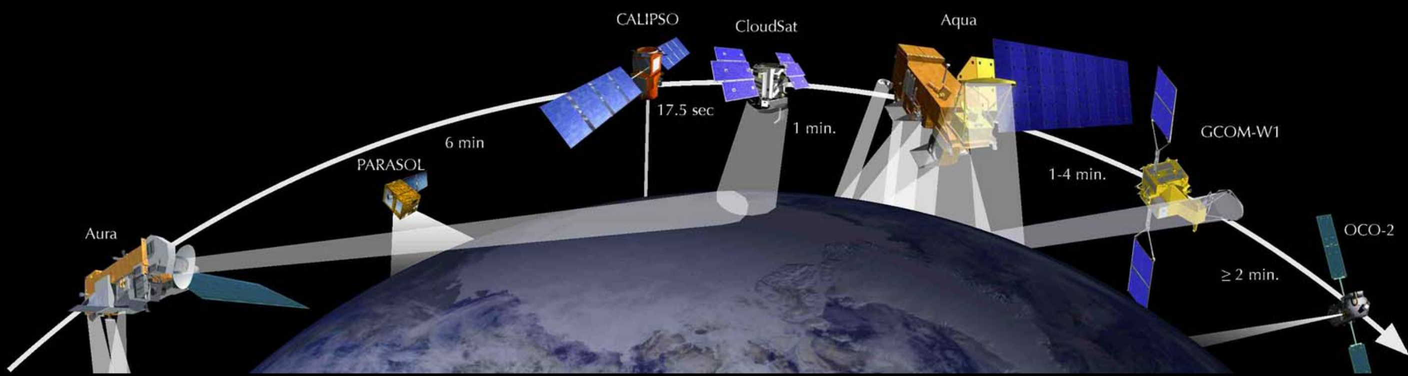
National Aeronautics and Space Administration











Eyes on Earth ⟷ ***Hands-on GLOBE***

Michael H. Freilich

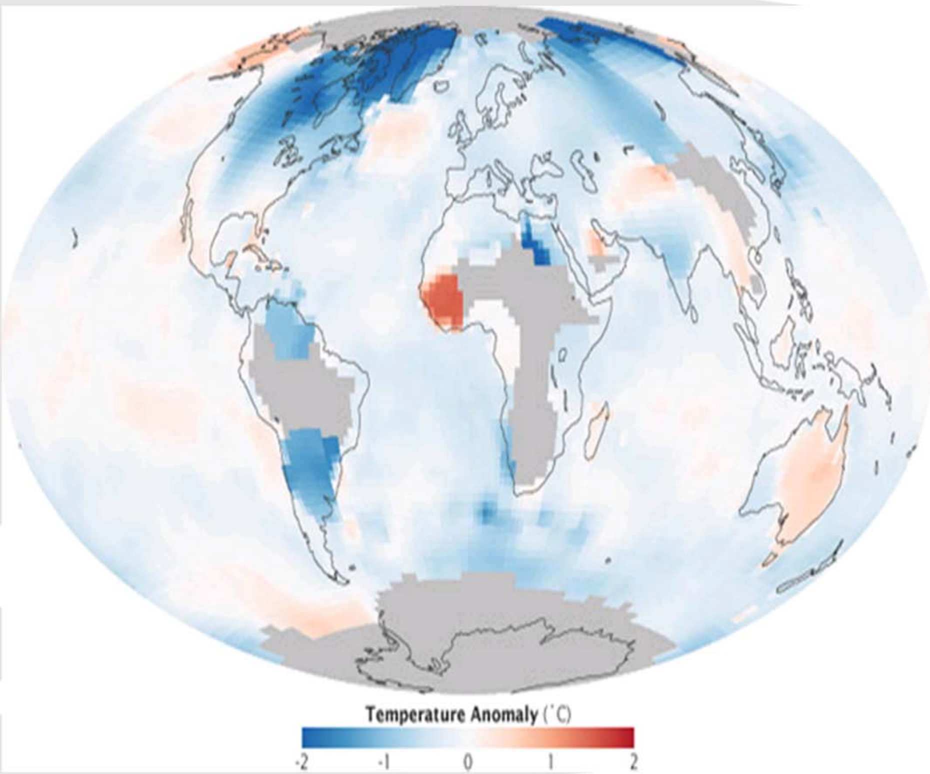
17th GLOBE Annual Partner Meeting

THE CLIMATE IS CHANGING

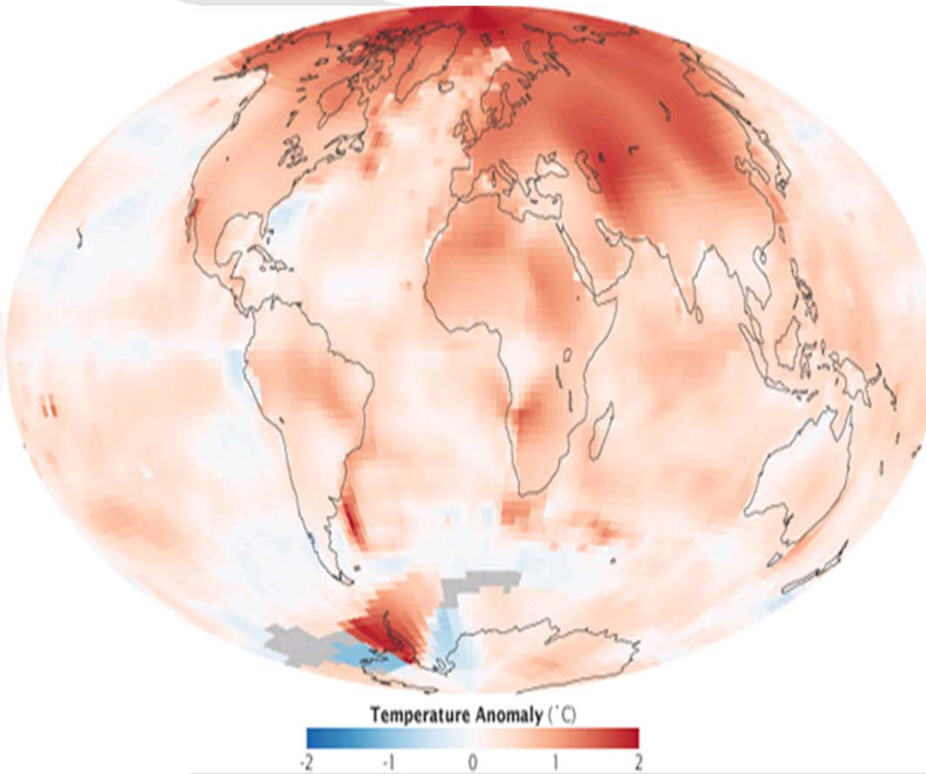
- Earth's changing environment will impact every aspect of life on our planet
  - ***Climate change has profound implications***
- Humans are the only creatures able to analyze, anticipate, and act now to influence events that will occur generations into the future
  - ***Climate change poses profound societal challenges***
- Detecting and separating secular global changes from small-scale variability requires technological skill and deep understanding of the Earth as an integrated system
  - ***The fact that we*** **know** ***the climate is changing is a profound testament to our human skills and intellect***

Global Surface Temperature: 1885 vs 2005

1880-1889



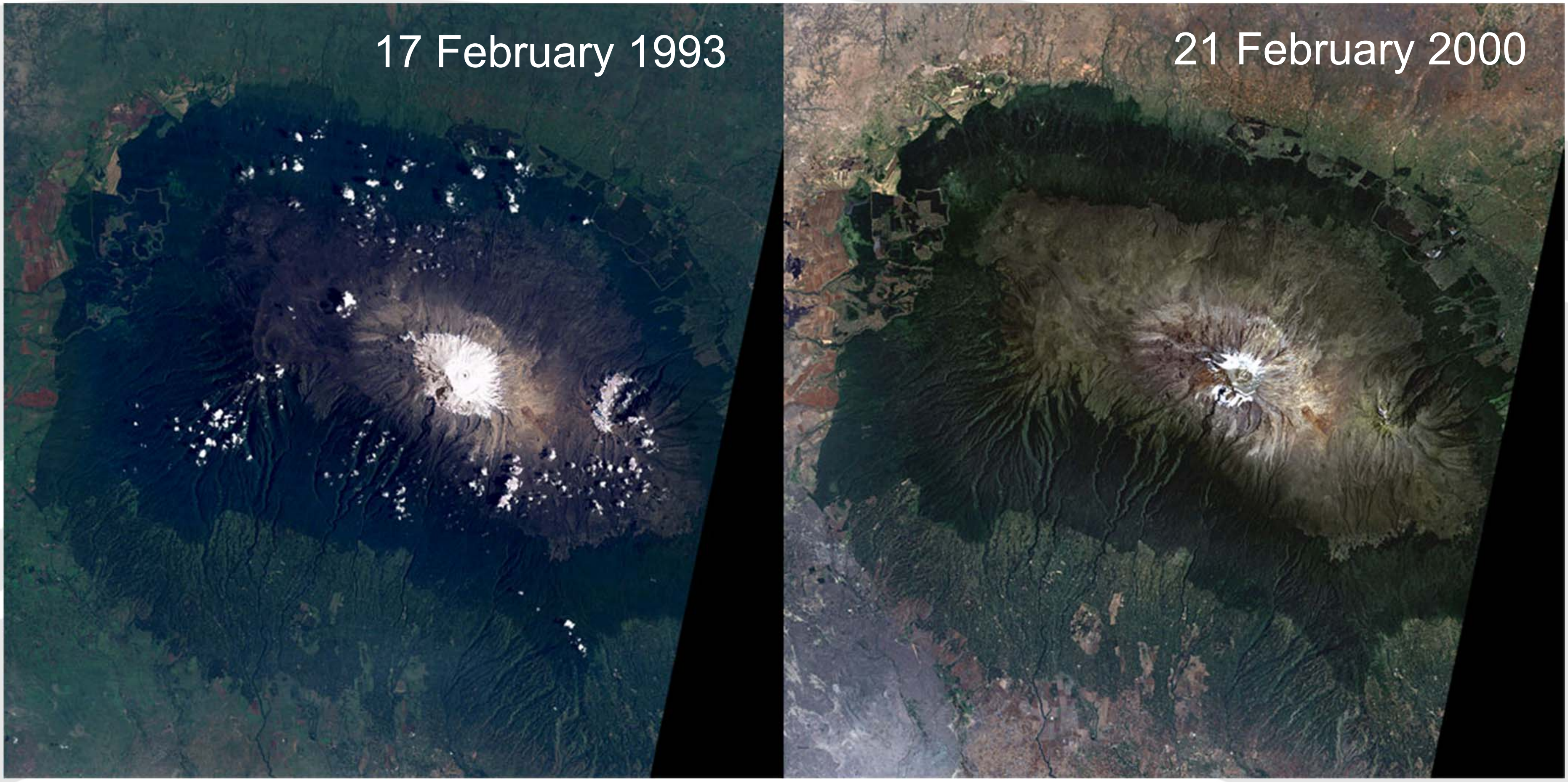
2000-2009



Anomalies relative to the 1951-1980 average.

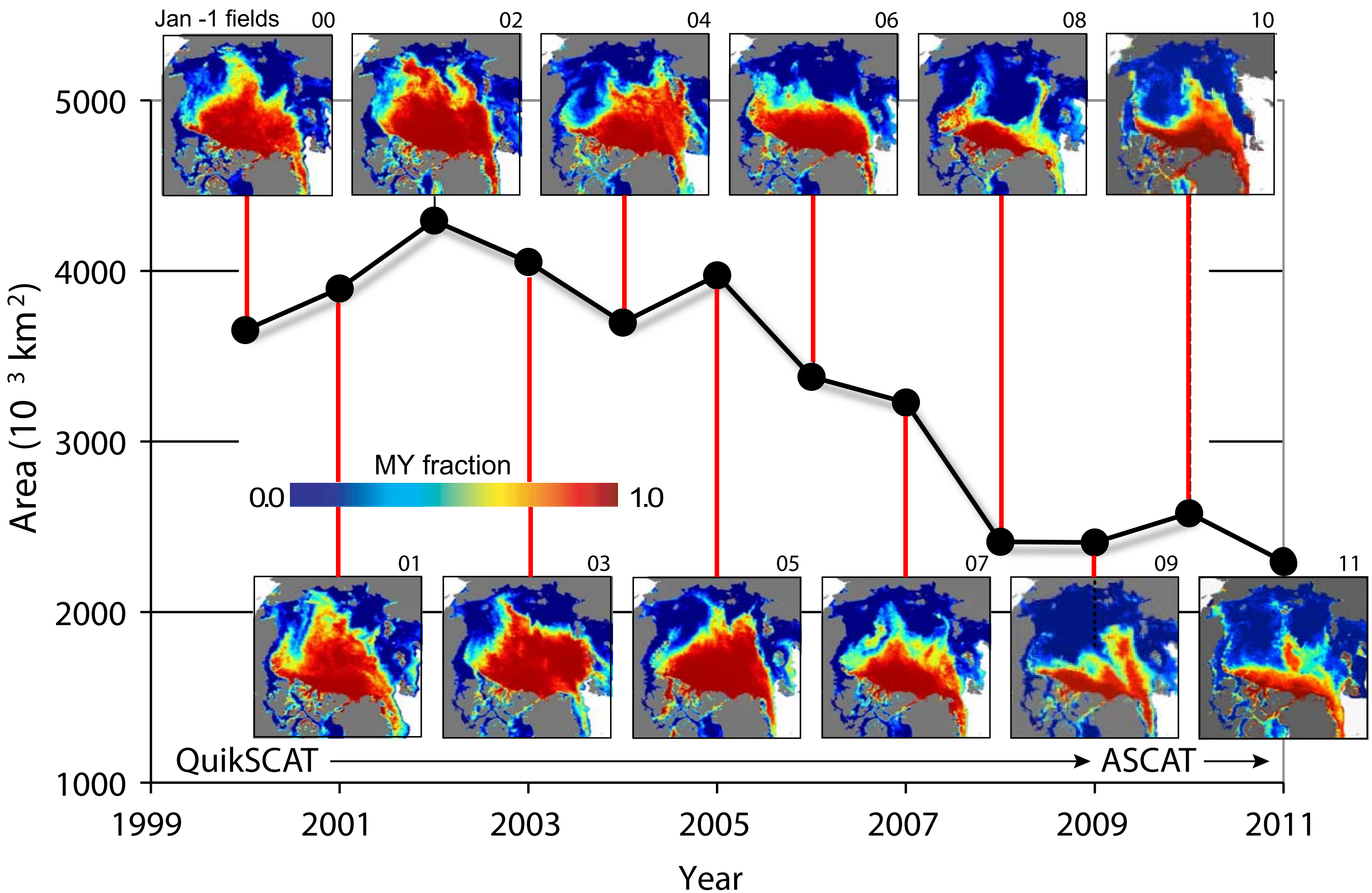
Data from NASA Goddard Institute for Space Studies.
Courtesy of the NASA Earth Observatory and Mike Carlowicz

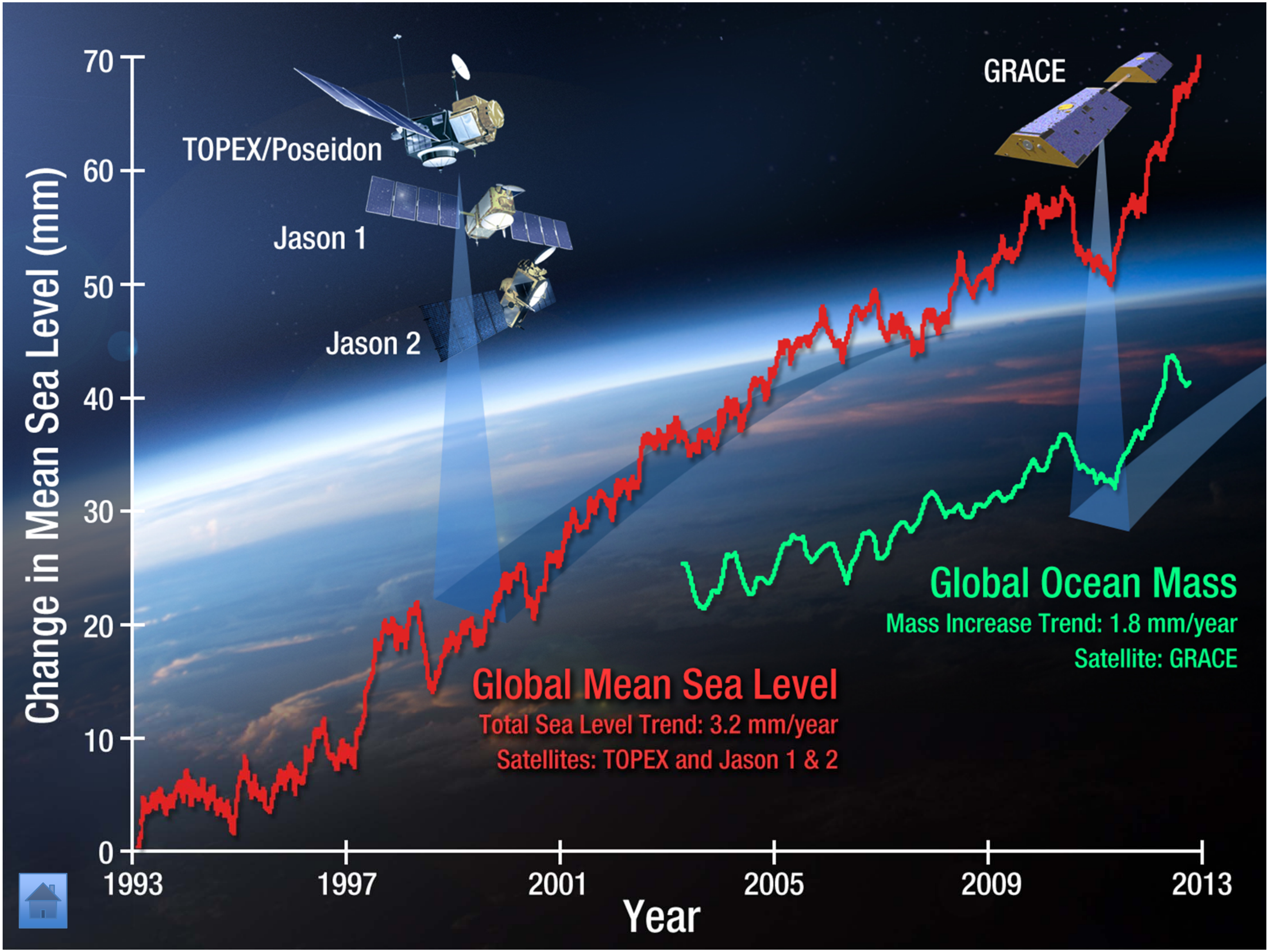
MOUNT KILIMANJARO GLACIERS, TANZANIA



Imagery from Landsat

Multi-year sea ice is vanishing – climate implications





TOPEX/Poseidon
Jason 1
Jason 2
GRACE
Change in Mean Sea Level (mm)
0
10
20
30
40
50
60
70
1993
1997
2001
2005
2009
2013
Year
Global Mean Sea Level
Total Sea Level Trend: 3.2 mm/year
Satellites: TOPEX and Jason 1 & 2
Global Ocean Mass
Mass Increase Trend: 1.8 mm/year
Satellite: GRACE

Flooding and Sea-Level Rise, Mombasa

Box 2-2. Impact of sea level rise on the city of Mombasa

Mombasa (700,000 inhabitants) is already affected by climate-related disasters, especially floods, droughts, and strong winds (El Nino in 1997, frequent floods, tsunami in 2006, drought in 2005/06). These disasters are projected to increase in frequency and intensity with long-term climate change. Sea level rise and frequent flooding damage existing infrastructure (transport, telecommunications), and thus negatively affect economic and commercial activities in the city. The IPCC has estimated that if the emission of greenhouse gases continues at the current rate, the sea level will rise by an additional 8 to 20 centimeters by 2030, and 21 to 71 centimeters by 2070 (IPCC, 2001). It is estimated that about 17 percent of Mombasa, or 4,600 hectares will be submerged with a sea level rise of only 0.3 meters. There will be also large areas rendered uninhabitable due to flooding or water logging or agriculturally unsuitable due to salt.

Source: Climate change and coastal cities: The Case of Mombasa, Kenya: African Centre for Technology Studies, Nairobi, 2007

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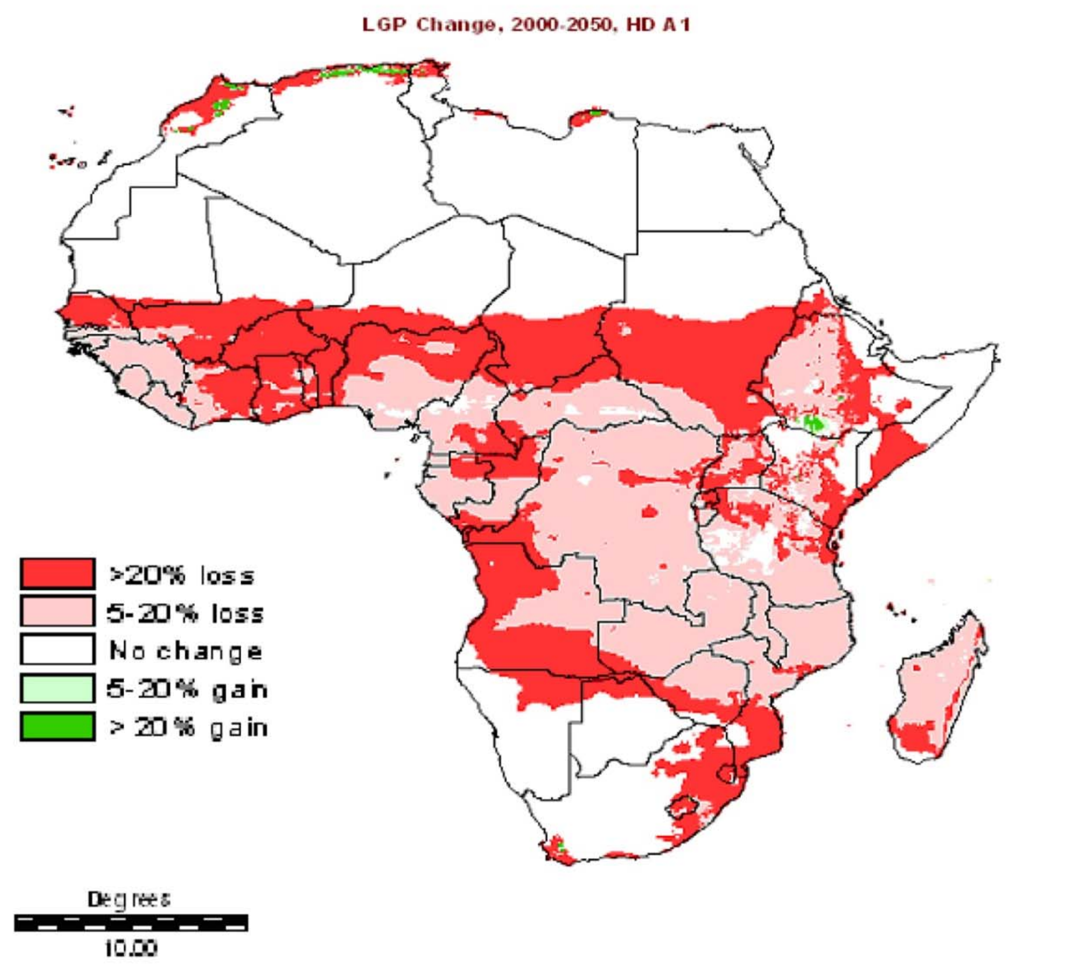
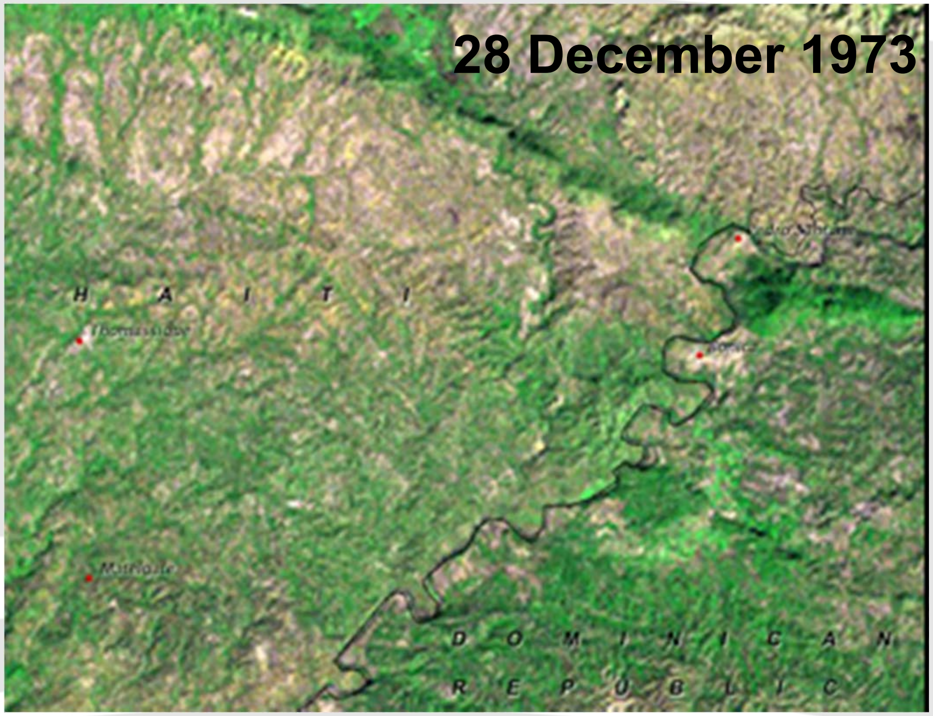
Estimated Change in Length of Growing Period – 2000-2050

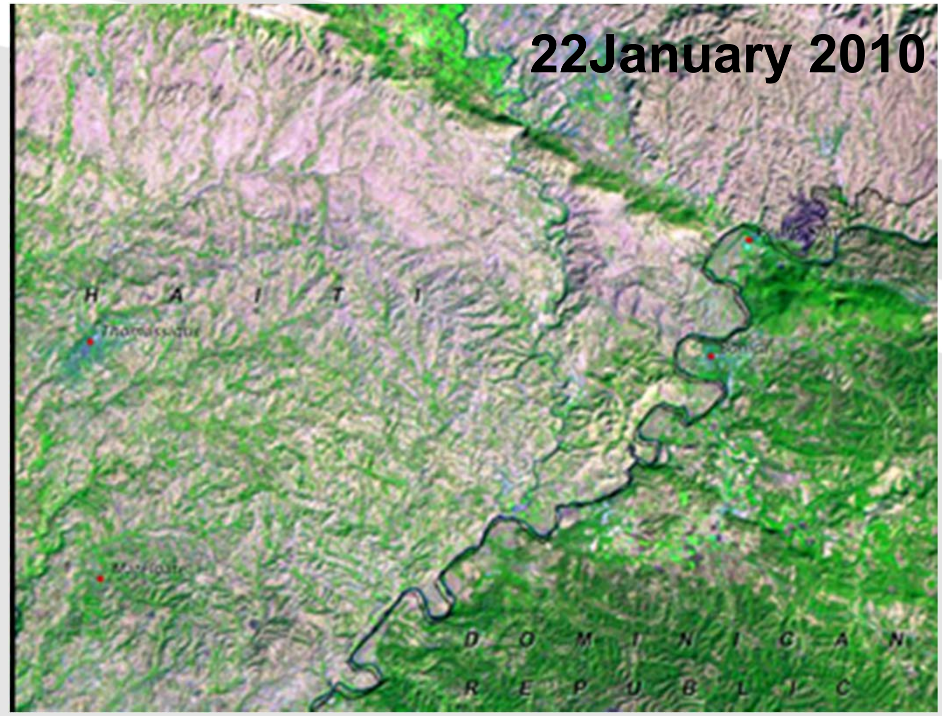
Figure 3-3. Relative change in length of growing period (LGP) by 2050 compared to present



Source: Thornton et al. (2006)

Haiti – Dominican Republic Border

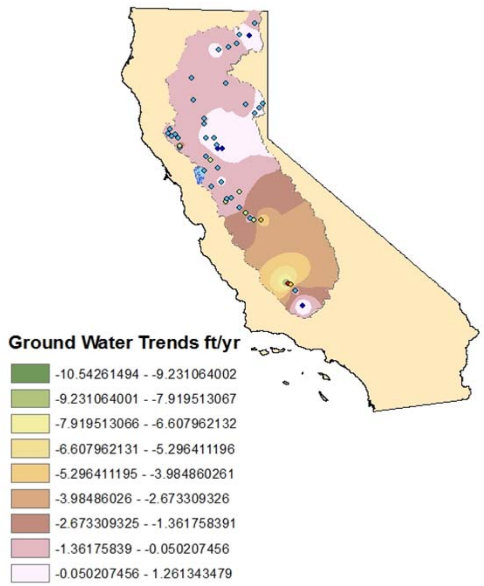




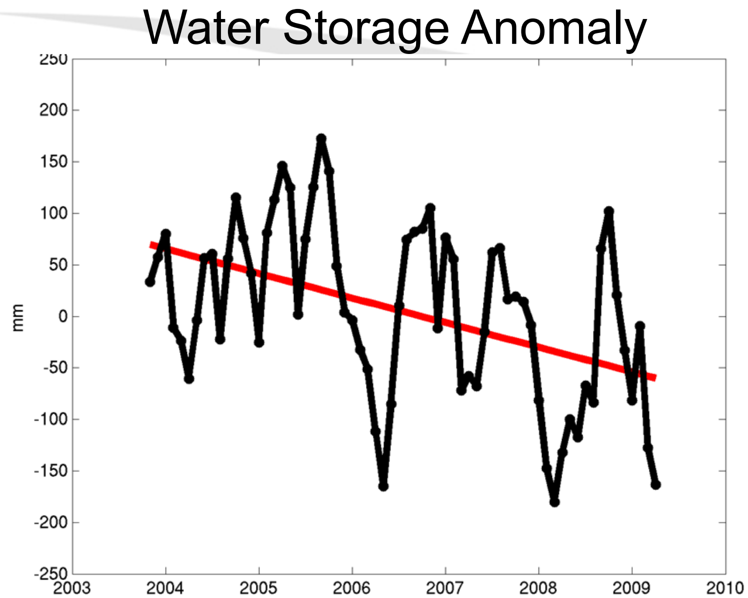
From 1973 to 2010, Haiti lost a substantial amount of vegetation near its border with the Dominican Republic, while the Dominican side did not. Both countries depend on low-return agriculture on poor, badly irrigated soils.

Source: United Nations Environment Programme (UNEP). From the *Latin America and the Caribbean Atlas of our Changing Environment* (2010).

GRACE DETECTS UNSUSTAINABLE GROUNDWATER LOSS

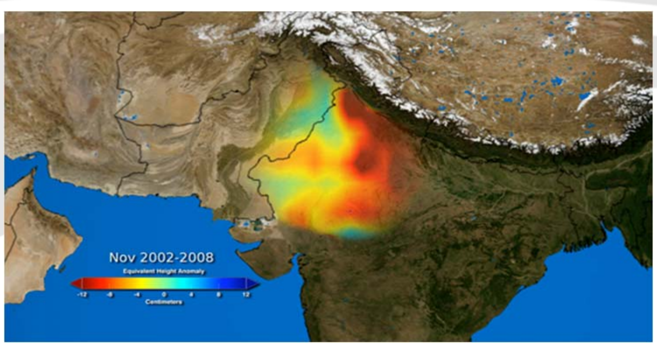


Observed trends in groundwater levels, October, 2003 – March, 2009

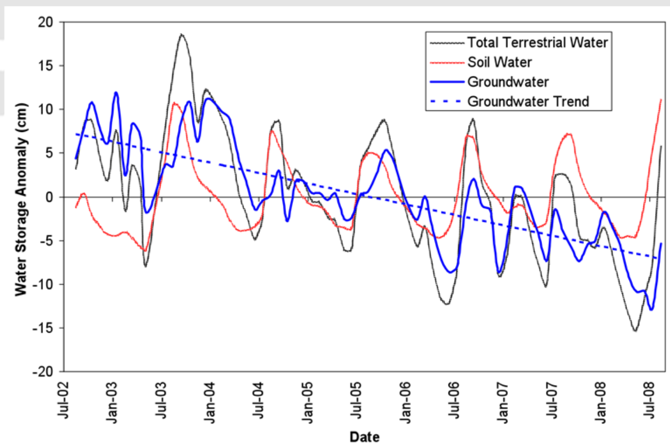


Drawdown by 31 km^3 (= 1 Lake Mead) in 66 months

Famiglietti et al., 2009



Pattern of groundwater depletion in NW India



Loss of 109 km^3 (3 Lake Meads) over 72 months

Rodell et al., 2009

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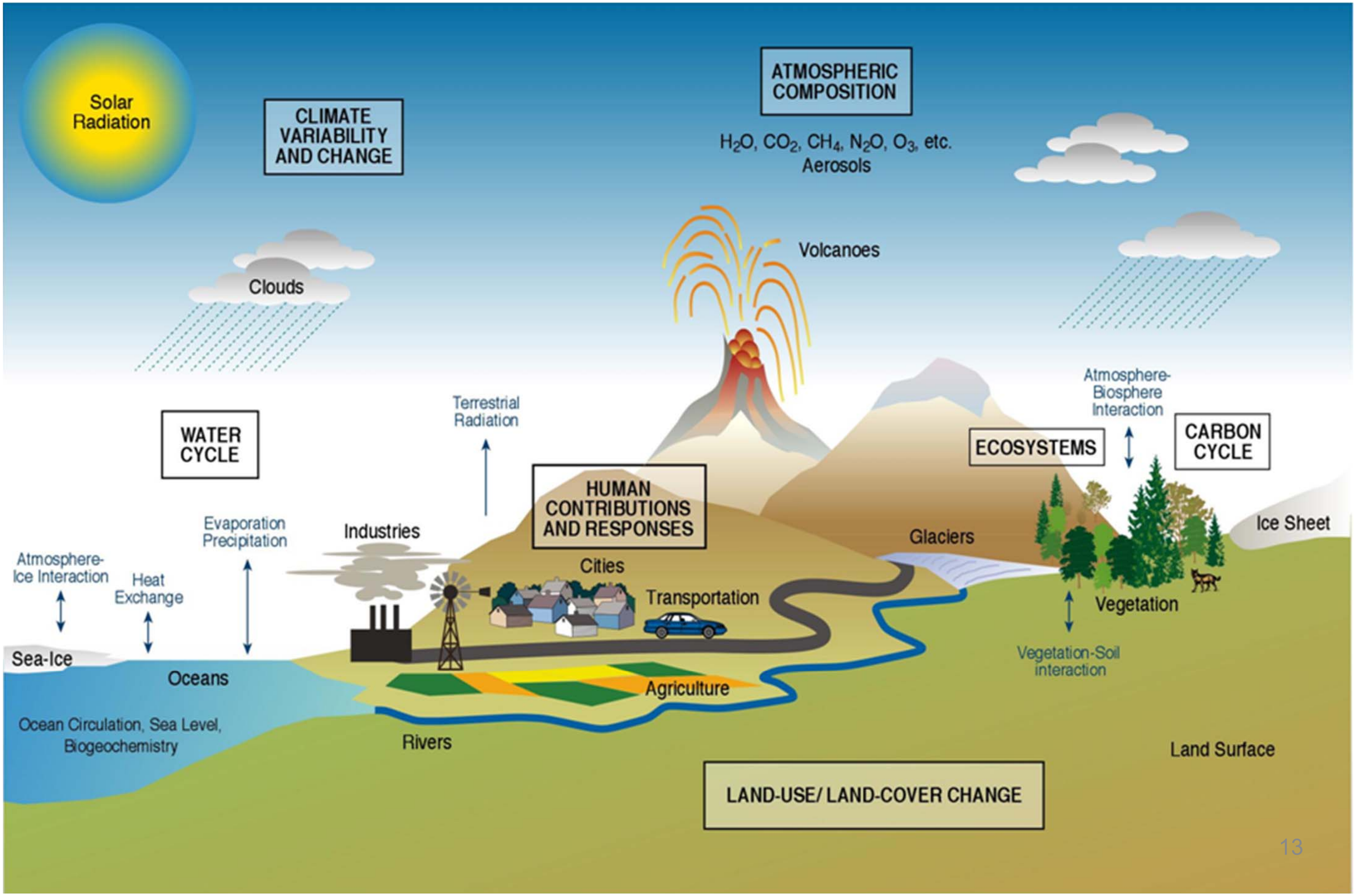
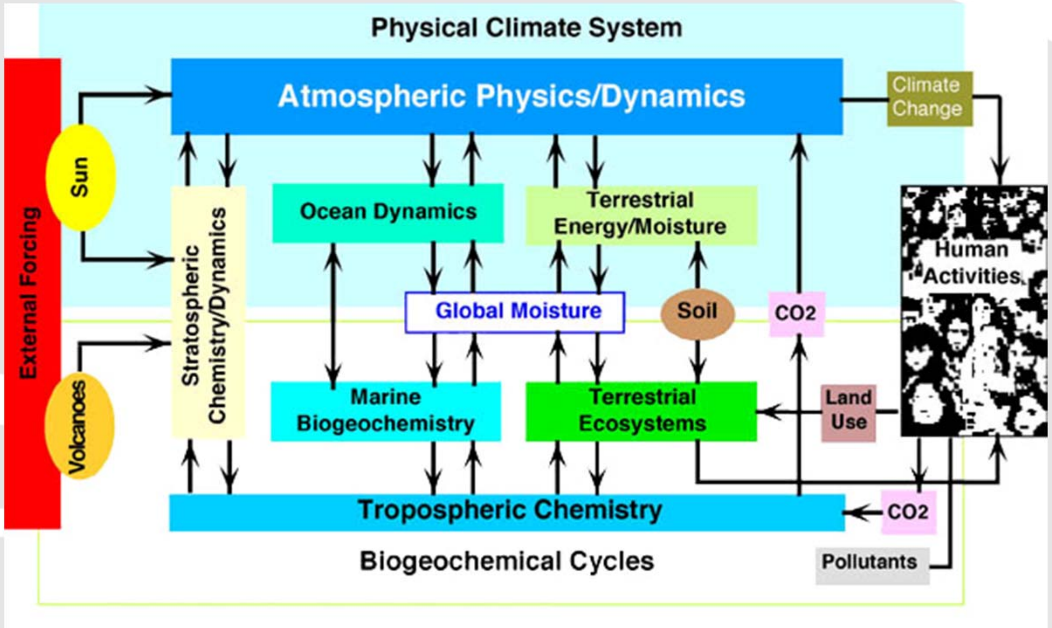
  - ***Climate change poses profound societal challenges***
- Detecting secular global changes amidst small-scale variability – and understanding the causes of the trends – requires technological skill and deep understanding of the Earth as an integrated system
  - ***The fact that we* know *the climate is changing is a profound testament to our human skills and intellect***

The Earth is a Complex System

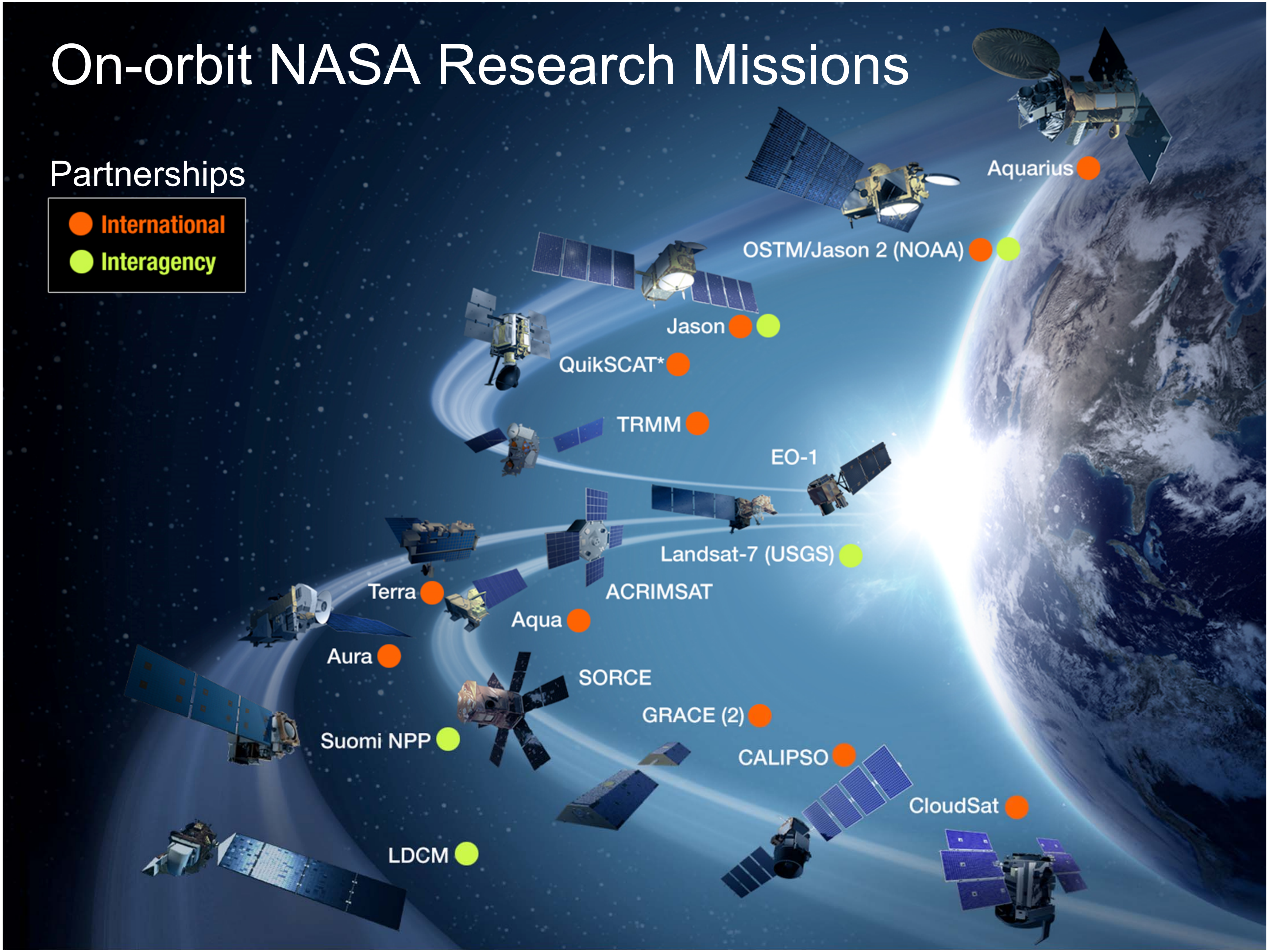


Earth System Science

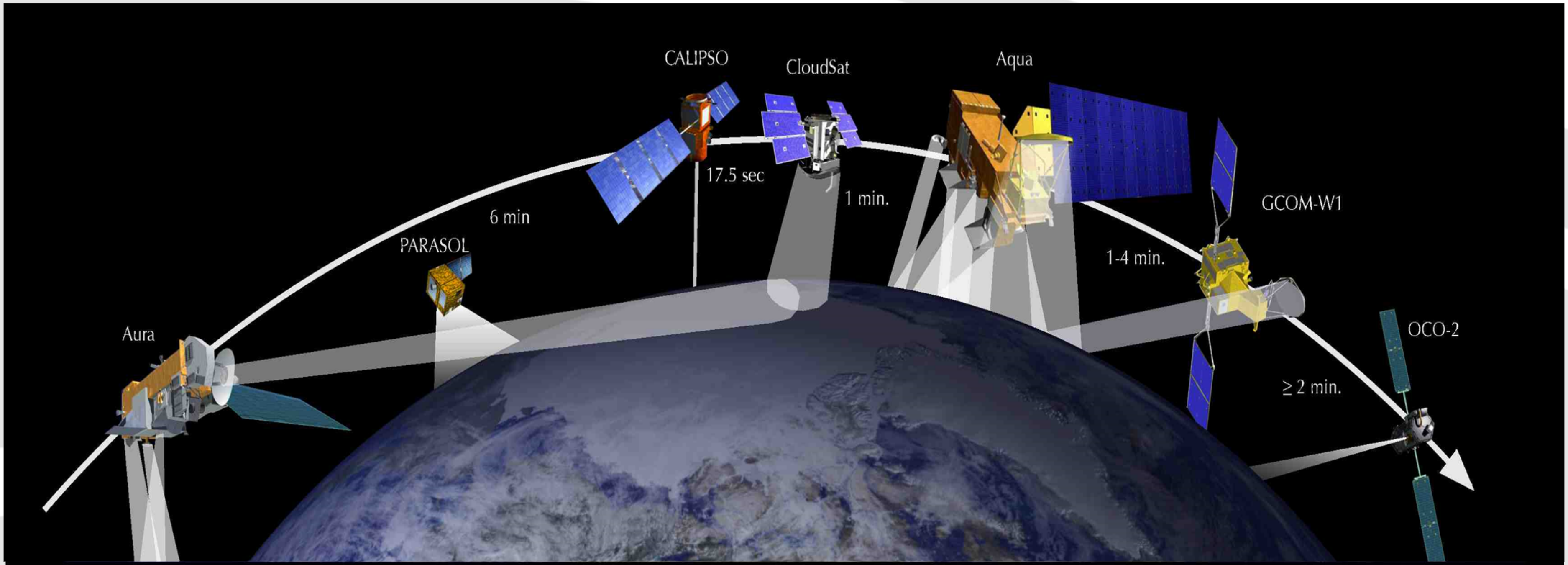
- ***Earth System Science***: Requires quantitative understanding of *interactions between processes* in order to define the Earth system – nonlinearities link spatial and temporal scales



- Satellites provide stable measurements with global coverage, high spatial resolution, frequent revisit; the constellation of Earth-observing satellites allows sustained measurements of many different quantities


On-orbit NASA Research Missions
Partnerships
International
Interagency
Aquarius
OSTM/Jason 2 (NOAA)
Jason
QuikSCAT*
TRMM
EO-1
Landsat-7 (USGS)
ACRIMSAT
Terra
Aqua
Aura
SORCE
GRACE (2)
Suomi NPP
CALIPSO
CloudSat
LDCM

The International A-Train

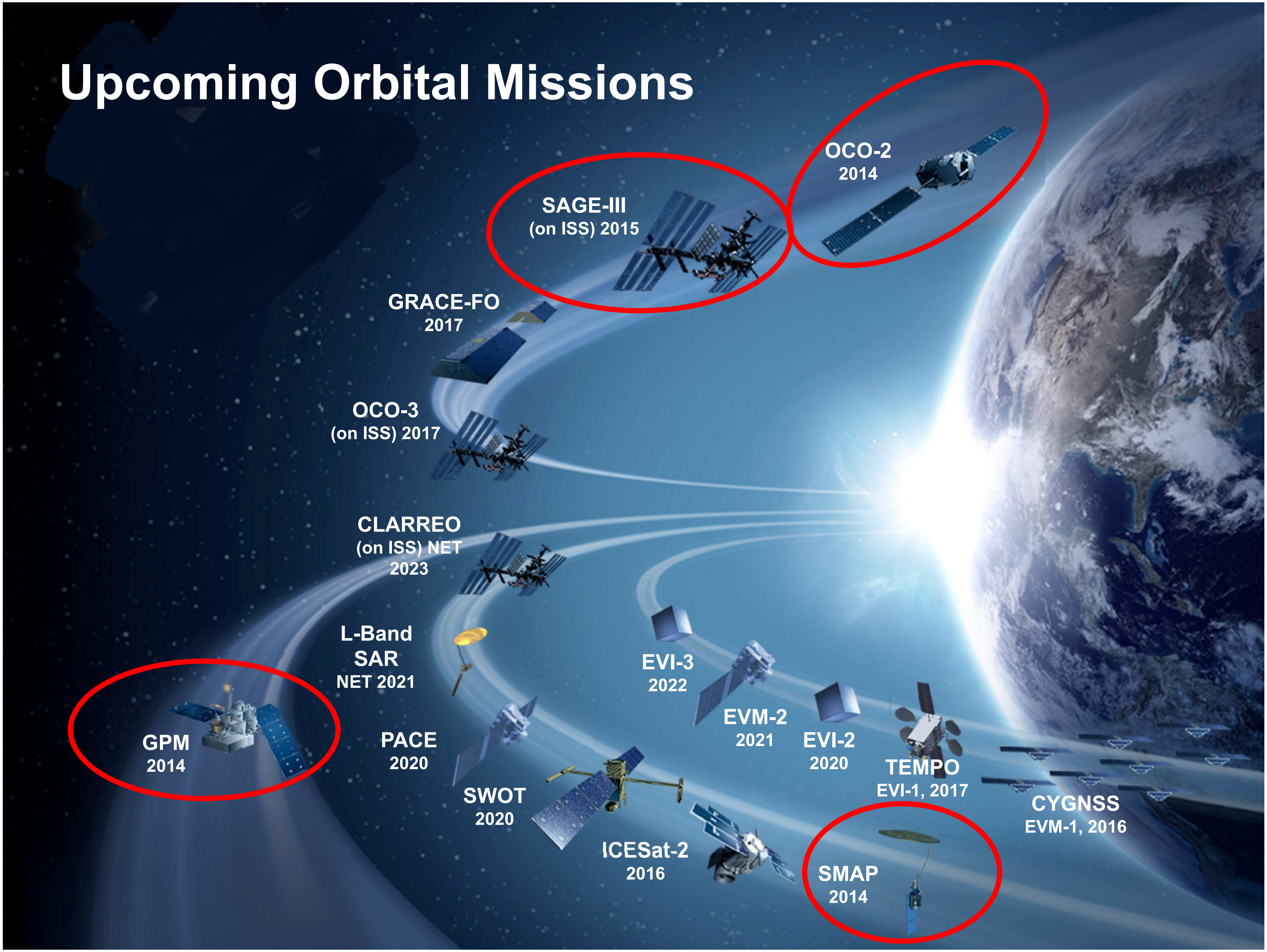


04/06/10

The Afternoon Constellation consists of eight U.S. and international Earth Science satellites that fly within approximately ten minutes of each other to enable concurrent science. The joint measurements provide an unprecedented sensor system for Earth Observations.

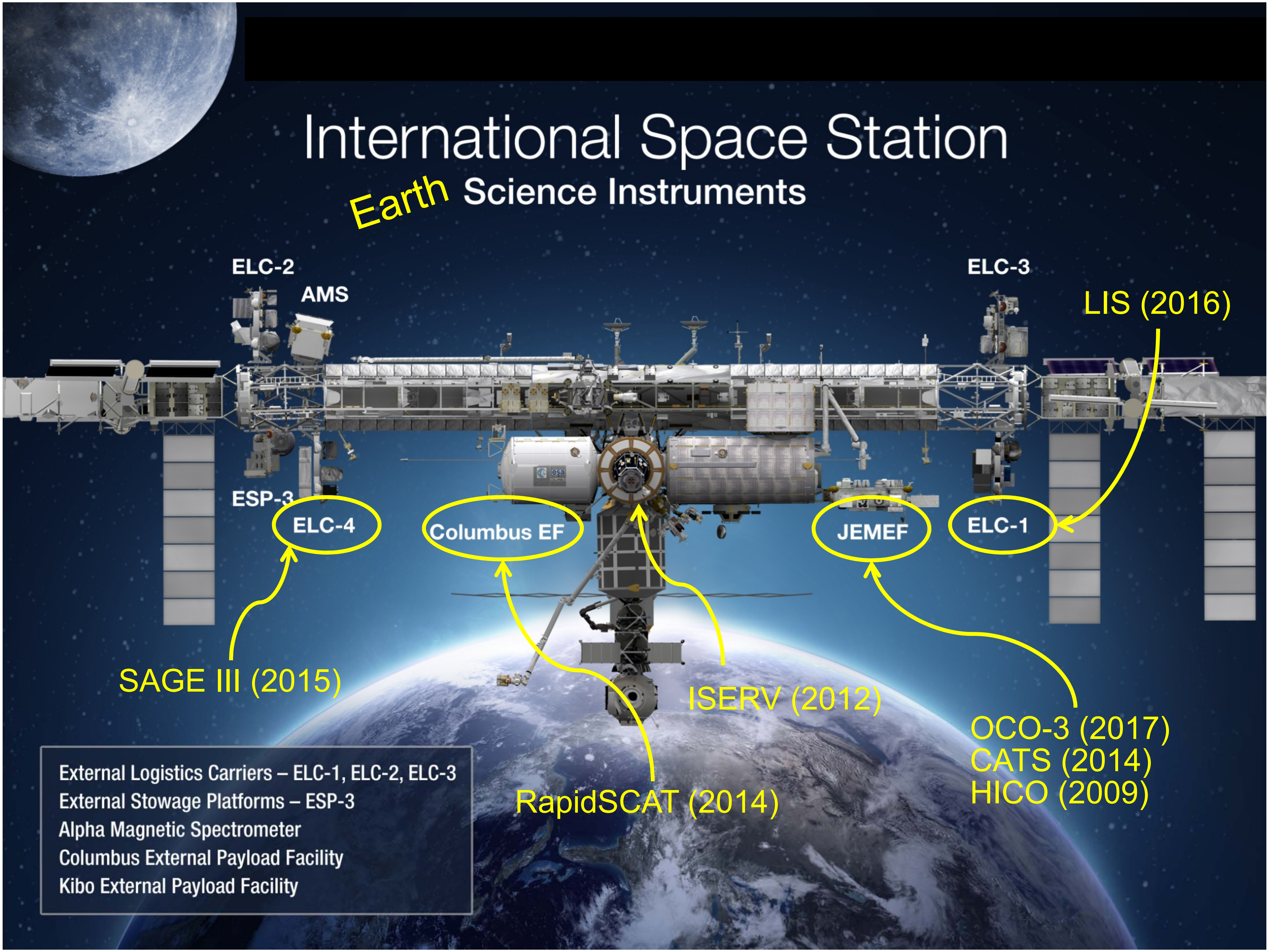
United States · Brazil · Canada · Finland · France · Japan · Netherlands · United Kingdom

www.nasa.gov


Upcoming Orbital Missions
OCO-2
2014
SAGE-III
(on ISS) 2015
GRACE-FO
2017
OCO-3
(on ISS) 2017
CLARREO
(on ISS) NET
2023
L-Band
SAR
NET 2021
GPM
2014
PACE
2020
SWOT
2020
ICESat-2
2016
EVI-3
2022
EVM-2
2021
EVI-2
2020
TEMPO
EVI-1, 2017
CYGNSS
EVM-1, 2016
SMAP
2014

Global Precipitation Mission

NASA/JAXA +International Partnership – Launch 14 February 2014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International Space Station
Earth Science Instruments
ELC-2
AMS
ELC-3
LIS (2016)
ESP-3
ELC-4
Columbus EF
JEMEF
ELC-1
SAGE III (2015)
ISERV (2012)
RapidSCAT (2014)
OCO-3 (2017)
CATS (2014)
HICO (2009)
External Logistics Carriers – ELC-1, ELC-2, ELC-3
External Stowage Platforms – ESP-3
Alpha Magnetic Spectrometer
Columbus External Payload Facility
Kibo External Payload Facility

GLOBE (K-12 Hands-on Educational Program)

THE HINDU

Life & Style » Metroplus

Mothering earth

NASA scientist Dr. Michael Freilich (centre) at Ahlcon

Eminent NASA scientist Dr. Michael Freilich urged the students to respect their planet

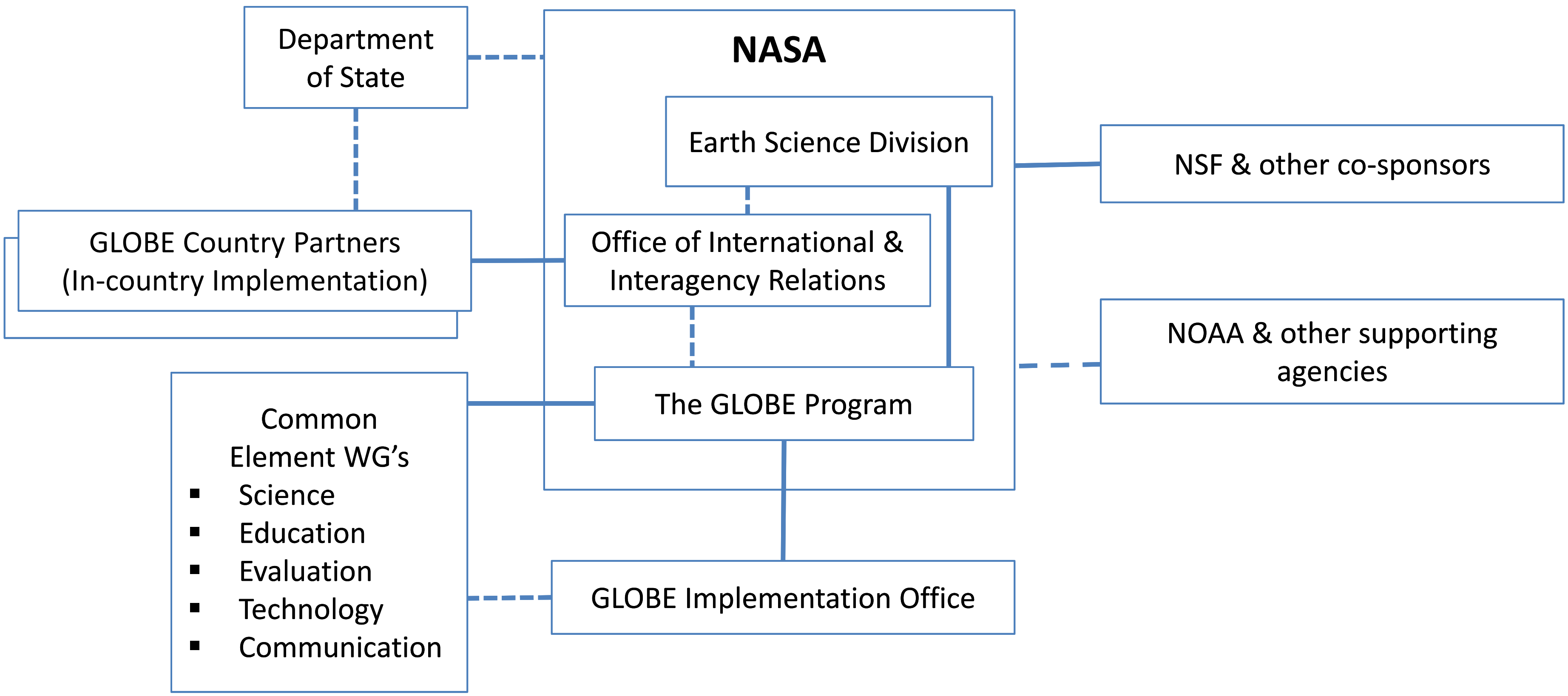
Director of the Earth Sciences division, NASA, Dr. Michael Freilich along with his colleagues, Dr. Marc Allen and Dr. Davis McSweeney visited Ahlcon International School, as part of his India tour. Ahlcon International School is part of Global Learning and Observation for the Benefit of the Earth (GLOBE), one of NASA's prestigious programs involving school children all over the world.

Describing his visit to school as the high point of his India tour, Dr. Freilich also witnessed a presentation made by the students that included imagery of Delhi's green cover and the study of a nearby water body called Sanjay Lake. Dr. Freilich advised the school children to respect our planet and to derive inspiration from our ancestors, who loved and worshiped nature. While replying to the queries from the students he impressed upon them how their actions today will influence the future of the world in the years to come.

On the occasion Dr. Freilich also presented a book "Our Changing Planet – The View from Space" — a stunning collection of images, data and information about the planet. Particularly noteworthy is the fact that the foreword of this edition begins with a quote from Mahatma Gandhi, "if a person dies the whole universe dies with him".

Keywords: NASA scientist, Dr. Michael Freilich

Partnerships for GLOBE



GLOBE DATA ARE SCIENTIFICALLY USEFUL

SURFACE OZONE MEASURED AT GLOBE SCHOOLS IN THE CZECH REPUBLIC A Demonstration of the Importance of Student Contribution to the Larger Science Picture

BY JOHN K. CREILSON, MARGARET R. PIPPIN, BRYANA L. HENDERSON,* IRENE H. LADD, JACK FISHMAN, DANA VOTÁPKOVÁ, AND ILONA KRPCOVÁ

Student measurements and observations taken as part of the GLOBE program can play an important role in both the analysis of scientific data and in the fostering of scientific curiosity.

SURFACE OZONE MEASUREMENTS IN THE CZECH REPUBLIC: A GLOBE SUCCESS STORY. When it was first established in 1994, one cornerstone of the vision for the Global Learning and Observations to Benefit the Environment (GLOBE) was that it would provide a mechanism by which kindergarten–12 students could contribute meaningfully to the Earth science community. The realization of such an ideal required the development of a set of instructions and standards that ensured measurements of a high enough quality that they could be published in peer-reviewed literature. These measurement procedures were established as GLOBE protocols, ▶

GLOBE DATA ARE SCIENTIFICALLY USEFUL

Atmos. Chem. Phys., 9, 1357–1364, 2009
www.atmos-chem-phys.net/9/1357/2009/

Atmospheric Chemistry and Physics

Relating observations of contrail persistence to numerical weather analysis output

D. P. Duda[1], R. Palikonda[2], and P. Minnis[3]

[1]National Institute of Aerospace, Hampton, Virginia, USA
[2]Science Systems and Applications, Inc., Hampton, Virginia, USA
[3]Science Directorate, NASA Langley Research Center, Hampton, Virginia, USA

Received: 7 April 2008 – Published in Atmos. Chem. Phys. Discuss.: 21 October 2008
Revised: 23 December 2008 – Accepted: 25 January 2009 – Published: 19 February 2009

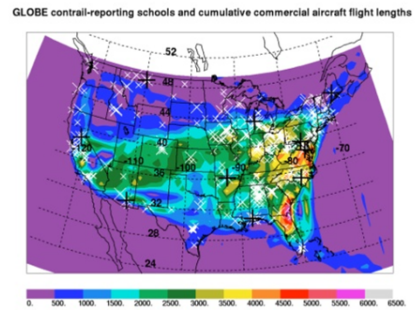


Fig. 1. Distribution of hourly mean cumulative flight lengths (in km) for all commercial flights with altitudes between 7 and 15 km for each 1×1 degree grid box for the time period between 15:00 and 20:00 UTC during November 2004 (see Garber et al., 2005). The crosses and plus signs indicate all GLOBE locations reporting contrail observations between April 2004 and June 2005. The small white crosses represent locations with 30 or fewer total observations, while the larger white crosses are locations with more than 30 total observations. The black plus signs denote locations with more than 50 observations taken during mostly clear (cloud coverage less than 25%) conditions.

(UTH) due to large dry biases in the balloon soundings used to construct the analyses and to internal adjustments made to meet the model's physical constraints (Minnis et al., 2005b). Although this dry bias prevents a straightforward determination of persistent contrail formation via Schmidt/Appleman theory, such a dry bias might be correctable if the numerical weather humidity data can be shown to be consistent with the appearance or non-appearance of contrails. Thus, one outstanding problem that must be addressed before a realistic simulation of contrails can be achieved is to determine how accurately the meteorological data provided by the numerical weather analyses and forecasts diagnose contrail formation conditions.

This paper evaluates the potential for using the RUC and ARPS models to diagnose and predict persistent contrail formation conditions using a variety of datasets. To achieve that goal, we match several months of contrail occurrence statistics derived from satellite and surface observations to the NWA-derived humidity, vertical velocity, wind shear and atmospheric stability. The relationships between contrail occurrence and the NWA-derived statistics are then analyzed to determine under which atmospheric conditions the formation of persistent contrails is favored.

2 Data and methodology

Two independent types of contrail observations are used to evaluate the NWA models. Satellite data can reveal contrails above lower level clouds that are missed by surface observers, but are biased, on average, toward lower occurrence rates. Surface observers can provide more reliable contrail observations and detect some of the thinner contrails missed by the satellite.

2.1 Surface data

The Global Learning and Observations to Benefit the Environment (GLOBE) program collects observations of cloud occurrence and coverage throughout the contiguous United States (CONUS) from primary and secondary schools across the country. (See www.globe.gov for more information about the GLOBE program.) In May 2003, GLOBE initiated a contrail observation protocol to measure and classify contrail observations. A primary goal of the GLOBE program is to use detailed written protocols to enable students to provide scientifically valuable measurements of environmental parameters (Brooks and Mims, 2001). Over 18 500 observations were reported over the region between 1 April 2004 and 27 June 2005. The observations usually include contrail coverage, contrail number, cloud coverage, cloud type and a classification of contrails into three categories, short-lived (SHRT), non-spreading persistent contrails (NSPR), and spreading persistent contrails (SPRD). The contrail categories are defined as follows: short-lived contrails are contrails that dissipate as the aircraft moves across the sky. Persistent contrails are contrails that remain in the sky after the aircraft has flown out of view of the observer. Spreading contrails are defined as persistent contrails wider than the width of a finger held at arm's length. This width corresponds to a contrail that is 2 degrees of arc wide, or at least 350 m wide (based on a contrail altitude of 10 km) (O'Shea, 1991), which is the minimum width expected to be detectable in NOAA's Advanced Very High Resolution Radiometer (AVHRR) imagery. The cloud coverage observations are reported within six categories based on total coverage of non-contrail cloudiness: no clouds (0% coverage), clear (1–9% coverage), isolated (10–24% coverage), scattered (25–49% coverage), broken (50–89% coverage) and overcast (90–100% coverage).

The GLOBE contrail dataset contains observations from 417 schools. The schools are mostly located in highly populated regions with substantial air traffic (Fig. 1). Only 123 of the schools (29.5%) reported more than 30 observations during the 15-month time period, but those schools reported 16 008 observations, 86.5% of the total. Nearly all schools reported only one observation/day. Approximately 92% of all observations were between 14:30 and 20:30 UTC, and nearly 58% of the total were between 16:30 and 18:30 UTC.

To test the quality of the surface-based observations, the set of 11 schools that had at least 50 observations taken under

GLOBE DATA ARE SCIENTIFICALLY USEFUL

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Remote Sensing of Environment 105 (2006) 341 – 353
Remote Sensing of Environment
www.elsevier.com/locate/rse

Validation of the MODIS snow product and cloud mask using student and NWS cooperative station observations in the Lower Great Lakes Region

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[b] Dept. of Earth, Ecological and Environmental Sciences, The University of Toledo, Toledo, OH 43606, United States
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[d] West Chester University, West Chester, PA 19383, United States

Received 13 April 2006; received in revised form 6 July 2006; accepted 15 July 2006

Abstract

NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) snow product (MOD10) creates automated daily, 8-day composite and monthly regional and global snow cover maps. In this study, the MOD10 daily swath imagery (MOD10_L2) and the MODIS cloud mask (MOD35) were validated in the Lower Great Lakes Region, specifically the area to the east of Lake Michigan. Validation of the MOD10_L2 snow product, MOD35 cloud mask and the MOD10_L2 Liberal Cloud Mask was performed using field observations from K-12 student GLOBE (Global Learning and Observations to Benefit the Environment) and SATELLITES (Students And Teachers Evaluating Local Landscapes to Interpret The Earth from Space) programs. Student data consisted of field observations of snow depth, snow water equivalency, cloud type, and total cloud cover. In addition, observations from the National Weather Service (NWS) Cooperative Observing Stations were used. Student observations were taken during field campaigns in the winter of 2001–2002, a winter with very little snow in the Great Lakes region, and the winters of 2000–2001 and 2002–2003, which had significant snow cover. Validation of the MOD10_L2 version 4 snow product with student observations produced an accuracy of 92% while comparison with the NWS stations produced an accuracy of 86%. The higher NWS error appears to come from forested areas. Twenty-five and fifty percent of the errors observed by the students and NWS stations, respectively, occurred when there was only a trace of snow. In addition, 82% of the MODIS cloud masked pixels were identified as either overcast or broken by the student observers while 74% of the pixels the MODIS cloud mask identified as cloudless were identified as clear, isolated or scattered cloud cover by the student observers. The experimental Liberal Cloud Mask eliminated some common errors associated with the MOD35 cloud mask, however, it was found to omit significant cloud cover.

Keywords: GLOBE; SATELLITES; Great Lakes; Snow; Cloud; Student; MODIS; Validation; MOD10; MOD10_L2; NASA; Liberal Cloud Mask; LCM

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D20311, doi:10.1029/2006JD007172, 2006

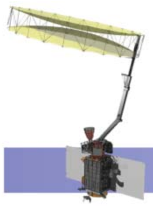
Validation of MODIS aerosol observations over the Netherlands with GLOBE student measurements

K. F. Boersma[1,2] and J. P. de Vroom[1]

Received 3 February 2006; revised 27 April 2006; accepted 17 July 2006; published 31 October 2006.

[1] We have established a network of secondary schools in the Netherlands with students routinely measuring aerosol optical thickness (AOT) at two wavelengths with hand-held Sun photometers. Students have performed more than 400 measurements between January 2002 and October 2005 over more than 12 locations within the Netherlands as a contribution to Global Learning and Observations to Benefit the Environment (GLOBE). We have developed an improved AOT retrieval algorithm that accounts for the effective wavelength of the broad-band GLOBE detectors and for the spatiotemporal variation of ozone. Results from a theoretical error analysis indicate that GLOBE measurements achieve a precision better than 0.02 AOT for both channels. Comparisons with professional instruments generally give high correlations and low scatter and bias. From these tests, we conclude that student data are scientifically valid and may be used to validate MODIS AOT retrievals over the Netherlands. We find that over land, MODIS AOT is biased by +0.03 (470 nm) and −0.01 AOT (660 nm). Over coastal areas, MODIS overestimates AOT by 0.10 (470 nm) and 0.08 AOT (660 nm). Seasonally averaged MODIS observations over northwestern Europe show relatively highest AOT values over the region of Flanders and the Netherlands, with a seasonal cycle peaking in spring/summer. Our study shows the potential of secondary school-based networks in addition to existing, professional networks that have much less spatial coverage.

Citation: Boersma, K. F., and J. P. de Vroom (2006), Validation of MODIS aerosol observations over the Netherlands with GLOBE student measurements, *J. Geophys. Res.*, *111*, D20311, doi:10.1029/2006JD007172.



The Upcoming Soil Moisture Active/Passive Mission: An Opportunity For Engagement With GLOBE

Among NASA's Earth and Space measurements, **soil moisture** is a particularly tangible one for the K-12 audience. It is a variable that most can understand and appreciate (floods, crop growth, etc.).

SMAP can engage GLOBE K-12 students in tangible and meaningful ways through their taking data following the Gravimetric Soil Moisture Protocol. ***Students can make valuable contributions to mission science.*** SMAP will launch in late October, 2014.

As stated in the SMAP Cal/Val Plan, the gold-standard for all soil moisture measurements is ultimately the tin-can sample. It is simple and inexpensive enough that K-12 students can actually do it daily.

Needed Material:

1. Soil sample can
2. Graduated cylinder
3. Balance
4. Drying oven

Here are the steps:

1. Measure the volume (V) of the sample can
2. Take soil sample in the sample can
3. Weigh moist sample (mass M_w)
4. Dry the sample
5. Weigh dried sample (mass M_d)

The soil moisture (in the same units as SMAP measurements) is:

$$\textbf{soil moisture} = (M_w - M_d) / (V * \rho) \ \ cm^3/cm^3$$

where $\rho = 1 \text{ g cm}^{-3}$ – the density of liquid water

MOST IMPORTANTLY . . .