CLIMATE DIAGNOSTICS BULLETIN

CLIMATE PREDICTION CENTER
Attn: Climate Diagnostics Bulletin
Room 3116, NCWCP
5830 University Research Court
College Park, MD 20740

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- Climate Diagnostics Bulletin available on the World Wide Web

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**Tropical Highlights - November 2023**

During December 2023, sea surface temperatures (SSTs) remained well above-average across the central and eastern equatorial Pacific (Fig. T18). The latest monthly Niño indices were +1.4°C for the Niño 1+2 region, +2.0°C for the Niño 3.4 region and +2.1°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 central and eastern equatorial Pacific (Figs. T15, T16). The corresponding sub-surface temperatures were 1-5°C above-average in the far eastern equatorial Pacific (Fig. T17).

Also during December, the lower-level wind anomalies were westerly over much of the central and eastern equatorial Pacific, while the upper-level wind anomalies were easterly over the eastern equatorial Pacific (Table T1, Figs. T20, T21). Meanwhile, tropical convection was enhanced around the Date Line and suppressed over Indonesia (Fig. T25). Collectively, these oceanic and atmospheric anomalies were consistent with strong 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
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**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.
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**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).
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.
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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 December 2023, 203 satellite-tracked surface drifting buoys were reporting from the tropical Pacific. Several drifters in the region 3-6N, 100-170W indicated eastward anomalies of 25-30 cm/s, hindcasting a strengthened and southward-shifted North Equatorial Countercurrent. This pattern has persisted since October.

Figure A1.1 Top: Movements of drifting buoys in the tropical Pacific Ocean during December 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.
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**

El Niño is expected to continue for the next several seasons, with ENSO-neutral favored during April-June 2024 (73% chance).

**Discussion**

Above-average sea surface temperatures (SST) persisted across the equatorial Pacific Ocean, with the largest anomalies observed in the central and east-central Pacific (Fig. T18). The monthly Niño index values were nearly unchanged: +1.4°C in Niño-4, +2.0°C in Niño-3.4, and +2.1°C in Niño-3. Only Niño-1+2 weakened to +1.4°C (Table T2). Area-averaged positive subsurface temperature anomalies decreased in December, reflecting the strengthening and eastward expansion of below-average subsurface temperatures in the western Pacific (Fig. T17). Over the east-central Pacific Ocean, low-level wind anomalies were westerly, while upper-level wind anomalies were easterly (Figs. T20 & T21). Convection/rainfall remained enhanced at the Date Line and was suppressed around Indonesia (Fig. T25). The equatorial and station-based SOI were negative (Figs. T1 & T2). Collectively, the coupled ocean-atmosphere system reflected a strong and mature El Niño.

The most recent IRI plume indicates El Niño will gradually weaken and then transition to ENSO-neutral during spring 2024 (Figs. F1-F12). Some state-of-the-art dynamical climate models suggest a transition to ENSO-neutral as soon as March-May 2024. The forecast team, however, delays this timing and strongly favors a transition to ENSO-neutral in April-June 2024. There are also increasing odds of La Niña in the seasons following a shift to ENSO-neutral. It is typical for
El Niño to peak in December/early January, but despite weakening, its impacts on the United States could last through April (see CPC seasonal outlooks for probabilities of temperature and precipitation). In summary, El Niño is expected to continue for the next several seasons, with ENSO-neutral favored during April-June 2024 (73% chance).

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.
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 (CFSv2). 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 DEC 2023. Contour interval is 0.3°C 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 Nino 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 Nino 3.4 SST anomalies are indicated by the black dashed lines. The Nino 3.4 region spans the east-central equatorial Pacific between 5N-5S, 170W-120W.
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).
FIGURE F8. LDEO forecasts of SST anomalies for the Nino 3 region using wind stresses obtained from (top) QuickSCAT, (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 – December 2023

1. Northern Hemisphere

The 500-hPa circulation during December favored an Arctic Oscillation (AO) teleconnection pattern that featured predominantly above-average height anomalies across North America and the Arctic (Fig. E9). Moderately above-average heights were observed over southern Europe and Eurasia (Fig. E9). Strongly below-average heights were observed over the Bering Strait and moderately below-average heights were observed over Scandinavia (Fig. E9). The main land-surface temperature signals include above-average temperatures across most of North America and Eurasia and below-average temperatures in Scandinavia and central Russia (Fig. E1). The main precipitation signals include above-average rainfall for the eastern coast of North America, United Kingdom, and regions of Europe and Russia (Fig. E3).

a. North America

The 500-hPa circulation over North America during December featured a large and strong ridge over most of Canada and the U.S., and a strong trough over Alaska (Fig. E9). Temperature anomalies were strongly above normal for most of North America with a majority of the area reaching the highest 90th percentile of occurrences (Fig. E1). Drier than average conditions were observed in western Alaska, and around the Hudson Bay, and wetter than average conditions were observed broadly along the Southeast and Atlantic coasts of the U.S. (Fig. E3). Some areas across the U.S. experienced significant departures from average rainfall. For example, the Great Lakes reached the lowest 20th percentile of occurrences, while the Great Plains, Gulf Coast, and Mid-Atlantic received rainfall in the highest 80th percentile (or higher) of occurrences (Figs. E5, E6).

b. Europe and Asia

The height pattern across Europe and Russia completed a wavetrain that originated in the North Pacific Ocean with above-average anomalies, below-average anomalies over the Bering Sea, above-average heights over the Kara Sea, below-average heights over Scandinavia, and above-average heights over the Mediterranean (Fig. E9). The troughing over Scandinavia, along with the weakness in heights over Greenland, shares characteristics of an atypical North Atlantic Oscillation (NAO) teleconnection pattern. This troughing coupled with the ridging over the North Atlantic Ocean and the Mediterranean contributes to the moderately strong positive NAO phase recorded for this December (Fig. E7). The ridging pattern across southern Europe, the Middle East, and into China contributed to the above-average temperature anomalies observed in these regions. Some areas,
for example southern Europe, reached the highest 90th percentile of occurrences. Some parts of Scandinavia and Russia recorded below-average temperatures with many areas reaching the lowest 30th percentile of occurrences, and some isolated areas reaching the lowest 10th percentile of occurrences, for example along the Great Khingan Range near Manchuria, China (Fig. E3). Northern Europe and India recorded above-average rainfall anomalies in the highest 90th percentile of occurrences (Figs. E3, E4). In southern Europe, conditions were drier than average with rainfall in the lowest 30th percentile of occurrences (Figs. E3, E4).

2. Southern Hemisphere

The 500-hPa height pattern during December favored a positive Antarctic Oscillation (AAO) teleconnection pattern (Fig. E15) with positive height anomalies along the middle latitudes and below-average heights centered over the pole. The ozone hole typically reaches a minimum by the end of December as the polar vortex decreases in response to a seasonally warming stratosphere (Fig. S8). Notably in early December, the ozone hole began a rapid decline, along with a rapid breakdown of the polar vortex (Fig. S8). These factors contributed to the ozone hole reaching just under the average size by the end of December. The main land-surface temperature signals include above-average temperatures across South America with regions such as Bolivia, Paraguay, and southern Brazil reaching the highest 90th percentile of occurrences (Fig. E1). Much of Africa recorded near-normal temperatures during December, and Queensland and New South Wales observed above-average temperatures that reached the highest 70th percentile of occurrences (Fig. E1). Across Brazil and most of Australia, drier than average conditions were recorded with the majority of those areas reaching the lowest 10th percentile of occurrences, while the African Sahel region recorded near-normal rainfall (Figs. E3, E4). The South African monsoon season runs from October to April. Precipitation in Southern Africa was above-average for December following dry conditions in November (Figs. E3, E4).
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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); Scandanavia 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 (°C, top) and surface temperature expressed as percentiles of the normal (Gaussian) distribution fit to the 1991-2020 base period data (bottom) for DEC 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 DEC 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 (%, 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.
MONTHLY ACCUMULATION —— December, 2023

Precip (mm)  Departure from Normal (mm)

Percent of Normal (%)  Normal (mm)

FIGURE E6. Observed precipitation (upper left), departure from average (upper right), percent of average (lower left), and average precipitation (lower right) for DEC 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/prodcuts/precip/realtime.
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.
FIGURE E8. Northern Hemisphere mean and anomalous sea level pressure (CDAS/Reanalysis) for DEC 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.
FIGURE E9. Northern Hemisphere mean and anomalous 500-hPa geopotential height (CDAS/Reanalysis) for DEC 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 DEC 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.
FIGURE E11. Northern Hemisphere percentage of days during DEC 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-
FIGURE E12. Northern Hemisphere: Daily 500-hPa height anomalies for DEC 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.
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.
FIGURE E14. Southern Hemisphere mean and anomalous sea level pressure (CDAS/Reanalysis) for DEC 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.
FIGURE E15. Southern Hemisphere mean and anomalous 500-hPa geopotential height (CDAS/Reanalysis) for DEC 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 DEC 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.
FIGURE E17. Southern Hemisphere percentage of days during DEC 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-
FIGURE E18. Southern Hemisphere: Daily 500-hPa height anomalies for DEC 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.
FIGURE S1. Stratospheric height anomalies (m) at selected levels for DEC 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 DEC 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 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.
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 DEC 2023. The EP flux unit (kg m⁻¹ 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 < -78°C 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 DEC 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.
FIGURE A2.2. SSM/I derived snow cover frequency (%) (left) and snow cover anomaly (%) (right) for the month of DEC 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.