WORLD
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WMO Global Annual to Decadal Climate Update

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Global Annual to Decadal Climate Update

Target years: 2023 and 2023-2027

Executive Summary

The Global Annual to Decadal Climate Update is issued annually by the World Meteorological Organization (WMO). It provides a synthesis of the global annual to decadal predictions produced by the WMO designated Global Producing Centres and other contributing centres for the period 2023-2027. Latest predictions suggest that:

- The annual mean global near-surface temperature for each year between 2023 and 2027 is predicted to be between 1.1°C and 1.8°C higher than the average over the years 1850-1900.
- The chance of global near-surface temperature exceeding 1.5°C above preindustrial levels for at least one year between 2023 and 2027 is more likely than not (66%). It is unlikely (32%) that the five-year mean will exceed this threshold.
- The chance of at least one year between 2023 and 2027 exceeding the warmest year on record, 2016, is very likely (98%). The chance of the five-year mean for 2023-2027 being higher than the last five years (2018-2022) is also very likely (98%).
- The El Niño Southern Oscillation (ENSO) is predicted to most likely be positive in December to February 2023/24.
- The Arctic temperature anomaly, relative to the 1991-2020 average, is predicted to be more than three times as large as the global mean anomaly when averaged over the next five northern hemisphere extended winters.
- Predicted precipitation patterns for 2023 relative to the 1991-2020 average suggest an increased chance of reduced rainfall in parts of Indonesia, the Amazon and central America.
- Predicted precipitation patterns for the May to September 2023-2027 average, relative to the 1991-2020 average, suggest an increased chance of above average rainfall in the Sahel, northern Europe, Alaska and northern Siberia, and reduced rainfall for this season over the Amazon and parts of Australia.
- Northern Eurasia is likely to have above average precipitation in December-February over 2023-2027, in line with recent trends there.

Current Observations

This section is a brief summary of the observed climate of the last five years to provide a context for the predictions shown later in this report. Please refer to the WMO State of the Global Climate report for a more complete discussion. Climate anomalies over the last year and last five years with respect to the most recent long-period average, 1991-2020, are shown in Figure 1.

Near-surface temperatures in 2022 showed a mixed pattern dominated by a colder tropical East Pacific, consistent with La Niña conditions, and mostly warmer anomalies over Eurasia. Over 2018-2022, apart from central Canada, the anomalies were close to zero or positive across the globe. Warm anomalies were greatest at high latitudes in the Northern Hemisphere, especially the Arctic, and generally larger over land than ocean. In 2022 and in the last five years, sea-level pressure was anomalously low over Antarctica. The Aleutian Low for 2018-2022 was anomalously weak, as expected for the extended La Niña conditions that prevailed.

During 2018-2022, parts of Asia, southeastern North America, northeastern South America and the African Sahel were wetter than average, and southern Africa, Australia, southern South America, and western Europe and parts of North America drier than average. These anomalies were generally also present for 2022, though less clearly, with the notable exception of eastern Australia which showed more widespread above average precipitation.

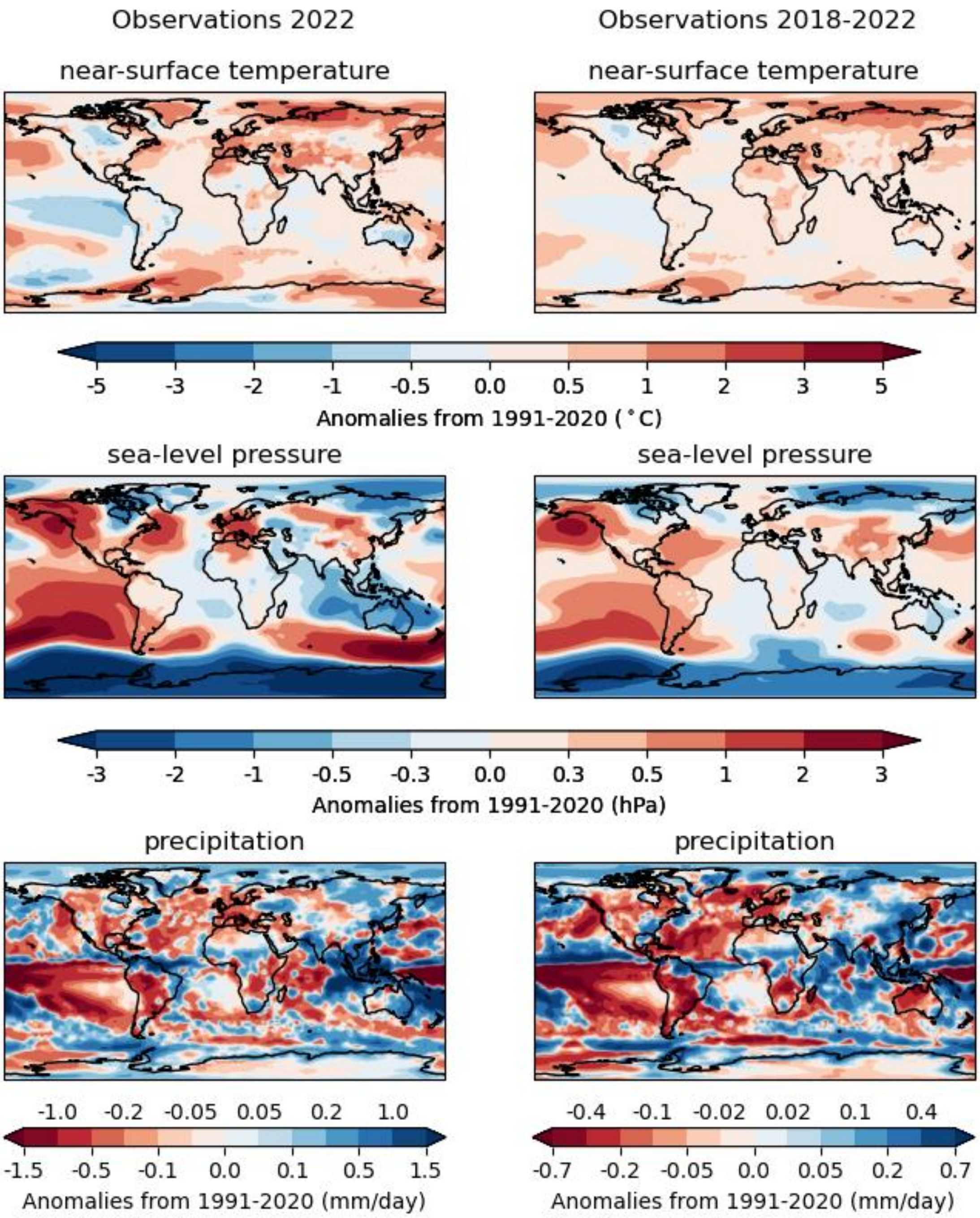

Figure 1*: Observed annual mean near-surface temperature (°C, top), pressure (hPa, middle) and precipitation (mm/day, bottom) anomalies relative to 1991-2020. The left column shows the year 2022, the right column refers to the average of the five-year period 2018-2022. Near-surface temperature is ERA5 2m temperature from ECMWF (Bell et al, 2021). Mean sea-level pressure is also from ERA5. Precipitation is from GPCP (Adler et al, 2003, updated).*

To highlight summer and winter differences, Figure 2 shows average anomalies over the last five years for two extended seasons, May to September and November to March. Both seasons had generally higher temperatures than the 1991-2020 average. Arctic anomalies were largest in November to March. The sea-level pressure anomalies seen in the five-year mean in Figure 1 over Antarctica were largest in May to September. The anomalies seen in the Aleutian Low in the North Pacific were largest in November to March when La Niña conditions were strongest. Eastern USA, parts of East Asia and South Asia, and the African Sahel were wetter than average in May to September. Australia and southern South America were mostly drier than average over the five years in both seasons.

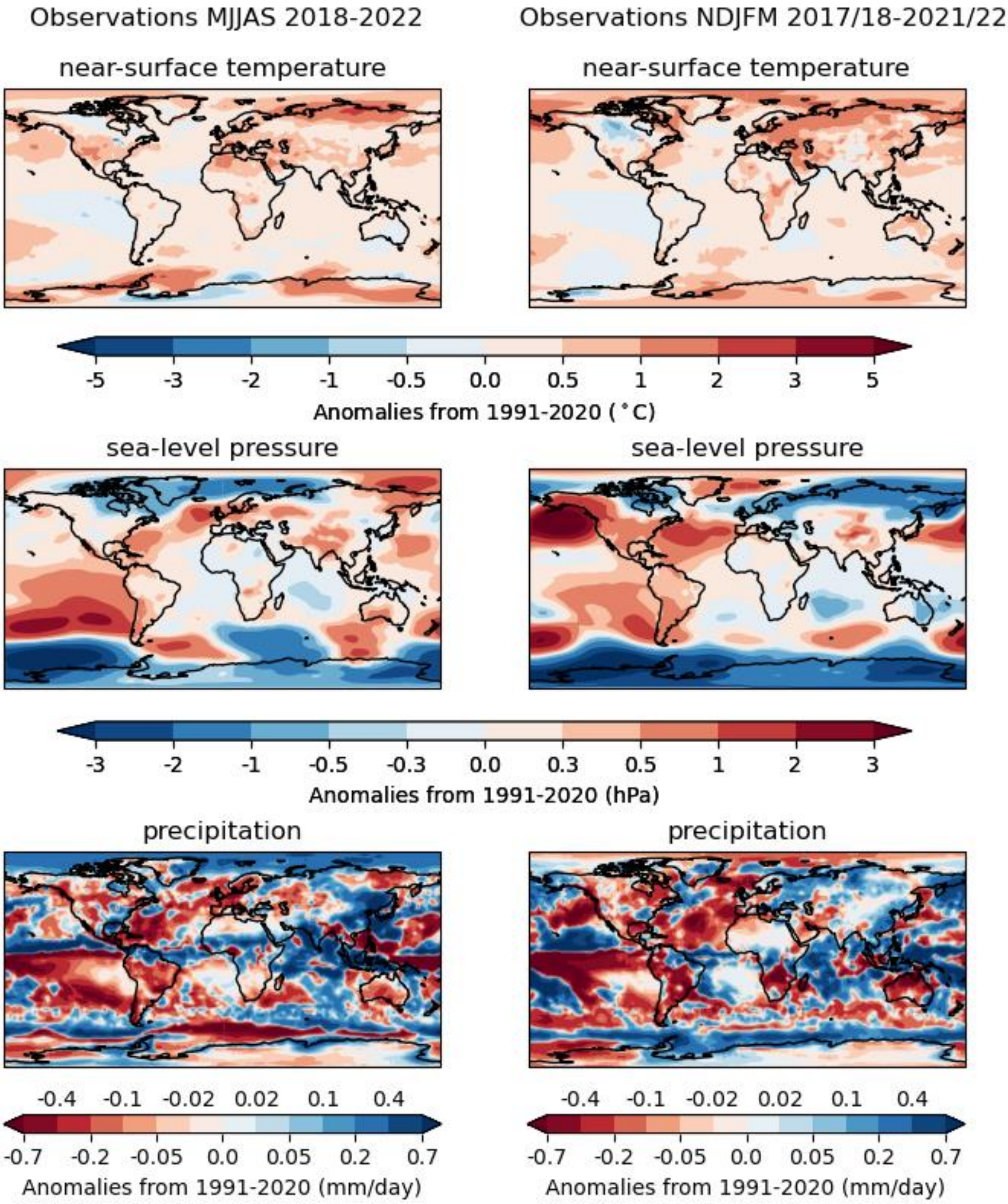

***Figure 2**: Observed five-year seasonal mean near-surface temperature (°C, top), pressure (hPa, middle) and precipitation (mm/day, bottom) anomalies relative to 1991-2020. The left column shows anomalies for May to September averaged over*

2018-2022, the right column shows anomalies for November to March averaged over 2017/2018-2021/2022. Observational datasets are the same as those in Figure 1.

Global (land and sea) mean near-surface temperatures have increased since the 1960s (Figure 3). The WMO State of the Global Climate report notes that the eight-year period 2015-2022 is likely the warmest eight-year period on record. The North Atlantic Multidecadal Variability (AMV) has been near-zero or negative since 2013 and the subpolar North Atlantic was anomalously cold on average over the last five years (Figure 1). The negative anomalies are consistent with the weakening of the Atlantic Meridional Overturning Circulation (AMOC) since 2005 (Figure 19 in the Appendix). Since one of the largest El Niño events on record occurred in 2015/16, annual mean anomalies in the tropical East Pacific relative to the rest of the tropics have been largely negative (La Niña) or neutral.

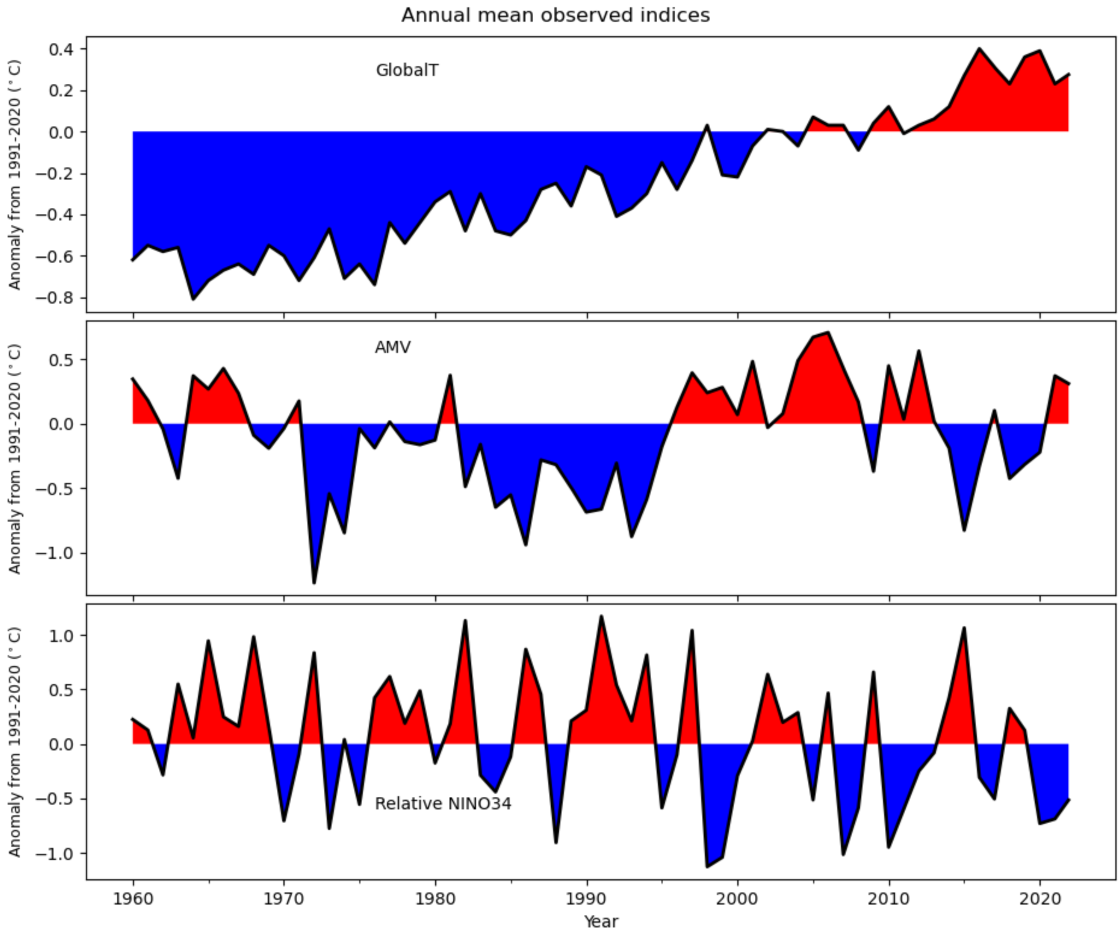

Figure 3: Observed climate indicators. Global annual mean near-surface temperature anomaly (top), annual mean Atlantic Multidecadal Variability (AMV) defined as the difference between two regions: 45°N-60°N,60°W-0°E minus 45°S-0°S, 30°W-10°E as in Roberts et al, 2013 (middle) and December to February Niño 3.4 defined as the average over 5°S-5°N, 170°W-120°W with the tropical average 20°S-20°N removed as in van Oldenborgh et al, 2021 (bottom). Anomalies are with respect to the 1991-2020 reference period. Six datasets are used in the calculation of global temperature and are the same as in the WMO State of Global Climate 2022 report. The other two indices are based on 2m temperature from ERA5 as in Figure 1.

Predictions from the WMO Lead Centre

Predictions of climate indices and global fields are obtained from multi-model initialised decadal climate predictions contributed to the WMO Lead Centre for Annual to Decadal Climate Prediction. This year there are 145 ensemble members contributed by 11 different institutes. Predictions are started at the end of 2022. Retrospective forecasts, or hindcasts, covering the period 1960-2018 are used to estimate forecast skill. Also shown for the climate indicators are uninitialised (historical) simulations and projections from the World Climate Research Programme's Coupled Model Intercomparison Project phase 6 (CMIP6). See Hermanson et al (2022) for more information.

Predictions of Global Climate Indicators

Global temperatures are likely to increase to record levels in the five-year period 2023-2027 and stay well above the 1991-2020 reference (Figure 4). Annual mean global near-surface temperature for each year in this five-year period is predicted to be between 1.1°C and 1.8°C (range of 90% confidence interval) higher than the period 1850 to 1900. The difference between this period and the 1991-2020 reference is estimated as 0.88°C, but this difference cannot be accurately estimated due to the incomplete observational network in the 19th century.

Using this estimate of the difference, the chance of the annual mean global near-surface temperature in 2023-2027 exceeding 1.5°C above 1850-1900 levels for at least one year is 66% and is increasing with time (brown histogram and right-hand axis in Figure 4). It is unlikely (32%) that the five-year mean will exceed this threshold. Note that the 1.5°C level specified in the Paris Agreement refers to long-term warming over many years, but temporary exceedances are expected to occur with increasing frequency as global temperatures approach the long-term threshold.

The chance of at least one year exceeding the warmest year on record, 2016, in the next five years is 98%. The chance of the five-year mean for 2022-2026 being higher than the last five years is also 98%. Confidence in forecasts of global mean temperature is high since hindcasts show very high skill in all measures (right-hand panels of Figure 4).

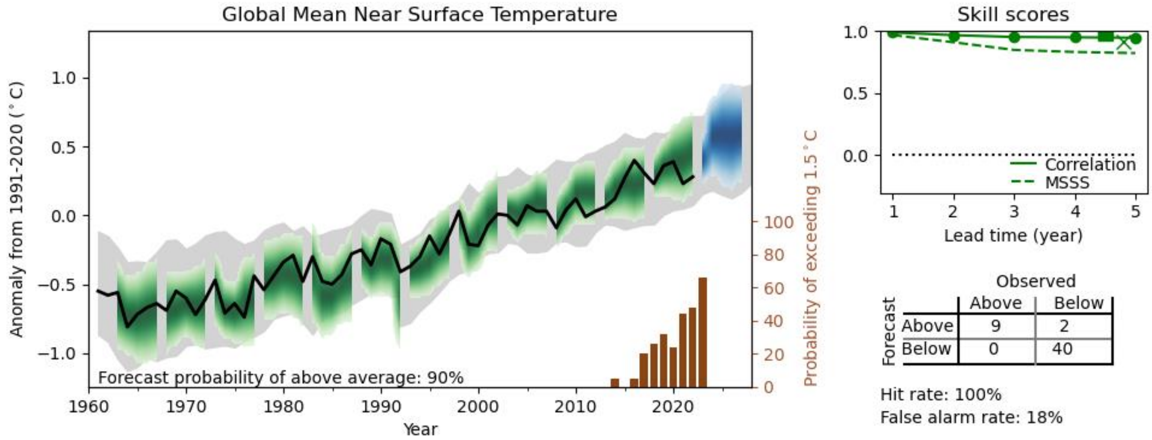

Figure 4: Multi-annual predictions of global mean near-surface temperature relative to 1991-2020. Annual global mean observations (see Figure 3) in black, forecast in blue, hindcasts in green and unininitialised simulations in grey. The shading indicates the 90% confidence range. The calibrated probability for the most likely category (above or below climatology) of the five-year-mean forecast is given at the bottom of the main panel. Hindcast skill scores are shown in the upper right panel; the square and the cross show the correlation skill and Mean Square Skill Score (MSSS) for five-year means, respectively. Statistically significant correlation skill (at the 5% confidence level) is indicated by solid circles/square. The contingency table for the prediction of above-average five-year means is shown in the bottom right panel. Also inset in the main panel, in brown, referring to the right hand axis, is the probability of global temperature exceeding 1.5°C above preindustrial levels for at least one of the five following years, starting from the year indicated. This probability is calculated as in Smith et al (2018) by counting the proportion of ensemble members that predict at least one year above 1.5°C.

Predictions indicate a 95% calibrated probability that Atlantic Multidecadal Variability (AMV) will be positive when averaged over the next five years (Figure 5). The hindcasts have medium skill in both measures and a medium hit rate, giving medium confidence in this prediction. The North Atlantic subpolar gyre, the main centre of action of the AMV, has had negative anomalies in the last five years (Figure 1). The predictions from different centres for the next five years vary between continued cool temperatures to warming of the region (individual contributions can be seen on the website). This disagreement further reduces our confidence in the predictions for the AMV. Predictions for the Atlantic Meridional Overturning Circulation (AMOC), which is related to AMV, can be found in the Appendix.

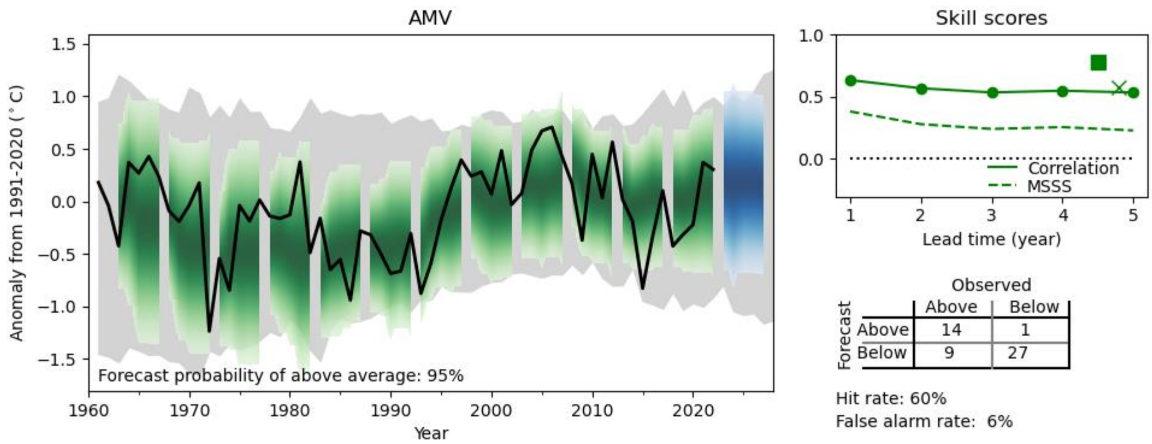

Figure 5: Multi-annual predictions of Atlantic Multidecadal Variability (AMV) relative to its 1991-2020 average, defined as the anomaly difference between two regions: 45°N-60°N, 60°W-0°E minus 45°S-0°S, 30°W-10°E as in Roberts et al (2013). Annual mean observations (see Figure 3) in black, forecast in blue, hindcasts in green and unininitialised simulations in grey. The shading indicates the 90% confidence range. The calibrated probability for the most likely category (above or below climatology) of the five-year-mean forecast is given at the bottom of the main panel. Hindcast skill scores are shown in the

upper right panel; the square and the cross show the correlation skill and Mean Square Skill Score (MSSS) for five-year means, respectively. Statistically significant correlation skill (at the 5% confidence level) is indicated by solid circles/square. The contingency table for the prediction of above average five year means is shown in the bottom right panel.

In last year's report there was no clear signal for the El Niño Southern Oscillation and a weak La Niña was observed for the third year in a row. This La Niña is predicted to decline, and the multi-model ensemble-mean temperature anomalies in the Niño 3.4 region are predicted to be positive for December 2023 – February 2024, indicating the onset of El Niño. There is a large ensemble spread (±1 ˚C) and skill is medium for year 1 (Figure 6). The five-year average temperature in the Niño 3.4 region relative to the whole tropics has a 92% calibrated probability of being above average. Skill is medium, giving medium confidence in this forecast.

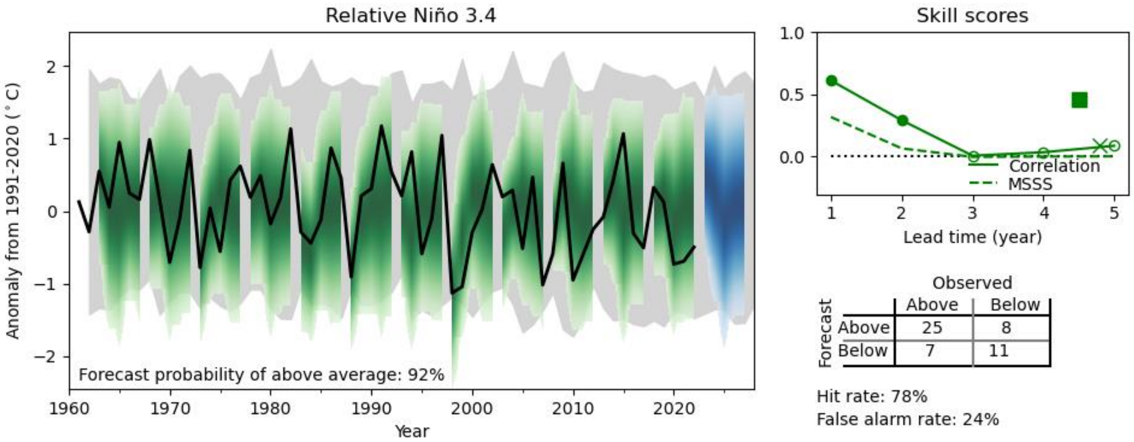

Figure 6: As Figure 5, but for December-February averaged Niño 3.4 relative to the tropical mean defined as the average over 5°S-5°N, 170°W-120°W with average over 20°S-20°N removed. This index is suitable for a warming climate (van Oldenborgh et al, 2021).

Regional Predictions for 2023

Near-surface temperatures in 2023 are likely to be higher than the 1991-2020 average in almost all regions except for Alaska, South Africa, South Asia and parts of Australia (Figure 7). Parts of the South Pacific Ocean are likely to be cooler than average. Skill is estimated from hindcasts to be medium or high in most regions (Figure 8) giving medium to high confidence in the forecast.

Sea-level pressure forecasts suggest anomalous low pressure over the Arctic. The skill is low but significant, giving low confidence in this prediction. The forecast also suggests low pressure over the Antarctic and high pressure over the southern hemisphere mid-latitudes, suggesting a positive Antarctic Oscillation index (see also Figure 21). There is medium to low skill for these regions giving medium to low confidence.

Precipitation patterns suggest an increased chance of drier conditions over central America and southwestern North America. Northern high latitudes are likely to have above average precipitation. Correlation skill for hindcasts is very low despite being significant in these regions, giving low confidence in the forecast.

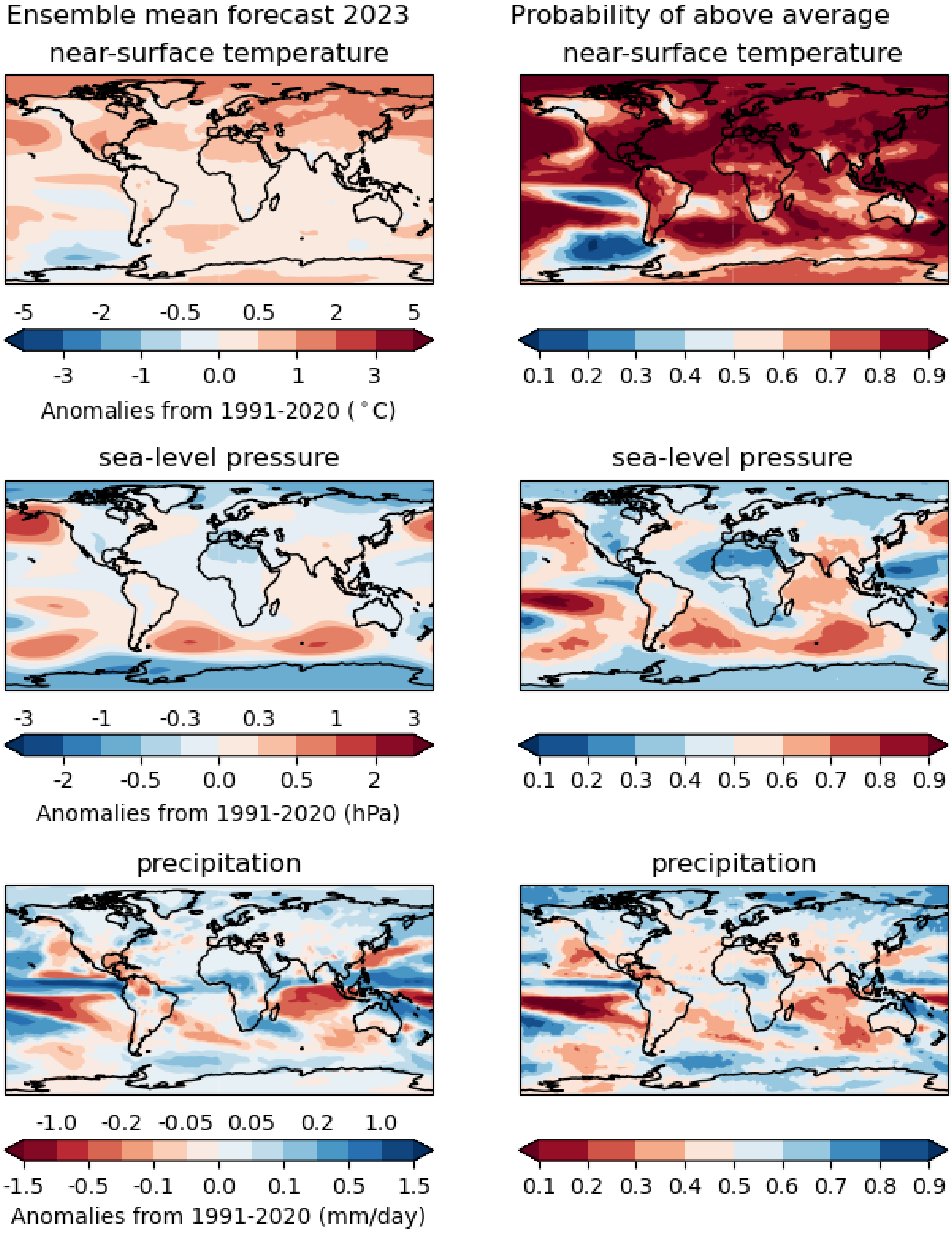

Figure 7: Annual mean anomaly predictions for 2023 relative to 1991-2020. Ensemble mean (left column) for temperature (top, °C), sea level pressure (middle, hPa), precipitation (bottom, mm/day) and probability of above average (right column). As this is an uncalibrated two-category forecast, the probability for below average is one minus the probability shown in the right column.

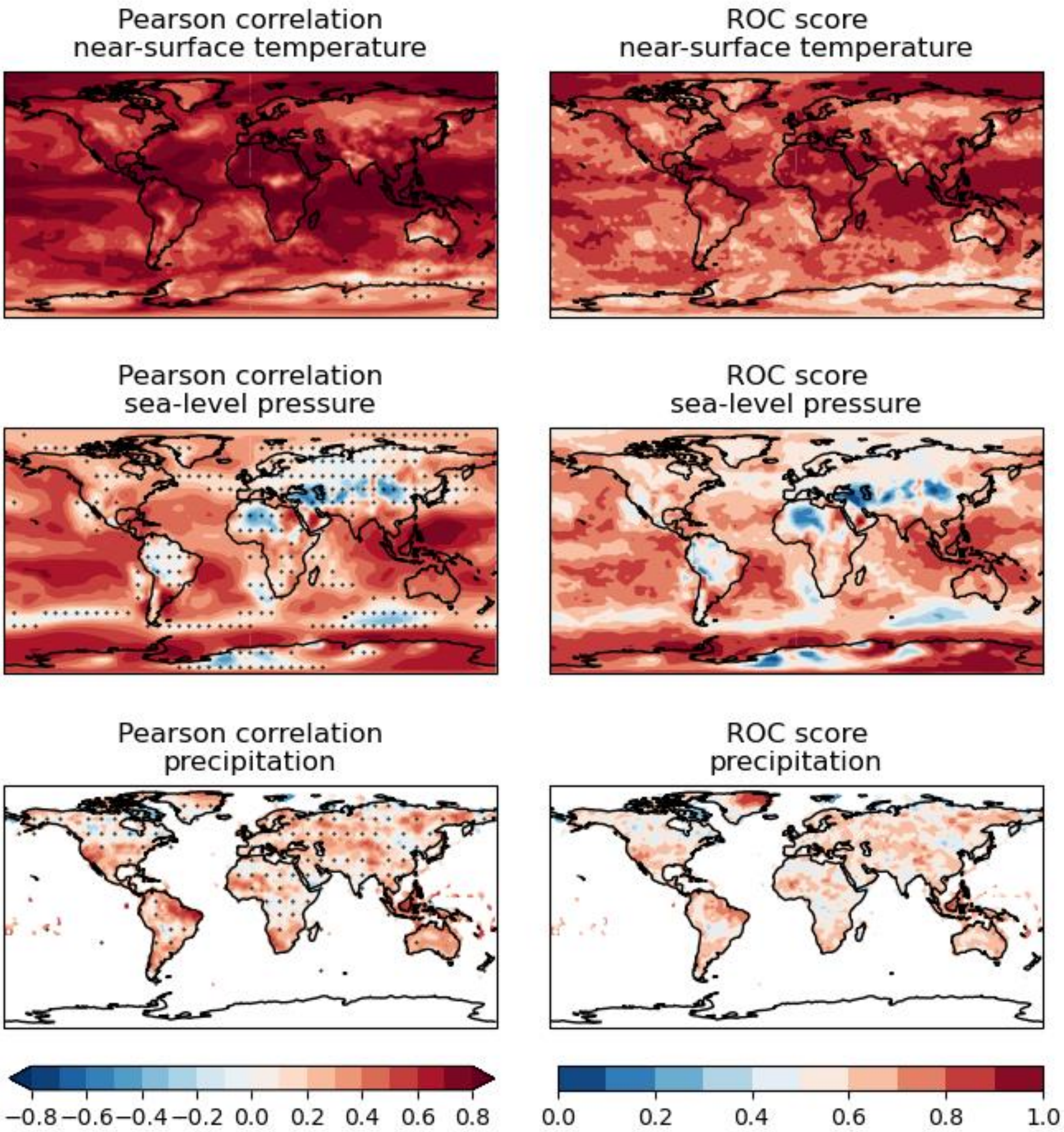

Figure 8: Prediction skill of annual means evaluated using hindcast experiments. Pearson correlation (left) and ROC score for predictions of above average conditions (right). For correlation stippling shows where skill is not significant (at the 5% level).

Regional Predictions for 2023-2027

This section shows predictions for the average of the next five extended seasons for May to September and November to March.

For the May to September average, predicted temperature patterns over the years 2023-2027 show a high probability of temperatures above the 1991-2020 average almost everywhere, with enhanced warming over land (Figure 9). Skill is very high in most regions, giving high confidence in this prediction (Figure 10).

For the same season, sea-level pressure is predicted to be anomalously low over the Mediterranean and surrounding countries, and high over the maritime continent and surrounding countries. There is medium skill for most of these regions, giving medium confidence. Predictions of precipitation show wet anomalies in the Sahel, northern Europe, Alaska and northern Siberia, and dry anomalies for this season over the Amazon and western Australia. Skill is low to medium for these regions, giving low to medium confidence.

For the November to March average over the years 2023/24-2027/28 (Figure 11), the predictions show warm anomalies are likely almost everywhere, with land temperatures showing larger anomalies than those over the ocean. The Arctic (north of 60°N) near-surface temperature anomaly is more than three times as large as the global mean anomaly. The North Atlantic subpolar gyre shows negative anomalies, the so-called warming hole, which has been liked to a reduction in the AMOC. Skill is high in most regions apart from parts of the North Pacific, some areas in Asia, Australia, and the Southern Ocean (Figure 12), giving medium to high confidence.

There is a low pressure anomaly over the tropical East Pacific. There is medium skill over the East Pacific, so confidence is medium for this prediction.

Precipitation predictions favour wetter than average conditions at high latitudes in the northern hemisphere for the next five extended winter seasons (November to March). The pattern of increased precipitation in the tropics and high latitudes and reduced precipitation in the subtropics compared to the 1991-2020 reference period is consistent with the climate warming. Skill is moderate over large parts of northern Eurasia, Greenland, and the Canadian Arctic Archipelago giving low to medium confidence in the forecast for an increased chance of precipitation in these regions. There is some indication of wetter than average conditions in the Greater Horn of Africa in this season, though skill is low so confidence is low.

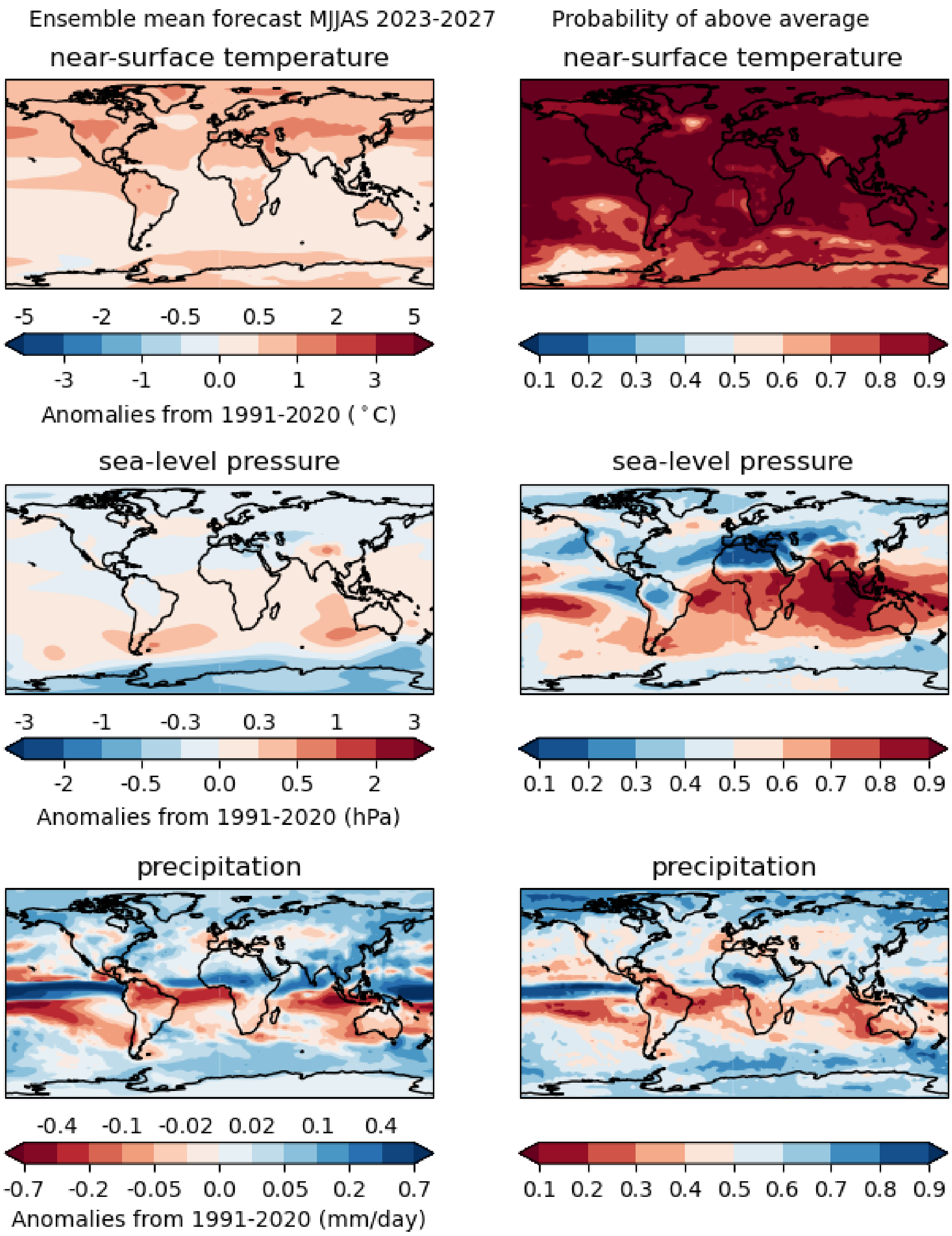

Figure 9: Predictions for 2023-2027 May to September anomalies relative to 1991-2020. Ensemble mean (left column) for temperature (top, °C), sea level pressure (middle, hPa), precipitation (bottom, mm/day) and probability of above average (right column). As this is an uncalibrated two-category forecast, the probability for below average is one minus the probability shown in the right column.

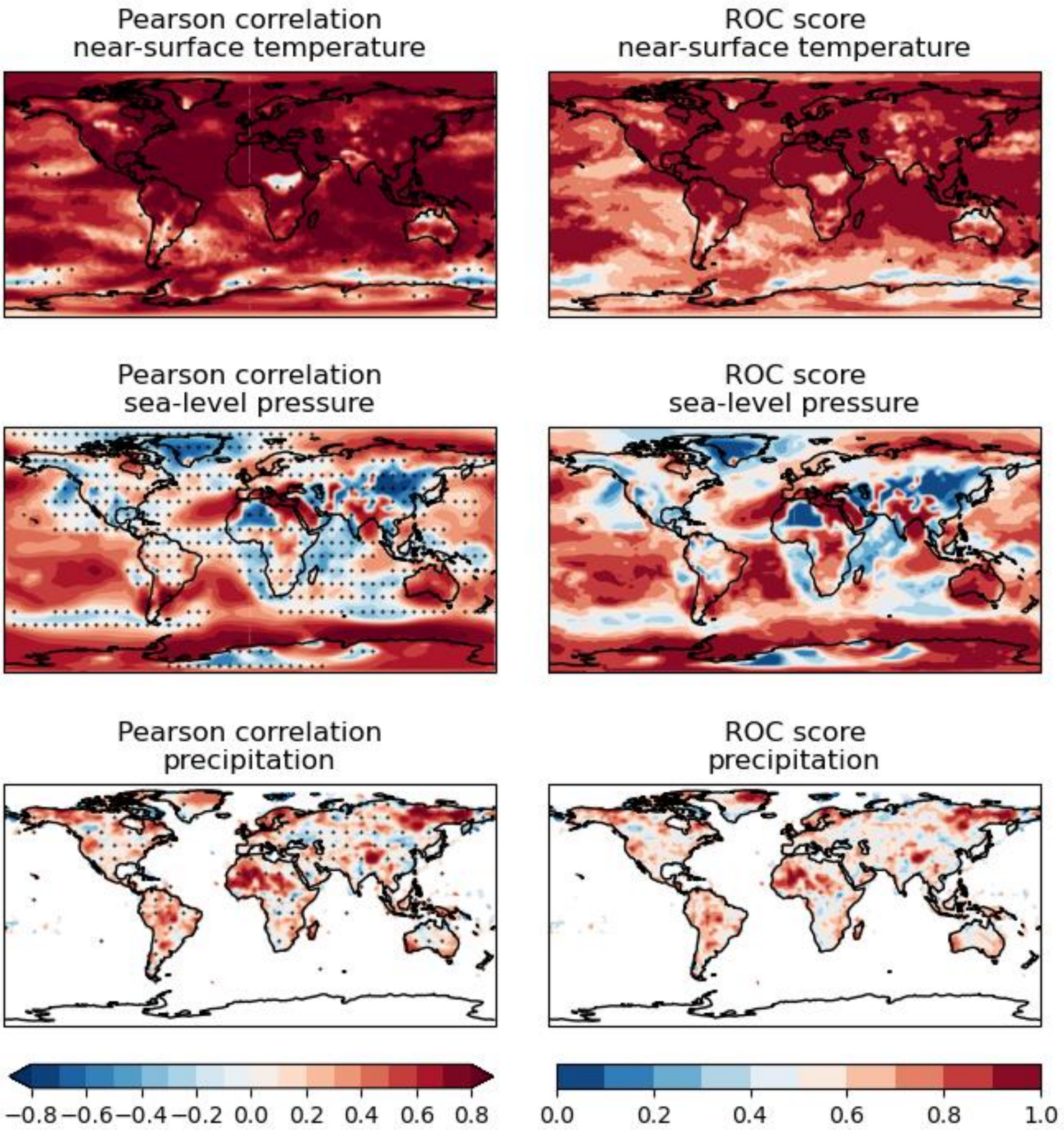

Figure 10: Prediction skill of five-year mean May to September anomalies evaluated using hindcast experiments. Pearson correlation (left) and ROC score for predictions of above average conditions (right). For correlation stippling shows where skill is not significantly positive (at the 5% level).

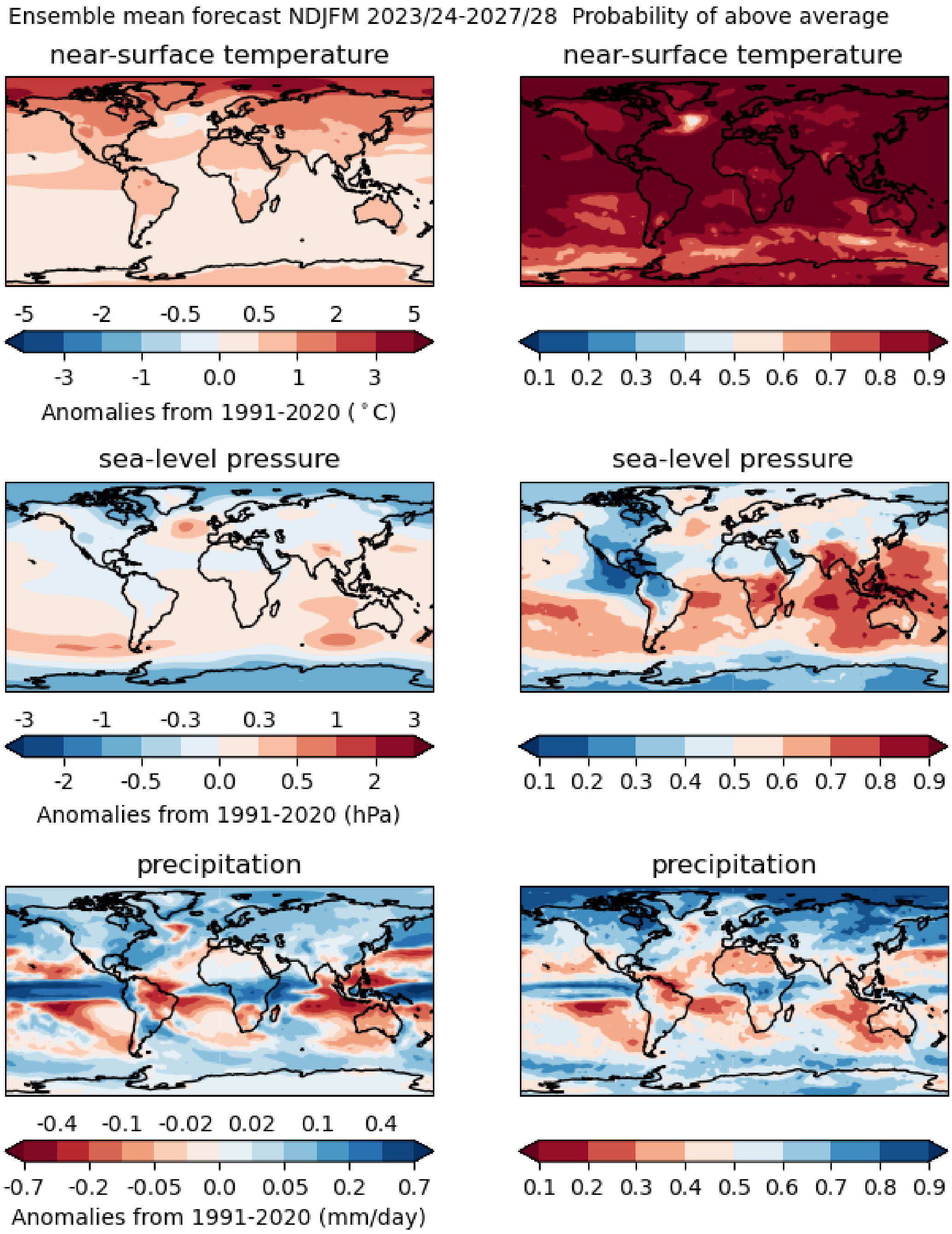

Figure 11: Predictions for 2023/2024-2027/2028 November to March anomalies relative to 1991-2020. Ensemble mean (left column) for temperature (top, °C), sea level pressure (middle, hPa), precipitation (bottom, mm/day) and probability of above average (right column). As this is an uncalibrated two-category forecast, the probability for below average is one minus the probability shown in the right column.

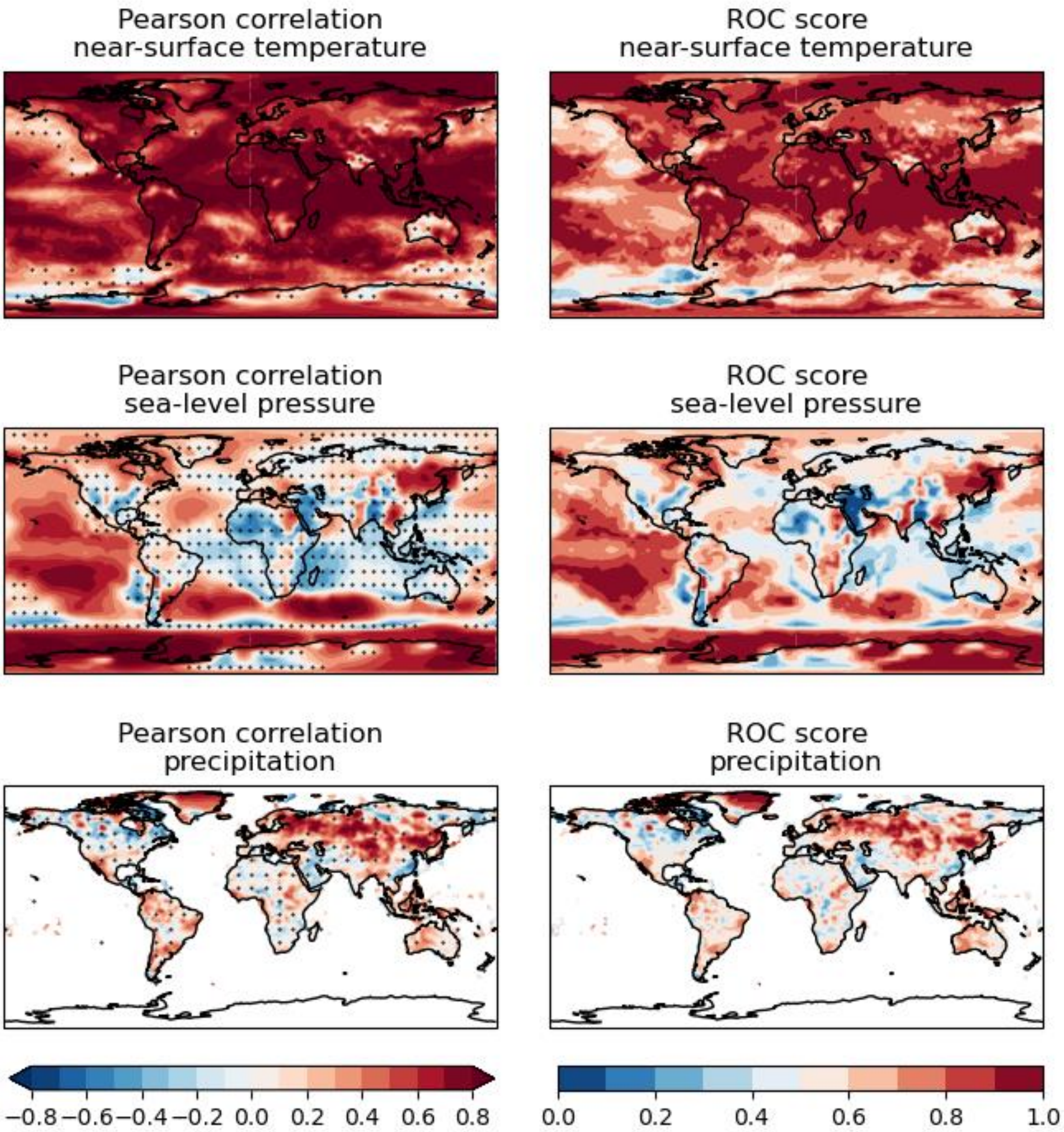

Figure 12: Prediction skill of five-year means November to March anomalies evaluated using hindcast experiments. Correlation (left) and ROC score for predictions of above average conditions (right). For correlation stippling shows where skill is not significantly positive (at the 5% level).

Regional Forecast Indices

This section shows some regional forecast indices based on notable forecast signals found in the previous section and where there is skill in the multi-model ensemble. The regions are based on the regions of Regional Climate Outlook Forums (RCOFs). The season used for the indices is the relevant season for that region, usually the wet season or monsoon season. The full set of forecasts and hindcasts can be found on the website on the "Regional" tab.

The North Eurasian Climate Outlook Forum (NEACOF) region has seen a positive trend in December-February precipitation since the early 1980s. This trend is predicted to continue with 2023-2027 predicted to be above average with an 88% probability (Figure 13). Skill is medium, so giving medium confidence for this prediction.

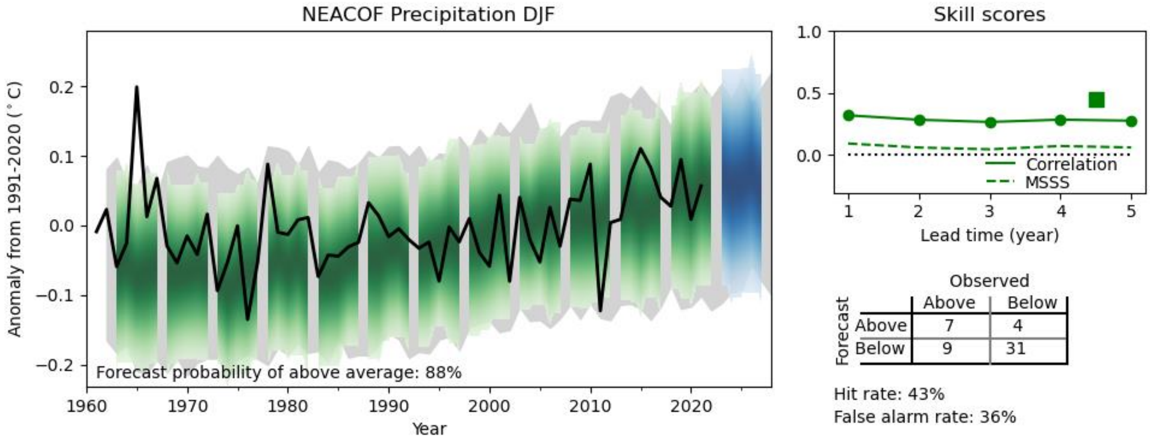

Figure 13: As Figure 5, but for December to February (DJF) averaged precipitation over the North Eurasian NEACOF region.

The Arctic Climate Forum region has experienced strong warming since the 1990s, especially in Northern Hemisphere winters. Predictions for December – February show that this is very likely to continue with a 95% probability of near-surface temperature being above average (Figure 14). Skill is very high, so confidence is high for this prediction.

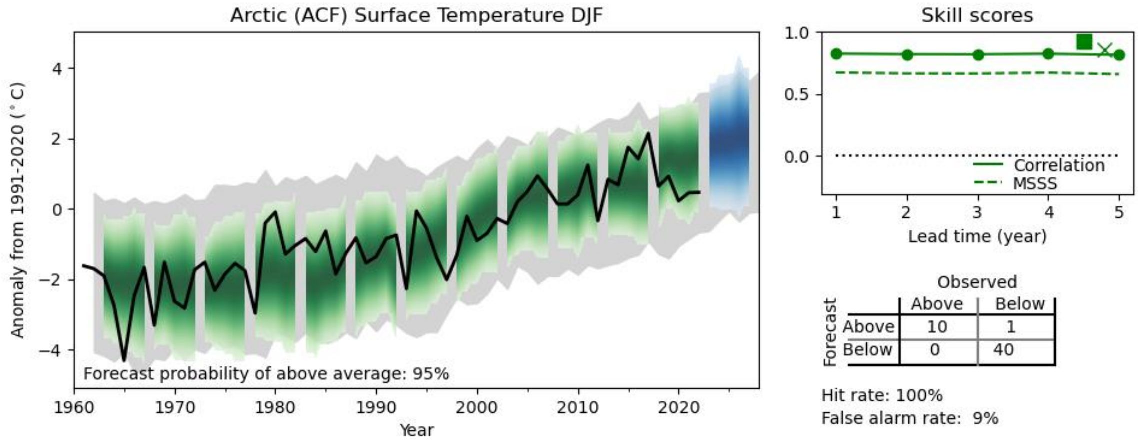

Figure 14: As Figure 5, but for December to February (DJF) averaged near-surface temperature over the Arctic region.

Evaluation of Previous Forecasts

This section assesses the most recent one year and five-year mean forecasts, that were made in real time, for which observations are available. The forecast for 2022, which was run at the end of 2021, is shown in Figure 15. Stippling in the right-hand panels indicates observations are outside the predicted 90% confidence interval. For near-surface temperatures the forecast shows generally good agreement with the observed pattern, but the anomalies were underestimated in many regions including the tropical East Pacific, western Europe, northwestern Africa, Middle East and East Australia. Cold anomalies in Antarctica and eastern Asia were not captured.

Sea-level pressure patterns agree reasonably well with the observations except for Antarctica, with anomalously low pressure over the Arctic, Australia and the Indian Ocean and anomalously high pressure over the East Pacific and western Europe. However, the predicted anomalies are small and the ensemble spread does not encompass the observed magnitude in most regions. Positive sea-level pressure anomalies in the North Atlantic south of Iceland were not captured by the ensemble.

The ensemble mean predictions of precipitation captured the correct sign of anomalies in many regions, including wetter conditions across the Sahel, northeastern south America and South Asia, and drier conditions in South America, the Mediterranean and southern Africa. Despite this, the ensemble spread did not encompass the observed values in most regions.

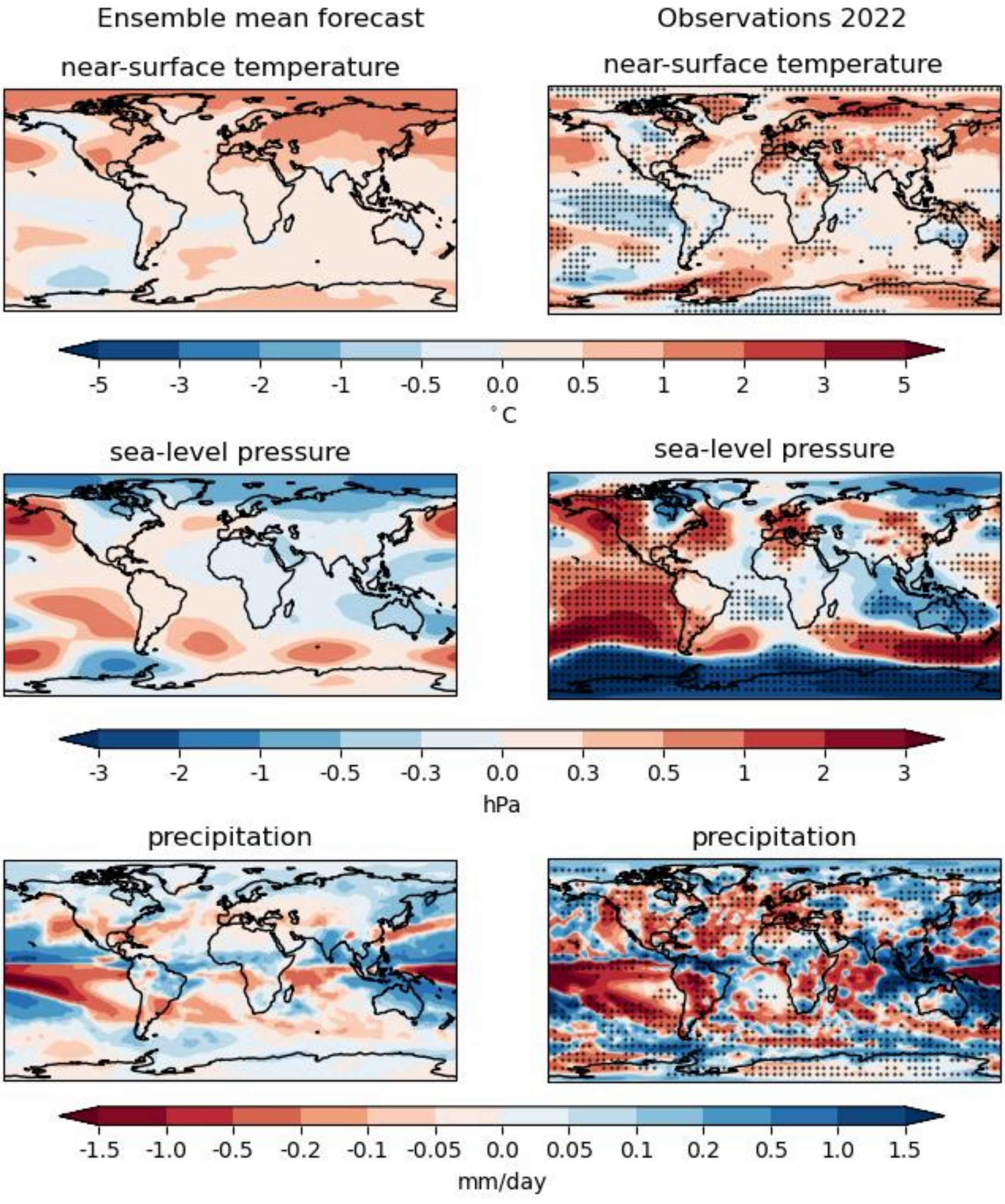

Figure 15: Evaluation of the one-year forecast for 2022 relative to 1981-2010. Ensemble mean forecast (left) and observed (right) anomalies. Top: temperature (°C); middle: sea level pressure (hPa); bottom: precipitation (mm/day). Stippling shows where the observations fall outside of the 90% range of the forecast ensemble.

Average forecast temperature anomalies for the last five years 2018-2022, from forecasts run at the end of 2017 (Figure 16), generally agree well with observations of very warm conditions over the Arctic and Eurasia, and enhanced warming over the land compared to the ocean, especially in the northern hemisphere. However, the magnitude of the Middle East warm anomalies was underestimated. Relatively cool conditions in the northern North Atlantic, South Pacific and Southern Ocean were mostly captured within the ensemble spread. Other cooler conditions in Canada, tropical North Atlantic and the East Pacific were not captured.

Sea-level pressure patterns show reasonable agreement with the observations, with lower than average pressure over the Arctic and Antarctic and higher than average pressure over most ocean regions. However, as with the one-year prediction evaluated above, the forecast anomalies are small and the observations are outside the forecast range in many regions even when the ensemble mean shows the correct sign. Lower than average pressure over the Indian Ocean was not captured by the ensemble.

Precipitation patterns over land show reasonable agreement with observations, including wetter than usual conditions across much of Asia and central Africa, and drier than usual conditions in southern North America and southern Africa. Drier than normal conditions in western Canada, southern South America and western Europe were not captured.

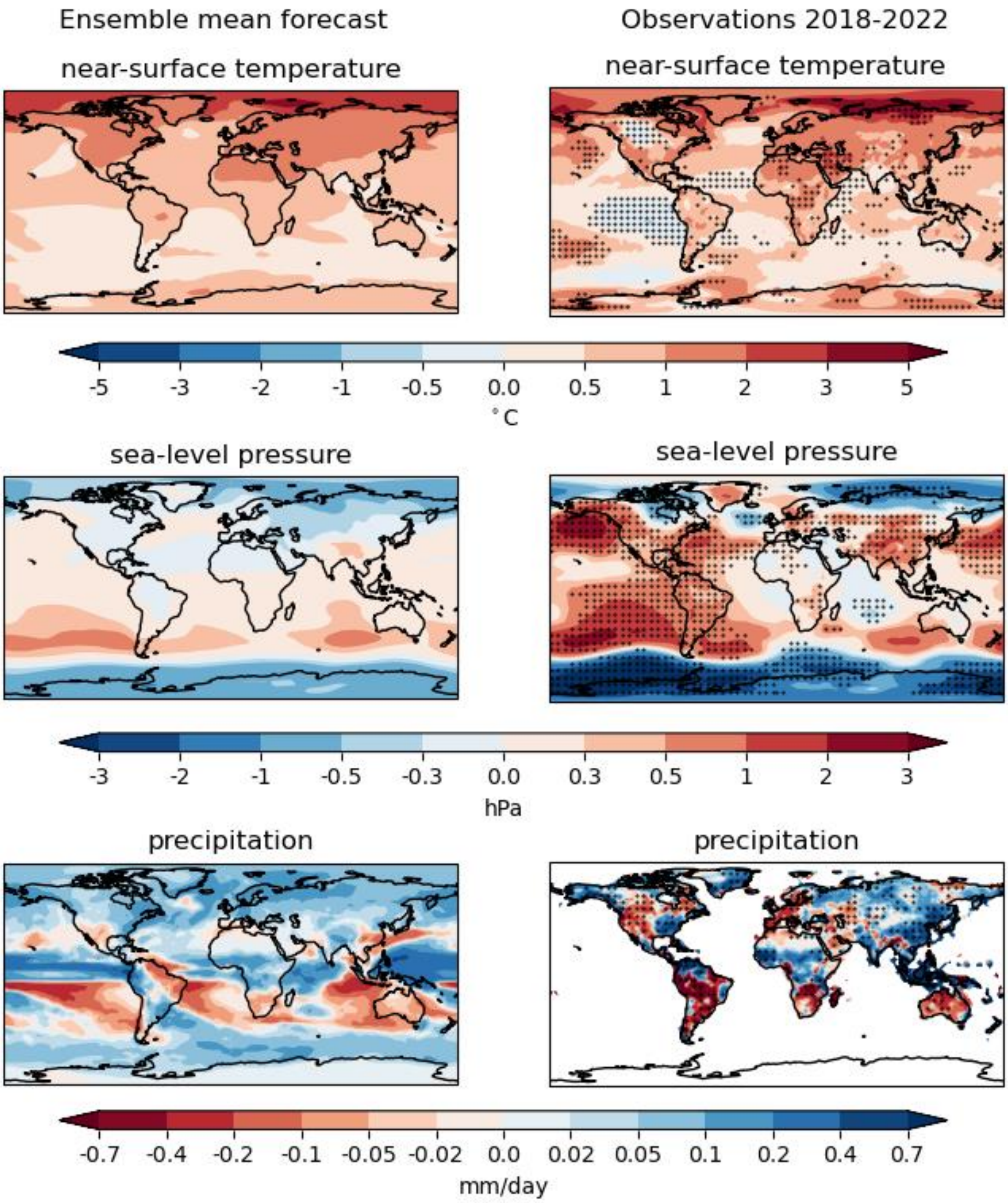

Figure 16: Evaluation of the five-year forecast for 2018-2022 relative to 1971-2000. Ensemble mean forecast (left) and observed (right) anomalies. Top: temperature (°C); middle: sea level pressure (hPa); bottom: precipitation (mm/day). Stippling shows where the observations fall outside of the 90% range of the forecast ensemble.

How to use the Global Annual to Decadal Climate Update

The forecasts shown here are intended as guidance for Regional Climate Centres (RCCs), Regional Climate Outlook Forums (RCOFs) and National Meteorological and Hydrological Services (NMHSs). It does not constitute an official forecast for any region or nation, but RCCs, RCOFs and NMHSs are encouraged to appropriately interpret and develop value-added forecasts from this Climate Update.

Where the ensemble mean is shown, this only shows the most likely outcome. Other outcomes are possible and may be almost as likely. Signals with small spatial extent are likely unreliable. See also Hermanson et al (2022) for more information.

The skill of interannual to decadal forecasts is different to that of weather and seasonal timescales and skill may vary considerably with region and season. It is important to view the forecast maps together with the skill maps provided to evaluate the confidence in a prediction. Skill and therefore the confidence in a forecast is evaluated from hindcasts. Note that skill is only an estimate. Correlation skill is classified into five categories: very low (below 0.2, but still significant), low (between 0.2-0.4), medium (between 0.4-0.6), high (between 0.6-0.8) and very high (0.8 and higher).

Appendix – predictions for other indices

Predictions of Atlantic Meridional Overturning Circulation (AMOC) are important for the climate of countries surrounding the North Atlantic and for global heat transport. The AMOC has only been measured at 26°N since 2004. The forecast shows reduced overturning in the North Atlantic tropics and mid-latitudes for 2023 (Figure 17, top row), but skill cannot be evaluated due to insufficient observations which only exist for particular locations.

The AMOC prediction for 2023-2027 (Figure 17, bottom row) shows anomalously low values in the ensemble mean throughout the Atlantic basin, particularly in the northern hemisphere mid-latitudes. There is large variability in the ensemble (individual models are shown on the WMO Lead Centre for Annual to Decadal Climate Prediction web page, www.wmolc-adcp.org). Confidence is low as there are insufficient observations to evaluate skill.

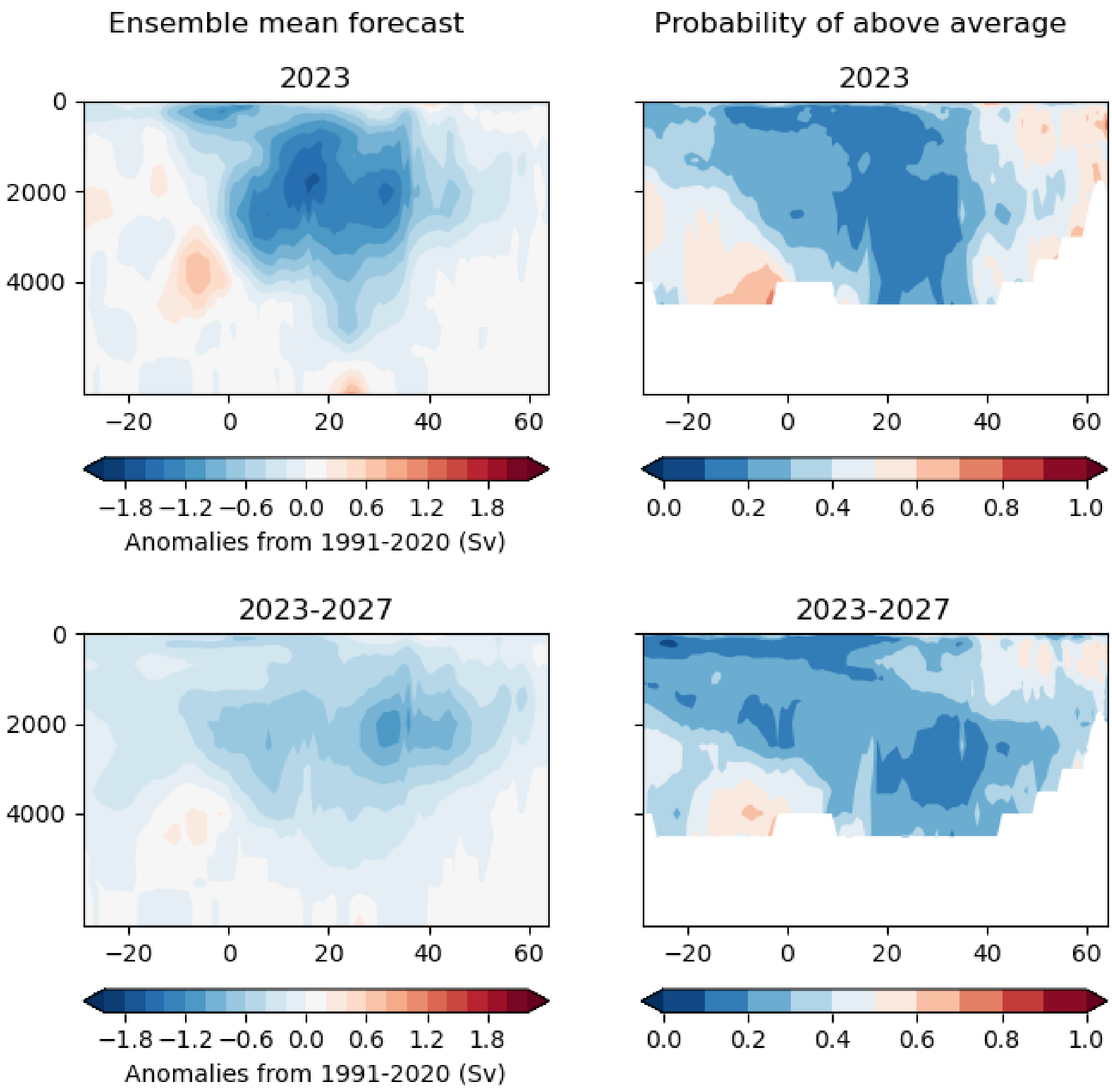

Figure 17: Atlantic Meridional Overturning Circulation (AMOC) forecast for 2023 (first row) and 2023-2027 (second row) relative to 1991-2020. The left column shows the ensemble mean prediction and the right column shows the probability of a stronger than average AMOC. As this is an uncalibrated two-category forecast, the probability for below average is one minus the probability shown in the right column.

The AMOC close to 30°N is predicted to be near or slightly below recent observed values (Figure 18). The strong decline observed during the 2000s is not predicted to continue, in line with the recent recovery. However, confidence in this forecast is low because there are insufficient past observations to evaluate skill.

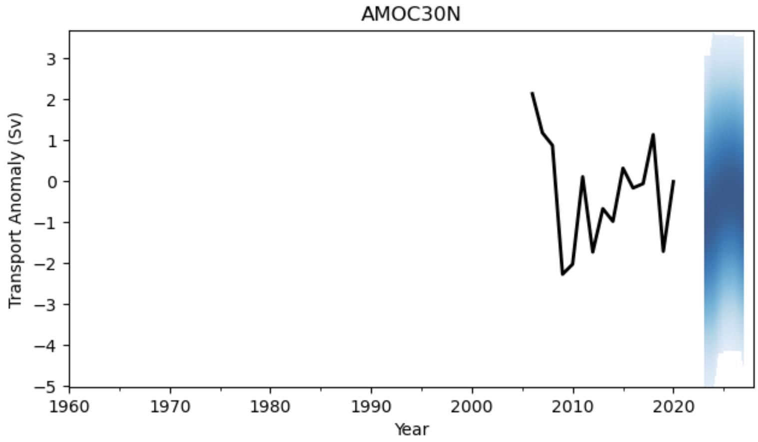

Figure 18: Atlantic Meridional Overturning Circulation close to 30°N and 1100m as in Roberts et al (2013). RAPID observations (26°N) in black (anomalies relative to its full time series 2005-2020) and model forecast in blue.

A positive phase of Pacific Decadal Variability (PDV) is characterised by warm anomalies in the tropical eastern Pacific and cold anomalies in the central North Pacific. Predictions for 2023 and the next five years show warming in both these regions and therefore do not show a typical PDV pattern. Nevertheless, the PDV index used here is predicted to be negative during 2023, despite predictions of El Niño, with a 95% calibrated probability for below average for 2023-2027 (Figure 19).

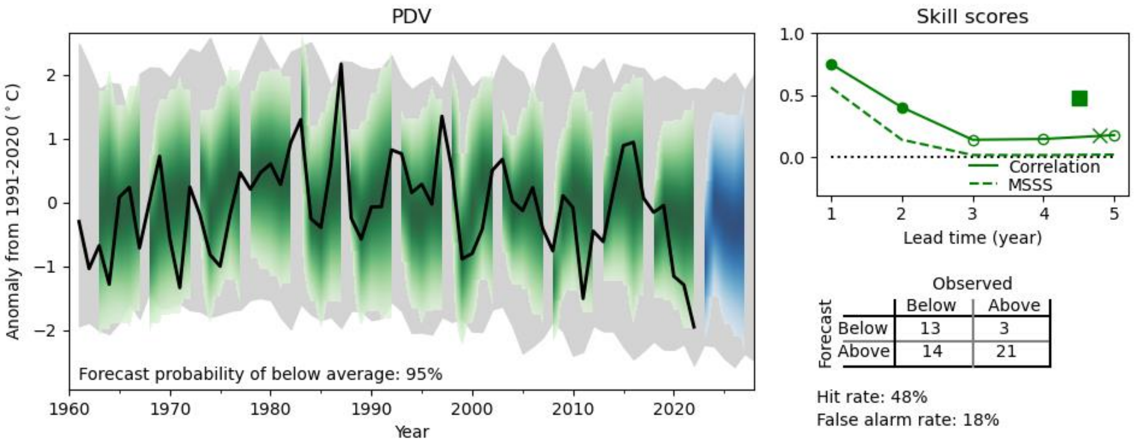

Figure 19: As Figure 5, but for Pacific Decadal Variability (PDV) defined as the difference in SST between the eastern tropical Pacific (10°S-6°N, 110°W-160°W) and the North Pacific (30°N-45°N, 145°W-180°W) as in Dong et al (2014).

The recent strong Antarctic Oscillation (AAO) is predicted to weaken (Figure 20). The calibrated probability of above average for 2023-2027 is 57%. Although skill is medium to high for individual years and for the next five years, the hindcasts (green) underestimate the strengthening of the AAO from 2005 and the forecast (blue) is lower than recent observations leading to less confidence in the prediction.

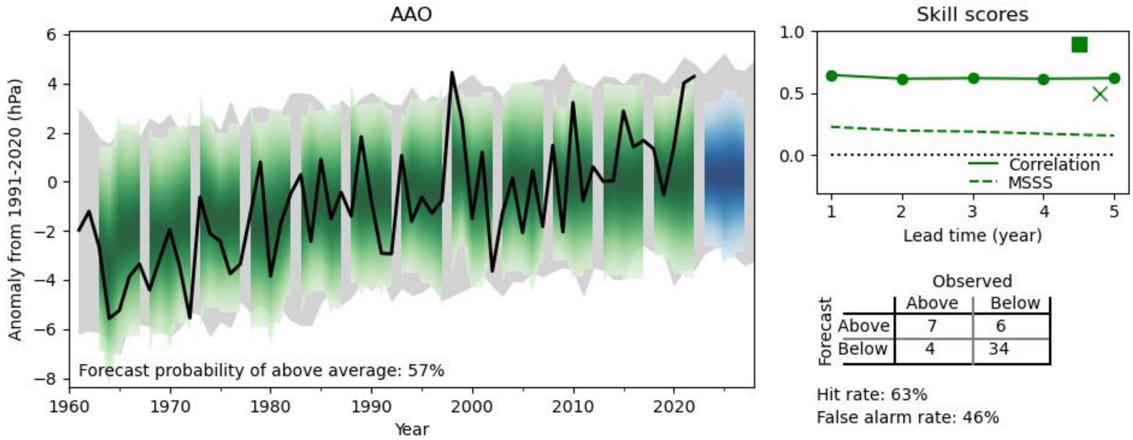

Figure 20: As Figure 5, but for the Antarctic Oscillation (AAO) defined as the difference in annual mean zonal mean sea-level pressure between 65°S and 40°S as in Gong & Wang (1999).

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