A Conventional Observation ENKF Atmospheric Reanalysis for Climate Monitoring at NCEP

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Introduction

Atmospheric reanalyses can be optimized to produce the most accurate reanalysis by assimilating all observations including satellite observations. This type of reanalysis often shows spurious "climate shifts" in various time series with the introduction of new satellite systems (ex., Zhang et al 2012). The 20th Century Reanalysis took another approach, and it made the time series more homogeneous by only assimilating surface pressure observations. Such a reanalysis is less accurate because it assimilates much fewer observations. The Climate Prediction Center (CPC) wanted a NCEP/NCAR Reanalysis (R1) replacement that would be between these extremes, The replacement reanalysis had to have accuracy of R1, eliminate the gross artifacts from the introduction of various satellites and span from the 1950's to the present. Can a conventional observation reanalysis (CORe) satisfy these requirements?

This is part of the hierarchy of NOAA reanalyses: (0) AMIP - SST, (1) 20th Century V3 - surface pressure + SST, (2) CORe - conventional obs + SST, (3) CFSv3 - all obs + ocean

Details of CORe (Conventional Observations Reanalysis)

Phase 1: experimental reanalysis
Phase 2: production reanalysis

Phase 1:
- Ensemble-Kalman-Filter atmospheric data assimilation system.
- 80-member ensemble
- Conventional observations, cloud track winds*
- T254 L64 Semi-Lagrangian spectral model (~2016 NCEP GFS model)
- 1950 to 2010 run in 6 streams with 1 year overlap between streams

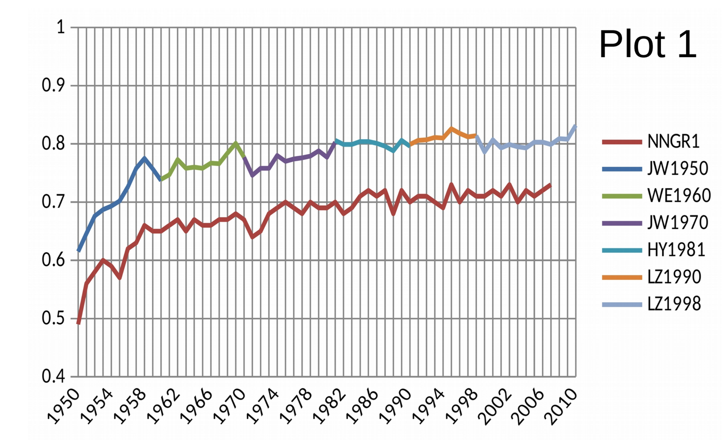
*cloud-track winds are not sensitive to biases in sensors

Phase 2:
- Ensemble-Kalman Filter atmospheric data assimilation system
- 80-member ensemble
- Conventional observations, cloud track winds
- C128 L64 finite volume model (FV3), 2019 NCEP GFS model
- 0.7 degree horizontal resolution and 64 vertical levels
- 1950-real time is planned
- One cycle every 6 hours using incremental update
- 3 hourly analyses, 0 and 3 hours after incremental update

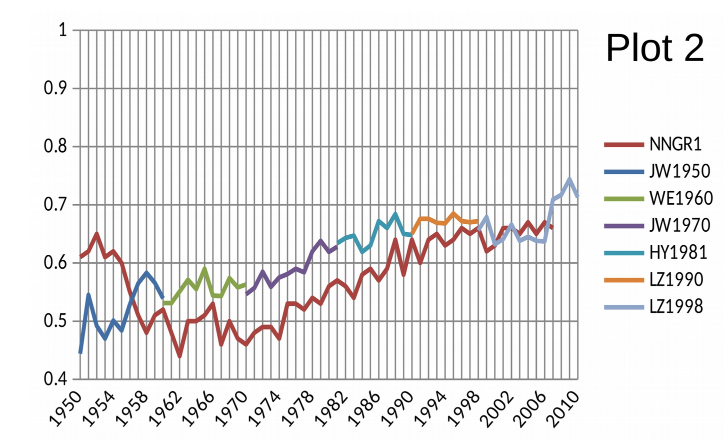
Evaluation of phase 1 CORe

Plot 1 shows the 5-day forecast skill (correlation) for the NH 500 hPa geopotential height (Z500). R1 (red) forecasts are not as skillful as CORe (multi-color). Plot 2 shows a similar plot for the SH. The first decade is unusual because R1 shows more skill than the following decade. We speculate it's artificial skill from a lack of SH observations.

Forecast skill is influenced by the model. CORe is higher resolution (T254 vs T62, 64 vs 28 levels) and has much better physics. So the improved forecast skill probably comes from a better model, higher resolution and improved analysis methods which more than compensated for the lack of satellite observations (temperature retrievals) that were used by R1.



Plot 1

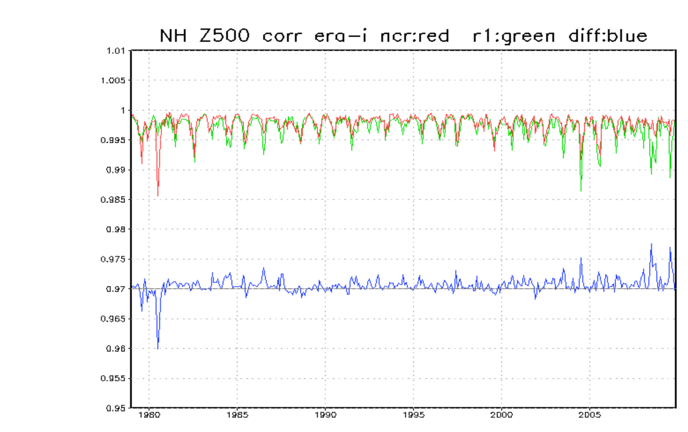


Plot 2

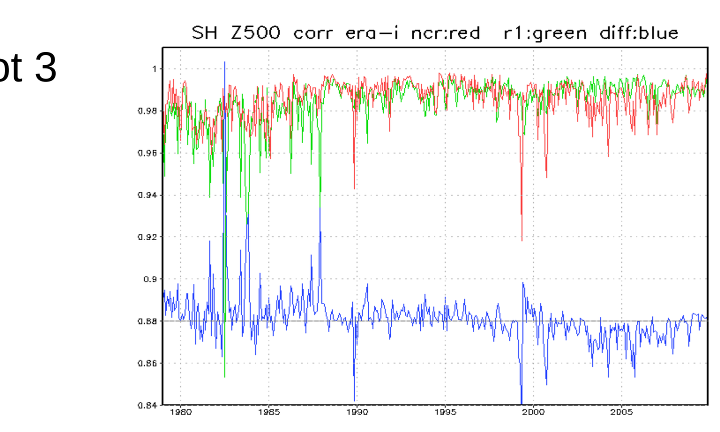
For climate monitoring and evaluation of the trends, monthly means are more often used that the instantaneous fields. In order to evaluate the skill of the analyses, we will use ERA-interim as a proxy for truth and evaluate the monthly means.

Plot 3 shows the anomaly correlation (AC) for the 30N-60N monthly Z500. The AC of CORe and ERA-interim is red. The AC of R1 And ERA-interim is green and the difference in AC is shown by the blue minus the black lines. Plot 3 shows that CORe is closer to ERA-interim than R1.

Plot 4 is similar to Plot 3 except for the SH (60S-30S). Both R1 and CORe have high ACs but not as high as in the NH. More often than not, CORe is closer to ERA-interim than R1 is to ERA-interim. The 2000-2007 period is an exception and may be the result of human error as surface pressure observations were not assimilated in CORe (2000+).

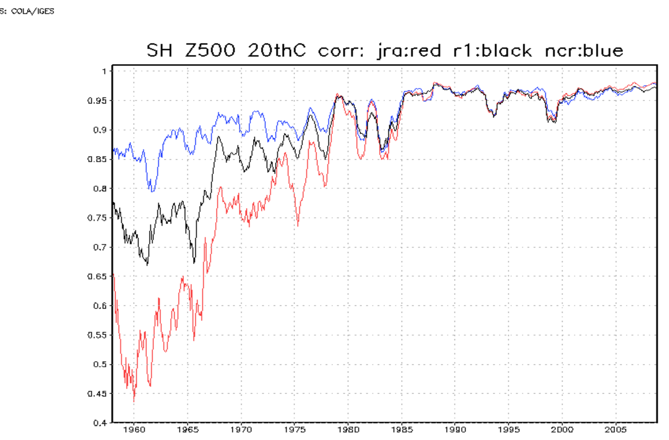


Plot 3



Plot 4

1950-2010



Plot 5

Reanalysis that assimilate satellite data should show an increase in skill when satellite observations start being assimilated. 20th Century reanalysis only assimilates surface pressure, so it provides a noisy but more more homogeneous reanalysis. Plot 5 shows the correlation of SH Z500 from 20th Century with CORe (blue), R1 (black) and JRA55 (red). The correlations are similar in the 1985-2010 period because there are many conventional observations, and CORe, R1 and JRA55 are similar to each other and 20th Century is the odd reanalysis because it is noisy. For the 1968-1985 period, the CORe-20th Century correlations are roughly flat, which suggests that CORe is not loosing skill in the early part of this period. R1 and JRA55 show a lower correlation in the early part the 1968-1985 period which suggests a loss of skill in the early period because of the absence of satellite observations.

Summary of Phase 1

A (mostly) conventional observation based reanalysis is attractive because it eliminates the "climate shifts" caused by the introduction of satellites and new satellites. Phase 1 CORe demonstrates that such an analysis can have similar or better skill than R1 which CPC uses for climate monitoring. In our internal evaluation of CORe, our main concerns were the overly large precipitation and radiative fluxes in the tropics (not shown).

CORe is attractive because it has doesn't suffer from "climate shifts" from the introduction of new satellites. There is some evidence that the CORe does well in the pre-satellite period.

Phase 2

We are testing the phase 2 CORe system and designing the output data sets. Transitioning to the FV3 model reduced the global precipitation to acceptable values (larger than observations but similar to other reanalyses).

Presently designing the output data sets. Saving all the data from a 80 member ensemble is not possible. Need input from the user community for which variables to save.

Output Format
- 512X256 Gaussian grid in GRIB2 format
  - Reasons: FV3 model transforms from the cubed sphere to the 512x256 Gaussian grid
  - Potentially reduce the number of interpolations by the user. GRIB2 saves space.

Variables Potentially Available
- Fields from NCEP post (ensemble mean), see URL below
- Some ensemble spread of fundamental variables on pressure levels
- N ensemble members of "bfg" file, see URL below
- Ensemble statistics from the "bfg" file, see URL below

Clouds:
- Clouds consist of 5 components: cloud water, ice, rain, snow and graupel
- Rather than save the vertical profile of these 5 components, plan to save layer averages. Layers are to be determined.

Fields planned to be saved
- Forcing for ocean and land-surface models from N ensemble members, N < 80
- Ensemble statistics for most of the bfg file.
  - Ensemble mean, spread, min, max, 10%, 25%, 50%, 75%, 90% percentiles,
  - Prob: precip > 0, temp2m > 0C, 95% percentile 10m wind speed
- most NCEP post variables: see URL below for various pressure levels
- Pressure levels: 1000,925,850,800,750,700,600,500,400,300,250,200,150,100, 70,50,30,20,10,5,2,1 hPa

BFG variables https://www.cpc.ncep.noaa.gov/products/wesley/CORe/bfg_var.html
NCEP post variables:
https://www.cpc.ncep.noaa.gov/products/wesley/CORe/post_var.html

Questions: what fields would be useful?
- At present, no forecasts are planned. Needed?
- N is undetermined.
- Pressure levels are not determined.
- The ensemble statistics are not finalized.

References

Compo et al, 2011, The Twentieth Century Reanalysis Project. Quarterly J. Roy. Meteorol. Soc., 137, 1-28.

Ebisuzaki et al, 2017: A Conventional Only stratospheric reanalysis (CORe) https://climate.copernicus.eu/sites/default/files/repository/Events/ICR5/Posters/02_S1_Ebisuzaki.pdf:

Ebisuzaki et al, 2016, A Preliminary Examination of a Conventional EnKF Atmospheric Reanalysis, http://www.nws.noaa.gov/ost/climate/STIP/41CDPW/41cdpw-Webisuzaki.pdf

Koayashi, et all, 2015: The JRA-55 Reanalysis: General specifications and basic characteristics, J. Meteor. Soc. Japan 93, 5-45

Zhang et al, 2012, Influence of changes in observations on precipitation: A case study for the Climate Forecast System Reanalysis (CFSR), JGR Atmospheres

Zhang et al 2016, Initial assessment of the Conventional Observation Reanalysis http://www.nws.noaa.gov/ost/climate/STIP/41CDPW/41cdpw-LZhang.pdf