



MERRA-2 and future reanalysis at GMAO

Ron Gelaro

Global Modeling and Assimilation Office

With thanks to many in the GMAO

MERRA-2 Motivation and Objectives

Produce an ongoing, intermediate reanalysis for the satellite era using a recent version of GEOS-5 to

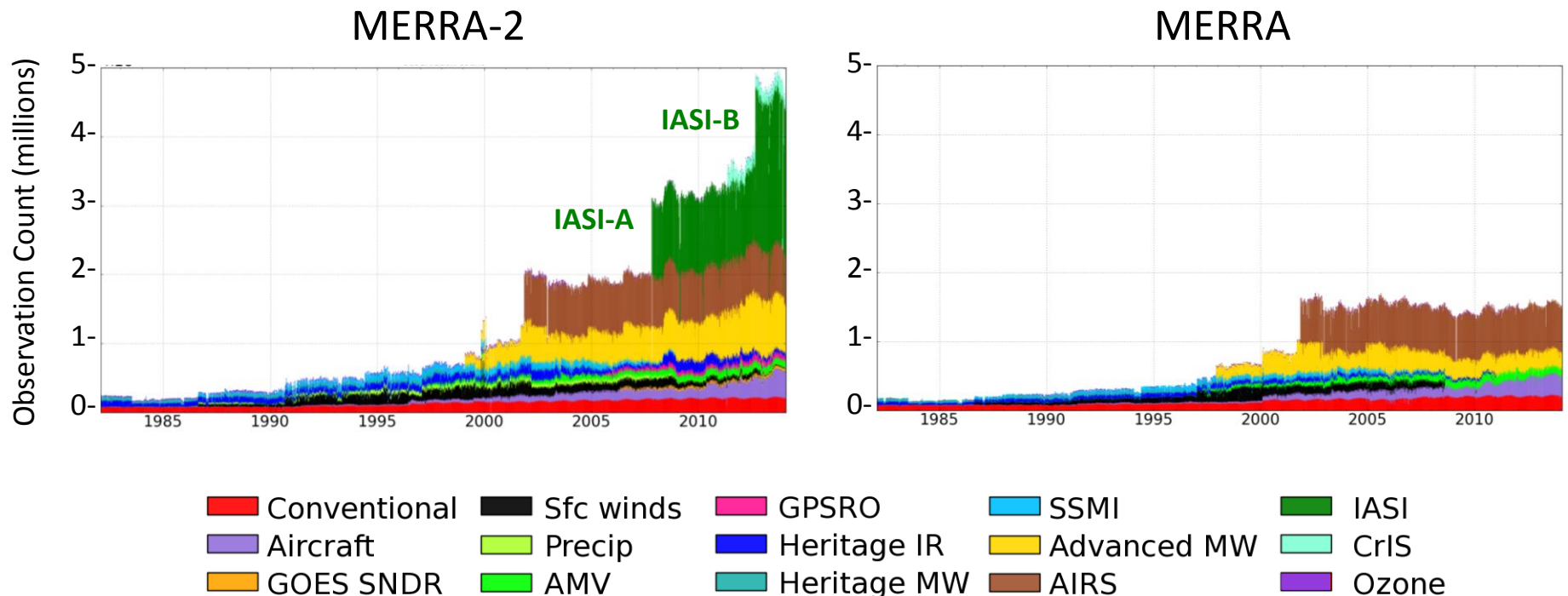
- (1) address known limitations of MERRA (c. 2008),
- (2) provide a stepping stone to a *future coupled Earth system reanalysis*.

Specifics:

- Incorporate modern satellite observation types not available to MERRA
- Reduce spurious trends and jumps related to changes in the observing system
- Reduce biases and imbalances in the water and energy cycles
- Test coupling GEOS-5 meteorology with other Earth system components

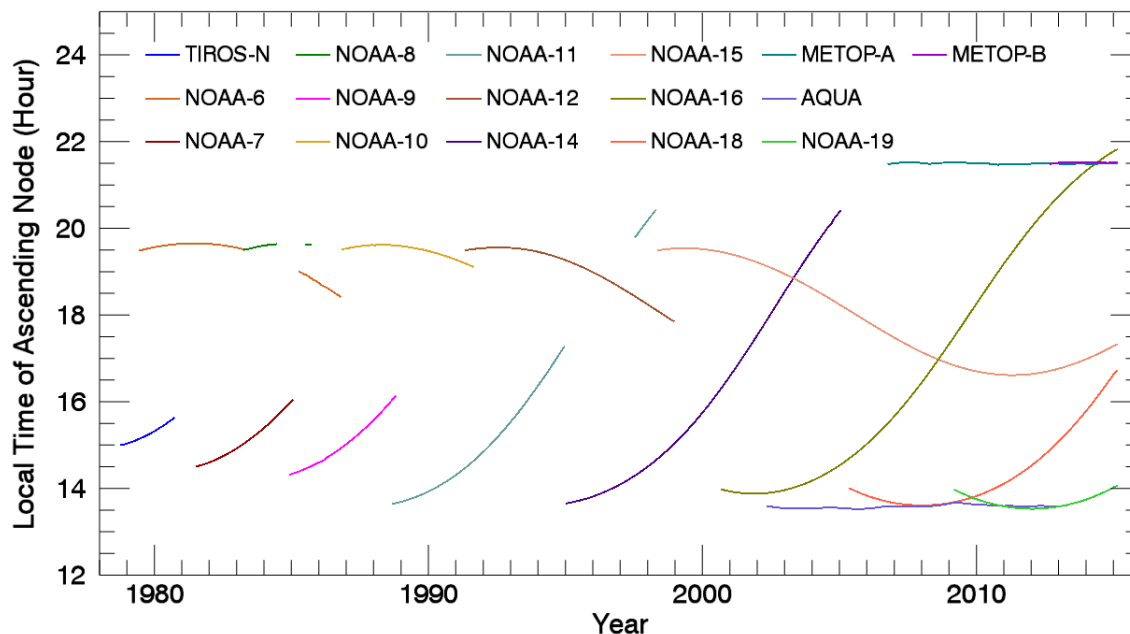
Time Series of Assimilated Observations

- Large increases as more hyper-spectral sensors become active
- No microwave radiance data after NOAA-18 in MERRA
- Data count for MERRA would decrease rapidly if Aqua were to fail



AMSU-A Spatial Coverage

Last Updated Wed Jan 14 11:33:03 2015



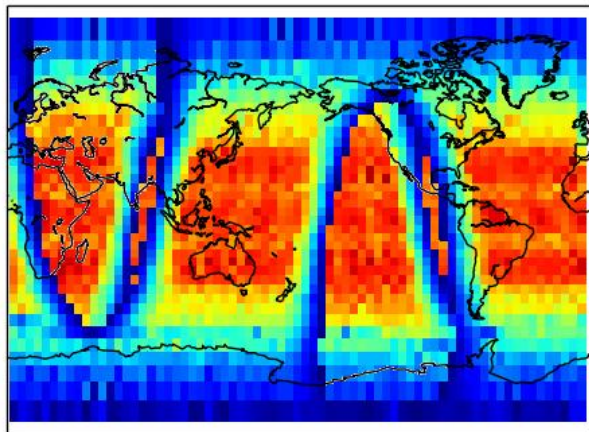
MetOp-A

NOAA-15
NOAA-18

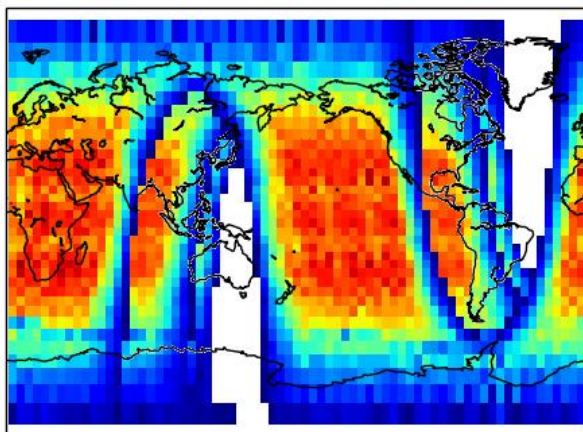
Aqua

Figure: Remote
Sensing Systems Inc.

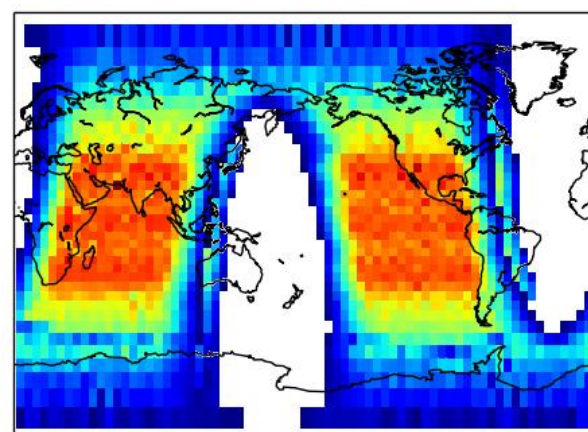
N-15, N18, Aqua, MetOp-A



N15, N18, Aqua (MERRA)



MERRA w/o Aqua



All 00 UTC cycles for May 2014

MERRA → MERRA-2 System Evolution

GEOS-5.12.4 AGCM / GSI 3D-Var

0.5° x 0.625° L72 to 0.01 hPa

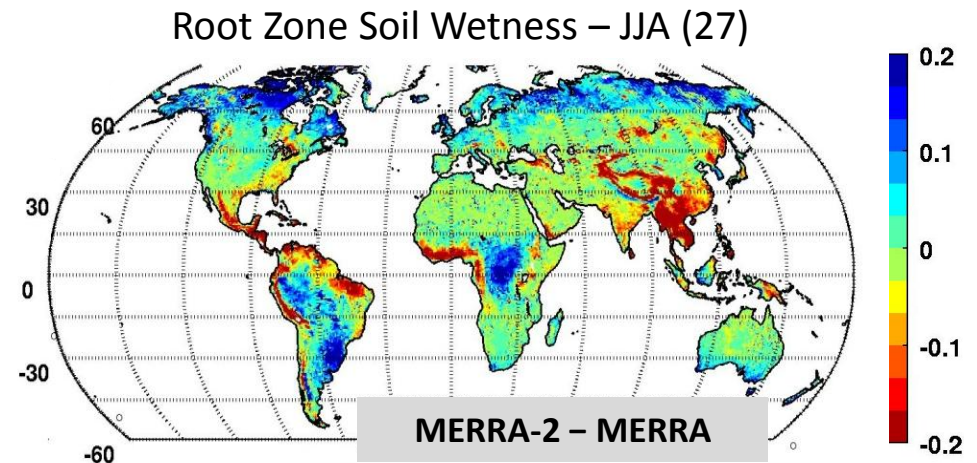
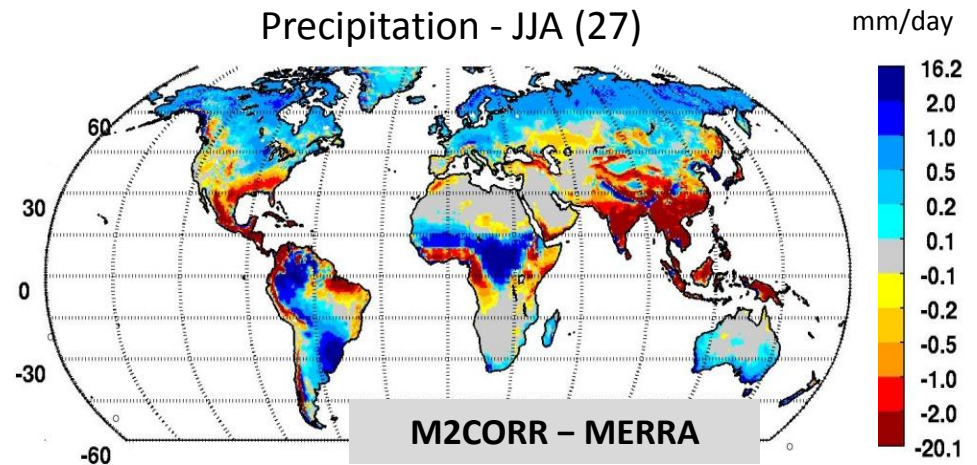
Key Updates

- ❑ Updates to the model, analysis, observations
 - *Cubed-sphere dynamics*
 - *Updated physics: convection, re-evap of rain, sublimation of snow*
 - *Improved glacier model and cryosphere albedos*
 - *More observations: through MetOp-B/SNPP, GPSRO, Aura OMI/MLS*
 - *New moisture control variable*
 - *Bias correction for aircraft temperature observations*
- ❑ Aerosol assimilation, radiatively coupled to AGCM (direct effects)
- ❑ Constraints on dry mass and globally integrated water for improved hydrology
- ❑ Corrected precipitation for land surface forcing and aerosol deposition over ocean

Corrected Precipitation Forcing of the Land Surface

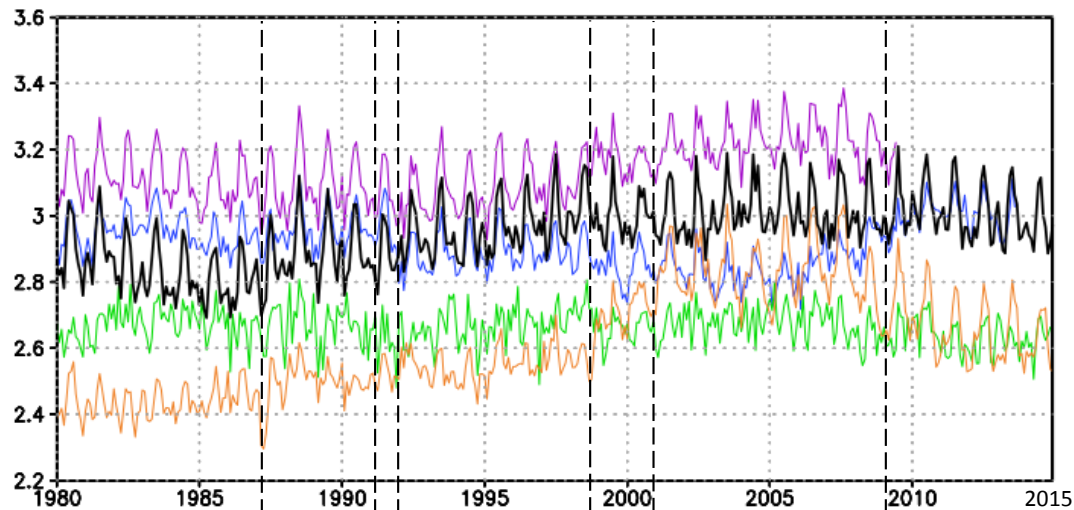
Reichle and Liu, *NASA GMAO Tech Memo* (2014)

- The **land surface** in MERRA-2 sees precipitation that is a mix of observations and model-generated precipitation.
- MERRA-2 **root zone soil wetness** differs from that of MERRA due to differences in precipitation forcing and, to a lesser extent, catchment model parameters.



Global Precipitation and Total Water

Global Mean Precipitation (mm/day)



MERRA-2

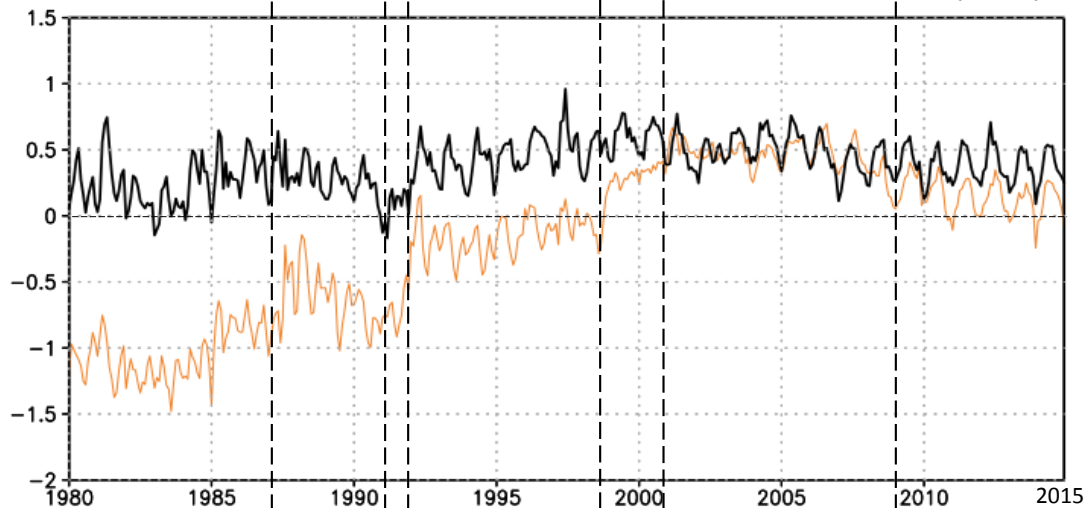
MERRA

CFSR

ERA-Int

GPCP

Global Mean Difference in TPW with ERA-Interim (mm)



MERRA-2

MERRA

F08

F10,11

N15,16

SSM/I ends

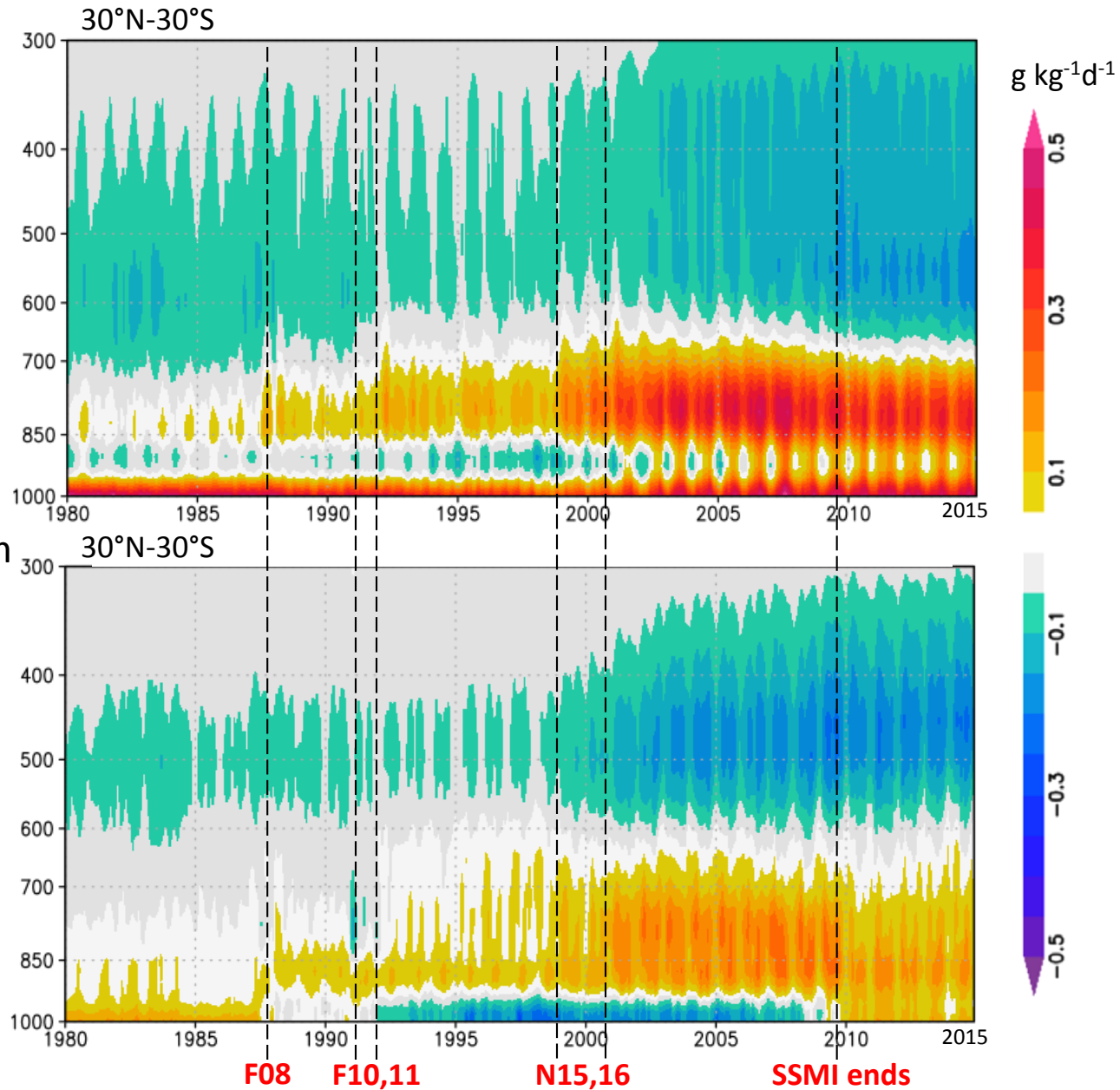
MW data sources
with large impact
on MERRA have
less impact on
MERRA-2

Mean Moisture Analysis Forcing (IAU)

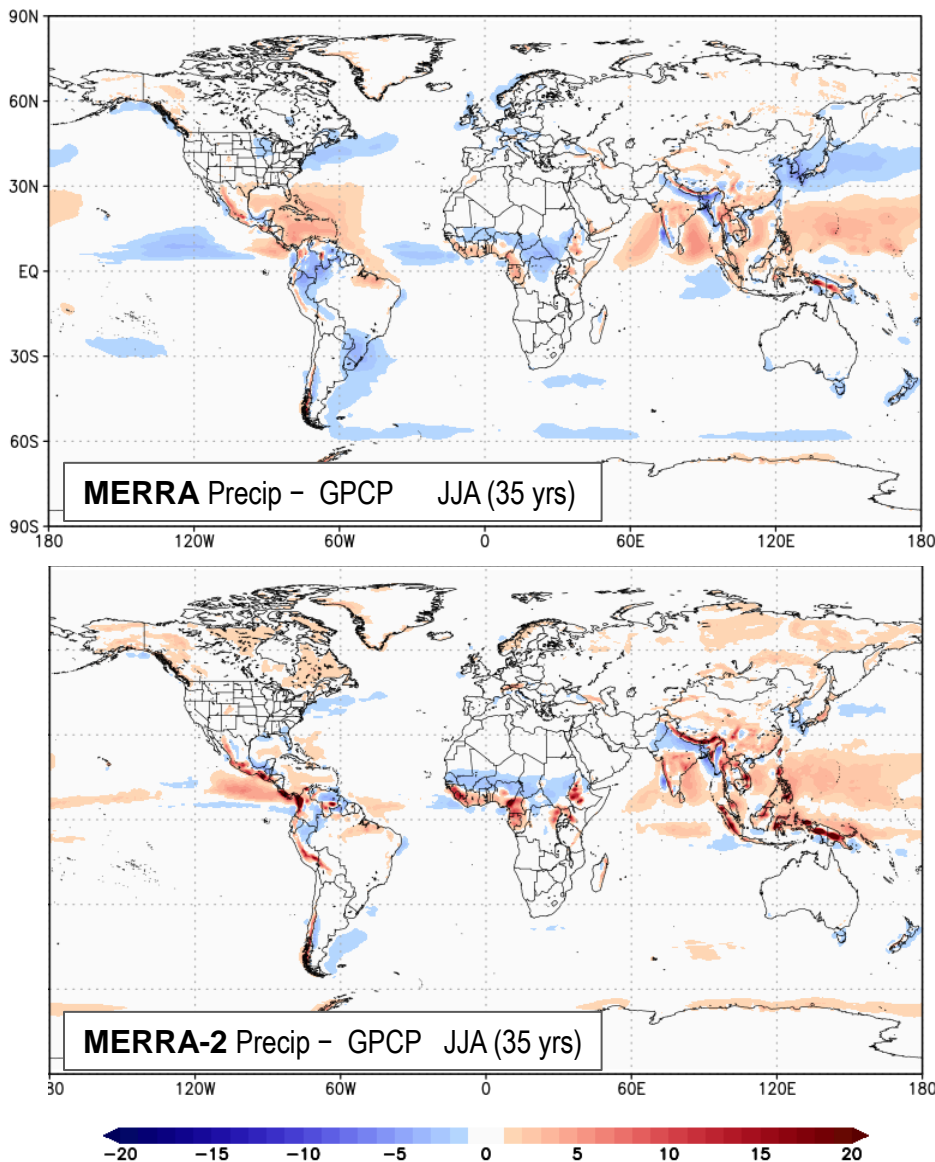
MERRA

Increments are smaller in MERRA-2 but observing system changes are evident in both reanalyses

MERRA-2

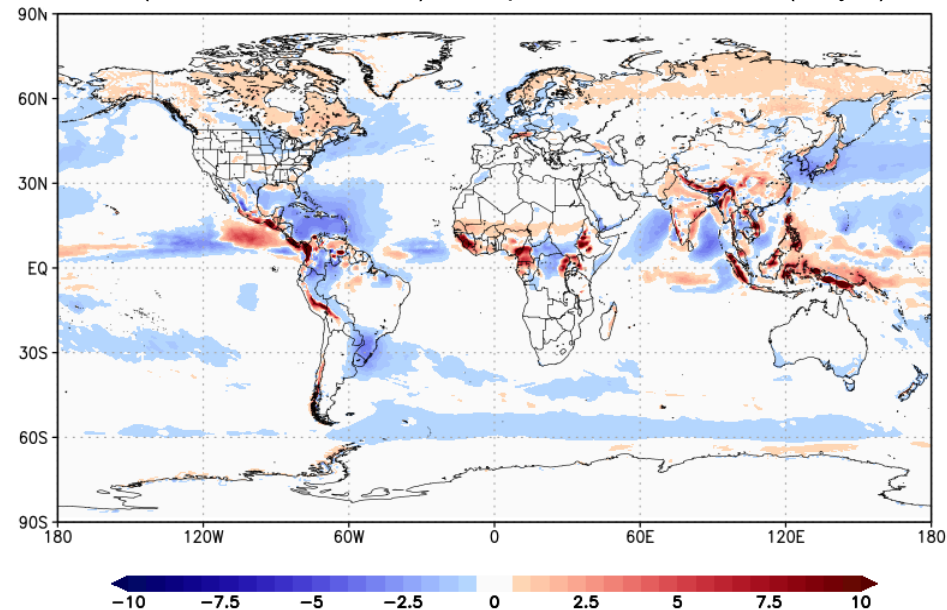


Precipitation vs. GPCP



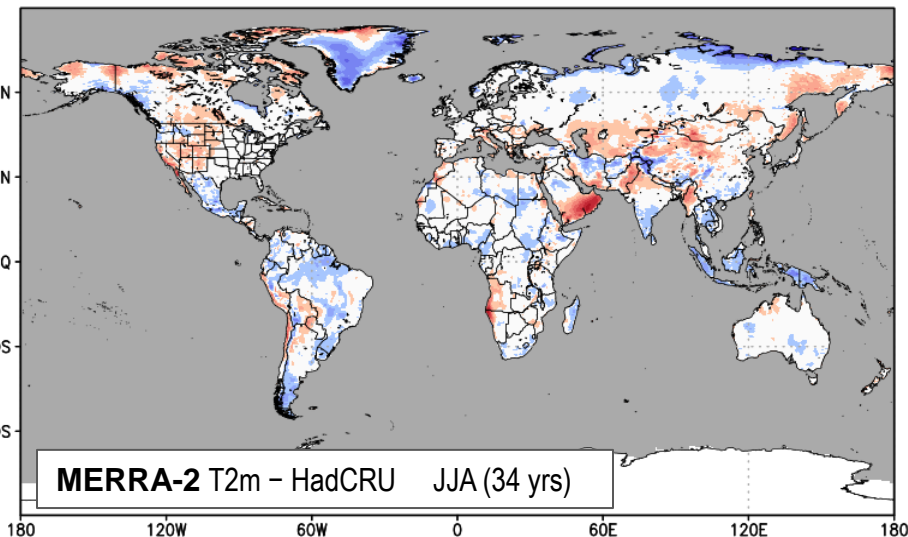
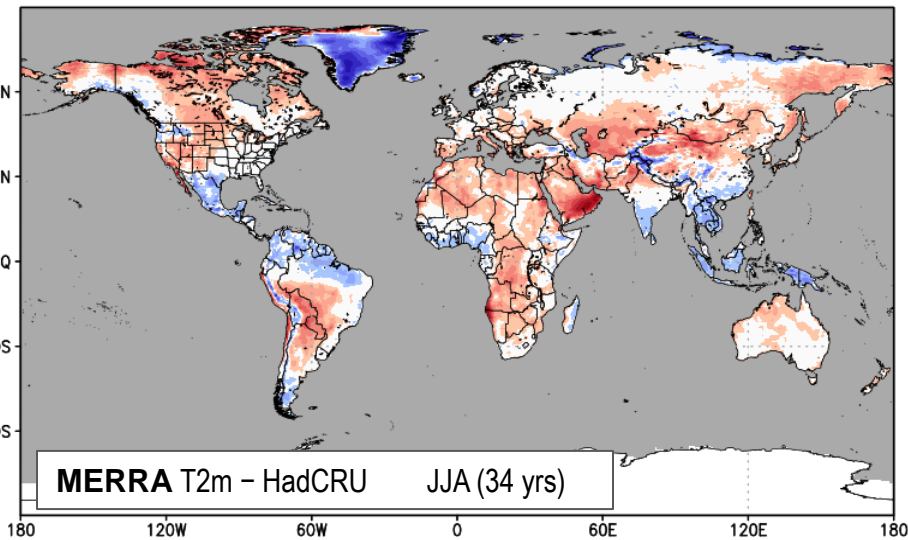
MERRA-2 improves over oceans,
but rains excessively over tropical
high terrain

ABS(MERRA-2, MERRA) Precip vs. GPCP JJA (35 yrs)



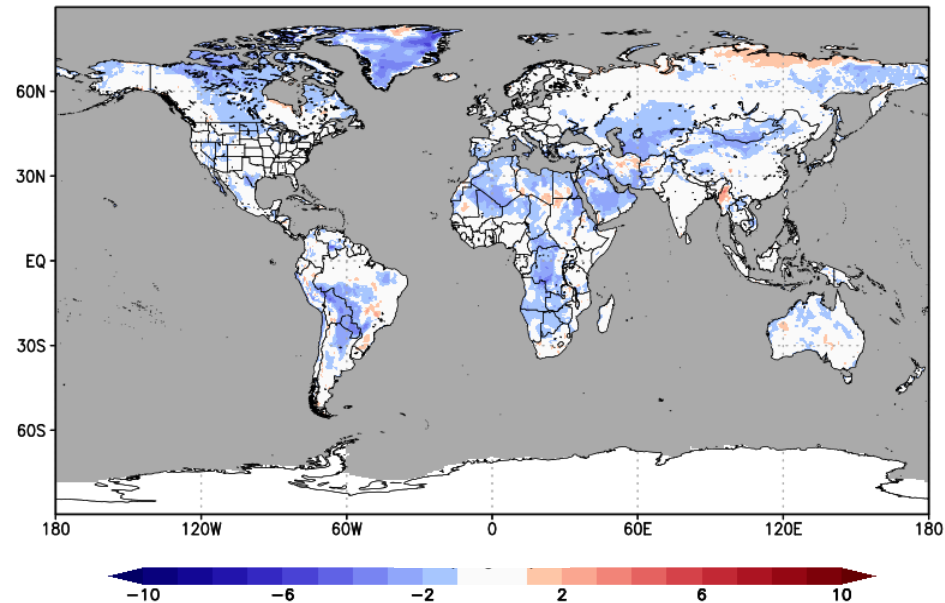
Blue shades imply MERRA-2 closer to
GPCP data than MERRA

Surface Air Temperature vs. HadCRU



General improvement of MERRA-2
over MERRA in summer (shown)
– less improvement in winter

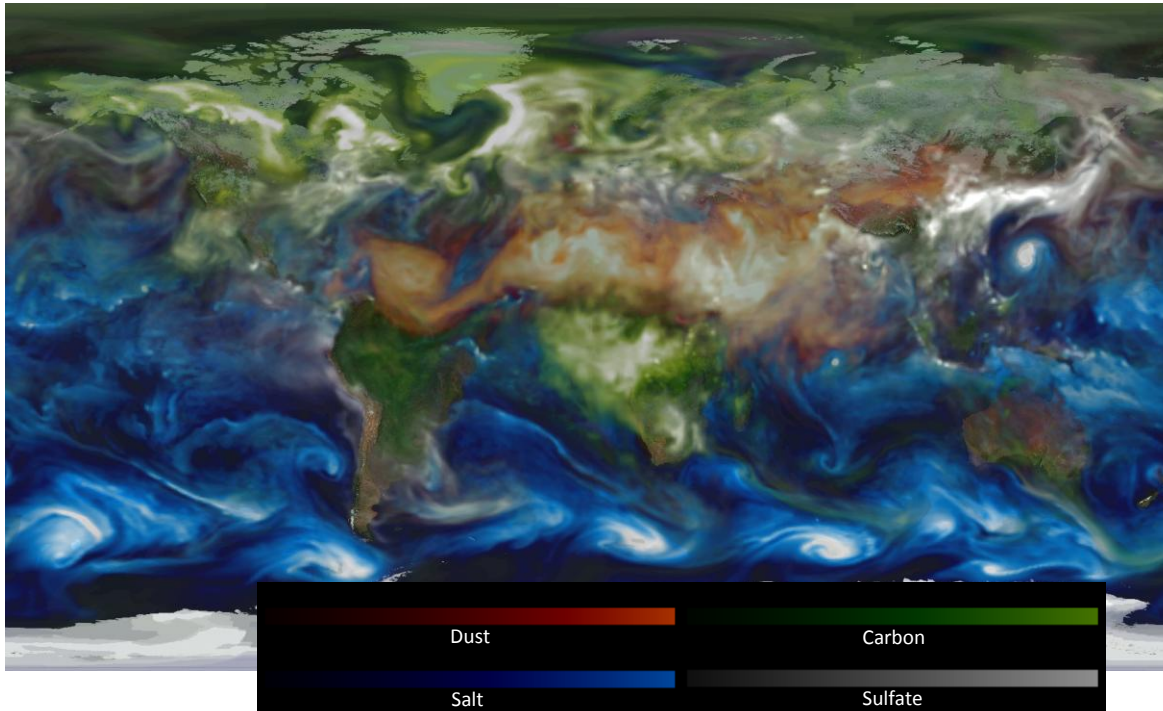
ABS(MERRA-2, MERRA) T2m vs. HadCRU JJA (34 yrs)



Blue shades imply MERRA-2 closer to
HadCRU data than MERRA

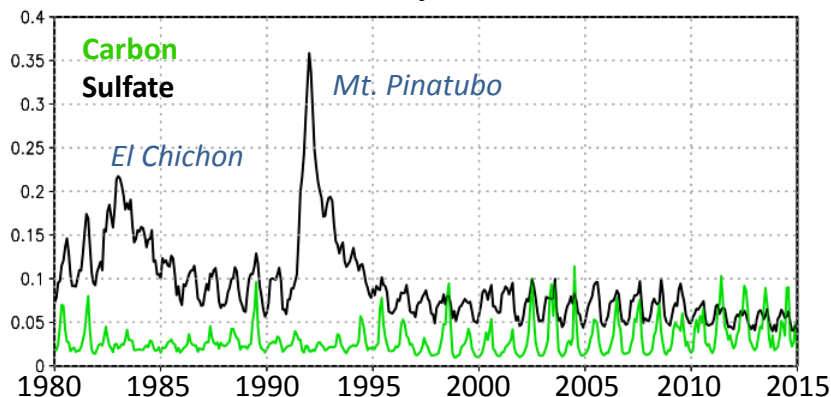
Aerosol Assimilation in MERRA-2

MERRA-2 Aerosol Analysis 10 July 2013 1200UTC

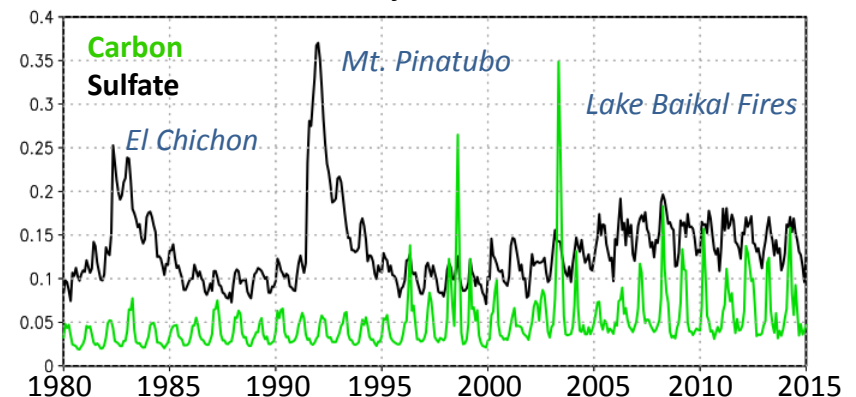


- **Black and organic carbon, dust, sea salt, sulfates**
- GOCART – mixing, chemistry and deposition
- Actively assimilated AOD from AVHRR, MODIS, MISR, AERONET
- Aerosols radiatively coupled with atmospheric model dynamics

North America/Adjacent Atlantic AOD

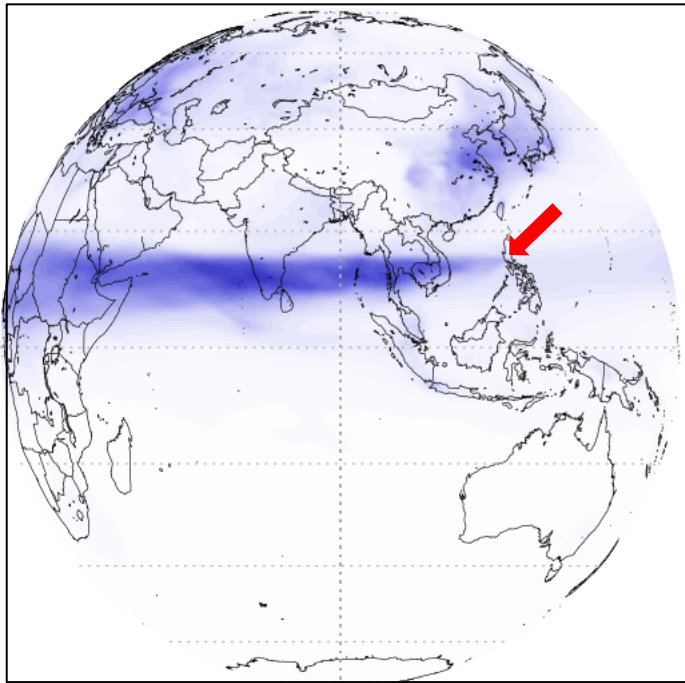


East Asia/Adjacent Pacific AOD

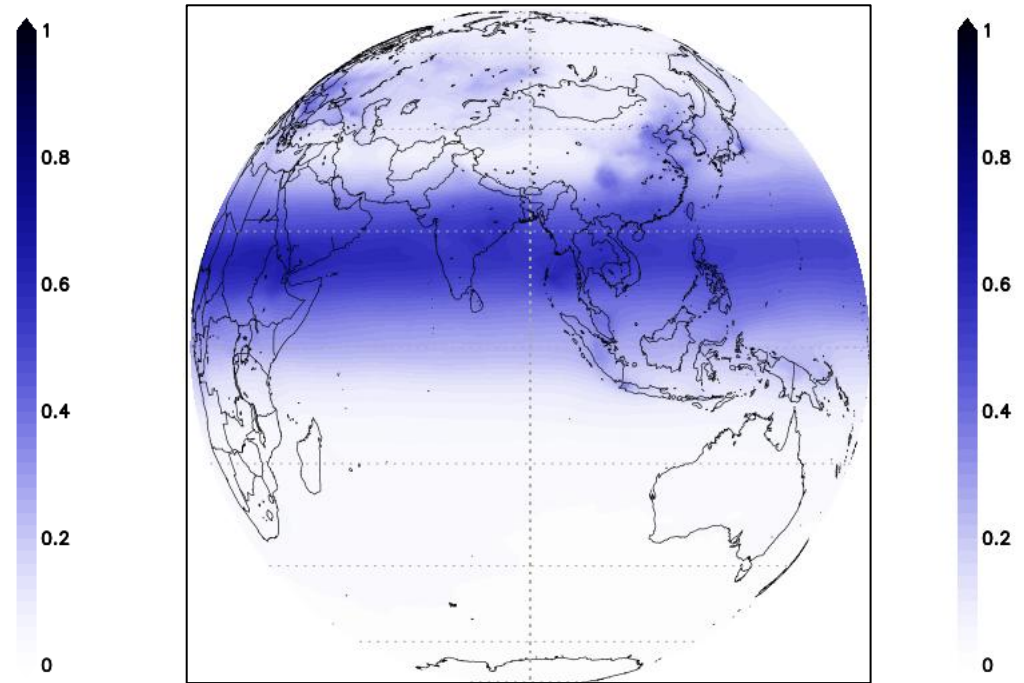


MERRA-2 Analysis of the Mt. Pinatubo Eruption

MERRA-2 Sulfate AOD June 1991



MERRA-2 Sulfate AOD July 1991



MERRA-2 captures the Mt. Pinatubo eruption in June 1991

The eruption sent a thick sulfate plume rapidly upwards into the stratosphere, which fanned out westward on the prevailing easterly winds aloft (left). By July 1991, the sulfate plume encompassed the tropics globally (right).

MERRA-2 Products and Ancillary Applications

Completed 1980-present, now running as a continuing climate analysis with 2-3 week latency

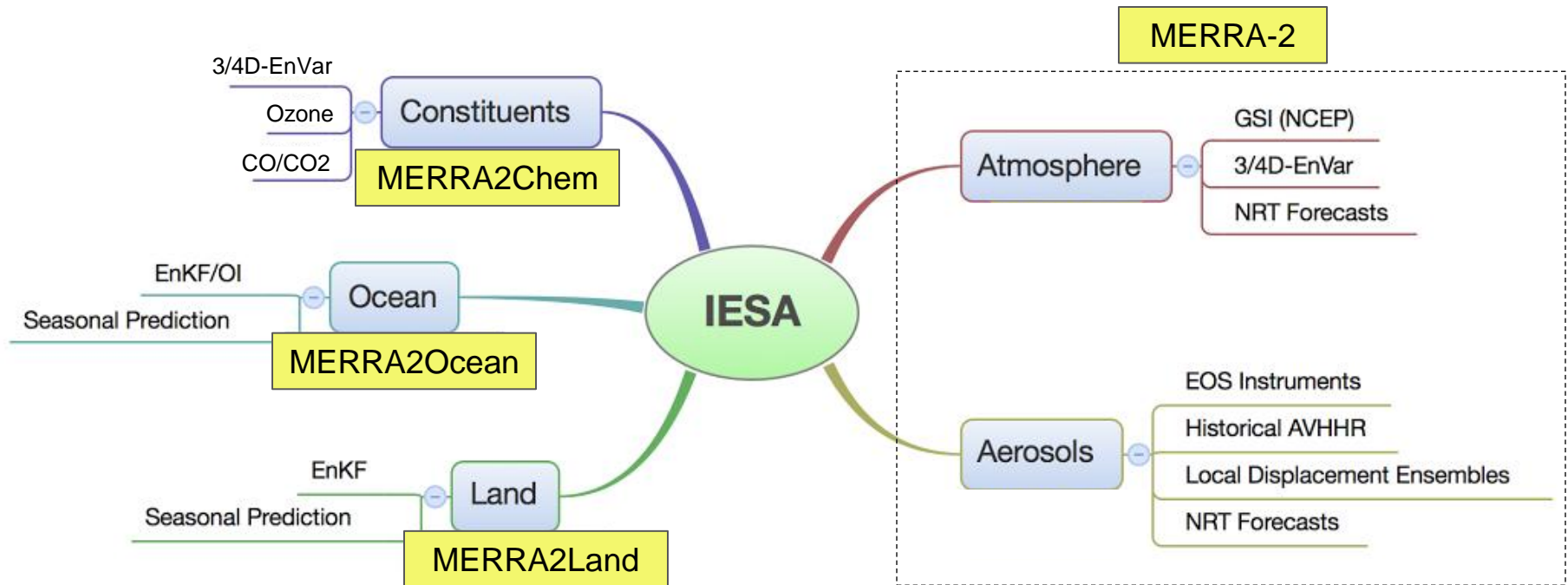
Data release expected to begin in July 2015 via the NASA Goddard Earth Sciences (GES) Data Information Services Center (DISC)

- 1-hourly surface/2D fields, 3- and 6-hourly 3D fields
- Daily Products ~25 GB/day (9.1 TB/yr)
- Monthly Products ~34 GB/mo (408 GB/yr)

Ensemble of (initially) 10 AMIP integrations using the MERRA-2 model configuration

MERRA-2-driven analyses of ocean state (physics and biogeochemistry), atmospheric chemistry (EOS period), and carbon cycle.

Toward an Integrated Earth System Analysis



Coupled and MERRA2-driven component reanalyses



Reanalysis Progression

	MERRA	MERRA-2	Next Target
System vintage	2008	2014	2017
Release	2009	mid 2015	late 2018
Scope	Atmosphere	Atmosphere, including aerosols and land correction	Atmosphere-ocean- ice-land
Resolution	0.5°×0.66° L72	0.5°×0.625° L72 (C180 cubed sphere)	0.25°×0.3125° L137 (C360 cubed sphere) + 25-km ocean
Analysis	3D-Var atmos	3D-Var atmos	4D EnsVar atmos + EnKF land + EnOI ocean