Discontinuities in Reanalysis Datasets: the Effect on Climate Trend Study and an Ongoing Homogenization Effort on MERRA

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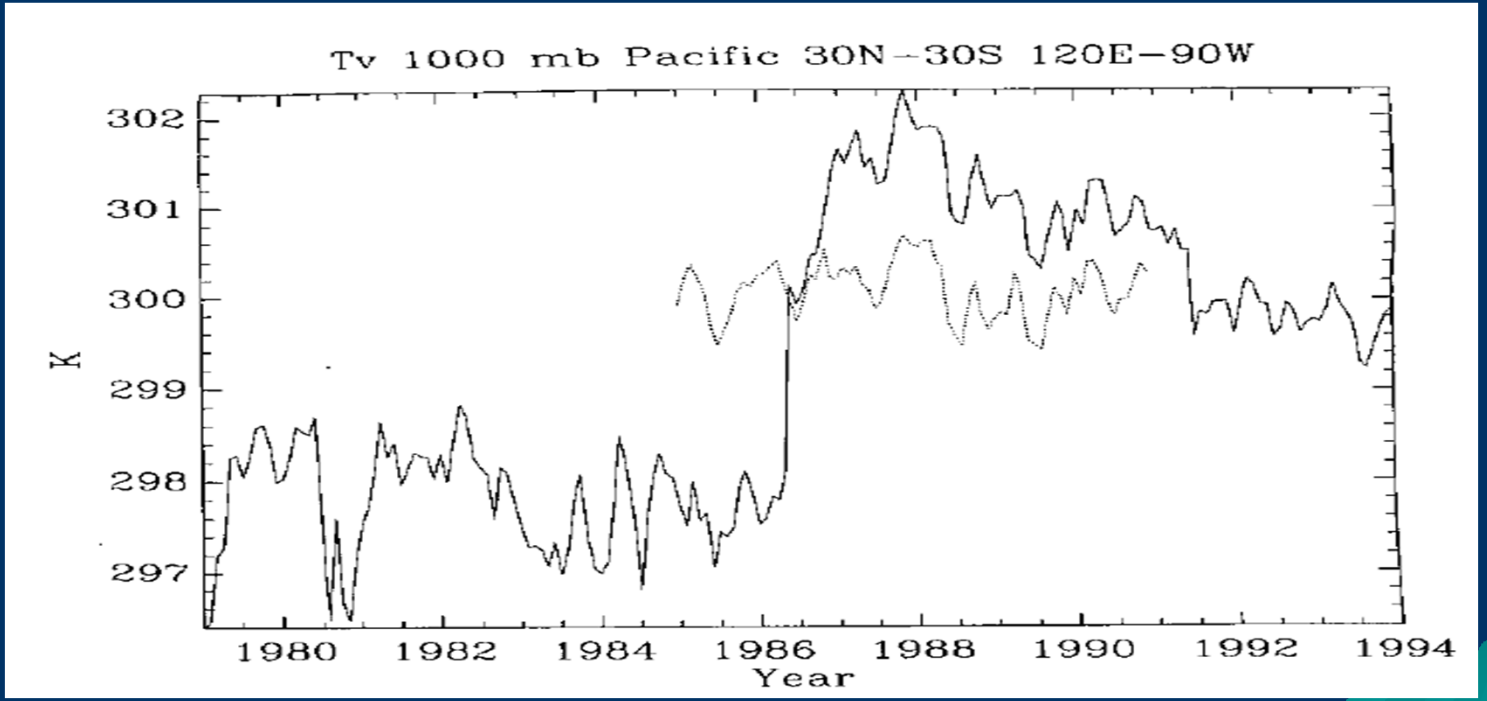
At the beginning, the idea of reanalysis was initiated for climate change study:

"to use a **frozen** state-of-the-art analysis/forecast system and perform data assimilation using past data" (Kalnay et al. 1996), thus "to produce **internally consistent, homogeneous, multivariate** data sets for the earth's climate system. … and such data sets will be quite **useful for studying global climate change**." (Bengtsson and Shukla 1988)

A fixed assimilation system eliminates inhomogeneity caused by analysis/model change:



Trace of the 1000-hPa virtual temperature (Kalnay et al. 1996)

The use of a stable data assimilation system in production of reanalysis has produced fairly reliable records. (Trenberth 2005)

More and more climate research activities are associated with reanalysis datasets:

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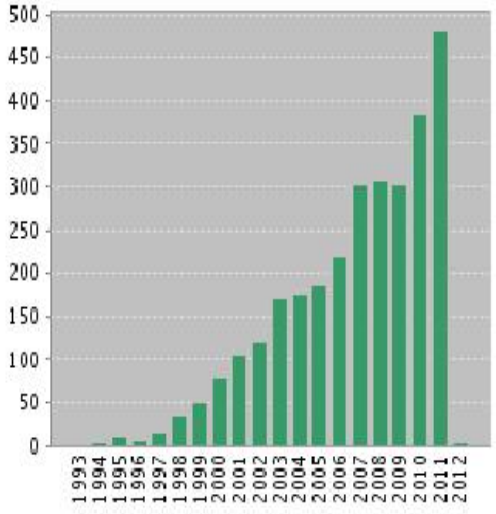

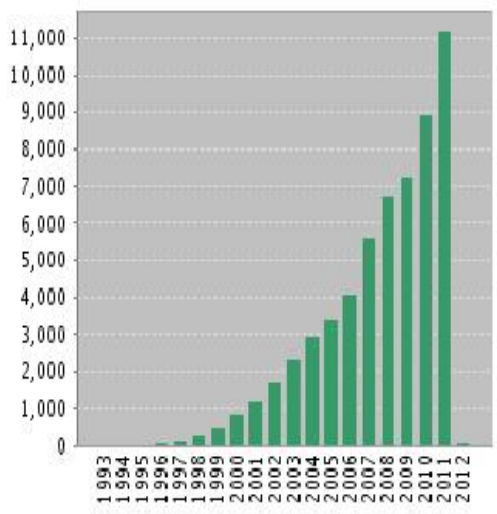

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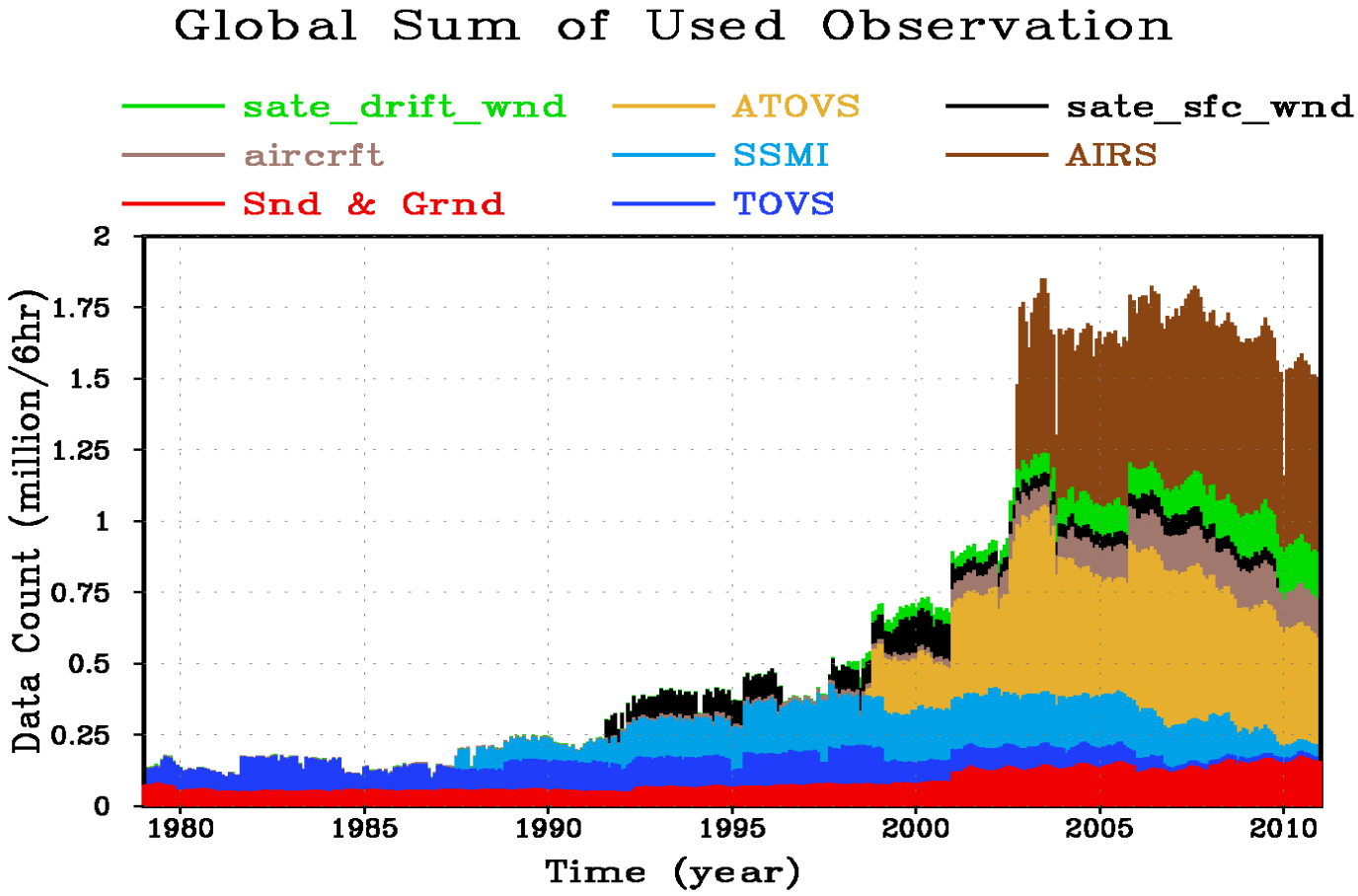
Except fixed model/analysis system, another principle of reanalysis is to use observation as much as available so to produce data of the highest quality. As the observing system changes along the time, especially the sequential introduction of new kinds of spaceborne platforms, more and more observations are assimilated in reanalysis datasets.

The evolution of used observation count in MERRA



RIENECKER et al., 2011

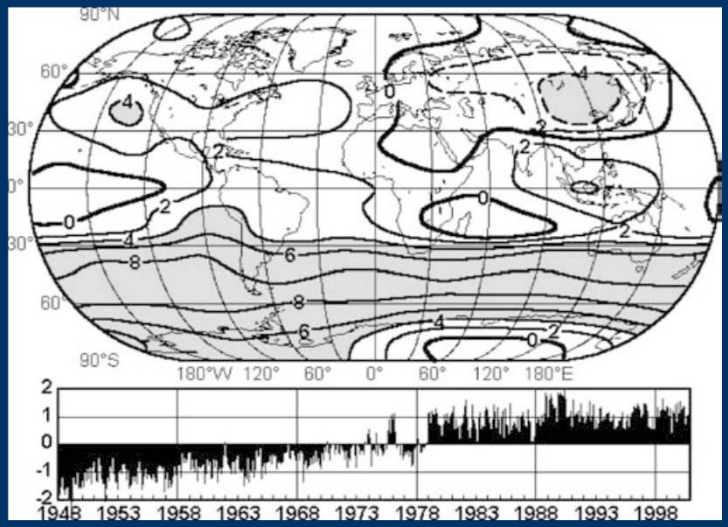
The changes in observing system bring impact on reanalysis in two aspects:

- On one hand, the increase of observation input enhances the quality of a reanalysis along the time.
- On the other hand, intermittent changes of observation input means possible temporal inhomogeneity in reanalysis time series if bias exists in observation and/or model.

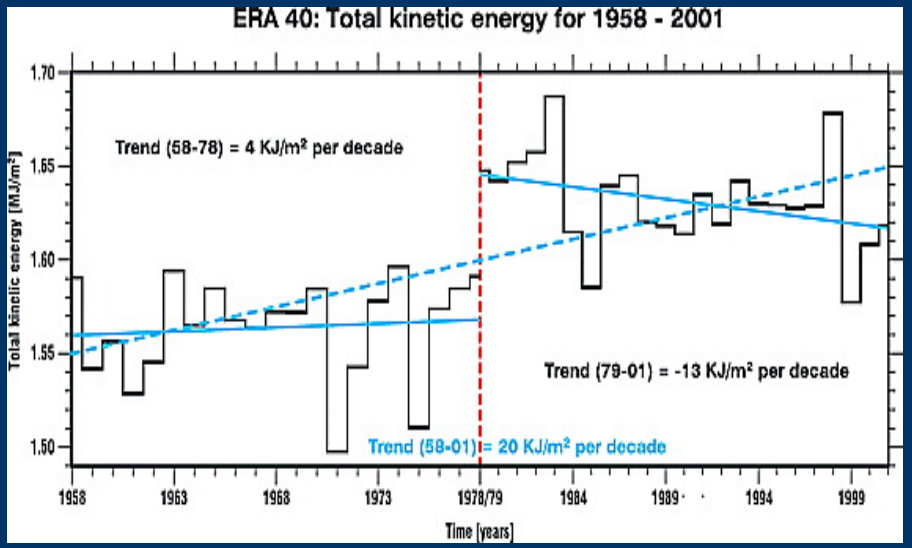
Ideally, when a reanalysis dataset is produced, if both observation and model are not biased, there will be no problem in long-term temporal consistency.

In reality, both observation and model are more or less biased. As the global observing system changes along the time, the homogeneity is hard to be kept, even with fixed model and analysis scheme.

Introduction of satellite data in 1979 causes jumps in both NCEP/NCAR and ERA-40 reanalysis:

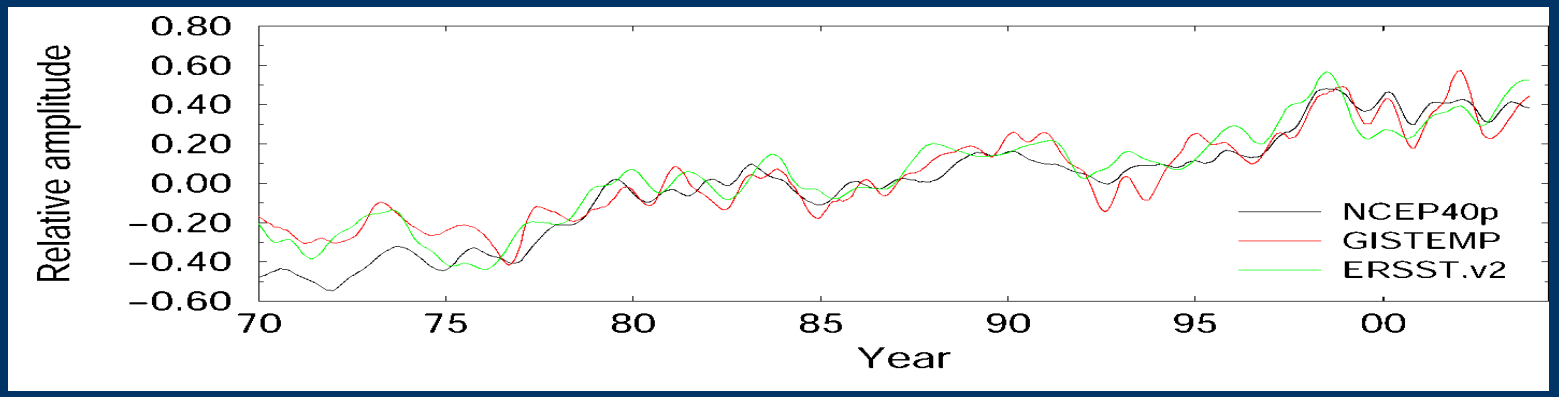


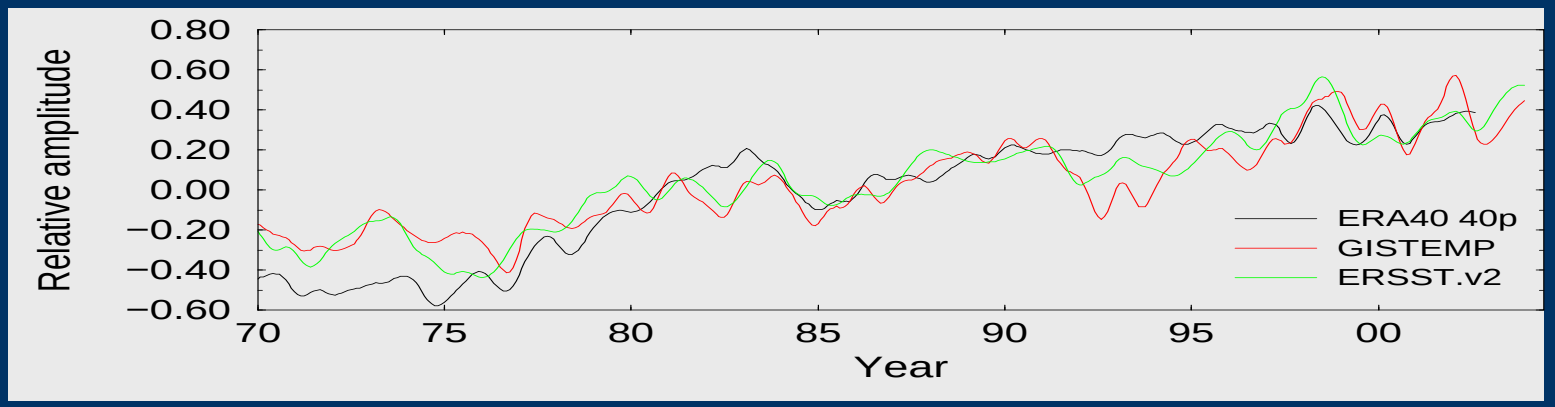
First REOF for air temperature at 300 hPa based on NCEP/NCAR reanalysis. This pattern explains 19.5% of the record variability (Sturaro 2003).



Total kinetic energy, K, annually averaged, calculated from ERA40 for the period 1958–2001. A trend line is indicated for the whole period as well as separately for the two periods (Bengtsson et al. 2004).

Combined EOF analysis based on multiple parameters from reanalyses could obtain the trend timeseries close to those based on surface temperature datasets:

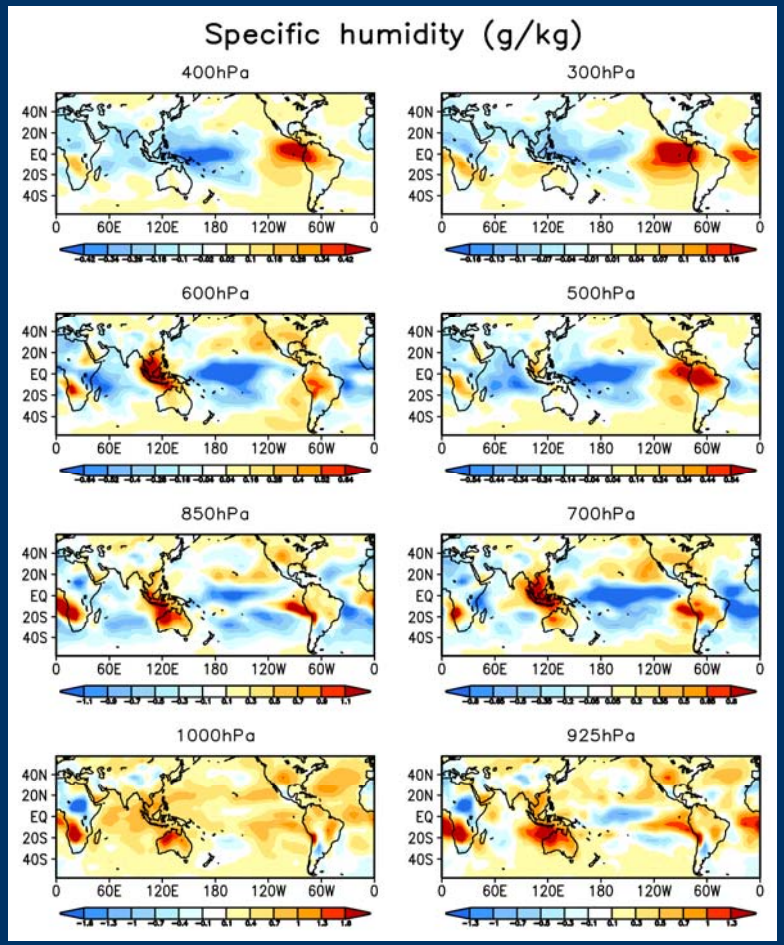




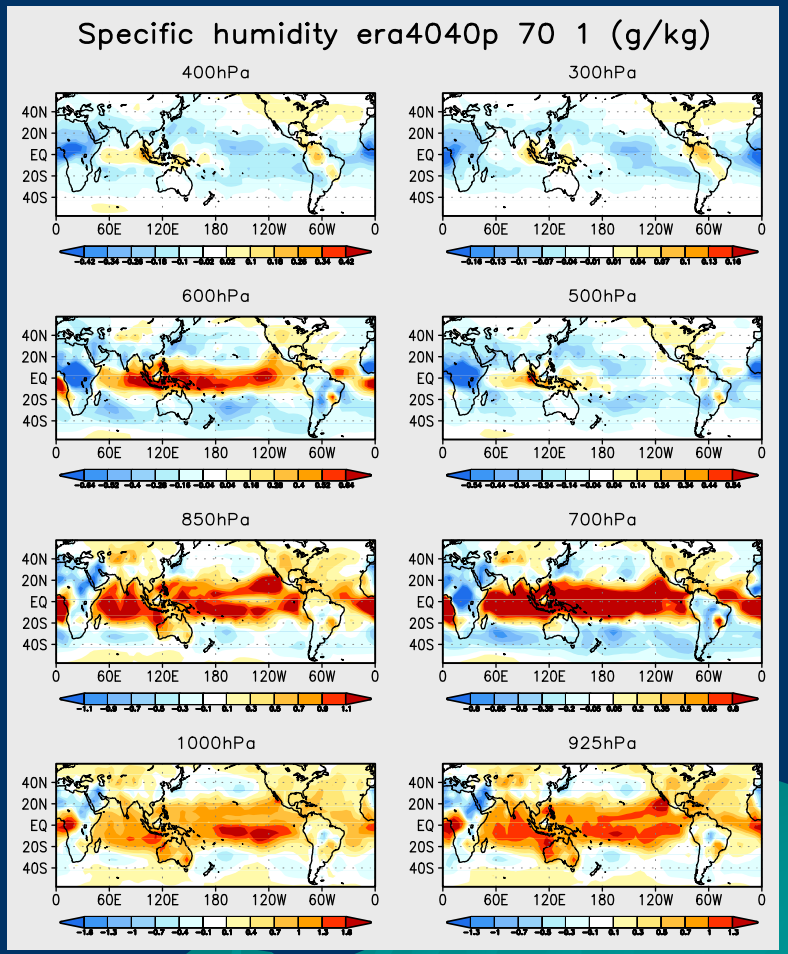
The trend mode PC timeseries of the ENSO-removed combined EOF analyses based on the atmospheric parameters from NCEP/NCAR (upper) and ERA-40 (lower) reanalyses (Chen et al., 2008).

But significant discrepancies are found in spatial patterns between the results based on NCEP/NCAR and ERA-40

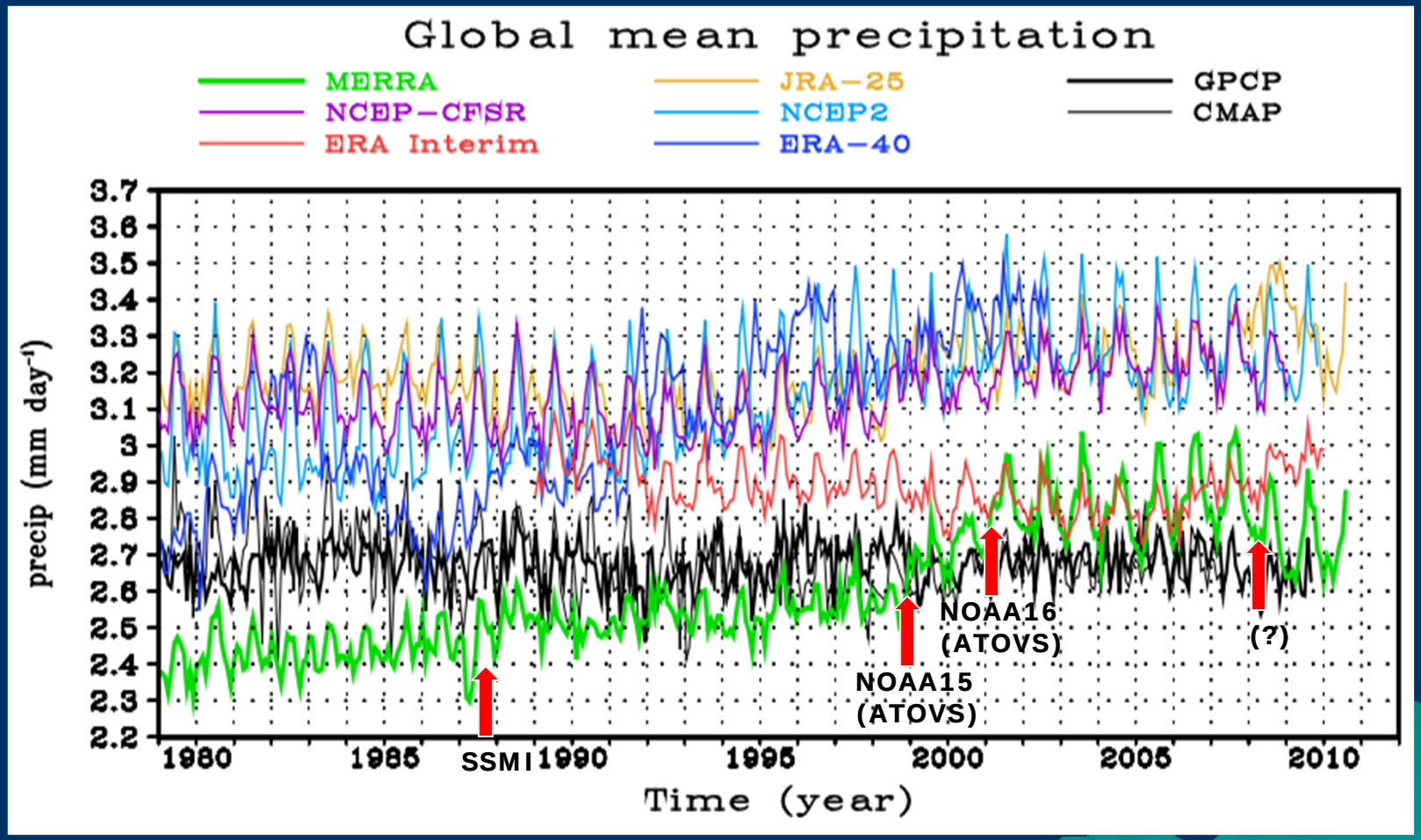
NCEP/NCAR



ERA-40



The recent reanalyses, including JRA-25, NCEP-CFSR, ERA Interim and MERRA, are not immune from the inhomogeneity issue caused by the changes of observing system.

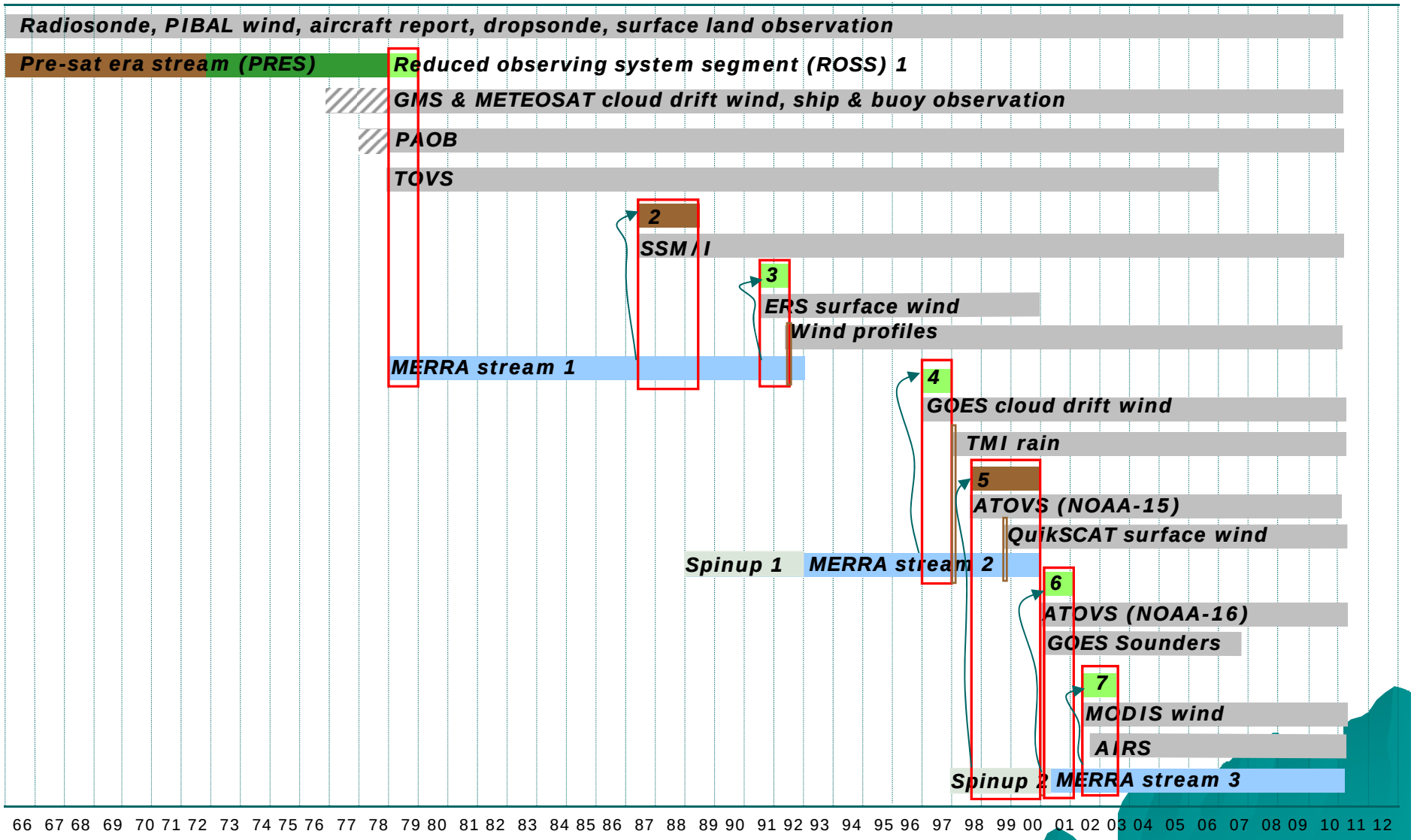


Like other reanalysis datasets, MERRA was initiated for climate study, but the issue of temporal inconsistency impedes the full realization of this goal. An effort is undergoing to address this issue.

The plan of MERRA Homogenization

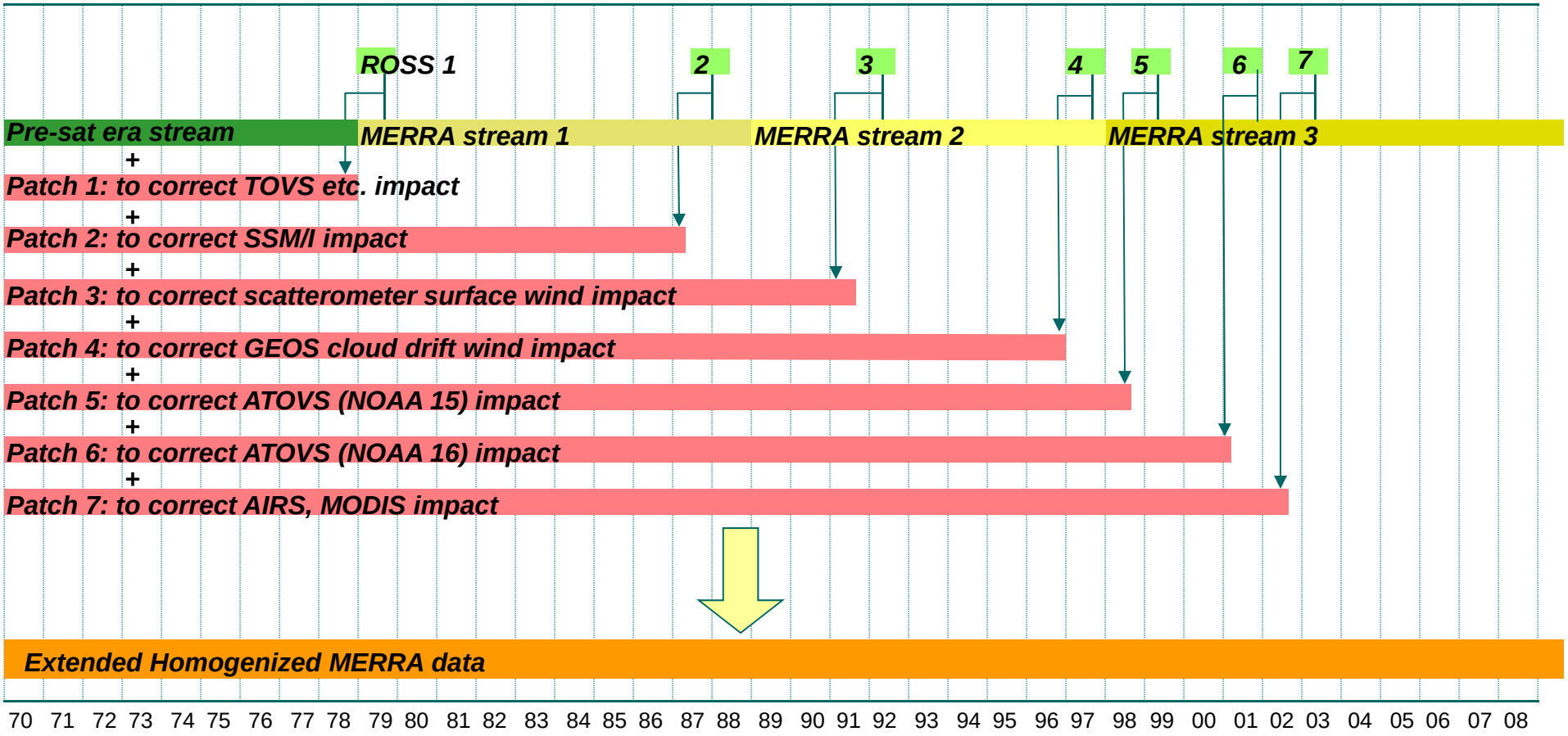
- Produce Reduced Observing System Segments (ROSS) of assimilation withholding new observation types when they are introduced in the MERRA data stream.
- By comparing a ROSS with the corresponding MERRA data segment, the impact of the related observation type can be cleanly isolated.
- The obtained information of the impacts will be used to generate patches to homogenize MERRA.

ROSSes to Address the Impacts of Introductions of New Observation Platforms



Grey: observations; Blue: MERRA streams; Brown: ROSSes done; Green: ROSSes to be done

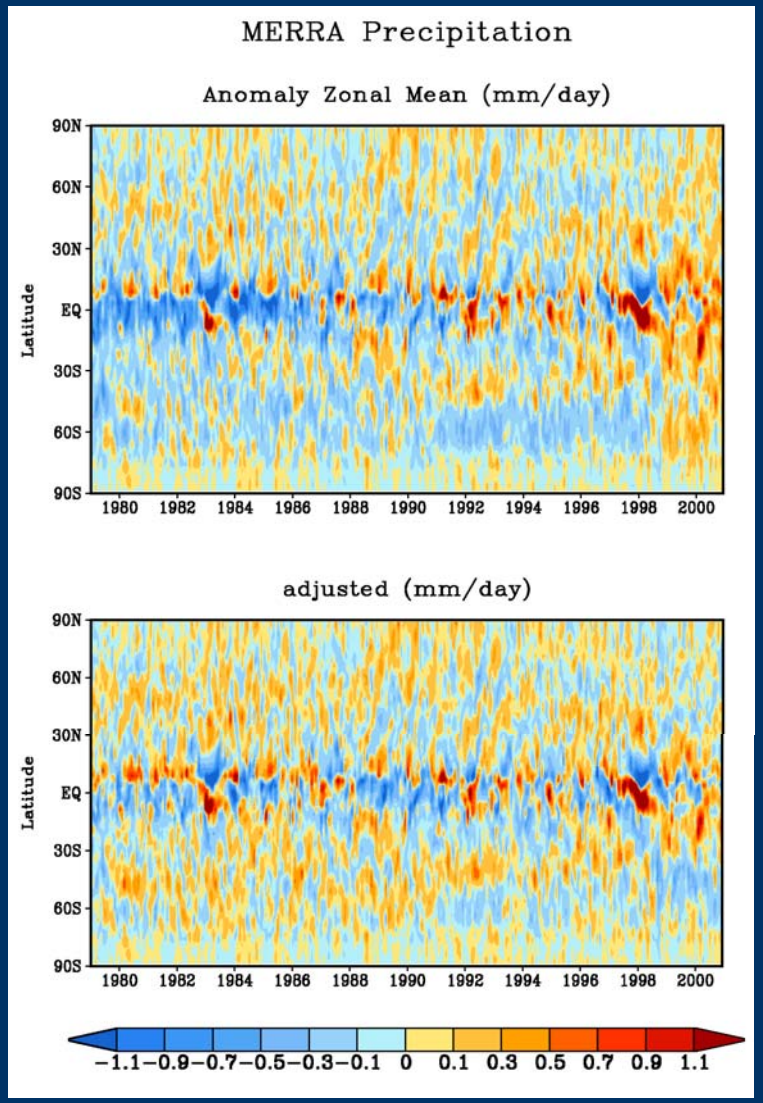
Produce Patches to Homogenize MERRA

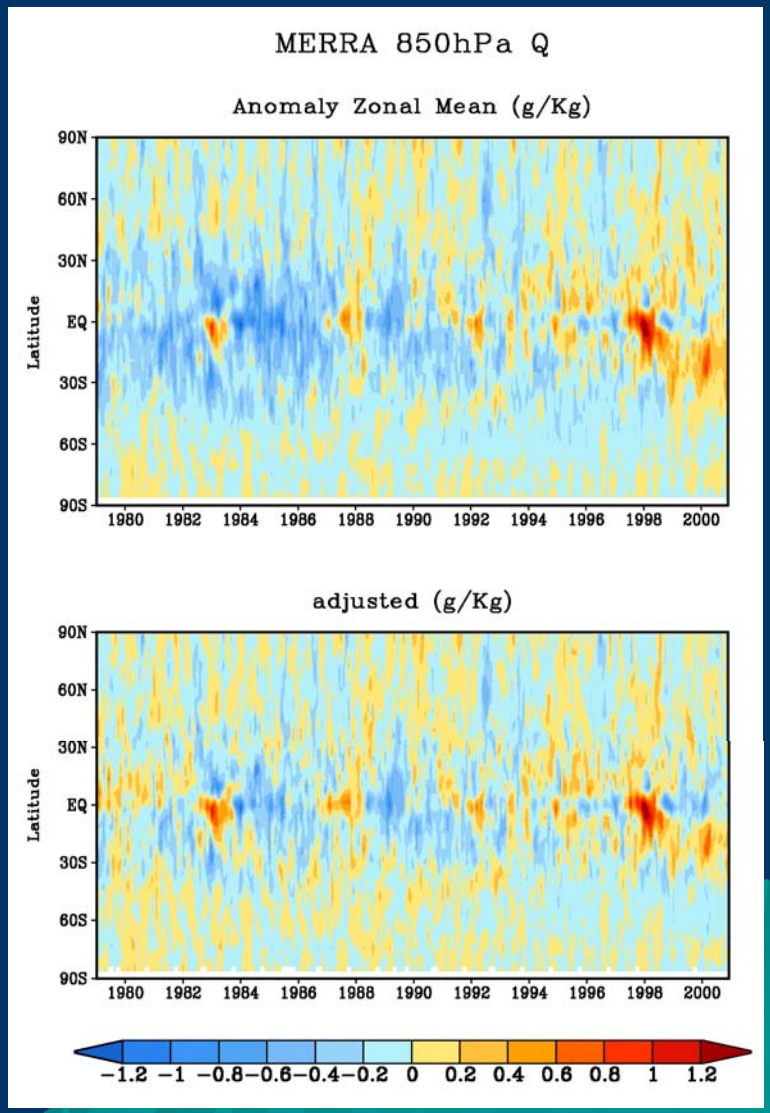


- Patches are applied on the MERRA data before the associated new observation, so the MERRA data in earlier period can be adjusted to match with data in later period.

- A pre-satellite era stream (1970 – 1979) will be produced, so the MERRA data can be extended to 1970. Including this period is important for climate change trend study, as the long-term trend can be distinguished from natural decadal variation by including the 1976 phase change of PDV into the timeseries (Chen et al. 2008).

Simple offset adjustment based on two ROSSes seems working for the monthly mean timeseries. More ROSSes and more sophisticated method will improve the result furthermore. Ongoing patch generation methods include posterior statistical process and prior model bias correction.





Important Climate Issues could be Addressed once MERRA is Homogenized

- To reconstruct the climate of the past 40 years more consistently.
- To clarify the three-dimensional trends of key meteorological parameters in the atmosphere and how these parameters are related to each other.
- To improve the understanding of the trend in the water and energy cycles, the fluxes at the top and bottom boundaries of the atmosphere.

Summary

- The historical changes of observing system cause inhomogeneities in reanalyses, and could compromise the related climate trend studies.

- A homogenization effort is ongoing for the NASA MERRA reanalysis, so to provide a reliable long-term reanalysis dataset for climate study. Preliminary results are encouraging.

Another detailed discussion about the impacts of SSM/I and NOAA-15 in MERRA will be presented on **2:15PM, Thursday**, 26 January 2012, in the **Room 340 and 341**, in the OSE and OSSE session of the 16th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface.