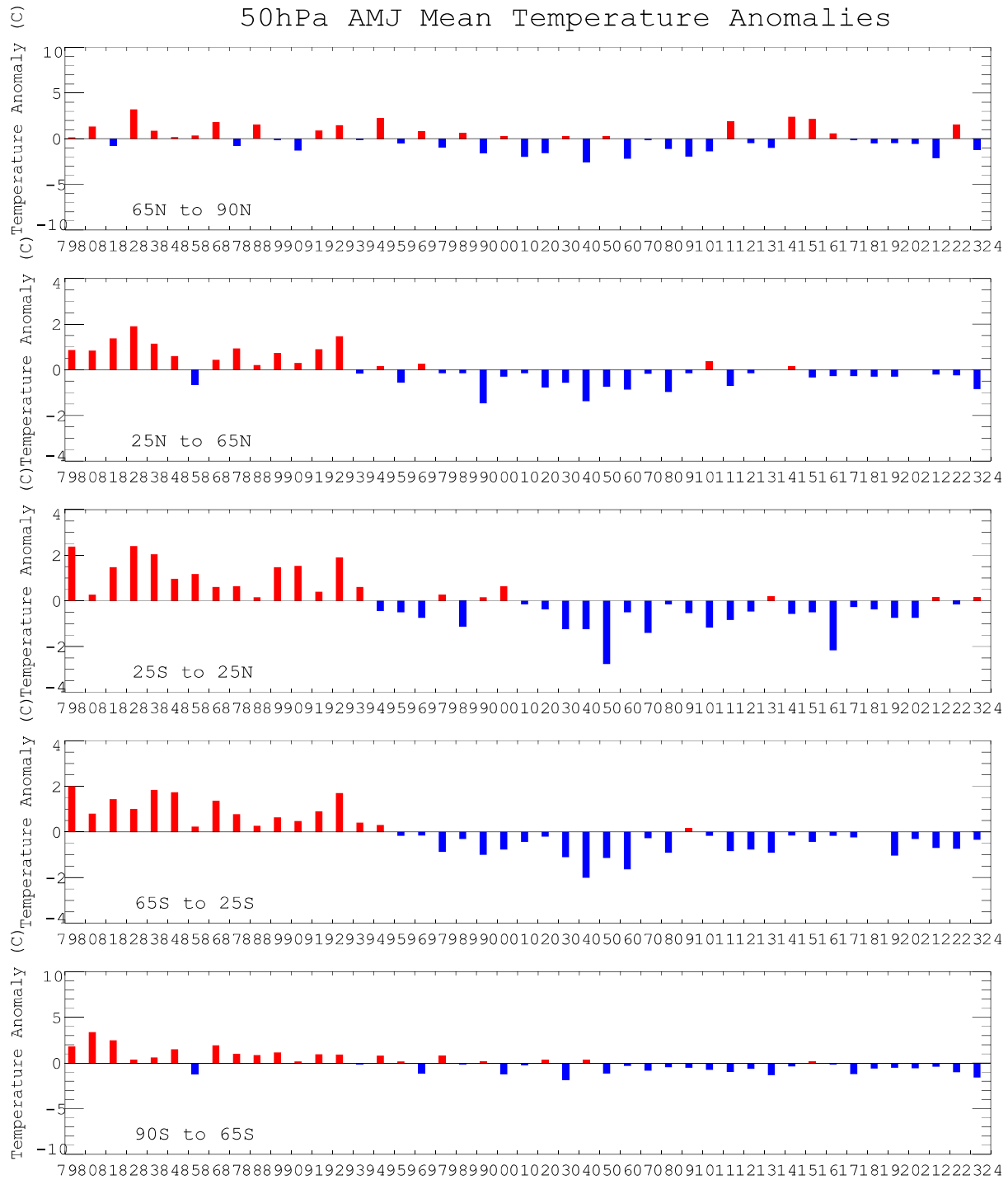


FIGURE S3. Seasonal mean temperature anomalies at 50-hPa for the latitude bands 65°–90°N, 25°–65°N, 25°N–25°S, 25°–65°S, 65°–90°S. The seasonal mean is comprised of the most recent three months. Zonal anomalies are taken from the mean of the entire data set.

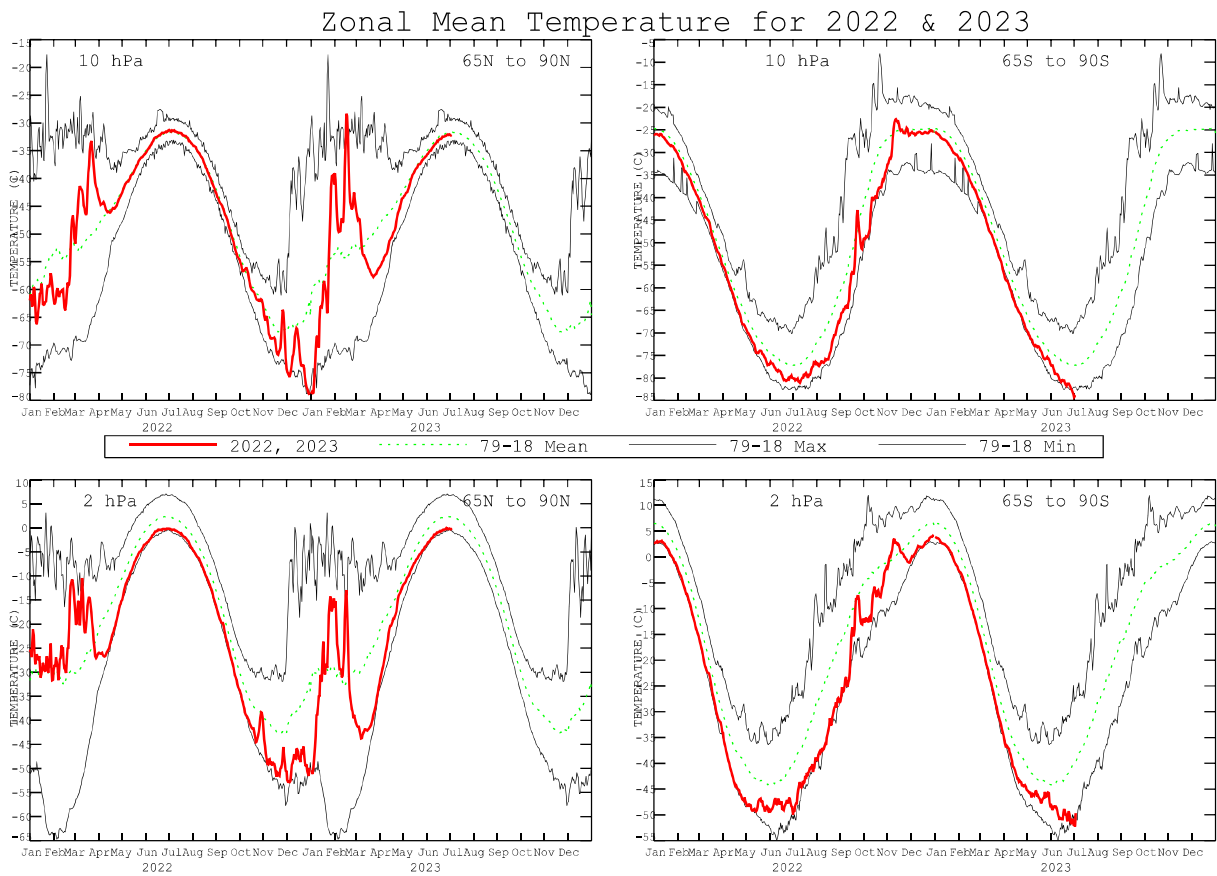


FIGURE S4. Daily mean temperatures at 10-hPa and 2-hPa (thick line) in the region 65°–90°N and 65°–90°S for the past two years. Dashed line depicts the 1991–2020 base period daily mean. Thin solid lines depict the daily extreme maximum and minimum temperatures.

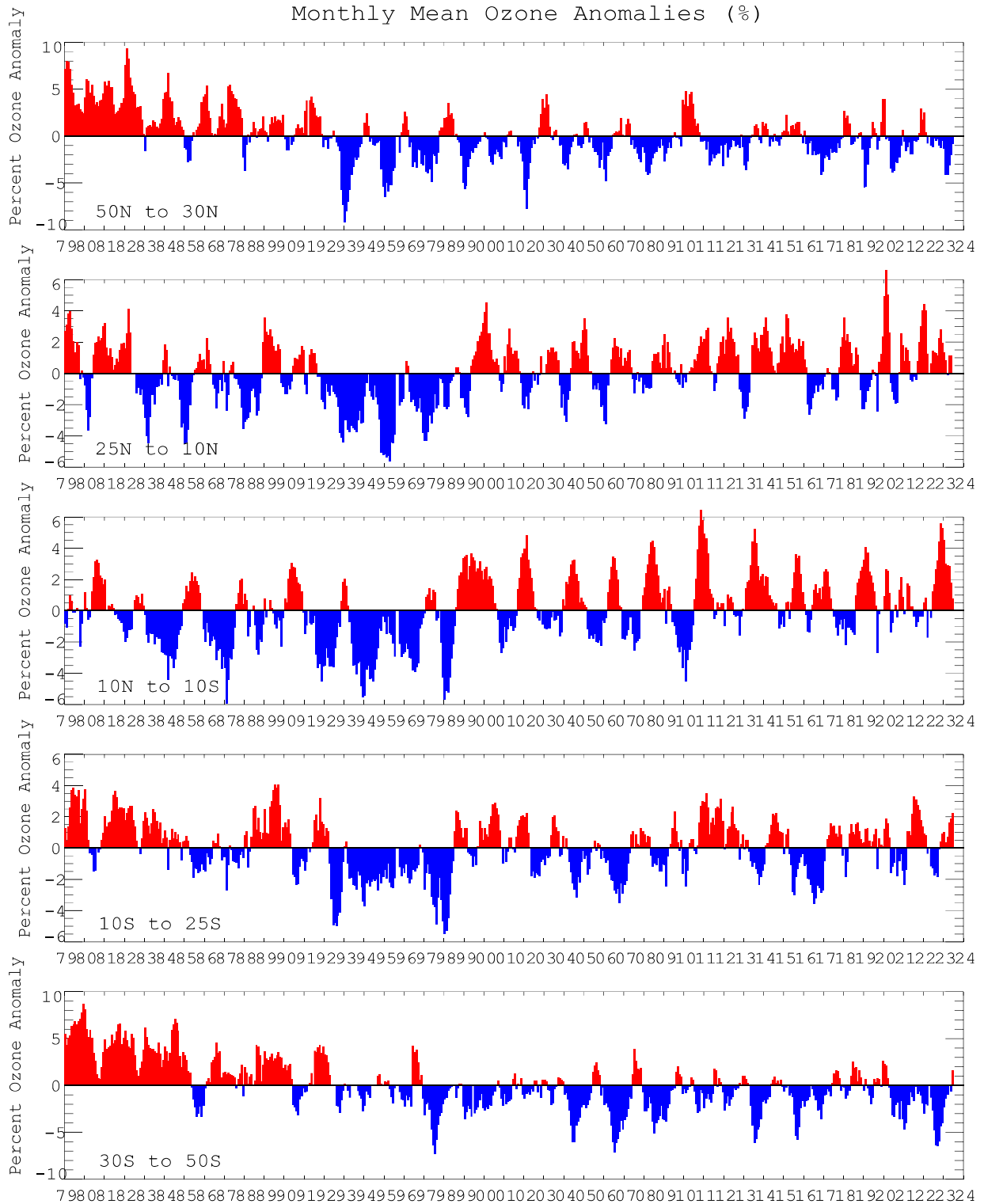


FIGURE S5. Monthly ozone anomalies (percent) from the long term monthly means for five zones: 50N-30N (NH mid-latitudes), 25N-10N (NH tropical surf zone), 10N-10S (Equatorial-QBO zone), 10S-25S (SH tropical surf zone), and 30S-50S (SH mid-latitudes). The long term monthly means are determined from the entire data set

JUNE PERCENT DIFF (2023 - AVG[79-86])

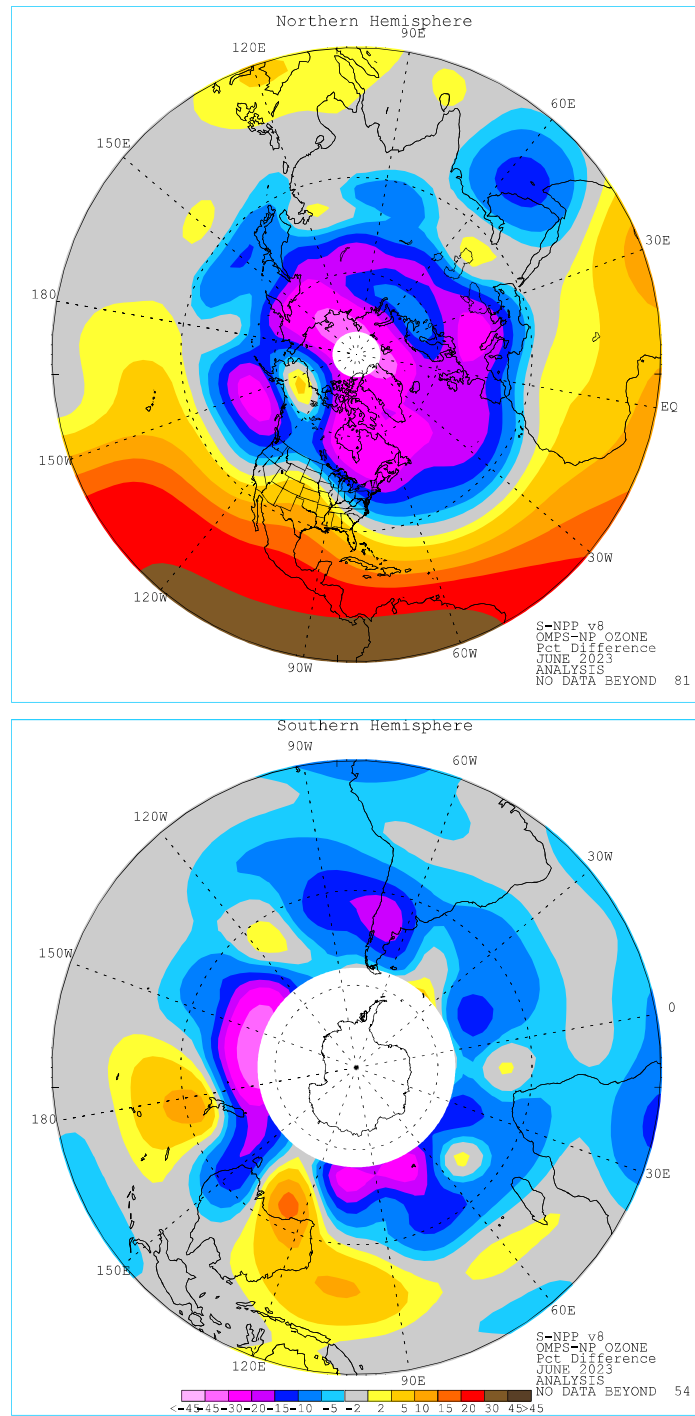


FIGURE S6. Northern (top) and Southern (bottom) Hemisphere total ozone anomaly (percent difference from monthly mean for the period 1979-1986). The region near the winter pole has no SBUV/2 data.

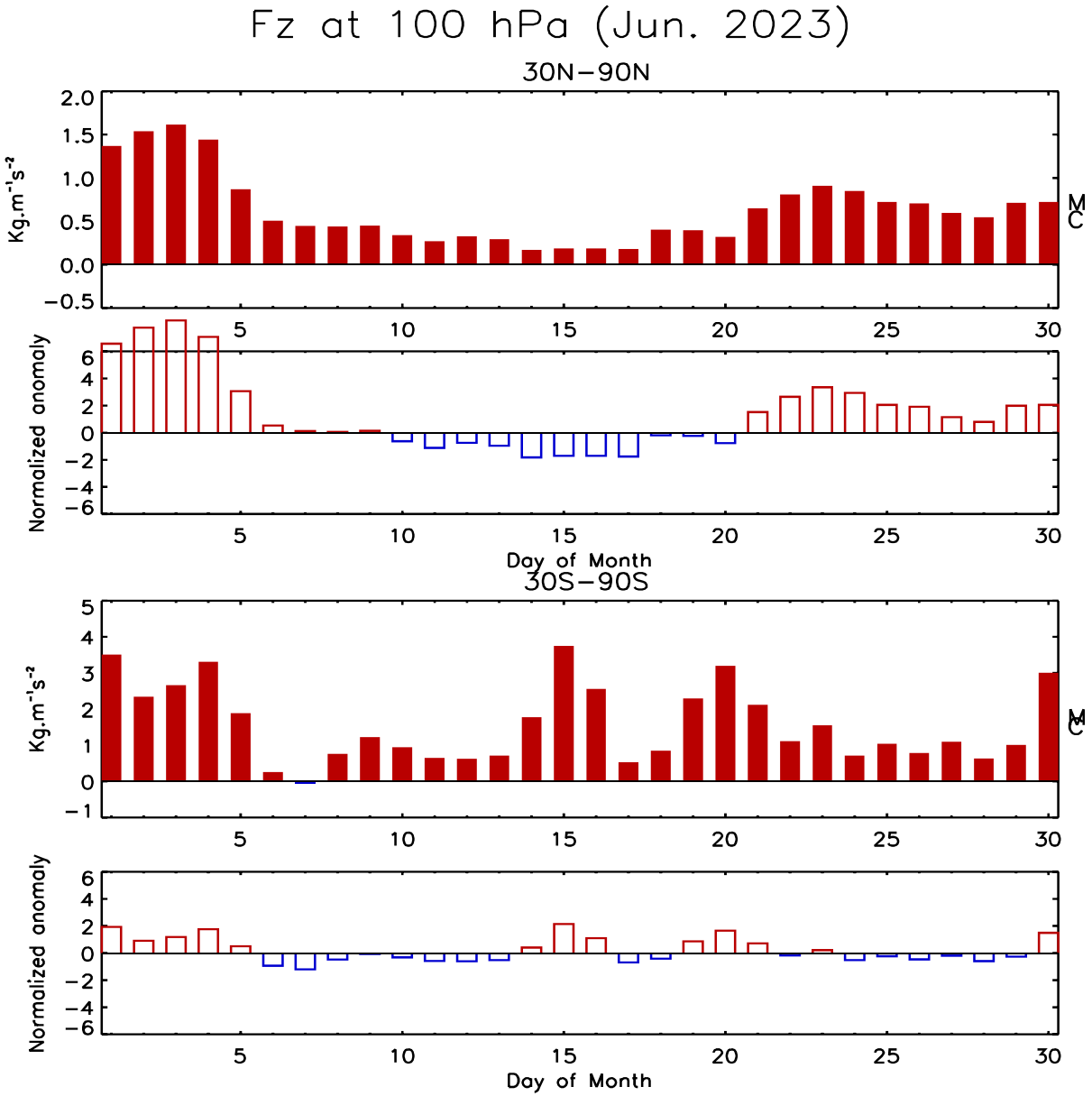


FIGURE S7. Daily vertical component of EP flux (which is proportional to the poleward transport of heat or upward transport of potential energy by planetary wave) at 100 hPa averaged over (top) 30°N–90°N and (bottom) 30°S–90°S for JUN 2023. The EP flux unit ($\text{kg m}^{-1} \text{s}^{-2}$) has been scaled by multiplying a factor of the Brunt Vaisala frequency divided by the Coriolis parameter and the radius of the earth. The letter ‘M’ indicates the current monthly mean value and the letter ‘C’ indicates the climatological mean value. Additionally, the normalized departures from the monthly climatological EP flux values are shown.

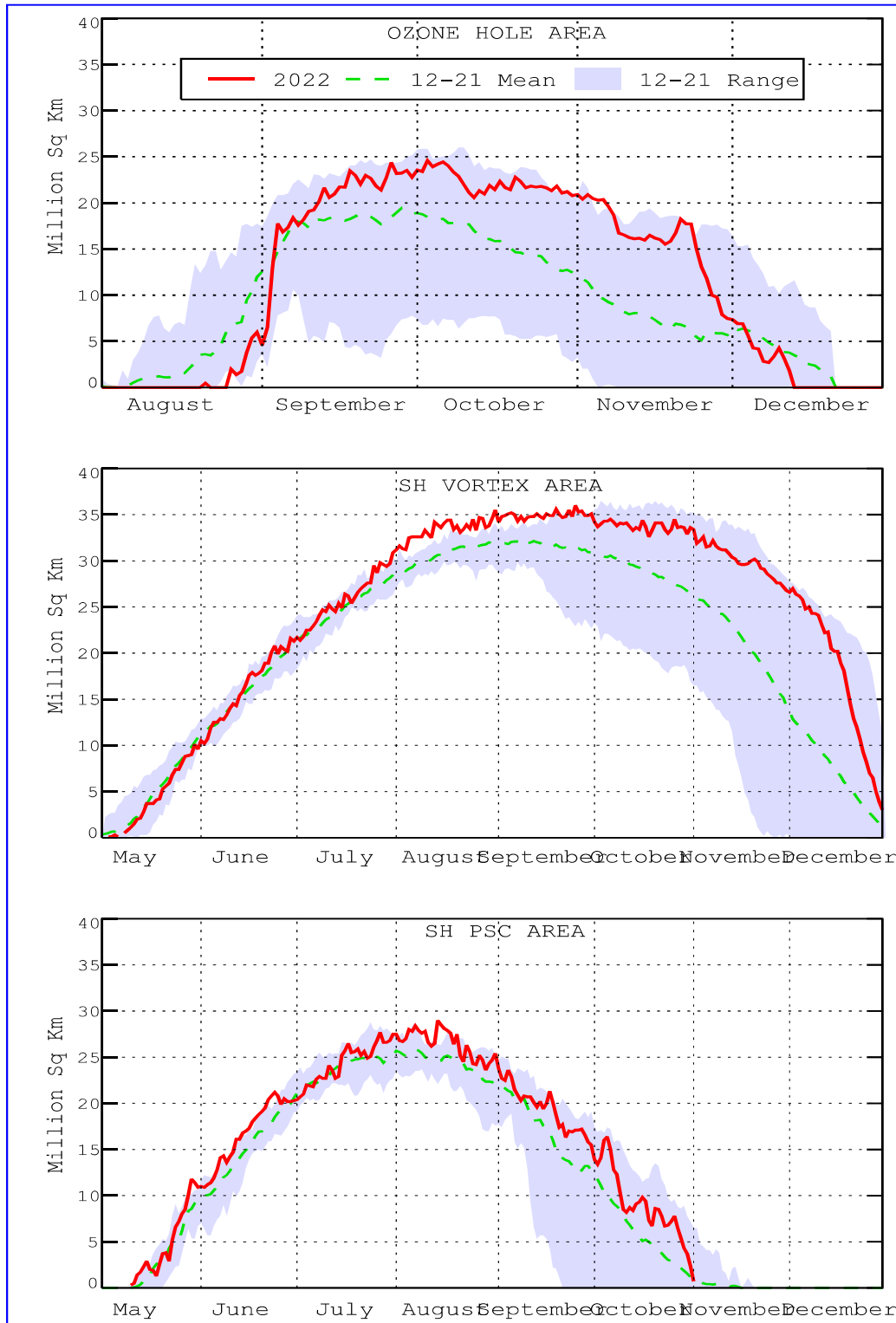


FIGURE S8. Daily time series showing the size of the SH polar vortex (representing the area enclosed by the 32 PVU contour on the 450K isentropic surface), and the areal coverage of temperatures < -78C on the 450K isentropic surface.

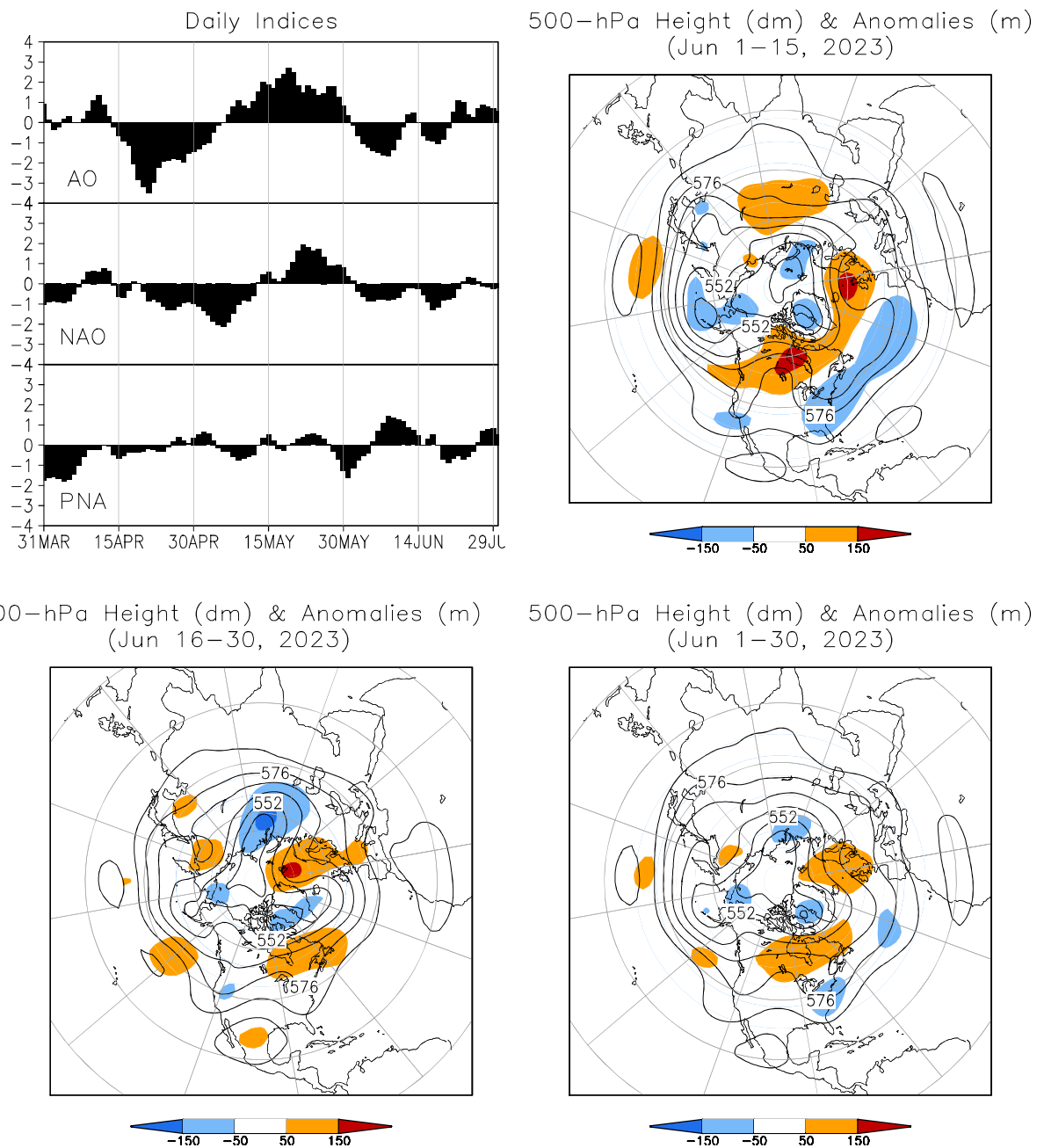


FIGURE A2.1. (a) Daily amplitudes of the Arctic Oscillation (AO) the North Atlantic Oscillation (NAO), and the Pacific-North American (PNA) pattern. The pattern amplitudes for the AO, (NAO, PNA) are calculated by projecting the daily 1000-hPa (500-hPa) height anomaly field onto the leading EOF obtained from standardized time-series of daily 1000-hPa (500-hPa) height for all months of the year. The base period is 1991-2020.

(b-d) Northern Hemisphere mean and anomalous 500-hPa geopotential height (CDAS/Reanalysis) for selected periods during JUN 2023 are shown in the remaining 3 panels. Mean heights are denoted by solid contours drawn at an interval of 8 dam. Dark (light) shading corresponds to anomalies greater than 50 m (less than -50 m). Anomalies are calculated as departures from the 1991-2020 base period daily means.

**SSM/I Snow Cover for Jun 2023
anomaly based on departure from 1987-2010 baseline**

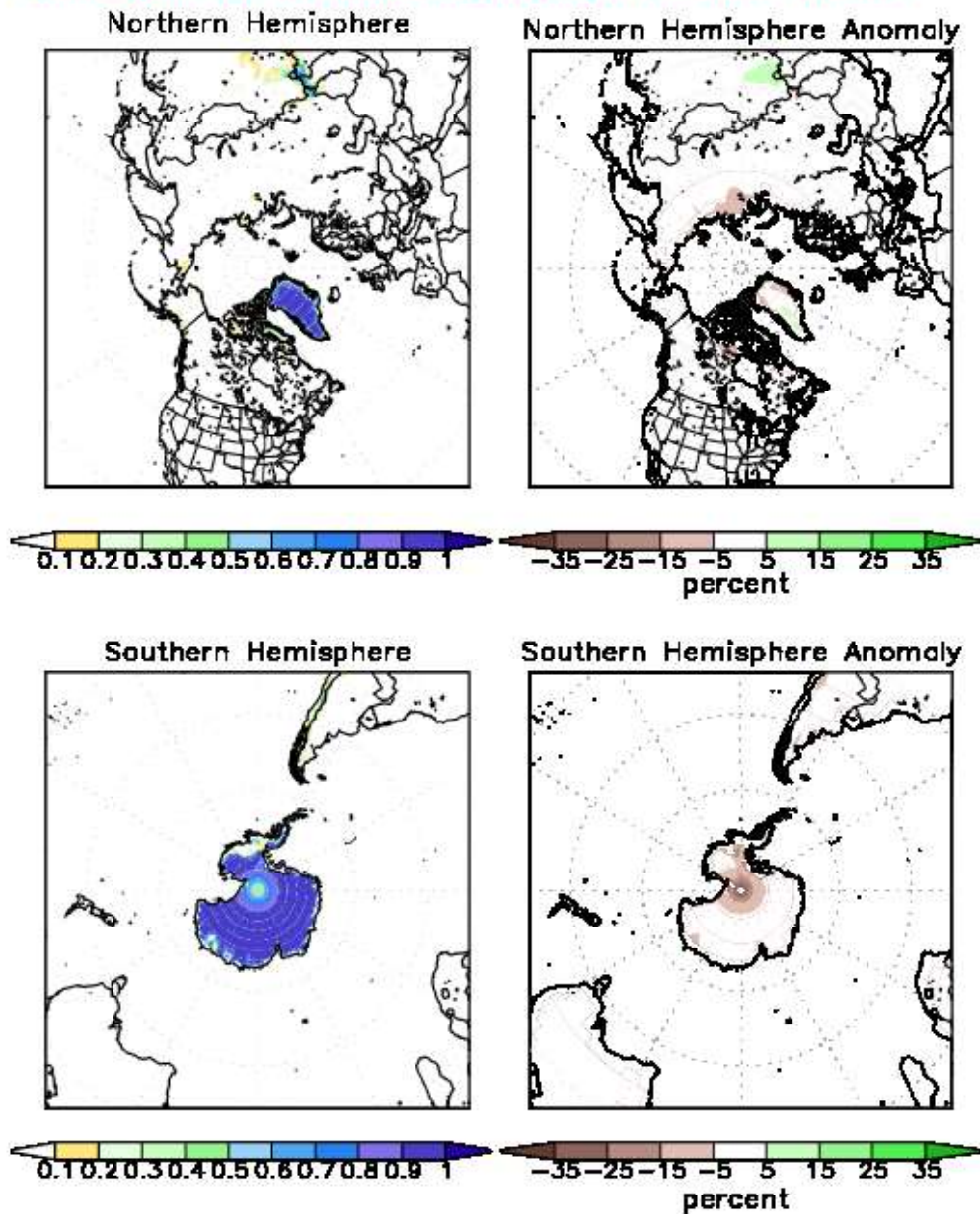


FIGURE A2.2. SSM/I derived snow cover frequency (%) (left) and snow cover anomaly (%) (right) for the month of JUN 2023 based on 1987 - 2010 base period for the Northern Hemisphere (top) and Southern Hemisphere (bottom). It is generated using the algorithm described by Ferraro et. al, 1996, Bull. Amer. Meteor. Soc., vol 77, 891-905.