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Initialized Decadal Predictions by LASG/IAP Climate System Model FGOALS-s2: Evaluations of Strengths and Weaknesses

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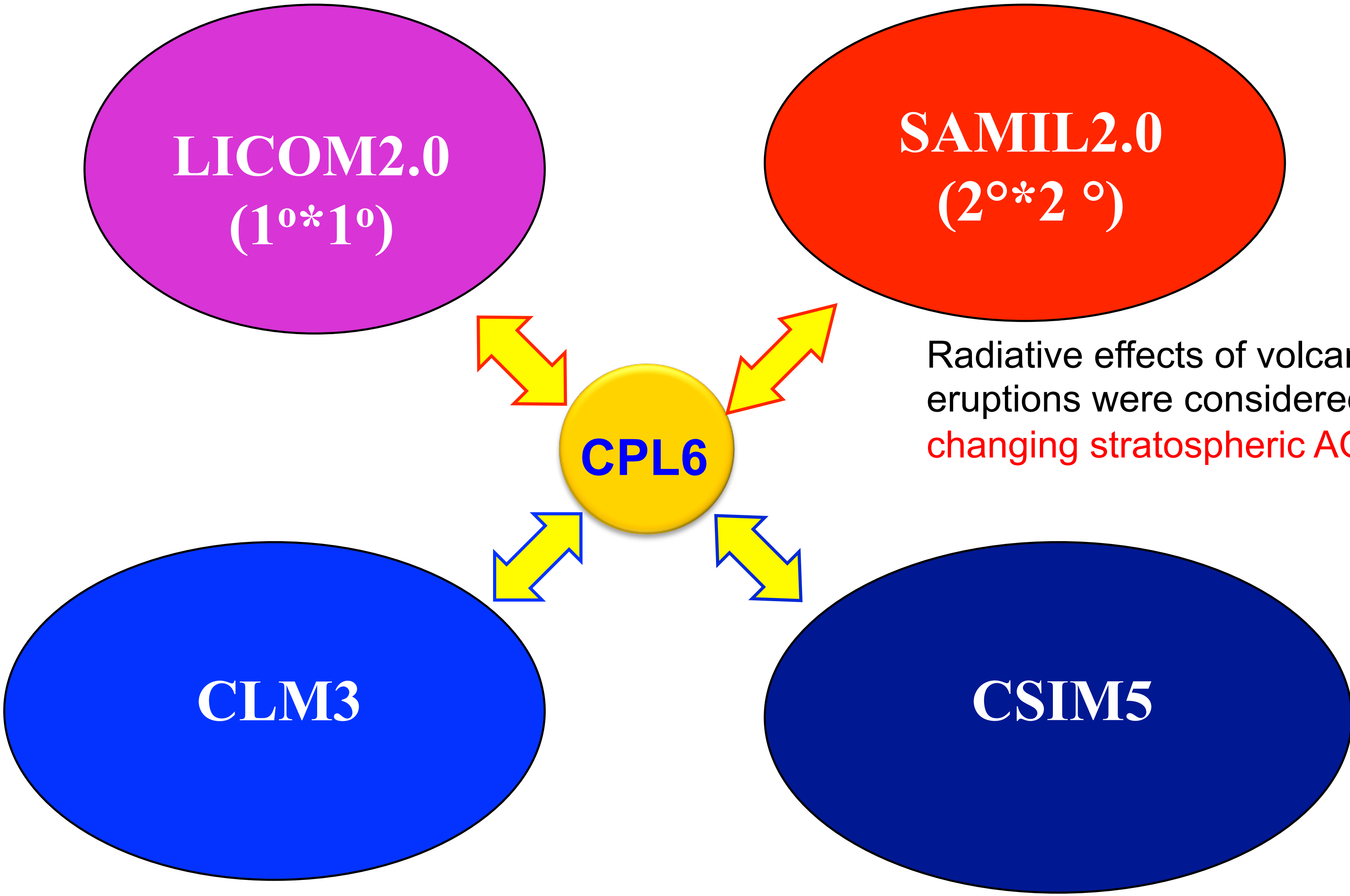
Outline

- Model and initialization scheme
- Evaluation of hindcast runs
- Challenge for the prediction of global monsoons
- Summary

FGOALS-s2 for CMIP5



Radiative effects of volcanic eruptions were considered by changing stratospheric AOD

Bao et al. 2013 AAS

Design of initialization scheme

- **Incremental analysis update (IAU)** scheme (*Bloom et al. 1996 MWR*).
- Observational oceanic temperature and salinity over upper 1000m derived from **the MetOffice gridded objective analysis data EN3_v2a** (Ingleby and Huddleston, 2007,J. *Mar.Sys.*).
- **Anomaly Assimilation approach**, no posterior bias correction .

Introduction of Incremental analysis update (IAU)

- In one assimilation cycle ($t \sim t+\tau$), the model was integrated freely firstly, which produced the first guess for the assimilation.
- The analysis increment were calculated
- The model was restated from *t* again and integrated to $t+\tau$, with analysis increments being introduced as a constant in every model step.
- **Designed for data assimilation system of meteorology** *(Bloom et al. 1996),* then **applied to the ocean assimilation** *(Huang et al. 2002),* and **coupled model initialization** (Tatebe et al. 2012).

Exp. Design: Hindcast and forecast runs follow **CMIP 5 protocol**

- The **10-year-long hindcasts/forecasts** were **started every five years** over the period of 1960-2005.
- Initial conditions were obtained from the ASSIM runs.
- In the hindcast and forecast stages (before and after 2005), the model was driven by the time-varying radiative forcing consistent with the historical and representative concentration pathways 4.5 (RCP4.5) simulations, respectively.
- To estimate the uncertainties of the prediction, we performed **3-member** ASSIM runs with different initial conditions, which further offered initial conditions for three sets of hindcasts/forecasts runs.

Skill Quantification

Root Mean Square Skill Score (**RMSSS**):

RMSSS= 1-RMSE(hindcast)/RMSE(climatology)

Where RMSE is the root mean square error of the hindcast and no skill baseline.

Ratio of RMSE= RMSE(INIT)/RMSE(NoINIT)

Doblas-Reyes et al. *2013,**Nature Communication***

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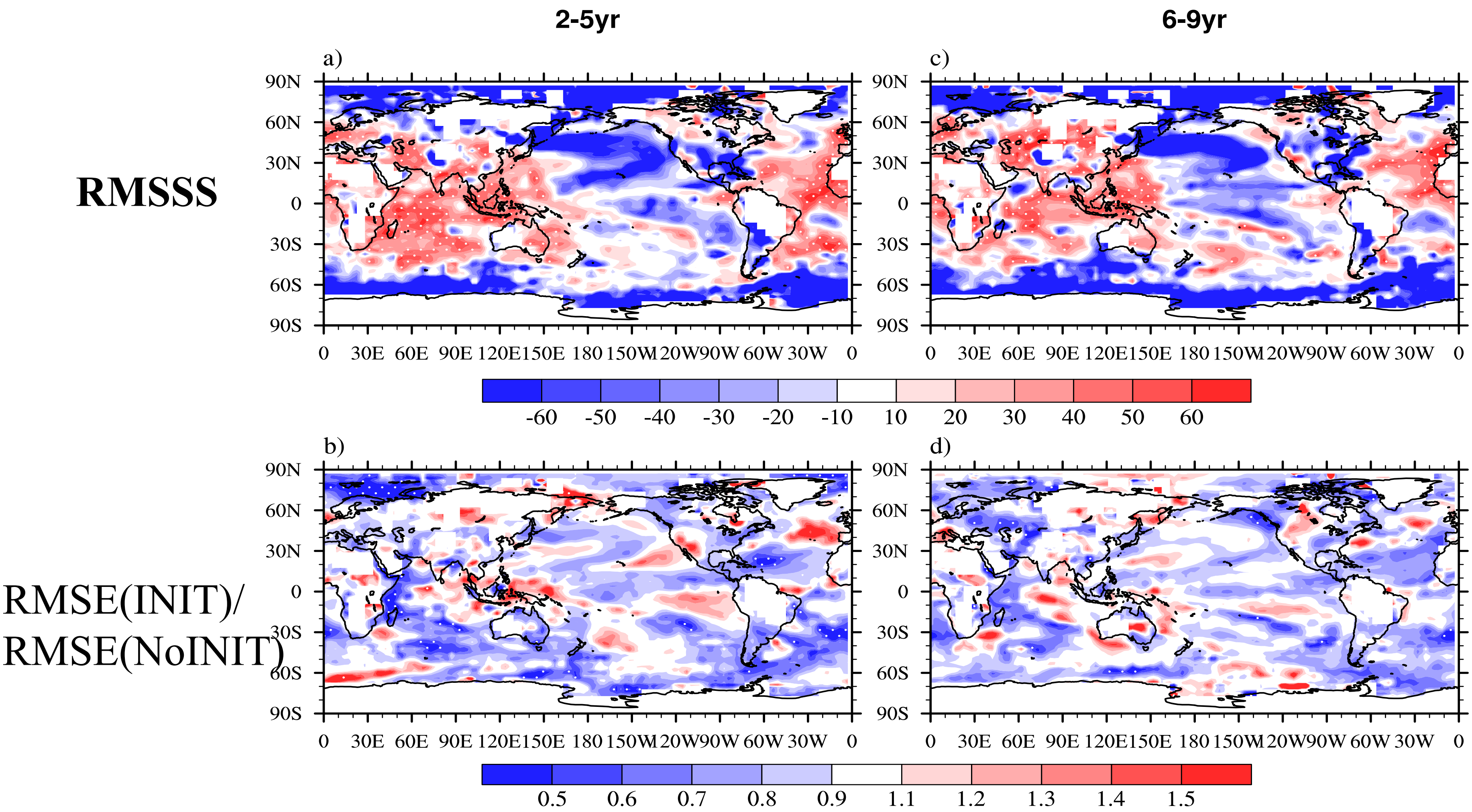
Metrics

1. Root Mean Square Skill Score of surface air temperature
2. RMSSS of land precipitation
3. Global mean surface air temperature time series
4. Atlantic multi-decadal variability (AMV)
5. Atlantic Meridional Overturning Circulation (AMOC)
6. IPO/PDO/Mega-ENSO

Hindcast of surface air temperature (FGOALS-s2)

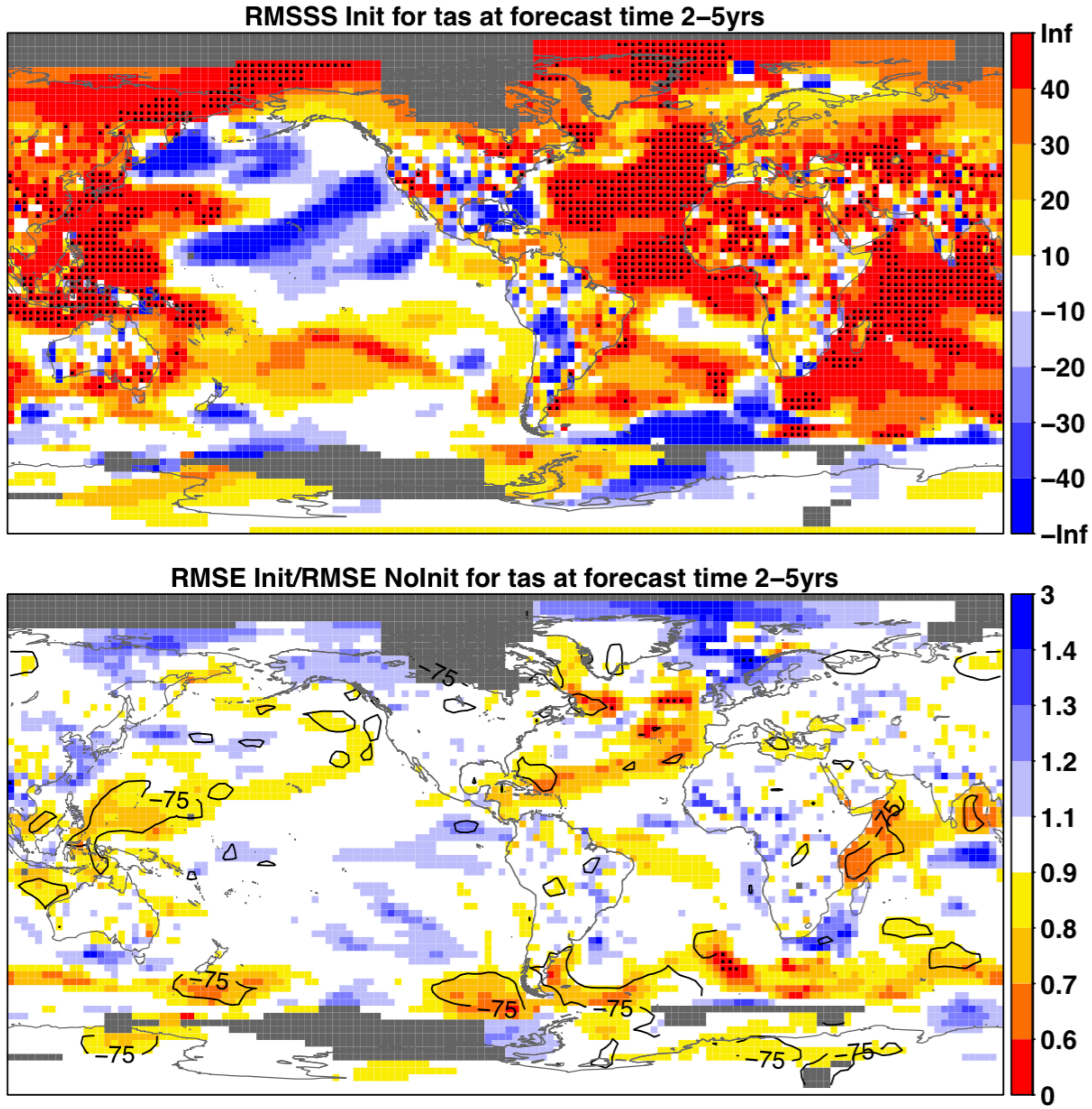


Significant high predictive skills in the Indian Ocean, tropical western Pacific and Atlantic

Hindcast of surface air temperature (CMIP5 MME)

RMSSS

RMSE(INIT)/
RMSE(NoINIT)



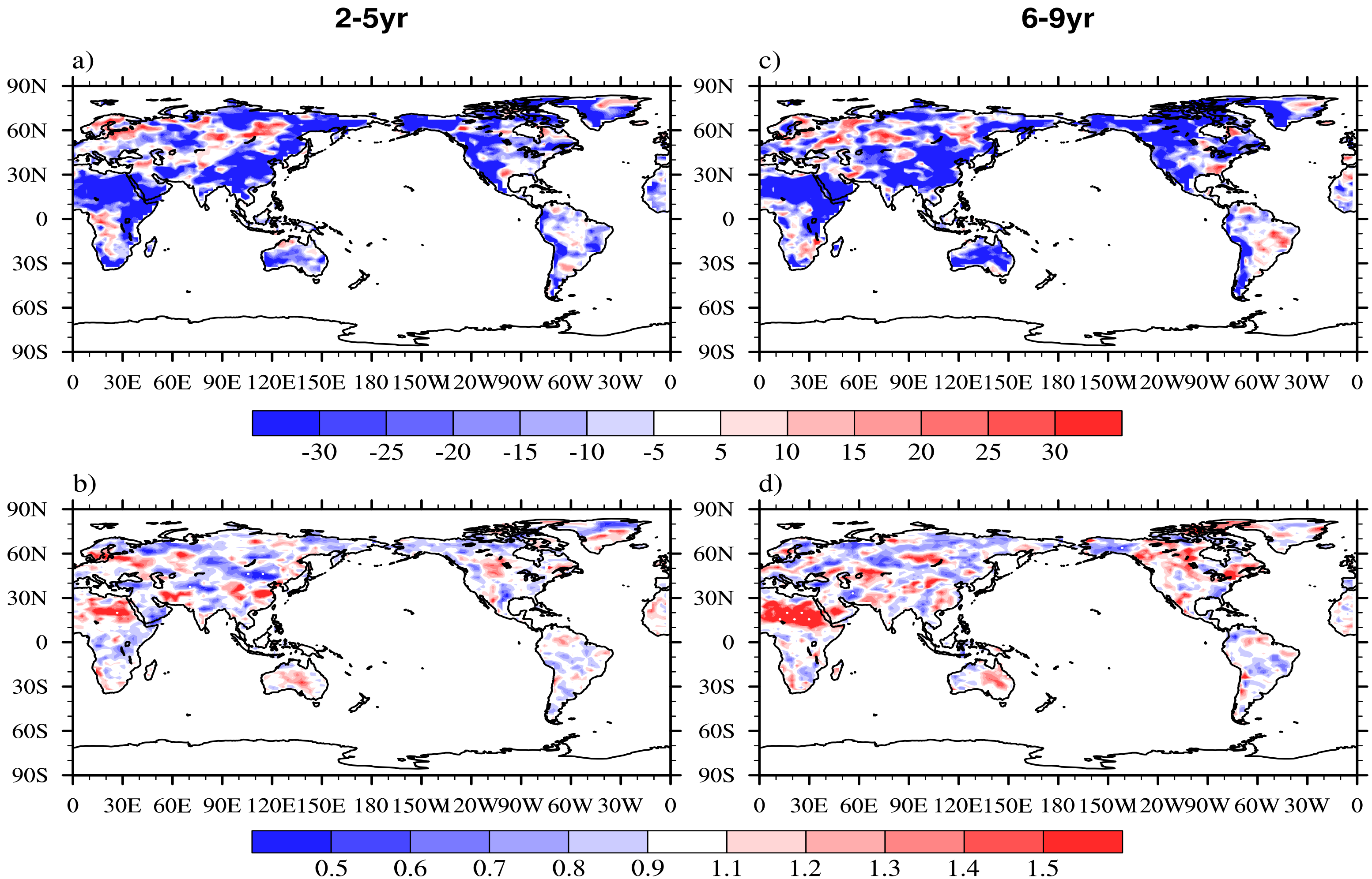
Also high skills in the Indian Ocean, tropical western Pacific and Atlantic

IPCC AR5 chp11

Hindcast of land precipitation (FGAOLS-

RMSSS

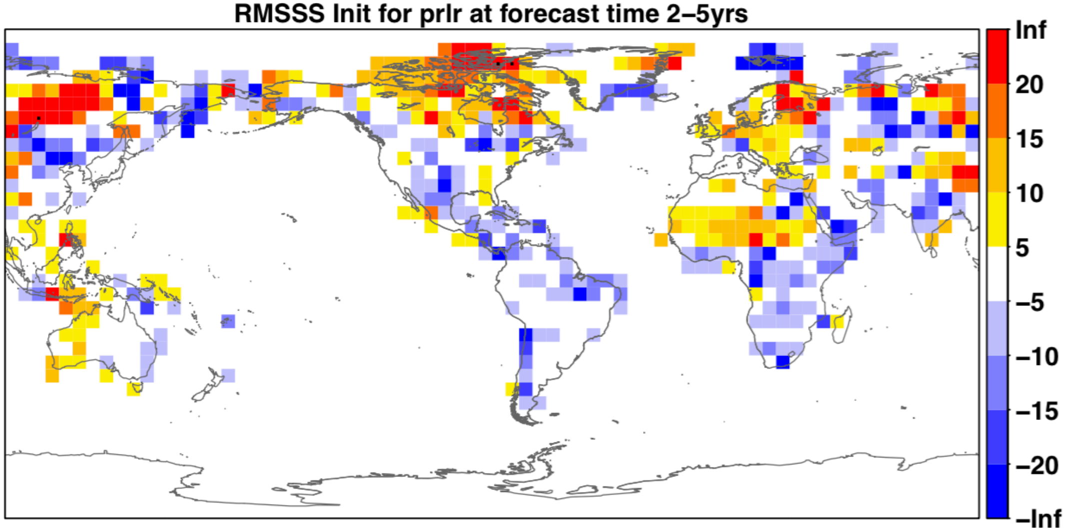
RMSE(INIT)/
RMSE(NoINIT)



Low skills over most part of the world

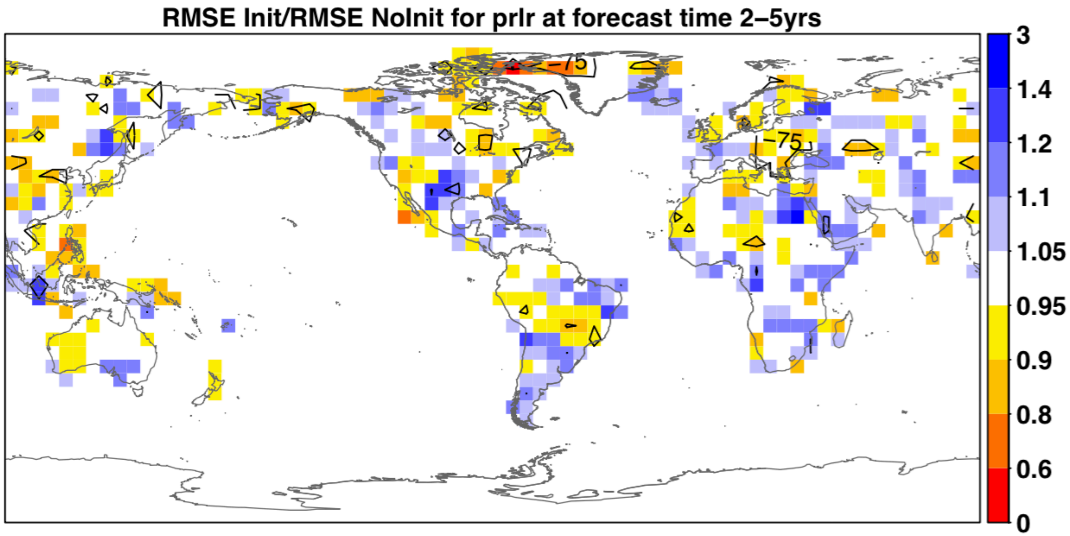
Hindcast of land precipitation (CMIP5 MME)

RMSSS



Better than FGOALS, but still low

RMSE(INIT)/
RMSE(NoINIT)

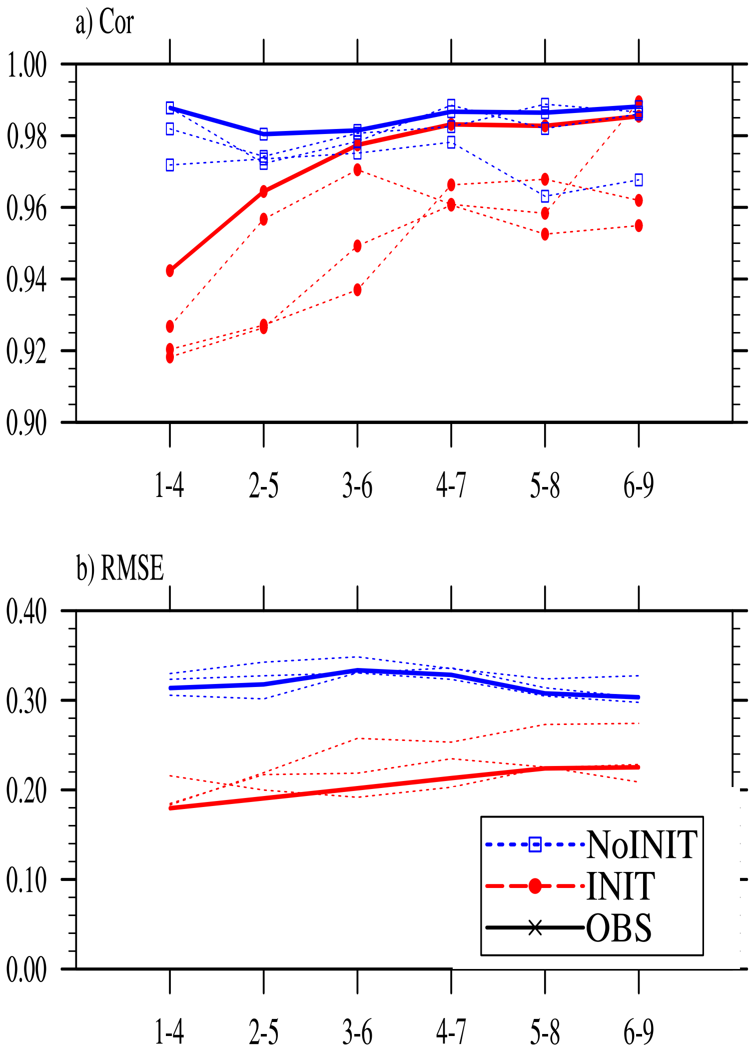


IPCC AR5 chp11

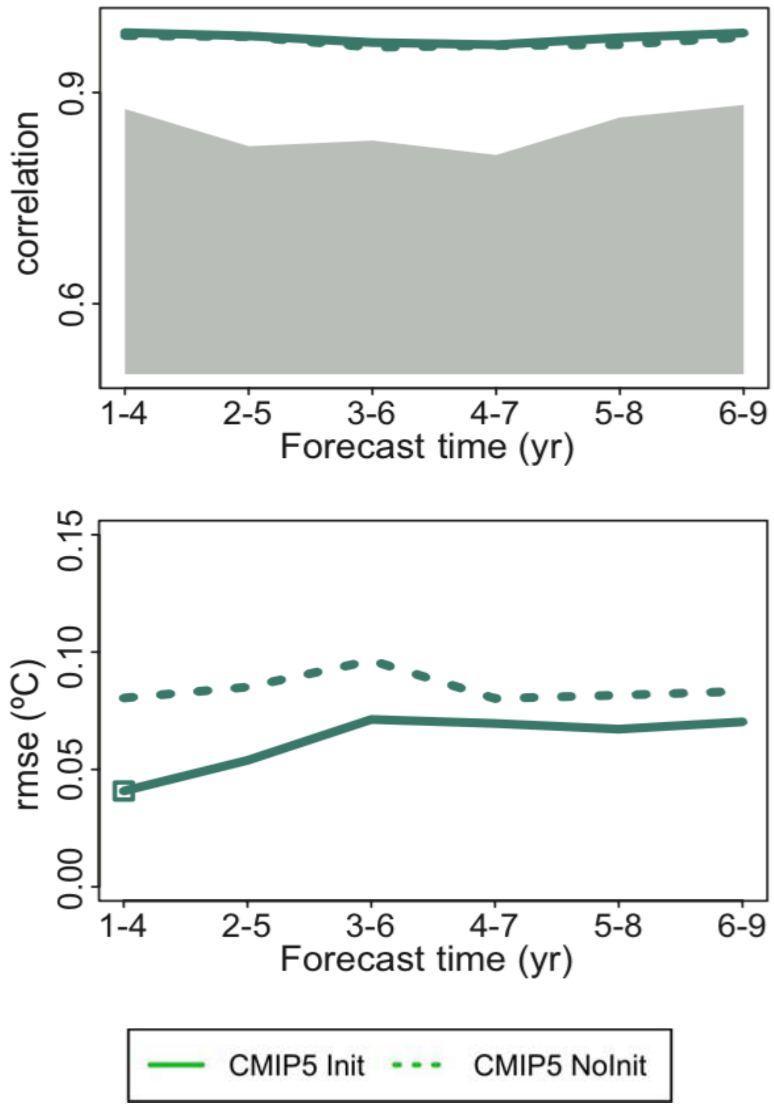
Hindcast of global mean surface air temperature (GMST)

Cor

RMSE

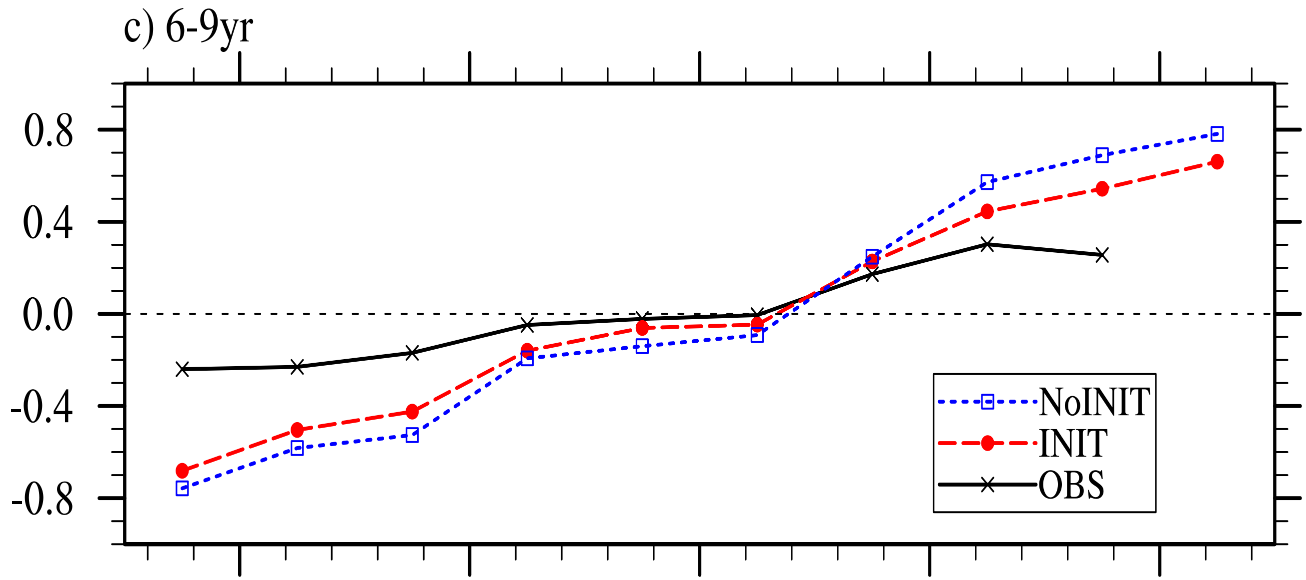


FGOALS-s2

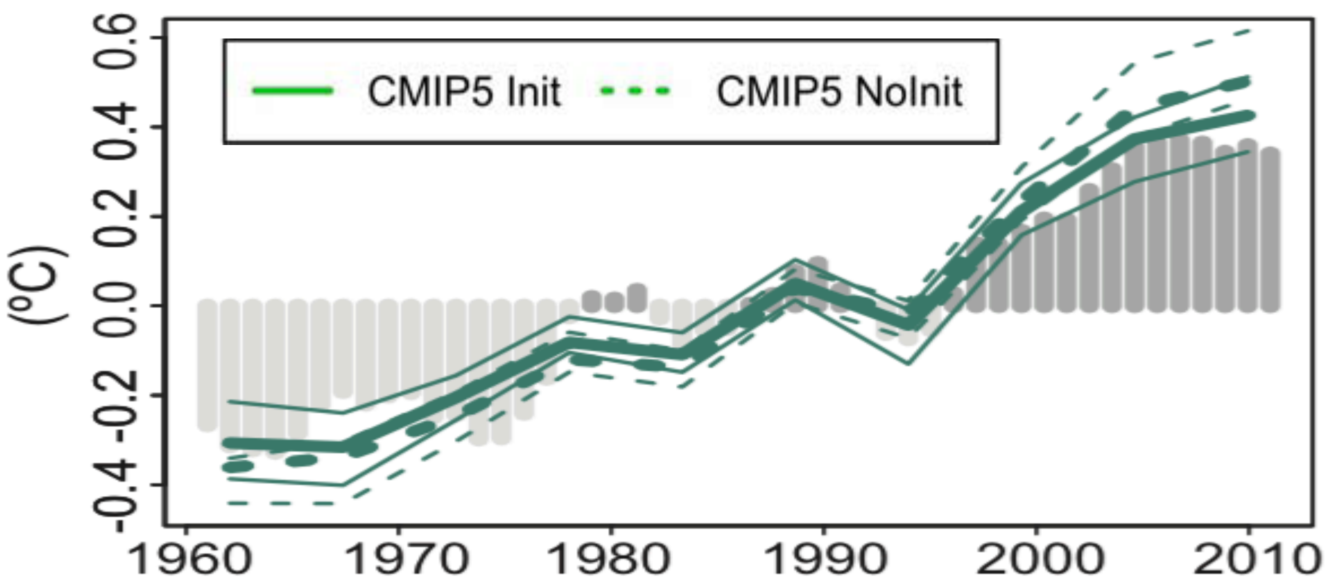


IPCC AR5 chp11

Hindcast of global mean surface air temperature (GMST)



FGOALS-s2

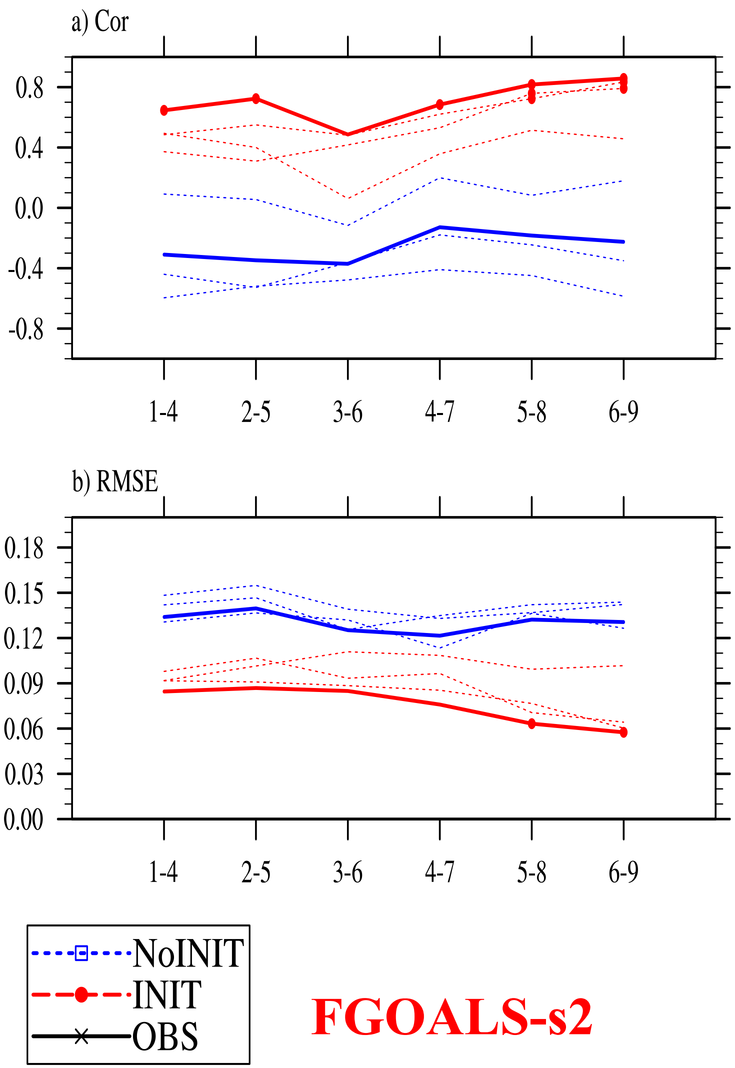


IPCC AR5 chp11

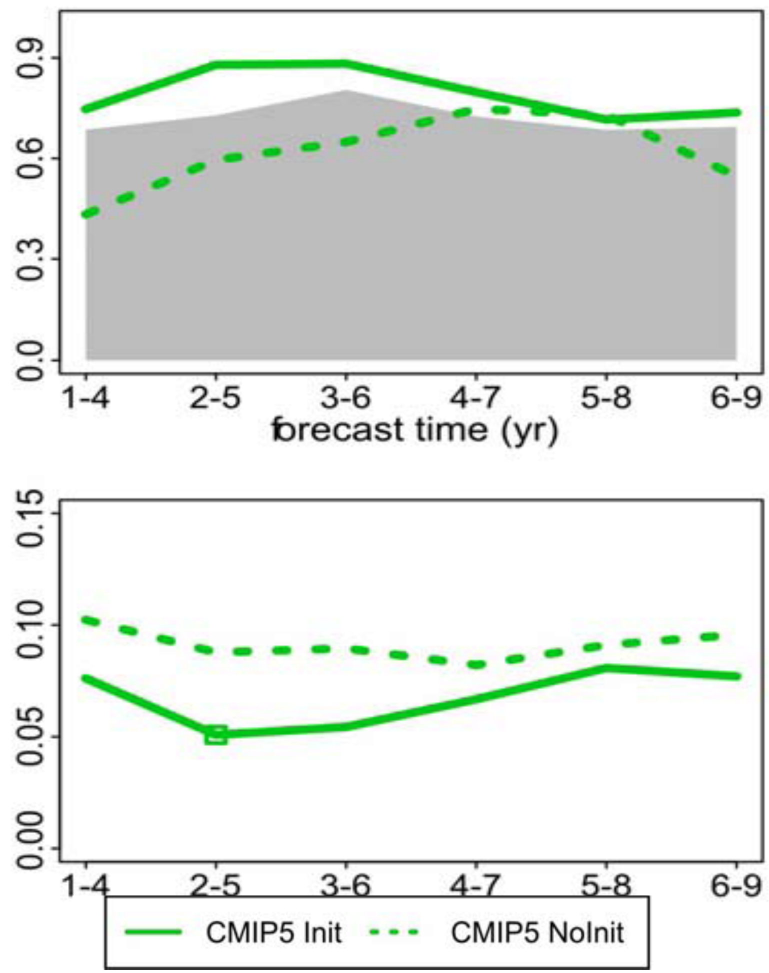
Hindcast of Atlantic multidecadal variability AMV

Cor

RMSE

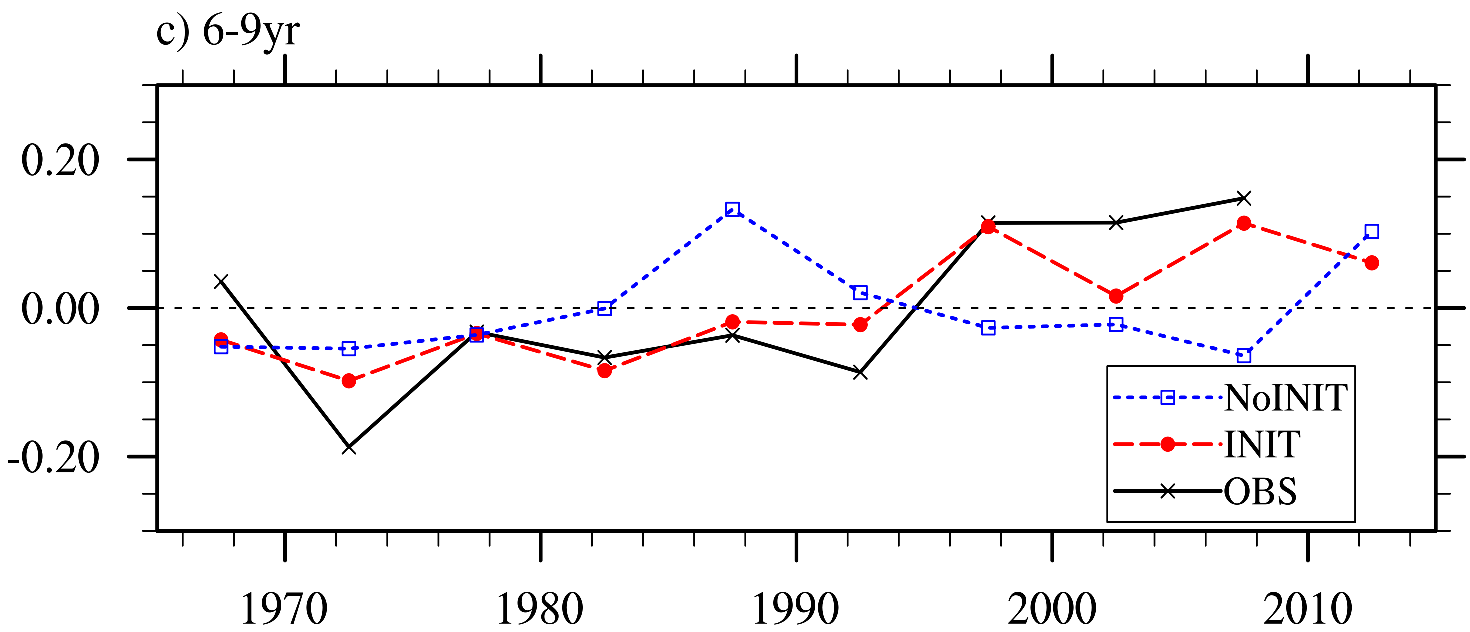


FGOALS-s2

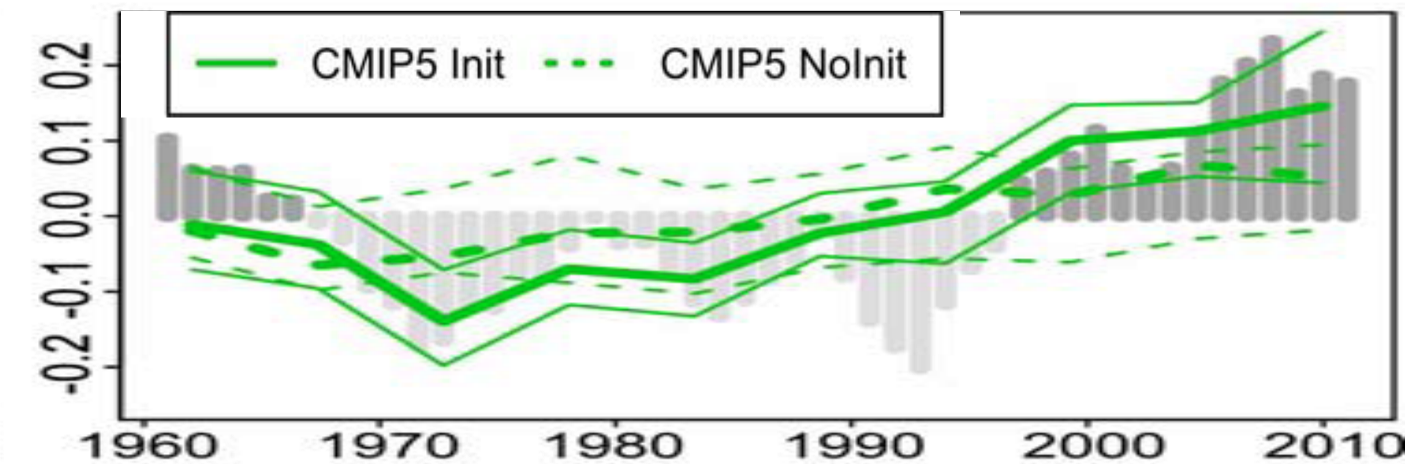


IPCC AR5 chp11

Hindcast of AMV Time Series

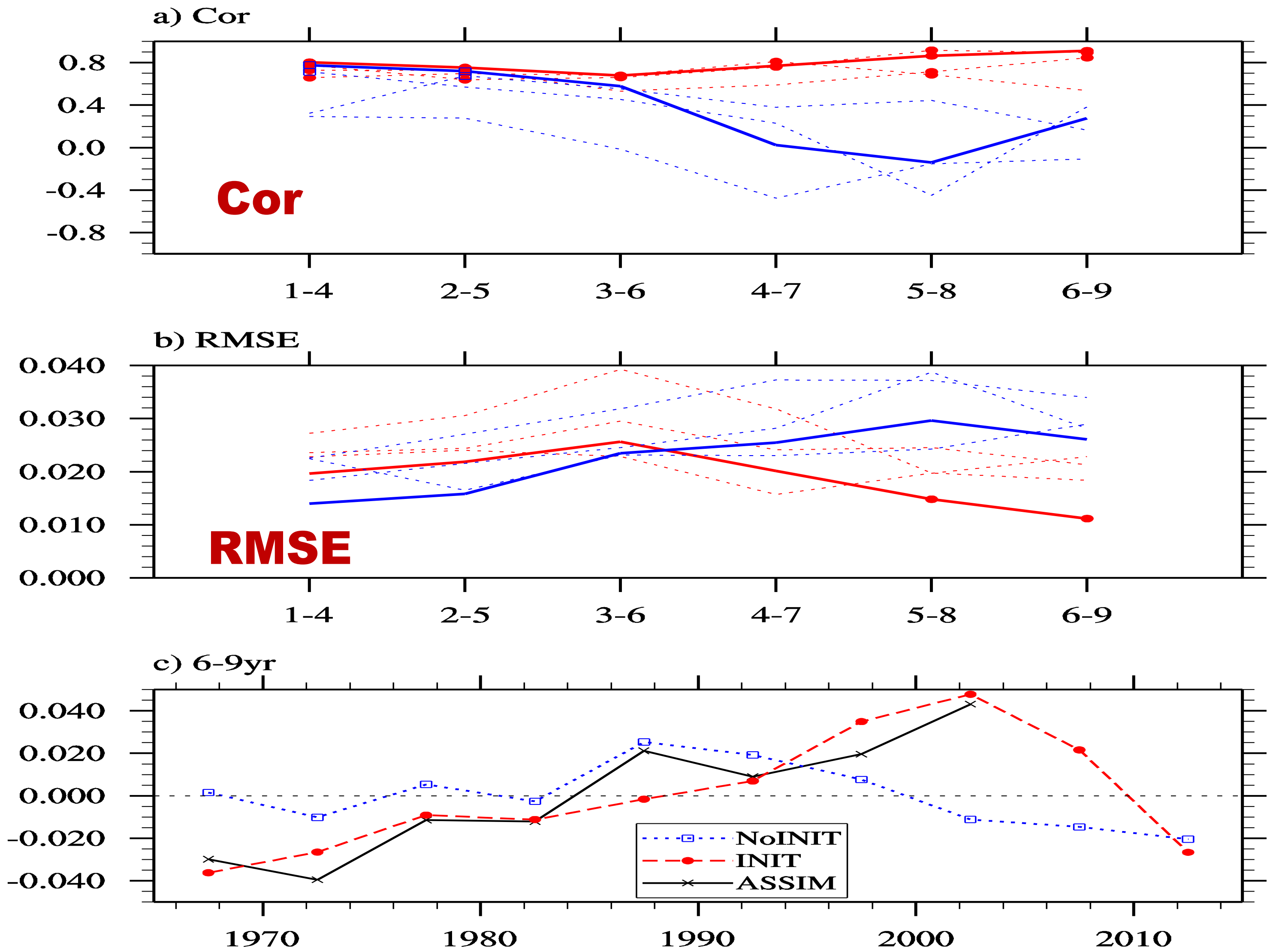


FGOALS-s2



IPCC AR5 chp11

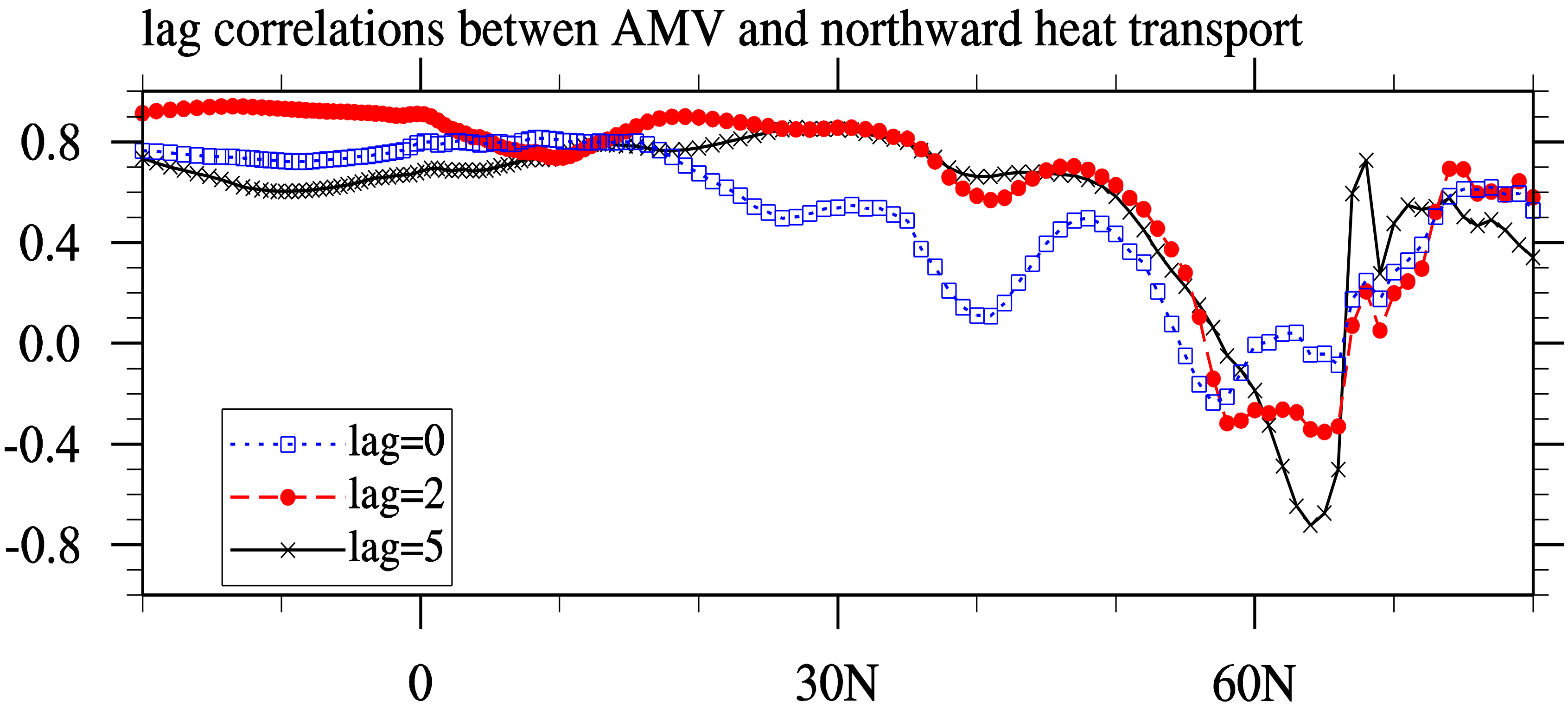
Variations of AMOC predicted by FGOLAS-s2



"Observed" AMOC derived from the assimilation (Yang et al. 2012 JC)

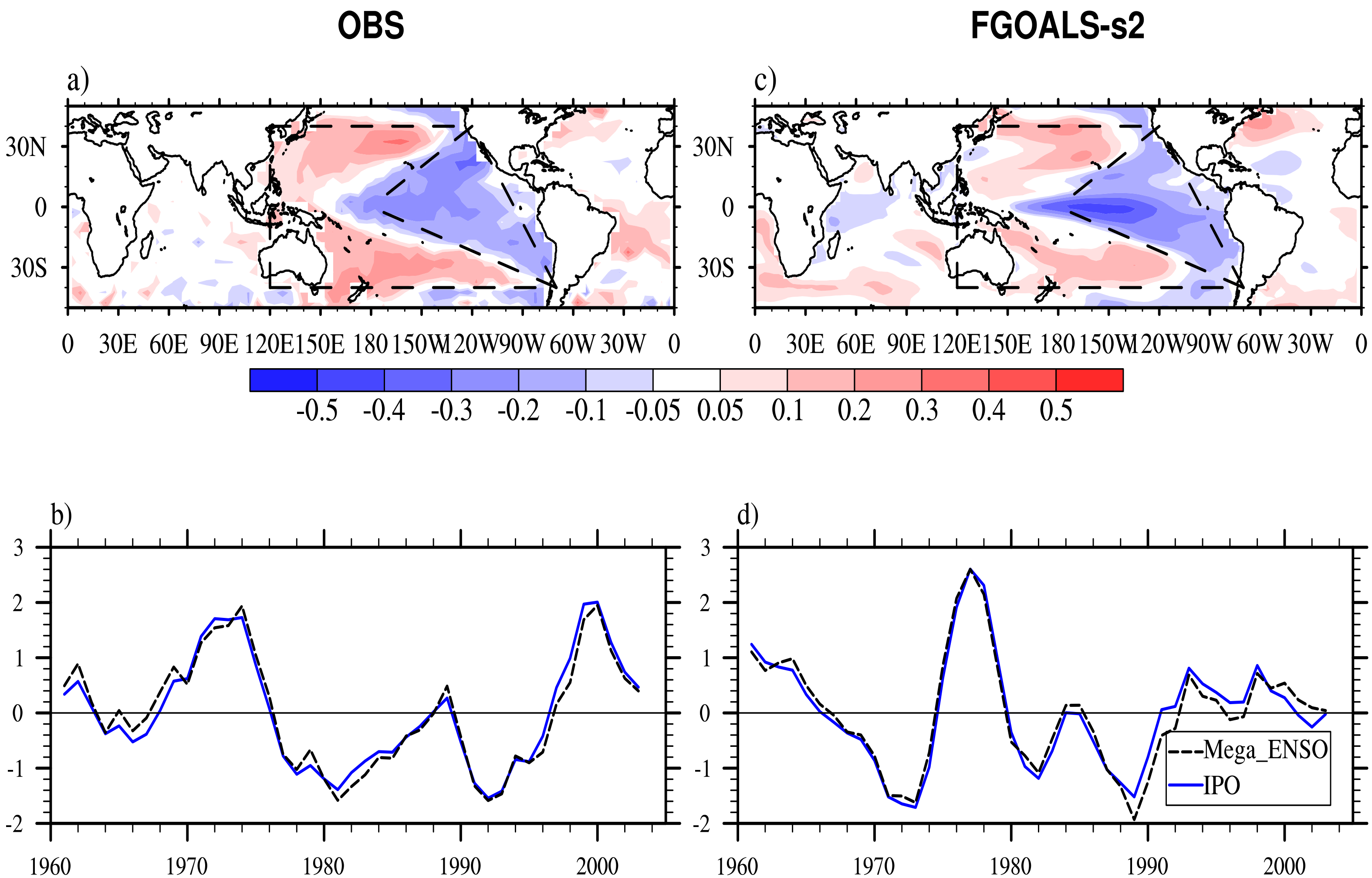
Interdecadal variation of AMOC is well predicted.

Where does the AMV skill come from?



Skills of the AMV prediction come from the prediction of AMOC.

Mega-ENSO/IPO simulated by FGOALS-s2 in the historical runs

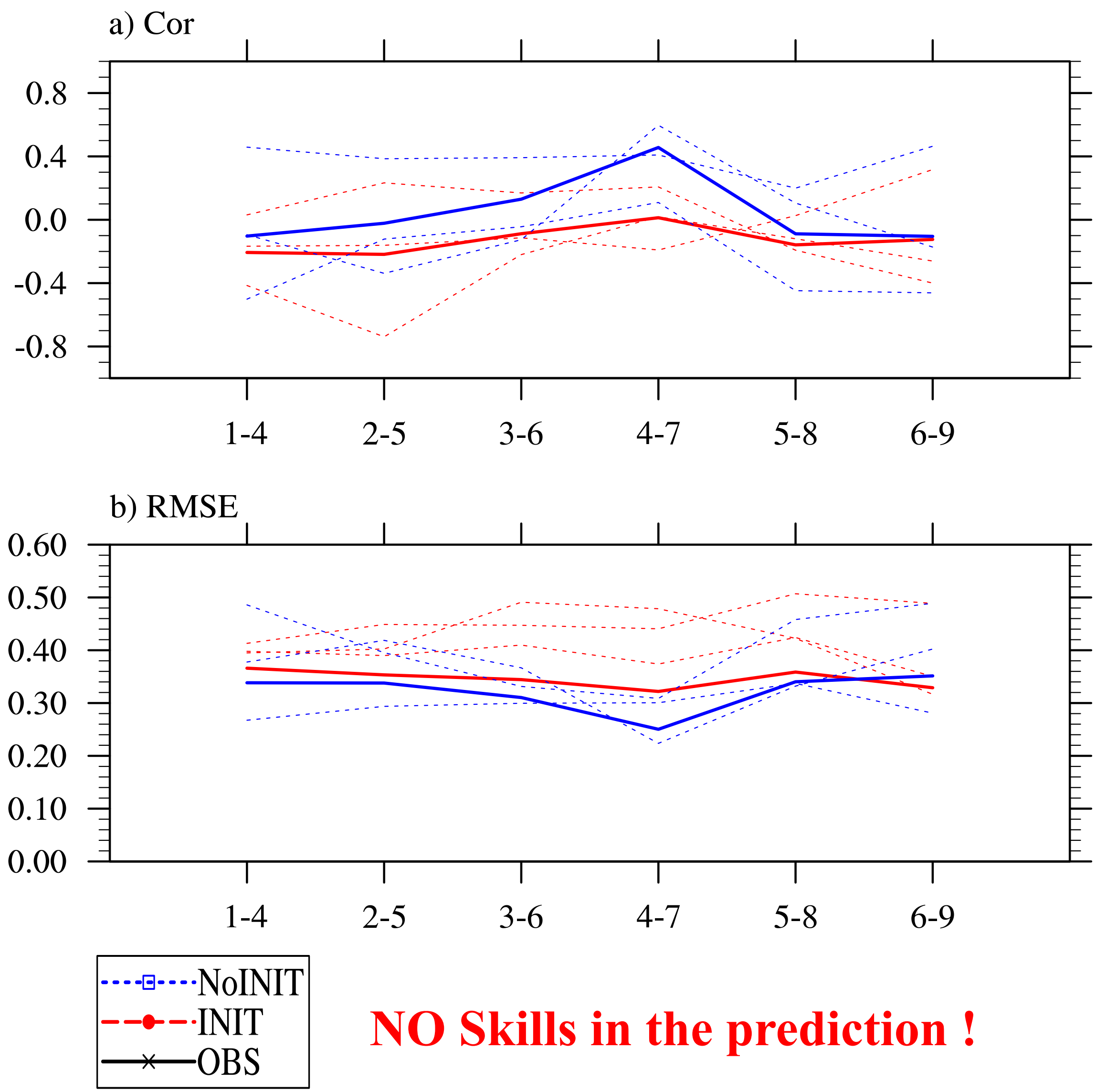


The spatial pattern of the IPO/Mega-ENSO simulated by the FGOALS-s2 resembles that in the observation

Hindcast of PDO/Mega-ENSO

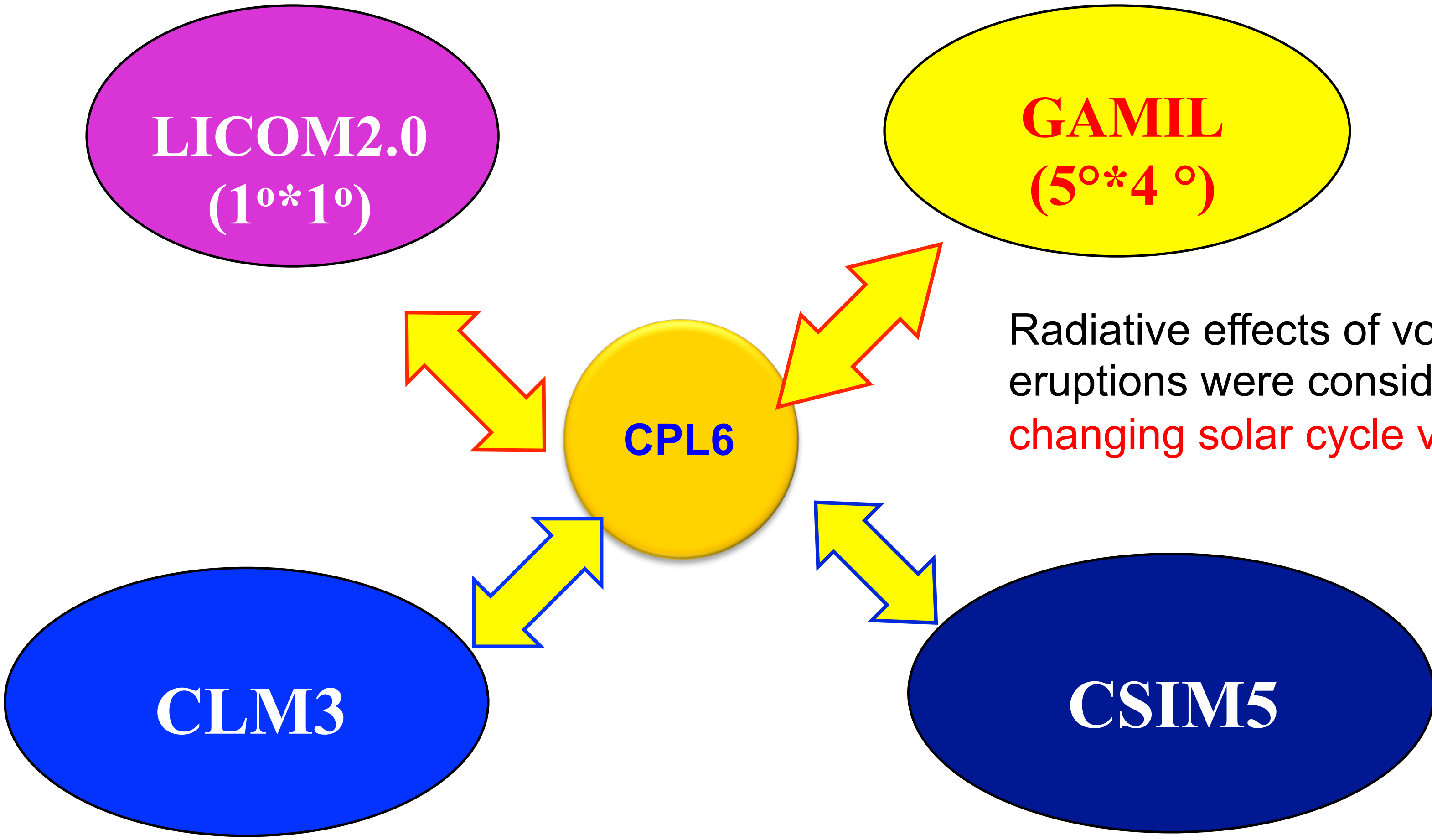
Cor

RMSE



NO Skills in the prediction !

Another Exp with FGOALS-gl



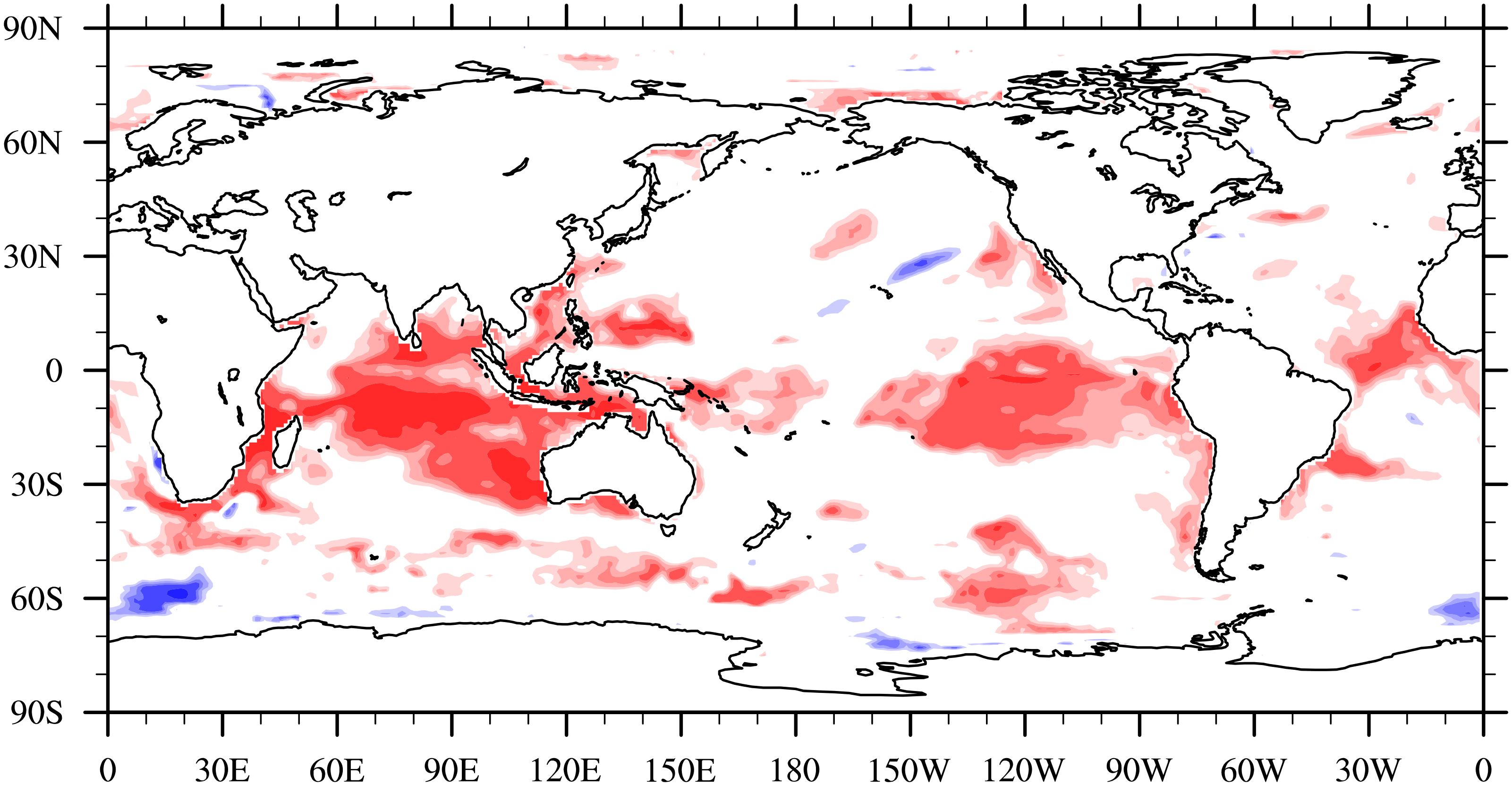
Radiative effects of volcanic eruptions were considered by changing solar cycle variations

- FGOALS-gl: low-resolution version of FGOALS.
- **Share the same initialization scheme with FGOALS-s2**

Zhou et al. 2008 AAS

Model dependent of the Skill

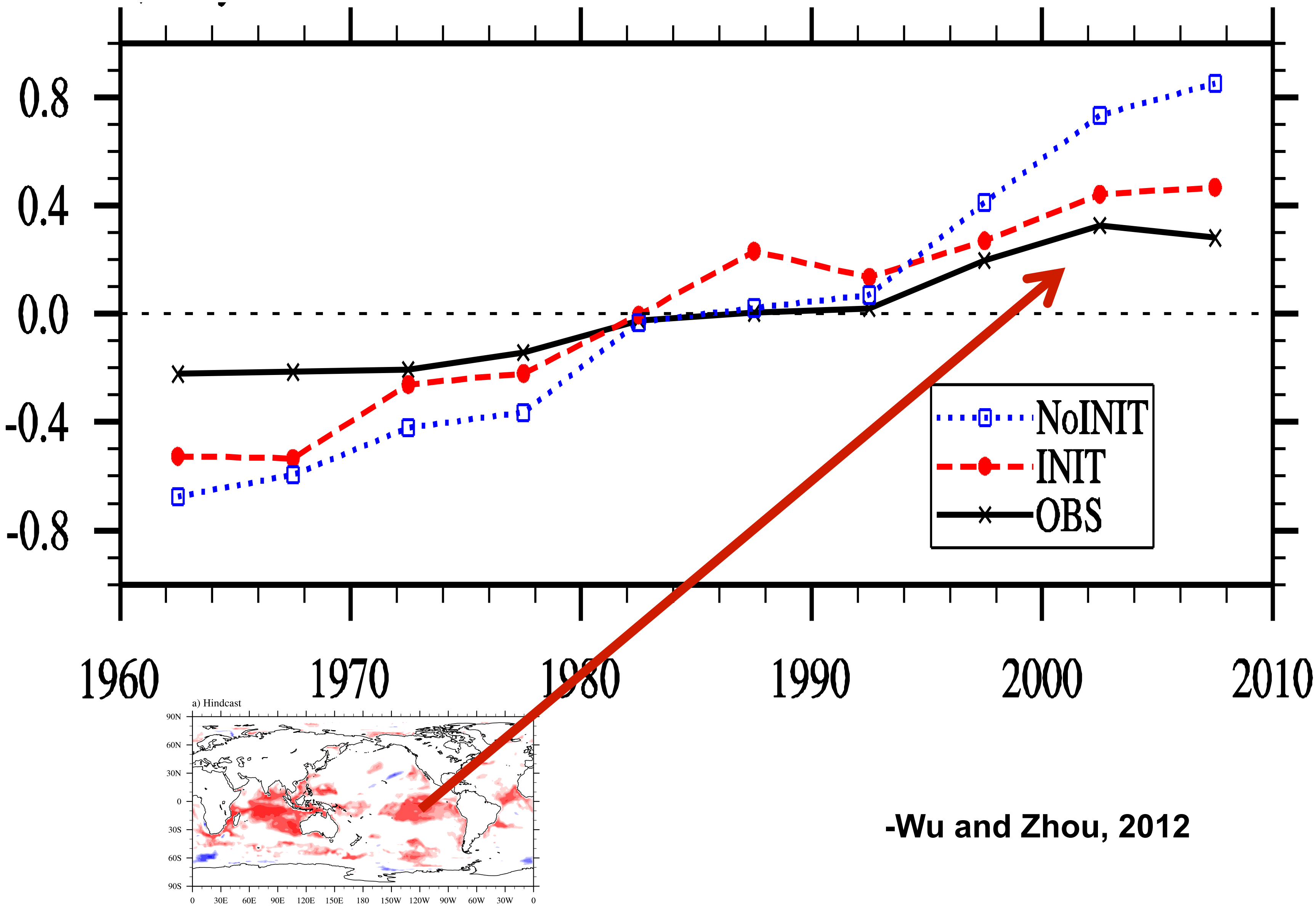
Correlations of the 10-year-mean SST predicted by FGOALS-gl



High skills in the equatorial Pacific, but **low skills in the Atlantic**.

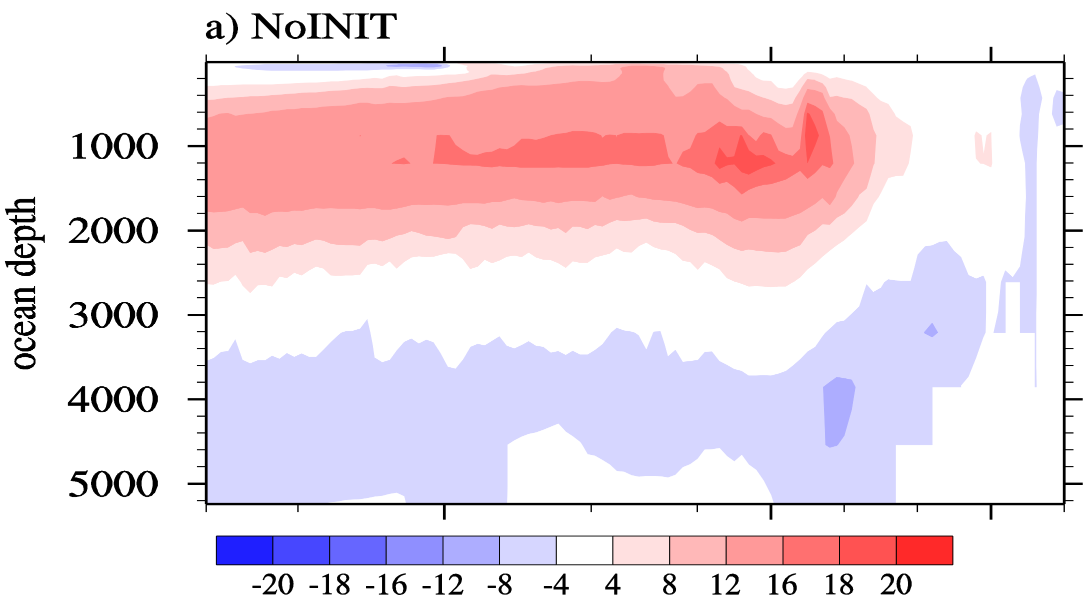
Skills of decadal prediction are highly model dependent!

Hiatus in FGOALS-gl hindcast

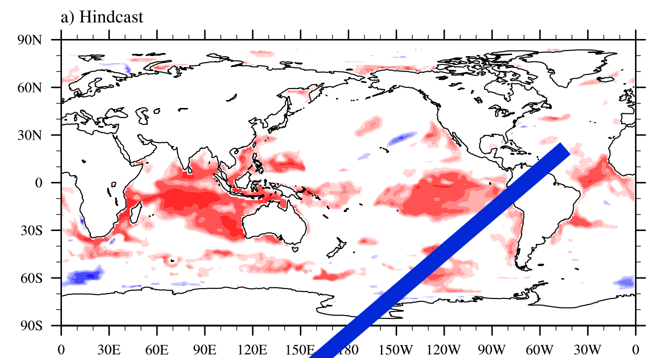


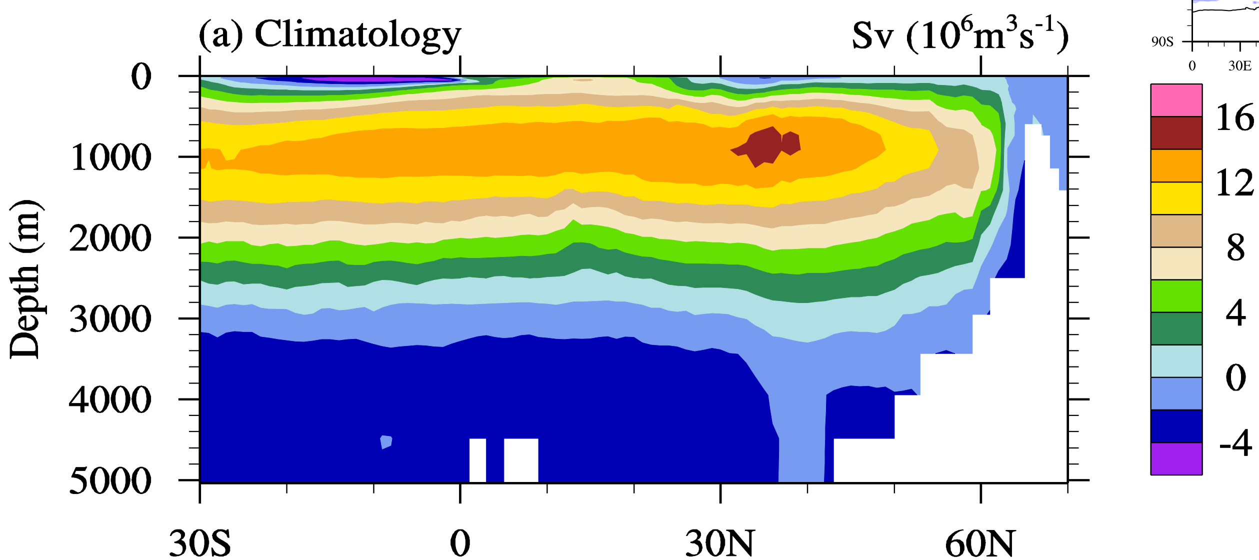
-Wu and Zhou, 2012

Climate mean states of AMOC



FGOALS-s2





FGOALS-gl

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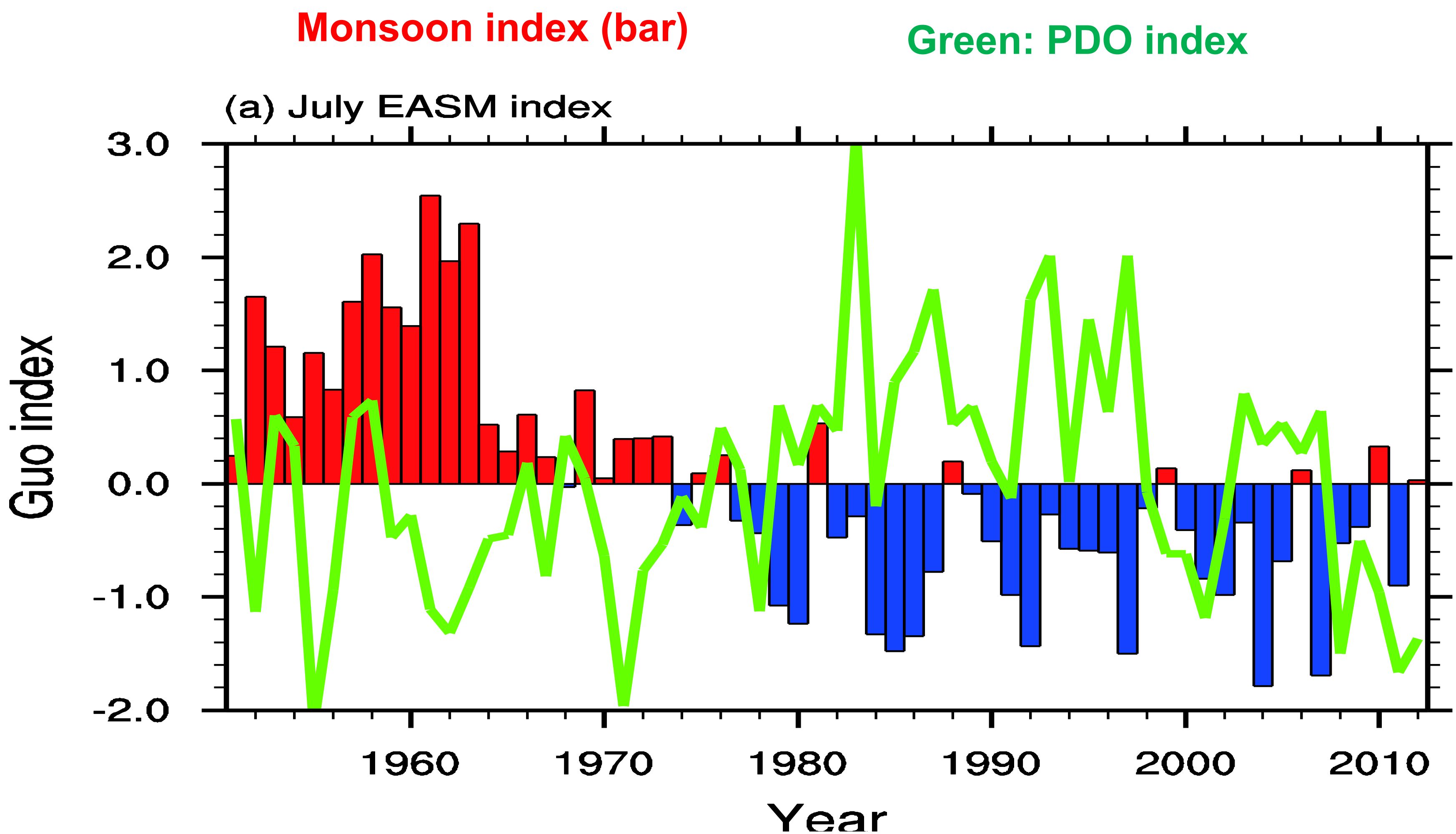
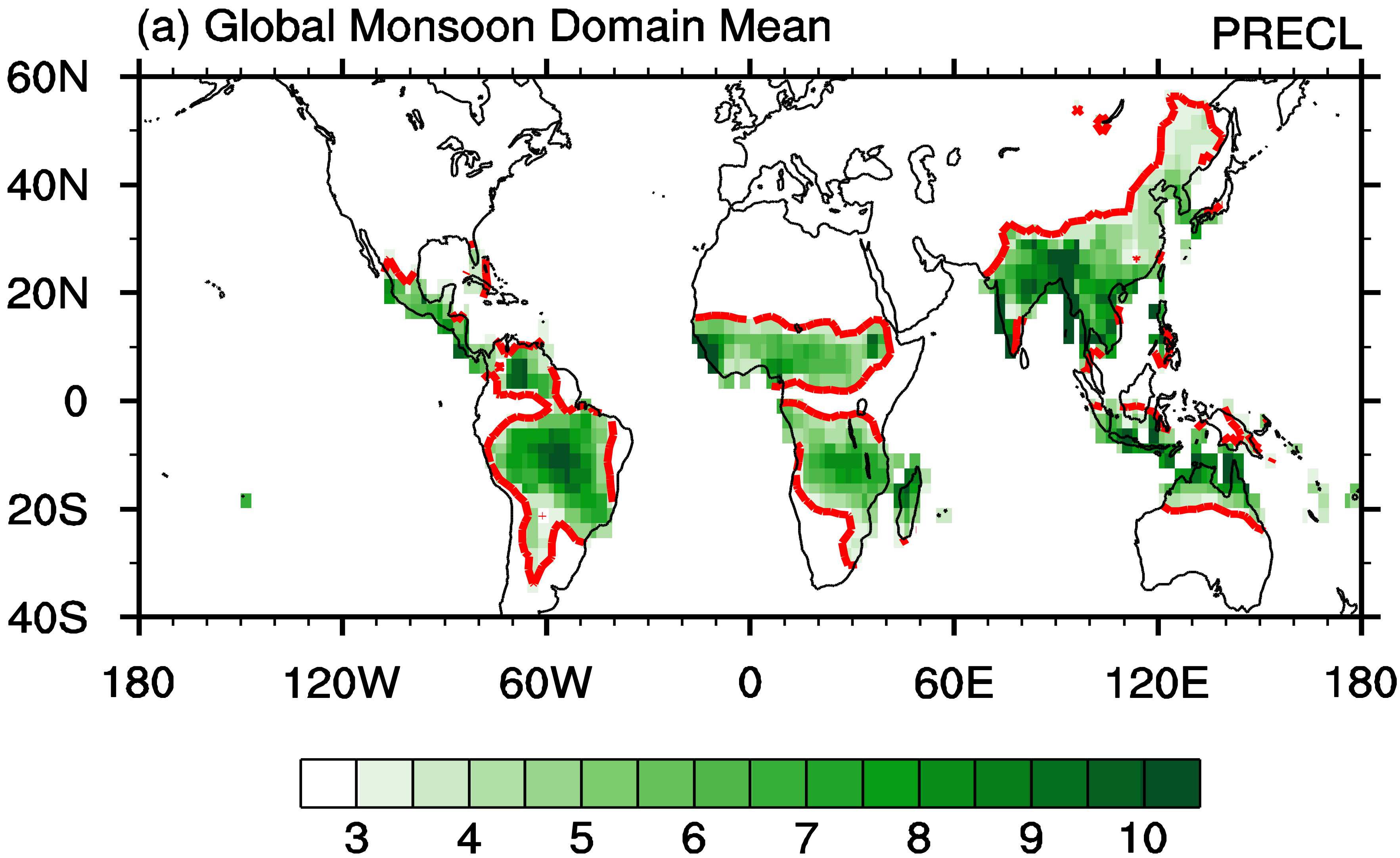
PDO and E. Asian monsoon



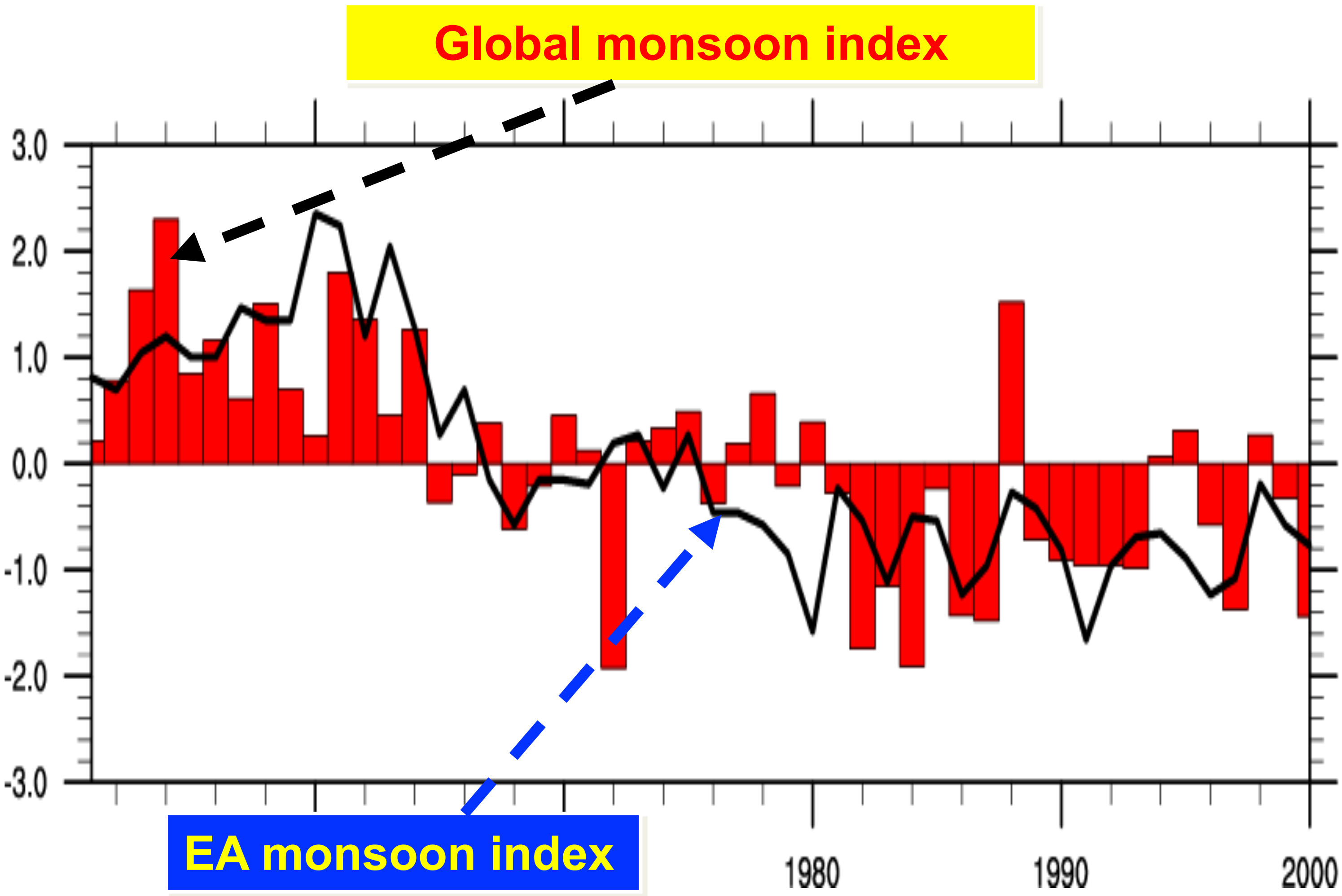
Zhou, T., F. Song, R. Lin, X. Chen and X. Chen, 2013: The 2012 North China floods: Explaining an extreme rainfall event in the context of a long-term drying tendency [in "Explaining Extreme Events of 2012 from a Climate Perspective"]. ***Bulletin of the American Meteorological Society***, 94(9), S49-S51

Global monsoon Domain



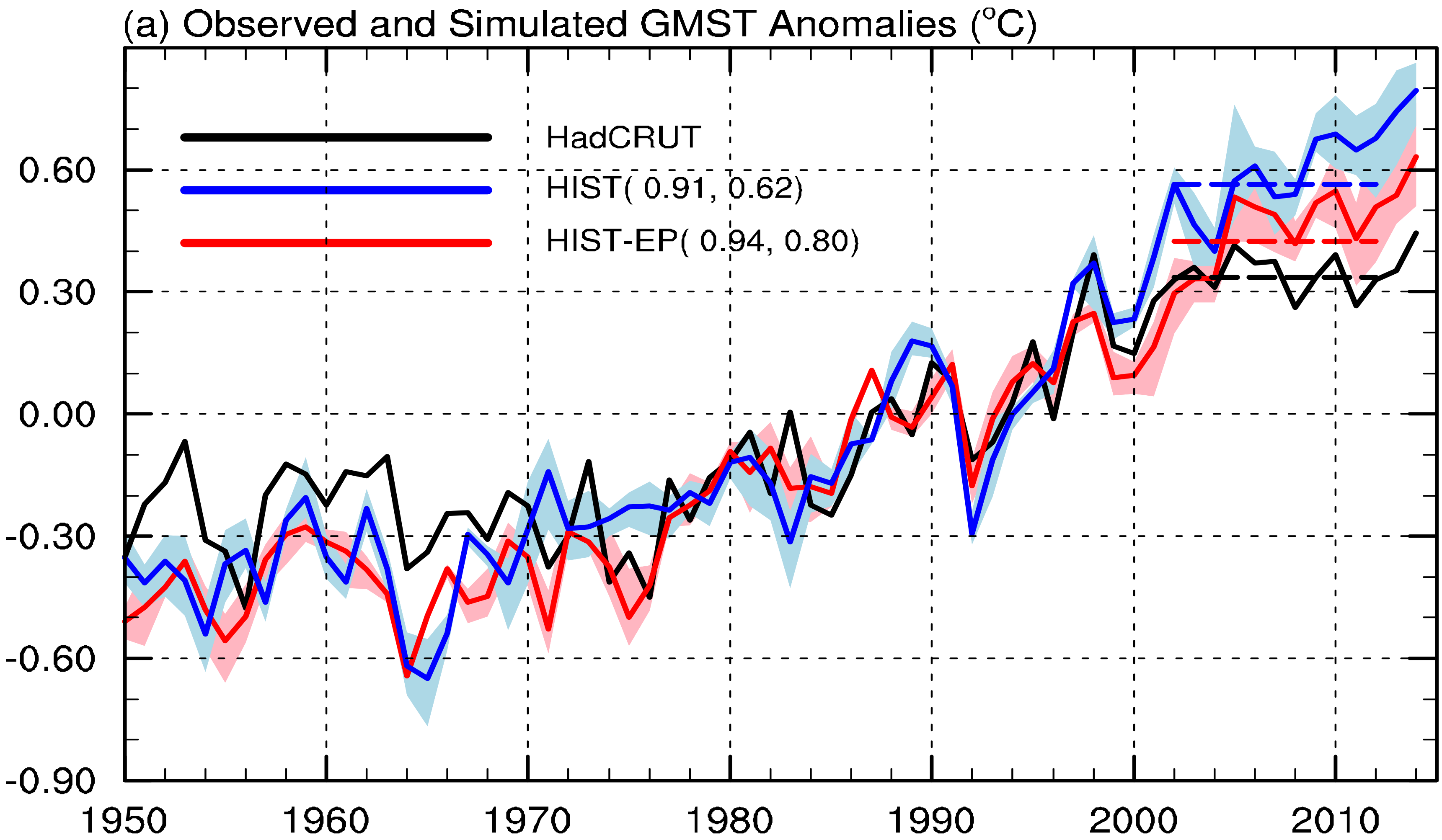
Lin, Zhou, Qian, 2014, *J. Climate*

E. Asian Summer Monsoon and Global Monsoon



Zhou T., L. Zhang, **Hongmei LI** 2008 Changes in global land monsoon area and total rainfall accumulation over the last half century, ***Geophysical Research Letters***, 35, L16707, doi:10.1029/2008GL034881

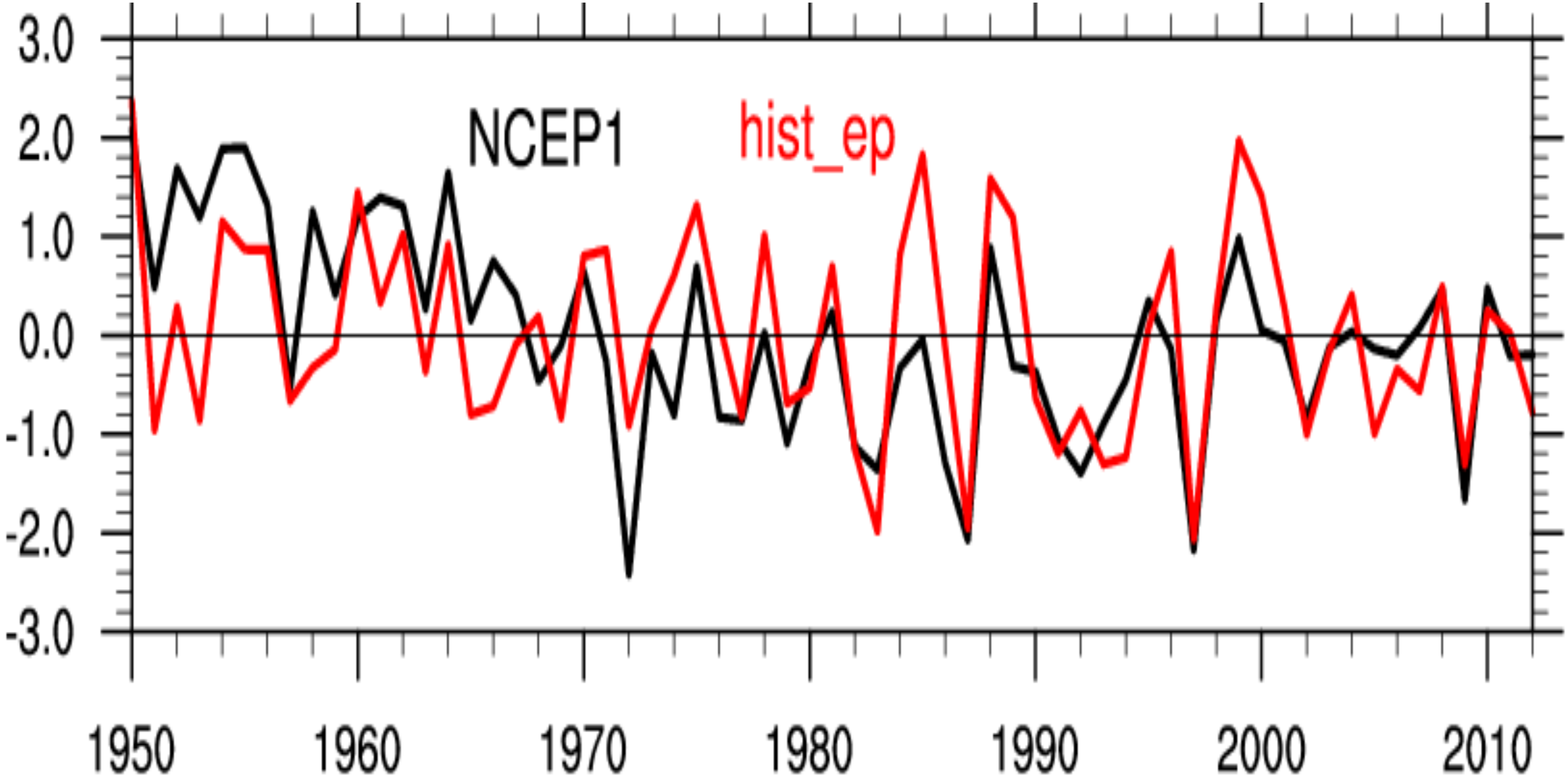
Hiatus in E.Pac Pacemaker run



Zhou, Song, Liu et al. 2015, to be submitted

Global Monsoon in E. Pacific Pacemaker run

Higher PDO skill, Higher GM skill



COR=0.65, after removing interannual signals, 0.49

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Summary

- **Strengths of FGOALS-s2**: Significant predictive skills in the Indian Ocean, tropical western Pacific and Atlantic, *similar to the results of the CMIP5 multi-model ensemble*.
- The predictive skills of AMV are resulted from the northward heat transport anomalies associated with the preceding fluctuations of the AMOC.
- **Weakness of FGOALS-s2:** No skill is seen for PDO, posing a challenge for global monsoon prediction.
- **Discussion:** The skills seem to be model-dependent, even the models share an identical initialization scheme. ***The treatment of volcanic effects may be one reason?***

- Wu, B., X. Chen, F. Song, Y. Sun, T. Zhou, 2015, Decadal predictions by a coupled global climate model FGOALS-s2, ***Advances in Meteorology***, accepted and In press
- Wu, B., T. Zhou, 2012: Prediction of decadal variability of sea surface temperature by a coupled global climate model FGOALS_gl developed in LASG/IAP. ***Chin. Sci. Bull.***, 57, doi: 10.1007/s11434-012-5134-y

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THANKS