ATMOSPHERIC REANALYSES: A MAJOR RESOURCE FOR CLIMATE SERVICES

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Atmospheric reanalyses have greatly improved our ability to analyse past climate variability. Further improvements to reanalyses, including expansion to encompass the ocean, land and sea-ice domains, hold promise for extending their use in climate change studies, research and applications.

Atmospheric analyses provide a synthesis of the available observations in the context of a physical model. Global analyses have been routinely done since the late 1970s for purposes of numerical weather prediction (NWP) and have been instrumental in shaping our understanding of climate variations on relatively short time scales, but the frequent changes in procedures used introduced many spurious variations in the perceived climate leading to a call to reanalyze the past observations using a constant state-of-the-art data assimilation system.

In spite of their shortcomings, the reanalysis products have proven to be among the most valuable and widely used in the history of climate science, as indicated both by the number of scholarly publications that rely upon them and by their widespread use in current climate services. In principle, through the reanalysis process, more complete and quality controlled observations are used with advantage of hindsight of problems in the original analysis, and with the benefit of a more up-to-date and constant state-of-the-art model. The full synoptic variability of the atmosphere and its evolution is captured. Comprehensive global gridded fields of variables result from this process.

The first generation of atmospheric reanalyses in the mid to late 1990s had substantial problems that limit their use, particularly for global climate change and variability studies. A second generation has now been done and newer reanalyses are recently complete or underway. A summary of the active reanalyses, their vintage and approximate resolution is given in Table 1.

A new reanalysis of the atmosphere, ocean, sea ice and land over 1979-2009 is being produced by NCEP/NOAA under the Climate Forecast System Reanalysis (CFSR) project and will continue with updates.

The NASA/Goddard atmospheric global reanalysis project is called the Modern Era Retrospective-Analysis for Research and Applications (MERRA). MERRA products are available on-line for 1979 to 2009 and ongoing.

ECMWF is currently producing ERA-Interim, a global reanalysis since 1989 and ongoing. As the name suggests, ERA-Interim represents a step towards ECMWF's next generation reanalysis system, tentatively called ERA-75, which will span at least a 75-year period, extending back to the first half of the 20th century. The target is to begin producing ERA-75 in 2013.

Following the successful completion of the JRA-25, the second Japanese atmospheric reanalysis project JRA-55 started in 2009 and the reanalysis period will be extended for 55 years from 1958 to 2012.

The Twentieth Century Reanalysis Project (C20r) is a promising new ensemble of reanalyses based solely on surface observations, and sea level pressure and sea surface temperature observations, with a goal to provide over 100 years of reanalyses along with uncertainty estimates.

Table 1. Summary of the main atmospheric reanalyses that are current or underway, with the horizontal resolution (latitude; T159 is equivalent to about 0.8°), the starting and ending dates, the approximate vintage of the model and analysis system, and current status.

Reanalysis	Horiz. Res.	Dates	Vintage	Status
NCEP/NCAR R1	T62	1948-present	1995	ongoing
NCEP-DOE R2	T62	1979-present	2001	ongoing
CFSR (NCEP)	T382	1979-present	2009	thru 2009, ongoing
C20r (NOAA)	2°	1891-2008	2009	complete, in progress
ERA-40	T159	1957-2002	2004	done
ERA-Interim	T255	1989-present	2009	ongoing
JRA-25	T106	1979-present	2006	ongoing
JRA-55	T319	1958-2012	2009	underway
MERRA (NASA)	0.5°	1979-present	2009	thru 2009, ongoing

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Besides improvement in the assimilating model and much better resolution, the datasets that have been analyzed have also evolved. Nonetheless, a serious problem is effects of changes in the observing system that produced spurious changes in the perceived climate. As a result, trends and low frequencies have been unreliable; this problem is exacerbated by model bias.

The several reanalyses that have been conducted have used a stable data assimilation system and have produced fairly reliable atmospheric climate records that have enabled (i) climatologies to be established; (ii) anomalies to be calculated; (iii) empirical and quantitative diagnostic studies to be conducted; (iv) exploration and improved understanding of climate system processes to be developed; and (v) model initialization and validation to be performed. The products provide the essential foundation for an accurate assessment of current climate ("climate nowcasts"), diagnostic studies of features such as weather systems, monsoons, El Niño-Southern Oscillation and other natural climate variations, seasonal prediction, and climate predictability. The reanalyses have provided a vitally needed test bed for model improvement on all time scales, especially for seasonal-to-interannual forecasts. Moreover, the basic assimilation and prediction systems are improved as deficiencies are identified and corrected by applying them both in reanalysis and routine weather and climate prediction.

Global reanalysis is also the foundation for regional reanalysis projects and downscaling where detailed climatologies can be prepared to support studies of local climate and climate impacts. There has been some progress in the use of reanalysis to investigate the difficult problem of the detection and attribution of long-term climate trends and variability. Reanalysis in the ocean and atmosphere has helped identify and correct deficiencies in the observational record, including the recovery of additional observations. Hence greatly improved basic observations and data bases are a side product of reanalyses.

Research into bias corrections and advanced reanalysis techniques is showing promise, and further reanalysis efforts are needed. A challenge is to improve estimates of uncertainty in the reanalysis products. Problems of biases in models and data are intricately connected with this challenge, because the ability to provide meaningful uncertainty estimates for reanalysis products ultimately depends on having information about the accuracy of the input data. Satellite instruments in particular can have substantial systematic errors that can dwarf the useful signal in the data. These errors are different for each instrument and can vary in space and time in a complex manner. In well-observed regions of the atmosphere it is possible to automatically correct such errors during the reanalysis procedure.

Some biases arise because the reanalyses are produced with specified sea surface temperatures (SSTs) that can not respond to large fluxes in one direction or the other, and thus there is an infinite source of heat and moisture at the surface that is not possible in a fully coupled system. Hence, even for a model that is perfectly in energy balance in the framework of the coupled system, as long as the model contains biases, the energy balance will be disrupted by specifying the SSTs.

Reanalyses to date have mainly focussed on producing the best set of analyses given the available observations. To reduce spurious trends, it is highly desirable to have one or more reanalyses performed with the objectives of producing the most consistent climate record, and which therefore confronts the observing system changes in new ways. This may require further observing system experiments and use of reduced observational datasets. Some plans are underway along these lines but have yet to take concrete form.

Reanalysis has proved to be as valuable for monitoring climate, climate research and applications as was believed when it was proposed twenty years ago. However, as the scope of global reanalysis grows, the research effort needed to optimise the benefits is so large that international cooperation will be essential. The potential for products useful for oceanography that are both bias free and which capture the variability on time scales from hours to decades is great.

A U.S. workshop is scheduled for November 2010 to take stock of the newest reanalyses, and plans are now underway for the next – the Fourth International Reanalysis Conference in the United States probably about April 2012.