Regional information in the Pacific decadal hindcasts

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SPAM:
System for
Prediction and
Assimilation by
MIROC

Near-term (decadal) prediction
- new topic in CMIP5 -

Long-term climate projection (**centennial** timescales)

Externally-forced variations (e.g., CO2, volcano, solar cycle, …)

-> model responses, climate sensitivity of models

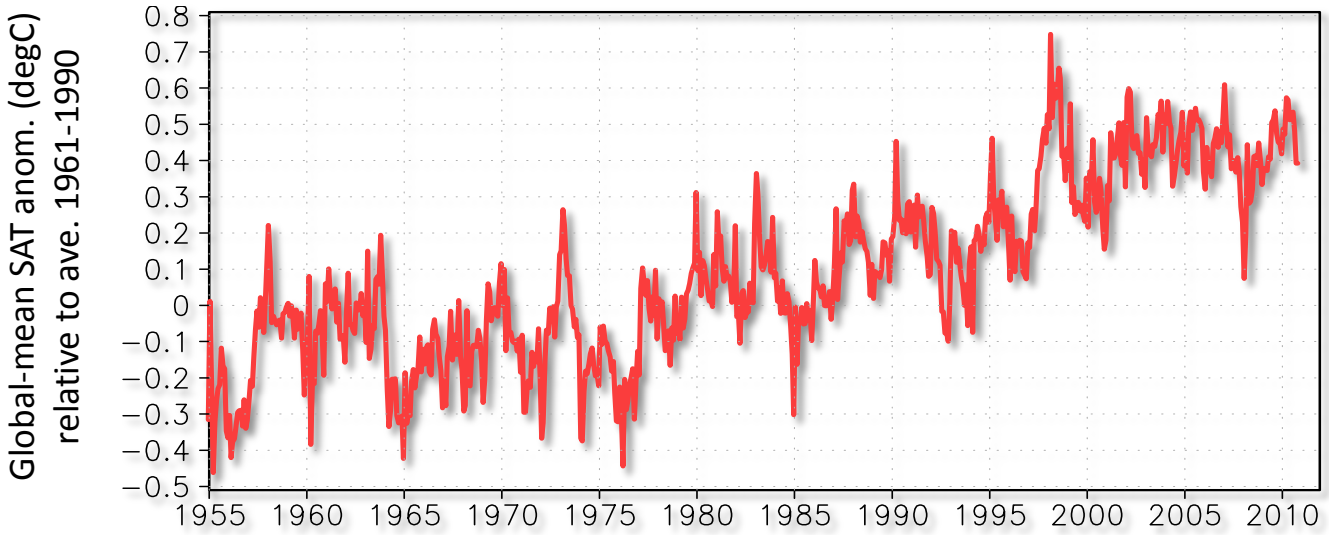
-> **global**

Near-term climate prediction (**decadal** timescales)

Internally-generated (and externally-forced) **variations** (e.g., PDO, IPO, NPGO, …)

-> initialization of climate states

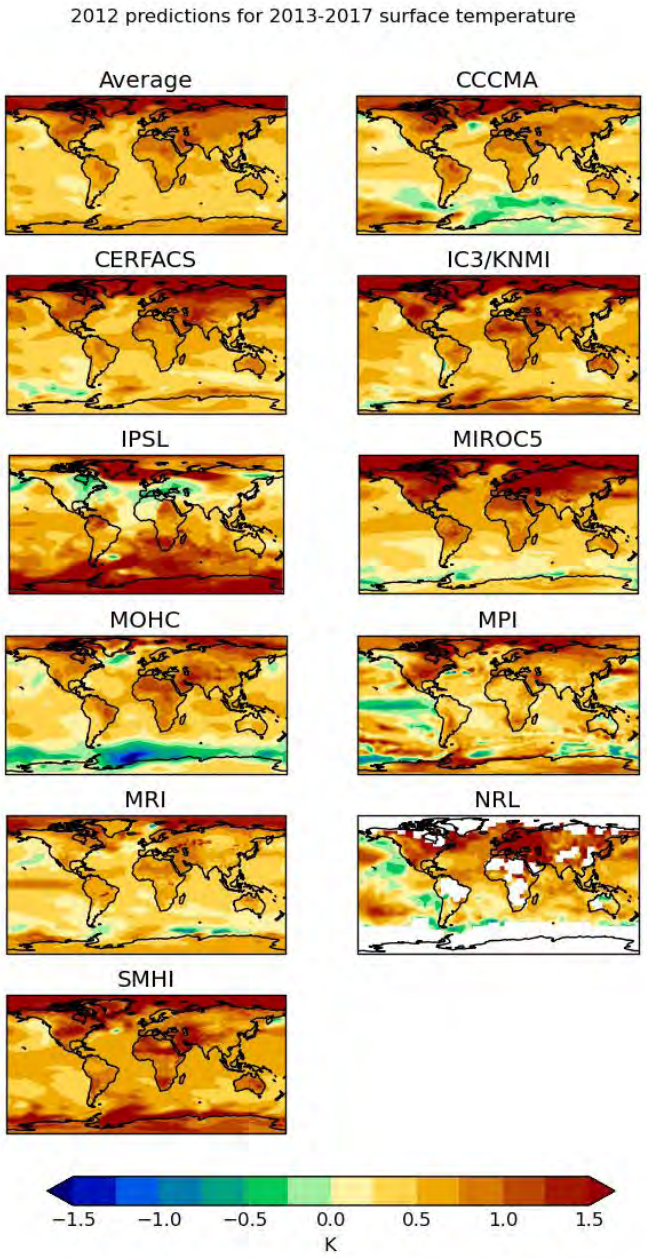
-> **regional**



Decadal modulation & regional changes due to internal variations (e.g., PDO, IPO NPGO,…)

http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/forecasts/

Multi-model decadal forecast exchange



"The Met Office coordinates an **informal exchange of near-real time decadal predictions**. Many institutions around the world are developing decadal prediction capability and this informal exchange is intended to facilitate research and collaboration on the topic."

Important!
"Decadal prediction is still experimental and the forecasts should not be relied on for making decisions, particularly on regional scales."

Decadal forecast exchange 2012 predictions for years 1 to 5 surface air temperature

“Regional” information in decadal prediction

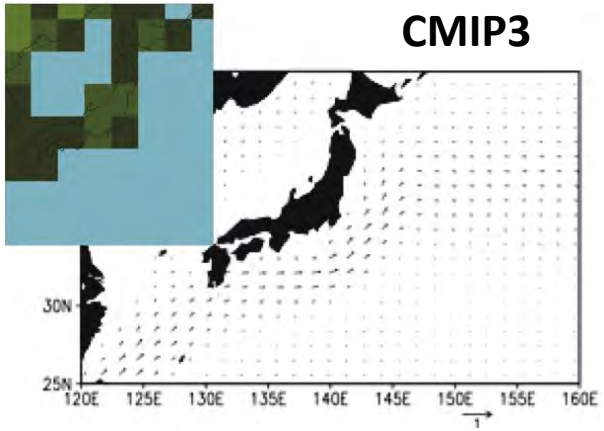
- “Regional”
  - Relative to global warming (i.e., not global mean)
    - ***PDO***, NPGO, ***basin-scale temperature change***, ***ocean gyre circulation***, …
    - Resolved by med- and high-resolution GCMs.
  - Smaller-scale variations
    - Kuroshio meandering**,** coastal upwelling, ***tropical cyclone***, extremes (daily temperature maximum), …
    - Not resolved by med-resolution GCMs. Resolved by high-resolution GCMs?
- Approaches
  - **Med- and High-resolution GCMs,** Nesting models
  - RCMs forced by IPCC outputs (GCMs), …
    - Historical + scenario-based projection (global warming)
    - **Initialized decadal prediction (global warming + internal fluctuations)**
- Help to address issues of RCM?
  - Potential effectiveness of RCM
  - Problems to be solved by RCM and in applying GCM output to RCM

Series of MIROC global climate model

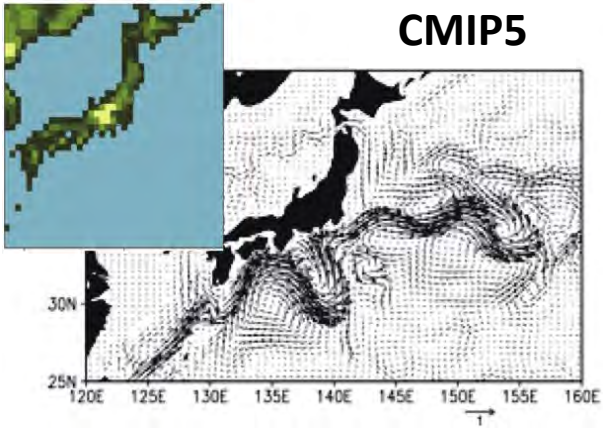
(**M**odel for **I**nterdisciplinary **R**esearch **O**n **C**limate)

		Atmosphere	Ocean
CMIP3	MIROC3m	T42 (128 × 64, ~2.8°), L20	1.4° × (0.5°–1.4°), L43+BBL 0-layer EVP sea ice
CMIP5 (near-term prediction)	**MIROC4h** (Sakamoto et al. 2012)	T213 (640 × 320, ~0.6°), L56	0.28125° × 0.1875°, L47+BBL 0-layer EVP sea ice
CMIP5 (near-term prediction)	**MIROC5** (Watanabe et al. 2010)	T85 (256 × 192, ~1.4°), L40 new physics	1.4° × (0.5°–1.4°), L49+BBL multi-category sea ice
	MIROC-ESM	T42 (128 × 64, ~2.8°), L20 carbon chemistry	1.4° × (0.5°–1.4°), L43+BBL 0-layer EVP sea ice

Decadal prediction using high-resolution model, MIROC4h



Medium resolution model
T42L20, 1.4x0.5-1.4deg. 44levs.



Higher resolution model
T213L56, 1/6-1/4deg. 48levs.

Fig. 1. Topographys used in the atmospheric models and snapshots of surface ocean current.

Advantage !

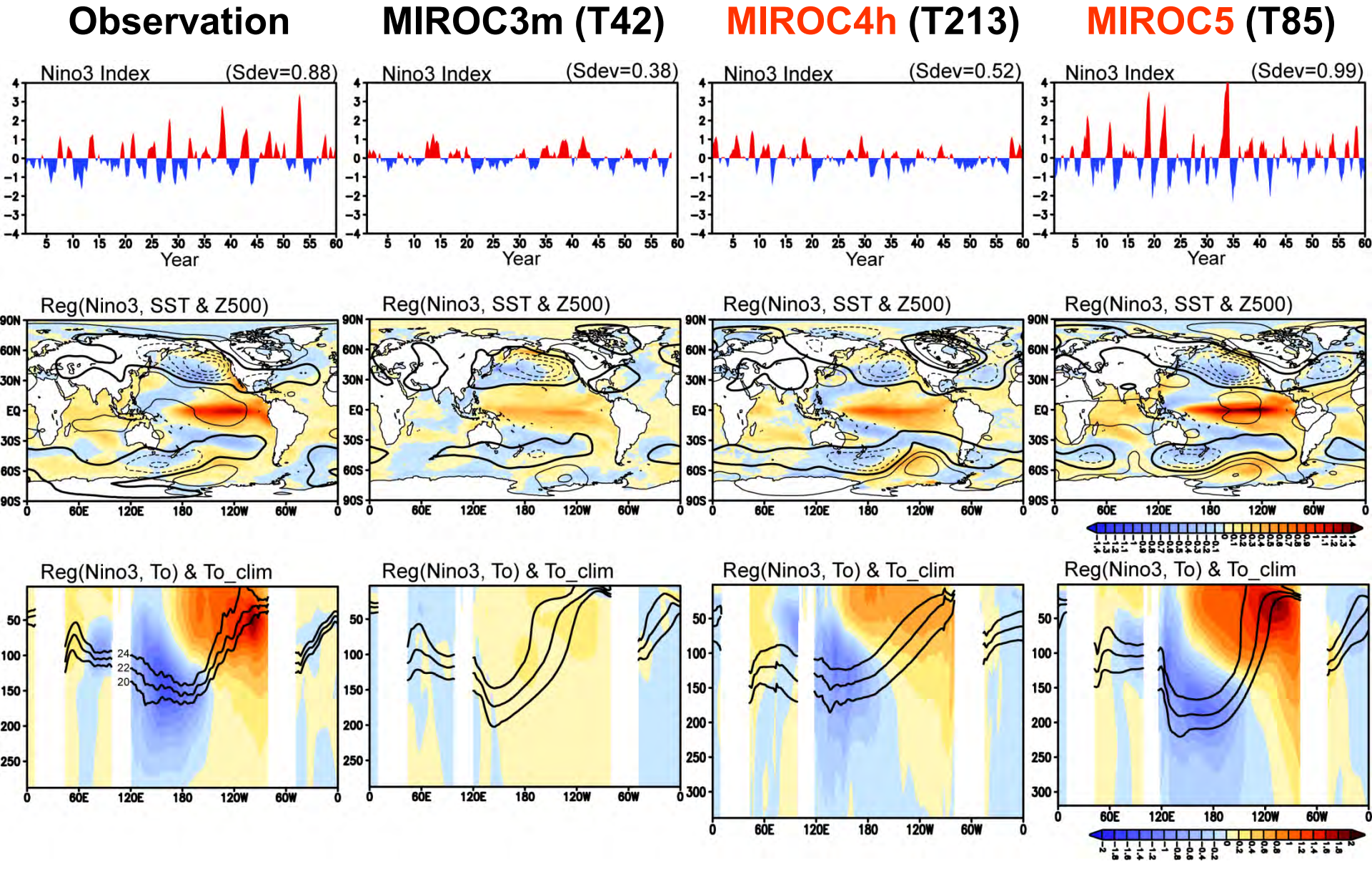
- Regional information (explicitly) toward marine-ecosystem, fishery, …
- Better performance for large-scale variability (logically)

Disadvantage !

- Huge resource of computation
  - Limited numbers of ensembles, hindcast cases
  - Issues in data assimilation / initialization (method, tuning, test, …)

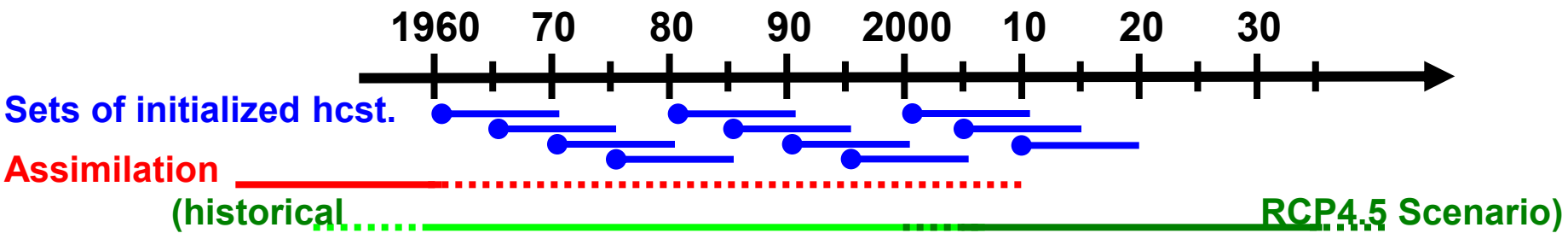
Sakamoto et al. (2012), *J. Meteor. Soc. Japan.*

Observed and modeled ENSO



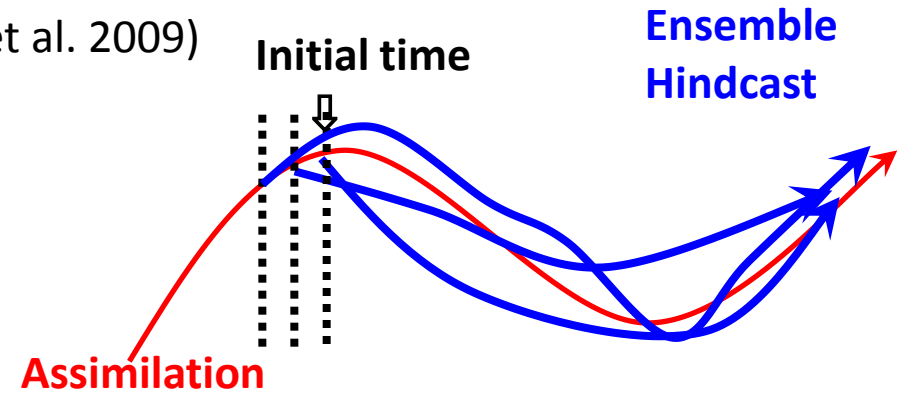
Tatebe et al. (2012), Mochizuki et al. (2012), *J. Meteor. Soc. Japan.*

Decadal Hindcasts in CMIP5



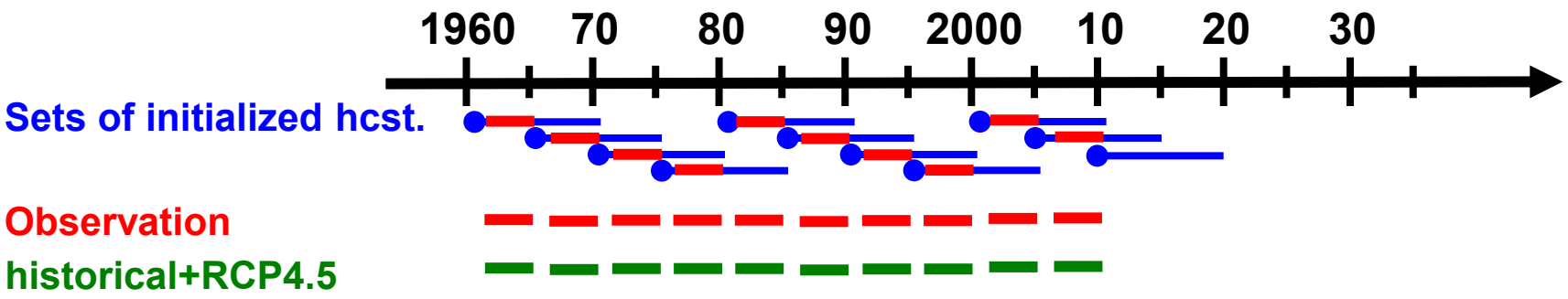
- **MIROC4h:** Assimilation: 1 ensemble, Hindcasts: 3 ensembles
  - Lagged Average Forecast (LAF) with 3-month intervals
    (e.g., For hindcast from 01Jan1971 -> IC:01Jul1970, 01Oct1970, 01Jan1971)

- **Assimilation**
  - *Updated* objective analysis of T/S (Ishii et al. 2009)
  - Anomaly assimilation
    relative to averages during 1971-2000
  - Upper 3000m depth
  - Interpolated from monthly mean values
  - Incremental Analysis Update (IAU)
  - No assimilation for sea ice
  - *Spatially-smoothed analysis increments* to assimilate only large-scale variations



c.f., Mochizuki et al. (2012), *J. Meteor. Soc. Japan*

Anomaly correlations of 2-5yr hindcasts

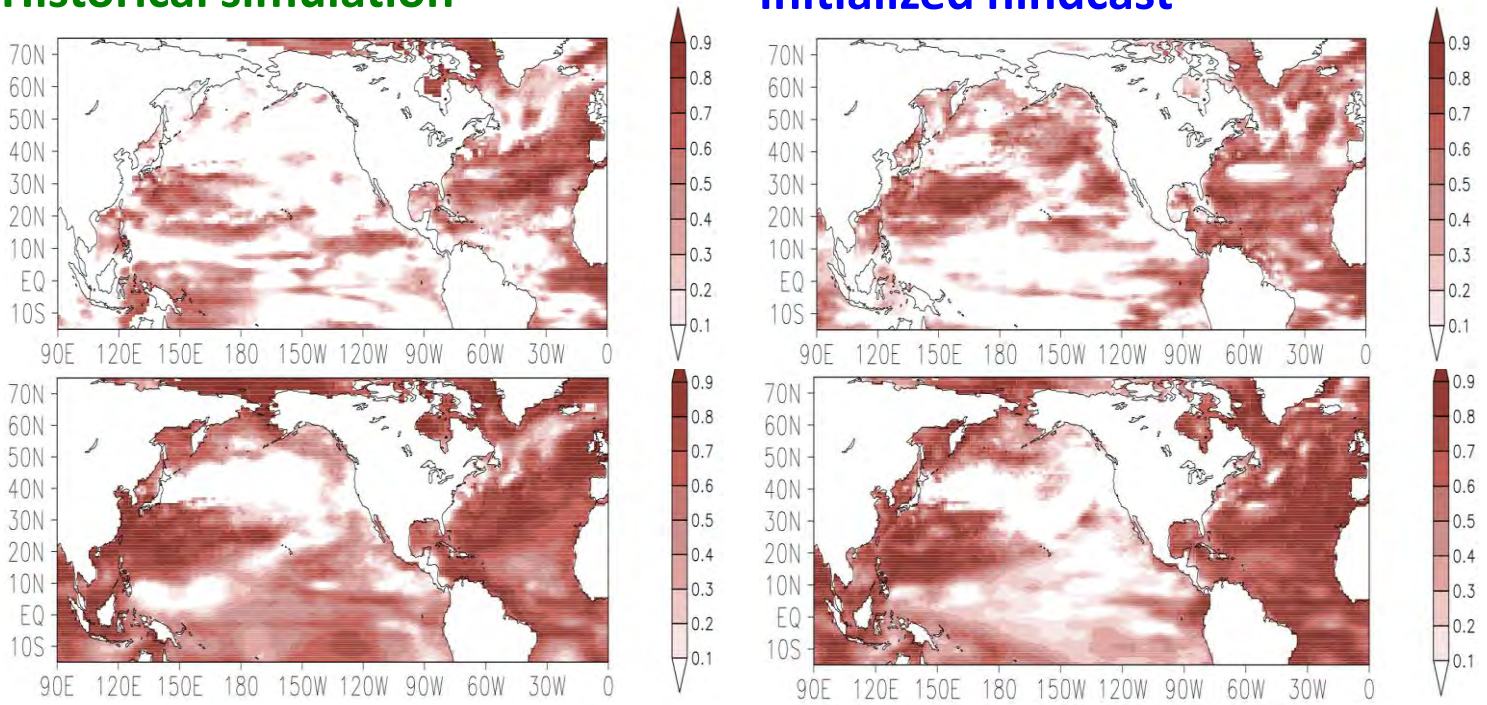


Historical simulation

Initialized hindcast

Ocean temp. @200m

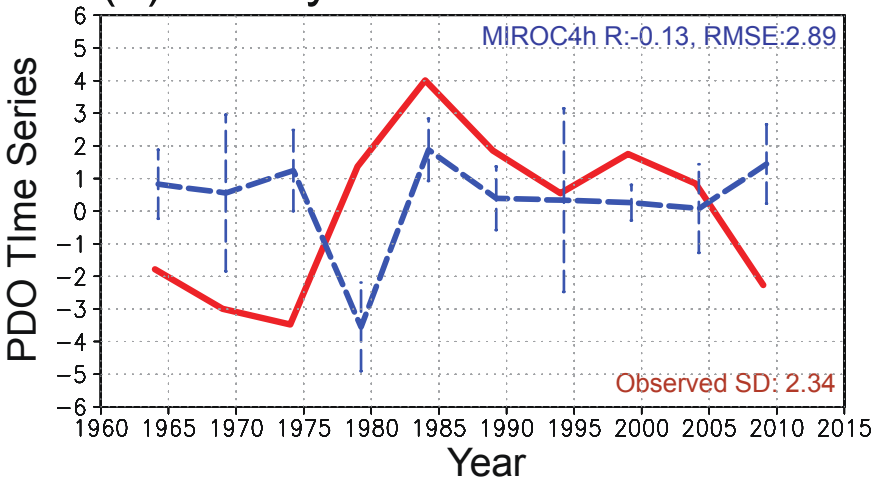
Ocean temp. @sfc



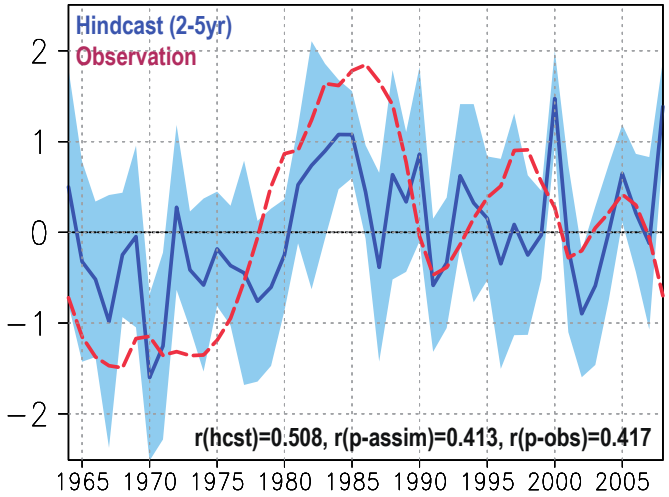
Statistically low skills in PDO hindcasts…

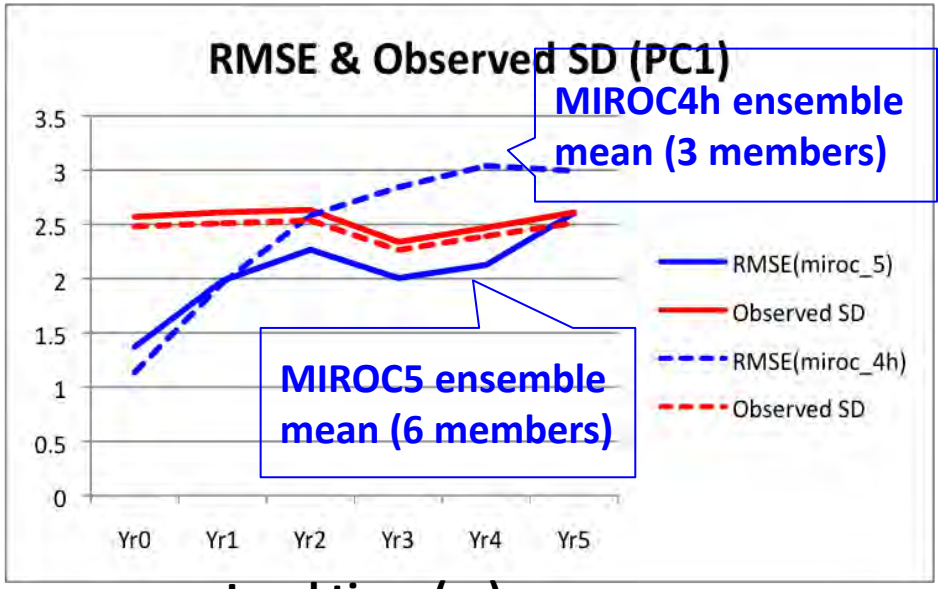
(a) PDO: yr2-5

MIROC4h: 3ensembles, 10cases



MIROC5: 6ensembles, 45cases





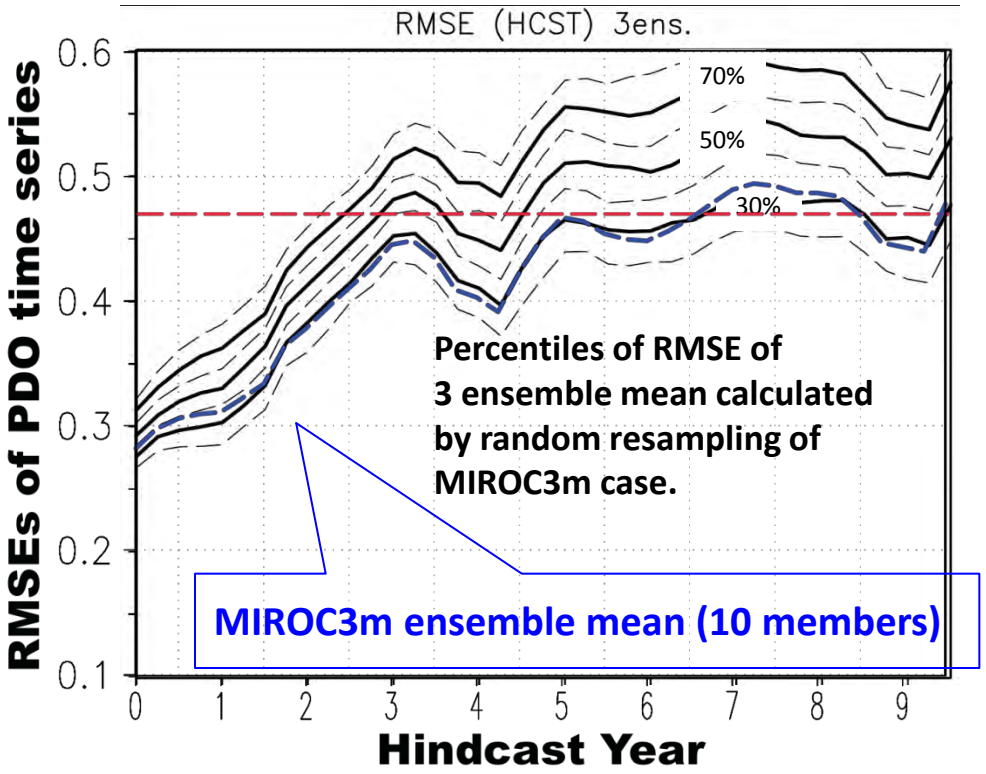
We need large numbers of ensembles and cases to validate hindcast skills.

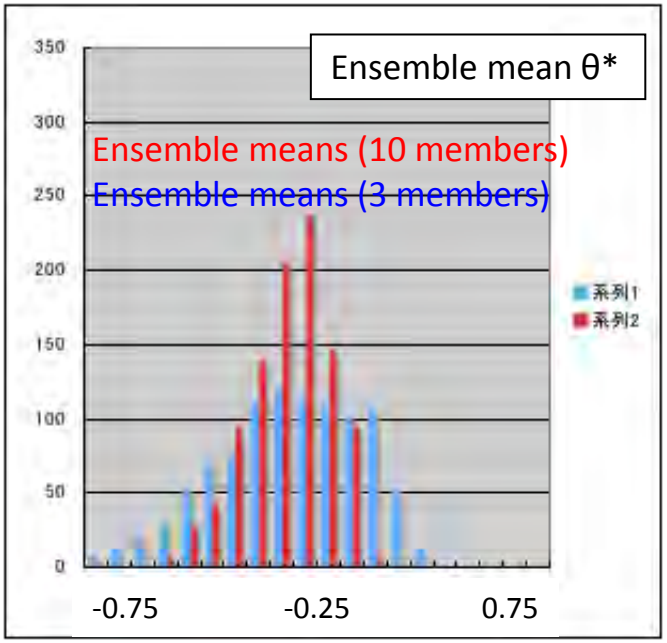
VAT400 (vertically averaged temperature in 100-400m depth) anomalies projected onto the leading EOF. (Observation, Initialized hindcasts)

c.f., Chikamoto et al. (2013), *Clim. Dyn.*

Small numbers of ensembles degrade statistical hindcast skill of ensemble mean.

Example: ensemble mean of the PDO index





Probability Distributions of ensemble means of 10 members and randomly-resampled 3 members (e.g., PDO index during 2006-2010)

It may not be easy to hold fully significant discussions due to the small number of ensembles particularly in MIROC4h case (i.e., three) at this stage.

How to discuss tropical cyclone (TC) in GCM
- Definition of TC -

Observed tropical cyclone

IBTrACS (International Best Track Archive for Climate Stewardship)
TC = cyclone with large wind speed (>34 knots ~ 18m/s)

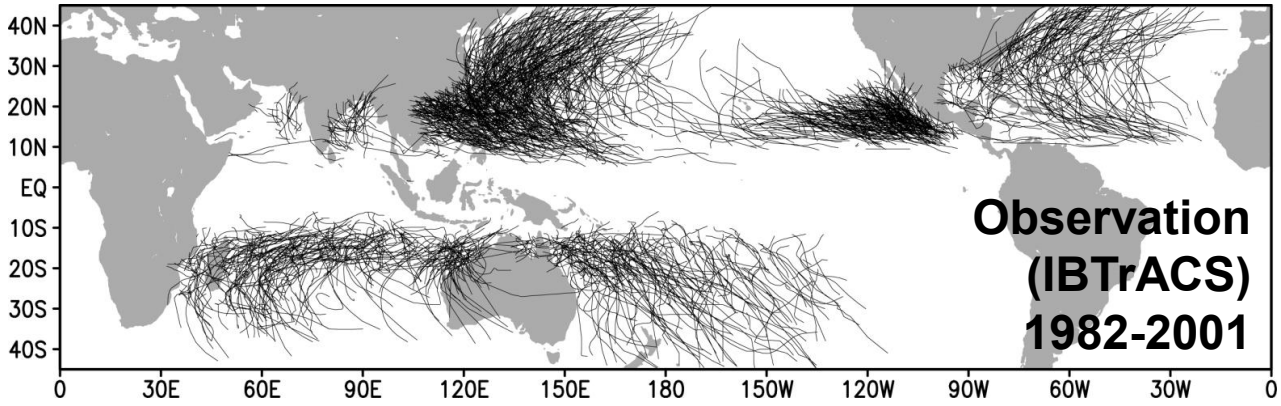
Modeled tropical cyclone (sugi et al., 2002; Oouchi et al., 2006)

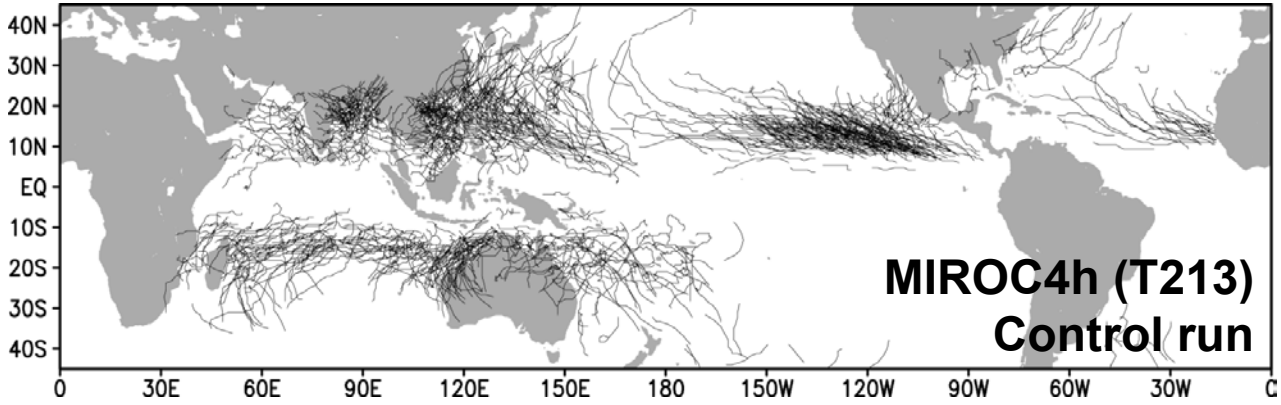
(1) it is generated above the ocean in 40N-40S.
(2) low SLP (>2hPa) relative to circumstance.
(3) maximum relative vorticity at 850hPa $\geqq 35 \times 10^{-6}$ 1/s.
(4) maximum wind speed at 850hPa $\geqq$ 15m/s.
(5) maximum wind speed at 850hPa $\geqq$ maximum wind speed at 250hPa.
(6) T* = temperature differences between inside and outside of cyclone
sum of T* at 850hPa, 500hPa and 250hPa is larger than 2K.
(7) all conditions (1-6) are satisfied over 2days.

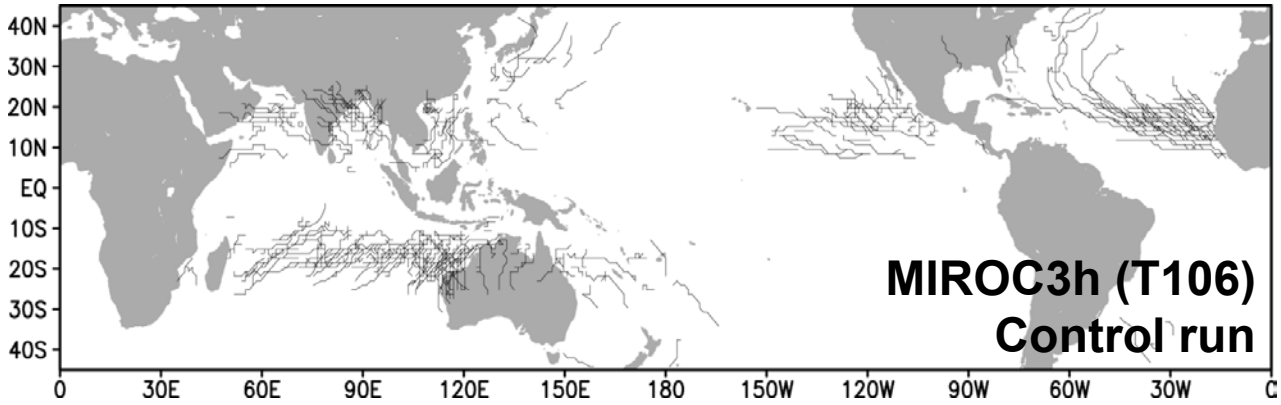
… we need complicated criterions to discuss TC genesis and track in GCM (to extract potential of GCM).

TC genesis and track

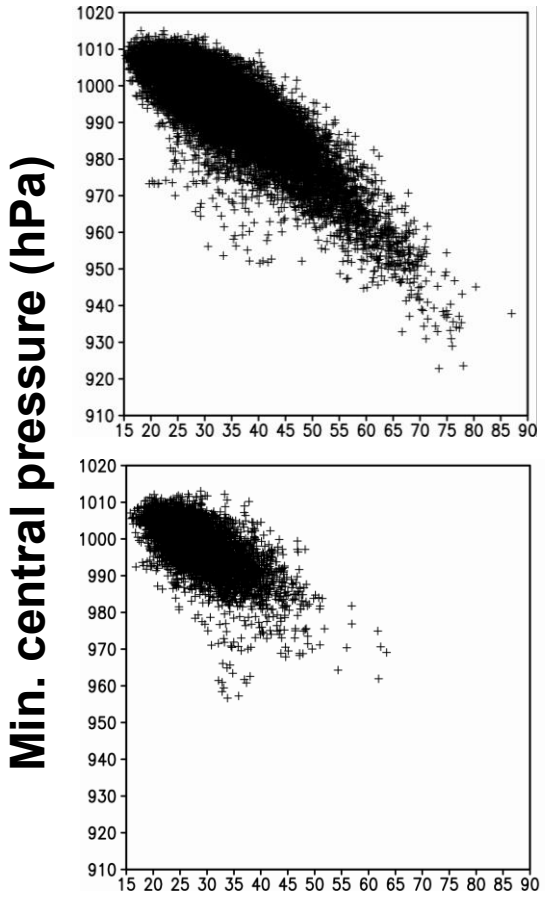
Sakamoto et al. (2012), *J. Meteor. Soc. Japan*







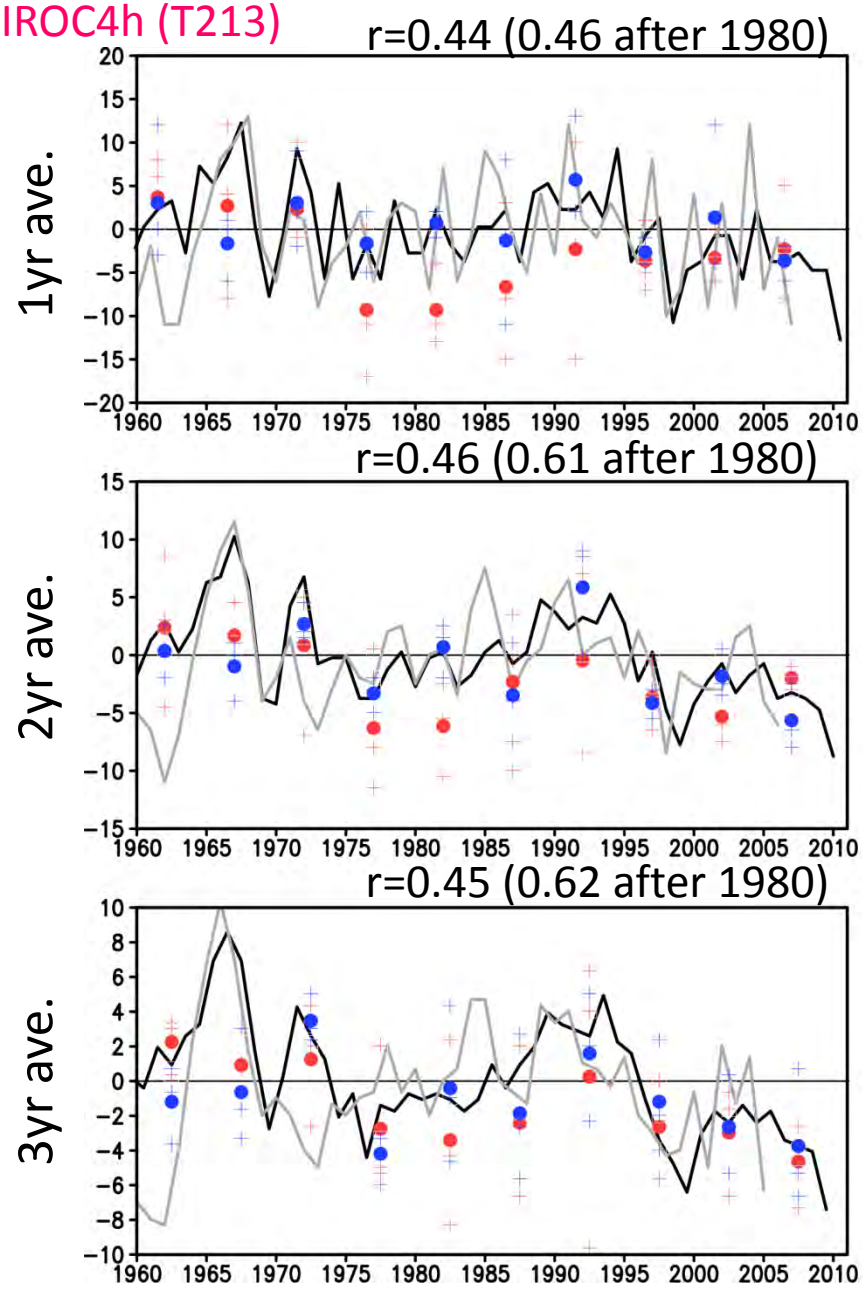
Max. sfc. wind speed (m/s)



c.f., Mori et al. (2013), *J. Meteor. Soc. Japan*

Hindcast of TC genesis number anomaly

MIROC4h (T213)



Observation: JMA Best Track

Assimilation

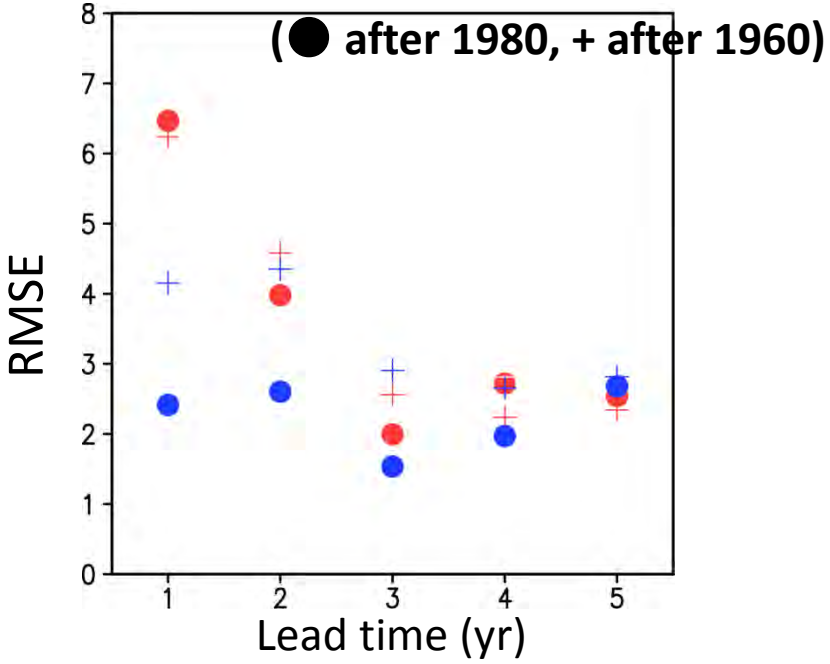
Initialized hindcasts (3 mem. ensemble)

Historical simulation (3 mem. ensemble)

Initialized hindcasts

Historical simulation

(● after 1980, + after 1960)



Summary

- Initialized decadal prediction using GCMs is still experimental and in developing phase. We should be careful of predictive skills in the variables and areas of interest.
- Overall, the initialized decadal hindcasts are superior to the conventional global warming simulations in some aspects.

- Regionally, well predictive skills are found in specific areas (at each grid point).
- The PDO requires large numbers of ensembles and cases to validate prediction skills in the med- and high-resolution GCMs.
- High-resolution GCM has a potential to add regional information of smaller-scale fluctuations such as tropical cyclone.

- In some areas, the decadal prediction data can be useful to force RCM, by providing better climate states of large-scale variations and better conditions for representing small-scale variations.