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WMO Global Annual to Decadal Climate Update

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Global Annual to Decadal Climate Update

Target years: 2021 and 2021-2025

Executive Summary

This update presents a summary of annual to decadal predictions from the WMO designated Global Producing Centres and other contributing centres for the period 2021-2025. Latest predictions suggest that:

- Annual mean global (land and sea) mean near-surface temperature is likely to be at least 1°C warmer than pre-industrial levels (defined as the average over the years 1850-1900) in each of the coming 5 years and is very likely to be within the range 0.9 – 1.8°C
- It is about as likely as not (40% chance) that at least one of the next 5 years will be 1.5°C warmer than pre-industrial levels and the chance is increasing with time
- It is very unlikely (10% chance) that the five-year mean global near-surface temperature for 2021-2025 will be 1.5°C warmer than pre-industrial levels
- The chance of at least one year exceeding the current warmest year, 2016, in the next five years is 90%
- Over 2021-2025, almost all regions, except parts of the southern oceans and the North Atlantic are likely to be warmer than the recent past (defined as the 1981-2010 average)
- Over 2021-2025, high latitude regions and the Sahel are likely to be wetter than the recent past
- Over 2021-2025 there is an increased chance of more tropical cyclones in the Atlantic compared to the recent past
- In 2021, large land areas in the Northern Hemisphere are likely to be over 0.8°C warmer than the recent past
- In 2021, the Arctic (north of 60°N) is likely to have warmed by more than twice as much as the global mean compared to the recent past
- In 2021, southwestern North America is likely to be drier whereas the Sahel region and Australia are likely to be wetter than the recent past.

Current Observations

This section is a short summary of the observed climate of the last five years to provide a context for the forecasts. Please refer to the WMO State of the Global Climate report for a more complete discussion. The climate over the last year and last five years as anomalies with respect to the recent period 1981-2010 is shown in Figure 1.

Most regions were warmer than the recent past. Warming was largest at high latitudes in the Northern Hemisphere, especially the Arctic, and generally larger over land than ocean, especially for the five-year mean 2016-2020. Parts of the Southern Ocean and the northern North Atlantic were cooler than the recent past.

In the last five years, sea-level pressure was anomalously low in both polar regions, with strongest negative anomalies over Antarctica. Hence both the Arctic and Antarctic Oscillations have been positive on average.

Parts of Eurasia, eastern USA and the African Sahel have been anomalously wet, with southern Africa, eastern Australia, north-east Brazil and western Europe anomalously dry 2016-2020.

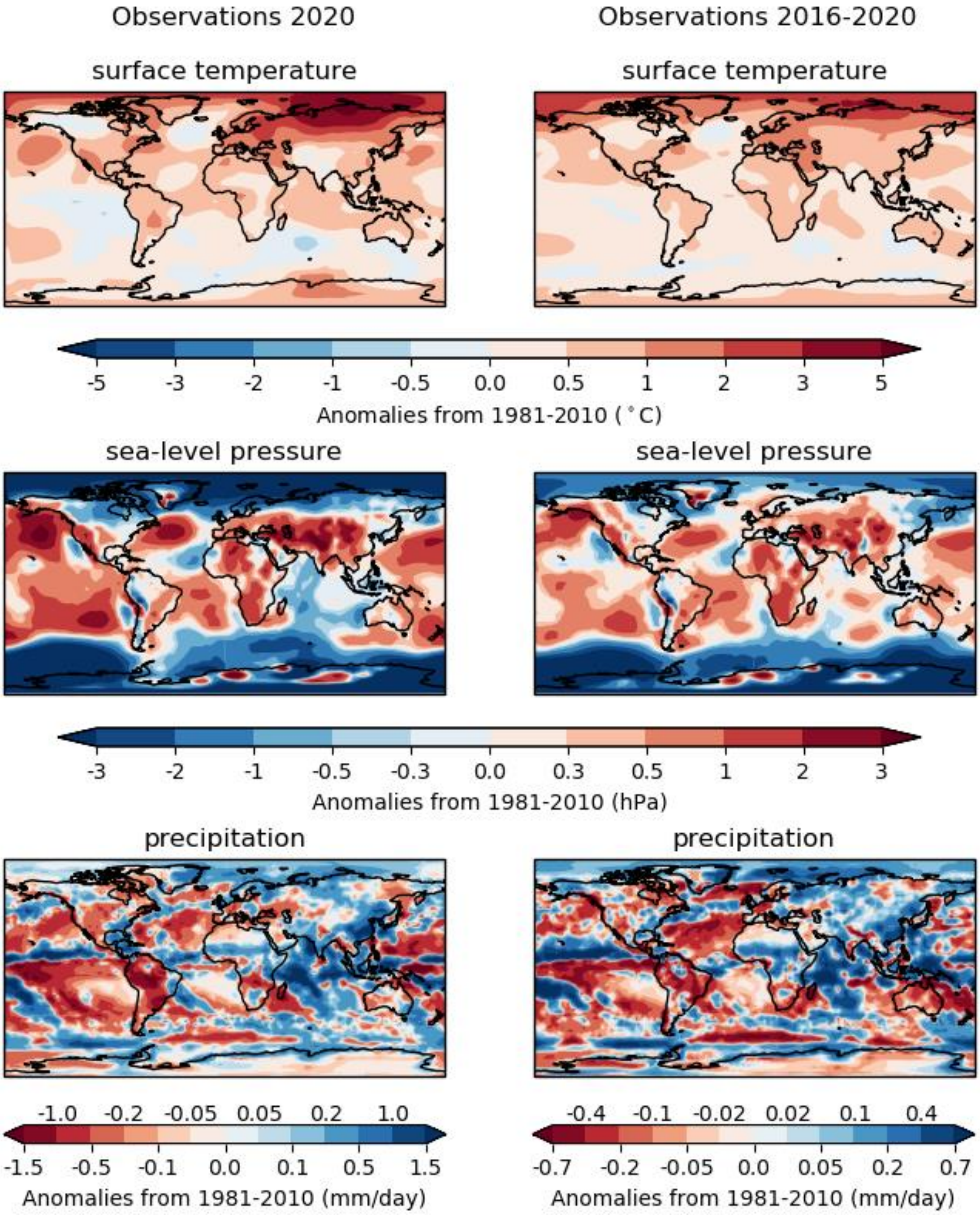

***Figure 1**: Observed annual mean near-surface temperature (°C, top), pressure (hPa; middle) and precipitation (mm/day, bottom) anomalies relative to 1981-2010. The left column shows the year 2020, the right column refers to the average of the five-year period 2016-2020. Temperatures are an average of three observational data sets: HadCRUT5 (Morice et al., 2021, updated), NASA-GISS (Hansen et al., 2010, updated), and the NCDC (Karl et al., 2015, updated). Sea-level pressure is HadSLP2r (Allan and Ansell, 2006, updated). Precipitation is GPCP (Adler et al, 2003, updated).*

Global (land and sea) mean near-surface temperatures have increased steadily since the 1960s (Figure 2). The period 2016-2020 is the warmest five-year period since records began in 1850. Since the mid-1990s the North Atlantic Ocean has been in a warm phase of Atlantic Multidecadal

Variability (AMV), but has been near zero or negative since 2015 and the subpolar North Atlantic is anomalously cold (Figure 1). The negative anomalies are consistent with the weakening of the Atlantic Meridional Overturning Circulation (AMOC) after 2005 (Fig 13 in Appendix), but are also likely related to the stronger atmospheric winter circulation with respect to the 2016-2020 average over the Atlantic (note pressure gradients in Figure 1 for annual mean). Subpolar temperatures reached a record minimum about 2015, but have been warming since and may be consistent with a recovery of the AMOC and hence increasing Atlantic sea surface temperatures. Note there are many different AMV indices, and some may not be as negative as the one used here, which is relative to 1981-2010. Since one of the largest El Niños on record in 2015/16, annual mean anomalies in the tropical East Pacific have been mainly positive apart from La Niña conditions during northern hemisphere winter in 2017/18 and the end of 2020 (Figure 2).

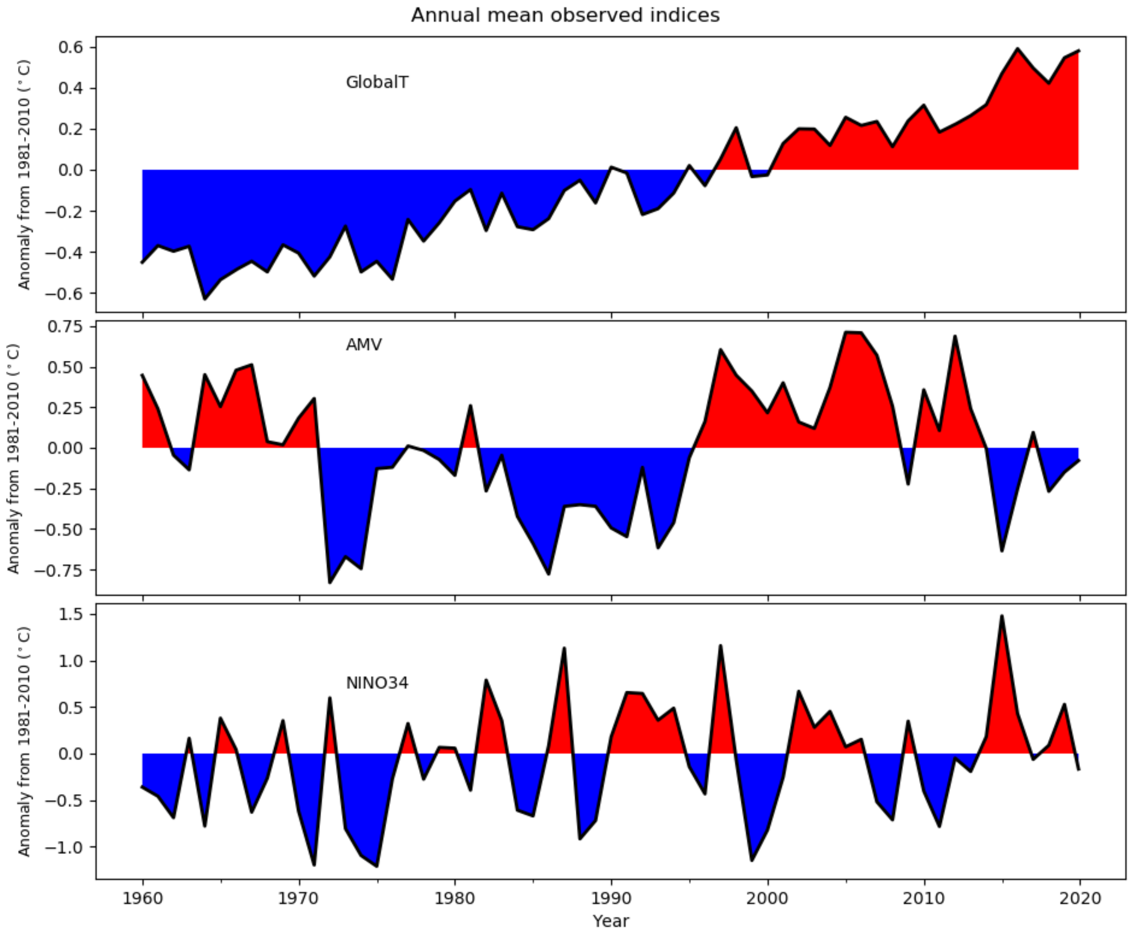

Figure 2: Observed annual mean climate indicators relative to 1981-2010. Global annual mean near-surface temperature (top), Atlantic Multidecadal Variability (AMV) defined as the difference between two regions: 45°N-60°N,60°W-0°E minus 45°S-0°S, 30°W-10°E (middle) and NINO3.4 defined as the average over 5°S-5°N, 170°W-120°W (bottom). The temperature data are the same as in Figure 1. Anomalies are with respect to the 1981-2010 reference period.

Predictions from the WMO Lead Centre

Predictions of climate indices and global fields are obtained from multi-model initialised decadal climate predictions that are started at the end of 2020 and contribute to the WMO Lead Centre for Annual to Decadal Climate Prediction (www.wmolc-adcp.org). Retrospective forecasts (hereafter hindcasts) covering the period since 1960 are used to estimate forecast skill. Also shown for the climate indicators are uninitialised (historical) simulations from the World Climate Research Programme's Coupled Model Intercomparison Project phase 5 (CMIP5).

Predictions of Global Climate Indicators

Figure 3 shows that global temperatures will increase in the five year period 2021-2025 and stay well above the 1981-2010 reference. Relative to pre-industrial conditions, the annual mean global near-surface temperature is predicted to be between 0.9°C and 1.8°C higher (90% confidence interval). The chance of at least one year exceeding 1.5°C above pre-industrial levels is 44% and is increasing with time. There is a very small chance (10%) of the five-year mean exceeding this threshold. The Paris Agreement refers to a global temperature increase of 1.5°C, which is normally interpreted as the long-term warming, but temporary exceedances would be expected as global temperatures approach the threshold.

The chance of at least one year exceeding the current warmest year, 2016, in the next five years is 90%. The chance of the five-year mean for 2021-2025 being higher than the last five years is 80%. Confidence in forecasts of global mean temperature is high since hindcasts show high skill in all measures (right-hand panels of Figure 3).

Pre-industrial conditions are defined as the average over the period 1850 to 1900, which is 0.68°C cooler than the 1981-2010 reference. This offset is uncertain and can vary between 0.61°C and 0.75°C depending on the observational data sets used. The chance of one year exceeding 1.5°C above pre-industrial levels is sensitive to the value used and gives a range of probabilities 25%-65% for the exceedance. The other probabilities of exceedance quoted above are less sensitive.

The coronavirus COVID-19 lockdowns are likely to cause changes in emissions of greenhouse gases and aerosols that are not included in the forecast models. The impact of changes in greenhouse gases is probably small, the reduction in anthropogenic aerosols will probably increase global mean temperatures by less than 0.05°C.

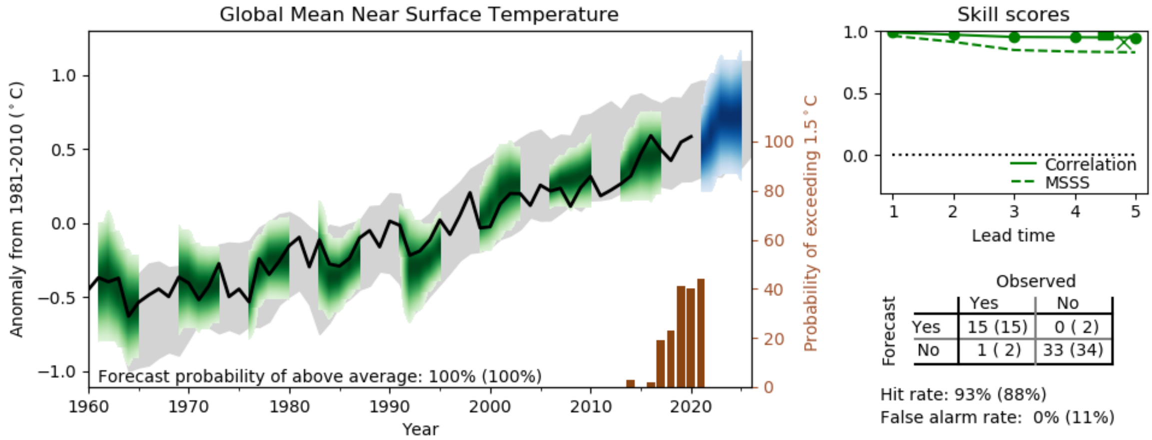

Figure 3: Multi-annual predictions of global mean near-surface temperature relative to 1981-2010. Annual global mean observations in black, forecast in blue, hindcasts in green and unininitialised simulations in grey. The shading indicates the 90% confidence range. The probability for above average in the five year mean of the forecast is given at the bottom of the main panel (in brackets the probability for above average in the next year). 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. 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 brackets values for above average in the next year). Also inset in the main panel, referring to the right hand axis, is the probability of global temperature exceeding 1.5°C above pre-industrial levels for at least one year during the five years starting in 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 (or month) above 1.5°C.

Predictions indicate a 77% probability that Atlantic Multidecadal Variability (AMV) will be positive when averaged over the next five years (Figure 4). However, AMV is likely to be lower than recent peak values seen in the 2000s. The hindcasts have reasonably high skill in all measures giving medium to high confidence in this prediction (not shown). Predictions for the Atlantic Meridional Overturning Circulation, that contributes to AMV, can be found in the appendix.

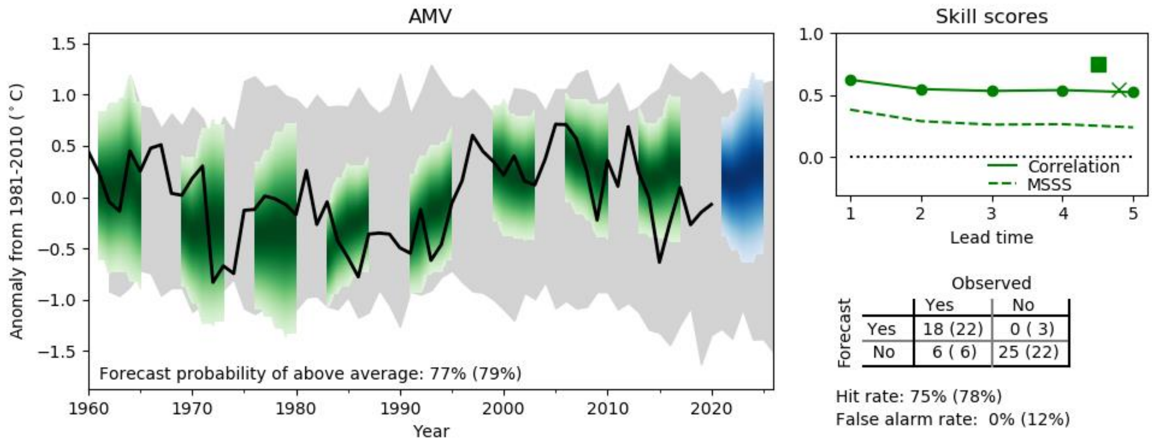

Figure 4: Multi-annual predictions of Atlantic Multidecadal Variability (AMV) relative to its 1981-2010 average, defined as the difference between two regions: 45°N-60°N,60°W-0°E minus 45°S-0°S, 30°W-10°E as in Roberts et al (2013). Annual mean observations in black, forecast in blue, hindcasts in green and unininitialised simulations in grey. The shading indicates the 90% confidence range. The probability for above average in the five year mean of the forecast is given at the bottom the main panel (in brackets the probability for above average in the next year). 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. 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 brackets values for above average in the next year).

Below average temperatures in the NINO3.4 region are predicted for 2021 with a probability of 63% (100% minus the 37% in brackets in Figure 5). The current La Niña is predicted to decline, and the five-year average prediction shows a continuation of the slight warming trend seen since the 1970s. Skill is moderate but significant, giving low to medium confidence in this forecast.

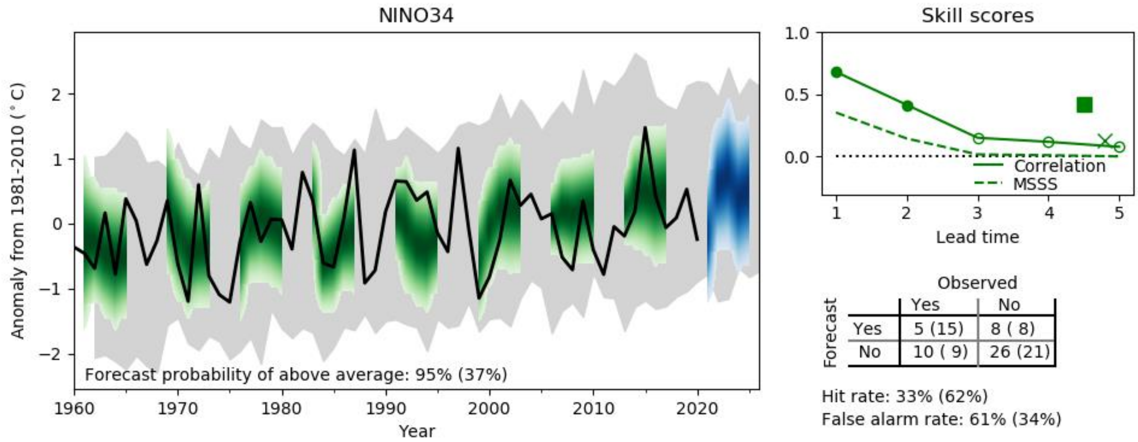

Figure 5: As Figure 4, but for NINO3.4 defined as the average over 5°S-5°N, 170°W-120°W.

Regional Predictions for 2021

Temperatures in 2021 are predicted to be higher than the 1981-2010 average in almost all regions except parts of the Southern Ocean and the tropical and south-east Pacific (Figure 6). Skill is reasonably high in most regions giving high to medium confidence (Figure 7).

Sea-level pressure forecasts suggest anomalous low pressure over the Arctic consistent with a positive Arctic Oscillation (AO, see Figure 16 in the appendix). The skill plots show moderate but significant correlations, giving medium confidence in this prediction. The forecast also suggests high pressure anomalies are likely over the tropical east Pacific and low over the Maritime Continent consistent with a positive Southern Oscillation (medium confidence).

Precipitation patterns suggest an increased chance of drier conditions over southwestern Europe and southwestern North America and wetter conditions in northern Europe, the Sahel and Australia. Correlation skill is low even if significant in these regions, giving low to medium confidence in the forecast.

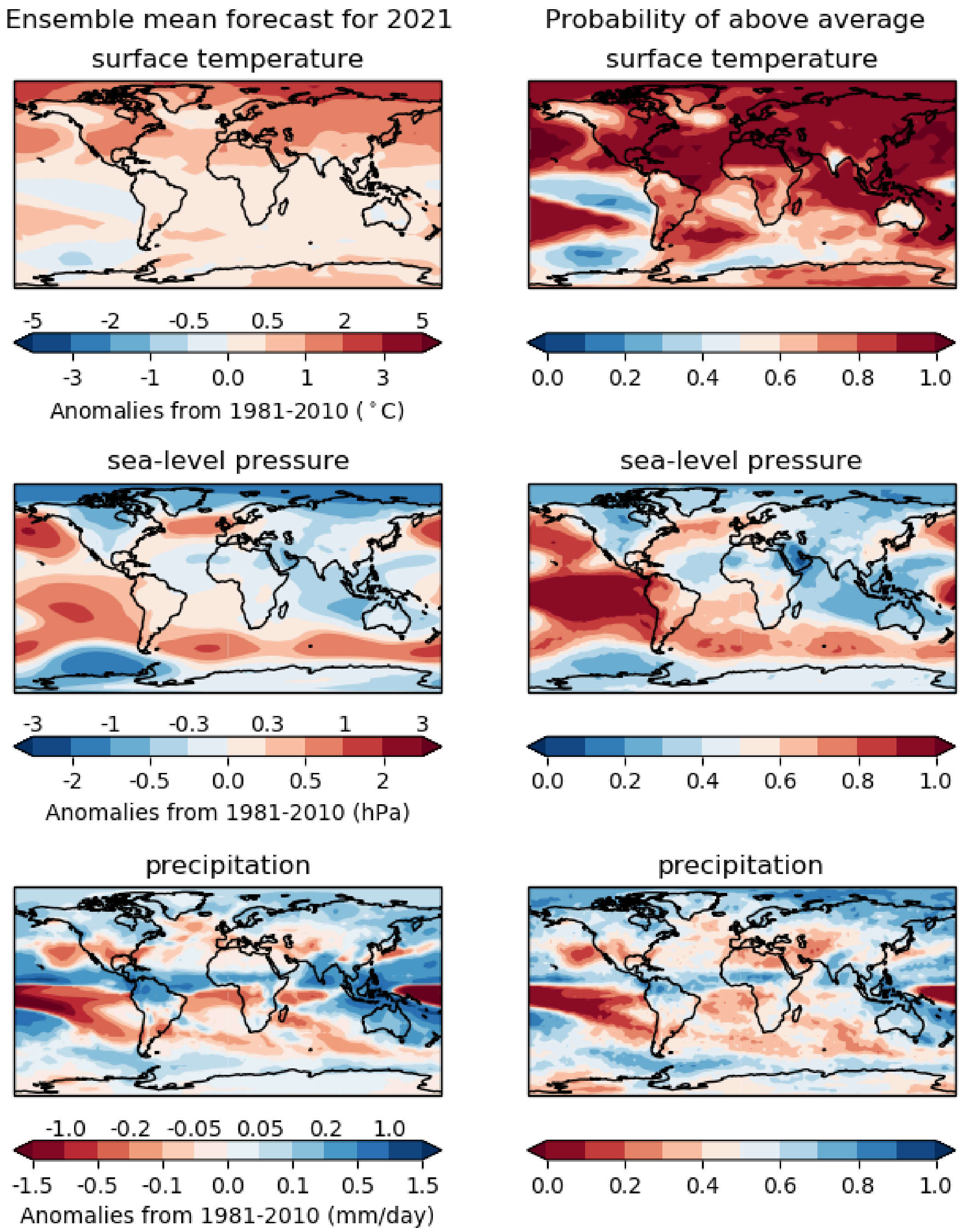

Figure 6: Annual mean anomaly predictions for 2021 relative to 1981-2010. Ensemble mean (left column) for temperature (top, °C), sea level pressure (middle, hPa), precipitation (bottom, mm/day) and probability of above average (right column). As this is a two-category forecast, the probability for below average is one minus the probability shown in the right column.

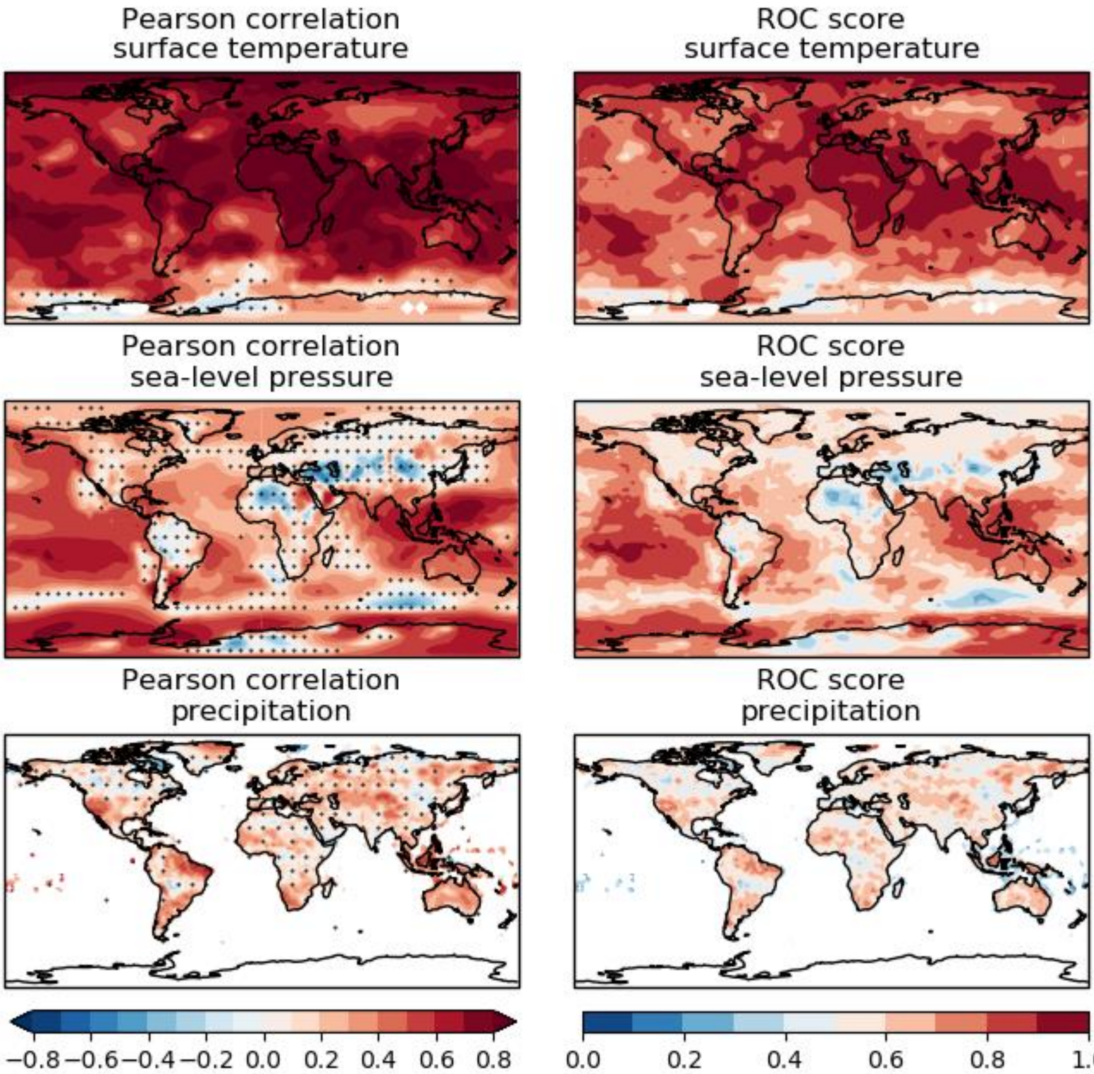

Figure 7: Prediction skill of annual mean hindcasts evaluated using hindcast experiments. Correlation (left) and ROC score for predictions of above average conditions (right). For correlation stippling shows where skill is not significant (at the 5% level).

Regional Predictions for 2021-2025

Predicted temperature patterns for 2021-2025 show a high probability for temperatures above the 1981-2010 average almost everywhere, with enhanced warming at high northern latitudes and over land compared to ocean (Figure 8). The Arctic (north of 60°N) anomaly is more than twice as large as the global mean anomaly. Skill is high in all regions apart from the eastern Pacific and Southern Ocean (Figure 9).

Sea-level pressure maps for 2021-2025 show increased probabilities for low pressure over both poles compared to the 1981-2010 reference period, consistent with positive Arctic Oscillation (AO) and Antarctic Oscillation (AAO) indices (see appendix), and for high pressure over most ocean regions. The subtropical North Atlantic, however, shows an increased chance of low pressure which, combined with higher temperatures and a northward displacement of the Intertropical Convergence Zone (ITCZ), suggests an increased chance of tropical cyclones in this basin. The increased north-south pressure gradient in the northern North Atlantic may also be indicative of stormier conditions over Scandinavia compared to 1981-2010. Skill is moderate and significant over these regions giving medium confidence in the forecast.

Precipitation predictions for 2021-2025 favour wetter than average conditions at high latitudes in both hemispheres. The pattern of increased precipitation in the tropics and midlatitudes and reduced precipitation in the subtropics compared to the 1981-2010 reference period is consistent with an increased hydrological cycle expected as the climate warms. There is moderate but significant correlation skill over the Sahel, Greenland and across northern Europe and Eurasia, giving medium confidence in the forecast for an increased chance of precipitation in these regions.

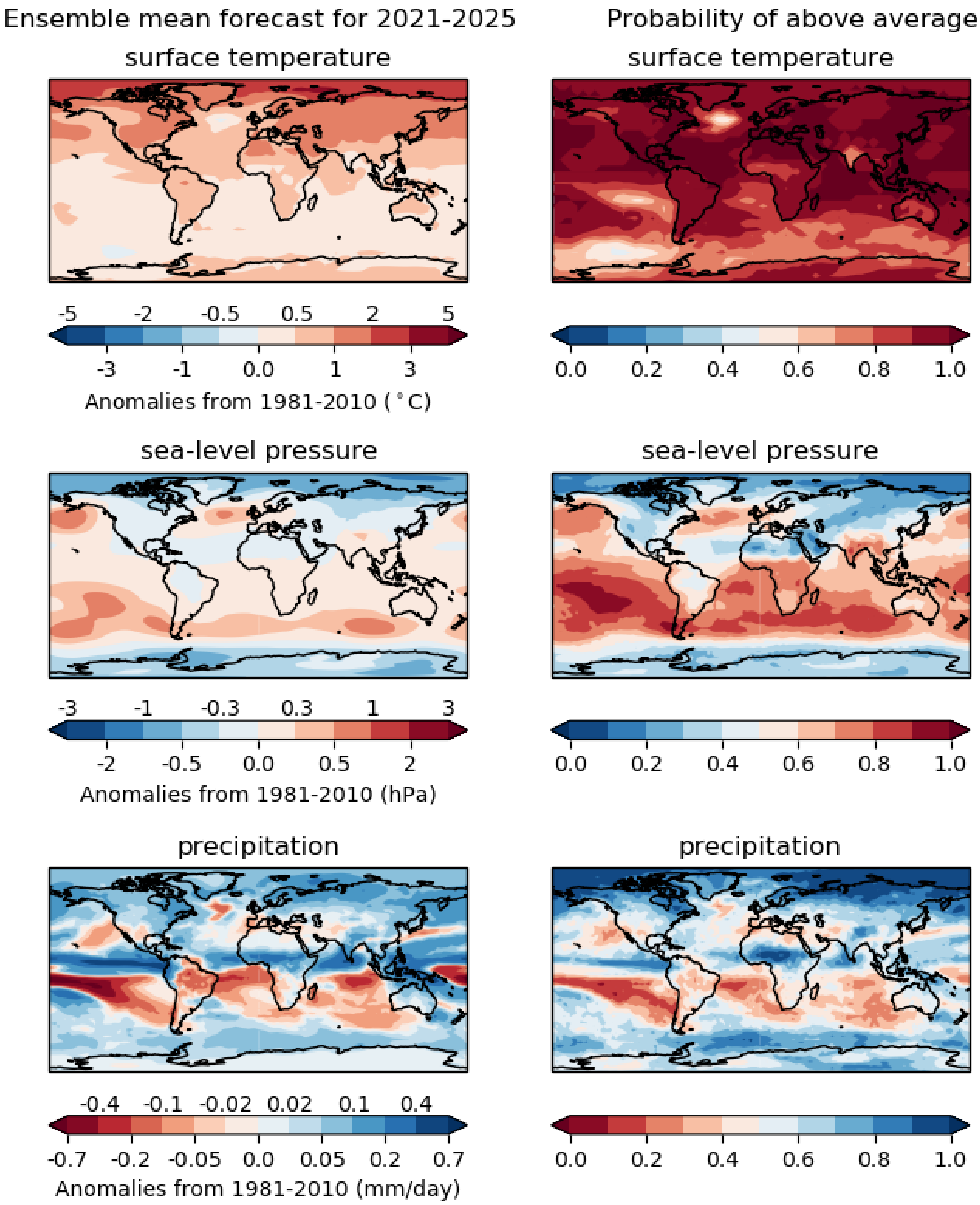

Figure 8: Predictions for 2021-2025 anomalies relative to 1981-2010. Ensemble mean (left column) for temperature (top, °C), sea level pressure (middle, hPa), precipitation (bottom, mm/day) and probability of above average (right column). As this is a two-category forecast, the probability for below average is one minus the probability shown in the right column.

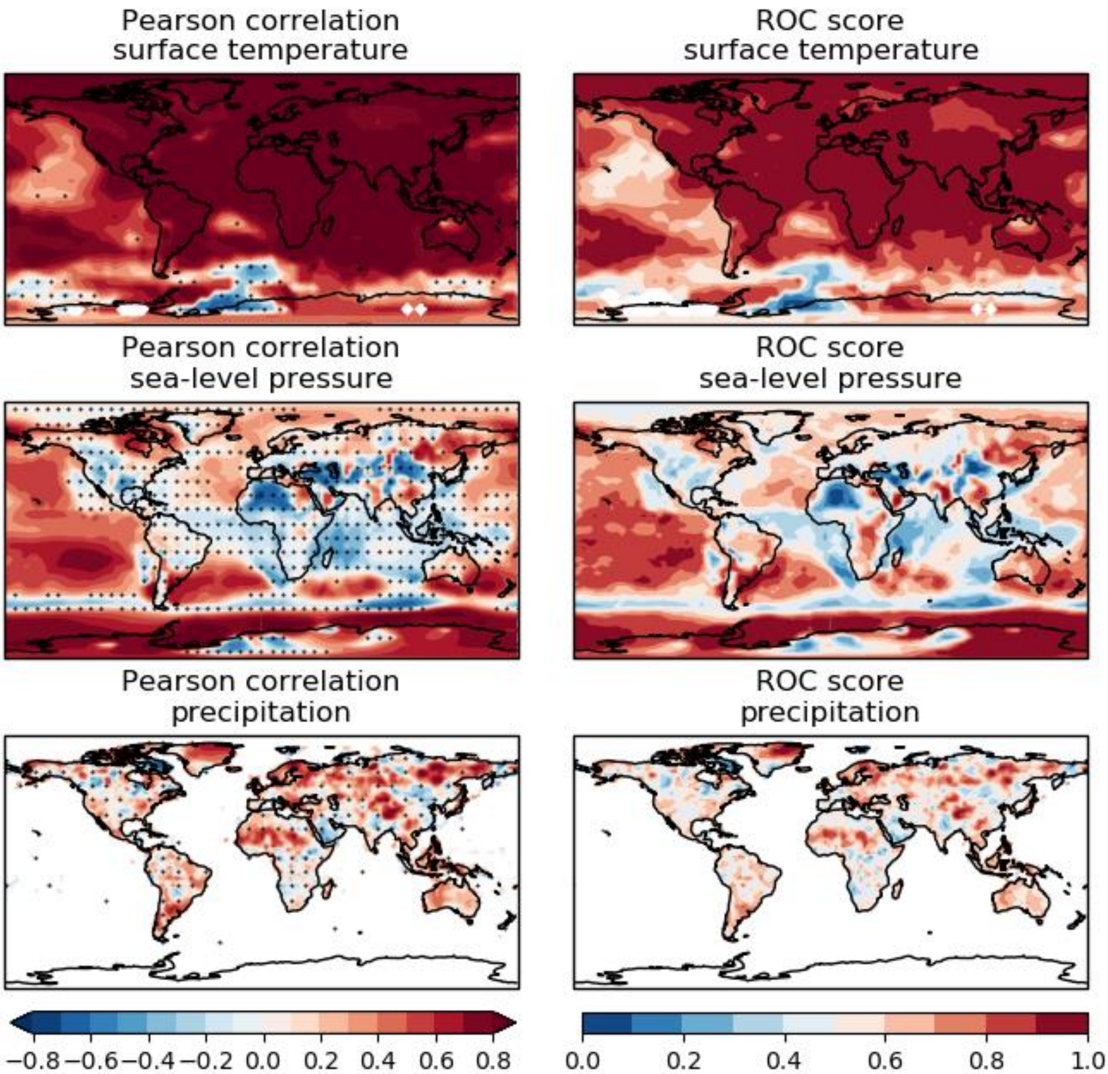

Figure 9: Prediction skill of five-year means evaluated using hindcast experiments. Correlation (left) and ROC score for predictions of above average conditions (right). For correlation stippling shows where skill is not significantly positive (at the 5% level).

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 2020, which was run at the end of 2019 (Figure 10), shows good agreement for near-surface temperatures with the observed pattern including very warm conditions over the Arctic and Eurasia, and relatively cool conditions in the Southern Ocean, northern North Atlantic and tropical Pacific. However, the anomalies are often too small. Observed cooler conditions in parts of North America and south Indian Ocean were not predicted.

Sea-level pressure patterns agree reasonably well with the observations, with low pressure over the Arctic and the western Indian Ocean and generally high pressure over the Pacific and South-East

Asia. However, the predicted anomalies are small and the ensemble spread does not encompass the observed magnitude in most regions.

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

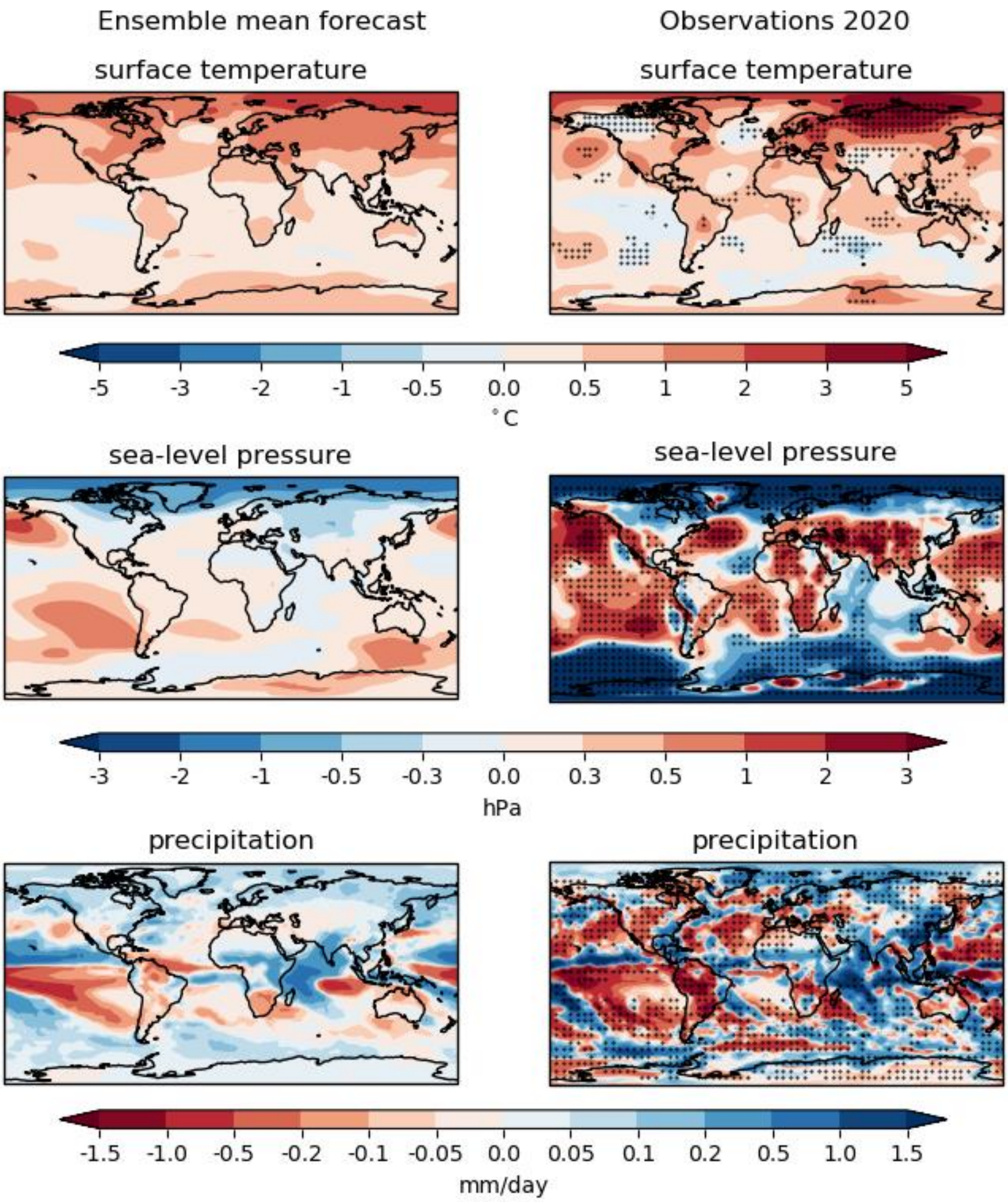

Figure 10: Evaluation of the one-year forecast for 2020 relative to 1981-2010. Ensemble mean forecast (left) and observed anomalies (right). Top: temperature (°C); middle: sea level pressure (hPa); bottom: precipitation (mm/day). Stippling shows where the observations fall outside of the 90% range of the forecast ensemble.

Average forecast temperature anomalies for the last five years 2016-2020, from forecasts run at the end of 2015 (Figure 11) generally agree well with observations of very warm conditions over the Arctic and Eurasia, and enhanced warming over the land compared to the ocean. However, the magnitude of Arctic warming was underestimated. Relatively cool conditions in the northern North Atlantic, South Pacific and Southern Ocean are also mostly captured within the ensemble spread. Other cooler conditions in Canada, the East Pacific and eastern and western Indian Ocean were not captured.

Sea-level pressure patterns show agreement with the observations, with low pressure over the Arctic and Antarctic and high 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 most regions even when the ensemble mean shows the correct sign. High pressure over Eurasia was not captured by the ensemble.

Precipitation patterns show reasonable agreement with observations, including wetter conditions across much of Eurasia and central Africa, and drier conditions in southern North America, north-east Brazil and southern Africa. Dry conditions in western Canada, Australia and western Europe were not captured.

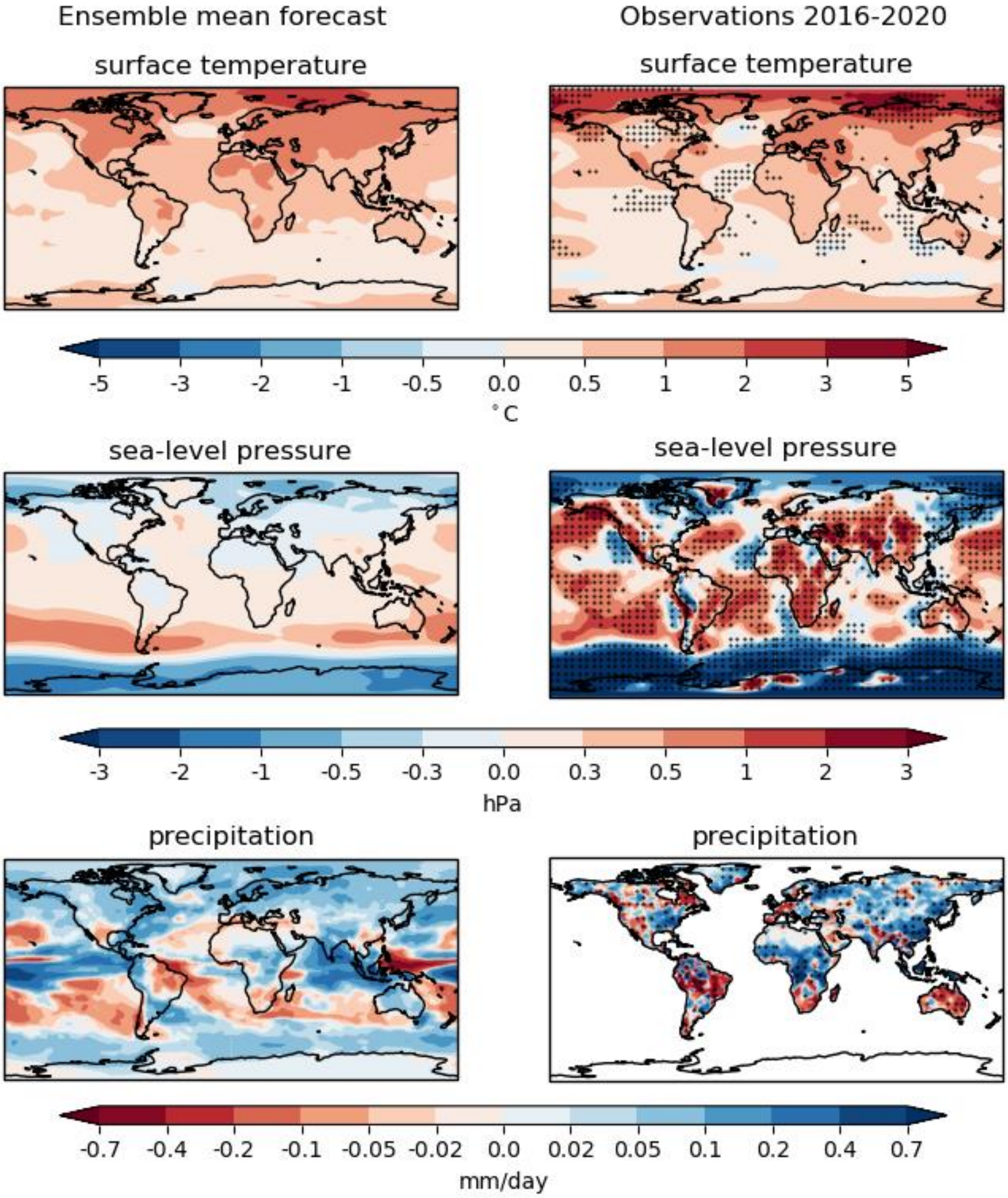

Figure 11: Evaluation of the five-year forecast for 2016-2020 relative to 1971-2000. Ensemble mean forecast (left) and observed anomalies (right). Top: temperature (°C); middle: sea level pressure (hPa); bottom: precipitation (mm/day). Stippling shows where the observations fall outside of the 90% range of the forecast ensemble.

Appendix – predictions for the AMOC and other indices

Predictions of Atlantic Meridional Overturning Circulation (AMOC) show reduced overturning in the mid-latitudes for 2021 (Figure 12, top row), but skill cannot be evaluated due to insufficient observations.

The AMOC prediction for 2021-2025 (Figure 12, 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 and almost half the models predict stronger overturning. The individual models are shown online. Confidence is low as there are insufficient observations to evaluate skill.

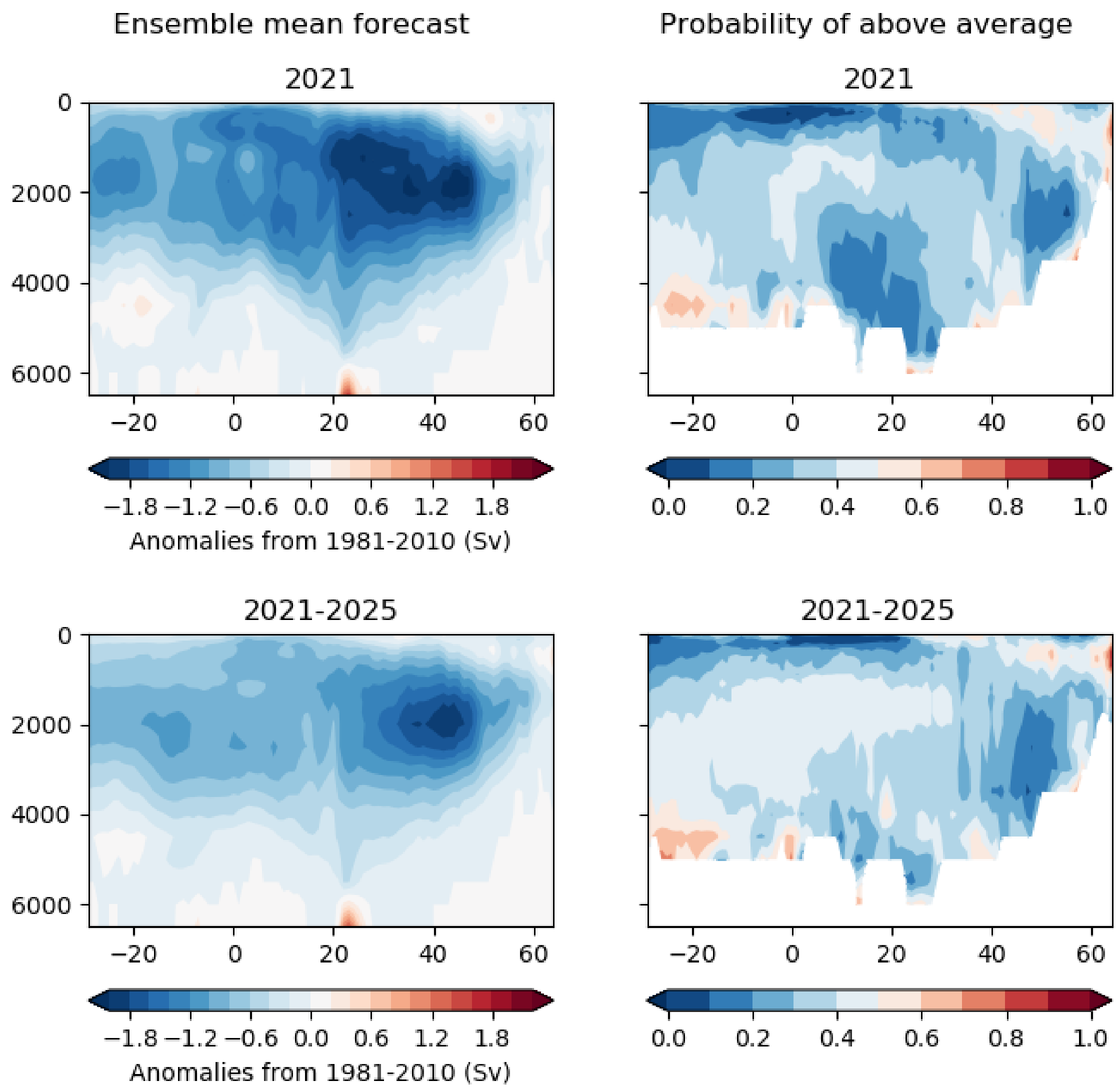

Figure 12: Atlantic Meridional Overturning Circulation (AMOC) forecast for 2021 (first row) and 2021-2025 (second row) relative to 1981-2010. The left column shows the ensemble mean prediction and the right column shows the probability of a stronger than average AMOC.

The AMOC close to 30°N is predicted to be near or slightly below recent values (Figure 13). 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.

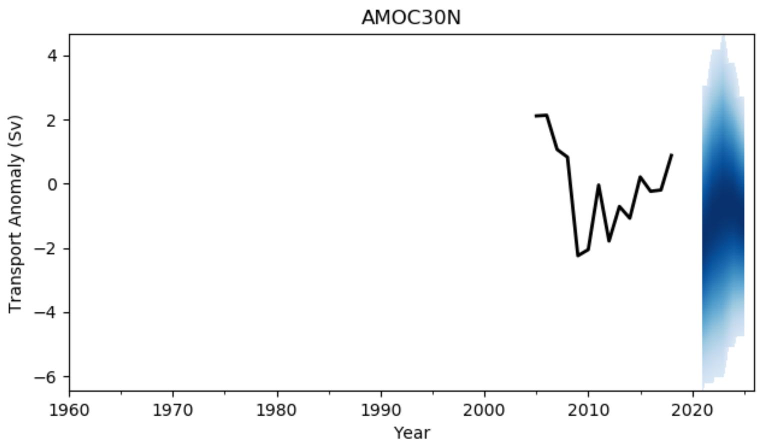

Figure 13: Atlantic Meridional Overturning Circulation at about 30°N and 1100m as in Roberts et al (2013). RAPID observations (26°N) in black (anomalies relative to its full time series 2005-2018) and model forecast in blue.

Pacific Decadal Variability (PDV) is predicted to be negative during 2021 with a 100% probability for below average (Figure 14). Good skill in year 1 gives medium confidence, but beyond two years there is no significant skill. The five-year mean has low skill and therefore the 97% probability of below average PDV has low confidence.

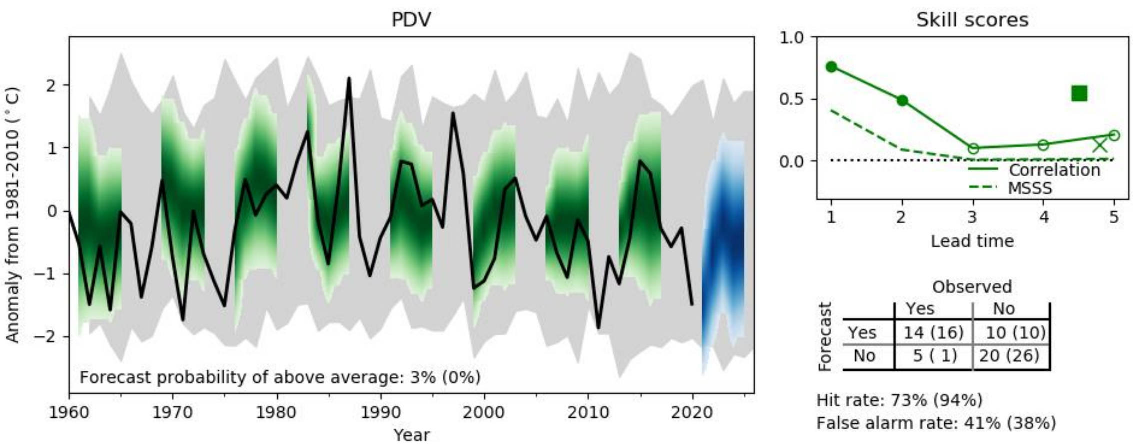

Figure 14: As Figure 4, but for Pacific Decadal Variability (PDV) defined as the difference in SST between the eastern tropical Pacific (10°S-6°N, 110°W-160°W) and the North Pacific (30°N-45°N, 145°W-180°W) as in Dong et al (2014).

The recent strong Antarctic Oscillation (AAO) is predicted to weaken but stay above average (Figure 15). Although skill is significant for individual years and for the next five years, the hindcasts (green) do not capture the strengthening of the AAO from 2005 very well, and the forecast (blue) is much lower than recent observations. Confidence is therefore low to medium for this forecast.

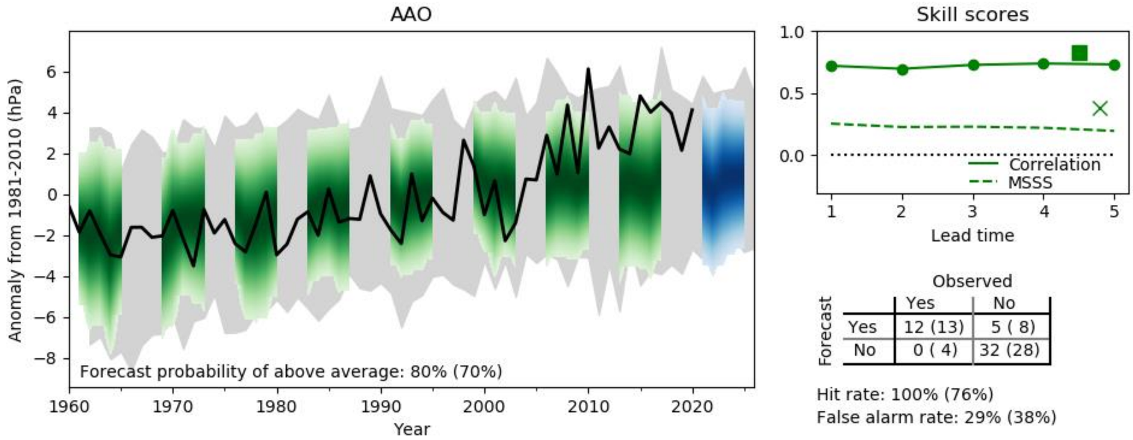

Figure 15: As Figure 4, but for the Antarctic Oscillation (AAO) defined as the difference in zonal mean sea-level pressure between 65°S and 40°S as in Dong & Wang (1999).

The Arctic Oscillation averaged over the next five years is likely to be above normal with a probability of 82% (Figure 16). Hindcasts show modest but significant correlation but probabilistic skill is low, so there is low to medium confidence in this prediction.

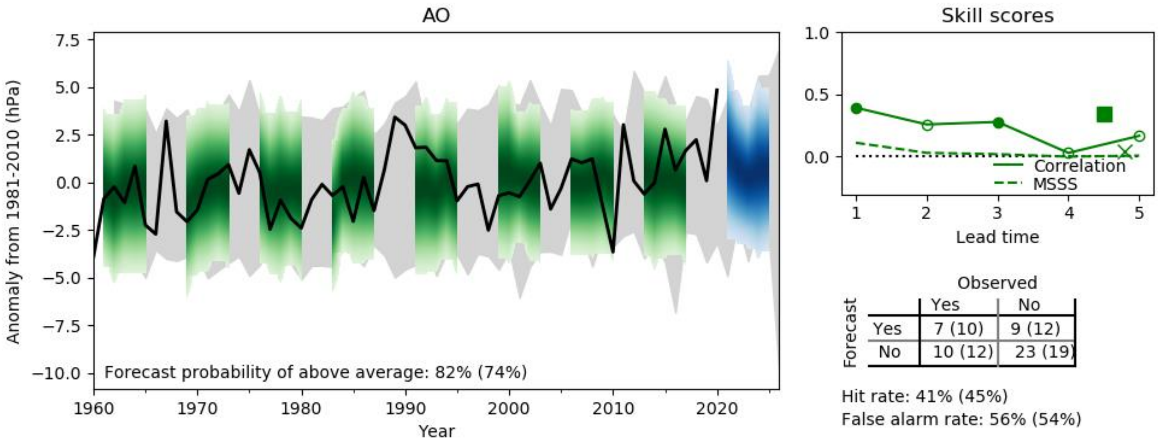

Figure 16: As Figure 4, but for Arctic Oscillation defined as the difference in zonal mean sea-level pressure between 80°N and 45°N, similar to Dong & Wang (1999), but for the Northern Hemisphere.

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