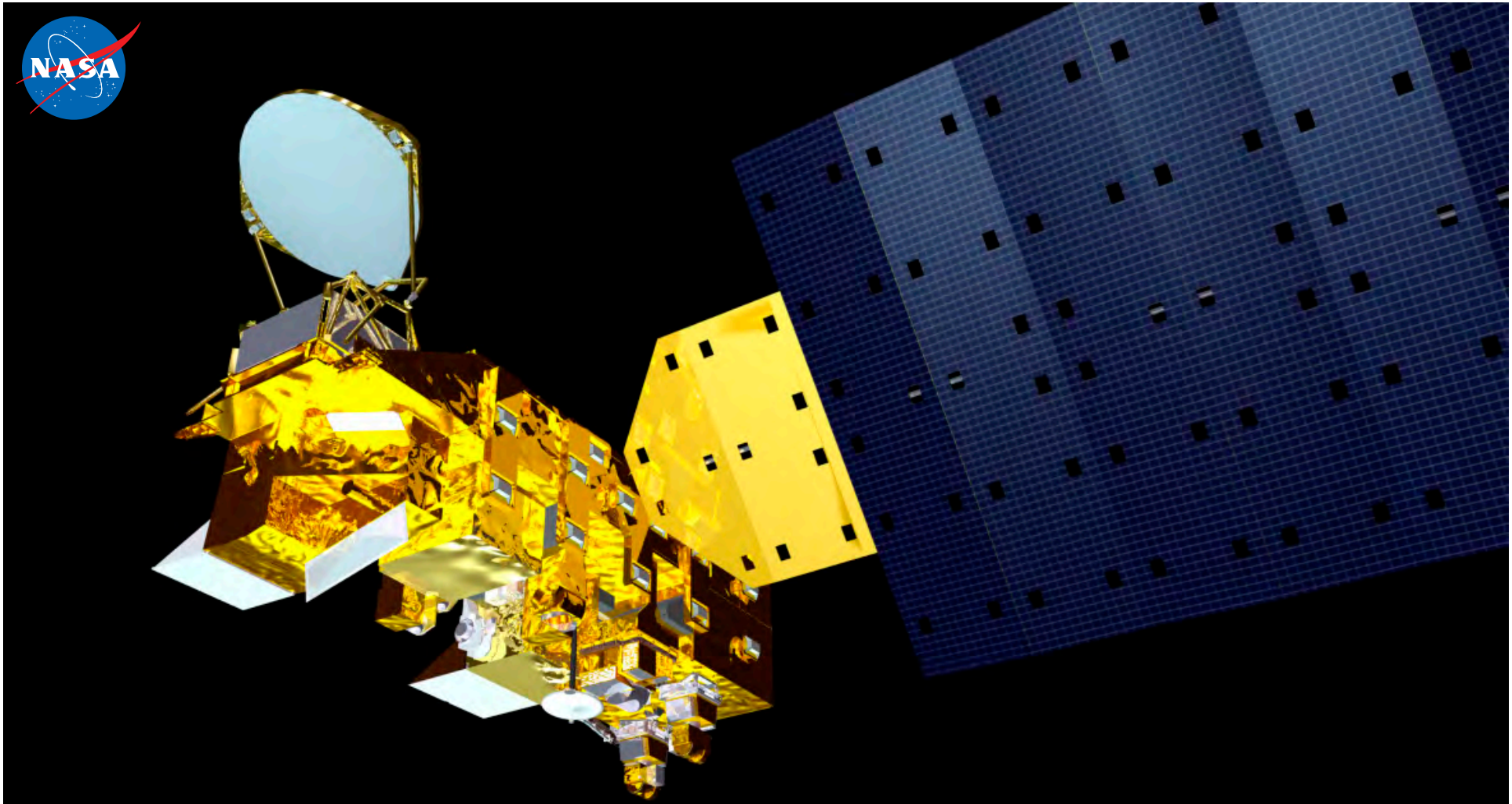


Aqua at Ten Years and Counting

Claire L. Parkinson/Aqua Project Scientist
NASA Goddard Space Flight Center

Goddard Scientific Colloquium, May 4, 2012

Aqua's Delta II Rocket

(photos by Bill Ingalls)

May 3, 2002

May 4, 2002

The Launch of Aqua, May 4, 2002

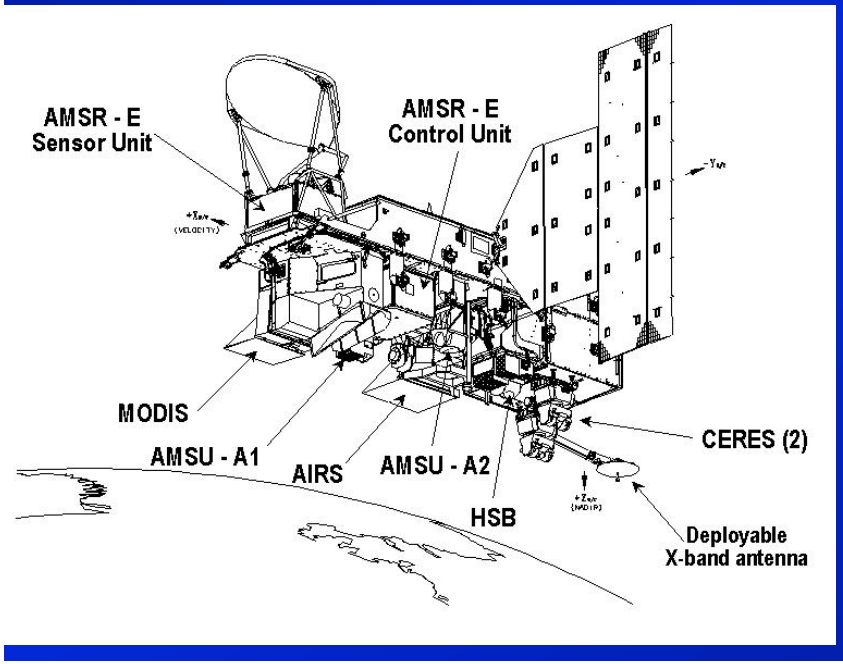
(video courtesy of Vandenberg Air Force Base, digitized by Vicky Weeks)

Aqua's Orbit

(animation by Jesse Allen and Claire Parkinson)

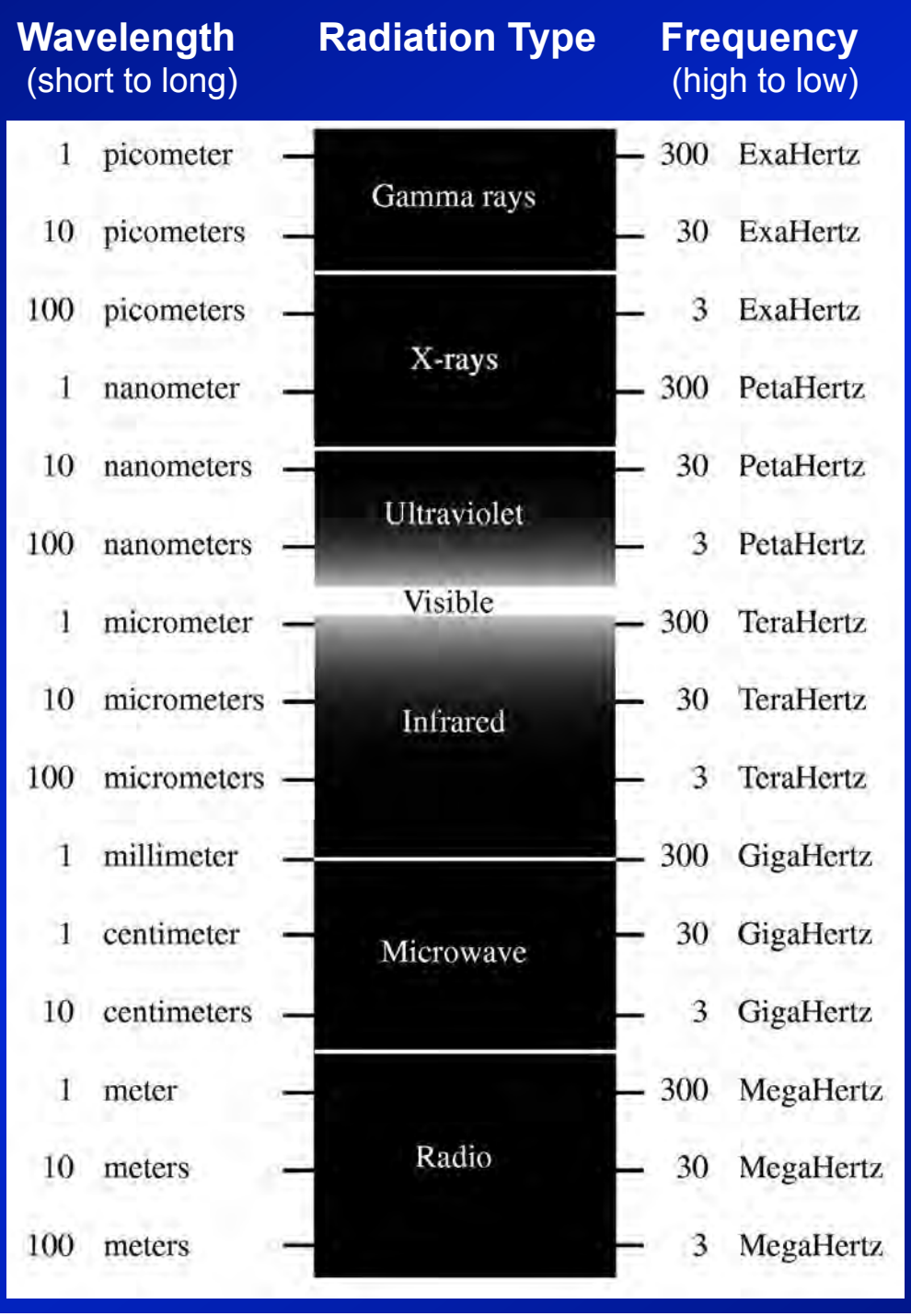
Aqua's Earth-Observing Instruments

- AIRS: Atmospheric Infrared Sounder
- AMSU: Advanced Microwave Sounding Unit
- HSB: Humidity Sounder for Brazil
- CERES: Clouds and the Earth's Radiant Energy System
- MODIS: Moderate Resolution Imaging Spectroradiometer
- AMSR-E: Advanced Microwave Scanning Radiometer for the Earth Observing System



Aqua space-viewing side (left) and Earth-viewing side (above), courtesy of Northrop Grumman.

Electro-magnetic Spectrum



Aqua measure-ment ranges

AIRS

MODIS

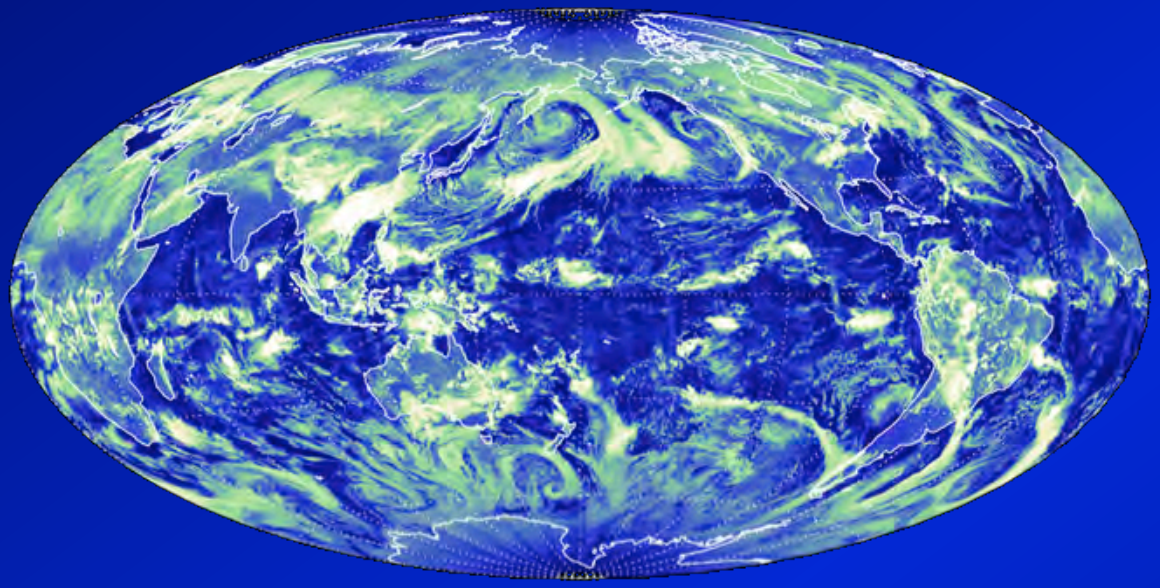
CERES

HSB

AMSU

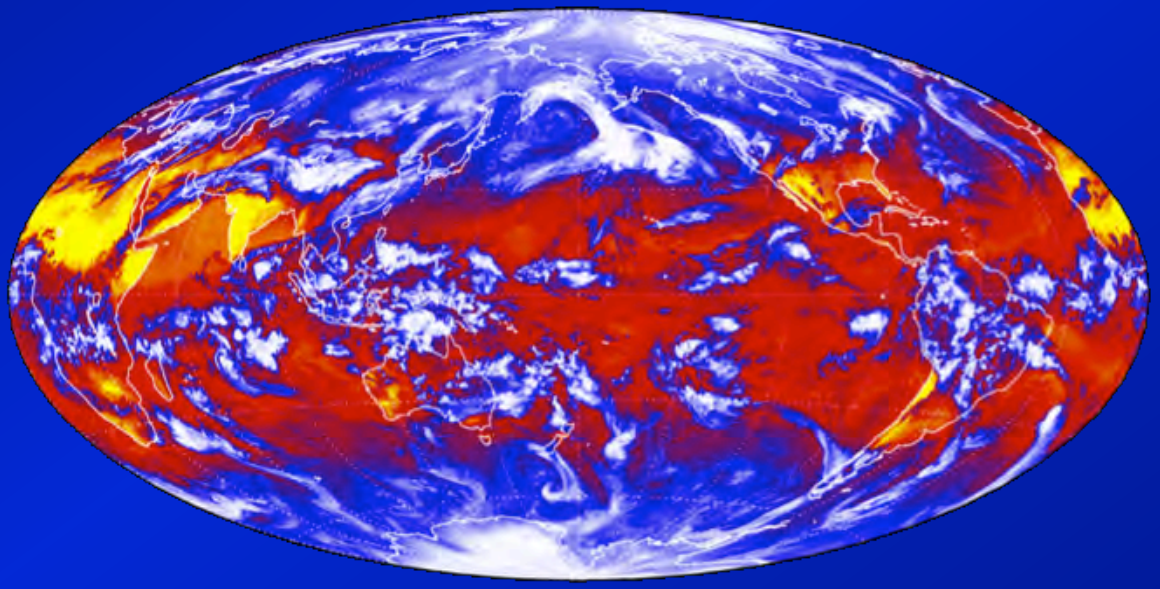
AMSR-E

Outgoing Shortwave and Longwave Radiation, March 18, 2011, from the Aqua CERES



750
400
50

Reflected shortwave radiation (W/m^2)



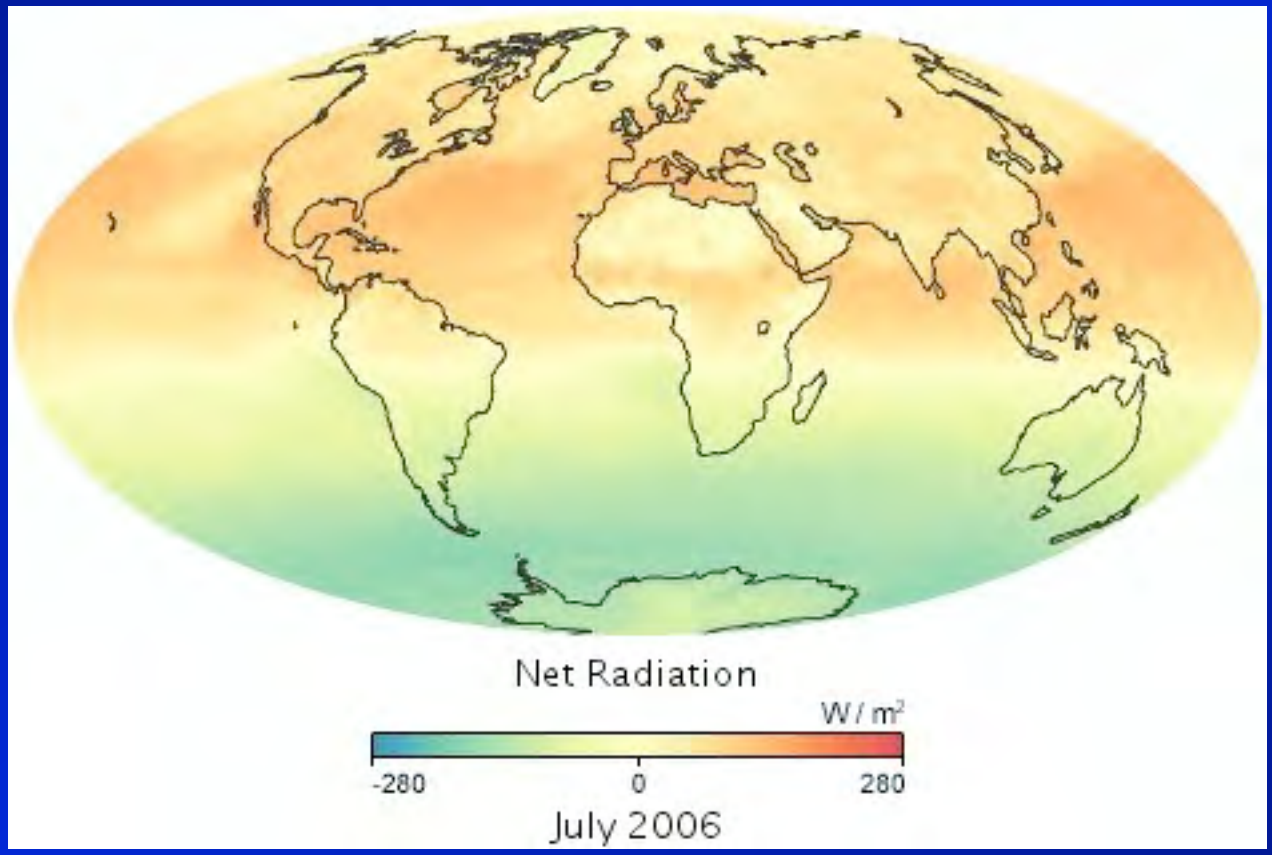
350
250
150

Outgoing longwave radiation (W/m^2)

(images courtesy of Tak Wong, N. Loeb, and the CERES Science Team)

Net Radiation at the Top of the Atmosphere, July 2006 - December 2011,

from the Aqua and Terra CERES and the Total Irradiance Monitor (TIM) on the Solar Radiation and Climate Experiment (SORCE)



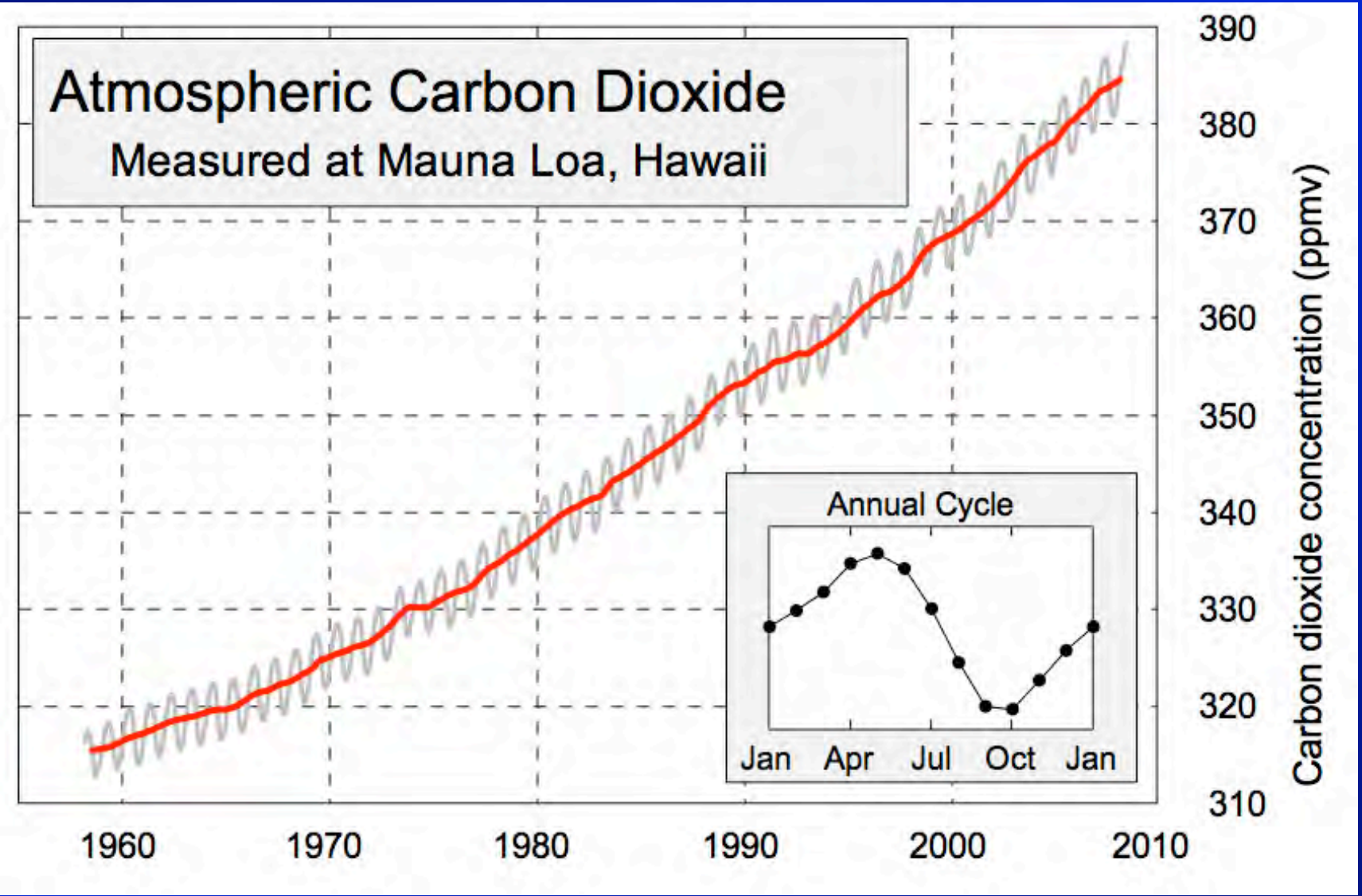
(animation from earthobservatory.nasa.gov)

Global energy imbalance = 0.50 ± 0.43 Wm^{-2} (from Loeb et al., 2012)

Key Variables Affecting the Earth's Energy Budget and Measured by Aqua

- Greenhouse gases
  - Water vapor
  - Carbon dioxide
  - Methane
- Particulate matter in the atmosphere
  - Volcanic emissions
  - Dust and other natural and anthropogenic aerosols
- Clouds
- Ice and snow covers
- Vegetation

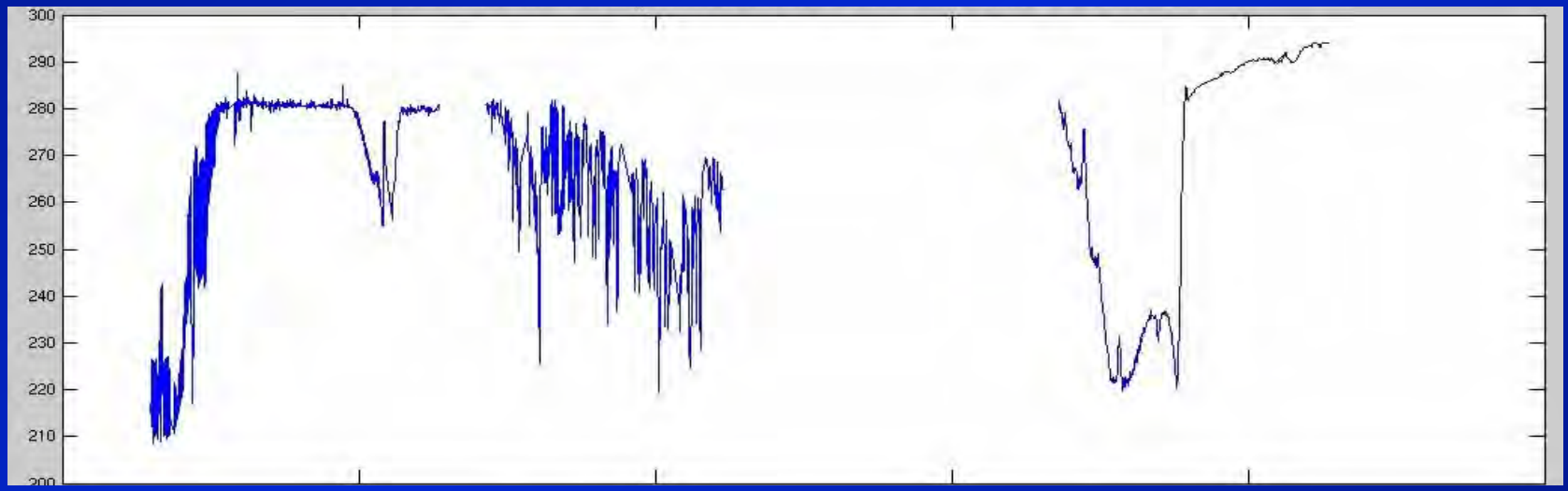
Keeling Curve: Atmospheric CO_2 Measured at Mauna Loa



(image from Wikipedia)

Sample Infrared Data at One Location and One Time, from the AIRS instrument

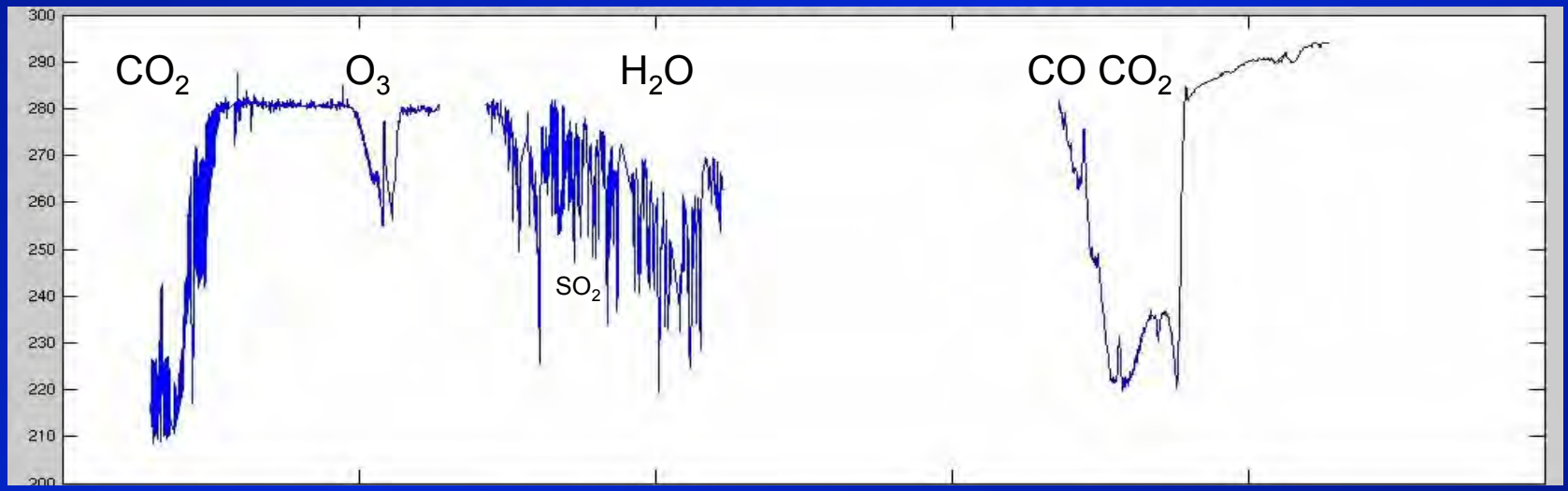
Data from all 2378 AIRS infrared channels for one footprint off the west coast of South Africa, June 13, 2002, 1:30 UTC.



(spectrum courtesy of M. Chahine and the AIRS Science Team)

Sample Infrared Data at One Location and One Time, from the AIRS instrument

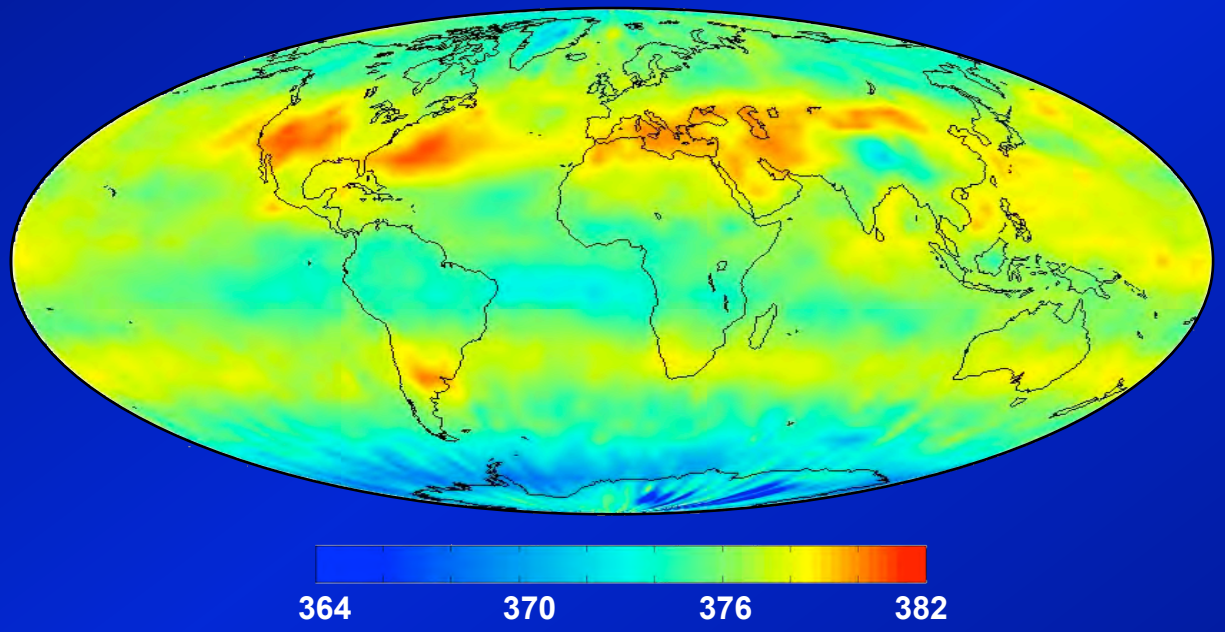
Data from all 2378 AIRS infrared channels for one footprint off the west coast of South Africa, June 13, 2002, 1:30 UTC.



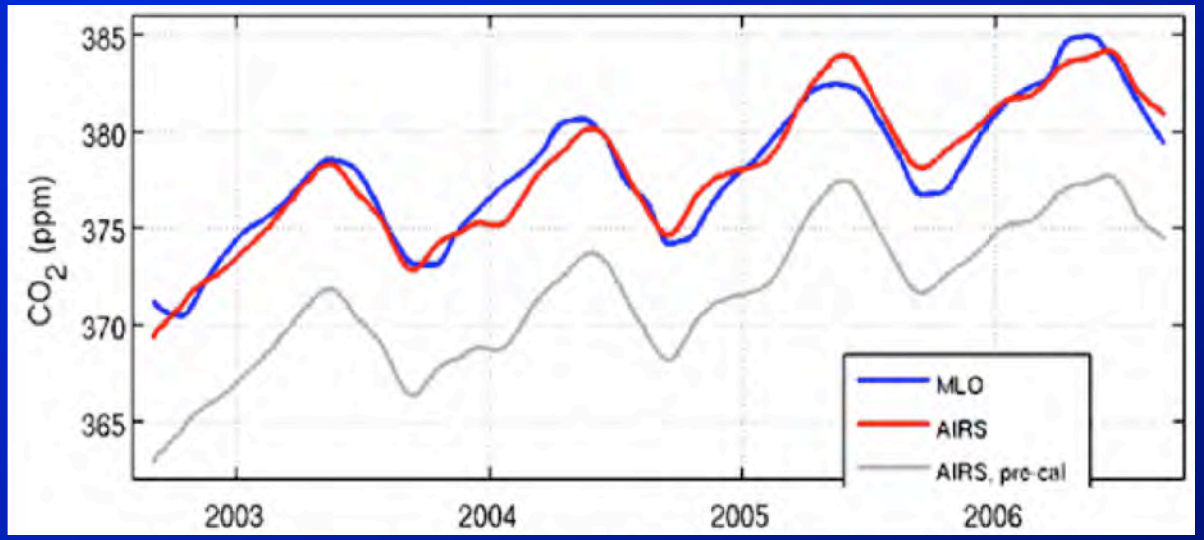
(spectrum courtesy of M. Chahine and the AIRS Science Team)

Mid-Troposphere CO_2 as derived from AIRS/AMSU Data

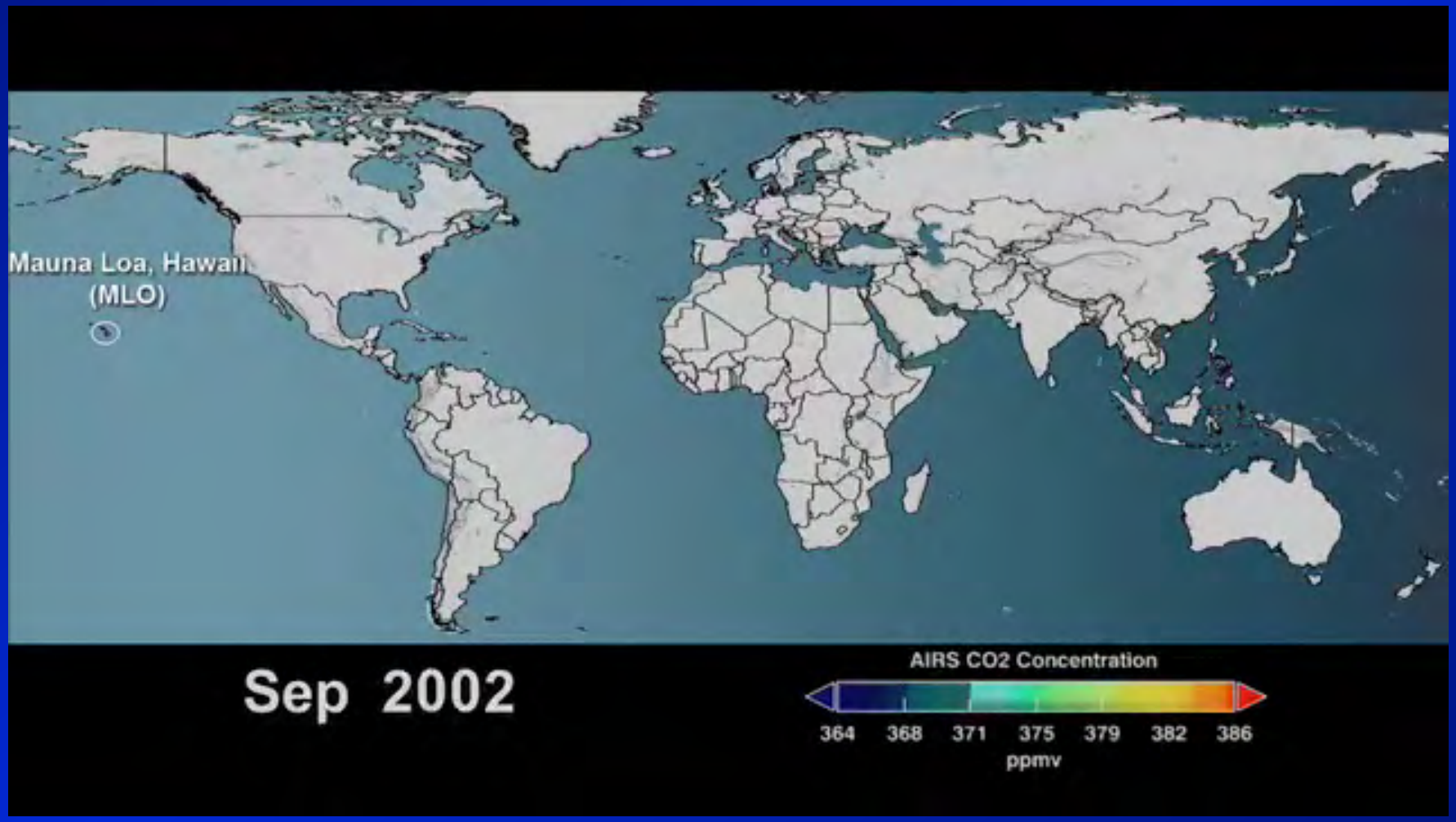
AIRS mid-troposphere CO_2 concentrations (ppm) for July 2003 (from Mous Chahine and the AIRS Science Team).



CO_2 time series from the Mauna Loa Observatory (MLO) and from AIRS retrievals for the Pacific Ocean before and after calibration (from Strow and Hannon 2008).



Animation of Global CO_2 Distributions from AIRS/AMSU data, September 2002 – July 2008



(animation from the NASA GSFC Scientific Visualization Studio [SVS] and the AIRS Science Team)

Eruption of the Eyjafjallajökull Volcano, Iceland, April 17, 2010, from Aqua MODIS data

Eruption of Chile's Puyehue Cordon Caulle Volcano, June 4, 2011, from Aqua MODIS data

Views from the Ground of the 6/4/2011 Eruption of Chile's Puyehue Cordon Caulle Volcano

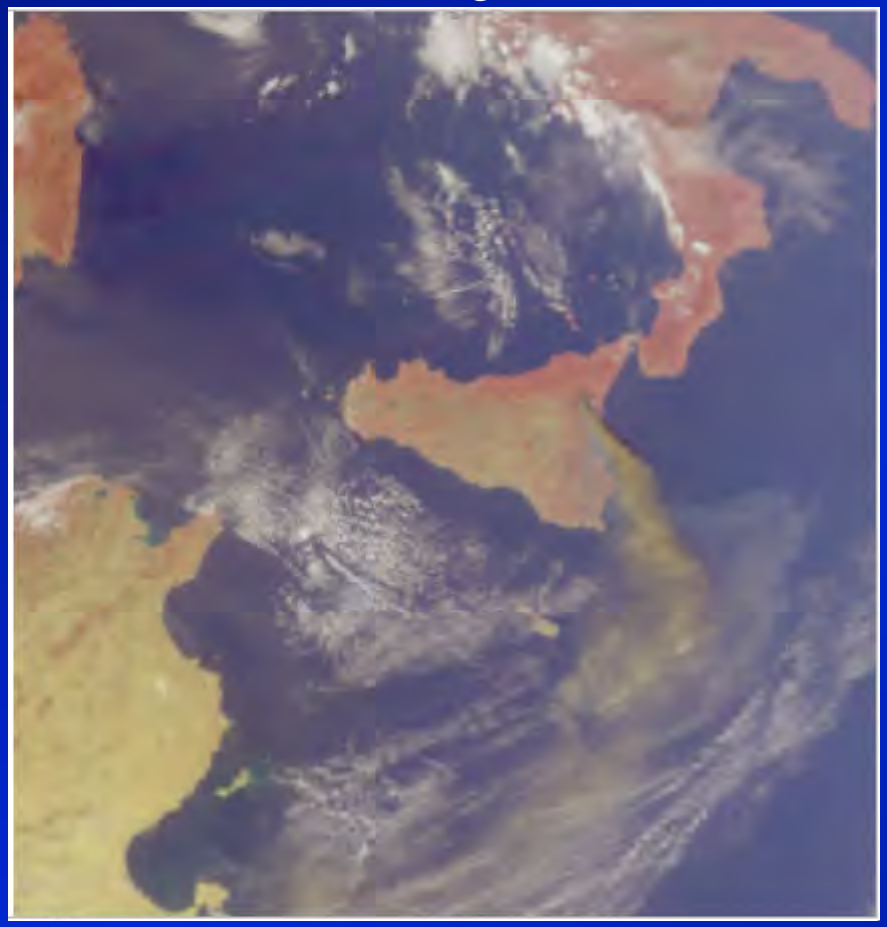
Road covered by pumice rocks

Ash-filled air in San Martin de los Andes, Argentina, 6/4/11.

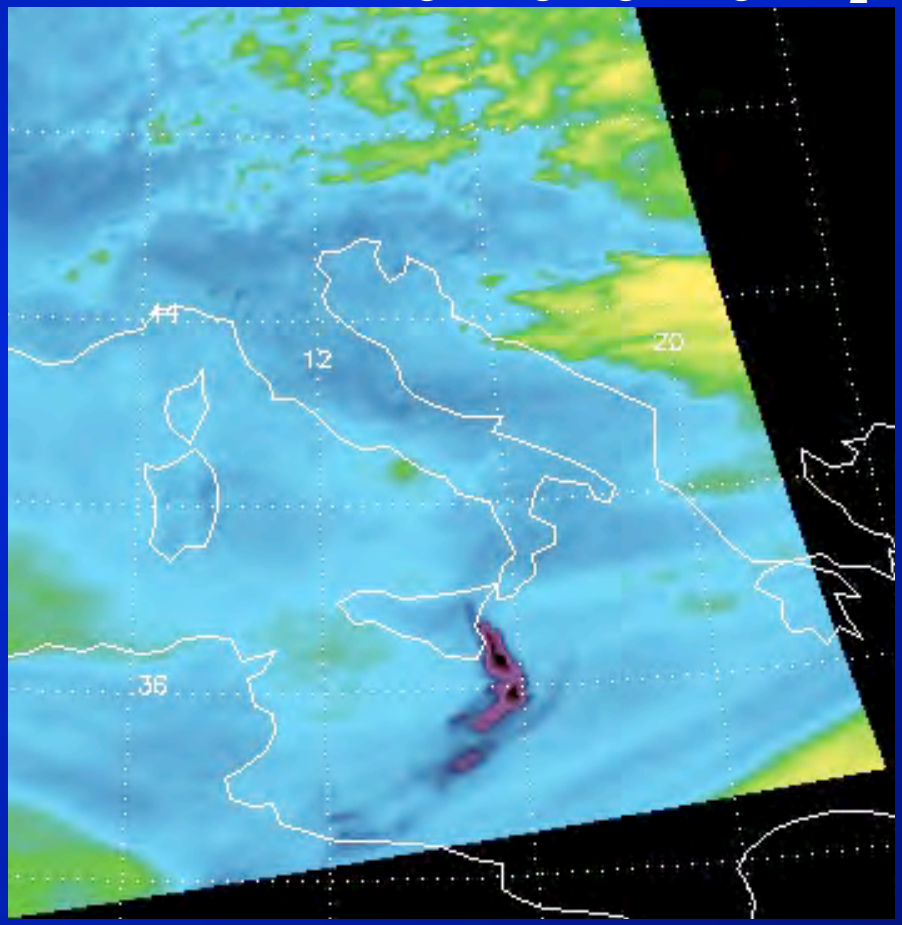
(Photos from Reuters and www.dailymail.co.uk)

Mt. Etna Eruption, October 28, 2002, from Aqua AIRS data

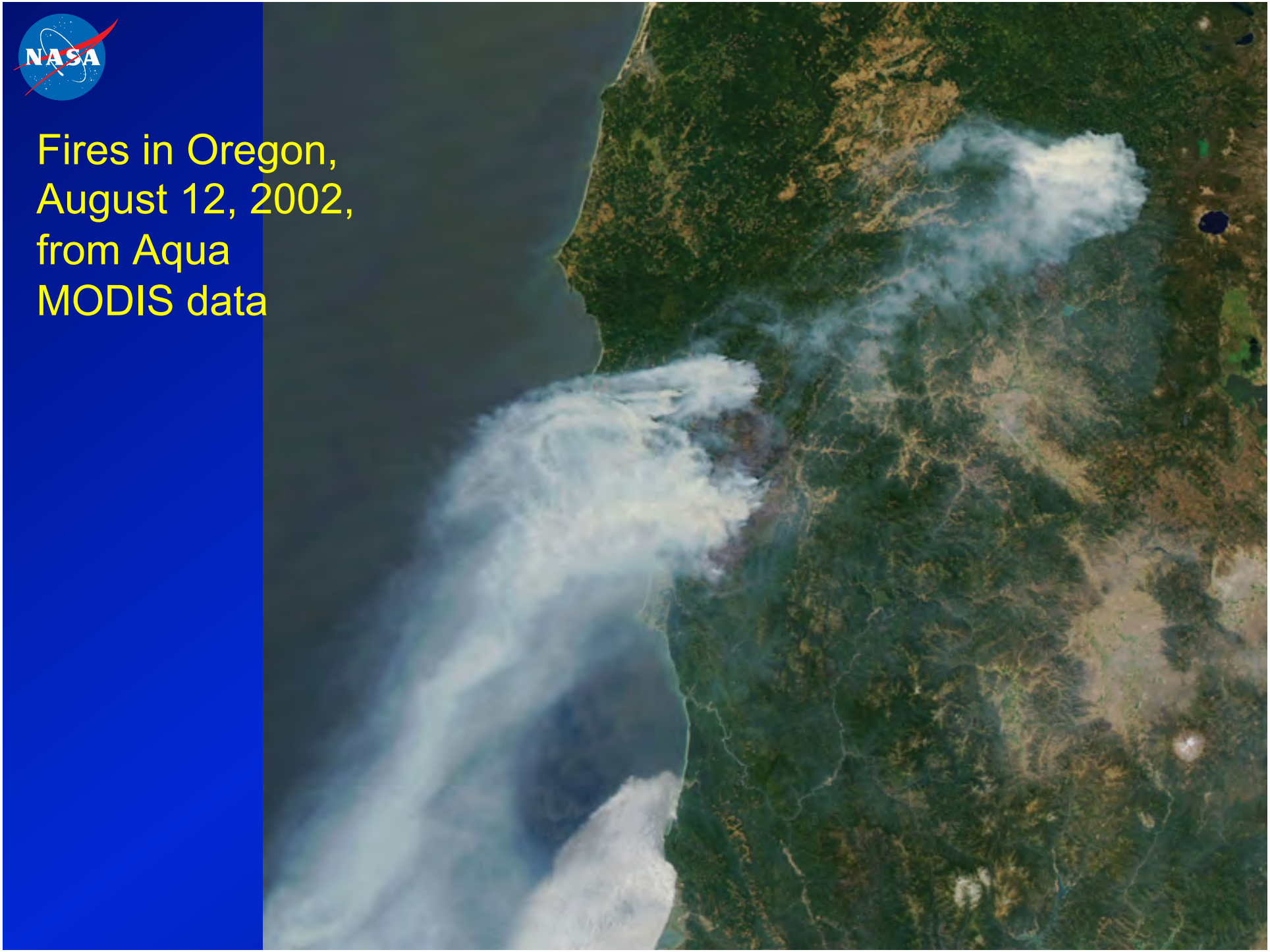
Visible/Near IR image



IR difference image highlighting SO_2

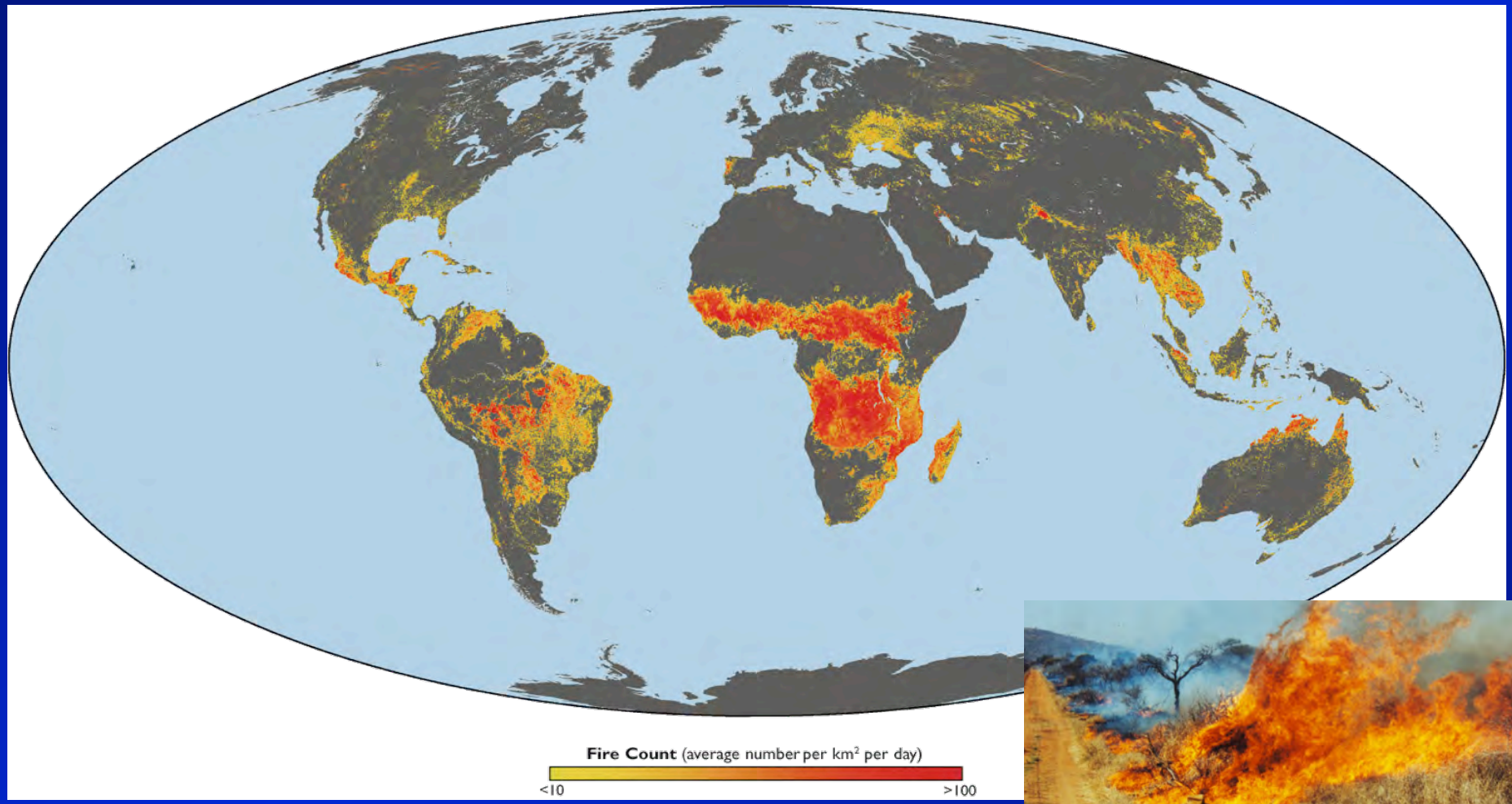


(images courtesy of M. Chahine and the AIRS Science Team)



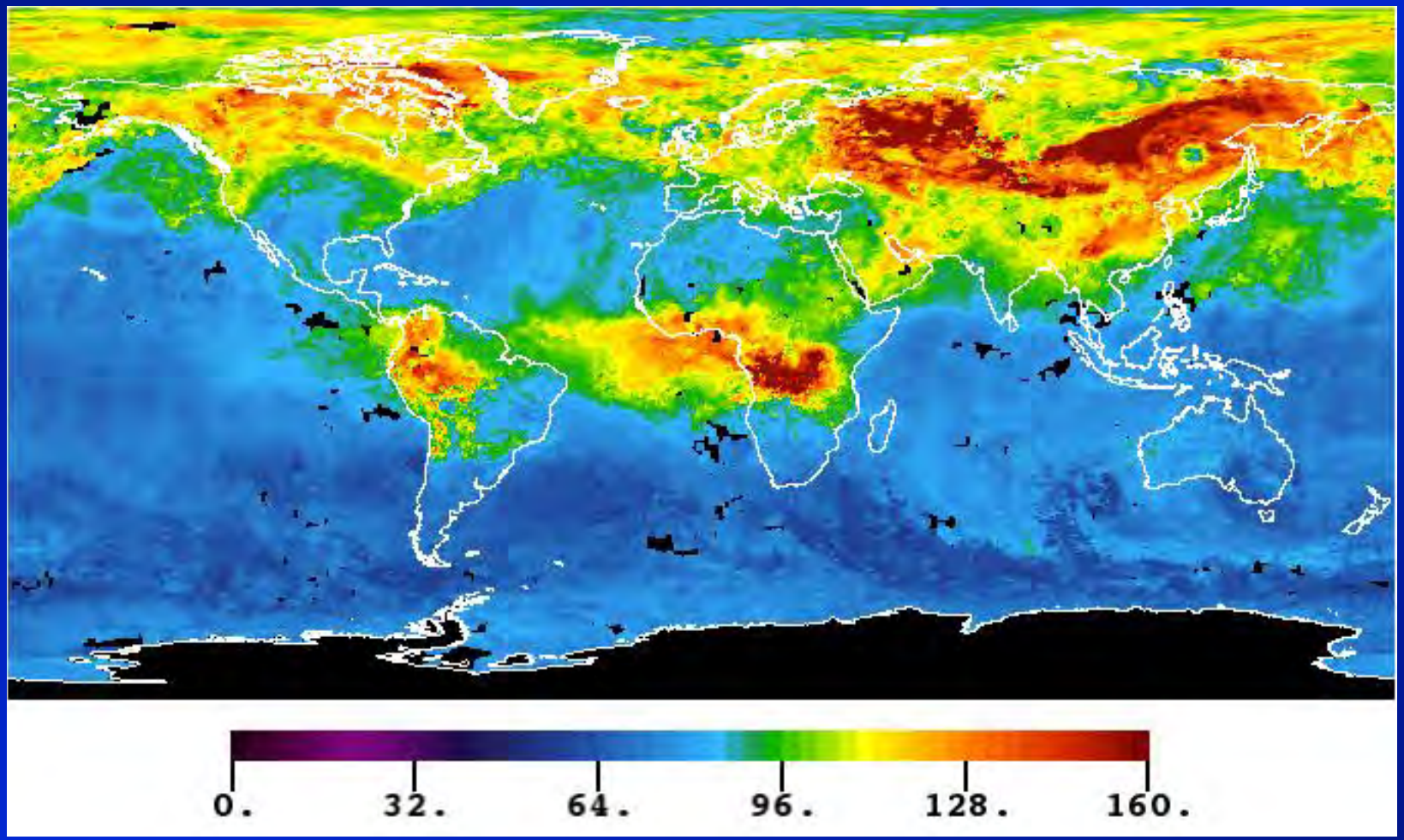
Fires in Oregon, August 12, 2002, from Aqua MODIS data

Global Distribution of Fires in 2005, from Aqua and Terra MODIS data



(from D. Roy and C. Justice, in *Our Changing Planet: The View From Space*, 2007; photo of fire management in South Africa by T. Landmann)

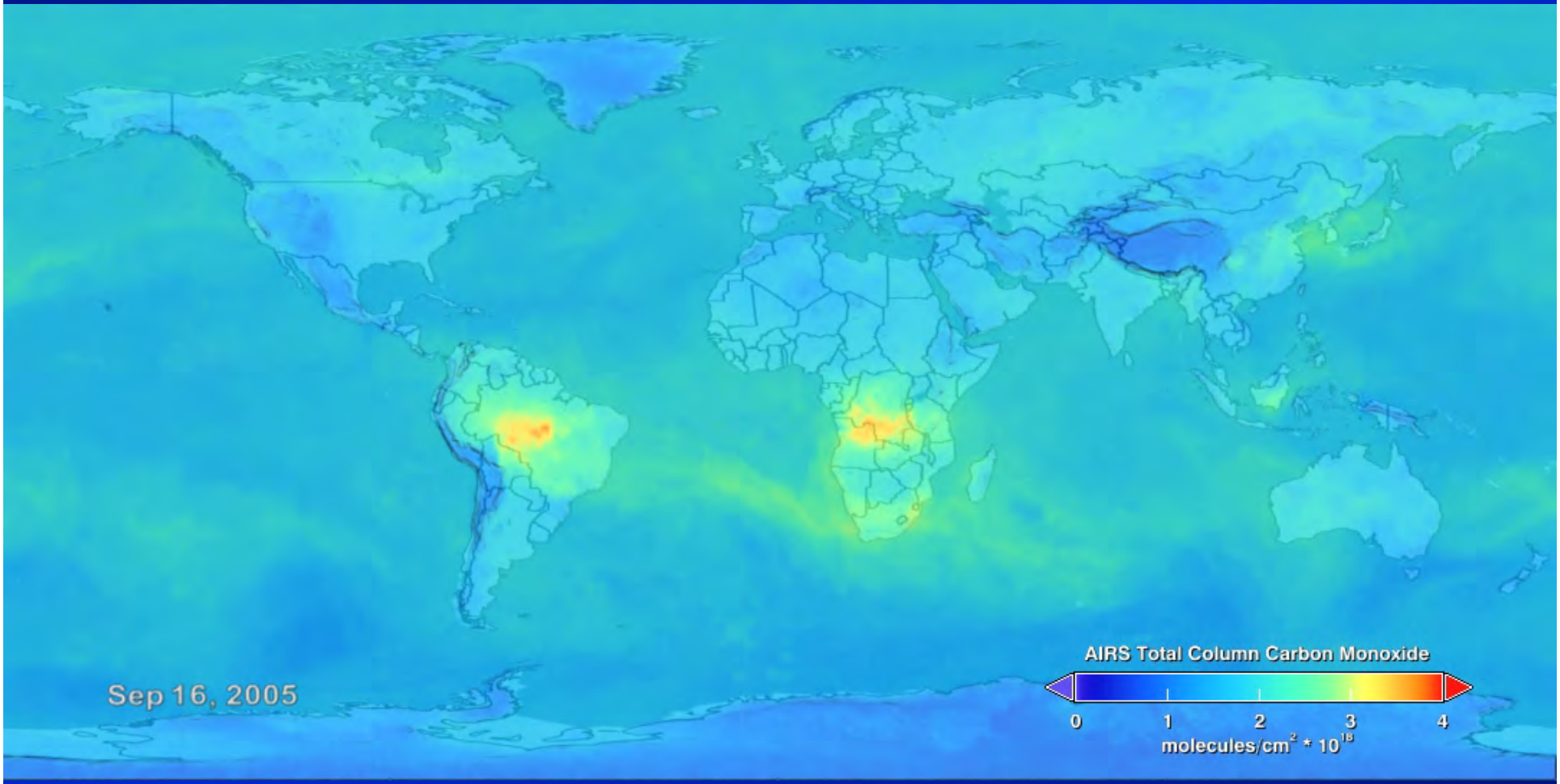
Global Mid-Troposphere CO, August 9-11, 2010, from AIRS/AMSU data



Carbon monoxide (ppbv)

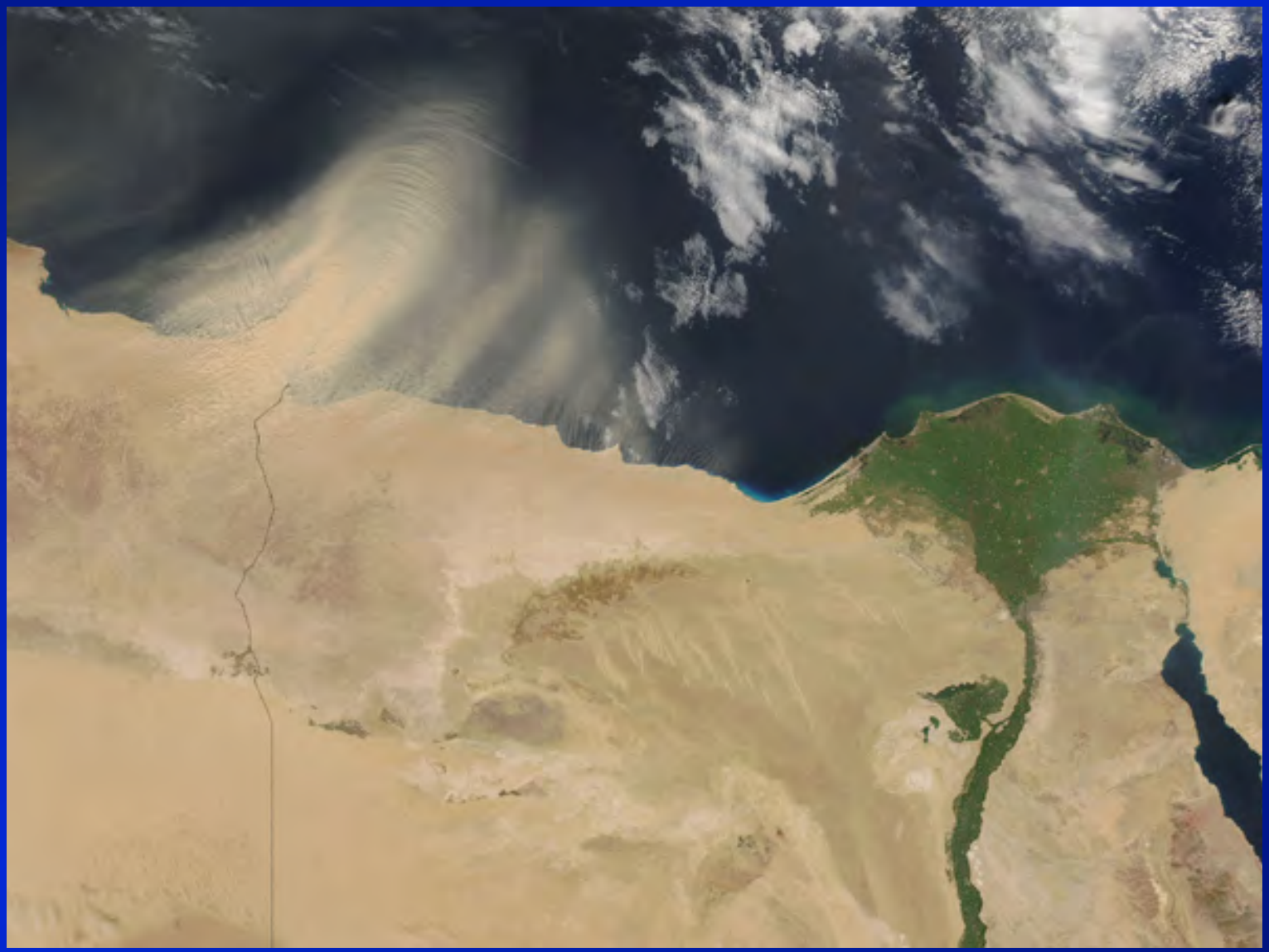
(from the AIRS Science Team)

CO Transport Across the Atlantic, 9/16/05-10/7/05, from AIRS/AMSU data

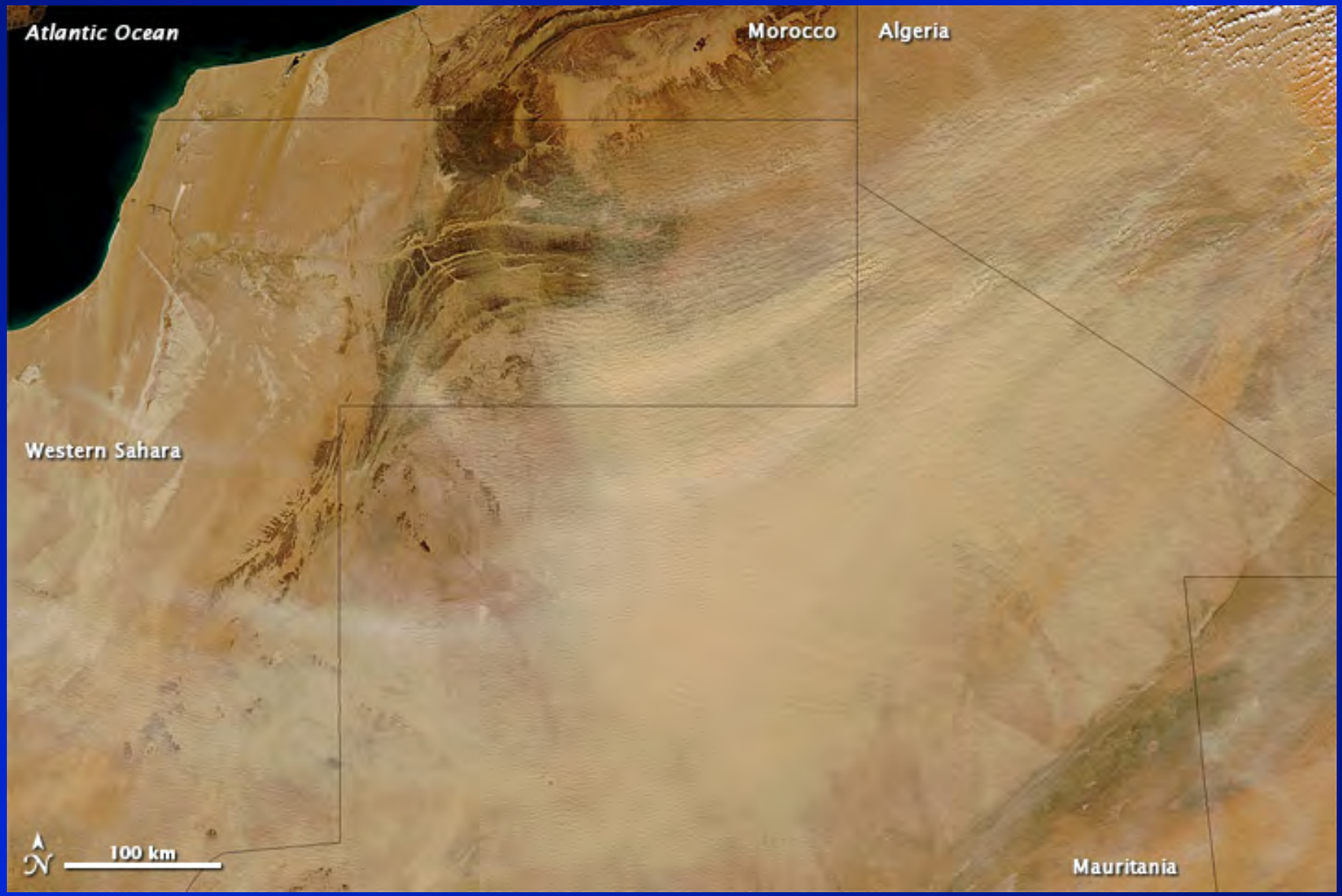


(from the AIRS Science Team)

Dust Storm Emerging from Libya, September 16, 2005, from Aqua MODIS data



Saharan Dust Storm, January 18, 2012, from Aqua MODIS data



Ground View of a Saharan Dust Front

(photo courtesy of Jim Tucker)

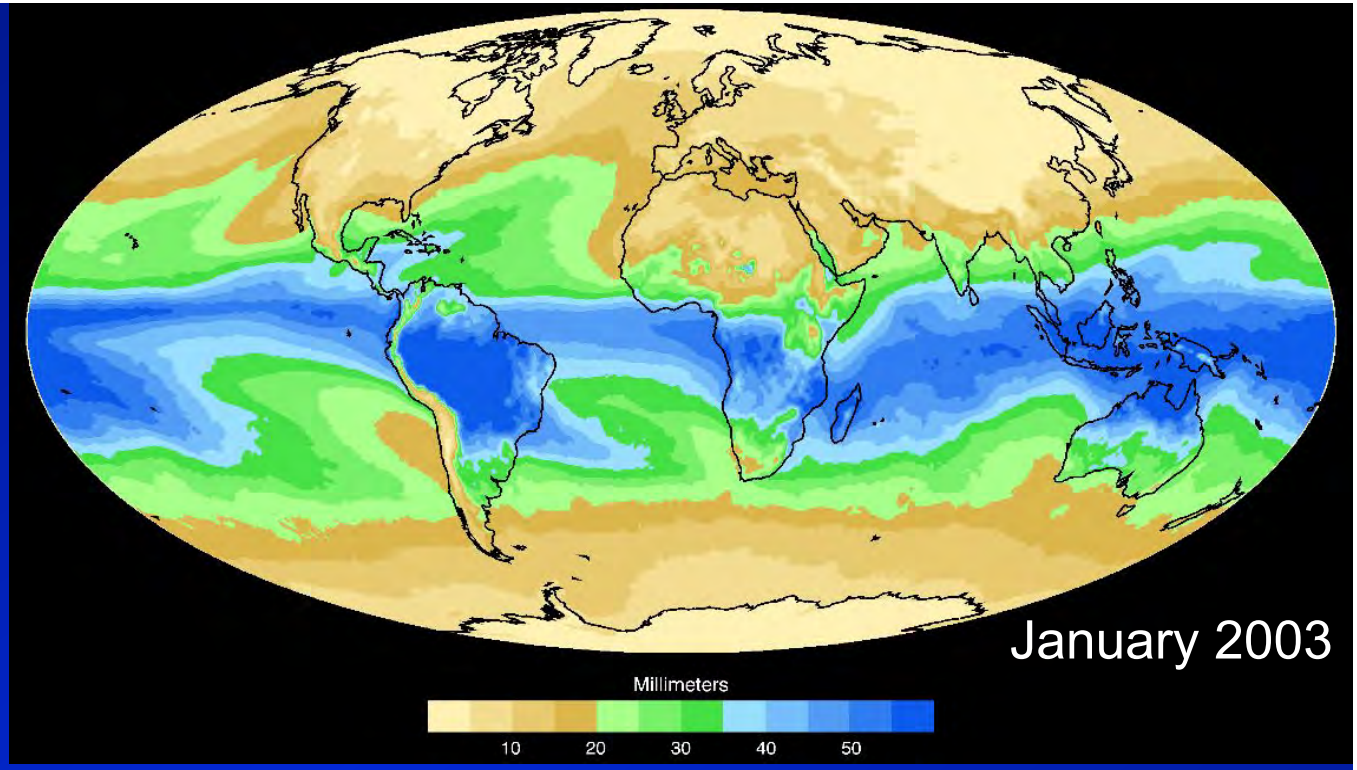
Ground View of a Dust Storm in Stratford, Texas, April 18, 1935

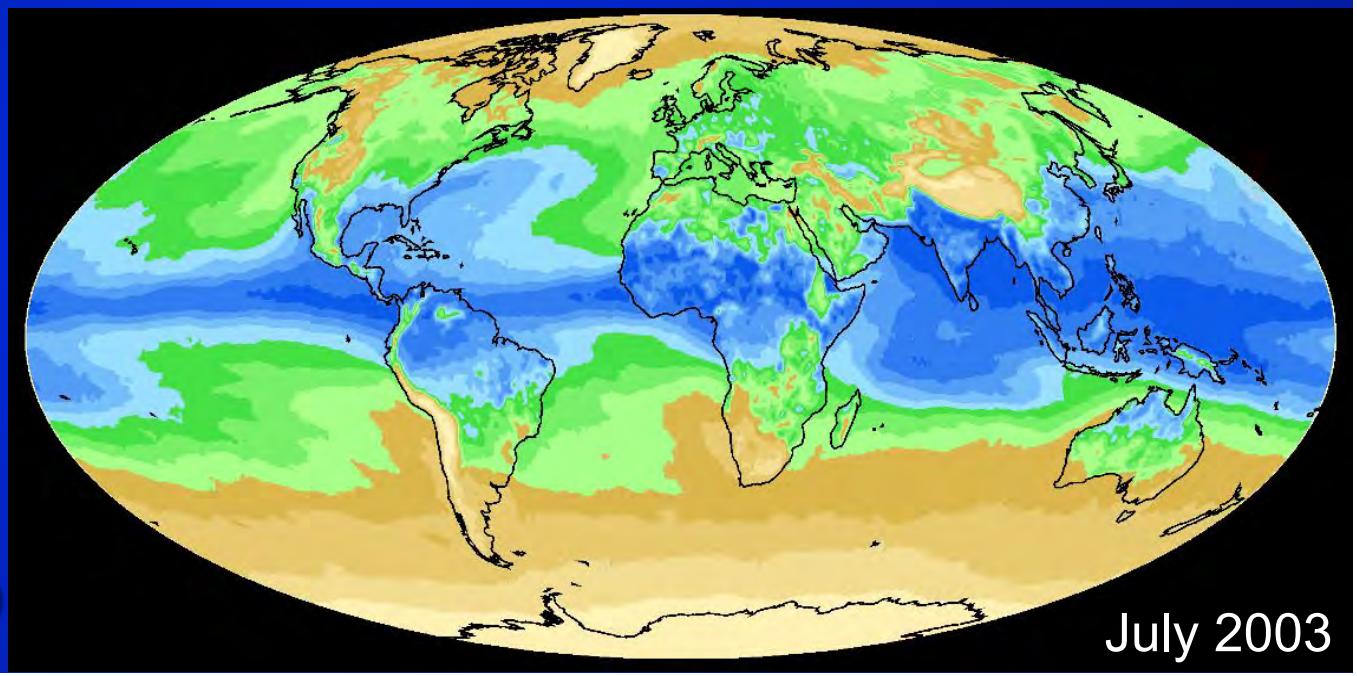
(photo from the NOAA George E. Marsh Album)

The Earth's Water Cycle

Logo of the AMSR-E Science Team
(designed by Hailey King)

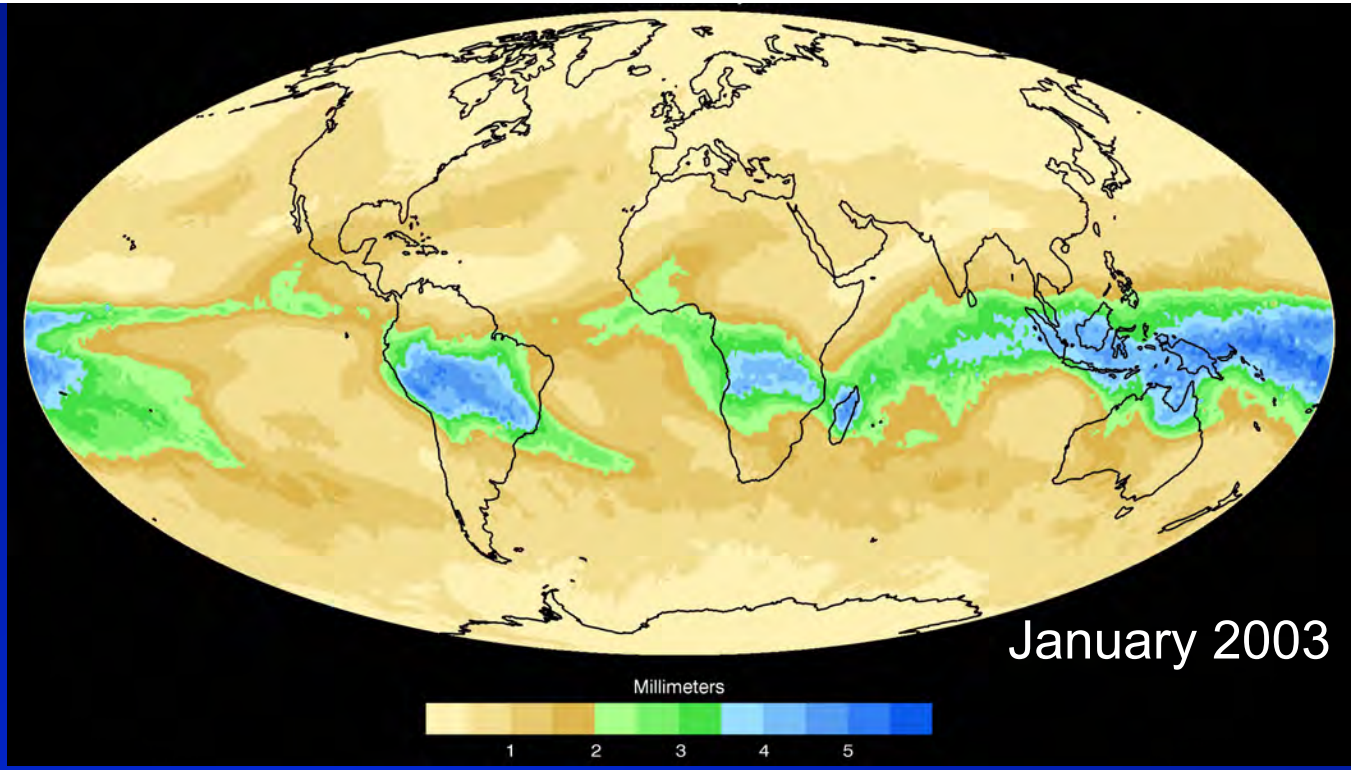
Water Vapor, January & July 2003, from AIRS/ AMSU data

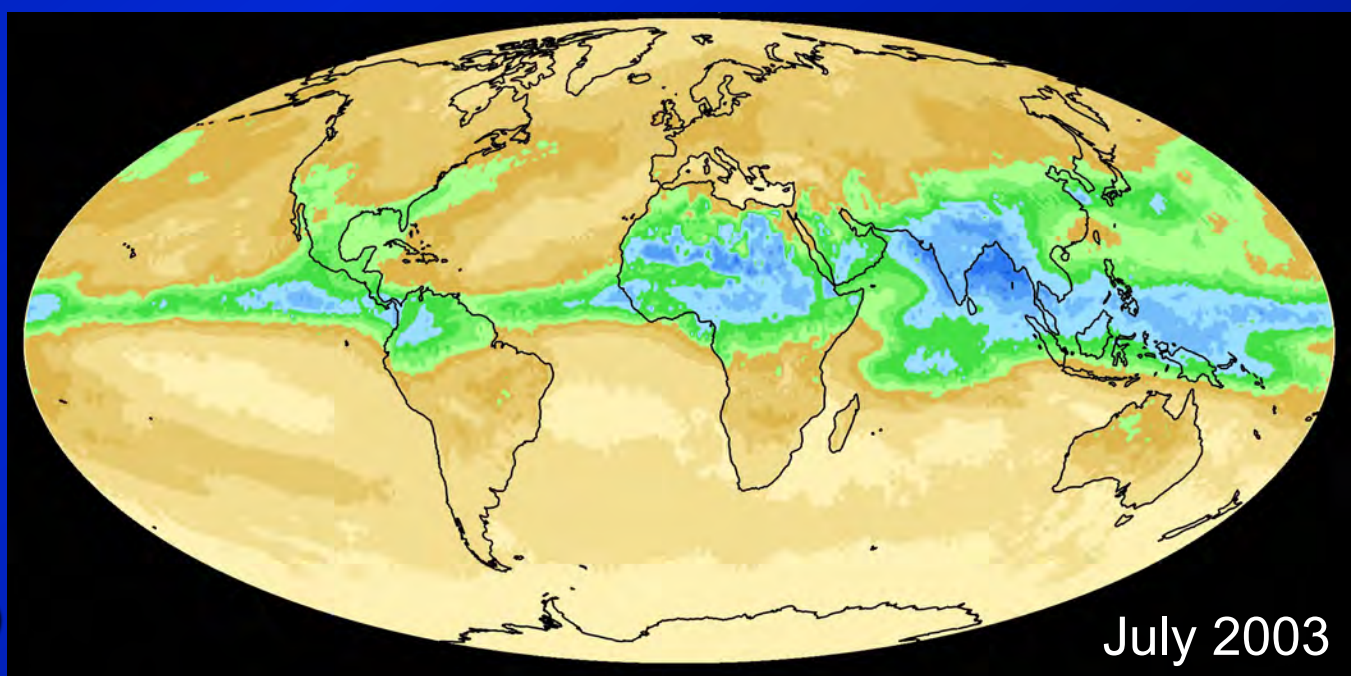




(images courtesy of C. Thompson and E. Olsen)

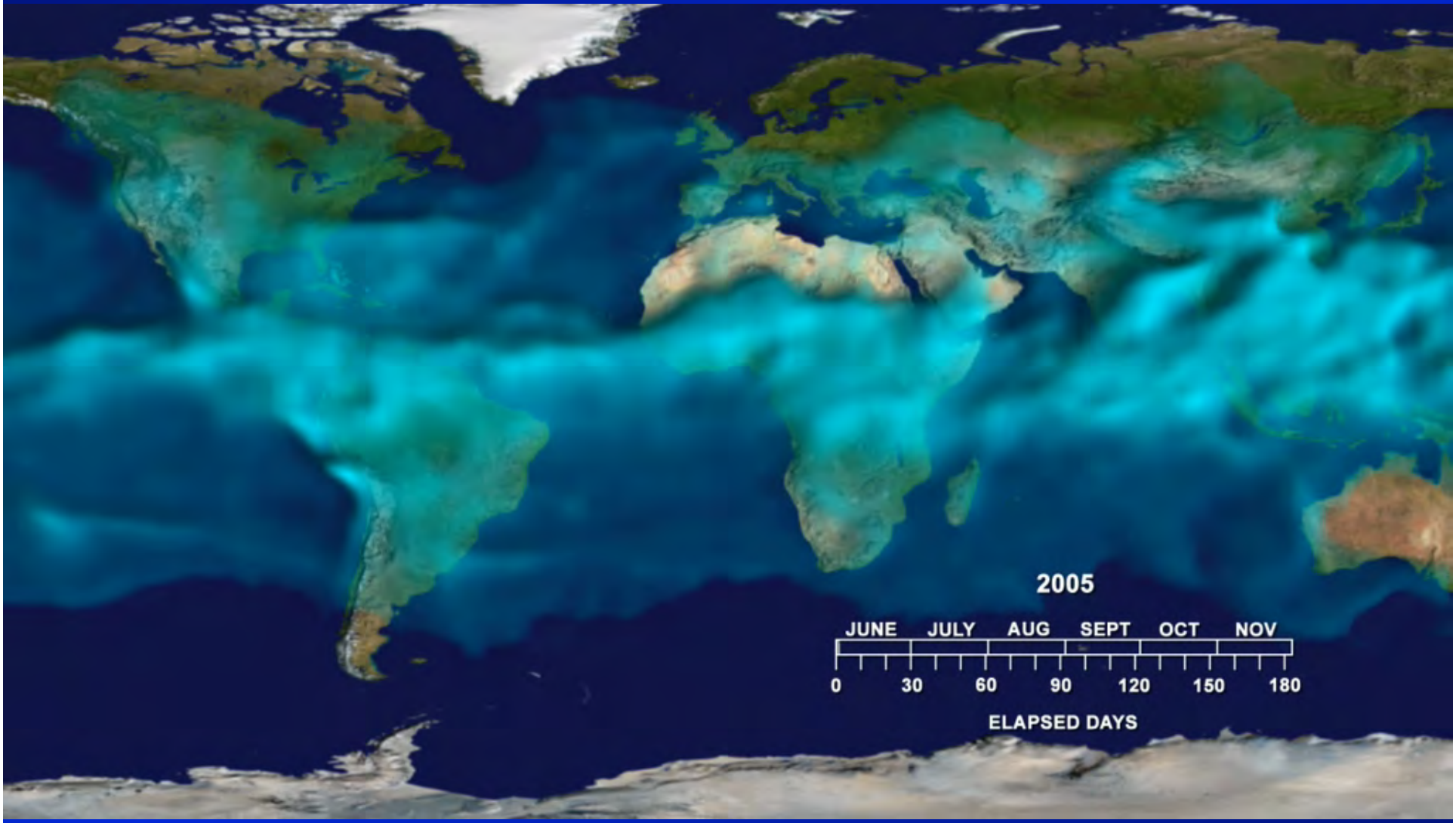
Water Vapor in the Upper Atmosphere, January & July 2003, from AIRS/ AMSU data





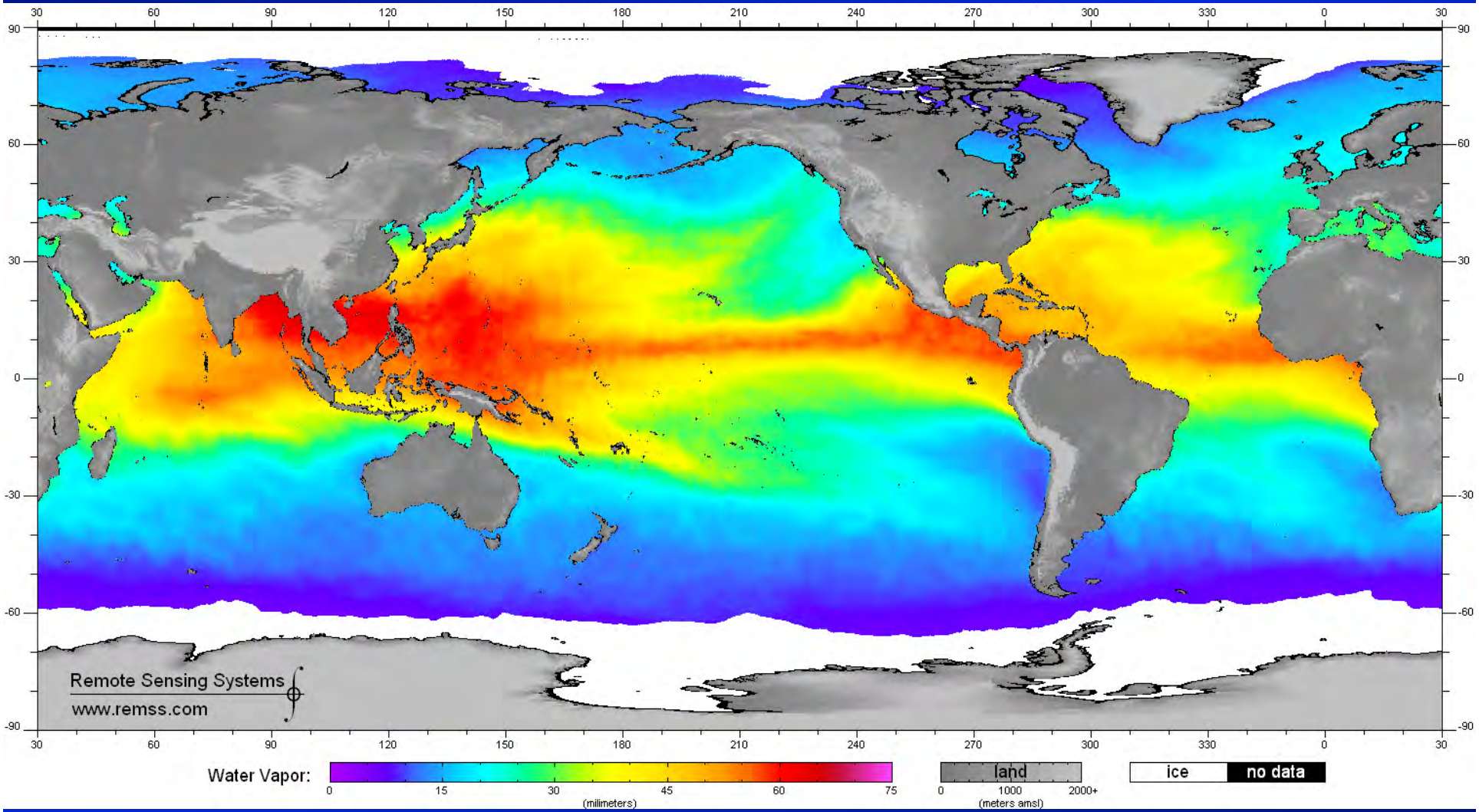
(images from C. Thompson and E. Olsen)

Global Water Vapor, June – November 2005, from AIRS/AMSU data

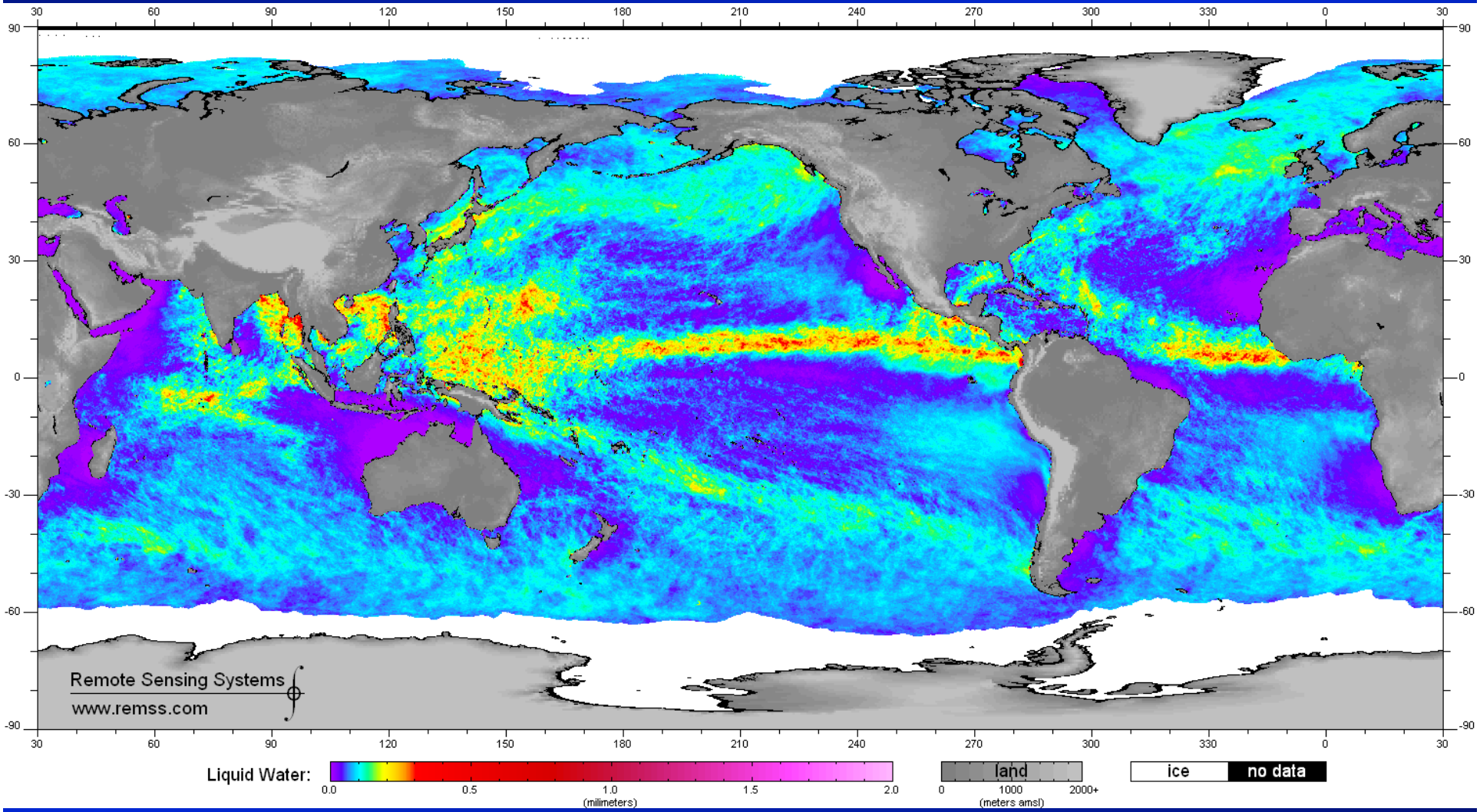


(animation by NASA/JPL, courtesy of the AIRS Science Team)

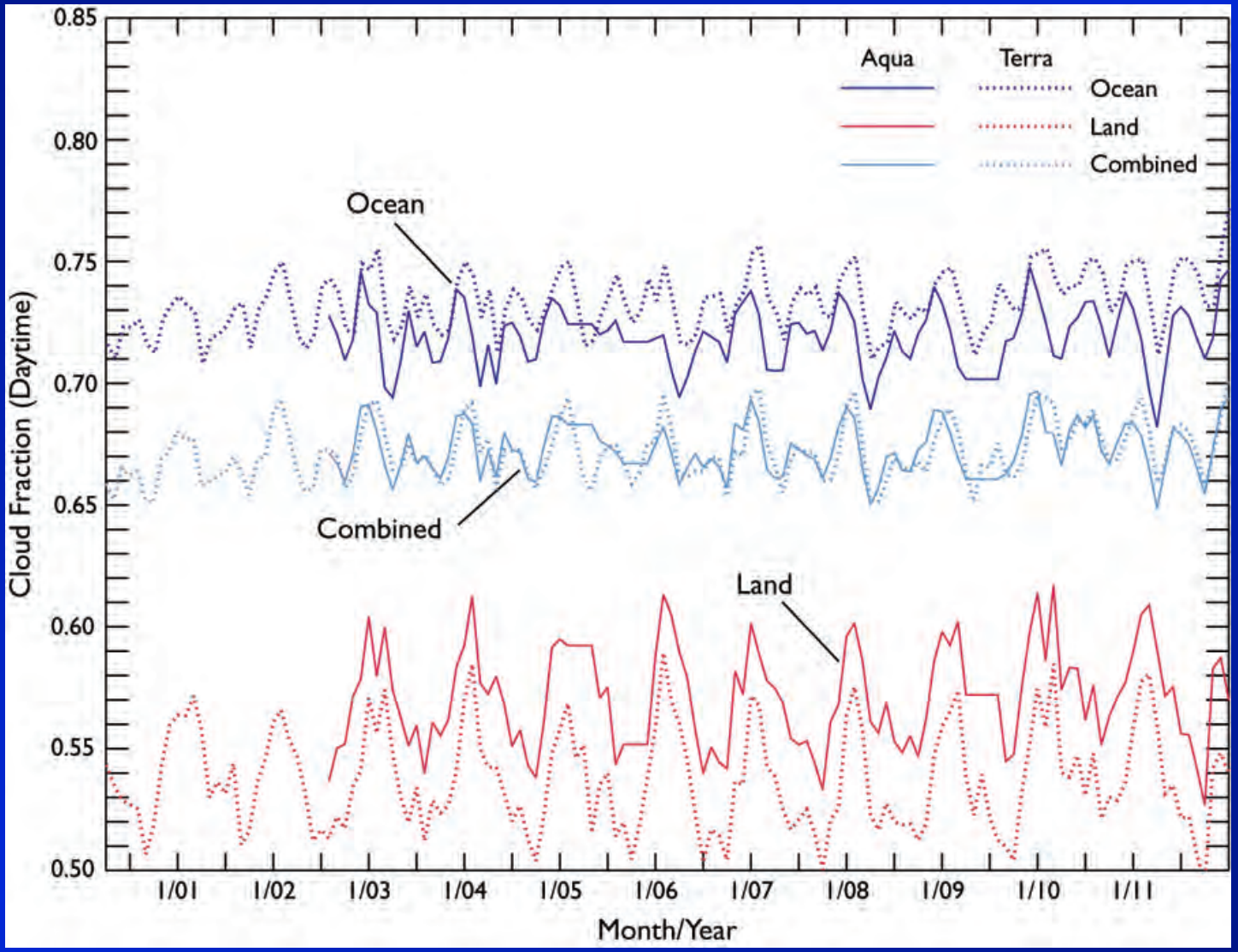
Water Vapor Over the Oceans, September 2011, from AMSR-E data



Cloud Liquid Water Over the Oceans, September 2011, from AMSR-E data



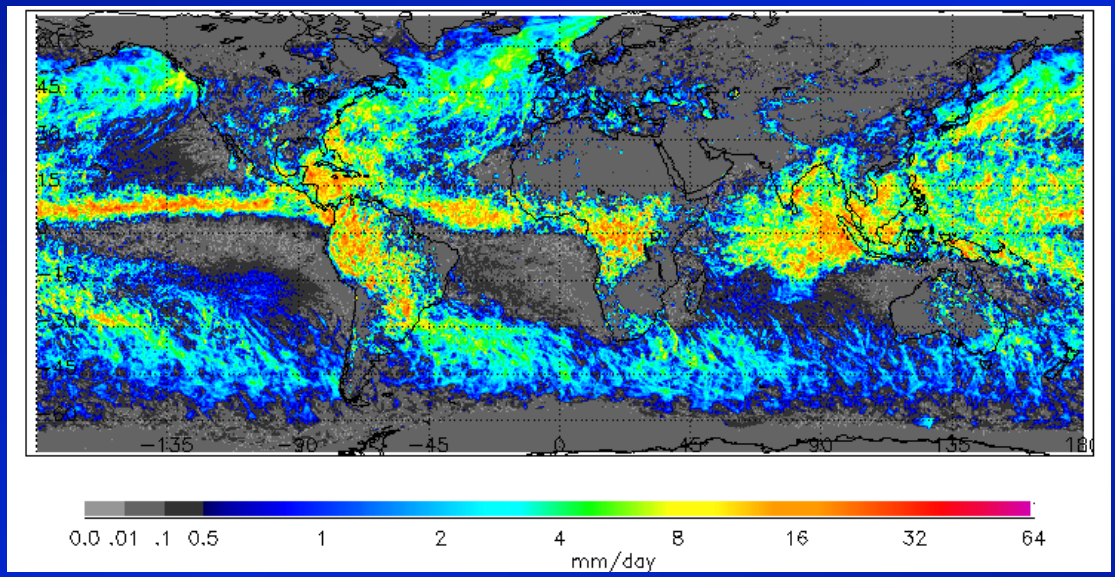
Global Mean Cloud Fraction, 2000 – 2011, , from Aqua and Terra MODIS data



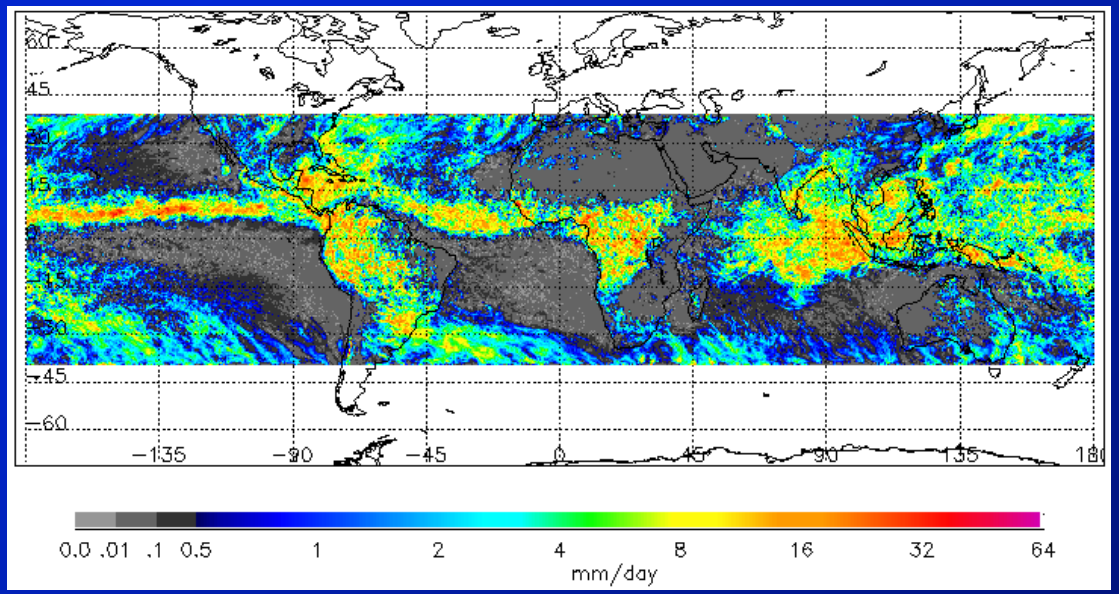
(from M. King, S. Platnick, P. Menzel, S. Ackerman, and P. Hubanks, 2012)

Global Rainfall Rates, from Aqua and TRMM

Aqua AMSR-E
October 2005
Rainfall

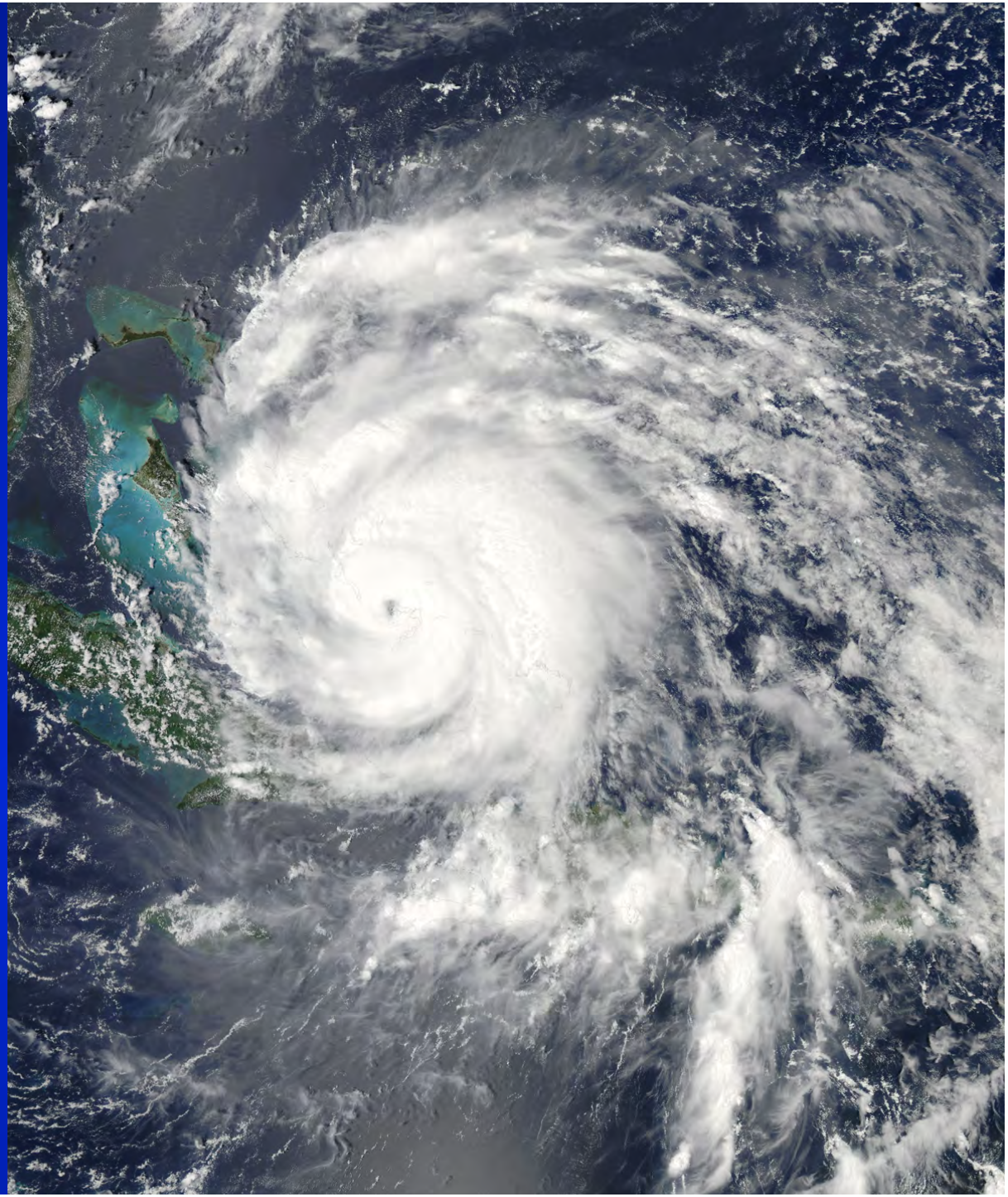


Tropical Rainfall
Measuring Mission
(TRMM) Microwave
Imager (TMI) October
2005 Rainfall

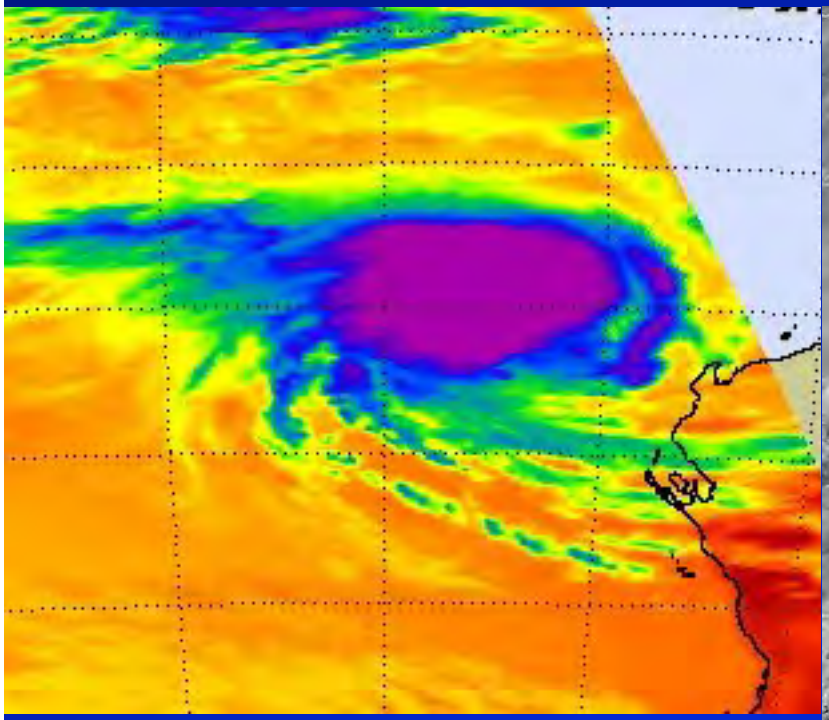


(images from Chris Kummerow and Ralph Ferraro, through Elena Lobl)

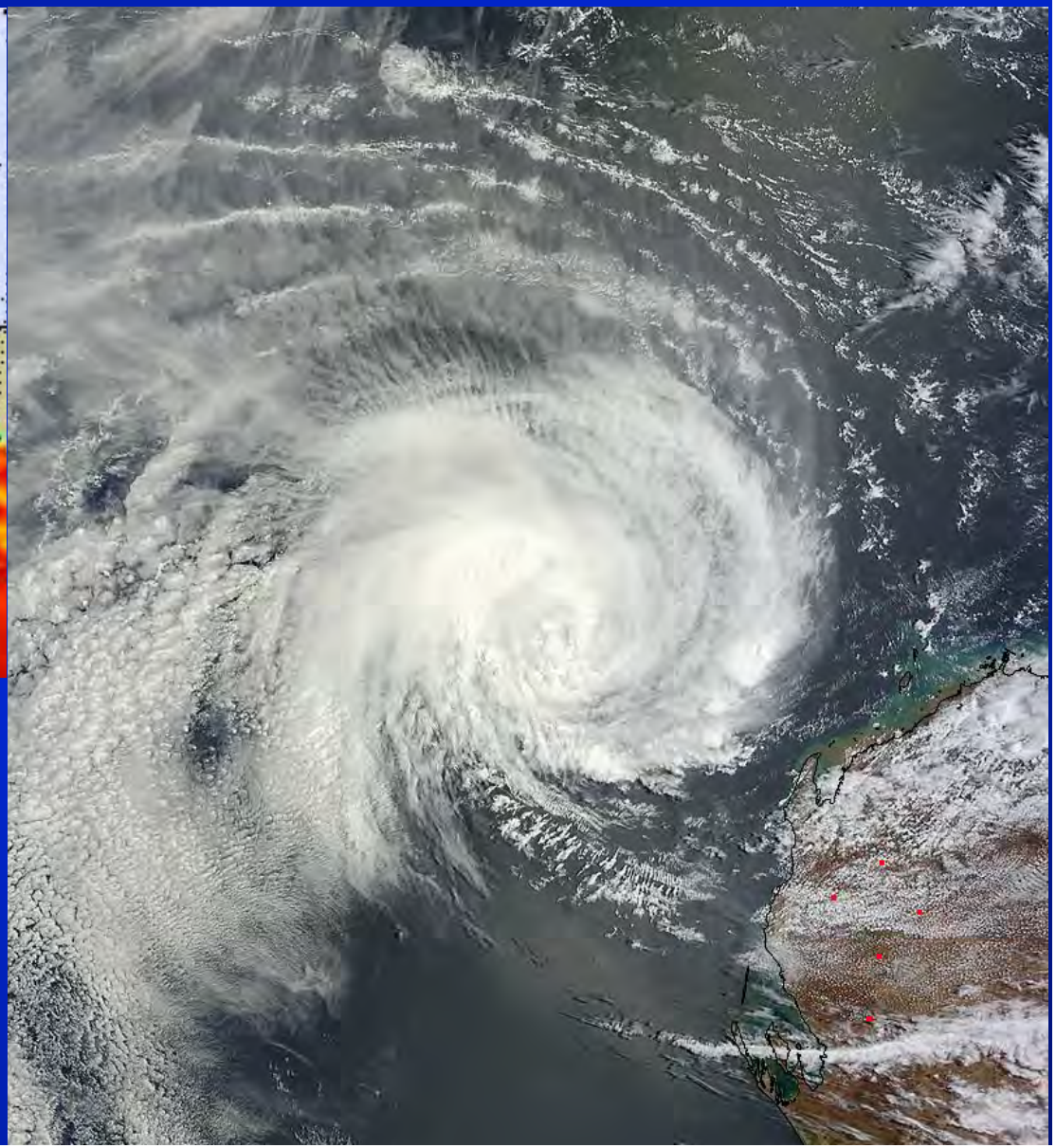
Hurricane Irene over the Bahamas, August 24, 2011, from Aqua MODIS data



Tropical Cyclone Iggy off the NW Coast of Australia, January 30, 2012

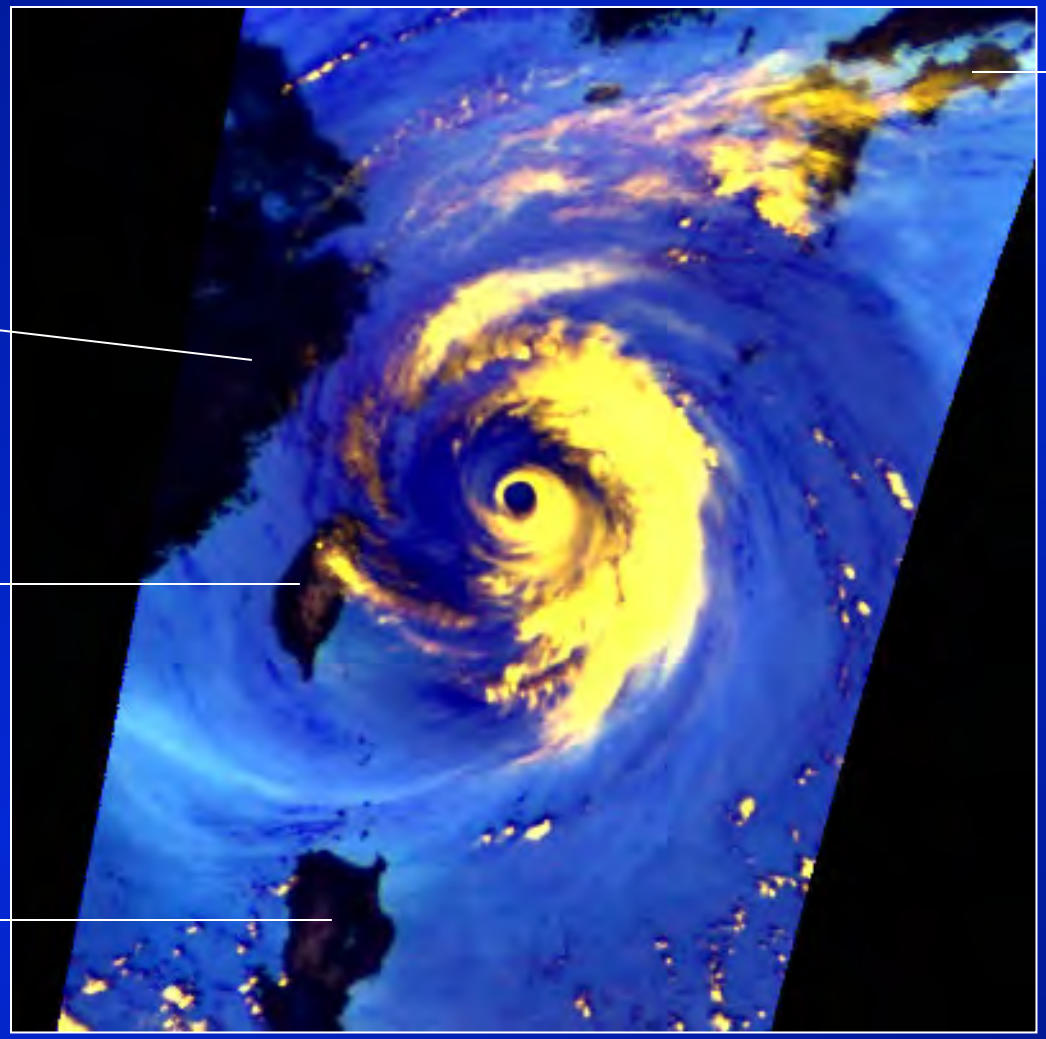


Infrared image from AIRS, indicating cloud-top temperatures (coldest: purple; hottest: orange/red) (from Ed Olsen, AIRS Science Team)



Visible image from the Aqua MODIS (from MODIS Rapid Response)

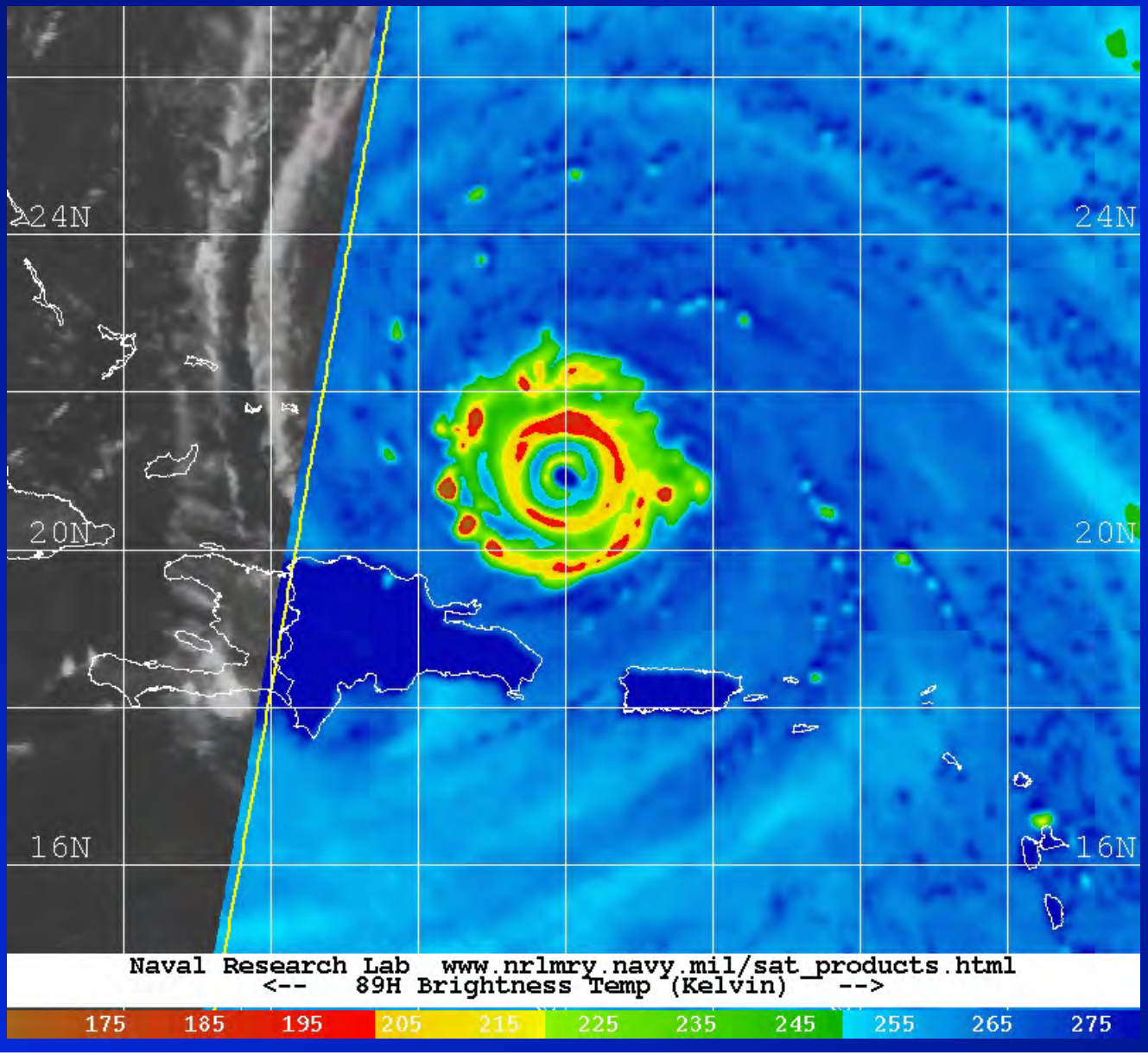
Typhoon in the East China Sea, July 4, 2002, from AMSR-E data



AMSR-E image, 2:26 a.m. Japan Standard Time (JST).

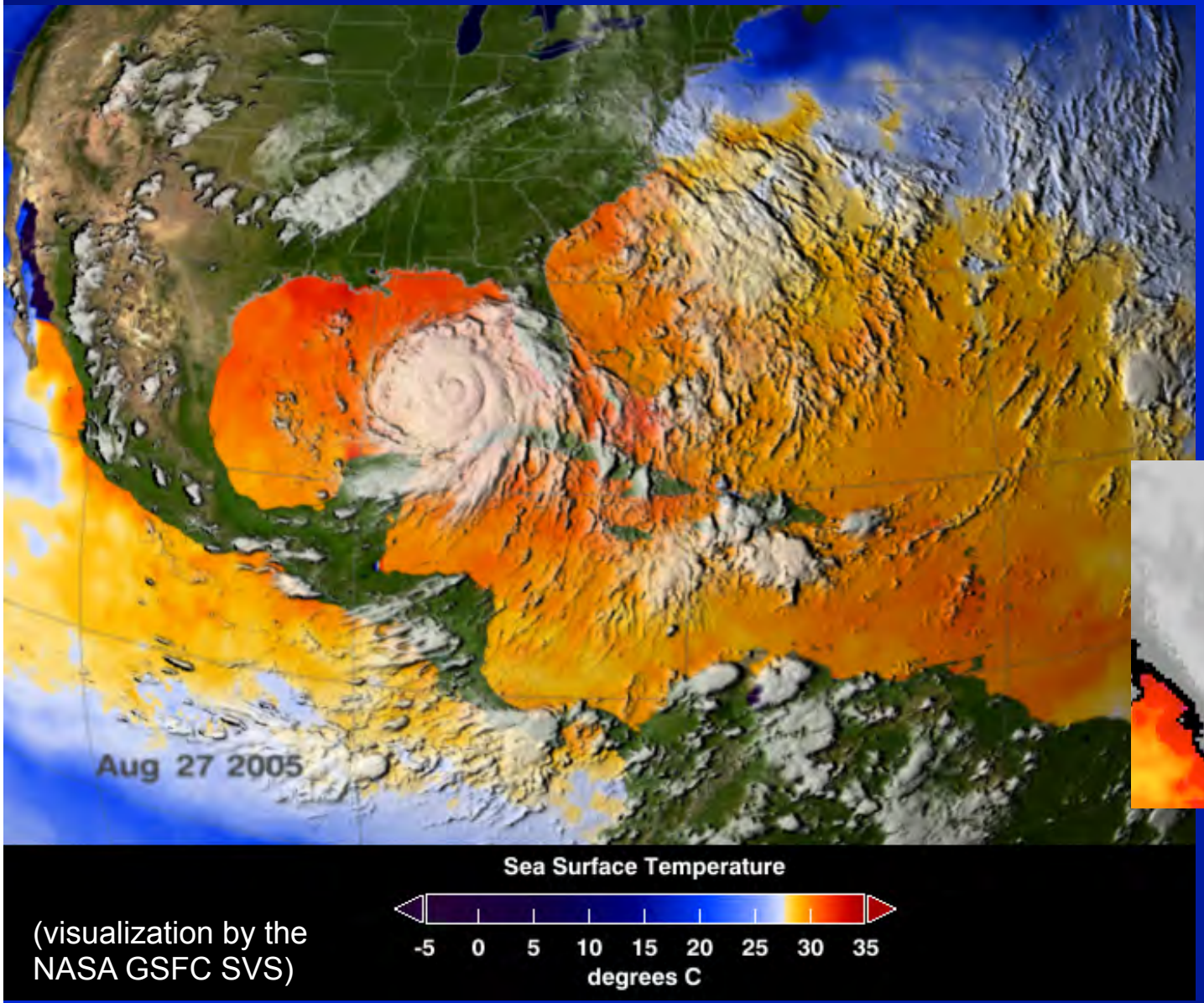
(image courtesy of JAXA)

Hurricane Frances, September 1, 2004, from AMSR-E 89 GHz Data



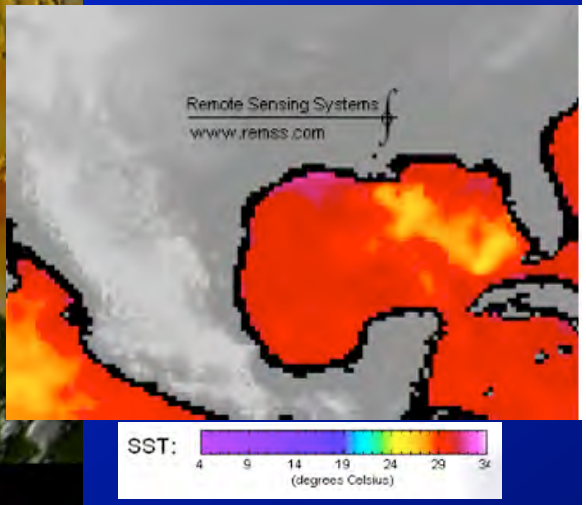
(image from the NOAA/ NASA Near Real Time Processing Effort)

Hurricane Katrina



(visualization by the NASA GSFC SVS)

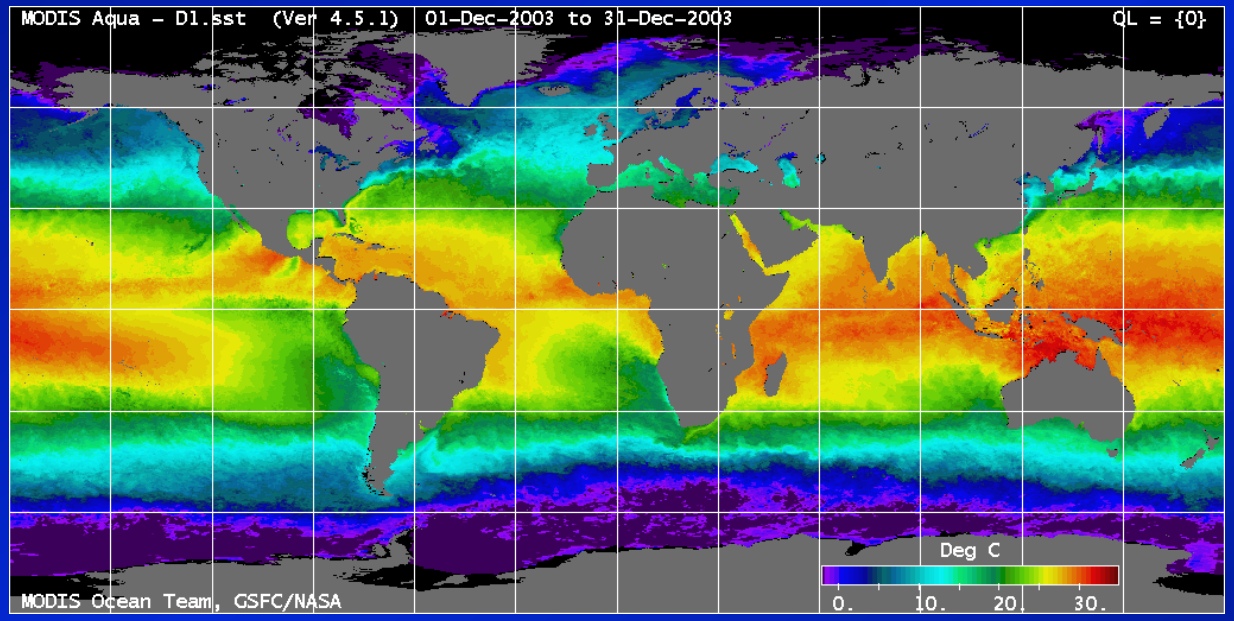
GOES clouds, AMSR-E SSTs, MODIS land, August 27, 2005



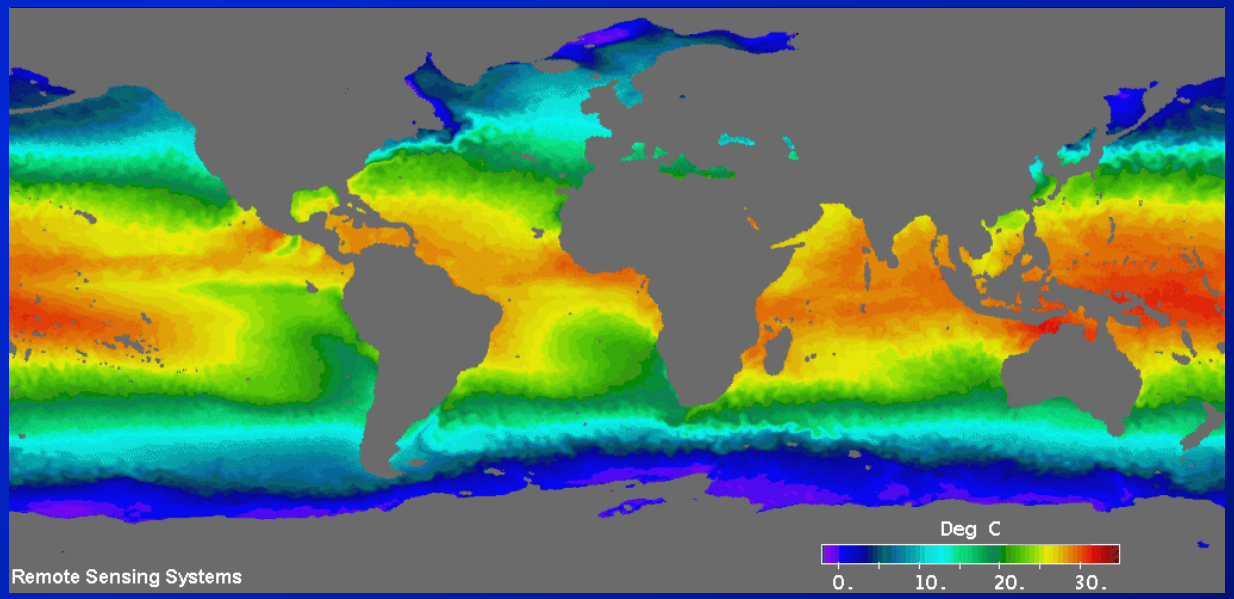
AMSR-E SSTs, showing the Katrina cold wake, August 30, 2005

Sea Surface Temperatures, December 2003, from Aqua MODIS and AMSR-E data

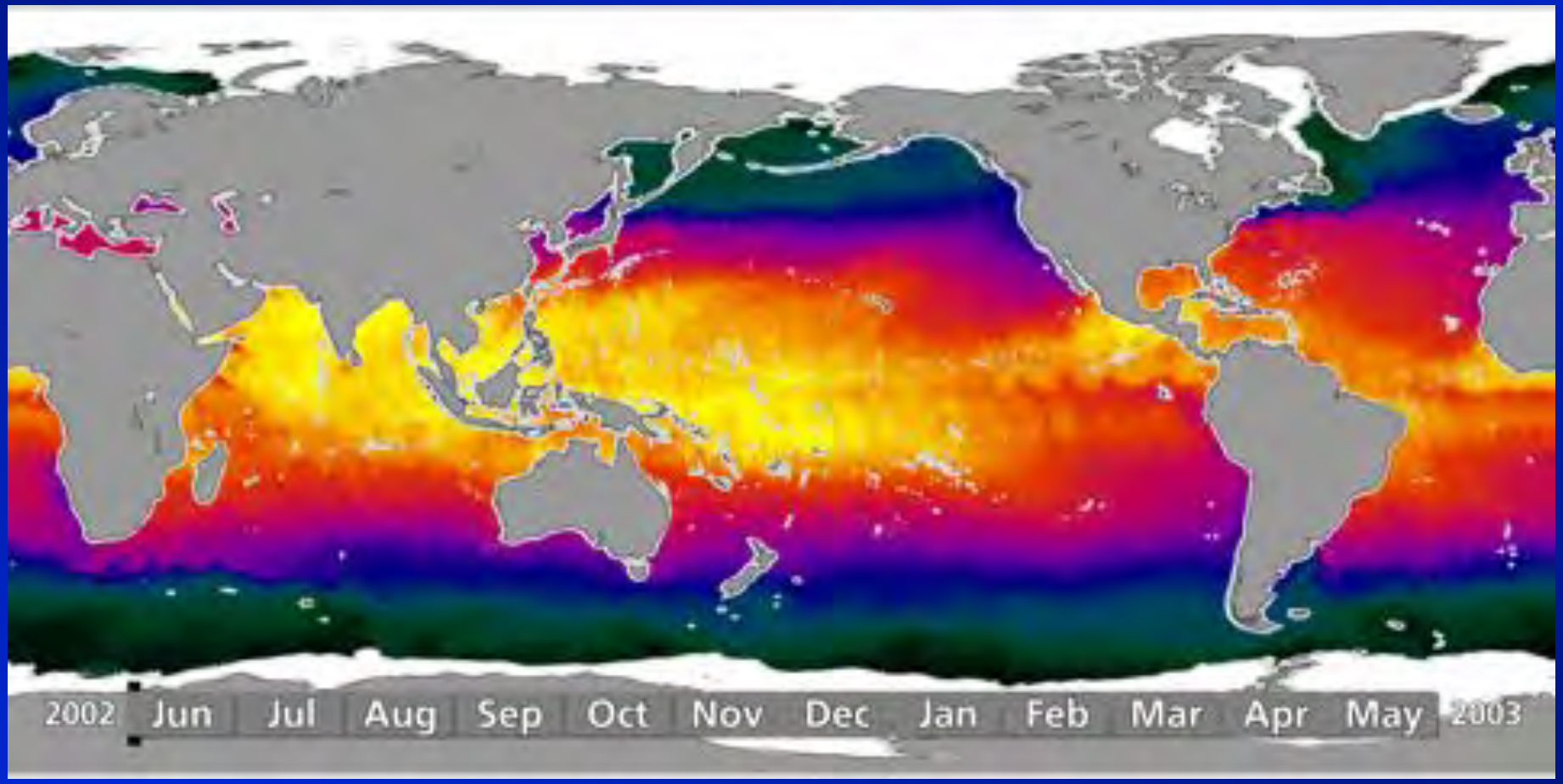
From MODIS



From AMSR-E

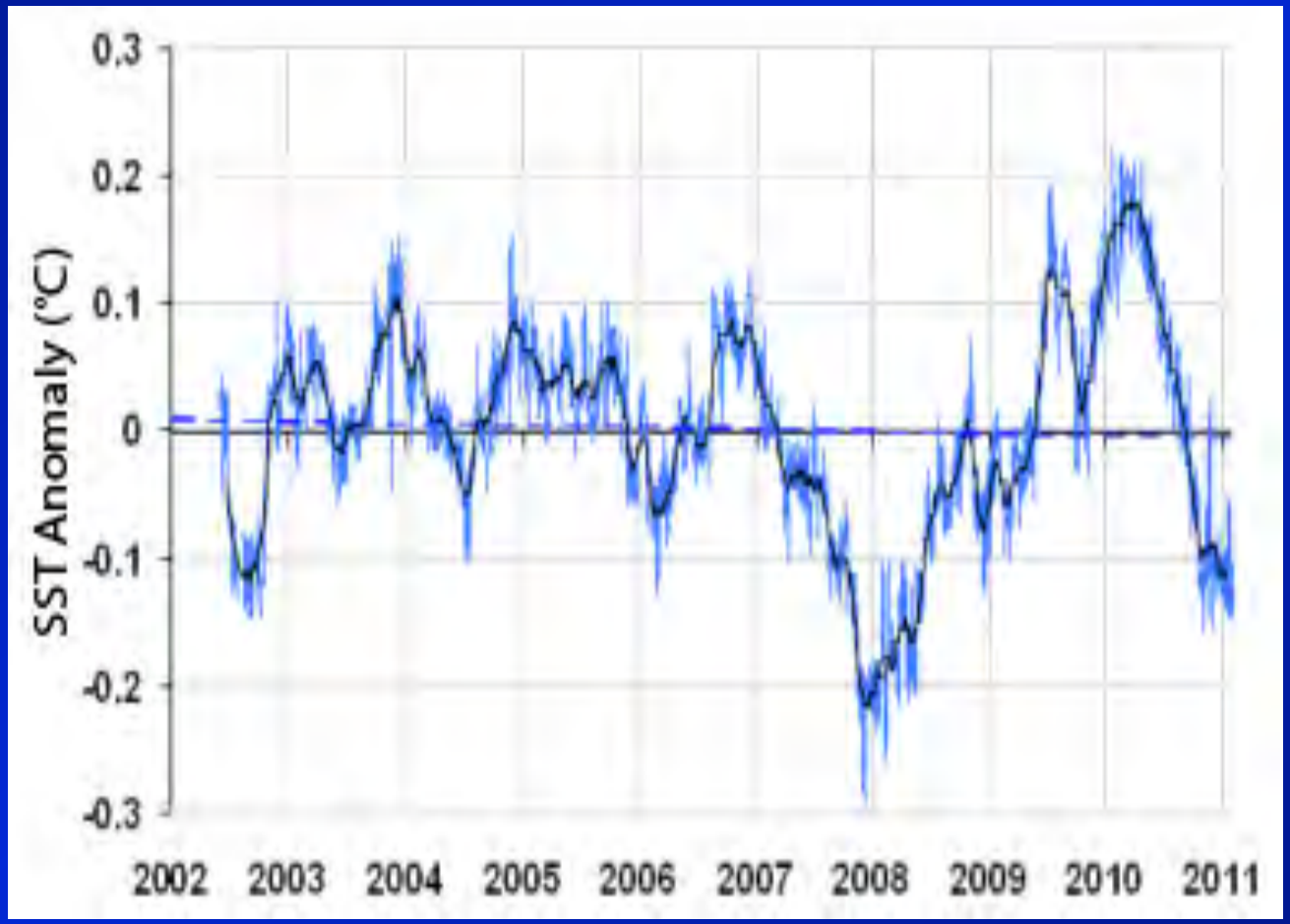


Sea Surface Temperatures, June 2002 - May 2003, from AMSR-E data



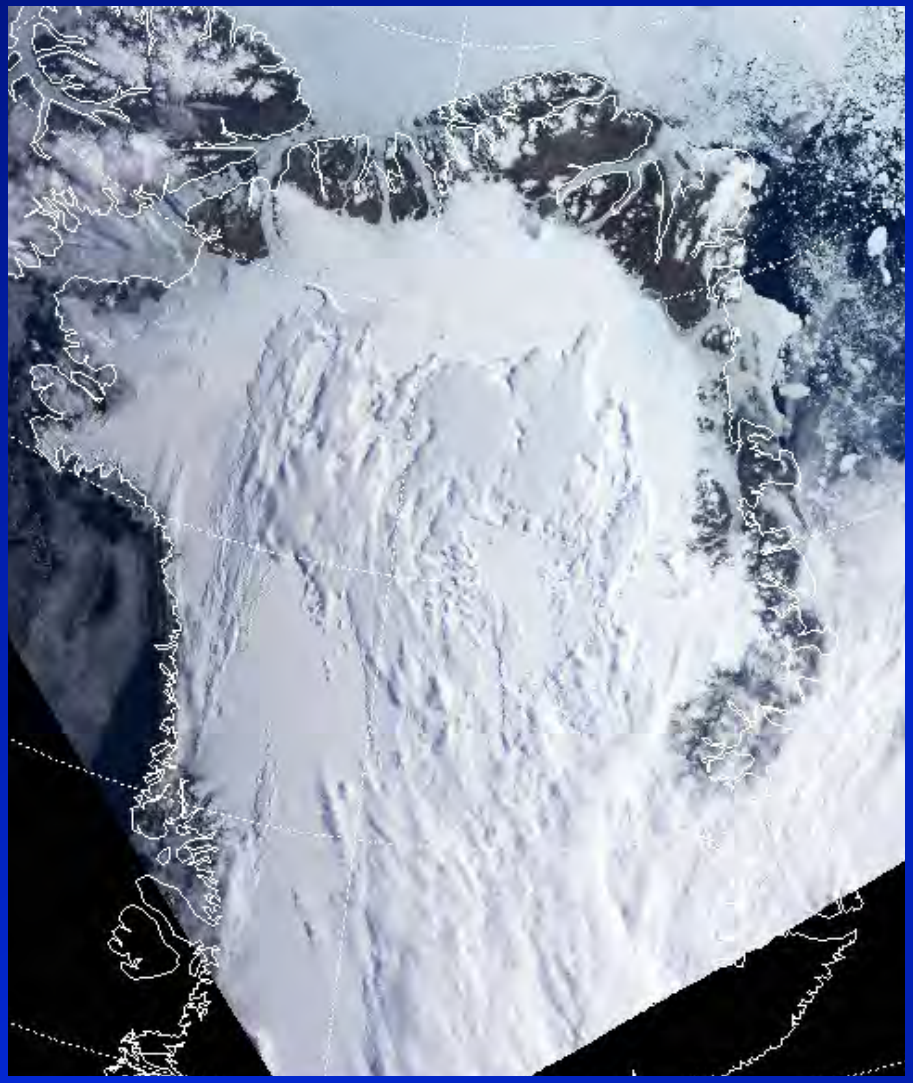
(animation courtesy of JAXA)

Global Sea Surface Temperature Anomalies, June 3, 2002 – January 31, 2011, from AMSR-E data

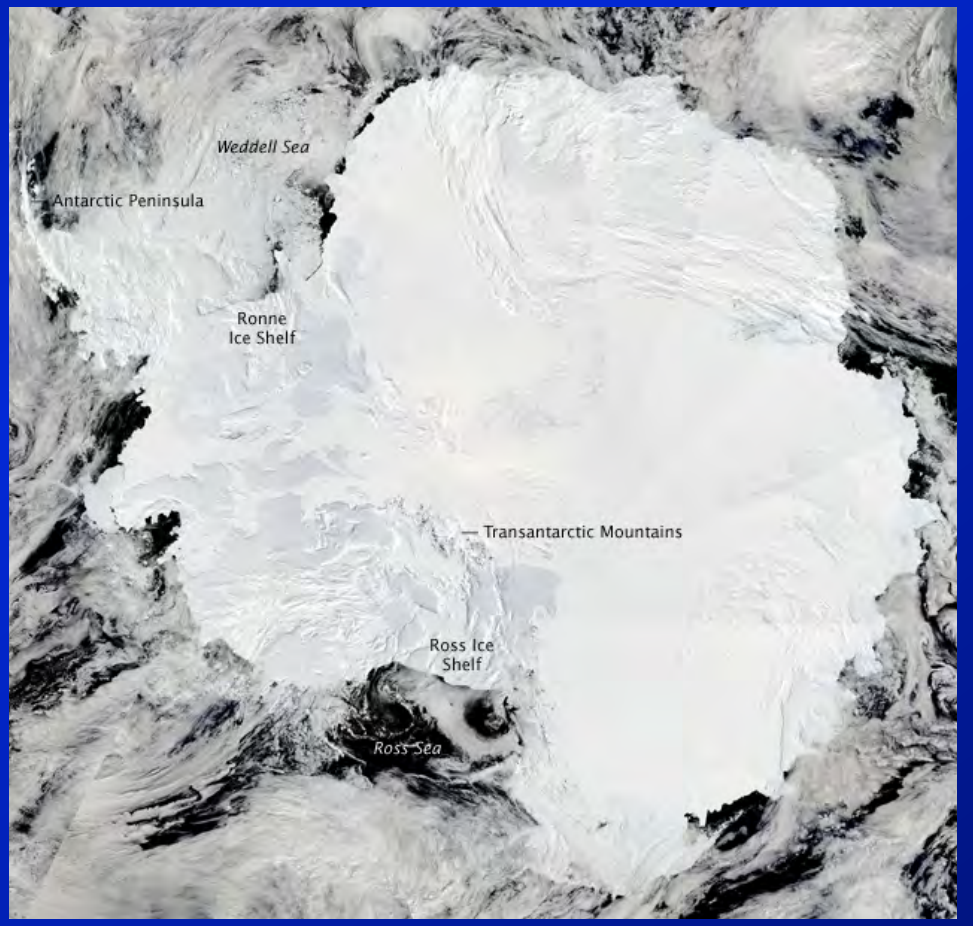


(courtesy of Roy Spencer/AMSR-E science team)

The Greenland and Antarctic Ice Sheets, from Aqua MODIS data

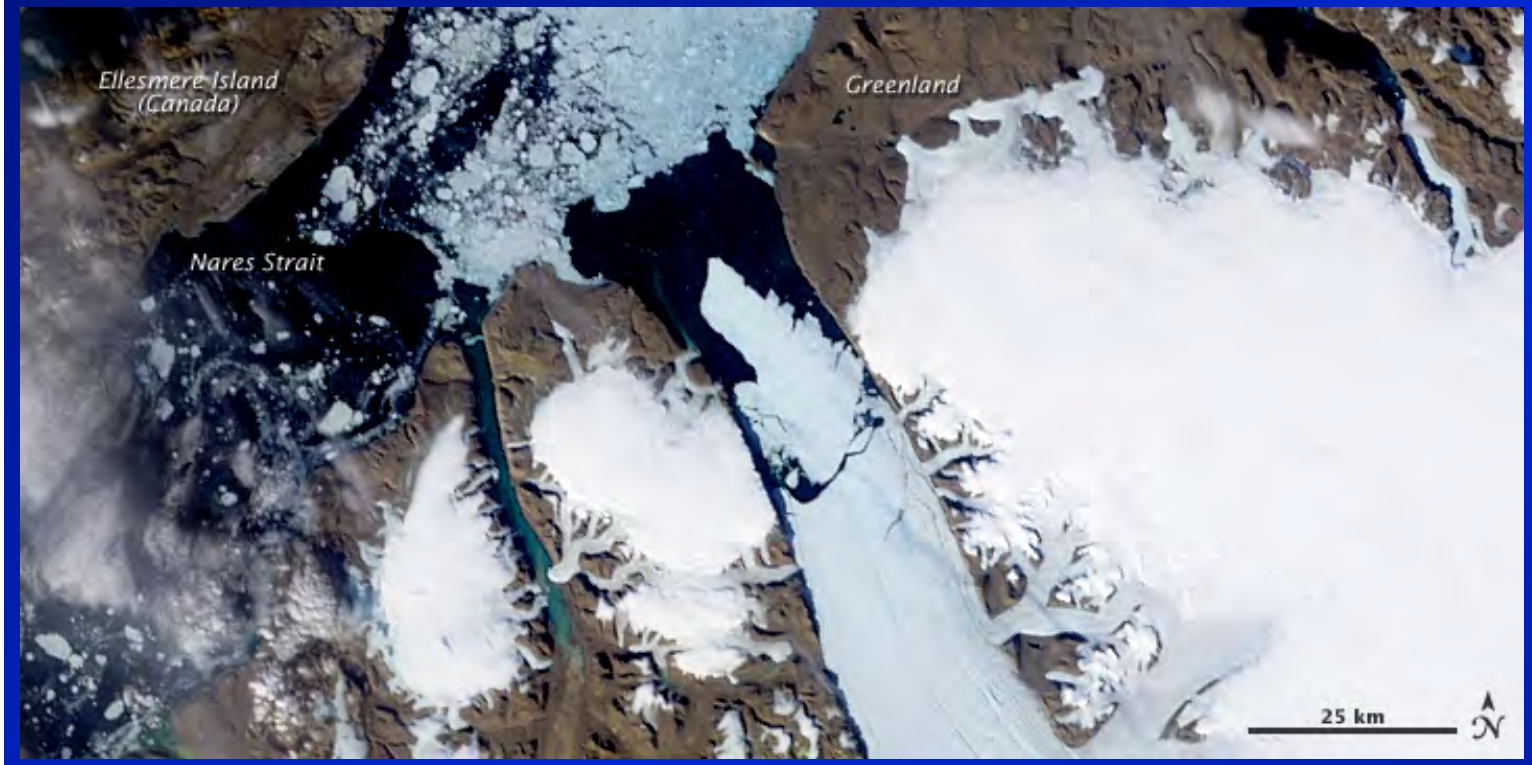


Greenland on July 13, 2002

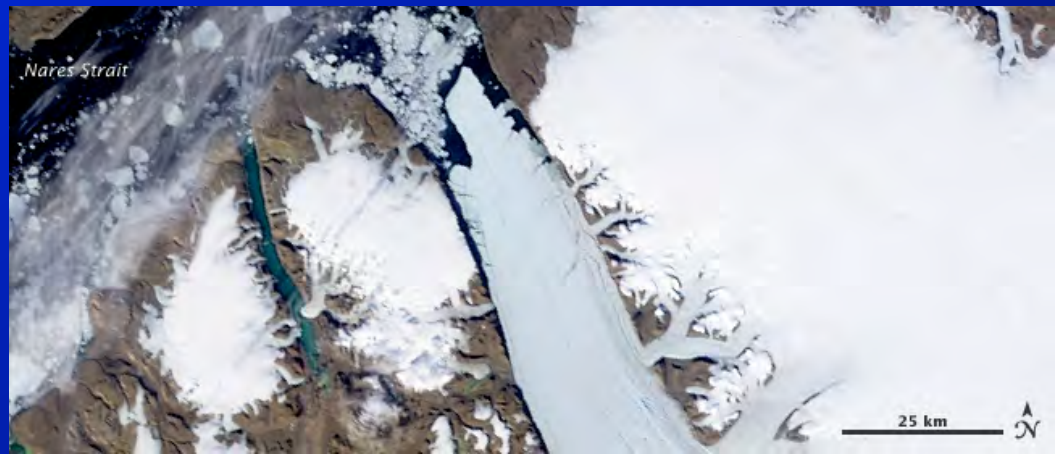


Composite image of Antarctica

Breaking Off of a Large Iceberg from the Petermann Glacier, Greenland, August 2010

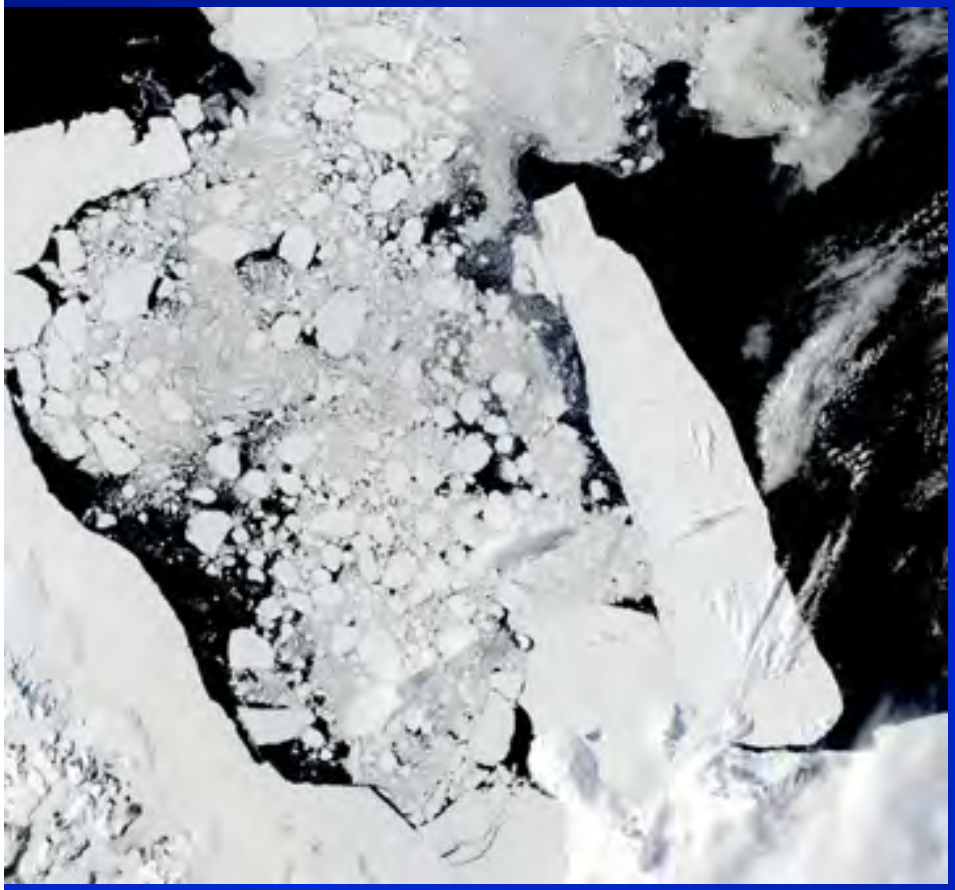


August 5, 2010 view from the Aqua MODIS

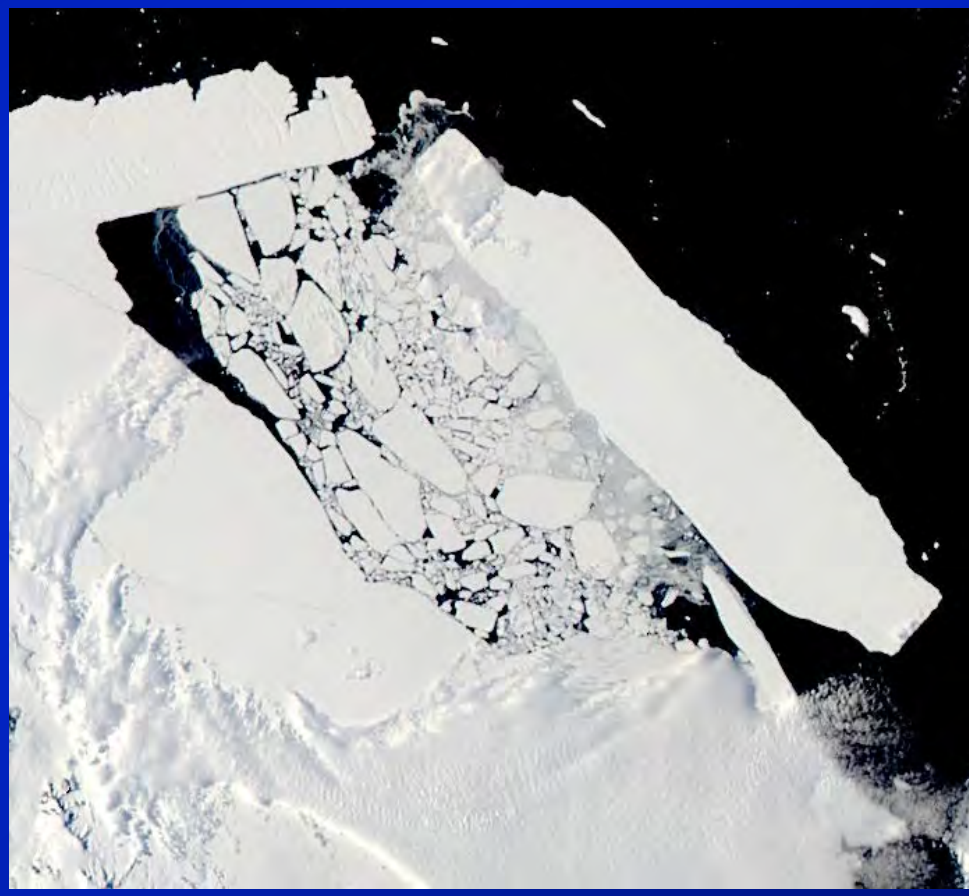


July 28, 2010 view from the Terra MODIS

Sea Ice and Iceberg B15A off the Coast of Antarctica, from Aqua MODIS data

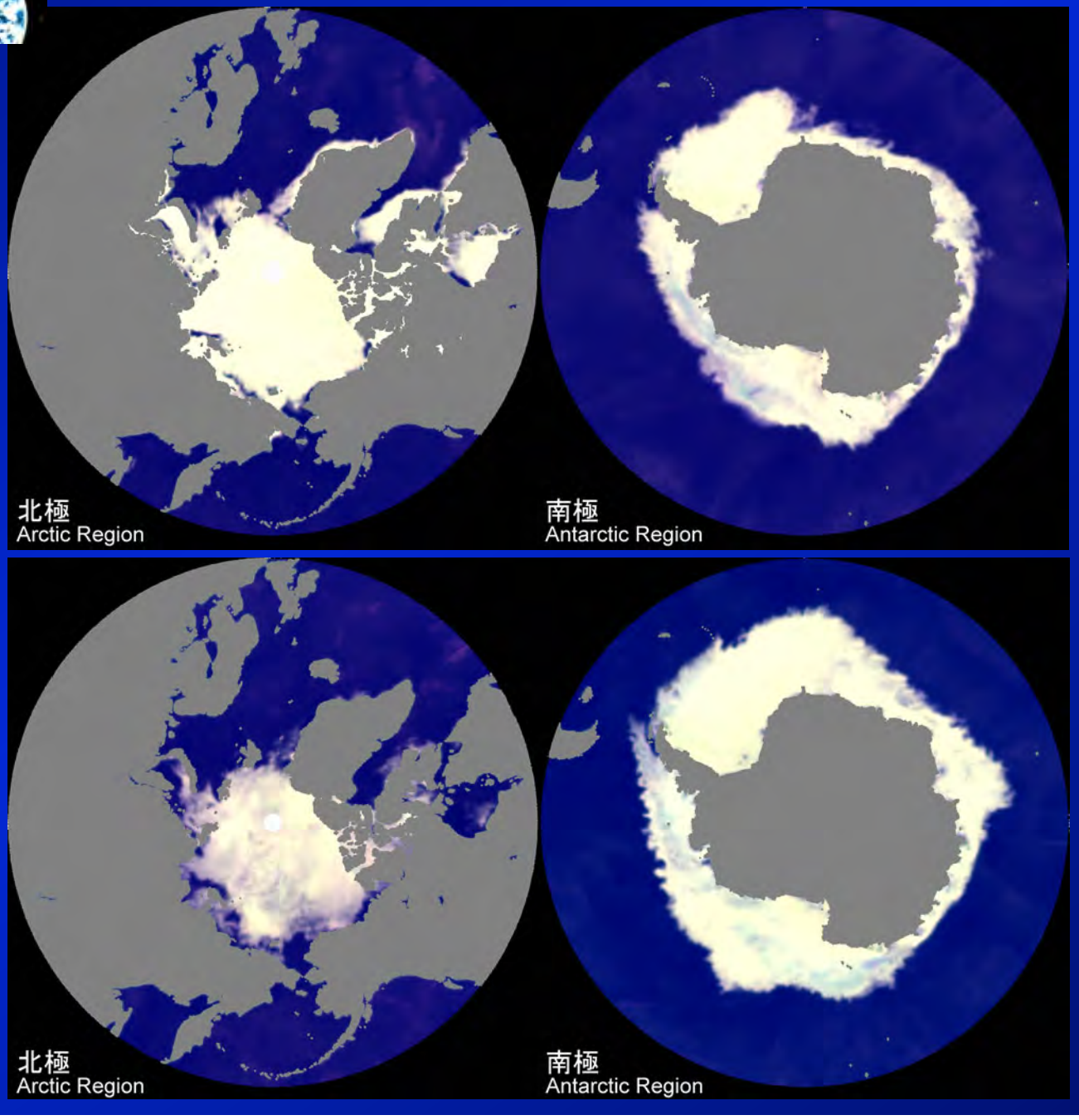


January 16, 2003



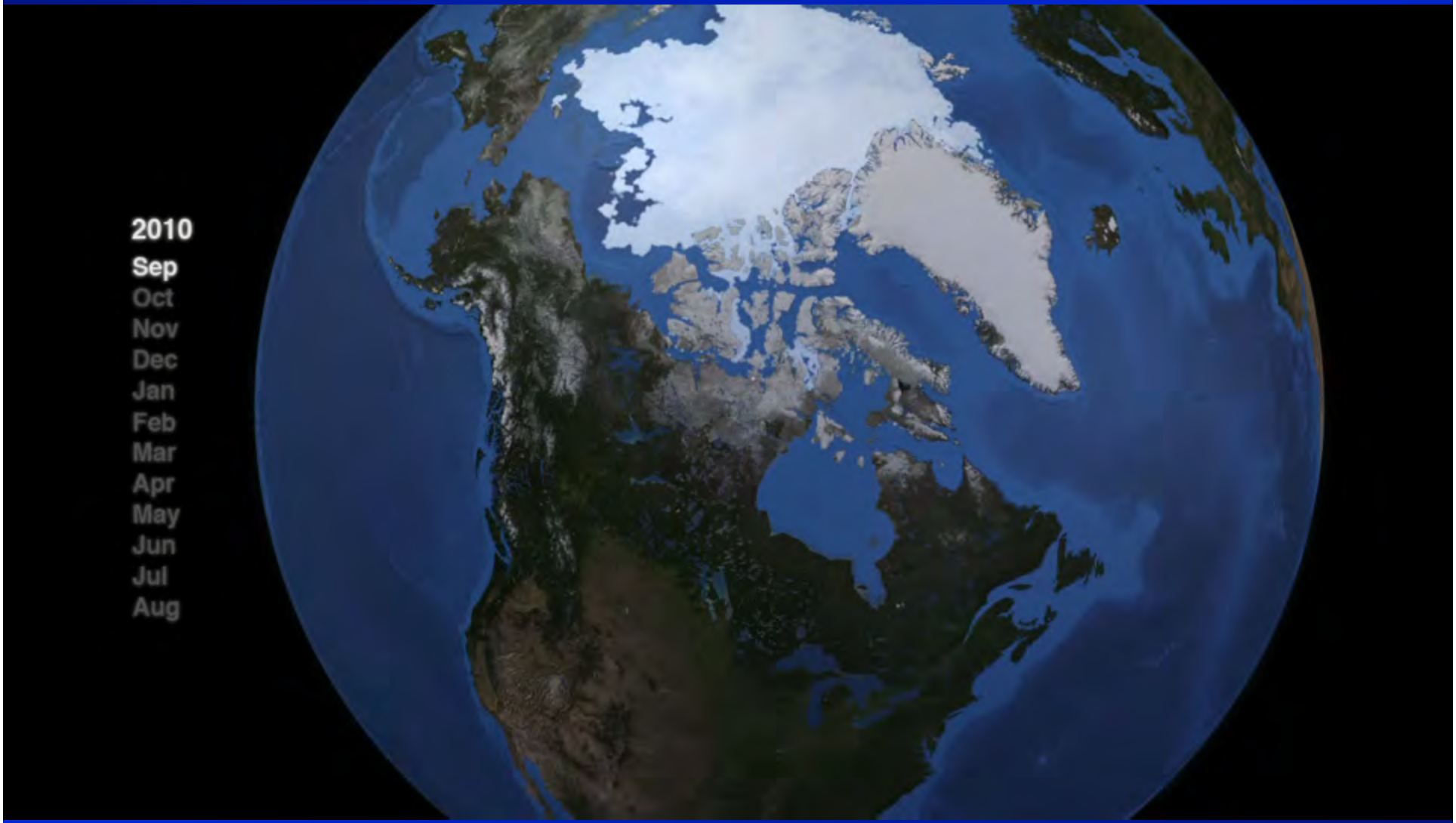
January 30, 2005

Global Sea Ice Coverage, June 2-4, 2002 (top) and July 21-22, 2002 (bottom), from AMSR-E data



(images courtesy of JAXA)

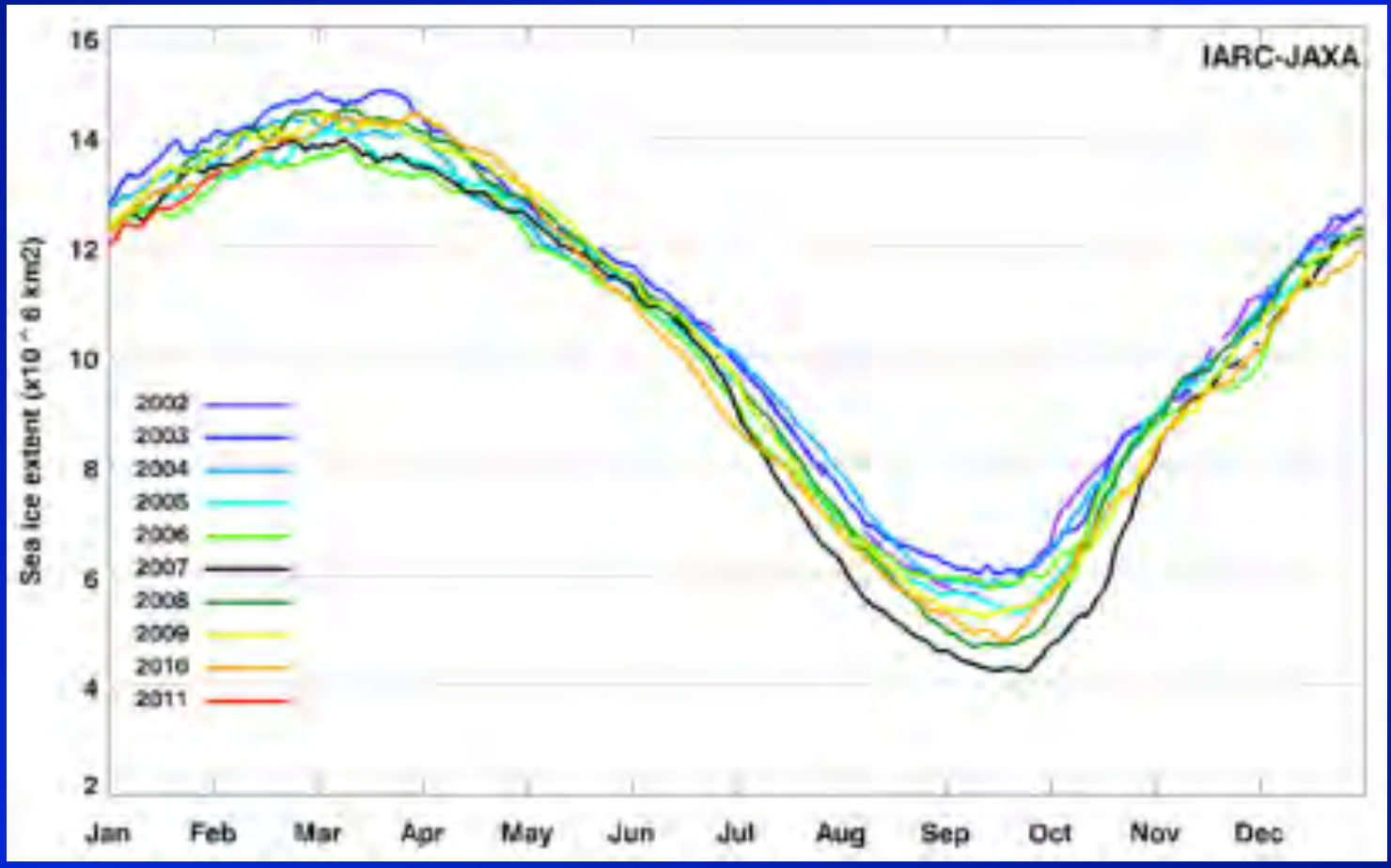
Animation of Arctic Sea Ice and Snow, Sept. 2010 – Aug. 2011, from AMSR-E data



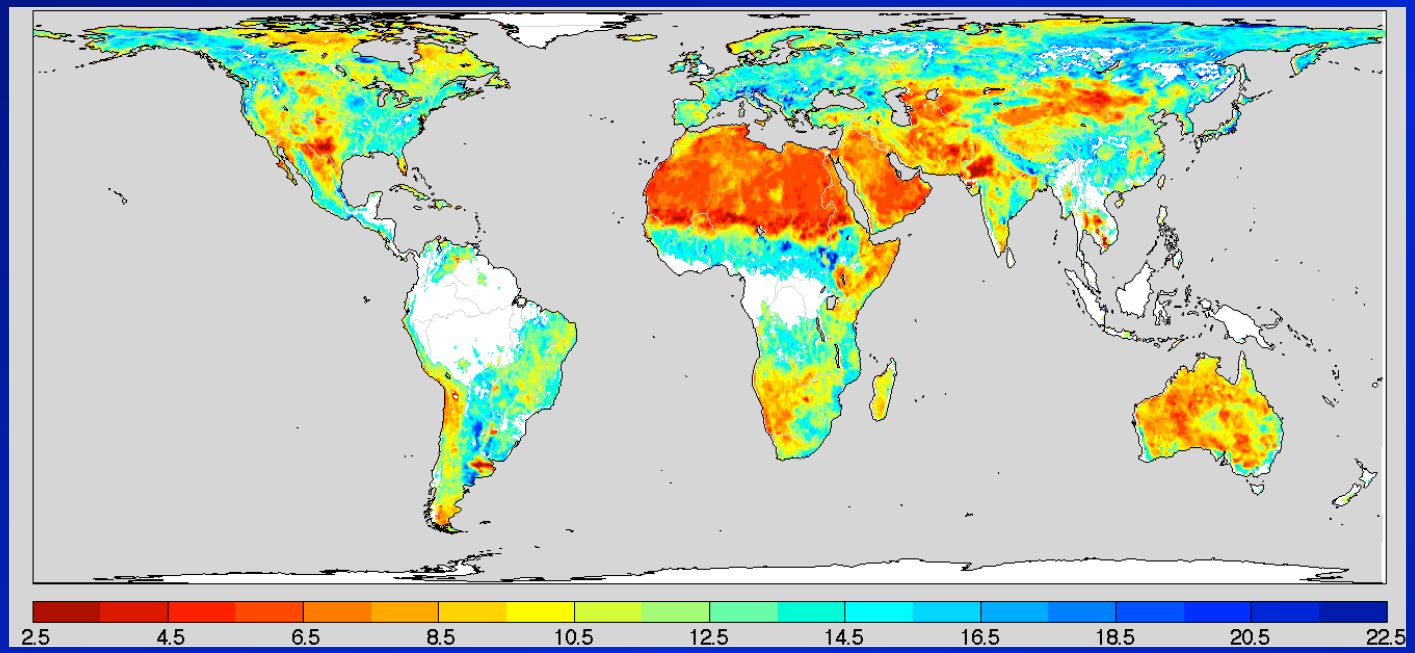
Arctic Record Low Sea Ice Coverage, September 14, 2007, from AMSR-E data

(visualization by the NASA Scientific Visualization Studio)

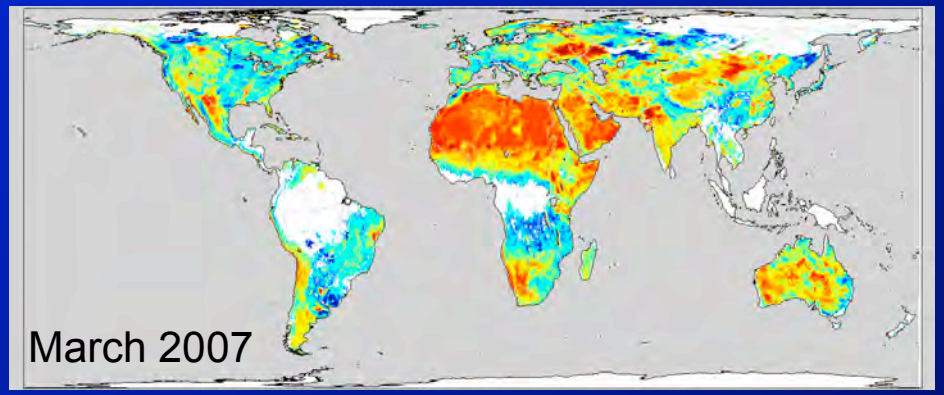
Arctic Sea Ice Extent, May 2003 - February 2011, from AMSR-E data



Global Soil Moisture Distribution for Regions with Low Vegetation, from AMSR-E data



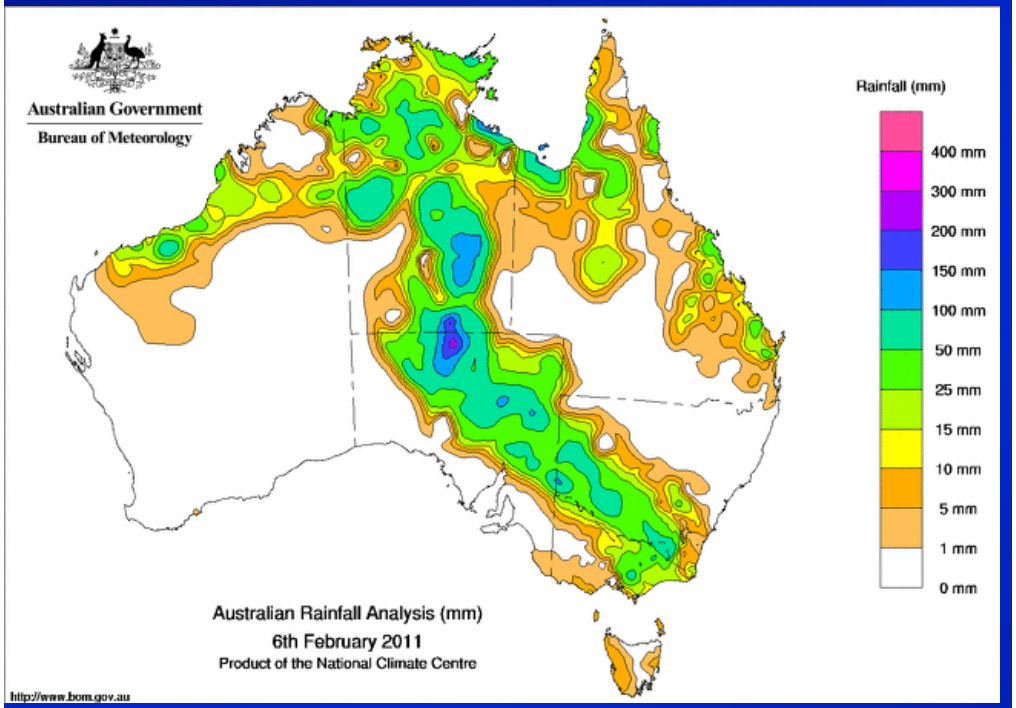
September 2007 Volumetric Soil Moisture (%)



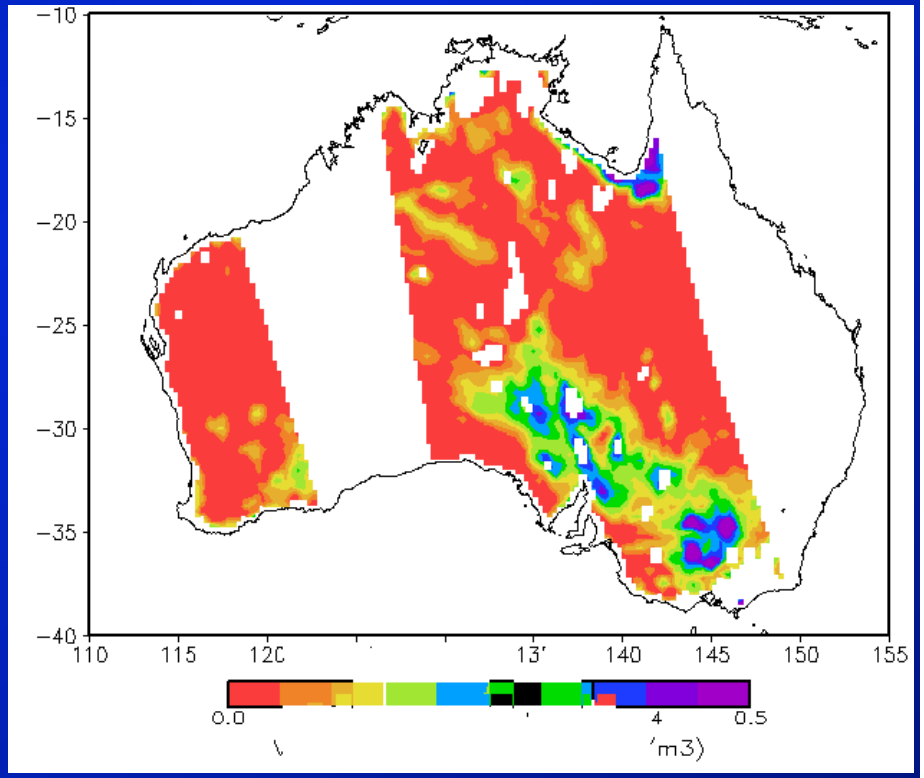
(images from Eni Njoku)

Rainfall and Soil Moisture in Australia, February 6, 2011, from AMSR-E data

Daily Rainfall



Soil Moisture



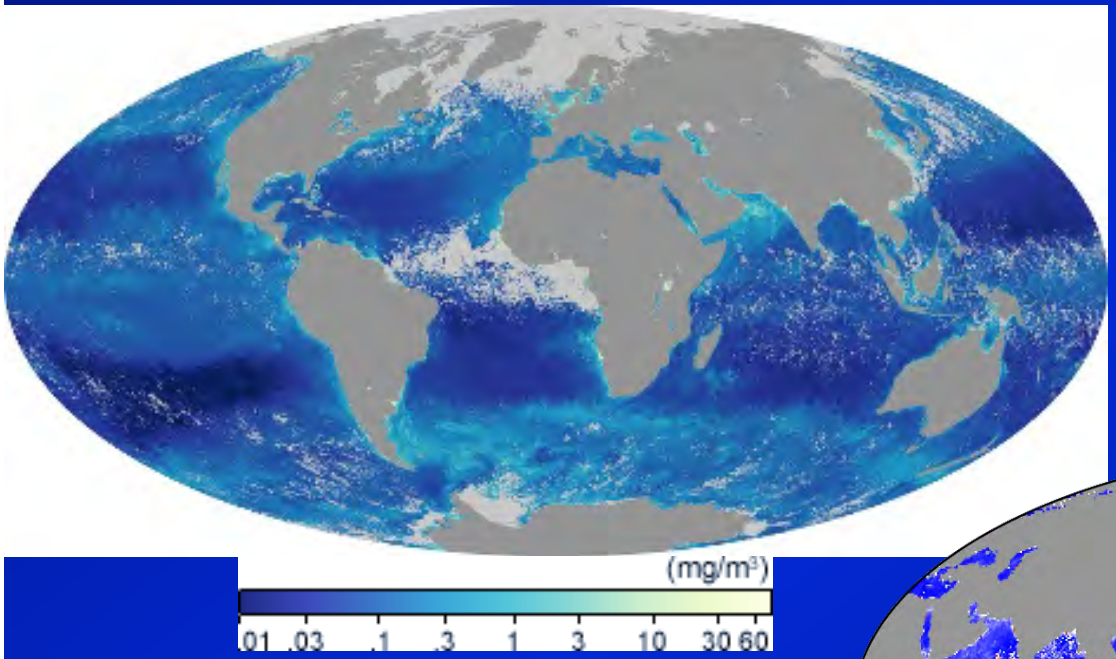
(images from the Australian Bureau of Meteorology)

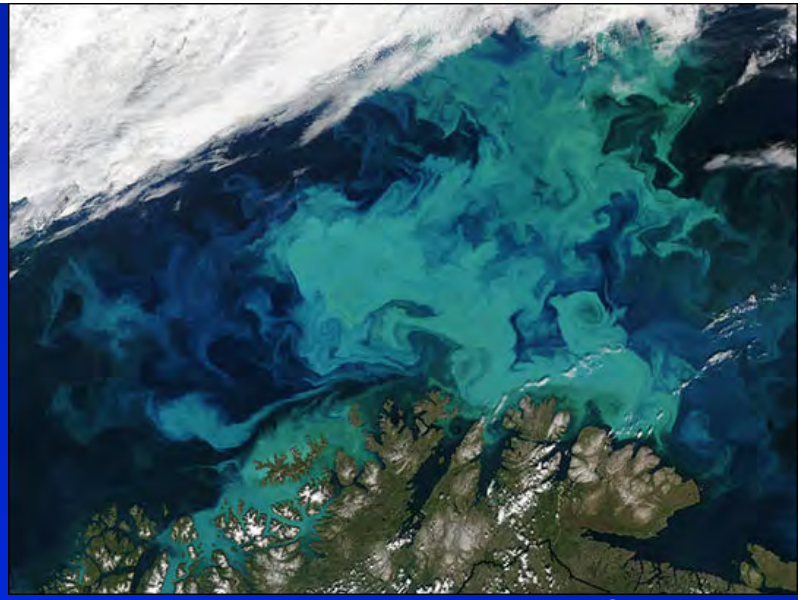
Enhanced Vegetation Index (EVI), December 19, 2003 - January 4, 2004, from Aqua MODIS data

(image courtesy of the University of Arizona and the MODIS Science Team)

Sample Measures of Marine Life, from Aqua MODIS data

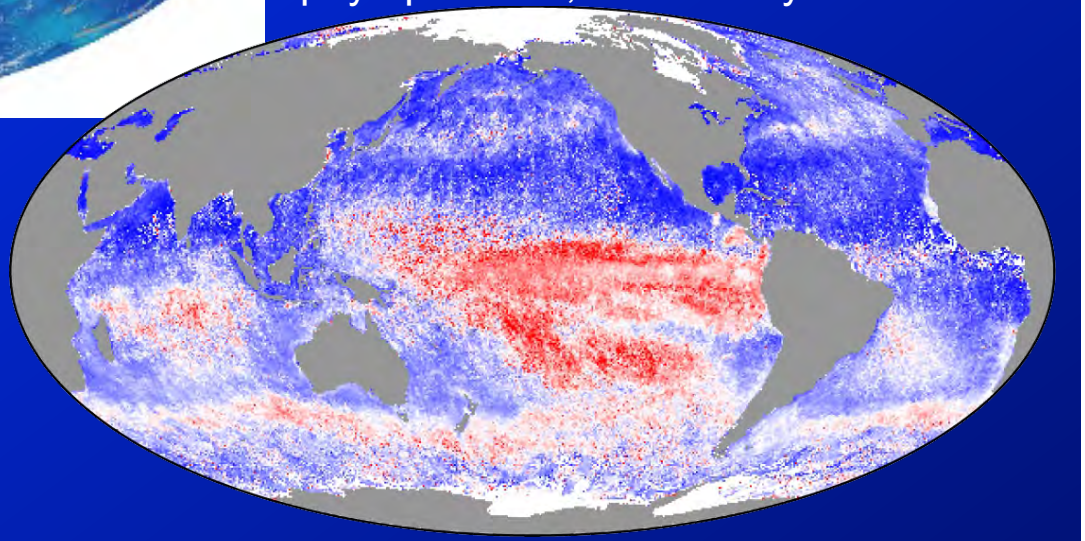
Ocean chlorophyll concentrations, February 2012





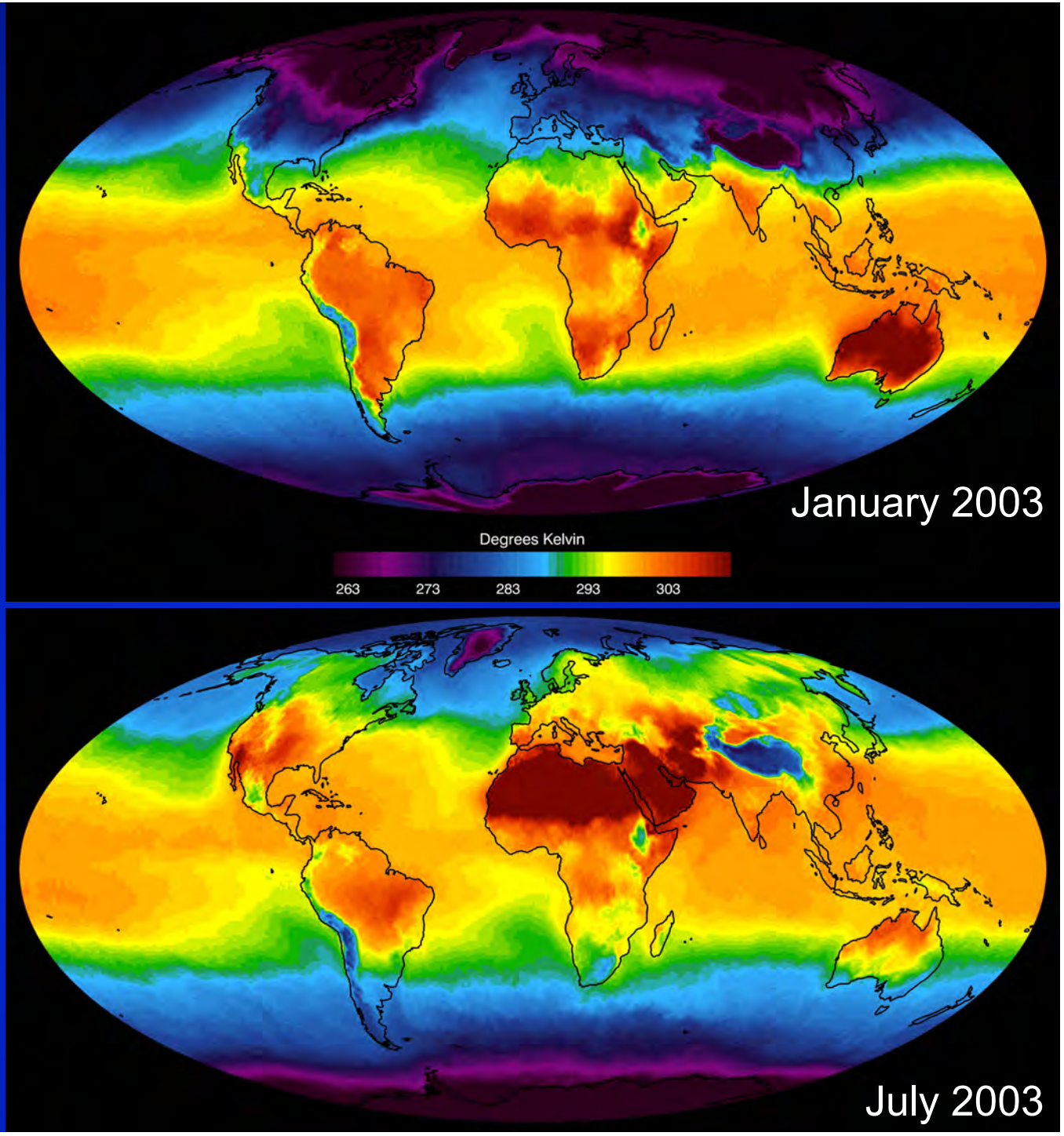
Phytoplankton bloom north of Norway, July 19, 2003

Fluorescence yield by ocean phytoplankton, March-May 2004



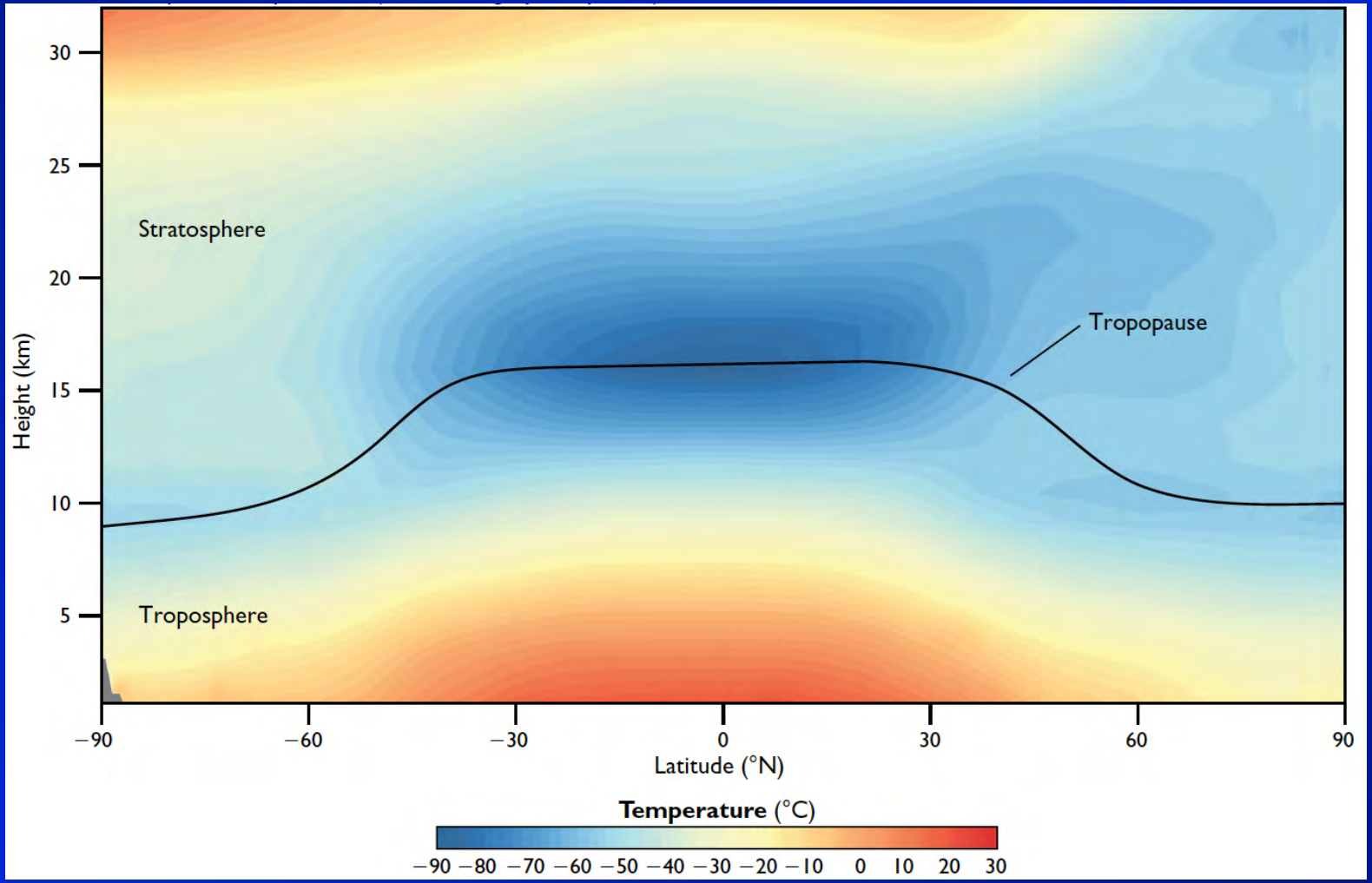
(phytoplankton bloom from the MODIS ocean color group; chlorophyll from the Earth Observatory; fluorescence from Behrenfeld et al. 2009)

Surface Air Temperatures, January and July 2003, from AIRS/ AMSU data



(images from C. Thompson and E. Olsen)

Atmospheric Temperatures, January 2004, averaged as a function of height and latitude, from AIRS/AMSU data

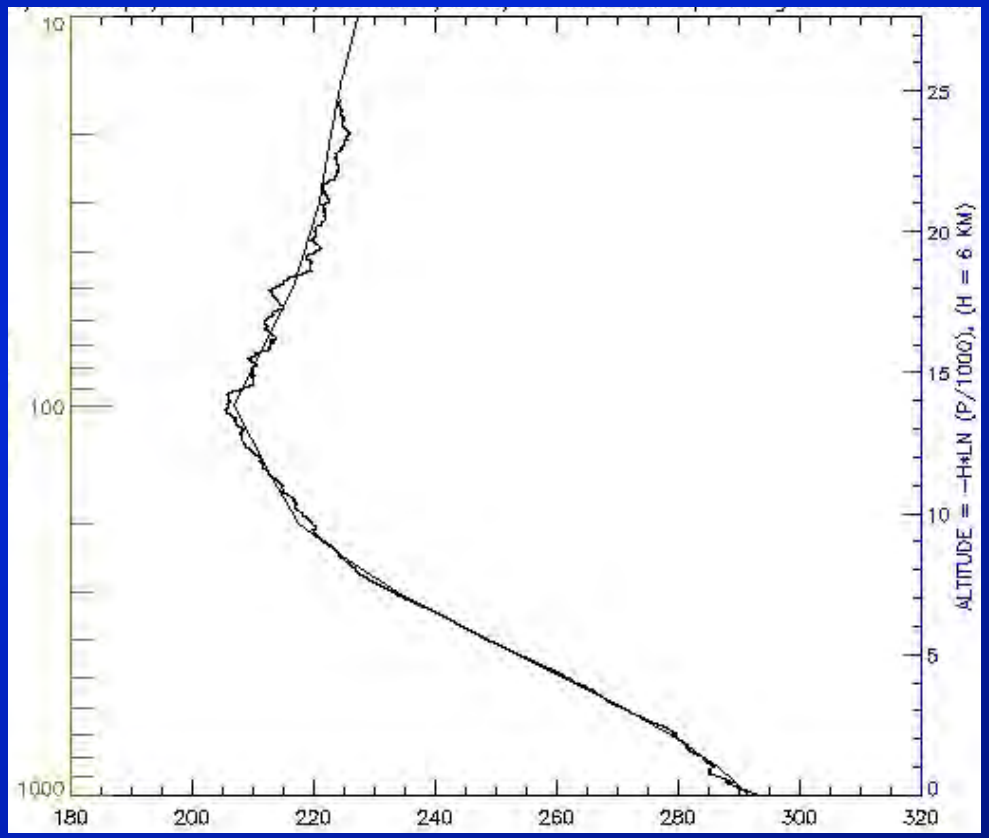


(from King, 2007, and the AIRS Science Team)

Sample Temperature Profiles: AIRS & Radiosonde

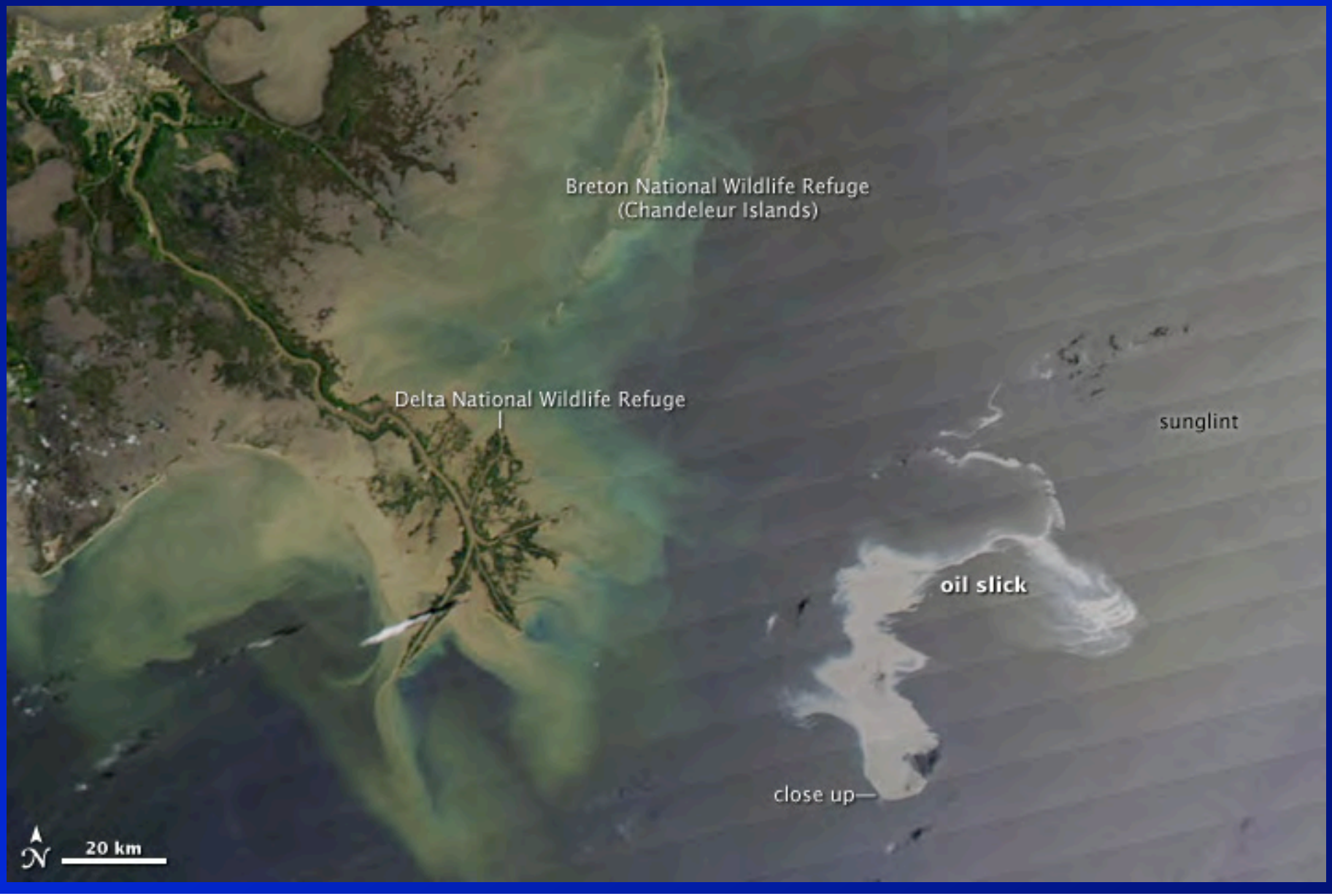
Chesapeake Bay Research Platform
(photo from the CERES Science Team)

AIRS Temperature Profile over the Chesapeake Bay (smooth curve) vs. a Radiosonde Profile (more jagged curve), for 9/13/2002

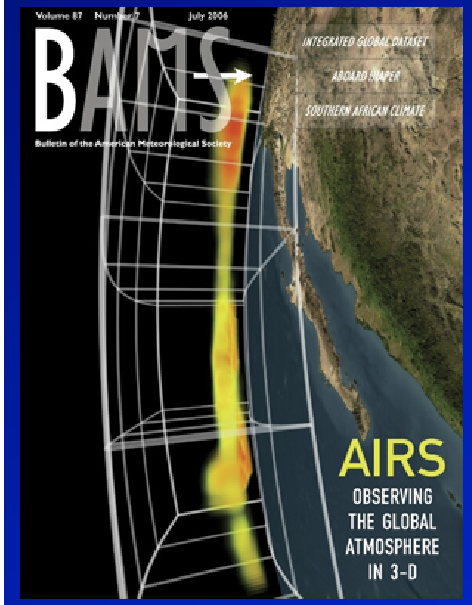


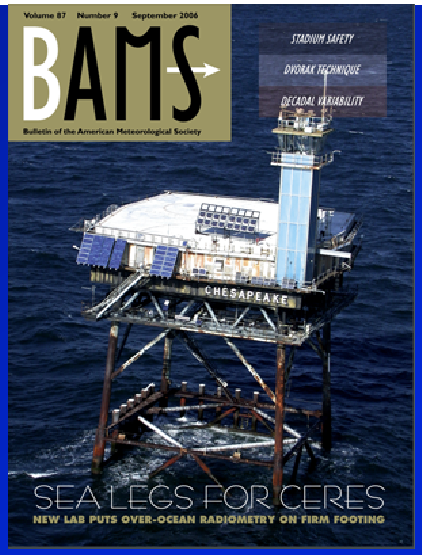
(plot from Wallace McMillan and the AIRS Science Team)

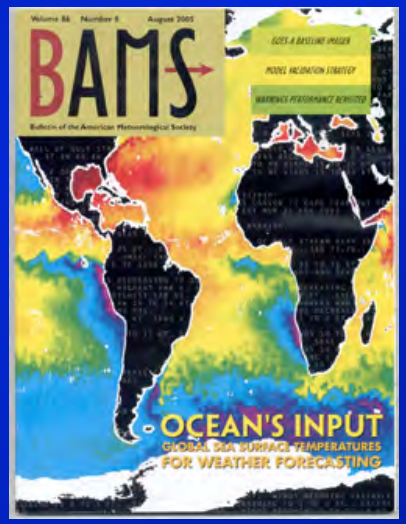
Deepwater Horizon Oil Spill in the Gulf of Mexico, April 25, 2010, from Aqua MODIS data

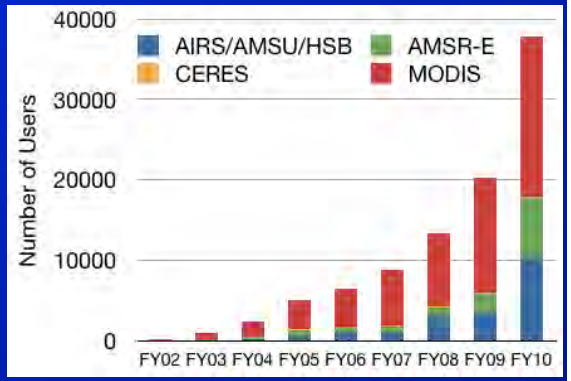


Visibility of Aqua Results

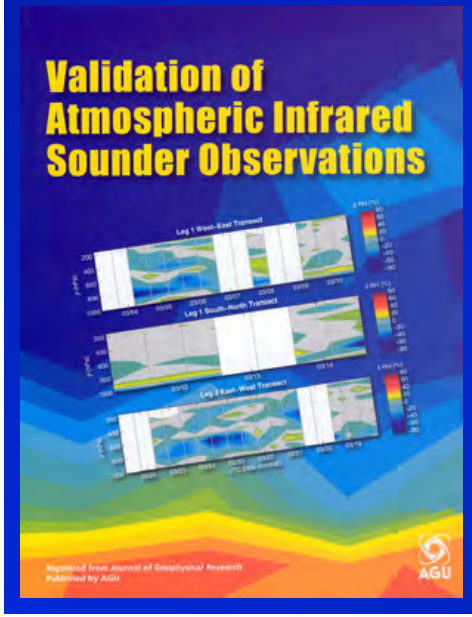


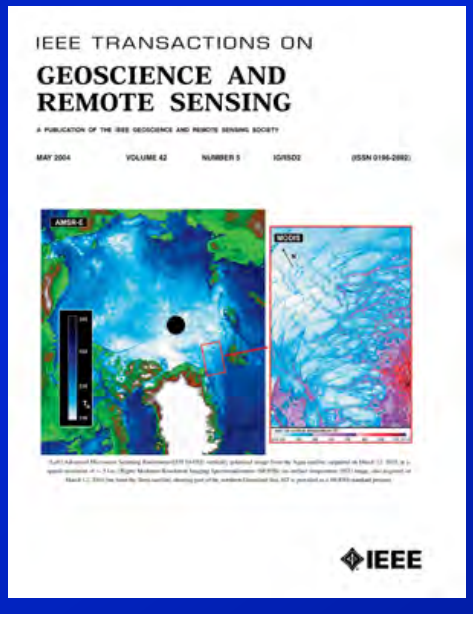


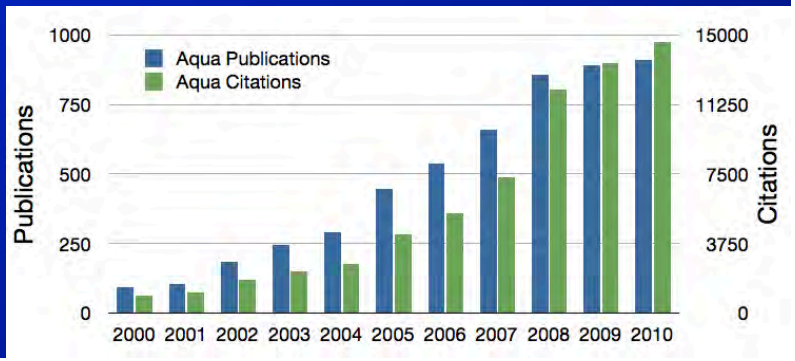




Number of users of Aqua data

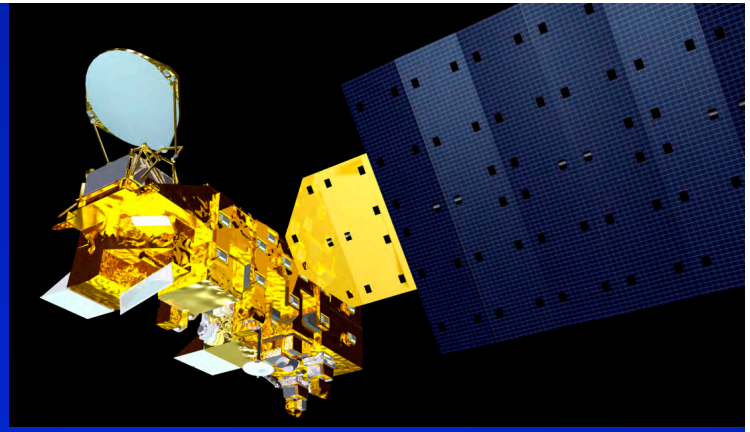






Summary

- Aqua was launched on May 4, 2002.
- Well over 2,000 scientific publications have used Aqua data.
- Aqua data have revealed much new information regarding many facets of the Earth system, including the Earth's energy budget and water cycle.
- Aqua data have also provided wide-ranging practical benefits, including for weather forecasting, deployment of fire fighters, routing of aircraft around volcanic ash, air quality monitoring, sea ice monitoring, and numerous others.
- Enough fuel remains on board for Aqua operations at least into the early 2020s.



(rendering by Reto Stockli, based on a version by TRW/Northrop Grumman)

(photograph by Apollo 17 astronauts, December 1972)

Selected Key Aqua Personnel

- Aqua Project Managers
  - Marty Donohoe
  - George Morrow
  - Phil Sabelhaus
- Aqua Science Team Leaders
  - AIRS/AMSU/HSB Science Team: Mous Chahine, then Joao Teixeira
  - AMSR-E Science Team: Roy Spencer (U.S.) and Akira Shibata (Japan)
  - CERES Science Team: Bruce Wielicki, then Norman Loeb
  - MODIS Science Team: Vince Salomonson, then Michael King
- Earth Science Mission Operations (ESMO)
  - Aqua Mission Director: Bill Guit
  - Science Interface Manager, ESMO: Angie Kelly
- Aqua Program Scientist: Ramesh Kakar
- Aqua Project Science Office
  - Aqua Project Scientist: Claire Parkinson
  - Deputy Aqua Project Scientists: Al Chang, then Peter Hildebrand, then Steve Platnick, and now Lazaros Oreopoulos
  - Aqua Outreach Coordinator: Steve Graham