Hiatus and decadal prediction research using MIROC climate model

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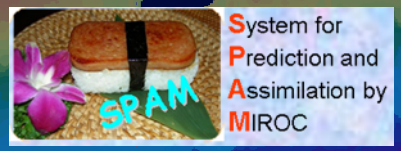
with

special thanks to

Masahiro Watanabe (AORI, Univ. Tokyo),
Masayoshi Ishii (MRI/JMA)

and

Team SPAM



SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

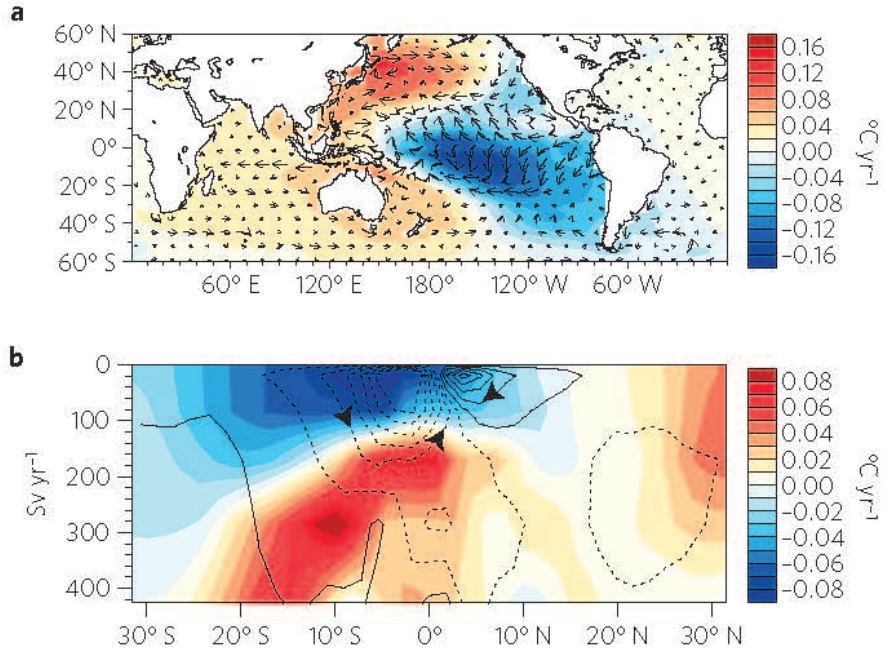
Intensified Pacific trades and heat uptake

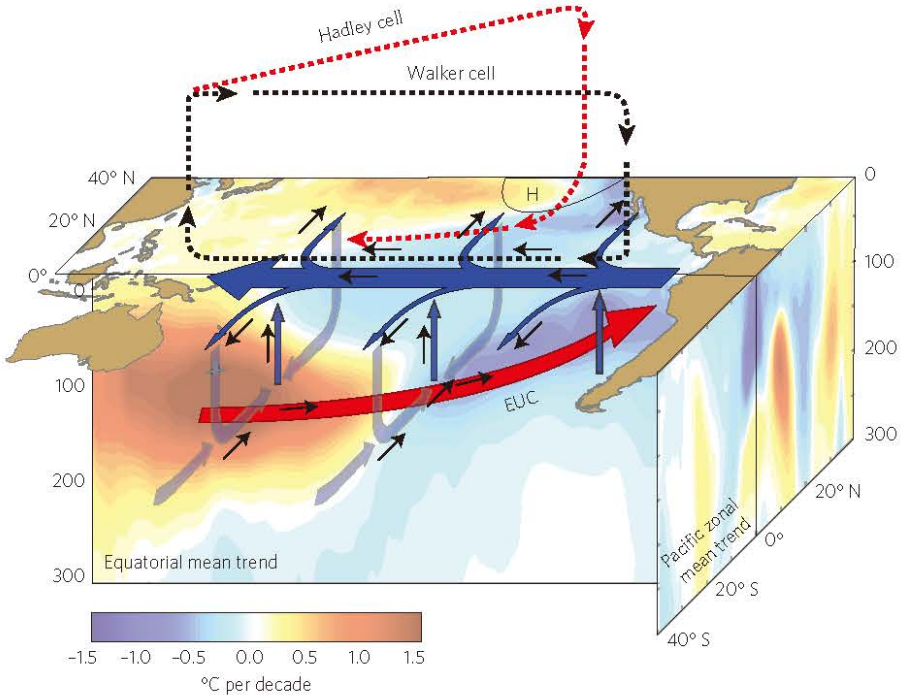
'Pacemaker' experiments using CGCM

*** Eastern Pacific cooling → hiatus** (Kosaka and Xie 2013 Nature)

*** Intensified Pacific trades in the 2000s**
→ hiatus w/ increasing ocean heat uptake (England et al. 2014 Nature CC)

Model response to 1992-2011 wind trend





England et al. (2014)

Partial Wind Overriding historical experiments

MIROC5.2 (T85L40) 5-member ensembles for 1958-2012

* **PWO-Hist: Tropical (30S-30N) τ anomaly replaced w/ JRA reanalysis**
* **PWO-Nat: As in PWO-hist but with external forcing fixed at 1850**

2001-2010 average:

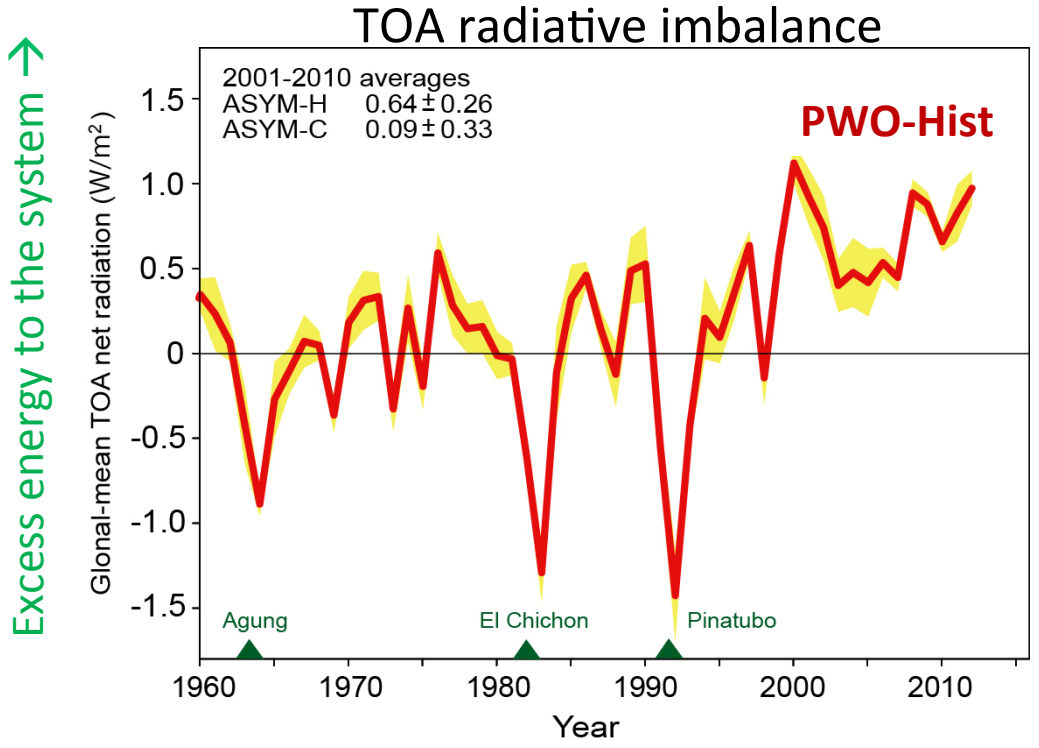
PWO-Hist

✓ **0.64±0.26 W/m^2**

CERES

✓ **0.5±0.43 W/m^2**
(Loeb et al. 2012 NGeo)

✓ **0.62±0.43 W/m^2**
(Allan et al. 2014 GRL)



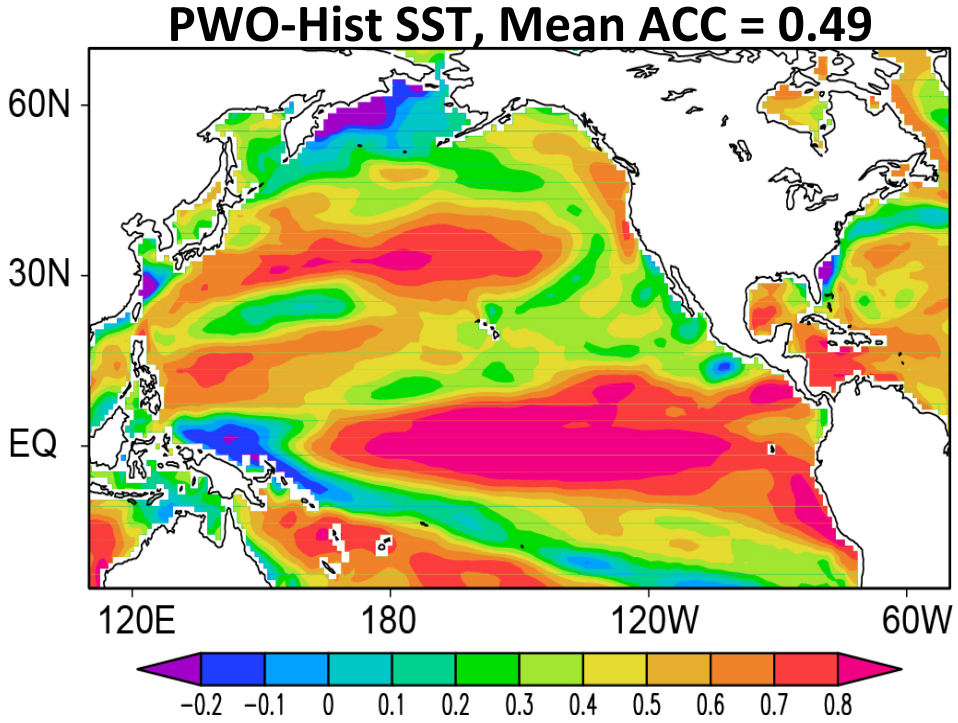
Watanabe et al. (2014)

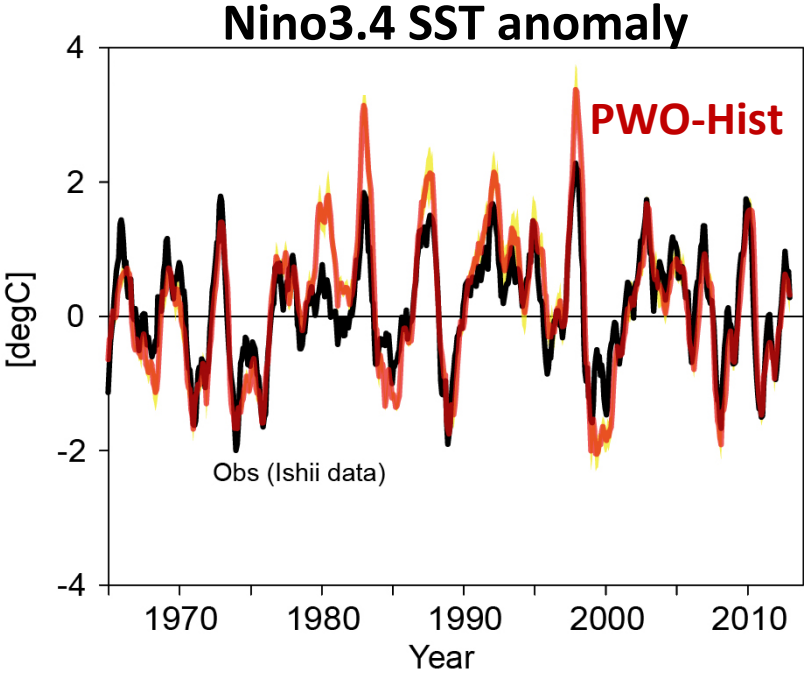
Partial Wind Overriding historical experiments

MIROC5.2 (T85L40) 5-member ensembles for 1958-2012

*** PWO-Hist: Tropical (30S-30N) τ anomaly replaced with JRA55 reanalysis**

Reproducibility of the Pacific SST variability



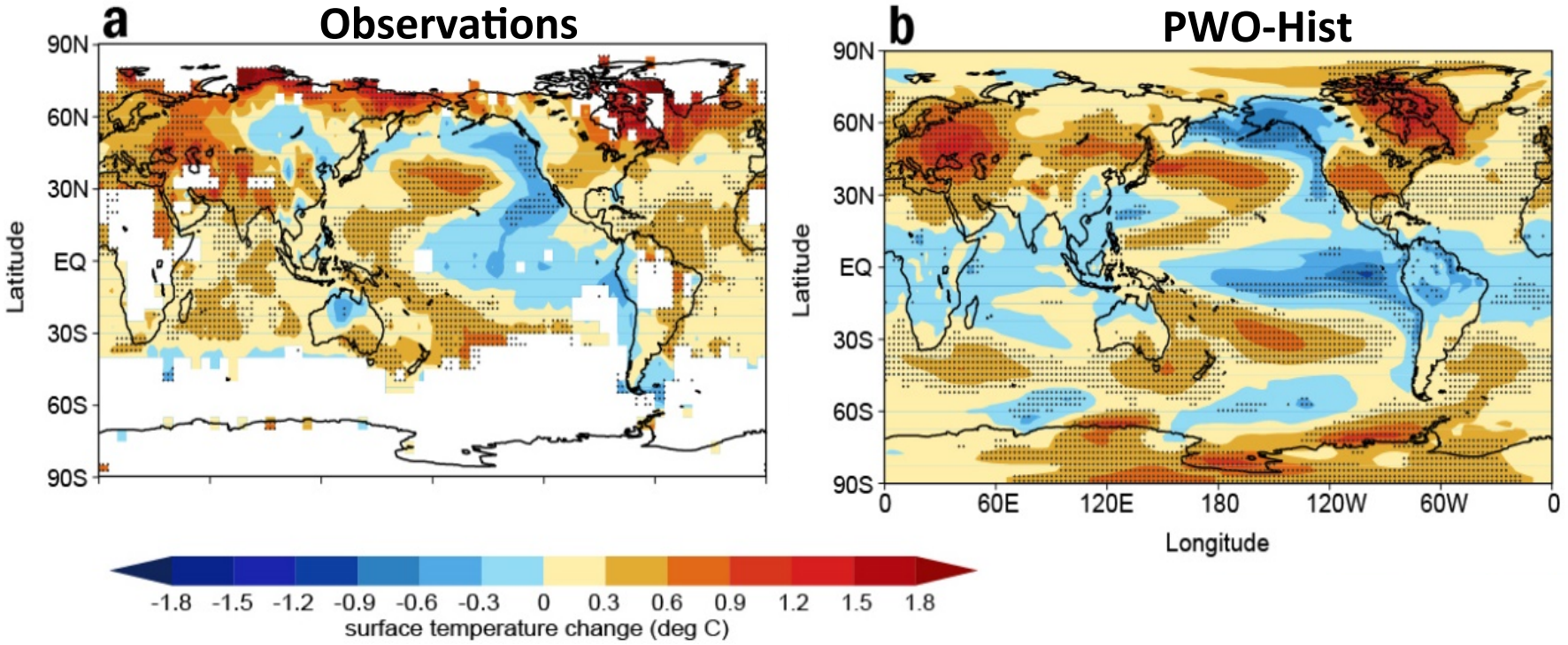


Hiatus reproduced in MIROC5.2

Partial wind overriding experiments

Tropical ocean wind stress anomalies are sufficient to reproduce surface temperature anomaly pattern in the hiatus

SAT change from 1990-1999 to 2001-2012

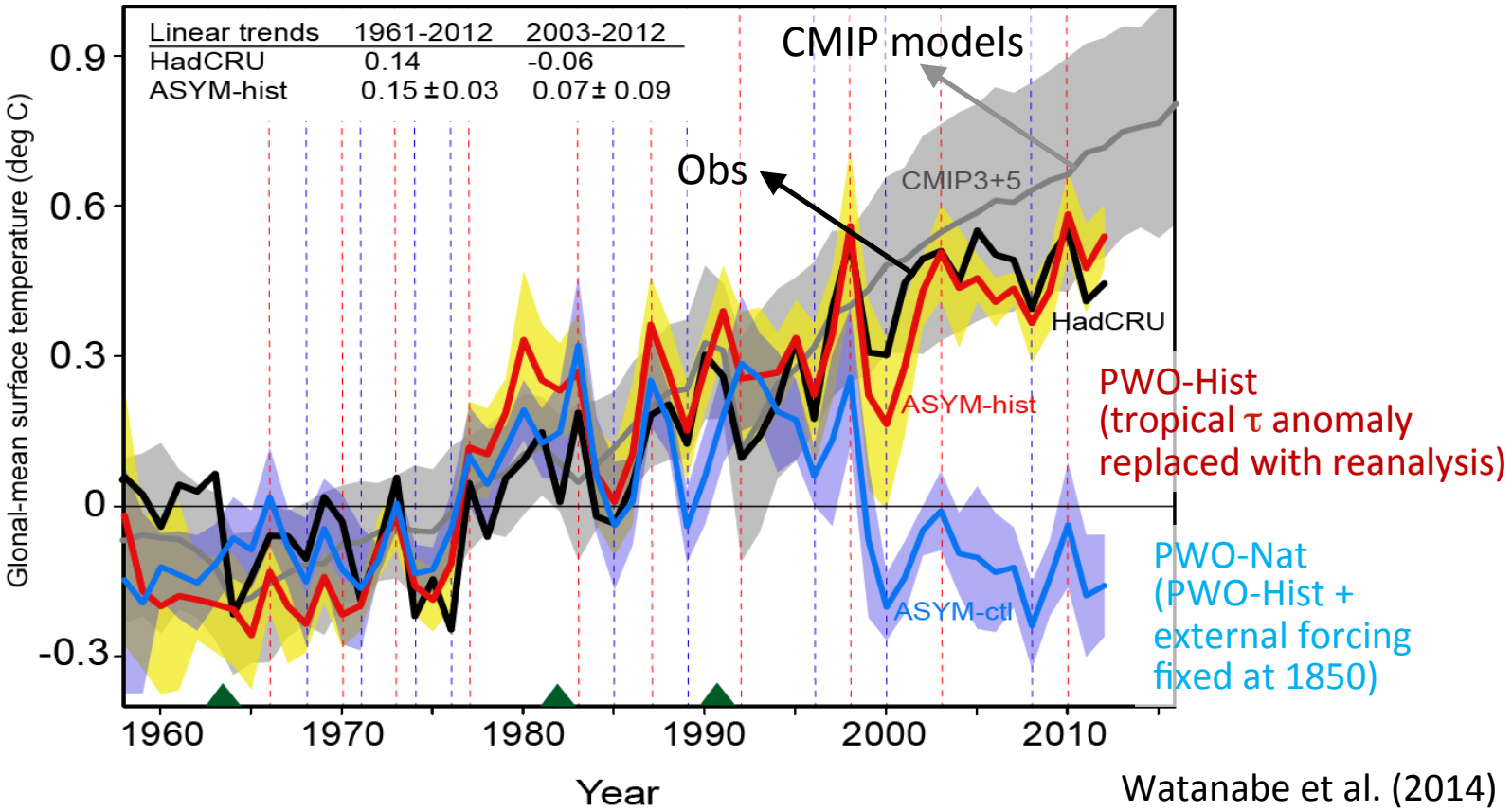


Watanabe et al. (2014)

Hiatus reproduced in MIROC5.2

Partial wind overriding experiments

Decadal wind stress variability substantially contributes to the warming acceleration in the 1980-90s and hiatus in the 2000s



Watanabe et al. (2014)

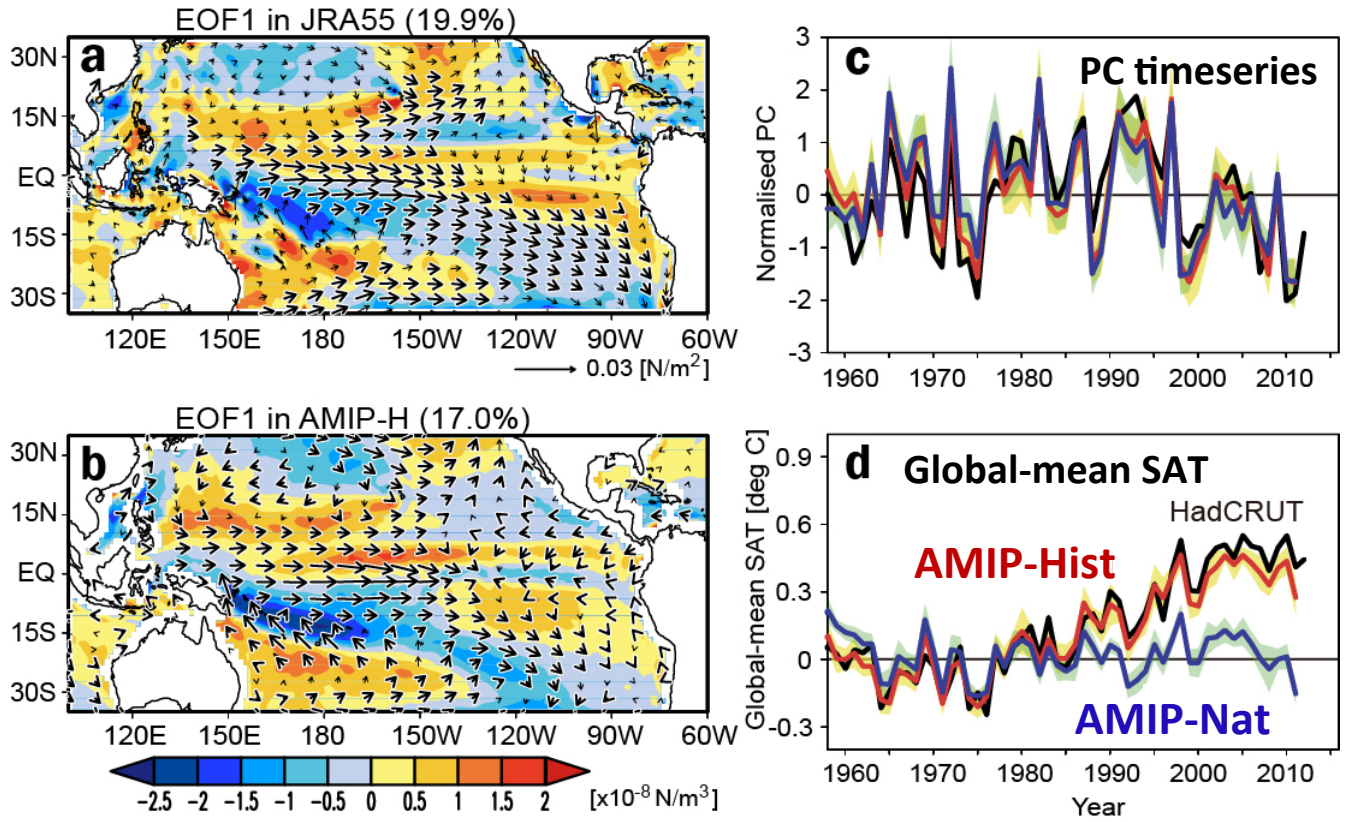
Attribution of hiatus

Wind stress variability responsible for the global-mean SAT change

10-member AMIP runs w/ and w/o anthropogenic warming (AMIP-Hist & AMIP-Nat) reveal the decadal τ variability is approximately independent of the global warming

τ EOF1 reanalysis

τ EOF1 AMIP-Hist

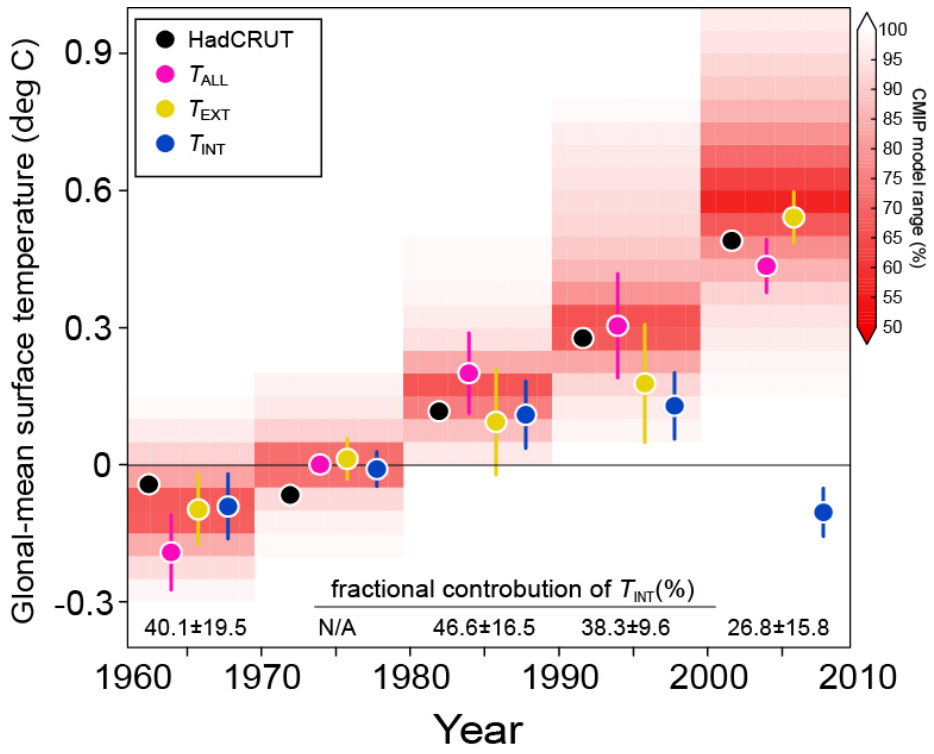


Watanabe et al. (2014)

Attribution of hiatus

Contribution of natural internal variability & external forced component to the global warming acceleration & hiatus

Substantial contribution of the internal decadal variations
Fractional contribution decreases as rising signal of anthropogenic warming



Decomposition of decadal-mean SAT changes

$$\Delta T_{ALL} = \Delta T_{INT} + \Delta T_{EXT}$$

PWO-Hist **PWO-Nat** **diff.**

Decade	ΔT_{INT}	$\Delta T_{INT}/\Delta T_{ALL}$
1980s	+0.11K	47%
1990s	+0.13K	38%
2000s	-0.11K	27%

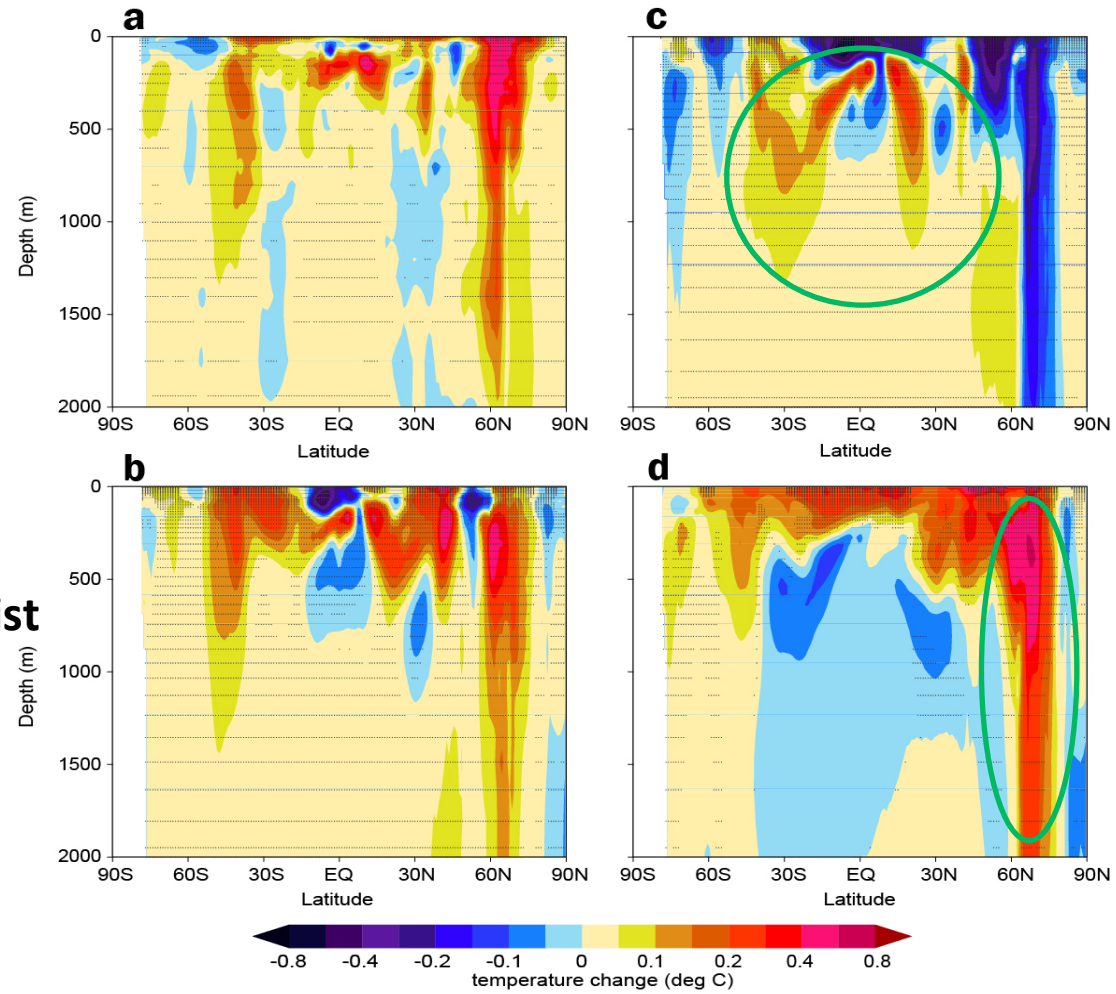
Watanabe et al. (2014)

Attribution of hiatus

Distinct structure of ocean warming

Zonal-mean temperature change from 1990-1999 to 2001-2012

Obs (Ishii)



ΔT_{ALL}= PWO-Hist

ΔT_{INT}

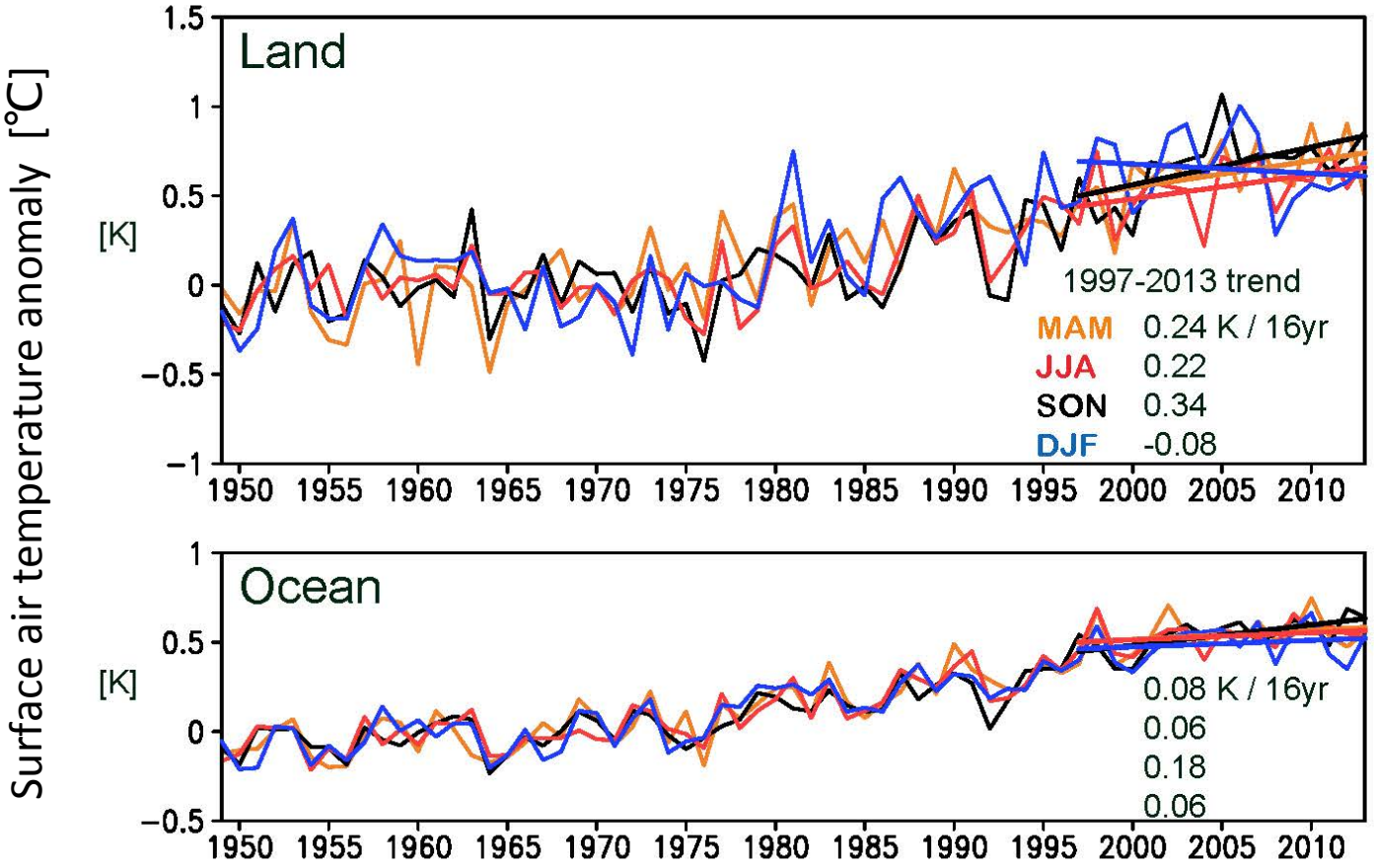
More heat uptake in the subtropics by the wind-driven circulation

ΔT_{EXT}

More heat uptake in northern high latitudes (mostly North Atlantic)

Watanabe et al. (2014)

Seasonality in warming trends



Courtesy of Y Kamae

- Hiatus seen year round over oceans
- Hiatus only in DJF over land → What's happened in warm seasons?

Attribution of increase in NH heat waves

MIROC5-AGCM (T85L40) C20C

Radiative forcing

SST/sea ice

	Historical	PI fixed
Historical	AMIP-Hist	AMIP-Nst
Natural*	AMIP-Alf	AMIP-Nat

Contribution to heatwave frequency (25-50N)

$$f = f_{ADIR} + f_{ASST} + f_{NAT}$$

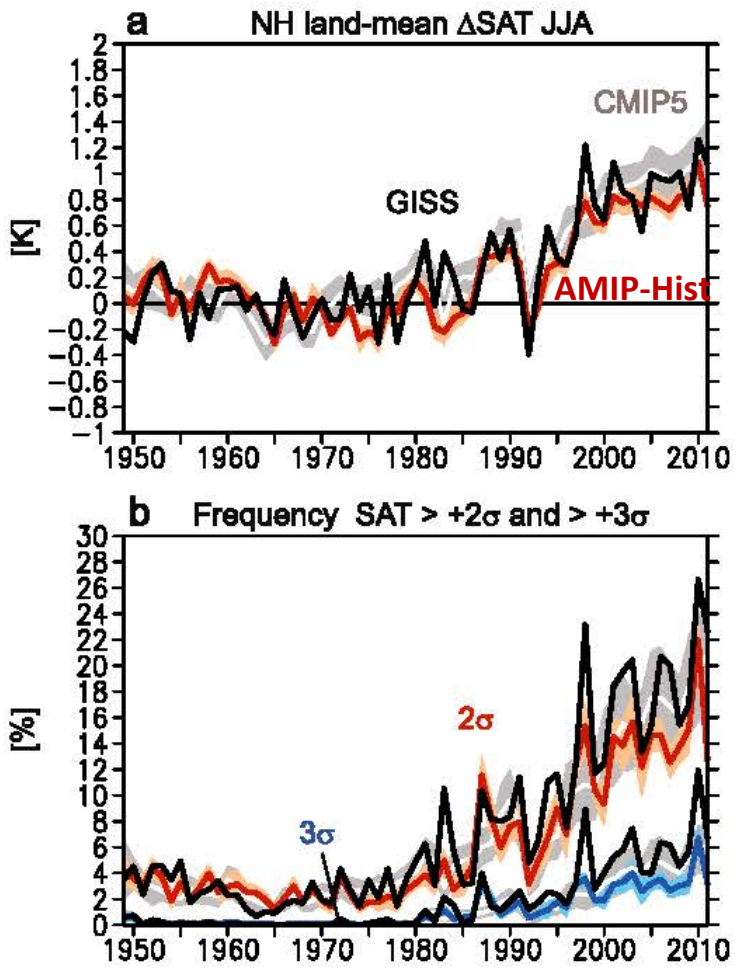
Direct GHG SST increase Natural Var

	f_{ADIR}	f_{NAT}	f_{ASST}
Decadal	38%	43%	19%
Long-term	40%	15%	45%

Combined analysis of AMIP-type ensembles

→ Considerable contribution of direct radiative effect of GHGs to increasing heat wave frequency

AMIP-Hist reproduces increasing *f*



Kamae et al. (2014 GRL)

Summary

- Coupled models can reproduce the hiatus well if the tropical Pacific is constrained with observations
- Natural decadal variability explains a significant fraction of warming hiatus as well as acceleration in the 1980-90s, but its contribution has declined
- Land surface shows a warming trend despite hiatus, due largely to direct effect by GHGs

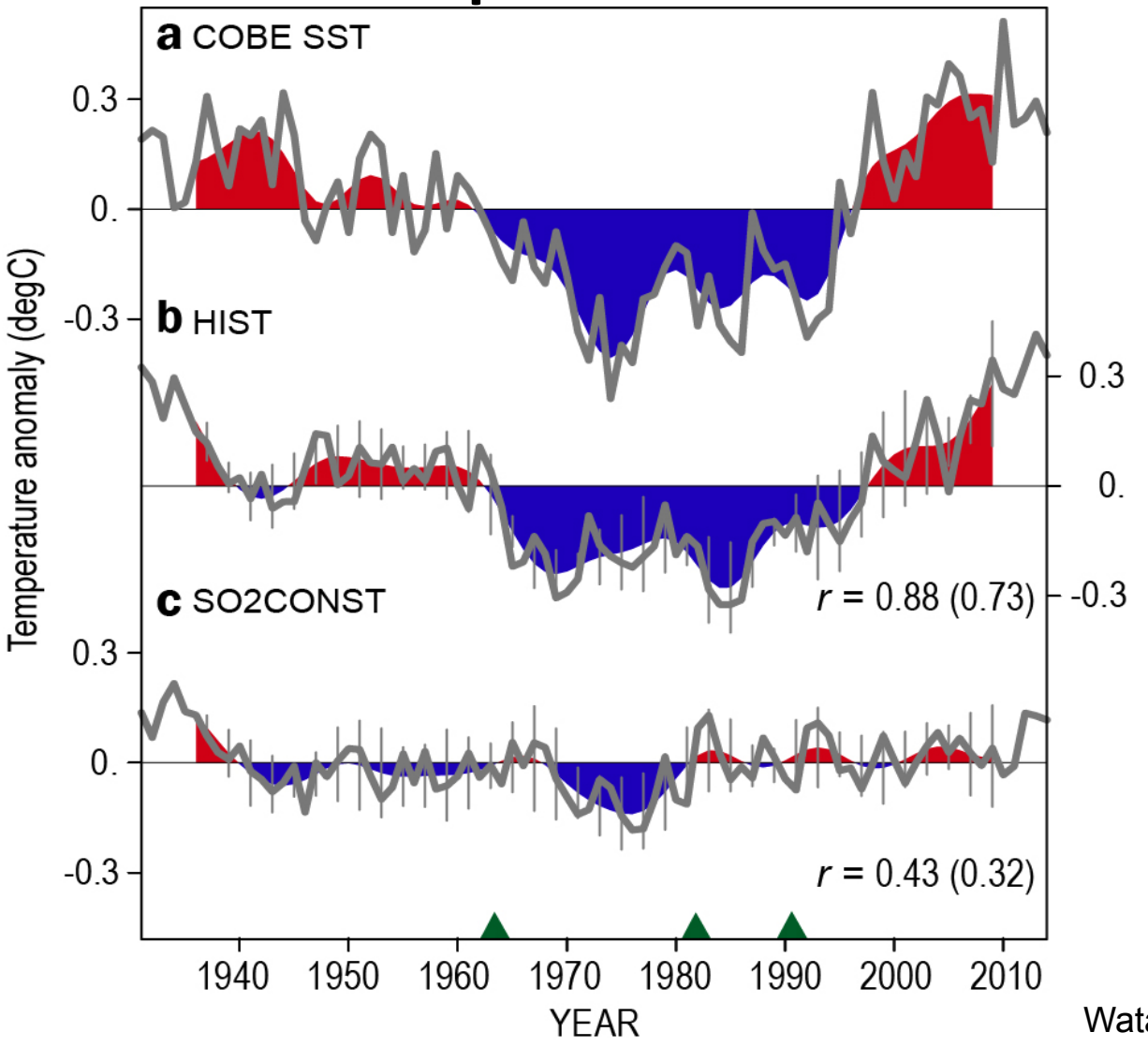
nature climate change
LETTERS
PUBLISHED ONLINE: 31 AUGUST 2014 | DOI: 10.1038/NCLIMATE2355

Contribution of natural decadal variability to global warming acceleration and hiatus

Masahiro Watanabe[1]*, Hideo Shiogama[2], Hiroaki Tatebe[3], Michiya Hayashi[1], Masayoshi Ishii[4] and Masahide Kimoto[1]

Watanabe et al. (2014)

Forced component in AMV?

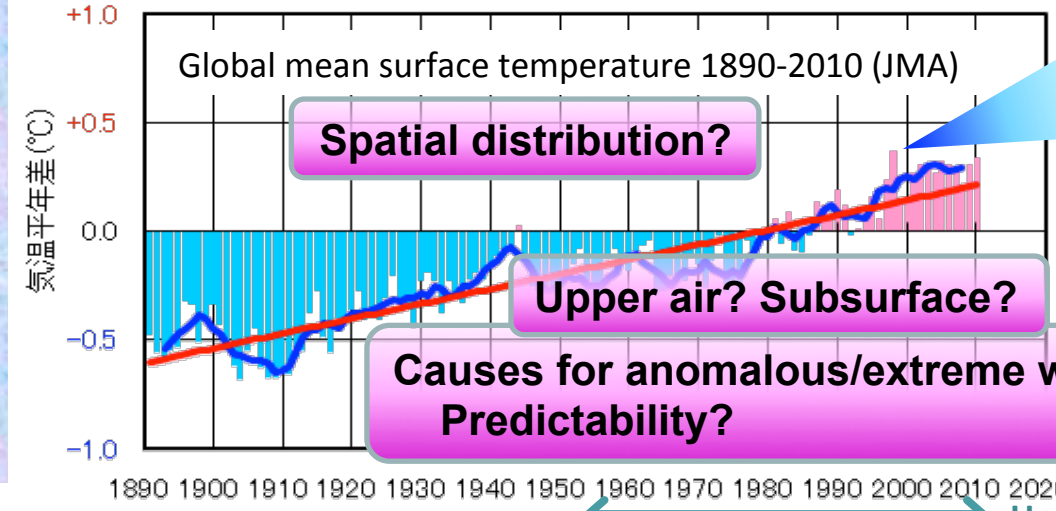


Watanabe et al. (2015)

AMV index: Obs (top), MIROC5.2 (5 members) FULL(middle) & NOSO2 (bottom)

System for Prediction and Assimilation by MIROC

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

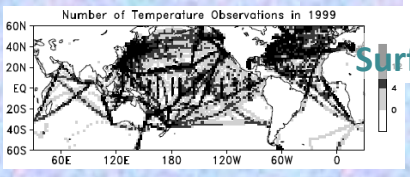


Prediction? Verification?

Spatial distribution?

Upper air? Subsurface?

Causes for anomalous/extreme weather? Predictability?



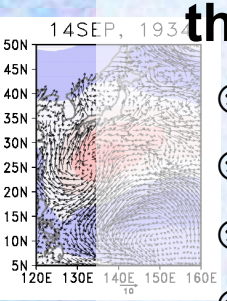
Surface Obs

Upper-air Obs

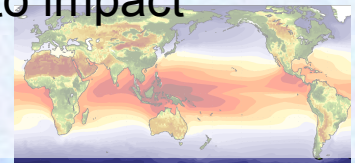
Ocean subsurface Obs

Coupled atmosphere-ocean reanalysis

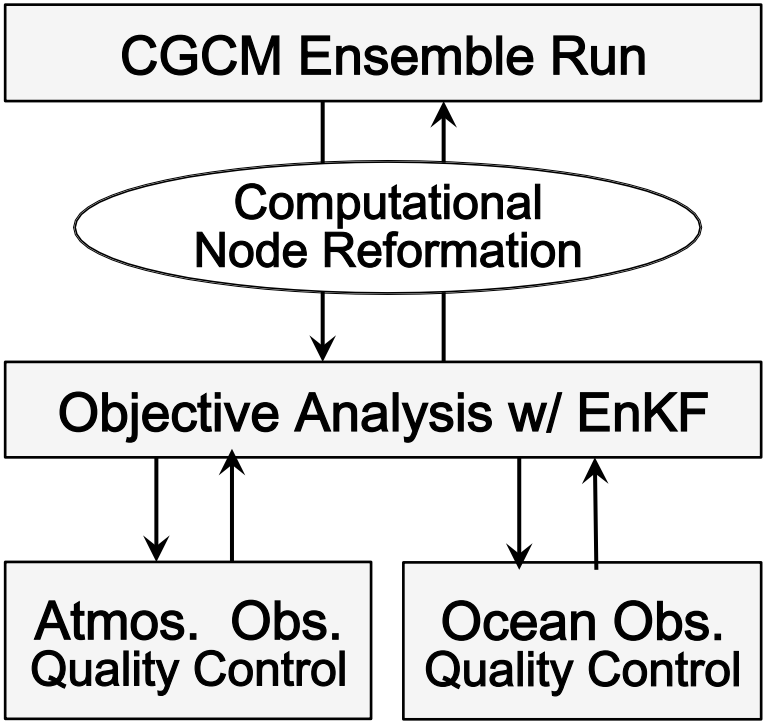
- **Reanalysis/reforecast of historical climate data using a state-of-the art coupled ocean-atmosphere climate model**



- ☺ 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



150-yr Reanalysis



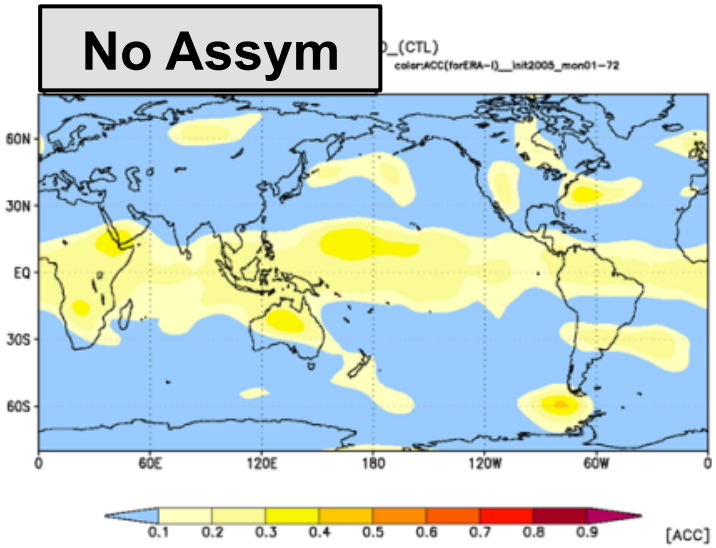
A new system configured specifically for long-term climate reanalysis

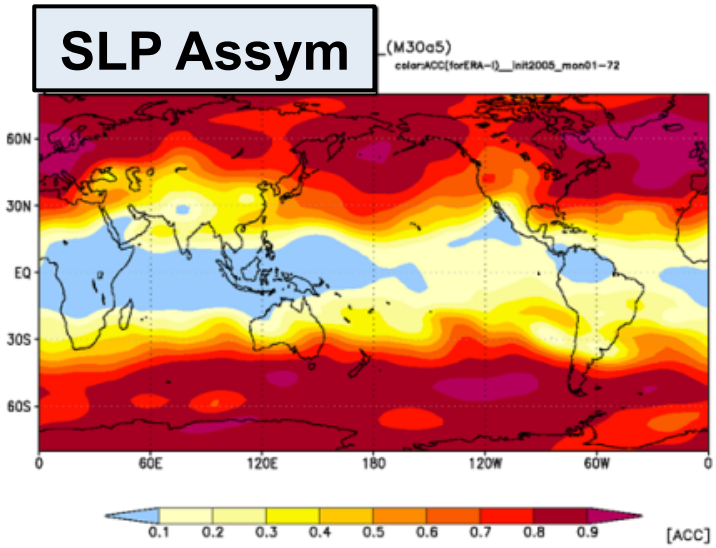
Coupled Model + EnKF
From 1850 to present
A Trial

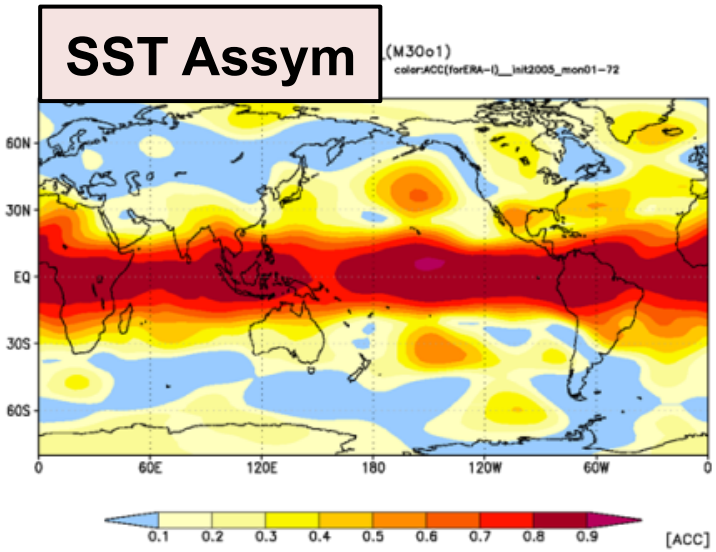
Spec. (ver. 1)

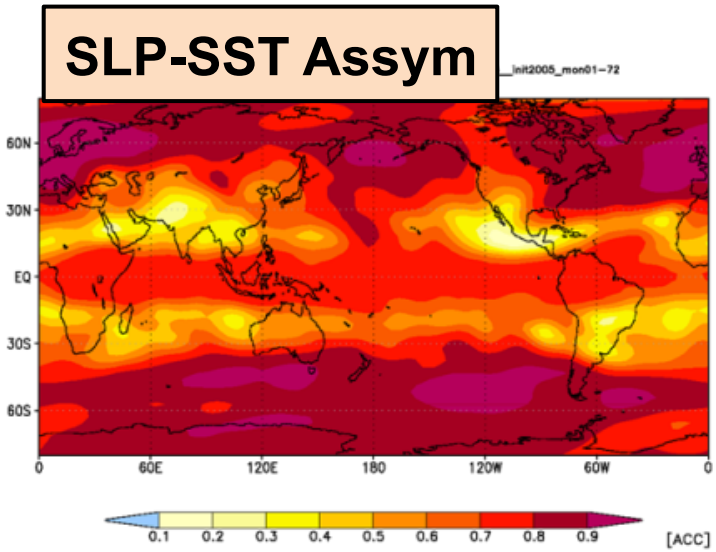
- **LETKF (Hunt et al. 2007)**
- **Loosely coupled**
- **Assimilation interval: 6 hours for Atmos. and 5 days for Ocean**
- **Surface Pressure Data (ISPD v.3.2.8)**
- **Typhoon bogus (IBTrACS v03r05)**
- **SST: COBE-SST2 + SST perturbations**
- **Gridded subsurface ocean T and S (Ishii and Kimoto 2009)**

Z500 ACC 2005-2010





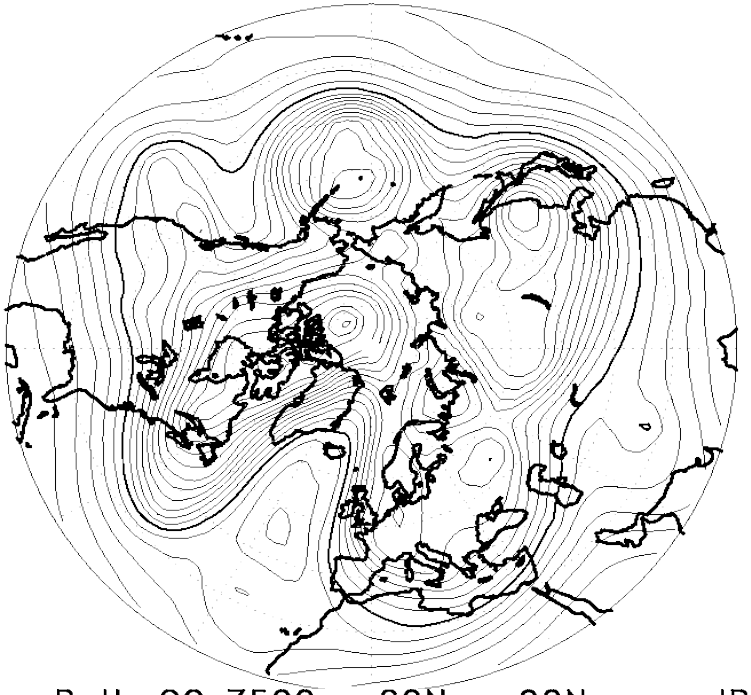




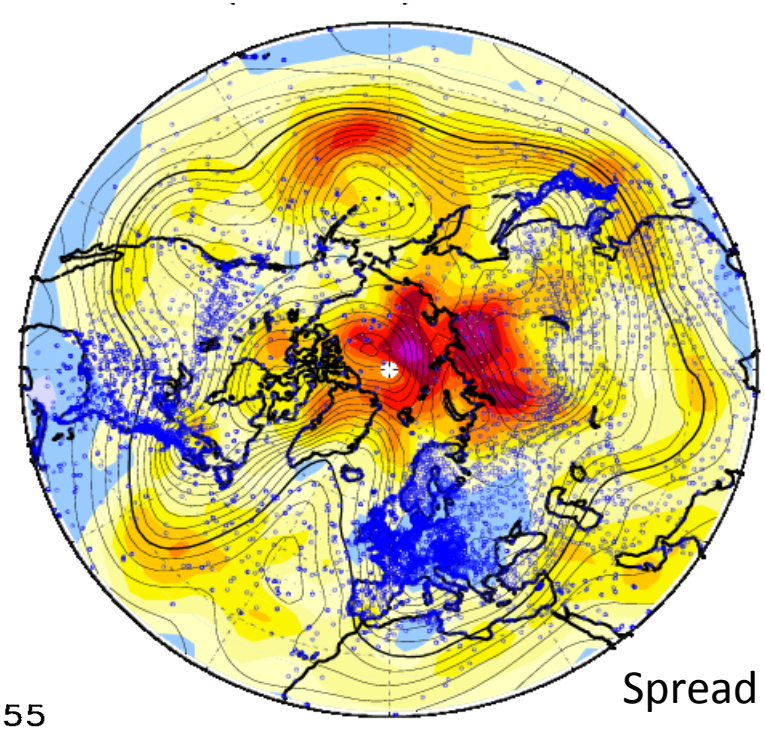
Z500 ACC 2005-2010

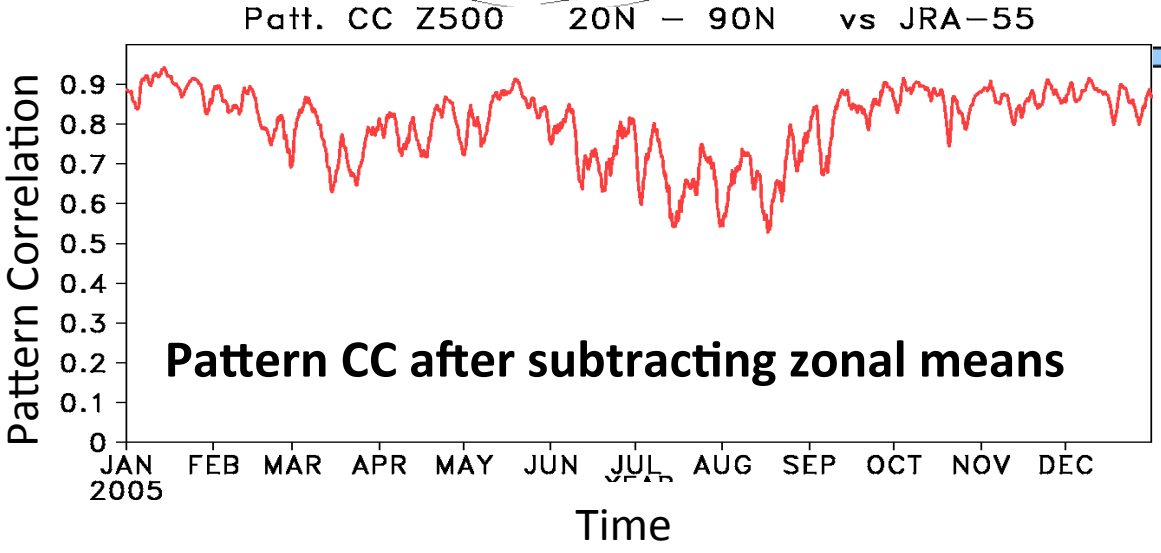
500hPa Geopotential height at 12UTC, February 20th, 2005

ERA-Interim



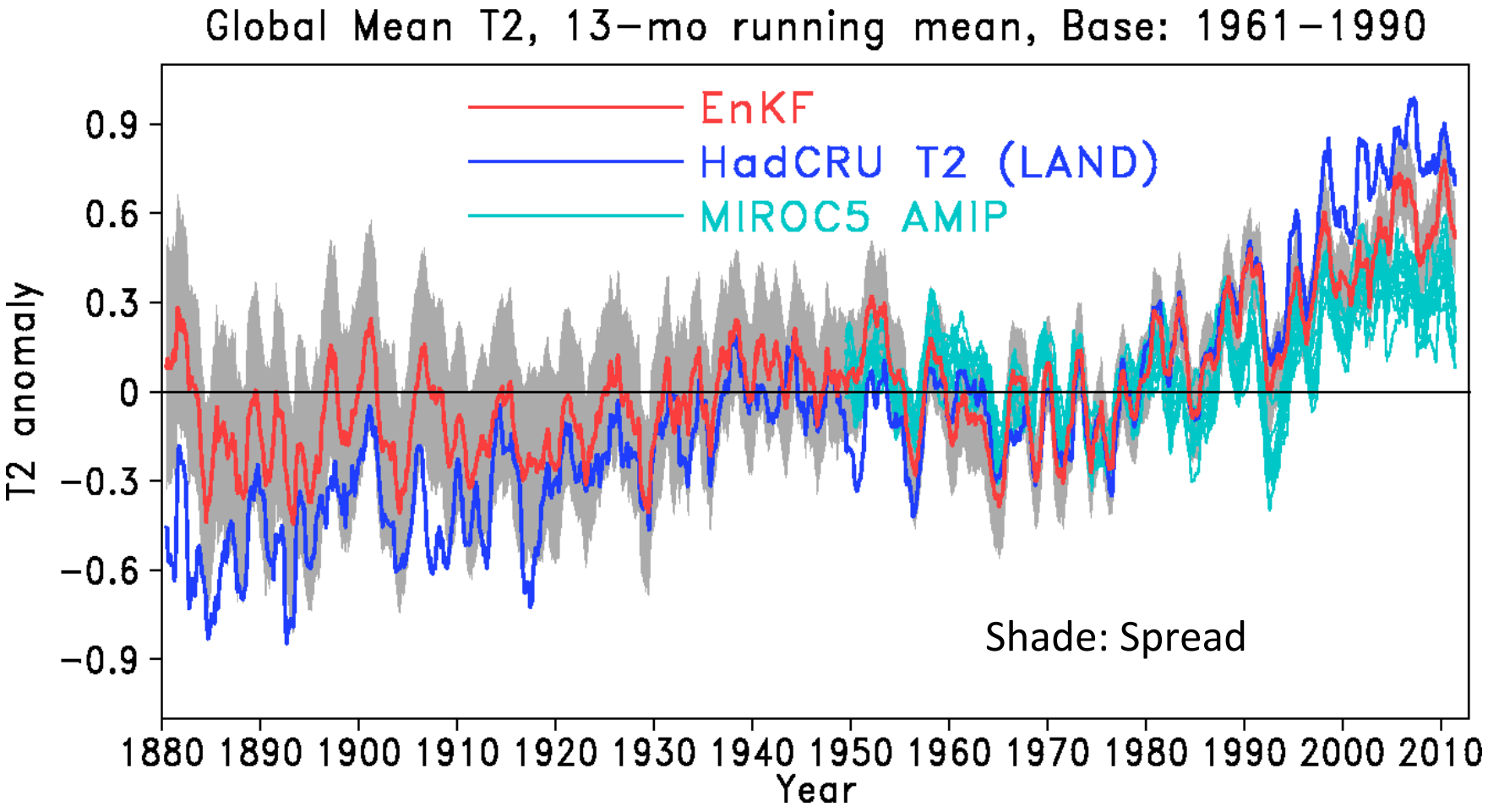
EnKF



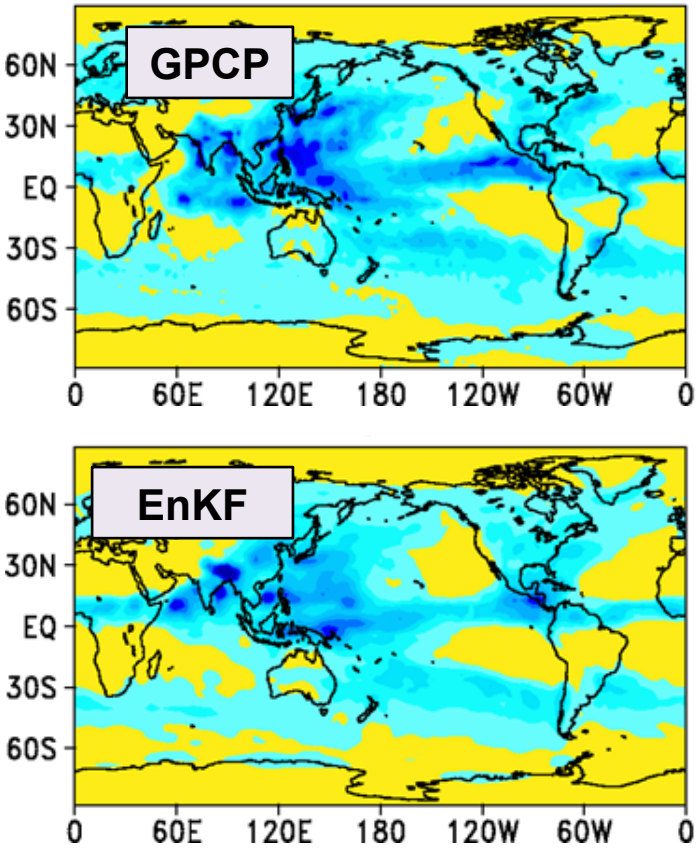


Preliminary Run with MIROC3m
(T42L20 AGCM and 1-deg OGCM)

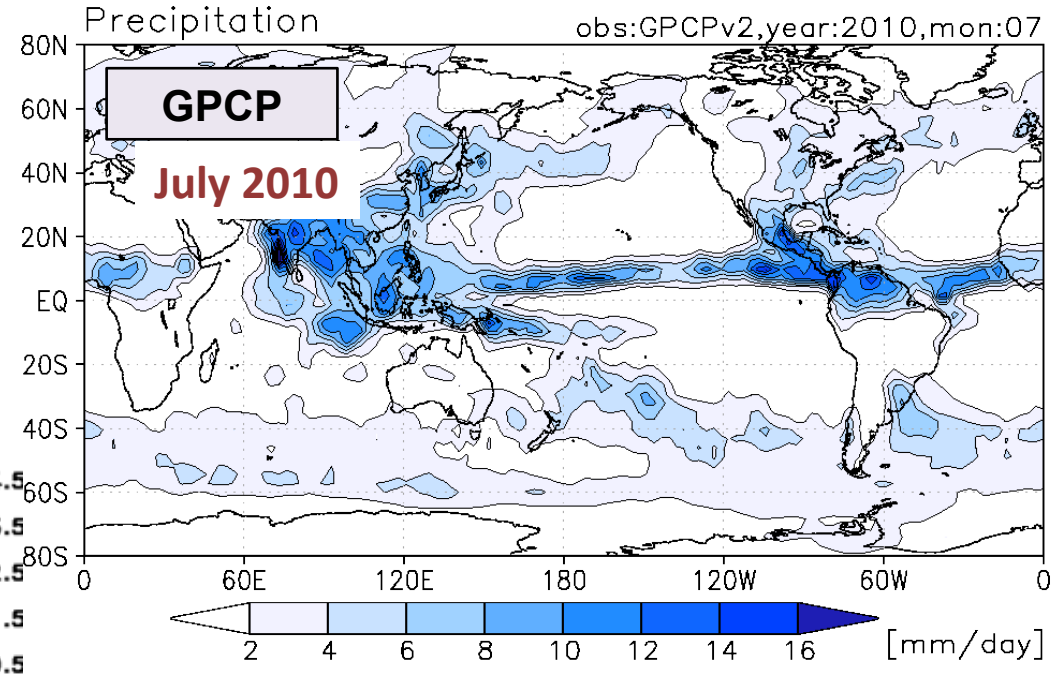
Global Mean Surface Temperature over Land

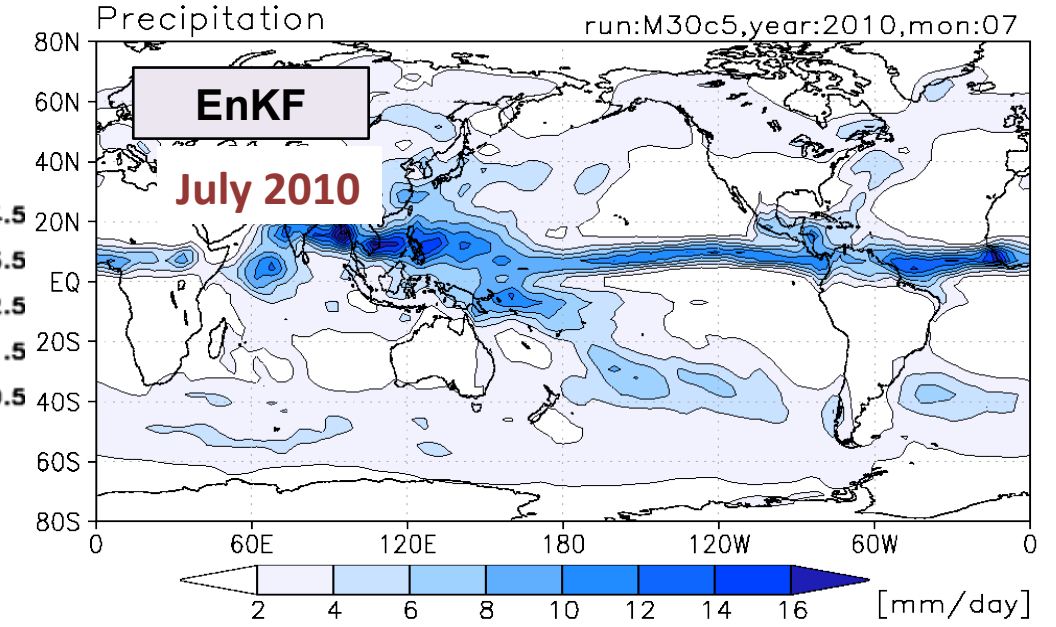


Monthly Mean Precipitation July 2010

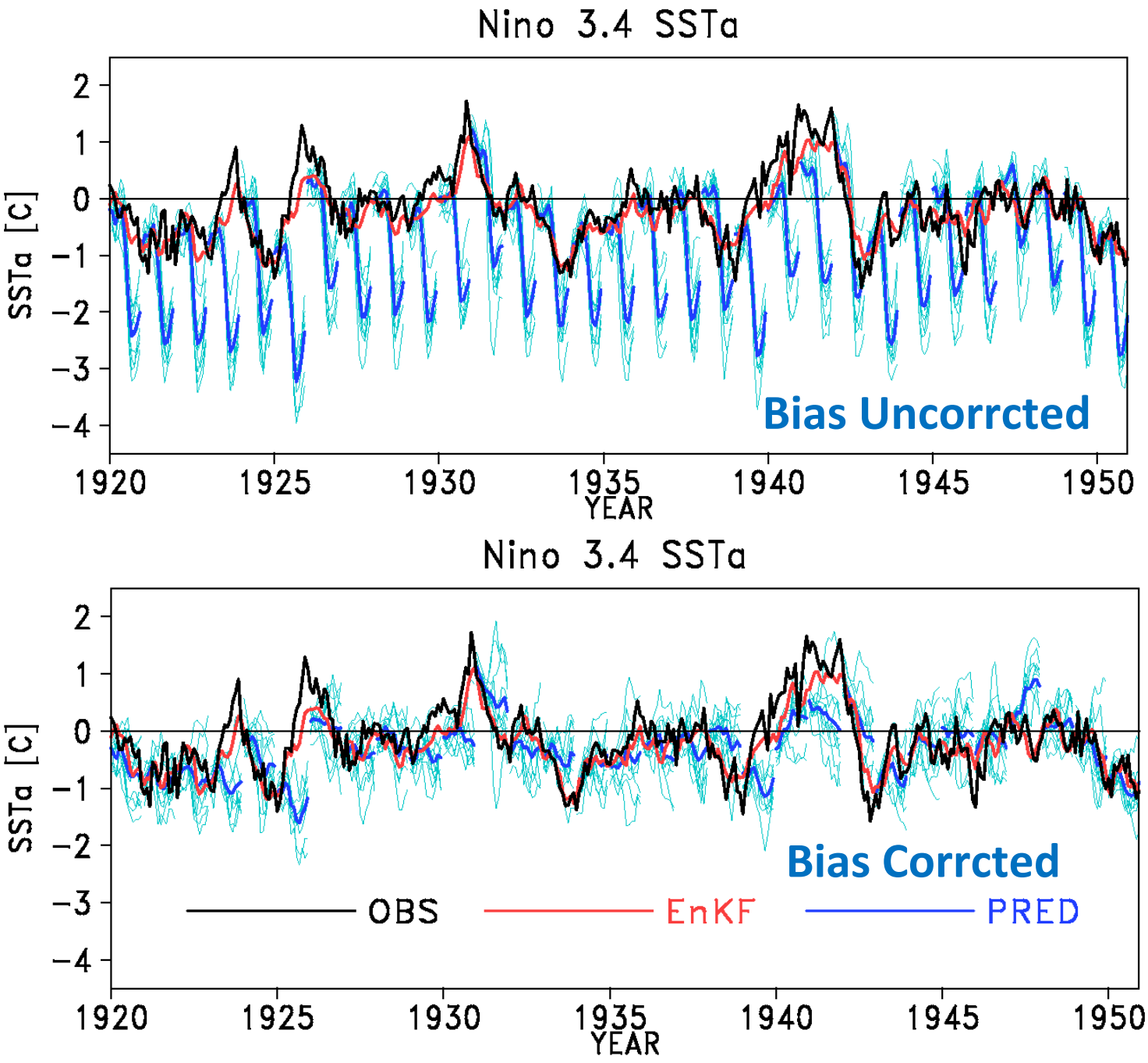


Internannual variability (1980-2010)

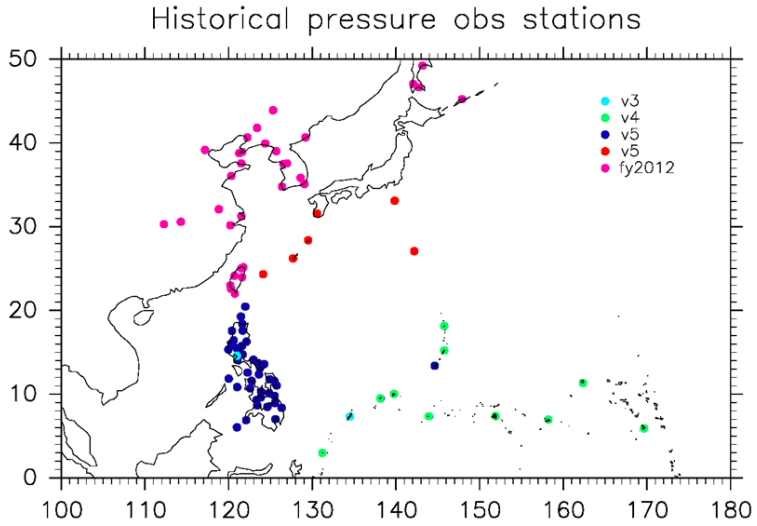




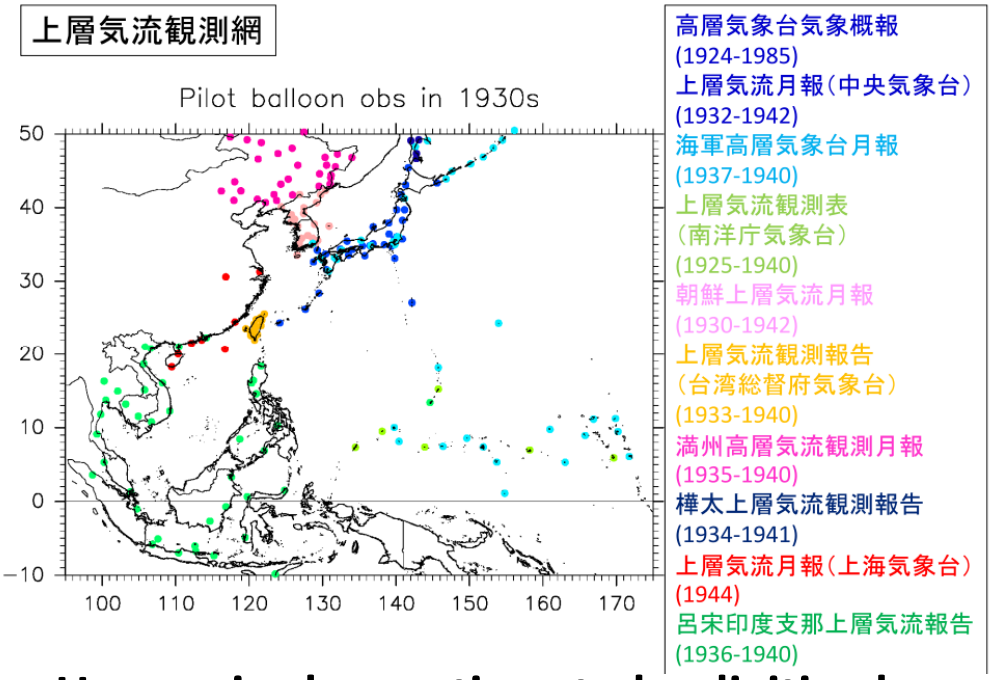
A trial of pre-1950 ENSO Predictions



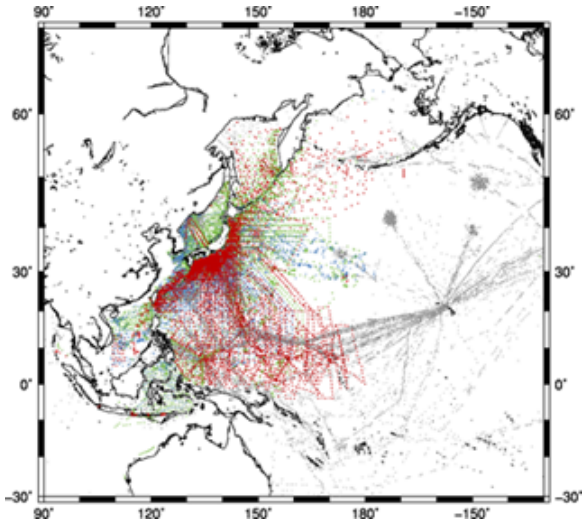
Atmosphere and Ocean Data Rescue



Recently processed SLP data (1890 – 1940; Kubota et al. JAMSTEC)



Upper air observations to be digitized



← Expected data distribution (red) of marine met. Obs. by the Japanese Imperial Navy (1903-1944, ~ 1 million)

Participating in and collaborating with international activities: ACRE, ICOADS, ICA&D, IQuOD