WCRP strategy

Scientific objectives

1. Fundamental understanding of the climate system
- Climate dynamics
- Reservoirs and flows

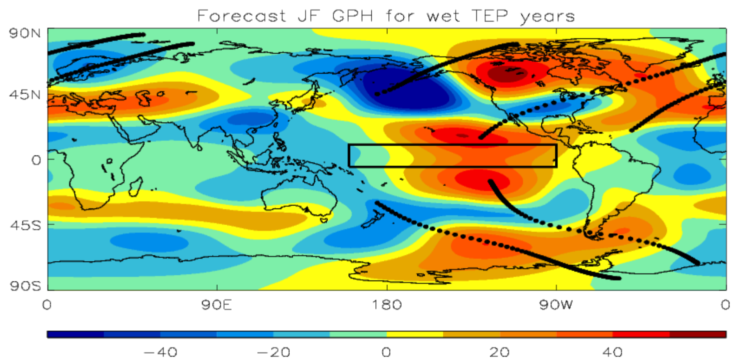
2. Prediction of the near-term evolution of the climate system
- Simulation capabilities
- Predicting extreme events

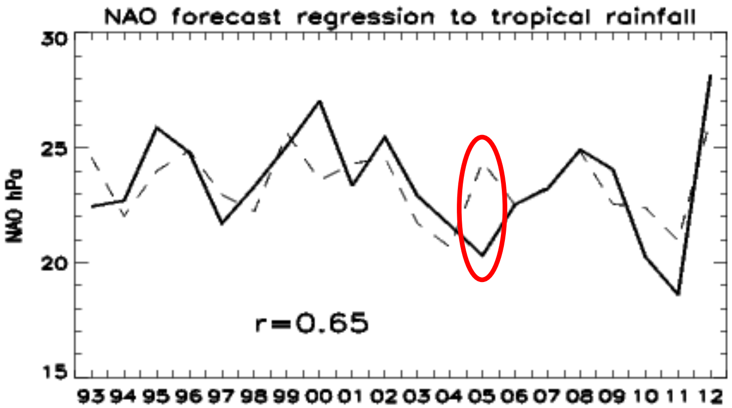
3. Future evolution of the climate system
- Simulation capabilities

4. Bridging climate science and society
- Interactions with social systems
- Engaging with society

UK Met Office

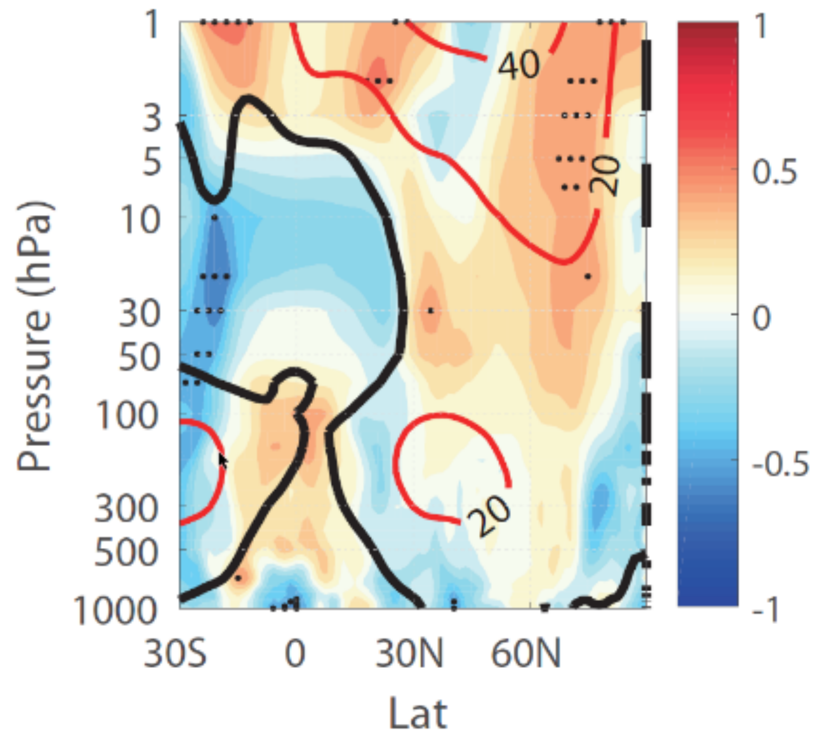
NAO





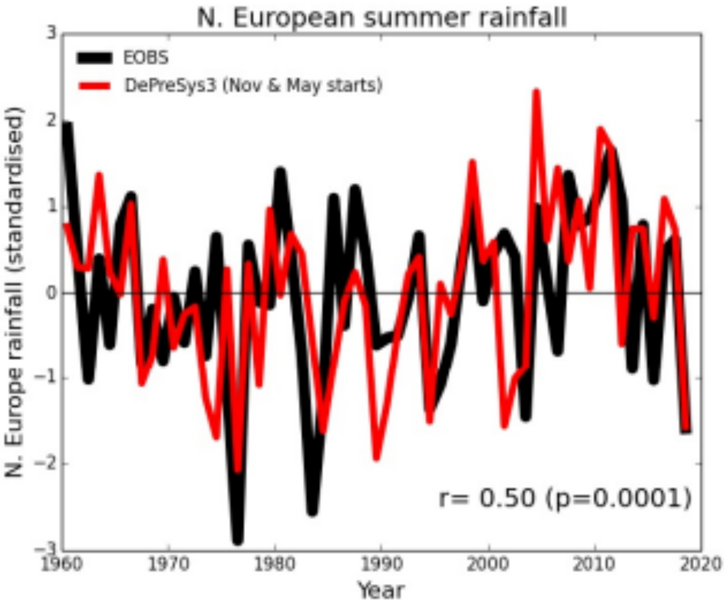
- Regression of tropical rainfall in 4 boxes (dashed) explains most of forecast NAO (solid)
- Potentially explains forecast bust in 2004/5 – model ignored tropical rainfall signal?

Correlation between initial wind and forecast NAO



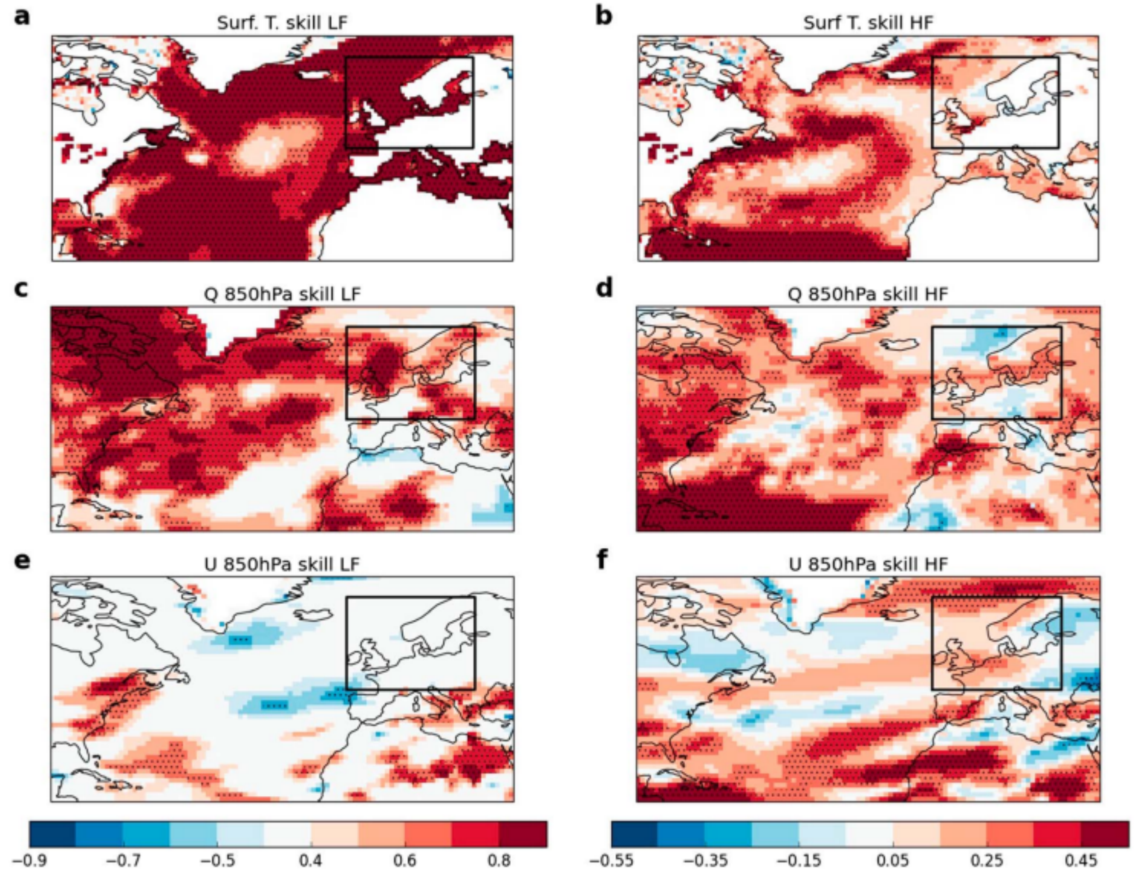
Scaife et al 2016, 2018; Nie et al, ERL, 2019

European summer rainfall



Low frequency (5 year)

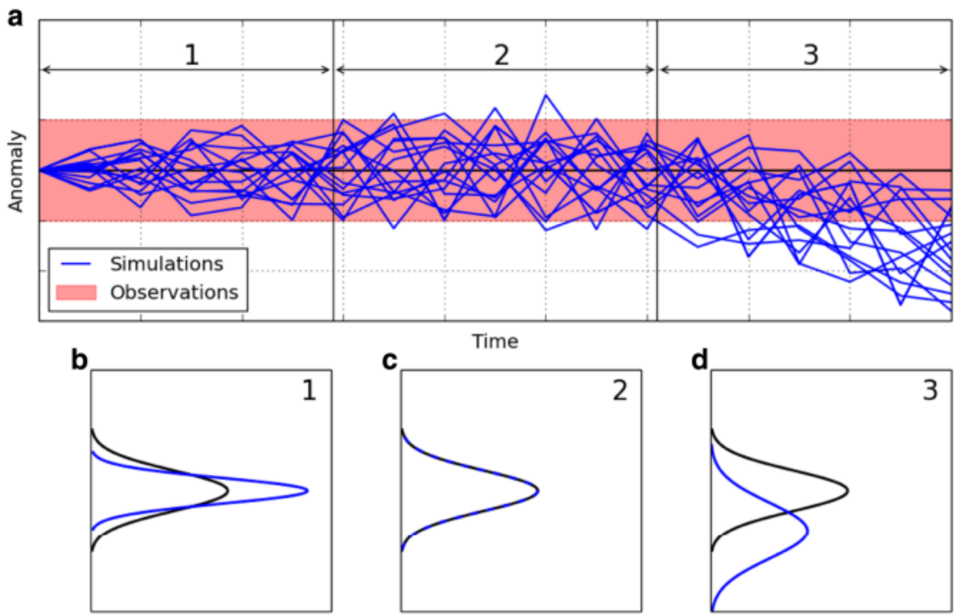
High frequency (1 year)



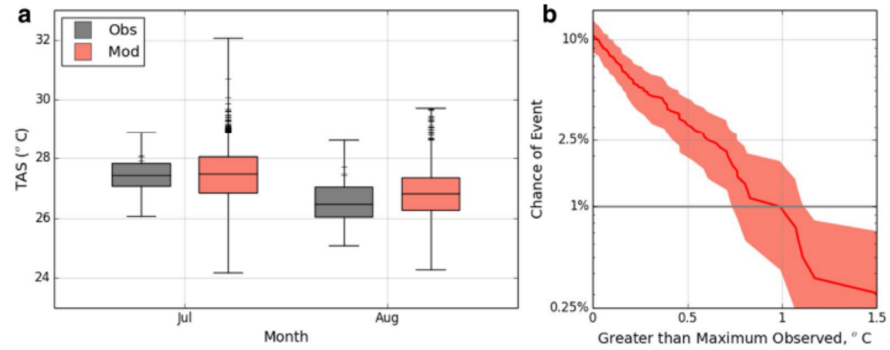
- Low frequency (5 year)
  - Skill for humidity (driven by SST)
  - No skill for circulation
- High frequency (1 year)
  - Some skill for circulation

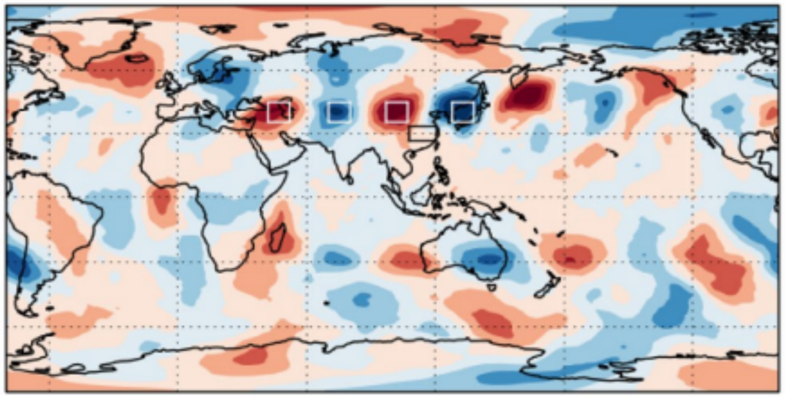
Unprecedented extremes

UNSEEN – Unprecedented Simulated Extremes using ENsembles



Chance of unprecedented hot months in South East China

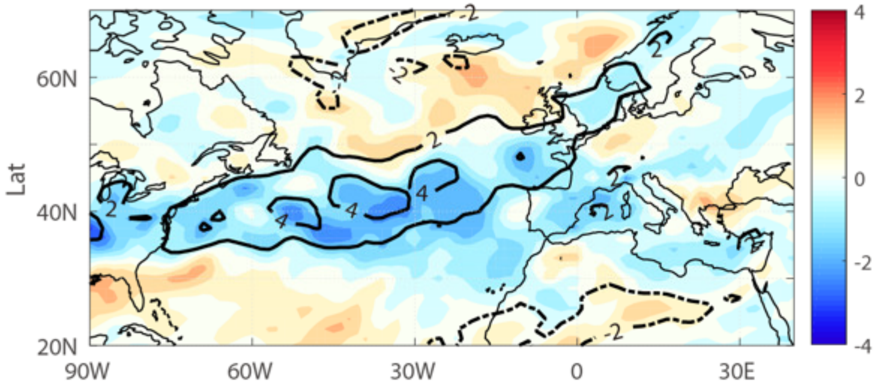


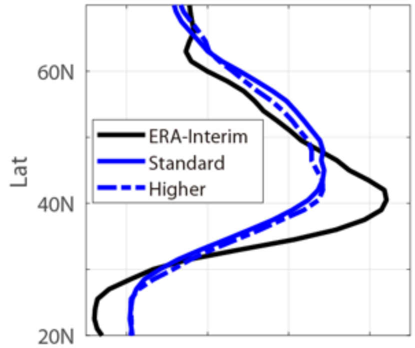


"Silk road" pattern, likely driven by Indian monsoon rainfall

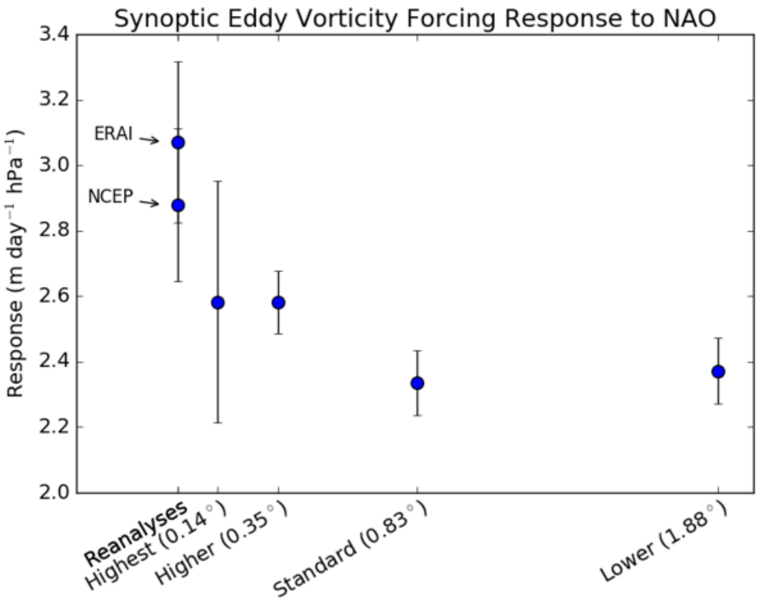
High atmosphere resolution (25 km)

Eddy feedback on climatological jet





Eddy Feedback onto the NAO



Skill is insensitive to a doubling of resolution

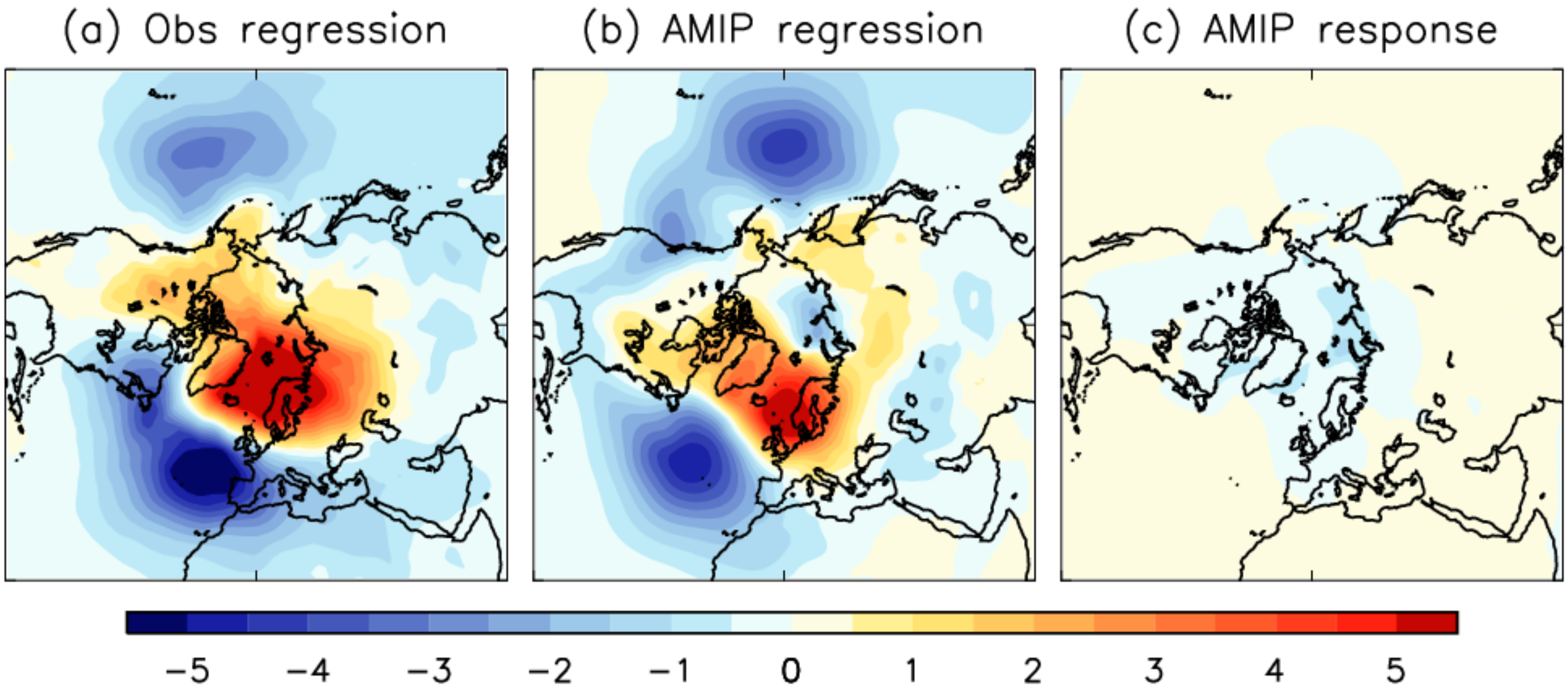
Eddy feedback is weak in models but increases at ~10km resolution

New hypothesis: the signal to noise paradox due to a lack of small scale eddy feedback

Scaife et al, in revision

PAMIP

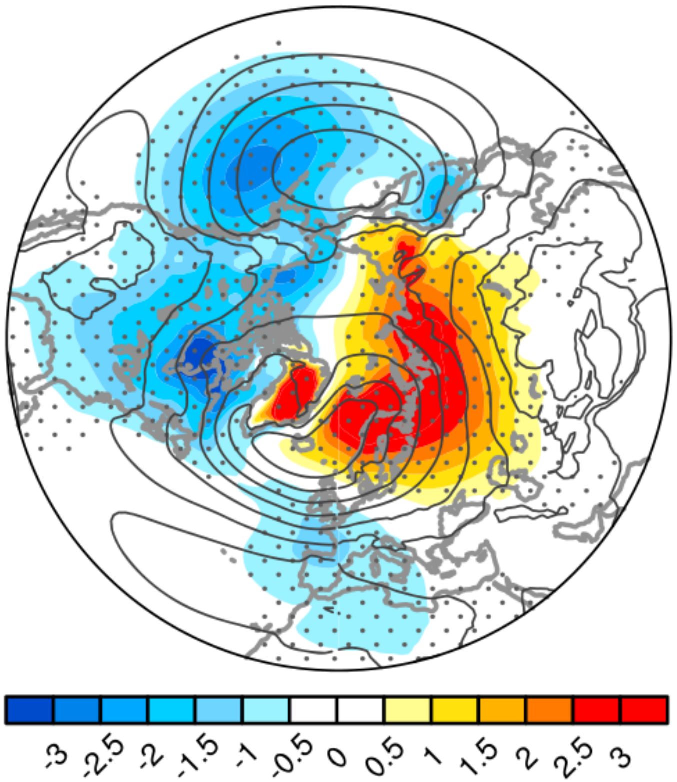
Real world response to sea ice?
Cannot be diagnosed from obs alone

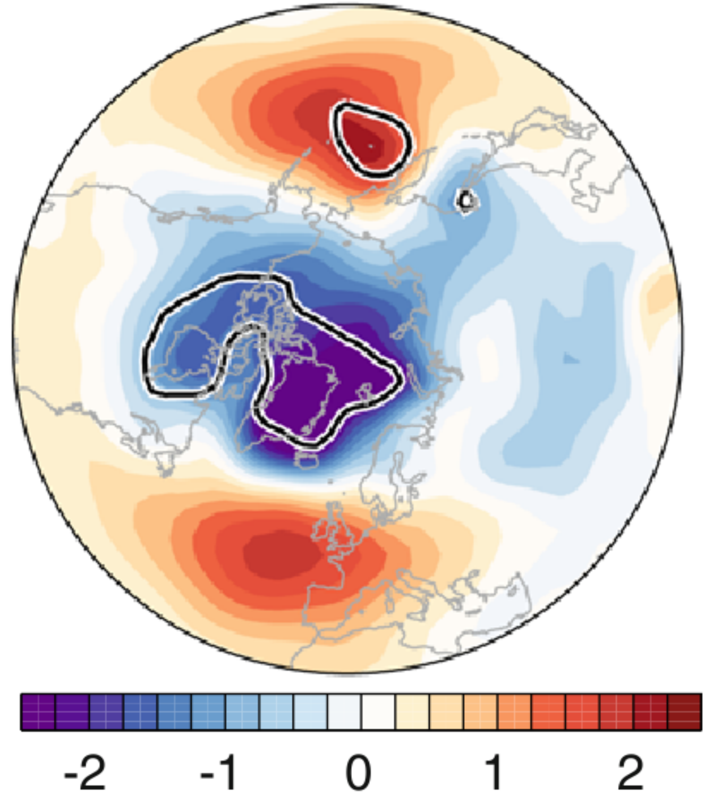


- **Regression between autumn (SON) Arctic sea ice extent and winter (DJF) sea level pressure (sign reversed)**
- **Obs and AMIP (atmosphere model forced by observed SST and sea ice) agree**
- **BUT AMIP model response forced by reduced ice in model experiments sea ice is completely different**
- **The pattern is likely forced by SSTs rather than sea ice in AMIP simulations**

Smith et al 2017

Non-robust response: full range of NAO responses have been reported





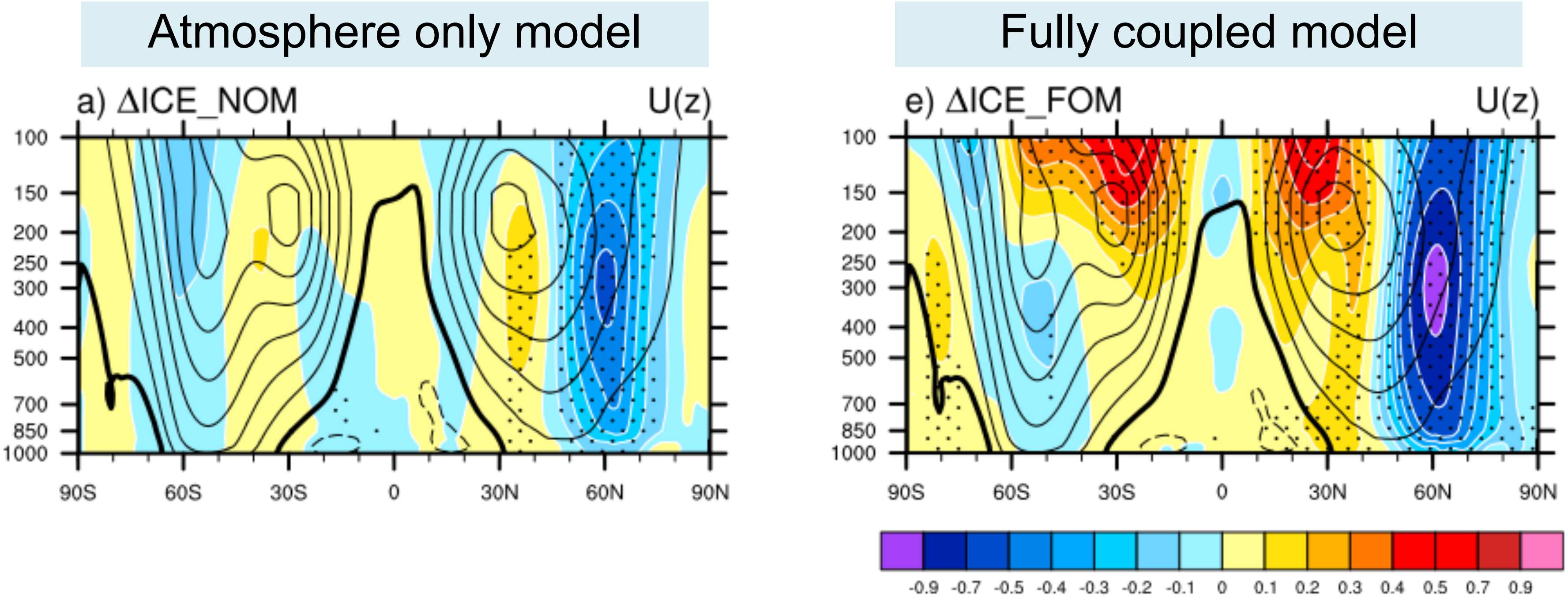
- **Negative NAO** (DJF, mslp, hPa)
  - Deser et al 2016; Honda et al 2009; Seierstad and Bader 2009; Mori et al 2014; Kim et al 2014; Nakamura et al 2015 …

- **Positive NAO**
  - Screen et al 2014; Singarayer et al 2006; Strey et al 2010; Orsolini et al 2012; Rinke et al 2013; Cassano et al 2014 …

- **Little NAO response**
  - Screen et al. 2013; Petrie et al 2015; Blackport and Kushner 2016 …

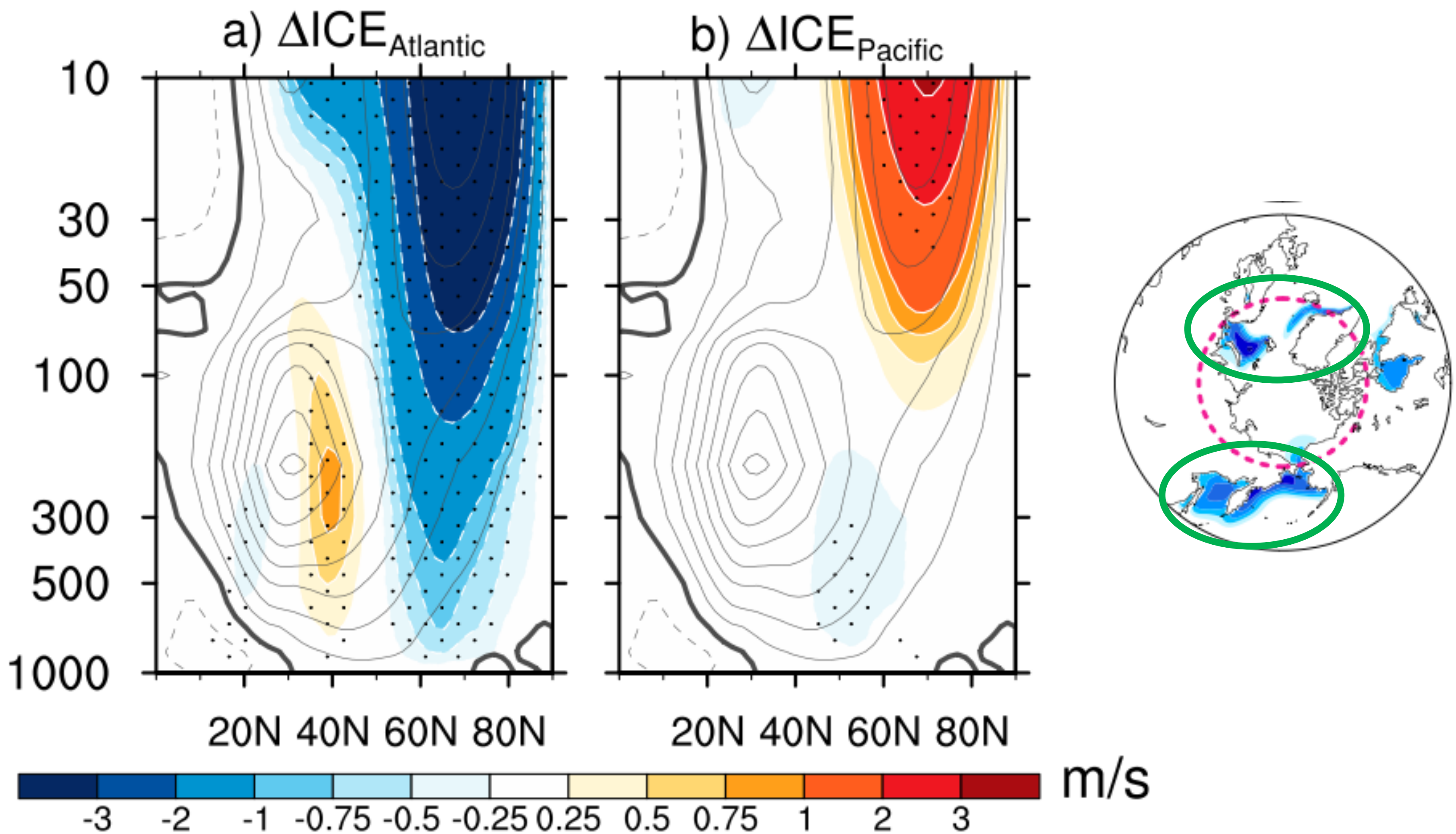
- **NAO response that depends on the forcing**
  - Alexander et al 2004; Petoukhov and Semenov 2010; Peings and Magnusdottir 2014; Sun et al. 2015; Pedersen et al 2016; Chen et al 2016 ...

Atmosphere vs coupled models



Deser et al 2016

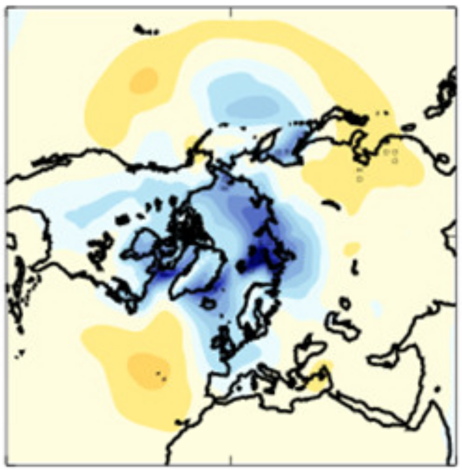
Response depends on pattern of forcing



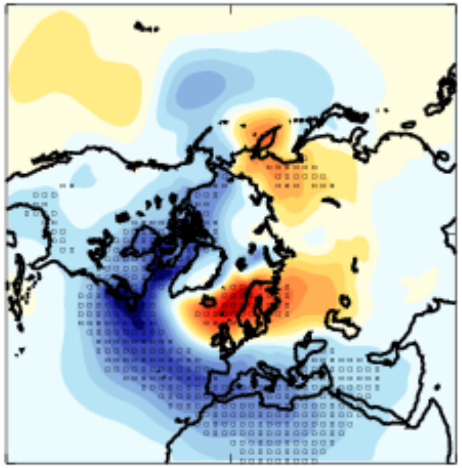
- Opposite response if forcing is applied in Atlantic and Pacific sectors separately
- Sun et al 2015; Alexander et al 2004; Peings and Magnusdottir 2014; Screen 2017; McKenna et al 2018

Dependence on background state

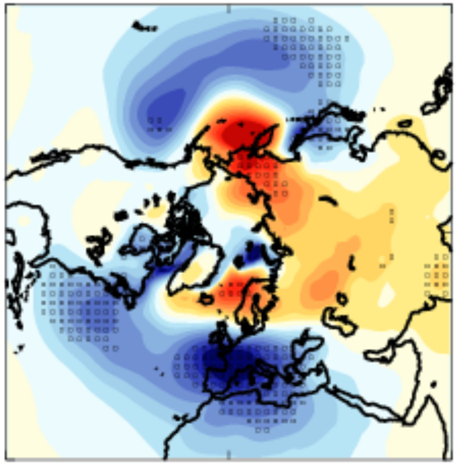
Atmosphere model



Coupled model



Atmosphere model with coupled model background state

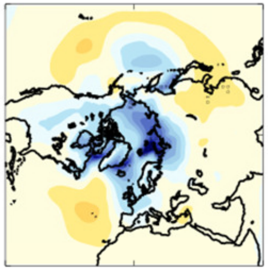


- **Different response could be caused by coupling or background state (model bias)**
- **Test by repeating atmosphere model but imposing COUPLED SST bias → AMIP_CPLD**
- **Reproduces COUPLED response → background state is key**

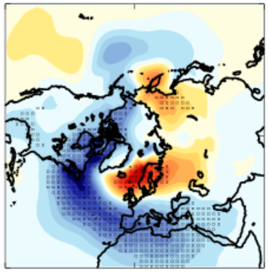
Smith et al 2017

Emergent constraint?

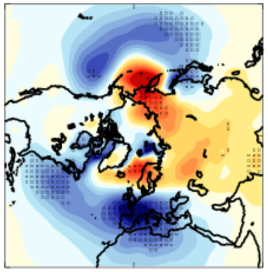
AMIP

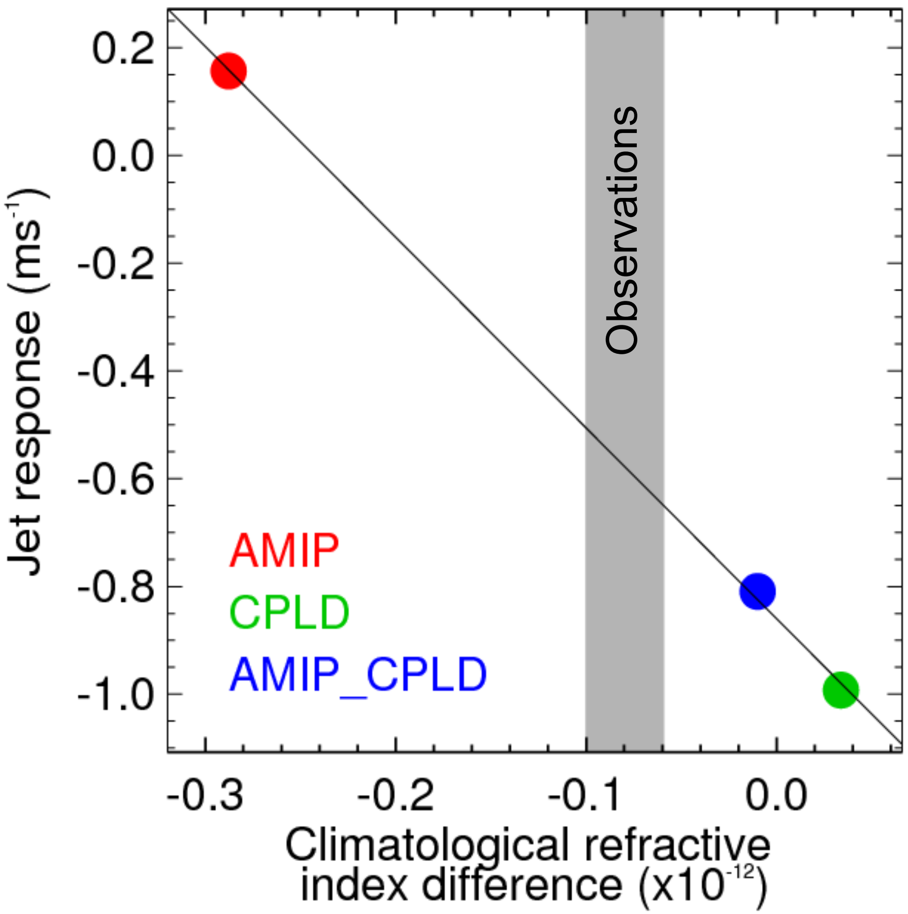


CPLD



AMIP_CPLD





- **Cannot trust model response if S/N ratio too small**
- **Response depends on wave propagation, and hence refractive index**
- **Observations (grey shading) closer to CPLD than AMIP, supporting –ve NAO response**
- **Need more models → coordinated multi-model experiments (PAMIP)**
- **Must understand the physical mechanism**

Smith et al 2017

PAMIP experiments (1)

Tier 1, atmosphere only

No.	Experiment name	Description	Notes	Tier	Start year	Number of years	Minimum ensemble size
1. Atmosphere-only time slice experiments							
1.1	pdSST-pdSIC	Time slice forced by climatological monthly mean SST and SIC for the present day (pd)[1,2]	Present-day SST and SIC	1	2000	1[2]	100
1.2	piSST-piSIC	Time slice forced by climatological monthly mean SST and SIC for pre-industrial (pi) conditions[3]	Pre-industrial SST and SIC	2	2000	1	100
1.3	piSST-pdSIC	Time slice forced by pi SST and pd SIC[3]	Different SST relative to 1.1 to investigate the role of SSTs in polar amplification	1	2000	1	100
1.4	futSST-pdSIC	Time slice forced by pd SIC and future SST representing 2° global warming (fut)[3]		2	2000	1	100
1.5	pdSST-piArcSIC	Time slice forced by pd SST and pi Arctic SIC[3]	Different Arctic SIC relative to 1.1 to investigate the impacts of present-day and future Arctic sea ice and the role of Arctic SIC in polar amplification	1	2000	1	100
1.6	pdSST-futArcSIC	Time slice forced by pd SST and fut Arctic SIC[3]		1	2000	1	100
1.7	pdSST-piAntSIC	Time slice forced by pd SST and pi Antarctic SIC[3]	Different Antarctic SIC relative to 1.1 to investigate the impacts of present-day and future Antarctic sea ice and the role of Antarctic SIC in polar amplification	1	2000	1	100
1.8	pdSST-futAntSIC	Time slice forced by pd SST and fut Antarctic SIC[3]		1	2000	1	100
1.9	pdSST-pdSICSIT	Time slice forced by pd sea ice thickness (SIT) in addition to SIC and SST	Investigate the impacts of sea ice thickness changes	3	2000	1	100
1.10	pdSST-futArcSICSIT	Time slice forced by pd SST and fut Arctic SIC and SIT	Investigate the impacts of sea ice thickness changes	3	2000	1	100
2. Coupled ocean–atmosphere time slice experiments							
2.1	pa-pdSIC	Coupled time slice constrained by pd SIC[2,4,5]		2	2000	1	100
2.2	pa-piArcSIC	Coupled time slice with pi Arctic SIC[3]	As 1.5 and 1.6 but with coupled model	2	2000	1	100
2.3	pa-futArcSIC	Coupled time slice with fut ArcticSIC[3]		2	2000	1	100

1.1 Present day SST and SIC

1.6 Future Arctic SIC

2.1 Present day SST and SIC

2.3 Coupled future Arctic SIC

PAMIP experiments (2)

No.	Experiment name	Description	Notes	Tier	Start year	Number of years	Minimum ensemble size
2.4	pa-piAntSIC	Coupled time slice with pi Antarctic SIC[3]	As 1.7 and 1.8 but with coupled model	2	2000	1	100
2.5	pa-futAntSIC	Coupled time slice with fut Antarctic SIC[3]		2	2000	1	100
3. Atmosphere-only time slice experiments to investigate regional forcing							
3.1	pdSST-futOkhotskSIC	Time slice forced by pd SST and fut Arctic SIC only in the Sea of Okhotsk	Investigate how the atmospheric response depends on the pattern of Arctic sea ice forcing	3	2000	1	100
3.2	pdSST-futBKSeasSIC	Time slice forced by pd SST and fut Arctic SIC only in the Barents/Kara seas		3	2000	1	100
4. Atmosphere-only time slice experiments to investigate the role of the background state							
4.1	modelSST-pdSIC	Time slice forced by pd SIC and pd SST from coupled model (2.1) rather than observations	In conjunction with experiments 1 and 2, isolate the effects of the background state from the effects of coupling	3	2000	1	100
4.2	modelSST-futArcSIC	Time slice forced by fut Arctic SIC and pd SST from coupled model (2.1) rather than observations		3	2000	1	100
5. Atmosphere-only transient experiments							
5.1	amip-climSST	Repeat CMIP6 AMIP (1979–2014) but with climatological monthly mean SST	Use CMIP6 AMIP as the control; investigate transient response, individual years and the contributions of SST and SIC to recent climate changes	3	1979	36	3
5.2	amip-climSIC	Repeat CMIP6 AMIP (1979–2014) but with climatological monthly mean SIC		3	1979	36	3
6. Coupled ocean–atmosphere extended experiments							
6.1	pa-pdSIC-ext	Coupled model extended simulation constrained with pd sea ice[4,6]	Experiments to investigate the decadal and longer impacts of Arctic and Antarctic sea ice	3	2000	100	1
6.2	pa-fut ArcSIC-ext	Coupled model extended simulation constrained with fut Arctic sea ice[4,6]		3	2000	100	1
6.3	pa-fut AntSIC-ext	Coupled model extended simulation constrained with fut Antarctic sea ice[4,6]		3	2000	100	1

3. Regional forcing

4. Different background state

5. Focus on 1979-2014

6. Long coupled runs → transient response, ocean response

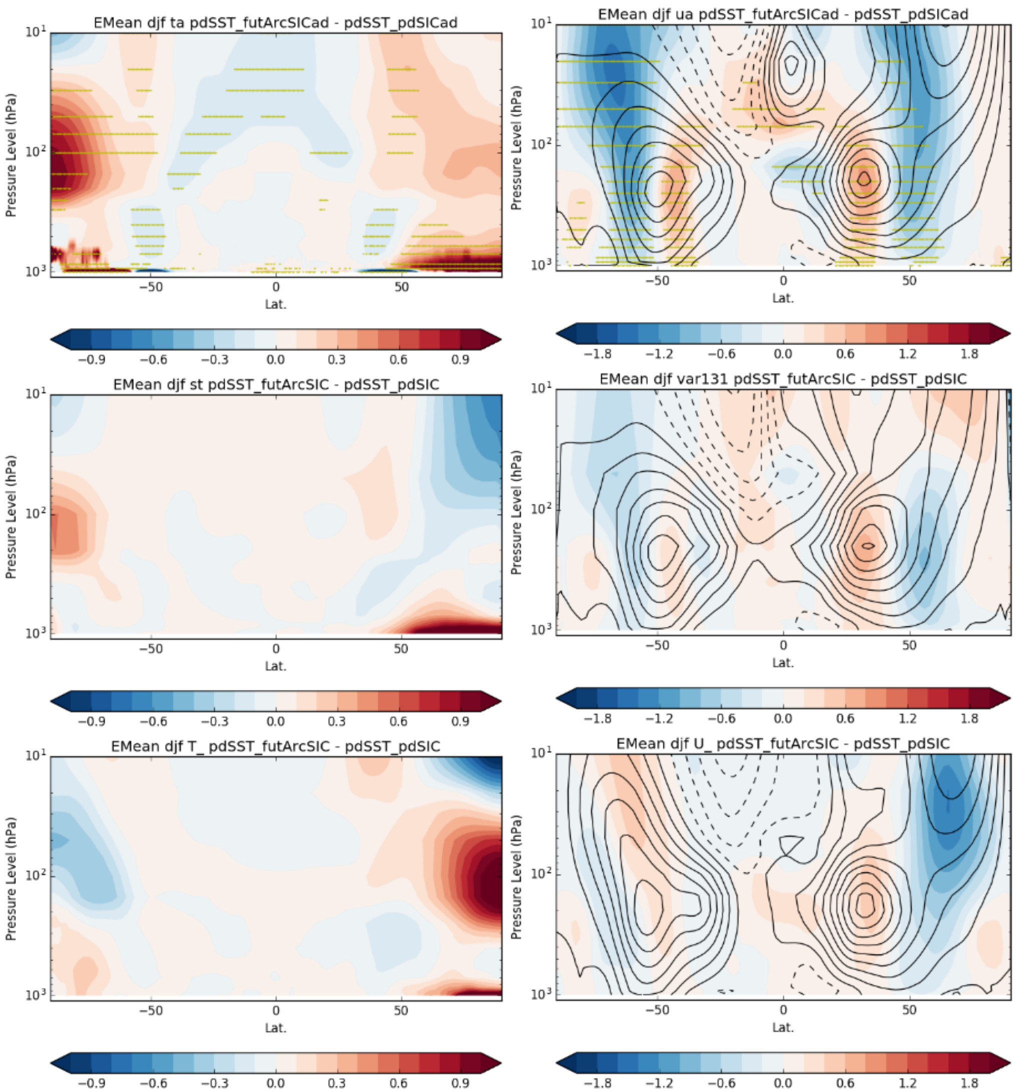
Reduced Arctic SIC

TEMPERATURE | U-WIND

Met Office

AWI

SC-WCCM



Multi-Model Results DJF

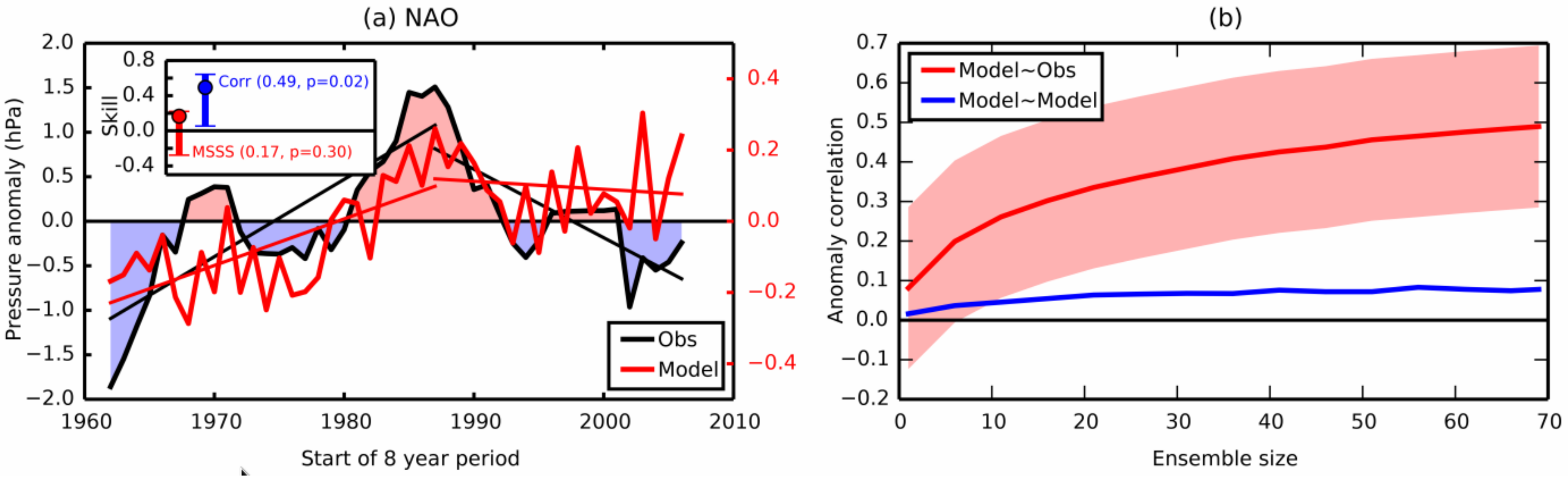
Local surface warming
- Different responses in upper atmosphere

Equatorward shift of jet
- MO jet shift in S hemi too

R. Eade, D. Smith

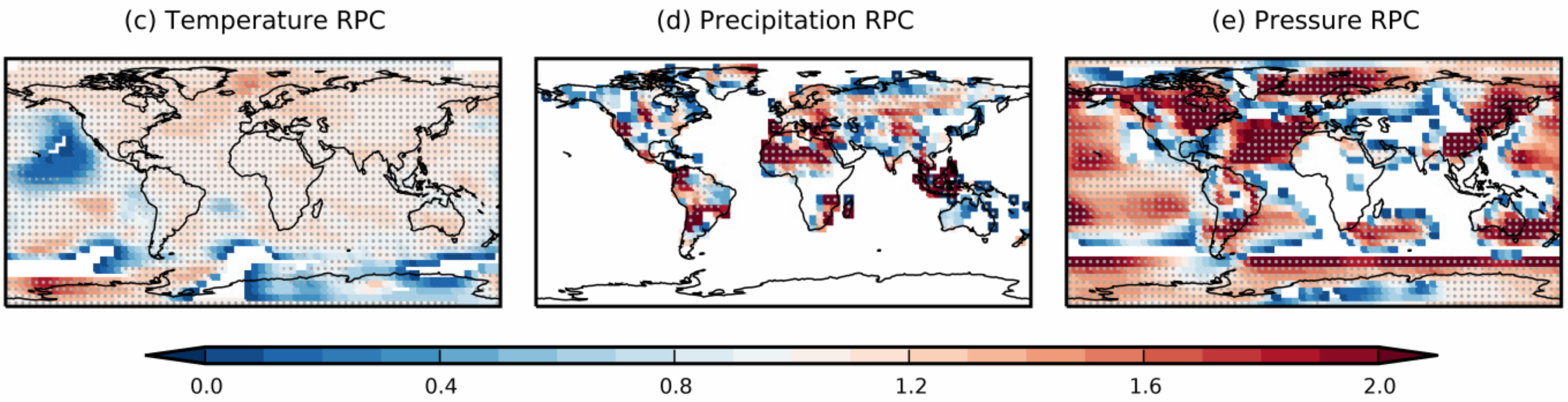
DCPP and GC-NTCP

Skill: years 2-9: NAO (annual)



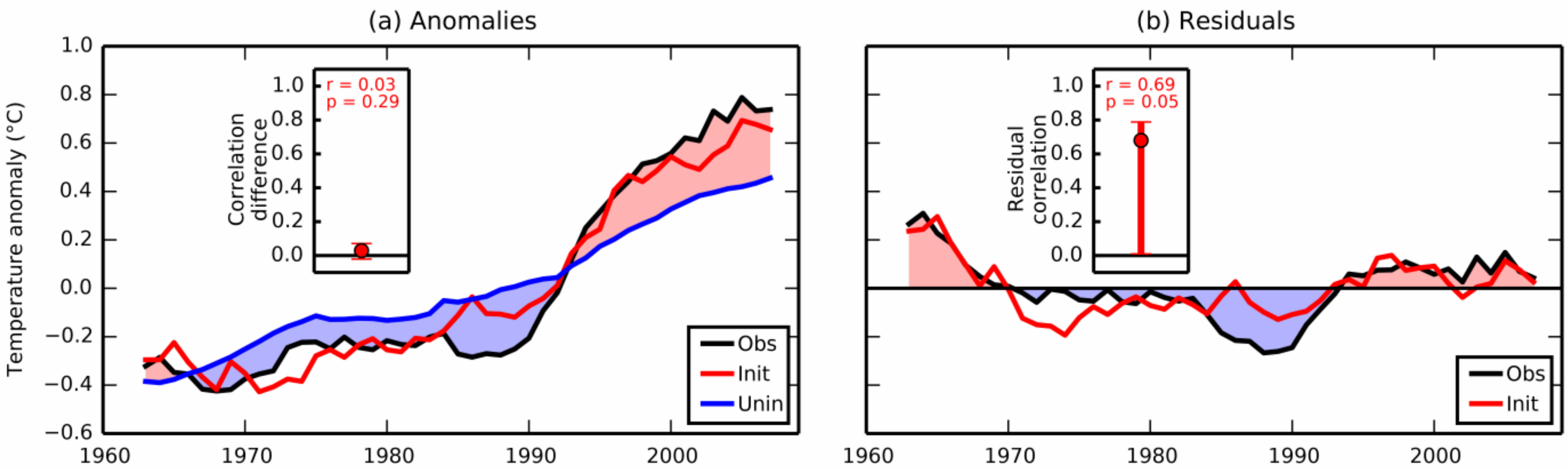
- Signal is somewhat similar to observations (increase from 1960s to 1990s, slight decrease thereafter)
- Predicted signal has very small amplitude → **MSSS positive but not significant**
- **Correlation is significant (r = 0.49, p = 0.02)**
- Skill is much higher with observations than with individual model members → **RPC > 6**

Ratio of predictable components (RPC): years 2-9



- RPC > 1 in many regions
- Especially for rainfall and pressure
- Signal to noise problem is **widespread** on decadal timescales
- **Should not look for model agreement! – skill is in the ensemble mean**

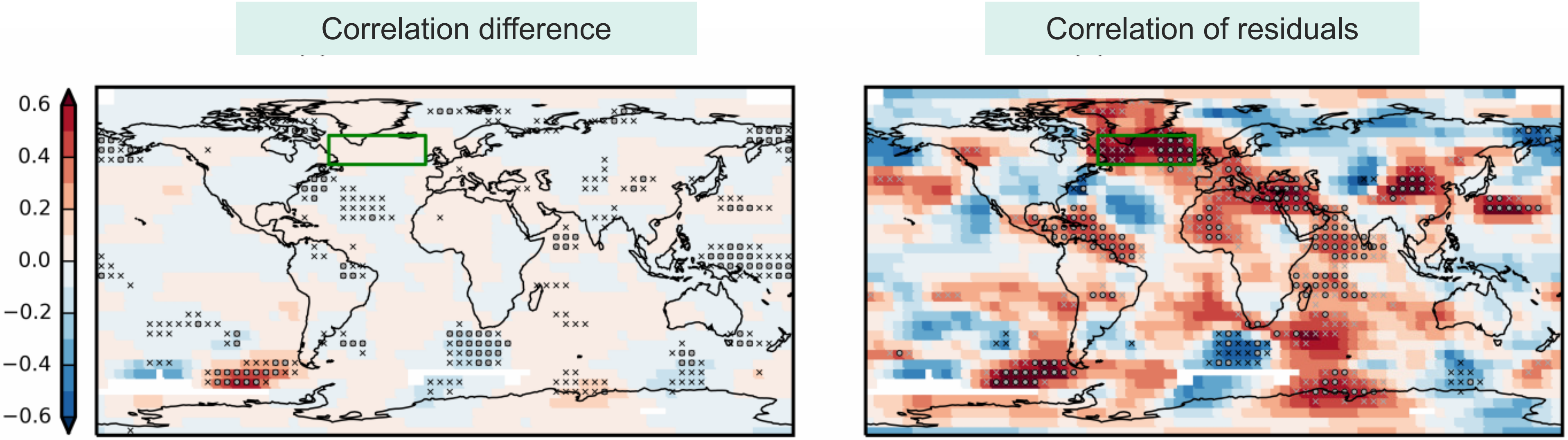
Impact of initialisation: subpolar gyre temperature, years 2-9,JJA



- Very high correlations for both initialised (Init r = 0.97) and uninitialized (Unin r = 0.94)
- Difference in correlations is not significant
- But residuals are significantly correlated (r = 0.69, p = 0.05)
- **Initialised predictions capture some of the variability that is missing from uninitialized simulations → more powerful test**

Smith et al, 2019

Impact of initialisation: temperature, years 2-9,JJA

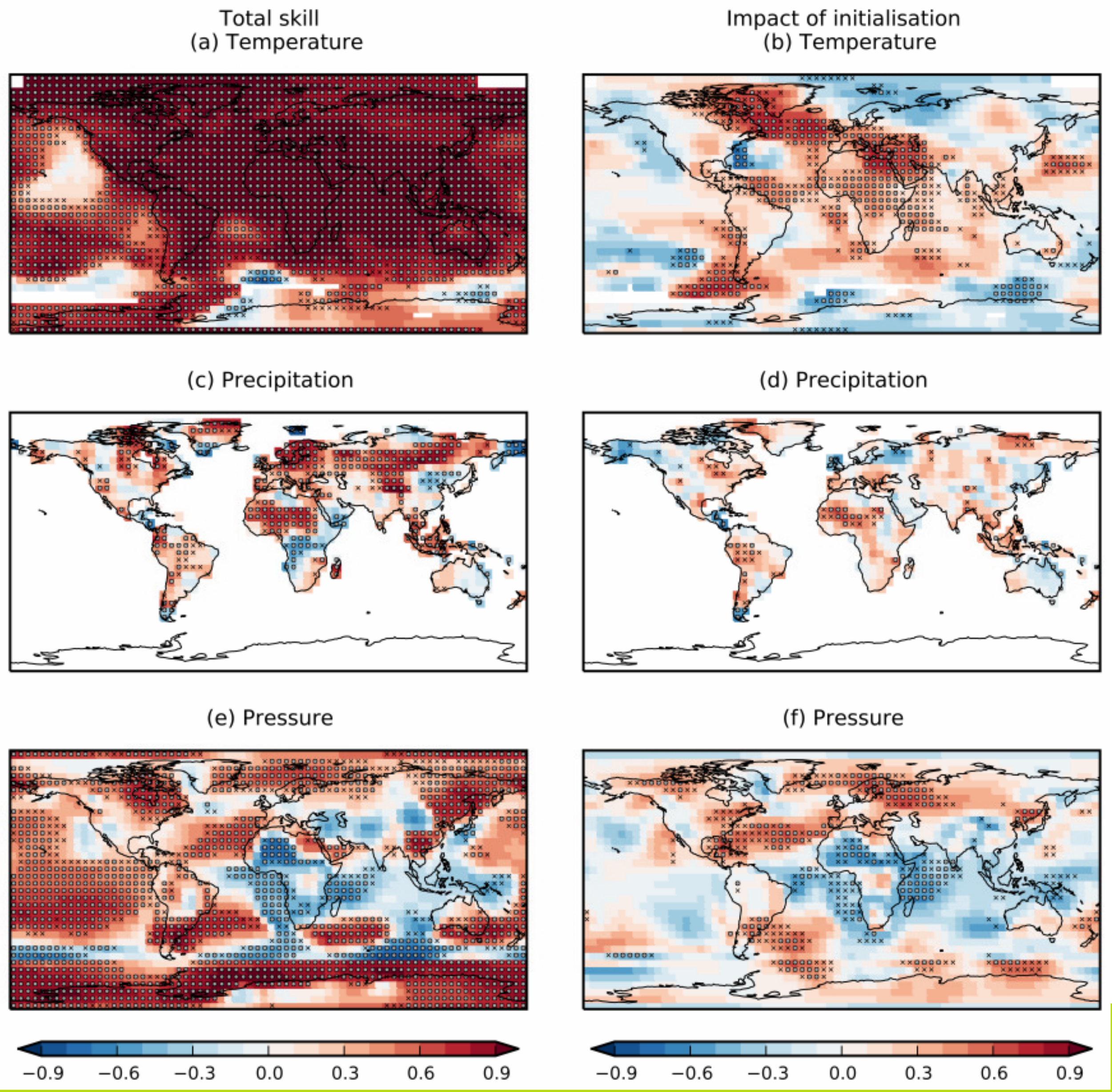


- Improvement from initialisation is much clearer in correlation of residuals
- Impacts now seen over some land areas, including Europe

Smith et al, 2019

Skill and impact of initialisation: years 2-9

• Residuals may be correlated but represent only a small fraction of total variance
• Compute ratio of predicted signal due to initialisation divided by total predicted signal: $r'\sigma'/r\sigma$



• High skill for temperature

• Significant skill for rainfall over land in many regions

• Significant skill for pressure (except Indian Ocean, Africa, eastern South Atlantic – problem with initialisation?)

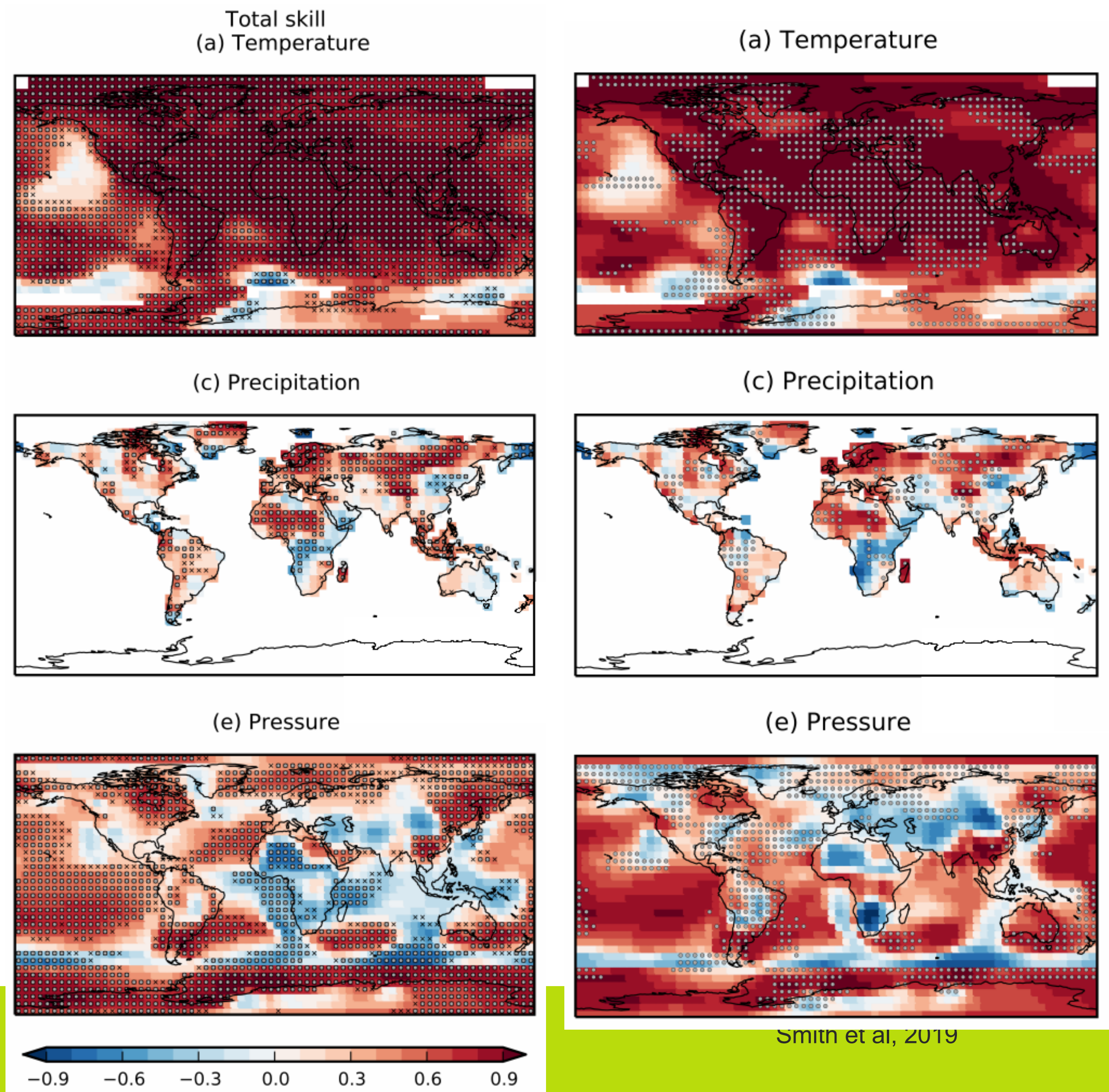
• Significant improvements from initialisation

Smith et al, 2019

Internal variability or external forcing?

- Patterns of skill are captured by uninitialized simulations
- Initialisation mainly improving the response to external forcings?

Initialised | Uninitialized



Smith et al, 2019

Future plans - DCPP

- Coordinate analysis of CMIP6
  - Compare hindcast skill with CMIP5, assess extreme event predictions
  - Component C "understanding" experiments (AMV, PDV → teleconnections, storm tracks, Sahel, aerosols, Mediterranean,…)
  - Volcano experiments
- new Earth System decadal predictions
- Contribute to global stocktake
- Run new forecasts if volcano erupts

GC-NTCP

WMO operational decadal predictions

WMO Lead Centre for Annual-to-Decadal Climate Prediction

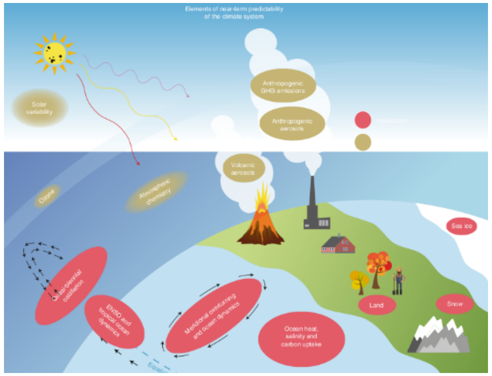
The Met Office is a designated Lead Centre for Annual-to-Decadal Climate Prediction (LC-ADCP). The LC-ADCP collects and provides hindcasts, forecasts and verification data from a number contributing centres worldwide.

- Lead centre for annual-to-decadal climate prediction
  - ➢ Met Office
- 4 global producing centres
  - ➢ BSC
  - ➢ DWD
  - ➢ Environment Canada
  - ➢ Met Office
- www.wmolc-adcp.org

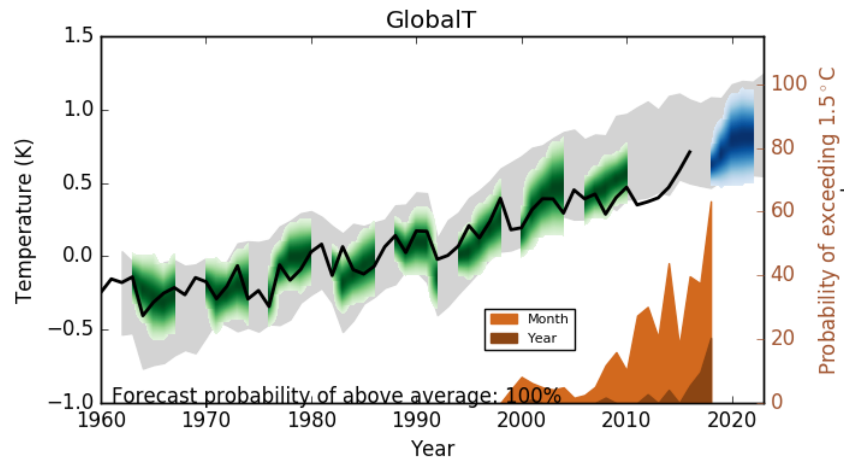
nature climate change
PERSPECTIVE
https://doi.org/10.1038/s41558-018-0359-7

Towards operational predictions of the near-term climate

- Sets out the case for operational decadal predictions
- Kushnir et al 2019



Annual-to-decadal climate update



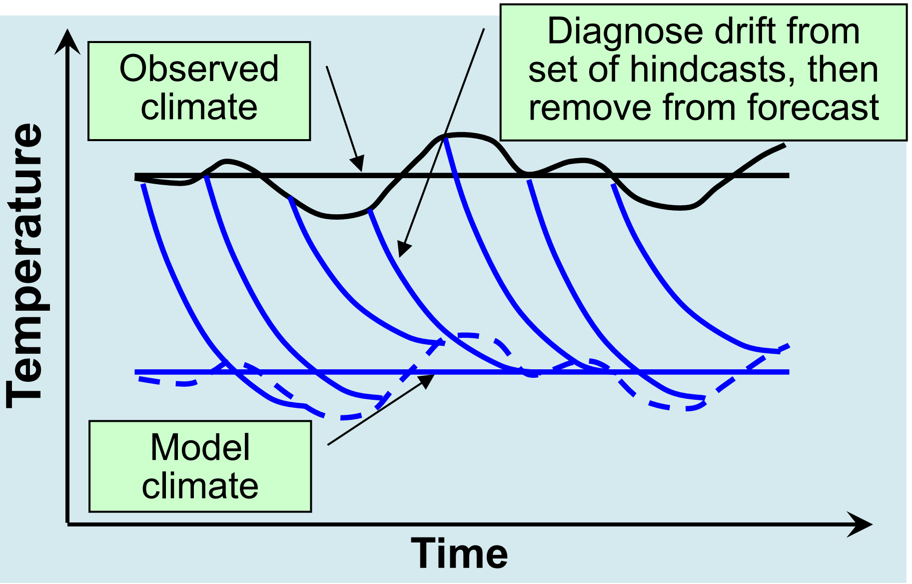
Future plans – GC-NTCP

- This year
  - Finish website development
  - Issue first Annual-to-Decadal Climate Update
  - Decadal session Fall AGU/WCRP Science Week
- Afterwards
  - Standards, verification methods and guidance for operational near-term predictions
  - Continued issuance of Annual-to-Decadal Climate Update including uncertainty, skill estimates
  - Focus on developing users, or wrap up having achieved main goals?

Decadal lab

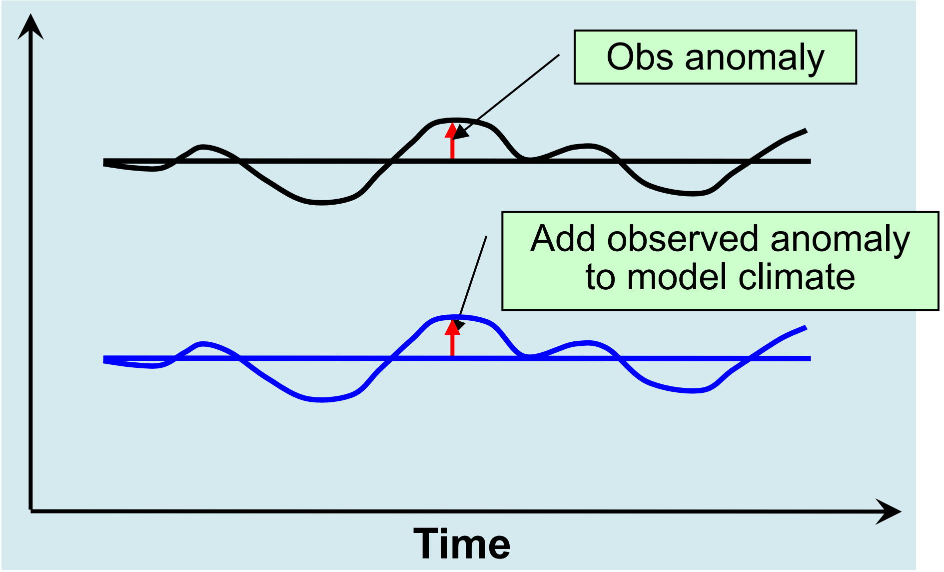
Models are imperfect: Dealing with model bias

Full field initialisation



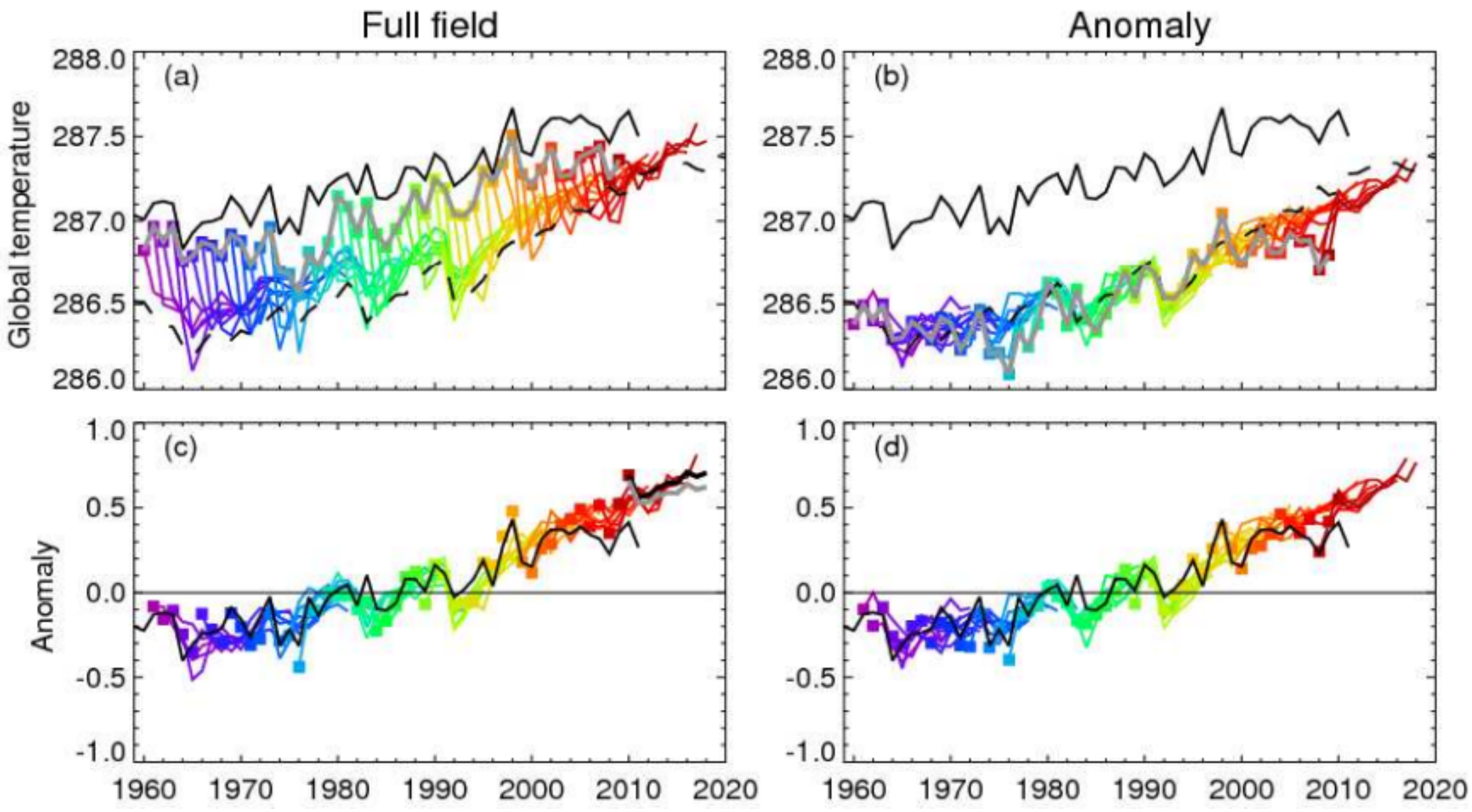
- Routinely used in seasonal forecasting
- Ideally need large hindcast set, sampling multiple phases of variability

Anomaly initialisation



- Needs model to be spun-up, together with simulation of recent period
- Observed anomalies could be in wrong location relative to model features

Bias correction



(Smith et al. 2013)