## Use of MERRA-2 for Atmospheric Chemistry and Transport Studies*

This is a brief guide concerning the use of MERRA-2 meteorological fields to study atmospheric composition based on transport modeling. The MERRA-2 file collections (*Bosilovich et al., 2015*) contain data written with different temporal frequencies and spatial resolution, but critically for transport studies there are two fundamentally different types of products: those labeled "ana" (*analysis*) and those labeled "asm" (*assimilation*). While both represent a blend between the underlying GEOS model and the observations, the "ana" products are the fields that result directly from the GSI analyses (labeled ANA in Fig. 1) while the "asm" products are the result of applying the Incremental Analysis Update, as described in *Bloom et al. (1996)* (labeled ASM in Fig. 1). The "ana" fields represent the best match to the global suite of observations at each analysis time, as determined by the optimal solution of the variational analysis technique. Because they are generated by forcing the GEOS model towards the analysis state, the "asm" output fields exhibit a greater degree of consistency among different fields than the "ana" product and also include global estimates of quantities that are not directly analyzed, such as vertical velocities. Because of this internal consistency of the fields, **the "asm" product is recommended for studies using nudged online GCMs, offline CTMs, and trajectory models.**

While the differences between the "ana" and "asm" products are generally quite subtle, there can be large and meaningful impacts on using them for certain types of study. Examples are for inferring trends in the Hadley Cell (*Garfinkel et al. 2015*) and for modeling lower stratospheric transport (*Orbe et al., 2017)*.

For MERRA-2 the collections that contain the three-dimensional winds and temperature fields U, V, OMEGA and T on model levels include the instantaneous three-dimensional collections *inst3_3d_asm_Nv* and their corresponding time-averaged product *tavg3_3d_asm_Nv*. It is these latter, three-hour (time) averaged data collections, that are recommended for use in constituent transport studies.

For MERRA, the collection *tavg3_3d_chm_Fv* includes the assimilated horizontal winds (U and V). For calculations that also require the vertical wind field (i.e. kinematic trajectories) the variables U, V and OMEGA are available in the assimilated state on pressure levels in the collection *inst3_3d_asm_Cp*. Users seeking the corresponding model-level fields will need to re-interpolate those fields from the pressure-level data. We strongly advise against combining the horizontal and vertical wind components from different collections, particularly if that means mixing analysed with assimilated fields, as such combinations of data are dynamically imbalanced and will lead to overly dispersive constituent transport.

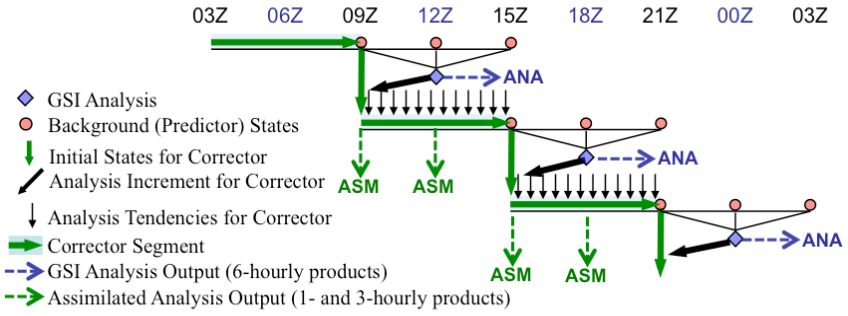


**Figure 1**: Schematic representation of the Incremental Analysis Update implementation in GEOS-5, modified from *Rienecker et al. (2011).*


Bosilovich, M. G., R. Lucchesi, and M. Suarez (2015). "MERRA-2: File Specification." GMAO Office Note No. 9 (Version 1.1)
Garfinkel, Chaim I., Darryn W. Waugh, and Lorenzo M. Polvani (2015), "Recent Hadley Cell Expansion: The Role of Internal Atmospheric Variability in Reconciling Modeled and Observed Trends." *Geophysical Research Letters* 42.24.
Lucchessi, R. (2012), *File specification for MERRA products. GMAO Office Note No. 1 (Version 2.3)*, *Tech. Rep*.
Orbe et al. (2017), Large-Scale Atmospheric Transport in GEOS Replay Simulations, *J. Adv. Mod. Ear. Sys*.
Rienecker, Michele M., et al. (2011) "MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications." *Journal of Climate* 24.14 (2011): 3624-3648.


*Please refer all questions to merra-questions@lists.nasa.gov.