Climatology and variability of rainfall in the 20th Century Reanalysis

Michela Biasutti and Dong Eun (Donna) Lee
Lamont Doherty Earth Observatory of Columbia University
based on observations, data assimilation algorithms, and models that were changing throughout the record as the centers worked to improve their forecast skill (Bengtsson and Shukla 1988). It was proposed that a “reanalysis” be performed, whereby a fixed NWP model and data assimilation algorithm would be used to blend the historical observations into a consistent set of analyses needed for climate research. This reanalysis methodology was expected to eliminate the spurious discontinuities present in the operational analyses. Reanalyses such as the National Centers for Environmental Prediction (NCEP)–National Center for Atmospheric Research (NCAR) reanalysis (Kalnay et al. 1996; Kistler et al. 2001) and the European Centre for Medium-Range Weather Forecasts (ECMWF) 40-year Re-Analysis (Simmons and Gibson 2000) have now been carried out by several centers. These datasets have been used in many studies of atmospheric variability, particularly at synoptic to interannual time scales.

In addition to reanalyses, several efforts have been successful at reconstructing global fields of monthly mean surface temperature (Kaplan et al. 1998; Rayner et al. 2003; Smith and Reynolds 2004a) and sea level pressure (Smith and Reynolds 2004b; Kaplan et al. 2000; Allan and Ansell 2005, manuscript submitted to J. Climate) over the past 150 yr using statistical methods. These longer datasets have been used in many studies of seasonal to decadal variability and climate change.

Three issues limit one’s ability to examine climate variability and climate change from synoptic to decadal time scales over the last century. First, the reanalysis datasets are only available from about 1948. Second, the reconstructed datasets are only at the surface and are only monthly means. Monthly means, while valuable in many respects, are unable to capture either high-frequency, synoptic-scale weather events (such as intense extratropical cyclones), or lower-frequency, planetary-scale climate events (such as blocking or the Madden–Julian oscillation) that are of interest in climate research. And finally, the only daily dataset for the first half of the twentieth century, the Northern Hemisphere SLP grids, is also only of a surface field and has well-documented problems. One might consider reanalyzing the available historical data to extend the record. Unfortunately, the modern reanalysis methodology of using all available observations has resulted in significant inhomogeneities from the time-changing observation network. These range from understated storm-track variability (Harnik and Chang 2003; Chang and Fu 2003; Hodges et al. 2003) to incorrect tropical variability (Newman et al. 2000) and spurious long-term trends (Trenberth and Smith 2005; Bengtsson et al. 2004a,b; Kinter et al. 2004; Kistler et al. 2001; Basist and Chelliah 1997). As one attempts to reanalyze the early twentieth century, or even the nineteenth century, scant upper-air data will be available (Bronnimann et al. 2005). Recent results suggest that the current generation of reanalyses depends on the upper-air data (Bengtsson et al. 2004b; Kanamitsu and Hwang 2006) to produce reasonable tropospheric fields. There are new research efforts to remedy this situation. Aided by the large quantity of newly recovered pressure observations, the European and North Atlantic Daily to Multidecadal Climate Variability (EMULATE) project has used statistical reconstruction to create 150 yr of daily sea level pressure maps over the data-rich North Atlantic and Europe (Ansell et al. 2005, manuscript submitted to J. Climate). The question remains open as to whether modern data assimilation systems can derive useful information.
Why focus on (tropical) rainfall?

Attribution of climate trends require knowing the trends in oceanic precipitation. Can the 20CRv2 fill the gaps?
Why focus on (tropical) rainfall?

Attribution of climate trends require knowing the trends in oceanic precipitation. Can the 20CRv2 fill the gaps?

**Example:** the idea that trends in the NAO are forced by the warming of the Indian Ocean rests on simulations that produce enhanced rainfall for warmer SST. Can we confirm or reject this link?
Climatology: MAM seasonal means

- **OBS**
- **20CRv2**
- **NCEP–DOE Reanalysis**
- **NCEP2**
Variability of seasonal means:
Can we trust the 20CRv2 estimates for the pre-satellite era?

1. Does the 20CRv2 reproduce the rainfall anomalies (land and ocean) over the satellite era?

2. How does it compare with (i) models that only know SST and (ii) reanalyses that assimilate more data?

3. How important is the quality and density of the assimilated data, that is, how much does the fit with observations vary over time?
Seasonal cycle of the anomaly pattern correlation over 1979-2008
Temporal anomaly correlation over 1979-2008
Mediterranean Winter

SST + SLP

20CReV2 0.87

ALL OBS

ERA-int 0.97

NCEP-DOE 0.88
Southwest US Winter
Each 20CRv2 ensemble member tracks observations as well as the ensemble mean. Largest spread and worst fit go together.
How does 20CRv2 perform in the Sahel?

- CCM3: > .21
- AM2: > .60
- NSIPP1: > .60
- ERA-I: > .15
- NCEP-II: > .71
In tropical locations, the best skill is at the edge of the convection centers, indicating that the 20CRv2 might be used to track the ITCZ location.

The skill at daily timescale has similar pattern, if overall lesser values.
Time evolution of regional pattern correlations (20CRv2,OBS) for seasonal mean rainfall
Conclusions:

20CRv2 captures the winter variability of rainfall in the mid-latitudes with great accuracy (comparable to ERA-interim).

Summer rainfall and tropical rainfall are not captured well enough to constrain the long-term trends.

The skill at the edge of the ITCZ suggests that the 20CRv2 might be used to track the position of convective centers (albeit probably not their intensity).

More observations can further improve the 20CRv2 performance, but even a sparse record is sufficient to constrain seasonal variability in the winter mid-latitudes.