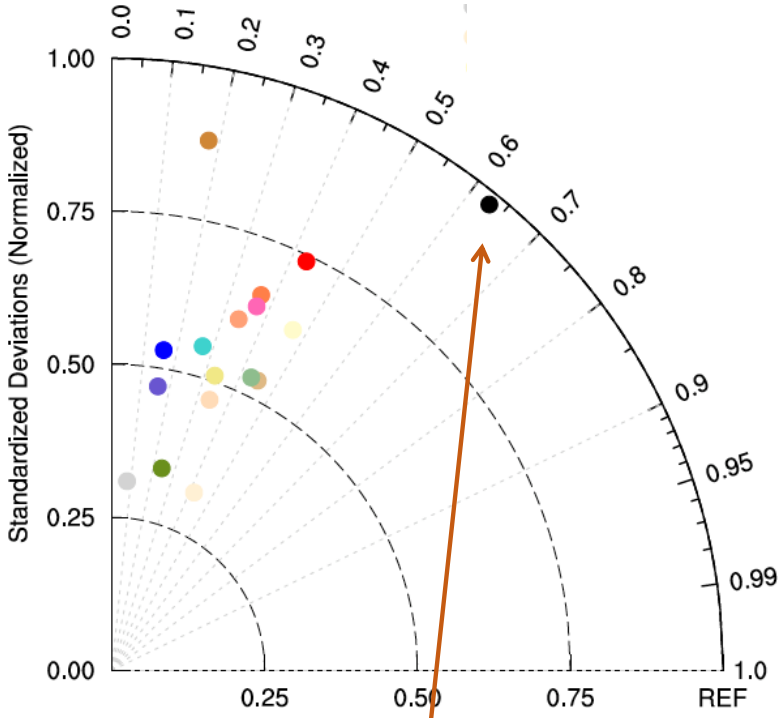
Ensemble Seasonal Prediction of Indian Summer Monsoon

Suryachandra A. Rao
Indian Institute of Tropical Meteorology
Pune, India

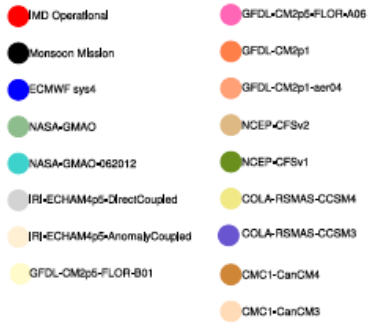
Collaborators: Ankur Srivastava, IITM, V.S. Prasad, NCMRWF

DATA and Methods

- Hindcast skill is referred as Anomaly correlation for JJAS (Summer Monsoon season)
- Rainfall reference data sets: GPCP, IMD Gridded
- AISMR: All India Summer Monsoon Rainfall averaged over Indian land.
- IODE: Indian Ocean Dipole Eastern pole (90-110^{o}E, -10^{o}s-Eq)

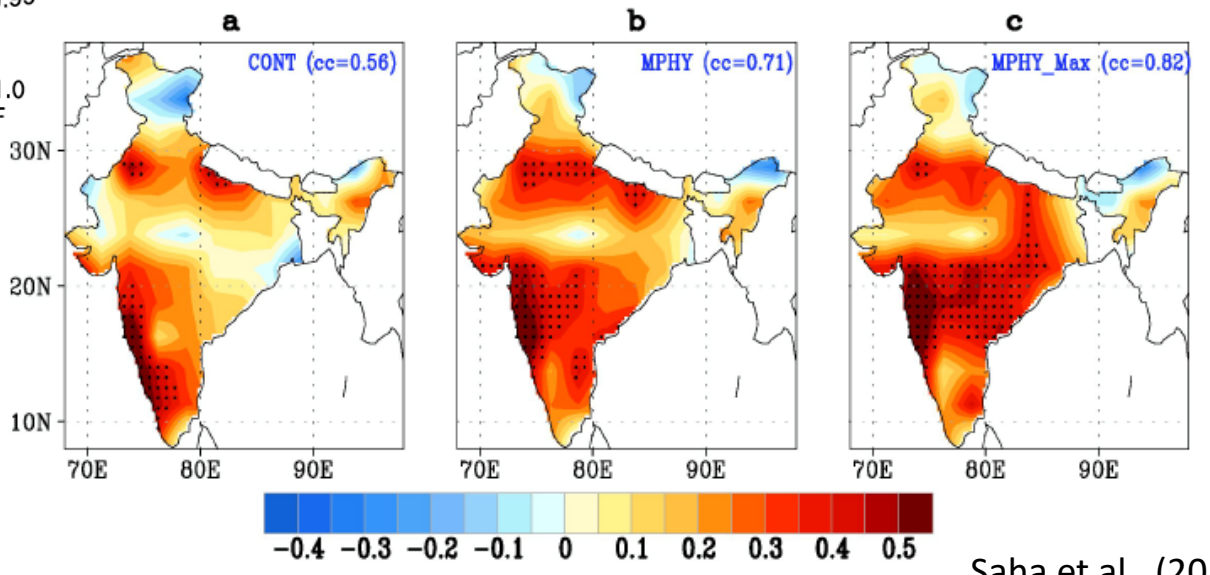


Pillai et al., (2019)



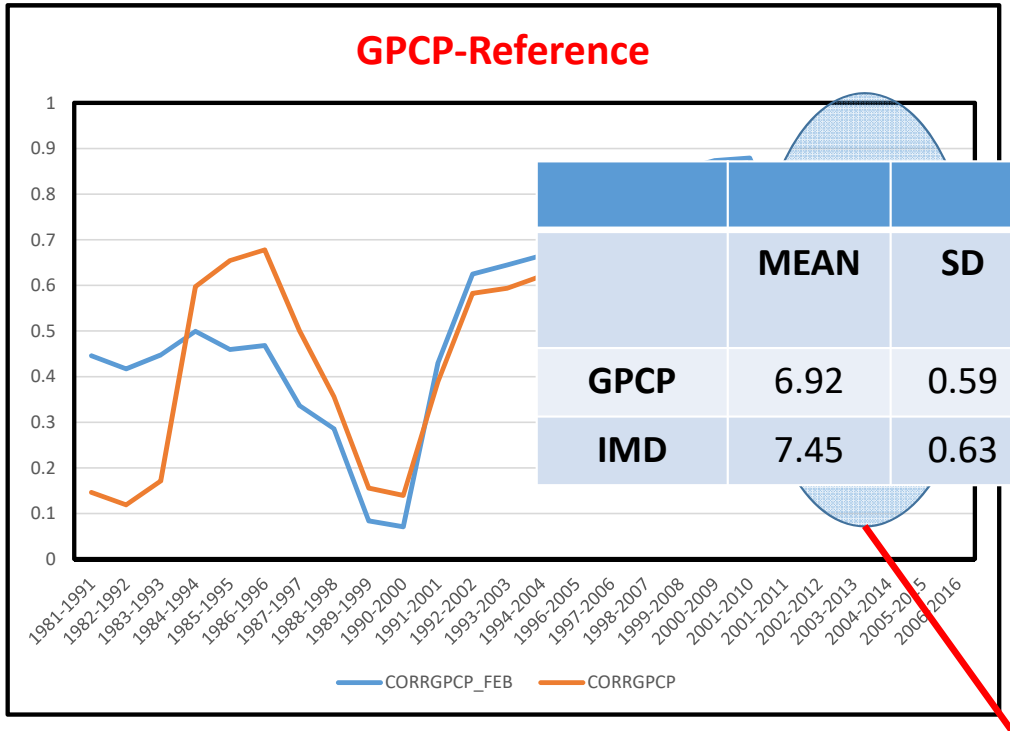
Monsoon Mission Model Performance (Prediction Skill as well as interannual variance) is better than other models for Indian Monsoon.

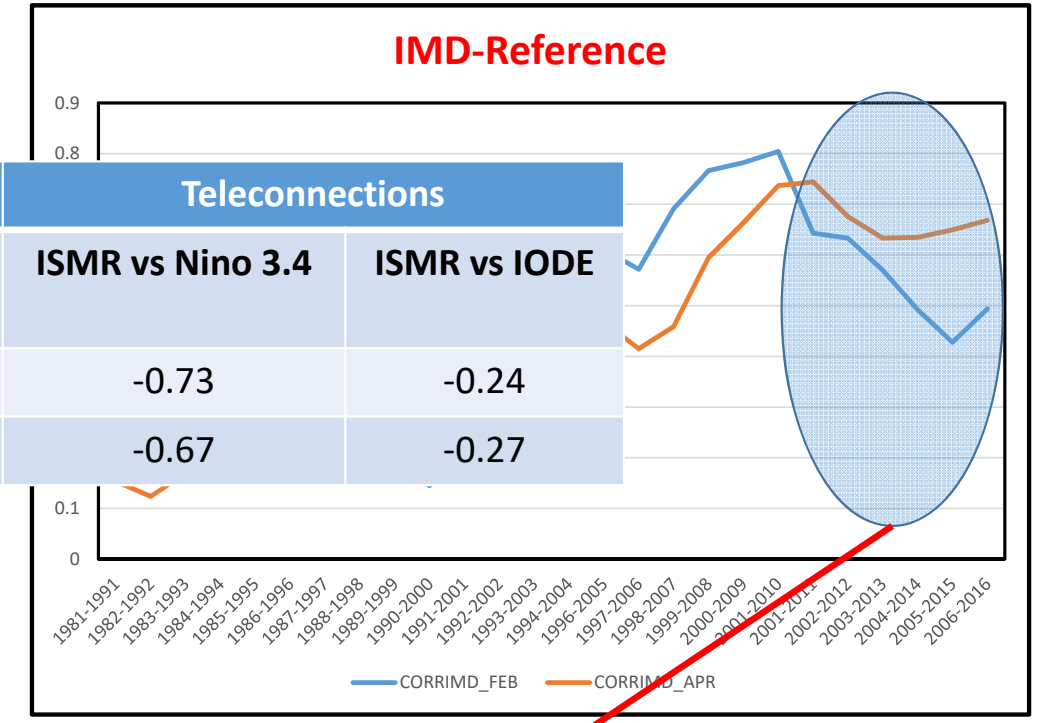
Indian Summer Monsoon Rainfall Prediction in coupled models operational at different world centers



Saha et al., (2019)

Running Correlation (11-yr) between Observed and Predicted AISMR with Feb. and Apr. IC

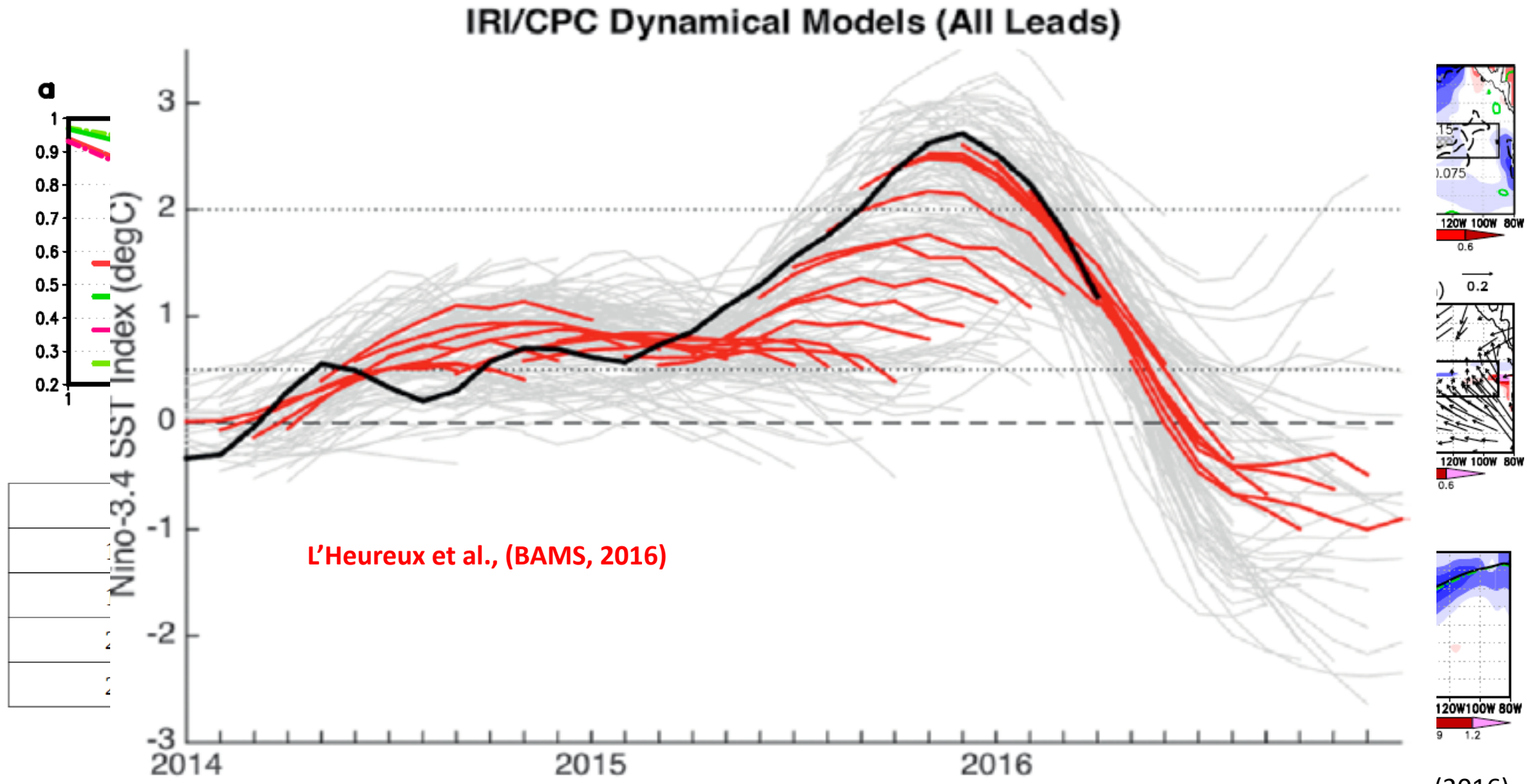




			Teleconnections	
	MEAN	SD	ISMR vs Nino 3.4	ISMR vs IODE
GPCP	6.92	0.59	-0.73	-0.24
IMD	7.45	0.63	-0.67	-0.27

Drop in Skill (ACC) of ISMR with Feb. IC is evident in recent decades

FEB. IC Vs. APR. IC Skill for AISMR



SST gradient and stronger Walker circulation.

Zhao et al. (2016)

Implications for non-perfect ensembles

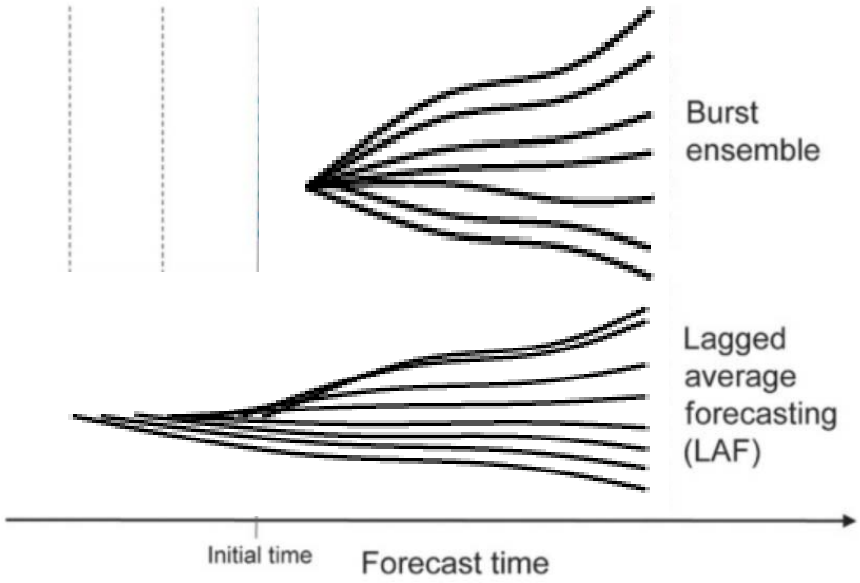
Time-mean ensemble spread ≠ RMSE of ensemble mean forecast

ensemble spread < RMSE → ensemble is *under dispersive*
ensemble spread > RMSE → ensemble is *over dispersive*

RPC > 1→ under confidence; VARsignal too small, model underestimates predictability of real world, observed correlation > perfect model correlation

RPC < 1→ overconfidence; observed correlation < perfect model correlation model predictability is larger than in real world

Methods of ensemble generation



- **Burst Ensemble**- Members of a large ensemble (e.g., 50 members are initialized from the same time)
- **Lagged ensemble**- Smaller set of model integrations are started from consecutive initial times

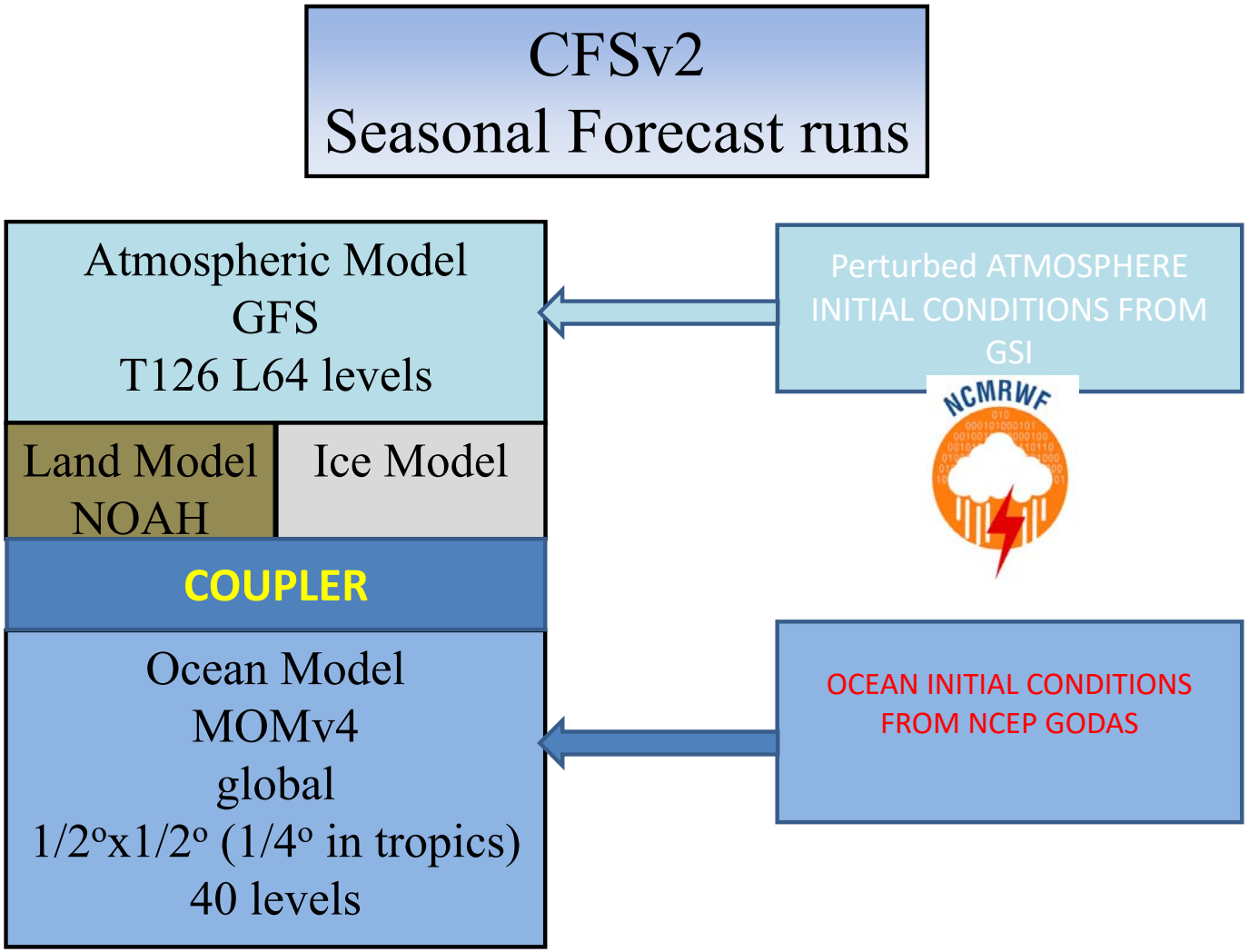
Hindcast Period: 2003-2017

ENSEMBLE GENERATION

- NCEP (NOAA) - GFS based atmospheric model and 3D variational Grid Statistical Interpolation (GSI) analysis Scheme.

- A ten member ensemble ICs for the above retrospective period for 00z and 18z cycles are created by adding samples of 48-24 hour forecasts differences of the same GFS model with a specified amplitude and of zero mean ensemble.

Experiment design



Hindcast period: 2003-2017

CTL run (L)

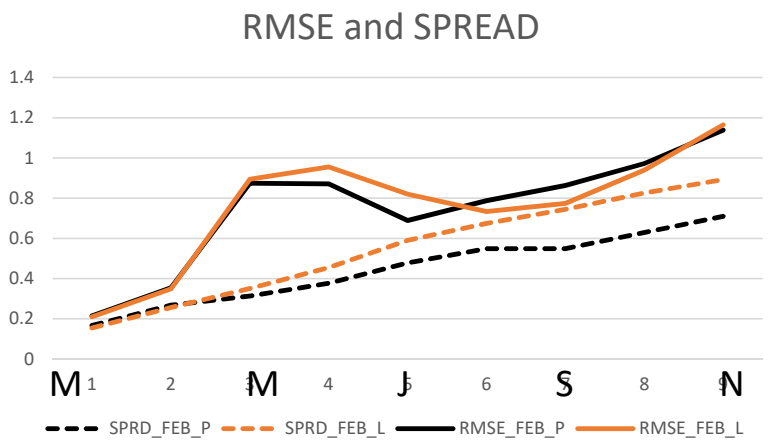
- Lagged initialization
- Feb, Mar & Apr ICs
- 10-12 members

Sensitivity run (P)

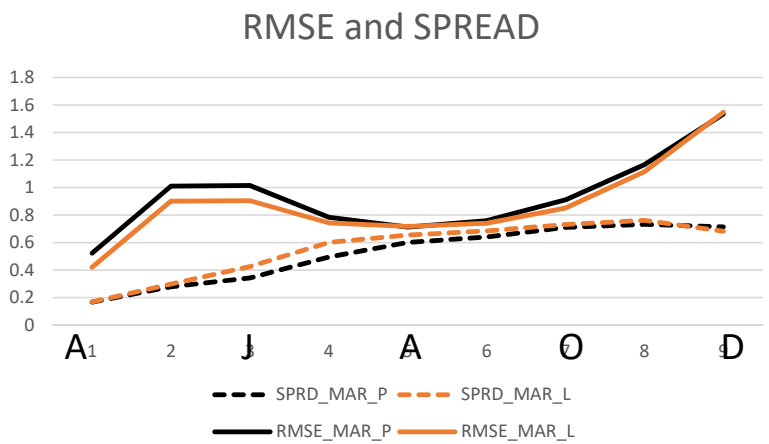
- Perturbed initialization
- 10 members
- Initialized on 01st of Feb, Mar & Apr

Model Spread and RMSE: NINO3.4

FEB IC

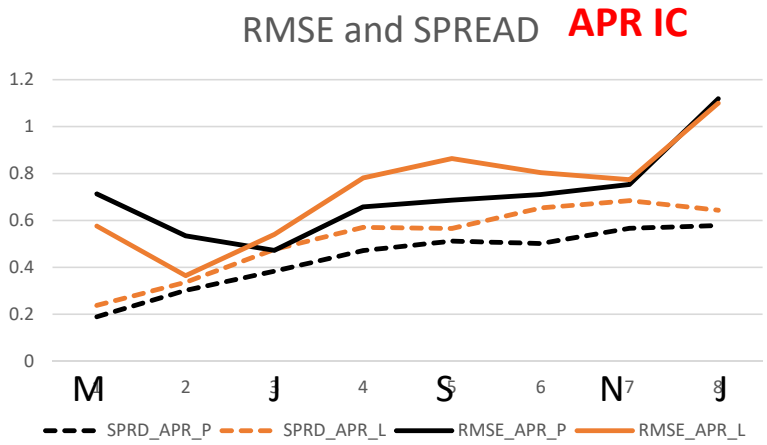


MAR IC



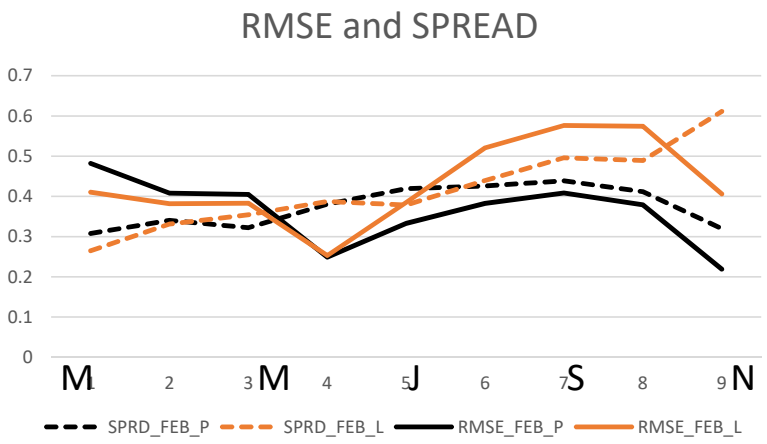
- RMSE is increasing with lead time with maximum in May/June
- Spread is close to RMSE except in AMJ in Feb. IC

APR IC

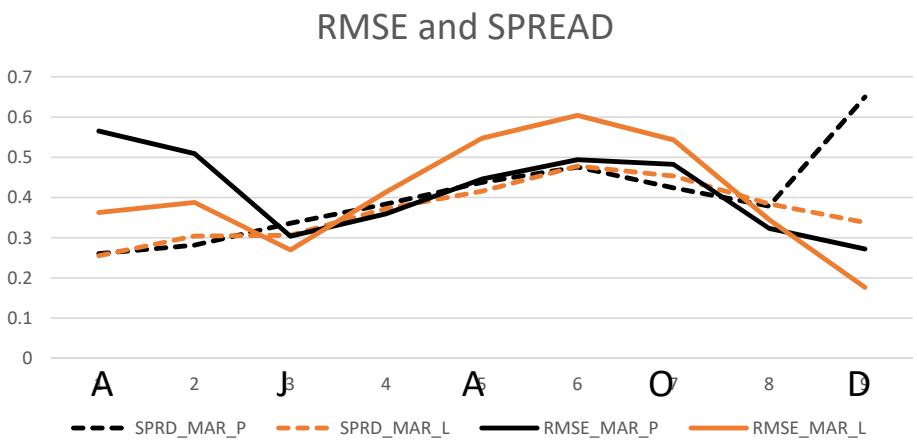


Model Spread and RMSE: IODE

FEB IC

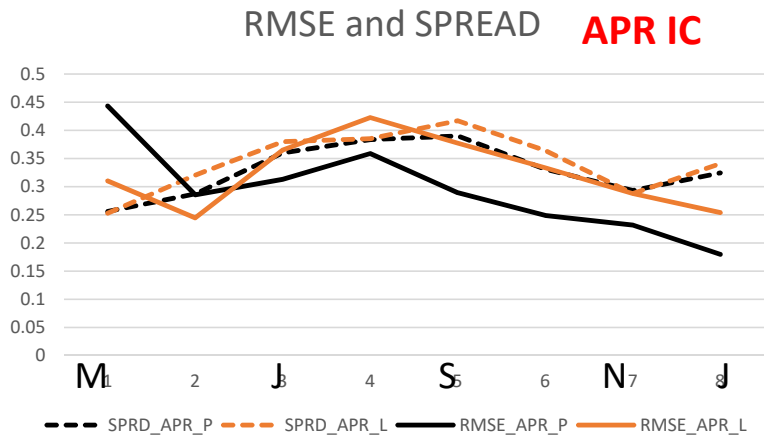


MAR IC



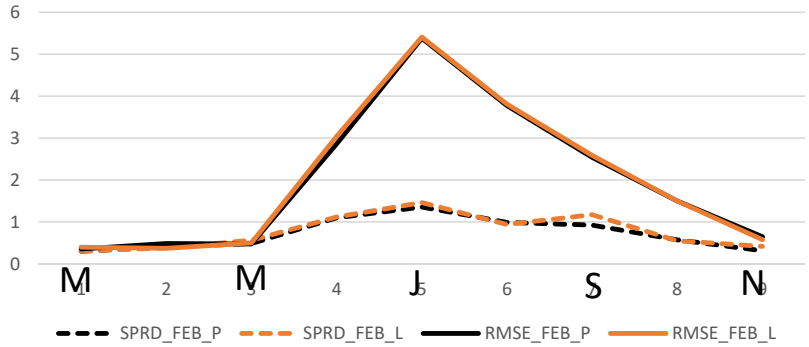
- RMSE is increasing with lead time with dip in June
- Spread is close to RMSE except in MJ in Feb. IC

APR IC

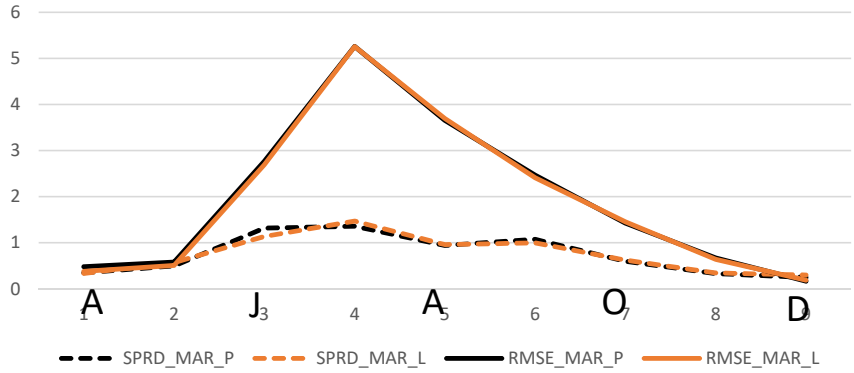


Model Spread and RMSE: All India Rainfall

FEB IC
RMSE and SPREAD

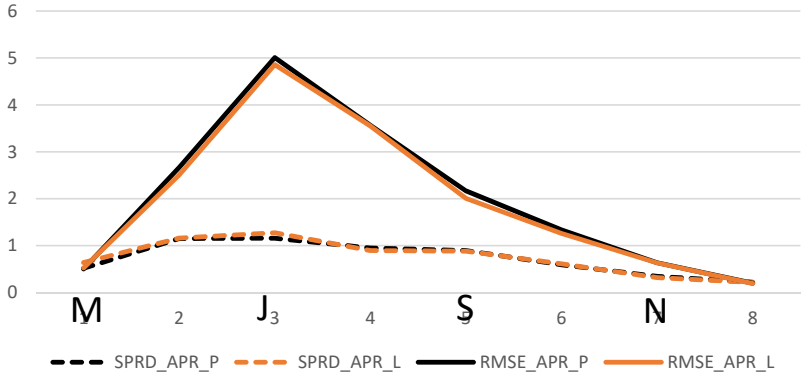


MAR IC
RMSE and SPREAD

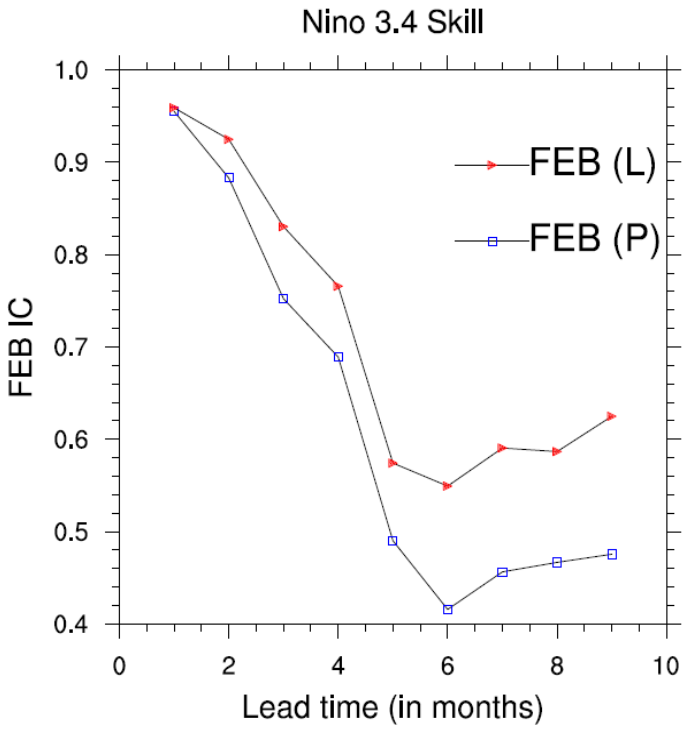


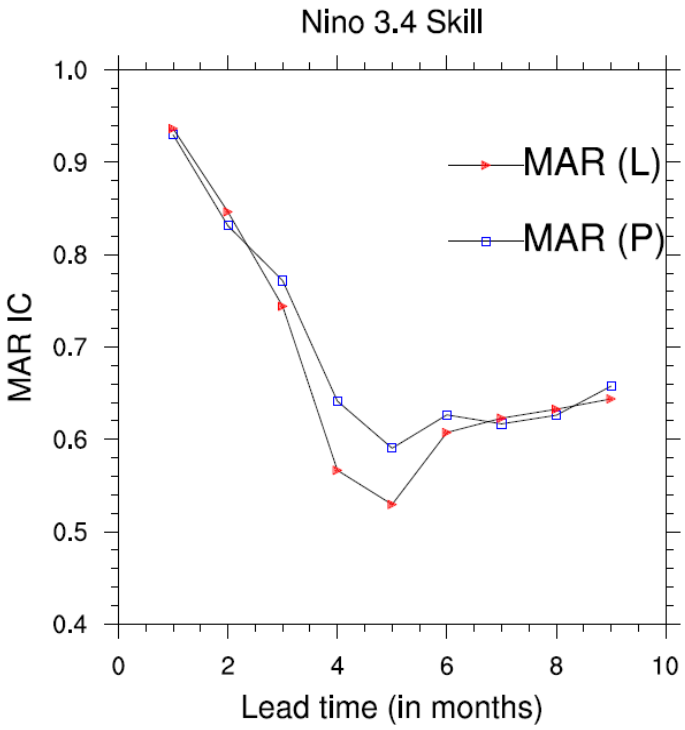
- RMSE is increasing in JJAS with maximum in Jul
- Spread is very small compared to RMSE and

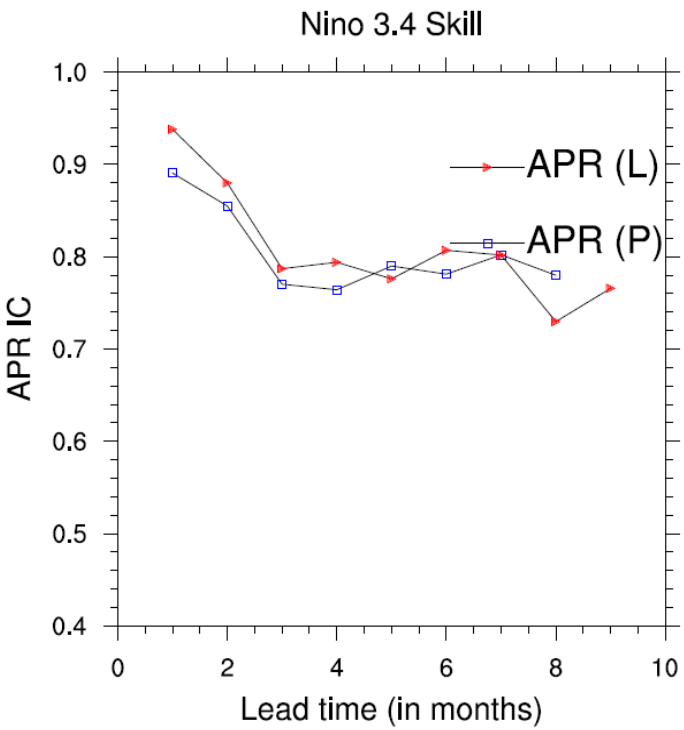
RMSE and SPREAD **APR IC**



Monthly Model Skill: Nino 3.4

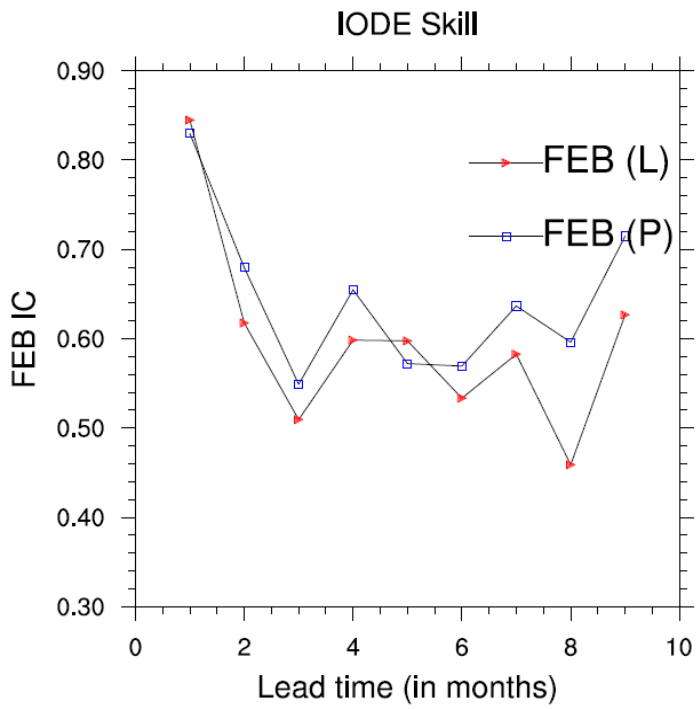


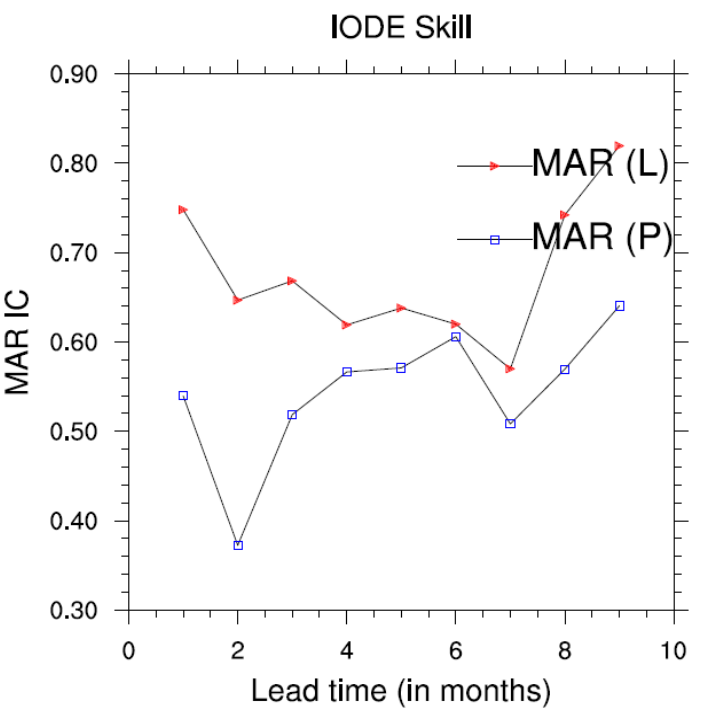


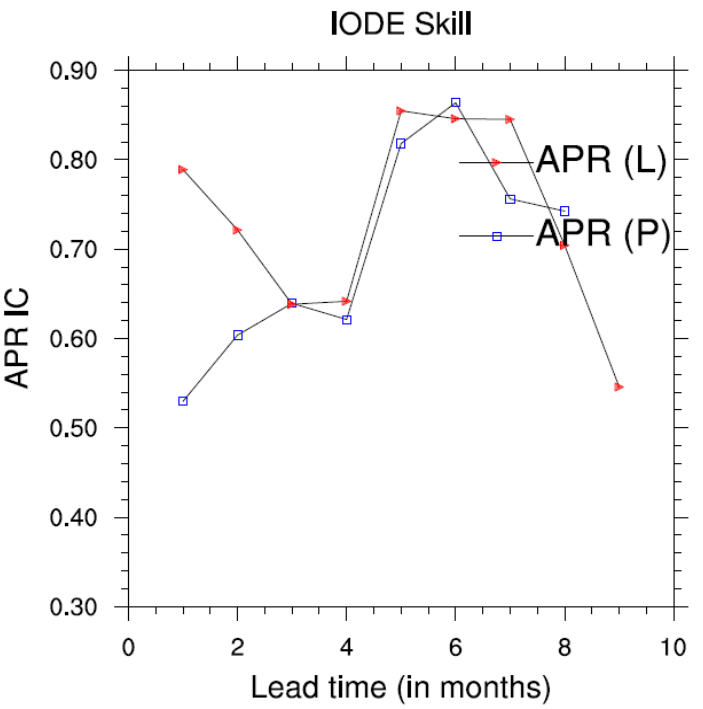


- At longer leads (FEB IC), the Nino 3.4 skill is higher in the later months for lagged method
- Comparable monthly evolution of skills at shorter leads

Monthly Model Skill: IOD East pole

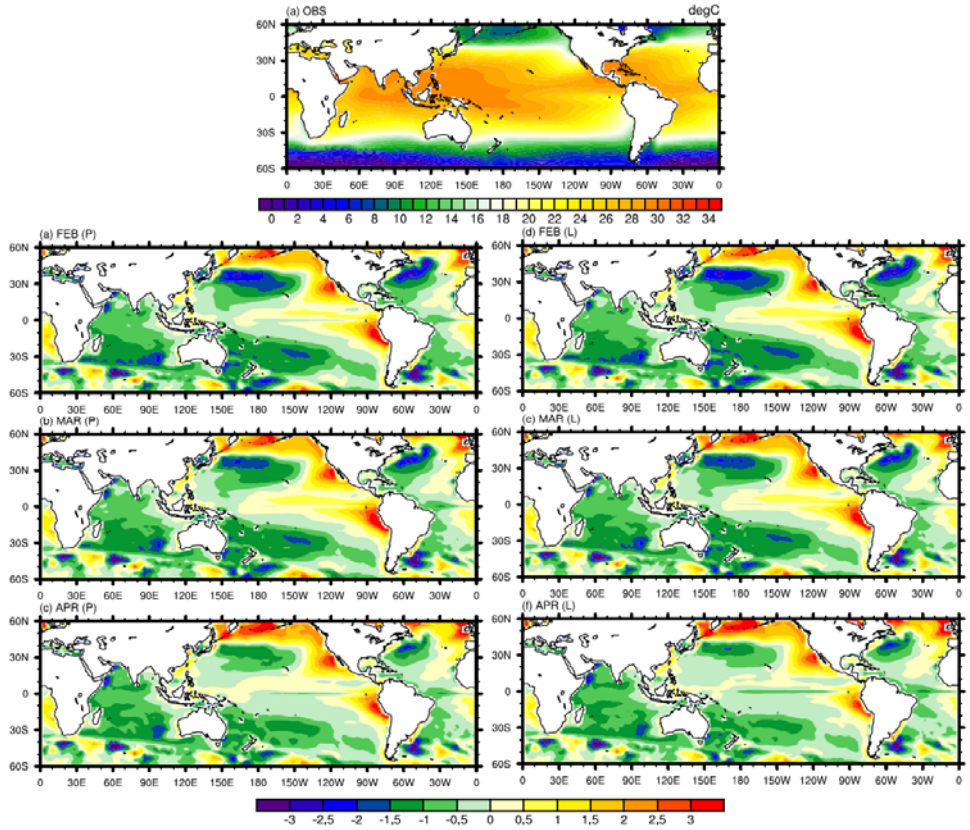


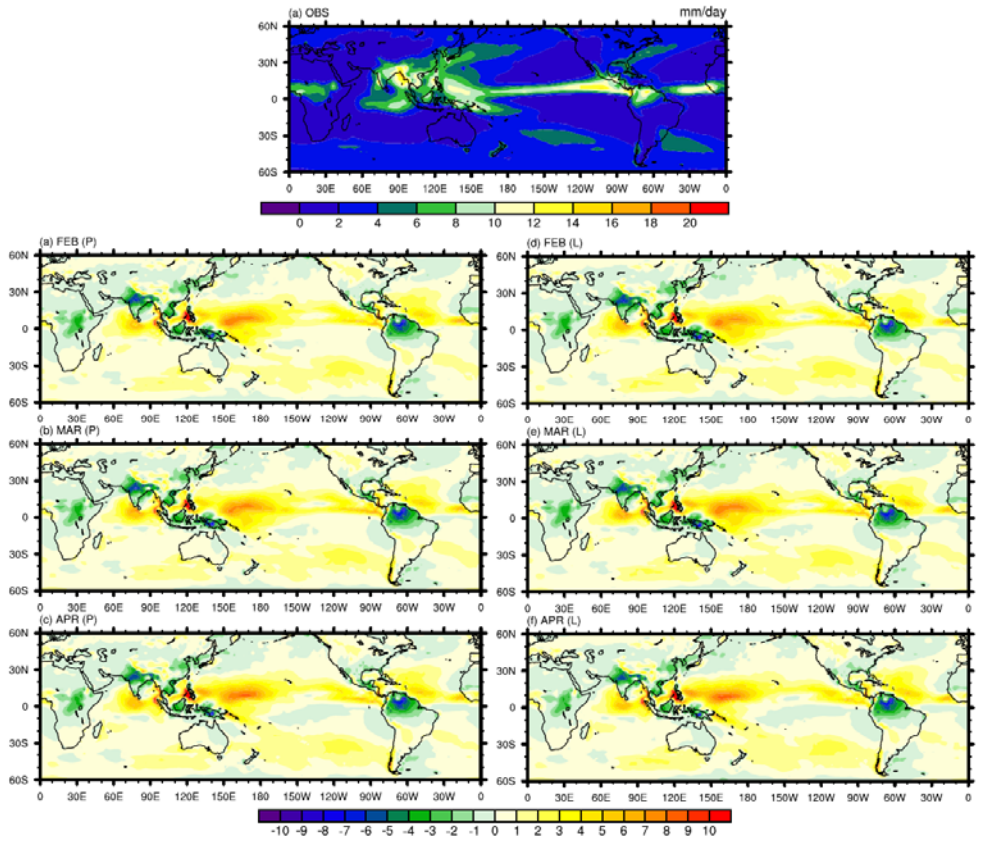




- At longer leads (FEB IC), the IOD skill is higher in the later months for perturbed method
- At shorter leads , the skill in the initial 2-3 months is higher for lagged method

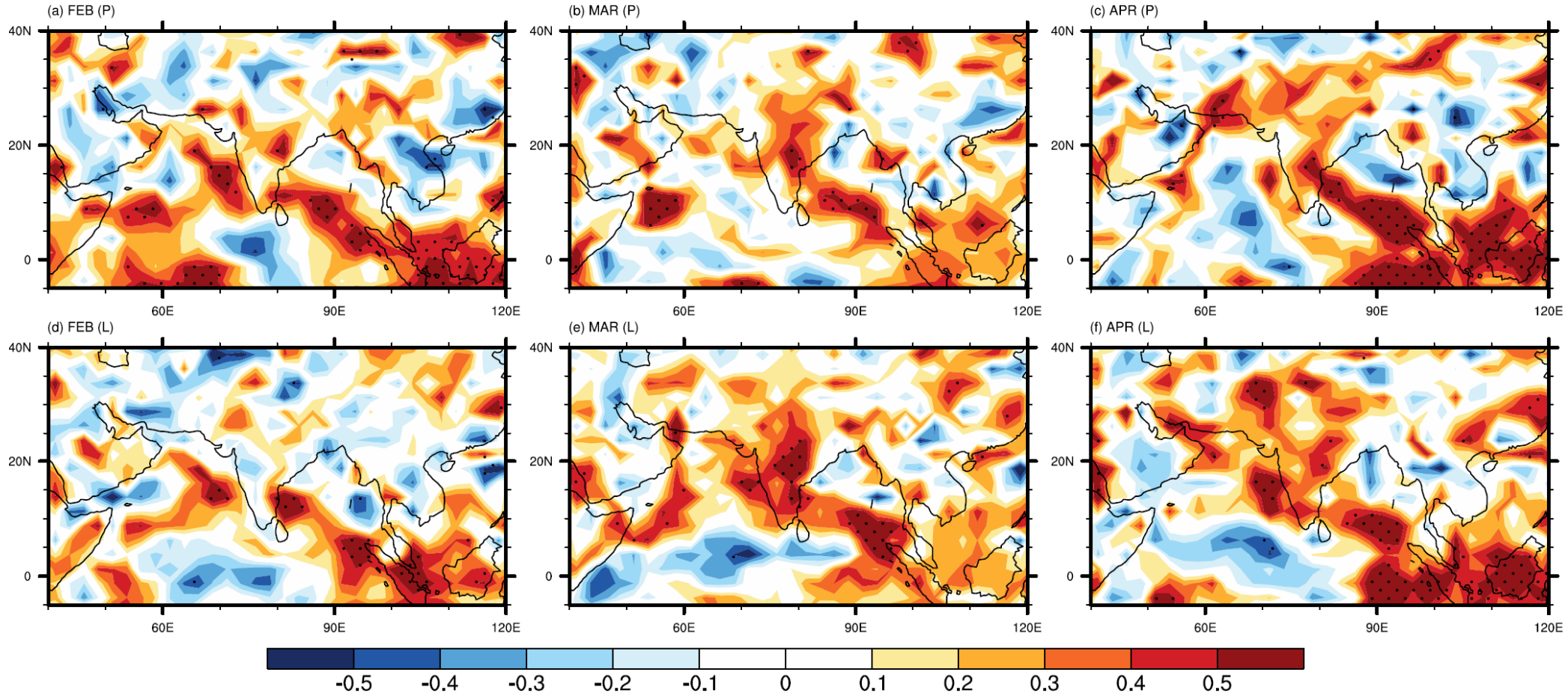
Mean biases: SST & Rainfall



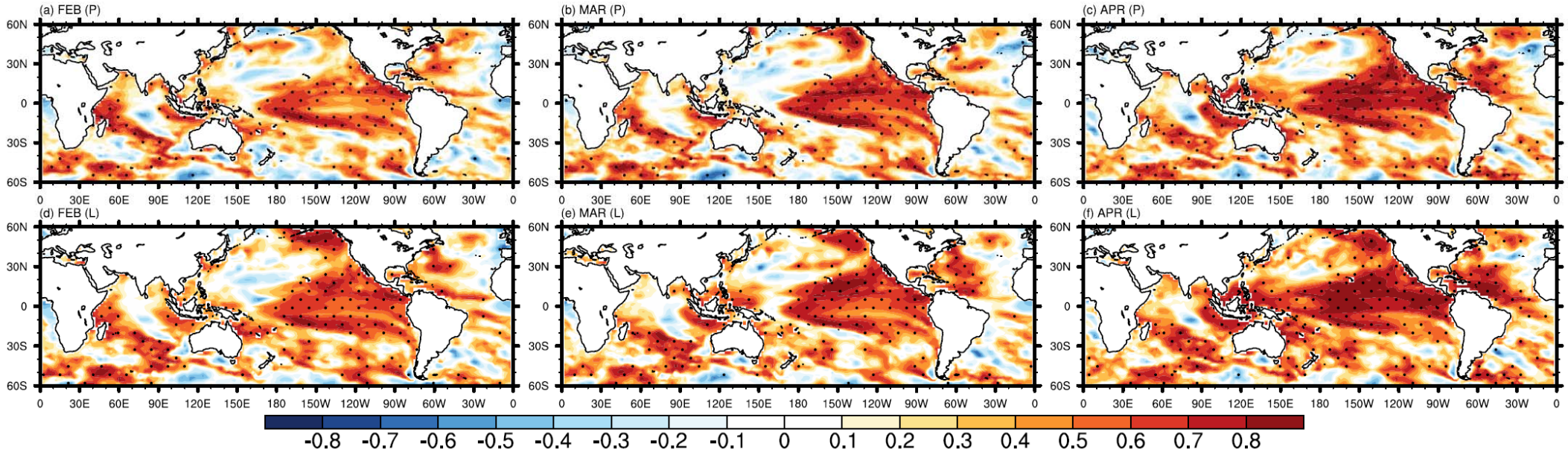


- Mean biases in SST & rainfall are almost similar

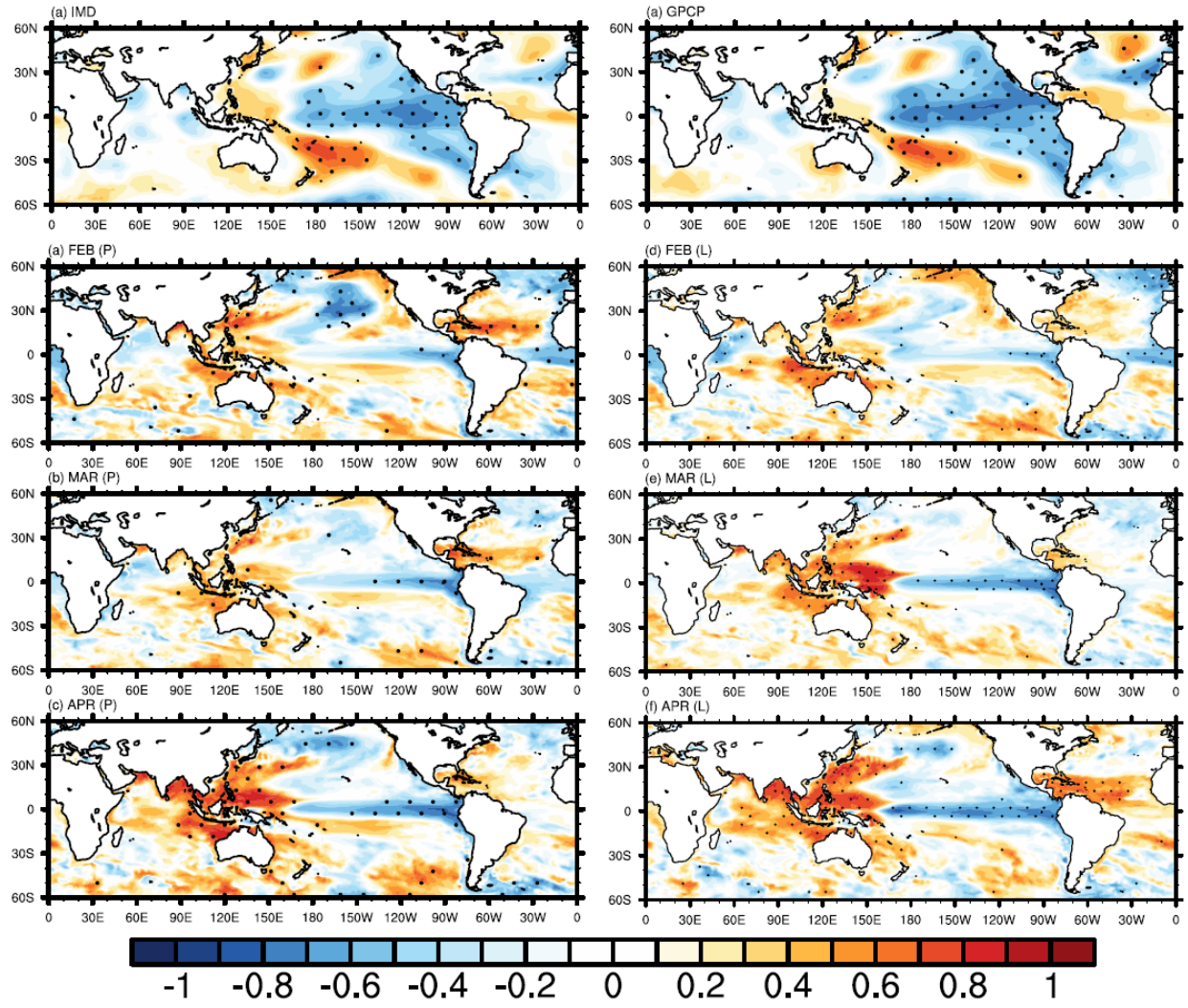
JJAS ACC for rainfall



JJAS ACC for SST



AISMR correlated with SST



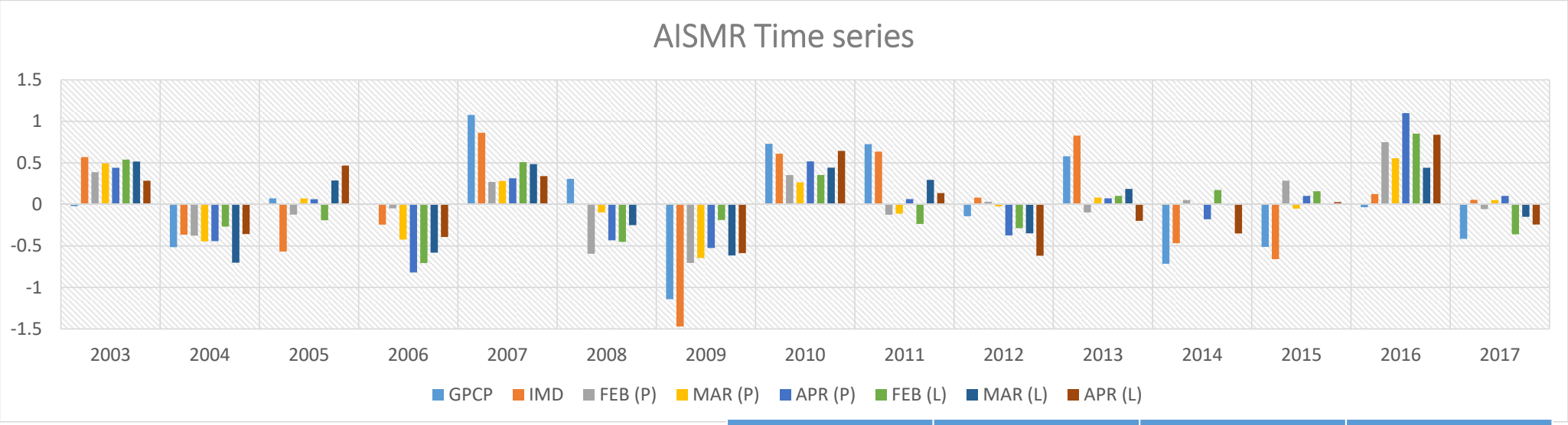
- Model simulated teleconnection with ENSO is very weak
- No other significant modulator of AISMR is seen in FEB ICs
- ENSO teleconnection are somewhat stronger in MAR & APR IC
- Strong positive correlations in the warm pool region for MAR & APR IC

Model Skill & Teleconnections

			Skill				Teleconnections	
	MEAN	**SD**	**ISMR (GPCP)**	**ISMR (IMD)**	**Nino 3.4**	**IODE**	**ISMR vs Nino 3.4**	**ISMR vs IODE**
GPCP	6.92	0.59	-	-	-	-	-0.73	-0.24
IMD	7.45	0.63	-	-	-	-	-0.67	-0.27
FEB P (Lagged)	3.95 (3.88)	0.37 (0.41)	0.31 (0.23)	**0.47** (0.37)	0.50 (**0.61**)	**0.70** (0.63)	-0.31 (-0.26)	0.55 (0.73)
MAR P (lagged)	4.06 (4.04)	0.32 (0.41)	0.49 (0.63)	0.65 (0.64)	0.66 (0.60)	0.63 (**0.71**)	-0.39 (-0.56)	0.46 (0.65)
APR P (lagged)	4.26 (4.39)	0.47 (0.47)	0.37 (0.55)	0.49 (0.44)	0.80 (0.82)	0.77 (0.78)	-0.55 (-0.64)	0.71 (0.58)

- Mean monsoon rainfall is similar across both lagged & perturbed model runs.
- FEB (L) & MAR (P) Nino 3.4 skill is slightly better but is similar for other ICs
- FEB (P) & MAR (L) IODE skill is better
- ENSO teleconnections have become stronger in the recent period 2003-2017
- Teleconnections with ENSO are surprisingly weak in the model for 2003-2017
- IOD teleconnections are opposite to what is expected

AISMR Skill



SKILL	FEBRUARY Perturbation (lagged)	MARCH Perturbation (lagged)	APRIL Perturbation (lagged)
IMD	**0.47** (0.37)	**0.65** (0.64)	**0.49** (0.44)
GPCP	**0.31** (0.23)	0.49 (**0.63**)	0.33 (**0.55**)

- ✓ For all initializations, the lagged and perturbed ICs have comparable skill scores
- ✓ Perturbed Feb IC is somewhat better compared to lagged initialization approach.

Summary

- **Both Burst and Lagged ensembles appears to be resulting in similar statistics for all India Summer Monsoon Rainfall**
- **One advantage of the perturbed ICs is that one do not have to wait for the whole month observations (Initiate all ensemble runs on 1st of each month)**
- **Both ICs resulted in RMSE >> Spread for AISMR (i.e under dispersive). For SST indices RMSE and Spread are almost equal**
- **The question of how to improve spread in ensembles is still eluding us for AISMR**

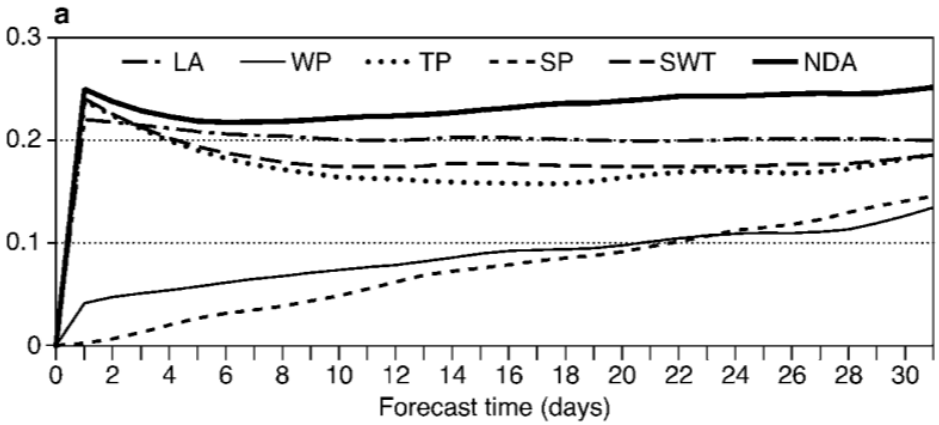
CAVEATS

- **The hindcast period is very short (15 years) for seasonal prediction**
- **Perturbations at this moment are only in atmosphere component**

Thank YOU

Ensemble spread of Nino 3 SST forecasts

LA – Lagged average	SP – Stochastic physics
WP – Wind perturbation	SWT – WP+TP+SP
TP – Temperature perturbation	NDA – No data assimilation

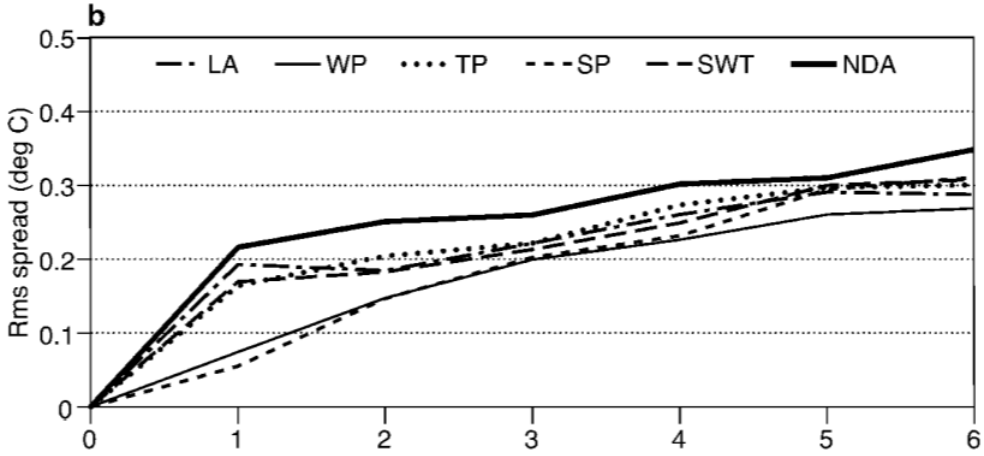


Ensemble spread of SST forecasts as a function of lead time: The daily evolution of the spread during the first month

- WP & SP display a different behavior
- Strong relaxation to observed SST during the analysis prevents any significant spread in SST at initial time in WP.
- TP, SWT, and LA provide a better estimate of the uncertainties during the early range of the forecast than WP and SP.
- In TP and SWT, there is a slight decrease of the spread during the first week of the forecast that might correspond to the noisy component of the SST perturbations being dissipated in the coupled model because it does not have a physical structure.

Vialard et al. (2004)

Ensemble spread of Nino 3 SST forecasts



Ensemble spread of SST forecasts as a function of lead time: the time evolution (in months) for the whole forecast period

LA – Lagged average	SP – Stochastic physics
WP – Wind perturbation	SWT – WP+TP+SP
TP – Temperature perturbation	NDA – No data assimilation

- For all lead times beyond month 3, the spread in SST forecasts given by the TP, WP, and SP methods is very similar.

Vialard et al. (2004)

Since El Niño predictability is generally believed to stem from the knowledge of oceanic initial conditions, one would normally expect uncertainties in oceanic initial conditions such as those generated in the WP experiment, to give rise to corresponding uncertainties in El Niño forecasts.

However, the spread in experiment WP (with uncertainties in initial conditions) is indistinguishable from the spread arising from purely internal atmospheric variability (experiment SP).

Since "burst ensembles" allow a more timely delivery of the forecasts than LA, they should be preferred to LA in an operational system.