Applications of Data Assimilation on the Seasonal-Decadal Prediction of Coupled Models in IAP

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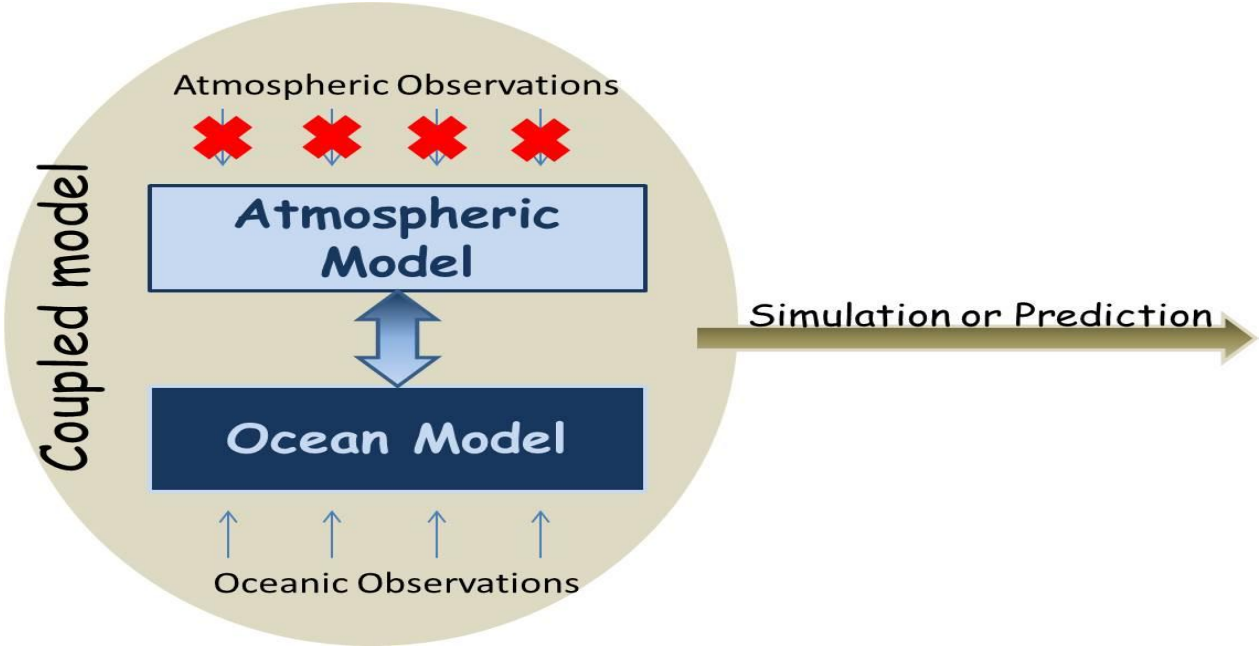
Drivers

Atmospheric and Oceanic boundary layers are not dynamically balanced during the data assimilation process

- Ocean analyses: inadequacy of surface fluxes from atmospheric analyses
- Need to reduce initialization shocks in seasonal prediction
- Need for better surface boundary estimates for (RT) atmospheric analyses
- Evidence of improved intraseasonal forecasts with interactive ocean surface layer (diurnal cycle)
- ……

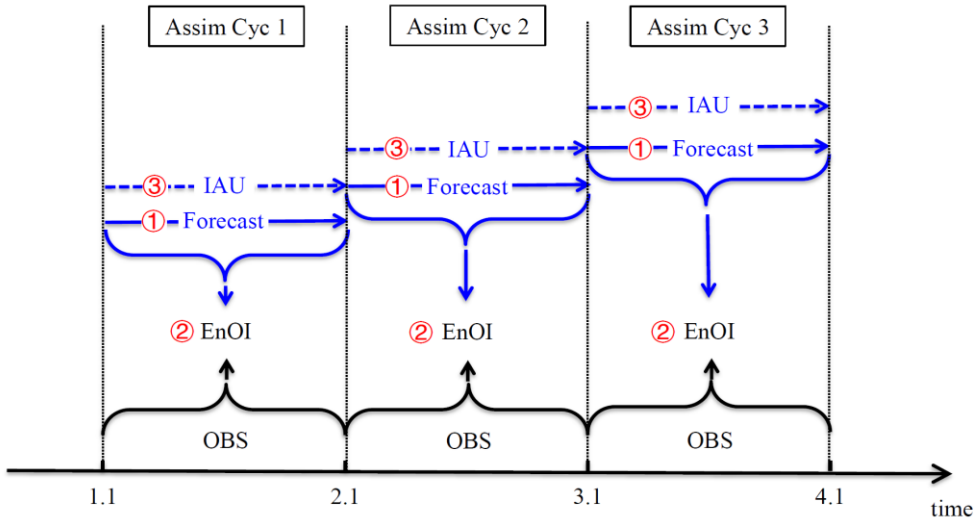
What has been done to date? (that I know of) – Ocean only

- Assimilation into intermediate coupled model for tropical Pacific (Zheng et al., 2006;2007; 2009; 2014)
- IAU scheme in coupled model framework – FGOALS-s2 (Wu et al. 2012), and a new developed EnOI-IAU system (Wu et al., 2016a,b)
- A dynamic bias correction is implemented in decadal prediction – FGOALS-g2 (Wang et al., 2013)
- EnOI-based ocean data assimilation into earth system model – CAS-ESM-C (Lin et al., 2016 also for Lin's presentation)



Decadal prediction experiments by FGOALS-s2

EnOI-IAU



FGOALS-s2

Step1: Initialization

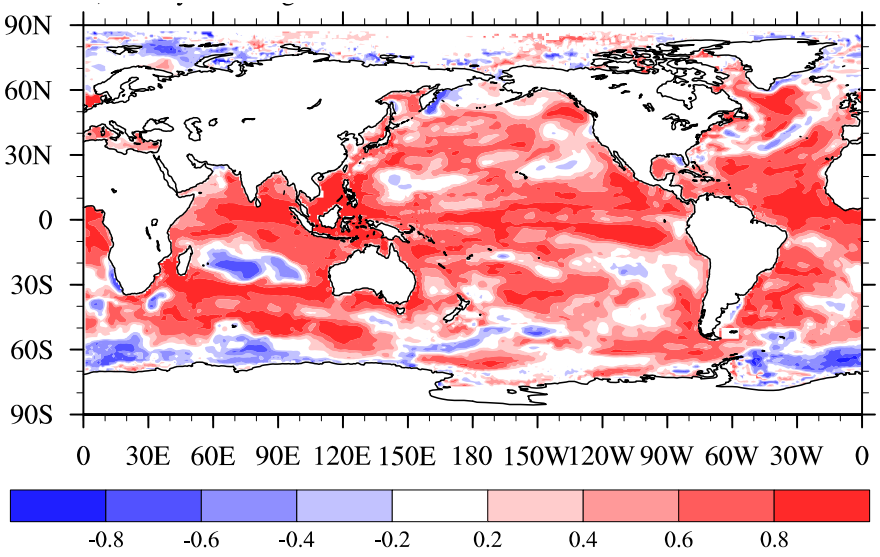
- Model integration for one month
- Calculating analysis increment through EnOI
- Introducing the increment to the model through IAU

Step2: hindcast/forecast

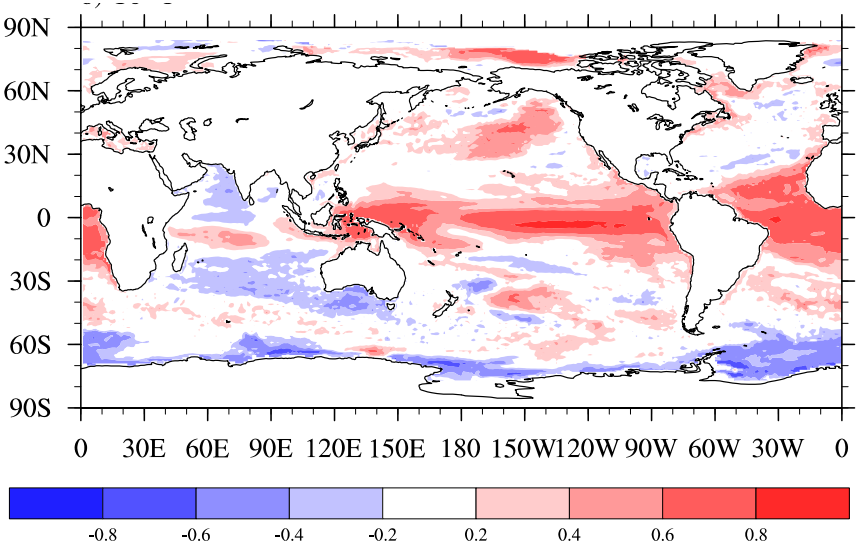
- Started from the initial conditions derived from the initialization run
- Three sets of the 10-year-long hindcast/forecast runs are conducted with 2-year intervals between start dates from 1960 to 2005, following the CMIP5 protocol.

Skill of initialization in SSTA (left) and SLA (right)

SSTA



SLA



Assimilating SST, T/S in-situ data into the model since 1950.
Correlations with the SSTA derived from HadISST
Correlations with the SLA derived from AVISO

Forecast qualities of sea surface temperature

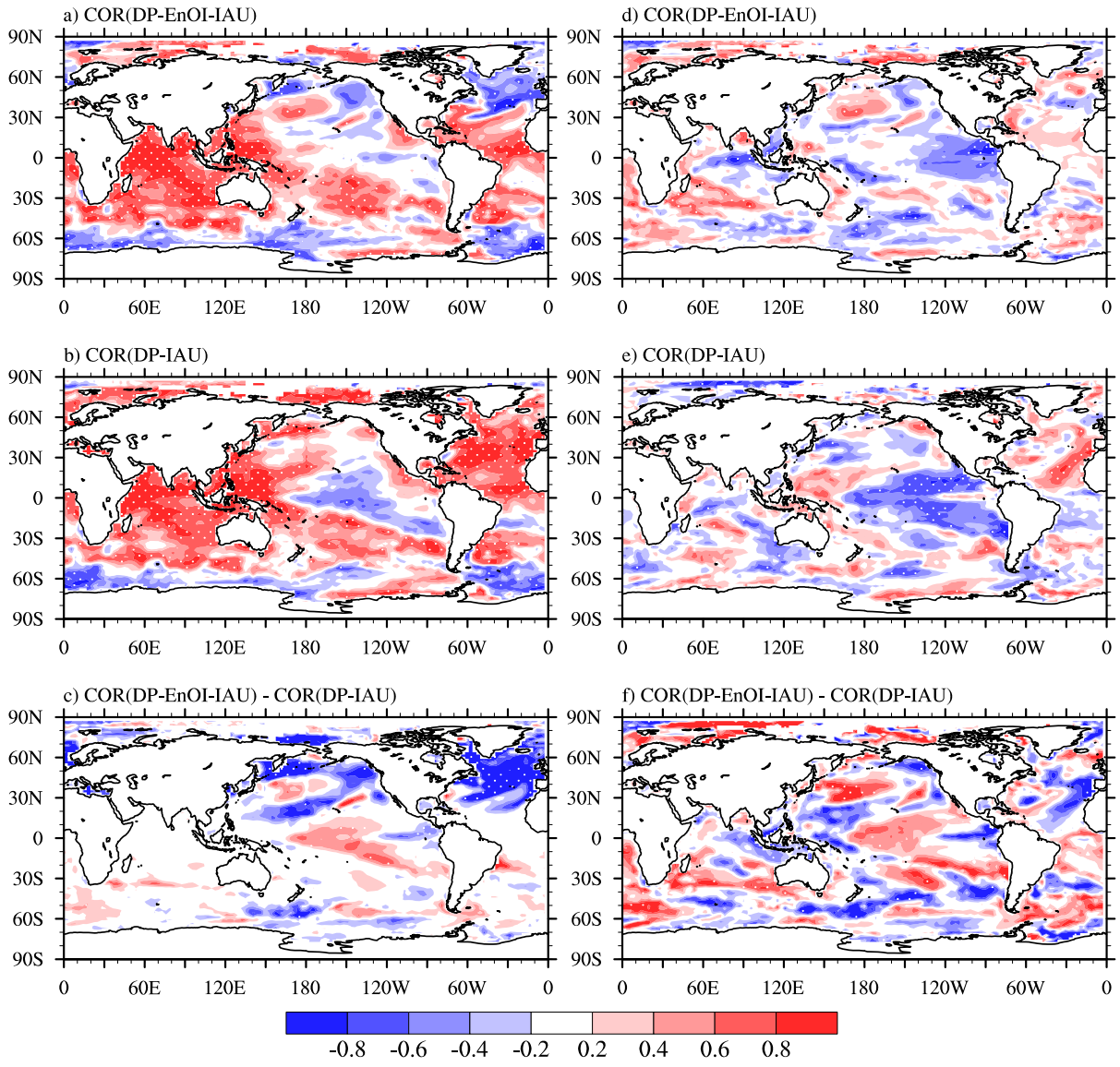
Raw DATA

De-trend DATA

EnOI-IAU

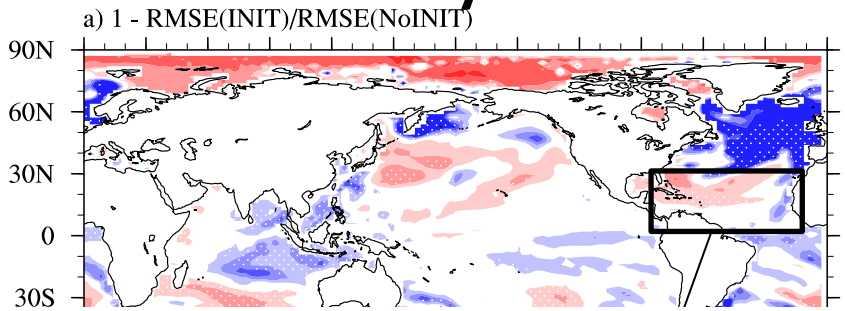
IAU

Improvements from IAU to EnOI-IAU

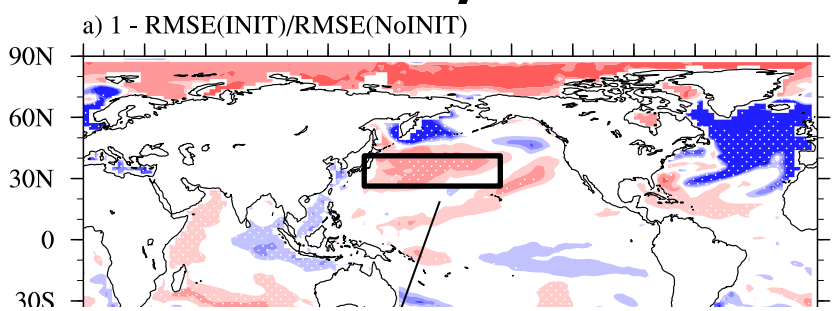


Skills of EnOI-IAU in SSTA prediction

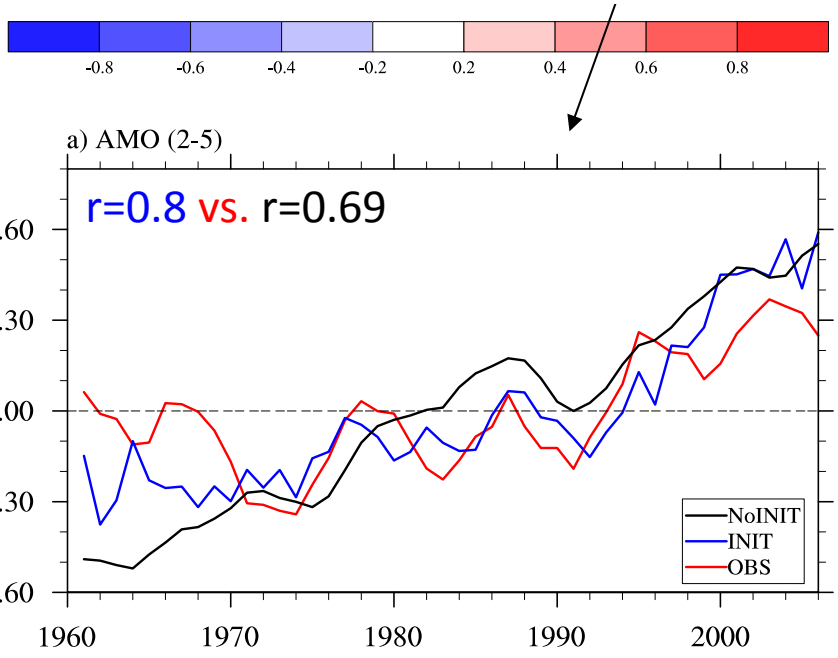
2-5yr

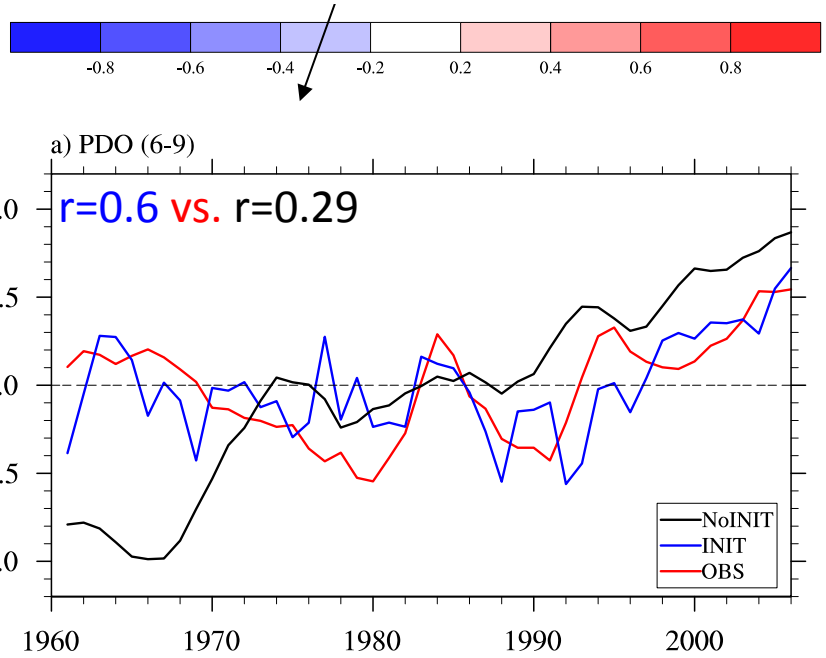


6-9yr



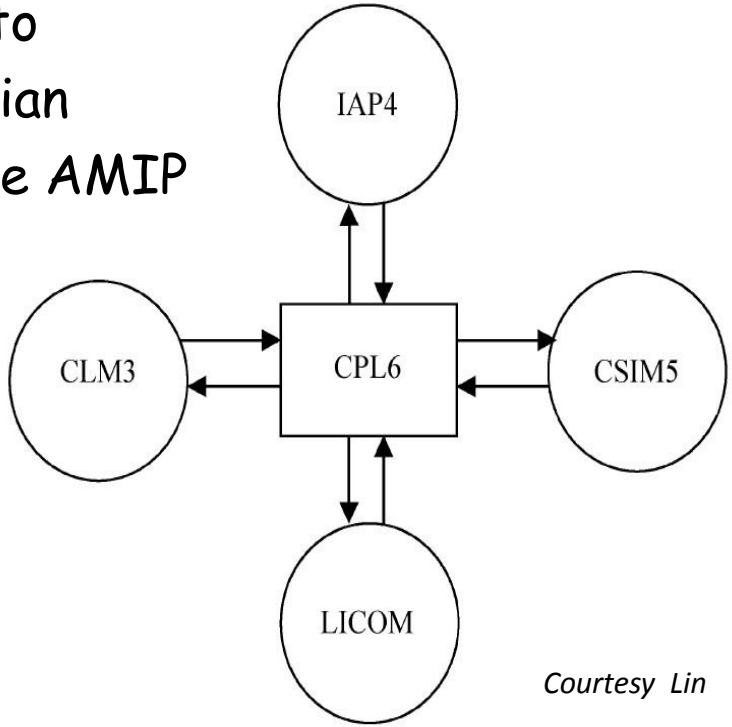
The model has a better prediction result for both of the AMO and PDO, and both beats the prediction without initialization.





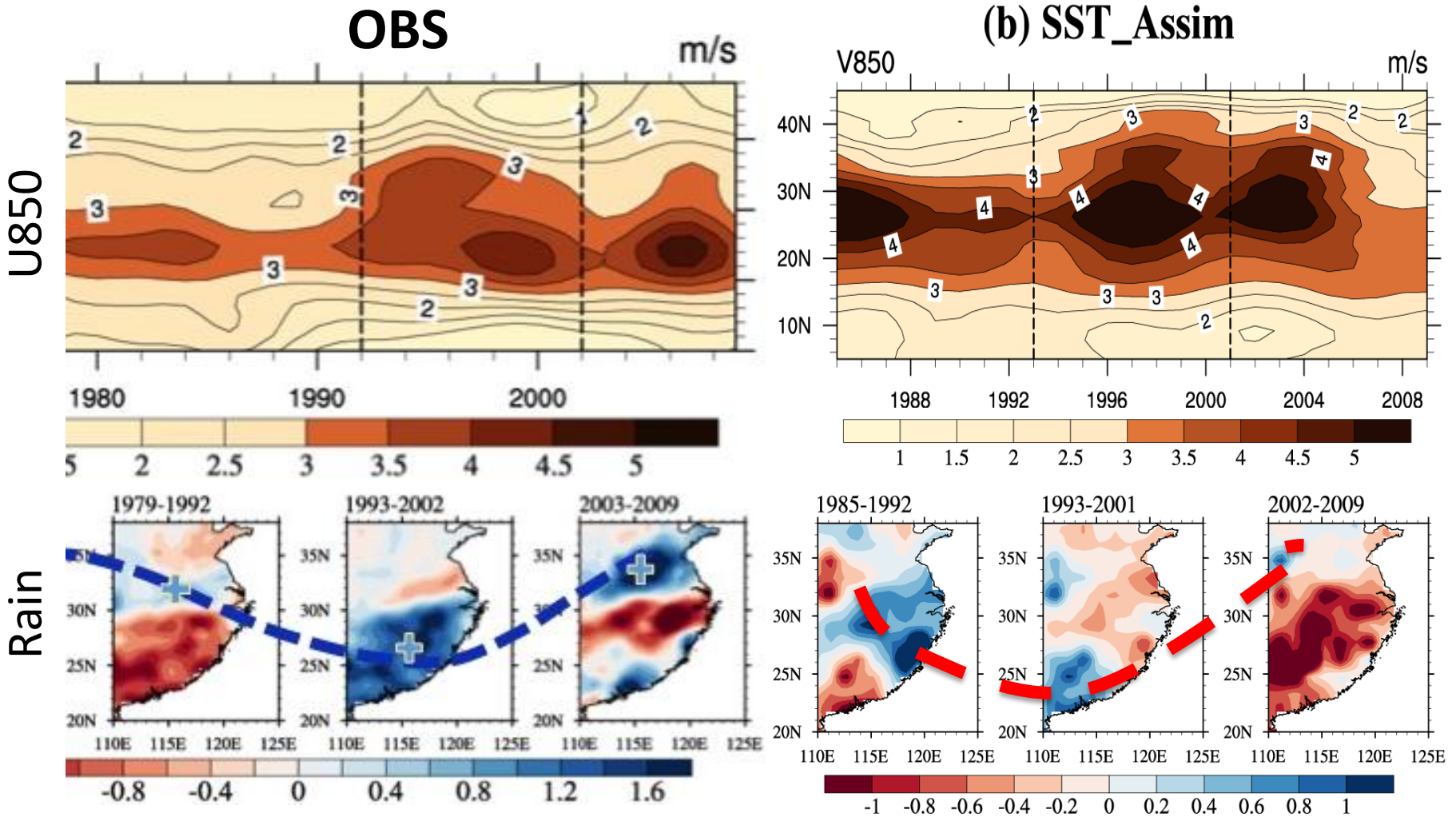
East Asian Monsoon Simulations by CAS-ESM-C

- A new earth system model CAS-ESM is developed for intra-seasonal to seasonal predictions, especially over east Asian monsoon region.
- An EnOI-based ocean data assimilation system is preliminarily established for the CAS-ESM, with constructing the background covariance from the snapshots of historical run.
- "Assim SST" experiment is performed to simulate the climate changes in east Asian from 1982 to 2014, and compared to the AMIP experiment (Atmospheric model forced by SST), and the model control run.

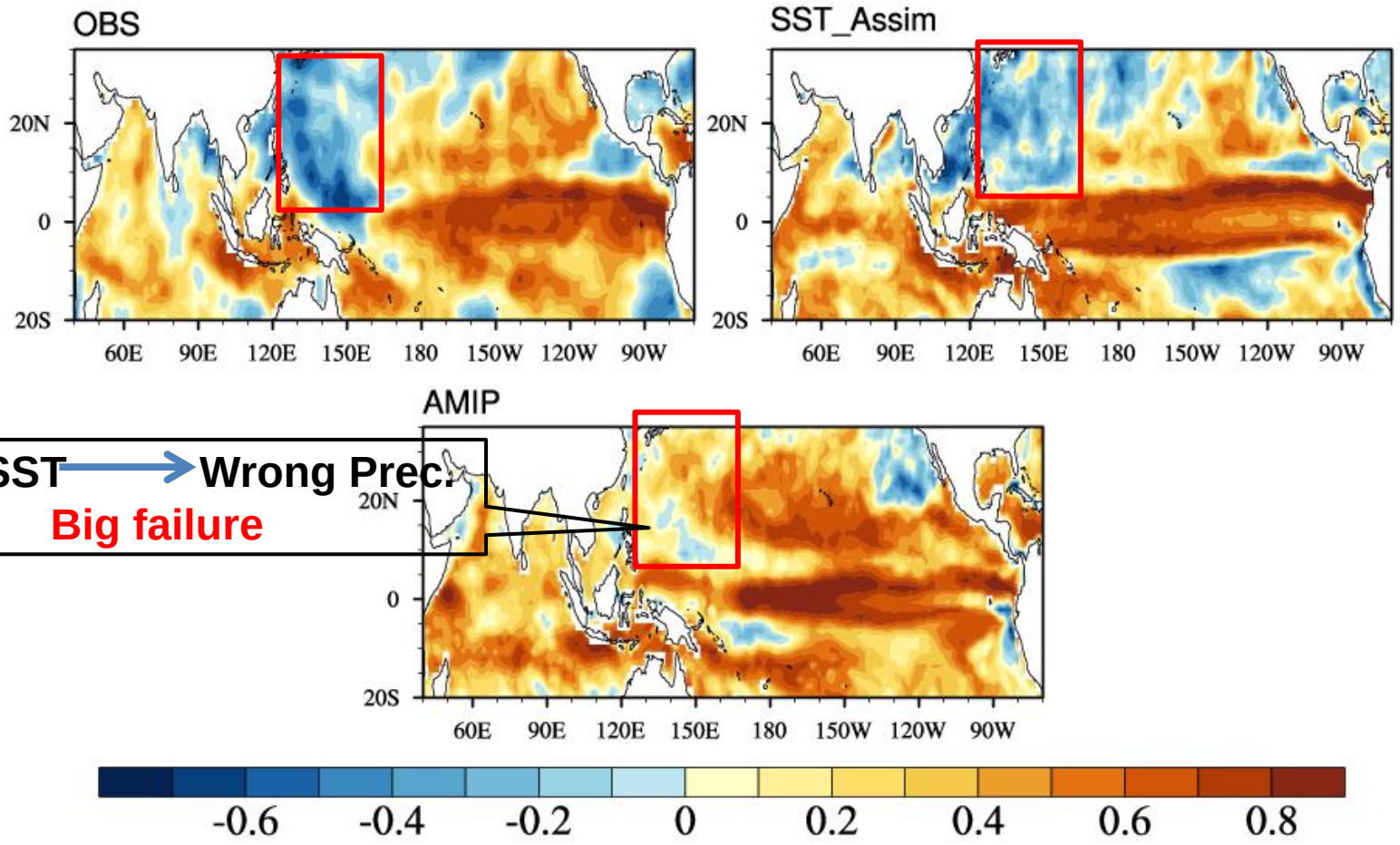


Courtesy Lin

Observed main features in the EASM at the decadal scale are well captured by the SST_Assim

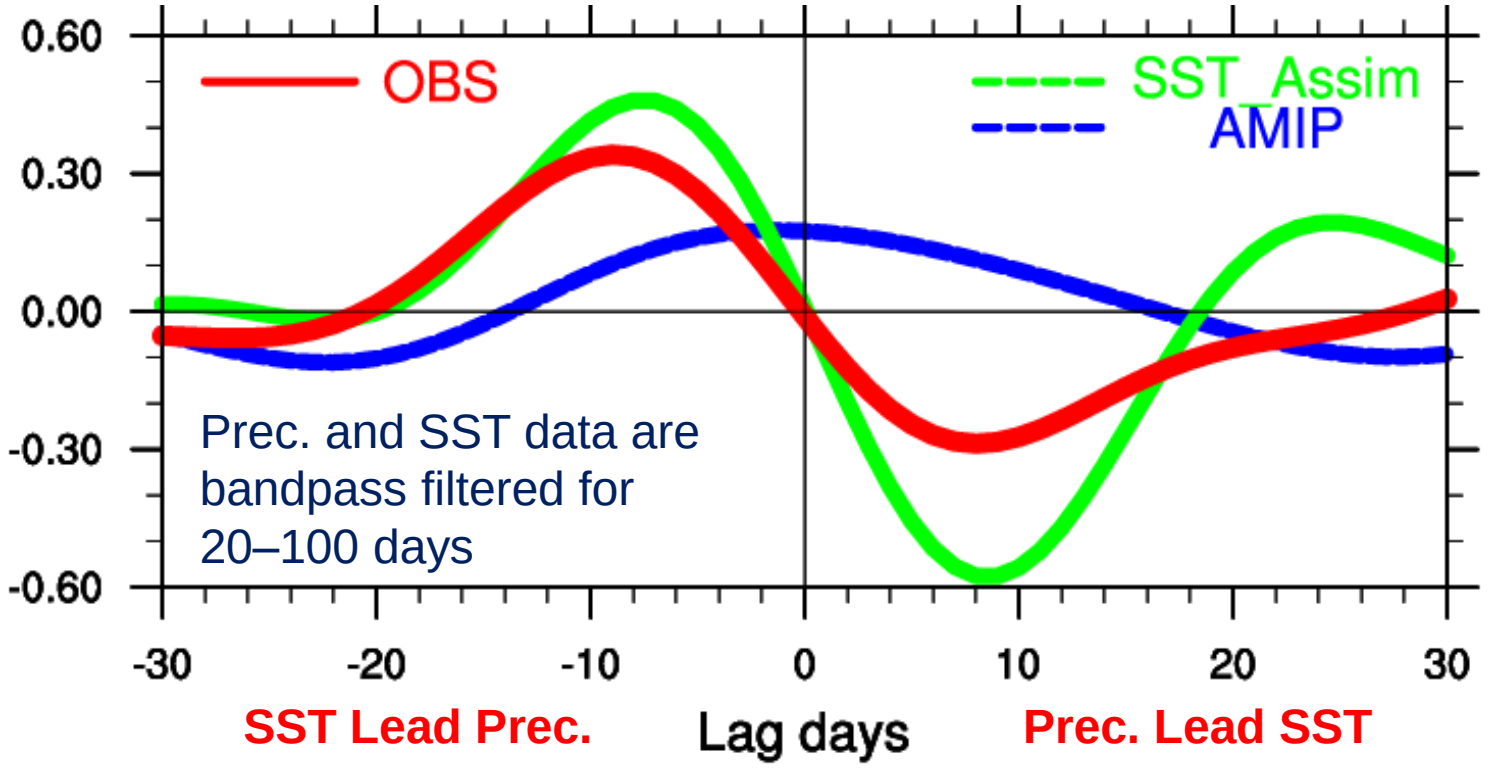


Correlation between SST and Prec. in JJA



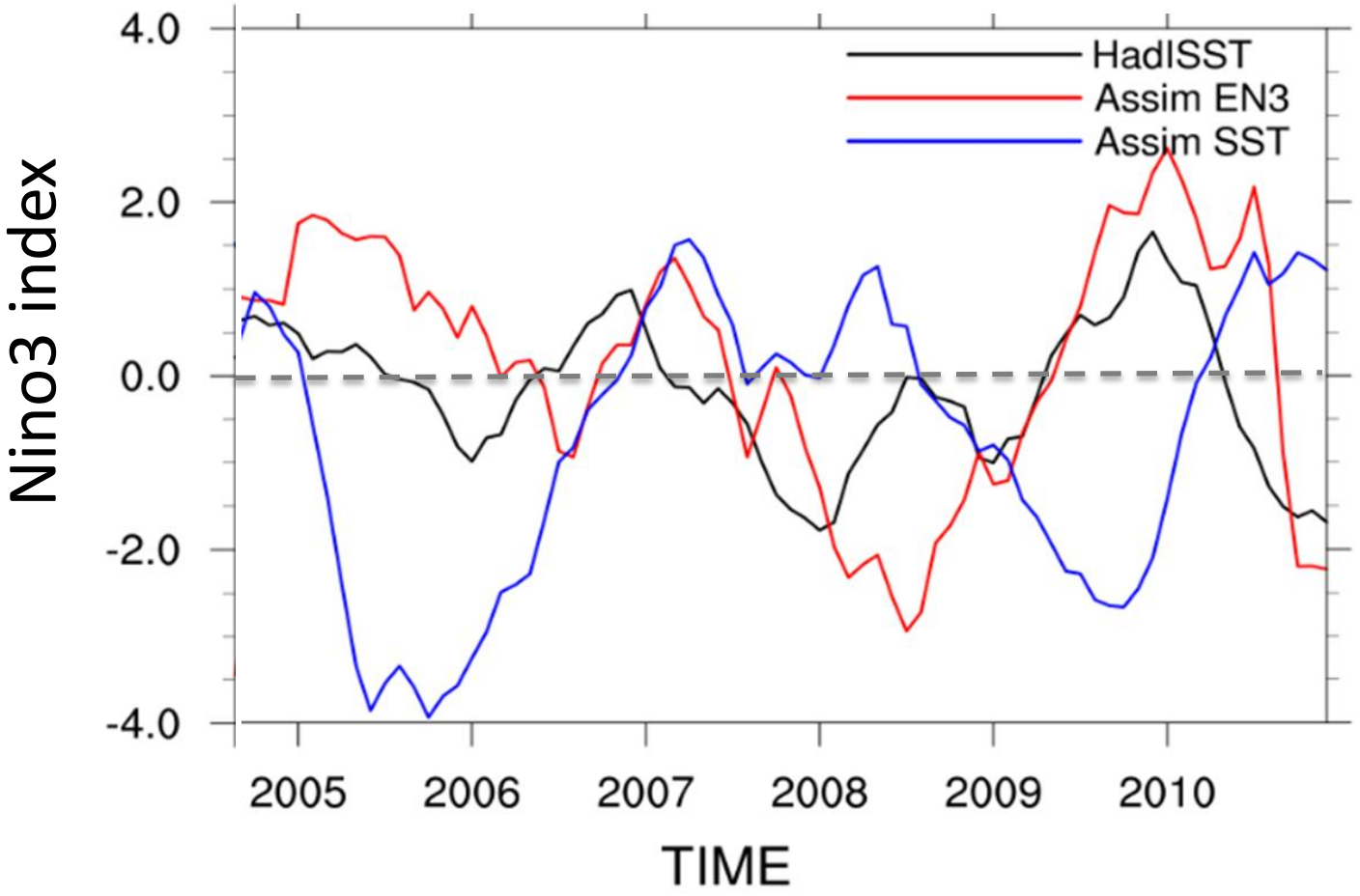
The reconstruction of the negative feedback is crucial to improved the precipitation fields in SST_Assim.

Intra-seasonal Lead or Lag correlations between SST and Prec. in WNP region

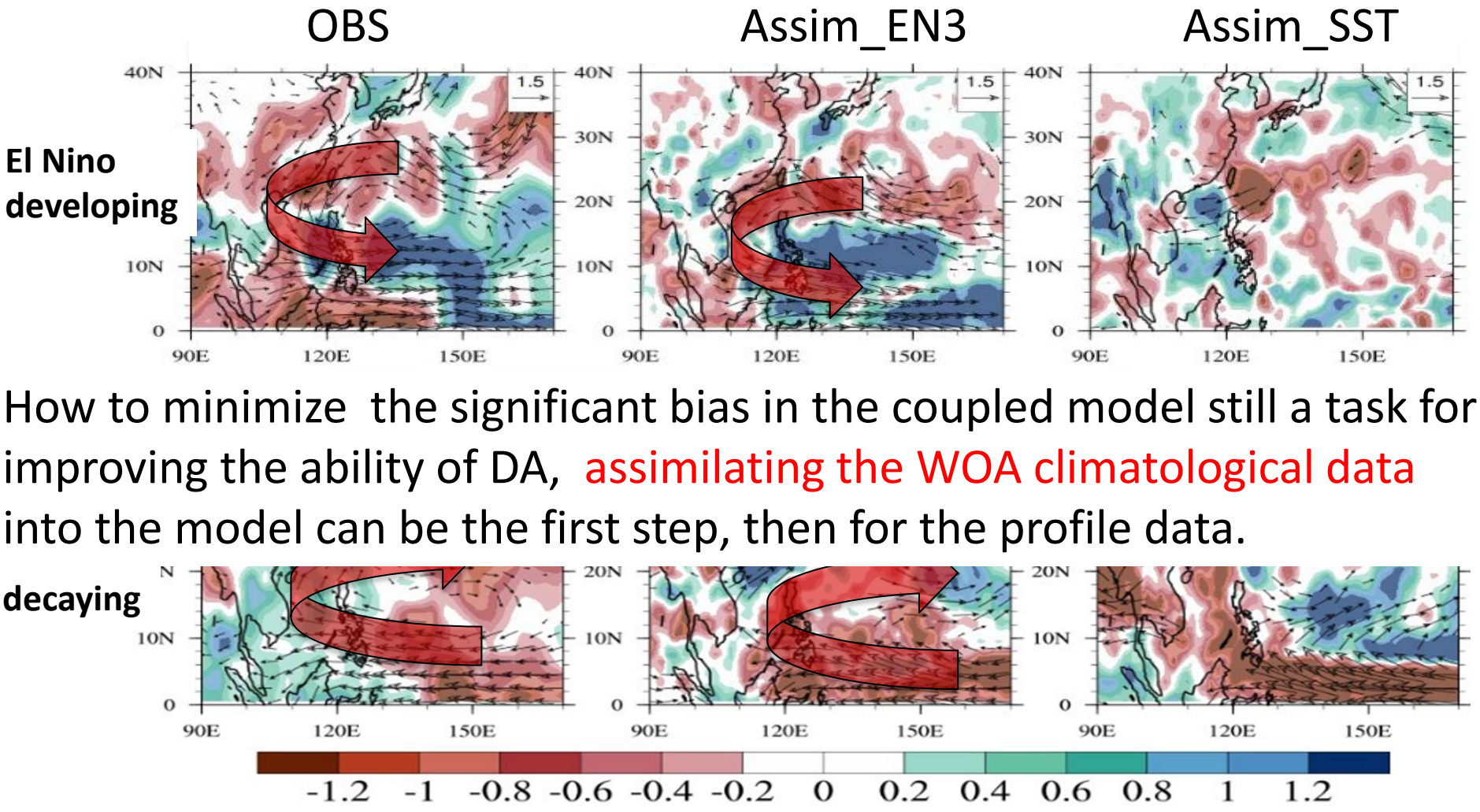


- obs. and SST_Assim: positive (negative) SST leads (lags) prec. by 10 days
- AMIP: positive SST is almost in phase with rainfall

Large temperature bias in tropical Pacific significantly induce a wrong ENSO cycle, while assimilating profile data can reduce the bias



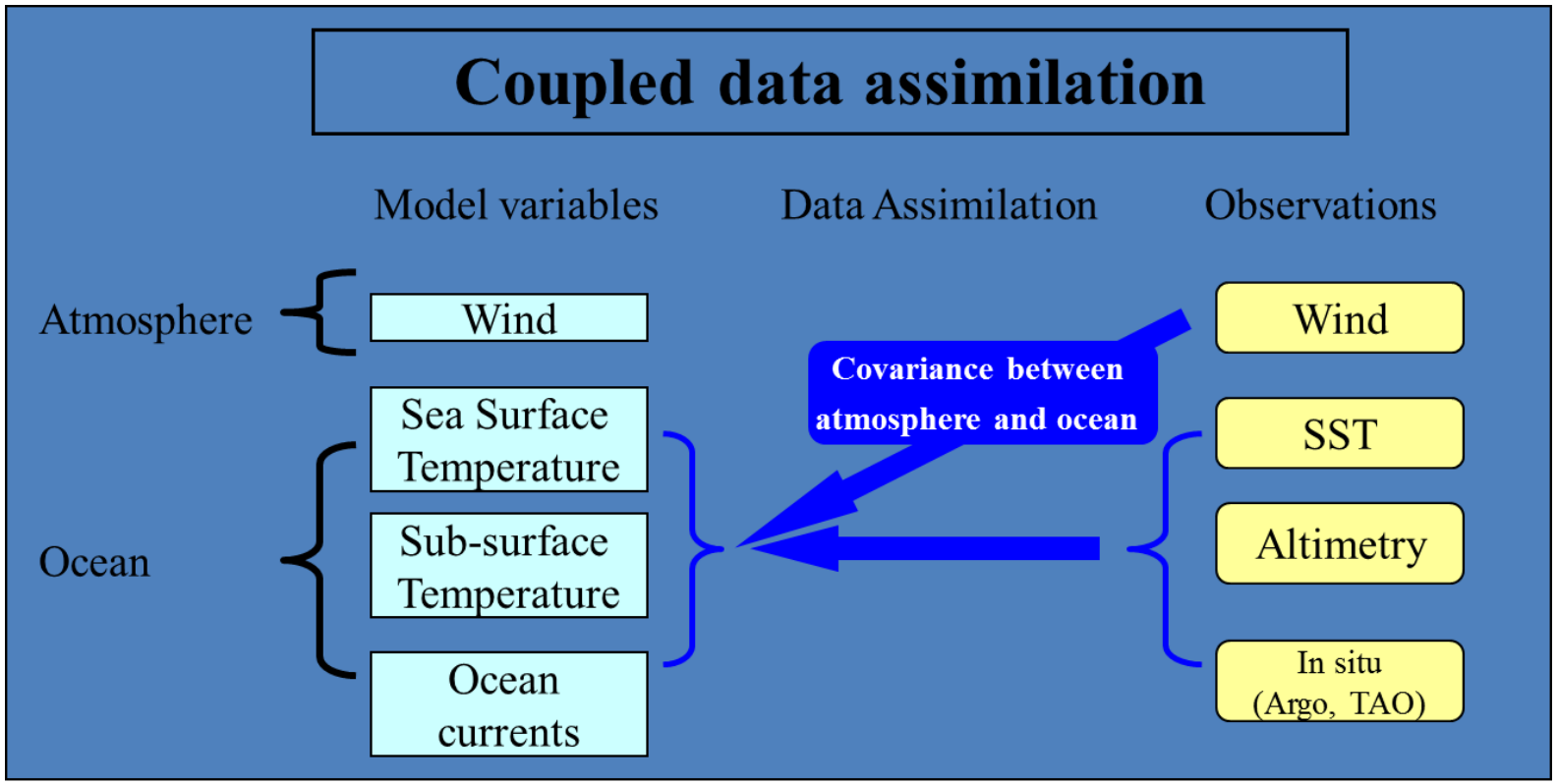
A better ENSO cycle simulation can help to improve the interannual variability in WNP



How to minimize the significant bias in the coupled model still a task for improving the ability of DA, assimilating the WOA climatological data into the model can be the first step, then for the profile data.

What has been done to date? (that I know of) – Coupled Data Assimilation

- Corrections of the ocean velocity through assimilating the surface wind stress data in an ICM (Zheng and Zhu, 2010; 2015)
- Applications of this idea into a fully coupled GCM – FGOALS-s2 (Luo et al., in preparation)



Coupled DA Seasonal prediction

Experiment Design

- Idealized data assimilation experiments: understanding

  - Using the coupled model results as "truth"

  - Pick up SST and Wind as "observations"

  - Run "coupled" assimilation and "ocean-only" assimilation

  - Compare results to "truth"

- Data assimilation experiments using real observations and impacts on ENSO forecast

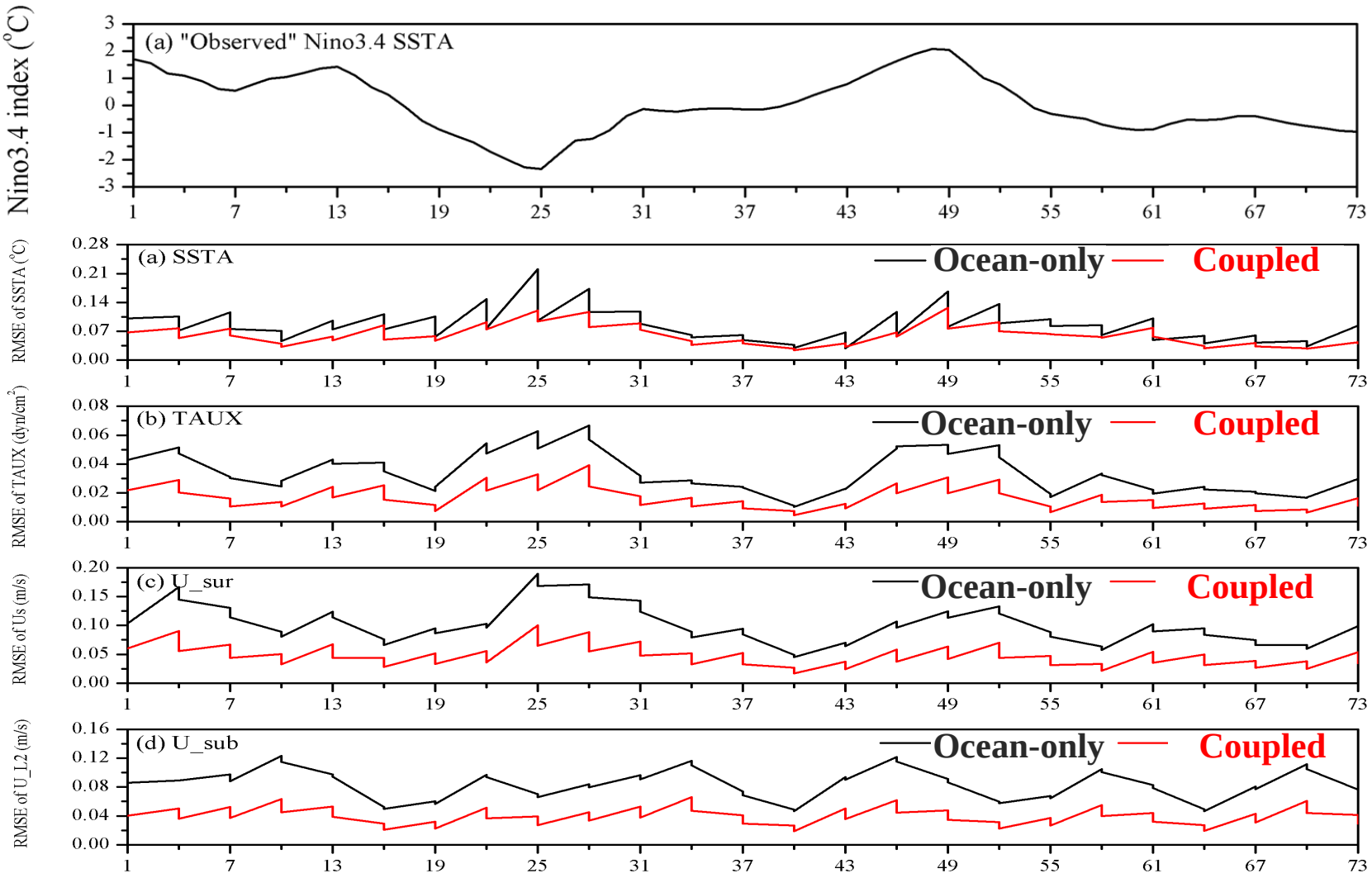
  - Run "coupled" assimilation and "ocean-only" assimilation

  - Make forecast

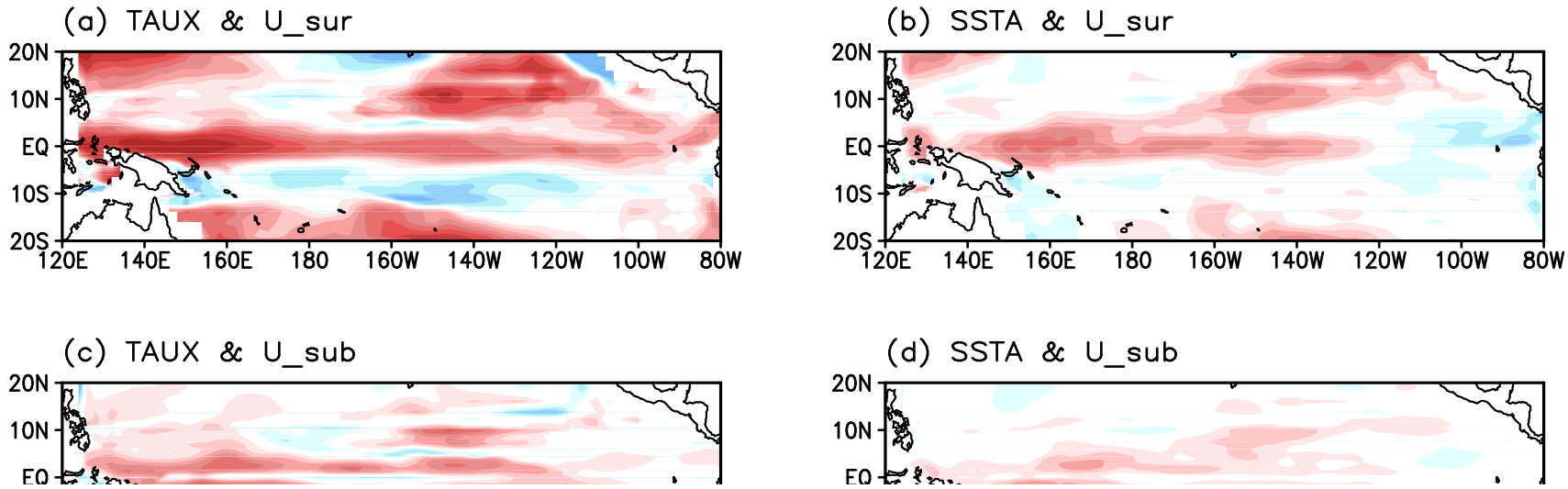
  - Compare forecast results

Coupled DA Seasonal prediction

Idealized assimilation results (3-month interval)

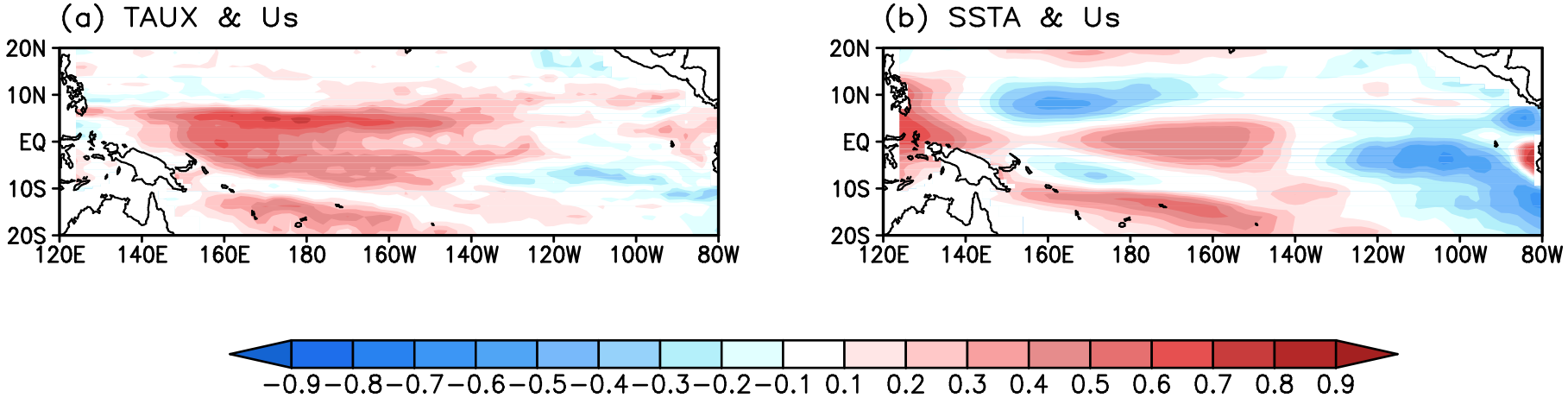


Spatial Distribution of Anomaly Correlations Between Forecasted Ensemble Members



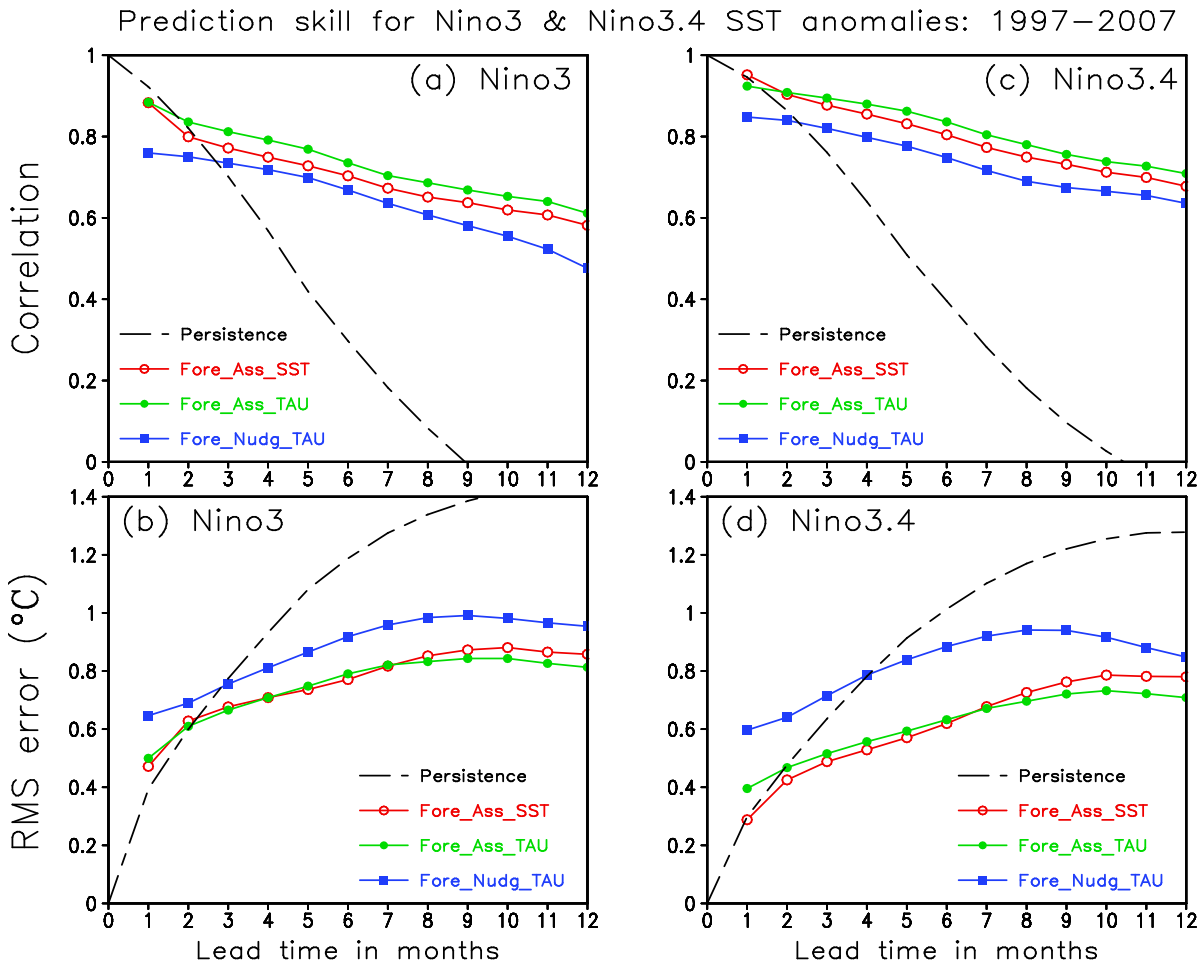
Zonal wind stress better correlates to the zonal surface and subsurface currents than SST in the background error covariance.

Spatial Distribution of Anomaly Correlations Between Different Observations



Coupled DA Seasonal prediction

Deterministic prediction skill

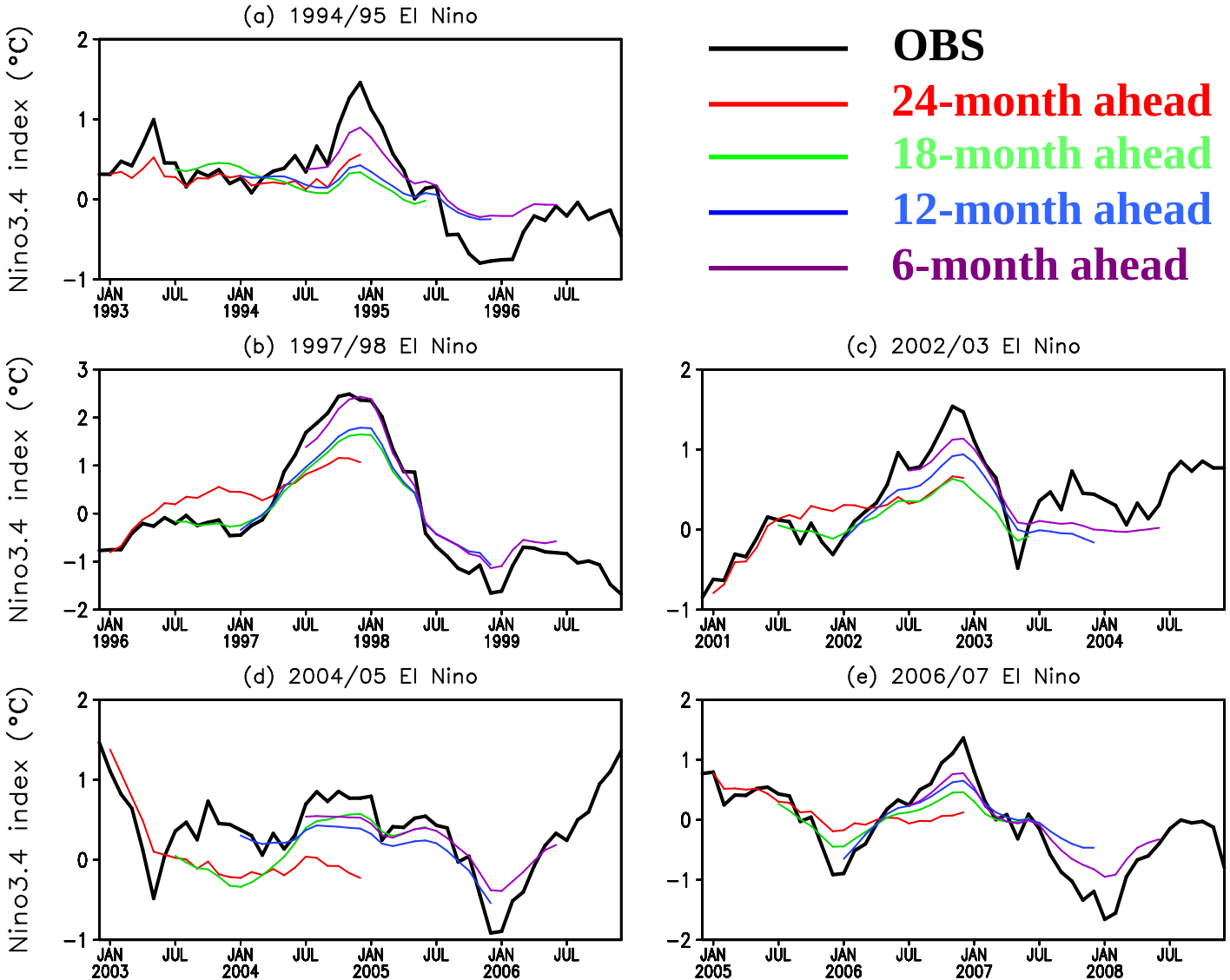


Nudging wind provides a baseline,

Ass_TAU can more obviously depress the error growth of the SST especially for the longer lead times according to provide more dynamically consistent initial ocean dynamical conditions than Ass_SST.

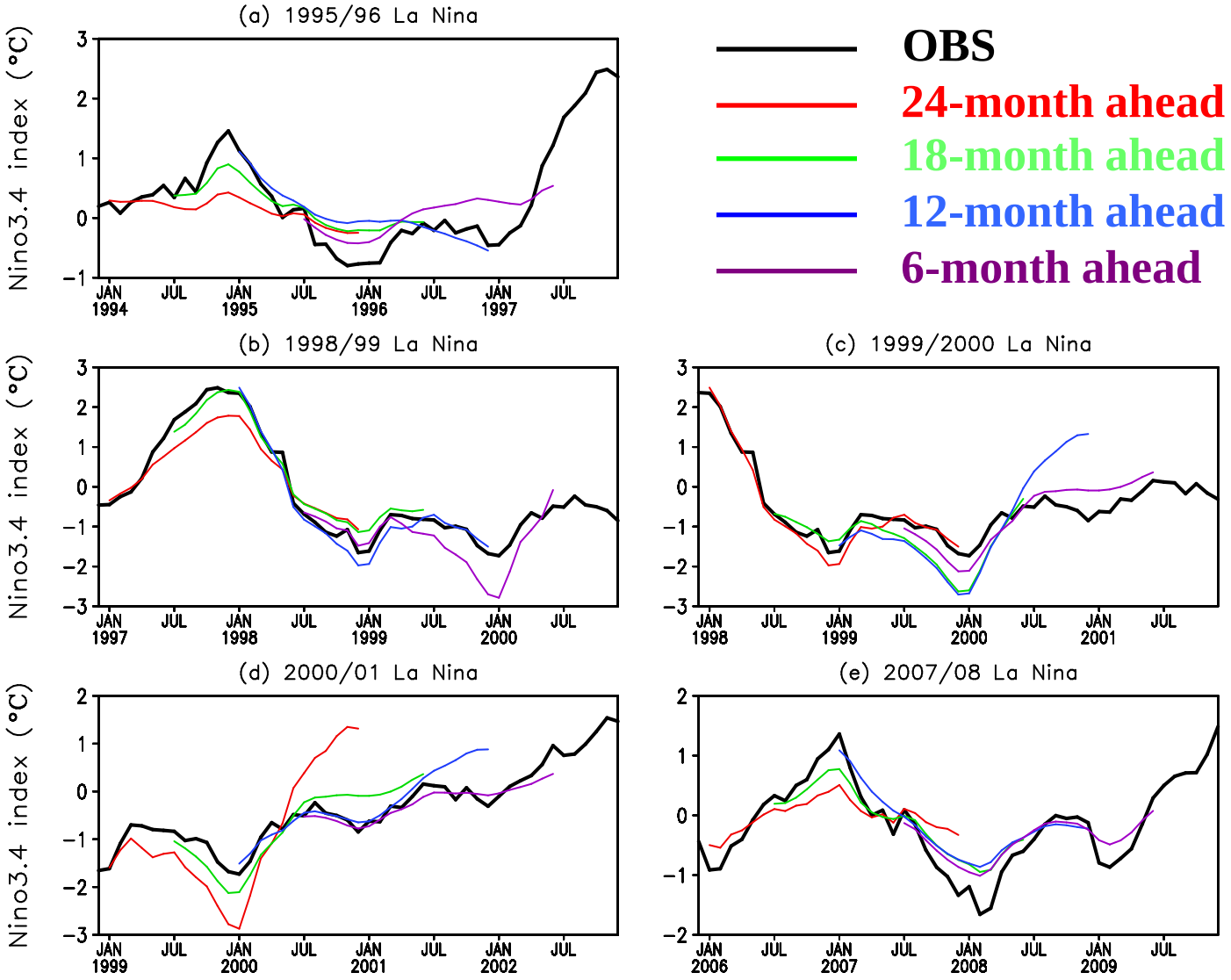
Coupled DA Seasonal prediction

Predictions of El Nino events



Coupled DA Seasonal prediction

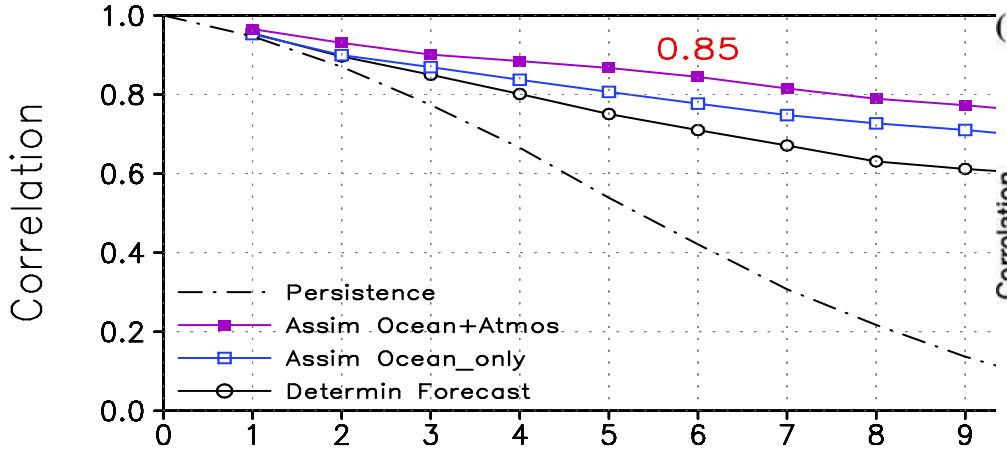
Predictions of La Nina events

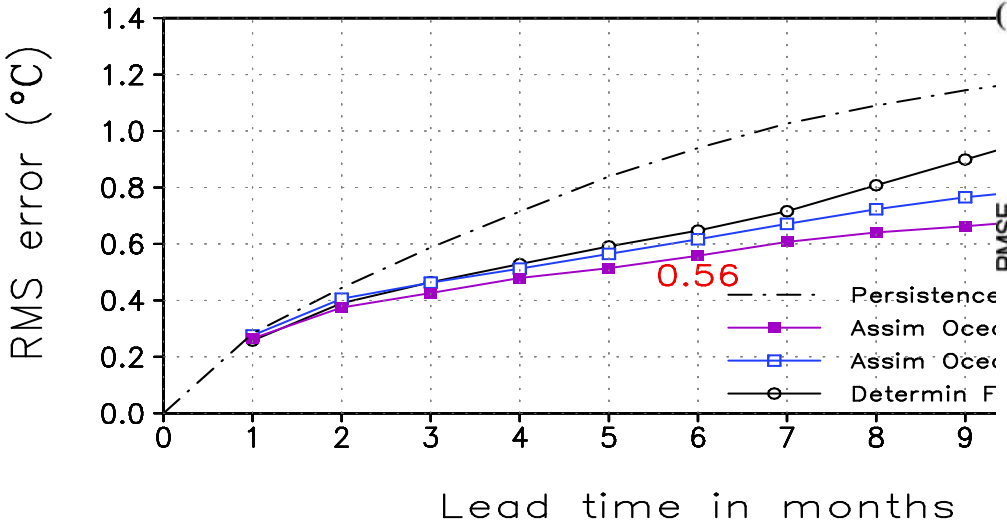


Coupled DA Seasonal prediction

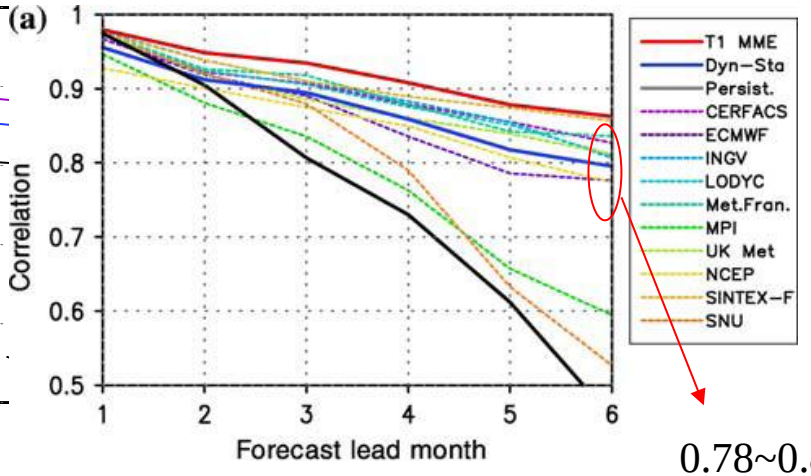
A large size ensemble ENSO forecast system with coupled data assimilation (Leefs_CDA)

Current Prediction Skill of Leefs_CDA (1993-2012)

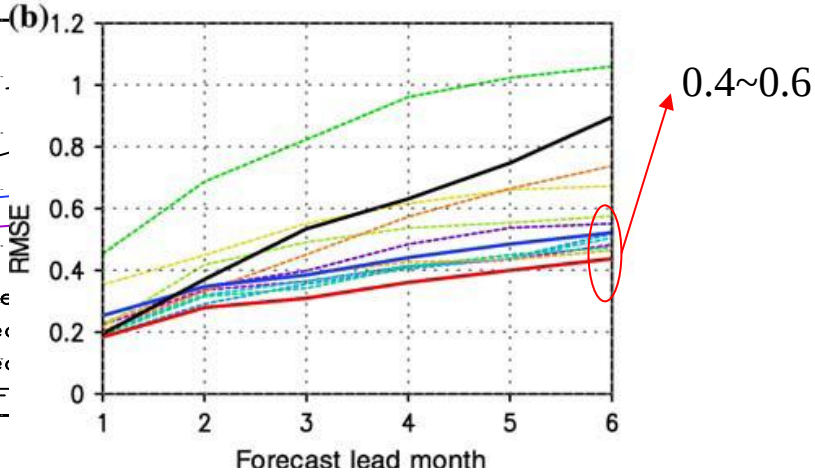




Most ENSO models



0.78~0.86

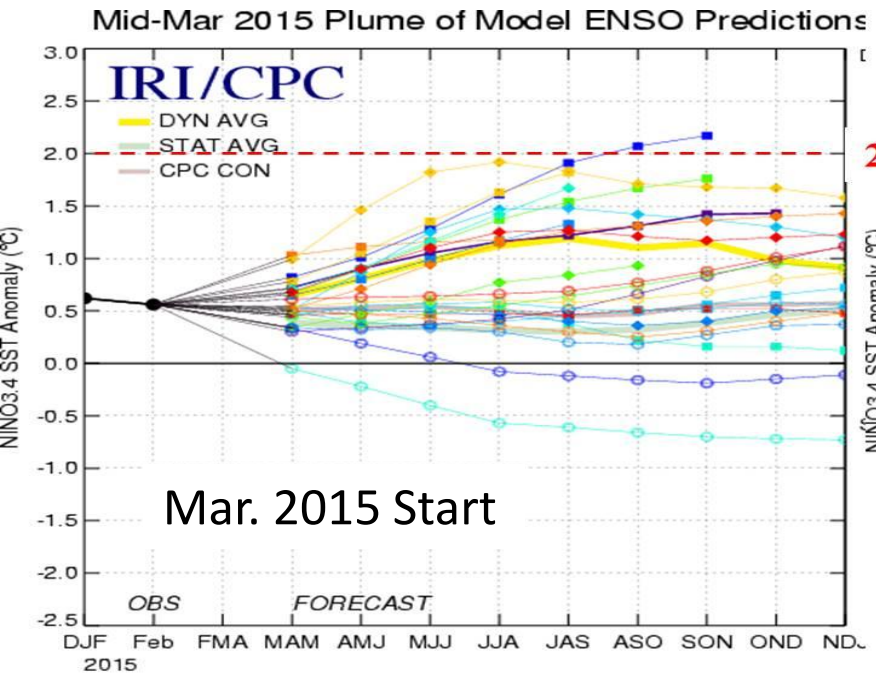


0.4~0.6

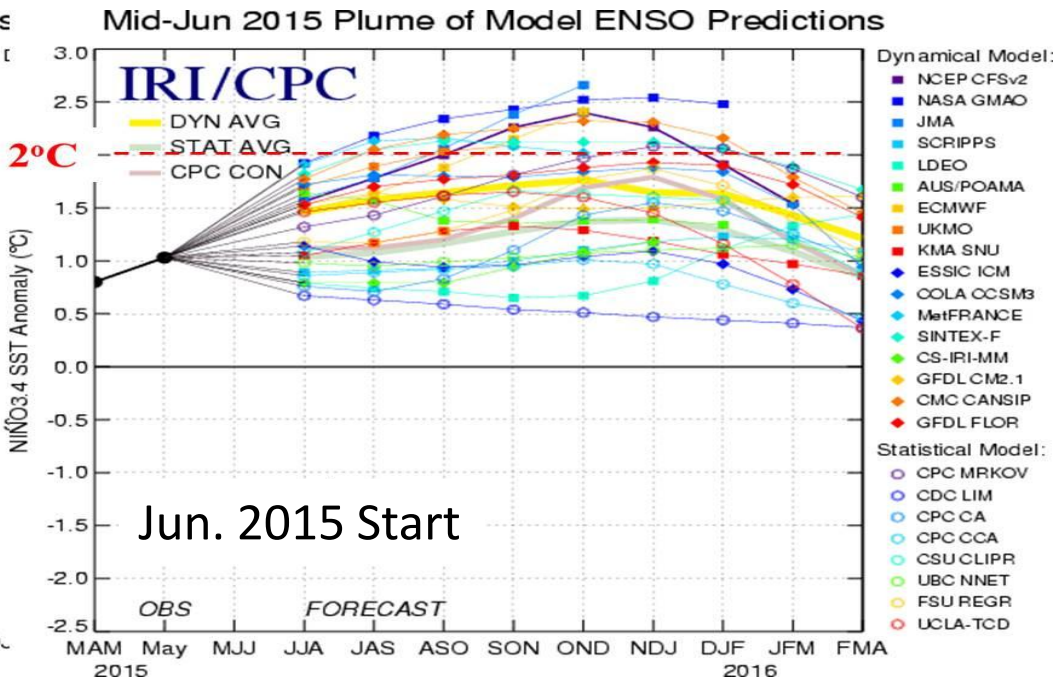
Jin et al., (2008)

Most climate models failed to predict the super 2015/16 El Nino before June

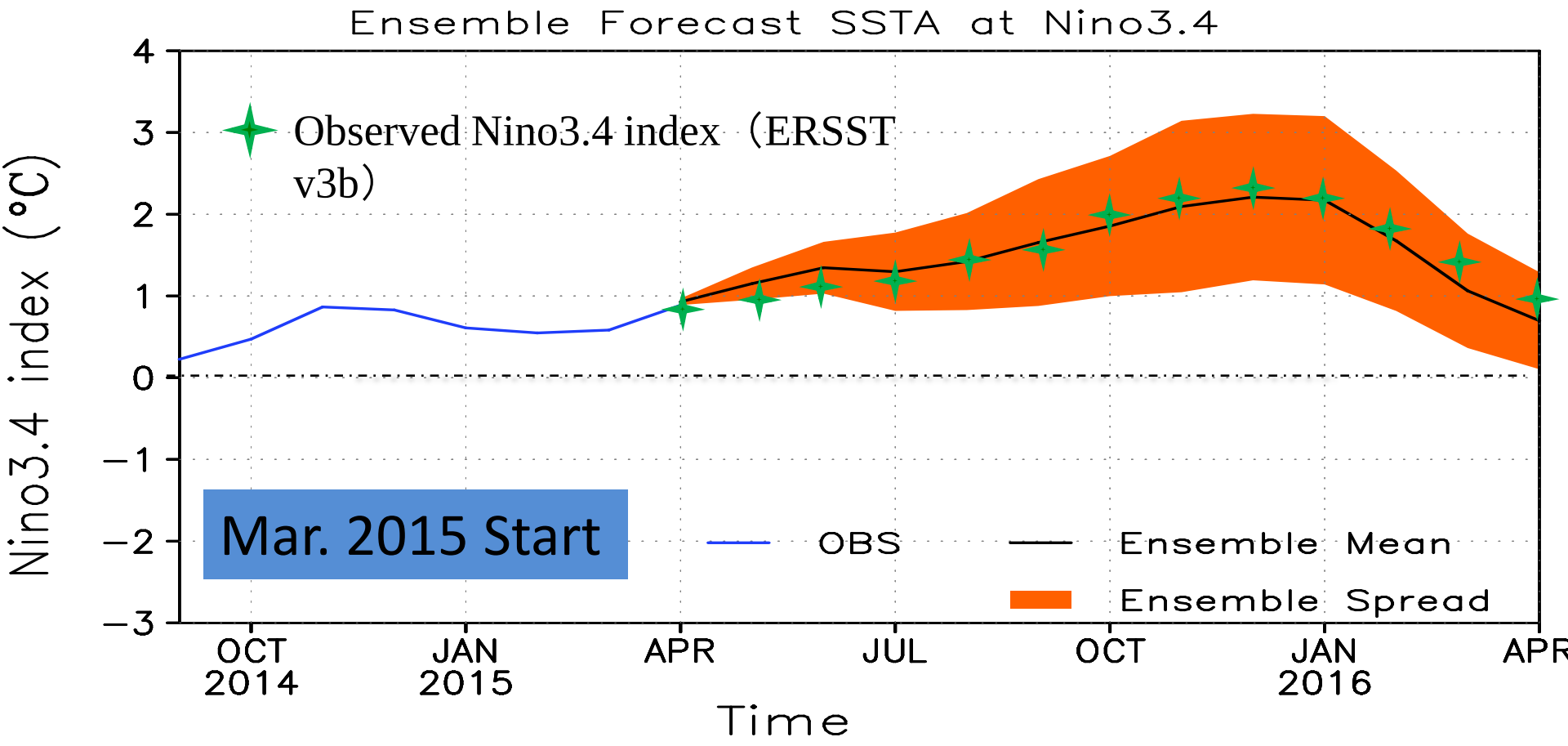
9 Months Ahead



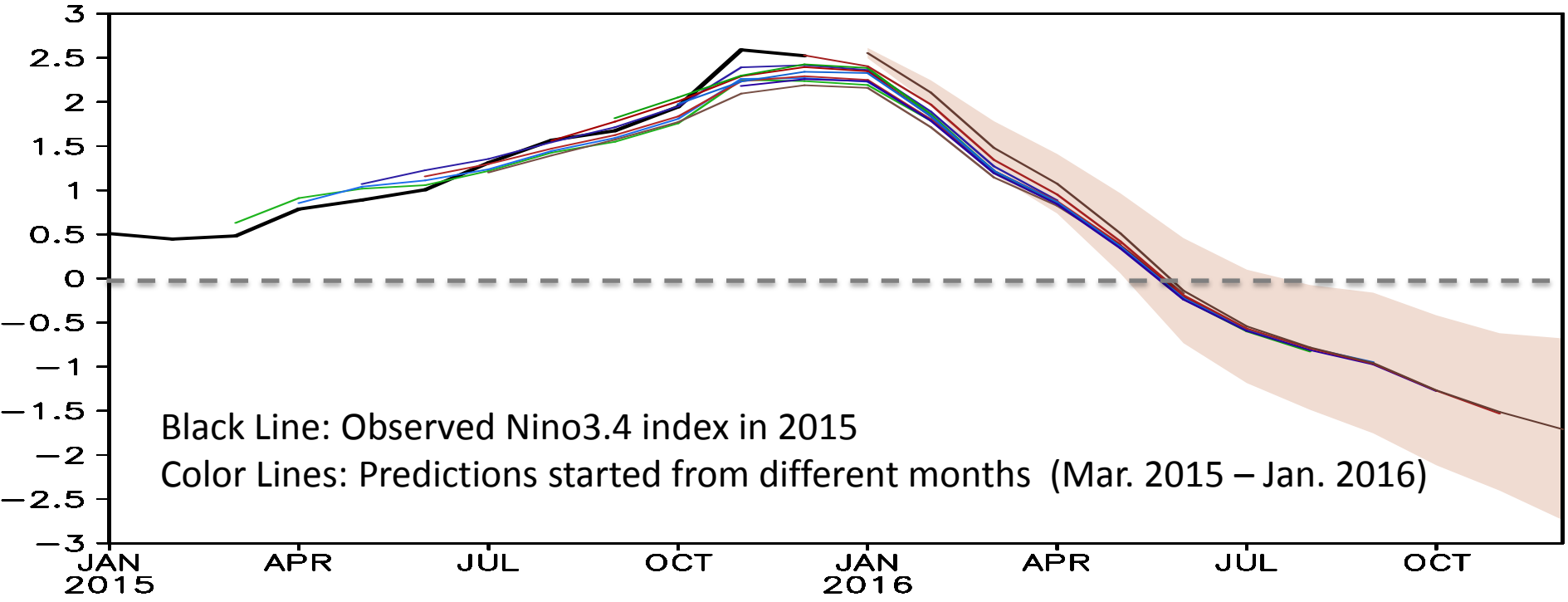
6 Months Ahead



IAP ENSO model successfully predicted this super El Nino even 9 month ahead



The system also provided consistent El Nino predictions started from different months



Summary

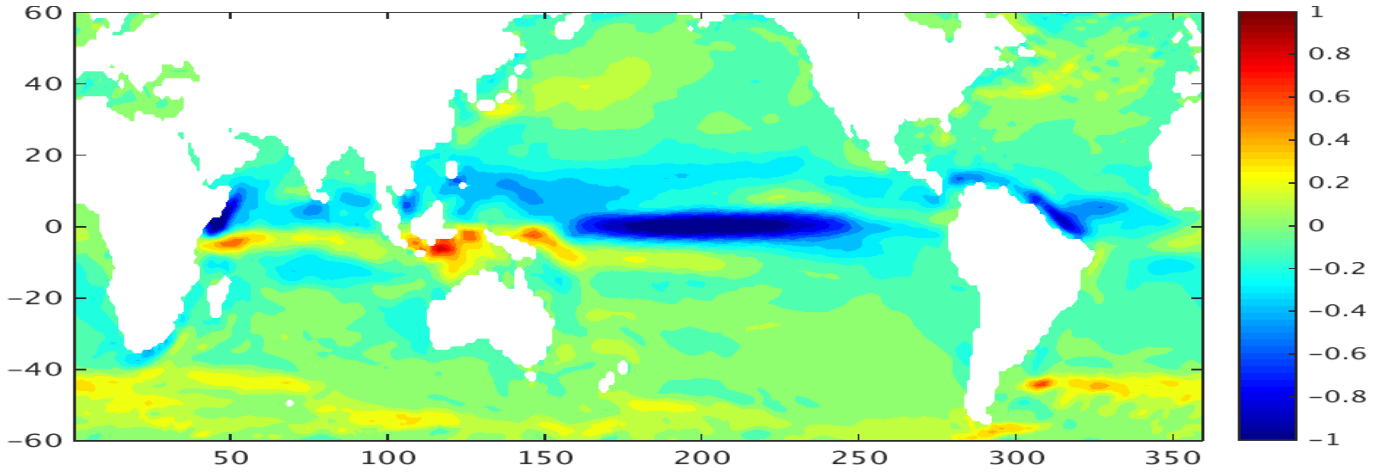
- Several progresses have been made in ocean data assimilation for seasonal and decadal simulation/prediction!
- Some examples that coupling improves simulations and forecasts ⇒ makes sense that paying attention to the coupled system during initialization should help with forecasts
- There is a push for "coupled" atmosphere-ocean assimilation

Future Plan

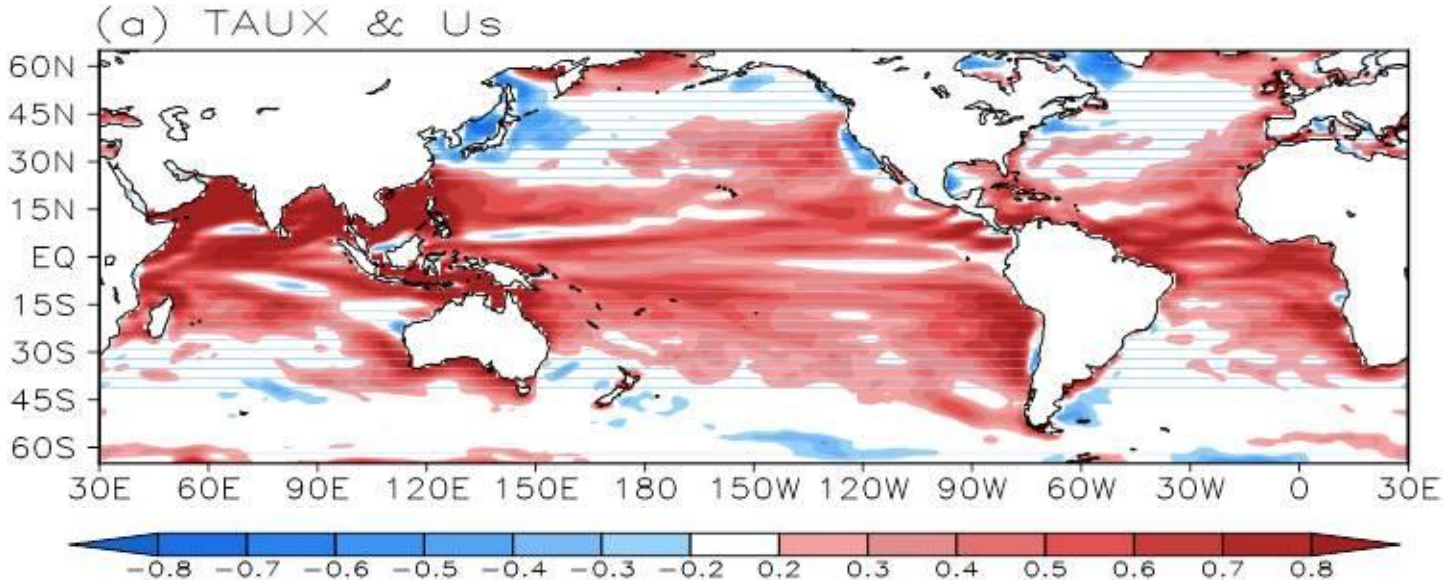
- Correcting the Flux terms might be a possible way to maintain the dynamically consistent interaction boundary (e.g., updating air-sea variables at the interface layer together), and then reduce the initial shocks for the seasonal predictions
- Adjusting the ocean velocity field through assimilating the surface wind/SLP data into the fully coupled GCM to improve the accuracy of the initial conditions

Bias of zonal surface velocity in FGOALS-s2 (Potential application of coupled assimilating wind data)

Bias



Correlation between Taux & Us

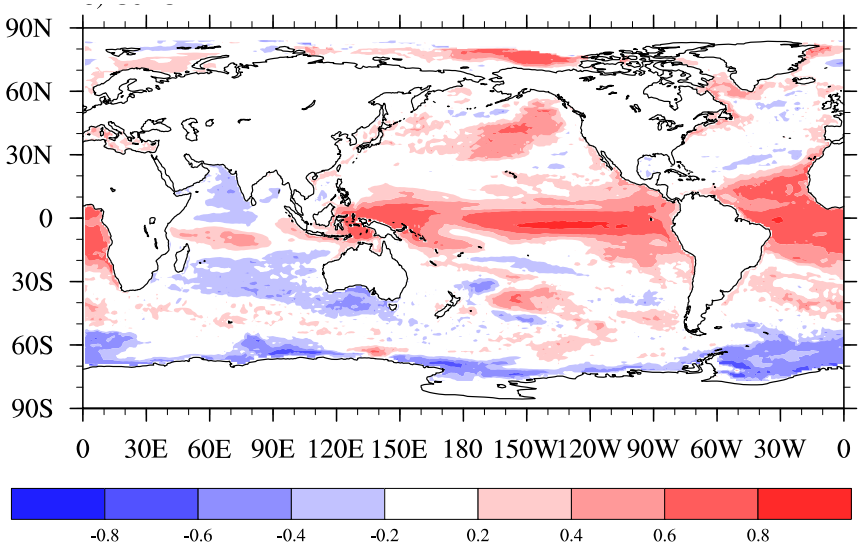


Thanks

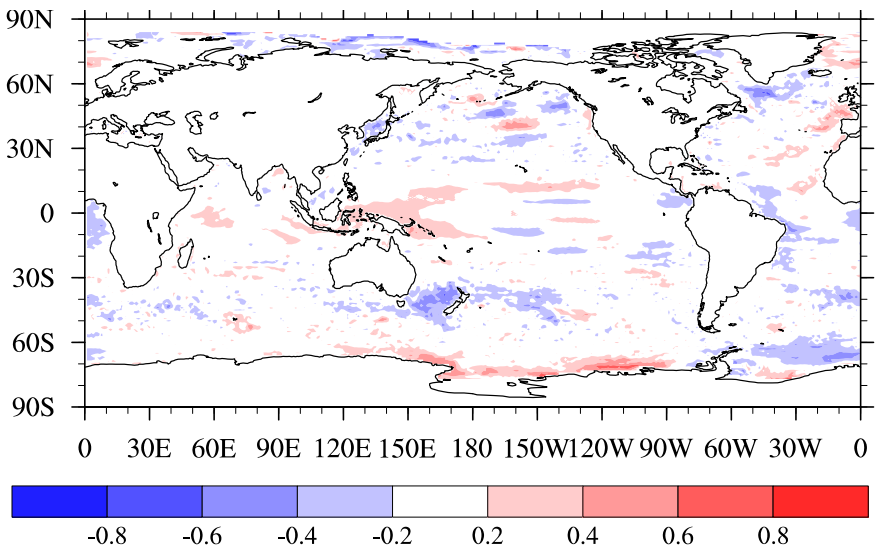
Contact: zhengfei@mail.iap.ac.cn

Skill of initialization in SLA

EnOI-IAU (New)



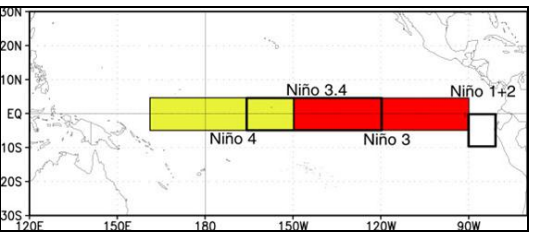
IAU (Old)



Correlations with the SLA derived from AVISO

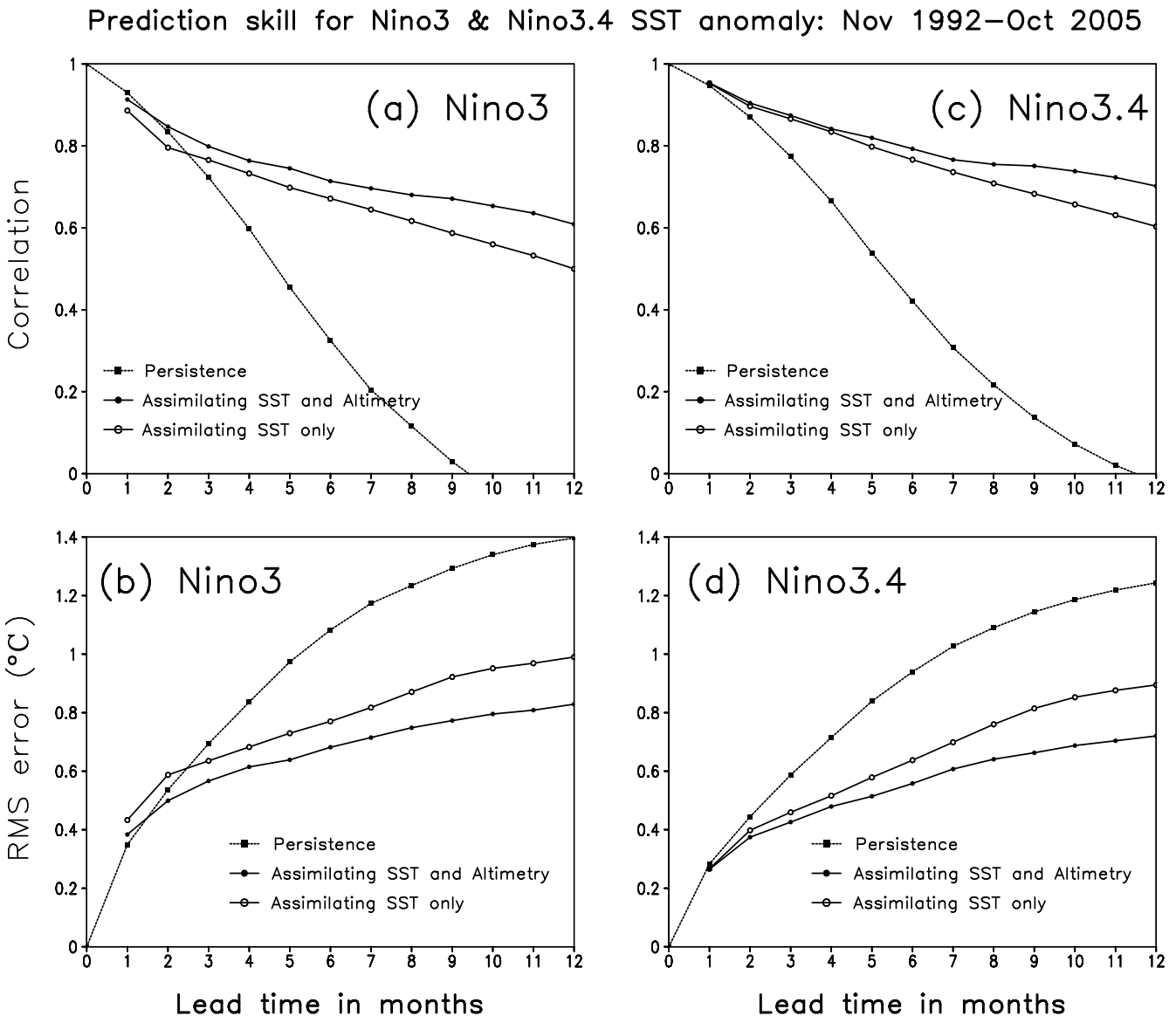
Coupled DA Seasonal prediction

Improvements by the ocean data assimilation



Zheng et al. 2006; 2007

Zheng and Zhu 2008, 2015

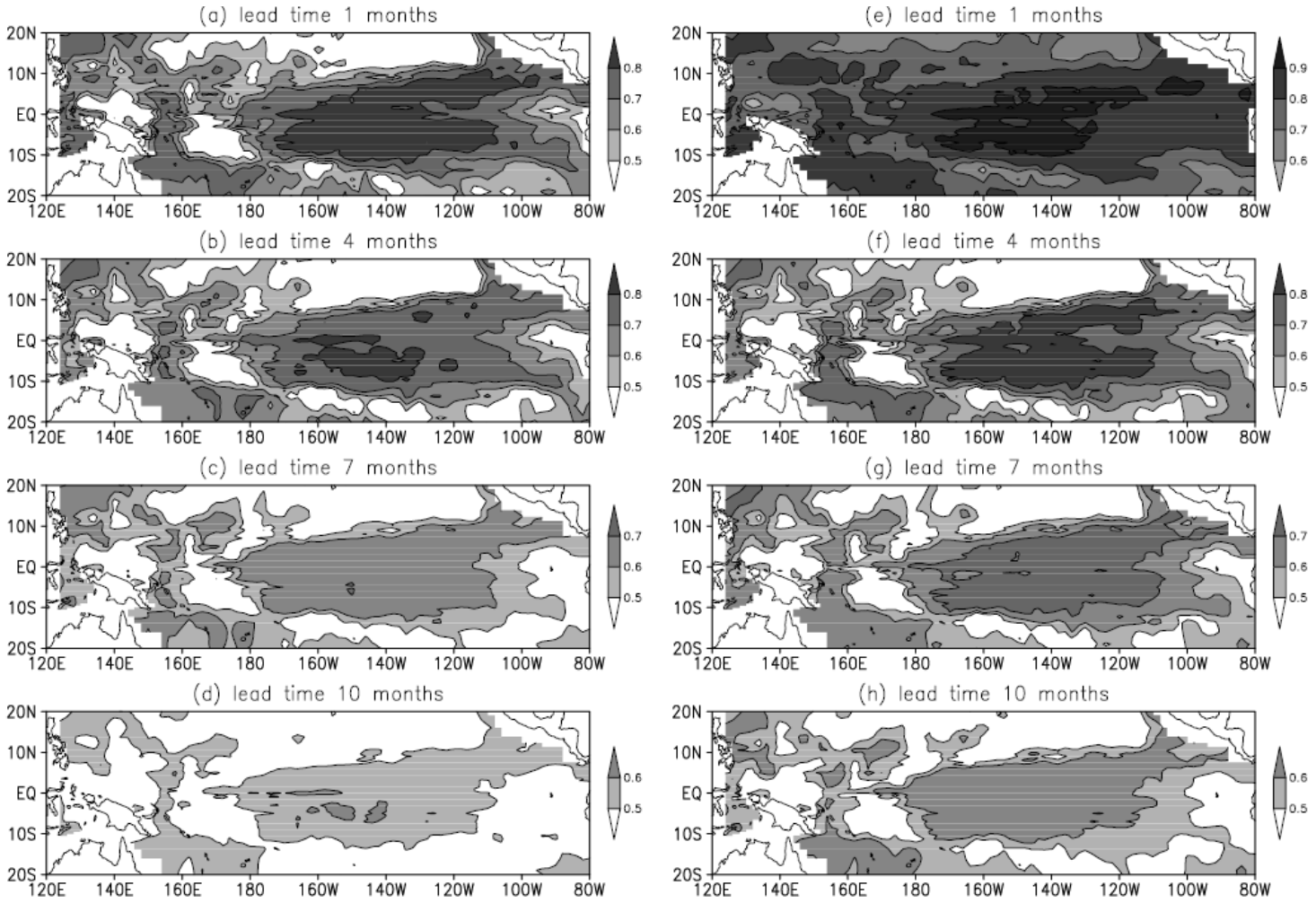


Coupled DA Seasonal prediction

Benefits from assimilating Altimetry

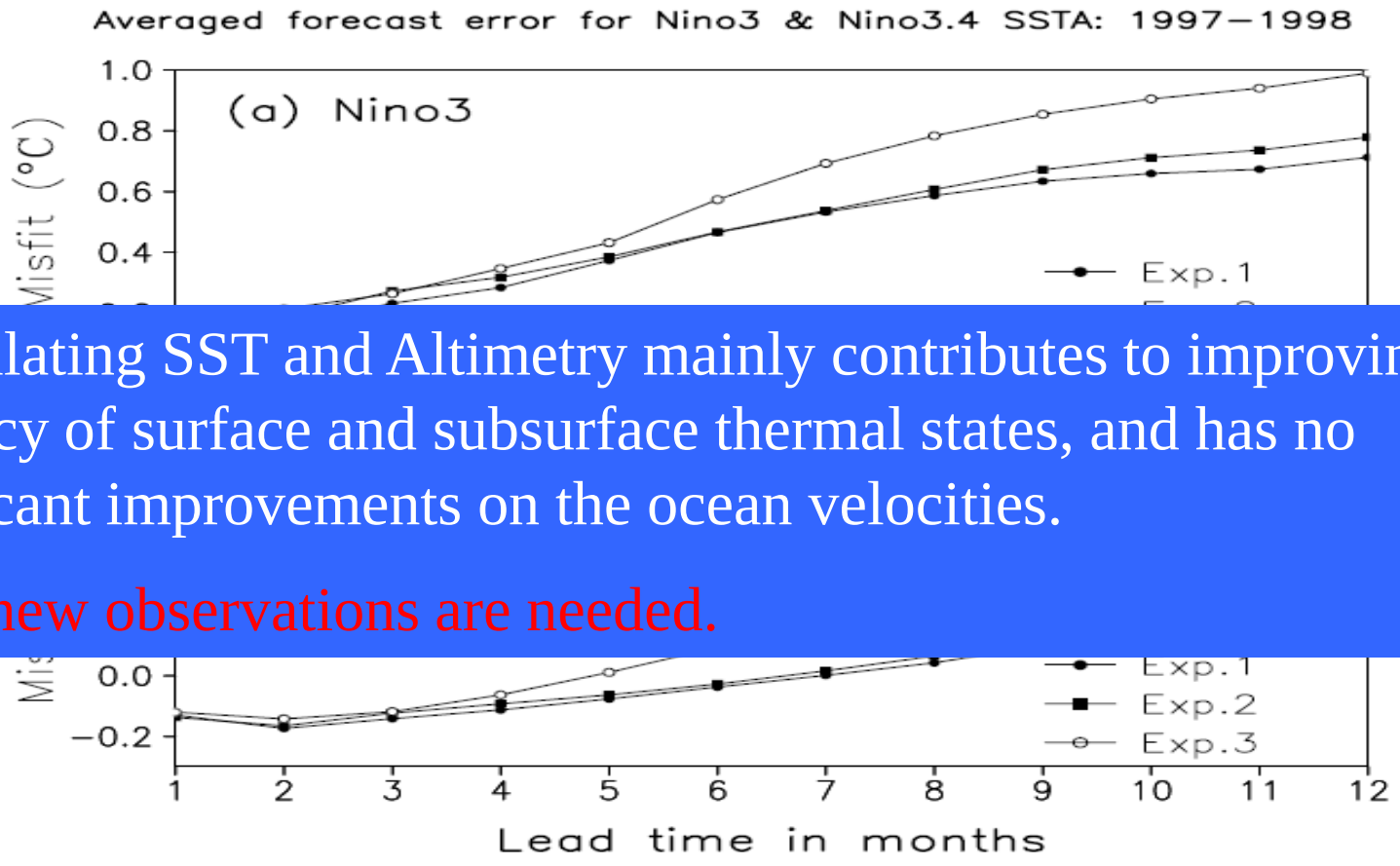
Assimilating SST only

Assimilating SST + Altimetry



Correlations between predicted & observed subsurface temperature

Ensemble Forecast Experiment	Description
Exp. 1	Ensemble initial conditions from both SSTA and SLA data assimilation with adjustment of the ocean horizontal and vertical velocities (i.e., new ensemble scheme in this paper)
Exp. 2	Ensemble initial conditions from both SST and SL anomaly data assimilation without adjustment of the ocean horizontal and vertical velocities (simply excluding these dynamical ocean variables from the matrix A)
Exp. 3	Ensemble initial conditions from only SST anomaly data assimilation with adjustment of the ocean horizontal and vertical velocities (i.e., original ensemble scheme by *Zheng et al.* [2006])

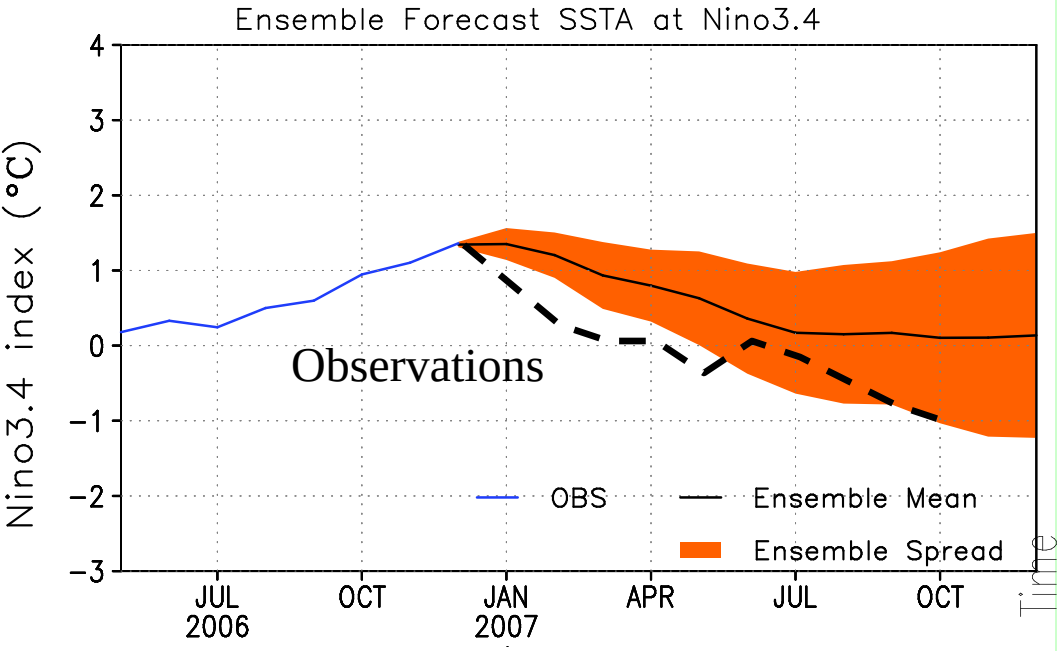


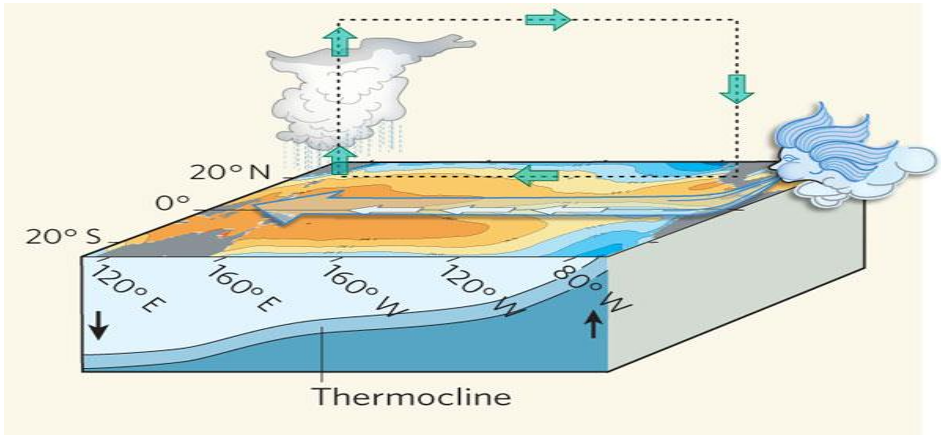
Assimilating SST and Altimetry mainly contributes to improving the accuracy of surface and subsurface thermal states, and has no significant improvements on the ocean velocities.

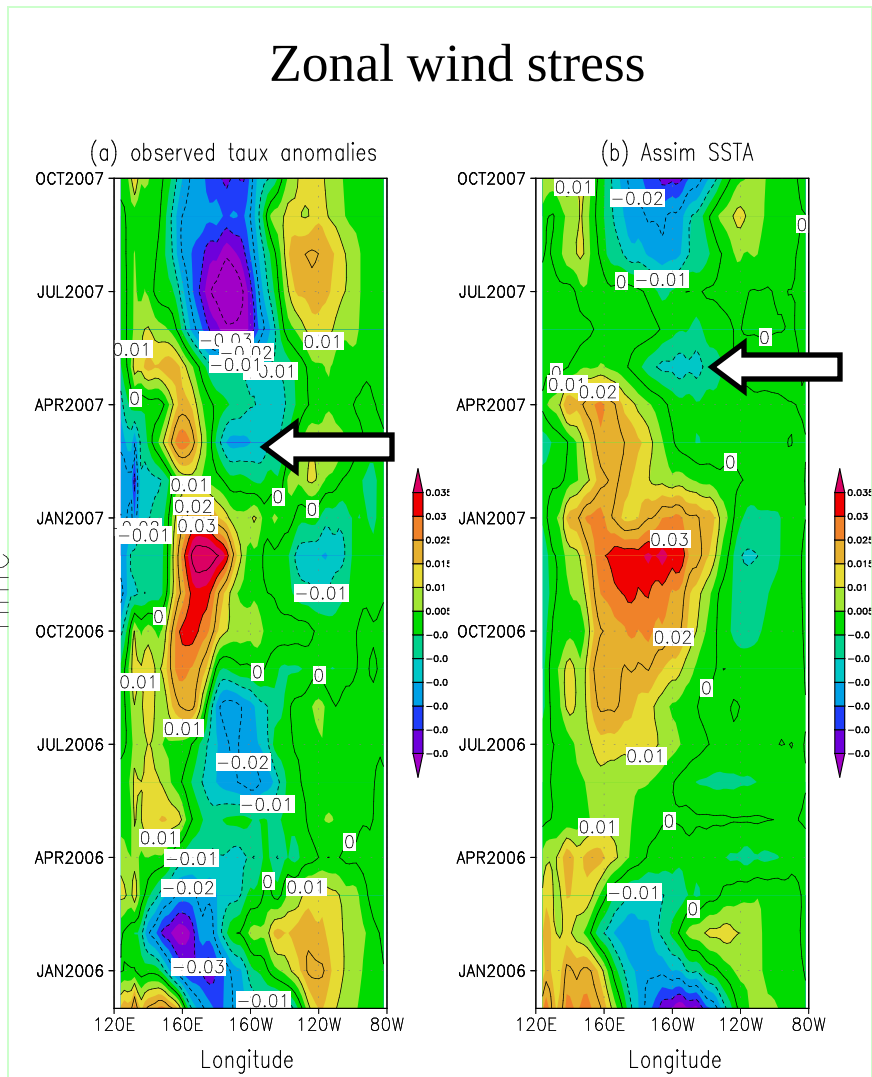
Other new observations are needed.

Coupled DA Seasonal prediction

A failure with ocean-only data assimilation in 2007 La Nina prediction

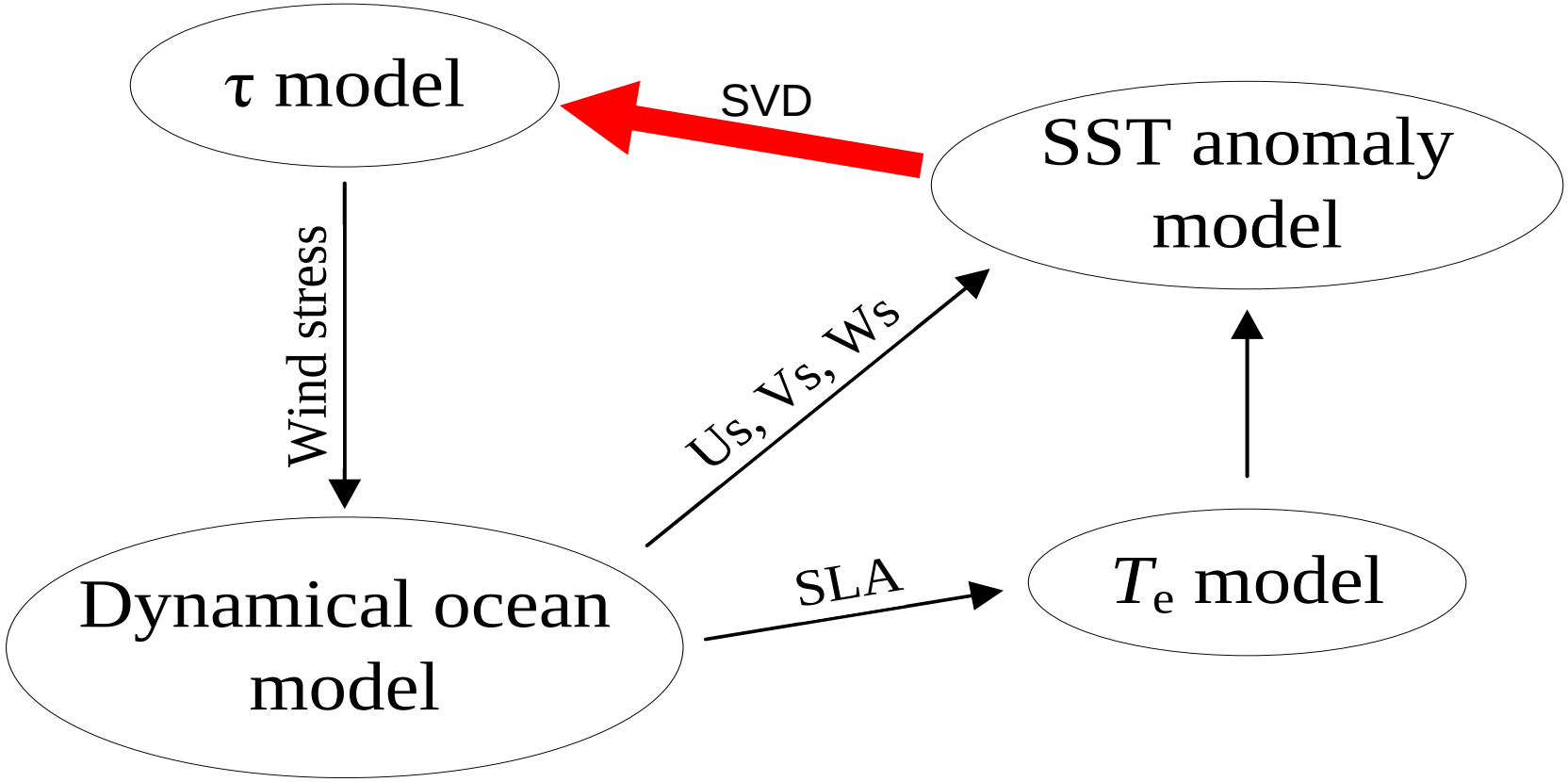






Coupled DA Seasonal prediction

Assimilating wind for a slave atmospheric model

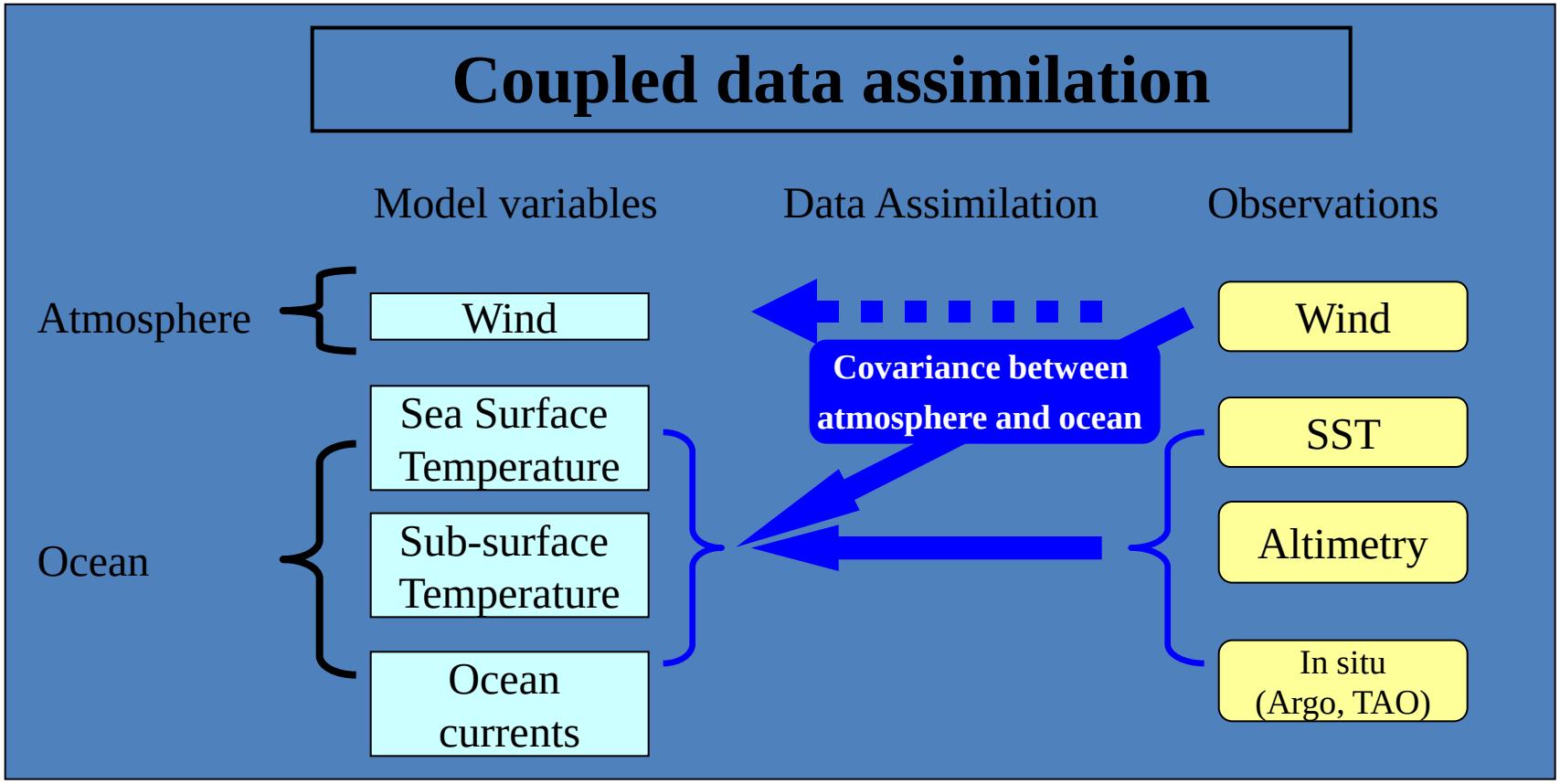


Model coupling

Keenlyside and Kleeman, 2002, JGR
Zhang et al., 2005, MWR

Coupled DA Seasonal prediction

How to assimilate wind into the ICM



Coupled DA Seasonal prediction

2007/08 La Nina forecast made by the coupled data assimilation