

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 **R**emote **S**ensing **T**raining

A project of NASA Applied Sciences



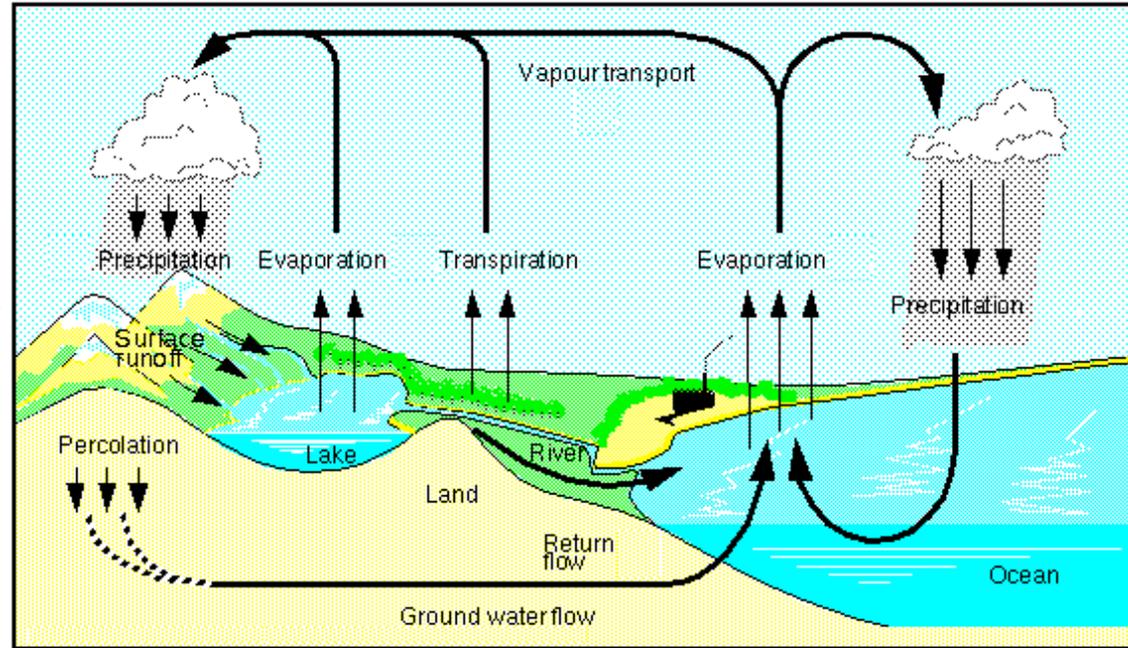
Objectives

To Present:

- A brief overview of MERRA Water Products
- Examples of analysis and visualization of weather events and climate variability

NASA Atmospheric Products

- **Water Products**
 - Snow/Ice
 - Rain, Clouds, Water Vapor
 - Evaporation/Transpiration
- **Water-related Products**
 - Surface Temperature
 - Winds

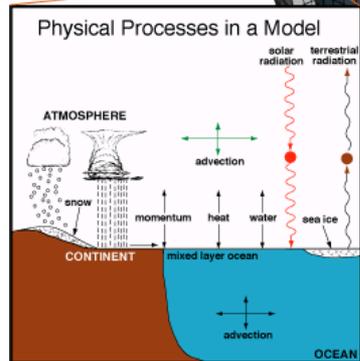
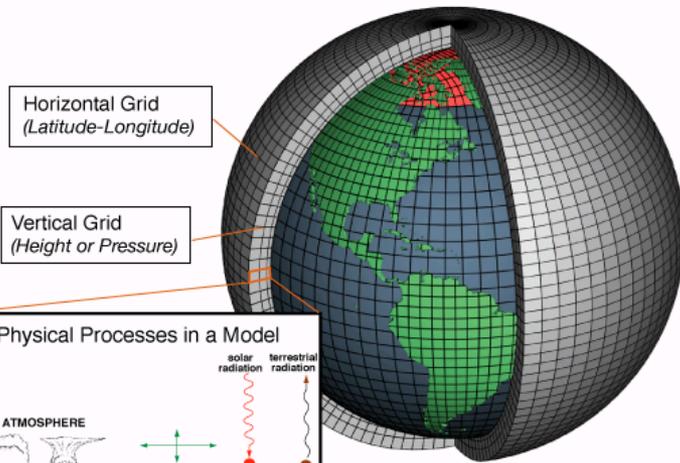


Courtesy Erich Roeckner, Max Planck Institute for Meteorology

Water Cycle Components

Modeling of the atmosphere-Land-Ocean Systems

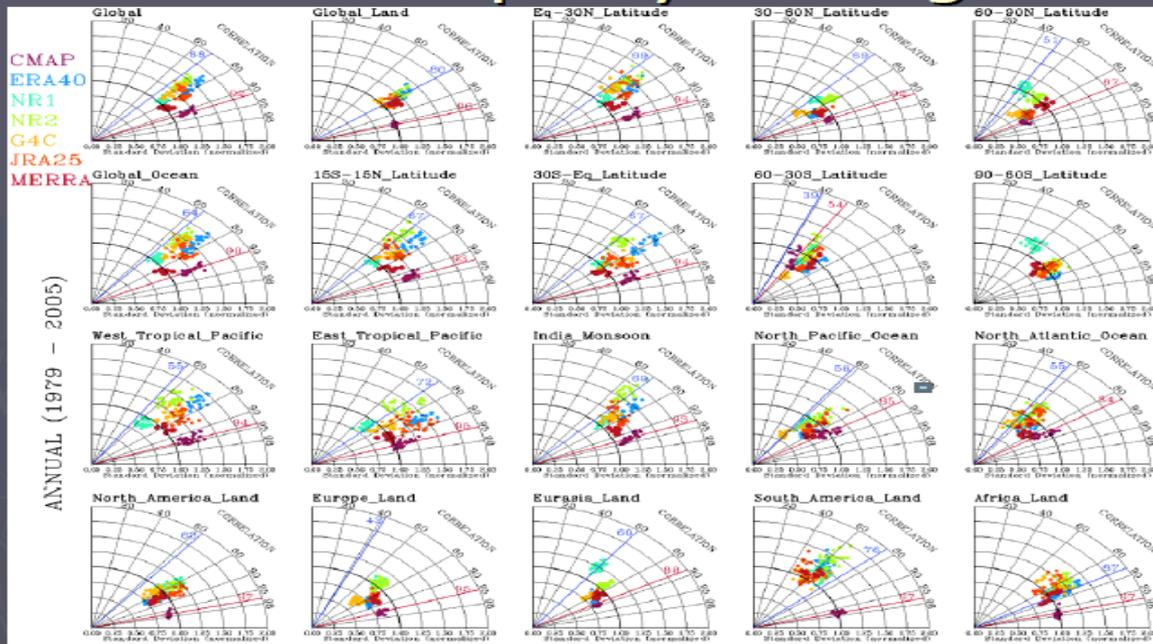
- Models use laws of physics in terms of mathematical equations to represent atmosphere, ocean, land systems and changes occurring in them in space and time
- Models apply these mathematical equations, on horizontal and vertical grids by using numerical methods
- Models use observations to represent 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 Precip Taylor Diagrams



MERRA precipitation comparison with other models

▶ See also: Bosilovich et al (2008, JAMC)

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

MERRA

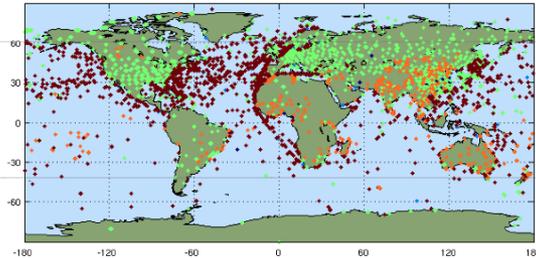
- Blends the vast quantities of observational data with output data of the Goddard Earth Observing System (GEOS) model [1979-present]

The Changing Observing System

07-Jan-1973 12UTC All data: 77098 observations

all lat; all lon; all lev; all kt; all k; all qcc; all qch
/data/austin/b500_swp_73/all_obs_workdir/SAVE_ODS/b500_swp_73.ana.obs.19730107_12z.ods

Observation Locations

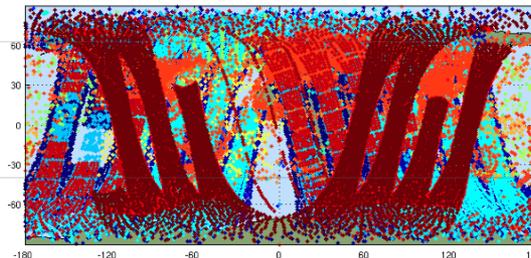


1973 – 77K Obs every 6hrs

02-Aug-1987 12UTC All data: 550602 observations

all lat; all lon; all lev; all kt; all k; all qcc; all qch
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Observation Locations

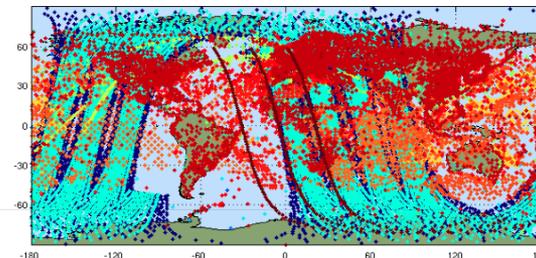


1987 – 550K Obs every 6hrs

07-Jan-1979 12UTC All data: 325765 observations

all lat; all lon; all lev; all kt; all k; all qcc; all qch
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Observation Locations

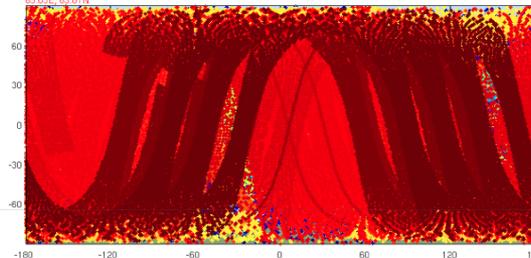


1979 – 325K Obs every 6hrs

07-Jan-2006 12UTC All data: 4217655 observations

all lat; all lon; all lev; all kt; all k; all qcc; all qch
/data/austin/d5_b10p9stab12_jan06/all_obs_workdir/d5_b10p9stab12_jan06.ana.obs.20060107_12z.ods

Observation Locations

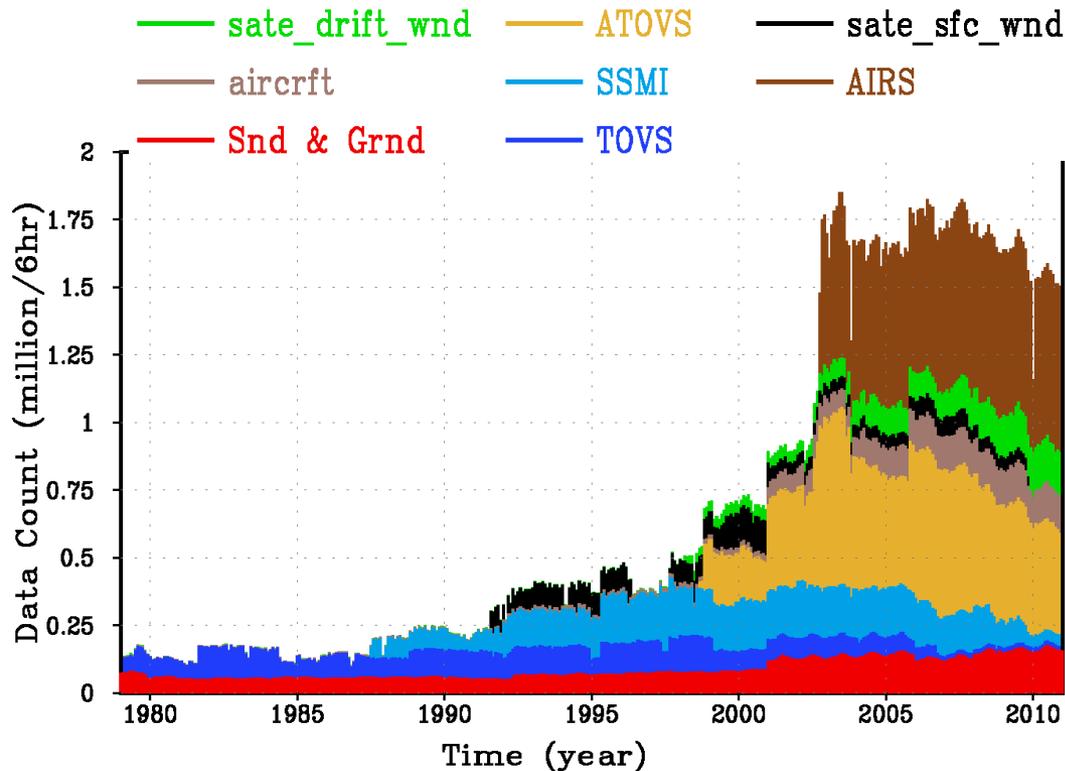


2006 – 4.2M Obs every 6hrs

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

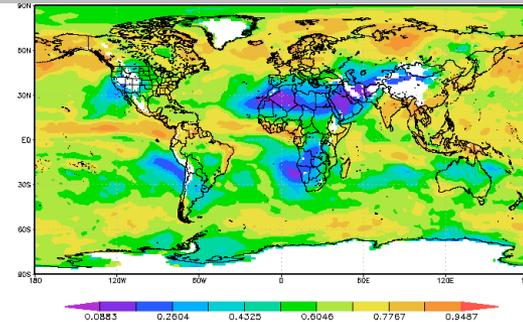


- Technologies change; Instrument life cycle

MERRA Reanalysis

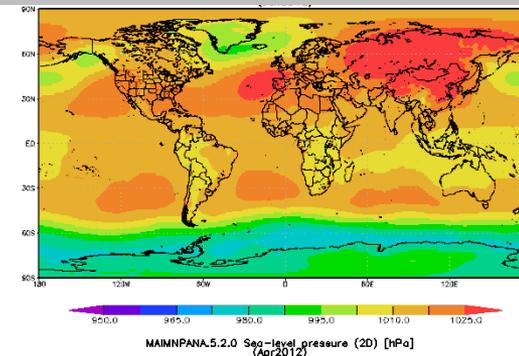
- **Strengths** – The processed data are globally continuous in space and time, and provide meteorological and climatological relevant fields
- **Weakness** – Earth system models represent the human knowledge of how the world works

Relative Humidity (fraction)

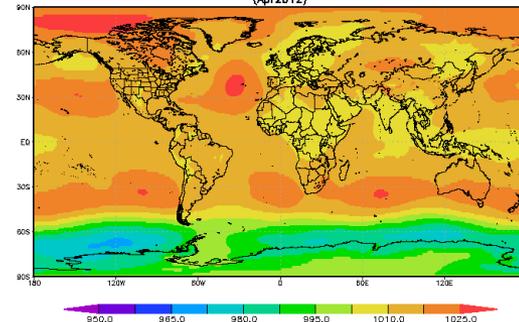


July 2011
(850 hPa)

Sea Level Pressure (hPa or mb)



January
2012

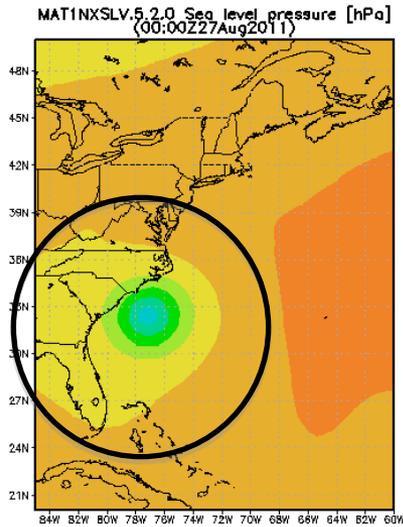


April
2012

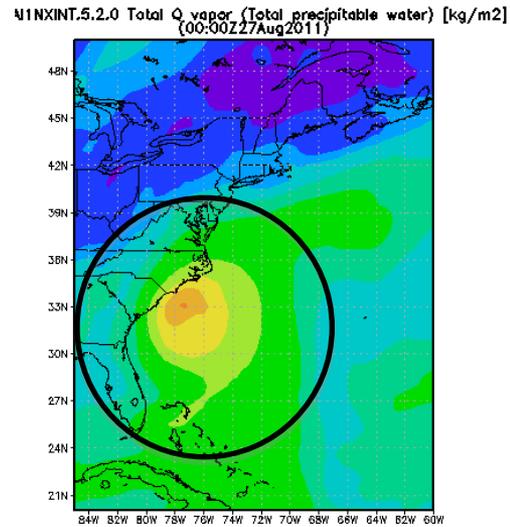
MERRA for Weather

Hurricane Irene August 27, 2011, 0 GMT

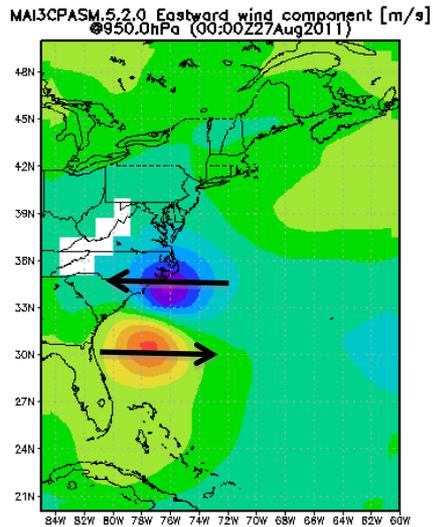
Sea Level Pressure



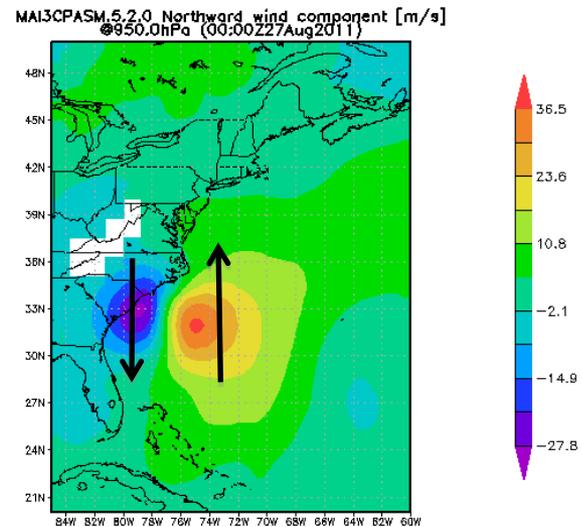
**Total Atmospheric
Moisture**



Eastward Wind



**Northward
Wind**



MERRA Water Products

Temporal Resolution: Monthly

Spatial Resolution: $1.25^{\circ} \times 1.25^{\circ}$ and 42 vertical levels

3-dimensional Parameters

Units

Specific Humidity

Kg/Kg

Relative Humidity

Fraction

Cloud Fraction

Fraction

Spatial Resolution: $2/3^{\circ} \times 1/2^{\circ}$

2-dimensional Parameters

Surface Rainfall Rate

Kg/m²/s

Surface Evaporation

Kg/m²/s

Cloud Top **Pressure** and **Temperature**

hPa and K

Vertically Integrated Water Vapor

Kg/m²

MERRA Water Products

Temporal Resolution: Hourly

Spatial Resolution: $1.25^{\circ} \times 1.25^{\circ}$ 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: $2/3^{\circ} \times 1/2^{\circ}$

2-dimensional Parameters

Surface Rainfall Rate

Kg/m²/s

Snow Mass

Kg/m²

Snow Cover

Fraction

Snow Depth

m

Surface Snowfall Rate

Kg/m²/s

Surface Evaporation

Kg/m²/s

Cloud Top **Pressure** and **Temperature**

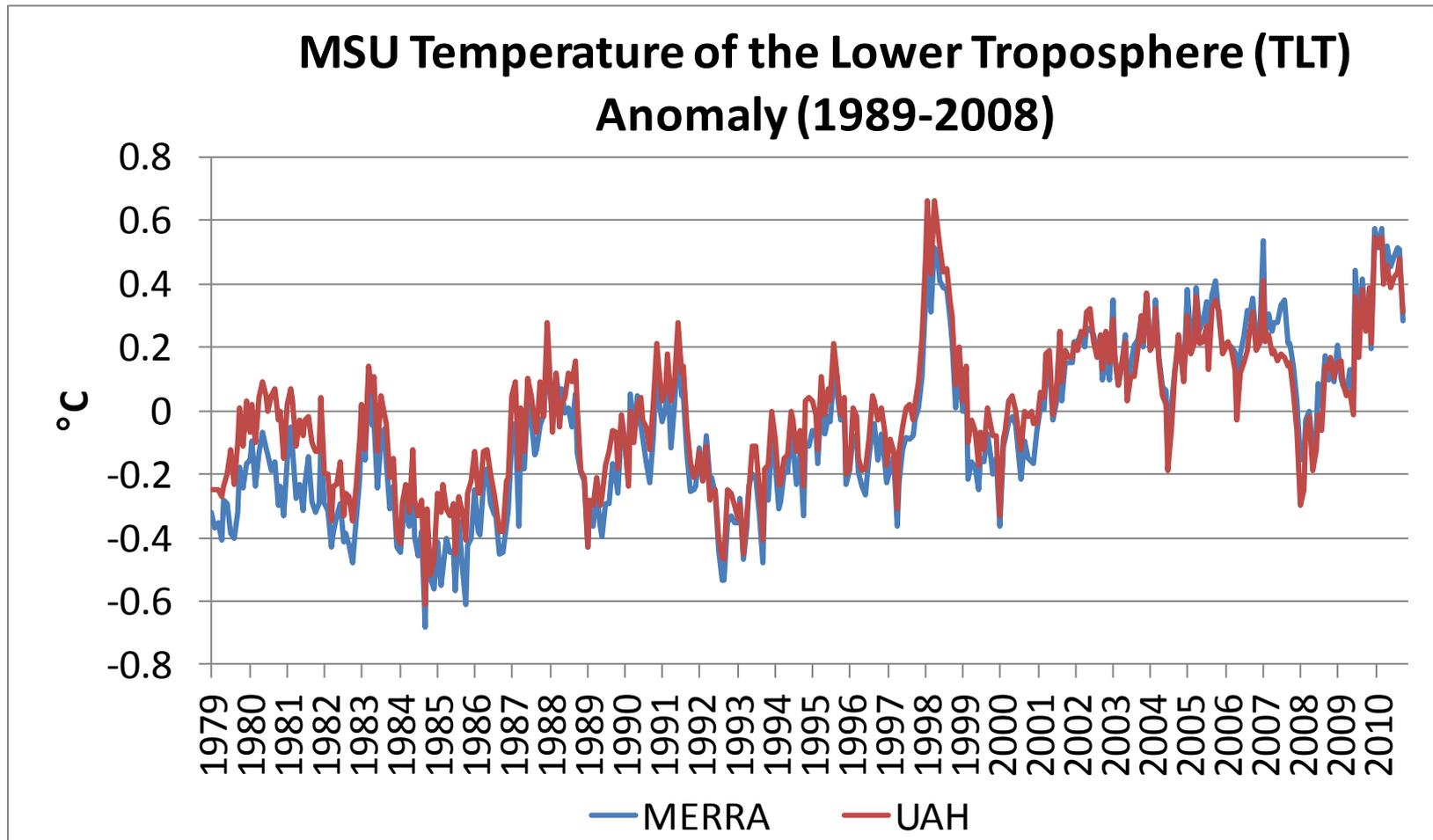
hPa and K

Vertically Integrated Water Vapor,

cloud liquid and ice water content

Kg/m²

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

Mirador Earth Science Data Search Tool

http://mirador.gsfc.nasa.gov/

NASA National Aeronautics and Space Administration

Goddard Earth Sciences Data and Information Services Center

Search DISC +60

+ ATMOS COMPOSITION + HYDROLOGY + A-TRAIN + AIRS + MODELING + NEESPI + PRECIPITATION

+ GES DISC Home

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Mirador
Data Access Made Simple

You are here: [Keyword Search](#)

Keyword Projects Science Areas

Keyword: MERRA

Location:

Time Span

From:

To:

Search GES-DISC

Advanced Search

Available: [AIRS, OMI, MLS, HIRDLS, TOMS, UARS, TRMM, GLDAS, SORCE, Subsets from A-Train Sensors \(e.g. MODIS, AIRS, OMI and MLS\), MERRA, GOCART, LIMS, MSU, NEESPI, NLDAS, SSBUV, SBUV, TOVS ACOS MEASUREs](#)

What's New: [Quality Screening for AIRS Level 2 Products is now combined with Variable Subsetting and NetCDF Conversion](#)

Acknowledgements:

Location Gazetteer data from: [National GeoSpatial Information Agency](#)

Events Gazetteer data from: [Unisys](#), [EPA](#) and [Smithsonian Global Volcanism Program](#)

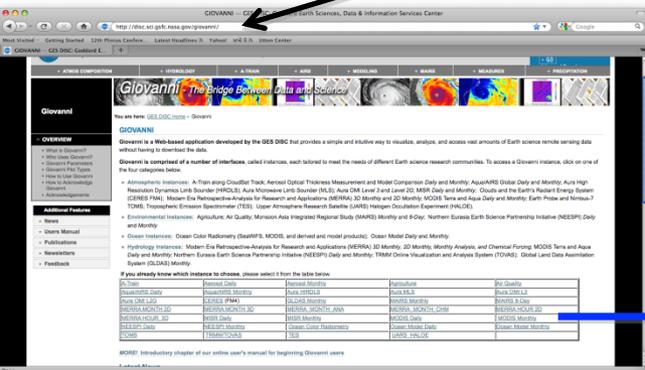
LATEST NEWS

2011-11-03T17:58:49Z - TRMM Version 7 data are now available
Tropical Rainfall Measuring Mission provides vital precipitation data
[+ Read More](#)

Done

MERRA Image Products

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



The screenshot shows the 'Data Assimilation System (GLDAS) monthly' selection page. It features a table of data products with a red box highlighting the 'MERRA HOUR 3D' product. Below the table, there is a link to an introductory chapter of the user's manual and a 'Latest News' section.

If you already know which instance to choose, please select it from the table below.

A-Train	Aerosol Daily	Aerosol Monthly	Agriculture	Air Quality
Aqua/AIRS Daily	Aqua/AIRS Monthly	Aura HIRDLS	Aura MLS	Aura OMI L3
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	

MORE! Introductory chapter of our online user's manual for beginning Giovanni users

[Latest News](#)

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

MERRA Giovanni Analysis