New Opportunities – International Collaboration
Understanding Climate Change

Jean-Louis FELLOUS
Executive Director
Committee on Space Research

Observing climate and climate change

- Climate observation present daunting challenges
  - Detecting global temperature trends of 0.1° per decade, or variations in solar constant of 0.1% over the same period of time, or global sea level rise of a few mm per year
- Characteristics of a global climate observing system
  - Climate-quality measurements should be taken with accurate, calibrated instruments, converted into geophysical data, quality-controlled and stored in standard format. Data sets should be precise enough for the early detection of trends over the next decade, homogeneous in location, time and method, uninterrupted and long enough to resolve decadal trends, and with sufficient coverage and resolution to permit a description of spatial and temporal patterns of change.
- Current observing systems are far for being adequate

Advances in observing techniques

- Progress in satellite techniques (e.g., electronics miniaturisation, antenna design, communication rates, microwave radar techniques, stability of oscillators, detector sensitivity, etc.) have led to the development of active sensors and of smaller/better/cheaper satellites, providing huge amount of all-weather observations with ever-increasing resolution in space and time.
  - Progress also affected ground-based (*in situ*) observing systems, computing capabilities and numerical models.
- Space-based measurements can give access (uniquely in some cases) to a wide range of climate variables relating to the atmosphere, ocean and land domains

Challenges and opportunities in building a global climate observing system

- Financial and geographic challenges
  - Necessary international cooperation and coordination
- Compatibility challenge
  - Combining data from different systems with varying original purposes and diverse data collection, processing and storage schemes
- Knowledge and innovation challenges
  - New capabilities from R&D space agencies
- Continuity challenge
  - Once their value has been established, these capabilities need to transition into ongoing, "operational" capabilities.

"Crossing the Valley of Death"

- In a report to the U.S. National Research Council, a group of experts have compared the challenge of bridging the gap between research and operations to "crossing the Valley of Death."

Four major issues

1. Observations of climate change
   - Which are the key observations that require space-based observations?
2. Understanding climate change
   - Which are the key parameters that we do not observe sufficiently well today?
3. Modeling and forecasting
   - Which are the observable parameters required by models?
4. Mitigating the consequences of climate change
   - What is the role of space observations?

Global observation needs for climate

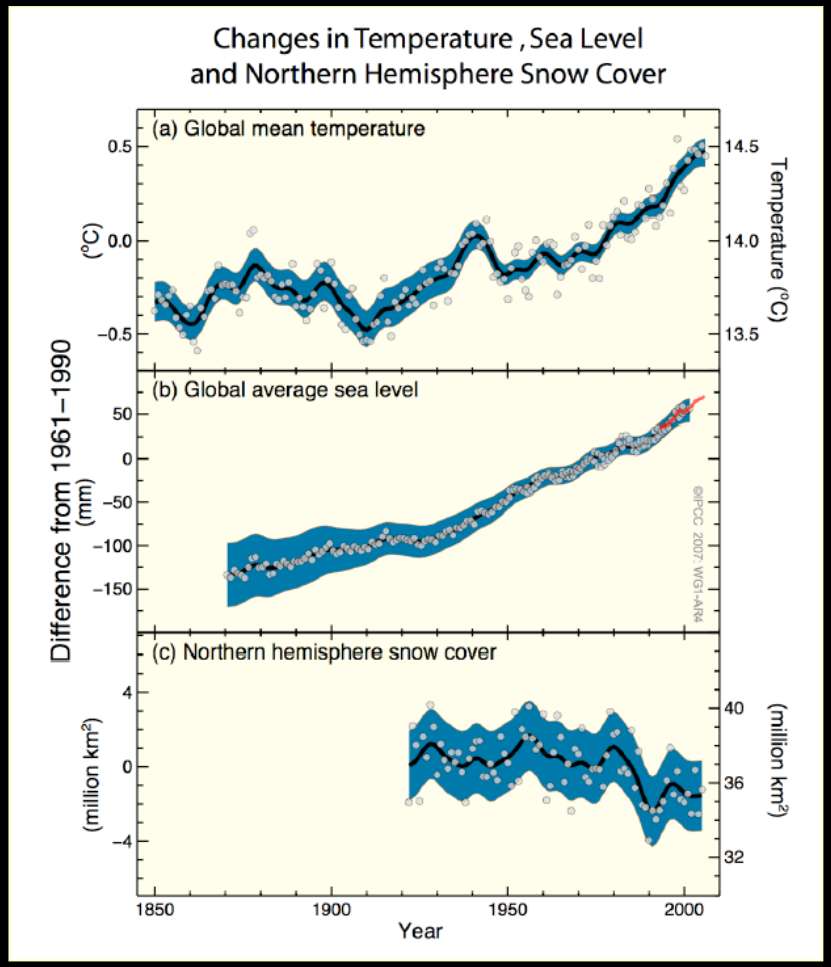
- The Global Climate Observing System (GCOS) was established in 1992 to address climate-related issues
  - Over the years GCOS has published Adequacy Reports and a 10-year Implementation Plan to resolve the inadequacies
- The COP-10 (10th Conference of the Parties to the United nations Framework Convention on Climate Change) adopted in December 2004 the following "Decision on research and Systematic Observation":
  - "*Invites Parties that support space agencies involved in global observations to request these agencies to provide a coordinated response to the needs expressed in the GCOS Implementation Plan*"
- The Committee on Earth Observation Satellites (CEOS) presented its response to COP-12 in November 2006

1. Do we know what needs to be observed and how?

- *"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."*

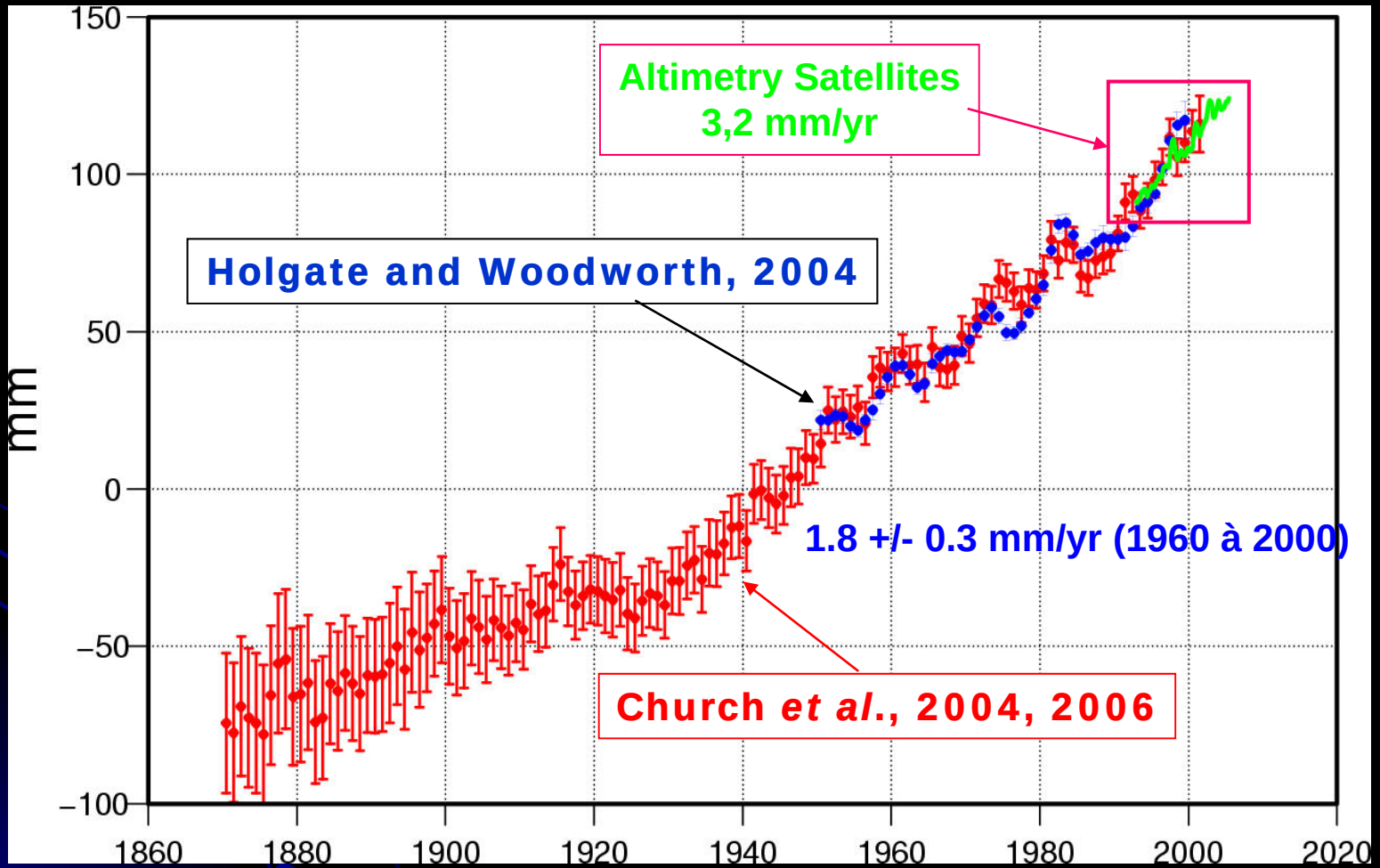
  (From IPCC AR4, Summary for Policy-makers)

- A large fraction of climate change observations now come from space-based systems.

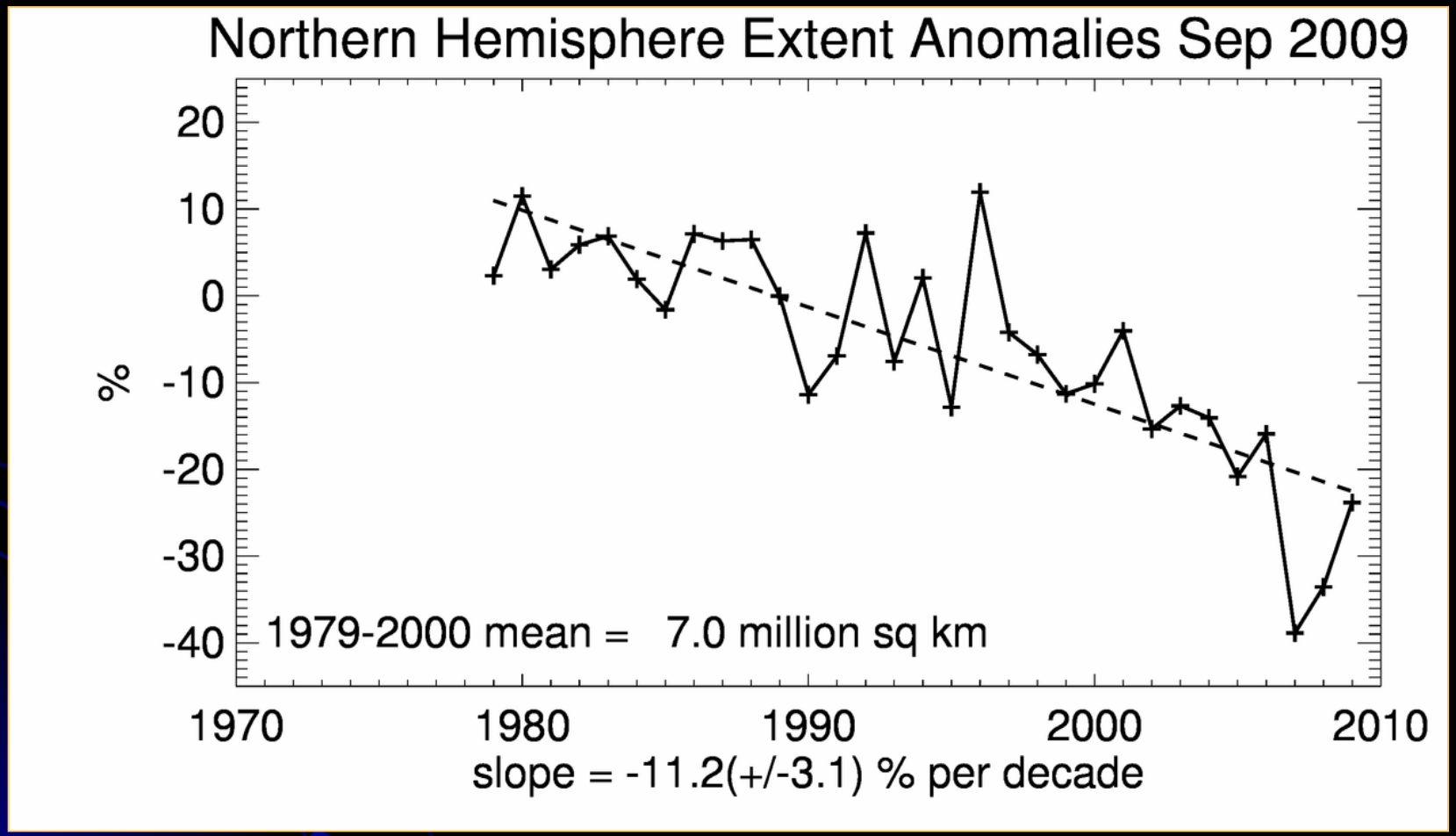


Source: IPCC AR4

Global Average Sea Level Rise: 1.3 mm/yr from 1960 to 2003



Arctic Sea Ice Extent Decline from microwave imagery – 1979-2009



Source: NSIDC

Yes, requirements have been carefully stated by GCOS…

Systematic Observation Requirements for Satellite-based Products for Climate

Supplemental details to the satellite-based component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS-92)"

****

GCOS Secretariat

GCOS-107
WMO/TD No. 1338 **September 2006**

… and space agencies are well aware of the GCOS requirements

CEOS Response to the GCOS Implementation Plan – September 2006

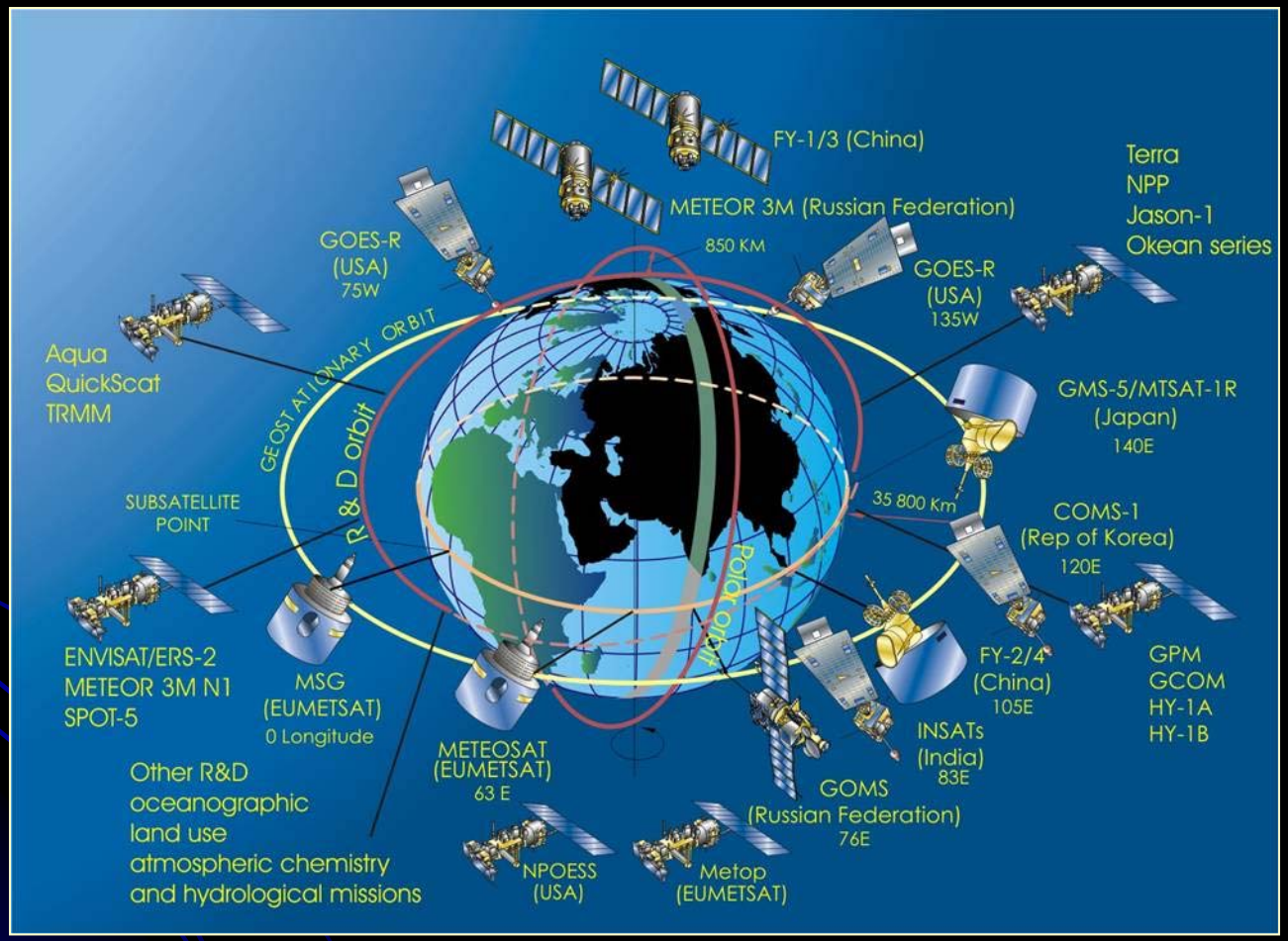
Satellite Observation of the Climate System

The Committee on Earth Observation Satellites (CEOS) Response to the Global Climate Observing System (GCOS) Implementation Plan (IP)

Developed by CEOS and submitted to the United Nations Framework Convention on Climate Change (UNFCCC) Subsidiary Body on Scientific and Technical Advice (SBSTA) on behalf of CEOS by the United States of America (USA) delegation

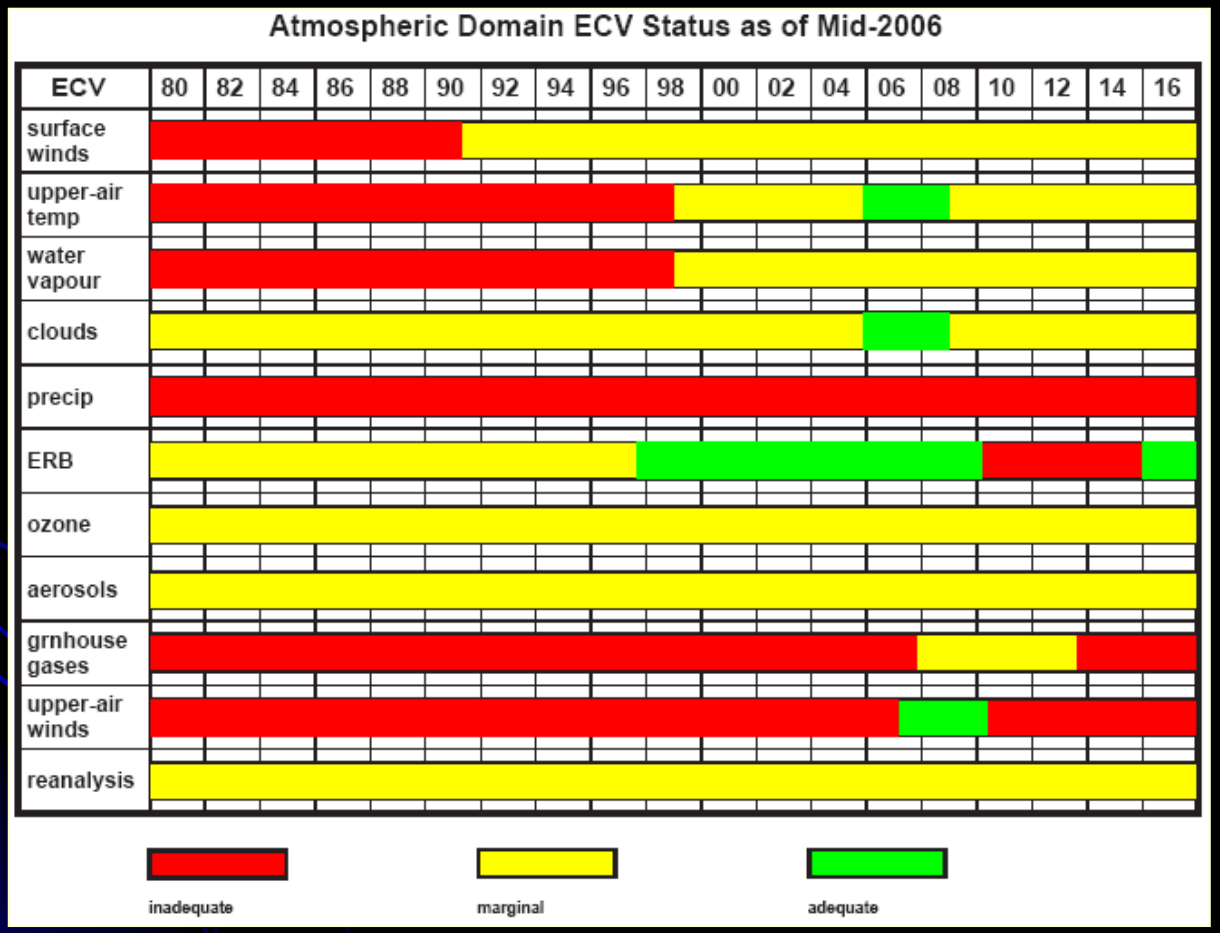
Visit *http://www.ceos.org* for the full report

Do we miss something?

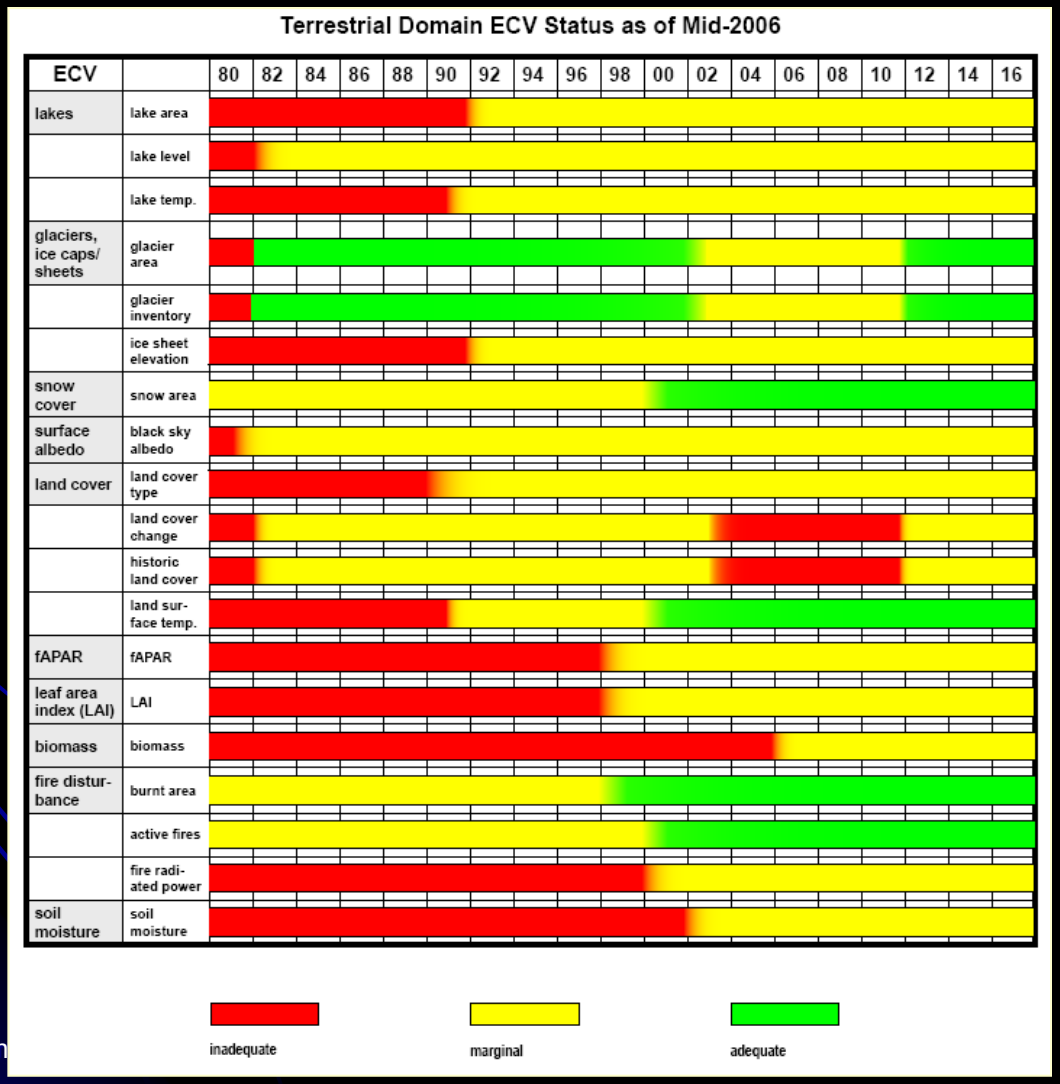


The space component of the World Weather Watch in 2006

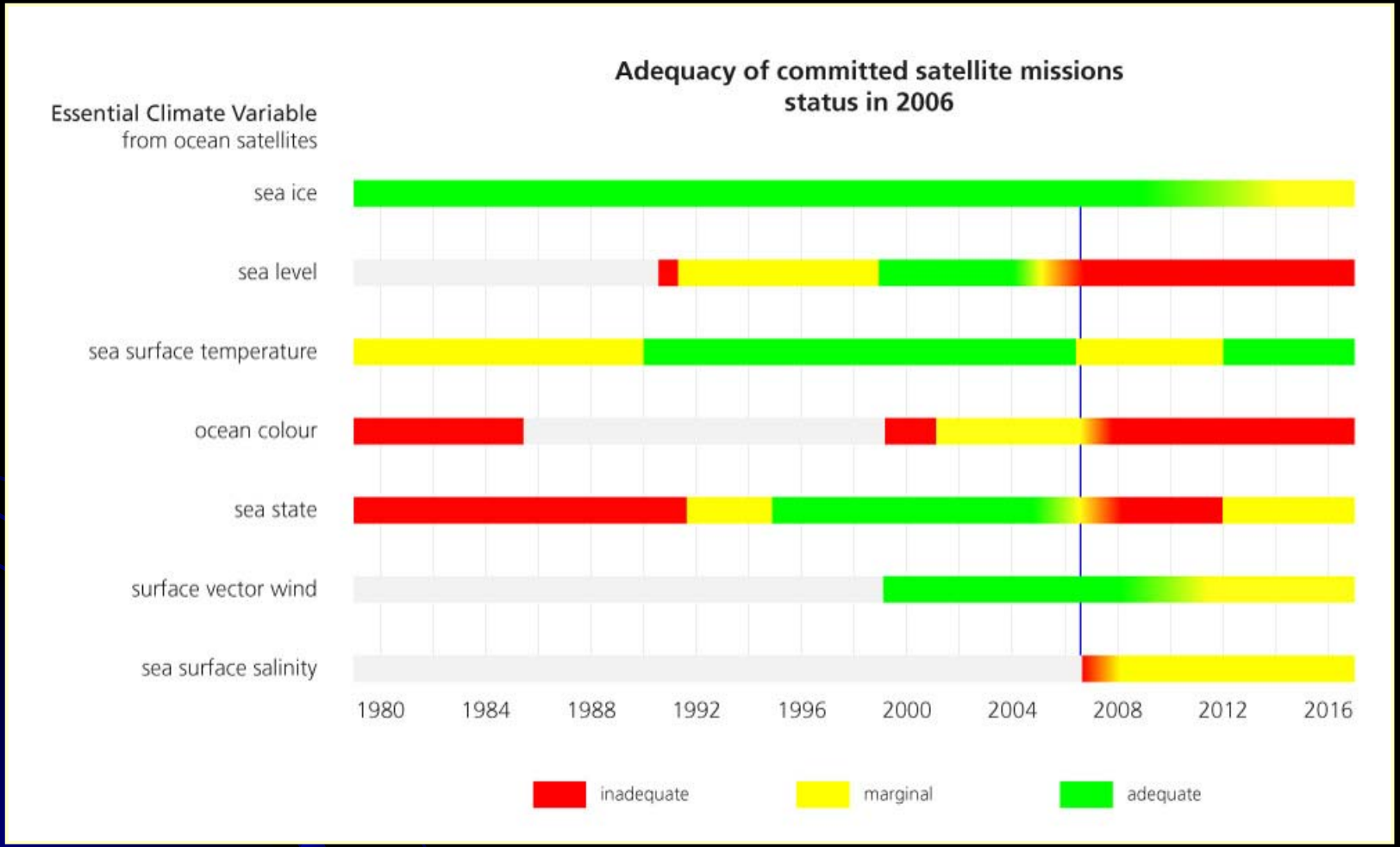
Atmospheric Essential Climate Variables, status as of mid-2006



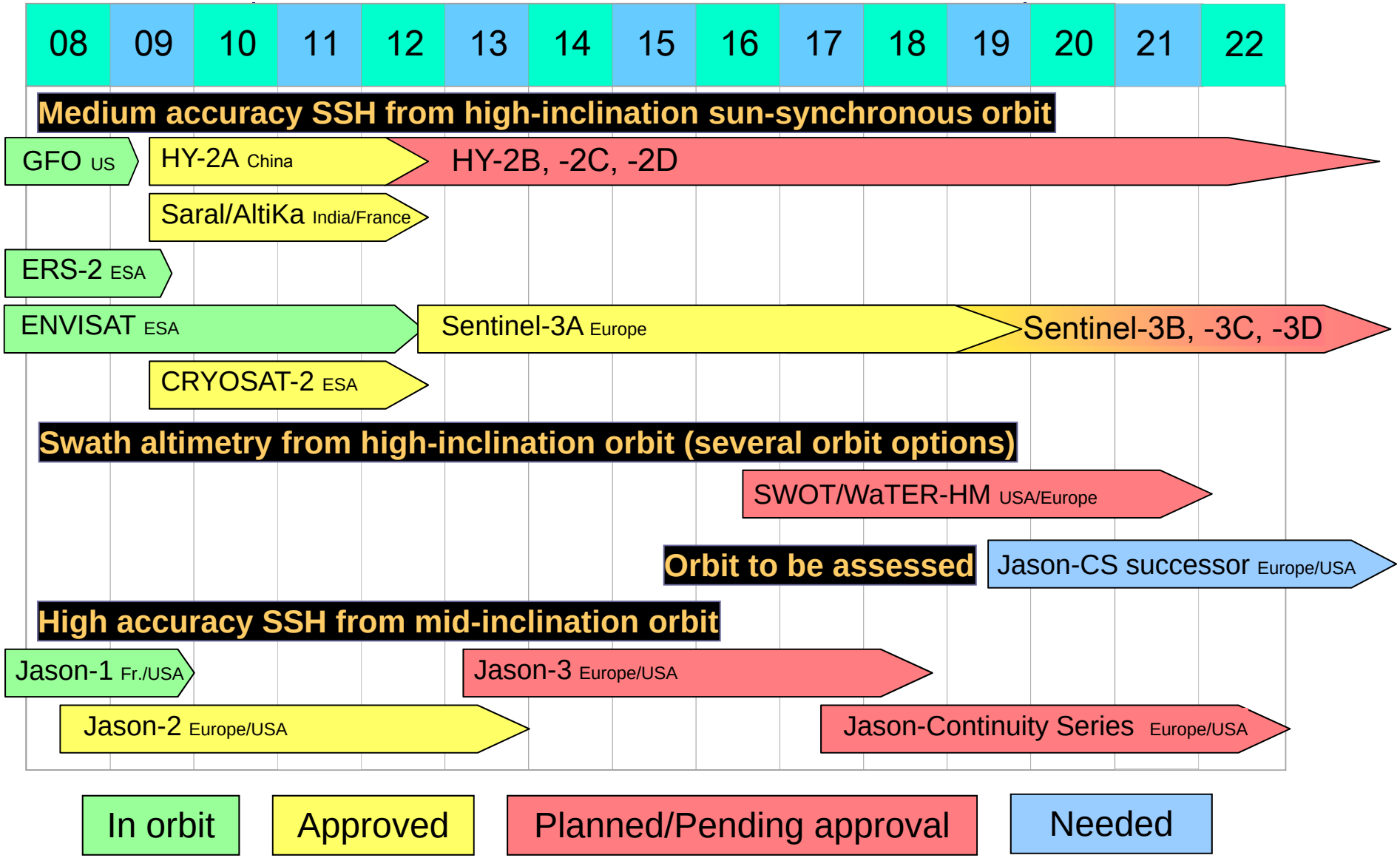
Terrestrial Essential Climate Variables, status as of mid-2006



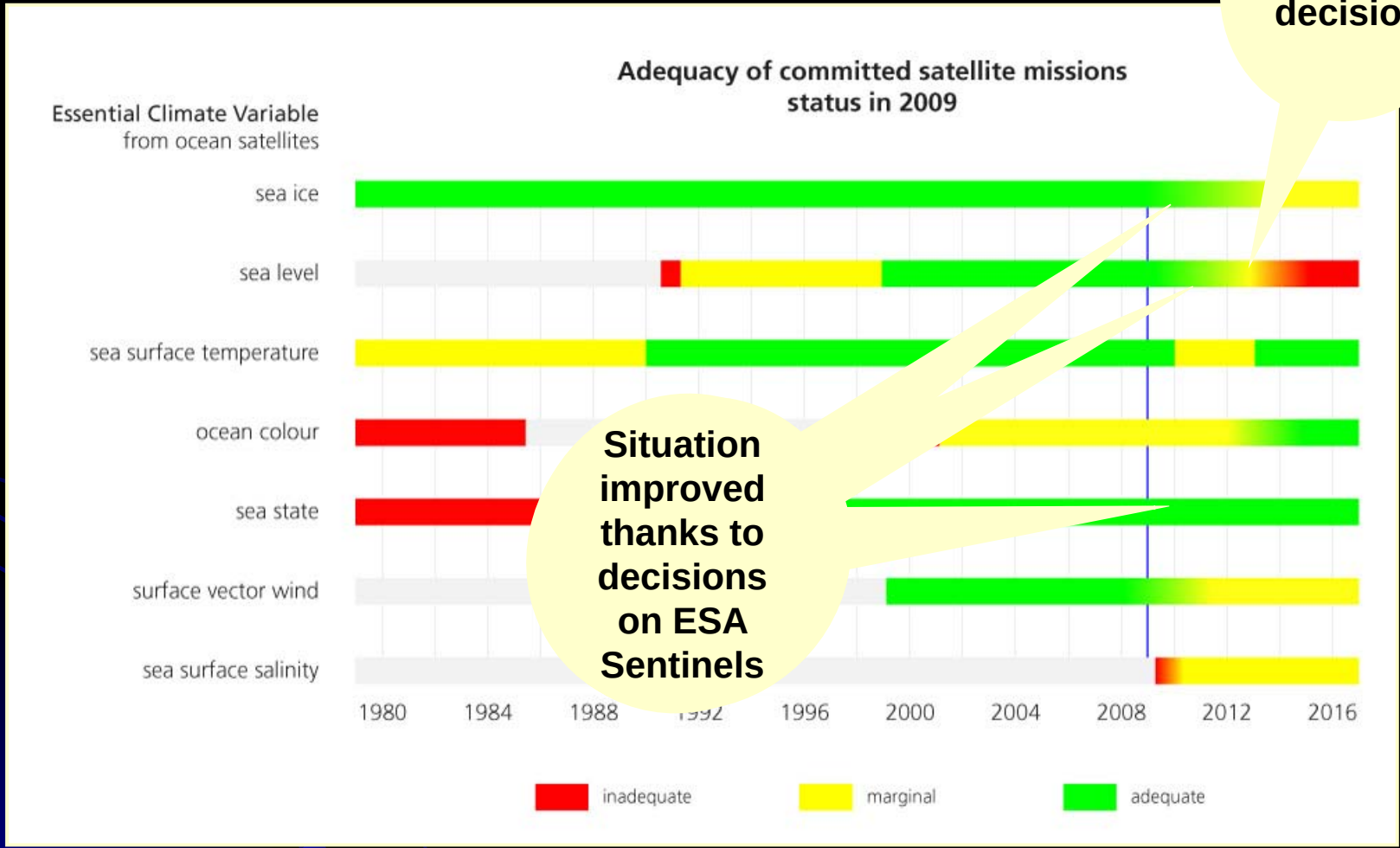
Oceanic Climate Variables, status as of mid-2006



Ocean Surface Topography Constellation Roadmap



Yes, we mostly miss continuit



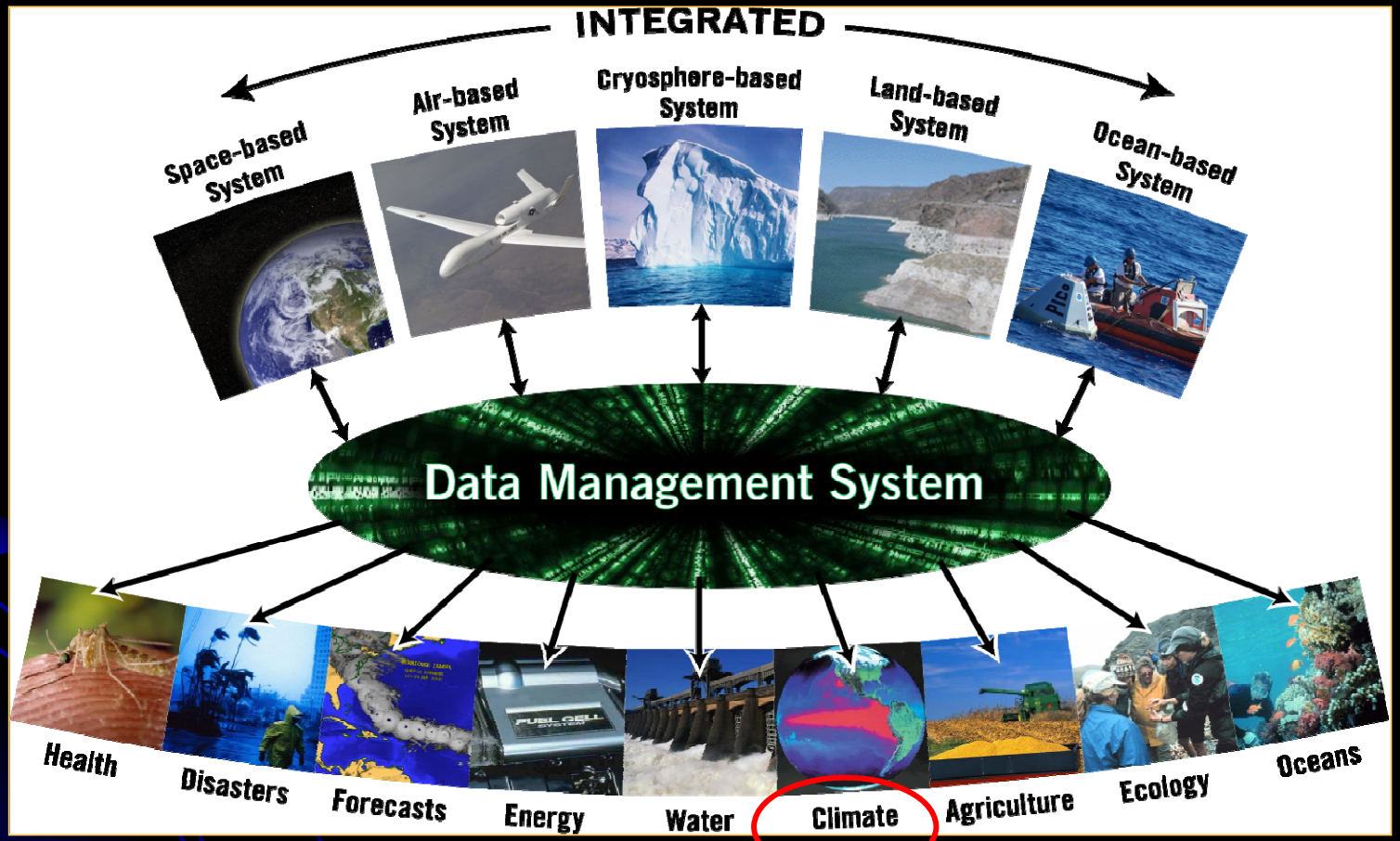
Pending Jason-3 decision

Situation improved thanks to decisions on ESA Sentinels

Press release – February 2, 2010

- Global sea level rise monitoring secured for next decade
  - The transatlantic Jason-3 Program has now been approved by EUMETSAT Member States (…).
  - Nineteen EUMETSAT Member States have agreed to subscribe to the Jason-3 ocean altimetry satellite program: Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom. Together, these countries are prepared to contribute €63.6 million (at 2009 economic conditions) to the €252-million program cost of Jason-3.
  - The Jason-3 program is led by EUMETSAT and the US National Oceanic and Atmospheric Administration (NOAA). In addition, the Centre National d'Etudes Spatiales (CNES), the French space agency, is making a significant in-kind contribution to the program (…). The US National Aeronautics and Space Administration (NASA), in conjunction with the three other partners, will support science team activities.

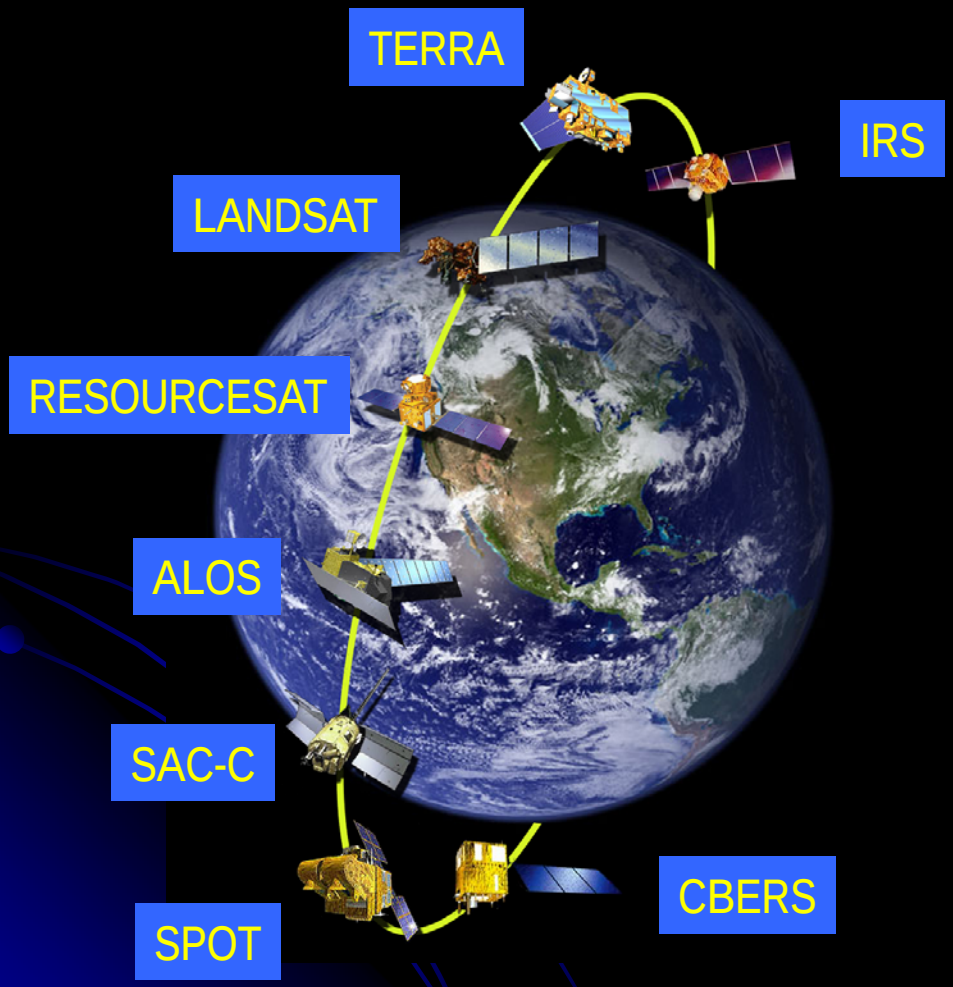
GEOSS – The Global Earth Observation System of Systems



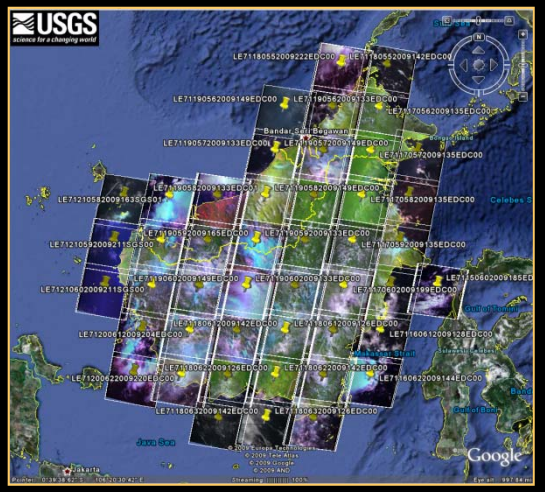
CEOS Virtual Constellations for GEO

- New implementation framework
  - To inspire and facilitate commitments aimed at harmonizing and sustaining observations within CEOS members in support of GEO and GEOSS
- Four Initial Prototype Constellations
  - Land Surface Imaging
  - Ocean Surface Topography
  - Global Precipitation Mission
  - Atmospheric Composition
- New Constellations
  - Ocean Surface Wind Vector
  - Ocean Color Radiometry

Land Surface Imaging Constellation



Forest Carbon Tracking Project



Landsat acquisition over Borneo

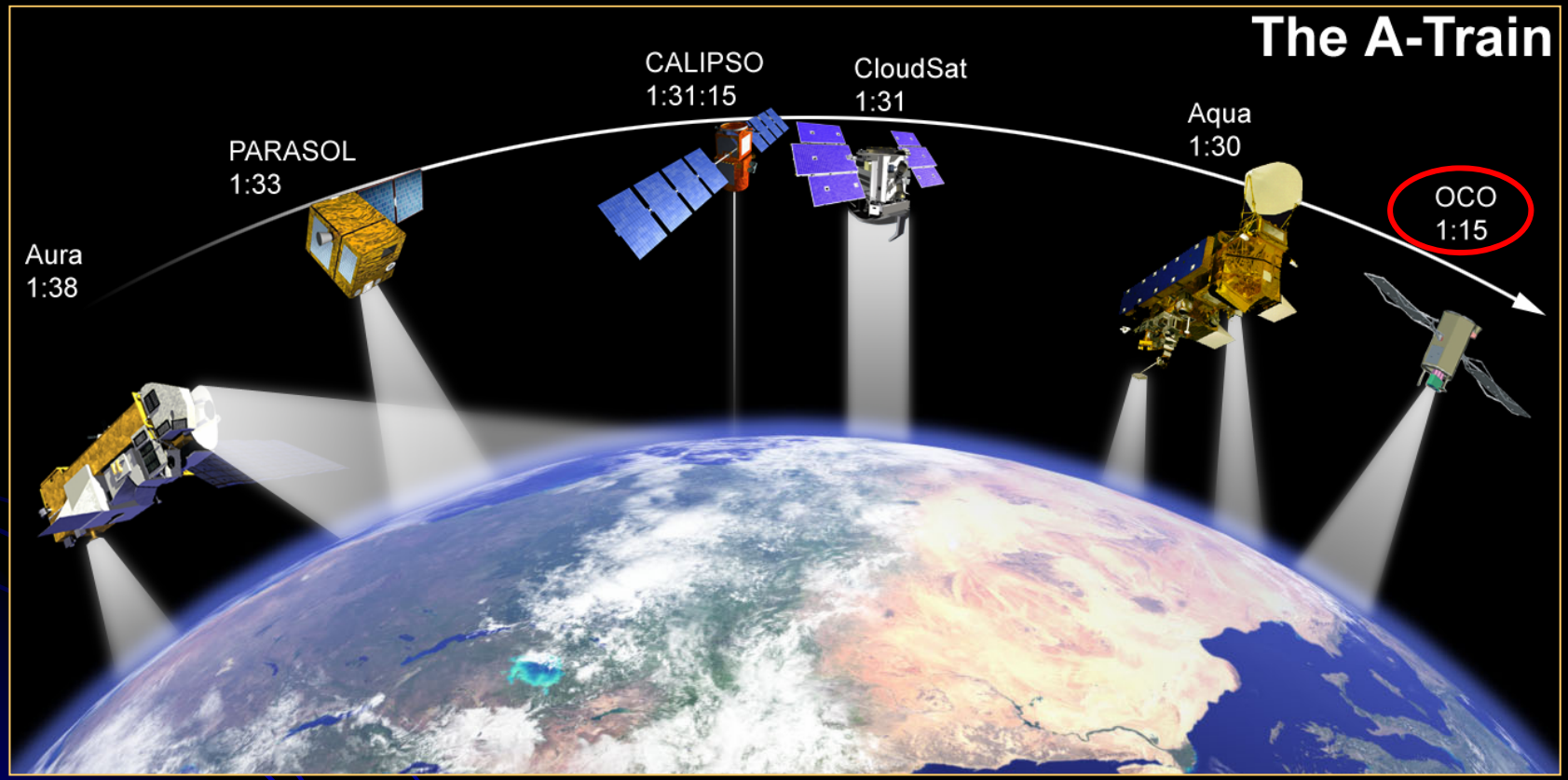
ALOS 50 m mosaic over Borneo

The Global Precipitation Constellation

The Global Precipitation Mission will include a rain radar and several passive microwave radiometers in polar-orbit …

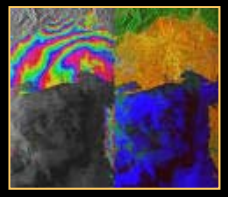
… and the French-Indian MEGHA-TROPIQUES satellite to be placed in 20° inclination orbit in 2010

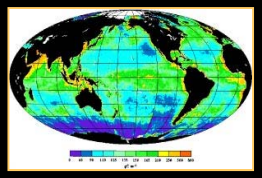
The Atmospheric Chemistry Constellation

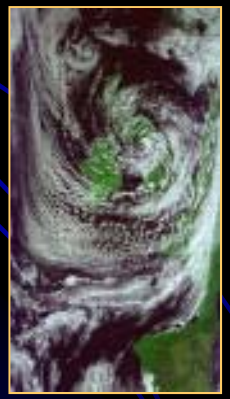


Five of the six missions from the A-Train are already in orbit providing coordinated atmospheric composition measurements

The European Space Agency Sentinels Program







Sentinel 1 – Synthetic Aperture Radar (SAR)

All weather imagery, interferometry, polar regions

Sentinel 2 – Super-spectral optical imagery

Continuity of Landsat, Spot & Vegetation data

Sentinel 3 – Ocean monitoring

Ocean color, sea surface temperature and sea surface topography

Sentinel 4 – Atmospheric Monitoring from GEO

Atmospheric composition, transboundary pollution

Sentinel 5 – Atmospheric Monitoring from LEO

Atmospheric composition

2. Some major uncertainties in climate change understanding

- Clouds and aerosols → A-Train
- Polar ice balance → CryoSat-2
- Ocean natural variability vs. trends → Jason + Goce
- GHG sources/sinks → Gosat/Ibuki, (OCO-2 ?)
- … and more

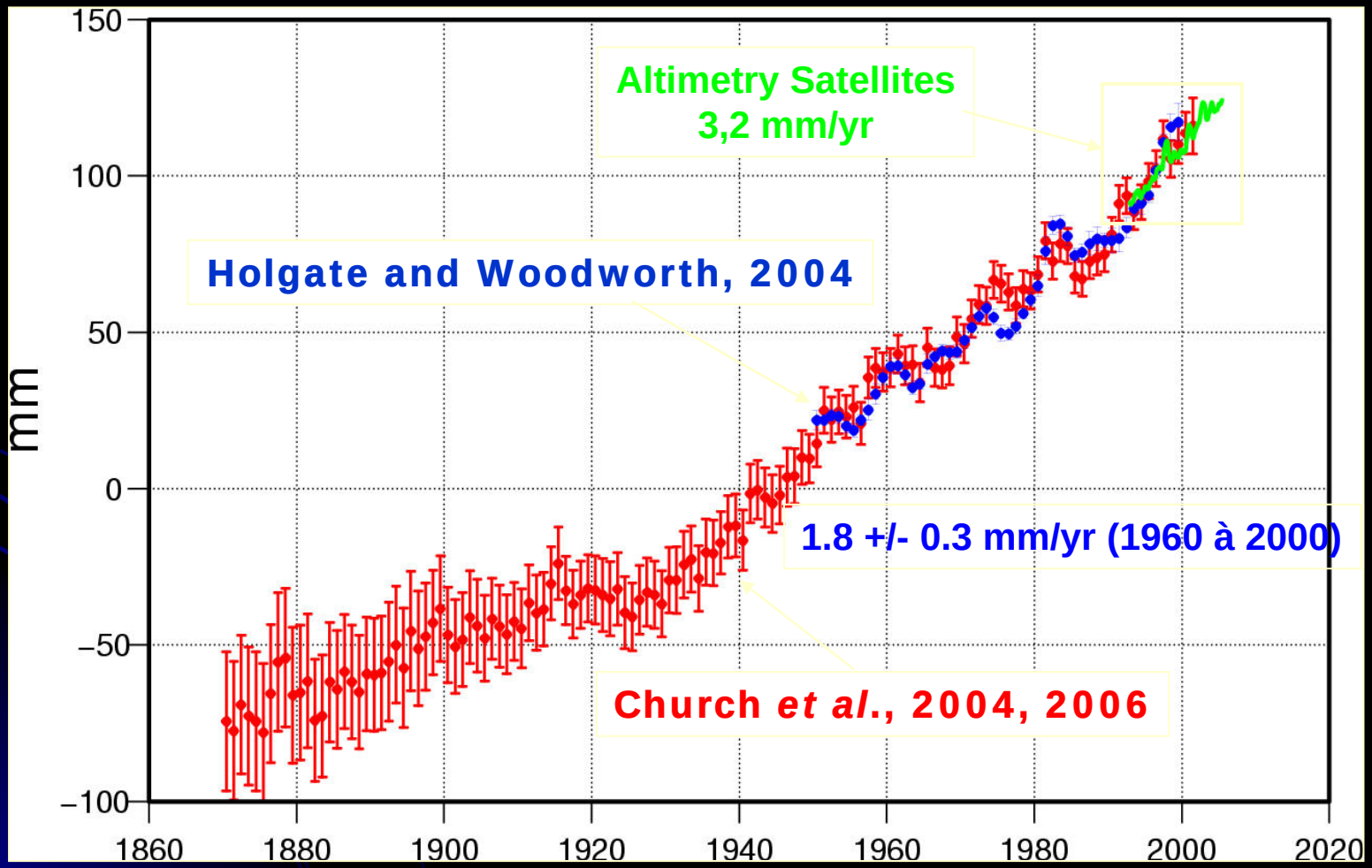
3. Space observations and ***decadal predictions*** *(after Trenberth, 2009)*

- **Initialization**
  - Ocean, sea ice, land processes.
- **Forward integration of the coupled model**
  - The external forcing by greenhouse gases is prescribed.
- **Ensemble generation**
  - To give probabilistic nature
- **Calibration of model output**
  - Because of deficiencies in the component models the coupled model output needs calibration.
- **Verification of results and skill assessment**
  - *A priori* knowledge of the quality of the forecast is required based on past performance.

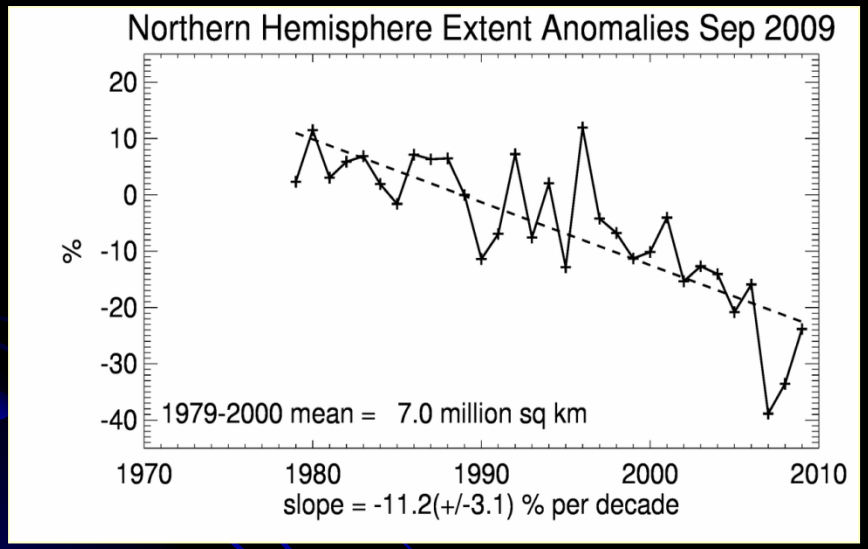
Requires observations

Requires observations

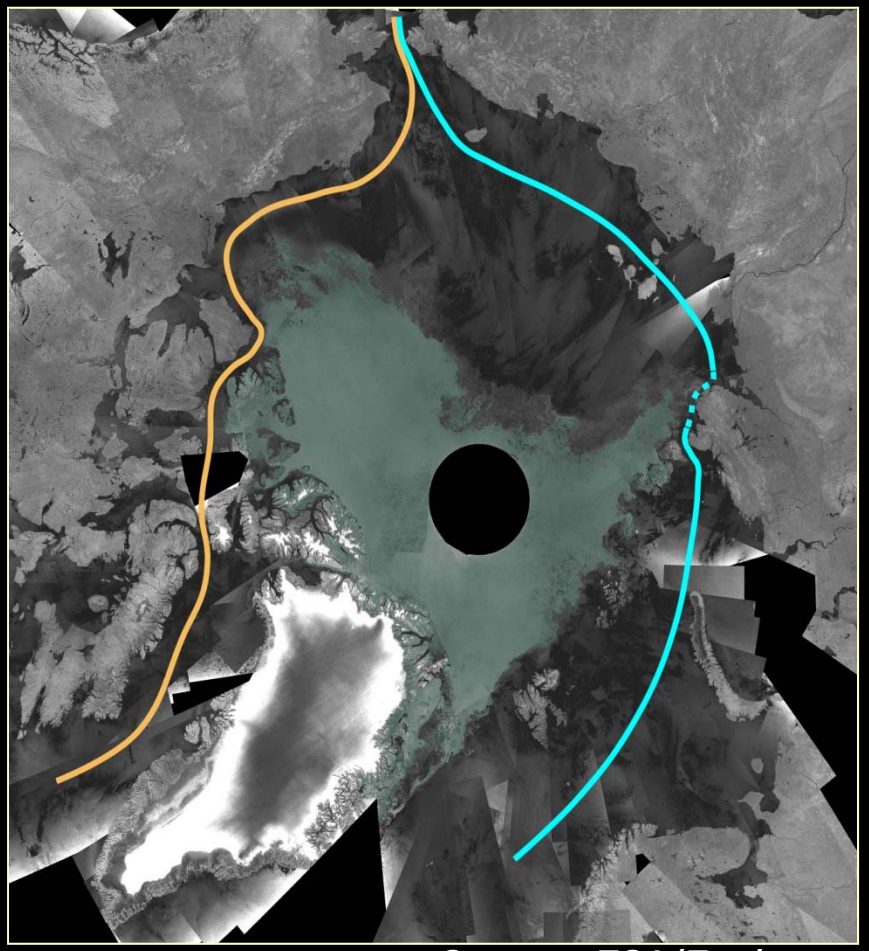
4. Many space observations of climate change impacts, e.g., sea level rise…



… or Arctic sea ice decline…

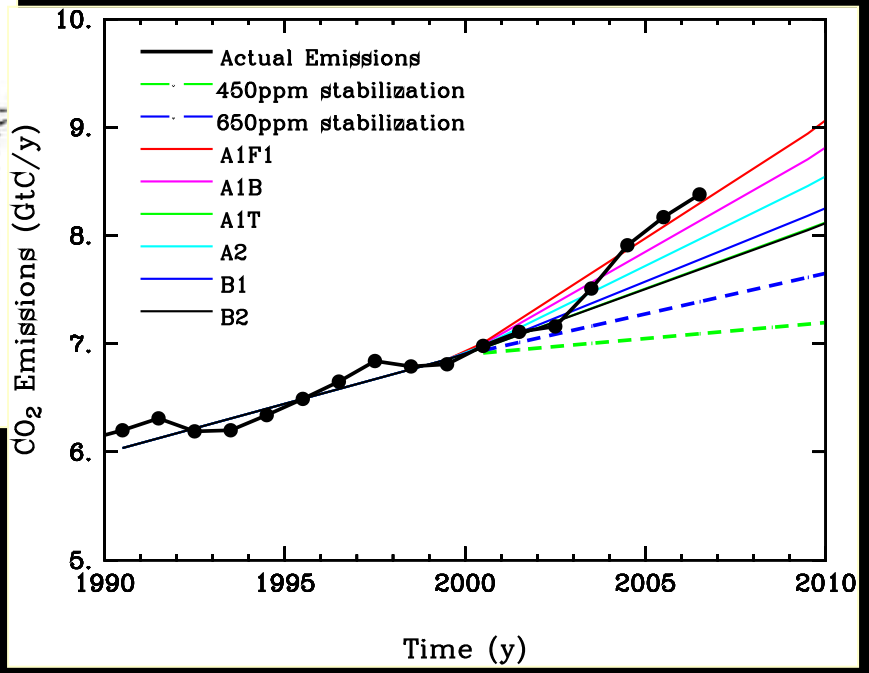


Source: NSIDC



Source: ESA/Envisat

… are there, but do we take these warnings seriously enough?



Raupach et al. 2007, PNAS