Decadal Prediction: A First-Round Report

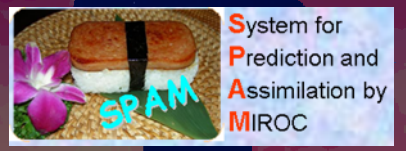
Masahide Kimoto

Atmosphere and Ocean Research Institute

The University of Tokyo

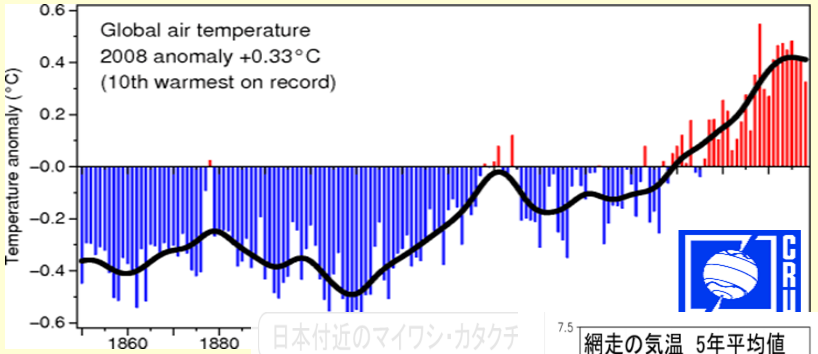
and

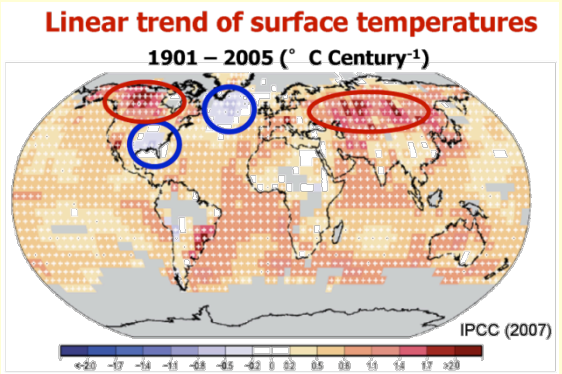
Team SPAM

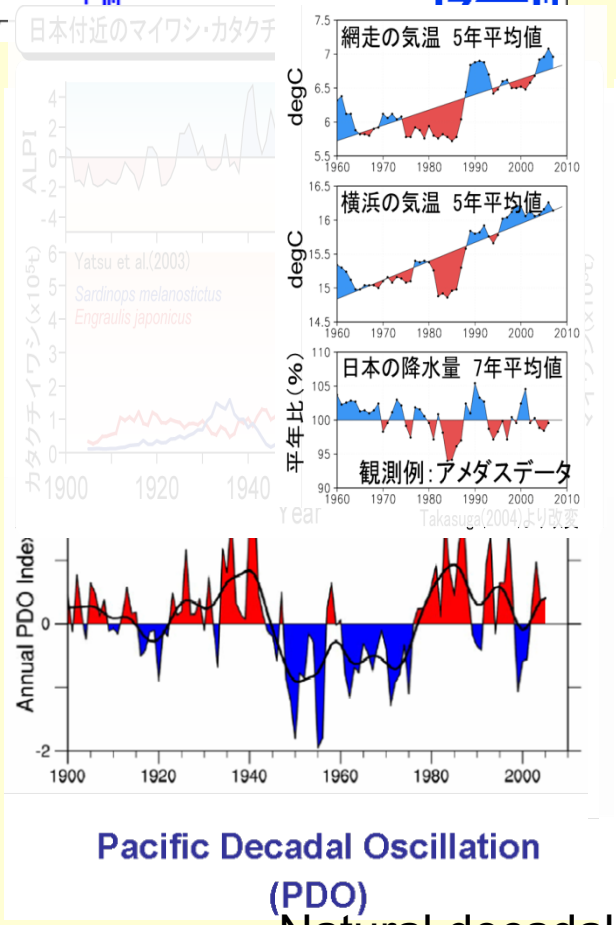


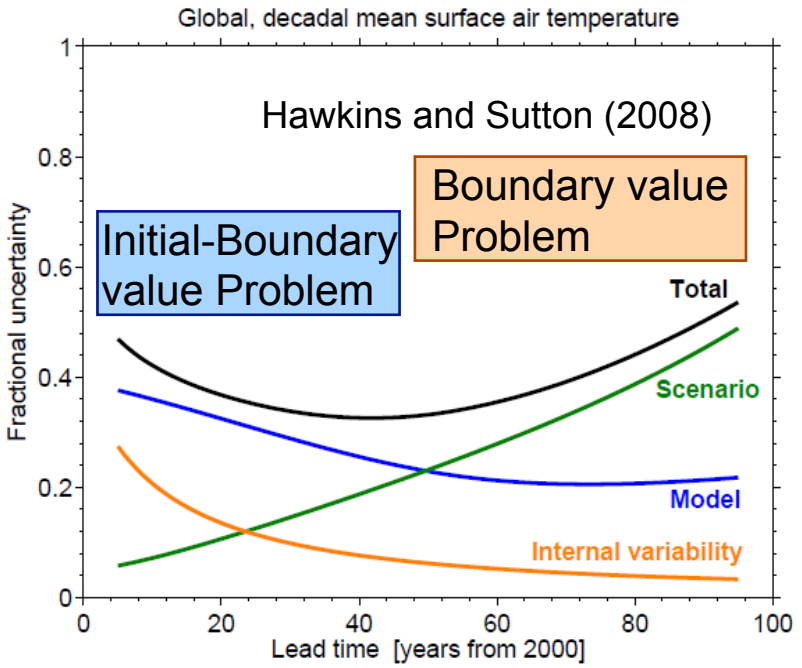
KAKUSHIN AORI NIES

Forced + Natural Climate Change





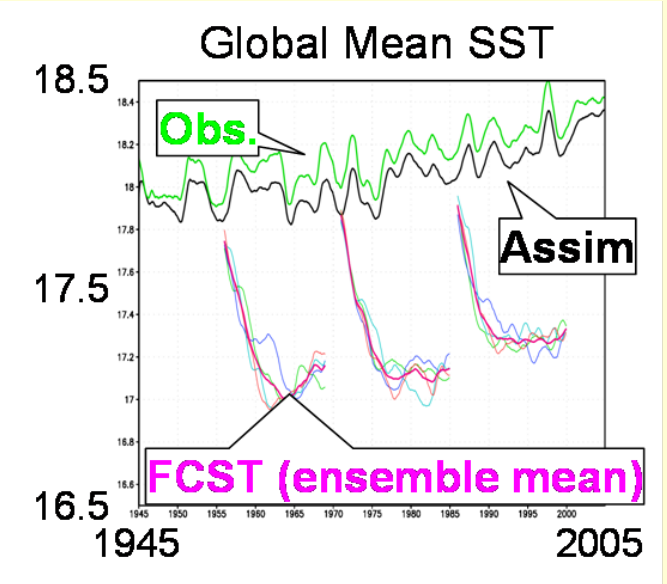


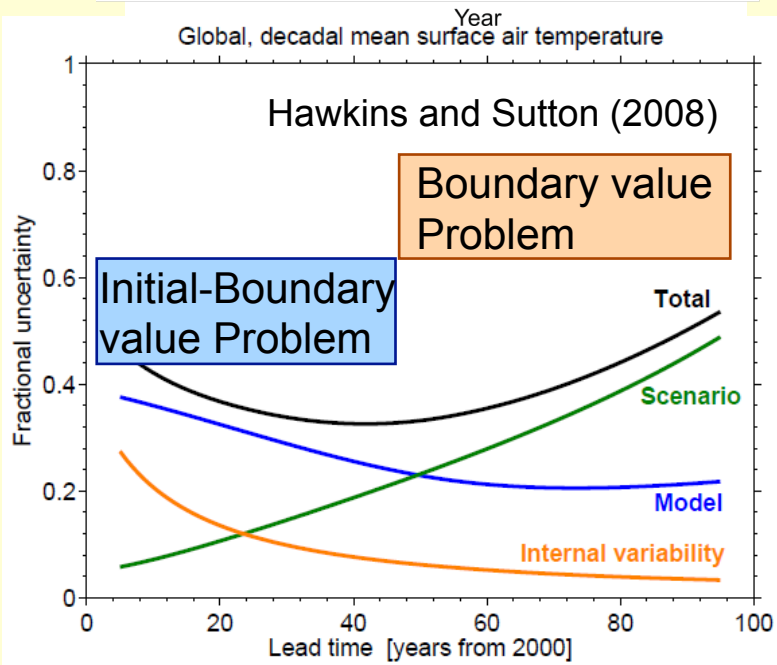


Natural decadal climate variability

Decadal Prediction: Issues

- Societal needs
- Regional details vs. Uncertainty
  i.e., Resolution vs. Ensemble
- Near-term uncertainty:
  Natural variability
  >> Socio-economic scenario
  → Mixed Initial-Boundary value problem
  → (a new category of CMIP/IPCC exp)
- Initialization? How?
- Drift?
- Decadal predictability?
- Models good enough?
- Chemistry? Aerosols?
- Volcanoes?

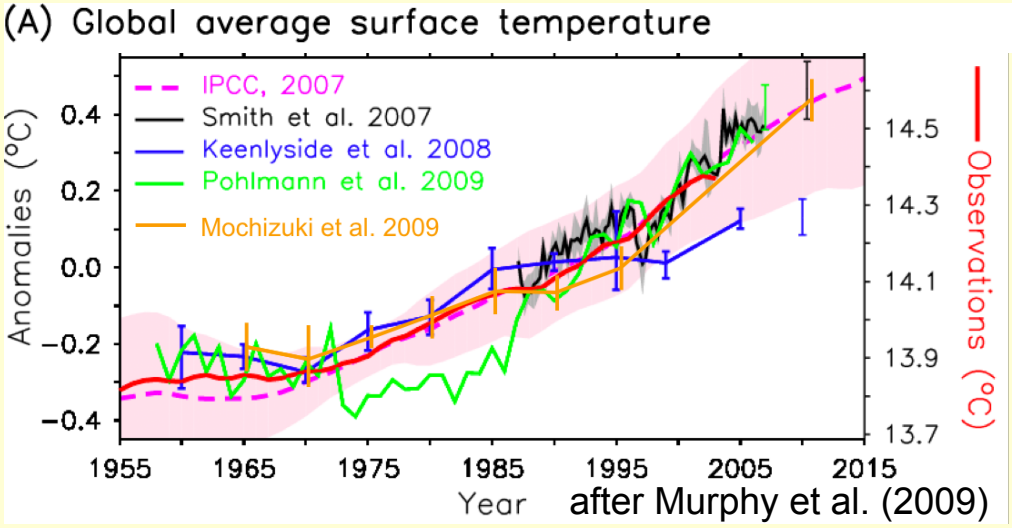




Meehl et al. (2009; BAMS), Hurrel et al. (2009; BAMS),
Murphy et al. (2009; WCC3), Vera et al. (2009; WCC3)

Decadal Prediction: Initialization?

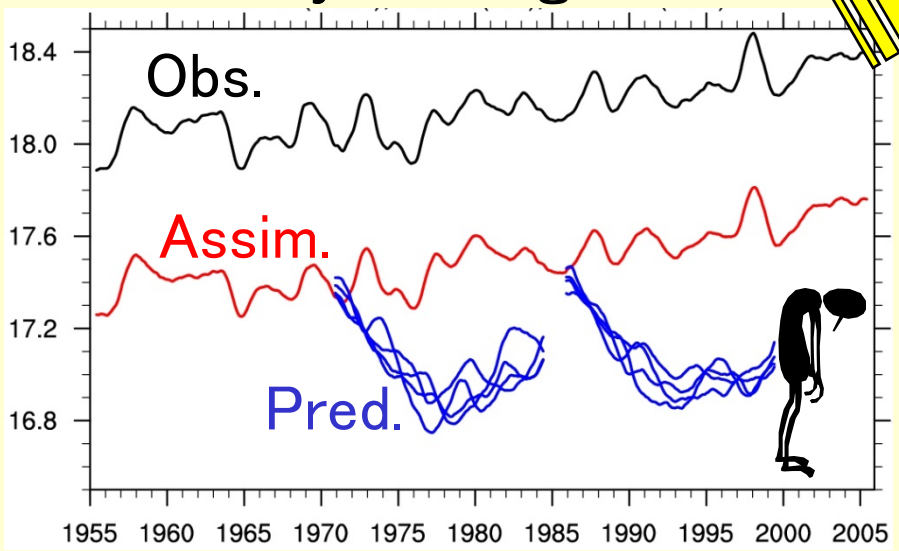
1. Nudging SST data to AOGCM
2. Assimilate subsurface ocean temp/salinity to AOGCM ("nudging", 3DVAR etc.)
3. Drive OGCM by atmospheric reanalysis → 2.
4. Fully coupled data assimilation (4DVAR (Awaji et al.), EnKF, etc.)

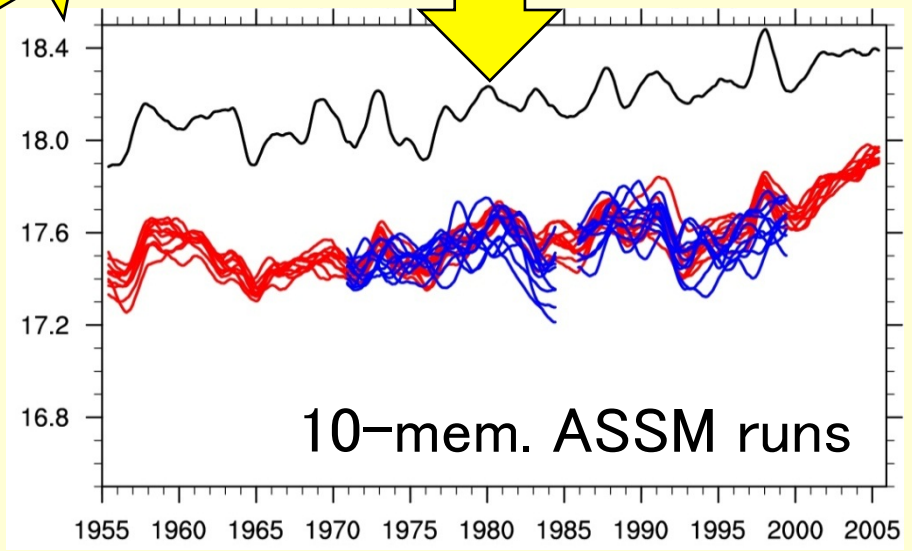


Preventing climate drift

- Anomalies of ocean T/S are assimilated into coupled model
- ~~Nudging~~ → IAU
- Weak assimilation

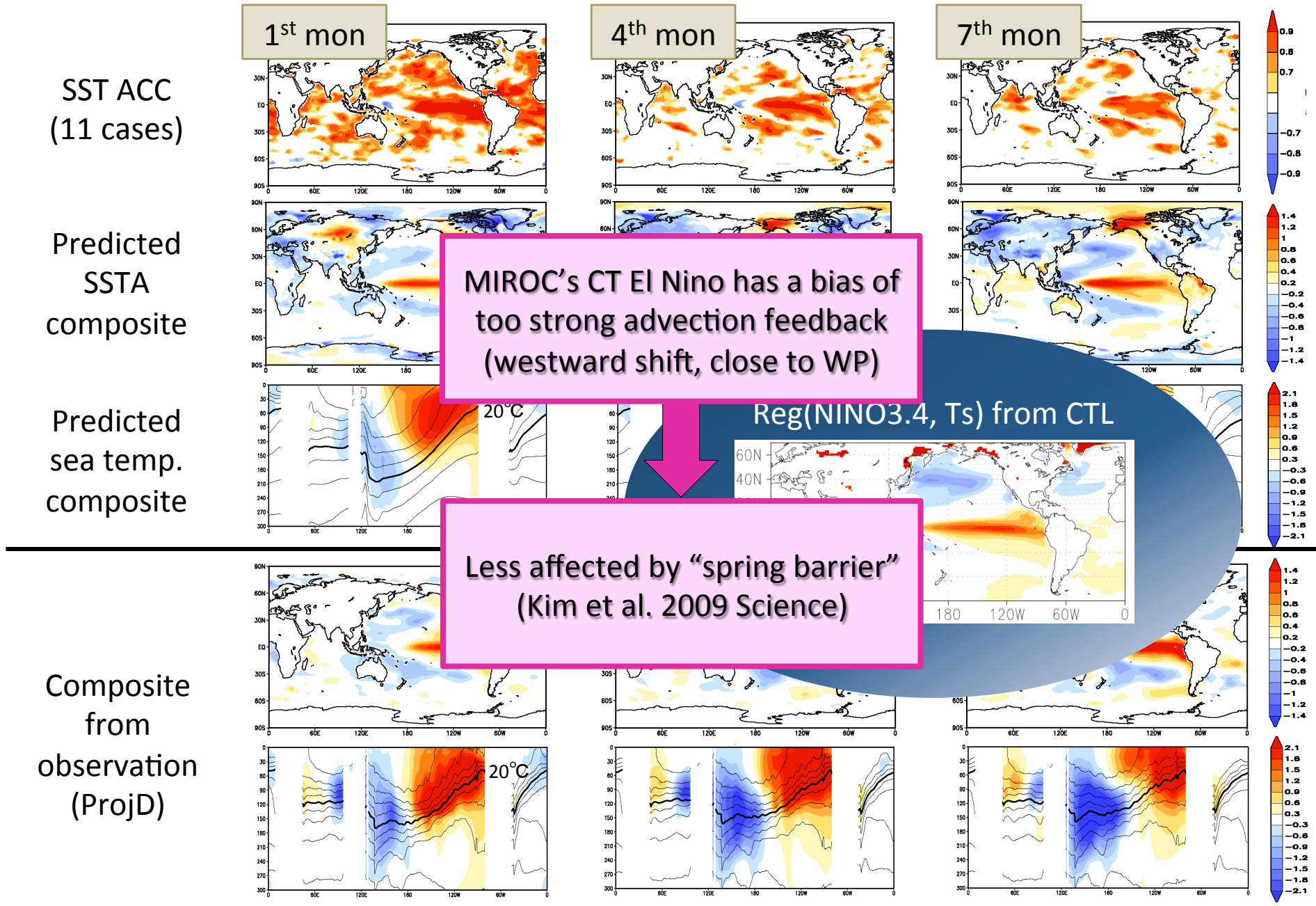
Globally averaged SST



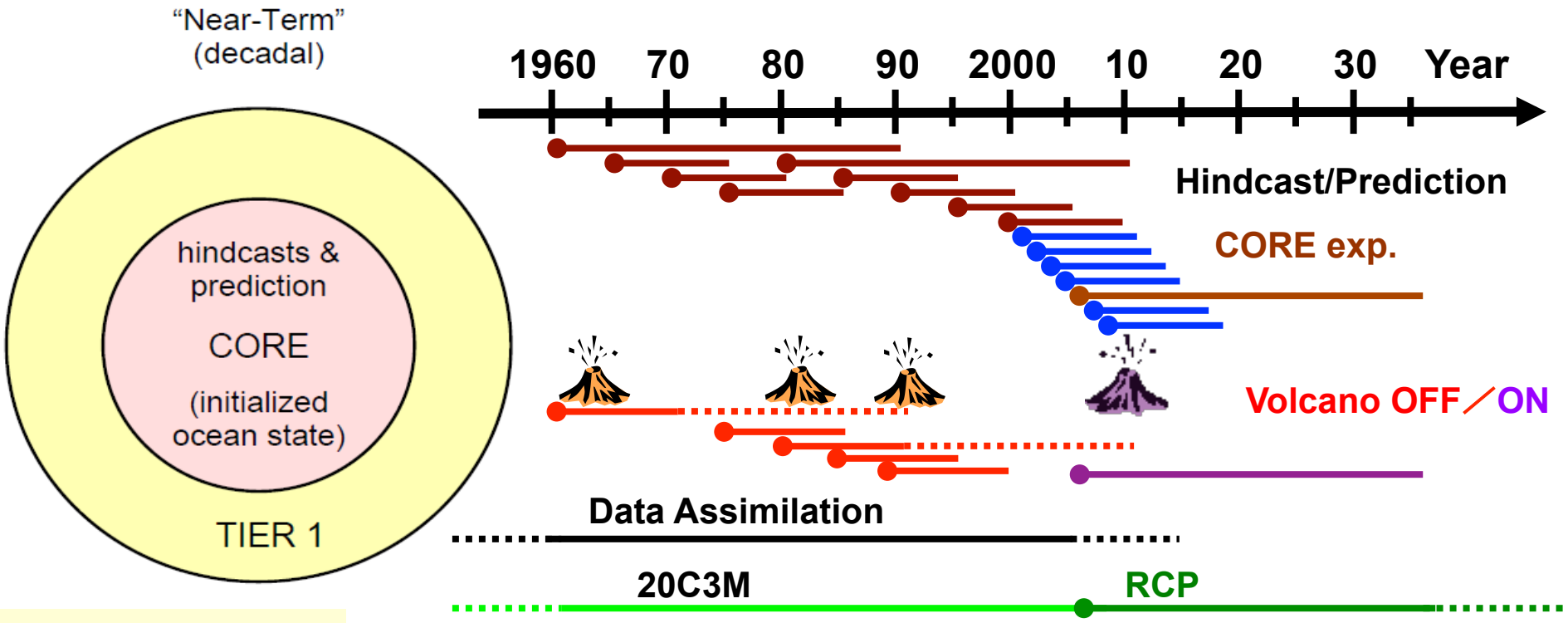


The anomaly assimilation: Smith et al. (2007), Keenlyside et al. (2008)

Anomaly progression by initial ENSO type: CT El Nino growing



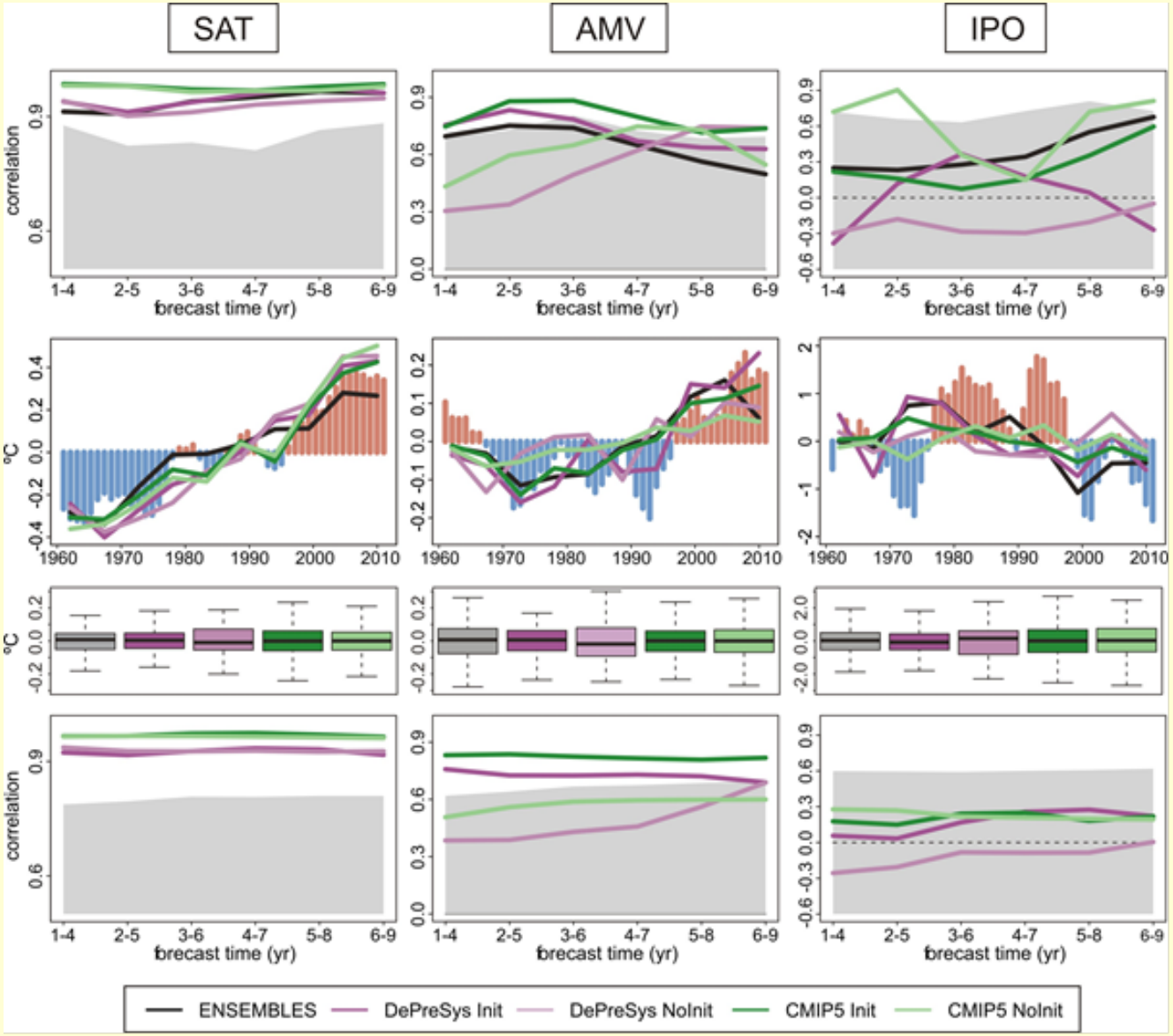
CMIP5 Experimental Design



Taylor et al. (2008)

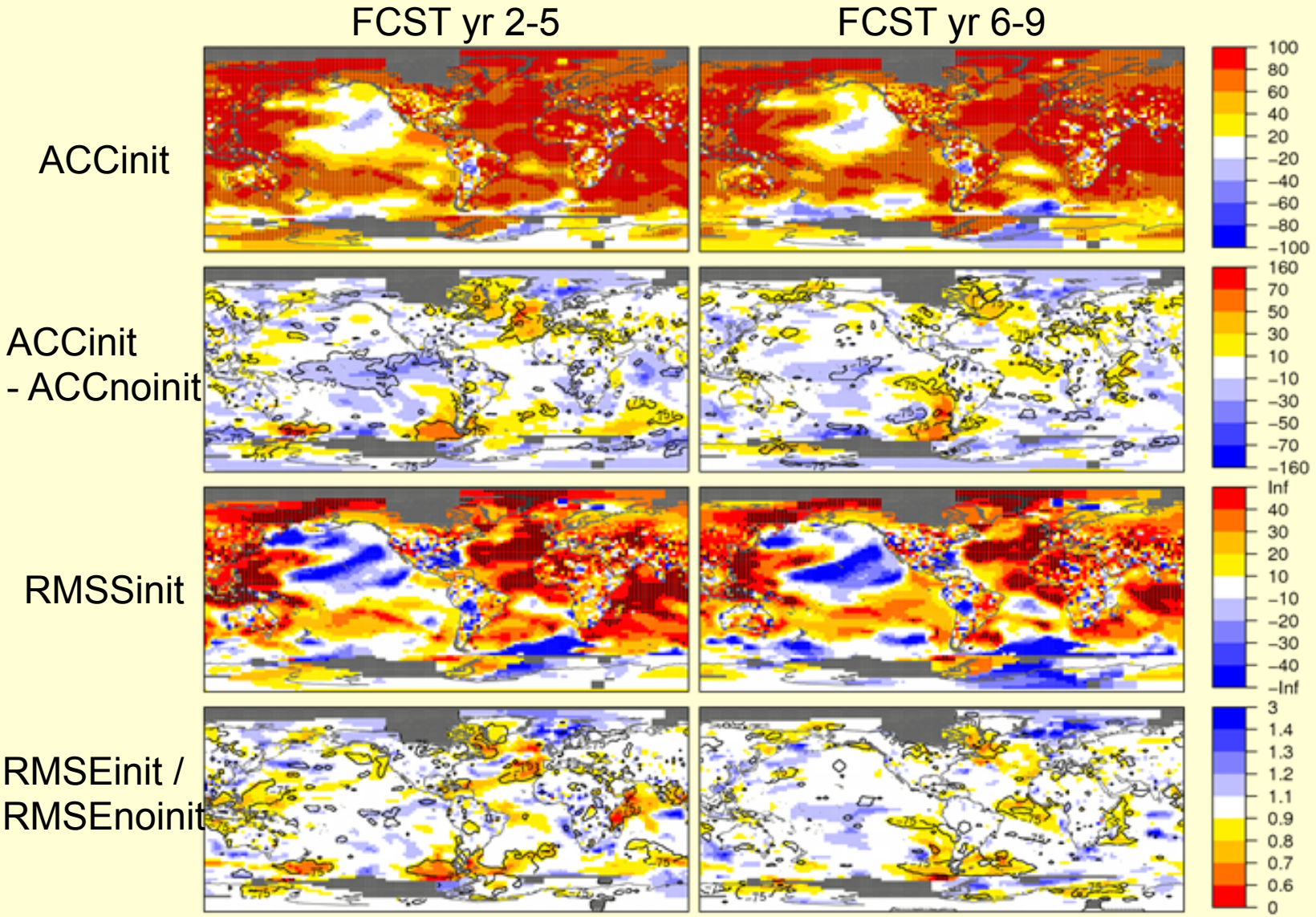
5000-Year Integration
for 10 member ensemble,

CMIP5 multimodel ensemble



Doblas-Reyes et al. (2012)

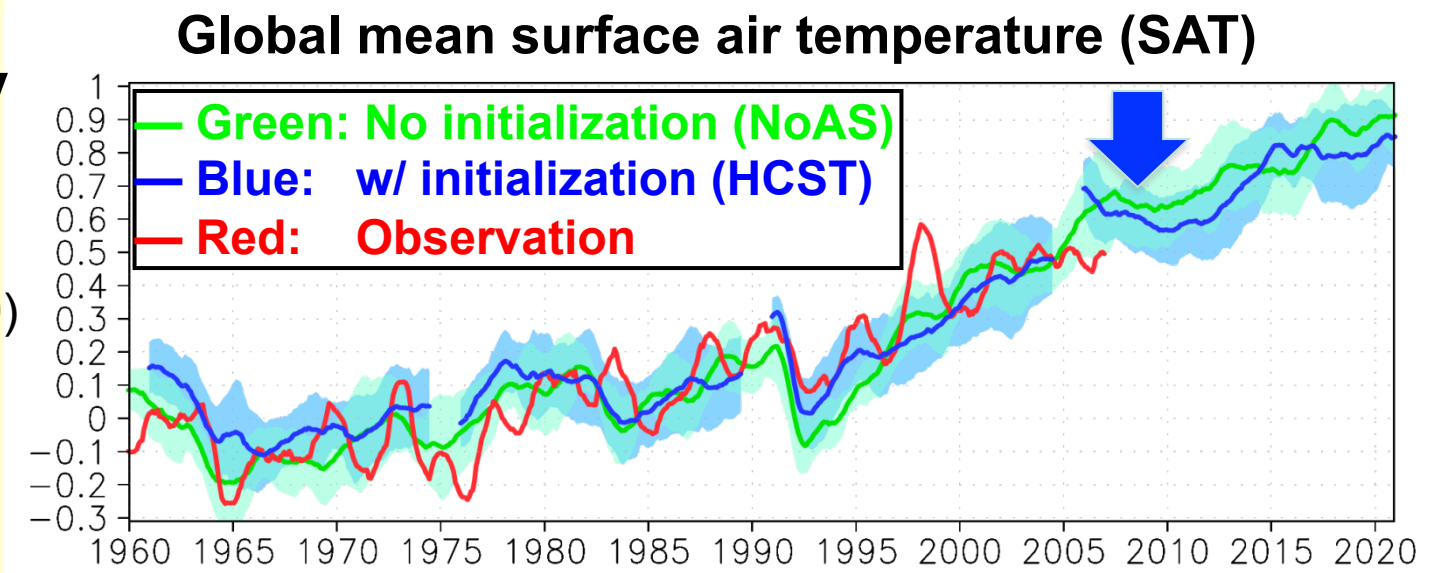
CMIP5 multimodel ensemble



Doblas-Reyes et al. (2012)

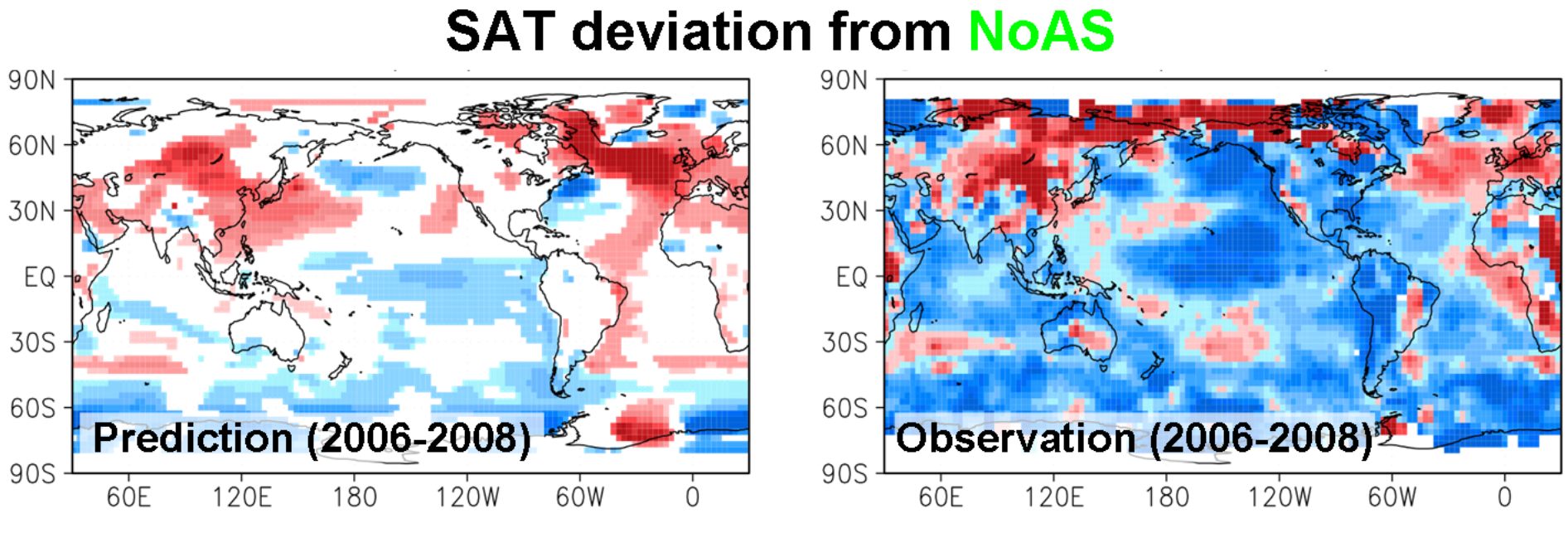
Predictability of PDO

Mochizuki et al. (2010)

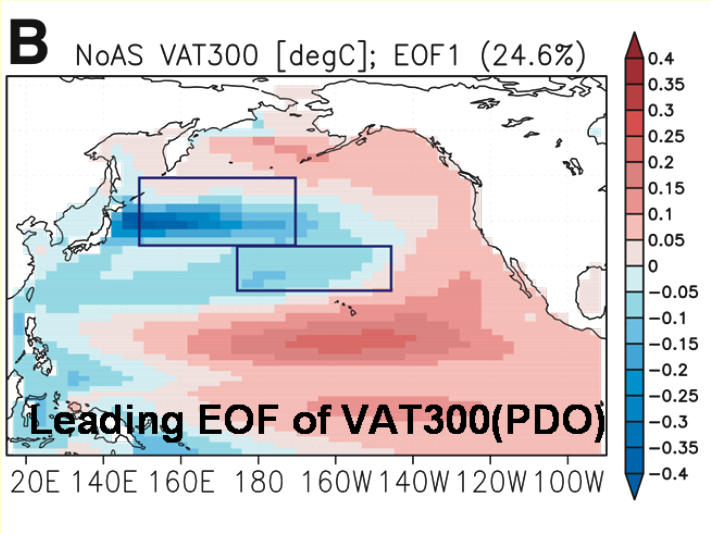


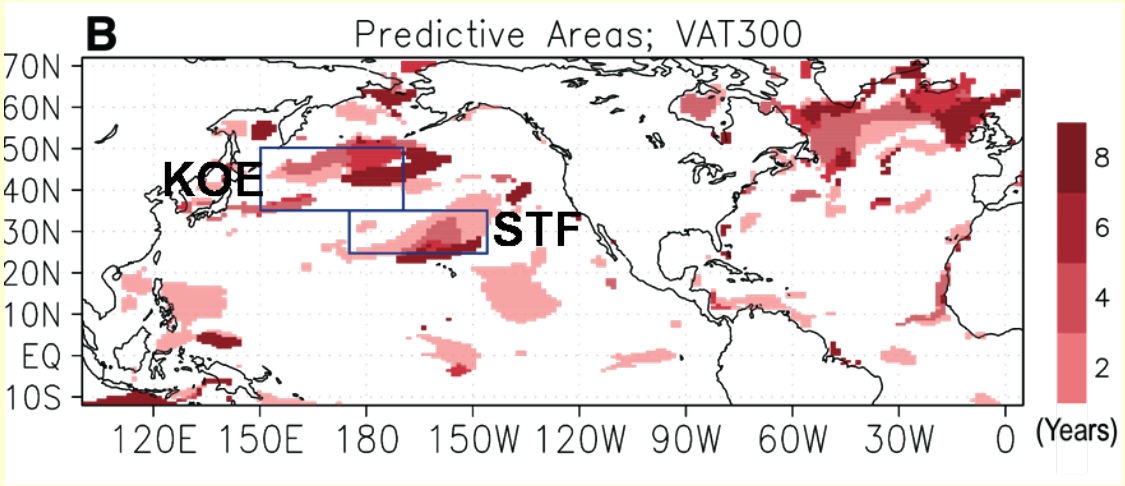
Deviation from forced comp

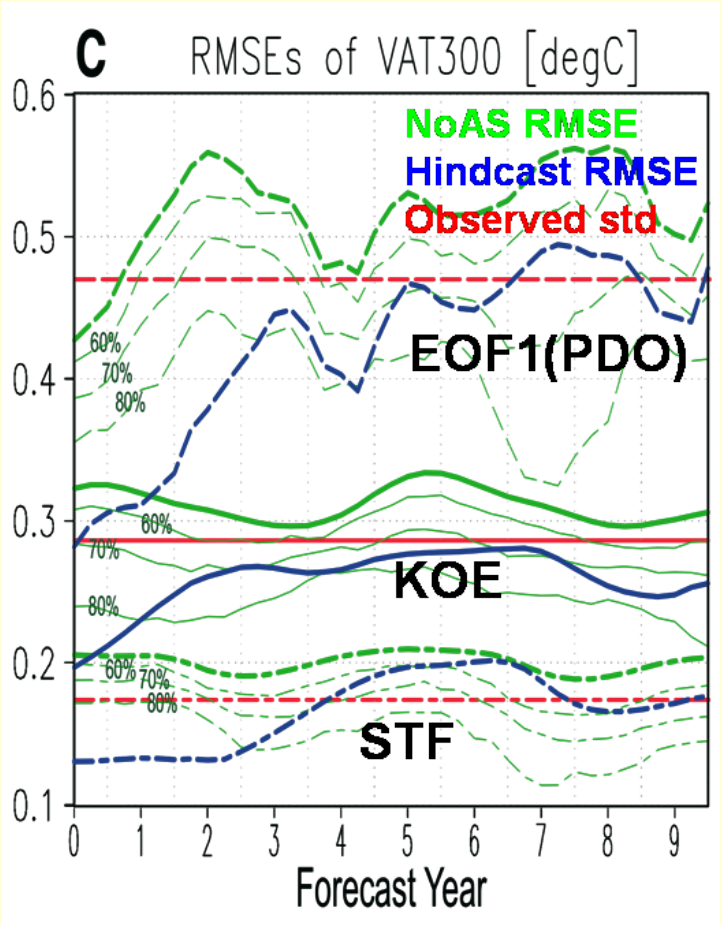
Prediction of PDO



Subsurface memory



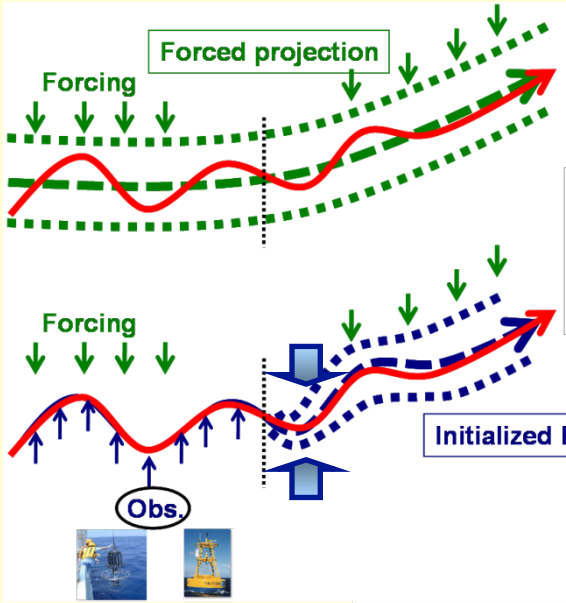




Mochizuki et al. (2010)

Midlatitude predictability of PDV

Sugiura et al. (2009)



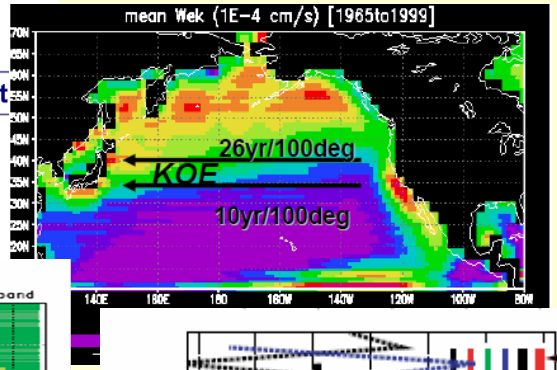
Predictable Component Analysis

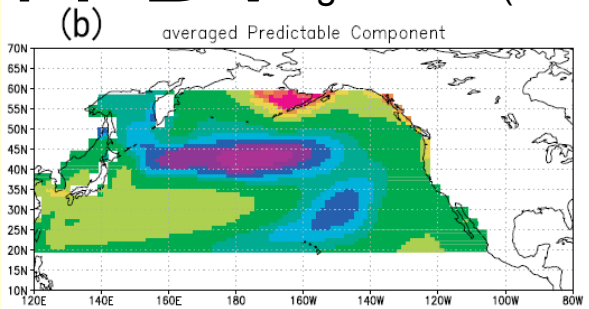
following *Schneider and Griffies [1999]*

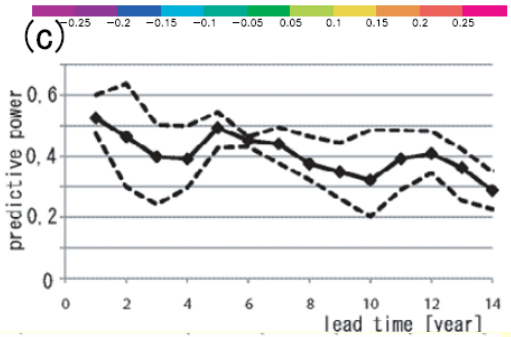
予測時にアンサンブルスプレッドが気候値に比べて収縮している箇所を調べる。

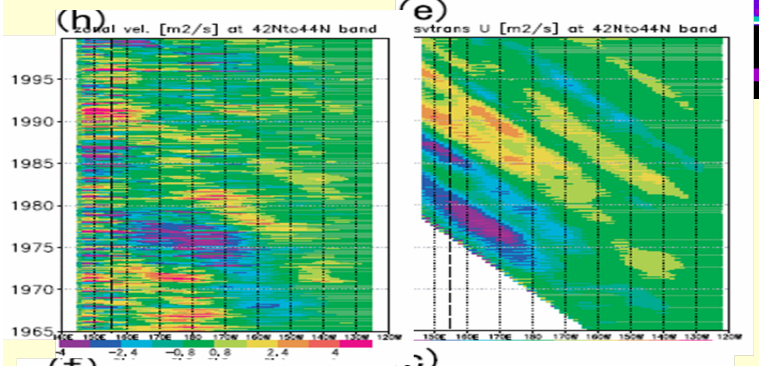
$$\lambda = \frac{\sigma^2_{\mathrm{fct}}}{\sigma^2_{\mathrm{clim}}} = \frac{\mathbf{v}^T \mathbf{C}_{\mathrm{fct}} \mathbf{v}}{\mathbf{v}^T \mathbf{C}_{\mathrm{clim}} \mathbf{v}} \rightarrow \min$$

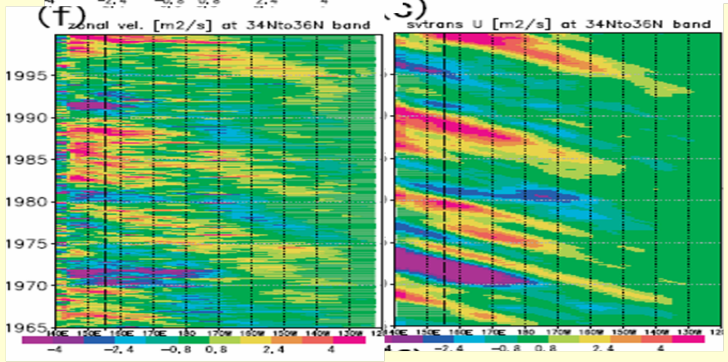
すなわち、 $\mathbf{C}^{-1}_{\mathrm{clim}} \mathbf{C}_{\mathrm{fct}}$ に対して最小固有値 λ をもたらす固有ベクトル $\mathbf{v}$ を見つける。

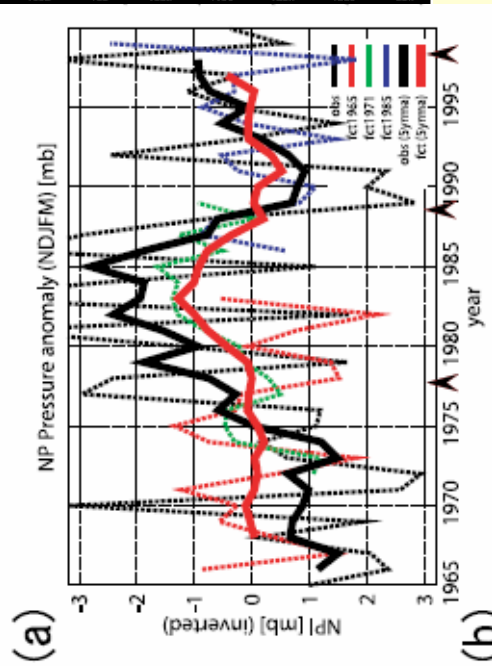


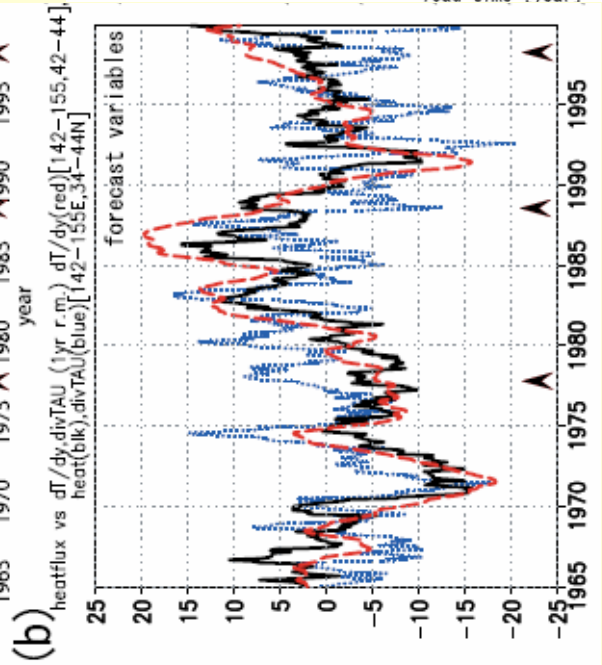






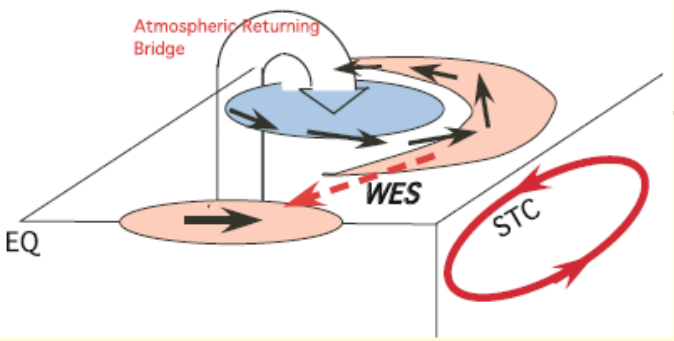


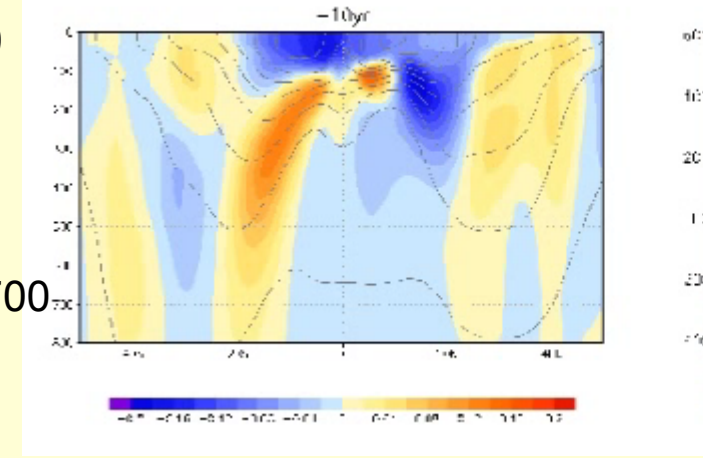


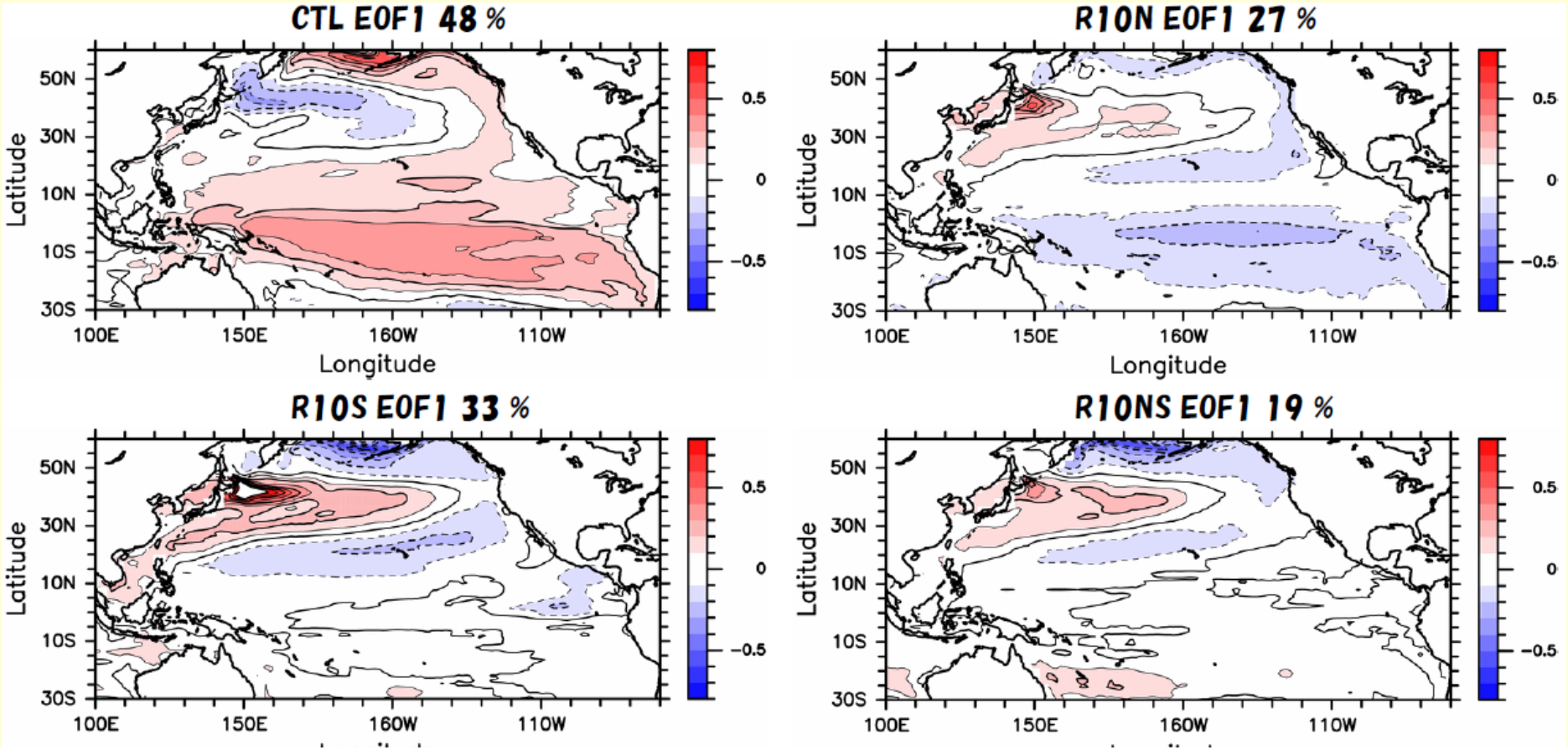


Origin of Pacific Decadal Variability?

Tatebe et al. (2013)



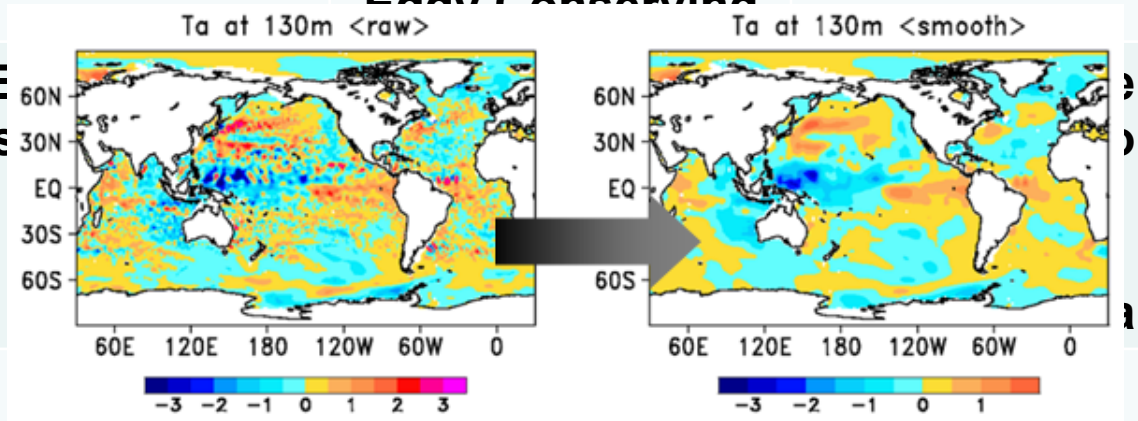




Decadal Prediction Experiments by MIROC

Chikamoto et al. (2012a, b), Mochizuki et al. (2012)

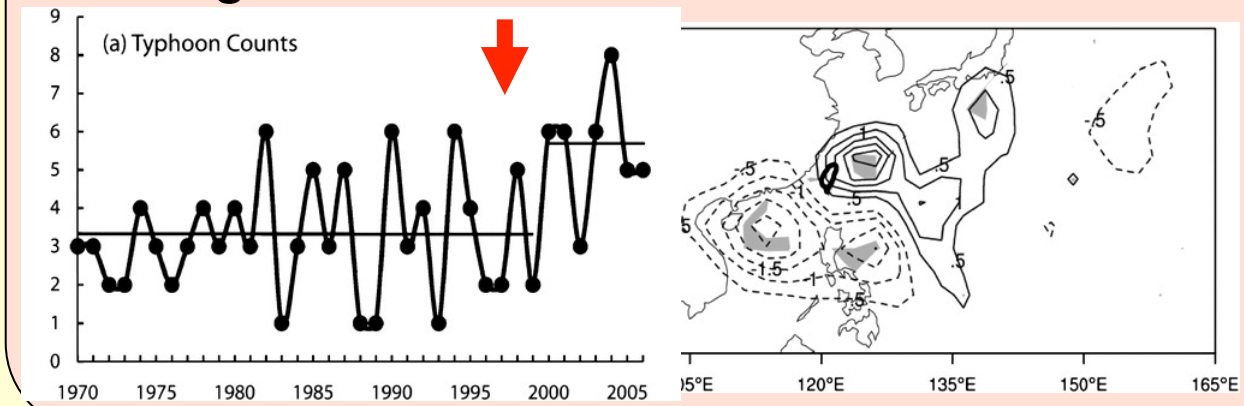
	MIROC3m Nozawa et al. (2005)	MIROC4h Sakamoto et al. (2012)	MIROC5 Watanabe et al. (2010)
Atmosphere	300km L20	60km L56	155 km L44
Ocean	1.4ºx0.5-1.4º L44	0.28ºx0.19º L48	1.4ºx 0.5-1.4º L50
Forcing	CMIP3/SRESA1B	CMIP5/RCP4.5	CMIP5/RCP4.5
Initialization Tatebe et al. (2012)	Ocean T&S IAU (0 ～700m)	Ocean T&S IAU (0～3000m) Eddy-Conserving	Ocean T&S IAU (0～3000m)
Ensemble generation	E As		e on an)
Ensemble Size			
20C3m	10	3	3
Assimilation	10	1	3
Hindcasts	10	3	6



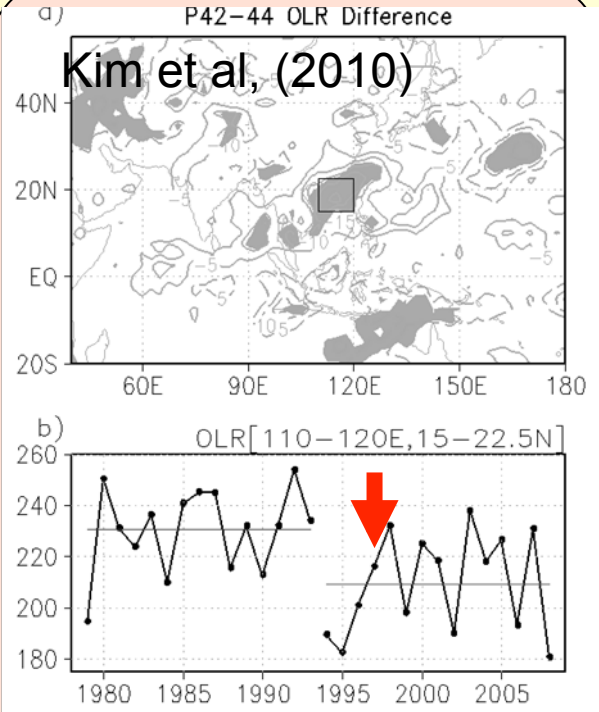
What happened around 1995?

TC regime shift

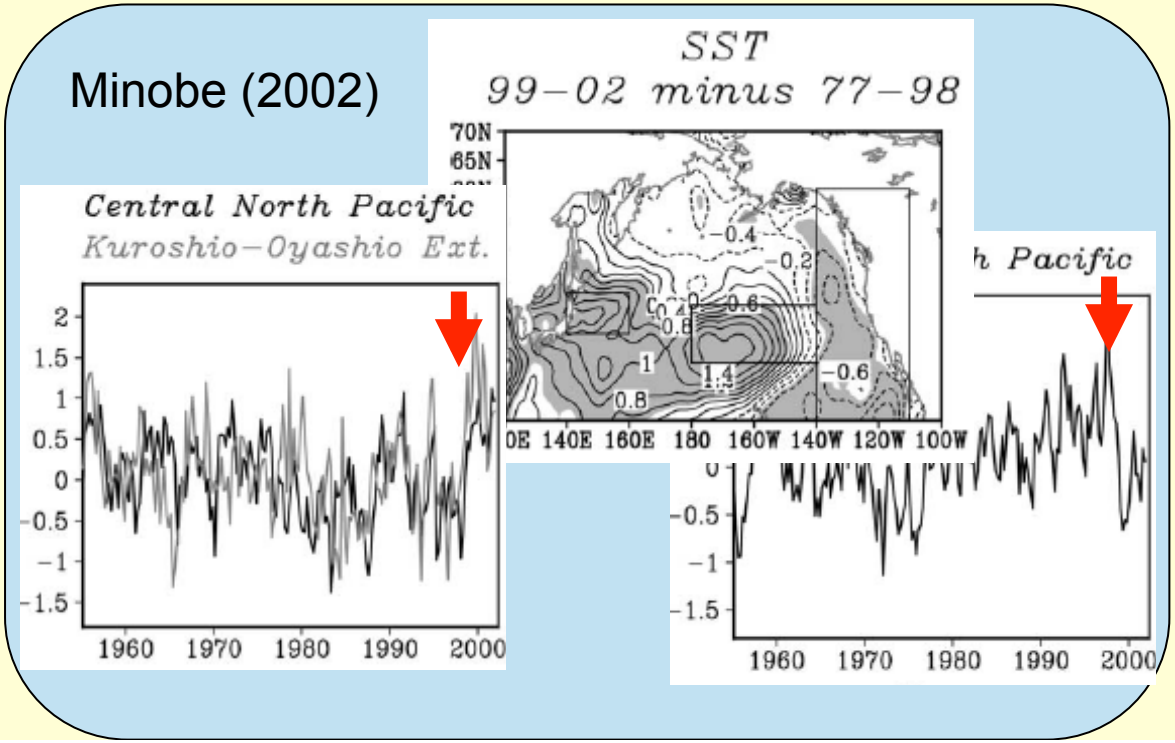
Tu et al. (2009)



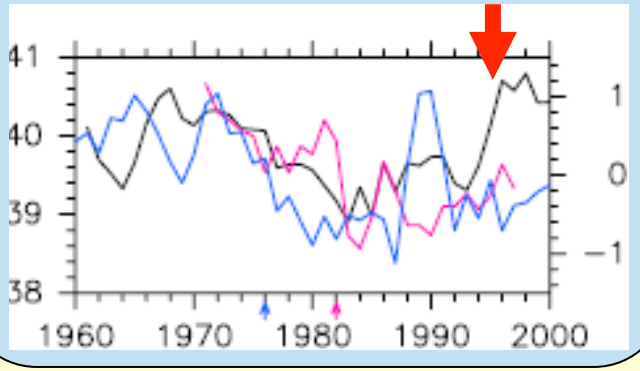
Kim et al, (2010)



Minobe (2002)



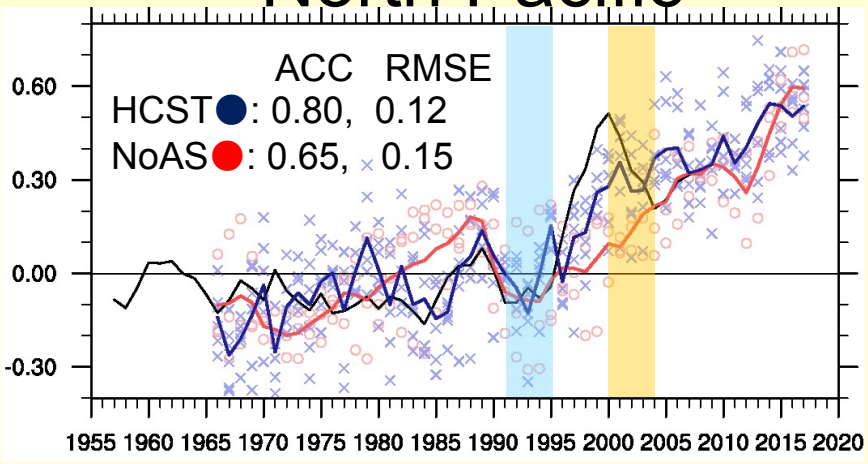
Tatebe and Yasuda (2005)



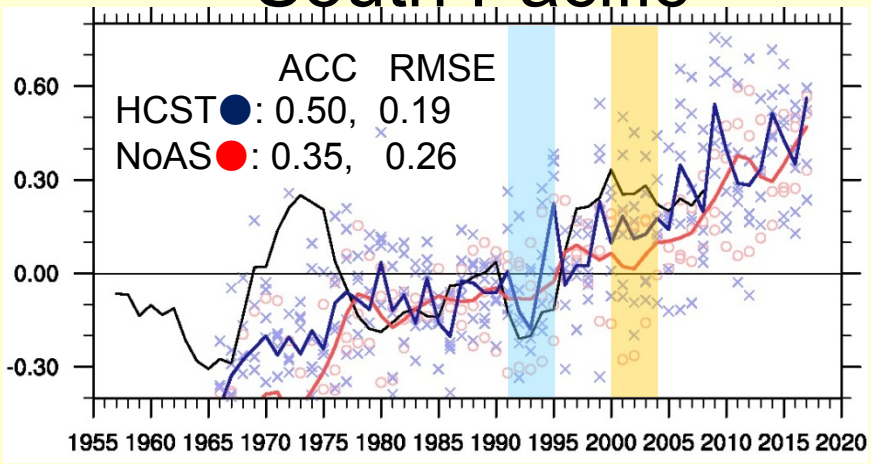
System for Prediction and Assimilation by MIROC

Climate shift in mid-1990s

North Pacific



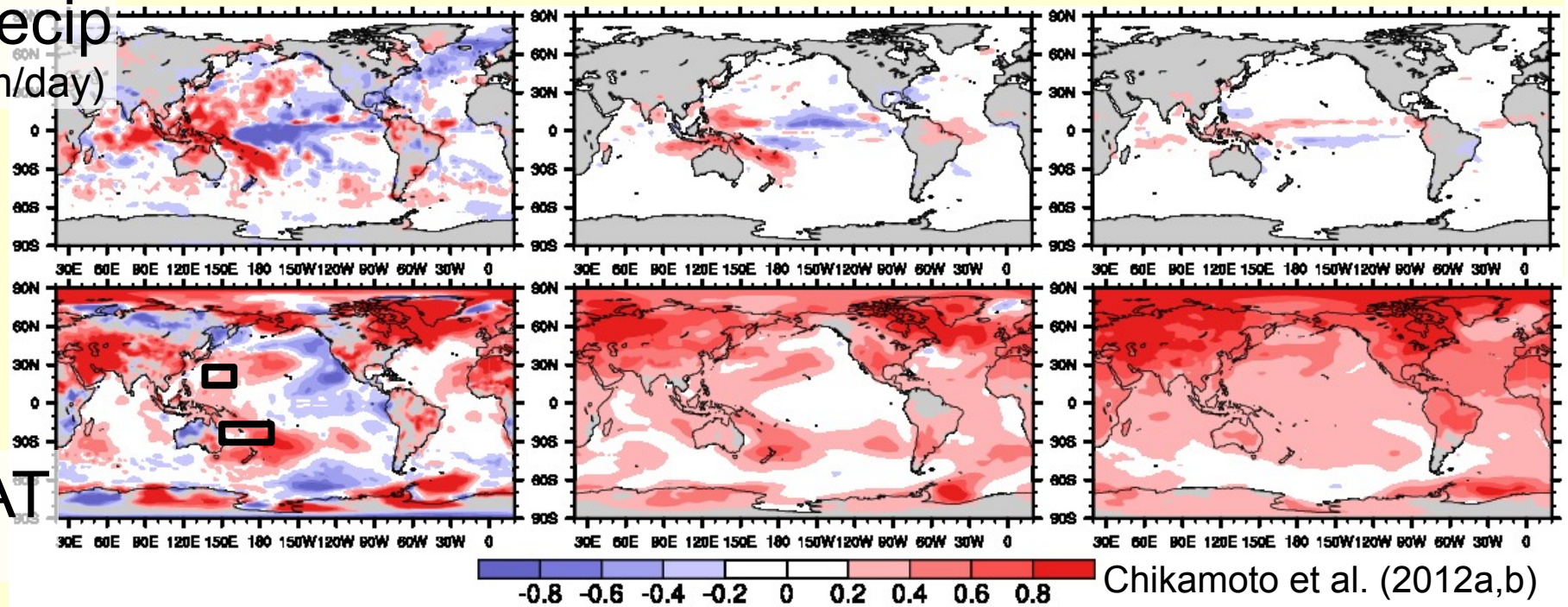
South Pacific



Obs HCST NoAS

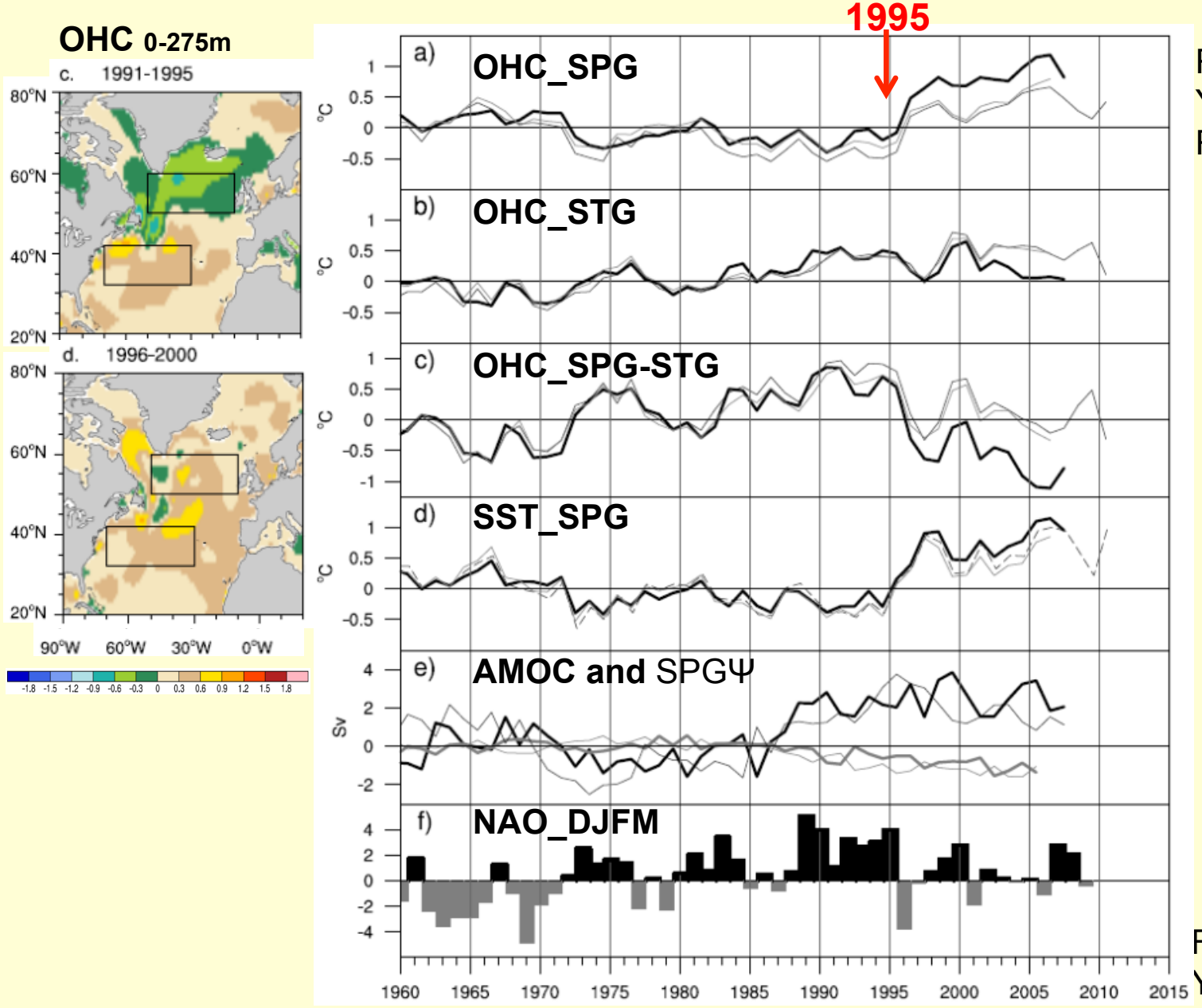
Precip (mm/day)

SAT (°C)



Chikamoto et al. (2012a,b)

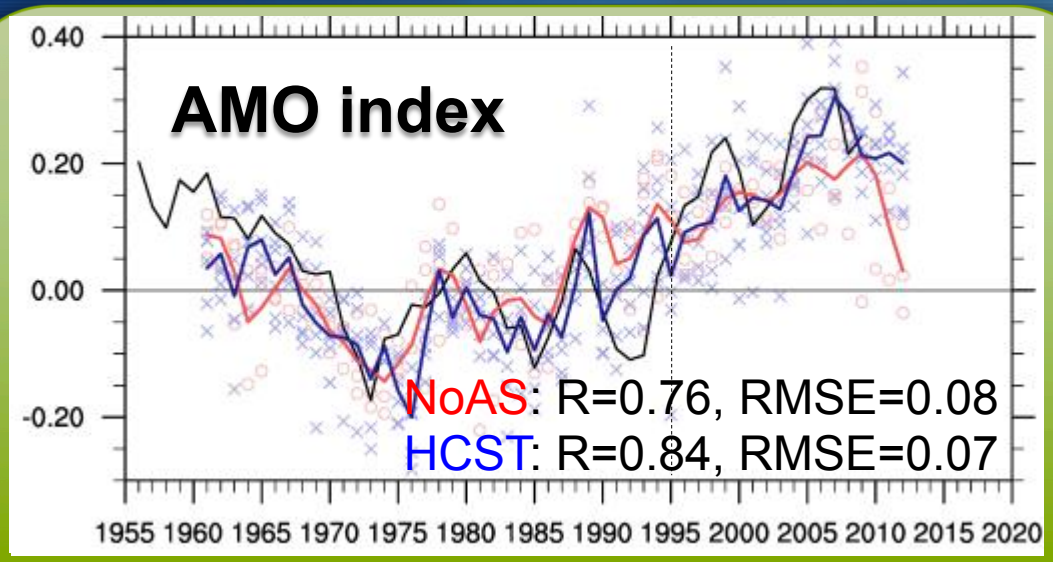
Mid-1990s Shift over the N Atlantic



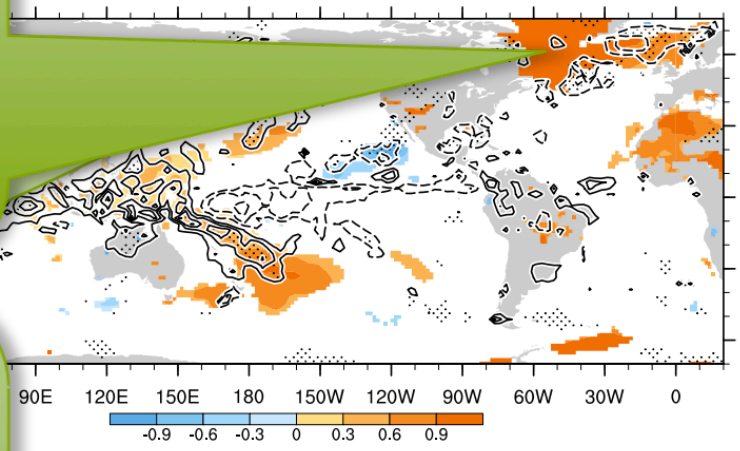
Robson (2010)
Yeager et al. (2012)
Robson et al. (2012)

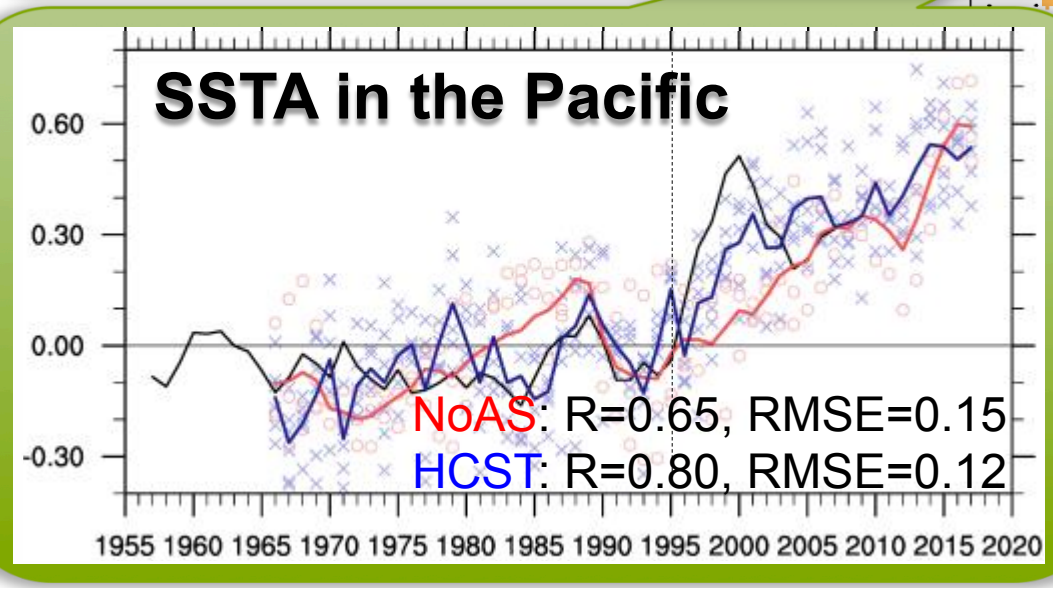
Fig from
Yeager et al. (2012)

Climate change in the Pacific and Atlantic



ed climate change
. & prcp. (5-year mean



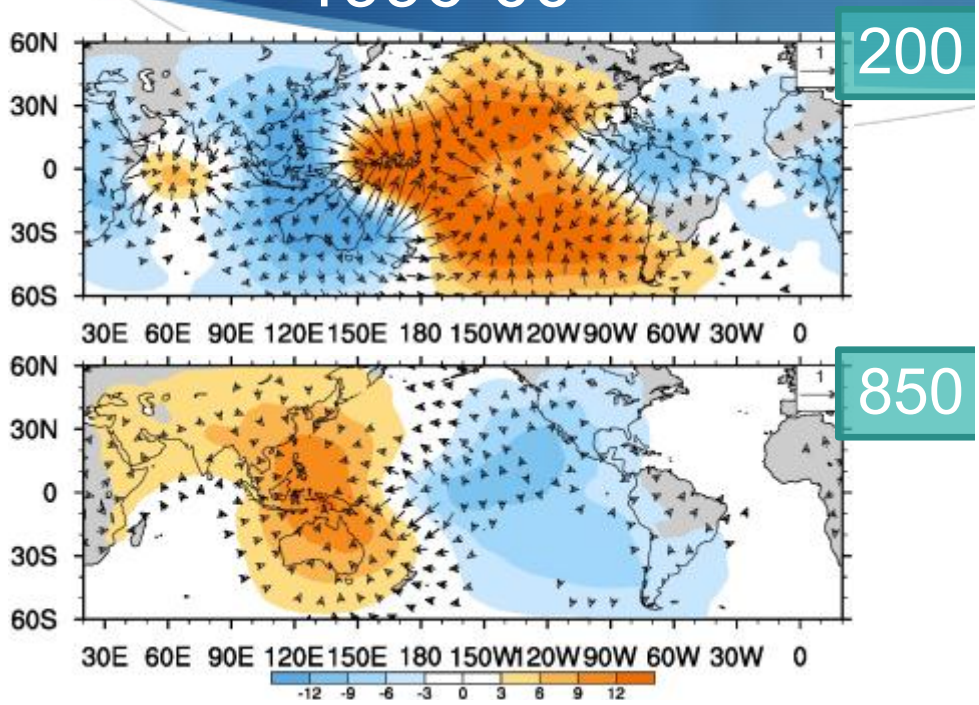


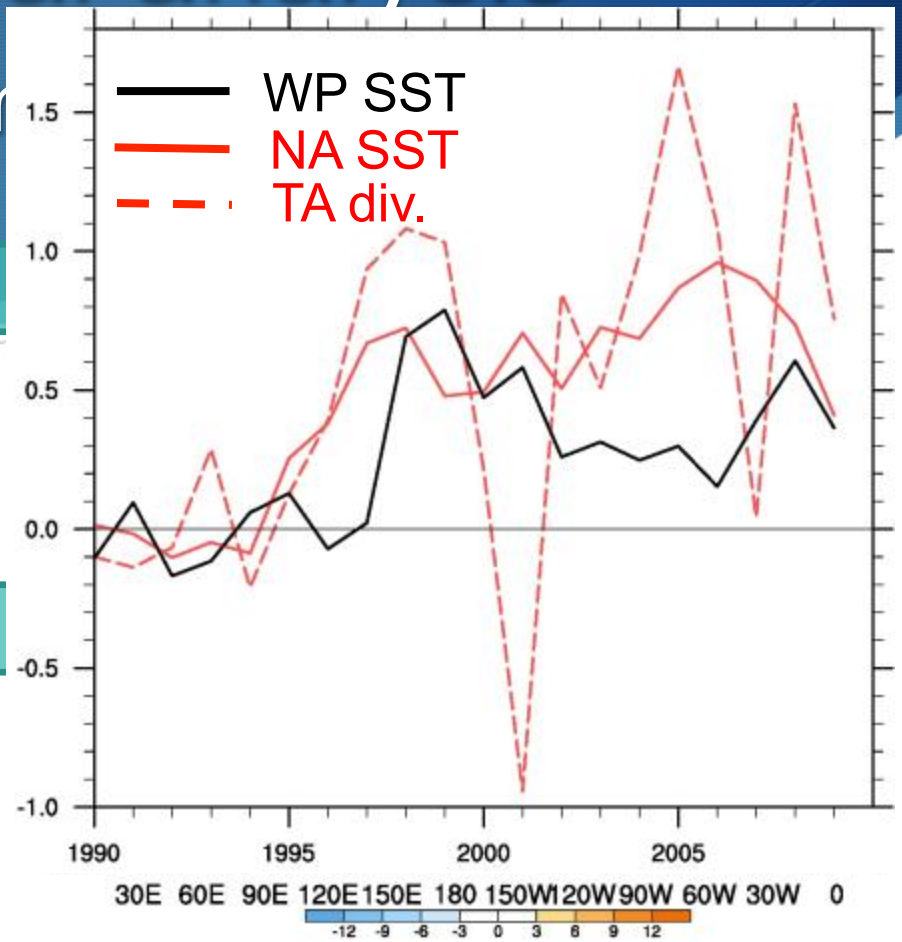
OBS
NoAS
HCST

Observational analysis

Divergent wind anor

1996-00

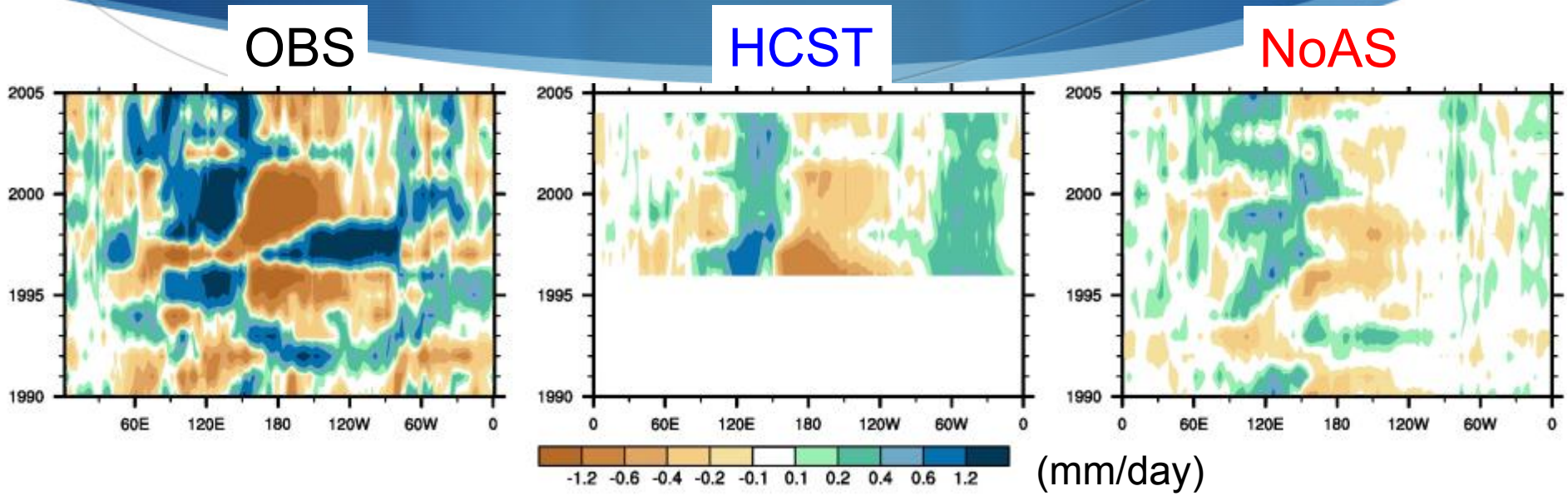




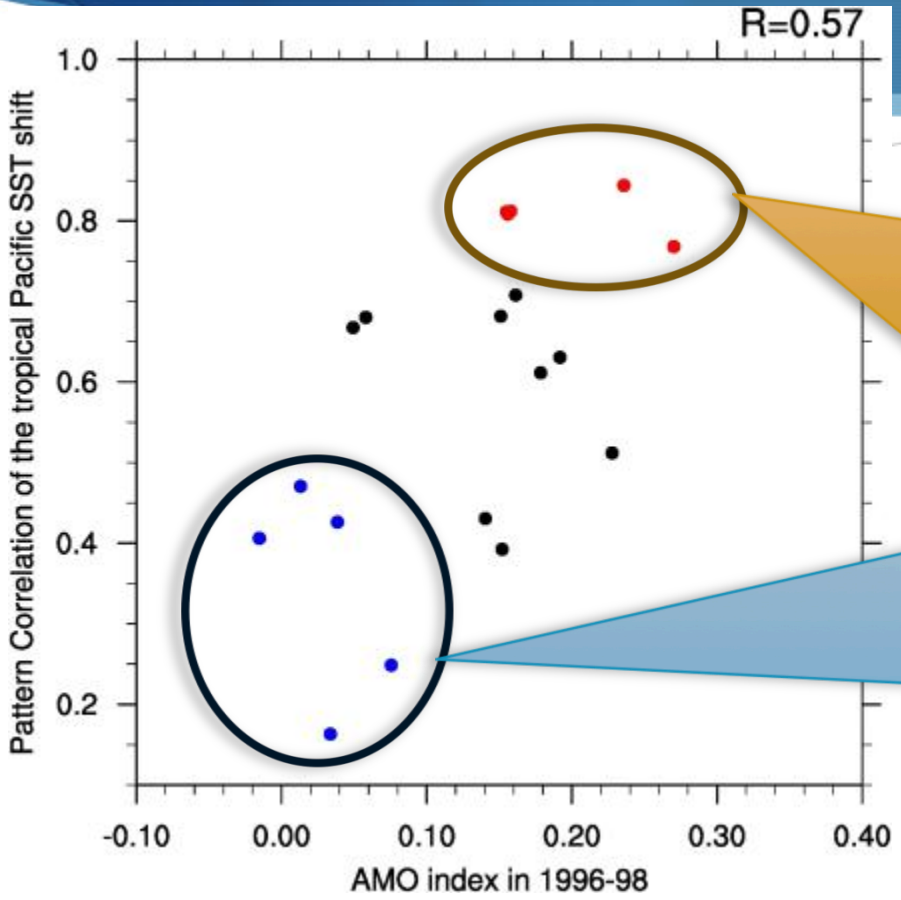
North Atlantic warming → Strengthened Walker circulation → La Nina response

Temporal variation in the tropical precipitation anomalies

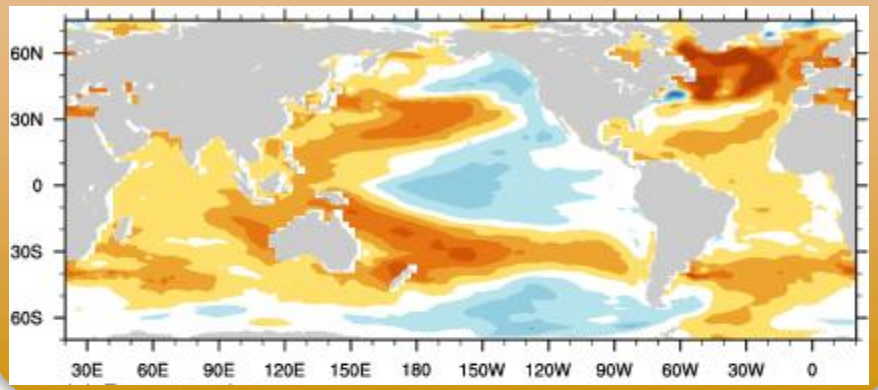
Annual rainfall anomalies from the 1991-95 mean



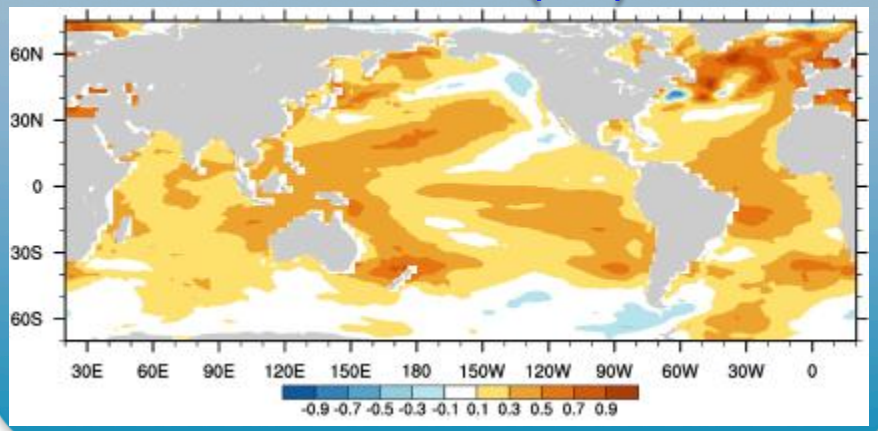
Each member in MIROCs



Good members (x5)



Poor members (x5)



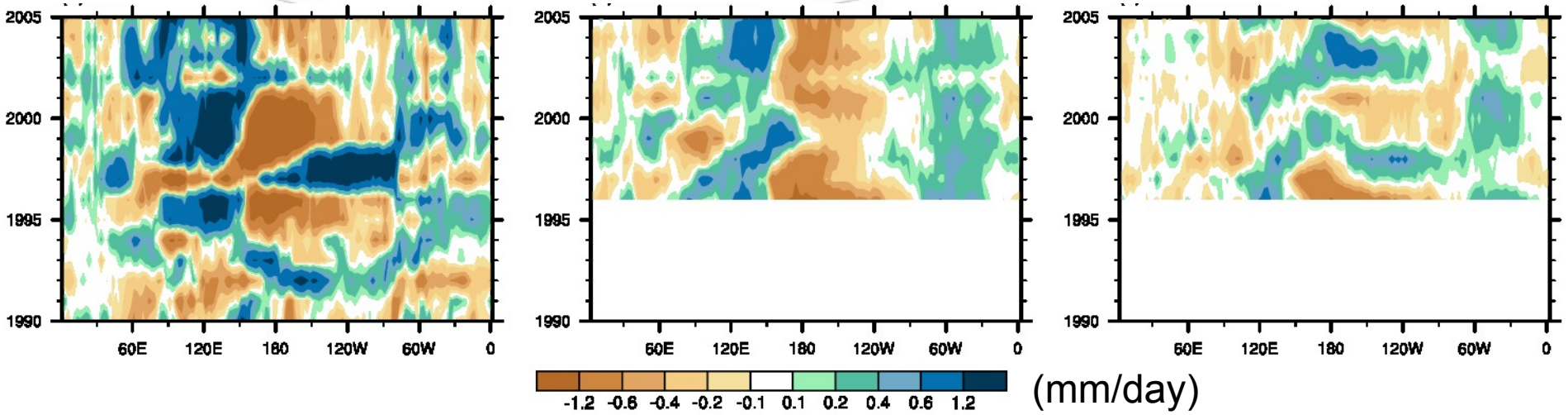
Temporal variation of precipitation in MIROC members

Annual rainfall anomalies from the 1991-95 mean

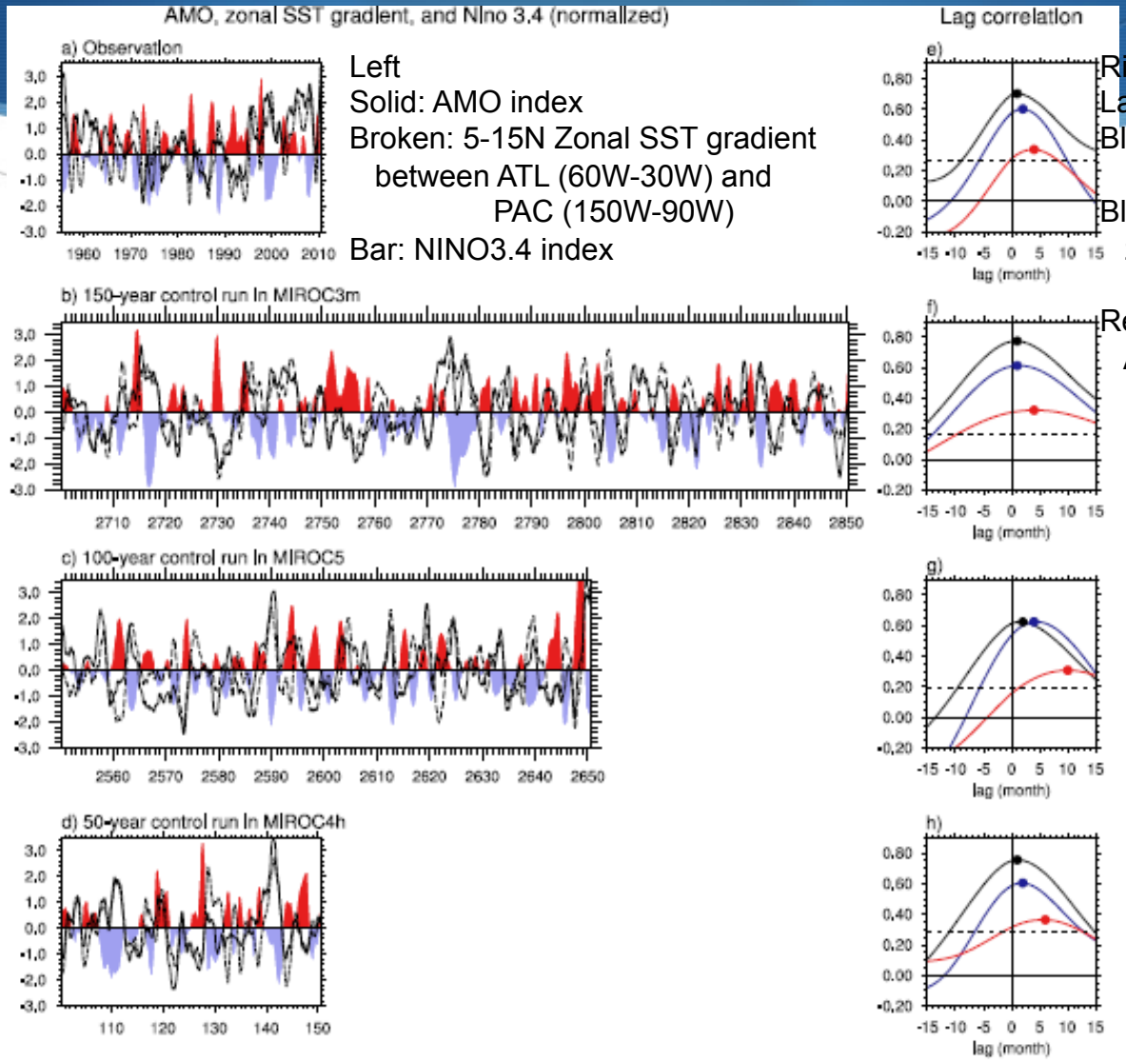
OBS

Good members

Poor members



ATL-PAC lagged relation in Obs and MIROC models



Left
Solid: AMO index
Broken: 5-15N Zonal SST gradient between ATL (60W-30W) and PAC (150W-90W)
Bar: NINO3.4 index

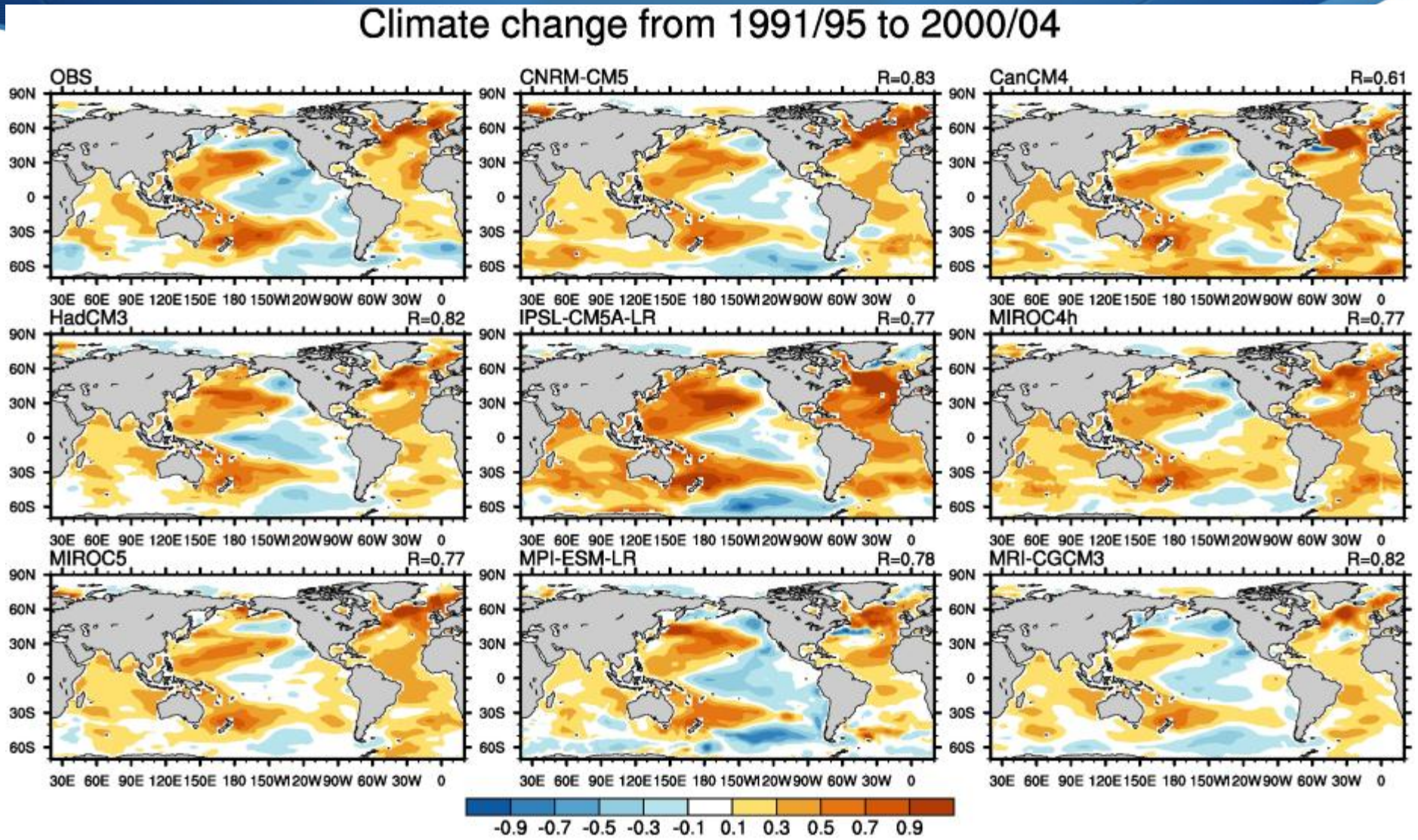
Right
Lag correlation between
Black: AMO and zonal SST gradient
Blue (sign reversed): zonal SST gradient and NINO3.4
Red (sign reversed): AMO and NINO3.4

CMIP5 experiment

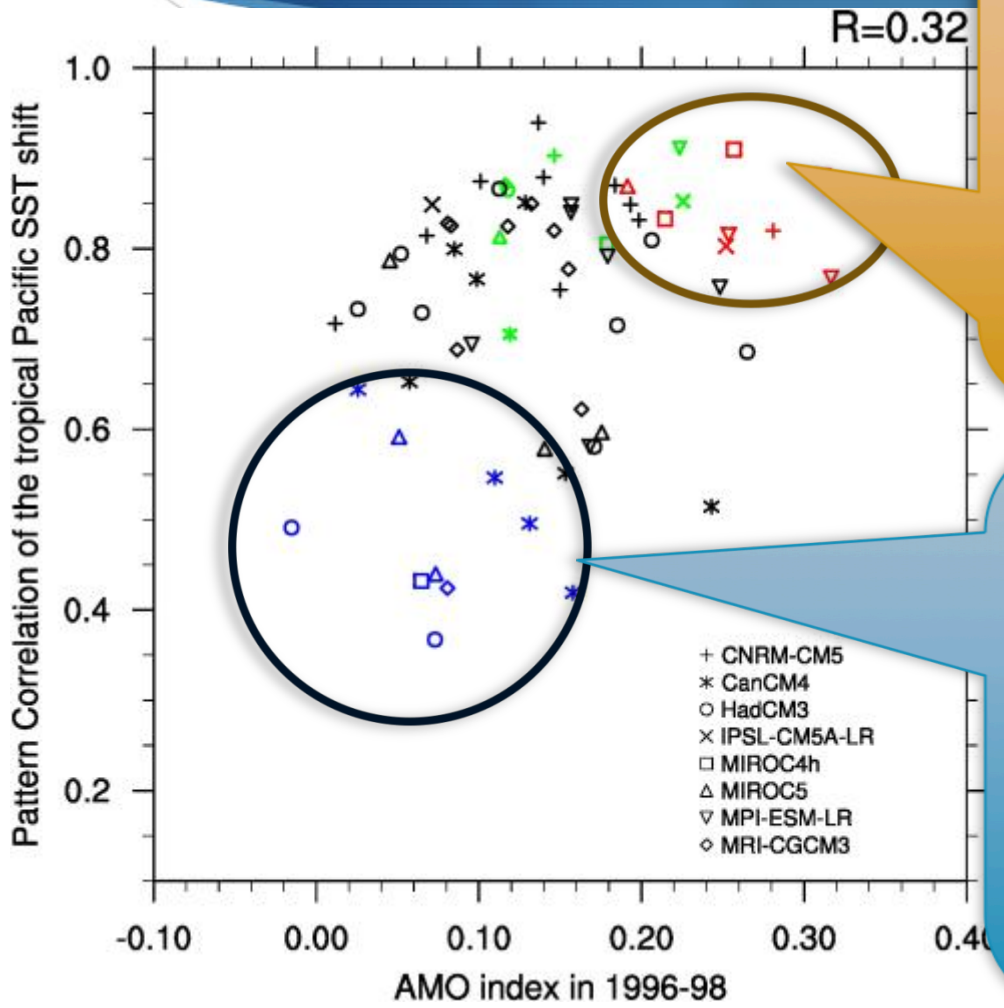
Model	Resolution (Atm., Ocn.)	Number of ens.
CNRM-CM5	TL127 L31, 362x292 L42	10
CanCM4	T63 L35, 256x192 L40	10
HadCM3	N48 L19, 288x144 L20	10
IPSL-CM5A-LR	96x95x39, 182x149 L31	3
MIROC4h	T213 L56, 1280x912 L48	3
MIROC5	T85 L40, 256x224 L50	6
MPI-ESM-LR	T63 L47, GR15L40	10
MRI-CGCM3	TL159 L48, 360x368 L51	9

1. A model drift is calculated by averaging the difference between the observation and the ensemble mean of prediction in each model.
2. Anomalies are defined as departure from the observed 1971-2000 mean after removing the model drift in each model.

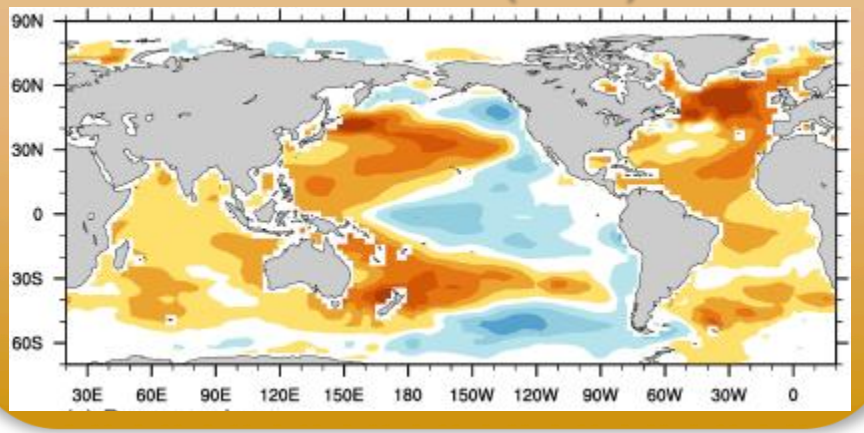
CMIP5 results



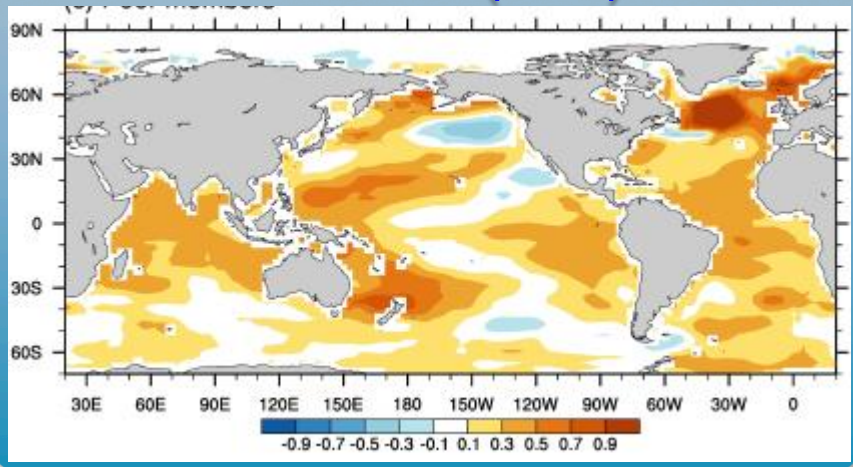
Each member in CMIP5



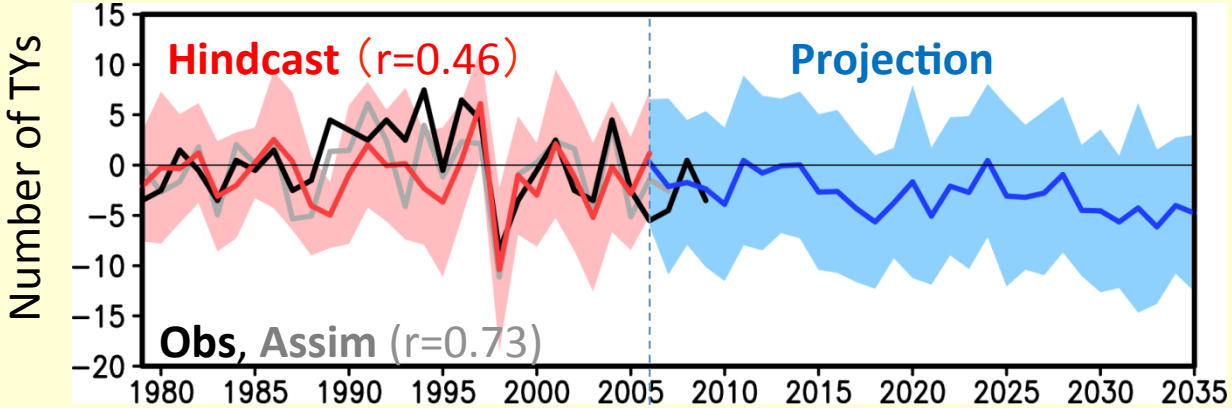
Good members (x10)



Poor members (x10)

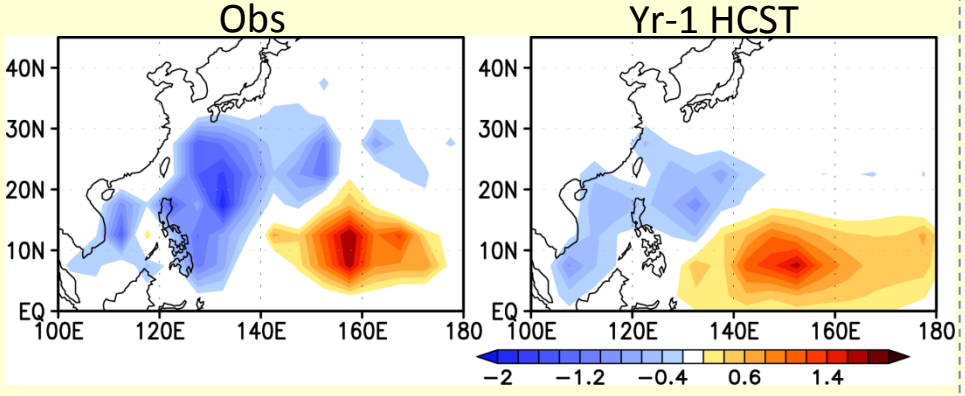


Projected changes in Typhoons

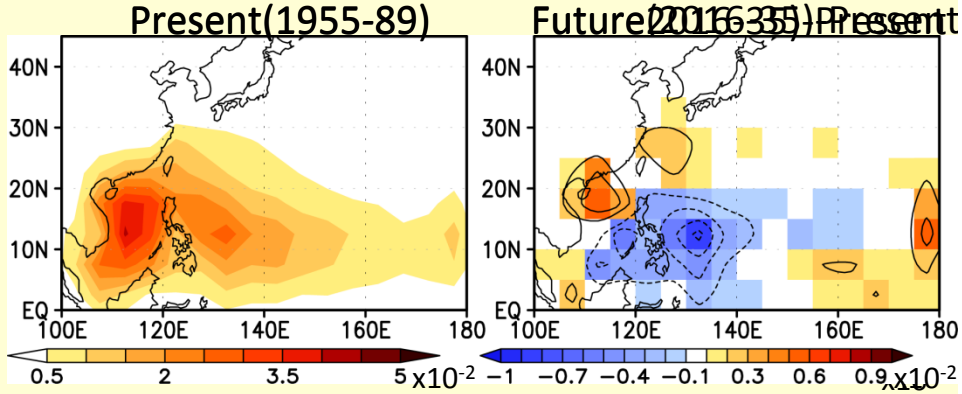


Mori et al. (2012)

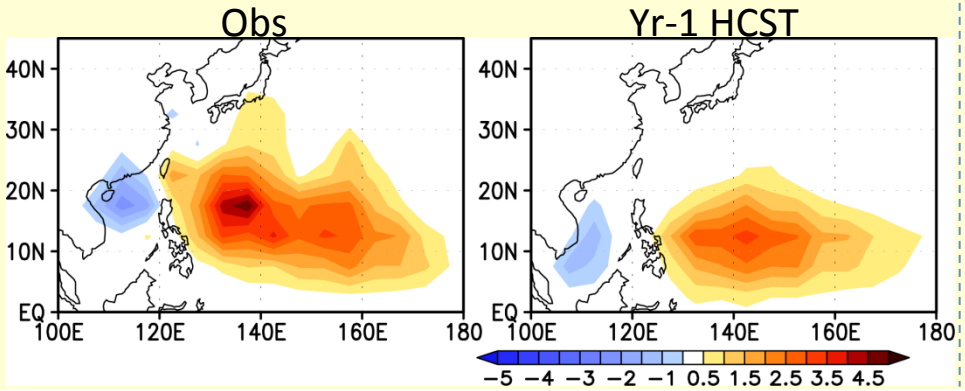
Genesis Frequency during El Nino



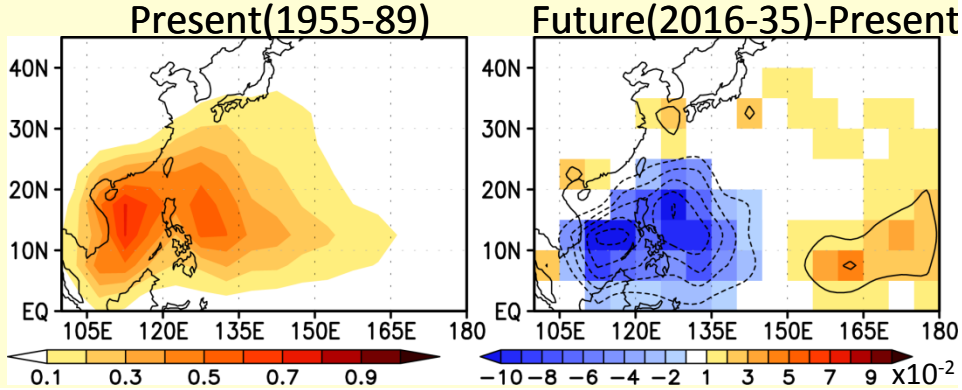
Future Change (Genesis) PDF)



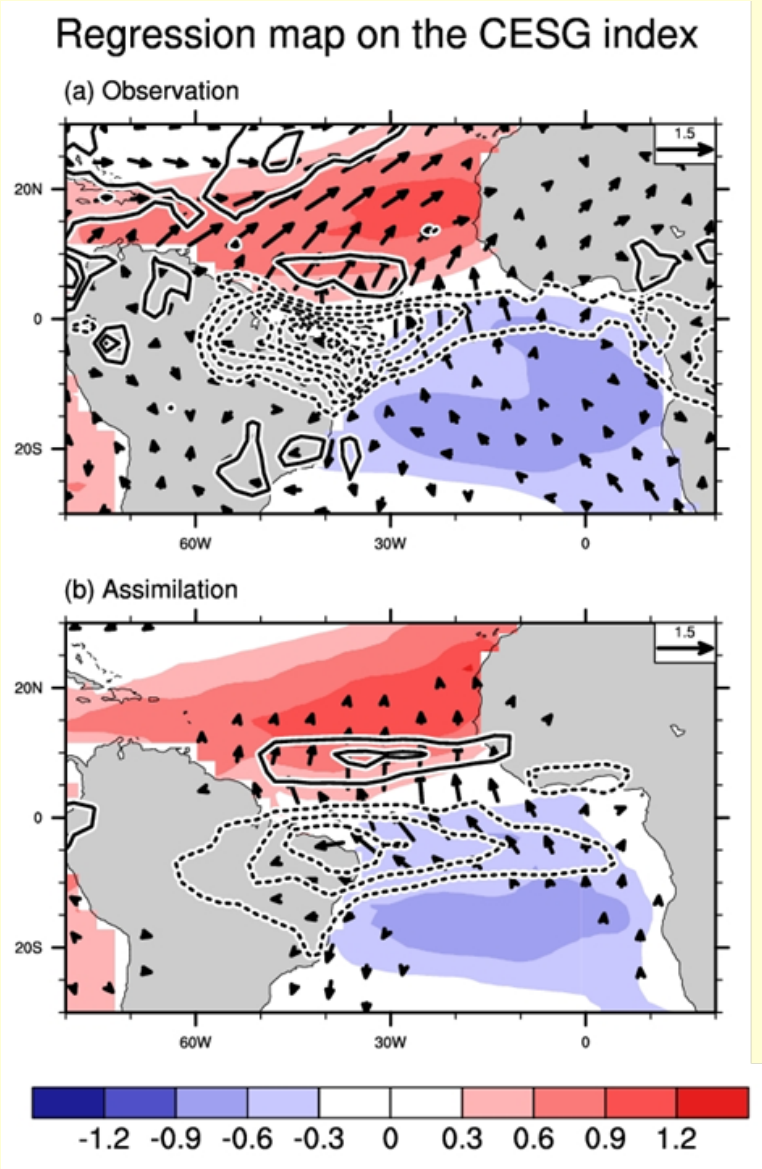
Occurrence Frequency during El Nino

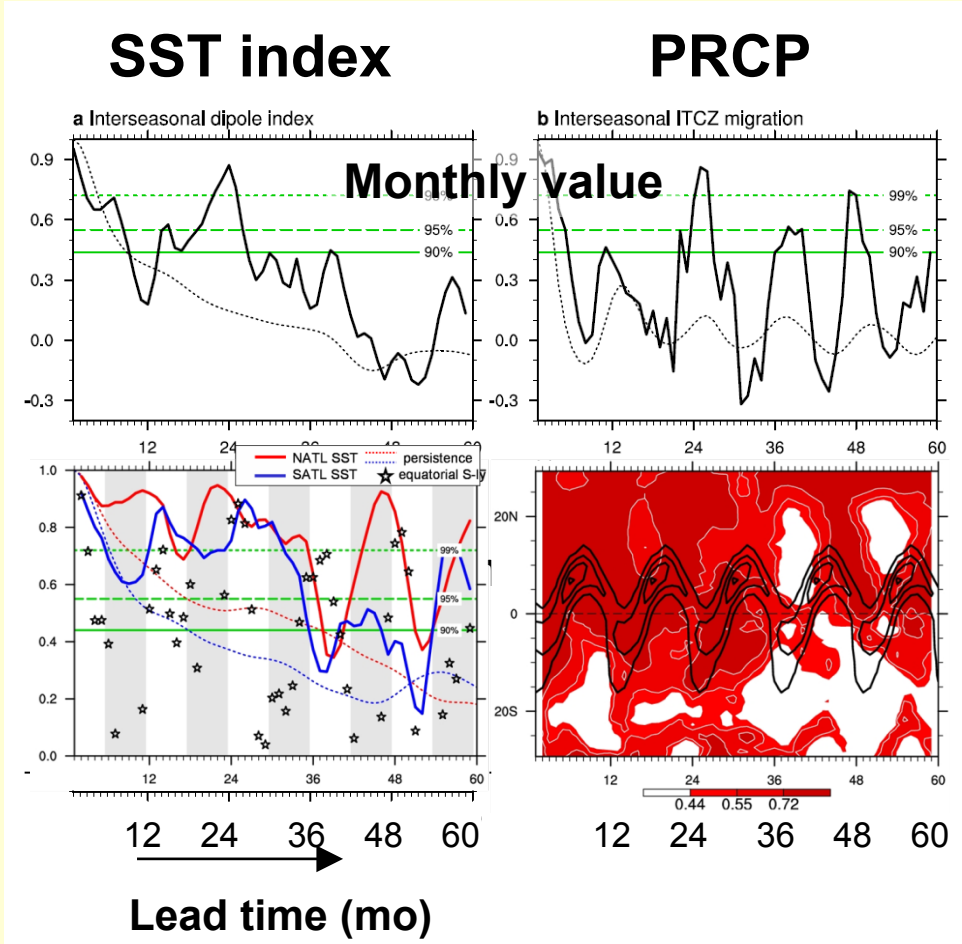


Future Change (Occurrence) PDF)



Tropical Atlantic dipolar mode

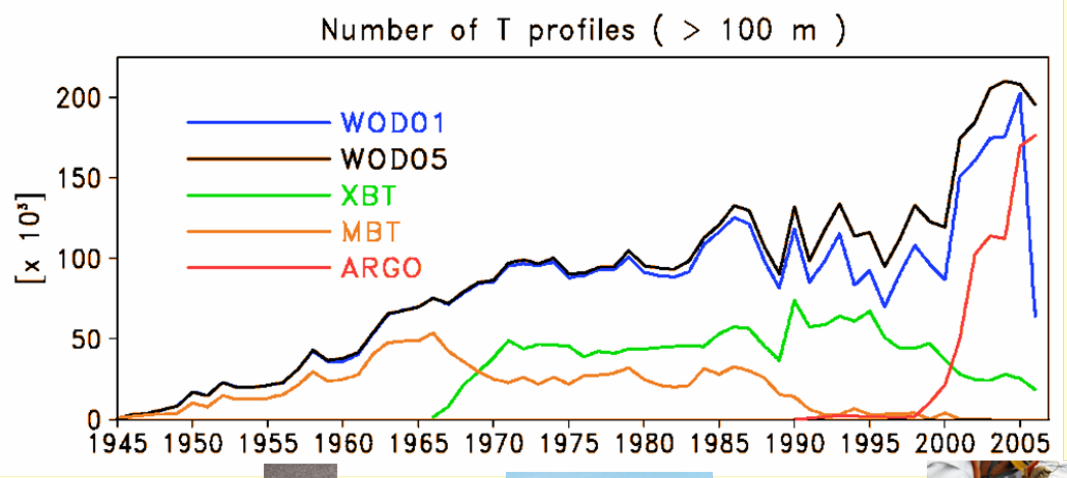


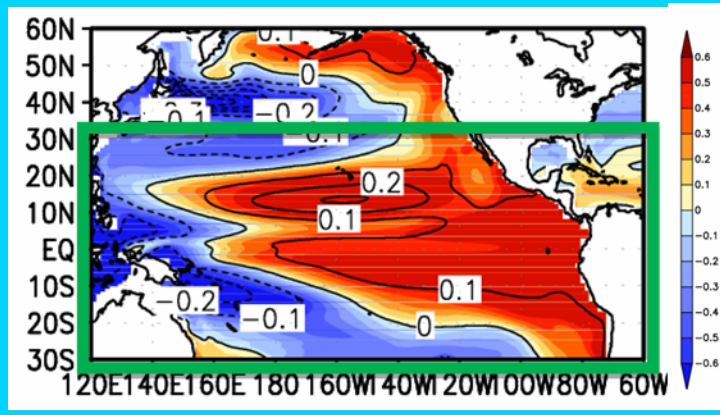


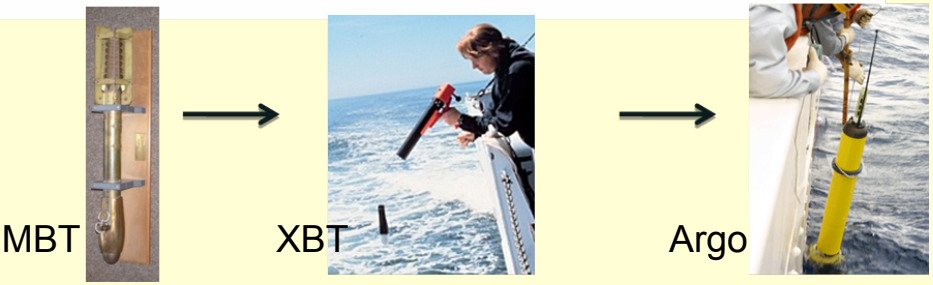
Chikamoto et al. (2010)

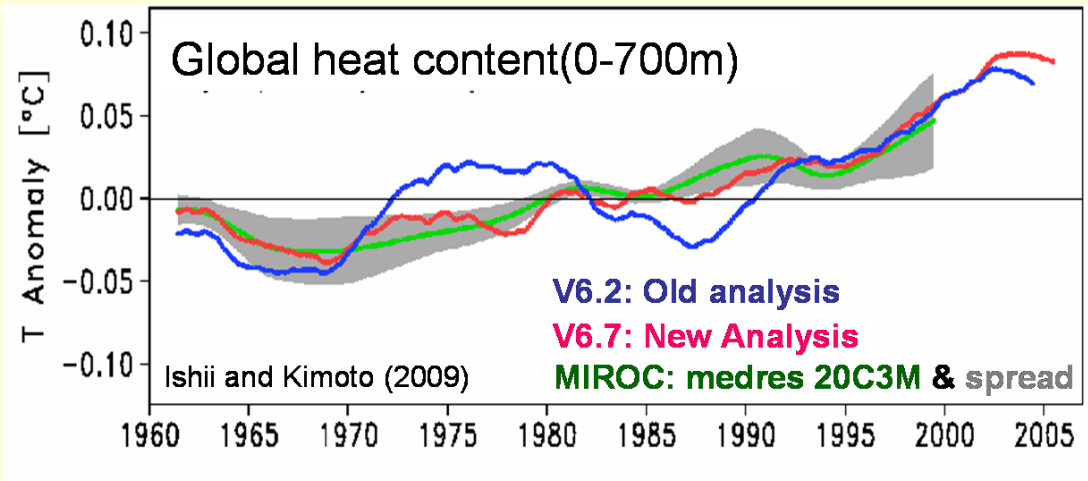
Impact of historical XBT bias correction

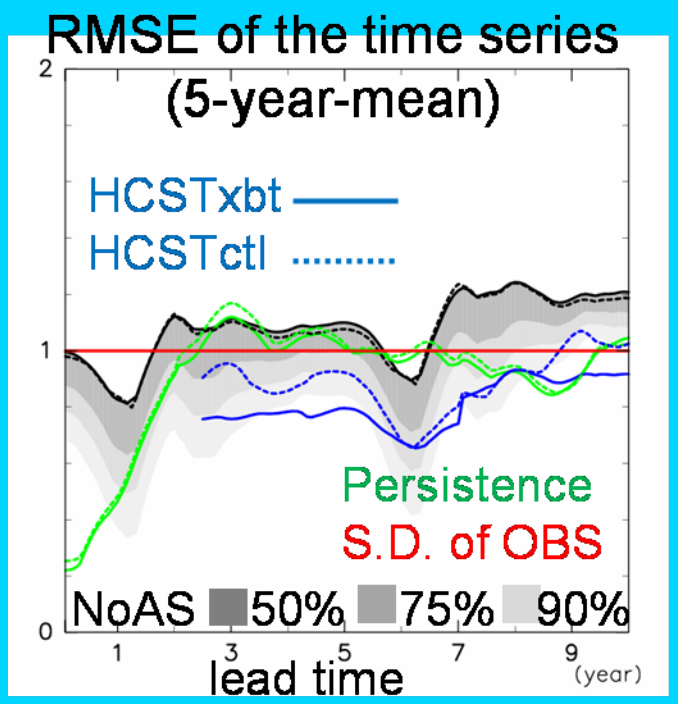
Yasunaka et al. JC, in press)



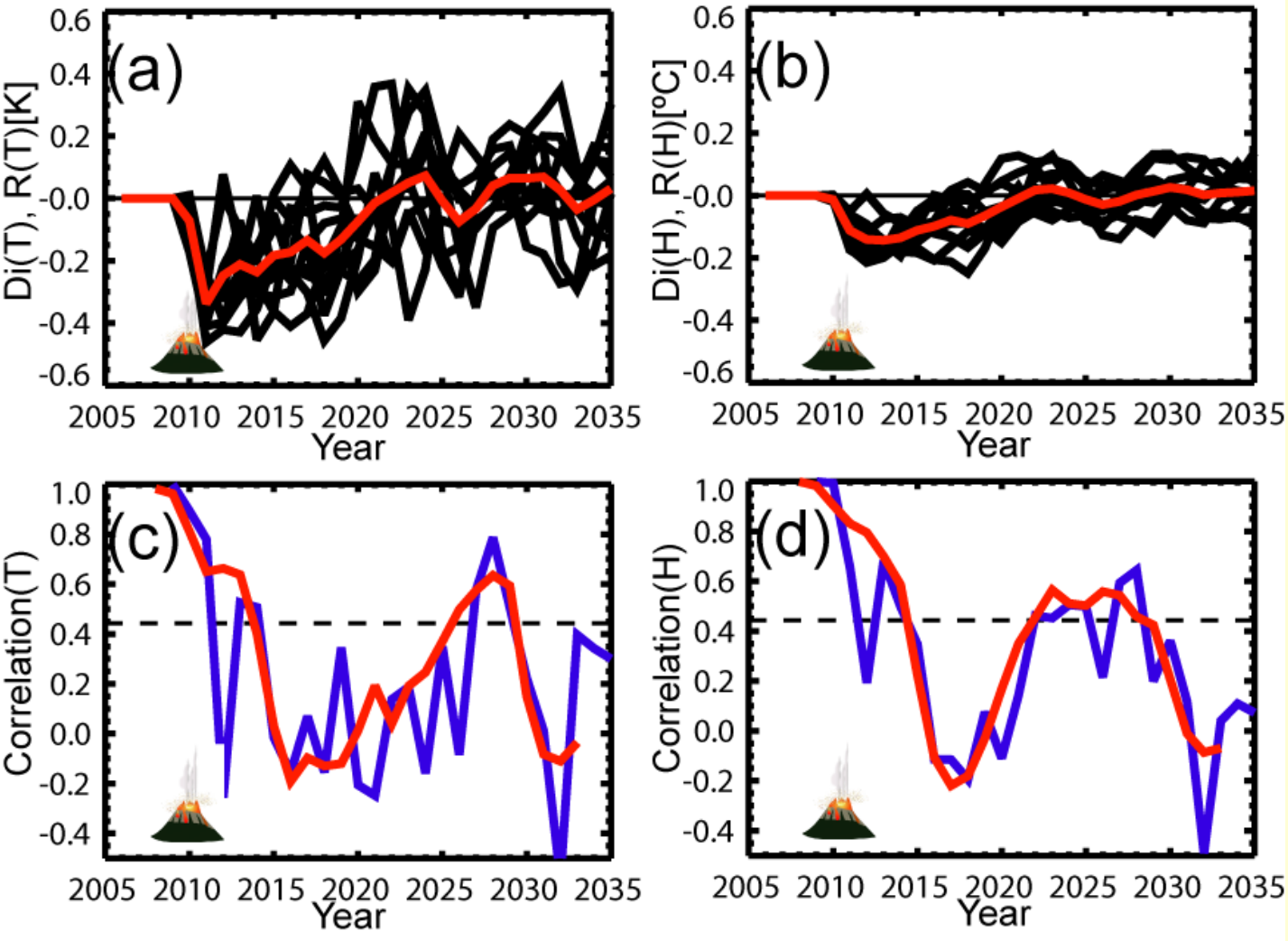








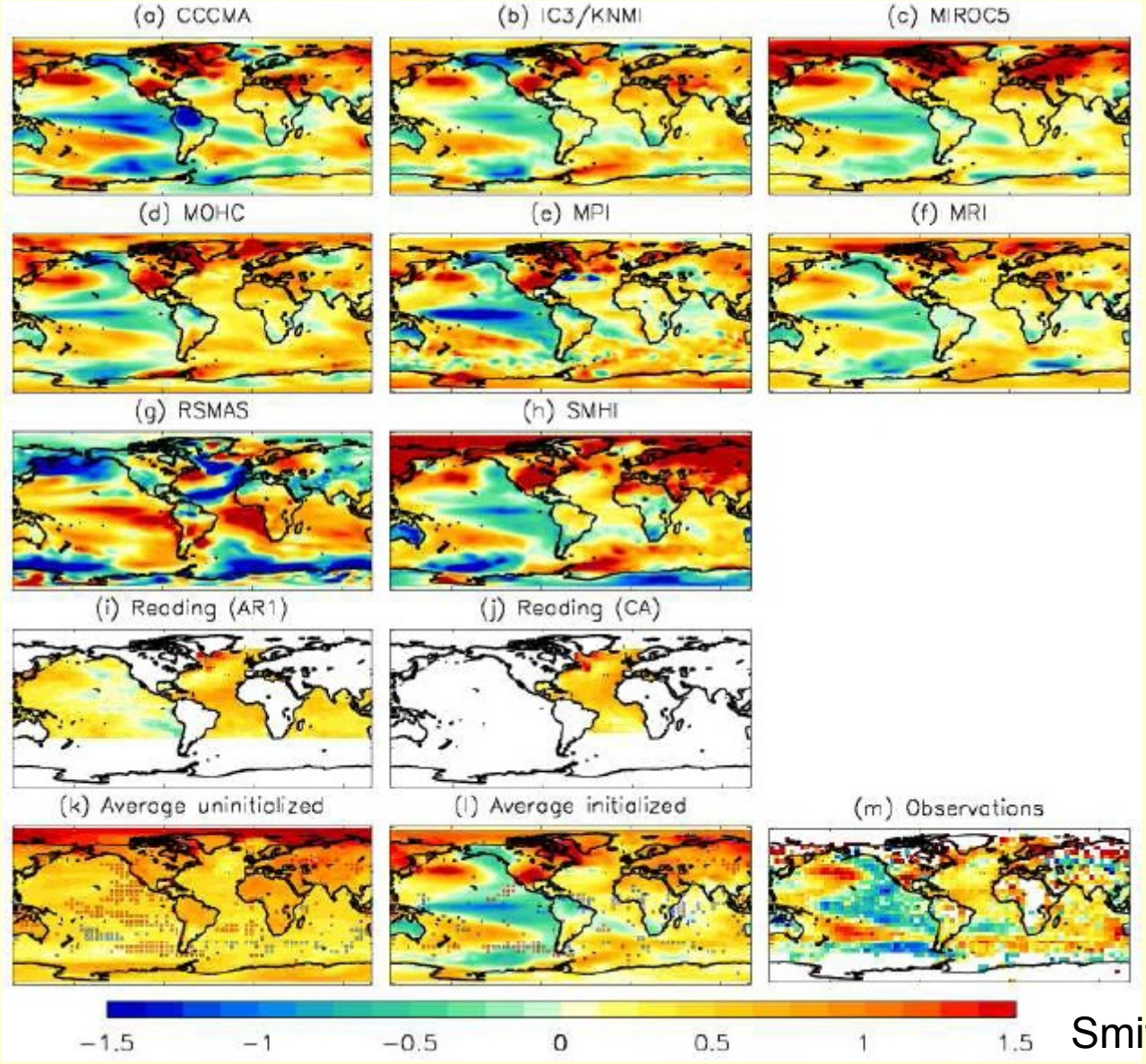
Impact of 2010 “Pinatubo” eruption



SST **T 0-125m**

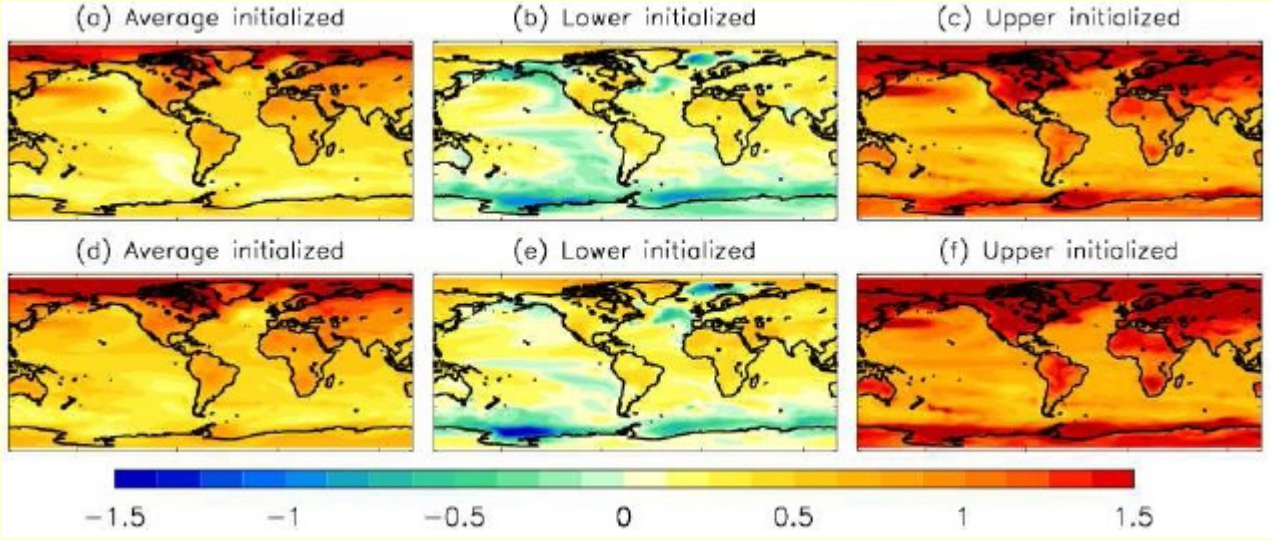
Shiogama et al. (2010; Adv. Meteor.)

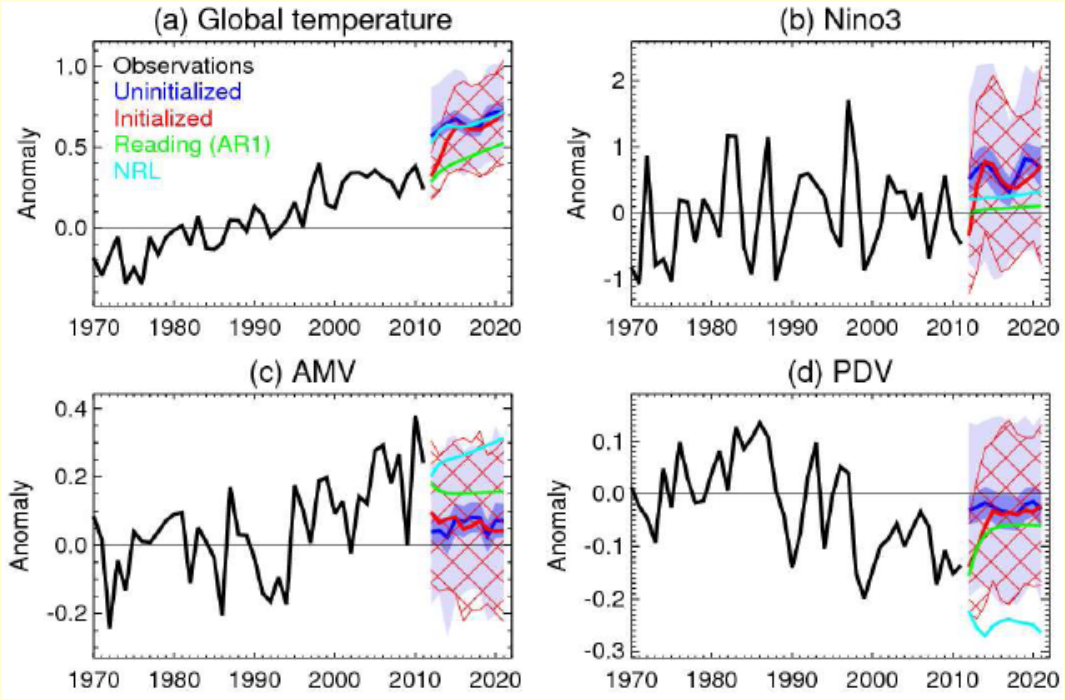
Real-time Forecast for 2011



Smith et al. (2012)

Real-time Forecast for 2012-16

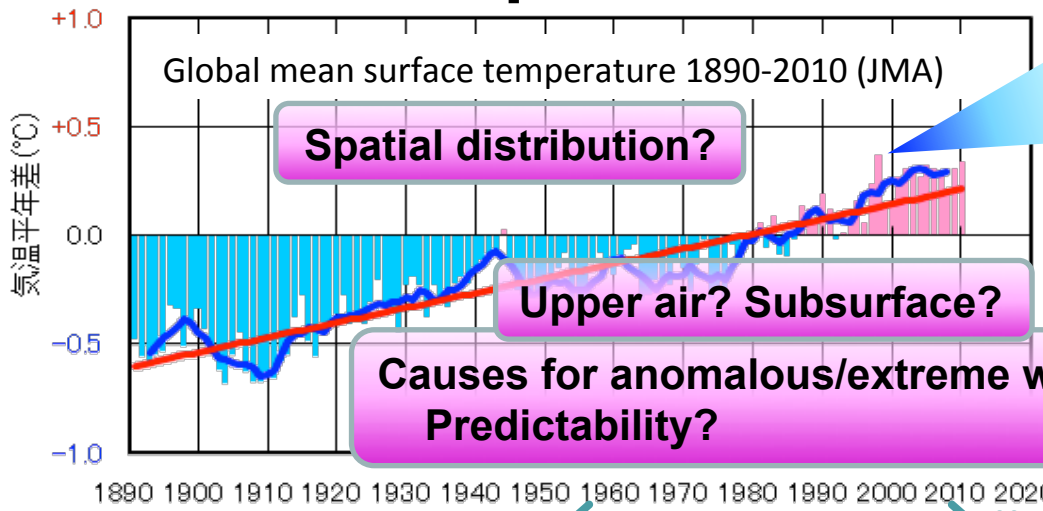


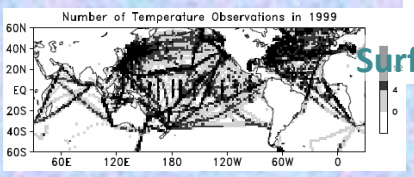


Smith et al. (2012)

100-year reanalysis/reforecast of coupled ocean-atmosphere climate system?

System for Prediction and Assimilation by MIROC





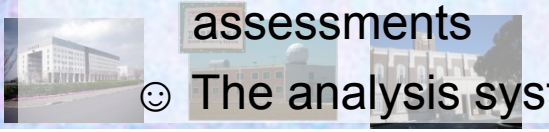
Surface Obs

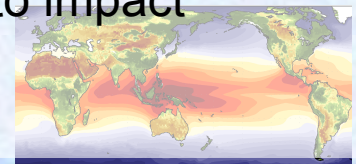
Upper-air Obs

Ocean subsurface Obs

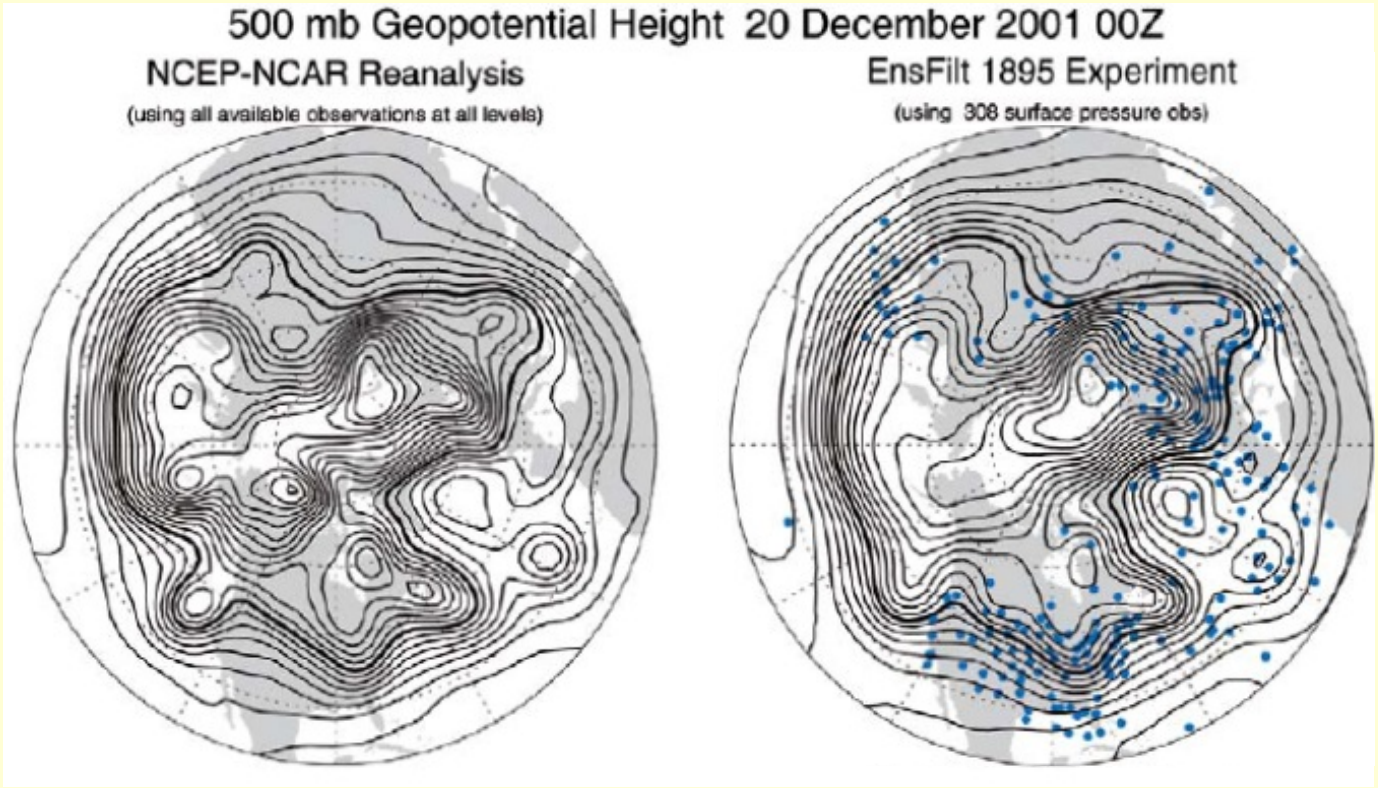
Coupled atmosphere-ocean reanalysis

- **Reanalysis/reforecast of historical climate data using a state-of-the art coupled ocean-atmosphere climate model**
  - ☺ A 100yr-long, 3D reconstruction of atmosphere and oceans
  - ☺ Promote studies of natural decadal variability
  - ☺ Assessments of anomalous/extreme weather and their predictability
  - ☺ Increased credibility of climate predictions, contributing to impact assessments
  - ☺ The analysis system can serve as a research platform





The 20th Century Reanalysis Project



RMSE=49.2m

Compo et al. (2006, 2011)