Department of Meteorology

University of Reading

Investigating Model Drift in ECMWF System 4 Hindcasts

Jon Shonk (1) | Eric Guilyardi (1/2) | Steve Woolnough (1) | Thomas Toniazzo (3) | Teferi Demissie (3)

Affiliations: (1) NCAS-Climate, University of Reading. (2) LOCEAN/IPSL, Paris. (3) Uni Research Climate/Bjerknes Centre for Climate Research, Bergen.

Aim of the Project

Systematic biases in climate models have existed for many years (Mechoso *et al* 1995). Despite two decades of progress, many of these systematic biases remain (Vannière *et al* 2012).

When using the climate models for seasonal and decadal forecasting, these biases must be removed using bias correction methods. It would be preferable , however, to eliminate the biases entirely. To do this, we first need to examine the biases in detail and identify their root cause.

In this project, using a model drift analysis method proposed by Vannière *et al* (2012, 2014), we aim to build an understanding of the chain of causality that leads to the development of these biases. The work spans both the SPECS and PREFACE projects, in which we will be investigating systematic biases in the tropical Pacific and tropical Atlantic respectively.

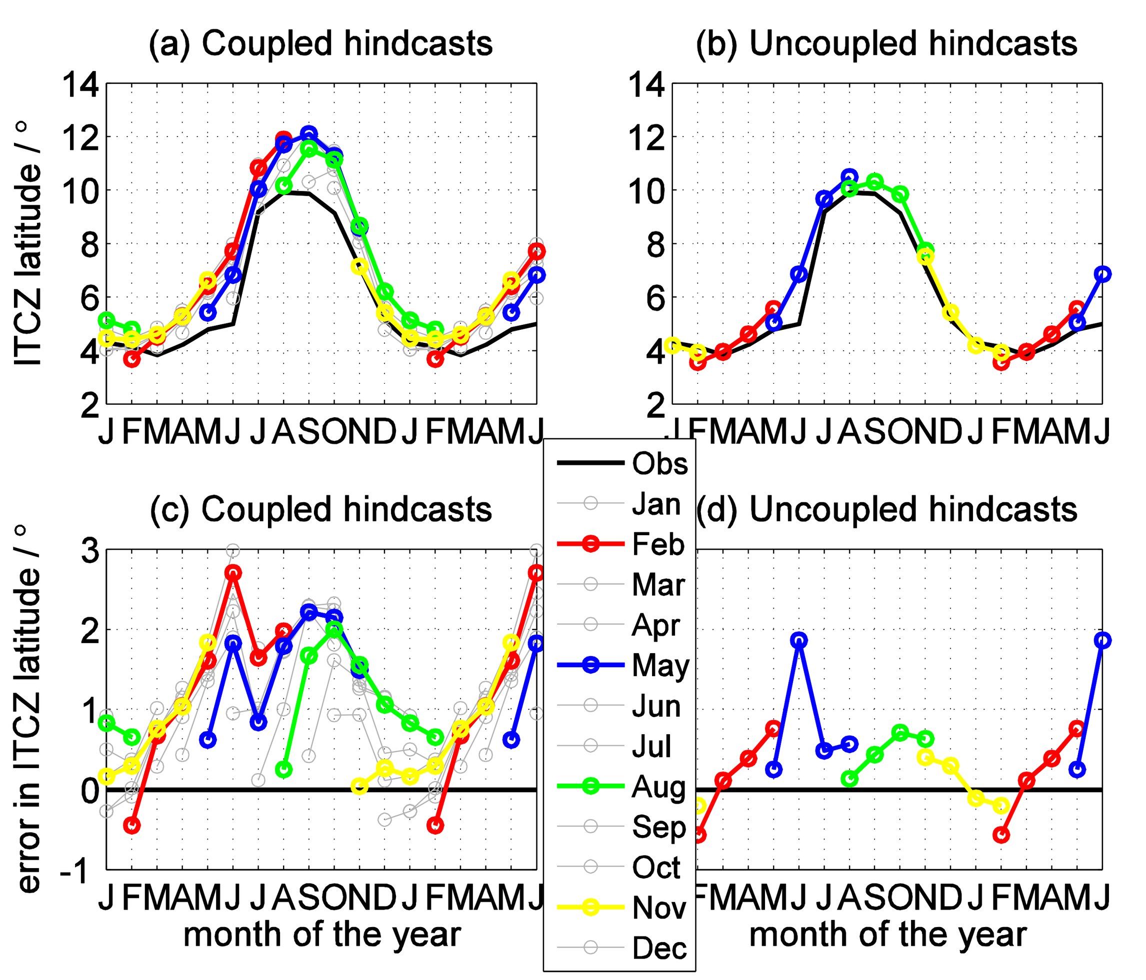

Figure 1. *"Worm plots" showing the location of the ITCZ in the P1/P2 boxes (see map in Figure 2), both for observed rainfall data from TRMM (black line) and ECMWF System 4 (grey and coloured lines). Each of the latter shows evolution of ITCZ location for each start month for which data is available. The top row shows the absolute location of the ITCZ; the bottom row shows biases with respect to the observed location.*

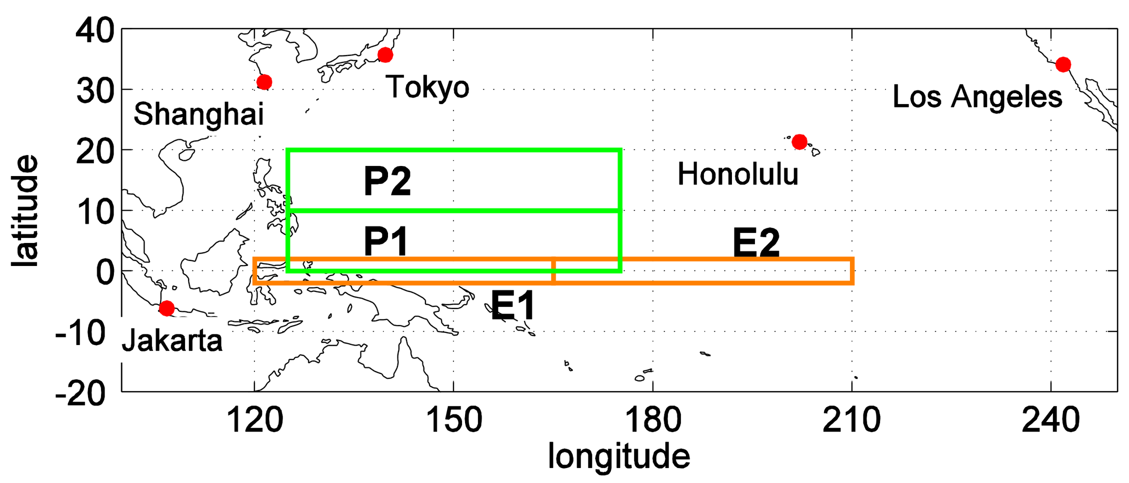

Figure 2. *Map of the regions referred to in this study.*

Model Data

For this study, we use both monthly and daily hindcast data from the ECMWF System 4 model from years 1996 to 2009.

- "Coupled" hindcasts use the full operational configuration, with atmosphere and ocean coupled together.
- "Uncoupled" hindcasts use the same model version, but with ocean properties prescribed.

We also use various "observation" datasets for bias calculation – OISSTv2, TRMM, CMAP, OAFlux and TropFlux.

Northward Drift of the ITCZ

In the ECMWF System 4 model, the intertropical convergence zone (ITCZ) drifts to the north from the observed location to its own preferred location during the first three months of forecast.

Figure 1 shows that this preferred location is between 1° and 3° to the north of where it should be.

The cause of this drift can be traced to cooling of the sea surface on the equator – see Figure 3. When coupled to the ocean, a four-month hindcast of February rainfall gives an ITCZ that is displaced to the north of its observed location.

A cooling of the ocean surface is also evident after four months. This suppresses convection on the equator and affects the local north—south temperature gradient which, in combination, push the rainfall to the north.

Even in the first month of hindcast, the equatorial cooling has begun. This suggests that, to investigate further, we need to look at the problem on a daily timescale.

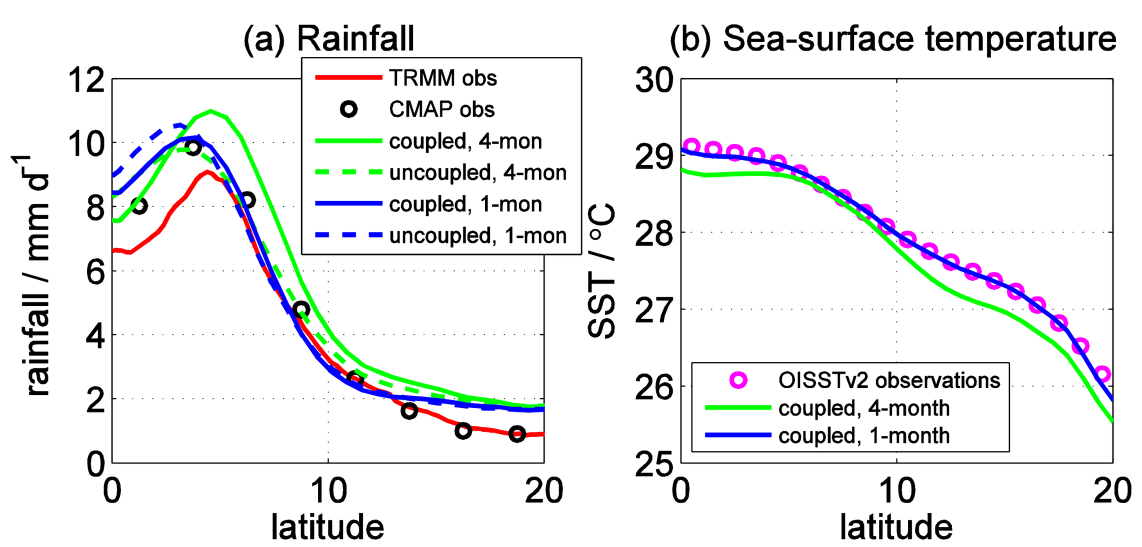

Figure 3. *Zonally averaged rainfall and sea-surface temperature over the longitude width of the P1/P2 boxes (see map in Figure 2), comparing observed values with model hindcasts for February, using coupled and uncoupled model output after one and four months.*

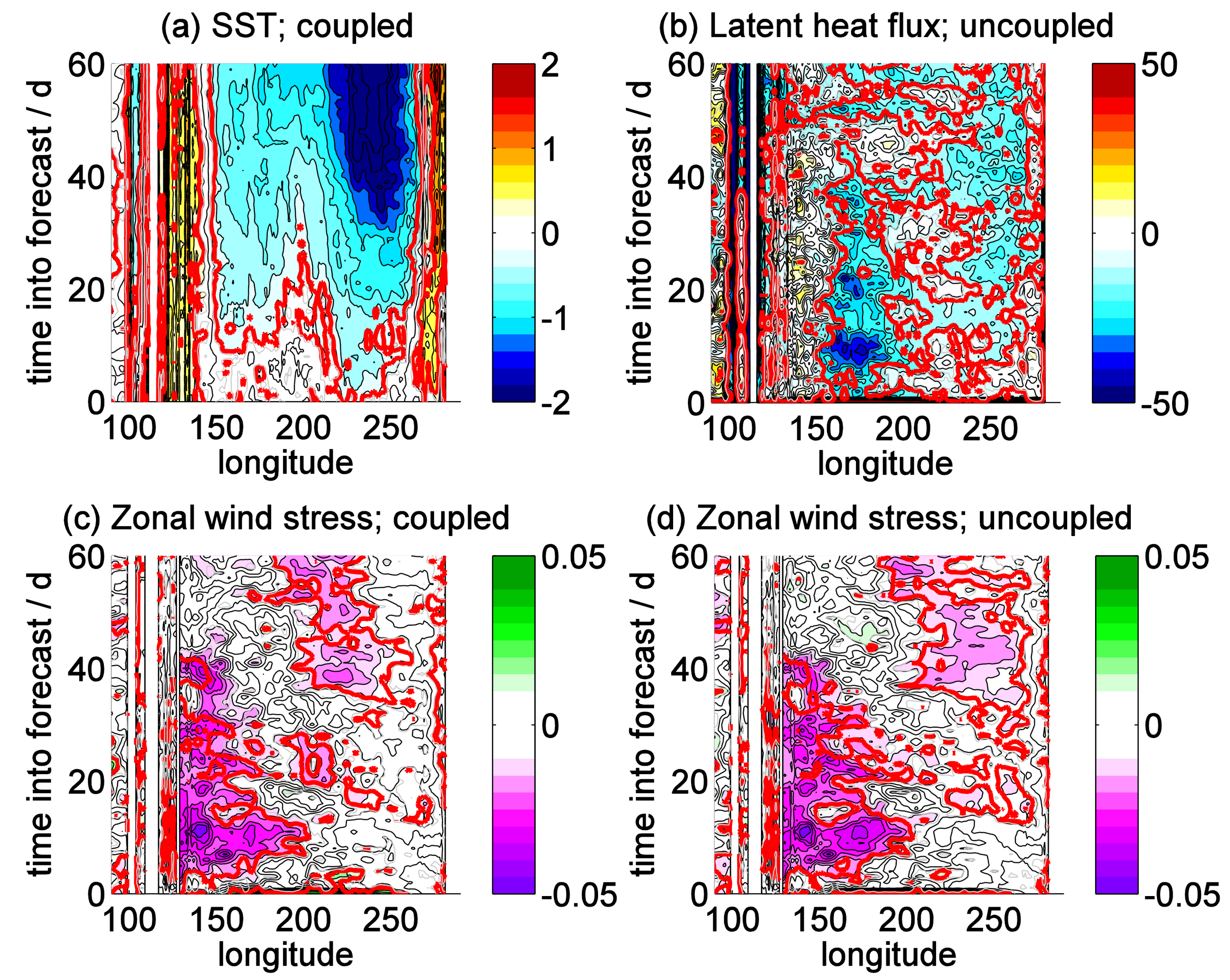

Figure 4. *Longitude—time plots, showing model bias growth in (a) sea-surface temperature in °C; (b) latent heat flux in W m⁻²; (c, d) zonal wind stress in N m⁻², averaged over the latitude width of the E1/E2 boxes. For observations, we use OISSTv2 for sea-surface temperature, OAFlux for latent heat and TropFlux for wind stress. Hindcasts starting on 01 February are shown, with statistics over years 1996 to 2009. Significance is indicated by the red contour.*

The Chain of Causality

By examining the model drift on a daily scale, we are able to build up a chain of causality that points towards what model process or variable is ultimately responsible for this cooling of the sea surface in the equatorial western Pacific.

- A pulse of excess easterly wind stress in the area, peaking in intensity after about ten days, is responsible for the cooling (compare Figures 4a and 4c).
- This pulse develops almost identically in the coupled and uncoupled hindcasts, implying that the error is in the atmosphere model rather than the ocean model (compare Figures 4c and 4d).
- The wind cools the surface, at least initially, by evaporative cooling – note the increase in latent cooling after ten days (Figure 4b). This can be confirmed by comparing the model cooling with a predicted cooling using latent heat error and the model mixed-layer depth.
- This wind error begins from the first day of simulation, originating as an easterly error at the surface over the central Pacific, then developing into a pattern similar to a stronger Walker circulation (Figure 5).

Next Steps of the Project

We have identified the root cause of the northward drift of the ITCZ in the ECMWF System 4 – it is caused by an easterly error in the atmospheric wind fields.

Next, we can test that this is the case by performing model simulations that correct for this wind error and see if this ITCZ drift still occurs.

We can also attempt to trace the chain of causality back further to determine why the wind error develops as it does.

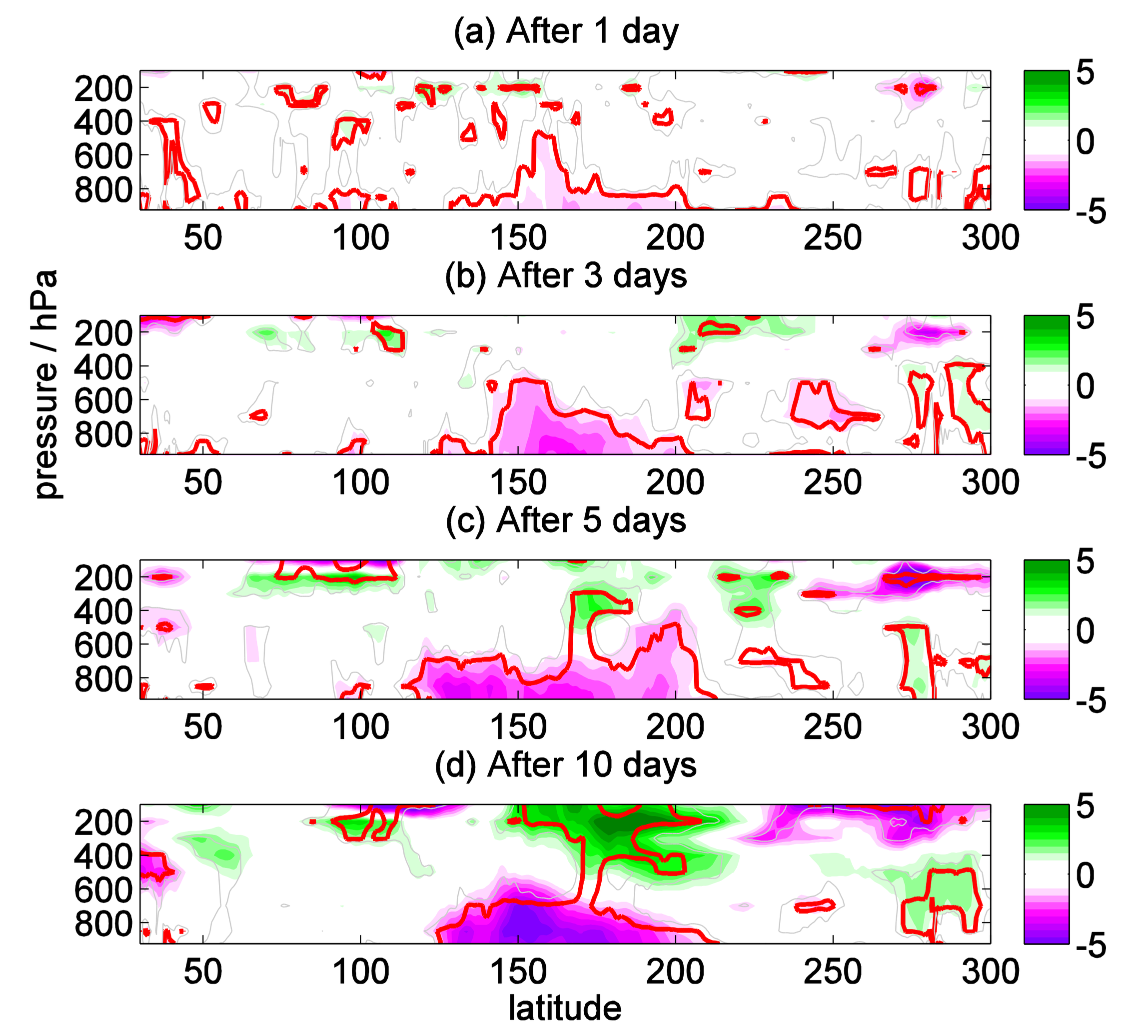

Figure 5. *Longitude—height plots, showing developing biases in zonal wind in m s⁻¹, averaged over the latitude band –5° to 5°.The observations use data from ERA-Interim. Hindcasts starting on 01 February are shown, with statistics over years 1996 to 2009. Significance is indicated by the red contour.*

References

- C R Mechoso, A W Robertson and co-authors, 1995: 'The Seasonal Cycle over the Tropical Pacific in Coupled Ocean—Atmosphere General Circulation Models', *Monthly Weather Review*, #123, 2,825—2,838.
- B Vannière, E Guilyardi, G Madec, F J Doblas-Reyes and S Woolnough, 2012: 'Using seasonal hindcasts to understand the origin of the equatorial cold tongue bias in CGCMs and its impact on ENSO', *Climate Dynamics*.
- B Vannière, E Guilyardi, T Toniazzo, G Madec and S Woolnough, 2014: 'A Systematic Approach to Identify the Sources of Tropical SST Errors in Coupled Models Using the Adjustment of Initialised Experiments', *Climate Dynamics*.

Contact Information

- Jon Shonk, Department of Meteorology, University of Reading, Earley Gate, PO Box 243, Reading RG6 6BB, Berkshire, UK. Email: j.k.p.shonk@reading.ac.uk