Difficulties with Snow in the Conventional Observation Reanalysis (CORe)

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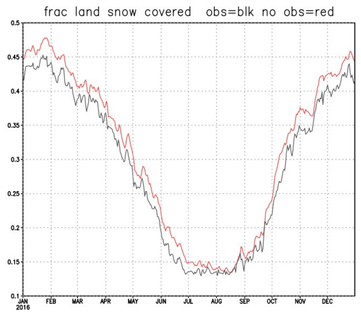
Introduction

This poster refers to CORe. CORe is a global reanalysis that is planned to replace the NCEP/NCAR Reanalysis for climate monitoring at the Climate Prediction Center. Core is based on the FV3/GFS-physics model using an 80-member ensemble Kalman filtering data assimilation. It assimilates conventional observations and Atmospheric Motion Vectors (AMVs). By not assimilating thermal radiances, we want to reduce the spurious trends introduced by the changing satellite systems. This poster details some of the difficulties in using a snow analysis in producing a reanalysis that goes back to 1950. See Li Zhang's poster for more details on CORe.

Atmospheric reanalyses have used observed snow cover/depth as an external boundary condition. However, global snow analyses depend on satellite observations so they unavailable before ~1979. Typically one uses a perhaps-adjusted model snow when the snow analyses were not available.

CORe uses the USAF snow depth analyses for 1979+. To prepare for the 1950-1978 CORe, we evaluated the impact of using model snow by comparing the CORe analysis (ctl) using USAF snow analysis with a data assimilation run using model snow (mdl). The mdl run was started on 9-27-2015 and was evaluated for 2016.



The above plot shows the factional snow coverage over land, mdl=red and ctl=black. A recent year was chosen to maximize the quality of the snow analysis.

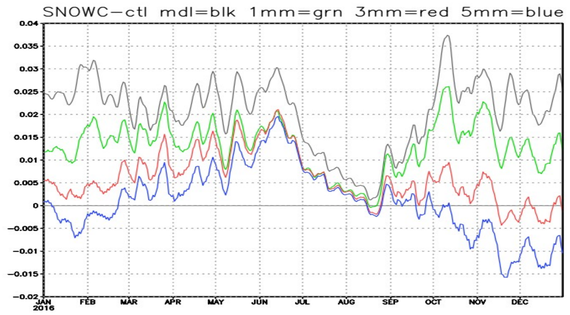
The plot shows that the model had about 0% (August) to 2.5% (NH Winter) too much snow coverage. Therefore using model snow would create cooler conditions, and an artificial warming trend. Of course the trend would be small in regions that were permanently snow-free or permanently snow covered. But using unmodified model snow would create an artificial trend in the mid-latitudes.

CORe's correction scheme:

The model forecasted too much snow. We wanted a simple scheme that could be physically justified.

The model snow and surface properties are calculated on grid point. A snow depth of 0.1 mm has the same albedo as 3 cm of snow. However 0.1 mm of snow in a 70km^2 grid cell would have very little coverage because of surface irregularities in the grid cell. So our scheme is

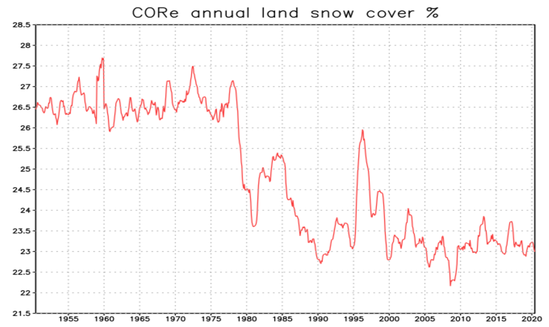
Every 2 days, take the model snow forecast.
If snow is less the X mm (threshold) of liquid water equivalent, set the snow to 0.
Convert the modified snow forecast to the format of a snow analysis.
Use the "snow analysis" in the data assimilation.



The above plot shows the "snow coverage – ctl" for various values of the snow threshold (in mm of liquid water). No snow removal=black, 1mm=green, 3mm=red, 5mm=blue.

No snow removal:	2.0% bias,	2.2% rms
1mm:	1.3% bias,	1.4% rms
3mm:	0.6% bias,	0.83% rms
5mm:	0.1% bias,	0.75% rms

By the bias and rms calculations, 5mm was the best choice for this simple scheme. However, the 5mm (blue) curve appears to need more than one year for the statistics to stabilize. With more time the 5mm results would likely be worse than for 3mm, so CORe used a 3mm threshold for the 1950-1978 analyses. The scheme is not perfect, the errors peaking in June which are probably the result of too much snow depth in certain regions. However, the scheme did reduce the annual global bias by 70% and RMS by 62%.



The above plot shows the 12-month running mean of global land snow coverage from CORe which used a 3mm threshold for 1950-1978, and USAF snow depth analysis for 1979-2020.

The 1950-1978 snow coverage is ~ 26.6%. The 1979-1999 average is 24.1% and the 2000-2020 average is 23.2%. From the tests for 2016, the expected bias is 0.6% for the 1950-1978 period. So the CORe is giving a decrease in snow coverage with time.

Concluding Remarks:

There are difficulties in using snow analyses for forcing reanalyses. CORe used the USAF snow analysis based on satellites. So the snow analysis is unavailable prior to 1979, and the quality varies with the satellites used.

The snow analysis may be inconsistent with the model. For example, the elevation of a model's grid point may be below than the 0C level but the snow analysis may have snow because much of the grid cell above the 0C level. So the snow analysis could be adding snow which the model keeps melting it because of the lower elevation. This would increase the soil moisture/

When a snow analysis is not available, a model derived snow can be used. However, the model snow may have errors that need to be fixed.