

## Web-Based Reanalysis Intercomparison Tools (WRIT) to Allow Easy Analysis and Comparison of Reanalyses and Other Datasets

Catherine A. Smith, Gilbert P. Compo, and Don K. Hooper

*Cooperative Institute for Research in Environmental Sciences, University of Colorado,  
and NOAA/Earth System Research Laboratory, Boulder, Colorado*

### 1. Motivation

There are currently at least 8 major reanalysis datasets available for scientists to study. Each dataset uses a different model, different observations and different assimilation algorithms. Comparing the reanalysis fields to each other and to observations may yield insights into climate processes. A host of issues make this difficult. The reanalysis data are available from different organizations, are stored in different formats with different file name architecture, have differing resolutions, file attributes, variable names, and units. Generally speaking, users have to download the data, convert it to a useable format, store it locally, change variable names, re-grid if needed, convert units and write code general enough that applications such as NCL, GrADS, IDL, or others can be used to read each dataset and compare the desired variables. Even if the dataset can be read via OPeNDAP or a similar remote protocol, most of this work is still needed. All of these tasks take time, effort and money. Our group at PSD has expertise both in storing and making reanalysis datasets available and in creating web-based climate analysis tools that have been widely used throughout the meteorological community. To overcome some of the obstacles in reanalysis inter-comparison, we have created a web-based reanalysis inter-comparison tool (WRIT), which allows users to easily plot and compare reanalysis datasets. Users may still want to download and analyze data but by using the page, they can test hypotheses and create basic plots to both narrow down scientific questions and have basic results. WRIT also facilitates the mission of the Reanalyses Intercomparison and Observations web-site (<http://reanalyses.org>) as a convenient toolkit for the study of these datasets.

### 2. Project overview

The reanalyses datasets we chose to make available now are the NCEP/NCAR Reanalysis I (Kalnay *et al.* 1996), NCEP/DOE Reanalysis 2 (Kanamitsu *et al.* 2002), ECMWF Interim Reanalysis (Dee *et al.* 2011), NASA Modern Era Reanalysis for Research and Applications (MERRA) (Rienecker *et al.* 2011), NCEP Climate Forecast System Reanalysis (CFSR) (Saha *et al.* 2010), and the NOAA-CIRES 20th Century Reanalysis V2 (20CR) (Compo *et al.* 2011) with more to be added later. Basic attributes are given in Table 1. The earliest reanalysis starts in 1871 and some are available near present. We have these pressure level variables: geopotential height, zonal and meridional winds, omega, air temperature, relative humidity and specific humidity. Each dataset outputs on different pressure levels but they generally start at 1000mb and go up as high as 1mb. We have a common set of levels available for all datasets that we use when making cross-

Reanalysis	Year Range at PSD	Levels/Output Resolution at PSD*
NCEP/NCAR R1	1948-present	17/2.5x2.5
NCEP/DOE R2	1979-Jun 2012	17/2.5x2.5
MERRA	1979-2012	31/1.25x1.25
20 <sup>th</sup> Century	1871-2010	24/2.0x2.0
ERA Interim	1979-2011	30/1.5x1.5
NCEP CFSR	1979-Mar 2011	37/2.5x2.5

**Table 1** Characteristics of the Reanalysis datasets as stored at NOAA/ESRL PSD.

section comparisons. Single level variables include 2m air temperature, 10m zonal and meridional winds, sea level pressure and precipitation rate. For comparison with observations, we also have available the U of Delaware V3.01 (Willmott and Matsuura 1995) land air temperature and precipitation dataset, NOAA's GHCN\_CAMS air temperature (Fan and van den Dool 2008), NOAA/NASA global precipitation analysis (GPCP) (Adler *et al.* 2003), Climatic Research Unit (CRU) air temperature (Mitchell and Jones 2005) and the NOAA precipitation analyses (Chen *et al.* 2002) over land. These datasets can be directly compared with 2m air temperature and precipitation from reanalyses. Comments and suggestions can be made at reanalysis.org. Additionally, user plots can be posted there.

Initially, we have developed three web tools. These are available from the URL <http://esrl.noaa.gov.psd/writ/> and include

1. Monthly/Seasonal plotting page: Plots composites and differences from the datasets including maps and vertical cross-sections
2. Monthly Timeseries:
3. Trajectory Plotting Tool:

We plan to add more tools later including shorter time-scales and more analyses types.

The screenshot shows the NOAA Earth System Research Laboratory Physical Sciences Division website. The main content area is titled "Web-based Reanalysis Intercomparison Tool: Monthly Maps". It includes a navigation menu with "Physical Sciences Division", "About", "Contact", "Research", "Data", "Products", "Outreach", and "Intranet". A sidebar on the left contains "Help" and "WRIT Monthly Map Tool" sections. The main content area has a red warning message: "The NOAA OLR dataset is missing Dec 1 and NCEP is investigating." Below this, there is a form with the following options:

- Dataset 1?** NCEP/NCAR R1 (dropdown) **Optional: subtract Dataset 2?** none (dropdown)
- Which variable?** Geopotential Height (dropdown) **Level?** 1000mb (dropdown)
- Enter years for composites (from 1 to 20):** e.g. 1972. For seasons that span a year (e.g. DJF), please enter year of the LAST month. (Input fields for years)
- OR**
- Enter year range (limit 50 years)**  
1st Year of range to last year of range (Input fields)
- 1st month "season"** Jan (dropdown) **2nd month of season?** Jan (dropdown)
- Enter years if subtracting a different set of dates from 1st dataset (from 1 to 20):** e.g. 1972. For seasons that span a year (e.g. DJF), please enter year of the LAST month. (Input fields for years)
- OR**
- Enter year range (limit 50 years)**  
1st year range to last year of range (Input fields)
- Variable statistic?**  Mean  Anomaly  Long Term Mean (climatology)
- Plot Type?**  Map  Height/Latitude  Height/Longitude
- Map Region (if Map)** All (dropdown)
- If Custom map OR Height/Latitude OR Height/Longitude:**

Fig. 1 Web Page Interface for Monthly Map Page showing user options.

### 3. Code development

The web tools are coded similarly. All use HTML web forms that have all necessary options available. The form variables are sent to a Perl program that reads in and validates the options. The Perl program also returns the locations of the data files needed from each dataset. They also create the temporary files needed for the web and pass along the variables needed for analysis and for plotting. We use NCL for both the monthly plotting and the time-series pages. NCL reads in files easily and has many built-in routines for meteorological processing (such as creating climatologies or calculating area averages). The code performs

the necessary analysis. This includes taking into account the differing grids and grid resolutions, attributes, levels, etc. When necessary, plots or cross-sections are interpolated to the same grid, converting from low to higher resolution. The Perl routine processes the results from the NCL script and also generates KML/Google Earth for the monthly plotting page.

#### 4. Features highlight

##### a) First page: Monthly Plotting Page

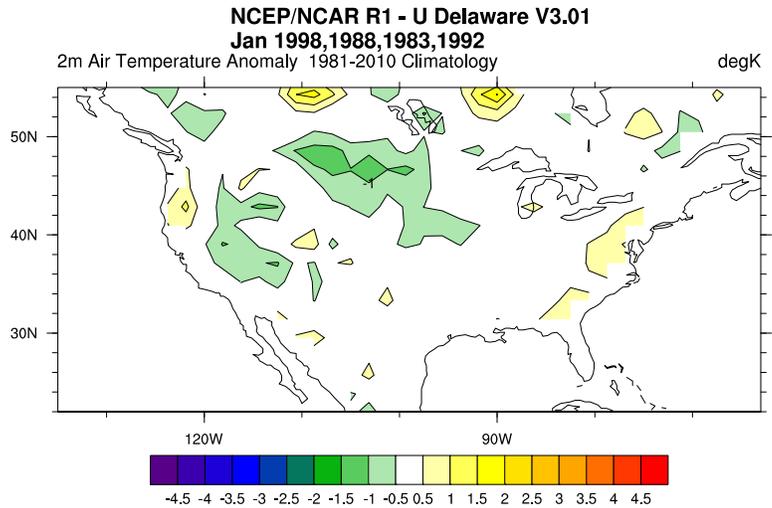
The interface, shown in Fig. 1, allows users to select one or two datasets, the level(s), the type of plot (map, latitude/height or longitude/height), the statistic (mean, anomaly, long term mean) and plotting options. They can also select a season and one or more years (for example, creating an El Nino composite). If two datasets are chosen, each grid or cross-section is calculated and then the resulting output differenced. Results are returned as images, NetCDF files and KML. Shown in Fig. 2 is a map of the difference between the NCEP/NCAR R1 and the U of Delaware 2m air temperatures for composite wintertime El Niño's. Fig. 3 shows the difference between zonally averaged winds for the 20CR dataset for 1970-1979 compared to 1990-1999.

##### b) Second page: Time Series Differences

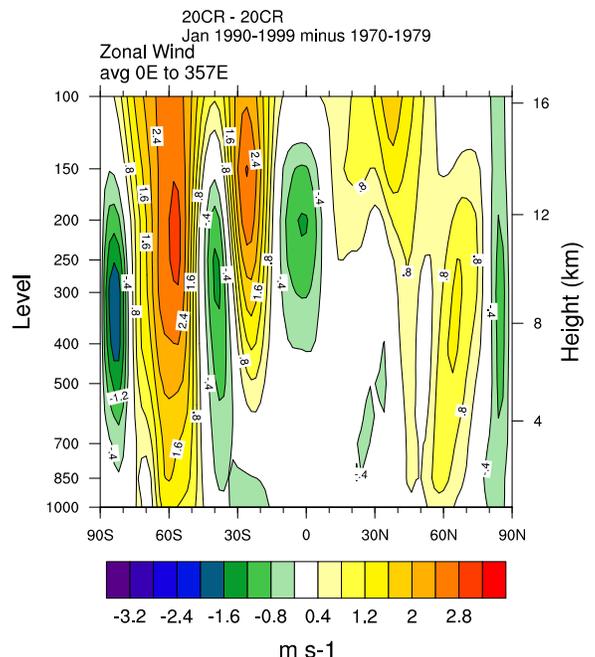
The interface for this page (not shown) is similar to the one used in the mapping page. The reanalysis datasets are the same as the mapping page but has just one observed dataset (more will be added). Selections include dataset, one or two variables/levels, area for 1<sup>st</sup> dataset, area for 2<sup>nd</sup> dataset, season, type of statistic and type of output plot. The types include two timeseries plots (same or different axis), difference of two timeseries, scatter plots, auto or cross correlation and distribution. Statistics from each plot (mean, median, standard deviation) are returned. Also returned is the correlation between two timeseries and the actual grid bounds used in each dataset (as grids differ for the different reanalyses). Shown in Fig. 4 is the difference of precipitation in the eastern tropical Pacific (4°N-4°S, 120°E-160°E) between the NCEP/NCAR R1 and the GPCP V2 dataset. Fig. 5 shows a scatter plot of 20CR vs. ERA-Interim zonally averaged 2 m air temperature south of 70°S.

##### c) Third page: Trajectory Tool

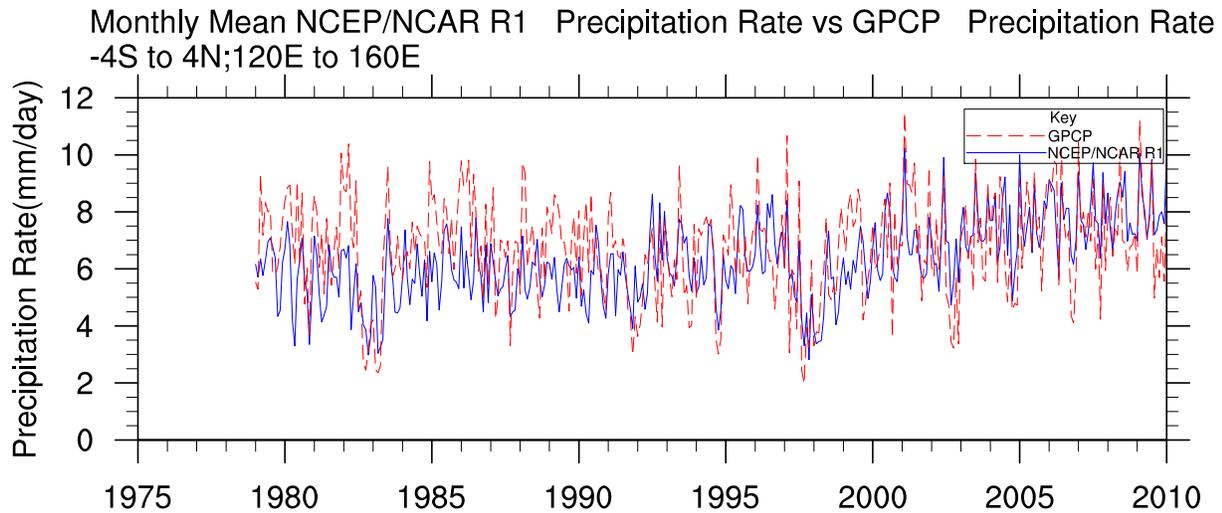
Finally, we have created a trajectory plotting tool that uses the three different reanalysis datasets in which we have 4-times daily data available: NCEP/NCAR R1, NCEP/DOE R2 and the 20CR. Users can select a start/end time, an initial level and location and plot the trajectory based on the 3-D winds from the reanalyses. The trajectory



**Fig. 2** Difference between the NCEP/NCAR R1 and the U of Delaware 2m air temperatures for January El Niño composite.



**Fig. 3** Plot produced from the WRIT Monthly Mapping Page, showing the cross-section of January zonal mean of zonal wind difference between 1970-1979 and 1990-1999 for the 20CR.



**Fig. 4** Plot is produced from the WRIT Time-Series Page, showing a comparison between the NCEP/NCAR R1 precipitation and that of the GPCP observational dataset over the eastern Tropical Pacific.

can be forward or backward. The trajectory code was obtained from the U of Australia in Melbourne courtesy of Ian Simmonds. It is based on 3-D advective model that is solved using a 4th order Runge-Kutta scheme. The trajectory is calculated using a time step of 1 hour and the results plotted on a map and are available as KML and in a Google Earth Web plugin. Plotted in Fig. 6 is a trajectory for the 20CR dataset for wintertime (October 28 1991; the so-called “Perfect storm”) for the starting location 48°N; 310°E. Also plotted is the pressure level at each trajectory point. Users can download the NetCDF files containing the trajectory points.

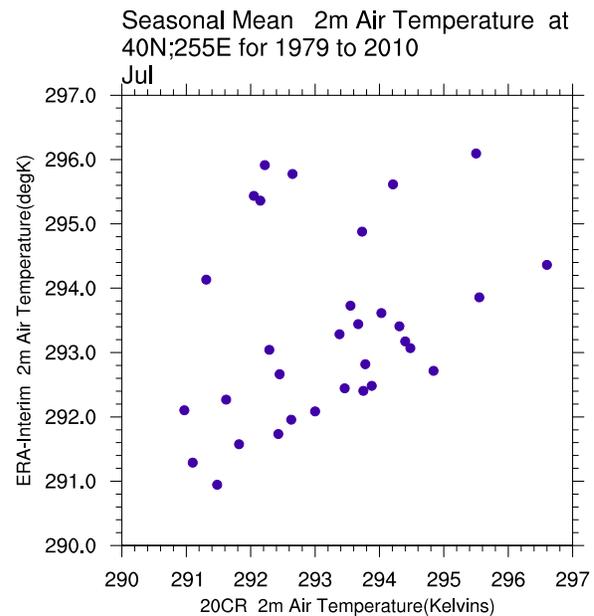
## 5. Summary/discussions and future works

### a) More features

We plan to add more observational datasets to the mapping and time series webpage. We also hope to add one or more reanalyses datasets to the trajectory tool. Features we plan to add to the mapping page include more observational datasets, the ability to obtain dates to composite with from a user supplied date file or from a climate index (*e.g.* highest PNA months). For time series, we will add climate indices as well as user files input via FTP. We may also look at fitting distributions. We may add additional plots such as whisker plots. Users can leave comments and suggestions at <http://reanalyses.org/atmosphere/web-based-reanalysis-intercomparison-tools-writ>

### b) Other issues

We started the project by attempting to use files via OPEnDAP. While we have many datasets at PSD, we cannot store all of them as we hoped that by being able to access datasets remotely, we could make available more datasets and variables. This was only partially successful. While we could read our own data via OPEnDAP easily, other datasets took too long depending on how their server was set up. In addition, we



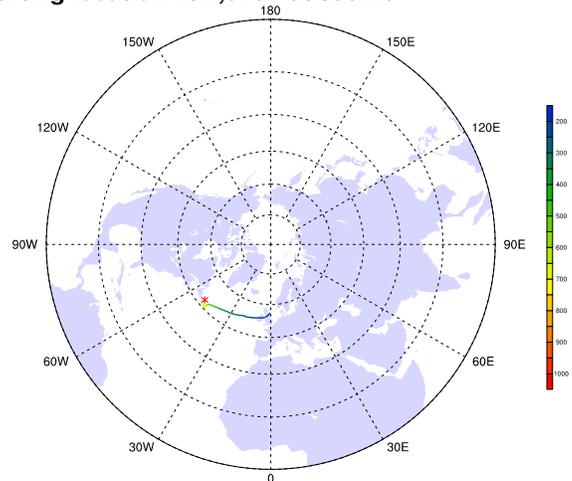
**Fig. 5** Scatter plot produced from the WRIT Monthly Time-Series Webpage showing 2m air temperature for July over Boulder, CO (40°N; 255°E) for the 20CR dataset vs. the ERA-Interim dataset.

had to rely on the metadata supplied at the source. In some cases the metadata was lacking, hard to use and/or in error. The metadata issues are likely addressable but access time remains an unresolved issue.

## References

- Adler, R.F., G.J. Huffman, A. Chang, R. Ferraro, P. Xie, J. Janowiak, B. Rudolf, U. Schneider, S. Curtis, D. Bolvin, A. Gruber, J. Susskind, and P. Arkin, 2003: The Version 2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis (1979-Present). *J. Hydrometeorol.*, **4**, 1147-1167.
- Chen, M., P. Xie, J. E. Janowiak, and P. A. Arkin, 2002: Global Land Precipitation: A 50-yr Monthly Analysis Based on Gauge Observations. *J. of Hydrometeorol.*, **3**, 249-266.
- Compo, G.P., J.S. Whitaker, P.D. Sardeshmukh, N. Matsui, R.J. Allan, X. Yin, B.E. Gleason, R.S. Vose, G. Rutledge, P. Bessemoulin, S. Brönnimann, M. Brunet, R.I. Crouthamel, A.N. Grant, P.Y. Groisman, P.D. Jones, M. Kruk, A.C. Kruger, G.J. Marshall, M. Maugeri, H.Y. Mok, Ø. Nordli, T.F. Ross, R.M. Trigo, X.L. Wang, S.D. Woodruff, and S.J. Worley, 2011: The Twentieth Century Reanalysis Project. *Quart. J. Roy. Meteorol. Soc.*, **137**, 1-28. doi: 10.1002/qj.776
- Dee, D. P., and Co-authors, 2011: The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. *Quart. J. Roy. Meteorol. Soc.*, **137**, 553-597. doi 10.1002/qj.828.
- Fan, Y., and H. van den Dool, 2008: A global monthly land surface air temperature analysis for 1948-present. *J. Geophys. Res.*, **113**, D01103, doi:10.1029/2007JD008470.
- Kalnay, E., and Co-authors, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437-470.
- Kanamitsu, M., W. Ebisuzaki, J. Woollen, S.-K. Yang, J. J. Hnilo, M. Fiorino, and G. L. Potter, 2002: NCEP-DOE AMIP-II Reanalysis (R-2). *Bull. Amer. Meteor. Soc.*, **83**, 1631-1643. doi:10.1175/BAMS-83-11-1631.
- Mitchell, T.D., and P.D. Jones, 2005: An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *Int. J. Climatol.*, **25**, 693-712. doi: 10.1002/joc.1181.
- Rienecker, M.M., and Co-authors, 2011: MERRA - NASA's Modern-Era Retrospective Analysis for Research and Applications. *J. Climate*, **24**, 3624-3648. doi: 10.1175/JCLI-D-11-00015.1.
- Saha, S., and Coauthors, 2010: The NCEP Climate Forecast System Reanalysis. *Bull. Amer. Meteor. Soc.*, **91**, 1015-1057. doi: 10.1175/2010BAMS3001.1 .
- Willmott, C. J. and K. Matsuura, 1995: Smart interpolation of annually averaged air temperature in the United States. *J. Appl. Meteor.*, **34**, 2577-2586.

**Forward Trajectory from the NCEP/DOE Reanalysis,  
Date: 1991/10/28/0 to 1991/10/31/0  
Starting location 48N,310E at 850mb**



**Fig. 6** Trajectory plot made from the WRIT Trajectory Webpage showing the forward trajectory of a point started at 850mb, 48°N, 210°E on 0Z Oct 28 1991 using the NCEP/DOE Reanalysis 2 dataset.