Decadal prediction in the Pacific

Gerald A. Meehl

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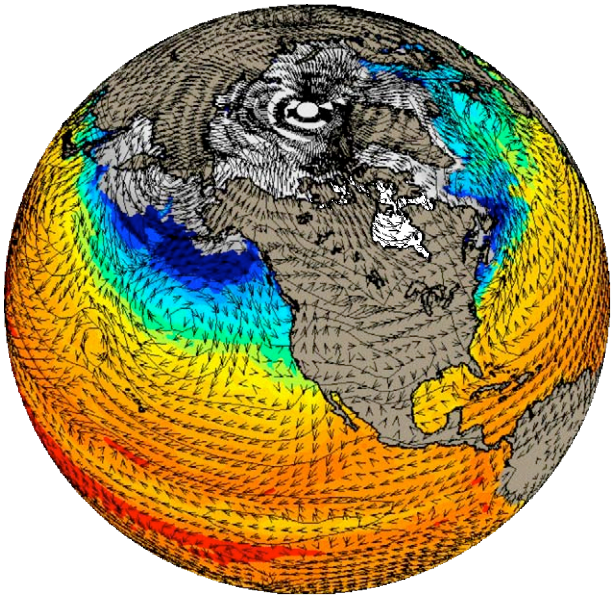


NCAR

At least two sources of decadal variability in the Pacific:

11 year solar cycle forcing

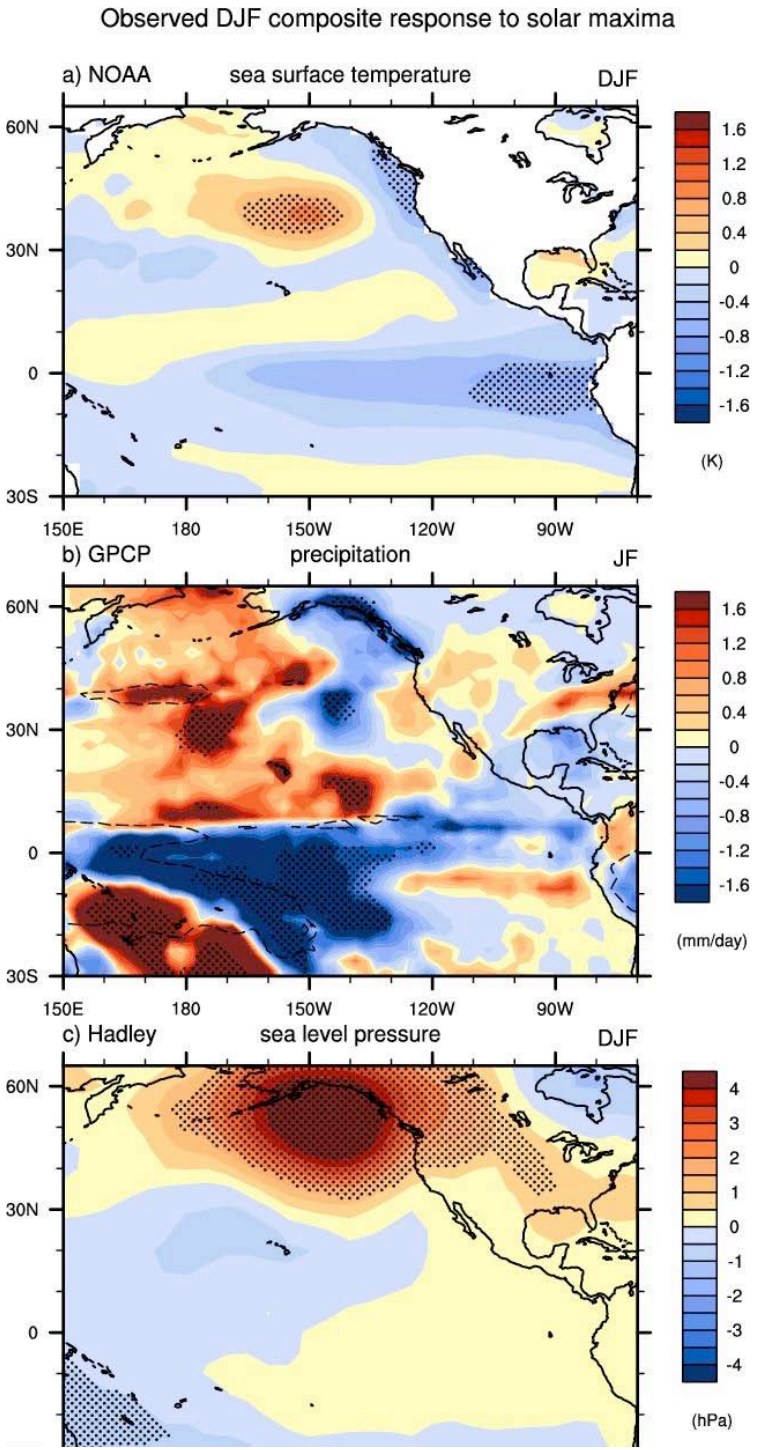
PDO/IPO

The 11 year solar cycle shows a similar pattern of response coincident with the peaks in solar forcing; also present a year or so before and after the peaks

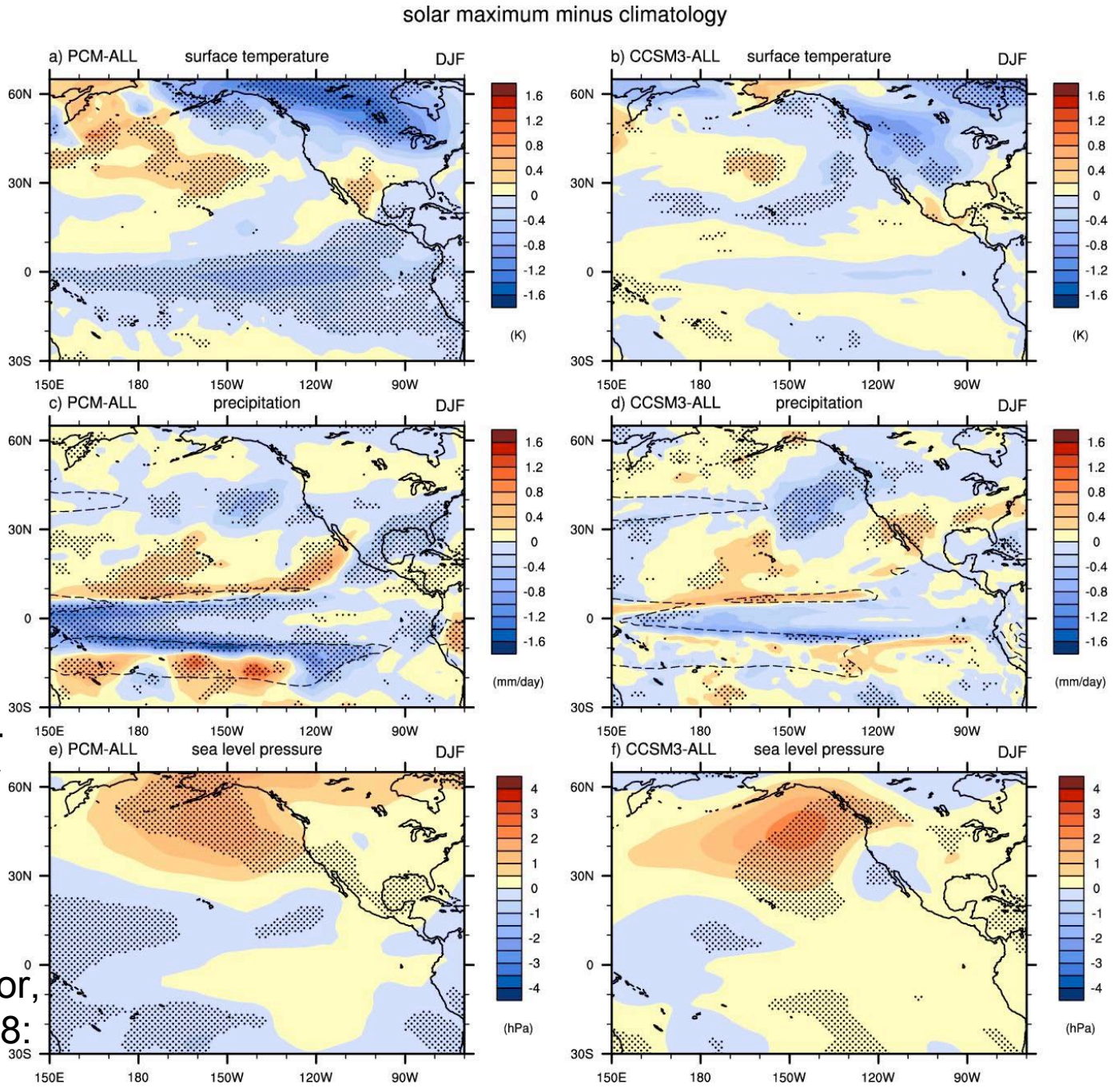
van Loon, H., G. A. Meehl, and D. J. Shea, 2007, *Journal of Geophysical Research*

Meehl, Arblaster and Branstator, 2008, *J. Climate*

van Loon, H., and G.A. Meehl, 2008: *J. Atmospheric. and Solar-Terrestrial Physics*



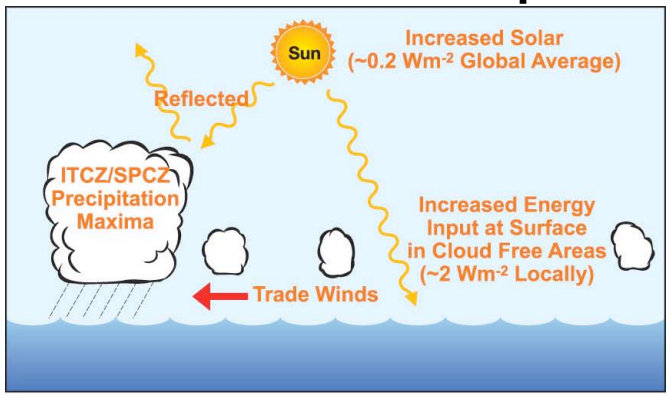
Two global coupled climate models show a similar La Niña-like response to peaks in the 11 year solar forcing

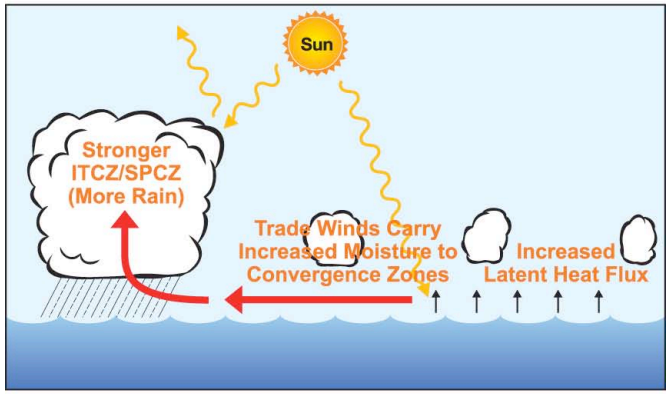


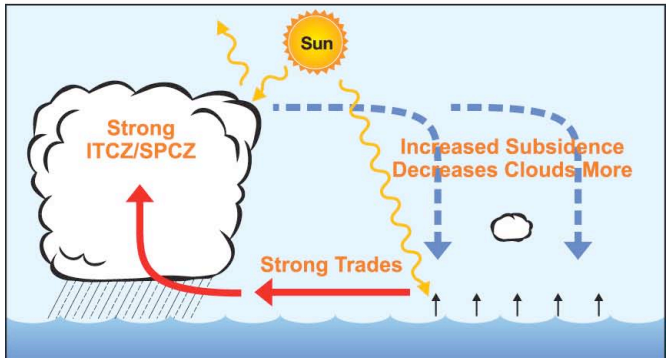
11 peak solar years, 4 member ensemble for PCM, 5 member ensemble for CCSM3

(Meehl, G.A., J.M. Arblaster, G. Branstator, and H. Van Loon, 2008: *J. Climate*)

The mechanism involves increased solar over cloud-free regions of the subtropics translating to greater evaporation, and moisture convergence and precipitation in the ITCZ and SPCZ (and south Asian monsoon), stronger trades, and cooler SSTs in eastern equatorial Pacific







Meehl, G.A., W.M. Washington, T.M.L. Wigley, J.M. Arblaster, and A. Dai, 2003, *J. Climate*

Van Loon, Meehl and Arblaster, 2004, *JASTP*

Meehl, G.A., J.M. Arblaster, G. Branstator, and H. Van Loon, 2008, *J. Climate*

UV part of the solar spectrum and stratospheric ozone:

1) stratospheric ozone absorbs UV and heats

2) increased UV produces more stratospheric ozone.

Modeling studies with resolved stratospheric processes and/or ozone effects show influence of UV variations with the 11 year solar cycle that reach the troposphere and could affect modes of variability (NAO) and the tropics

Increased solar → increased ozone heating/increased ozone amount → modified zonal wind/Brewer-Dobson Circulation → altered wave propagation → changed equator to pole energy transport and circulation → enhanced tropical precipitation

(e.g. Haigh, 1996; Shindell et al., 1999; Balachandran et al., 1999)

Fully coupled

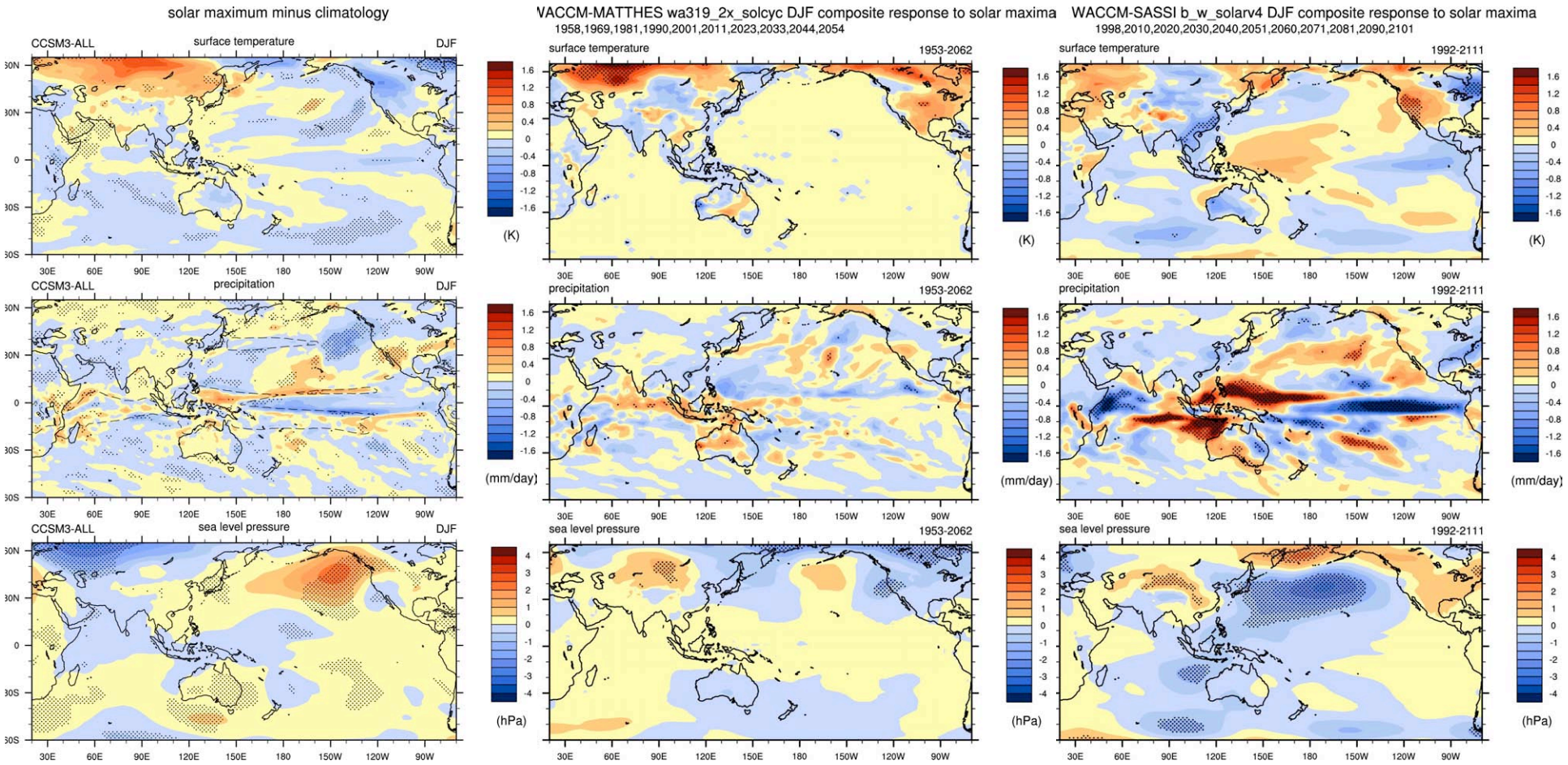
no stratosphere

resolved stratosphere

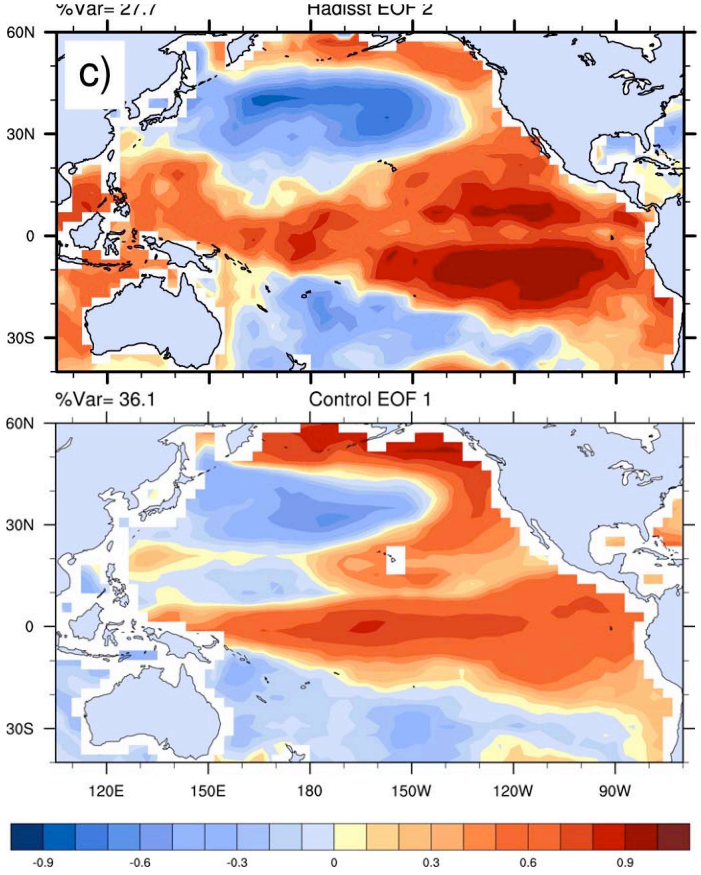
fixed SSTs

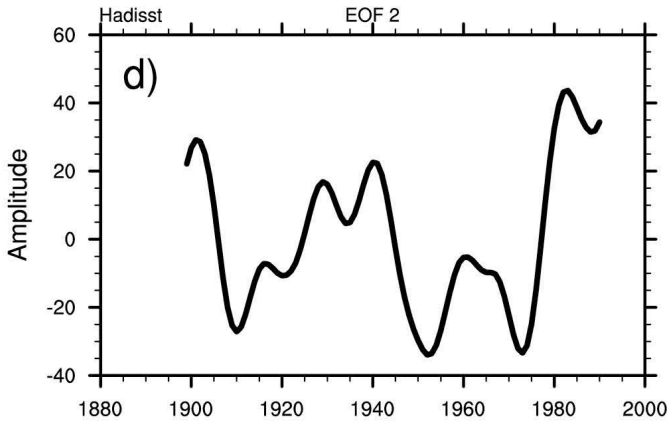
resolved stratosphere

fully coupled



The Pacific Decadal Oscillation (PDO) or Interdecadal Pacific Oscillation (IPO)



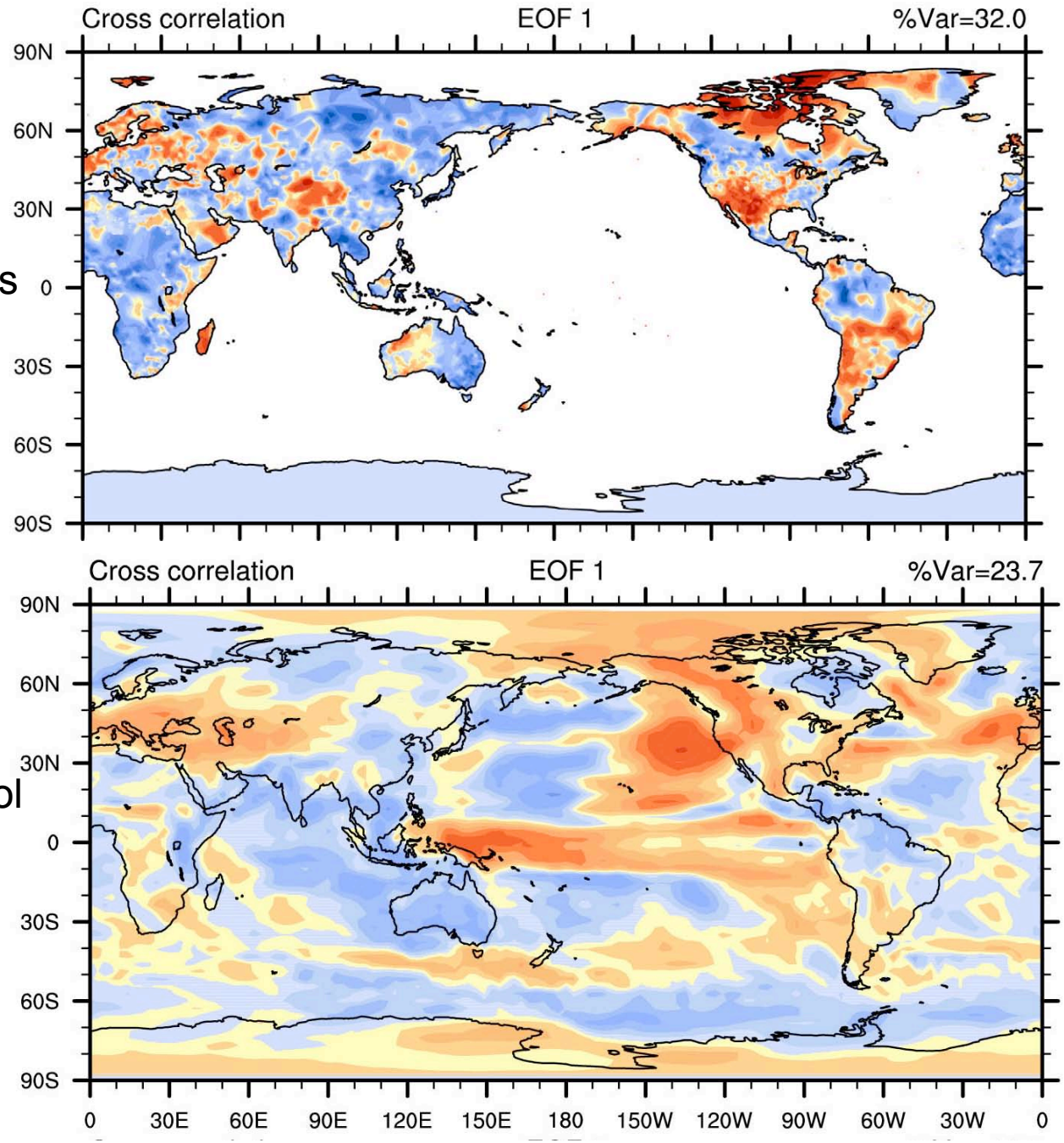


The observed IPO pattern resembles “inherent” decadal pattern from unforced model control run (pattern correlation= +0.63)

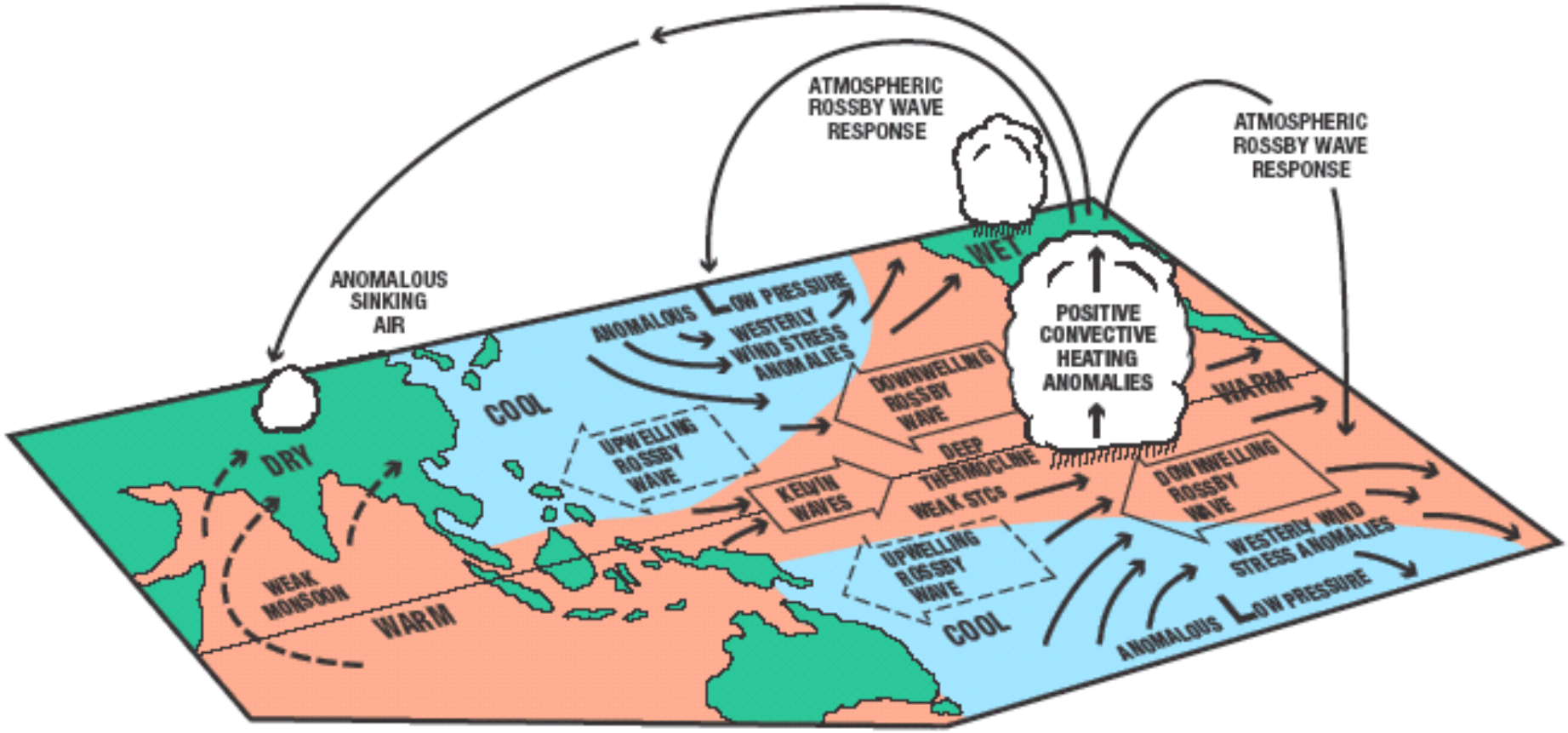
IPO correlated with low pass filtered precipitation

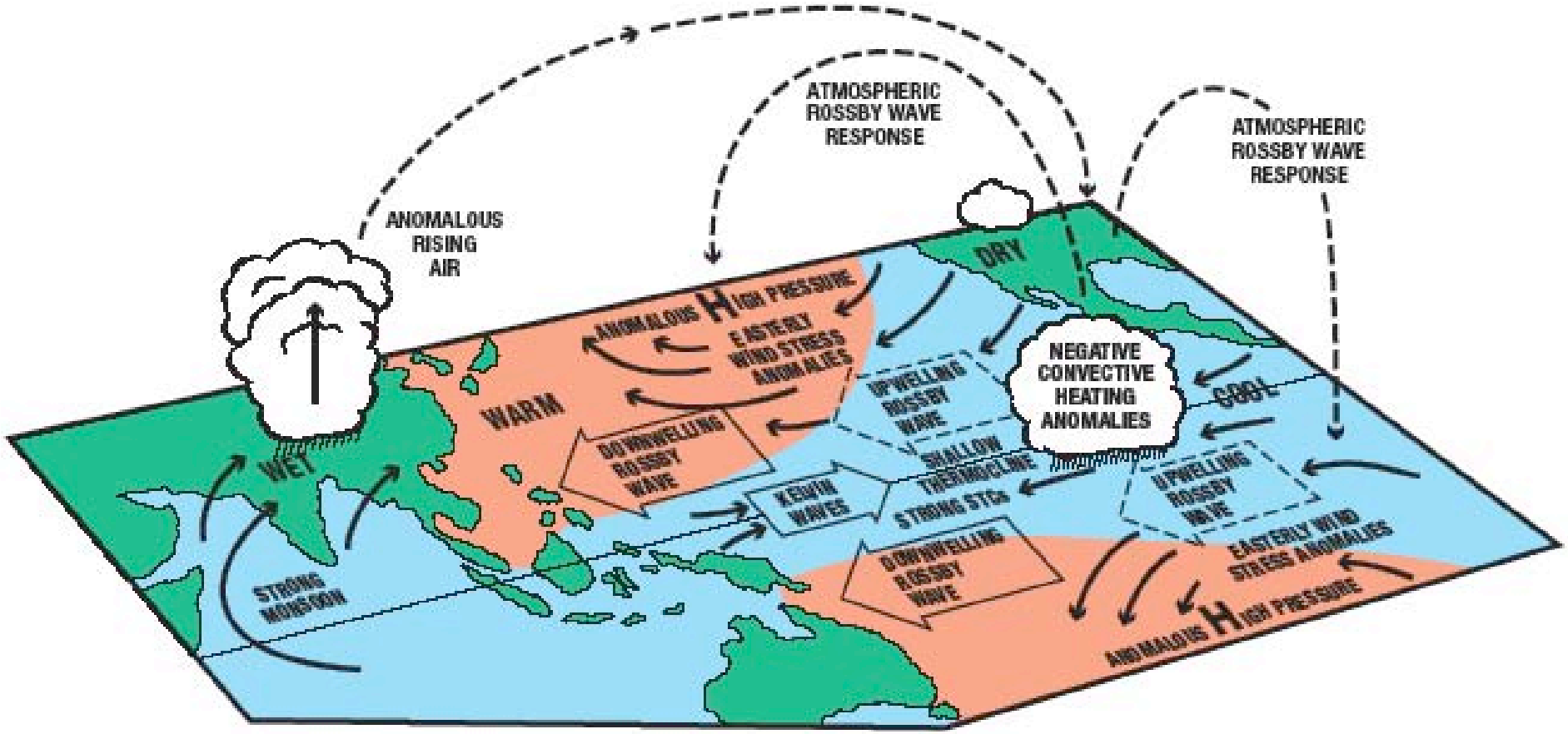
Observations

Model control



Mechanism for IPO (multi-decadal SST) and associated precipitation variability in the Indo-Pacific region (Meehl, G. A., and A. Hu, 2006, *Journal of Climate,* **19**, 1605–1623.)

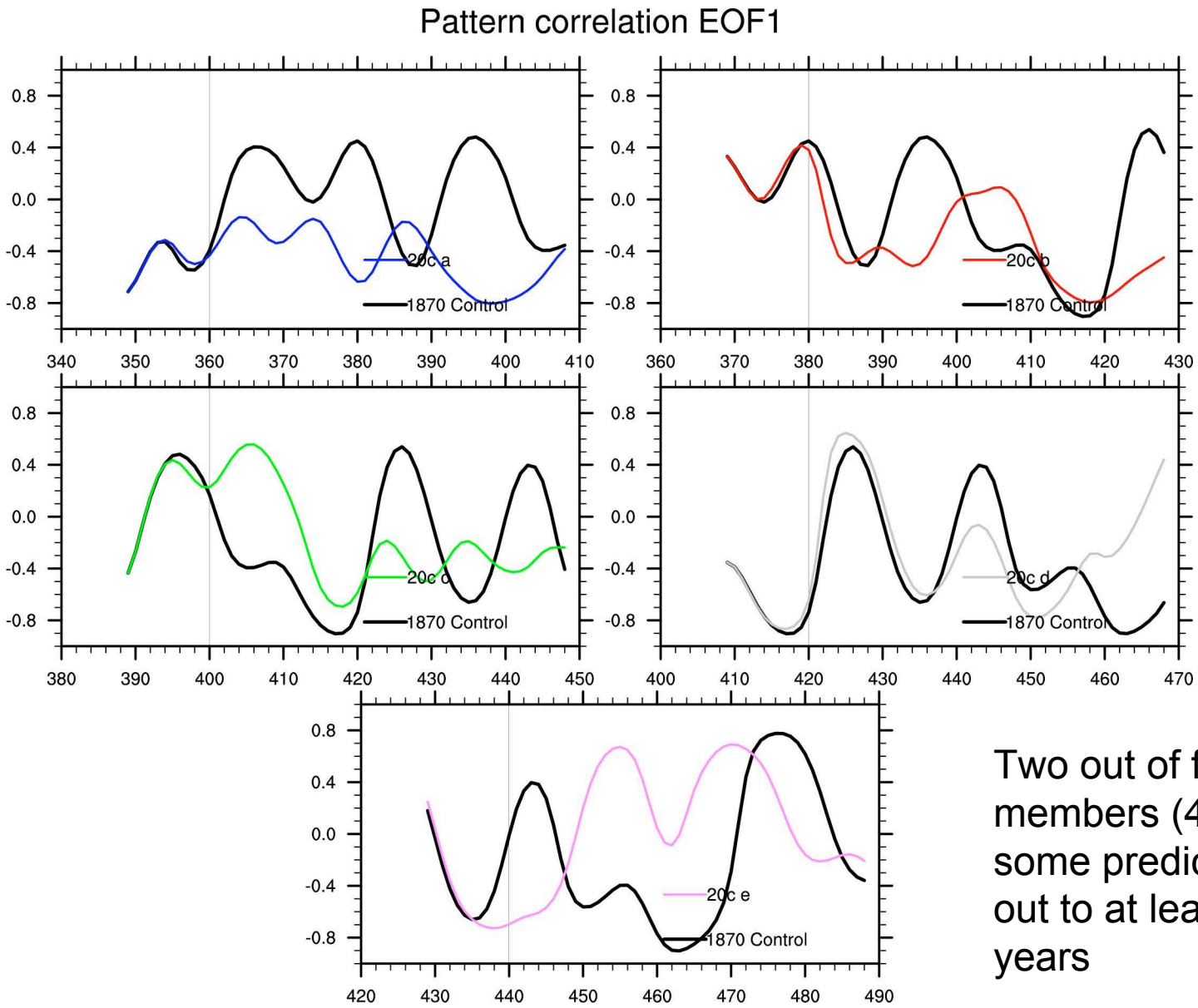



ATMOSPHERIC
ROSSBY WAVE
RESPONSE
ATMOSPHERIC
ROSSBY WAVE
RESPONSE
ANOMALOUS
RISING
AIR
DRY
ANOMALOUS H IGH PRESSURE
EASTERLY
WIND STRESS
ANOMALIES
WARM
WET
NEGATIVE
CONVECTIVE
HEATING
ANOMALIES
COOL
UPWELLING
ROSSBY
WAVE
DOWNWELLING
ROSSBY
WAVE
SHALLOW
THERMOCLINE
STRONG STCs
KELVIN
WAVES
UPWELLING
ROSSBY
WAVE
DOWNWELLING
ROSSBY
WAVE
STRONG
MONSOON
EASTERLY WIND
STRESS ANOMALIES
ANOMALOUS H IGH PRESSURE

Can the IPO pattern be “predicted” in five 20th century runs?

CCSM3 (T85, ~140km resolution) 20th century simulations branched from different times in the pre-industrial control run (Different initial states of the coupled climate system)

Track the IPO index (EOF1 pattern from the control run) in the initial stages of each 20th century run, and compare to the same period in the control run (all low pass filtered)



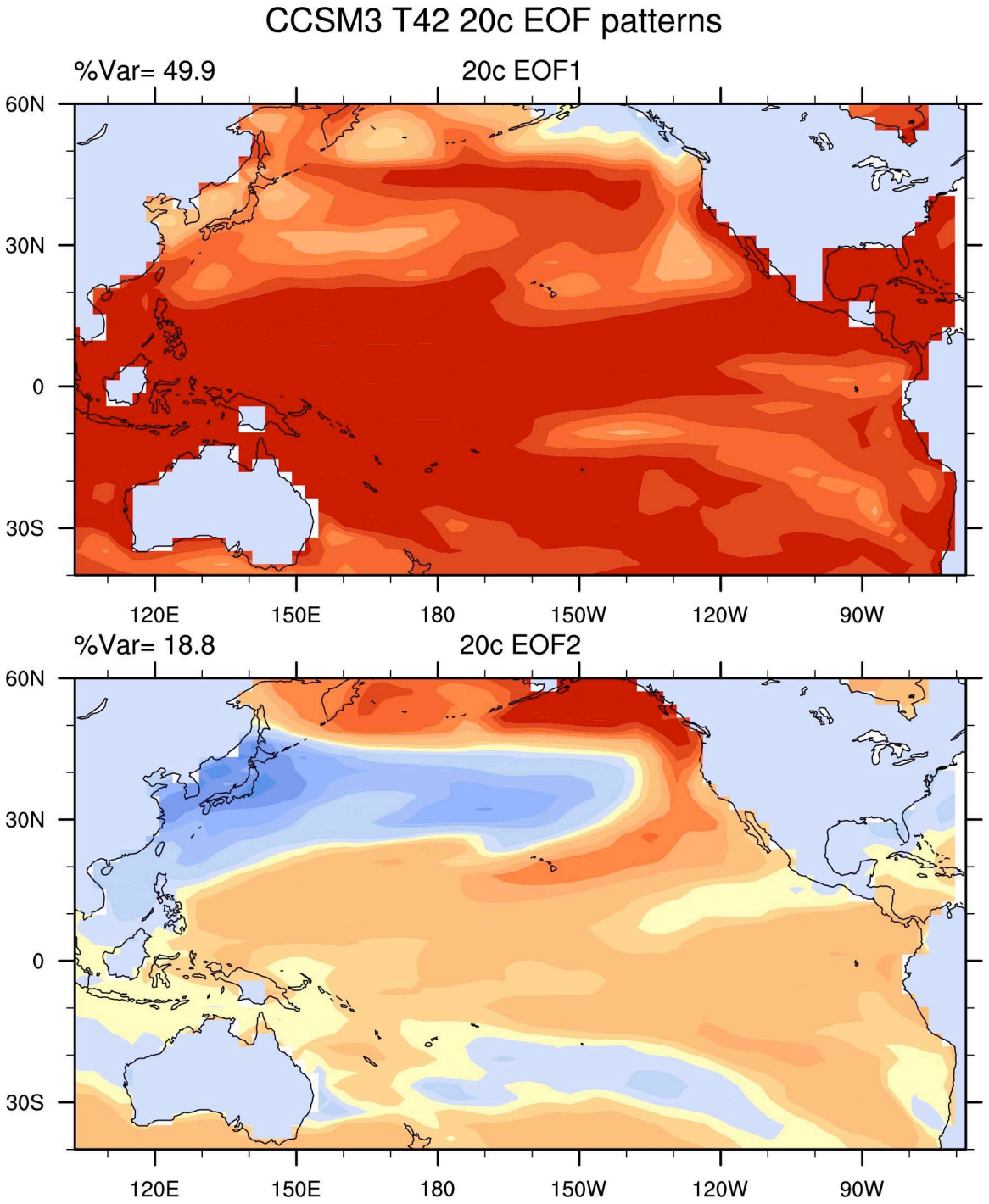
Two out of five members (40%) show some predictive skill out to at least 10 years

Can the IPO pattern be “predicted” in a large ensemble of early 21st century simulations?

CCSM3 (T42, ~280 km resolution) 21st century simulations branched from the end of a single 20th century run; one member is the reference (continuous simulation from 20th to 21st century with A1B scenario)

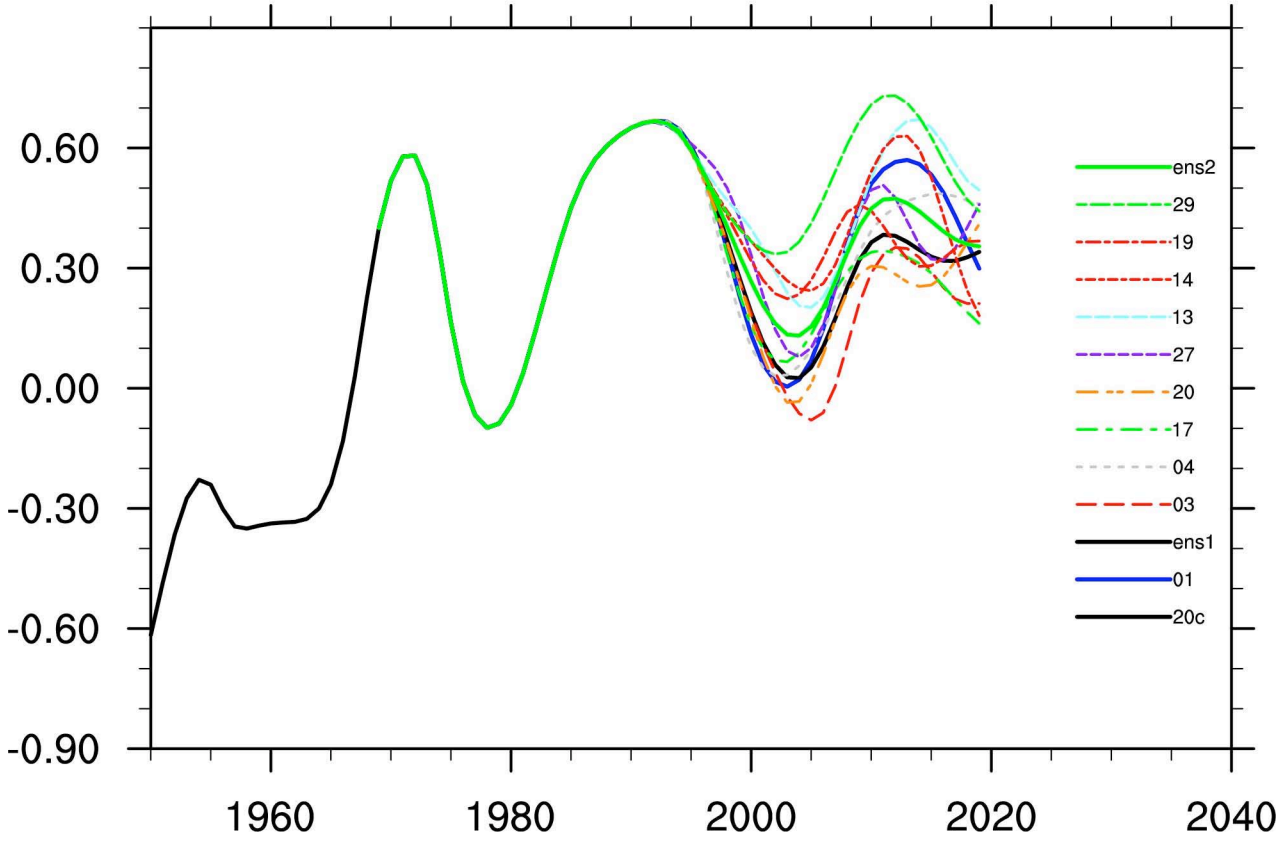
29 ensemble members using end of 20th century ocean initial state but perturb the atmospheric initial state (using atmospheric state from different days around the initial ocean state)

Track the IPO index (IPO pattern in transient simulations is EOF2; EOF1 is forced warming trend) in the initial stages of each 21st century run, and compare to the reference 21st century simulation


CCSM3 T42 20c EOF patterns
%Var= 49.9
20c EOF1
60N
30N
0
30S
120E
150E
180
150W
120W
90W
%Var= 18.8
20c EOF2
60N
30N
0
30S
120E
150E
180
150W
120W
90W

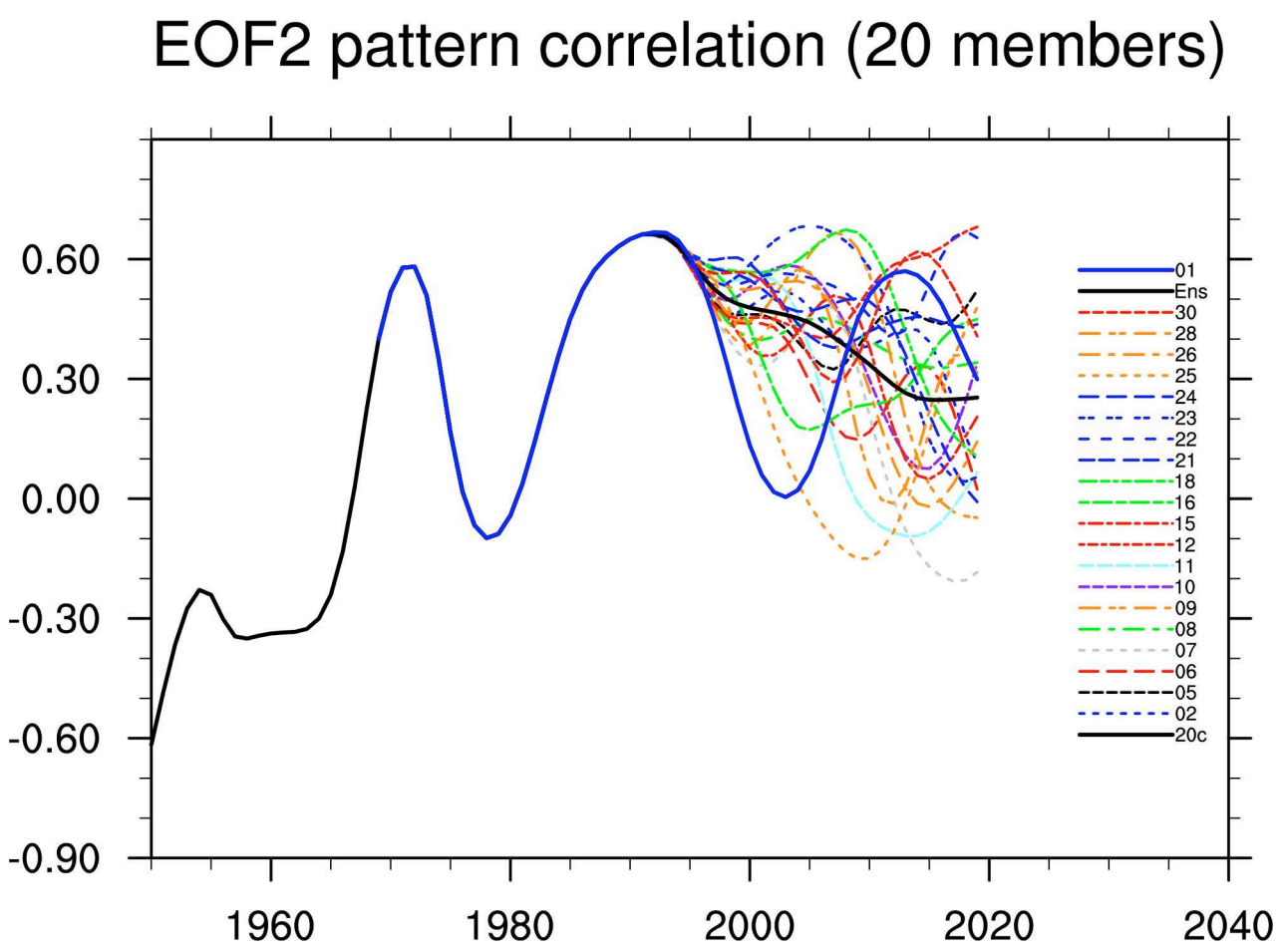
Decadal predictions of IPO index for the Pacific

EOF2 pattern correlation (9 members)



9 out of 29 members (31%) show some predictive skill out to 20 years

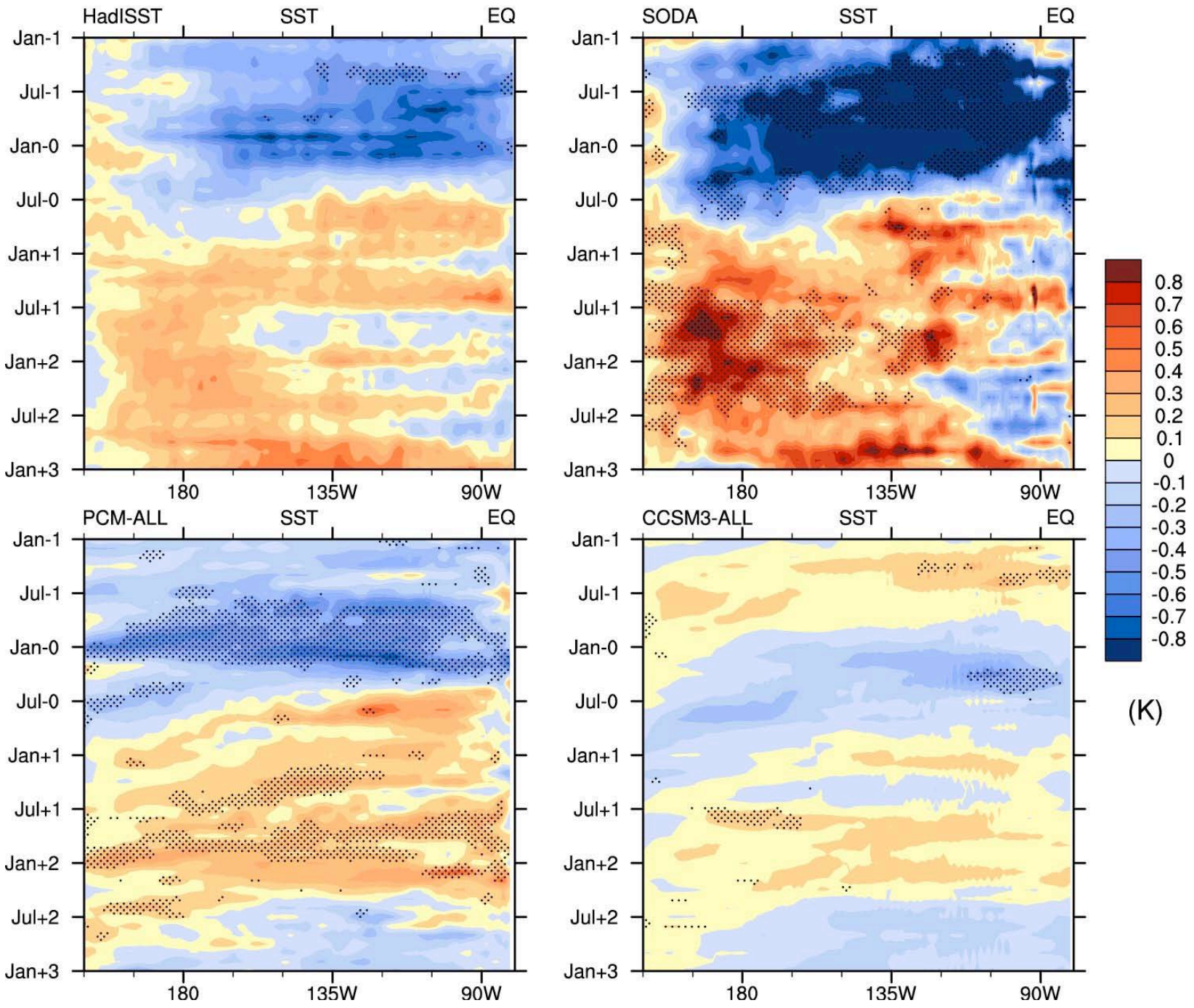
(CCSM3.0, T42, atmospheric initial state perturbed with same ocean initial state at year 2000; one reference, 29 ensemble members)


EOF2 pattern correlation (20 members)
0.60
0.30
0.00
-0.30
-0.60
-0.90
1960
1980
2000
2020
2040
01
Ens
30
28
26
25
24
23
22
21
18
16
15
12
11
10
09
08
07
06
05
02
20c

Conclusions

1. 11 year solar cycle forcing produces SST and precipitation anomalies with a La Nina-like pattern in the Pacific on decadal timescales
2. “Decadal” (PDO or IPO) pattern in observations is dominant low frequency mode of SST variability in the Pacific; connected with regional rainfall anomalies in south and east Asian region and southwest North America
2. Predicting the decadal evolution of this pattern would add regional skill to forced response and climate change commitment
3. Five 20th century simulations branched from different initial states in the pre-industrial control run show some skill in a subset (2 out of 5, 40%) of the ensemble members for predicting the IPO pattern 10-15 years in advance
4. A reference simulation and a 29 member ensemble of predictions for the first half of the 21st century show 9 out of 29 members (~30%) with predictive skill for the IPO
5. Why do some ensemble members (30-40% from two different experimental configurations) show decadal predictive skill for the IPO and others do not?

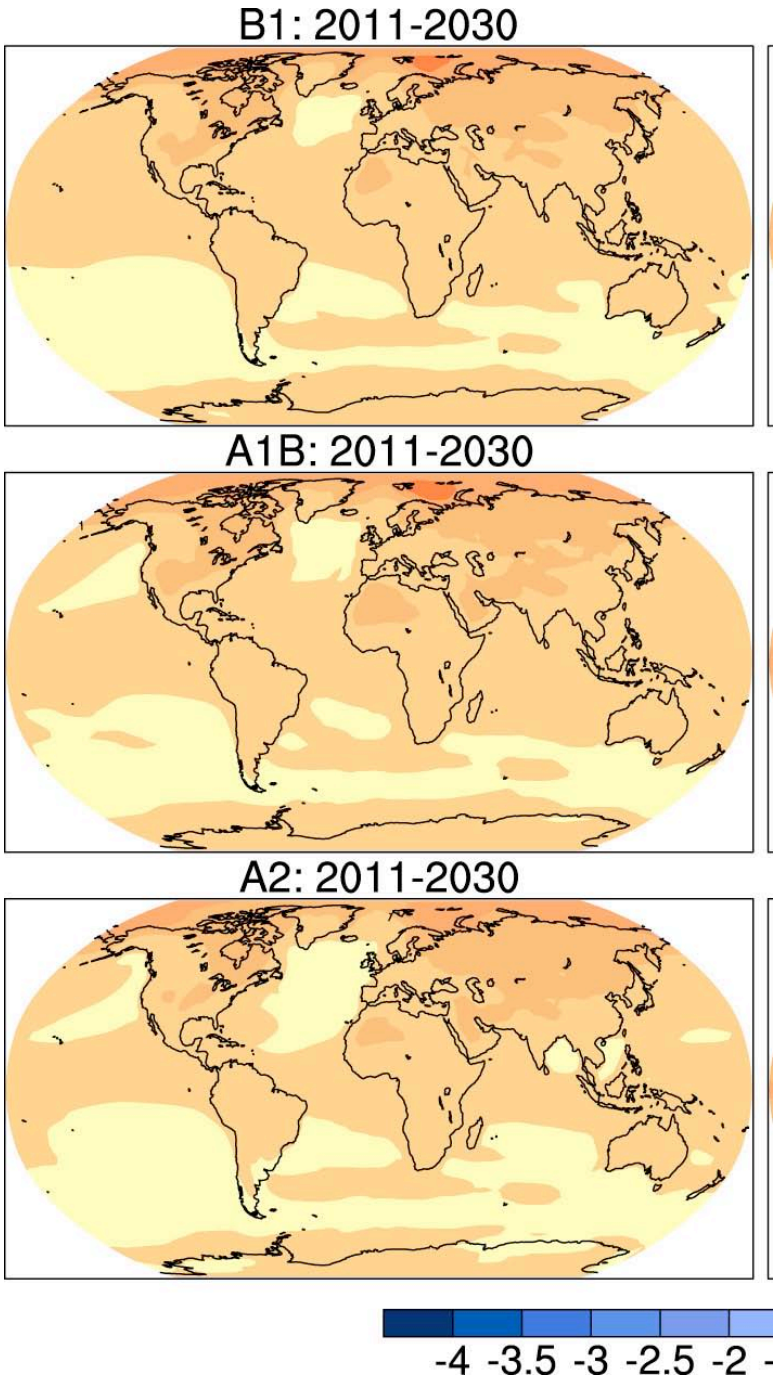
solar maximum minus climatology



Decadal prediction from a multi-model ensemble (IPCC AR4, Ch. 10 Fig. 10.8)

By averaging over a multi-model ensemble, the decadal signal is, at minimum, 1) the forced response to increasing GHGs (doesn't depend much on which scenario is used) and 2) climate change commitment

But if there are modes of decadal variability that could be predicted, the regional skill of decadal predictions could be increased



WACCM coupled in CCSM; composite of peak solar, 11 solar cycles

(WACCM experiment recently completed by Fabrizio Sassi)