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A Conventional Observation Reanalysis (CORe) for Climate Monitoring

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ABSTRACT

The Conventional Observation Reanalysis (CORe) is a global atmospheric reanalysis designed for climate monitoring, and in particular to be a replacement for the venerable NCEP/NCAR Reanalysis which is used by the Climate Prediction Center for its climate monitoring. CORe has more spatial resolution (0.7 degrees *vs* 2.5 degrees, 64 *vs* 28 model levels), and higher temporal resolution (3 hourly *vs* 6 hourly analyses). CORe is created using a modern data assimilation system (ensemble Kalman filter *vs* 3-D Var), and model (2018 FV3 cubed sphere *vs* 1995 GFS spectral model) which allows it to produce analyses better than the NCEP/NCAR Reanalysis without using satellite data except for Atmospheric Motion Vectors (AMVs), and satellite observations used to produce the sea-surface temperatures and snow depths. Consequently many of the problems with the Climate Forecast System Reanalysis (CFSR, Suru *et al.*, 2010) can be avoided. This extended abstract details the status of the project for Oct 2020, with an update for January 2021.

1. Introduction

Many reanalyses try to produce the best analysis by assimilating all useful satellite observations. This approach produces an analysis with the best forecast skill. However, this approach leads to spurious jumps in the time series often caused by changes in the satellite data (ex. Ebisuzaki and Zhang, 2011; Chelliah *et al.*, 2011; Zhang *et al.*, 2012). Another class of reanalyses use a more homogeneous observational data set to eliminate the spurious temporal jumps. This class of reanalyses only depend on surface data and span many years (20th Century reanalysis, Compo *et al.*, 2011; ERA-20C, Poli *et al.*, 2016). By using fewer but more consistent observations, the resulting analyses avoid the spurious jumps at the cost of being spatially and temporally noisier. For climate monitoring, we want a reanalysis that produces good trends and good spatial patterns. We want a reanalysis that is between the all-satellite reanalysis and surface-observations-only reanalysis.

2. Project phases

The first (prototype) phase of the CORe project was to make a 1950-2010 reanalysis using an 80-member ensemble Kalman filter data assimilation using the NCEP spectral model with conventional observations, and atmospheric motion vectors (AMVs). This preliminary reanalysis was similar or better in quality than the NCEP/NCAR reanalysis even though that reanalysis used satellite data (Zhang *et al.*, 2017, Ebisuzaki *et al.*, 2017).

The second phase of CORe is to make a 1950-present reanalysis using the FV3 model which is the basis for NOAA's Unified Forecast System. When complete, CORe will cover 1950-present with a 0.7 degree grid (512x256 Gaussian) and a 3 hour temporal resolution (Ebisuzaki *et al.*, 2019). Following are the specifics.

Model: Cubed sphere FV3-GFS model, 64 vertical levels, C128 grid.

Data assimilation: Ensemble Kalman Filter (from PSD), 80 ensemble members

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80 analyses are produced which are equally likely (no control run).

6 hour Incremental Analysis Update (IAU), force the model for 6 hours, and then make short free forecast,

The 03/09/15/21Z analyses are immediately after the IAU forcing has finished

The 00/06/12/18Z analyses are 3 hours after the IAU forcing has finished

3. Status of satellite period analyses (10/2020)

3.1 Multiple streams from 1982-2019 (80% done)

The first stream started in 1982 because we lost 1979-1983 analyses and data from the other streams due to a file system crash on the high performance computer that we were using. We managed to recover enough to create restart files in 1982 and the ends of the other streams. We used this reboot to change the SST from Reynolds Optimum Interpolation (OI) SST to the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) because Reynolds SST ceased operational production.

3.2 Early evaluation using ERA5 as truth

Fv3GFS and GFS-spectral are different models, so the results are not the same between the CORe and the prototype CORe. However, there are many common features. Monthly means relative to ERA-5 are similar to prototype CORe but show tropospheric heights are worse, and tropospheric T, U are better. The too large precipitation in the prototype CORe has been much improved. The global precipitation is now similar to other reanalyses which tend to be larger than observed. CORe's global precipitation shows smaller trends than the modern reanalyses which use satellite data (Fig. 1).

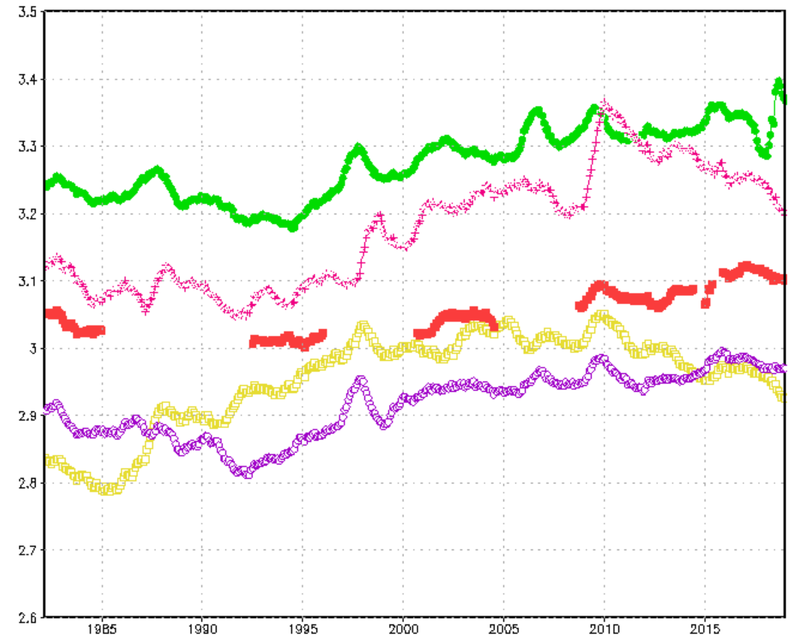

Fig. 1 Global precipitation with 12-month running mean from various reanalysis (mm/day). CORe (red), ERA-5 (purple), CFSR (rose), JRA-55 (green) and MERRA-2 (gold). Except for CORe, the other reanalyses ingest thermal radiance data from satellites.

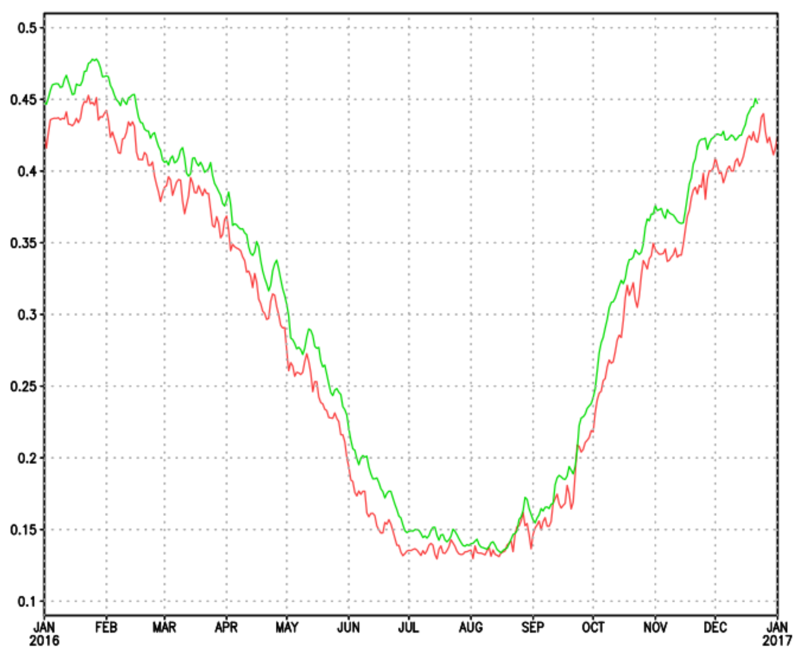

Fig. 2 Fraction land snow cover, observed (red), model forecast (green).

4. Status of pre-satellite analyses

Prior to the mid-1970s, there are no AMVs. The AMVs are not a crucial observation type in modern data assimilation systems during the current period because AMVs have large observation errors. The large errors are caused by difficulties in assigning the height to the vectors.

The SST analyses prior to 1981 are of worse quality than current analyses because the lack of satellite data. This will affect the temperature analyses near the ocean. However, one expects that atmospheric observations will reduce the impact of the SST errors away from the ocean surface.

The global snow-depth analyses requires satellite data, and the snow analyses is unavailable prior to 1979. One can use the snow from the model forecast. We will validate the snow cover because the snow-depth analyses loses accuracy for deep snow, and the snow cover has the larger effect on the atmosphere through the albedo than the depth of the snow through its heat content and insulation effects. Figure 2 shows the observed fractional snow cover over land (red) and the model forecast (green). Generally the model derived snow cover is 2.5% larger than the observed snow cover over land. While 2.5% is small for a global value, it understates the regional value in certain seasons. In addition, variations in the snow cover can have a strong effect on the societally important 2-meter temperature in some populated areas. Therefore, it is desirable to improve the snow cover.

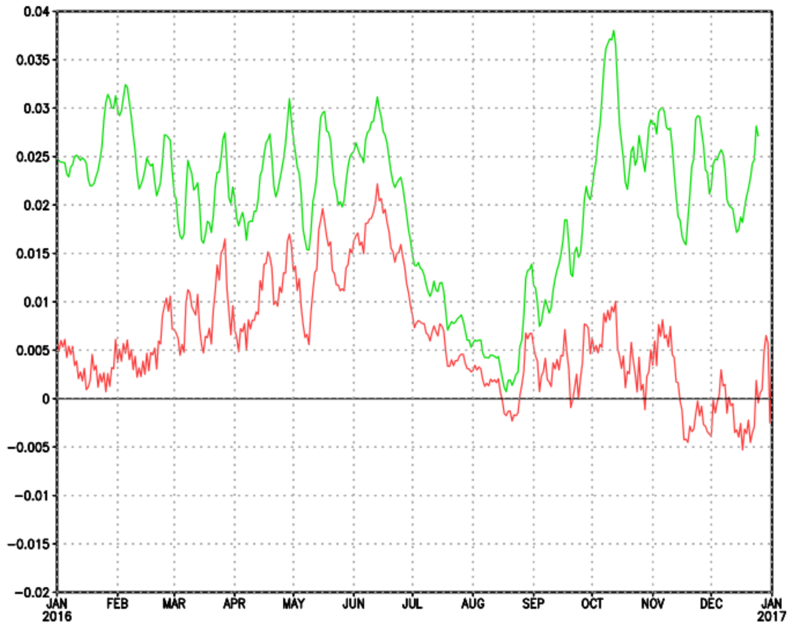

Fig. 3 Model forecast minus observed land snow cover fraction (green), and adjusted model forecast minus observed land snow cover fraction (red).

The adjusted model snow consists of taking the model forecast snow, setting the snow to zero if the model snow is less than 3 mm of liquid water equivalent (roughly 3 cm snow), and using this as a snow analysis. This adjustment is done every 48 hours to reduce the chance of adjusting the snow during the middle of a snow storm. This adjustment is to account for the albedo effects from a non-uniform snow depth in the grid box. (Presumably for a 3 cm snow, the grid cell is only half snow covered, and needs to be treated as snow free rather than snow covered.) Figure 3, based on work conducted through mid-January 2021, shows the anomalous snow cover (relative to observations) for the model snow (green), and anomalous adjusted model snow cover (red). As seen in Figure 3, the snow cover is much better estimated by this simple adjustment (closer to the zero line). For Figure 3, we used the snow cover for each ensemble member and averaged the snow cover fraction. Calculating the snow cover from the ensemble-mean snow depth would overestimate the snow cover. In mid-January 2021, we started running CORe for the pre-satellite period using this adjustment.

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