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A Conventional Observation Reanalysis (CORe) for Climate Monitoring

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1. Background

The first generation of atmospheric reanalyses, such as the National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Reanalysis (NCEP and NCAR) and the Japanese 25-year Reanalysis (JRA-25, JMA), have evolved to modern reanalyses like the Climate Forecast System Reanalysis (CFSR, NCEP), the Modern-Era Retrospective Analysis for Research and Applications Version 2 (MERRA2, NASA), the Japanese 55-year Reanalysis (JRA-55, JMA) and the fifth generation European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis (ERA5, ECMWF). These newer reanalyses use higher resolution models with more advanced physics and data assimilation, and with more reliance on the satellite observations. These systems produce more accurate analyses as indicated by the much improved forecast skill and the fits of the forecasts to observations. The more reliance on satellite observations, however, had adverse effects on climate monitoring, especially with the CFSR, as shown below.

The first example is the introduction of AMSU (Advanced Microwave Sounding Unit, in late 1998), which produced a large improvement in the forecast skill at NCEP. However, Fig. 1 demonstrates how ingesting the AMSU data clearly affected the precipitation and humidity analyses as shown by globally averaged precipitation – evaporation.

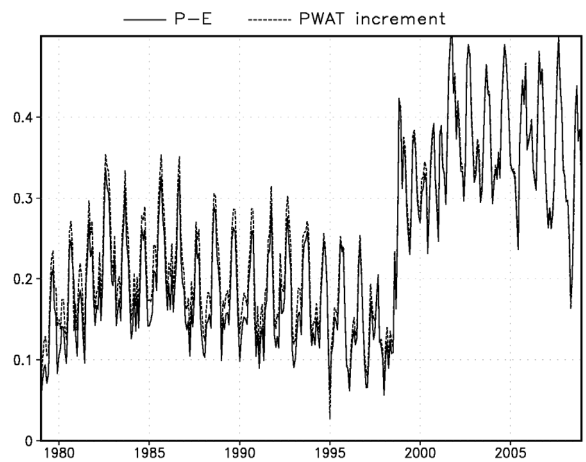

Fig. 1 Globally averaged Precipitation-Evaporation (mm/day)

Figure 2 shows the CFSR (red) 12-month running mean 200 hPa geopotential height at Singapore, compared with observations (black), ERA-40 (green), MERRA (purple), JRA-25 (blue), NCAR/NCAR (orange) and NCEP/DOE (brown). Prior to year 2000, CFSR is much lower than observations and the other reanalyses. This problem was caused by the CFSR being "tuned" to the modern era where there are many more satellite observations. In the earlier periods, the conventional observations have to be given more weight both as a value and in horizontal extent (CFSR is using 3D-Var.). The Singapore height problem is duplicated with the equatorial zonal mean 200 hPa heights (not shown).

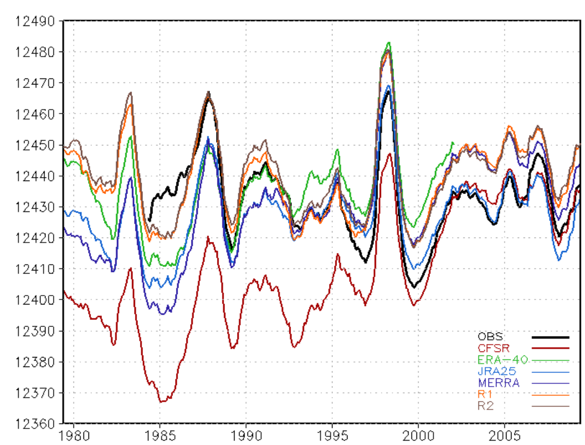

Fig. 2 Singapore 200 mb Geopotential Height (m)

The Climate Prediction Center (CPC) does ENSO monitoring, in which the low-level equatorial Pacific winds

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are important for the ENSO development. The problem reflected by the 200 hPa equatorial heights in Fig. 2 is also seen by the 850 hPa equatorial Pacific zonal winds on the date line (Fig. 3). In this figure, CORe (black) refers the phase-1 experimental reanalysis.

The CPC does seasonal hurricane outlooks, with some of the predictability coming from statistical tools using reanalyses. The ASO (August-September-October) vertical shear in the Atlantic hurricane main development region is a predictor for hurricane activity. As seen in Fig. 4, the CFSR (red) does not represent the trend of weakening of the shear as seen in ERA-40 (green), JRA-25 (blue), MERRA (purple), NCEP/NCAR (black), and NCEP/DOE (brown).

The CPC does drought monitoring and prediction. The CFSR global mean soil moisture showed a sudden change when the CFSR transitioned to the CFSv2 with its higher horizontal resolution as shown in Fig 5.

Another problem with CFSR was that it had problems capturing the QBO (not shown), and had to ingest ERA-interim tropical winds (July 1981-December 1998).

2. Conventional Observation Reanalysis (CORe)

The phase-1 of a new reanalysis CORe for climate monitoring was described in Ebisuzaki *et al*. (2017), and Zhang *et al.* (2017). Using an Ensemble Kalman Filter (ENKF) data assimilation, a modern model (GFS spectral model), this system assimilated conventional and atmospheric motion vectors (AMV) observations. The analyses had similar or better performance than the NCEP/NCAR Reanalysis that assimilated satellite retrievals. The advantages of the experimental reanalysis were: 1) it was better for climate monitoring than the currently used NCEP/NCAR Reanalysis because it did not assimilate satellite data which had caused spurious changes; 2) it was based on a modern model so its climatology was better; and 3) it had higher spatial resolution (512x256 Gaussian grid vs 192x94 Gaussian grid) and more vertical levels (64 vs. 28 model levels).

The phase-2 of CORe is to develop and produce an operational climate reanalysis. The problems found in the phase-1 need to be addressed and a new numerical forecast model needs to be used because NOAA is concentrating its modeling resources on the Finite Volume 3 (FV3) model development. The new model is C128, 64-level FV3 model. This model is a cubed sphere with each face being 128x128 cells on a gnomonic-type grid. The data assimilation grid is 512x256 Gaussian grid, which is the same as the spectral model used in phase-1. Again the data assimilation is Ensemble Kalman Filter based using 80 ensemble members.

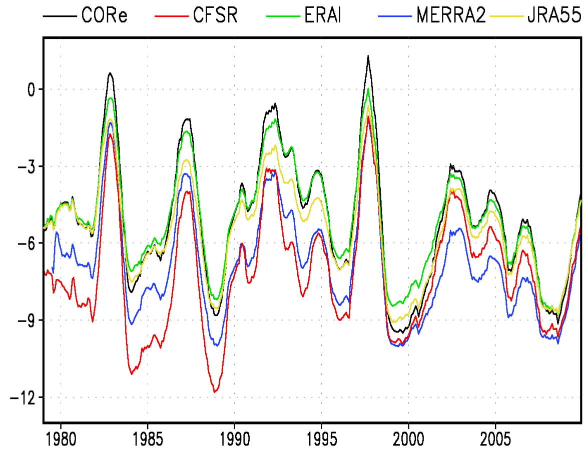

Fig. 3 850 hPa zonal winds at 0°N, 180°E

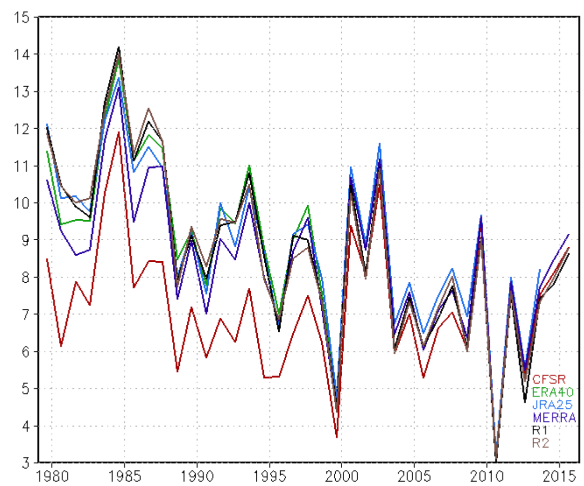

Fig. 4 Aug-Sep-Oct zonal wind shear (200 hPa-850 hPa) of 60°W-20°W, 10°N-20°N average

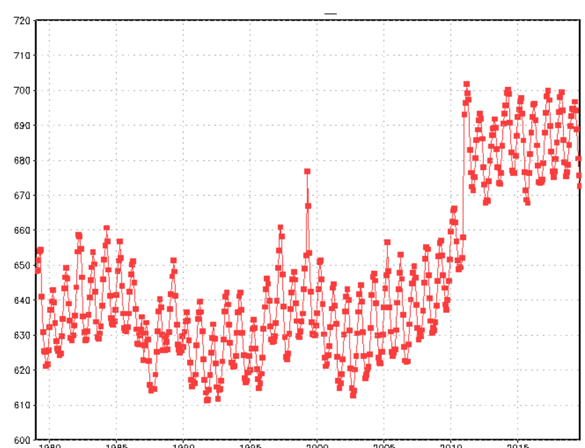

Fig. 5 Global mean 0-2m soil moisture CFSR/ CFSv2

The major problem with the phase-1 reanalysis was that the global mean precipitation was 3.5 mm/day, compared with an observed 2.8-2.9 mm/day. Moving to the FV3 model fixes this problem. Figure 6 shows for the period of 2004-2005 phase-2 (red) had a precipitation of 3.04 mm/day which was better than the CFSR (green) in the same period (3.24 mm/day). The phase-2 precipitation is larger than observed but more reasonable.

3. Output analyses for climate monitoring

The main product will be the ensemble means that will be similar to the current reanalyses. The ensemble means will be produced every 3 hours and will have flux files and pressure level analyses that resemble other NCEP reanalyses because they will be produced using the NCEP post (Unified Post-Processor, UPP). The NCEP post was used by many NCEP reanalysis, *i.e.* CFSR and GEFSR, and forecast models, *i.e.* GFS and NAM. In addition, the 3 hour analyses will be saved as nemsio (NOAA Environmental Modeling System Input/Output) files, so that forecasts can be made as well as additional processing can be done at a later time.

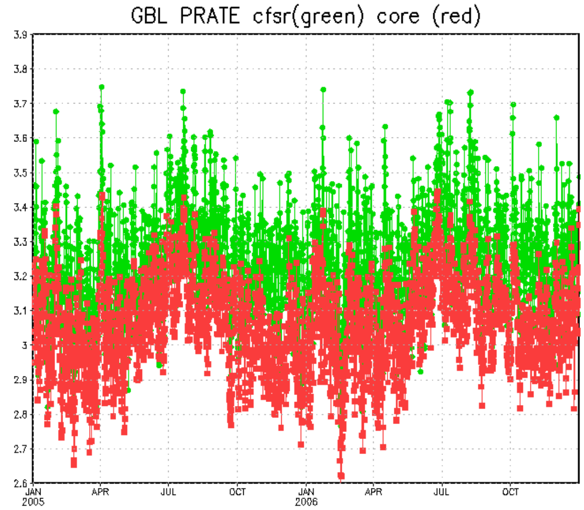

Fig. 6 Global mean precipitation of CFSR, phase-2 (mm/day).

The phase-2 is being produced using an ENKF data assimilation with 80 ensemble members. Besides the ensemble mean, we now have analyses from the ensemble members. The importance of making the 80-ensemble-member analyses is yet to be determined. One application is driving an ensemble of land-surface or ocean models. Ensemble statistics will be produced, and some of the ensemble members will be saved.

Ensemble mean: every 3 hours

grib2: 512x256 Gaussian grid (data assimilation grid), produced by NCEP post
grib2: 512x256 Gaussian grid flux file
nemsio: 512x256 Gaussian grid, restart files for forecasts, 3 hour forecast for "data assimilation" budgets, redo pressure level analyses with more precision and levels

Ensemble members: every 3 hours

grib2: 512x256 Gaussian grid, flux files, 80 members
grib2: 512x256 Gaussian grid, limited pressure levels, limited variables, number of members to be determined
nemsio: 512x256 Gaussian grid, 80 members
nemsio: 512x256 Gaussian grid, atmospheric fields, number to be determined.

Ensemble statistics: every 3 hours

grib2: 512x256 Gaussian grid, flux
grib2: 512x256 Gaussian grid, limited pressure levels, limited variables

The current plan for 2020 is to produce analyses for much of the satellite era. In 2021, we plan on distribution, conversion to an operational system and extension to the pre-snow-analysis period.

References

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