

Evaluating the Tropospheric Variability in NCEP's Climate Forecast System Reanalysis

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The National Centers for Environmental Prediction (NCEP) recently completed the latest, and partially coupled, atmosphere/ocean/sea-ice model based climate forecast system reanalysis (CFSR) for the 1979-current satellite era. In the reanalysis, the observed CO₂ concentration, and the volcanic aerosols were also prescribed. This paper provides an initial overview of the tropospheric variability in the CFSR by comparing it against available previous reanalyses. CFSR data from 1979-current was generated in six independent and parallel streams covering different periods with a one year overlap between streams. CFSR's monthly mean zonal and meridional component of wind, U and V, temperature (T) and geopotential height (H) at pressure levels up to 100 mb are compared against those of three other readily available reanalyses NCEP/R1, NCEP/R2 and ERA40 for the period from 1979 to 2008 (2002 for ERA40) and also against modern reanalyses such as JRA, MERRA and C20.

Correlation time series of monthly mean CFSR's H, T, U and V, averaged over the globe at pressure levels up to 100 mb as compared to the R1, R2 and ERA40, show values as high as 0.95-0.99 throughout the period from January 1979 till December 2008 and display a gradual increase with time. This demonstrates that the CFSR tropospheric analyses are closer to the other three analyses in the later years than in the previous years. The impact of the assimilation of ATOVS satellite radiances from October 1998 onwards in CFSR is the most likely cause for the agreement with other reanalyses. This is also reflected in the generally higher root mean square (rms) difference values of CFSR with respect to the other reanalyses in the earlier periods which slowly decreases to lower rms values in the later periods at all pressure levels and for all variables considered. Even though the high correlations of CFSR tropospheric variables with R1/R2/ERA40 reanalyses do not show any significant impact of the CFSR data generation in multiple streams, examination of rms maps do show some impact.

While the agreement among all the other reanalyses is relatively better in the later years, during the early period the CFSR 850 mb temperature is colder and hence the 200mb heights are lower than the other reanalyses, particularly before 1998, thus implying a greater trend in CFSR in these and other variables at equatorial latitudes. However, the linear trends of CFSR 850 annual mean T, over the common 1979-2001 period, over the entire globe resemble the ERA40 trends than those of R1 and R2, while the latter two agree better with each other. Over this period, significant differences exist in the tropical east Pacific region, with R1 and R2 showing a cooling trend, whereas CFSR and ERA40 depict a warming trend there and over most regions of the globe as well. At 200 mb, both ERA40, and CFSR show a broad warming trend in the tropics and subtropics over the past 30 years, whereas R1 and R2 show a cooling trend over much of the globe. An examination of time series of some climate indices, such as the various Nino wind indices in the tropical Pacific at 850 and 200 mb suggests that the other reanalysis data sets tend to agree more closely with each other than with CFSR, thus clearly making it an outlier until the late 1990s. Similar bias in the CFSR temperature field in the near equatorial latitudes is also noted as compared to the other three reanalyses, with CFSR being colder. Consistently, CFSR's 200 mb heights at the equatorial are also lower than the other three reanalyses. Mb heights at the equatorial latitudes are also lower than the other three reanalyses.

Despite the JRA and MERRA reanalysis monthly mean data sets becoming available toward the completion of this project they were employed to examine the vertical shear (200-850 mb) of the zonal wind from the CFSR over the main hurricane development region (10N-20N, 60W-20W) in the tropical North Atlantic during the peak hurricane season (Aug-Sep-Oct). The CFSR wind

shear in the Atlantic MDR is not only lower than R1, R2 and ERA40, but also than that of JRA and MERRA particularly before 1998, thus making CFSR an outlier as compared to all other reanalyses. Interestingly the shear from all five other reanalyses agreed more with each other.

We also found that based on MSLP differences between the tropical Indian and east Pacific tropical oceans, the strength of the Walker circulation in CFSR did not show any noticeable trend. However, consistent with a few previous modeling and observational studies from other reanalysis data sets of a strengthening Walker circulation in a globally warming climate, R1 and R2 reanalyses data did exhibit a minor strengthening and low level increased easterlies from 1979 to 2008. Finally, our lag-correlation analysis and results indicate that the CFSR model and analyses exhibit a better coupling and internal consistency between the model precipitation and low level wind field in its eastward propagation time scales associated with the MJO, thus making any dynamical prediction of MJO events likely to be improved when compared to the NCEP/R1 based reanalysis and model.

In summary, at any given time (analysis hour, daily or month), for the globe as a whole, CFSR analysis agrees reasonably well with the other reanalyses. The CFSR's new coupled model and assimilation system makes use of the recent advances in these areas, and hence is possibly an improvement to NCEP's previous reanalyses R1 and R2 which are fifteen and ten years old respectively. For these longterm climate variability measures the analysis indicates that the CFSR was generally the outlier, with much stronger easterly trades, cooler tropospheric temperatures and lower geopotential heights during much of the earlier part of the analysis period (1979 to ~1998). Consequently, real-time monitoring of many of the ENSO related climate wind indices in the equatorial Pacific or the wind shear index in the tropical North Atlantic from CFSR may be problematic in the context of historical variability.

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