Department of Meteorology

University of Reading

Calculation of ensemble spread and coupled error covariances from Coupled ECMWF Reanalysis

Xiangbo Feng | Keith Haines | David Mulholland

Aim

We are targeting the possibility of developing 'strongly' coupled ocean-atmosphere data assimilation (DA), where coupled error covariances are calculated and used, based on ECMWF 'weakly' coupled DA system CERA. For achieving it, 1) Ensemble model errors on different time scales, and 2) cross error covariances are diagnosed.

About coupled ECMWF ReAnalysis (CERA)

The Coupled ECMWF ReAnalysis (CERA) system has been built under ESA CERA and EU ERA-CLIM2 projects based on an ocean-wave-atmosphere coupled system with DA applied individually for each component. 4D-VAR and 3D-VAR are used to produce atmosphere and ocean increments respectively, based on hourly coupled IFS and NEMO system. Assimilation windows are 24 hours.

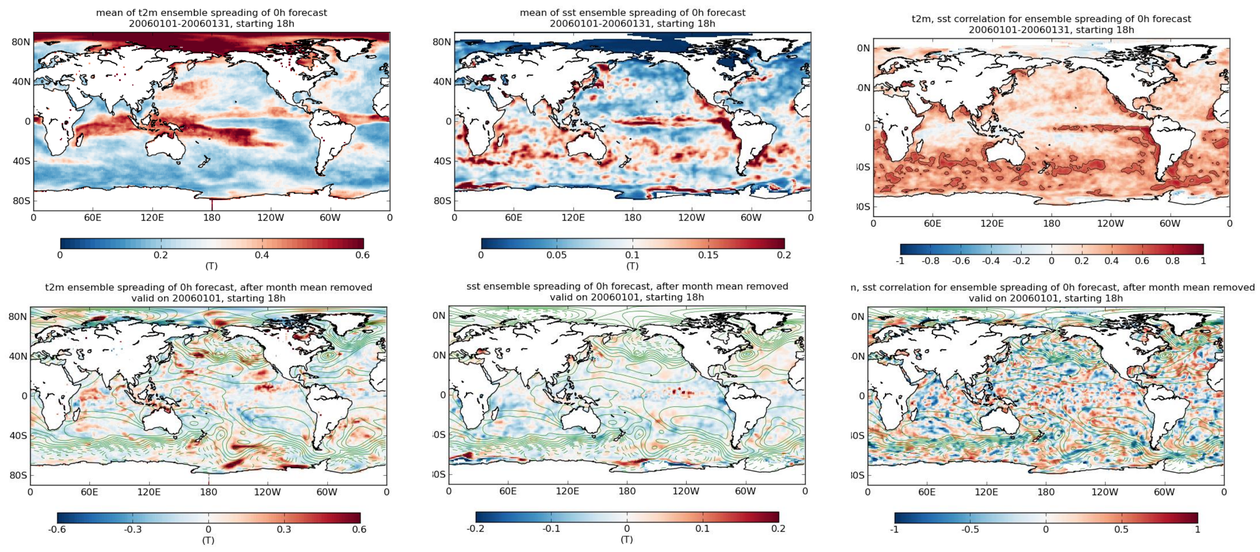
This system is classified as 'weakly' coupled DA as no cross error covariances are used in the assimilation procedure, although multiple iterations allow ocean and atmospheric increments to interact.

CERA has produced a major new ensemble product for 20th century climate, CERA-20C, which provides atmosphere and ocean states at 3 hours resolution 1900-2010. CERA-20C is a 10 member ensemble coupled ocean-atmosphere reanalysis, using HadISST2 daily data to constrain SST. CERA-20C is the first ensemble product in the context of coupled reanalysis.

In this work, the 10 member ensemble of daily and monthly forecast and analyses is used. Ensemble departures from the mean represent uncertainty. Results focus on SST and 2-m air temperature (T2m), and their relationship.

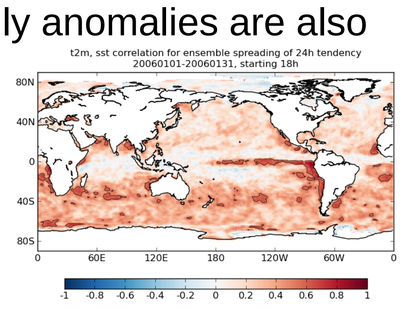
Ensemble spread and correlations

Daily variations (Jan 2006)



Upper panels are monthly means of the daily ensemble spread (for T2m and SST) and monthly means of T2m-SST daily ensemble correlations. Lower panels are the anomalies from these means on 1st Jan 2006.

- Large T2m spreads can be seen in tropical areas with deep convection (*top left*), but daily weather spread signatures appear in middle latitudes (*bottom left*).
- Large mean SST spread is associated with strong ocean dynamics but also with shallow mixed layers in the summer hemisphere (*top middle*), daily anomalies can also be seen (*bottom middle*).
- Mean T2m-SST correlations are higher in the summer hemisphere and in dry regions (*top right*). Small scale daily anomalies are also seen (*bottom right*).
- Interestingly, at 24hr forecast lead times, mean T2m-SST ensemble correlations are weaker than at analysis time (*right)*.



References

Laloyaux, P., et al., 2016. A coupled data assimilation system for climate reanalysis. Q.J.R. Meteorol. Soc., 142: 65–78. doi: 10.1002/qj.2629

Acknowledgements

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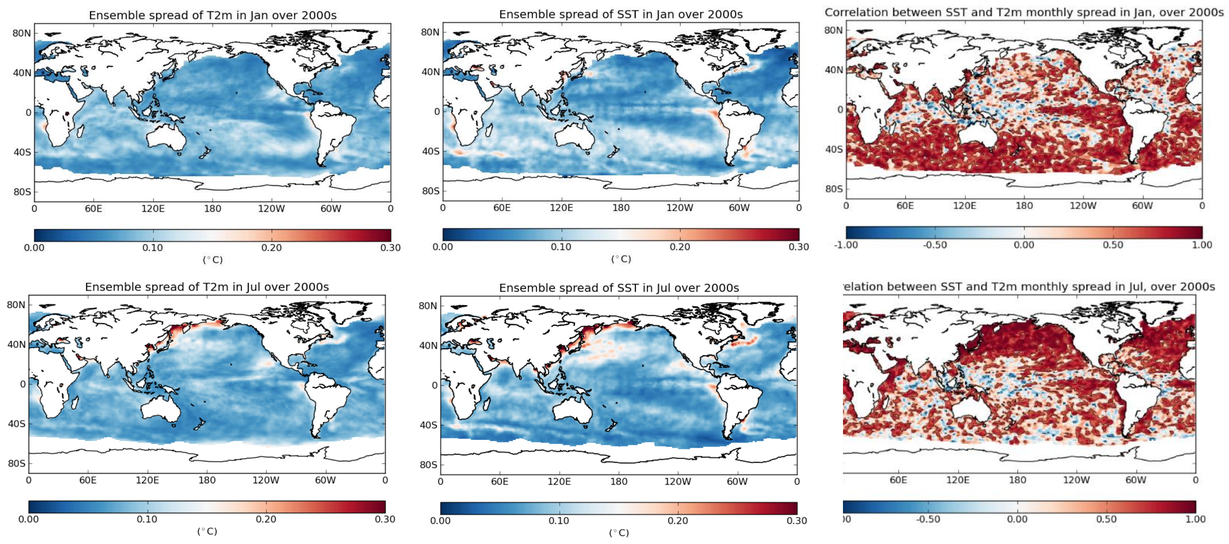
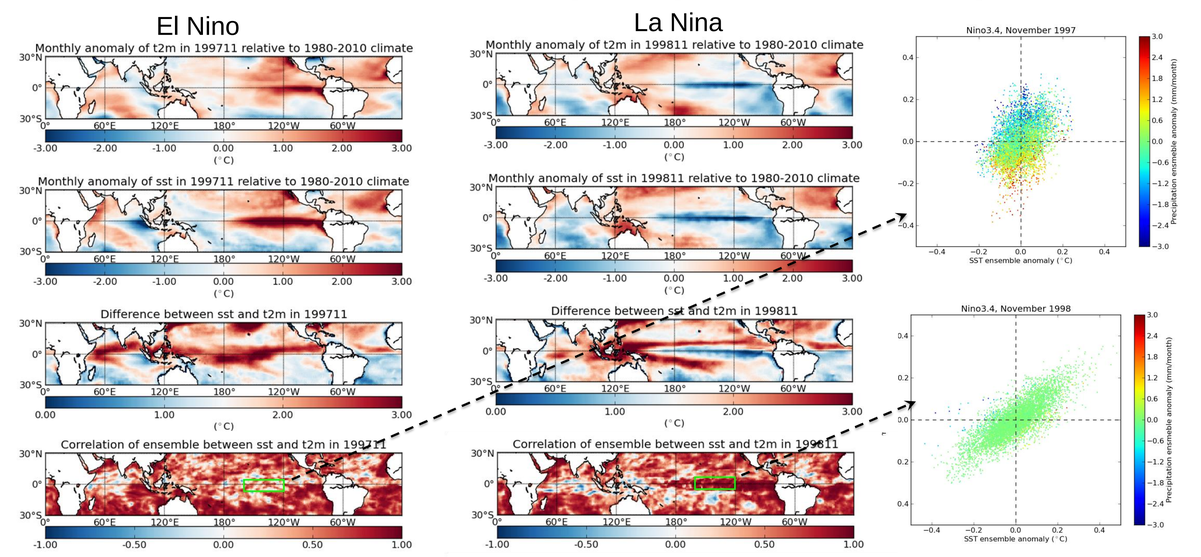
Seasonal variations (2001-2010)



- Both T2m (*left*) and SST (*middle*) based on the monthly means, show seasonal variations for their ensemble spread, with more (less) spread in local summer (winter).
- T2m-SST ensemble correlation is season-dependent, strong in summer, except in tropical E. Pacific (*right*).

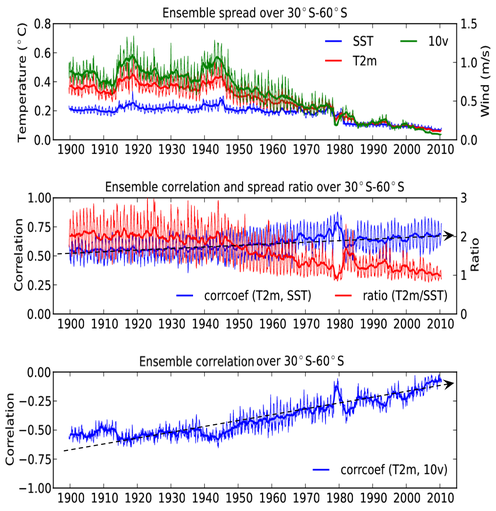
Inter-annual variations in tropics (1997 and 1998)



- In the tropics inter-annual variations are seen in correlations between T2m and SST anomalies (*left and middle*), without much changes in ensemble spread.
- Pacific warm pool exhibits large SST-T2m differences and low anomaly correlations, which both move out into the central Pacific during ENSO events.
- T2m-SST ensemble correlations in tropics are modulated by precipitation (*right*), which is an indication of convection. For example, in Nino3.4 region, when strong convection occurs during El Nino, with heavy precipitation, T2m is depressed (*top right*). Conversely when convection is weak during La Nina, T2m is strongly correlated with SST (*bottom right*).

Long-term changes (1900-2010)

- Ensemble spread is overall declining in T2m and SST (30S-60S average shown in *top)*, as more observations become available, e.g. after the world wars and later into the satellite era.
- T2m-SST ensemble correlation is increasing (*middle*), while anti-correlation between T2m and 10m winds is reducing with time (*bottom*). This is true especially in mid-latitudes with the many storms.



Short summary

- **Ensemble spread and T2m-SST ensemble covariances from CERA-20C are both time and region-dependent.**
- **Continuing investigations of ensemble characteristics within CERA-20C will give indications how to develop coupled error covariances.**

Contact information: xiangbo.feng@reading.ac.uk