WP2.5 – Coupled error covariances and bias correction

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UREAD: Deliverables

- D2.8 Report on strengths and weaknesses of weakly coupled DA methods for Earth system reanalysis. UREAD18
- D2.9 Report on techniques for calculating coupled error covariances from outputs of a weakly coupled DA experiment. METO+UREAD 18

- D2.10 Report on assessment of coupled-model drift and approaches for obtaining consistent ocean and atmospheric bias corrections.

UREAD 34 +12 =46

Outline

1. Calculation of cross error covariances at varying timescales from CERA-20C (D2.9)
2. Strengths of CERA-20C over ERA-20C: SST-*P* relationship (D2.8)
3. Temporal variability of ocean bias in CERA-20C (D2.10)

1. Calculating cross error covariances based on CERA-20C

- Method: CERA-20C => 10 member ensemble product

Ensemble mean <> = Best estimate

Ensemble spread = Uncertainty estimate (errors)

Ensembles available for both 24 hour background fields $\boldsymbol{x^b}$ and the analyses $\boldsymbol{x^a}$

$$\boldsymbol{B} \approx \left\langle \left(\boldsymbol{x}^b - \langle \boldsymbol{x}^b \rangle\right)\left(\boldsymbol{x}^b - \langle \boldsymbol{x}^b \rangle\right)^T \right\rangle,$$

Background error covariance provides background error information for assimilation of subsequent observations leading to analysis

- Data

SST, T2m, Mixed layer depths, u10, v10 and precipitation have been studied

3-hour fields used for January 2006

monthly fields used for 1900-2010

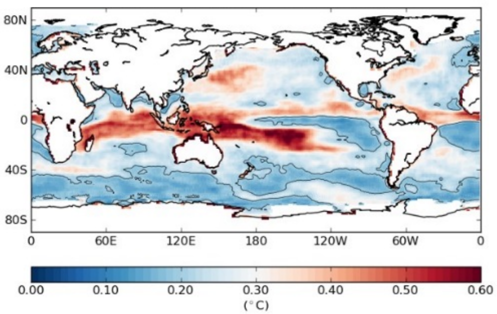
Most analyses based on analysis ensembles $\boldsymbol{x^a}$

- Paper Submitted to QJRMS

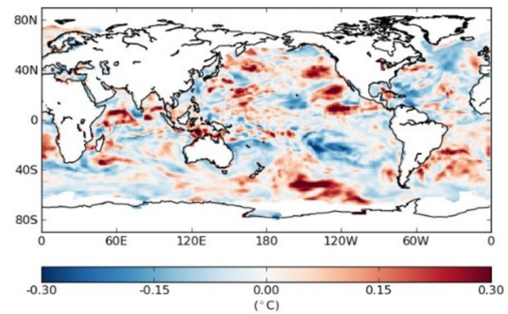
High-frequency variations

3-hour fields for 1st-31st January 2006

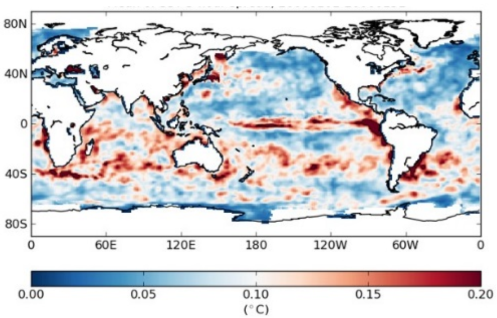
T2m spread



1 Jan anom.



SST spread



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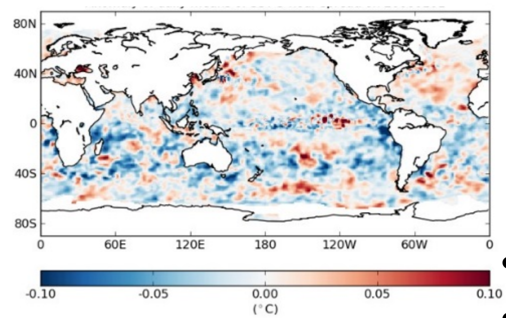
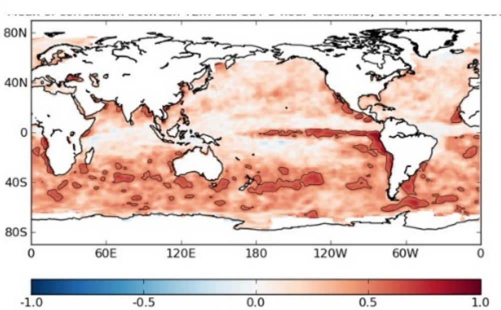


SST-T2m correlation



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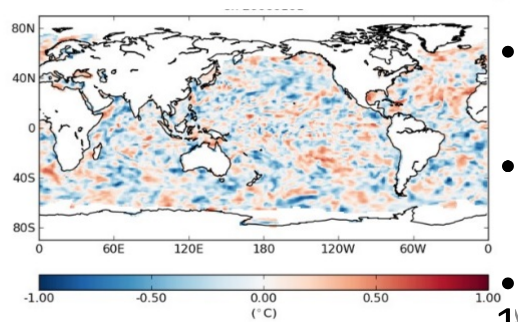
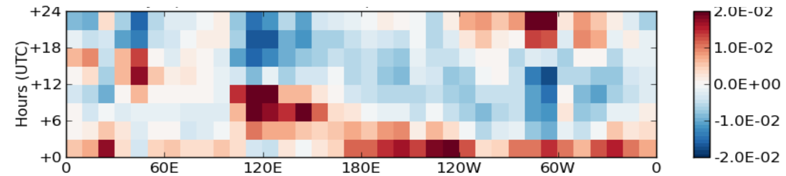
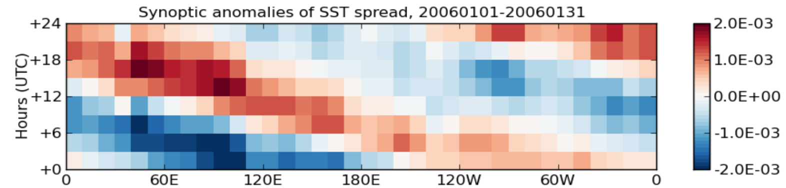
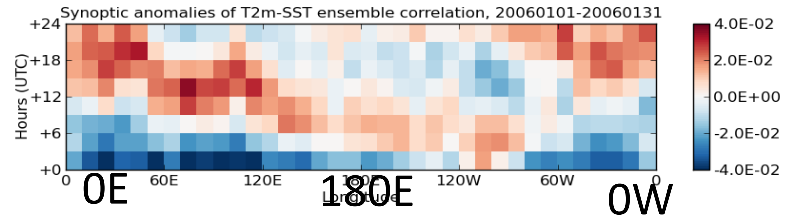


Diurnal cycles of spreads

T2m, SST, SST-T2m Correl.





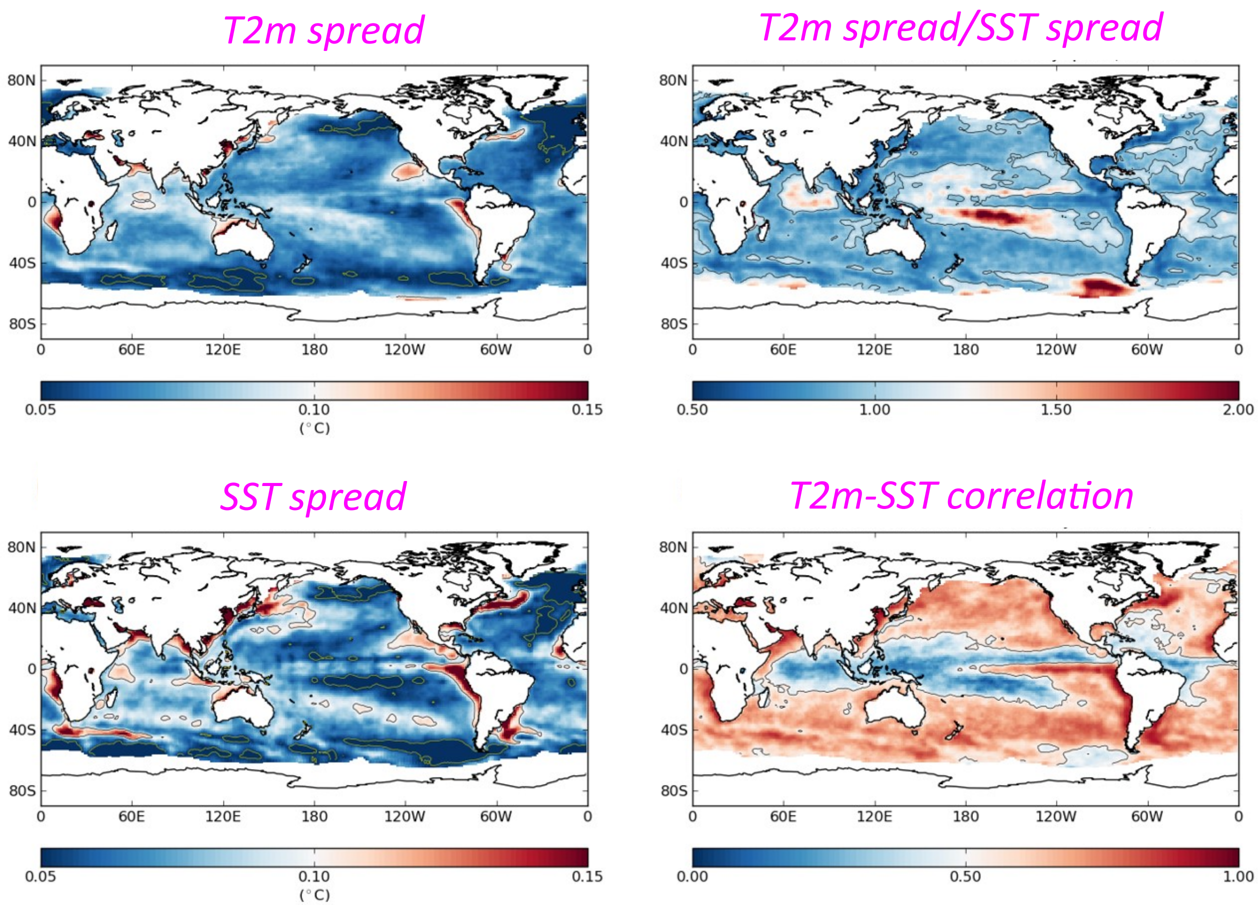


- T2m spread > SST Spread
- T2m spread large in ITCZ and in areas with western boundary currents
- SST spread is large in summer and in upwelling regions
- T2m-SST error correlations are stronger in summer (SH) and upwelling regions.
- Small-scale daily anomalies and diurnal cycles are also seen

1 Assembly

Time mean of monthly timescale variations

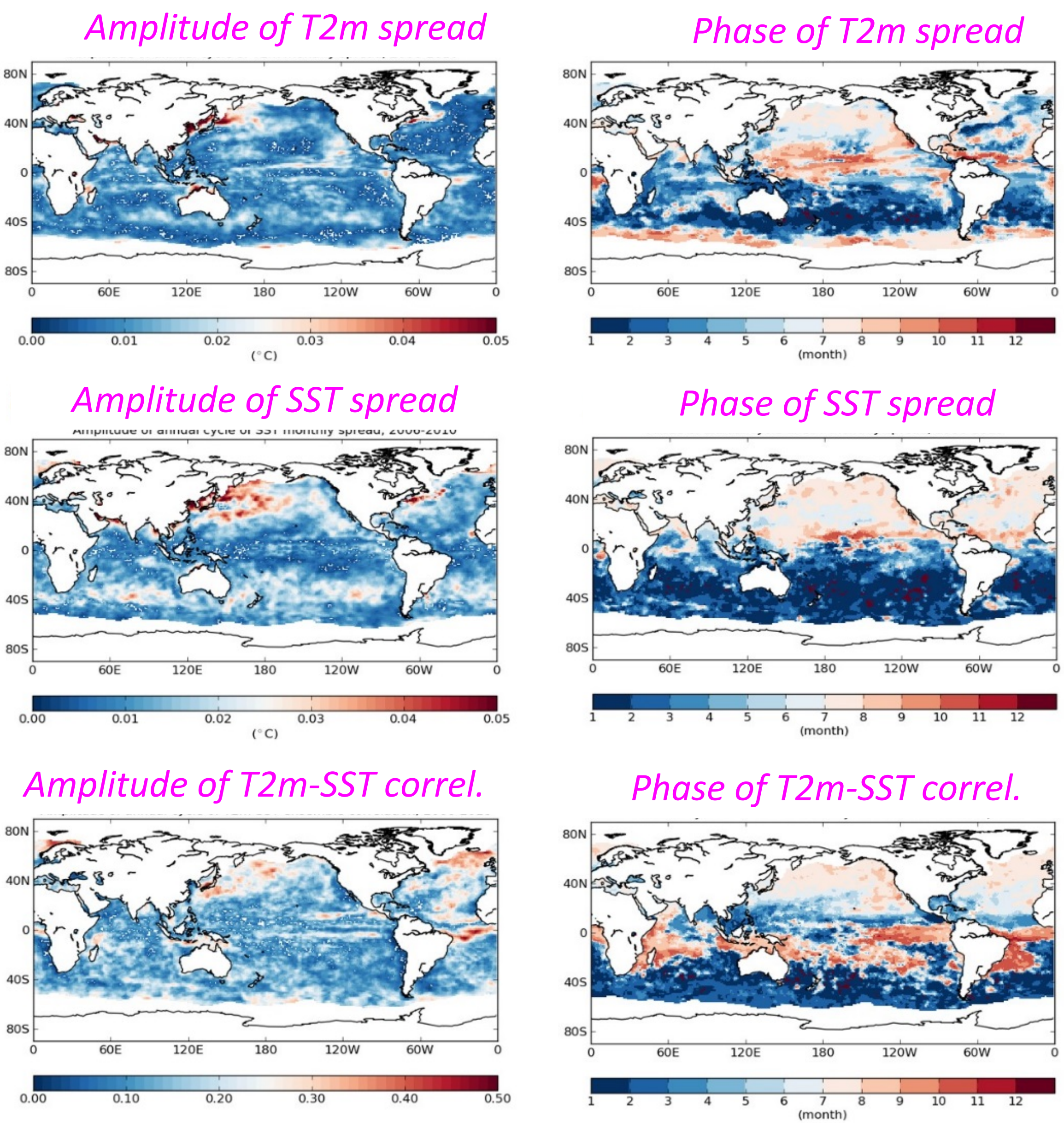
Data: Monthly average of each ensemble member, 2006-2010



- T2m and SST have similar large-scale variations
- T2m < SST spread, except in ITCZ
- Correlations mostly smaller where T2m spread larger
- Note: TAO mooring is positioned

Seasonal cycles

Data: Monthly average of each ensemble member, 2006-2010

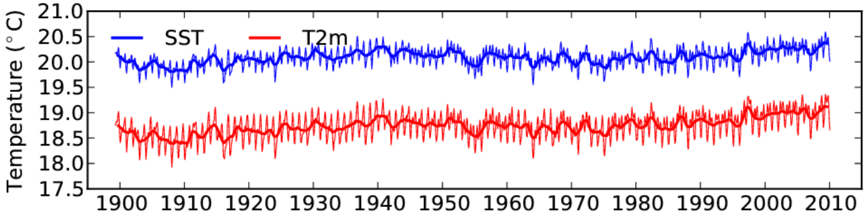


- Both T2m and SST spreads exhibit a clear large-scale seasonal cycle, 0.02°C (10-20% of the time mean), with larger values in summer hemisphere.
- SST spread has ±1-2month time lag.
- Annual amplitude of T2m-SST ensemble correlation is >0.1 (15% of the time mean).
- MLD and atmospheric convection are distinguished to be the causes for such seasonal variability.

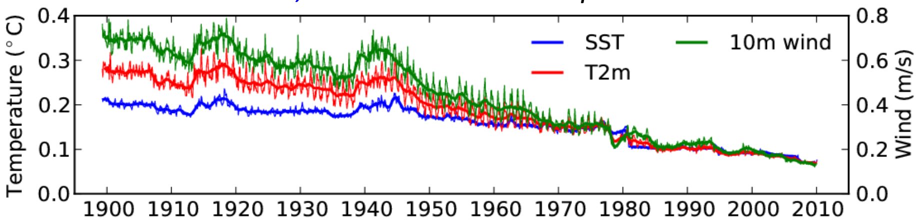
Long-term changes

Data: Monthly averages of each ensemble member, 1900-2010

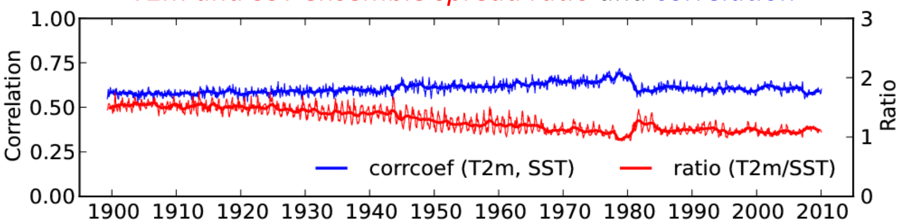
SST and T2m mean

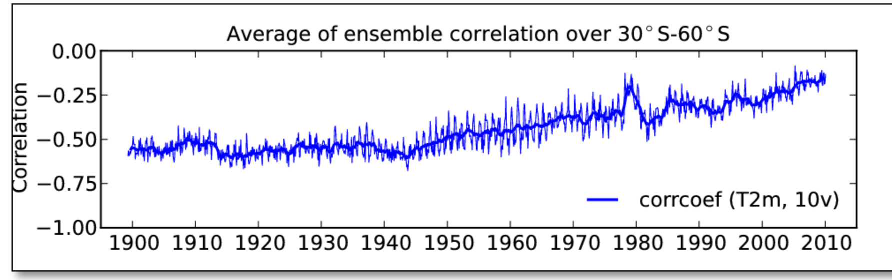


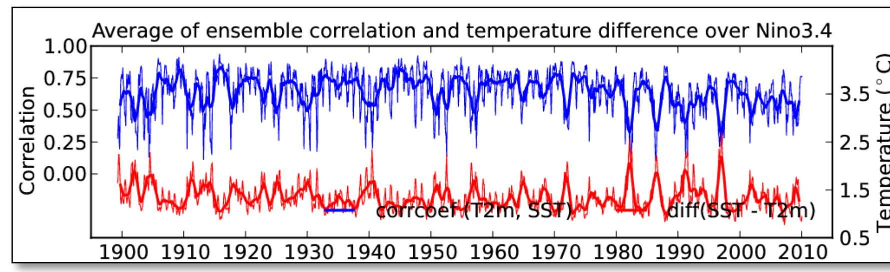
SST, T2m and 10m wind spreads



T2m and SST ensemble spread ratio and correlation







- Spreads decrease as observations increase
- Changes around WWs, 1980 and 2008 corresponding to abrupt data changes
- T2m spread regulated by wind uncertainties in early years
- Correlations steadily increase then level off after 1980
- Inter-annual variability strong in Nino3.4 due to the deep convection movement

2. Strengths of weakly coupled DA for CERA-20C

SST-precipitation relationship

- Aim

To evaluate the improvements of CERA-20C in representing atmosphere-ocean feedbacks

- Method

Linear correlation between SST and *Precipitation* monthly variability

- Data

CERA-20C member 0

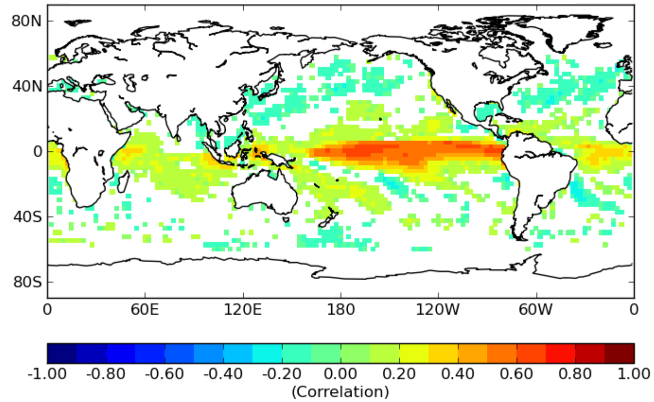
ERA-20C

Observations: HadISST2 ensemble mean, GPCP observations

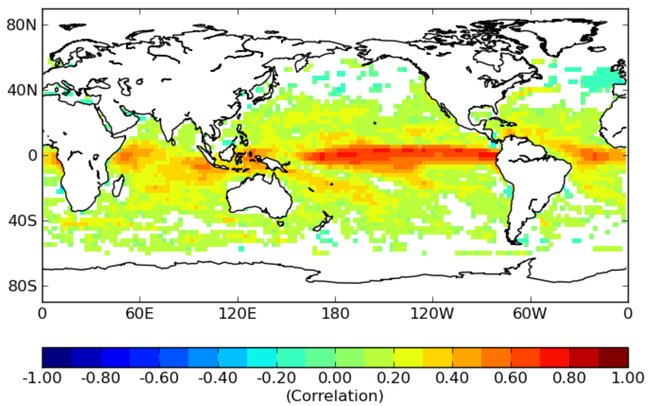
Monthly fields with seasonal cycle removed for 1979-2010

SST-*P* monthly variability correlations

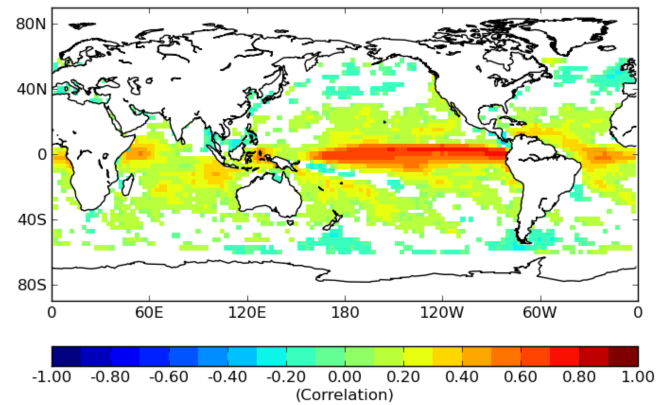
Observations



ERA-20C

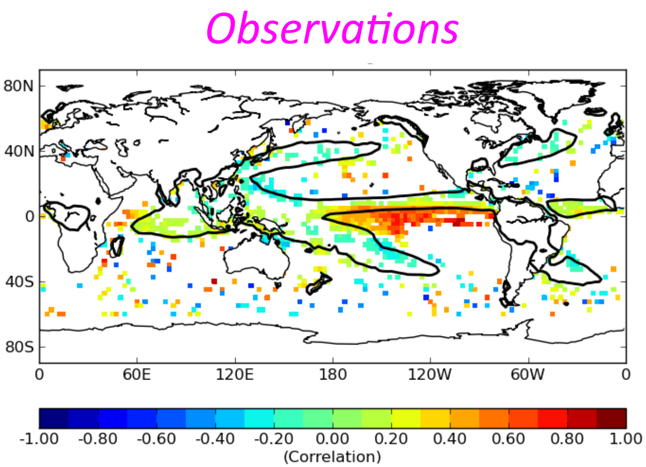


CERA-20C

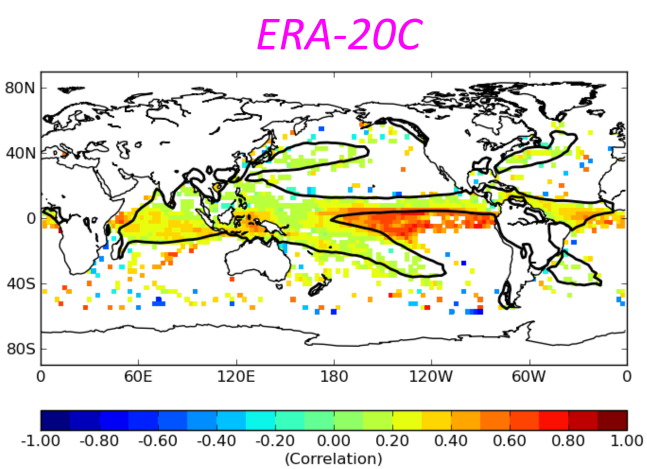


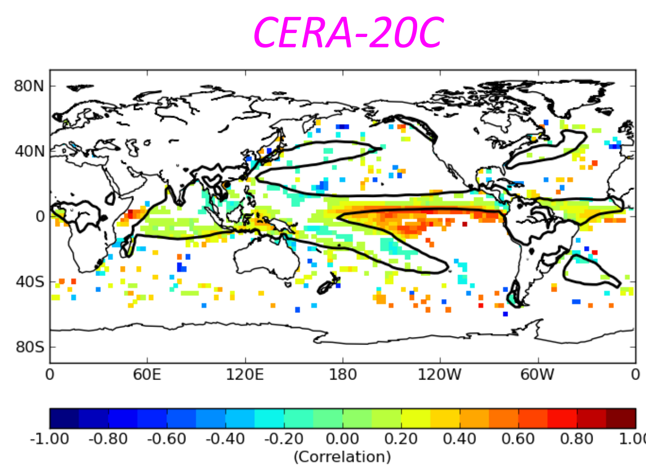
- ERA-20C has wider spread of positive correlations
- CERA-20C more consistent with observations

SST-*P* correlations: High Precip. *P* > 12cm/month



Black contour is high P regions
Climatological P>12cm/month

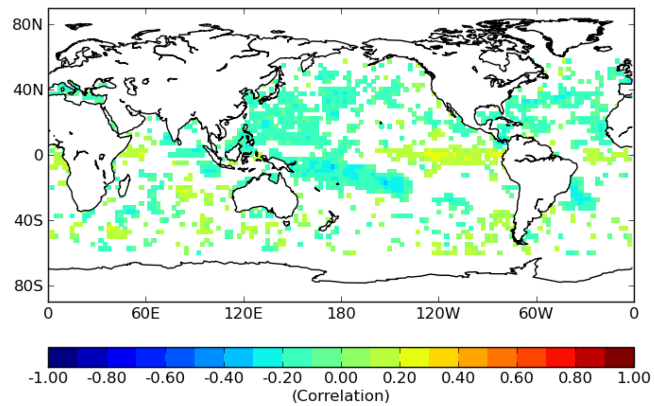




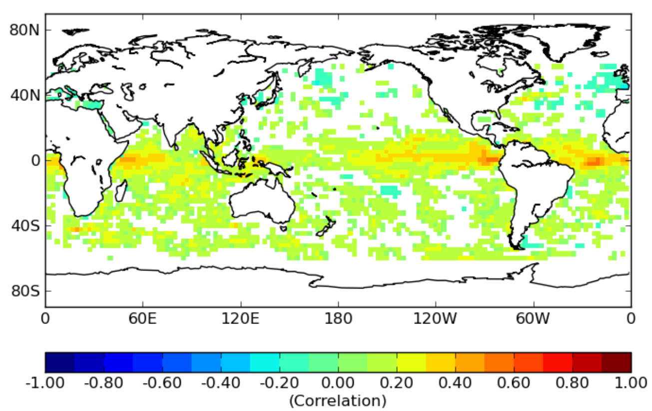
- CERA-20C especially improves the relationship for high *P* regions, where air-sea coupling is strong

SST-*P* correlations: Sub-seasonal variability (3-month running mean removed)

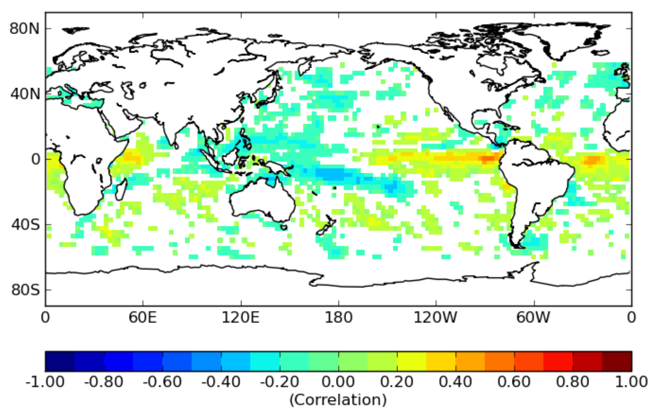
Observations



ERA-20C



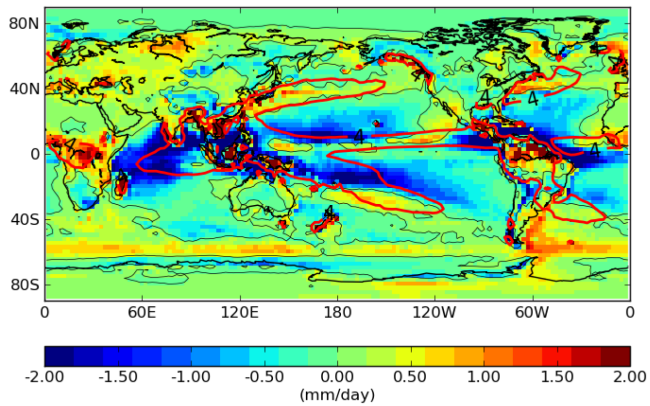
CERA-20C



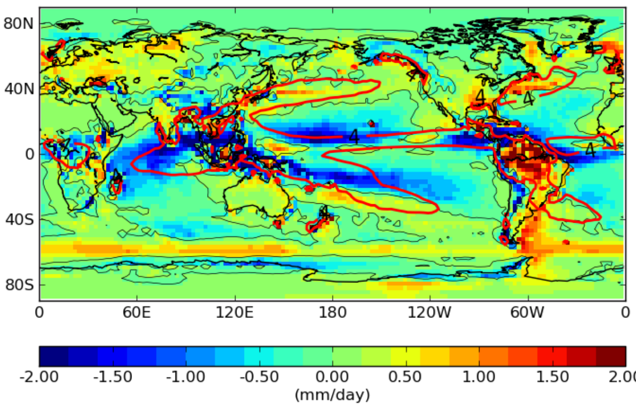
- CERA-20C also greatly improves the relationship for the high-frequency (sub-seasonal) variability.
- Obs. and CERA-20C: negative correlation => Precip. is cooling SSTs.

Monthly precipitation differences for time mean

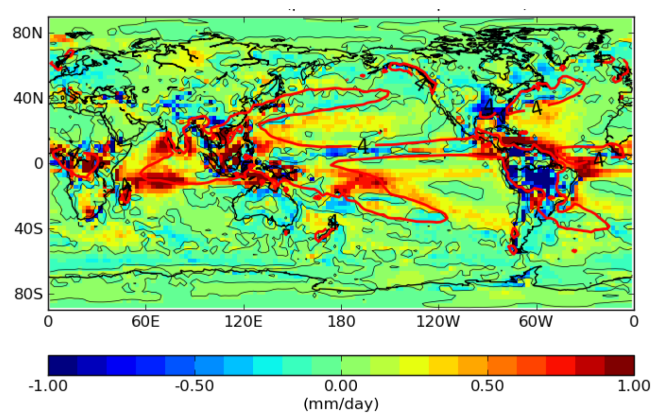
GPCP - ERA-20C



GPCP - CERA-20C



Error reduction in CERA-20C compared to ERA-20C
(positive for improvement)

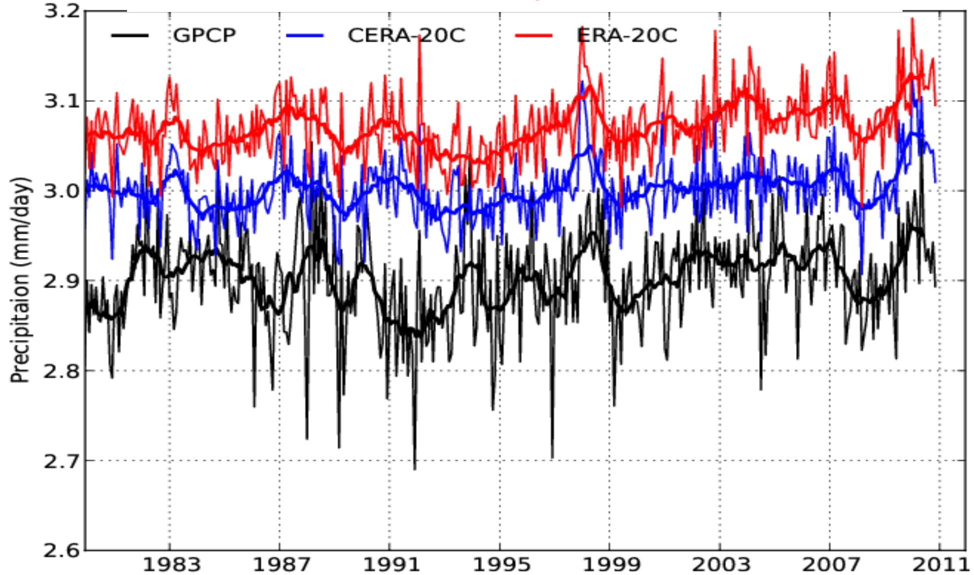


Red contour is high P regions
Climatological P>12cm/month

- CERA-20C provides a better estimate of *P* rate over oceans than ERA-20C, presumably as a result of the better simulated SST-*P* relationship.

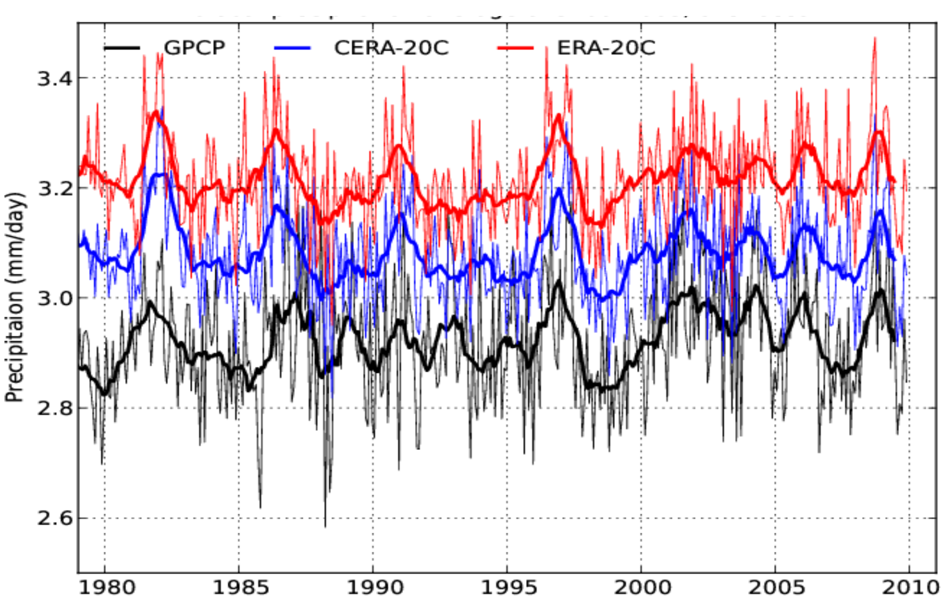
Monthly variations

Global P. average, 60°N-60°S

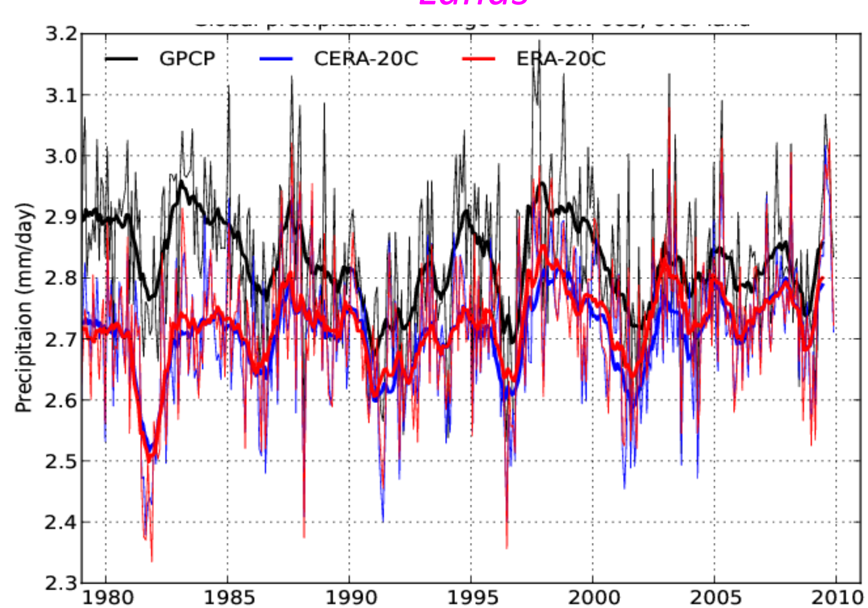


ERA-20C
CERA-20C
GPCP

Oceans



Lands



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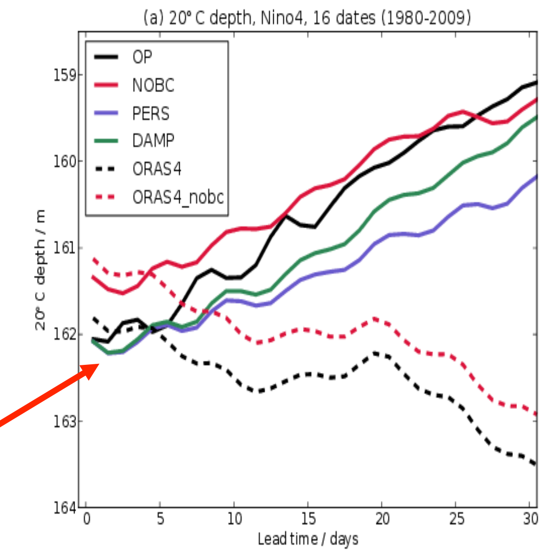
UREAD 34 +12 =46

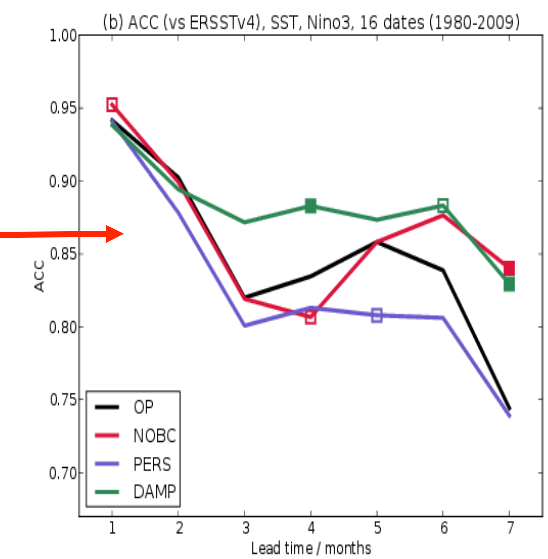
3.1 Bias in Seasonal Forecasting system 4

- Reported at last ERACLIM2 meeting
- Publ. Mulholland et al 2016

- Ocean Assimilation Bias corrections (T,S) maintained into coupled forecast runs
- Corrections Damped over 20 days
- Equatorial wave noise reduced
- Many hindcast initial conditions tested 1980's onwards
- Nino3.4 SST forecast skill increased in 4-7 months

- Available for testing at ECMWF (also MetO)



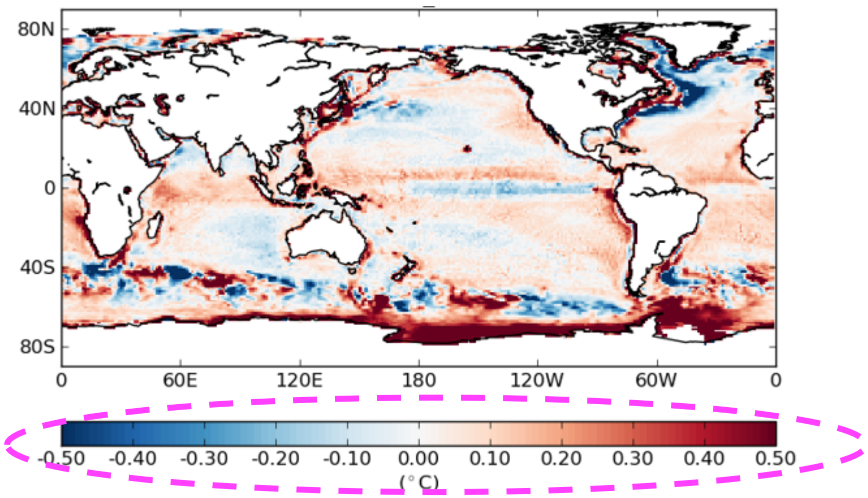


Mulholland, Haines and Balmaseda 2016 QJRMS

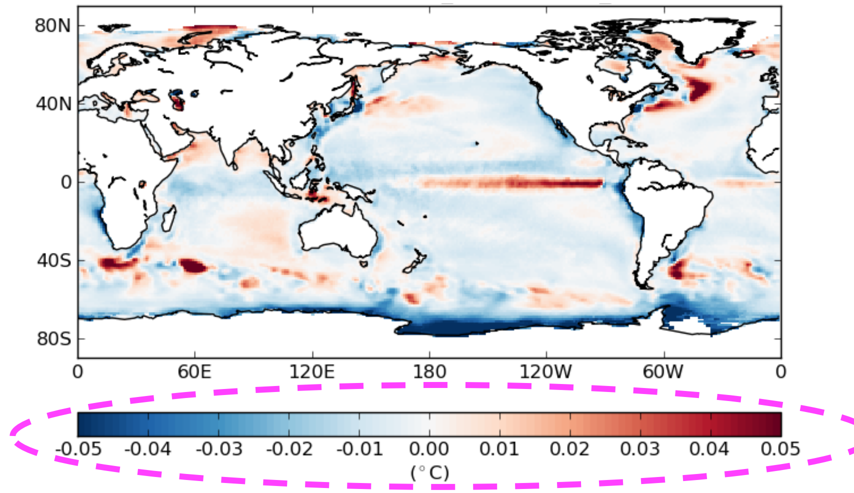
3.2 Ocean bias in CERA-20C

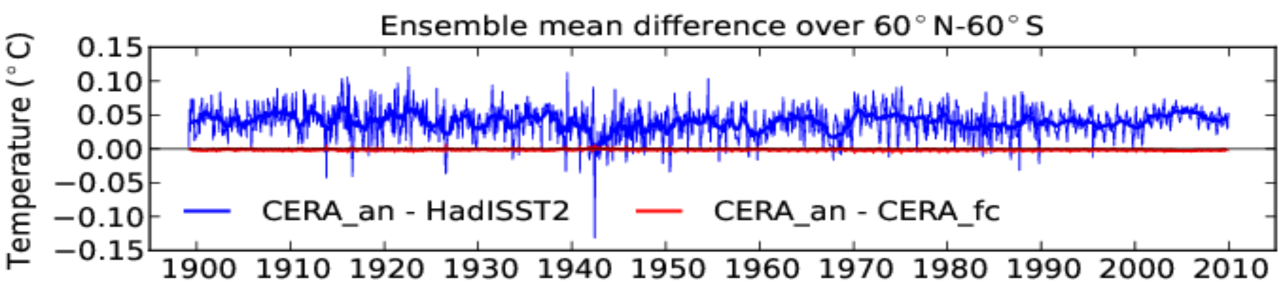
ΔSST = CERA_an - HadISST2, and CERA_an- CERA_fc, 1900-2010

ΔSST



SST increment



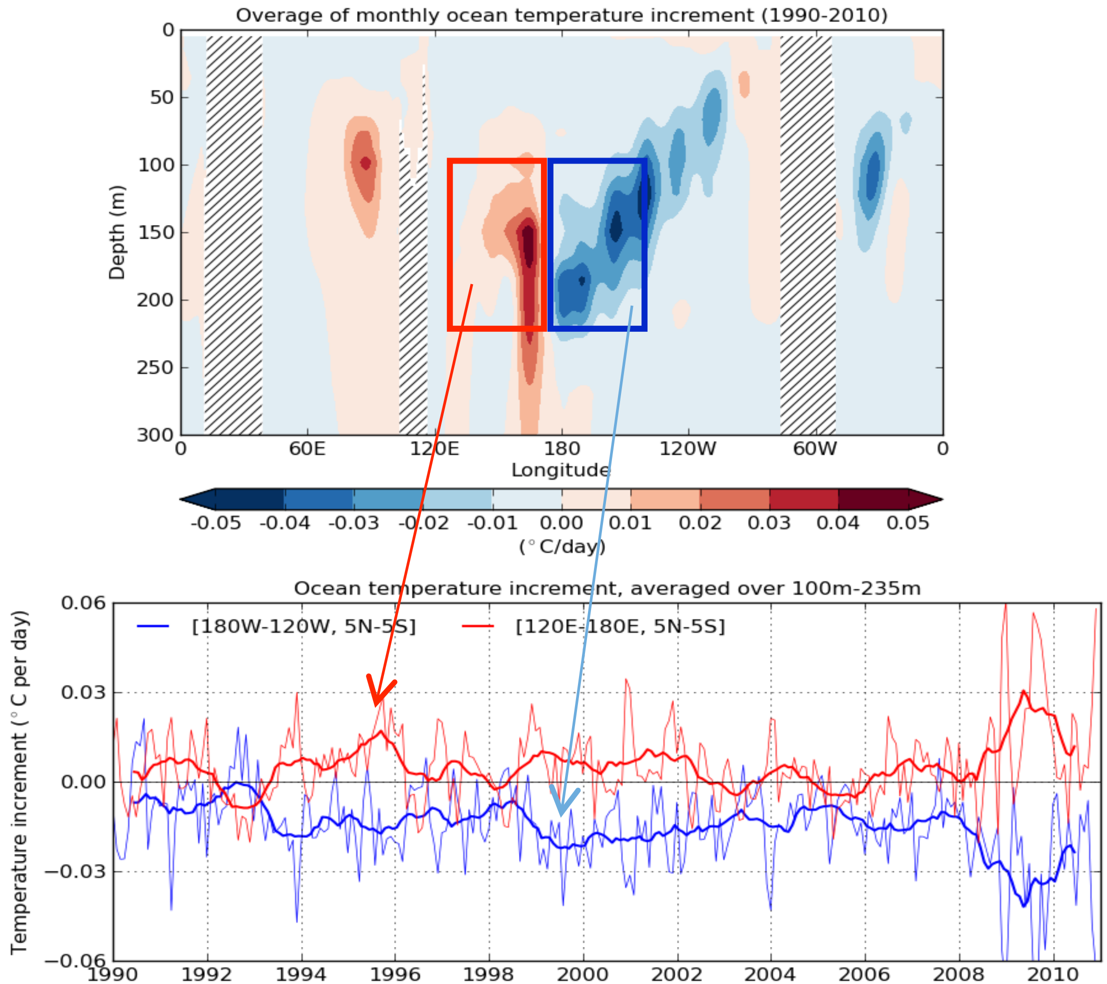


- SST in CERA-20C has regional biases w.r.t HadISST2 by ±0.5°C, and is ~0.05°C warmer on global average
- SST increment is usually negative, and is one order of magnitude smaller than ΔSST
- SST bias is considerably constant with time

Mean subsurface T increment along tropics (5°N-5°S), 1990-2010

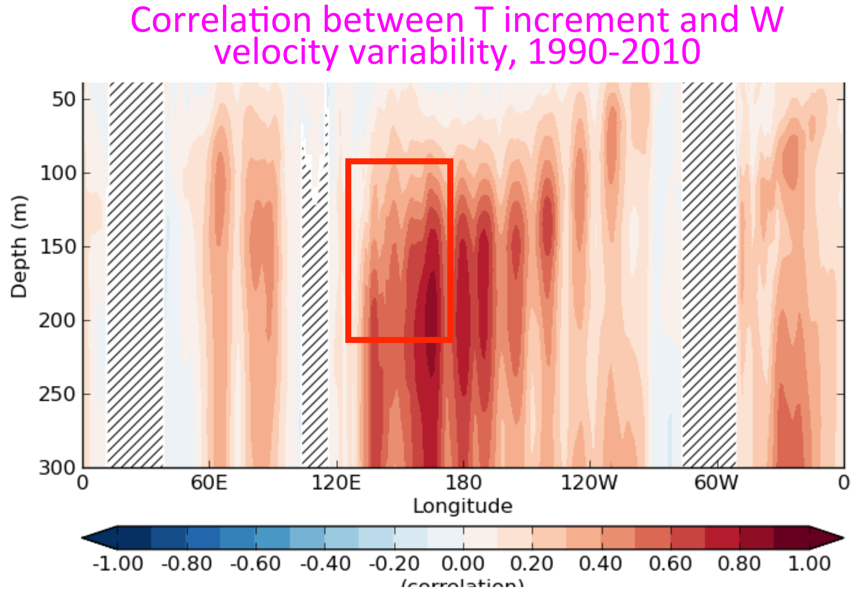
Time mean

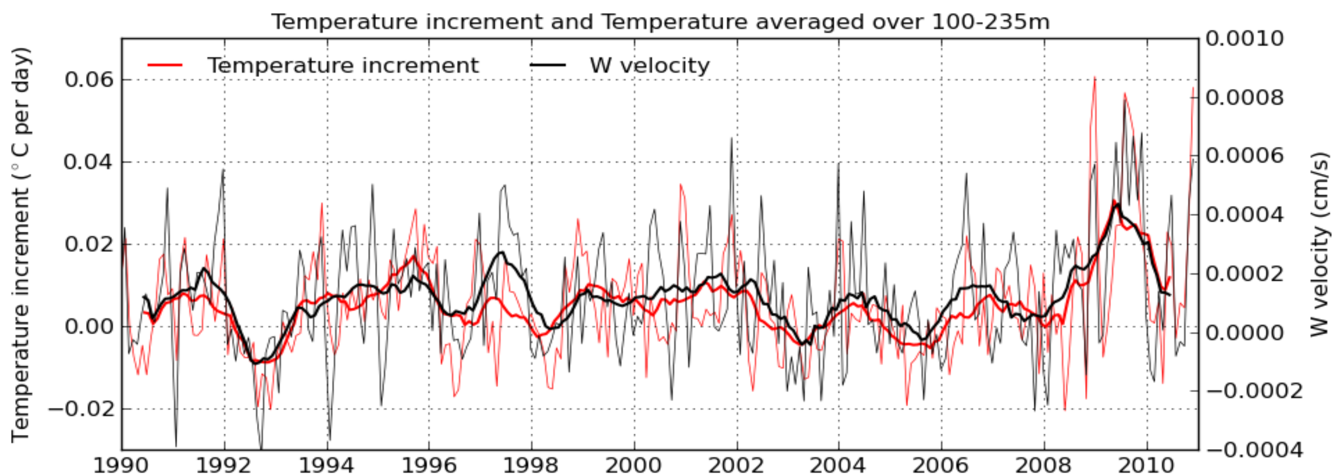
Temporal variability



- Model zonal heat redistribution in error near date line
- Errors clearly anti-correlated
- No bias corrections currently being applied which could reduce these mean increments cf. Mulholland

Association with vertical thermocline advection





- Monthly temporal variations are associated with local vertical velocity, by ~66.6 deg.C/day per cm/s.
- Note TAO mooring sites

Further bias correction work

- Ocean bias correction methods have (a) Climatological correction (needing long prior run) + (b) Online correction
- Test whether Online corrections can compensate for “approximate” climatological correction e.g. use ORAS4 pre-processed climatological corrections in CERA-20C?
- Investigate applying bias correction in CERA-20C (short runs to test impact)
- Investigate bias corrections in CERA-SAT? Short runs e.g. using CERA-20C or ORAP/S5 climatological corrections
- Investigate other approaches for correcting ocean bias in the tropical thermocline, e.g. parametrized with vertical velocity.

Thanks!