Seasonal forecasts of the 20th Century:

Multi-decadal variability in predictive skill of the winter NAO

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[2]*University of Oxford*

With particular thanks to Chris O'Reilly[2], Damien Decremer[1] and Tim Palmer[2]

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ECMWF

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Introduction

How robust are winter NAO seasonal skill estimates if tested during independent past hindcast period? Can models successfully predict the NAO in earlier decades of the 20th Century? How confident are we to predict future winters?

Introduction

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Re-forecast experiments over the period 1901-2010:

ECMWF's atmospheric model with prescribed SSTs and sea-ice (uncoupled)

Initial cond.: ECMWF atmospheric re-analysis of the 20th Century ERA-20C *(Poli et al., JCLIM 2016)*

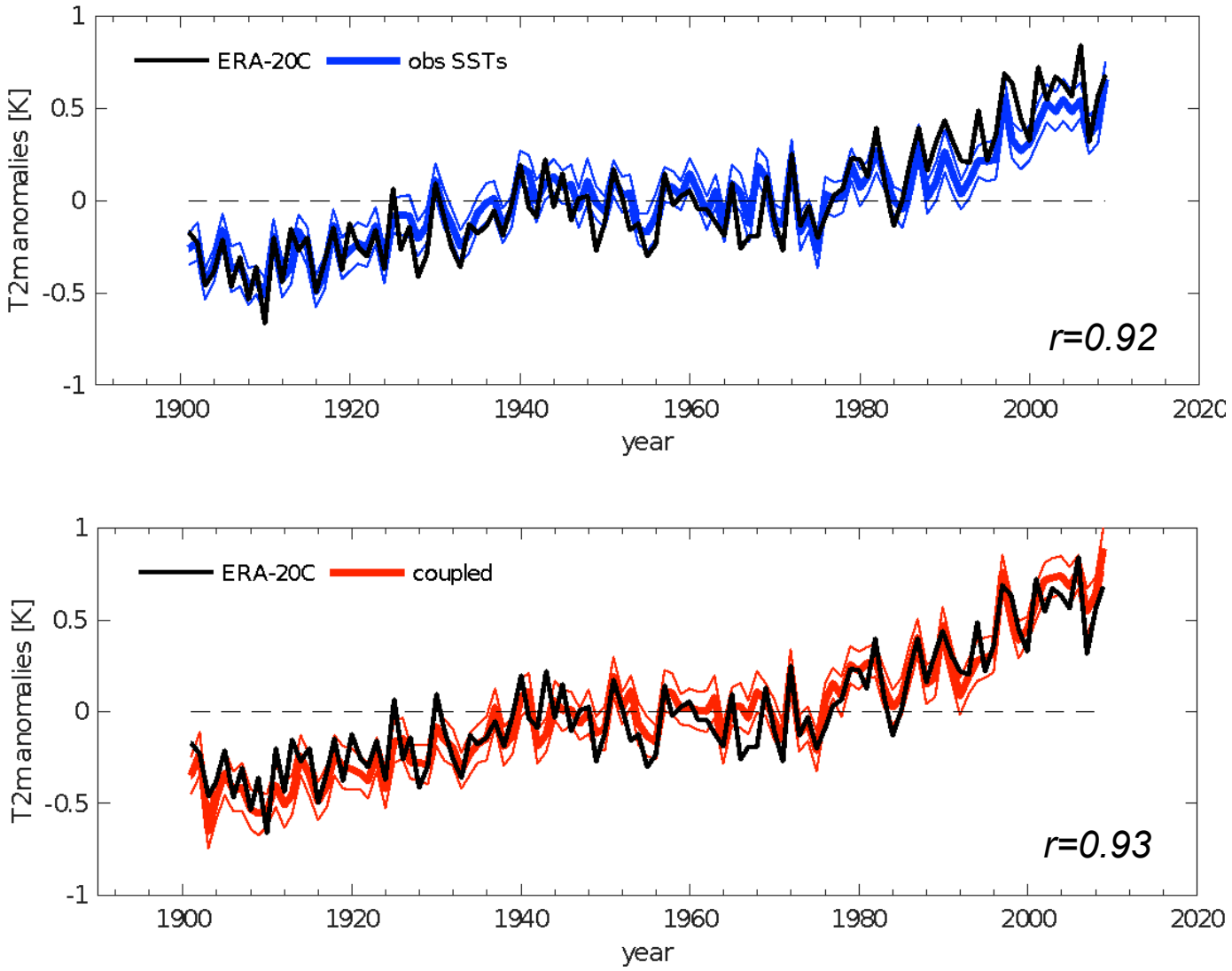
See *Weisheimer et al. (QJ 2017), O'Reilly et al. (GRL 2017)* and *Weisheimer et al. (QJ 2018 under rev.)*

ECMWF's fully coupled atmosphere-ocean-sea-ice model (coupled)

Initial cond.: New ECMWF coupled re-analysis of the 20th Century CERA-20C (*Laloyaux et al., JAMES 2018*)

- **IFS model cycle 41R1** (in-between S4 and SEAS5), **T_L255L91** (ca. 60km)) **+ NEMO ORCA1L42 + LIM2**
- **Ensemble with 51 perturbed members**
- Focus here: **4-month forecast initialised on 1st of Nov each year (→ DJF)**

Global mean (60ºN-60ºS) 2m temperature forecast anomalies in DJF



Bias and skill for Z500 in DJF

bias

1981-2009

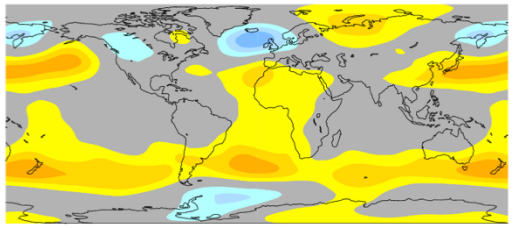
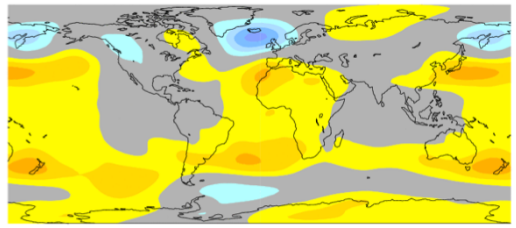
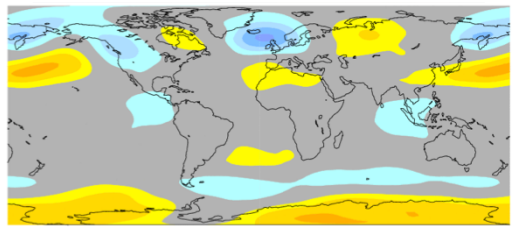
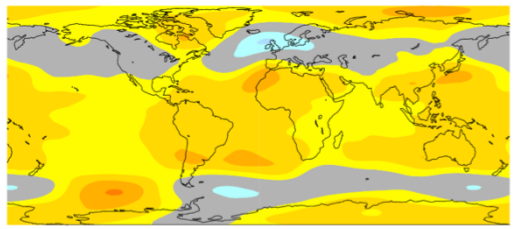
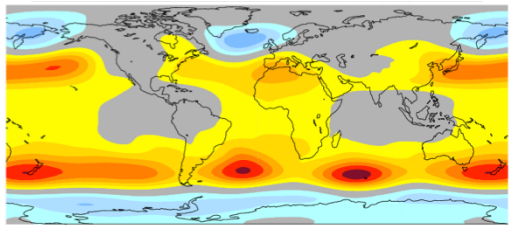
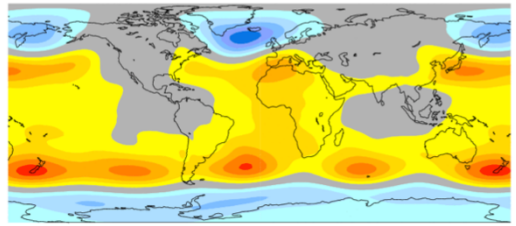
1901-2009

correlation skill

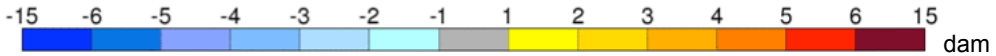
1981-2009

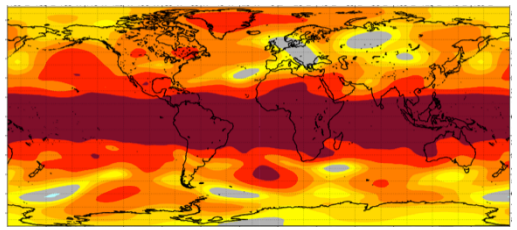
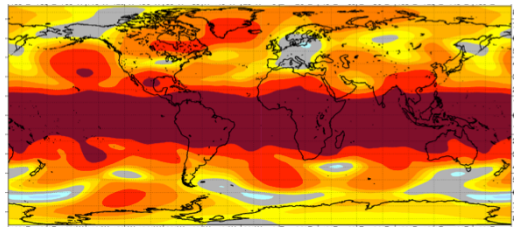
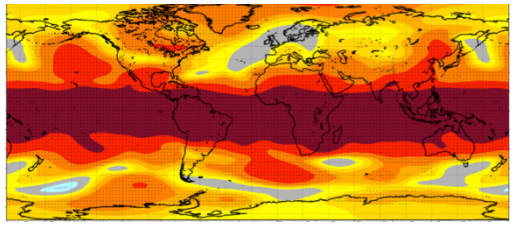
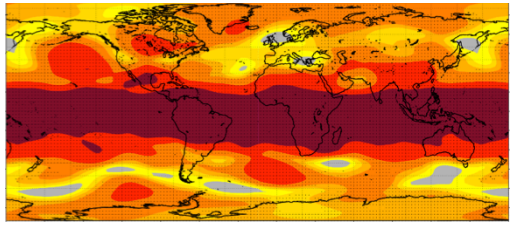
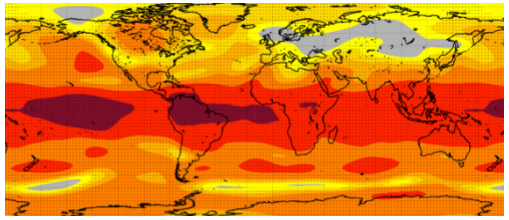
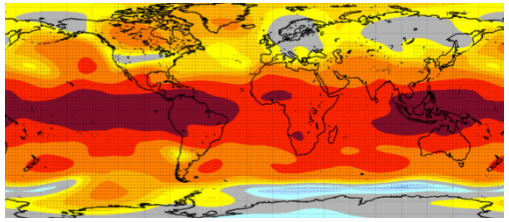
1901-2009

uncoupled | **coupled** | **S4** | **SEAS5**

- Similar bias in uncoupled and coupled model
- consistent with biases of operational models

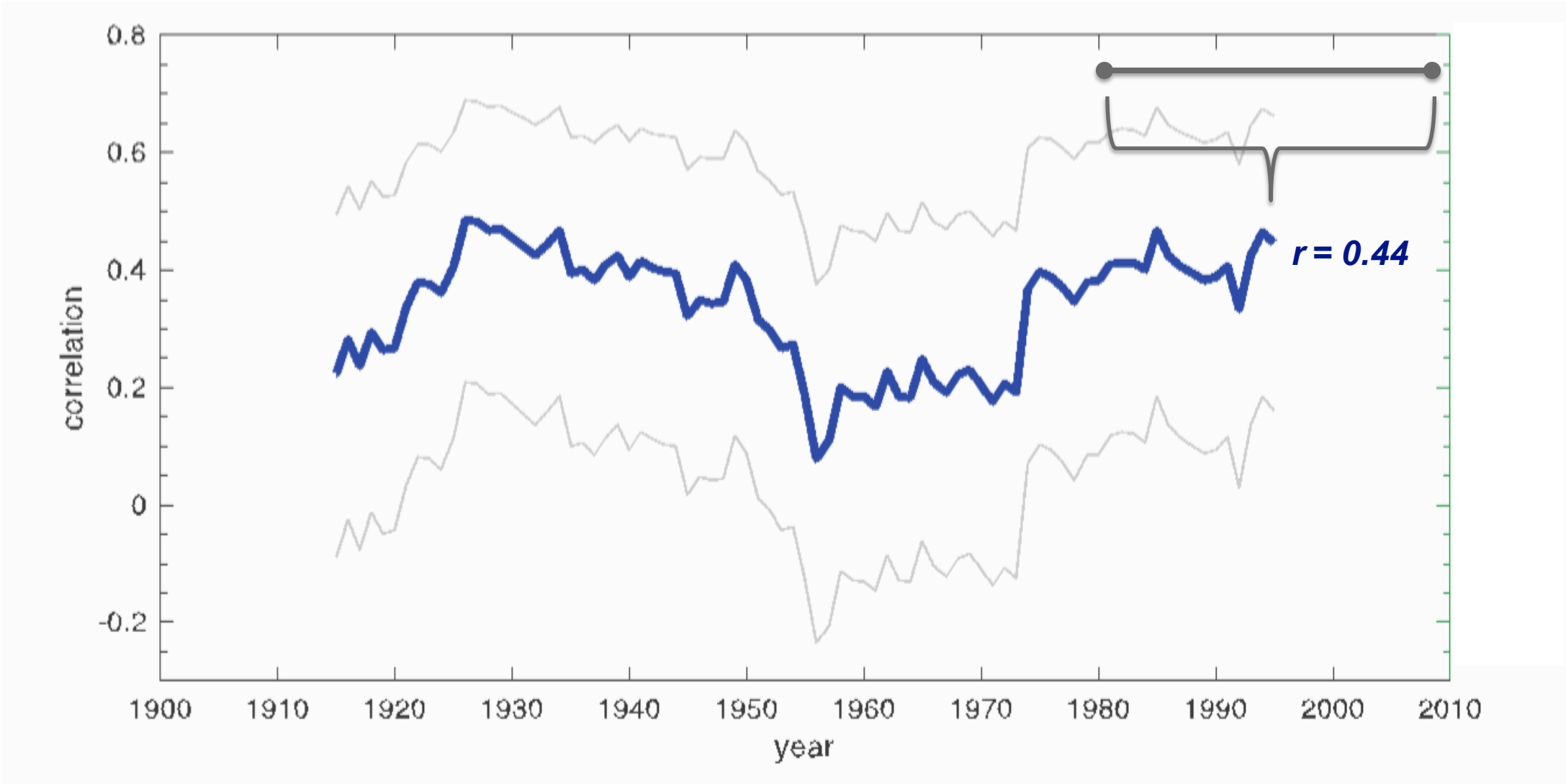


- Comparable levels of NH extratropical skill in uncoupled, coupled and operational models

Multi-decadal variability of NAO forecast skill (moving window)

$r_{1901\text{-}2009} = 0.31$



Weisheimer et al. (QJ 2017)

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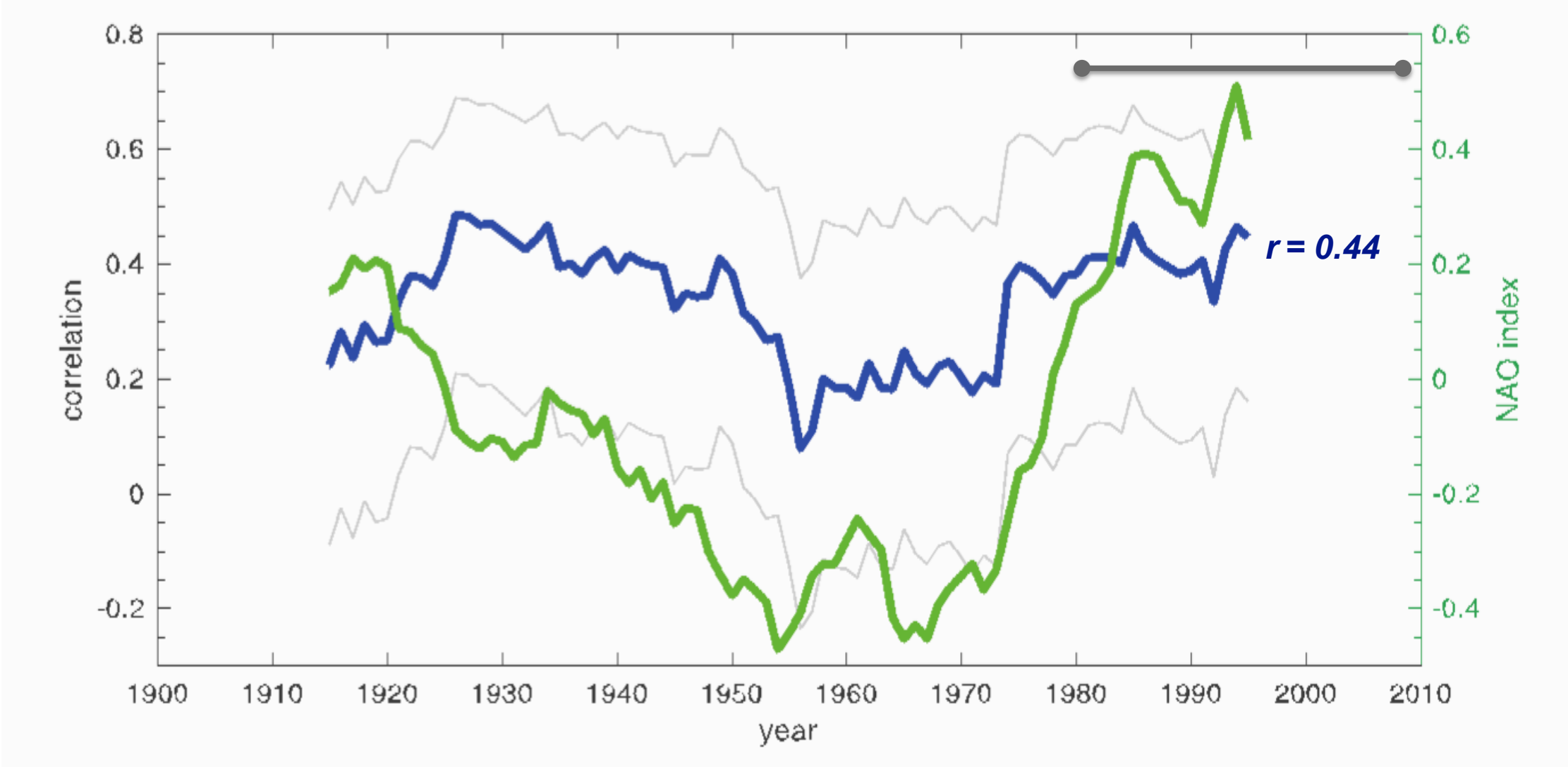
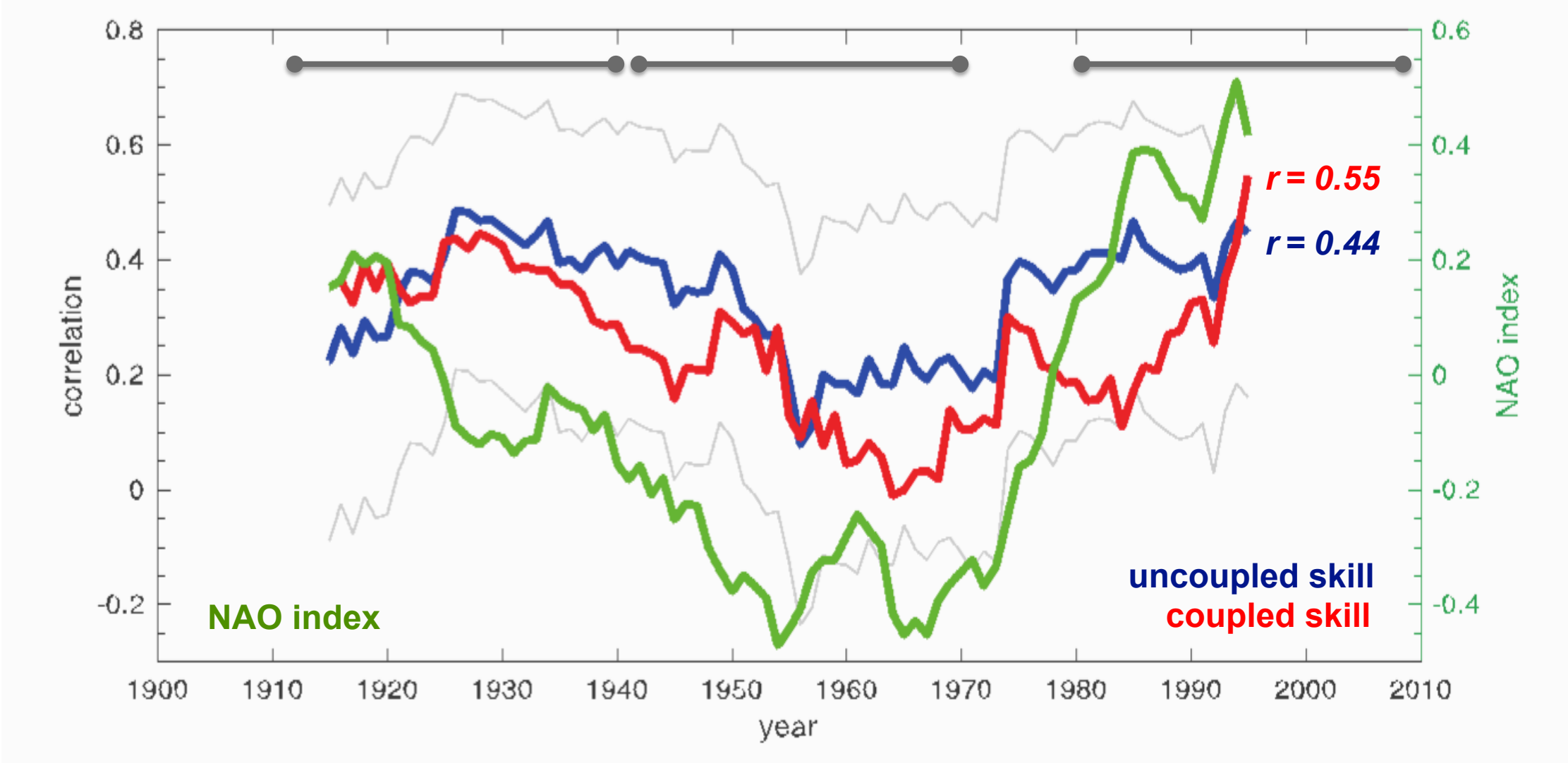


Weisheimer et al. (QJ 2017)

Multi-decadal variability of NAO forecast skill (moving window)

$r_{1901\text{-}2009} = 0.31$ $r_{1901\text{-}2009} = 0.28$

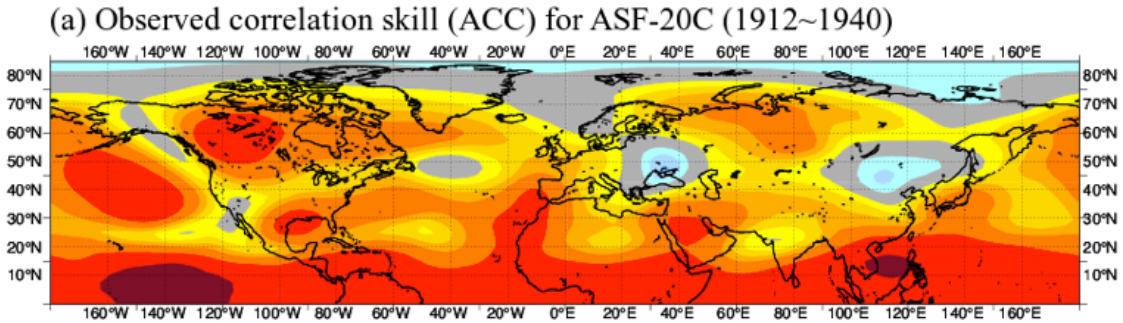


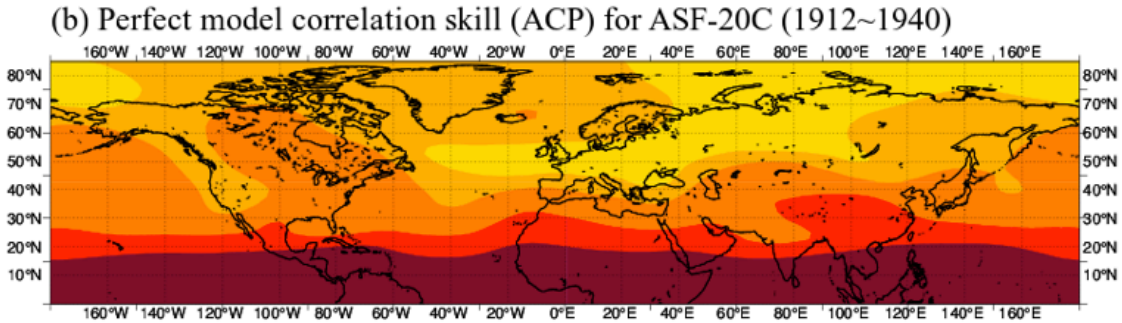
Multi-decadal variability of Z500 correlation skill in DJF

Does the model underestimate the skill?

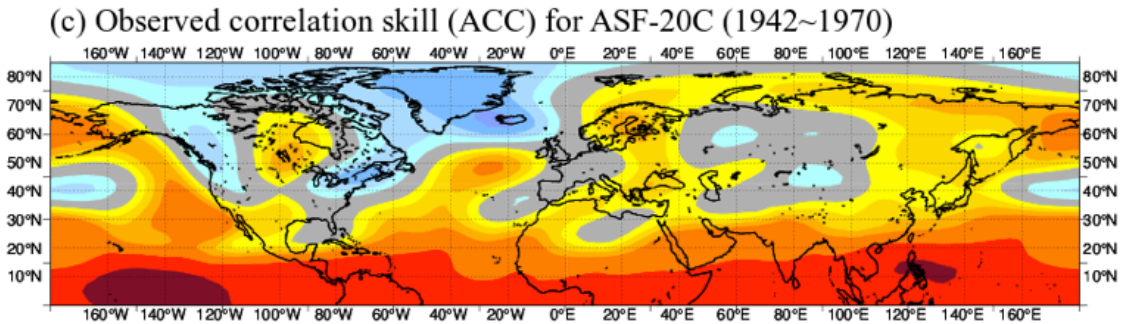
observed predictability | **model predictability (perfect model)**

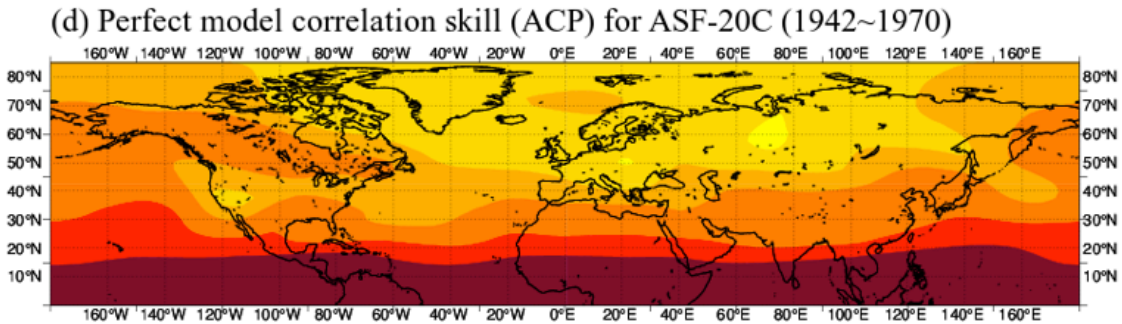
1912-1940



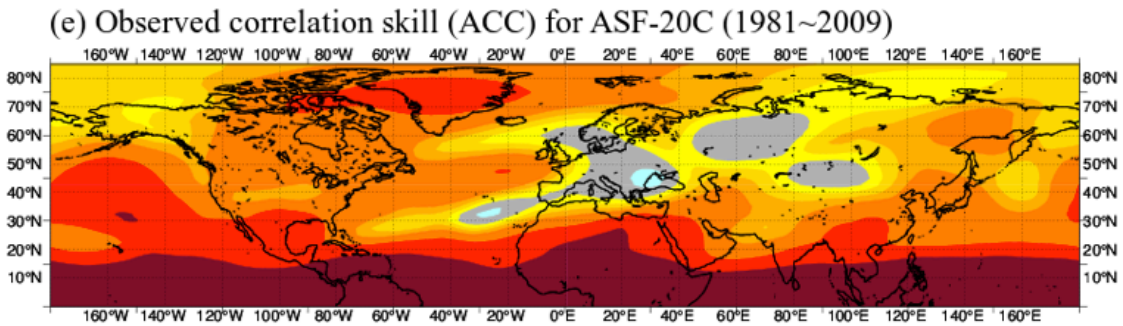


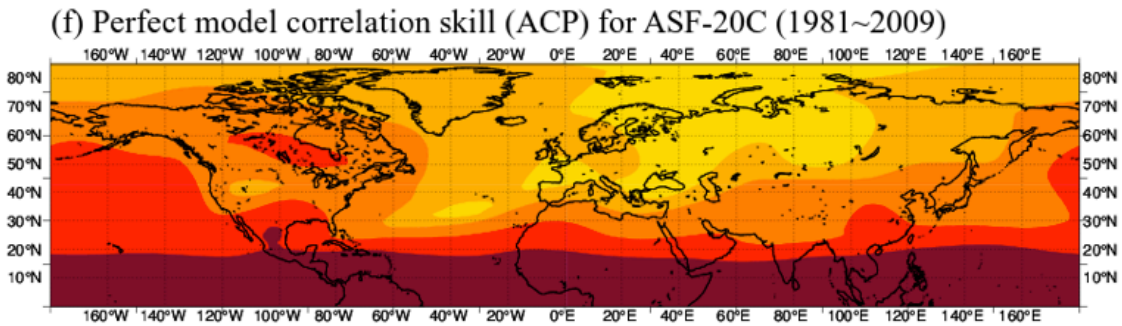
1942-1970

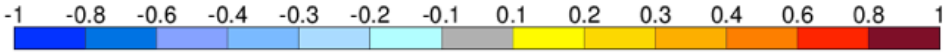




1981-2009



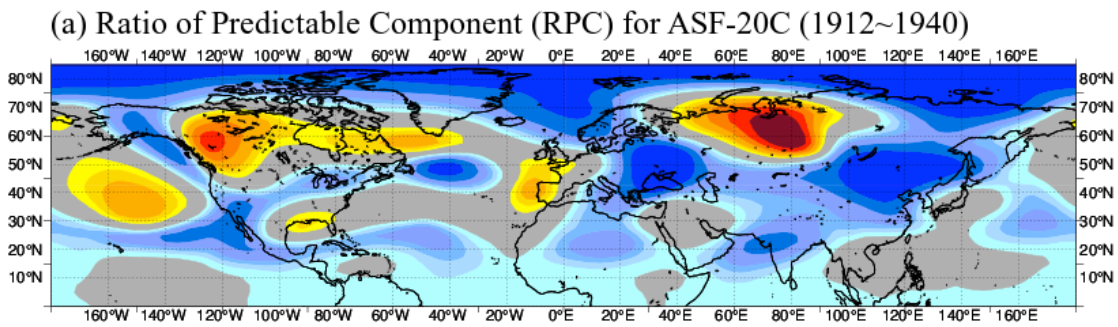




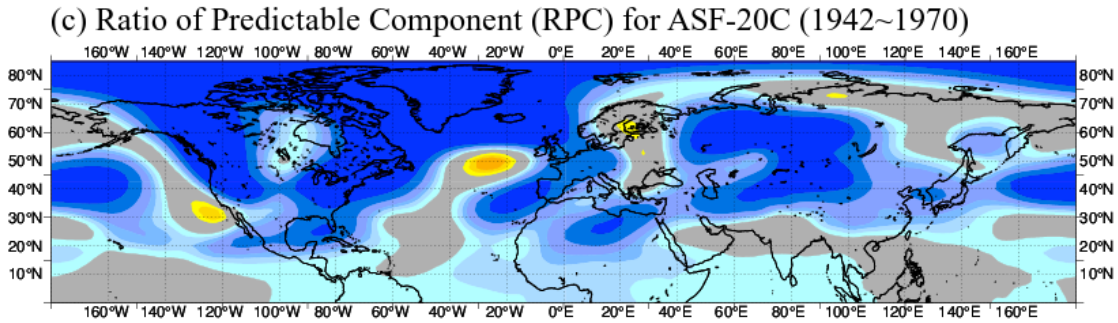
Weisheimer et al. (QJ, 2018, under rev.)

Multi-decadal variability of Z500 RPC in DJF

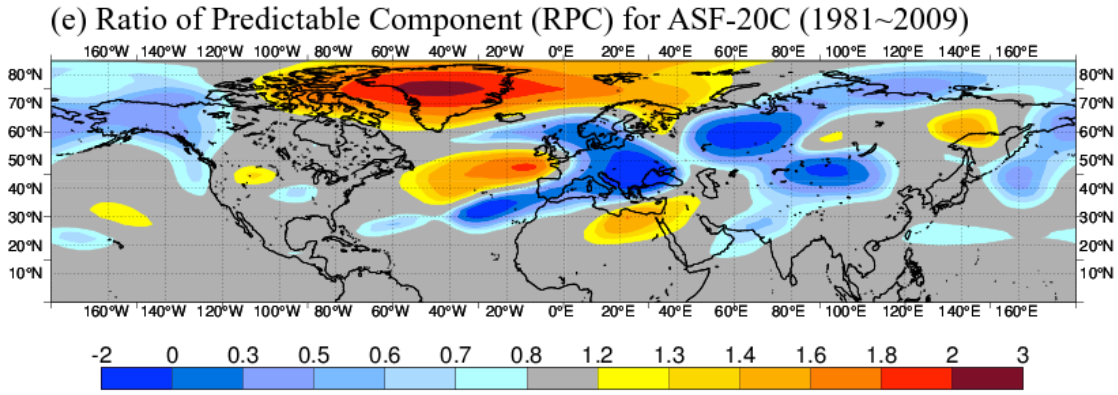
1912-1940



1942-1970



1981-2009



Weisheimer et al. (QJ, 2018, under rev.)

RPC – Ratio of Predictable Components
(the signal-to-noise "paradox")

$$RPC = \frac{PC_{obs}}{PC_{model}} \geq \frac{r(obs, ens\ mean)}{\sqrt{VAR_{signal}/VAR_{total}}}$$

see *Eade et al (GRL, 2014)*

PC: predictable parts of the total variance

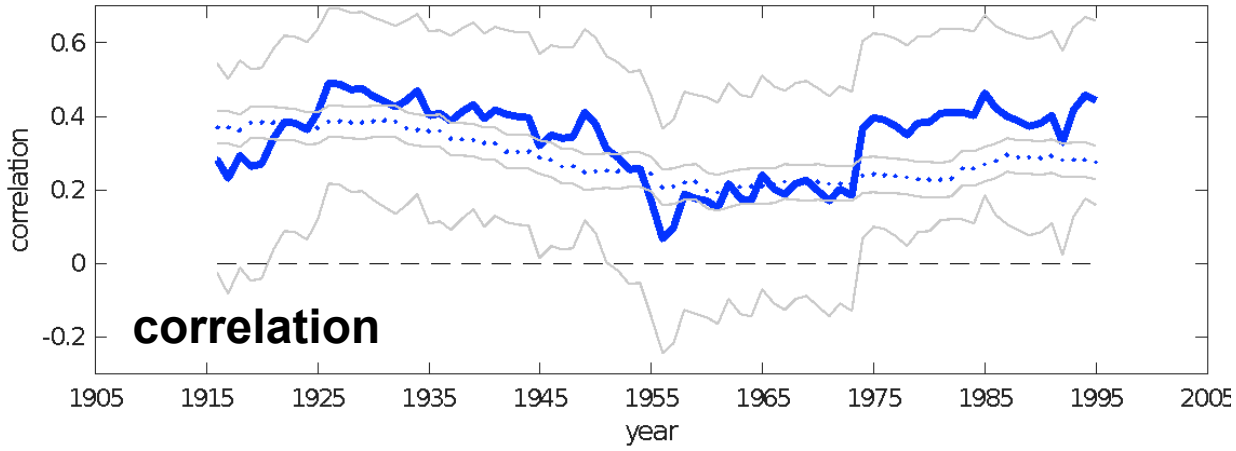
PC_{obs} : predictable component of the observations

PC_{model}: predictable component in the model

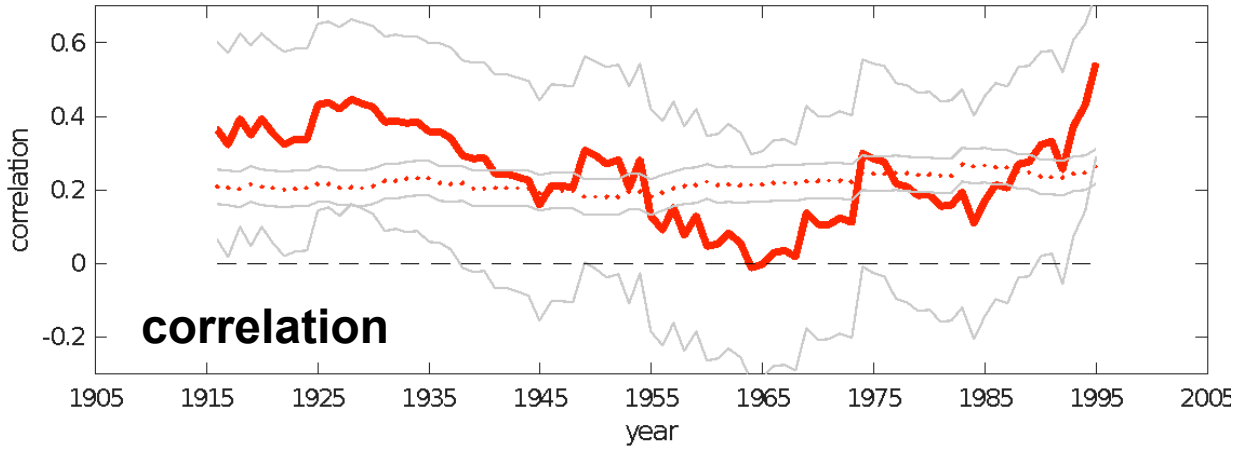
- Perfect model ensemble: **RPC==1**
- **RPC > 1** → underconfidence (overdispersive);
  model underestimates real-world predictability
- **RPC < 1** → overconfidence (underdispersive);
  model predictability is larger than in real world

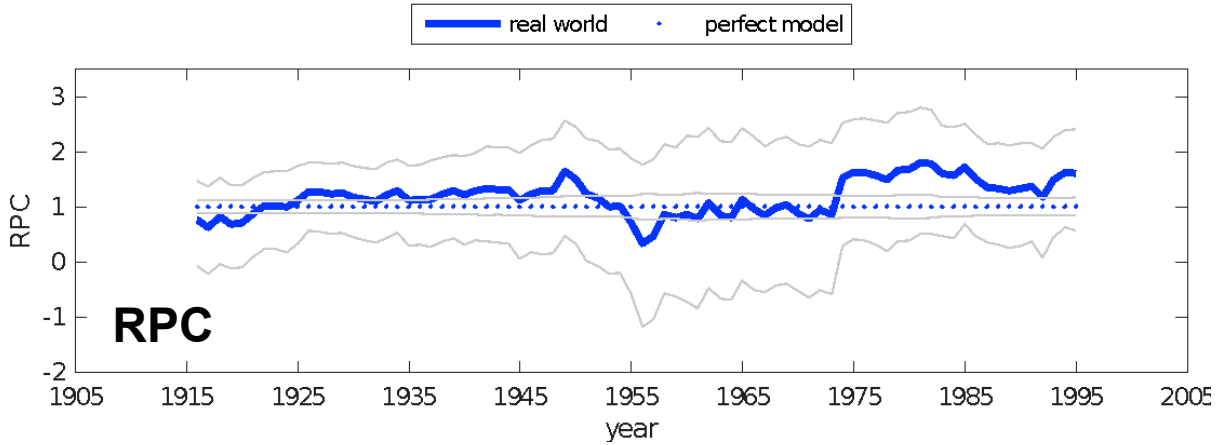
How confident are predictability estimates of the NAO?

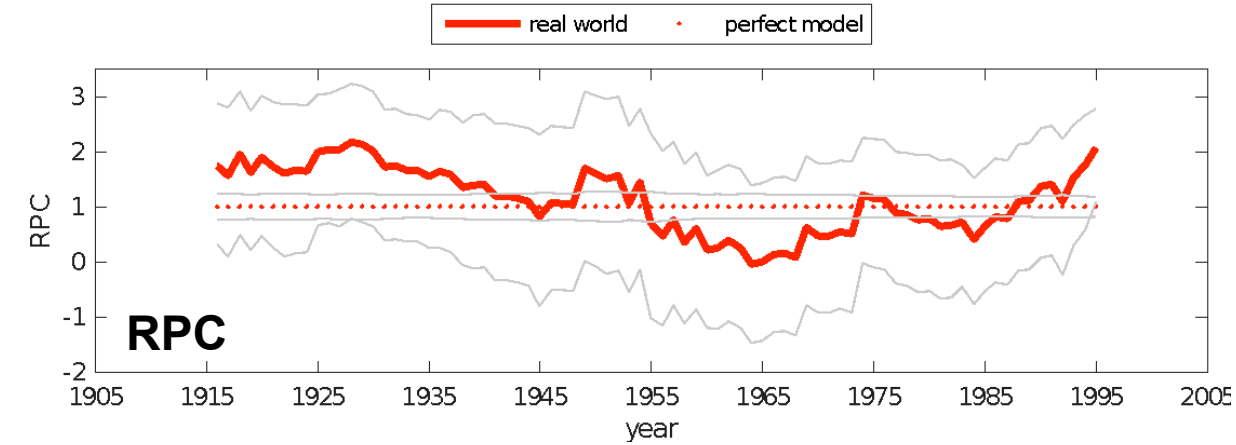
uncoupled *r = 0.31* *RPC = 1.06*



coupled *r = 0.28* *RPC = 1.19*





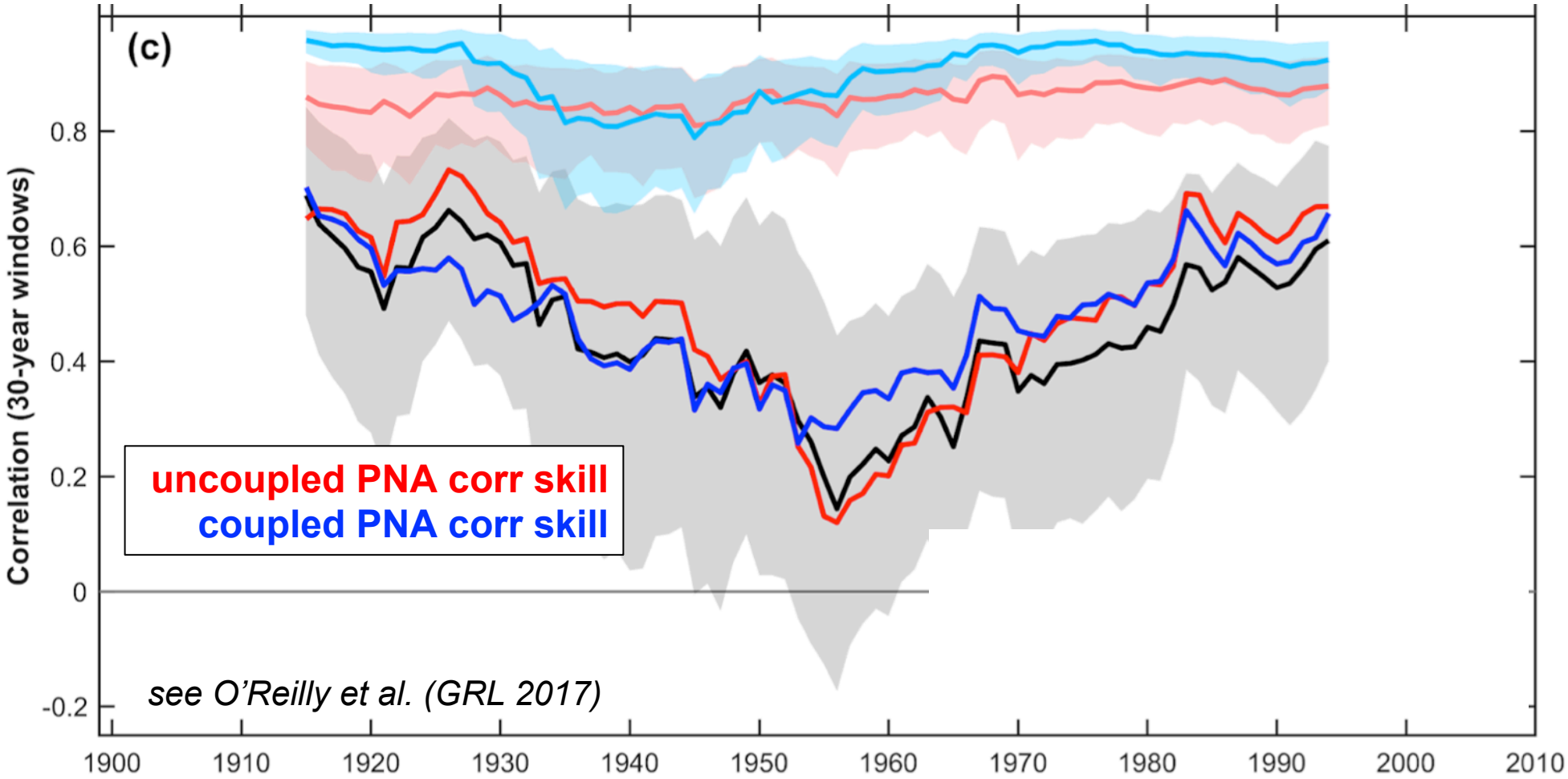


The NAO predictability of the real world is not (only slightly) underestimated in Century-long uncoupled (coupled) hindcasts.

Multi-decadal variations in PNA skill and teleconnections from the tropics

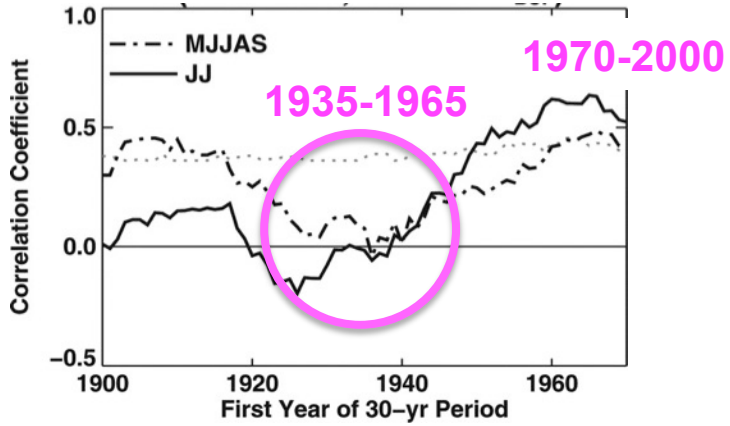
- **Weakening of the obs. relationship between NINO3 SSTs and PNA during the mid-Century period**
- **Model PNA response to NINO3 SSTs is very stable over time (no weakening)**

  → Lack of PNA skill in the mid-Century period



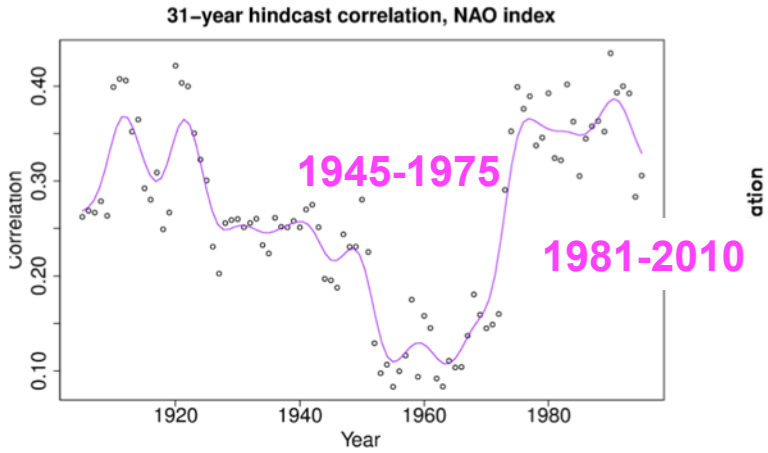
20th Century NAO/AO forecast skill and changes in tropical forcings?

Statistical NAO forecasts



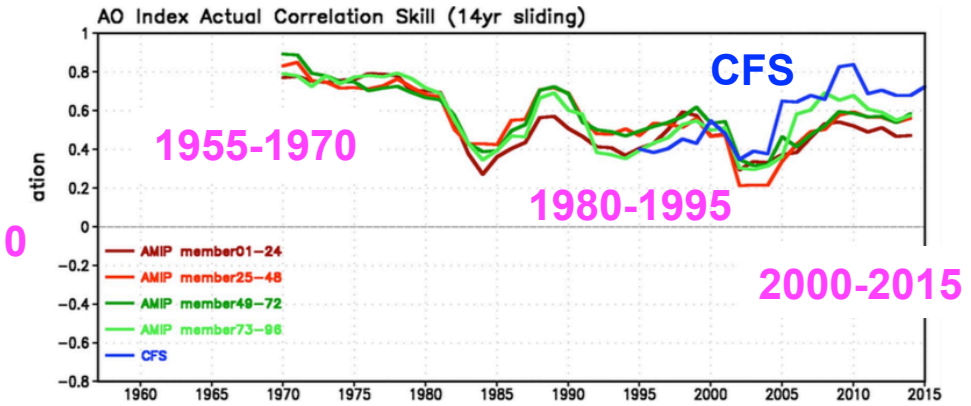
Fletcher & Saunders (J. Clim. 2006)

ARPEGE 20CR reforecasts



Batté & Déqué (pers. comm.)

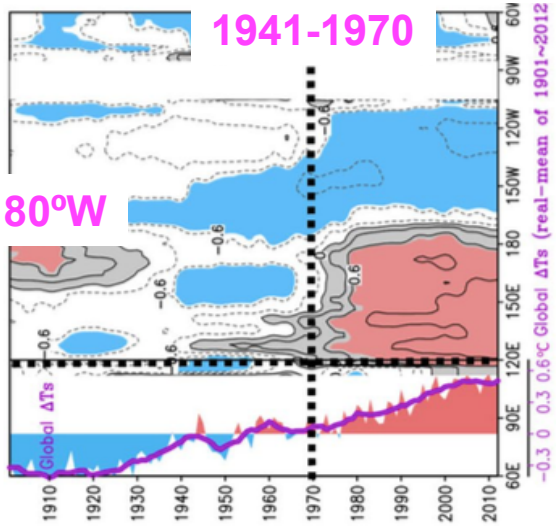
CFSv2 forecasts and AMIP runs



Kumar & Chen (Clim. Dyn. 2017)

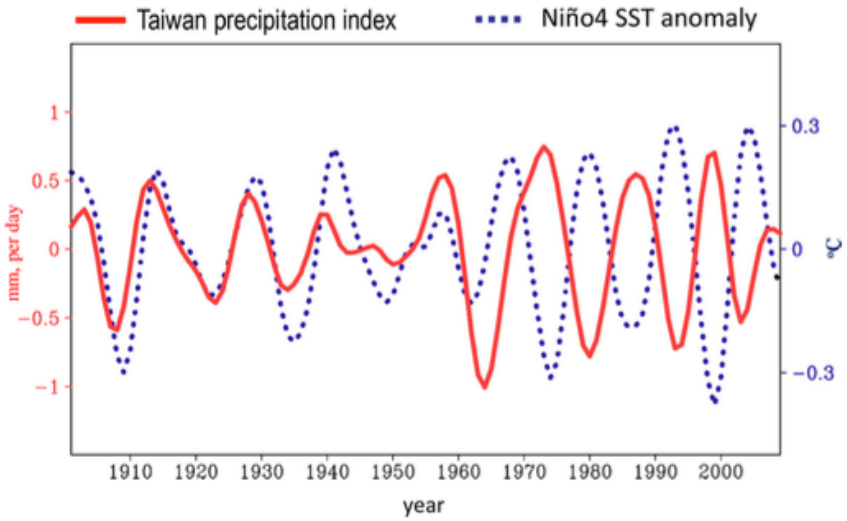
Tropical-subtropical teleconnections in 20CR

correlation between NINO4 and Pacific SSTs across 22-25ºN



Huang et al. (Clim. Dyn. 2018)

Observed rainfall – NINO4 links in Taiwan



observed precip in Taiwan (22-25ºN)

NINO4 SST

Huang et al. (Clim. Dyn. 2018)

Summary and Conclusions

Distinct multi-decadal variability of winter NAO forecast skill in coupled and uncoupled hindcasts over the 20th Century (1901-2010)

- Significant skill for early decades (*r~0.4*) followed by lack of skill in mid-Century (*r~0.1*) and significant skill for most recent decades (*r~0.5*)
- NAO predictability of the real world is not (*only slightly*) underestimated in the uncoupled (*coupled*) hindcasts over the full 110 years

Strong co-variability of NAO and PNA forecast skill with lack of skill in mid-Century

Relationship between tropical Pacific SSTs and PNA during mid-Century: strong weakening in observations which is not captured by the models

→ **Short hindcast period are not sufficiently representative for longer-term behaviour (skill, confidence) due to decadal climate variability**

Mid-Century period stands out as an important period on which to test the performance of future seasonal forecast systems

→ **Achieving good forecast skill for recent decades is not sufficient to guarantee similar good performance in the future** (due to e.g. alterations of predominant phase of the NAO or changes to strength of tropical forcings or others)

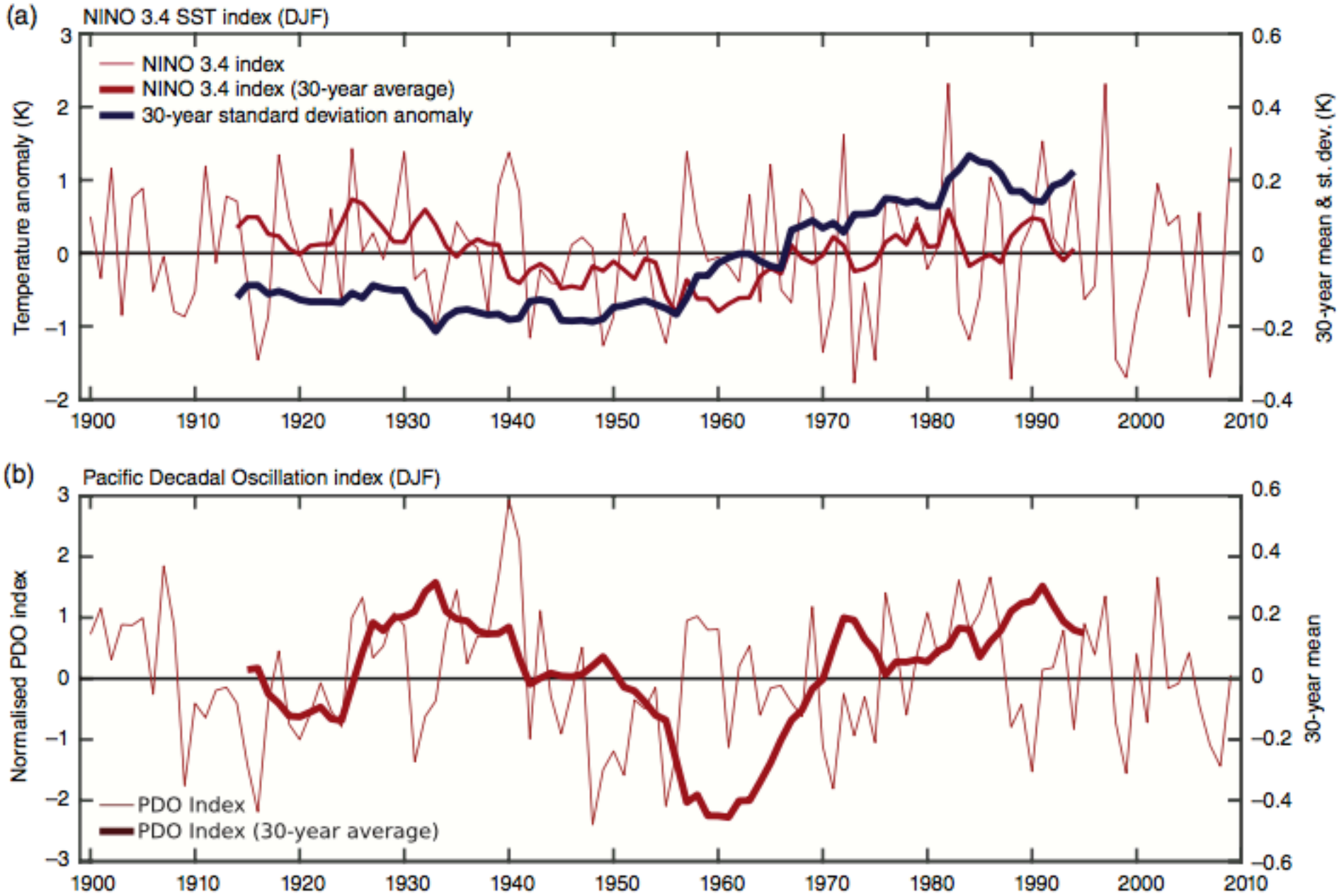
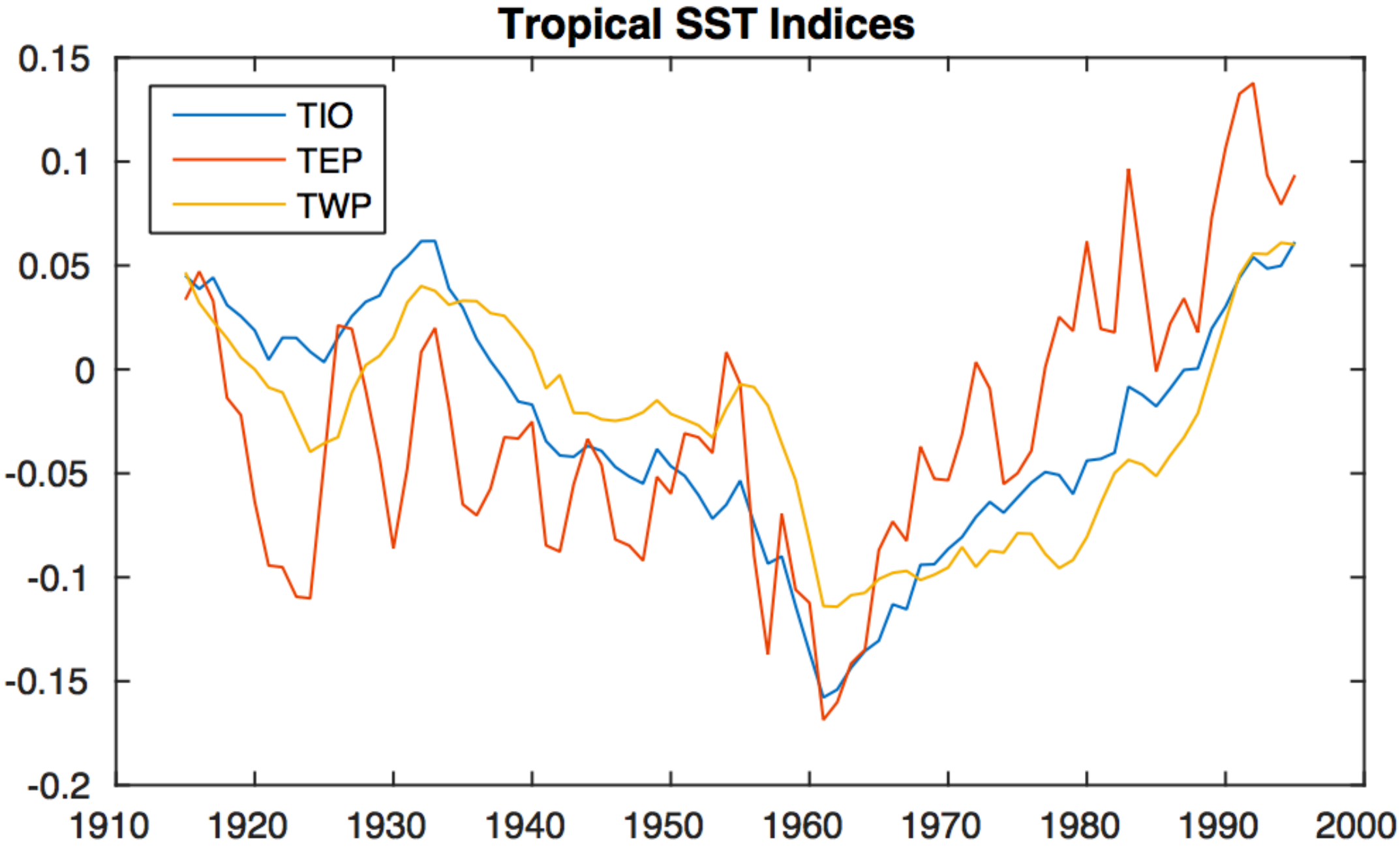
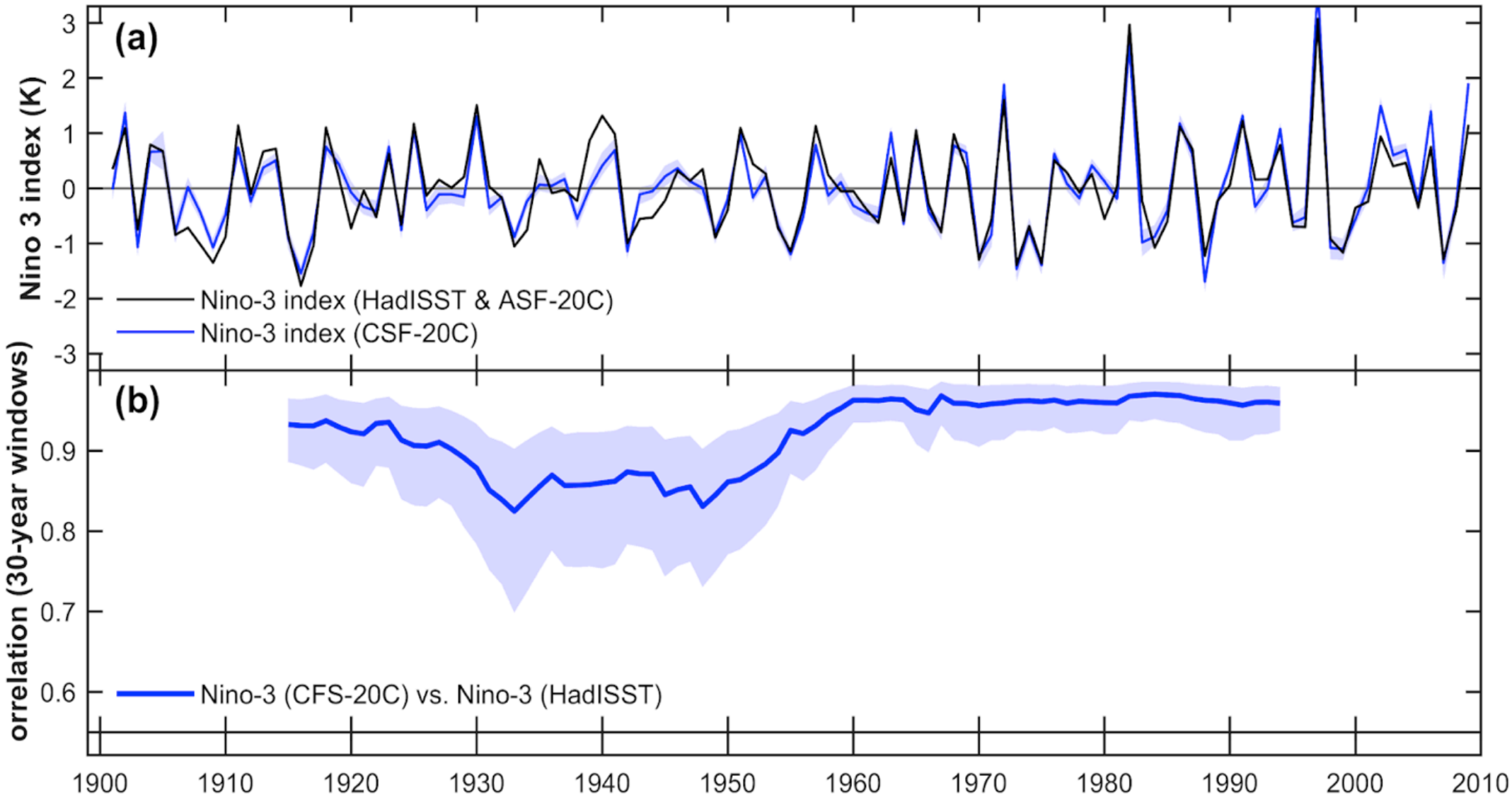


Figure 5. (a) Time series of DJF-mean central tropical Pacific SST anomalies of annual (light blue) and 30-year average (dark blue) data and their variability during moving 30-year windows (black line) in HadISST (Rayner *et al.*, 2003) for the Niño 3.4 index. (b) The annual and 30-year mean PDO index (from https://www.ncdc.noaa.gov/teleconnections/pdo/).

Weisheimer et al. (QJ 2017)


Tropical SST Indices
TIO
TEP
TWP
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000


(a)
Nino 3 index (K)
3
2
1
0
-1
-2
-3
Nino-3 index (HadISST & ASF-20C)
Nino-3 index (CSF-20C)
(b)
orrelation (30-year windows)
0.9
0.8
0.7
0.6
Nino-3 (CFS-20C) vs. Nino-3 (HadISST)
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010