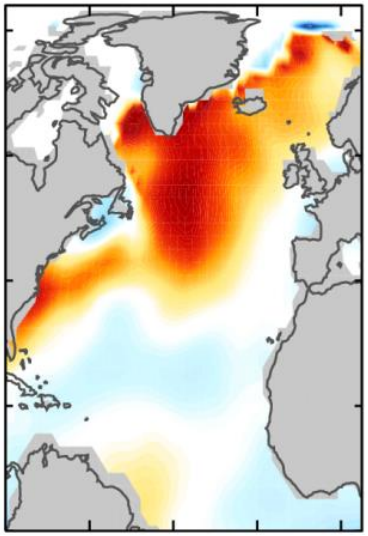
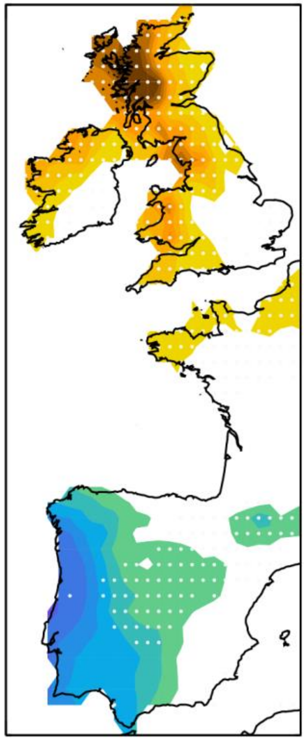
The predictability of late winter precipitation in western Europe





Isla Simpson
Steve Yeager, Karen McKinnon, Clara Deser

NCAR

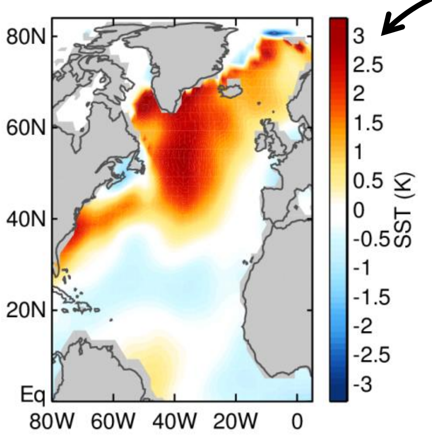
Previous work: Simpson et al 2018, J. Clim., 31, 8313-8338

Demonstrated pronounced multi-decadal variability in the North Atlantic jet stream in the late winter, March in particular, and found this to be strongly connected to variability in North Atlantic SSTs

Models appear to be deficient in this multi-decadal variability in the North Atlantic jet stream and its connection to SSTs.

March Connections

20y running means



Regression of SST onto normalized Trenberth and Shea (2006) AMV index

March Connections

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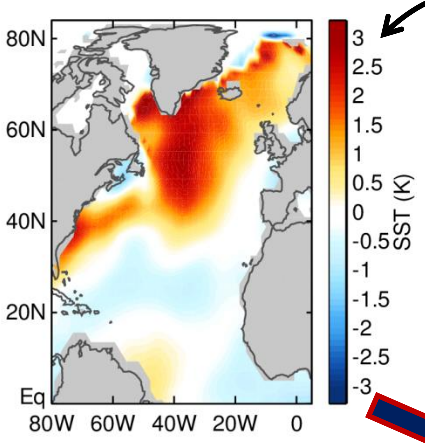

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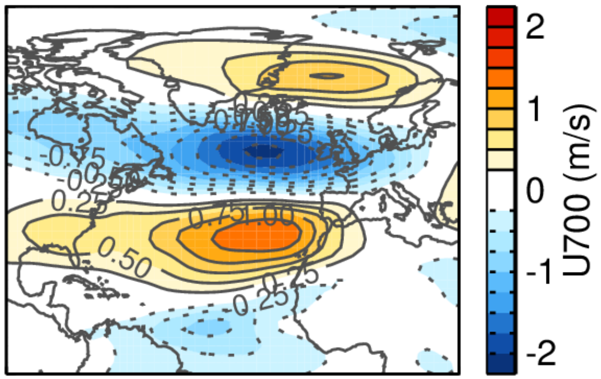

Regression of U700 onto normalized Trenberth and Shea (2006) AMV

March Connections

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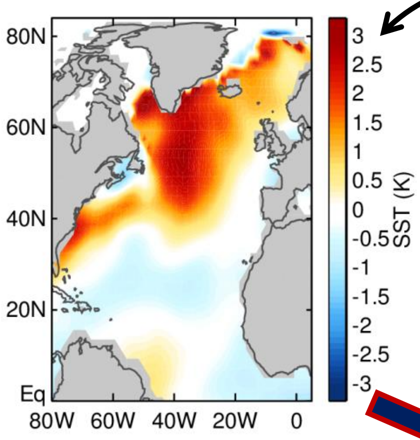

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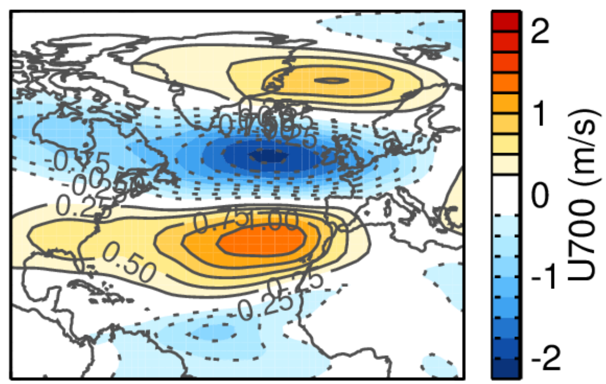


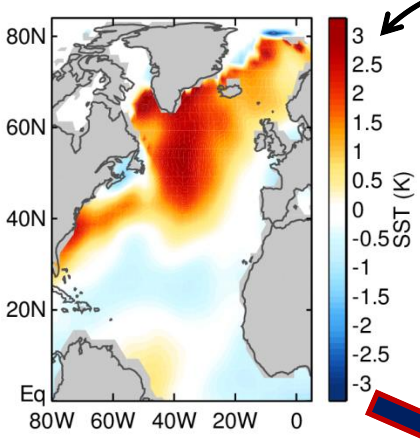
Regression of U700 onto normalized Trenberth and Shea (2006) AMV

Connection between the jet stream and the AMV seems to be far stronger in late winter (March) than other times of the year

Mechanism and reason for model deficiencies remain to be understood?

March Connections

20y running means



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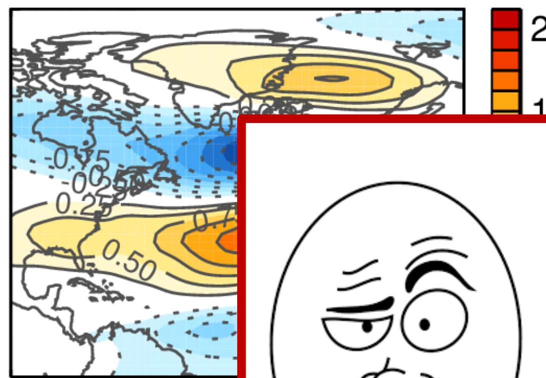

Worried about statistical significance? Causality?

Ask me later

Or see Simpson et al 2018

Regression of U700 onto normalized Trenberth and Shea (2006) AMV

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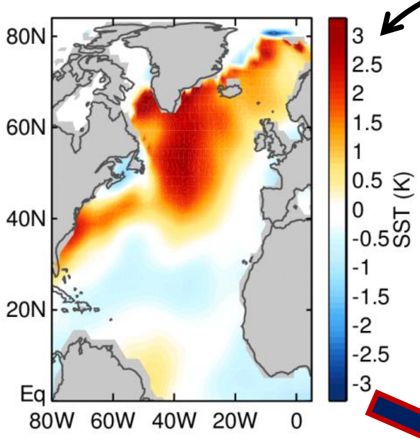

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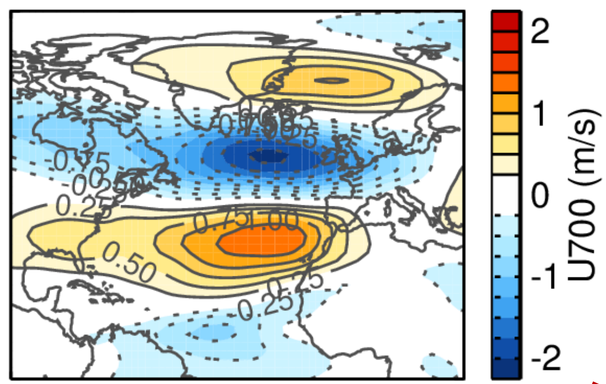

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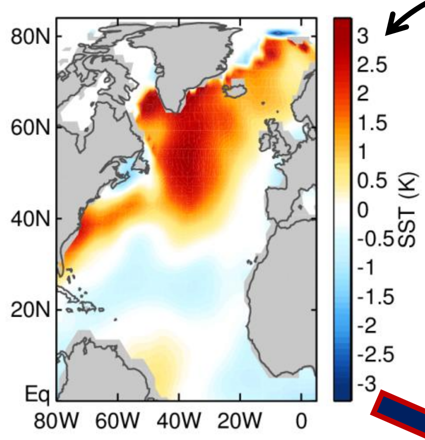

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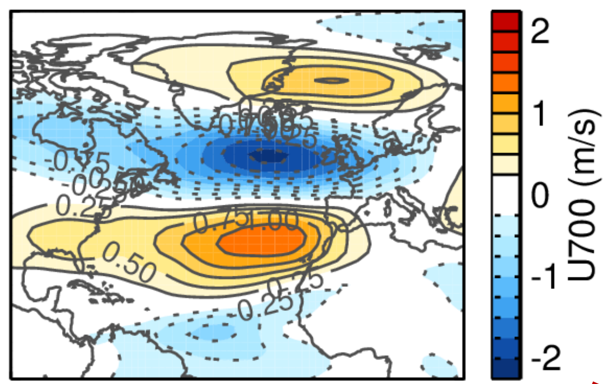


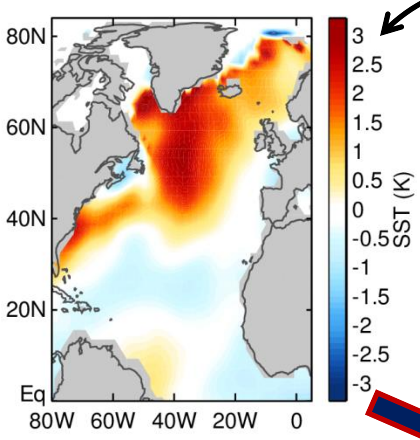
Regression of U700 onto normalized Trenberth and Shea (2006) AMV

Two Goals:

(a) Provide independent verification of the low frequency jet stream variability found in reanalyses

March Connections

20y running means



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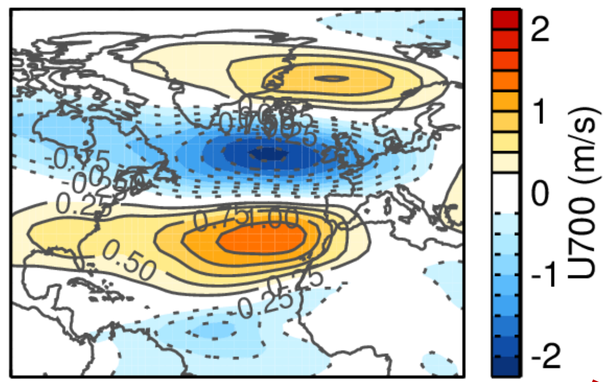


Regression of U700 onto normalized Trenberth and Shea (2006) AMV

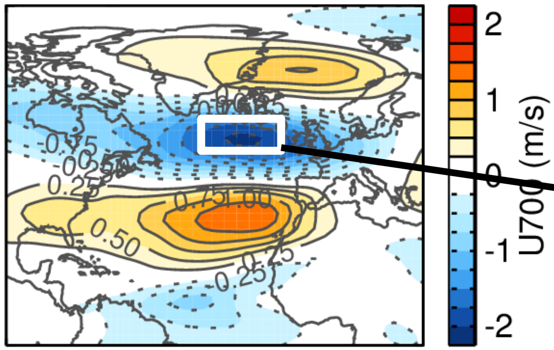
Two Goals:

(a) Provide independent verification of the low frequency jet stream variability found in reanalyses

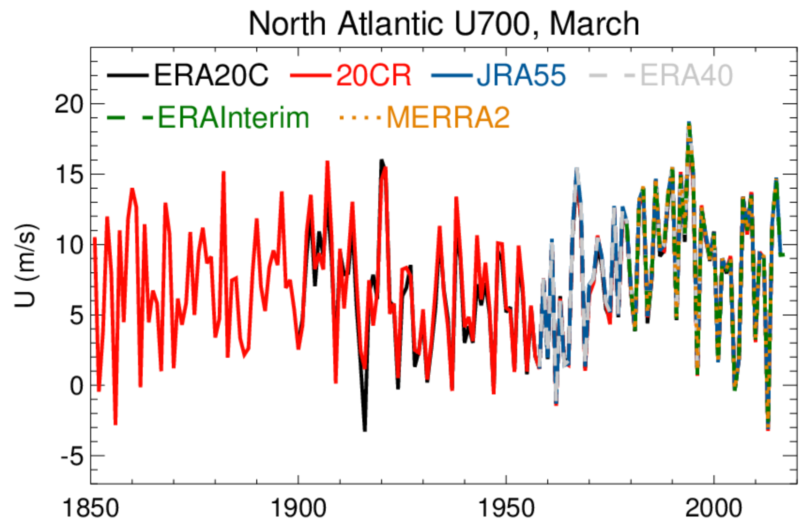
(b) Explore the potential for predictability of low frequency variability in precipitation in western Europe.

The link between low frequency jet stream variability and precipitation

Implications of this variability



Regression of 20y running mean ERA20C U700 onto the AMV



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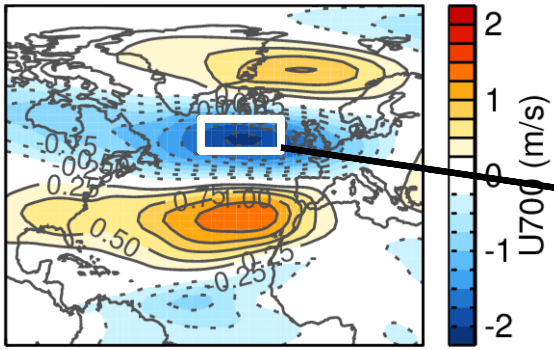

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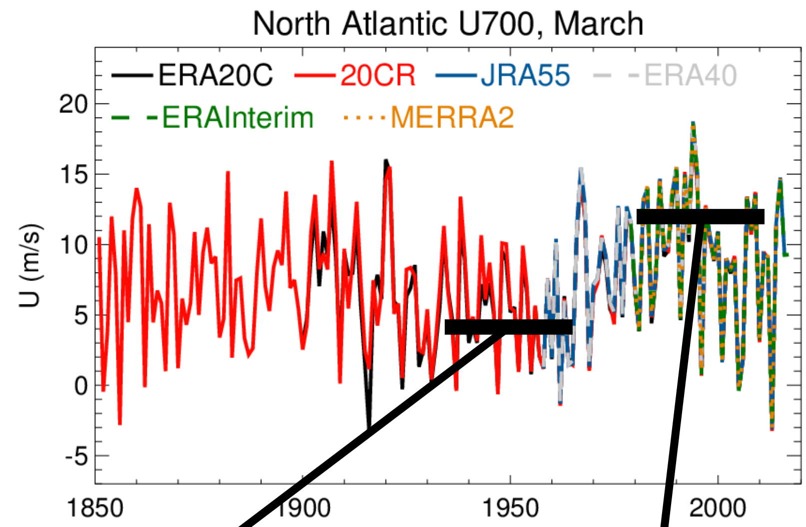

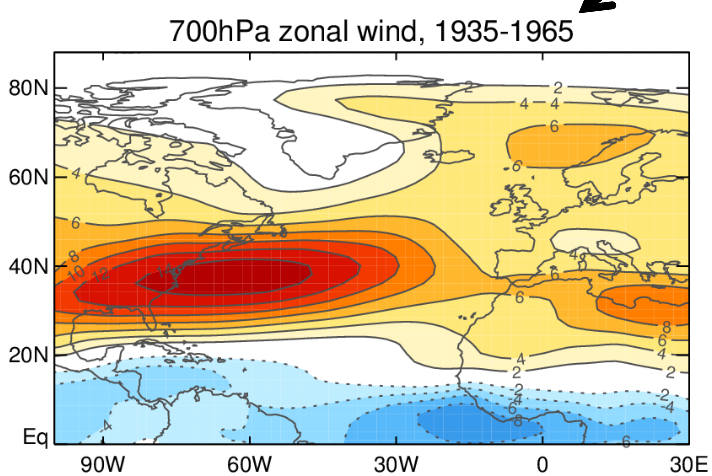

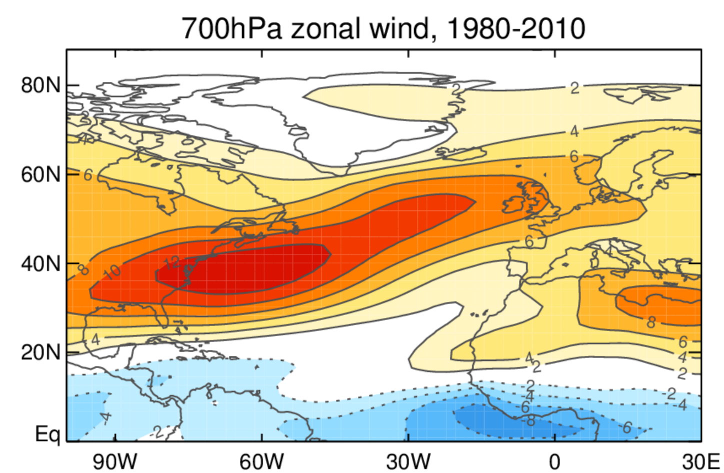

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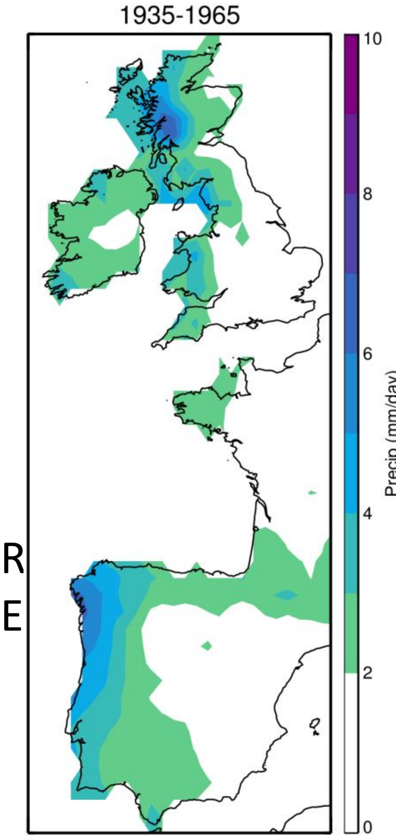

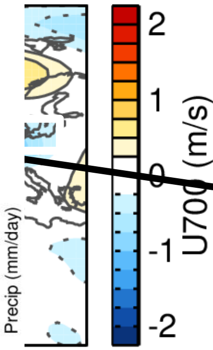

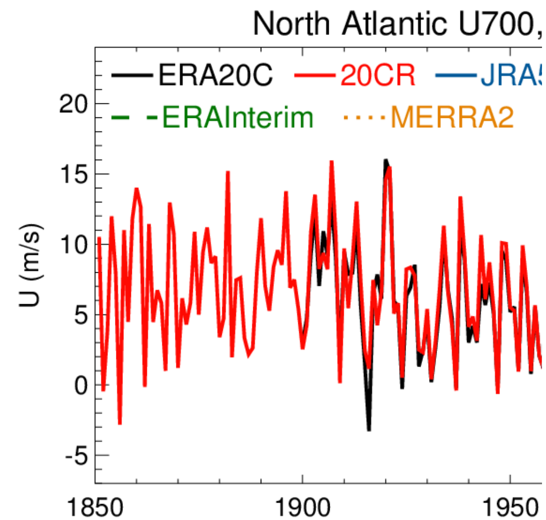

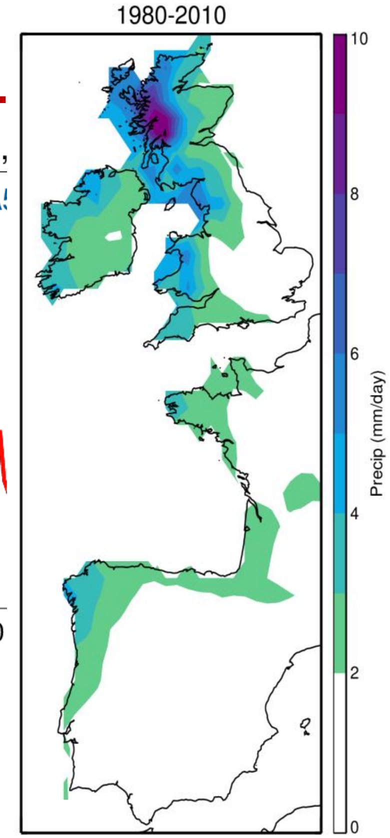

R
E

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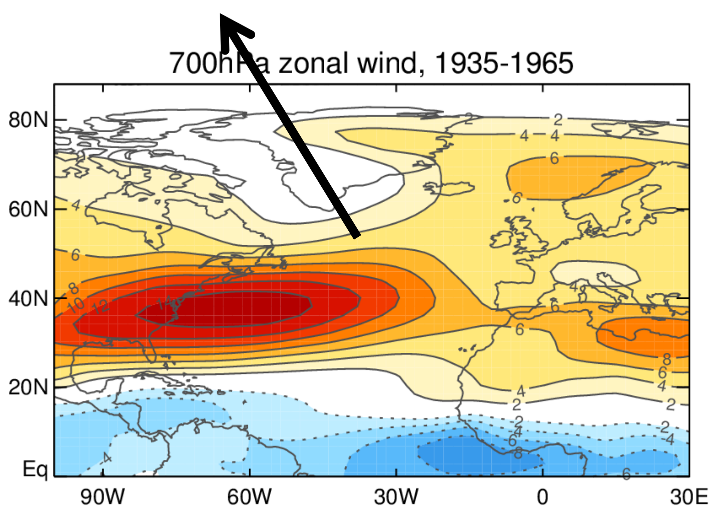
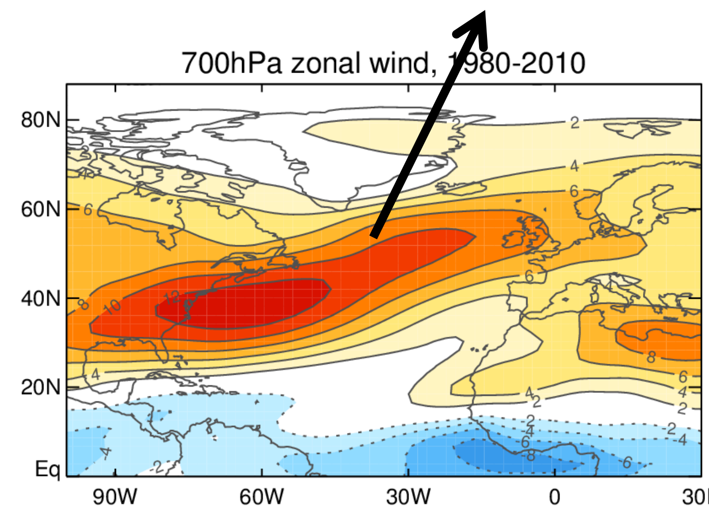
ne AMV

CRU TS precipitation (March)

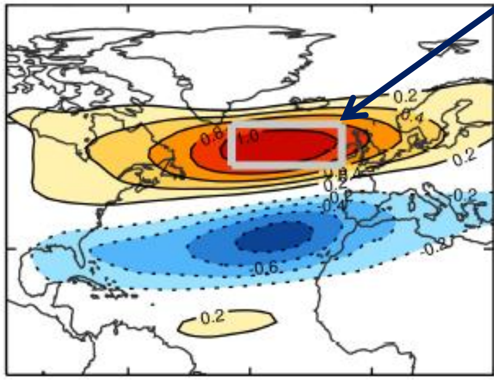




Can we use precipitation observations to verify the low frequency U700 variability found in the reanalysis?

Reconstructing jet stream variability from precipitation observations

U700NA = winds in this North Atlantic box



Regression of March U700 onto March U700NA, interannual, 1979-2016

ERA-Interim over the satellite record i.e., more observationally constrained than 20th century reanalyses

Reconstructing jet stream variability from precipitation observations

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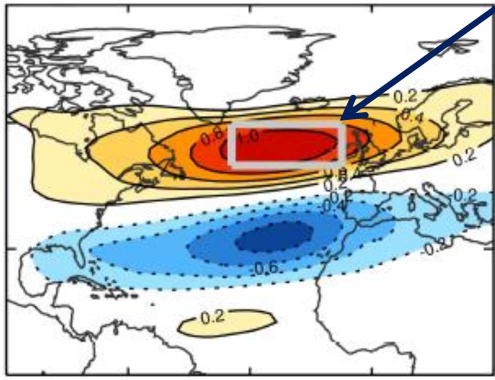

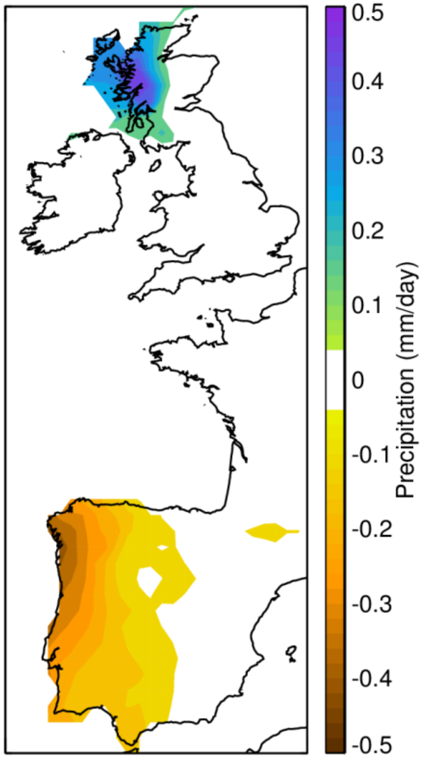

Regression of March precip (CRU) onto March U700NA, interannual, 1979-2016

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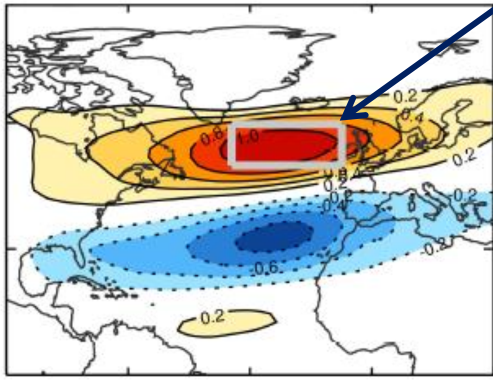
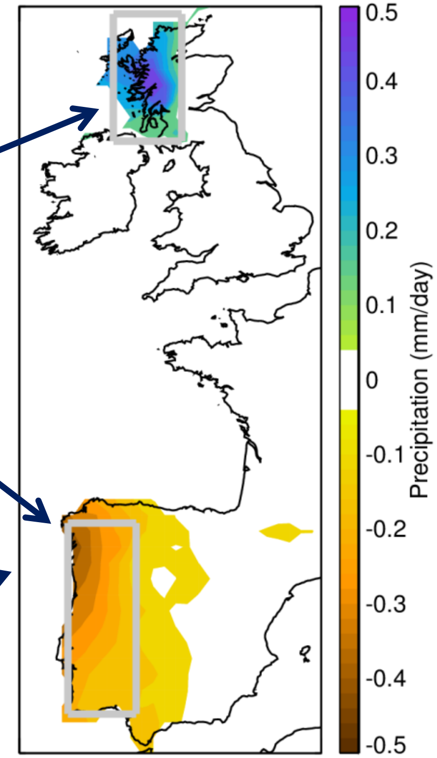


prdif index = Scotland - Portugal



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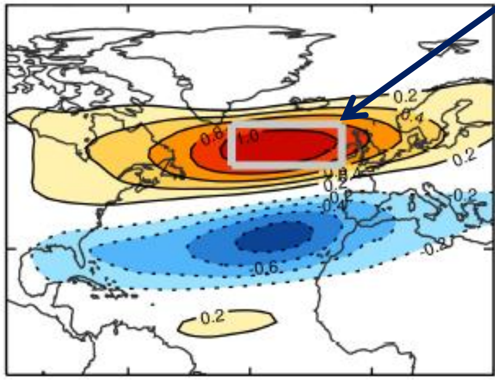

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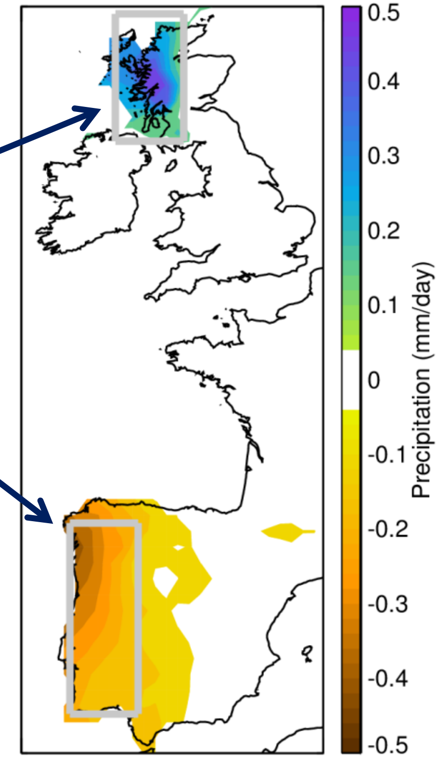
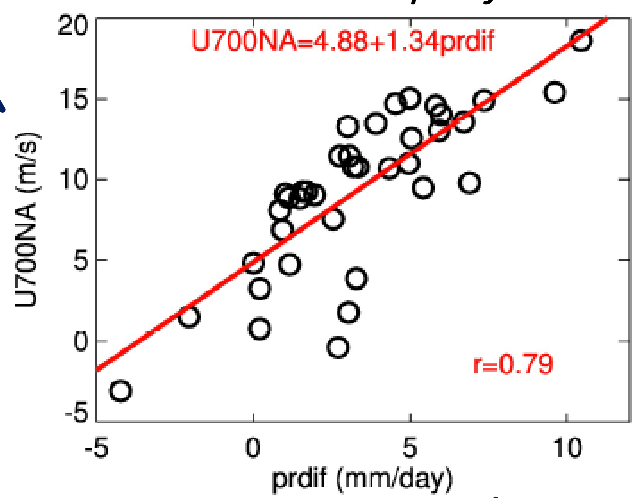


U700NA vs *prdif*

U700NA



prdif

From interannual variability over the satellite-era record…

$$U700NA(iy) = a + b \times prdif(iy) + \varepsilon(iy)$$

a=4.88 and b=1.34

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Can we reconstruct low frequency U700 variability over the 20th century based on this relationship derived from interannual variability?

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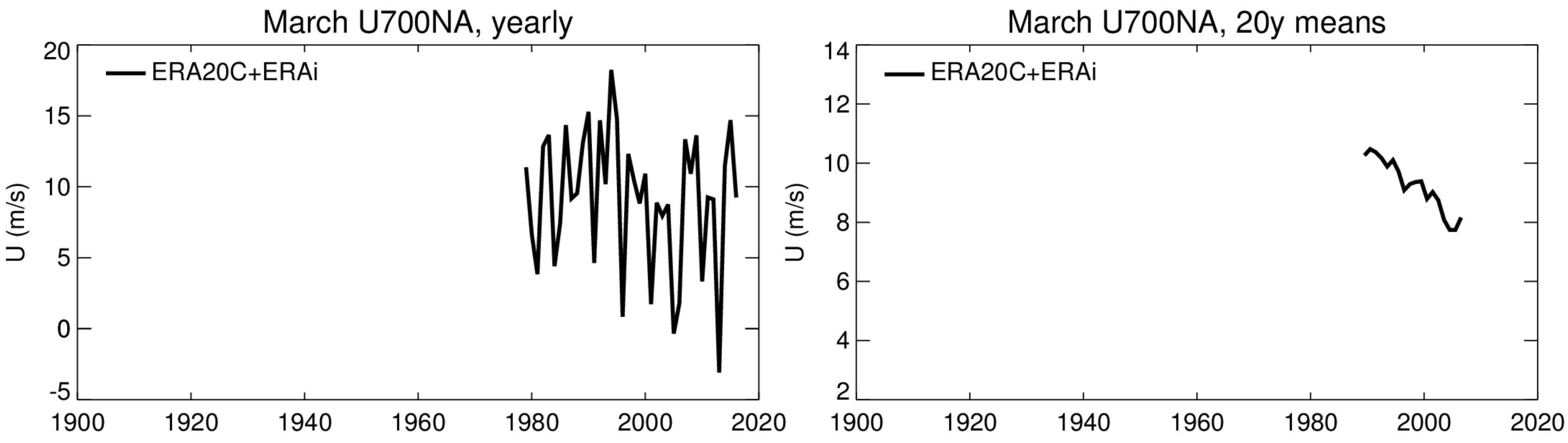

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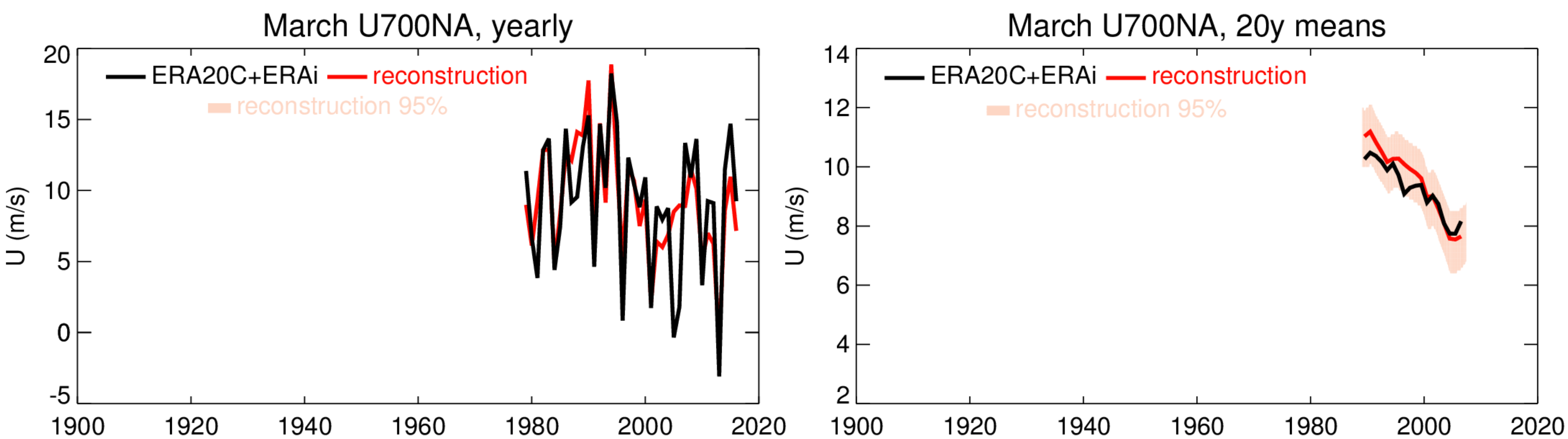

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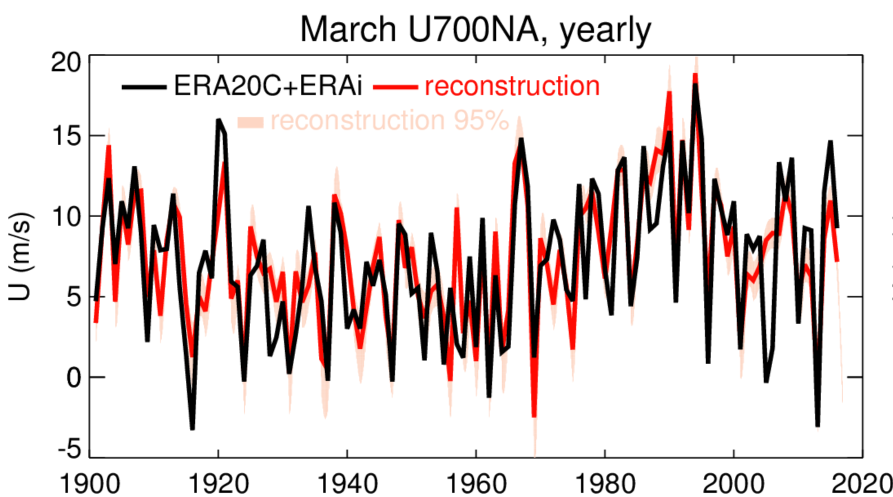
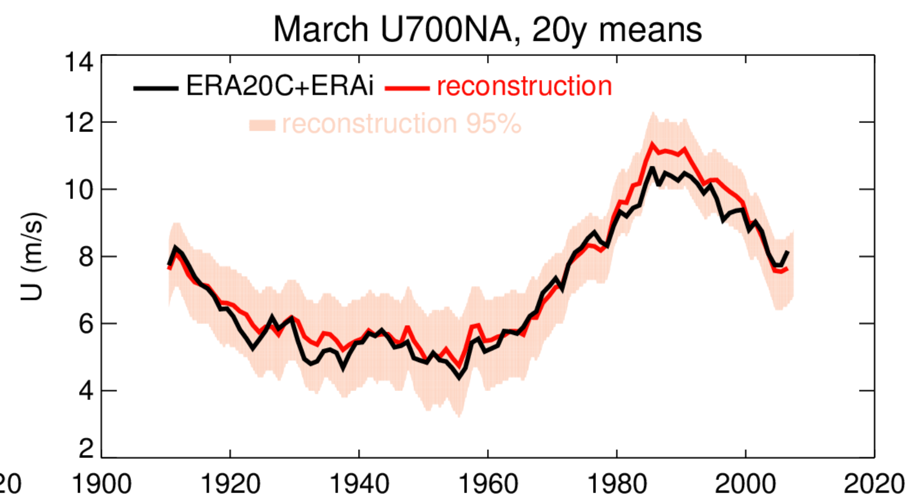




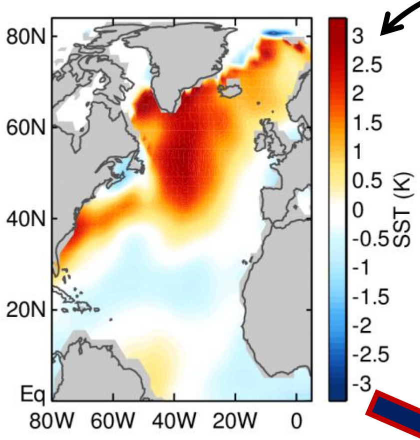
The U700 reconstruction based on precipitation agrees very well with the reanalysis

→ We can have confidence in both the low frequency variability in precipitation and zonal wind.

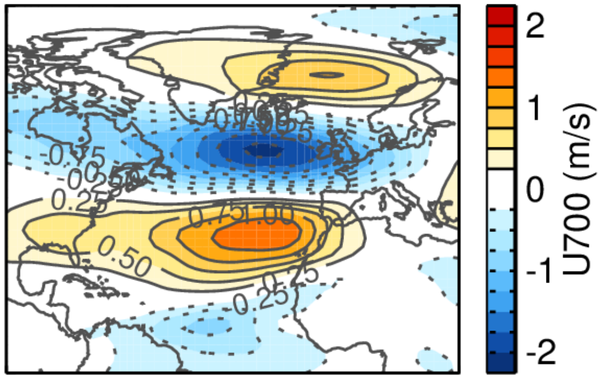
The connection between the AMV and precipitation in western Europe

March Connections

20y running means



Regression of SST onto normalized AMV



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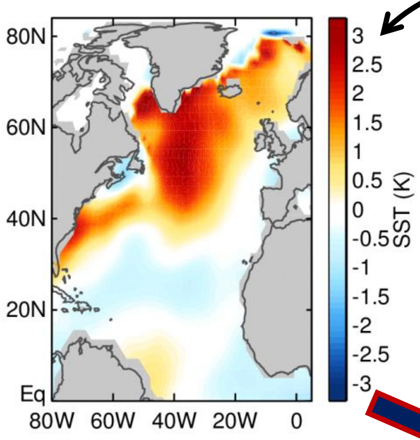

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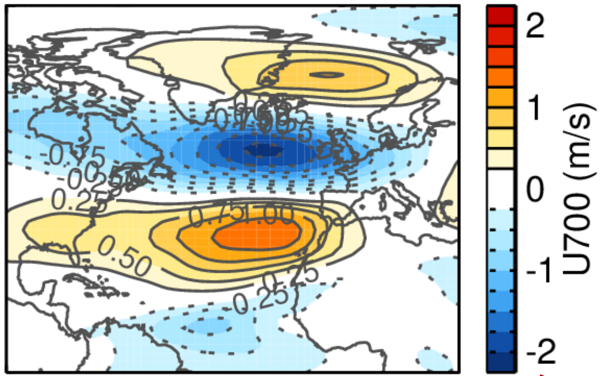

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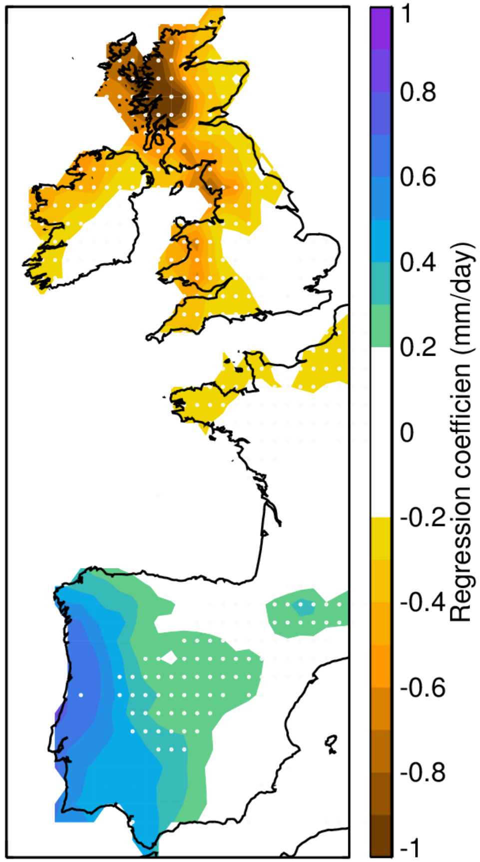
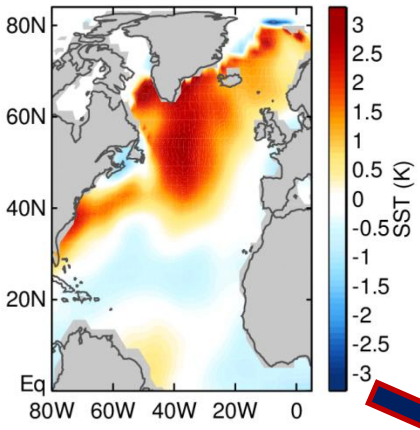


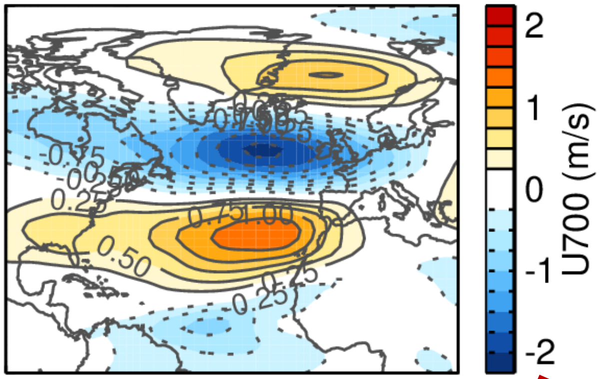
Regression of precipitation onto normalized AMV

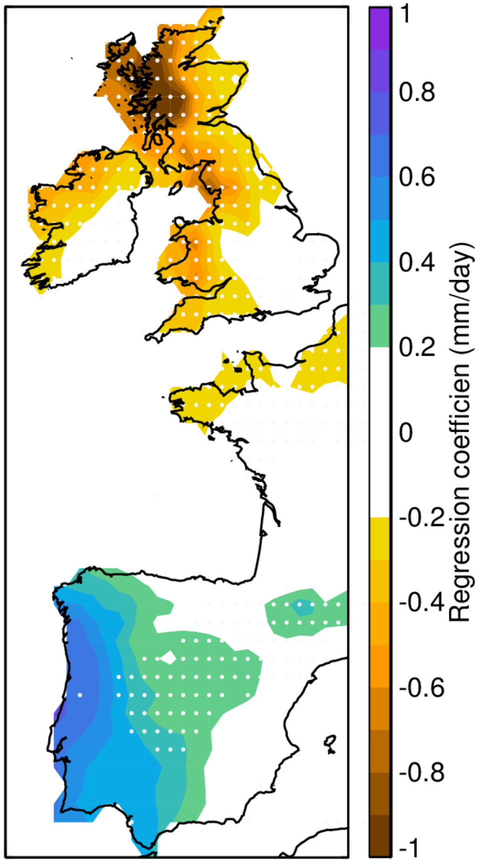
Stippling = significant at 95% accounting for temporal and spatial autocorrelation

March Connections

20y running means



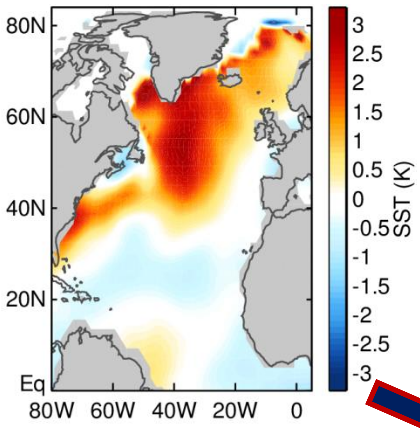


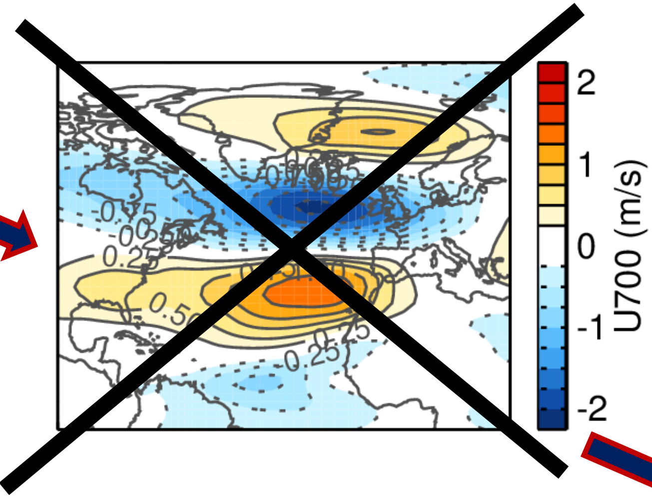


Is there predictability of low frequency variability in precipitation in western Europe arising from this connection with SST variability?

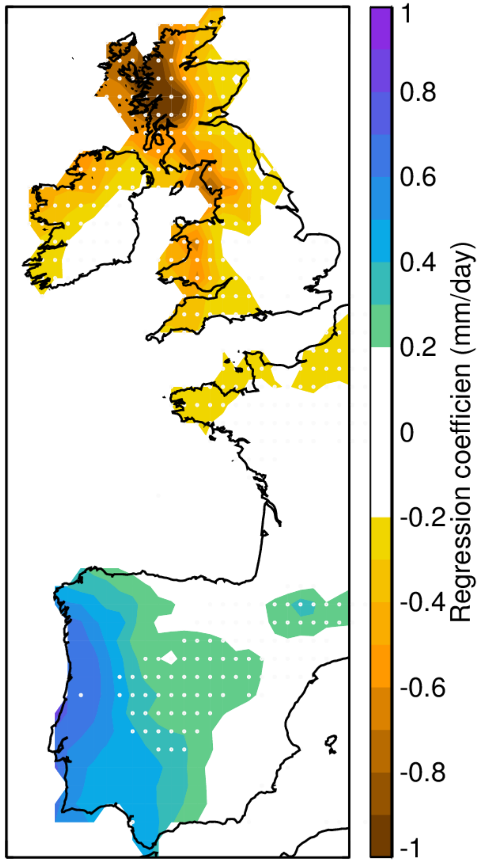
March Connections

20y running means





Models



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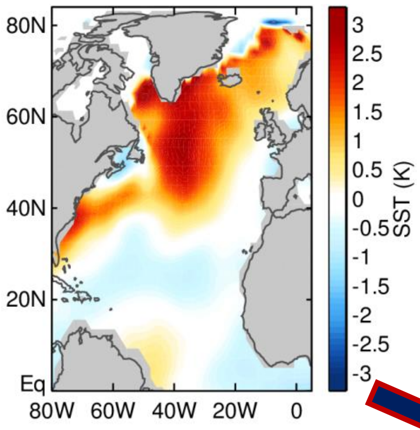

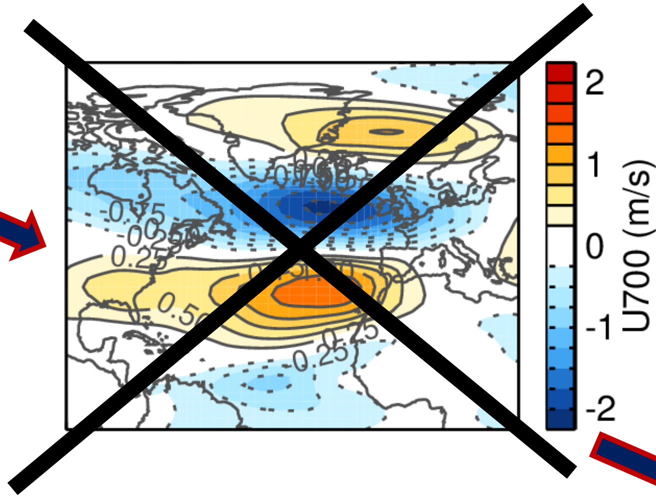

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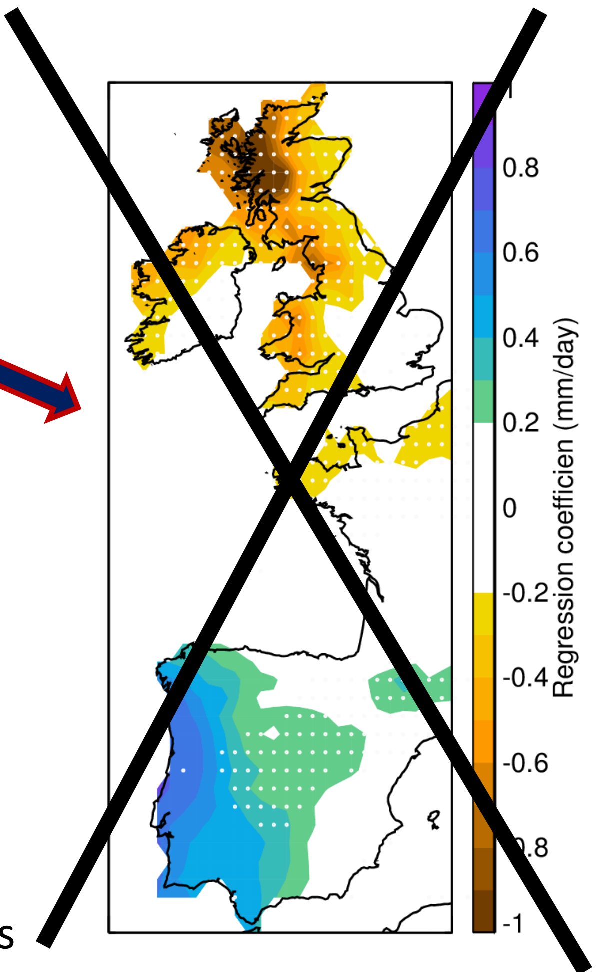

Models

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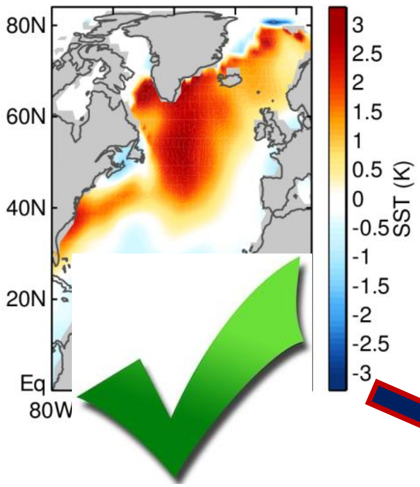

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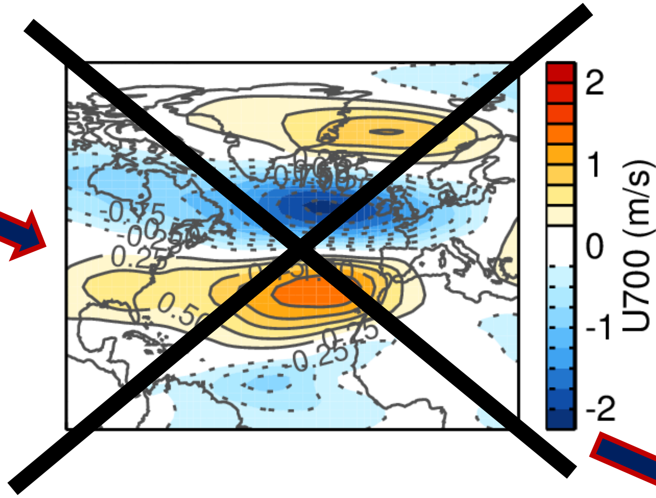

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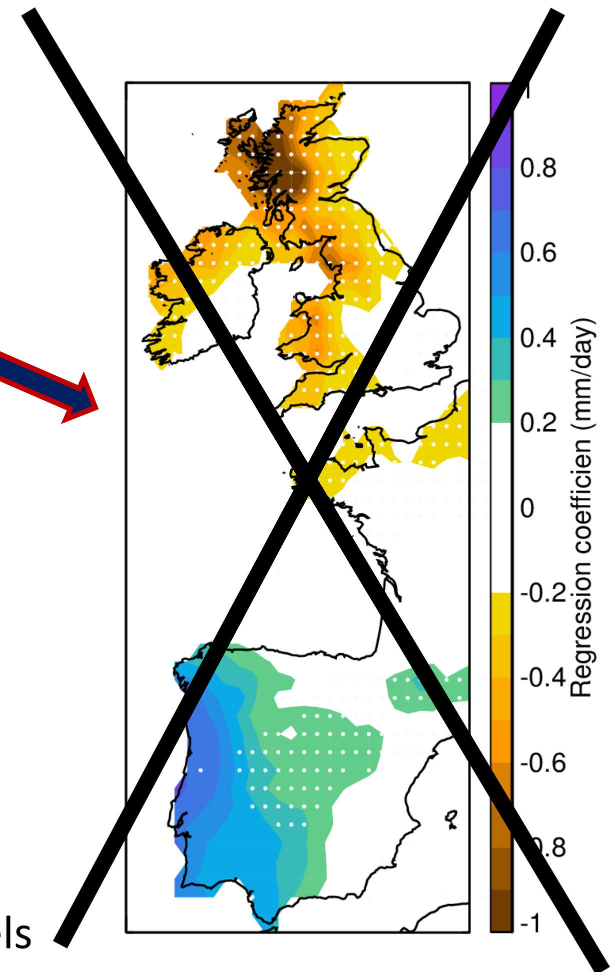

Models

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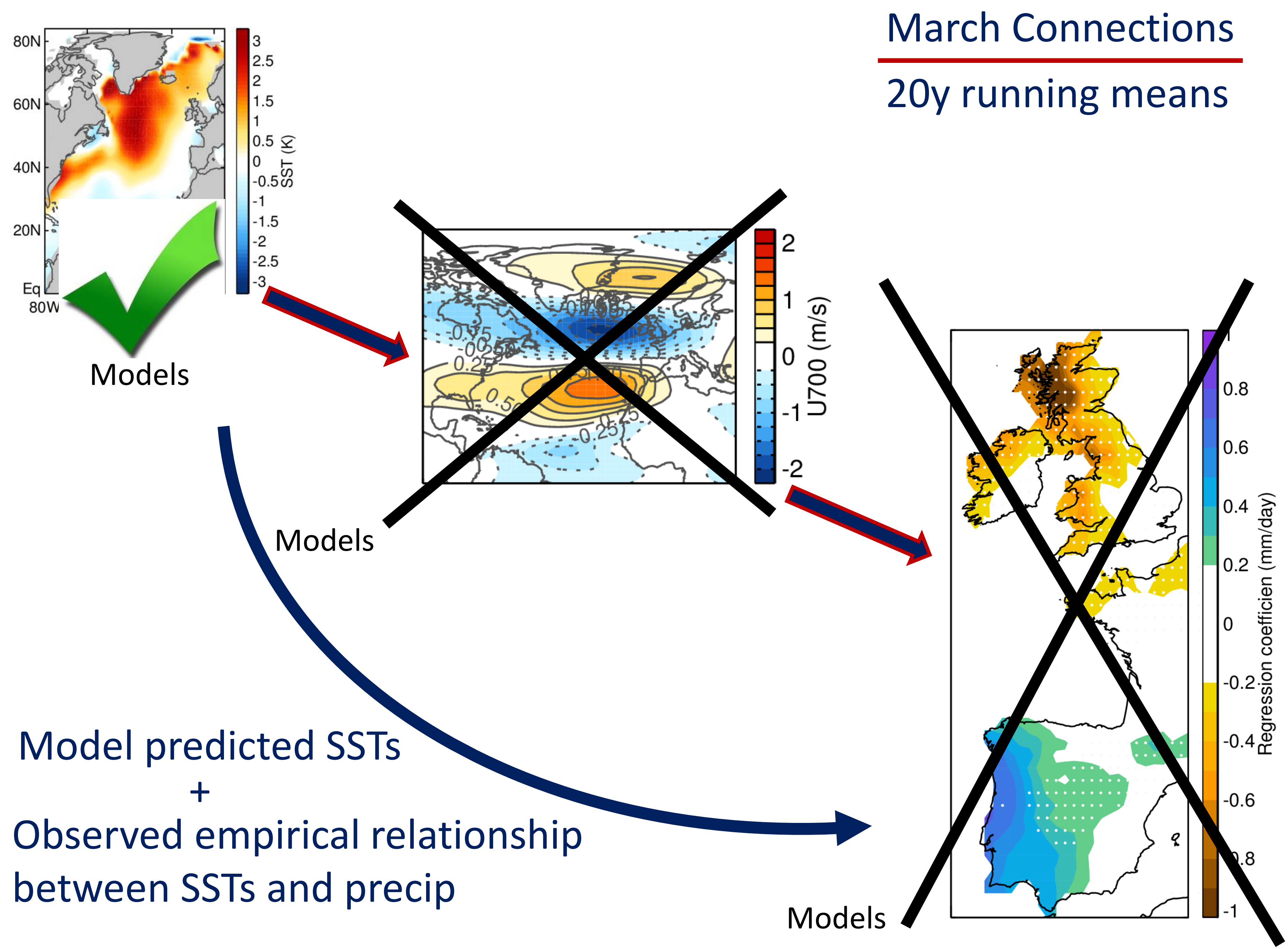
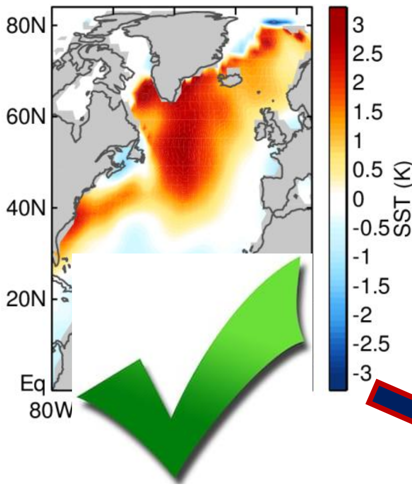
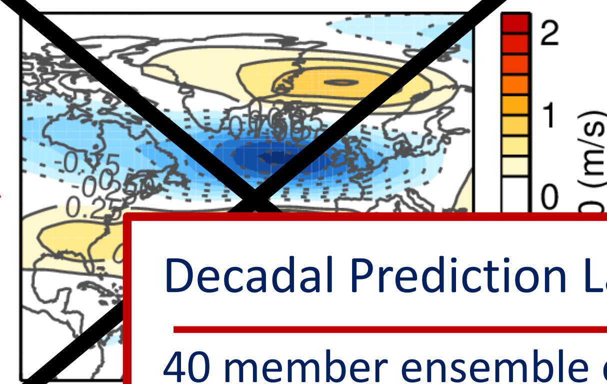

March Connections
20y running means
80N
60N
40N
20N
Eq
80W
SST (K)
Models
U700 (m/s)
Models
Regression coefficien (mm/day)
Models
Model predicted SSTs
+
Observed empirical relationship
between SSTs and precip

March Connections

20y running means



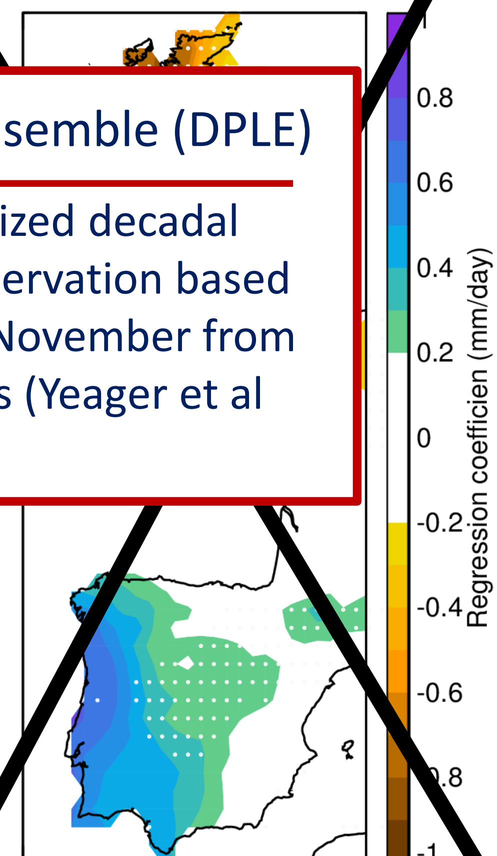
Models



Models

Decadal Prediction Large Ensemble (DPLE)

40 member ensemble of initialized decadal predictions initialized from observation based ocean and sea ice states each November from 1954-2017 and run for 10 years (Yeager et al 2018)

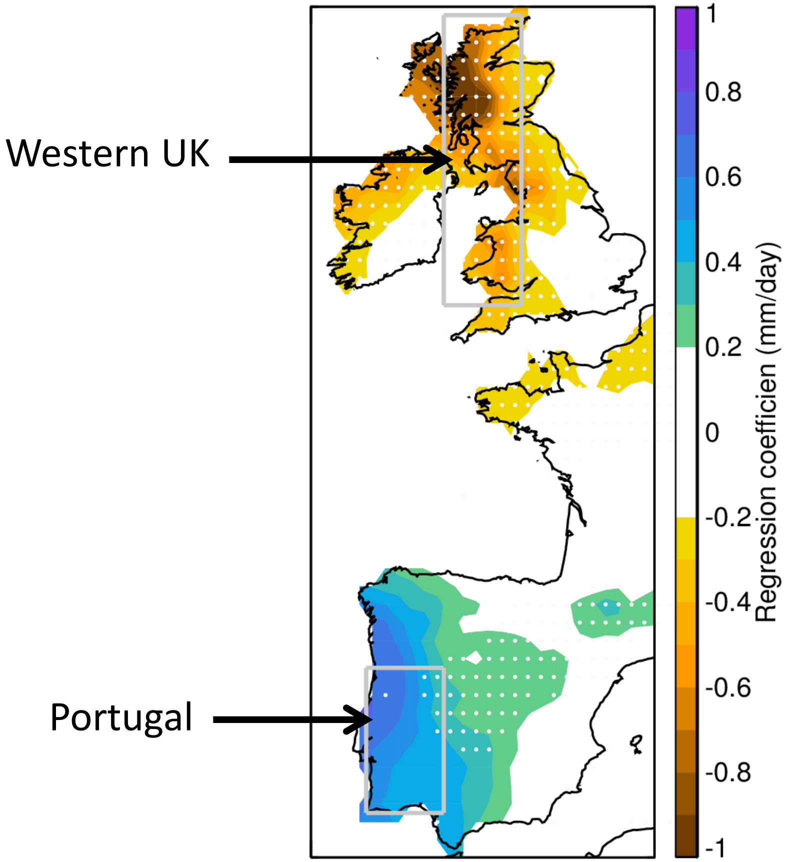


Models

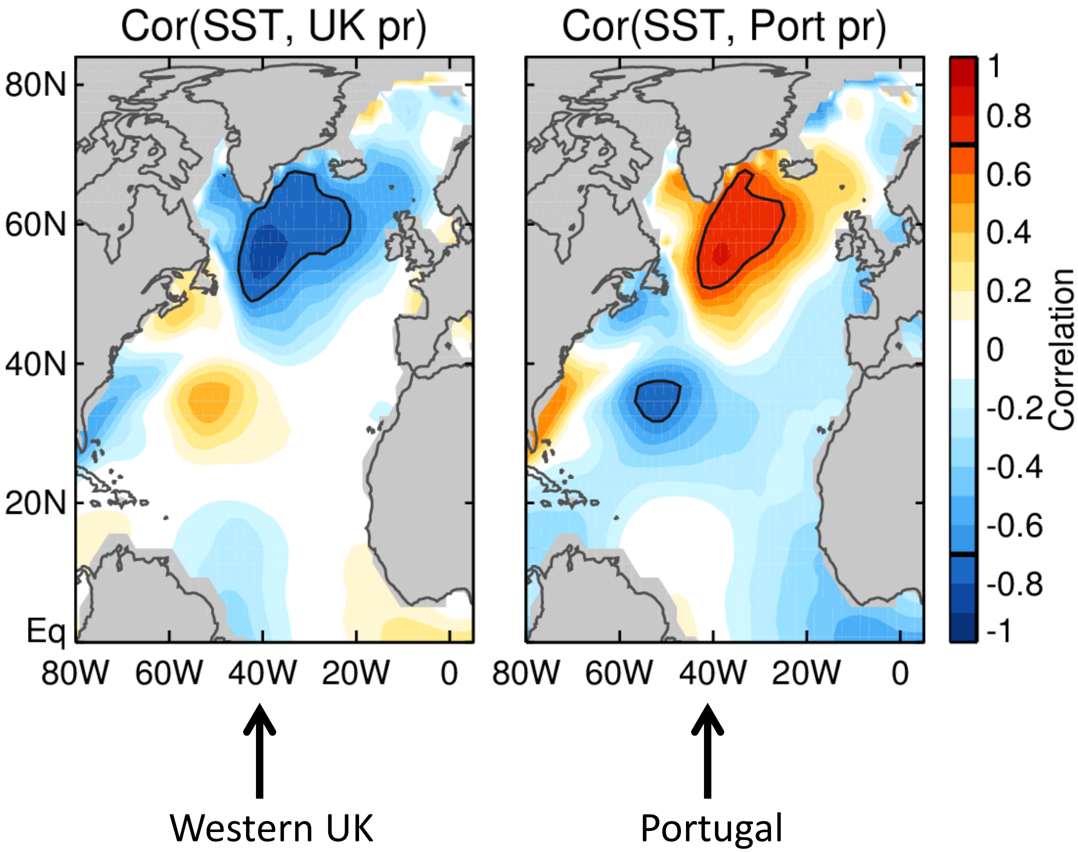
Model predicted SSTs
+
Observed empirical relationship between SSTs and precip

March Predictability

Precipitation regressed onto AMV (20y running means)

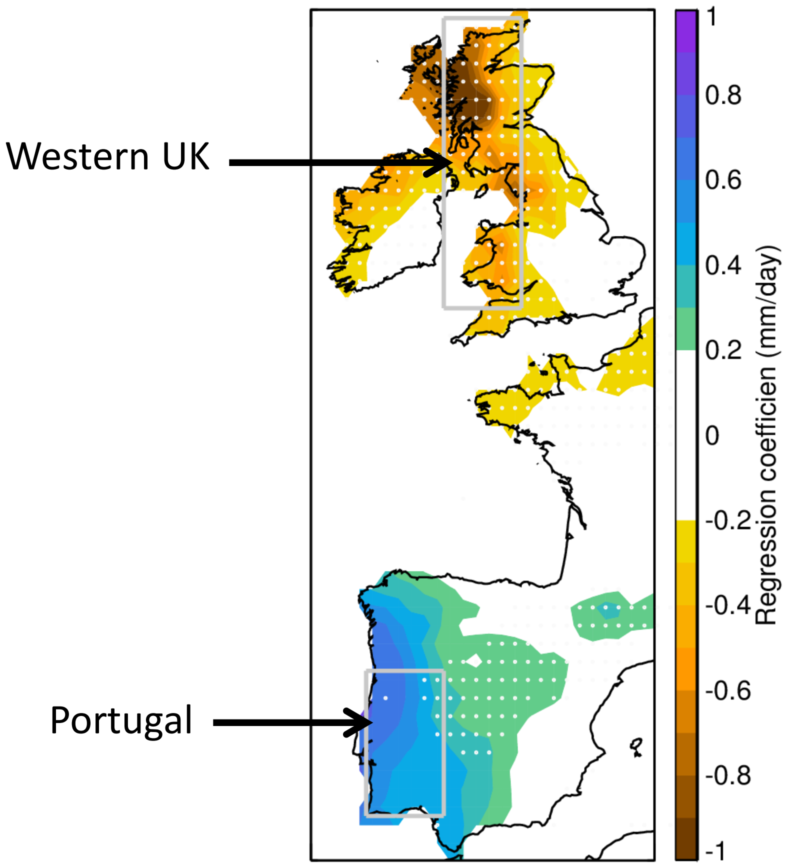


March Predictability

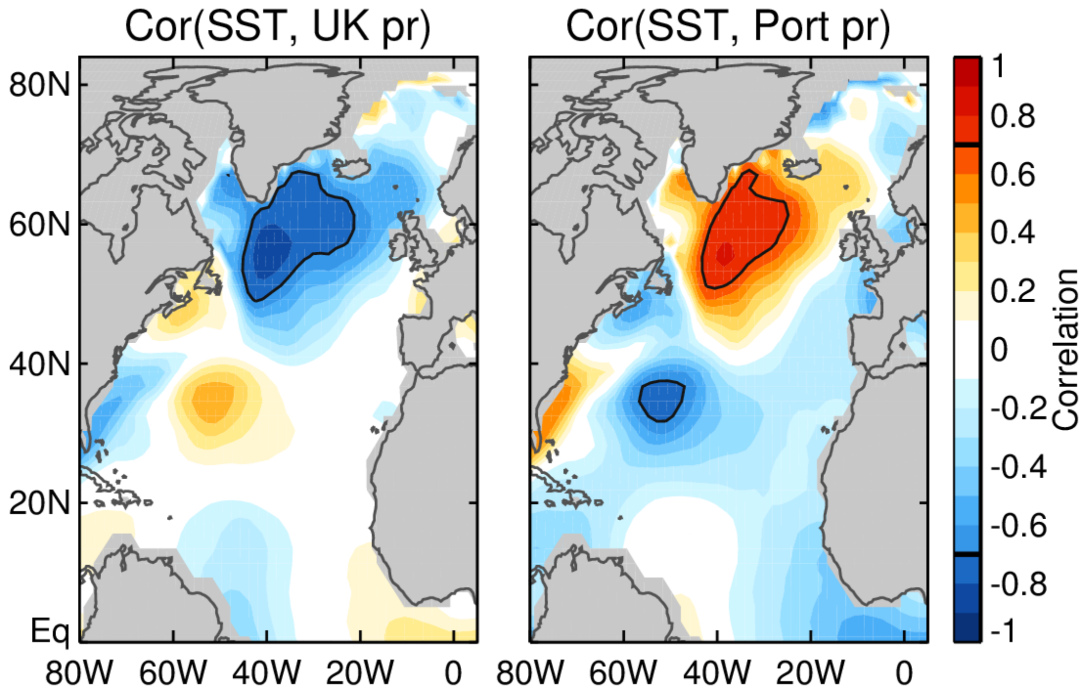


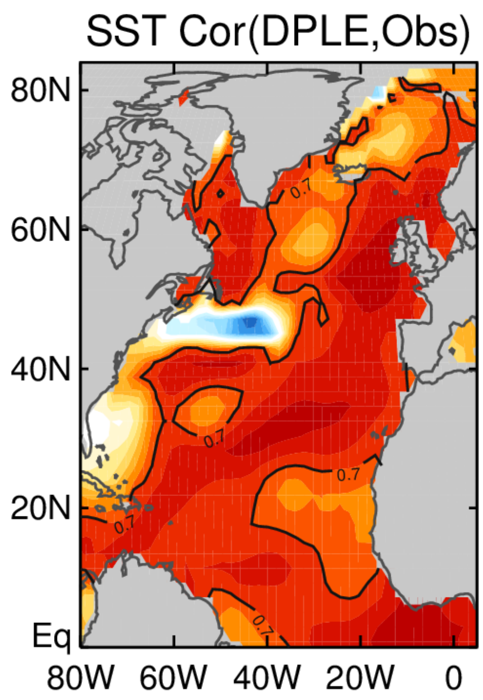
Correlation between area averaged CRU precipitation and ERSSTv5 SSTs (decadal averages)

Precipitation regressed onto AMV (20y running means)



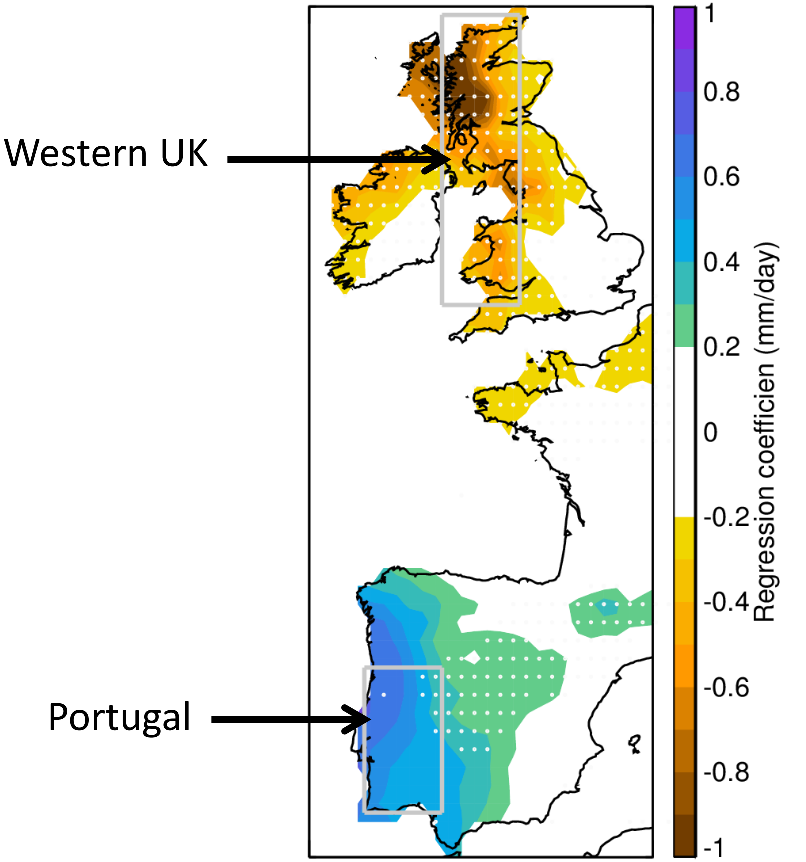
March Predictability



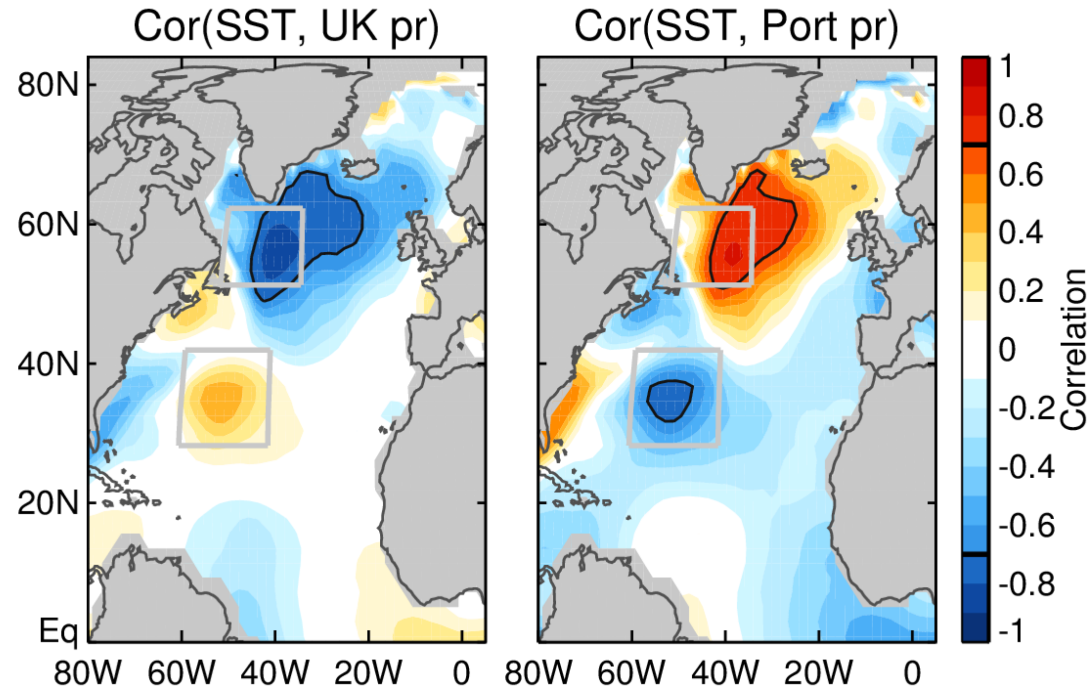


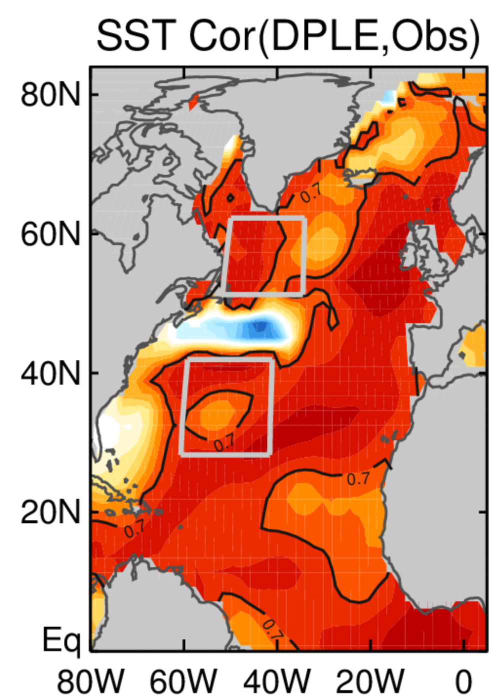
DPLE SST skill (decadal averages)

Precipitation regressed onto AMV (20y running means)



March Predictability

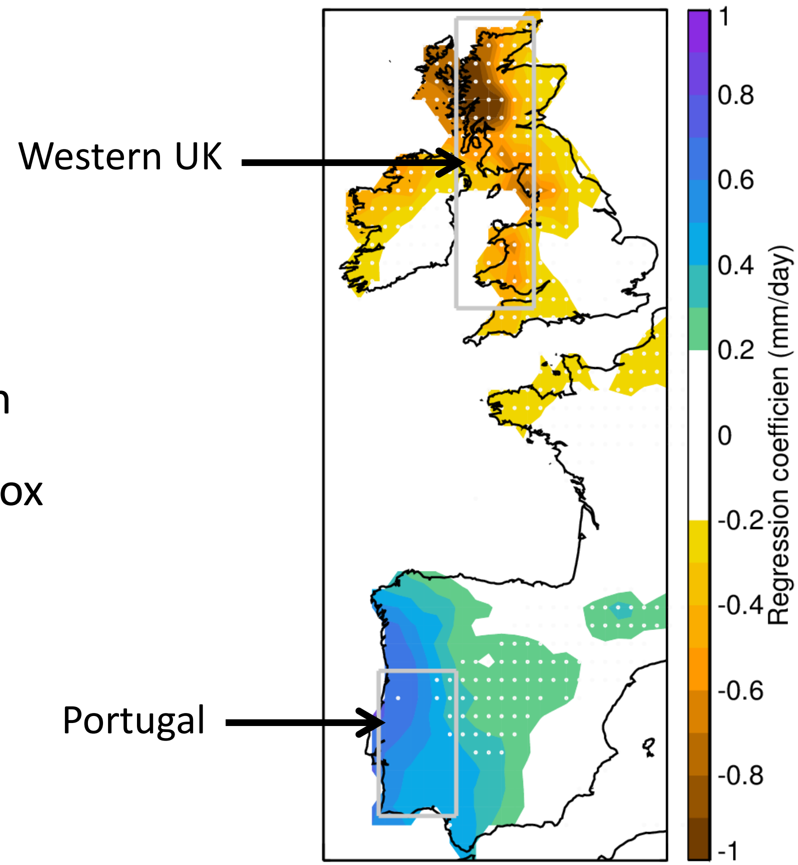




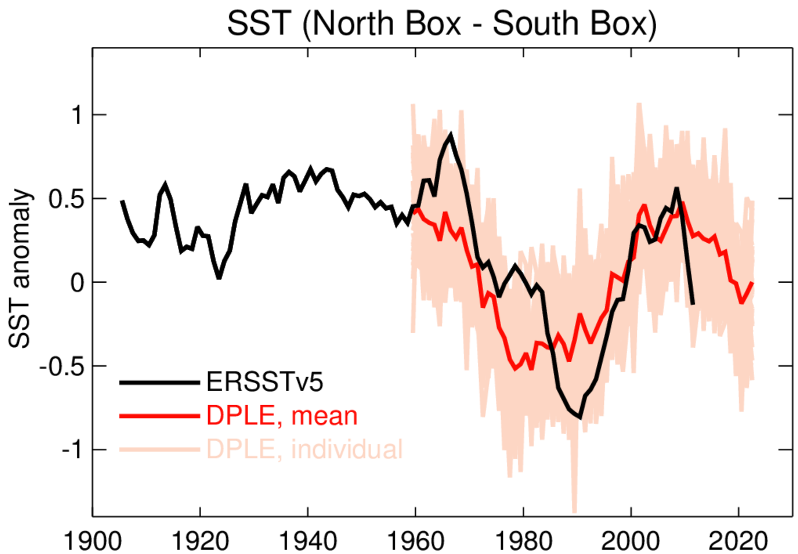
Make precipitation predictions based on

North Box – South Box

Precipitation regressed onto AMV (20y running means)

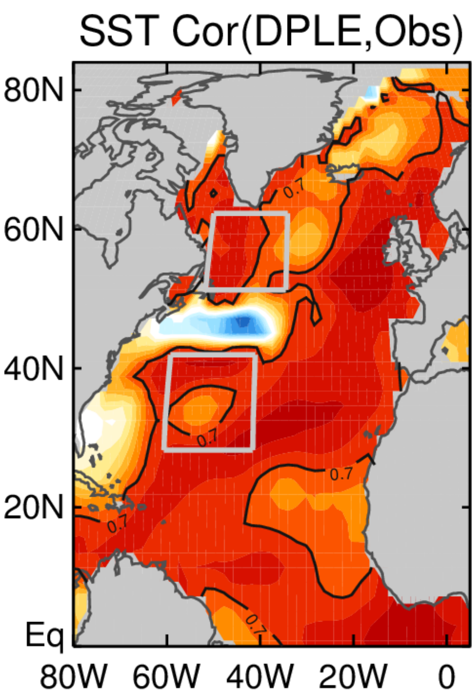


March Predictability



Decadal averaged SST anomalies

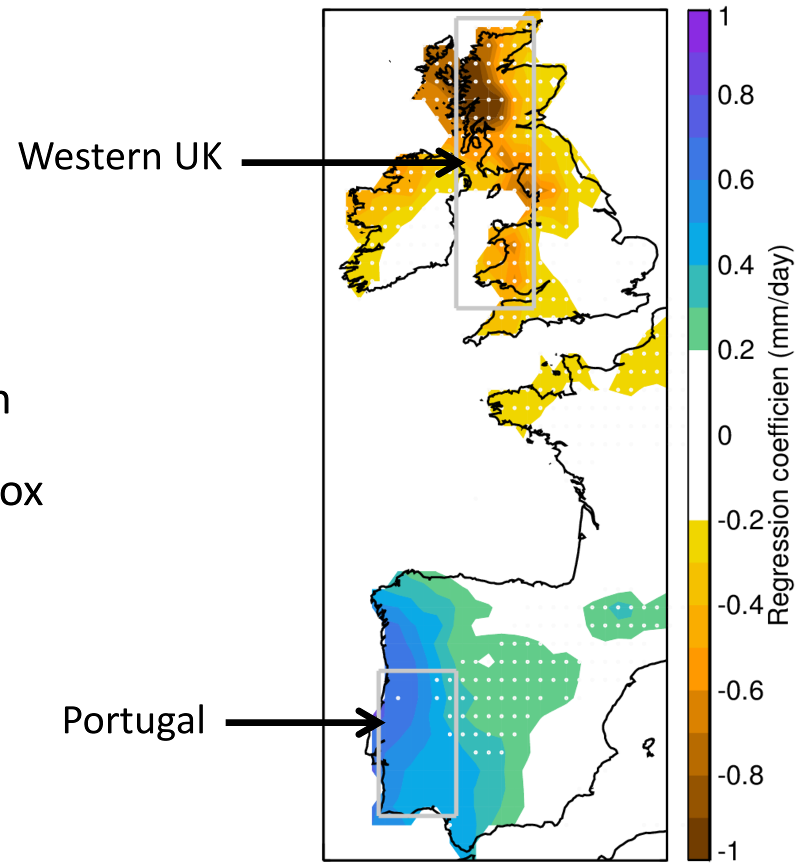
North Box – South Box



Make precipitation predictions based on

North Box – South Box

Precipitation regressed onto AMV (20y running means)



Making decadal predictions

Making decadal predictions

Use observed relationship between decadal averaged precip and SST index (North box – South box)

$$pr(i) = a + b \times sstindex(i) + \varepsilon(i)$$

Decadal Averages

Making decadal predictions

Use observed relationship between decadal averaged precip and SST index (North box – South box)

$$pr(i) = a + b \times sstindex(i) + \varepsilon(i)$$

Decadal Averages

Obtain a and b from the full observational record

Making decadal predictions

Use observed relationship between decadal averaged precip and SST index (North box – South box)

$$pr(i) = a + b \times sstindex(i) + \varepsilon(i)$$

Decadal Averages

Obtain a and b from the full observational record

Predict precipitation based on this observed relationship and the DPLE predicted SST index

Making decadal predictions

Use observed relationship between decadal averaged precip and SST index (North box – South box)

$$pr(i) = a + b \times sstindex(i) + \varepsilon(i)$$

Decadal Averages

Obtain a and b from the full observational record

Predict precipitation based on this observed relationship and the DPLE predicted SST index

Skill measures:

Anomaly Correlation Coefficient:

$$ACC = \frac{cov(hc, obs)}{\sigma_{hc}\sigma_{obs}}$$

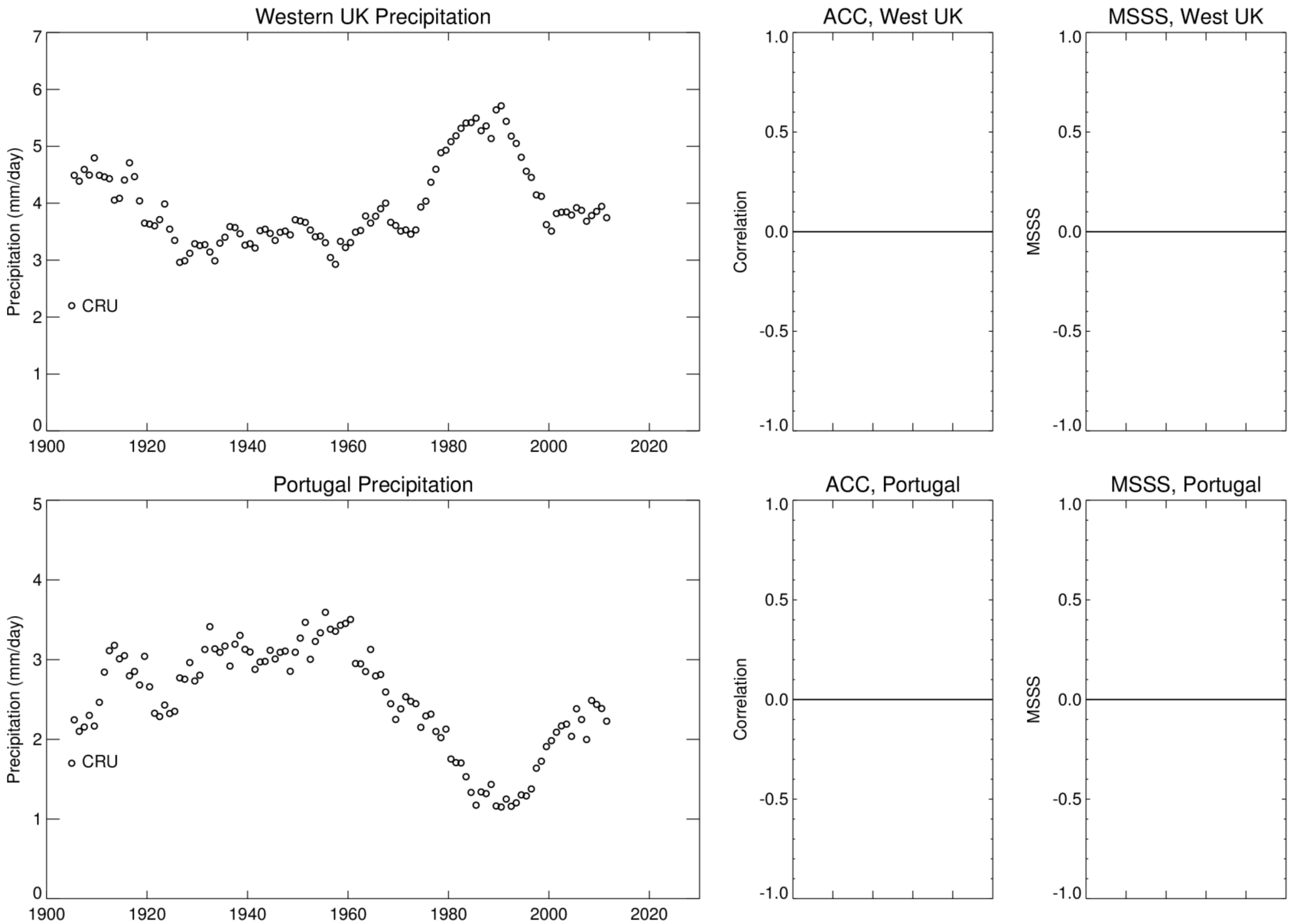
Mean Squared Skill Score:

$$MSSS = 1 - \frac{MSE_{hc}}{MSE_{obs}}$$

Mean squared error of hindcast

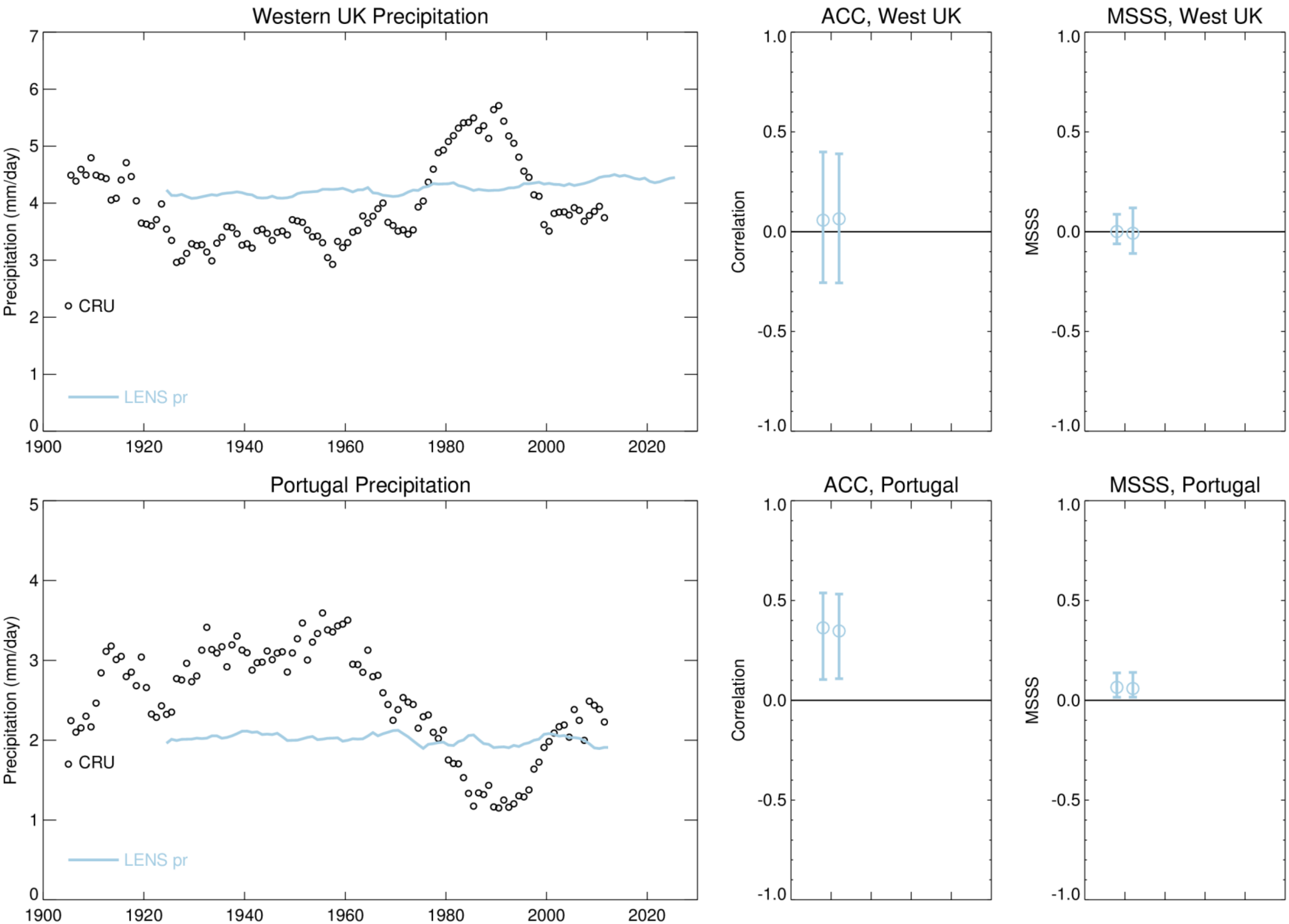
Mean squared difference between obs and climatology

Precipitation Hindcasts



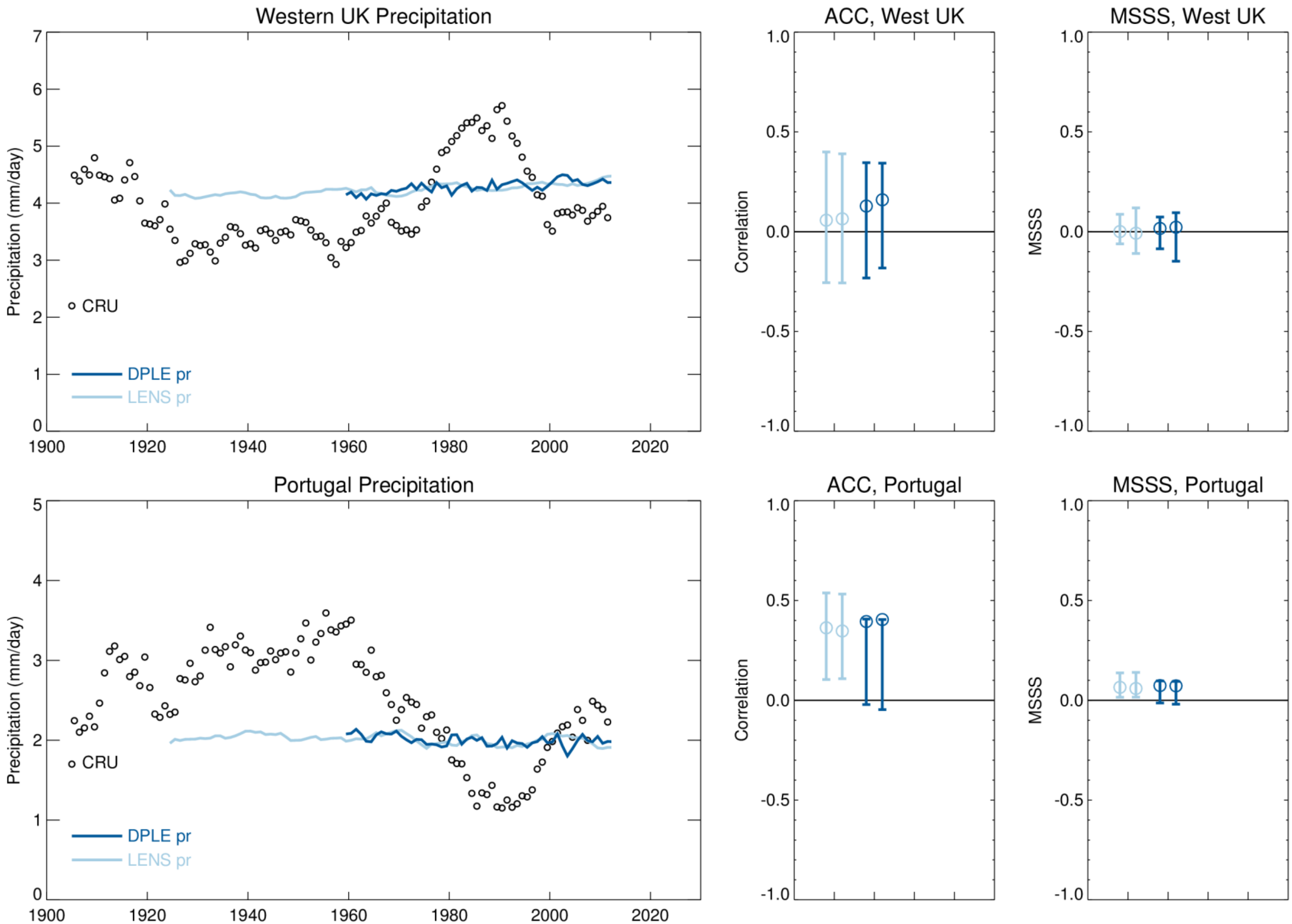
Skill based on DPLE period

Precipitation Hindcasts



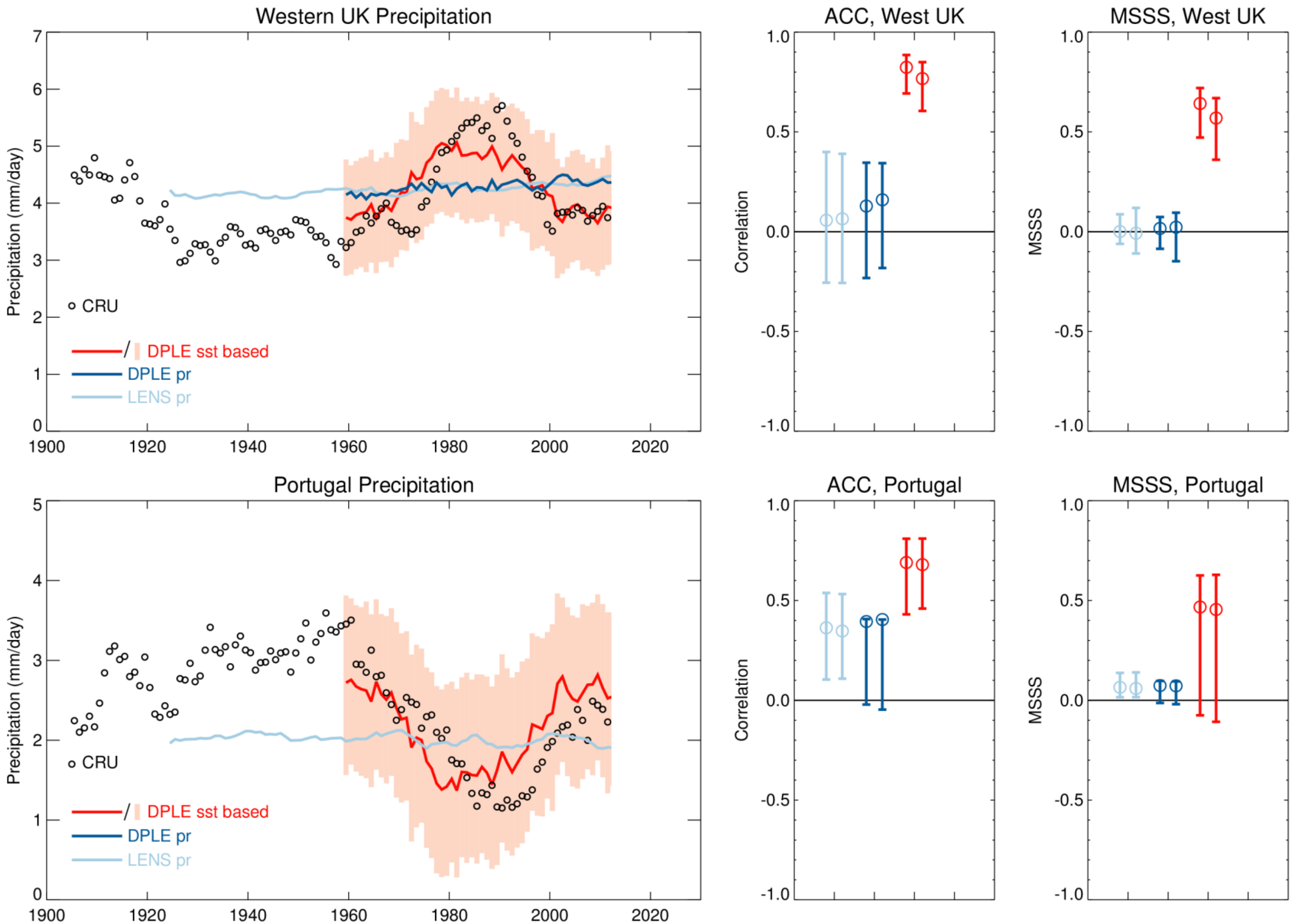
Skill based on DPLE period

Precipitation Hindcasts



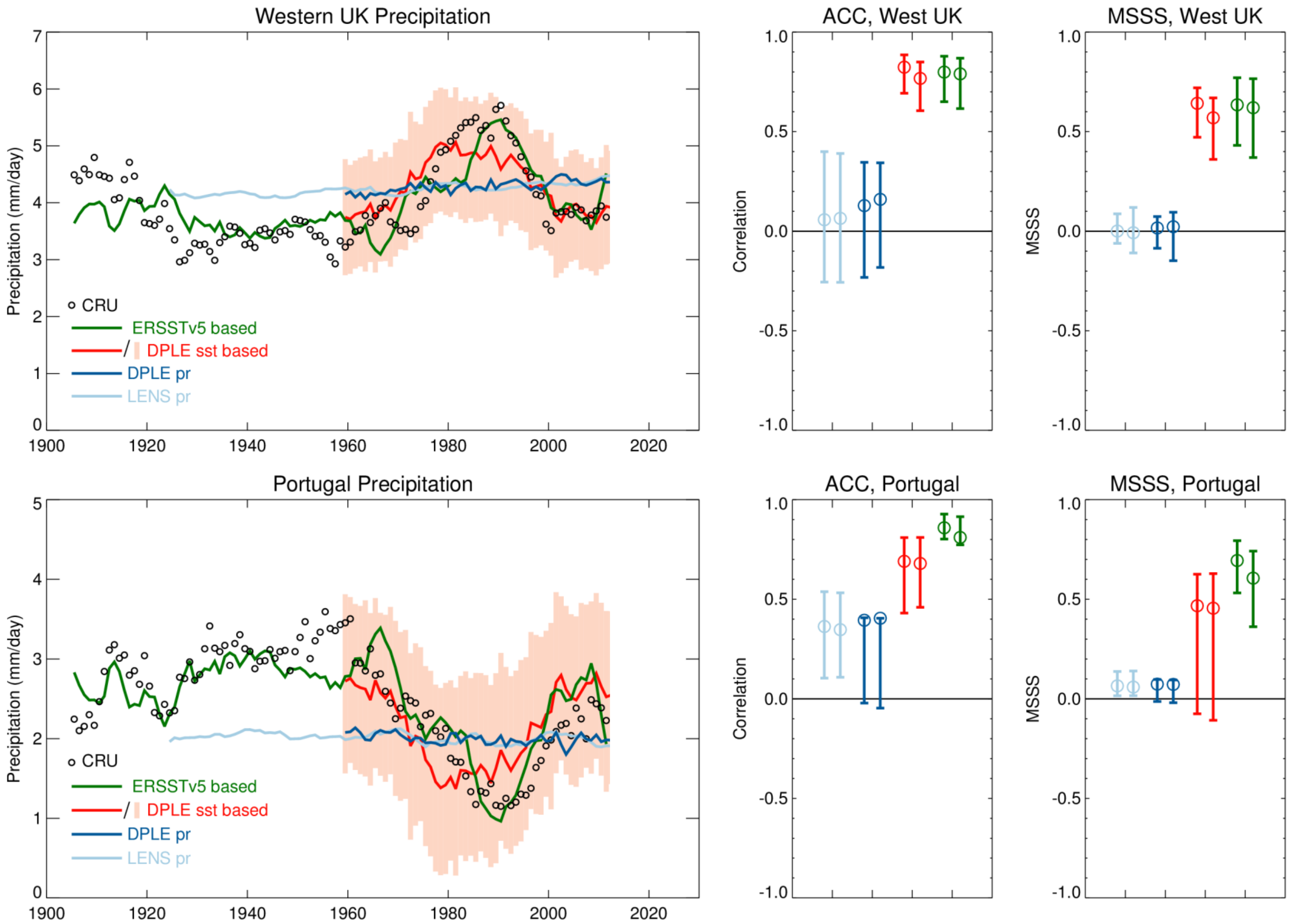
Skill based on DPLE period

Precipitation Hindcasts



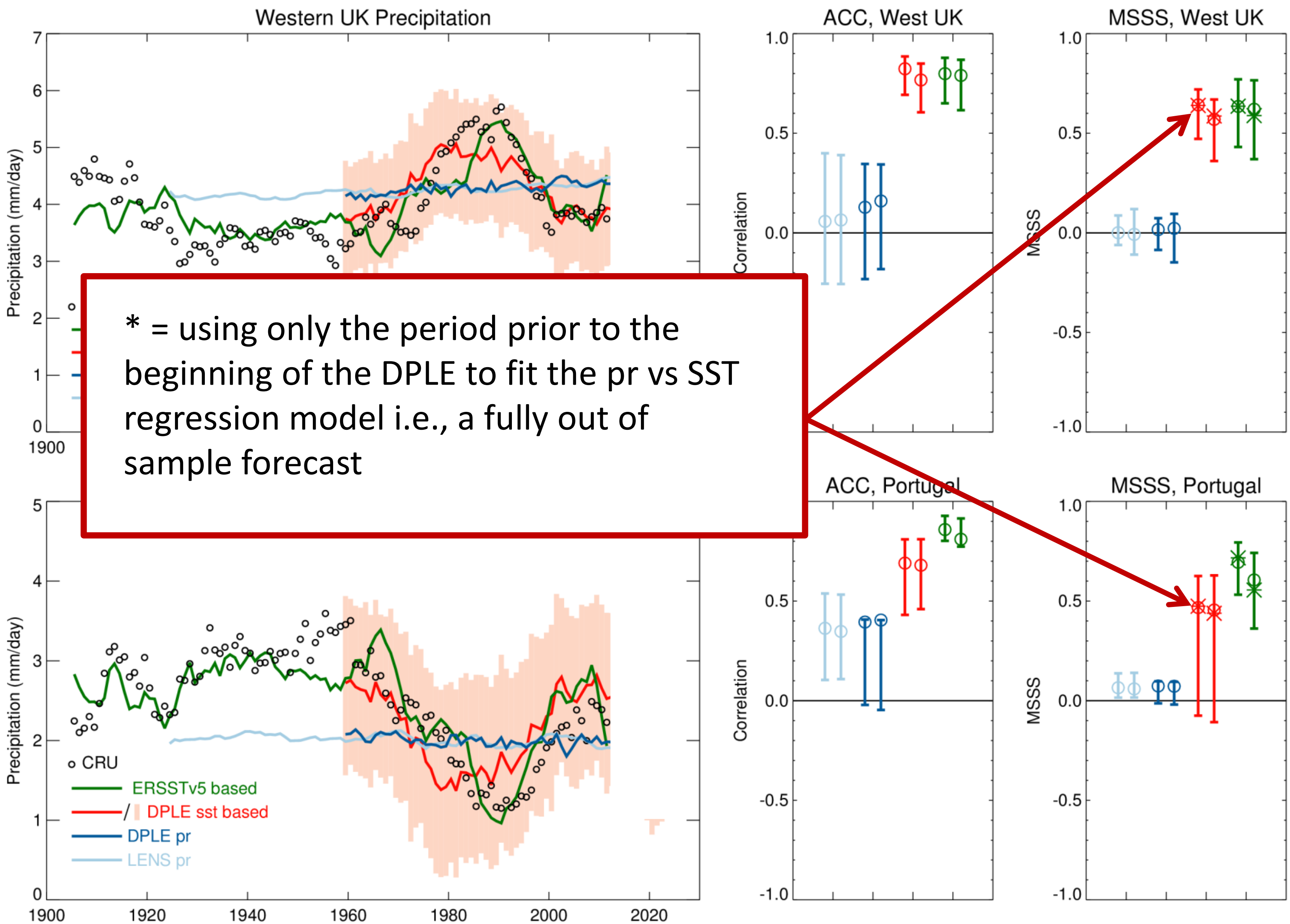
Skill based on DPLE period

Precipitation Hindcasts



Skill based on DPLE period

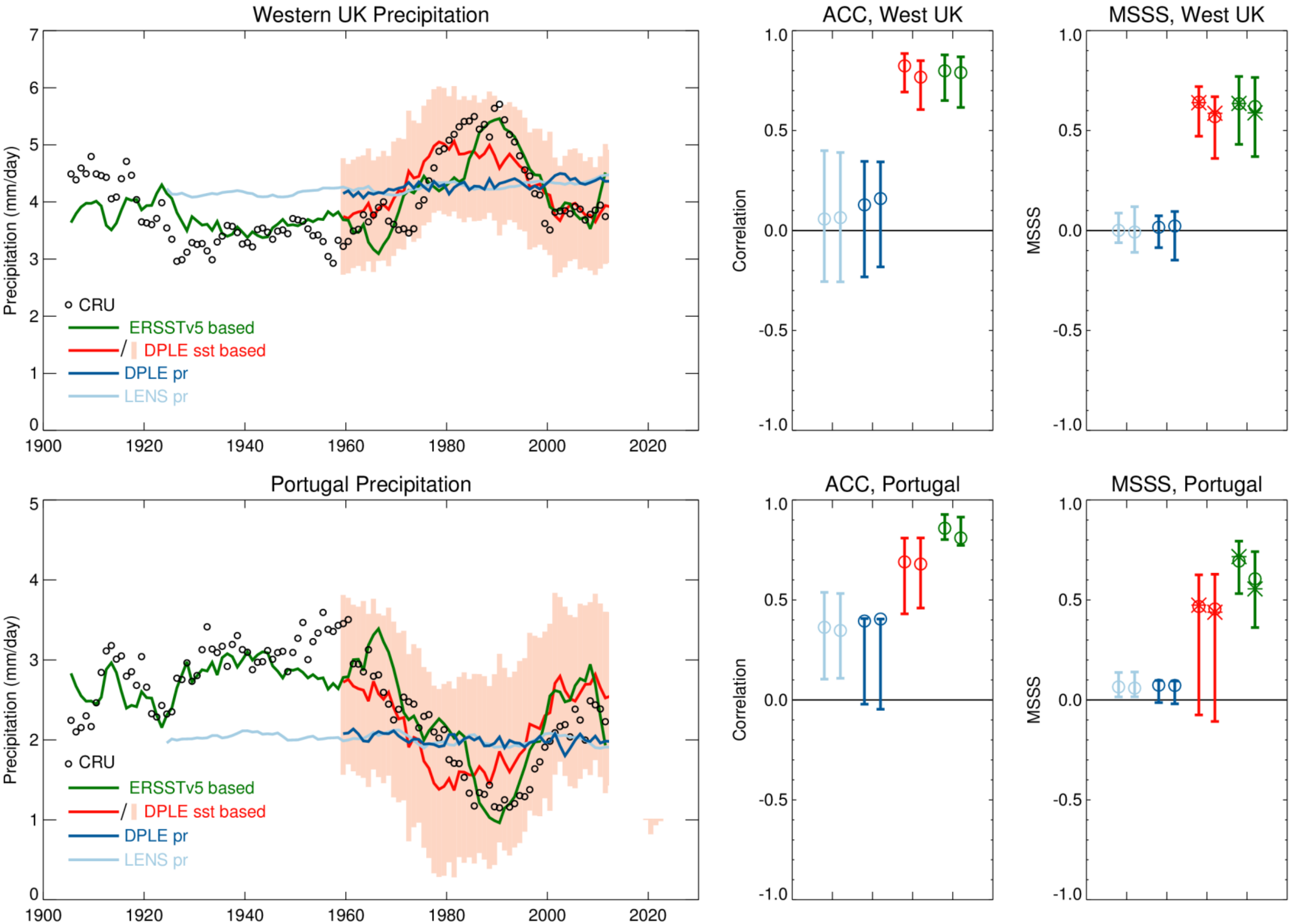
Precipitation Hindcasts



* = using only the period prior to the beginning of the DPLE to fit the pr vs SST regression model i.e., a fully out of sample forecast

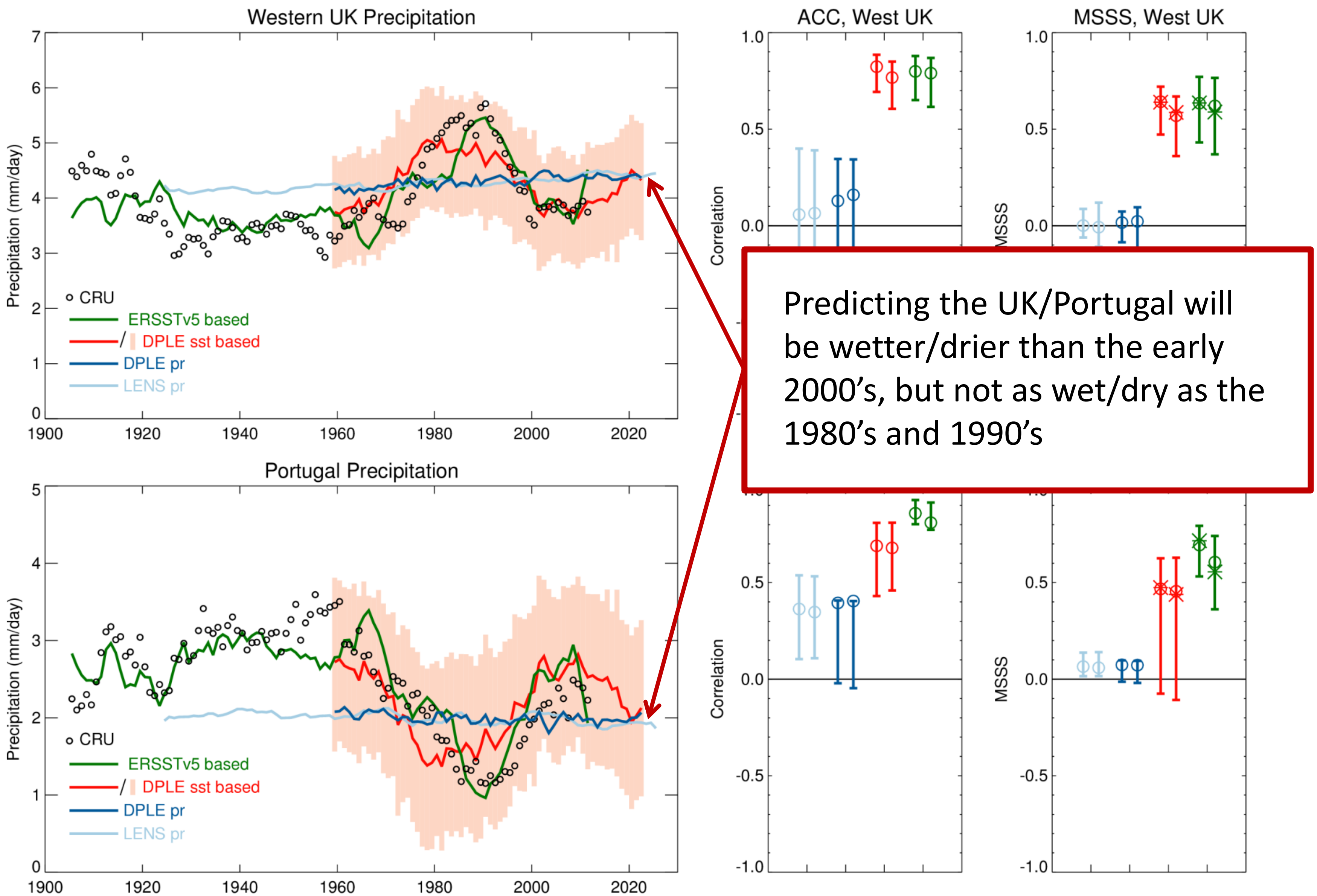
Skill based on DPLE period

Precipitation Hindcasts



Skill based on DPLE period

Precipitation Hindcasts

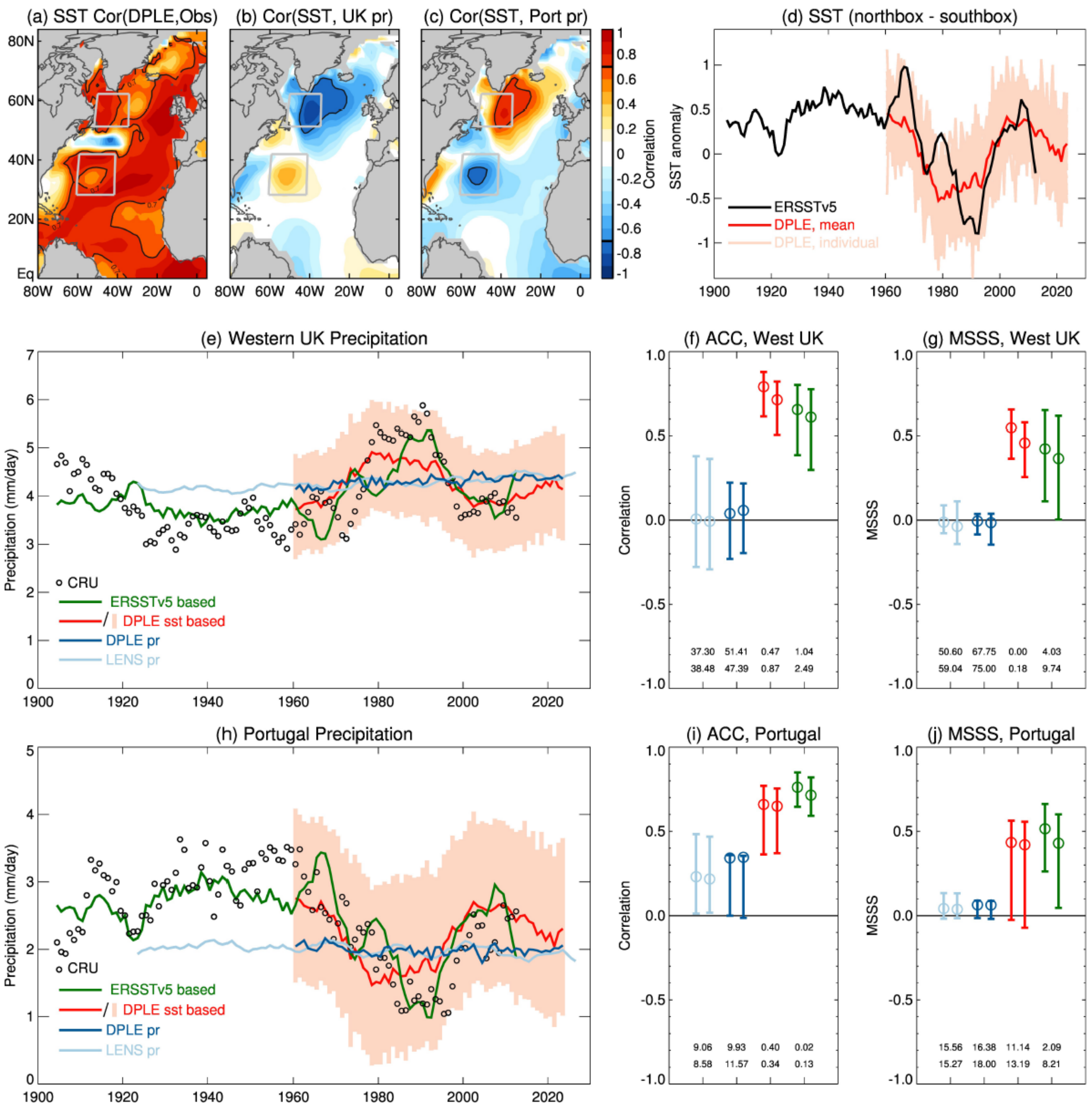


Skill based on DPLE period

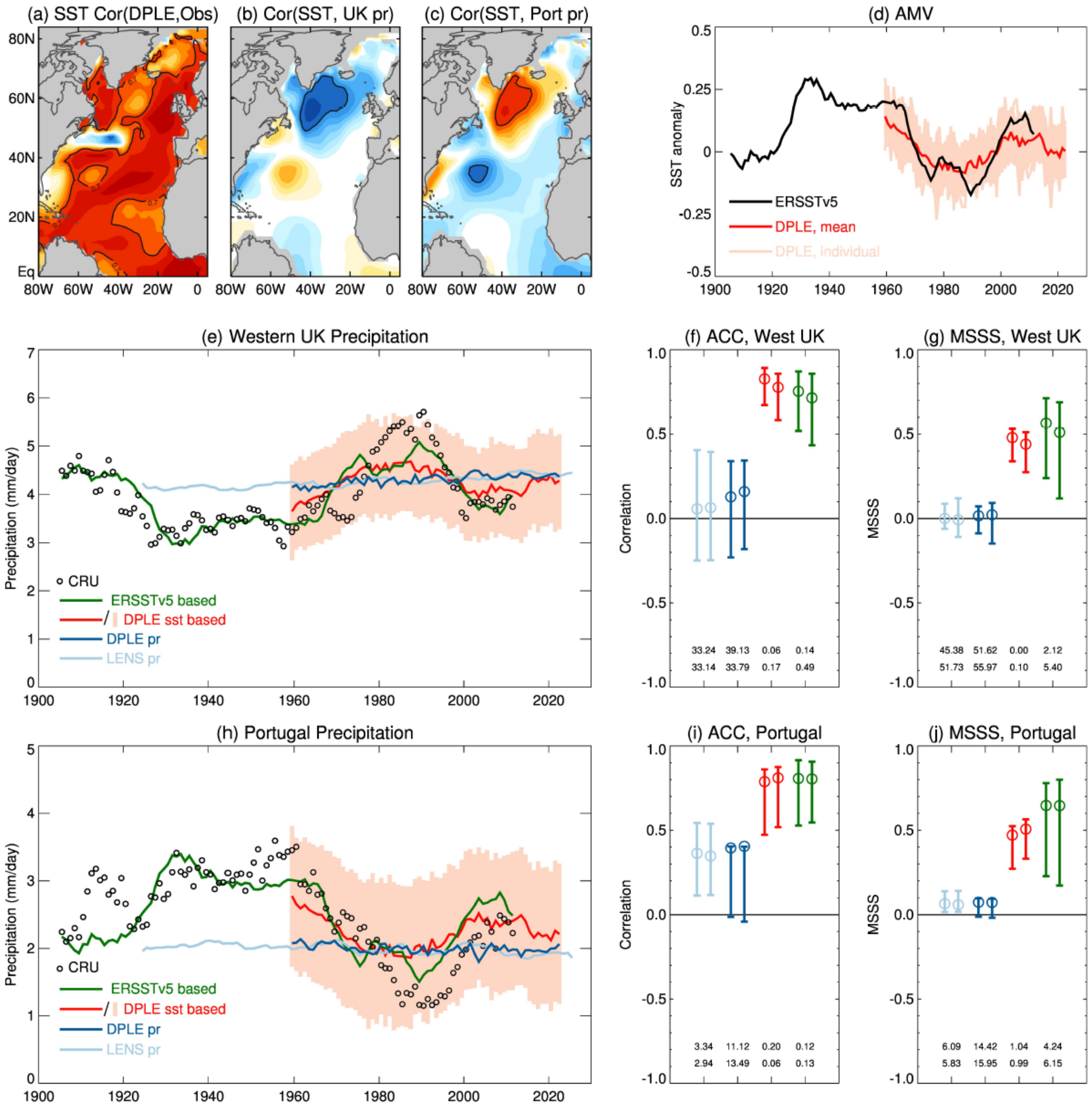
Conclusions

- There is pronounced multi-decadal variability in precipitation in western Europe in the late winter (March in particular).
- This precipitation variability provides an independent, quantitative, verification of low frequency jet stream variability found in reanalysis products.
- The precipitation variability is strongly connected to sea surface temperature variability in the North Atlantic. SST variability that accompanies AMV indices on multi-decadal timescales.
- CESM decadal predictions can predict the SST variability on decadal timescales, but it doesn't predict the precipitation variability since the connection between the SSTs/jet stream/precipitation seems to be lacking in the model.
- We can use the decadal prediction SSTs and the observed empirical relationship between SSTs and precipitation, to provide prediction for decadal averaged precipitation in western Europe that is skillful in many regards.
- Verification of this forecast over the coming decade and an improved mechanistic understanding of the relationship between SSTs and the jet stream will improve our confidence in these forecasts.

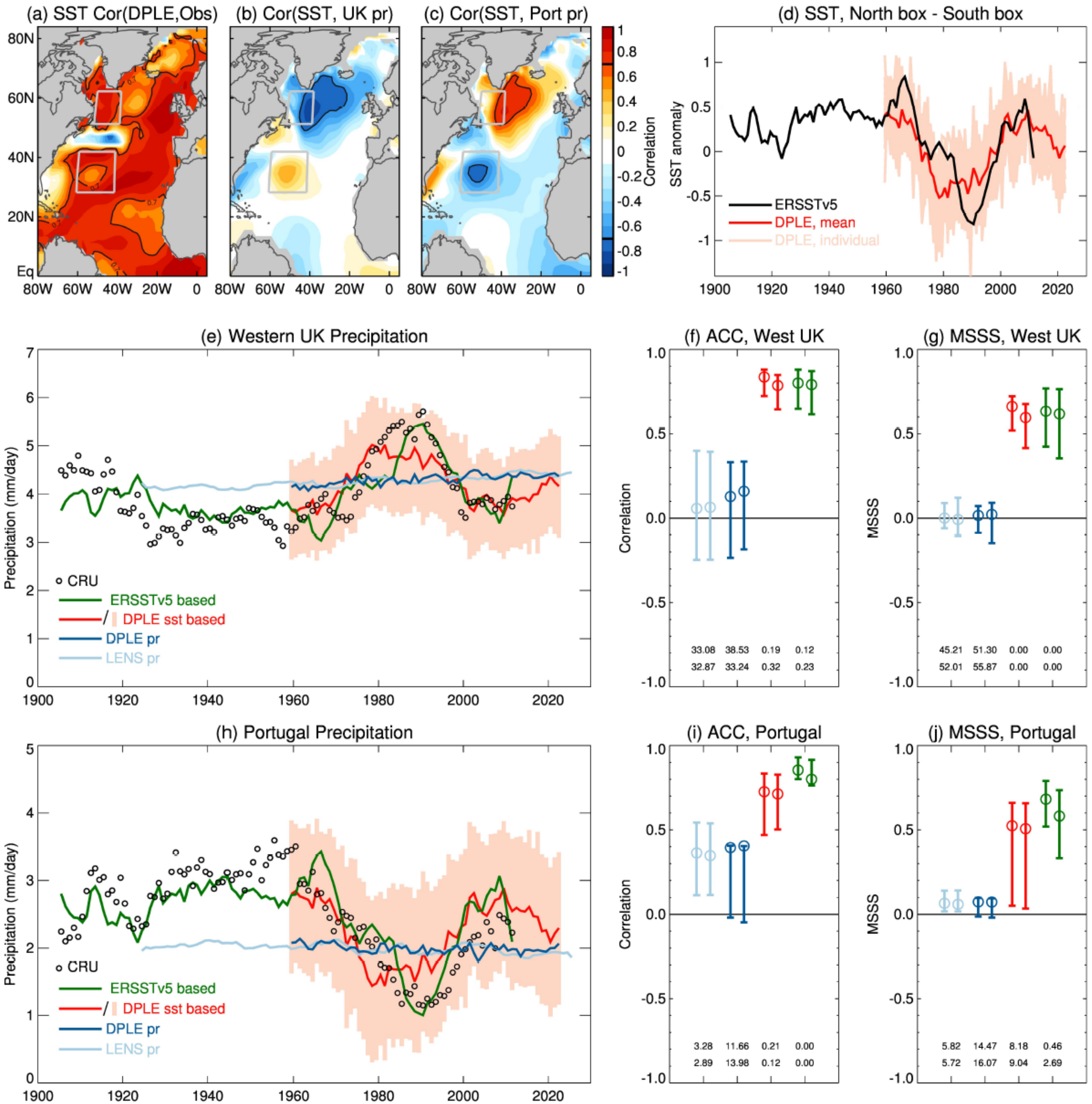
Extra Slides



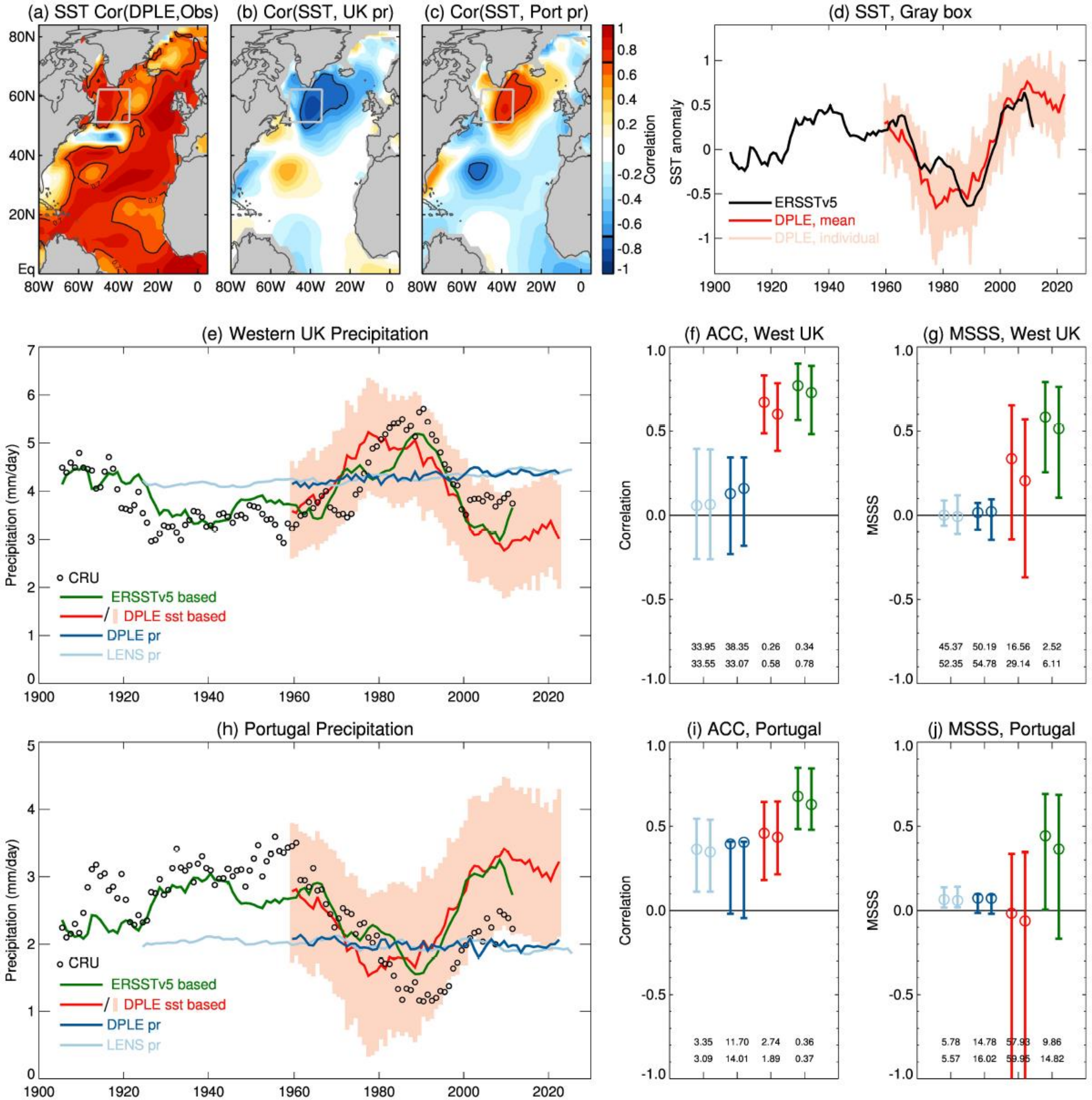
8 year averages, lead years 3-10



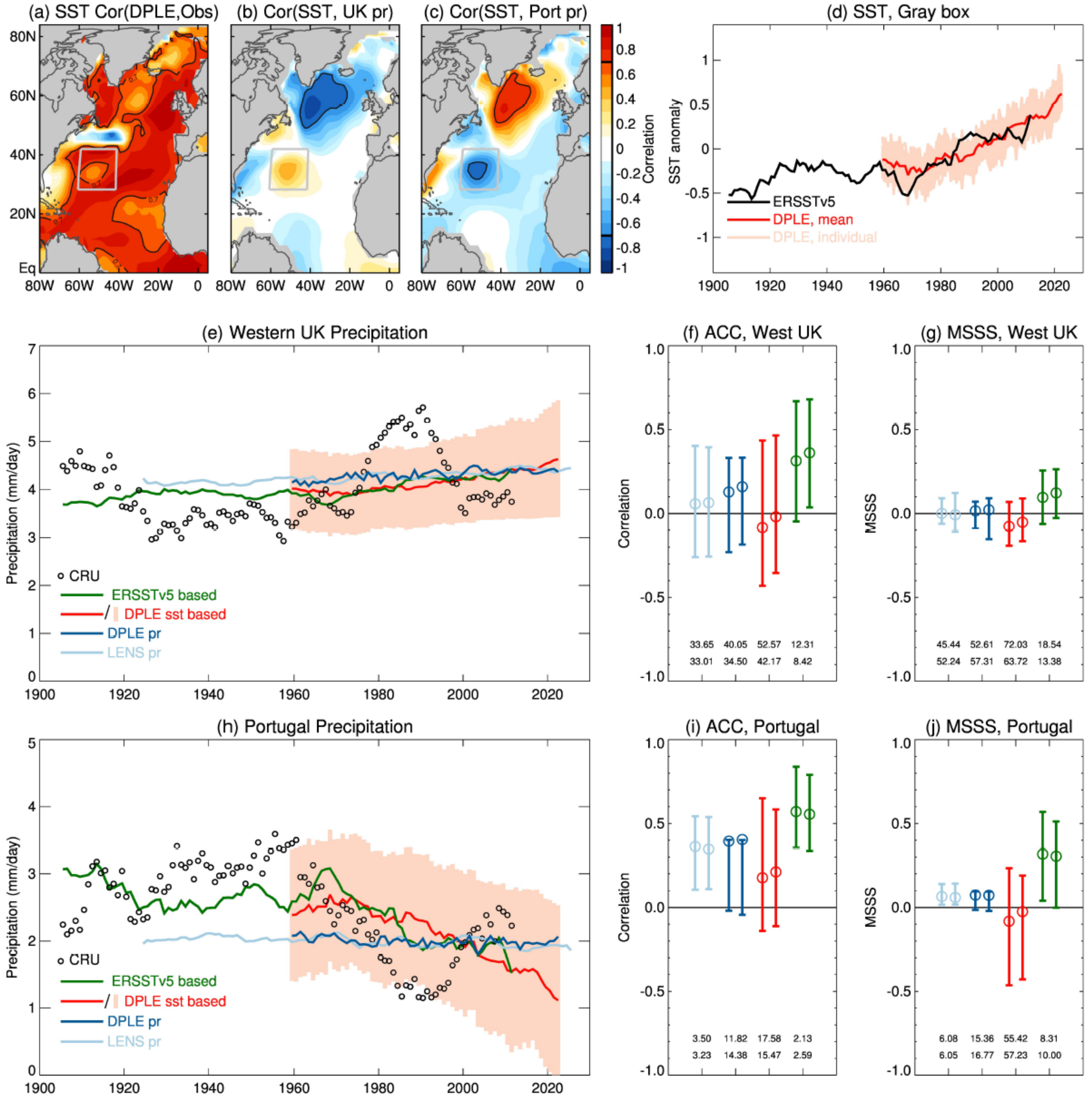
AMV as predictor



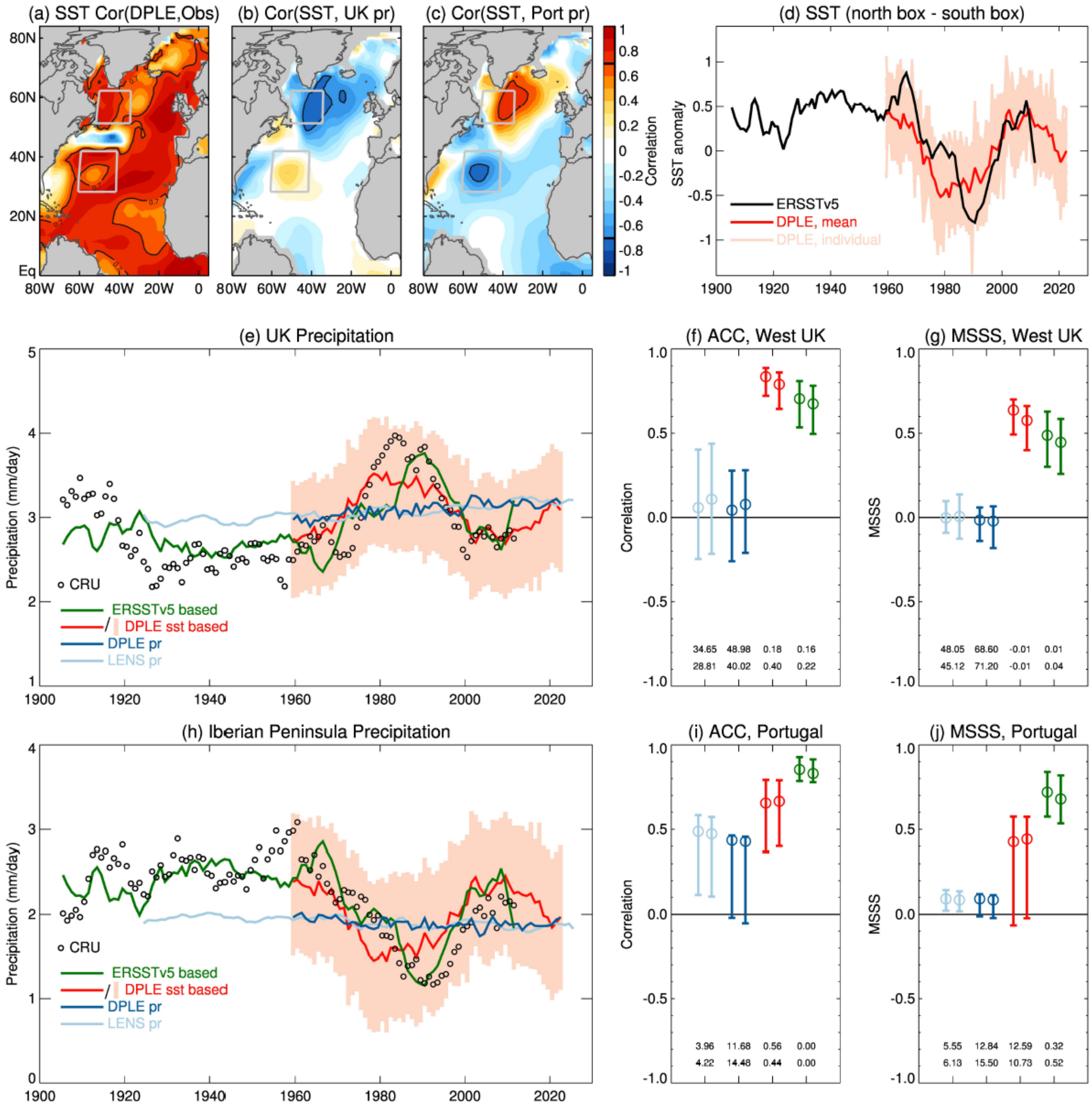
Northern box more localized over the region where the DPLE has skill



Only using the Northern Box



Only using the Southern Box



Using larger areas for precipitation. The whole of the UK and the whole of the Iberian peninsula

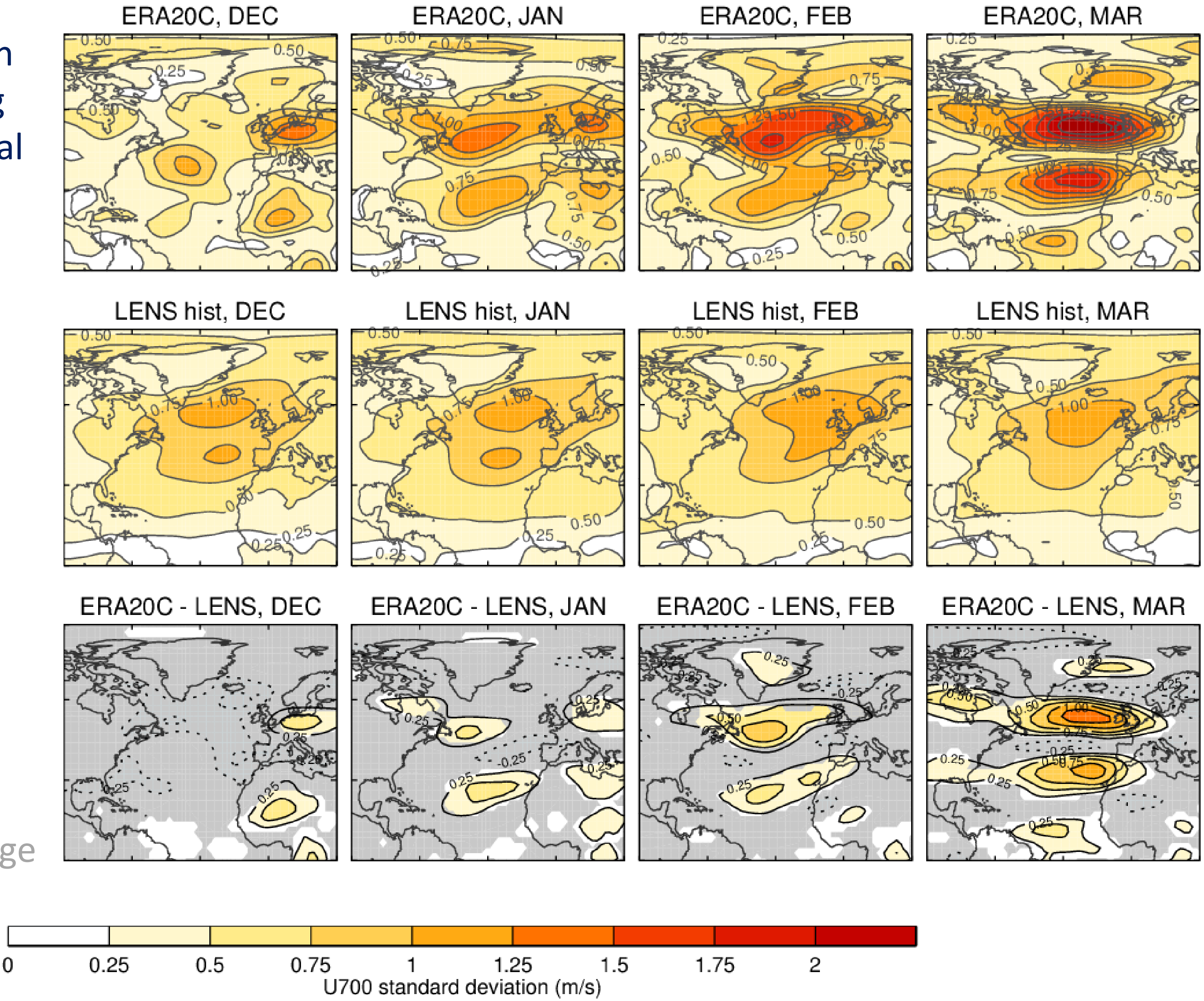
Previous work: Simpson et al 2018, J. Clim., 31, 8313-8338

Standard deviation of 20 year running mean 700hPa zonal wind in ERA20C reanalysis

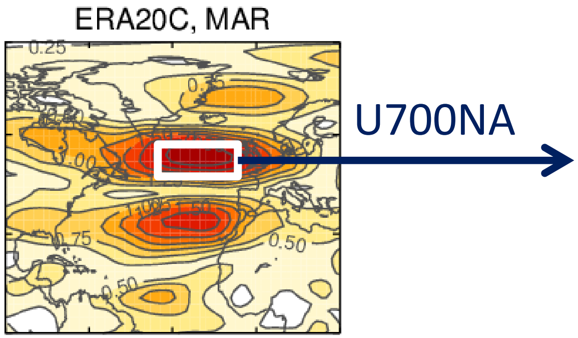
CESM Large Ensemble

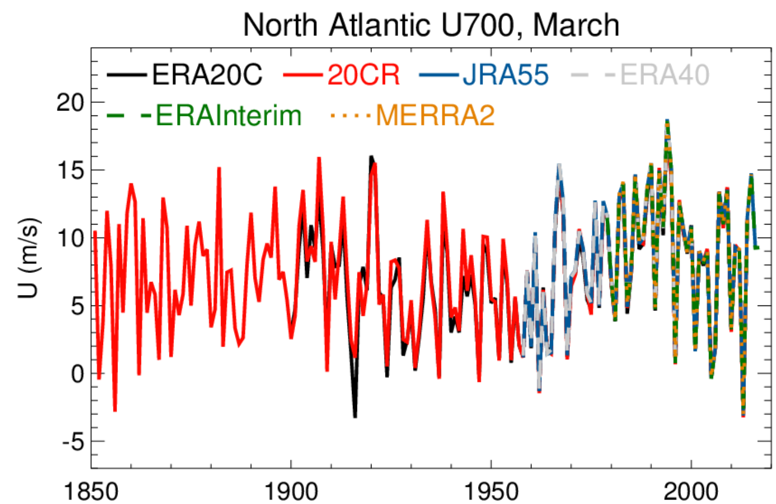
ERA20C-CESM Large Ensemble

Gray = where the reanalysis lies outside of the large ensemble spread



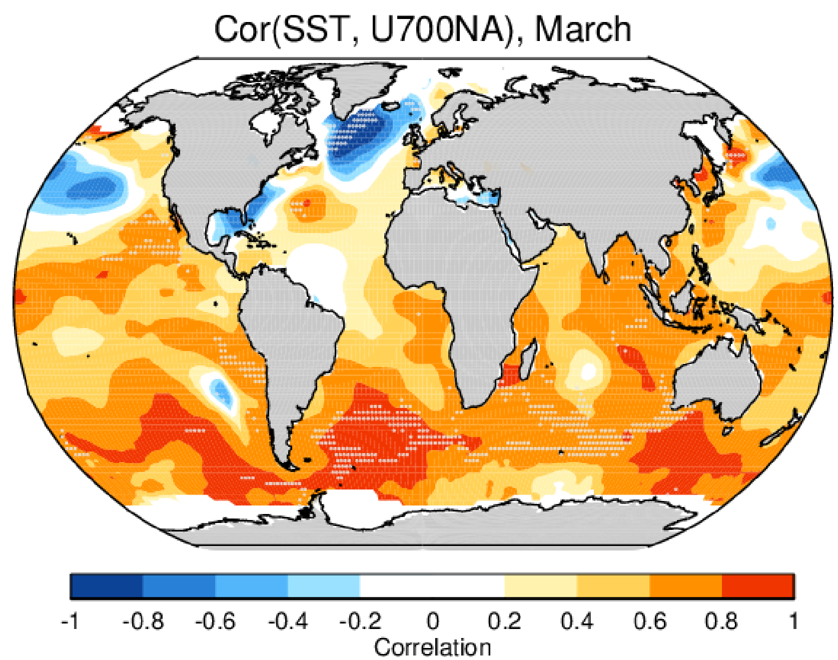
Previous work: Simpson et al 2018, J. Clim., 31, 8313-8338



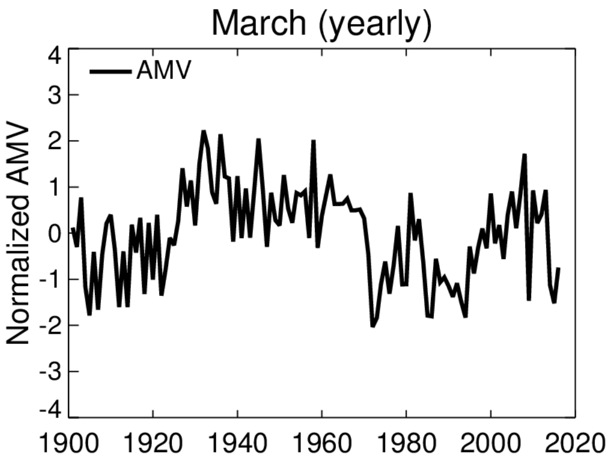


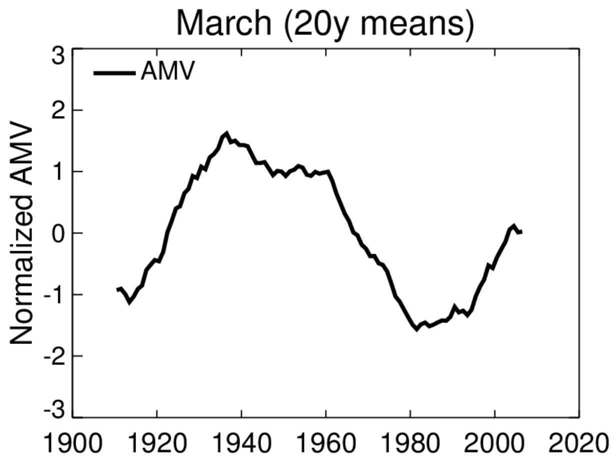
Correlation between low frequency U700NA and SSTs.

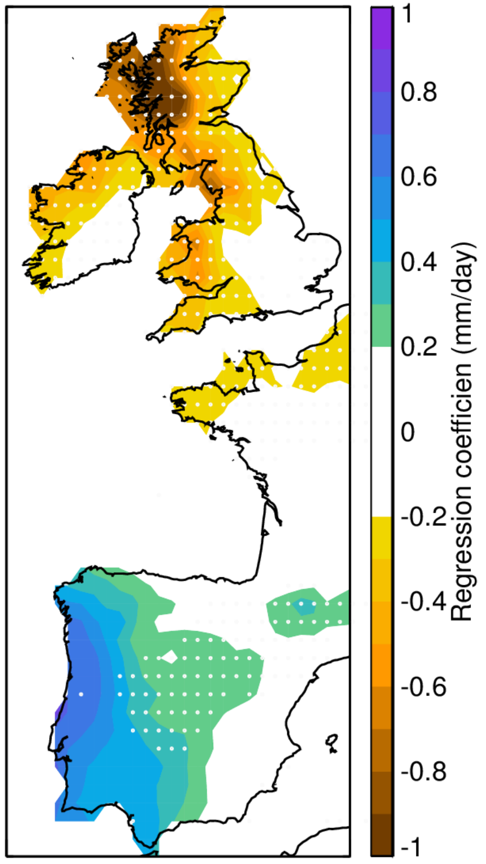
Stippling = significant at the 95% level using a test that accounts for the lack of degrees of freedom (Delworth et al 2017)



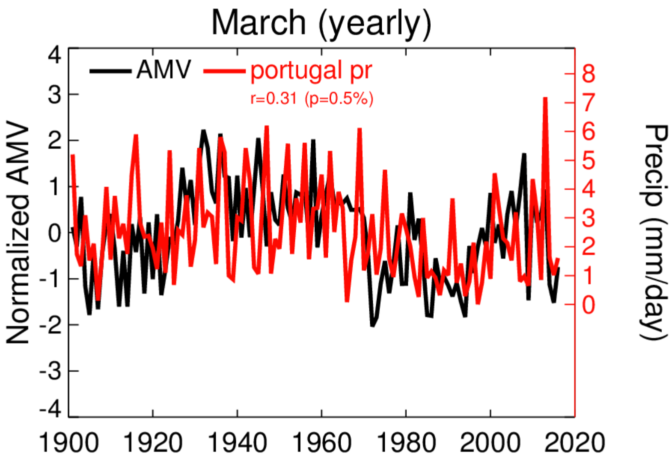
March Connections

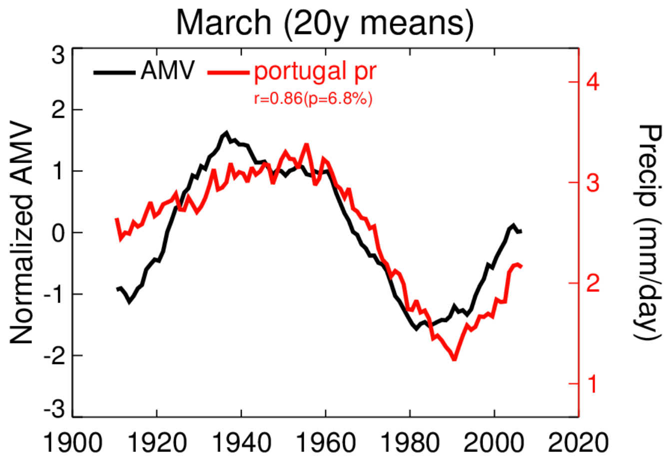


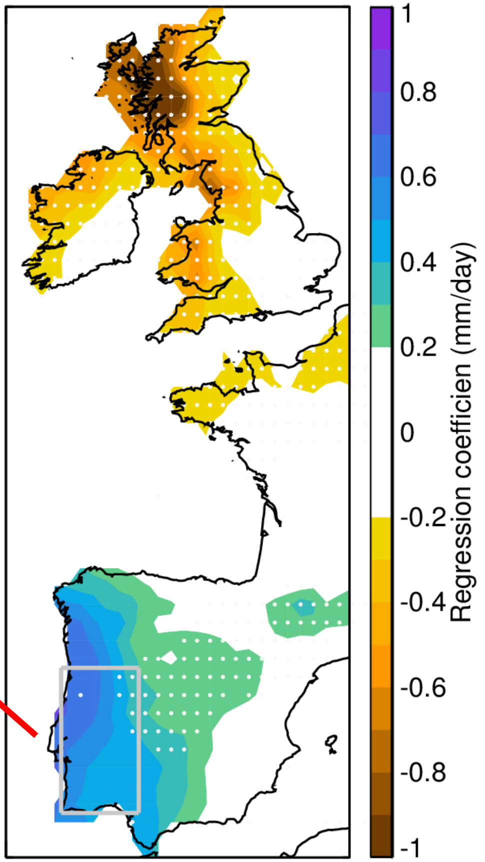




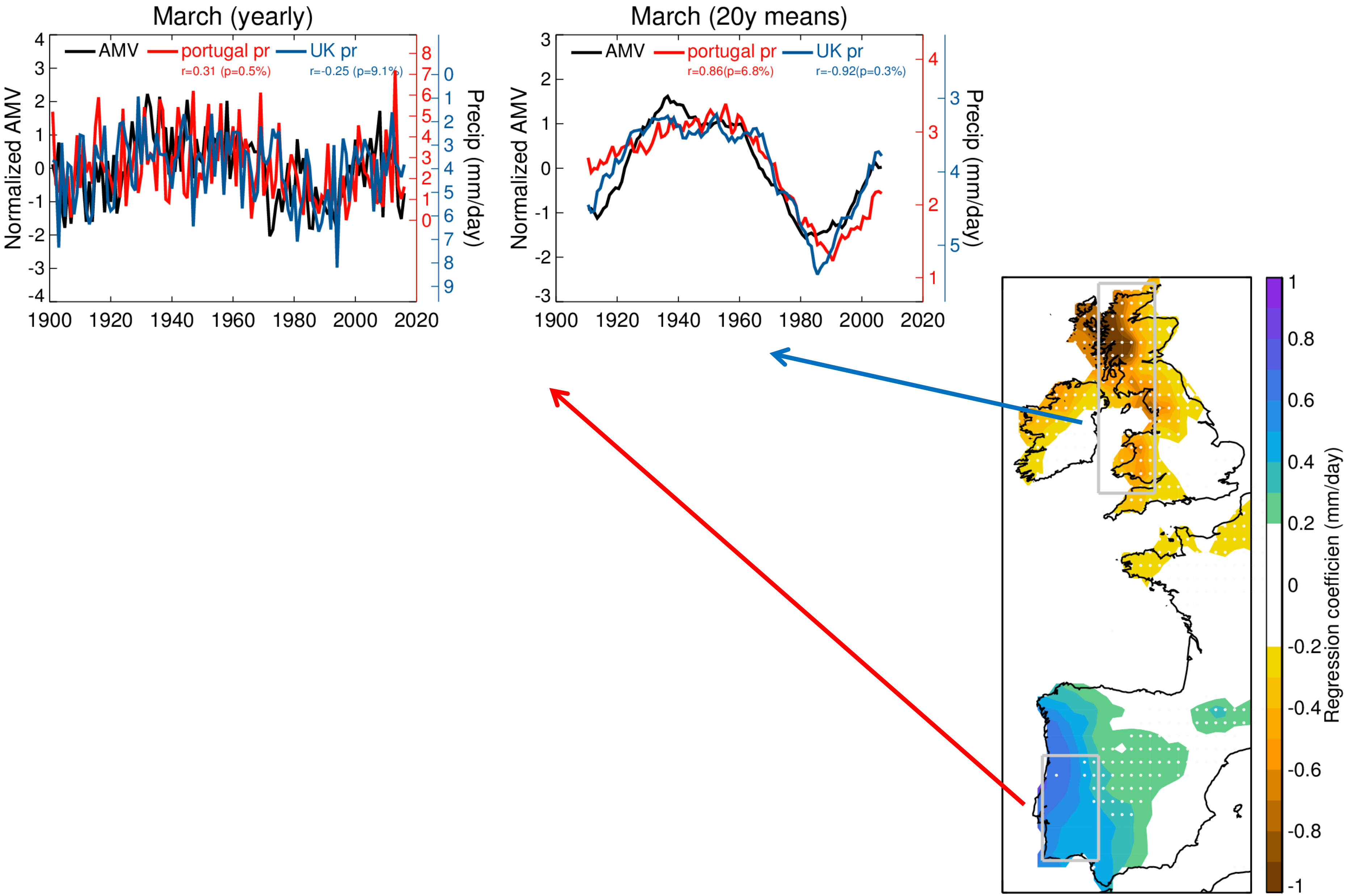
March Connections





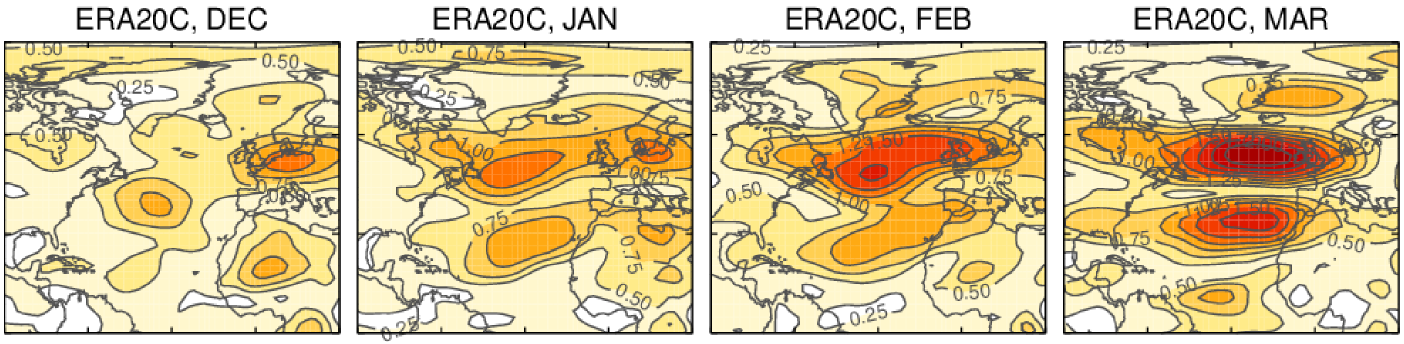


March Connections



Previous work: Simpson et al 2018, J. Clim., 31, 8313-8338

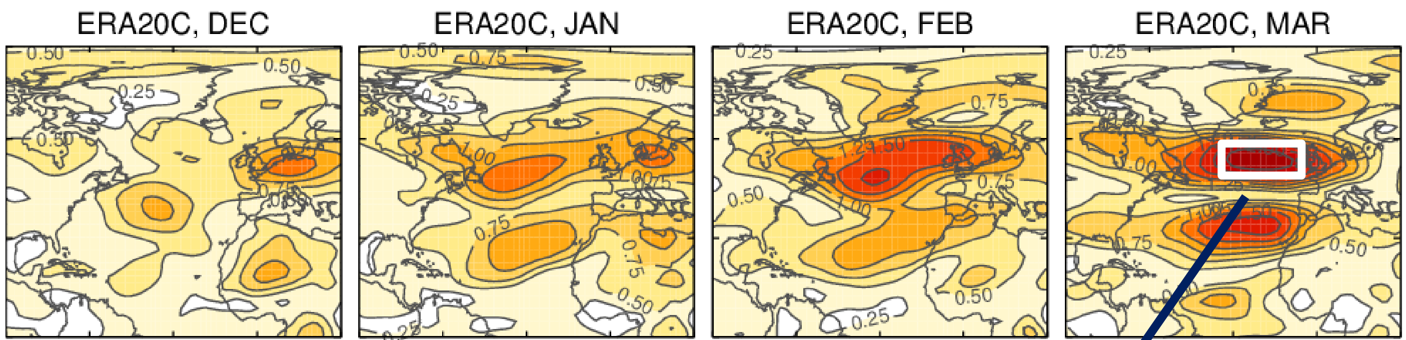
Standard deviation of 20 year running mean 700hPa zonal wind in ERA20C reanalysis



More variability toward the late winter

Previous work: Simpson et al 2018, J. Clim., 31, 8313-8338

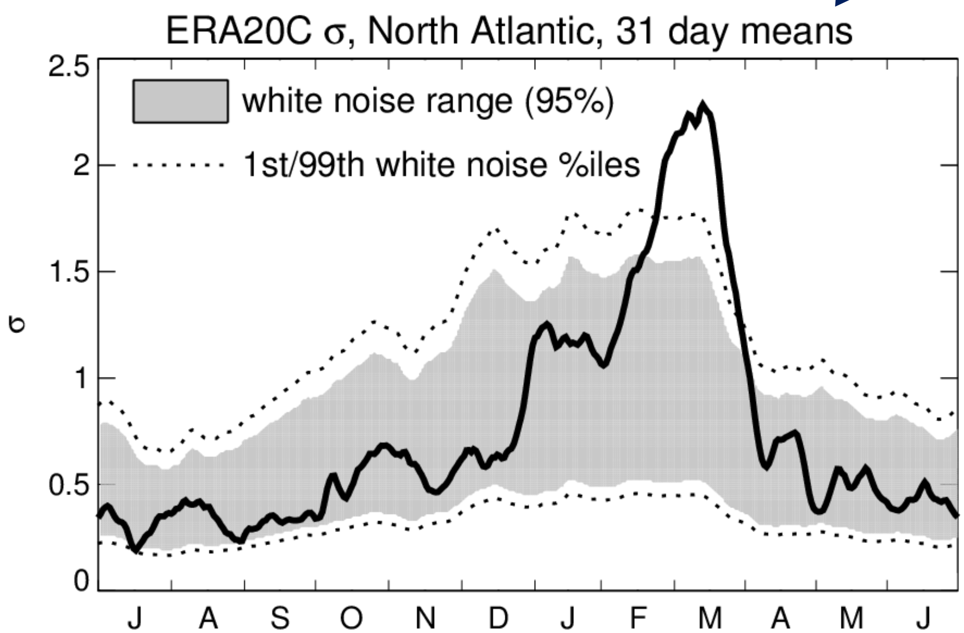
Standard deviation of 20 year running mean 700hPa zonal wind in ERA20C reanalysis



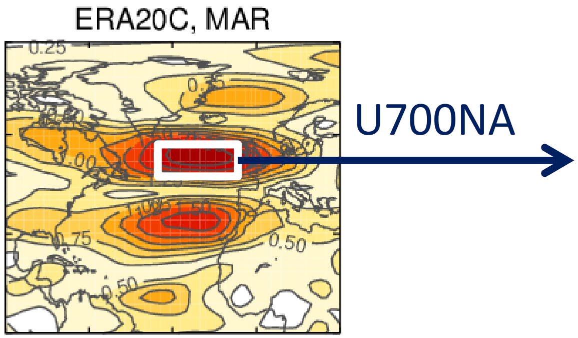
More variability toward the late winter

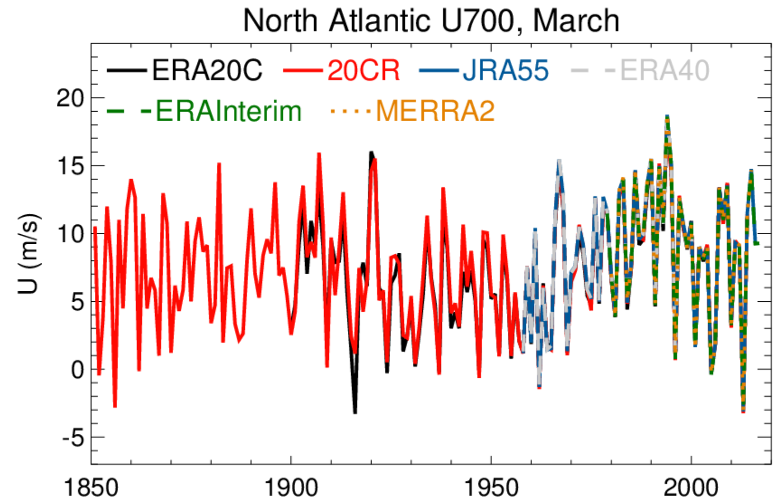
Standard deviation of 20 year running means for 31 day running means

Range of variability in 20 year running means that could arise from sampling of white noise year-to-year variability

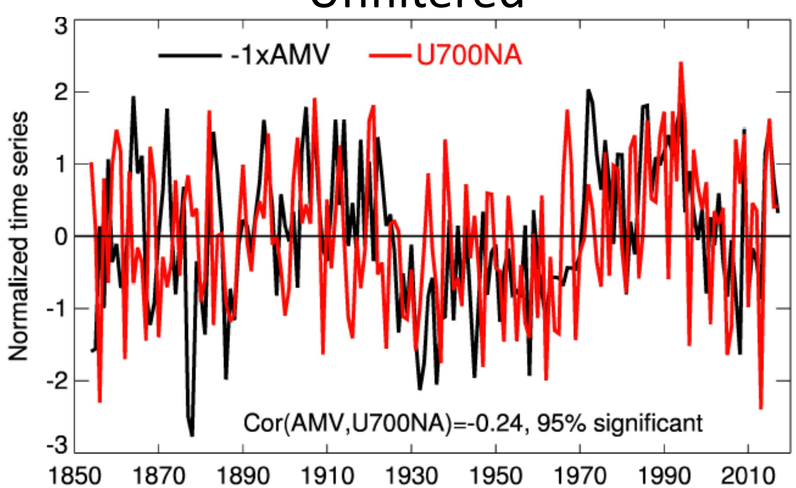


Previous work: Simpson et al 2018, J. Clim., 31, 8313-8338

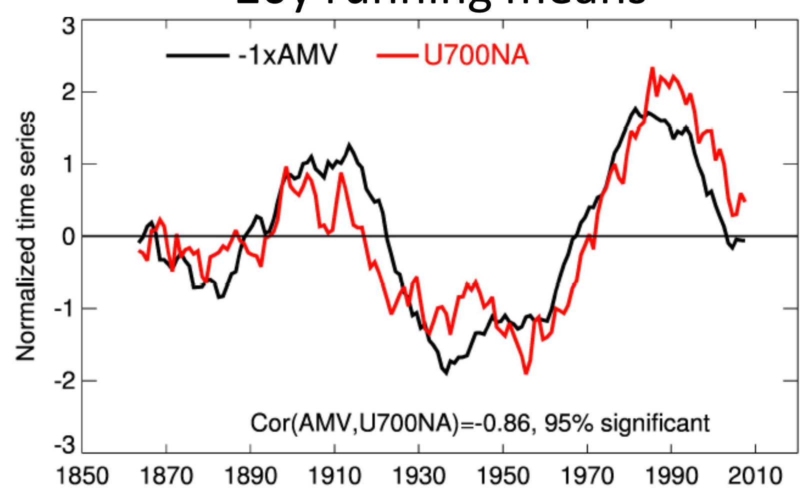




Unfiltered



20y running means

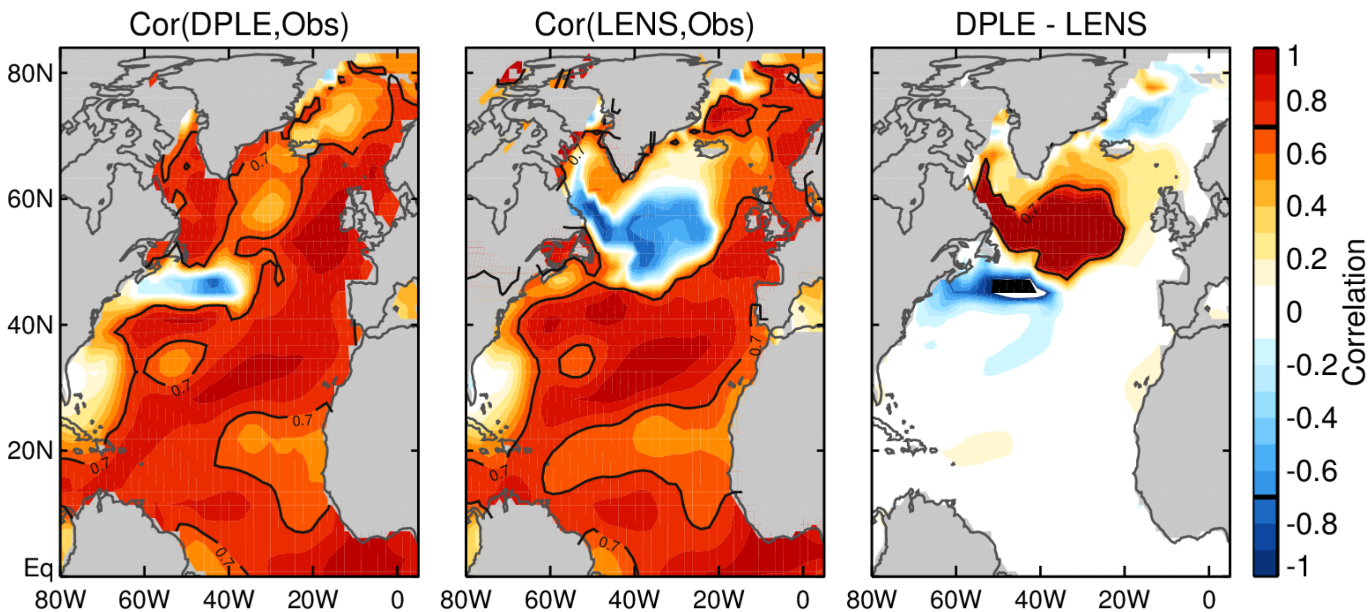


AMV = Trenberth and Shea (2006) AMV index

Frankignoul et al (2017) LIMOptimal index looks similar

March Predictability

Decadal averaged SST skill, anomaly correlations



Correlation between ERSSTv5 SST anomalies and DPLE SST anomalies

i.e., skill from ocean initialization and external forcing

Correlation between ERSSTv5 SST anomalies and uninitialized LENS anomalies

i.e., skill from external forcing only

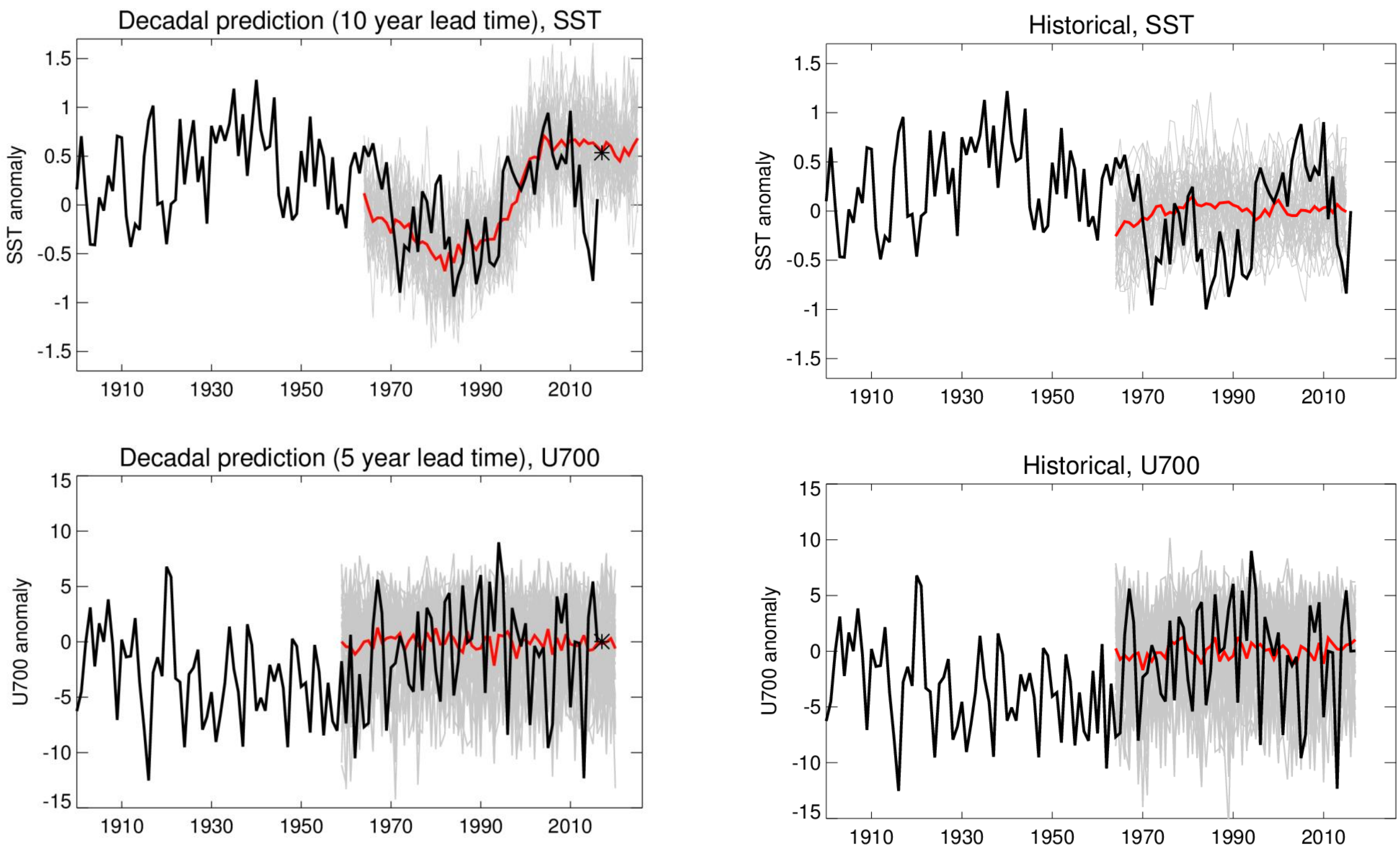
Difference (Left – Right)

Increase in skill when the ocean is initialized

See also Yeager et al (2018, 2019)

(3) Initialized decadal predictions can predict the SST variability in the sub-polar North Atlantic without predicting the winds.

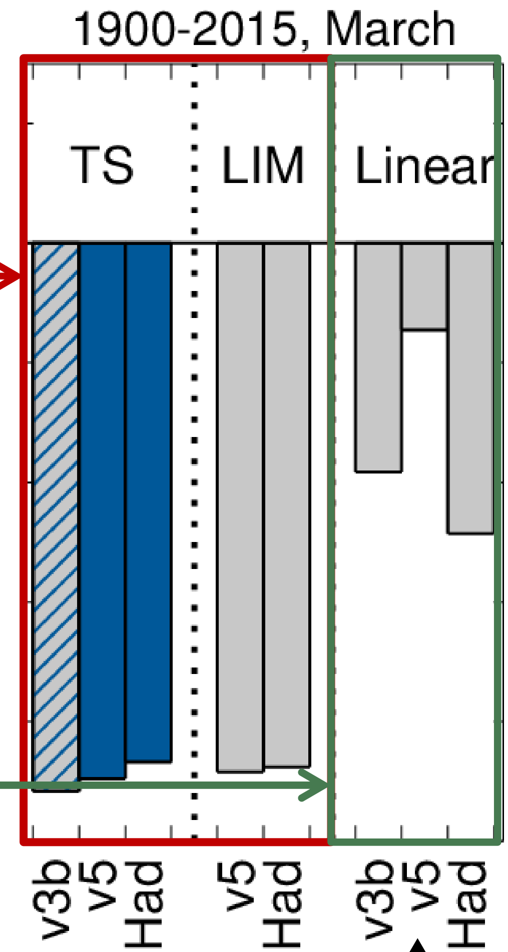
CESM initialized decadal prediction large ensemble (Yeager et al 2018): A 40 member ensemble of decadal predictions initialized with observed ocean and sea ice states, each November from 1954-2015



Correlation between North Atlantic U700 and AMV

These indices are designed to isolate the internal variability component. Has been shown to work well in large ensembles by Frankignoul et al 2017

This index has been argued by Murphy et al 2017, Bellomo et al 2018 to contain an externally forced component



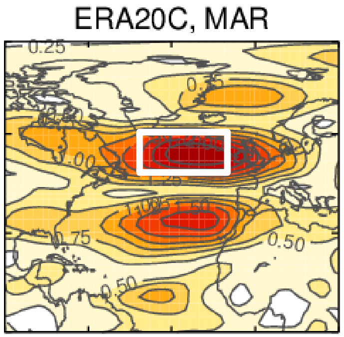
Linear detrending. Argued to retain some externally forced variability due to multi-decadal variability in aerosol forcings e.g., Murphy et al 2017

Not Significant

Significant at 90% level

Significant at 95% level

The problem is not resolved by prescribing observed SSTs



Standard deviation of 20 year running means of March U700 in the North Atlantic Box (U700NA) for 1900-2005.