An Assessment of Oceanic Variability in the NCEP Climate Forecast System Reanalysis

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Abstract

At National Centers for Environmental Prediction (NCEP), a reanalysis of the atmosphere, ocean, sea ice and land over 1979-2009 has been recently completed as the Climate Forecast System Reanalysis (CFSR). The oceanic component of the CFSR includes many advances: (a) the MOM4 ocean model with an interactive sea-ice, (b) a 6 hour coupled model forecast as the first guess, (c) inclusion of the mean climatological river runoff, and (d) high spatial (0.5° by 0.5°) and temporal (hourly) model output. The primary use of the CFSR is to provide initial conditions for a reforecast of the new operational Climate Forecast System (CFS.v2) over 1979-2009 for seasonal climate forecast. Since the CFSR will be used by many in initializing/validating ocean models and climate research, here we intend to inform the user community about the salient features in the CFSR ocean component.

The net ocean surface heat flux of the CFSR has smaller biases than the NCEP/NCAR reanalysis (R1) and NCEP/DOE reanalysis (R2) in both the tropics and extratropics, when compared with the sum of the latent and sensible heat fluxes from the Objectively Analyzed air-sea Fluxes (OAFlux) and the shortwave and longwave radiation fluxes from the International Satellite Cloud Climatology Project (ISCCP-FD). However, the mean shortwave radiation is about 20 W/m² larger than observational analyses, consistent with the mean negative biases in cloudness and positive biases in the sea surface temperature. The evaporative latent heat flux appears to be 10-20 W/m² larger than other observational estimates in the tropical oceans.

The ocean surface wind stress of the CFSR has smaller biases and higher correlation with the ERA40 than the R1 and R2, particularly in the tropical Indian and Pacific Ocean. *However, the trade winds of the CFSR in the central equatorial Pacific are too strong prior to 1999, and become close to observations once the ATOVS radiance data are assimilated in late 1998. A sudden reduction of easterly wind bias is related to the sudden onset of a warm bias in the eastern equatorial Pacific temperature around 1998/99.*

The CFSR has improved time-mean precipitation distribution over various regions compared to the ERA40, R1 and R2, leading to a better representation of freshwater flux (evaporation minus precipitation). For interannual variability, the CFSR shows improved precipitation correlation with observations over the Indian Ocean, the Maritime Continent, and western Pacific.

The sea surface height and upper 300 m heat content (HC300) of the CFSR compare with observations better than the GODAS in the tropical Indian Ocean and extratropics, but *worse in the tropical Atlantic, probably due to discontinuity in the deep ocean temperature and salinity caused by the six data streams in the CFSR.*

Xue, Y., B. Huang, Z.Z. Hu, A. Kumar, C. Wen, D. Behringer, S. Nadiga, 2011: An Assessment of Oceanic Variability in the NCEP Climate Forecast System Reanalysis. Clim Dyn., DOI 10.1007/s00382-010-0954-4.

Wang, W., P. Xie, S.H. Yoo, Y. Xue, A. Kumar, X. Wu, 2011: An assessment of the surface climate in the NCEP Climate Forecast System Reanalysis. Clim Dyn., DOI 10.1007/s00382-010-0935-7.

Validation Data

- OAFlux latent and sensible heat fluxes;
- ISCCP Shortwave and longwave radiation;
- NCEP/NCAR (R1) and NCEP/DOE (R2) reanalysis; ERA40 reanalysis;
- World Ocean Atlas 2005;
- NODC seasonal temperature analysis; NODC 5-year mean salinity analysis;
- AVISO altimetry sea surface height;
- OSCAR ocean surface currents;
- TAO temperature and currents.

CFSR Configuration

- NCEP atmosphere model T382L64 including assimilation of satellite radiances and observed CO2 and aerosols;
- GFDL MOM4 ocean model with an interactive sea-ice and mean river runoff;
- High spatial and temporal resolution (1/2° by 1/2° with meridional refinement to 1/4° in 10°S-10°N, 40 levels; hourly output);
- 3D-Var ocean data assimilation scheme;
- 6-hour coupled model forecast as the first guess field;
- SST nudged to daily OI SST;
- Six data streams, each from a different initial condition;
- Temperature profiles from XBT, moorings and Argo;
- Synthetic salinity using climatological temperature and salinity correlation.

Surface Wind Stress

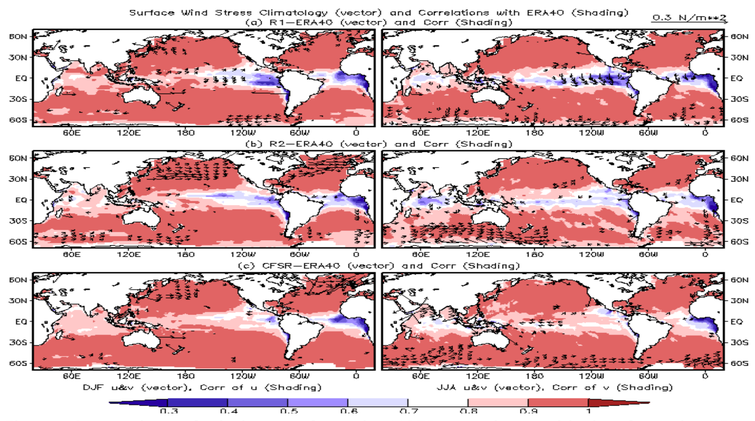


Figure: Comparison of wind stress from the NCEP reanalyses with that from the ERA40 for Dec-Jan-Feb (left column) and for Jun-Jul-Aug (right column) averaged over the years 1979-2001. Difference vectors (N/m2) are shown if their amplitudes exceed 0.015 N/m2. Anomaly correlations (shading) are shown for the zonal component (left column) and for the meridional component (right column). The comparisons are for (a) R1, (b) R2, and (c) CFSR.

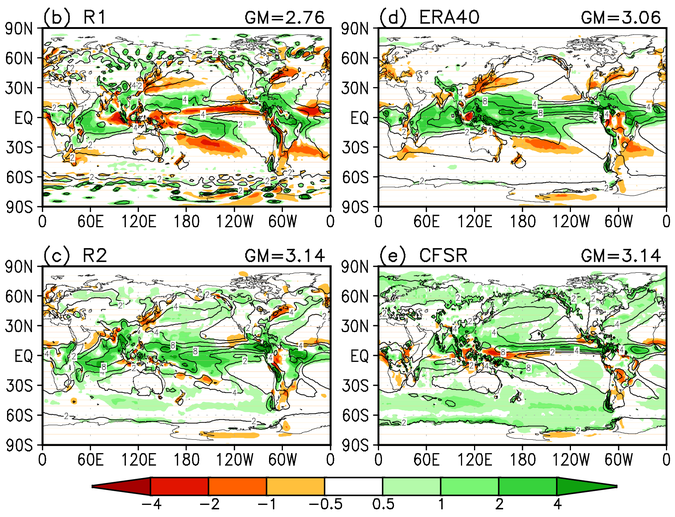


Figure : Precipitation climatology (contour) and differences (shading) from the observation taken as the average of CMAP and GPCP.

Precipitation

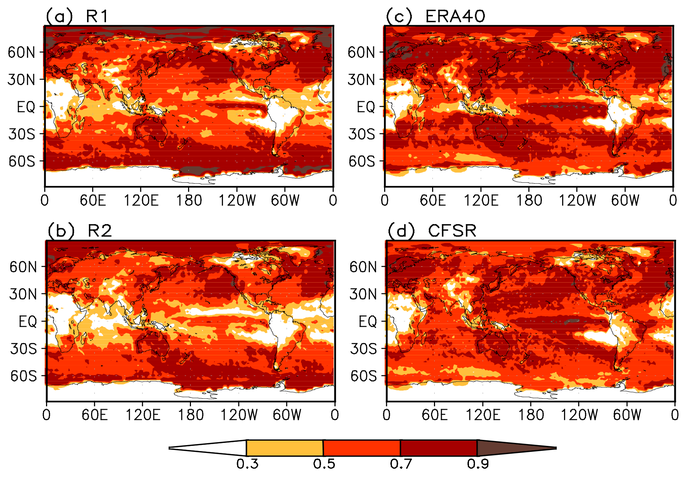
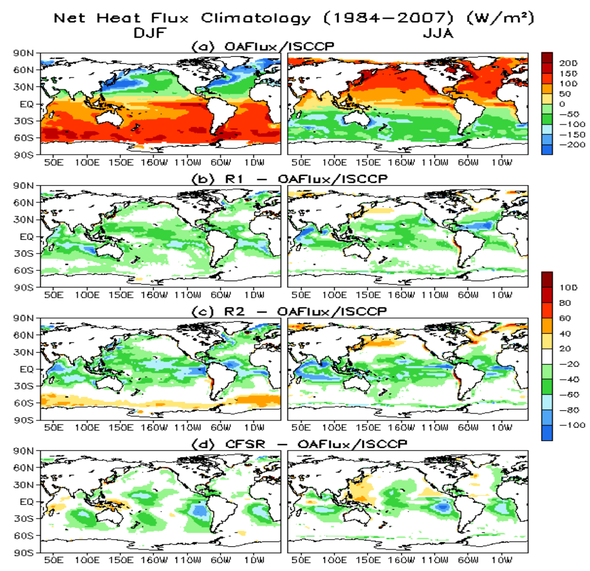


Figure : Temporal correlation of monthly mean precipitation with the CMAP.

- The CFSR has improved time-mean precipitation distribution over various regions compared to the ERA40, R1 and R2, leading to a better representation of freshwater flux (evaporation minus precipitation).

- For interannual variability, the CFSR shows improved precipitation correlation with observations over the Indian Ocean, the Maritime Continent, and western Pacific.



- The net ocean surface heat flux of the CFSR has smaller biases compared to the combination of the LH and SH from the OAFlux and the SW and LW from the ISCCP than the R1 and R2 in both the tropics and extratropics (Xue et al. 2011).

Surface Heat Fluxes

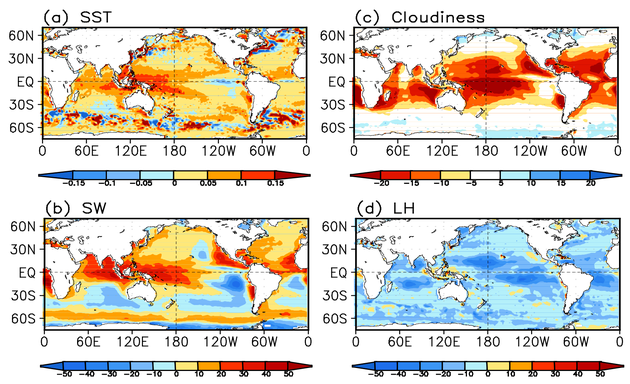
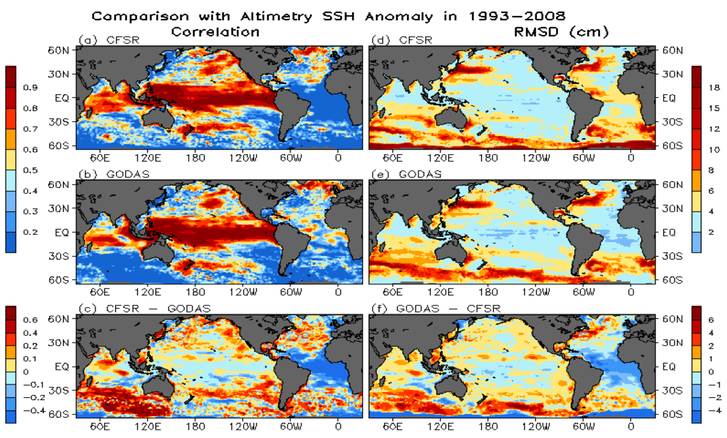
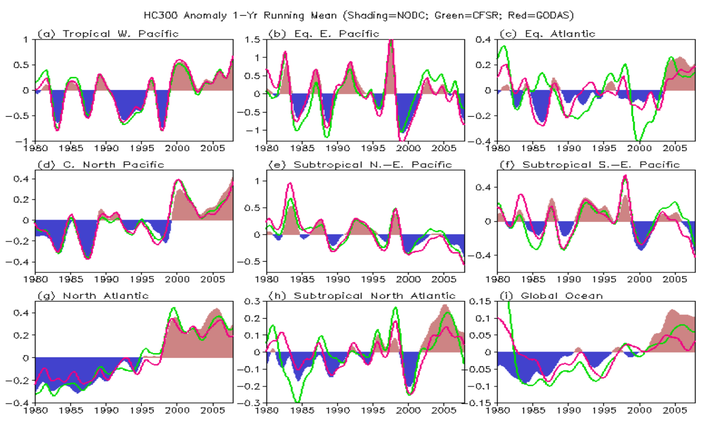


Figure : 1984–2004 annual mean differences between the CFSR and observations.

- The mean shortwave radiation is about 20 W/m² larger than observational analyses, consistent with the mean negative biases in cloudness and positive biases in the sea surface temperature. The evaporative latent heat flux appears to be 10-20 W/m² larger than other observational estimates in the tropical oceans (Wang et al. 2011).

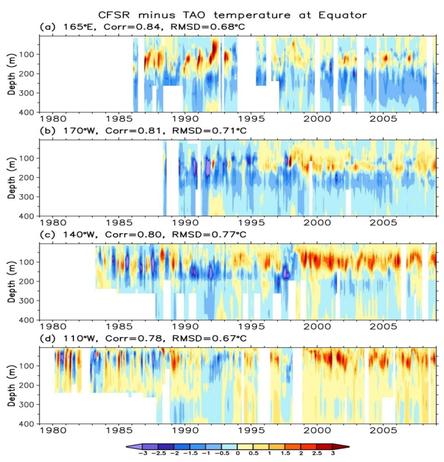
Sea Surface Height and Top 300m Heat Content (HC300)

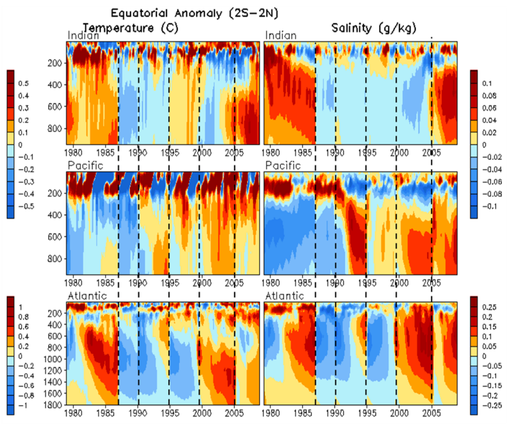




As compared to the altimetry, SSH variability is simulated better by the CFSR than by the GODAS in the tropical Indian Ocean and extratropics, but *worse in the tropical Atlantic, which is related to the drifts in the deep ocean.*

Unsatisfactory Features





- *Compared with the TAO temperature and currents, the CFSR generally has lower skill than the GODAS, because of the sudden onset of a warm bias in the eastern equatorial Pacific temperature around 1998/99.*
- *Drifts in the subsurface temperature and salinity within each data stream are quite large in the equatorial Atlantic.*