CLIMATE ANALYSIS FORECAST ENSEMBLE system

Coupled data assimilation and ensemble initialization with application to multi-year ENSO prediction.

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Data Assimilation Experiments

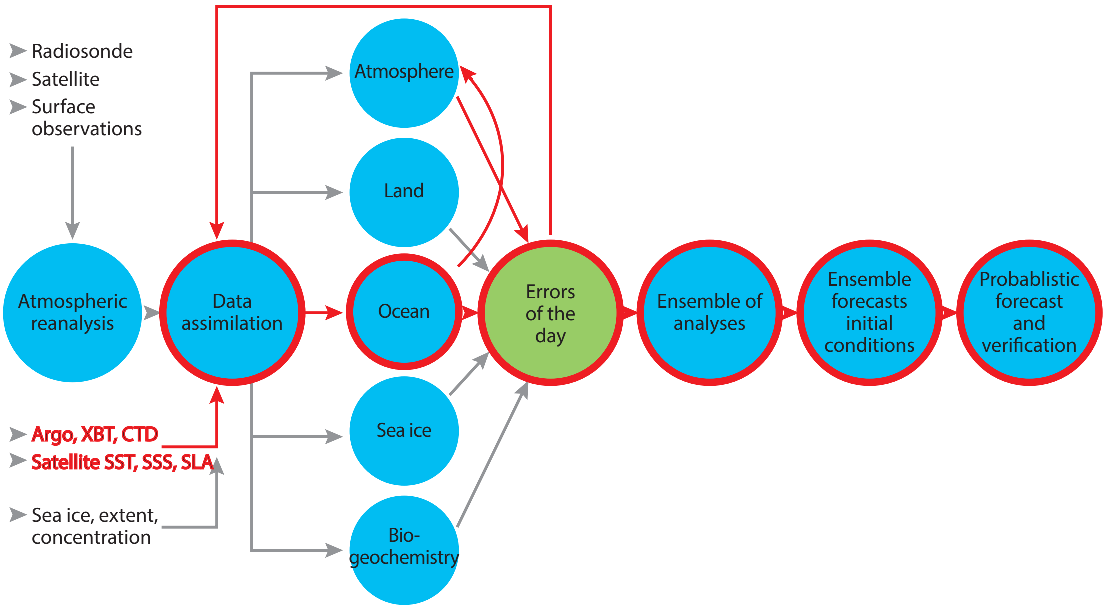
The aim of these Experiments was to

- compare variants of coupled data assimilation (DA) systems based on ensemble optimal interpolation (EnOI) and ensemble transform Kalman filter (ETKF) methods
- to assess the impact of assimilating ocean observations on the atmospheric state analysis update via the cross-domain error covariances from the coupled-model background ensemble.
- examine the relationship between ensemble spread, analysis increments and forecast skill in multi-year ENSO prediction experiments with a particular focus on the atmospheric response to tropical ocean perturbations.
- explore various approaches to generating initial forecast perturbations, either in terms of ETKF or bred vectors

O'Kane, T.J., P.A. Sandery, D.P. Monselesan, P. Sakov, M.A. Chamberlain, R. Matear, M. Collier & L. Stevens (2018) *Coupled data assimilation and ensemble initialization with application to multi-year ENSO prediction* (in review J. Climate)

CAFE system design

Schematic of the CAFE system



Observations assimilated

R-factor to adjust model error variances and K-Factor to adjust observation error variances. ETKF employs SST and SLA bias correction via AR(1) model fit.

TABLE Number of ocean observations and superobs assimilated on 03/2012 & 12/2017

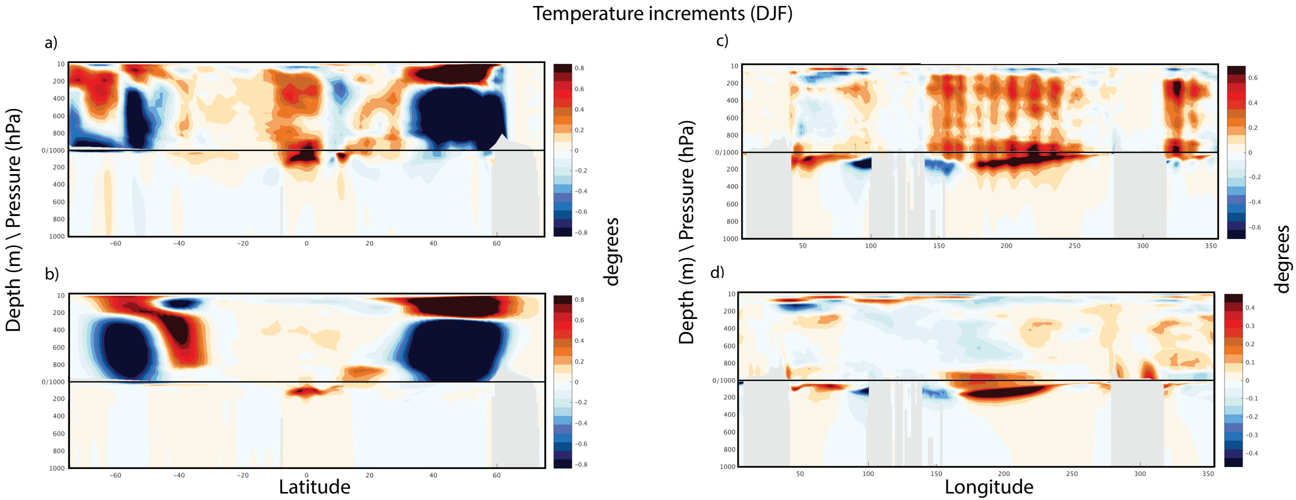
Date	03/2012		
type	# used	# discarded	# superobs
SLA	2249101	122202	245742
SST	19147820	250250	478420
TEM	1341154	14956	298345
SAL	1253298	15470	269894
SSS	2163235	96132	828292
Total	26154608	499010	2120693
Date	12/2017		
type	# used	# discarded	# superobs
SLA	2836923	175817	290120
SST	121295481	1026776	1059509
TEM	10432222	211906	363541
SAL	9452414	285884	337366
SSS	0	0	0
Total	144017040	1700383	2050536

TABLE Summary of ocean observations assimilated into the Global Climate Model

SST	RADS altimetry	SSS	In-situ T/S (WMO GTS)
NAVO-AVHRR	JASON	AQUARIUS	Argo
AMSR-E	CryoSat2	SMOS	CTD
AMSR-2	EnviSat2		XBT
WindSat	Altika		RAMA
PATHFINDER	SARAL		PIRATA
VIIRS	Sentinel3		TAO-TRITON

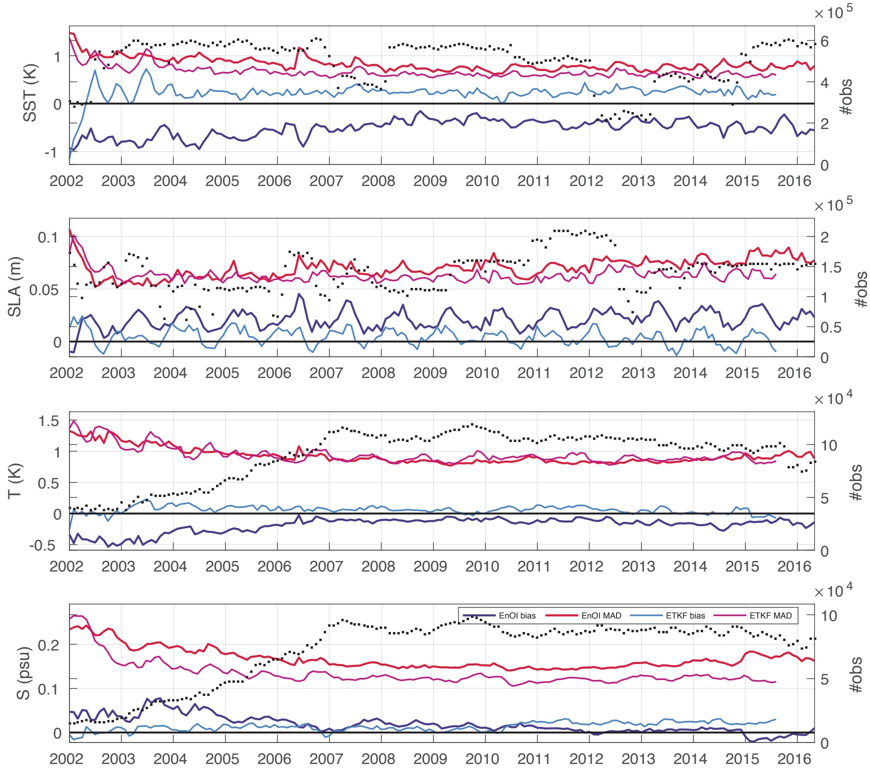
Tropics-Extra-tropics (seasonal increments)

Comparison of ocean and atmosphere increments averaged over the boreal winter (DJF) along 140°W (ETKF a); EnOI b) and 2°S (ETKF c); EnOI d)



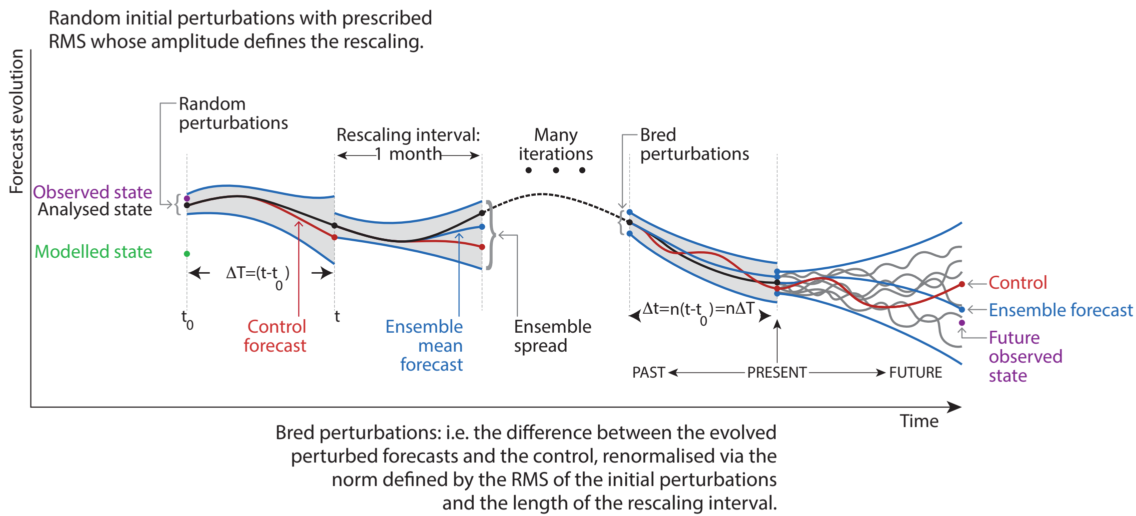
3: Assimilation statistics (20°S-20°N)

EnOI (1 analysis, static cov) versus ETKF (96 analyses, flow dependent + SST bias correction)



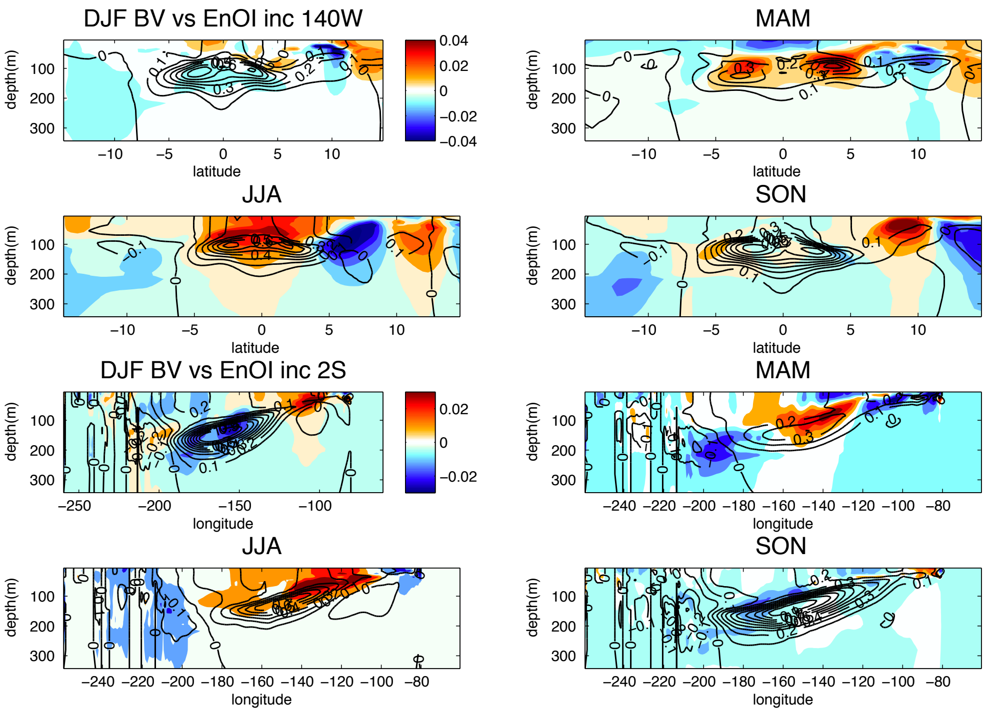
Ensemble Prediction System

Bred vector generation



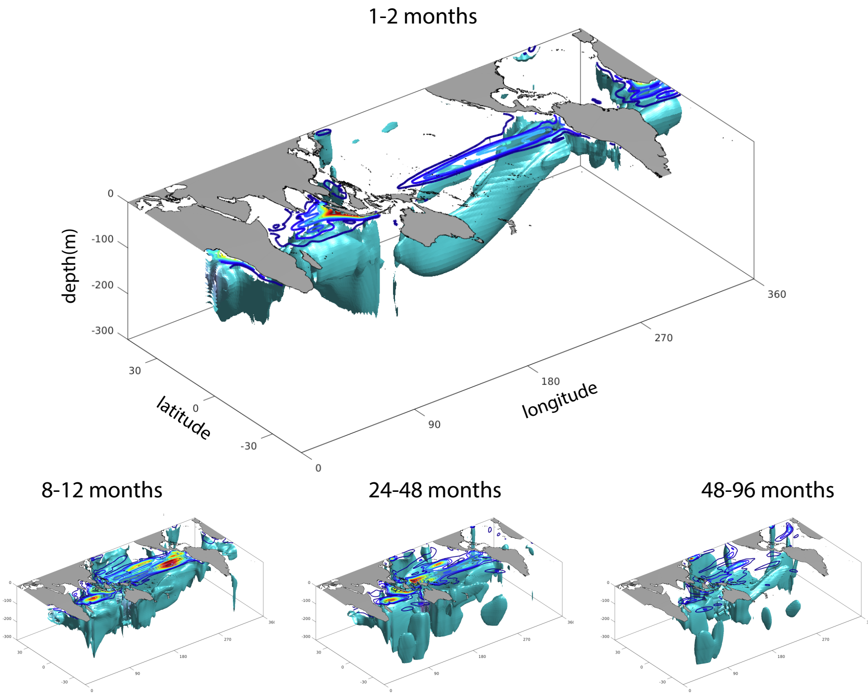
BV's versus 28 day forecast errors

Comparison of ensemble averaged BV's (shaded) and EnOI/ETKF analysis increment (contour) along sections at $140°$W and $2°$S.



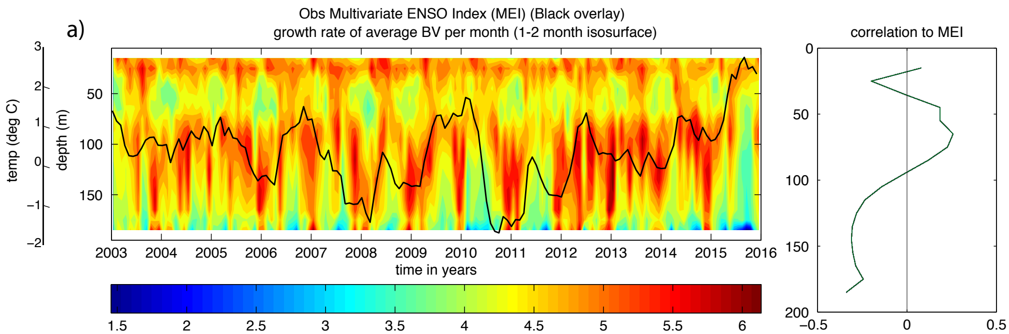
Scale selection

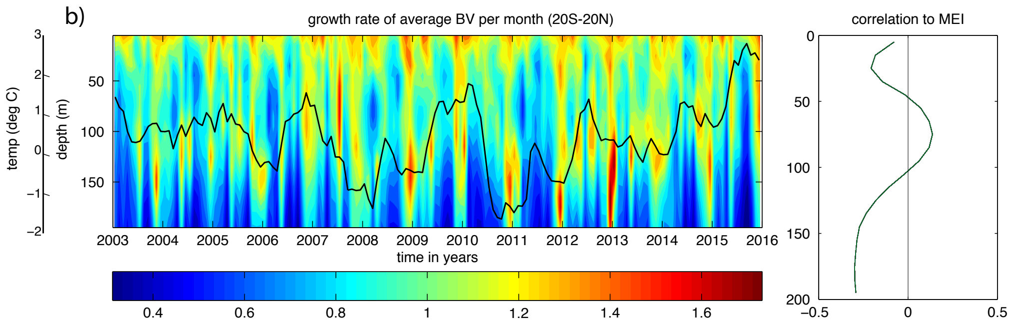
● localisation length scales and adjustment of observation impact factors to "tune" increments to select spatio-temporal scales of relevance to given forecast lead times.
● mask regions of variance relevant to those chosen spatio-temporal scales such as the in band variance for temperature with an appropriate threshold (0.5 RMSE calculated from 500 years of control simulation).



Error growth rates

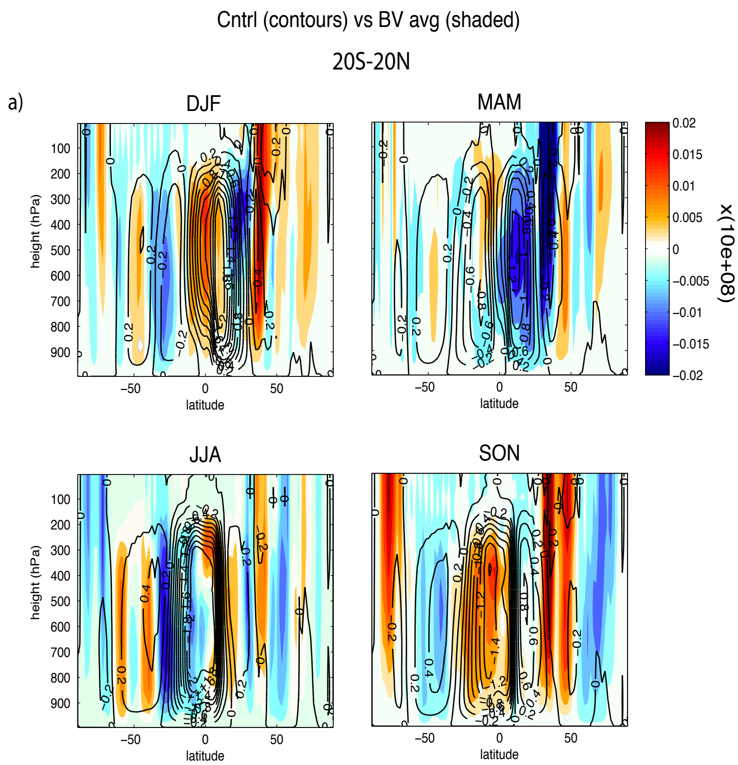
isosurface BV growth rates 3 times larger than 20°S-20°N BVs





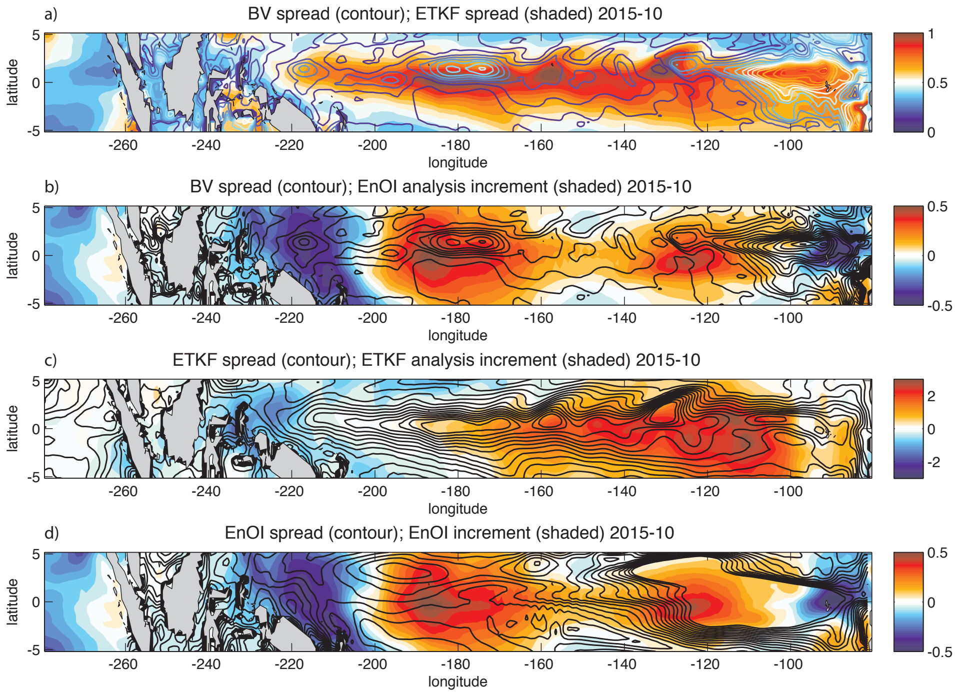
Tropics-Extra-tropics

Coherent tropospheric response to modulation of tropical convection



ETKF versus BVs case study 2016 El Nino

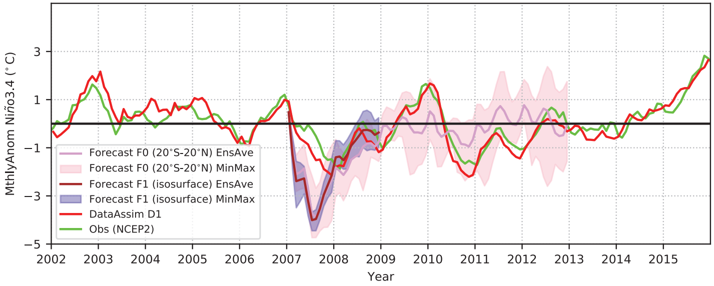
- Ensemble spread versus analysis increment during build up to 2016 El Niño.
- BVs add similar flow dependent structures to ETKF background covariances.



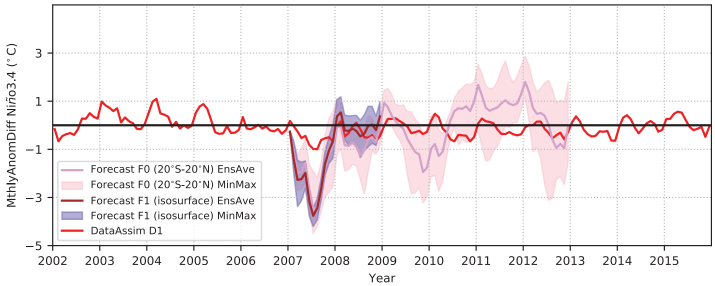
ENSO Prediction case study

- Ensemble forecasts (no bias correction) of NINO3.4 beginning January 2007 comparing isosurface BVs (F1) to BVs generated between 20°N-20°N renormalised to 1% of the background RMSE (F0).
- Spread reduced in isosurface ensemble due to reduced error growth in regions unrelated to the thermocline.
- D1 is the reanalysed state estimates as compared to NCEP reanalysis v2.

a)

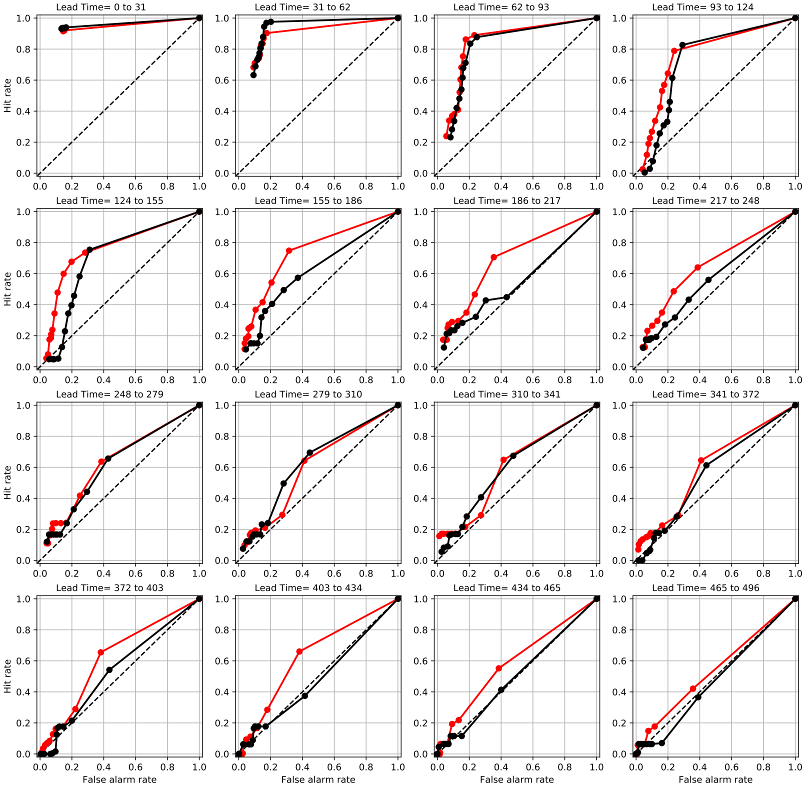


b)



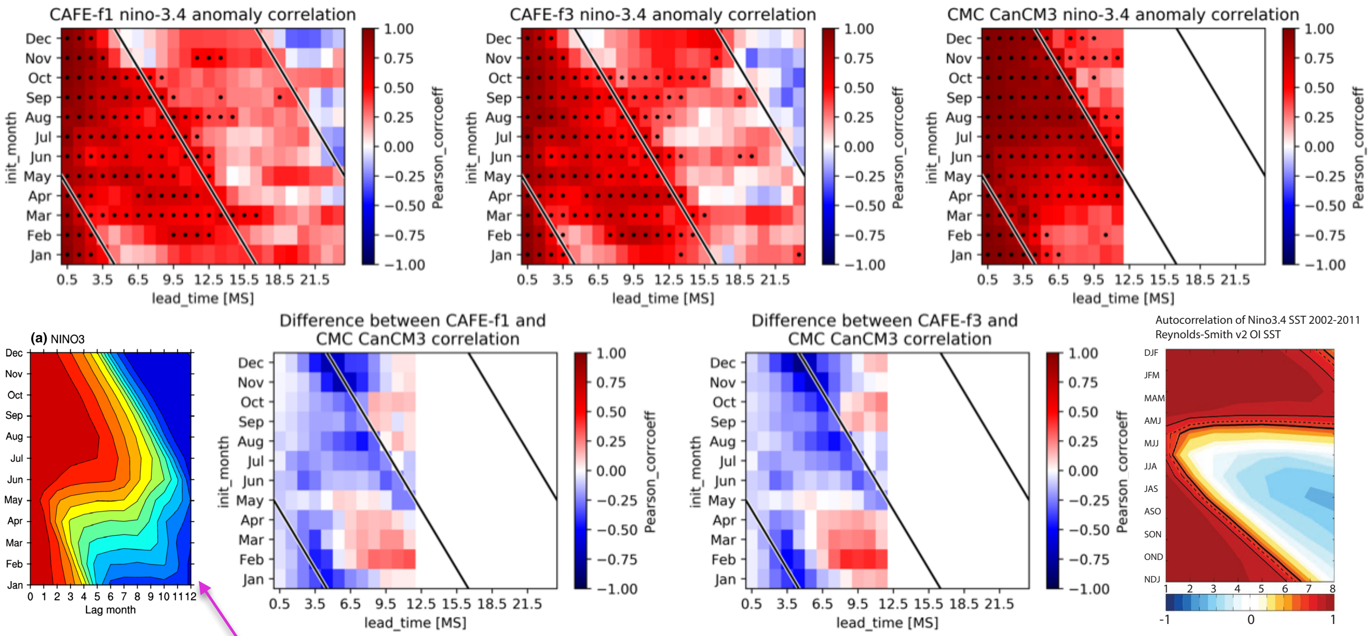
ENSO Prediction: ROC curves for NINO4

ROC curves of the F0 20°S-20°N (black) and F1 isosurface (red) hindcasts (3960 model years) for NINO4 calculated over a 15 year period (2 year lead-times, 11 members each starting every month over the period 2003 to July 2017)



ENSO skill comparison

Nino 3.4 anomaly correlation coefficients for CAFE BV and CanCM3 forecasts



Lagged auto-correlation coefficients of monthly Nino SST based on100 years of control simulation

Projection onto only those disturbances relevant to the Eq. Pacific thermocline enhances long range ENSO prediction

Conclusion

- A properly observed ocean is required to constrain the slow climate ”manifold”
- For multi-year forecasting we do not try to track the fast convective or synoptic scales of the atmosphere but rather excite the slow predictable modes coupled to the ocean.
- Optimal perturbations for state estimation are not necessarily optimal for forecasting a given climate mode at a given lead time and should be augmented or replaced by perturbations specific to the phenomena of interest.
- Here we show that it is possible on seasonal timescales to modulate the mid-troposphere jets via targeted perturbations to the tropical thermocline however, how longer timescale memory residing in the subtropical oceans affects the atmosphere and predictability is still unclear.
- The CAFE system is being developed as a tool to target and understand the mechanisms by which coherent variability determines predictability in the climate system in the near term.

References

- O’Kane, T.J., P.A. Sandery, D.P. Monselesan, P. Sakov, M.A. Chamberlain, R. Matear, & M. Collier (2018) ”Coupled data assimilation and ensemble initialization in CAFE with application to near term ENSO prediction.” (In review)

Thank You

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