Introduction to NASA's Modern Era Retrospective-analysis for Research and Applications: MERRA

NASA Remote Sensing Training
Norman, Oklahoma
June 19-20, 2012

ARSET

Applied Remote SEnsing Training

A project of NASA Applied Sciences

Objectives

To Present:

- A brief overview of MERRA Water Products

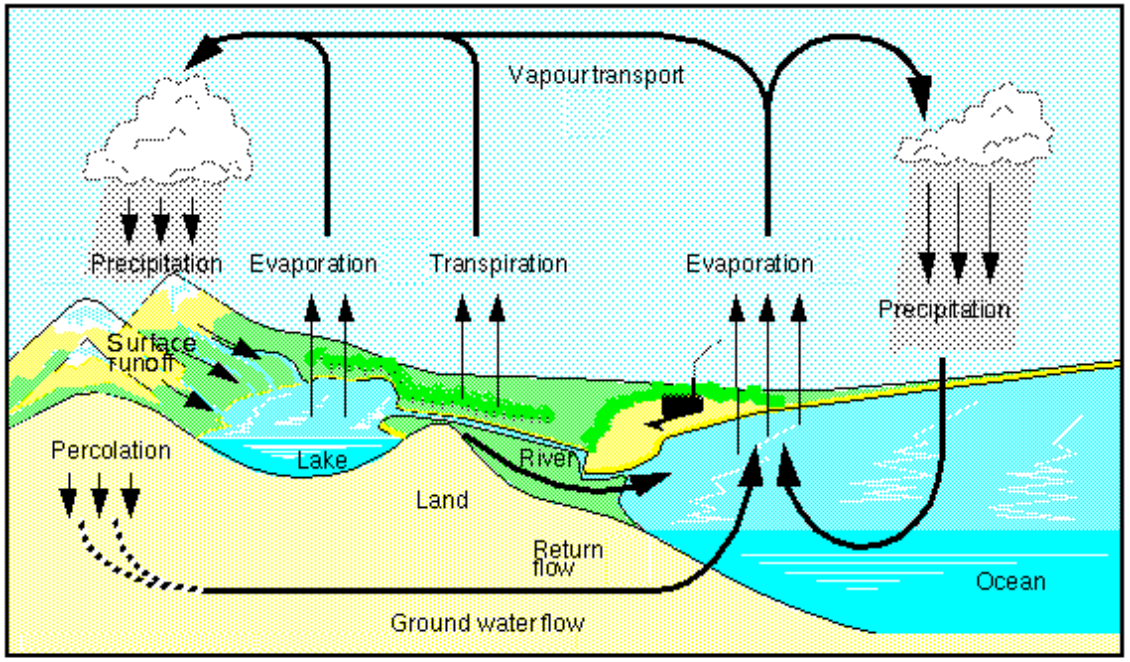
- Examples of analysis and visualization of weather events and climate variability

For details see **http://gmao.gsfc.nasa.gov/research/merra/**

NASA Atmospheric Products

- **Water Products**
- Snow/Ice
- Rain, Clouds, Water Vapor
- Evaporation/Transpiration

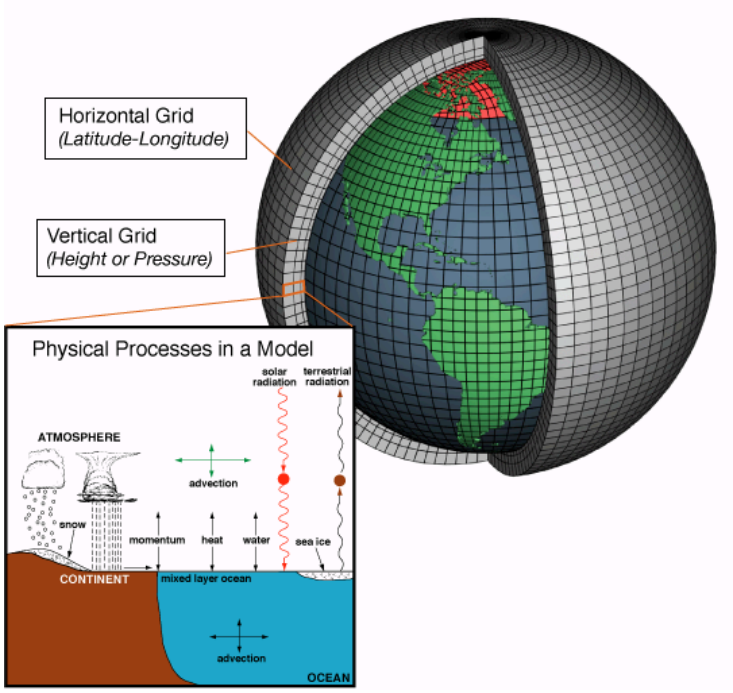
- **Water-related Products**
- Surface Temperature
- Winds



Courtesy Erich Roeckner, Max Planck Institute for Meteorology

Water Cycle Components

Modeling of the atmosphere-Land-Ocean Systems

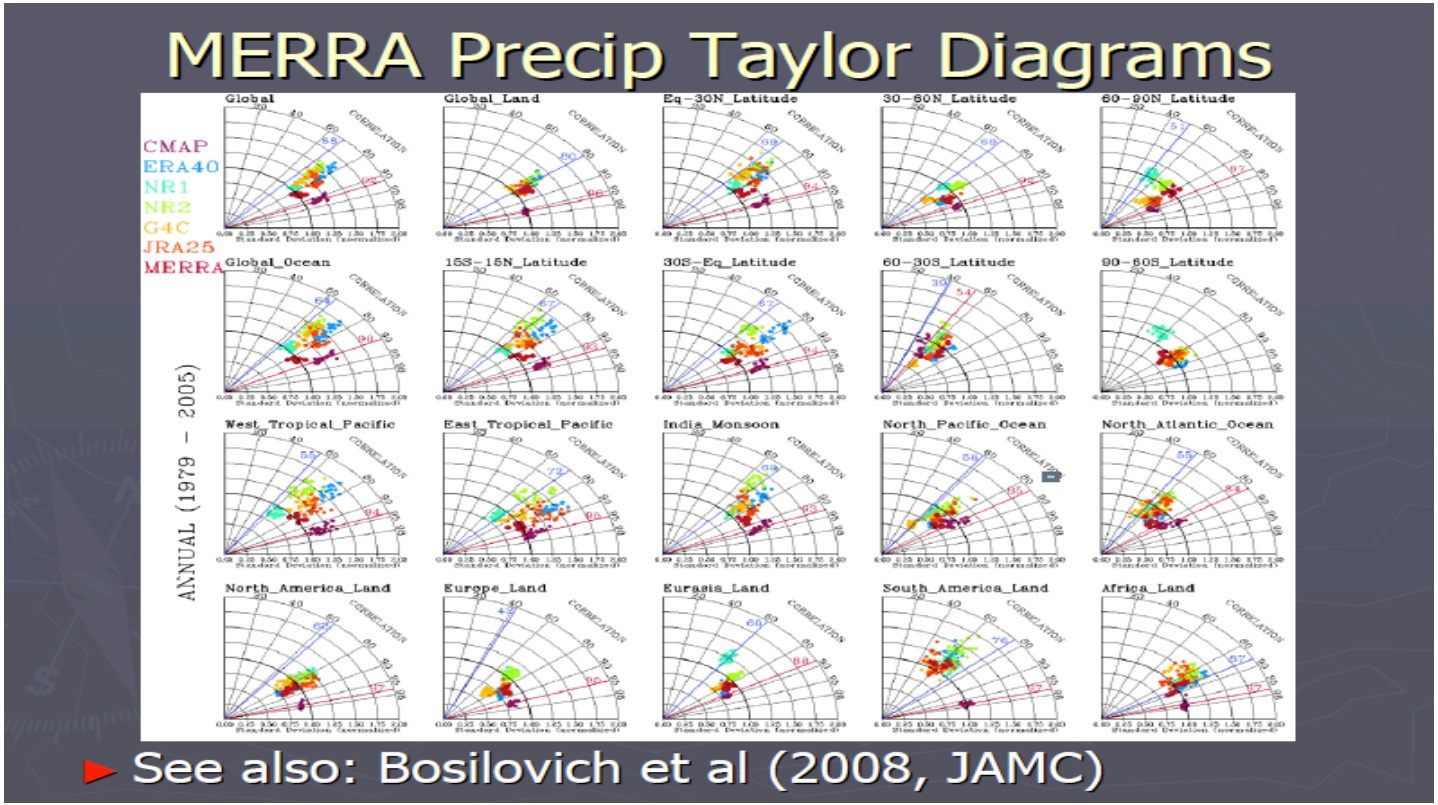


- Models use laws of physics in terms of mathematical equations to represent atmosphere, ocean, land systems and changes occurring in them in space and time
- Models apply these mathematical equations, on horizontal and vertical grids by using numerical methods
- Models use observations to represent the atmosphere ocean-land system at a given time to deduct how the system will evolve over space/ time
- Models ‘parameterize’ physical processes based on physical/statistical/empirical techniques derived or verified by using observed quantities

Modeling of the atmosphere-Land-Ocean Systems

- Modeling of water-related processes is complex due to presence of water in gaseous, liquid, and solid forms in the atmosphere-ocean-land system

- Rigorous validation with observations and model to model inter-comparisons are conducted to assess uncertainties in models



MERRA precipitation comparison with other models

What is Reanalysis?

- A technique to produce multiple climate variables in which past observations are combined with a model
- Past observations of basic meteorological data such as temperature, wind speed, and pressure are analyzed and interpolated onto model grids
- 3-D forecasting model is initialized and constrained with the observations
- The model simulations provide many climate variables which are not observed, for example moisture flux
- The model simulations also provide more frequent (hourly, 6- hourly) output than observations

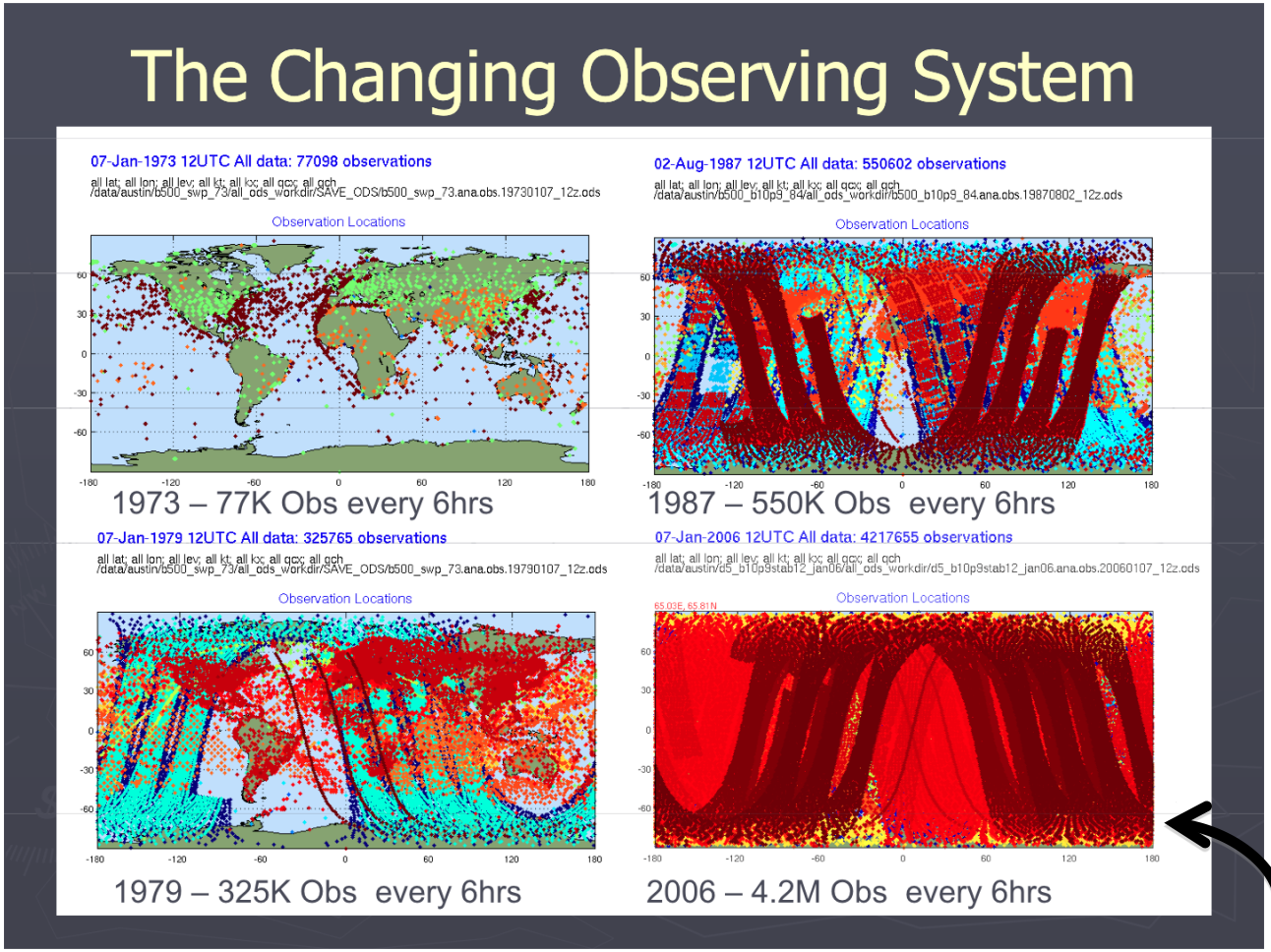
MERRA Reanalysis Data

- **Input**: Standard Meteorology
  - Temperature, Pressure, Wind, Moisture, Radiance
  - Chemistry: Ozone; Aerosol and Carbon under development
  - Irregularly distributed in space and time
- **Output**
  - Clouds and their properties
  - Water Cycle
  - Energy Budget from the top of atmosphere to the surface of the Earth
  - Global coverage at regular frequency

From: Michael Bosilovich, NASA-GSFC-GMAO

MERRA

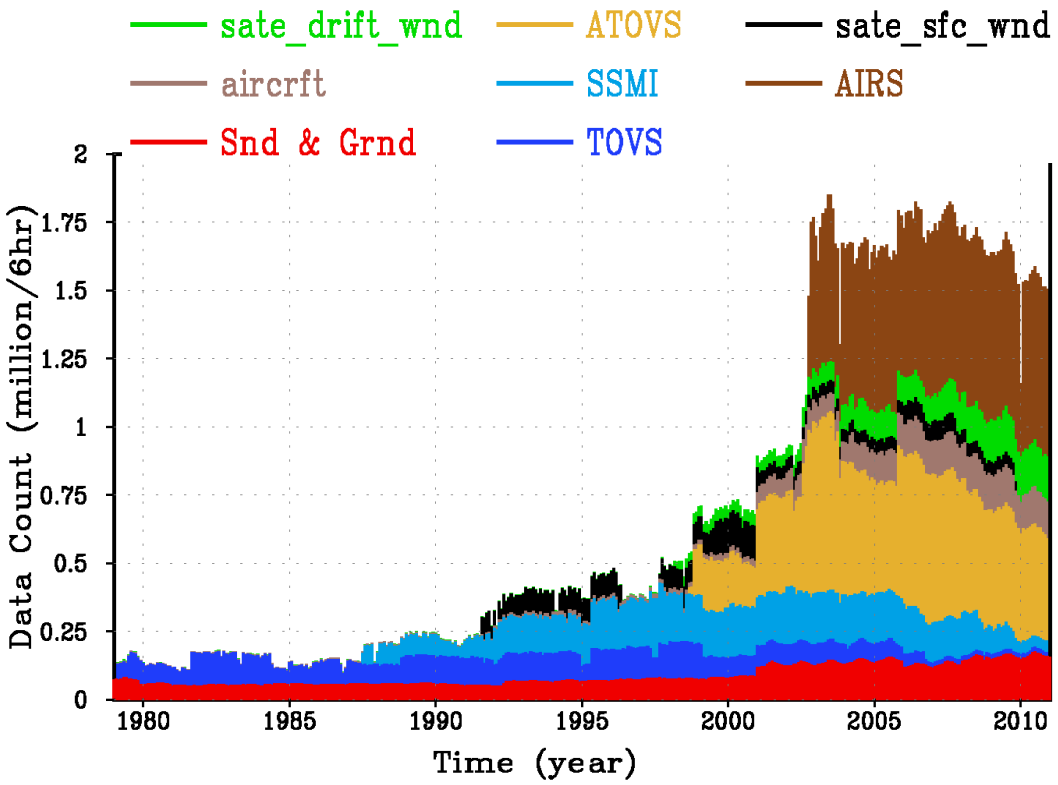
- Blends the vast quantities of observational data with output data of the Goddard Earth Observing System (GEOS) model [**1979-present**]



Current satellite coverage assimilated in MERRA

Observations used in Reanalysis

MERRA Focuses on historical analyses of the water cycle on a broad range of weather and climate time scales (hours to years) and places the NASA satellite observations in a climate context



- Technologies change; Instrument life cycle

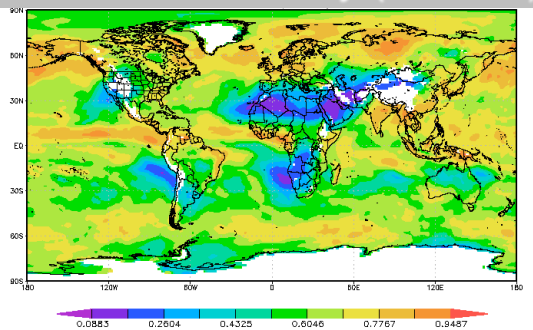
From: Michael Bosilovich, NASA-GSFC-GMAO

MERRA Reanalysis

- **Strengths** – The processed data are globally continuous in space and time, and provide meteorological and climatological relevant fields

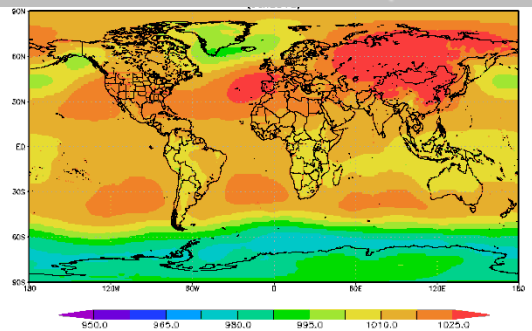
- **Weakness** – Earth system models represent the human knowledge of how the world works

Relative Humidity (fraction)

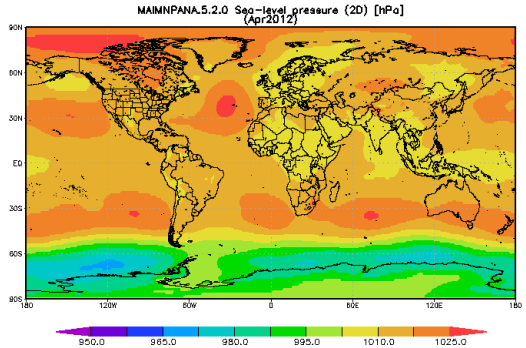


July 2011
(850 hPa)

Sea Level Pressure (hPa or mb)



January
2012



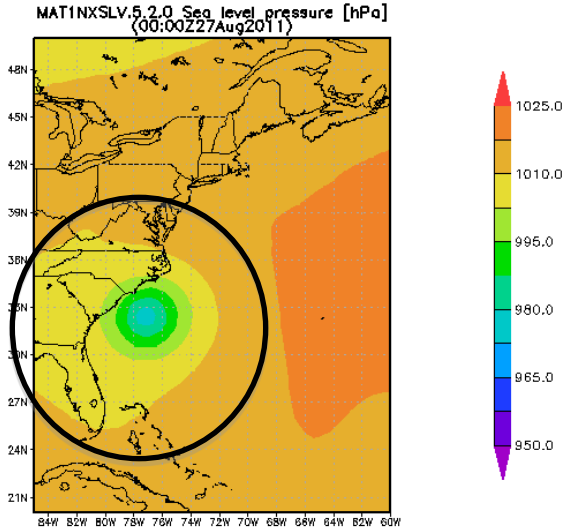
April
2012

From: Michael Bosilovich, NASA-GSFC-GMAO

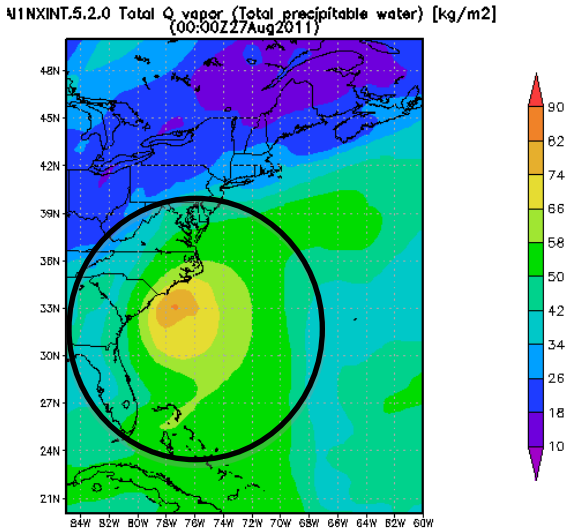
MERRA for Weather

Hurricane Irene August 27, 2011, 0 GMT

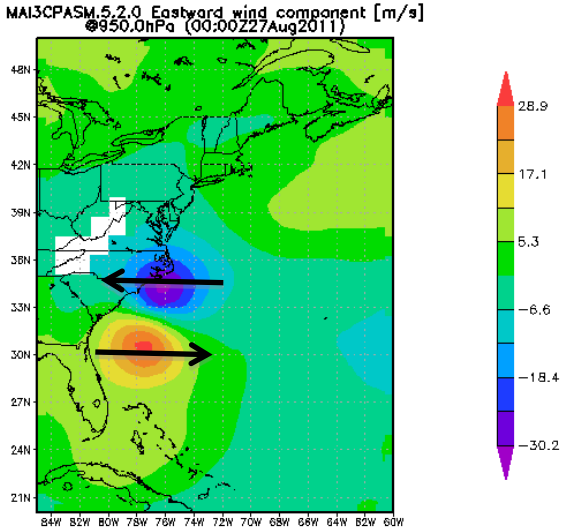
Sea Level Pressure



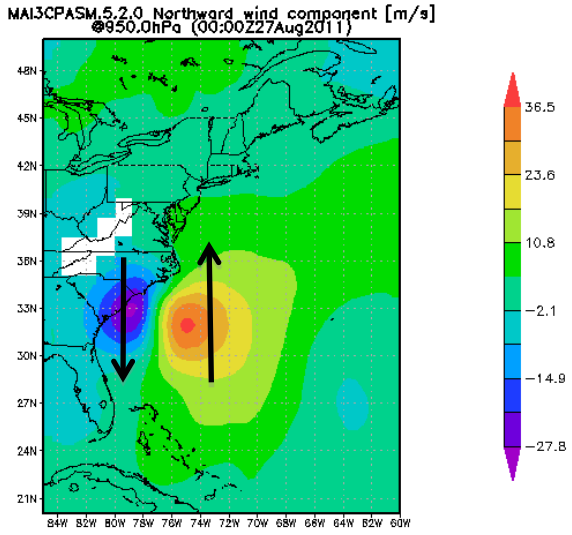
Total Atmospheric Moisture



Eastward Wind



Northward Wind



MERRA Water Products

Temporal Resolution: Monthly

Spatial Resolution: 1.25°x1.25° and 42 vertical levels

3-dimensional Parameters	**Units**
Specific Humidity	Kg/Kg
Relative Humidity	Fraction
Cloud Fraction	Fraction

Spatial Resolution: 2/3°x1/2°

2-dimensional Parameters	
Surface Rainfall Rate	$Kg/m^2/s$
Surface Evaporation	$Kg/m^2/s$
Cloud Top **Pressure** and **Temperature**	hPa and K
Vertically Integrated Water Vapor	Kg/m^2

MERRA Water Products

Temporal Resolution: Hourly

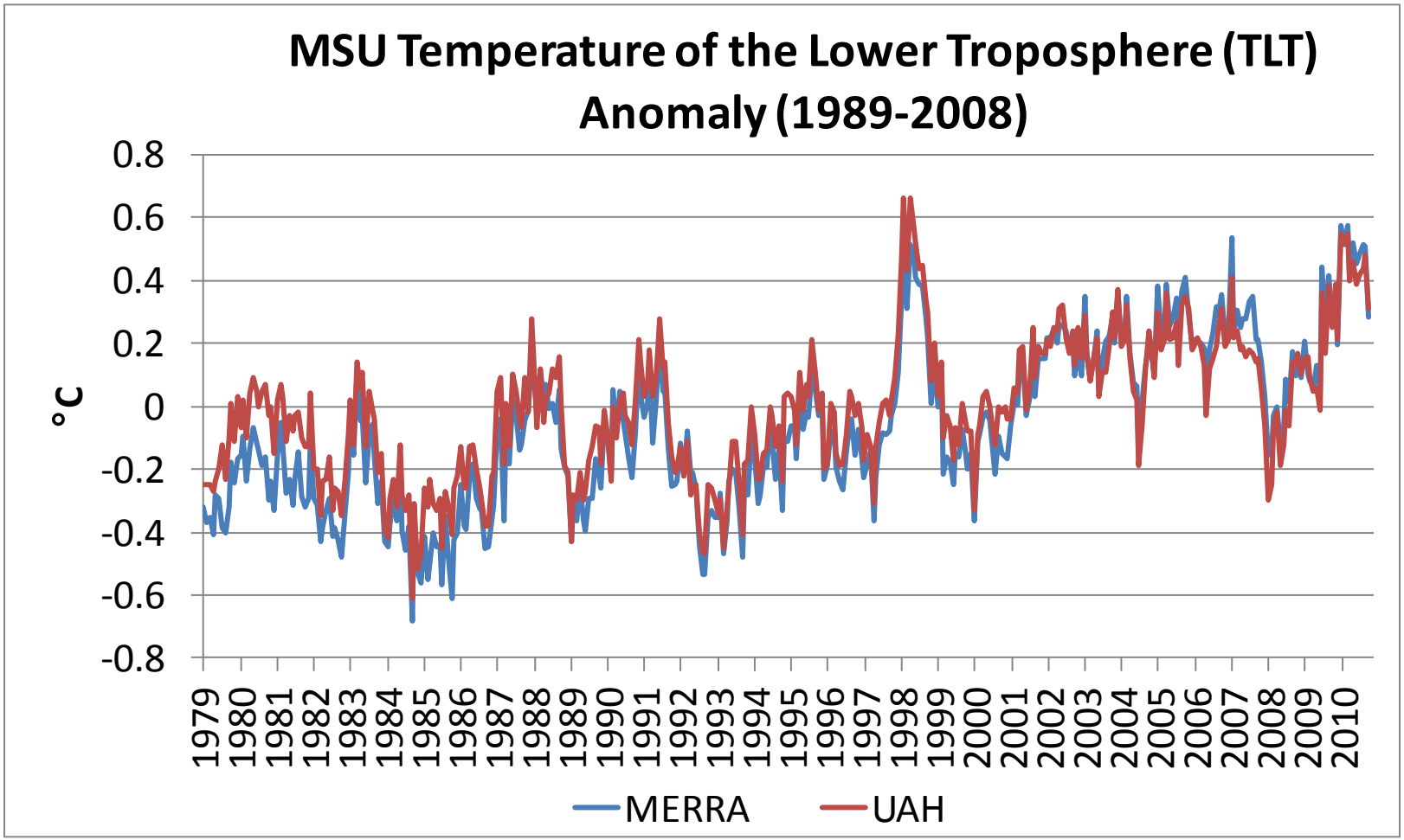
Spatial Resolution: 1.25°x1.25° and 42 vertical levels

3-dimensional Parameters	**Units**
Specific Humidity	Kg/Kg
Relative Humidity	Fraction
Cloud Fraction	Fraction
Cloud liquid and ice water mixing ratio	Kg/Kg

Spatial Resolution: 2/3°x1/2°

2-dimensional Parameters	
Surface Rainfall Rate	$Kg/m^2/s$
Snow Mass	Kg/m^2
Snow Cover	Fraction
Snow Depth	m
Surface Snowfall Rate	$Kg/m^2/s$
Surface Evaporation	$Kg/m^2/s$
Cloud Top **Pressure** and **Temperature**	hPa and K
Vertically Integrated Water Vapor, cloud liquid and ice water content	Kg/m^2

MERRA Climate data

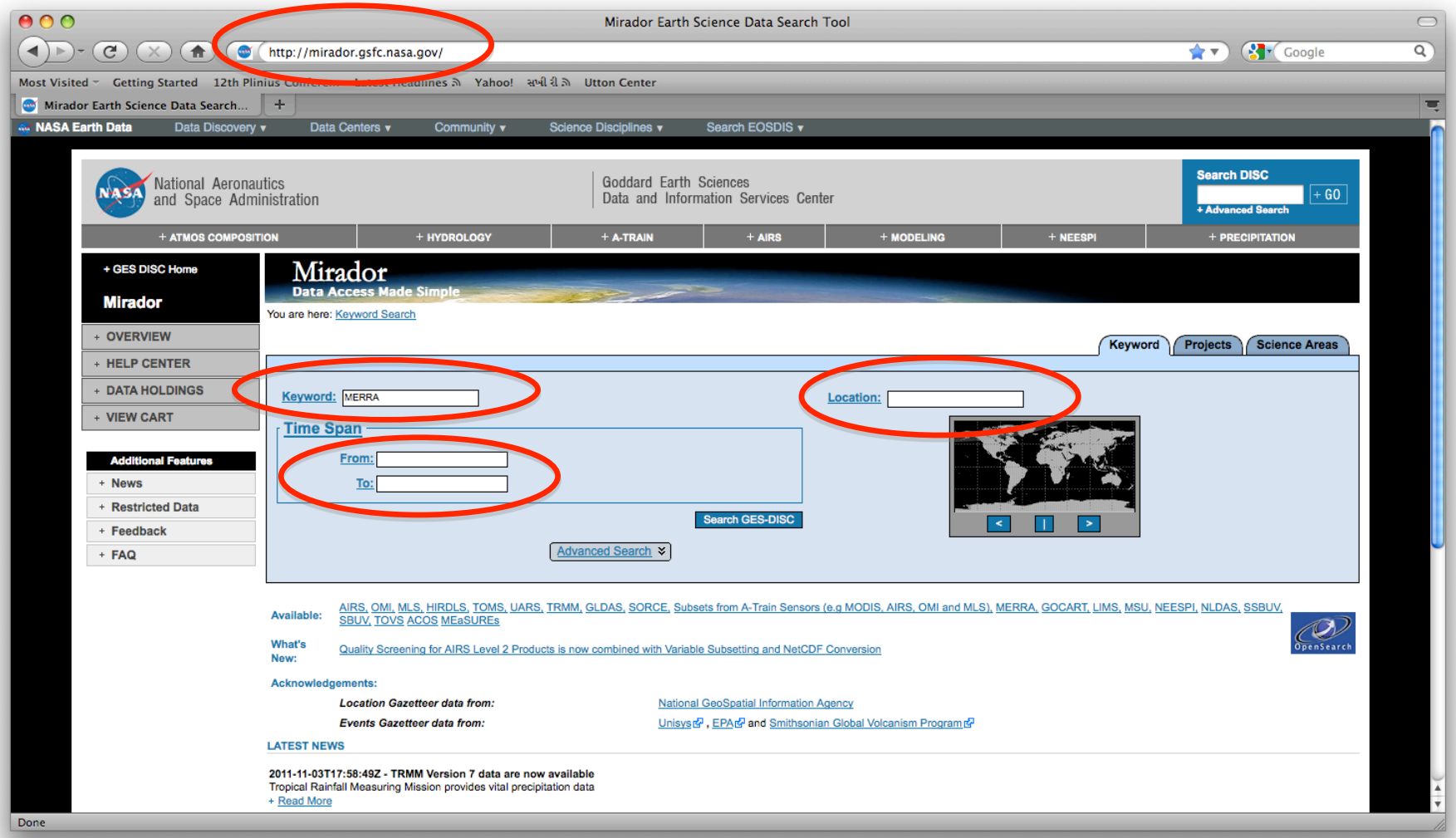


MSU data is assimilated, so the apparent correlation is expected

From: Michael G. Bosilovich, NASA-GSFC-GMAO

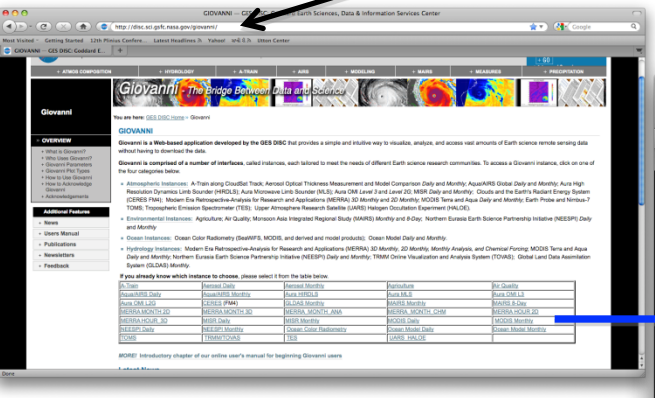
MERRA products

Can be downloaded from http://mirador.gsfc.nasa.gov by a keyword search. Also, can search by time and location/region



MERRA Image Products

Numerous atmospheric and surface parameters available from http://disc.sci.gsfc.nasa.gov/giovanni



GIOVANNI — GES DISC: Goddard Earth Sciences, Data & Information Services Center

http://disc.sci.gsfc.nasa.gov/giovanni/

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Aura OMI L2G	CERES (FM4)	GLDAS Monthly	MAIRS Monthly	MAIRS 8-Day
MERRA MONTH 2D	MERRA MONTH 3D	MERRA_MONTH_ANA	MERRA_MONTH_CHM	MERRA HOUR 2D
MERRA HOUR_3D	MISR Daily	MISR Monthly	MODIS Daily	MODIS Monthly
NEESPI Daily	NEESPI Monthly	Ocean Color Radiometry	Ocean Model Daily	Ocean Model Monthly
TOMS	TRMM/TOVAS	TES	UARS_HALOE	

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Retrospective-Analyses

- Value added merger of many types of observations with the latest Earth systems models
- Development of reanalyses lead to improved models and observations
- As the observing system improves, uncertainties decrease
- Weather, climate, climate variation in both research and applied decision making
- Some climate trend study can be made, significantly more research and development is needed

From: Michael Bosilovich, NASA-GSFC-GMAO

MERRA Giovanni Analysis