Analysis of the Asian monsoon response to ENSO in the Met Office GloSea4 seasonal hindcasts

A G Turner, G Martin* & R Levine* (*UK Met Office)

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL
Met Office
Walker INSTITUTE
University of Reading

Introduction

GloSea4 is version 4 of the Met Office Global Seasonal Prediction system, based on the HadGEM3 model and designed to integrate closely with other Met Office models designed for NWP to climate timescales.

The atmospheric model is the Met Office Unified Model (MetUM) at N96 resolution (1.875°x1.25°, L85) while the NEMO ORCA1 ocean model (1°, refined to ⅓ within 20°N-20°S, L75) is used, in addition to the MOSES land surface scheme. No artificial heat flux corrections or relaxations to climatology are employed. Aerosol and greenhouse gas concentrations are set to observed values before 2000 and follow the SRESA1B scenario afterwards. The forecast is initialised on 4 occasions each month, 3 of which are used for this study (25 April, 1 May, 9 May), each lasting for 5 months. In addition to the initial condition uncertainty, the effects of structural uncertainty are taken into account by using the SKEB2 stochastic physics scheme giving 3 ensemble members per start date. The model output used here consist of daily and seasonal mean (JJA) hindcast data for the 1992—2005 period. Note that one member for 1994 and two for 1996 are missing. Means over start date and ensemble members are shown.

Comparisons are made with 1992—2005 observed data: All-India Rainfall (Parthasarathy *et al*., 1994); GPCP (Huffman *et al*. 2001,); HadISST (Rayner *et al*., 2003); ERA-Interim.

Mean state and ENSO behaviour

Indian summer monsoon precipitation shows a good seasonal cycle when averaged over all-India (not shown) however there are biases in its spatial distribution (Fig. 1), notably excessive rainfall in preferred locations of convection over the Western Ghats and Himalayan foothills (although the latter is subject to considerable observational uncertainty). Central India is too dry in the model.

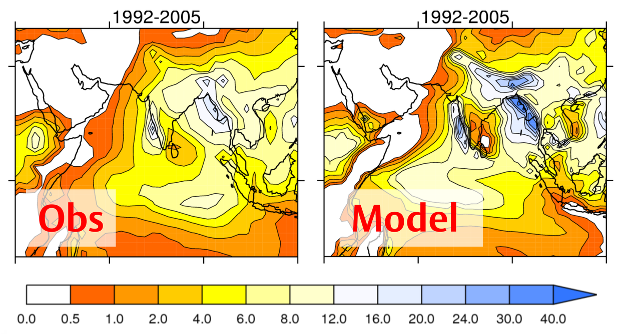


Fig 1: Mean JJA rainfall in GPCP (left) and GloSea4 hindcasts (right).

Interannual variations in monsoon rainfall do not match well with those in observations (Fig. 2) in part relating to a poor monsoon-ENSO teleconnection (a common problem in coupled GCMs; Annamalai *et al*., 2007). However, forced interannual variations in various dynamical measures of the monsoon are well simulated (not shown).

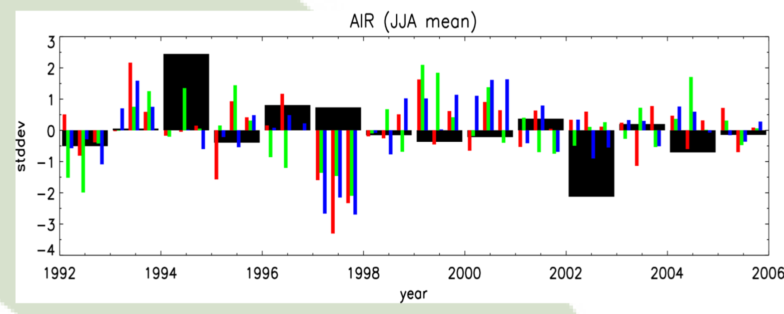


Fig 2: Timeseries of anomalous all-India rainfall in observations (black) and GloSea4 hindcasts (r, g, b for each ensemble member in each of 3 start dates, left to right).

While GloSea4 is initialised from observations, there are still coupled SST biases, most notably a confined warm pool and an anomalously cold equatorial Pacific cold tongue that extends too far westwards (Fig. 3). This also relates to excessive trade winds (not shown). These biases are common among many coupled GCMs and also older versions of the MetUM such as HadCM3 (see Turner *et al*., 2005).

Regressions of global SST onto ENSO (the Niño-3.4 index) reveal strong ENSO variability extending to the west-central Pacific (Fig. 4), and a meridionally-confined ENSO.

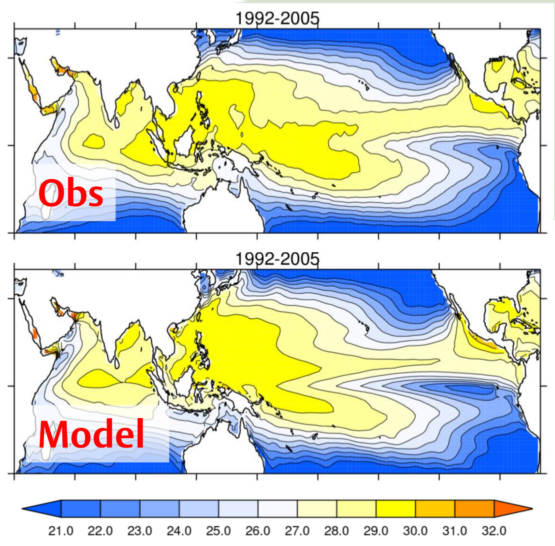


Fig 3: (left) Mean JJA SST (°C) in HadISST observations (top) and GloSea4 hindcasts (bottom).

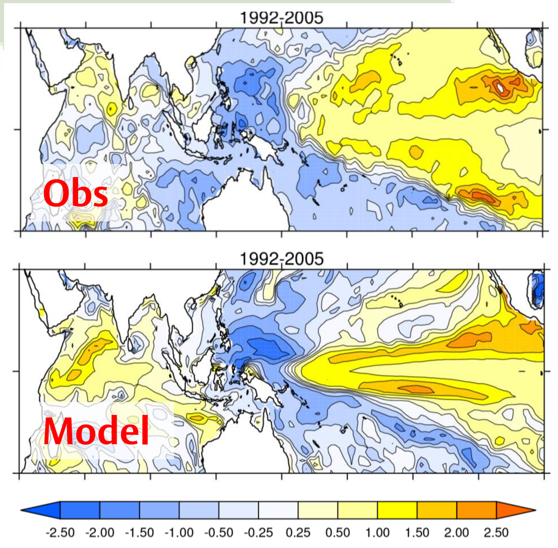


Fig 4: (right) Regression of JJA global SST onto Niño-3.4 in HadISST observations (top) and GloSea4 hindcasts (bottom).

1997 and 2002 El Niño case studies

Unusual ENSO events have been selected as case studies. The 1997 El Niño was the largest on record and concentrated in the East Pacific. While the eastward focus may suggest a weakened teleconnection (Krishna Kumar *et al*., 2006), weakening of the large-scale Walker Circulation was observed and simulated for this year (not shown). The development of an Indian Ocean dipole, and an enhanced local Hadley Circulation leading to several monsoon depressions meant monsoon rainfall was unexpectedly good this year (~102% of long period average; Slingo & Annamalai, 2000). Such features were not well simulated in the model. The 2002 El Niño featured rapid warming of the central Pacific, forcing one of the largest monsoon droughts in recent history (~81% LPA).

Fig. 5 shows that although the model has simulated the diverse nature of these events reasonably well in JJA, there are strong biases toward warming of the west-central Pacific not present in observations. As shown in Turner *et al*. (2005) in an earlier version of the MetUM (HadCM3), and explained elegantly for the CMIP3 models in Annamalai *et al*. (2007), this westward bias can lead to the anomalous diabatic heating being situated too far west, disrupting the placement of the Walker Circulation and hence the teleconnection to the monsoon.

The evolution of daily SST in Fig. 6 demonstrates that SST anomalies associated with El Niño are pushing too far to the west along the equator, particularly in the early part of the monsoon season.

Fig 6: Hovmöller plots depicting daily evolution of SST anomalies in 1997 and 2002 case studies in HadISST observations (left) and GloSea4 hindcast (right).

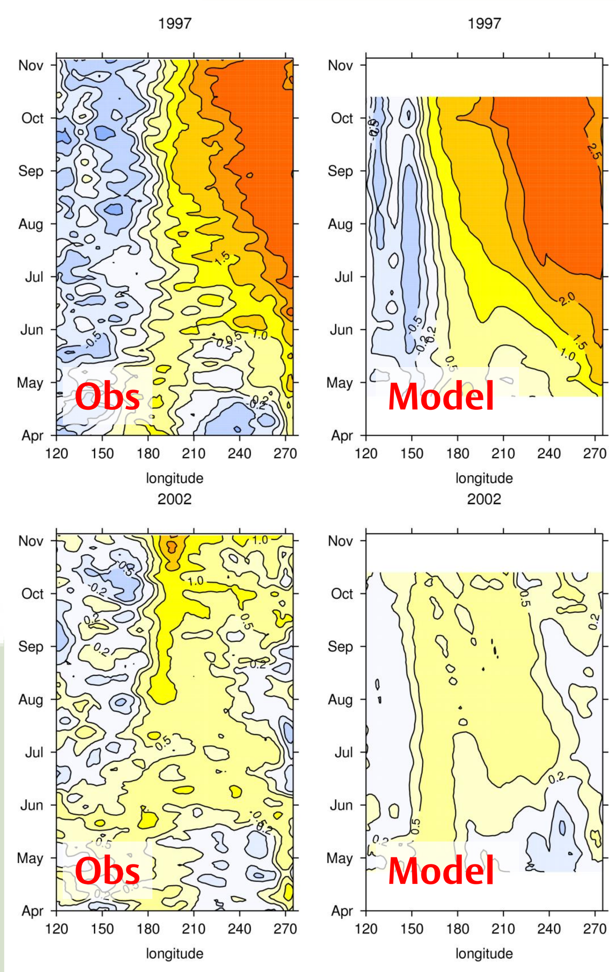
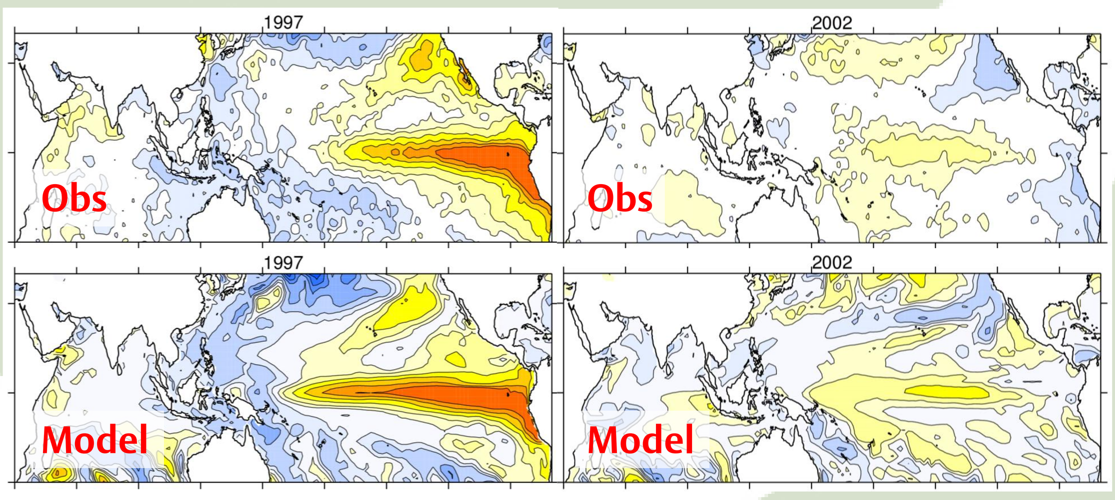


Fig 5: Anomalous JJA SST (°C) in 1997 and 2002 case studies in HadISST observations (top) and GloSea4 hindcasts (bottom).



Position of anomalous descent

To examine the effect of ENSO on the Walker Circulation, anomalous upper-tropospheric velocity potentials are shown in Fig. 8. These indicate enhanced upper-level divergence and hence ascent over the El Niño heating region of the central-east Pacific, and associated anomalous subsidence further west over the India sector. This acts to suppress the climatological monsoon convection shown in Fig. 7. As a consequence of the surface heating extending too far west, the anomalous ascent also extends too far west, pushing the associated subsidence further west towards Africa. For 1997, while the bulk of the anomalous descent in observations occurs over the Maritime Continent, this is shifted west to Indian longitudes, hence leading to an erroneously weakened monsoon. In 2002 however, while subsidence was concentrated on peninsular India in observations, this is pushed towards the African coast in the GloSea4 hindcasts..

Fig 7: Mean JJA 200hPa velocity potential (m^2/s) in ERA-Interim reanalysis.

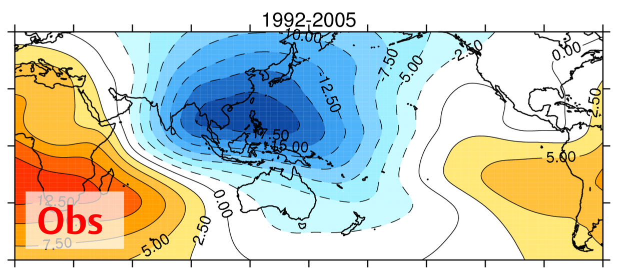
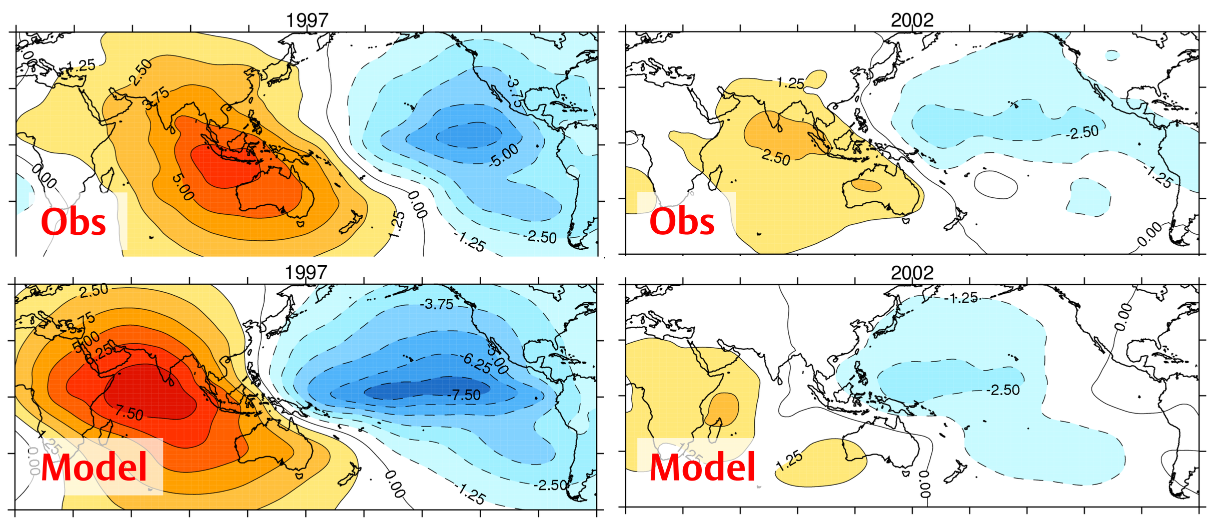


Fig 8: Anomalous JJA 200hPa velocity potential (m^2/s) in ERA-Interim reanalysis (top) and GloSea4 hindcasts (bottom) for 1997 (left) and 2002 (right).



Conclusions and further work

- **Mean state SST biases suggest a confined warm pool and exaggerated cold tongue in the central equatorial Pacific.**
- **Teleconnections between Indian monsoon rainfall and ENSO are weak in the GloSea4 hindcasts, despite initialisation from a realistic mean state. Forced changes in large-scale dynamical measures of the monsoon are however well simulated. This inconsistency requires further investigation.**
- **Case studies of 1997 (strong, east Pacific El Niño) and 2002 (moderate central Pacific El Niño “Modoki”) reveal anomalous descent is situated too far west relative to observations, consistent with anomalous diabatic heating and ascent occurring too far west in the west/central Pacific.**
- **Further work will examine the role of the IOD and start dates on the monsoon response.**
- **We will also explore the use of heat flux or windstress corrections to test mean state-teleconnection interactions as in earlier studies.**

References Annamalai, H, K Hamilton & KR Sperber (2007) *J. Clim.* **20**: 1071—1092. // Bowler, NE, A Arribas, KR Mylne, KB Robertson & S Beare (2008) *QJRMS* **134**: 703—722. // Huffman G, RF Adler, M Morrissey, DT Bolvin, S Curtis, R Joyce, B McGavock & J Susskind (2001) *J Hydrometeorol*. **2**: 36—50. // Krishna Kumar, K, B Rajagopalan, M Hoerling, G Bates & M Cane (2006) *Science* **314**: 115—119. // Parthasarathy, B, AA Munot & DR Kothawale (1994) *Theor. Appl. Clim*. **49**: 217—224. // Rayner, NA, DE Parker, EB Horton, CK Folland, LV Alexander, DP Rowell, EC Kent & A Kaplan (2003) *J. Geophys. Res*. **108**, D14, 4407. // Slingo, JM & H Annamalai (2000) *MWR* **128**: 1778—1797. // Turner, AG, PM Inness & JM Slingo (2005) *QJRMS* **131**: 781—804.

E: a.g.turner@reading.ac.uk
T: +44 118 378 6019
F: +44 118 378 8905

Department of Meteorology
University of Reading
Reading RG6 6BB, UK