Challenges of a sustained climate observing system

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Observations of planet Earth and all climate system components and forcings

are increasingly needed for planning and decisions related to climate services in the broadest sense.

Climate change from human activities adds a whole new dimension and an **imperative**:

To acquire climate quality observations and analyze them into products for multiple purposes:

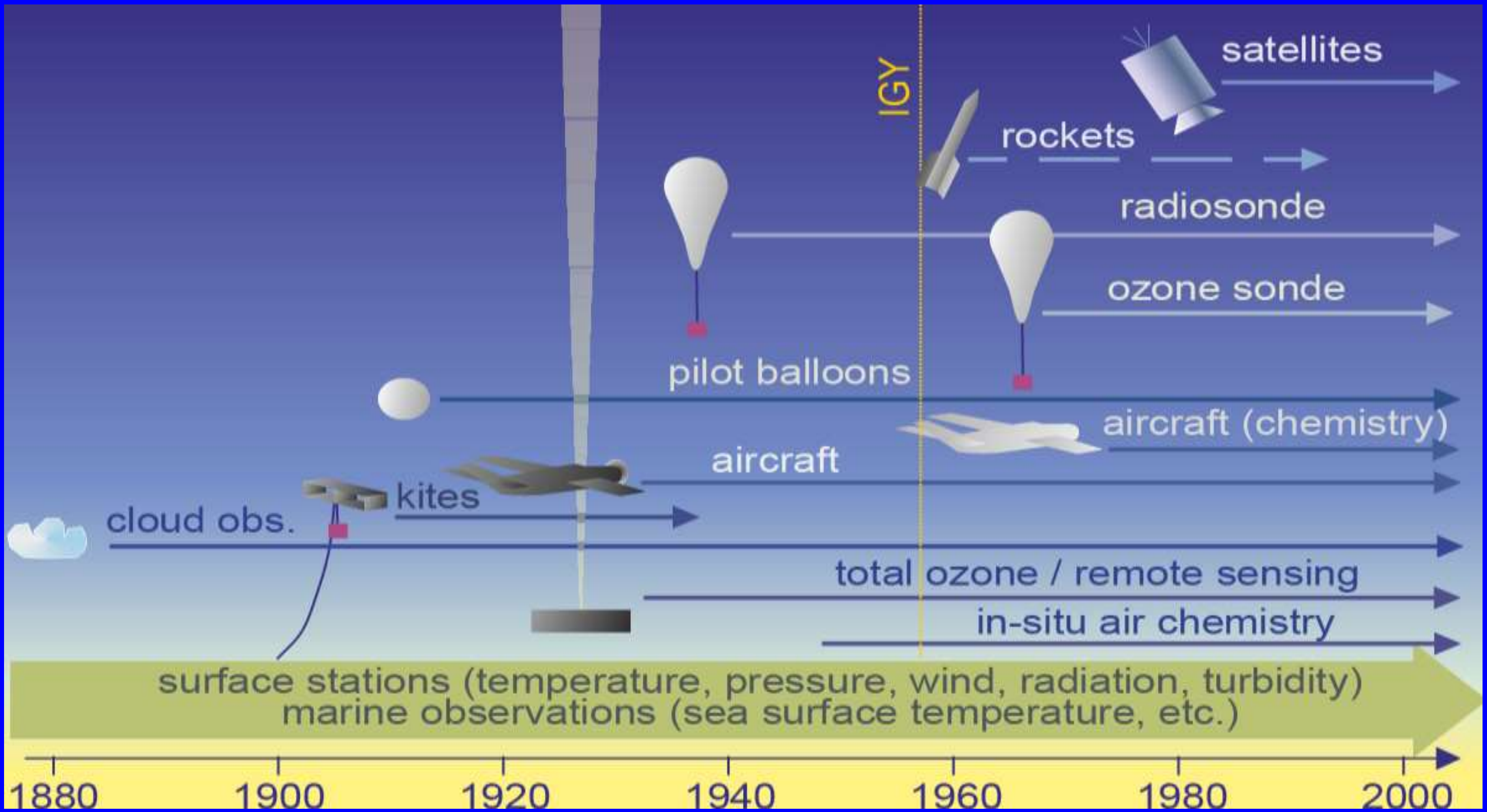
- **diagnostics and empirical studies**
- to inform decisions for **mitigation, adaptation**
- assess **vulnerability** and **impacts,**
- plan and monitor ***geo-engineering***
- predict **climate variability** and **change**
- cope with consequences of **variability** and **change**

First rule of management

"You can't manage what you can't measure"

A challenge:

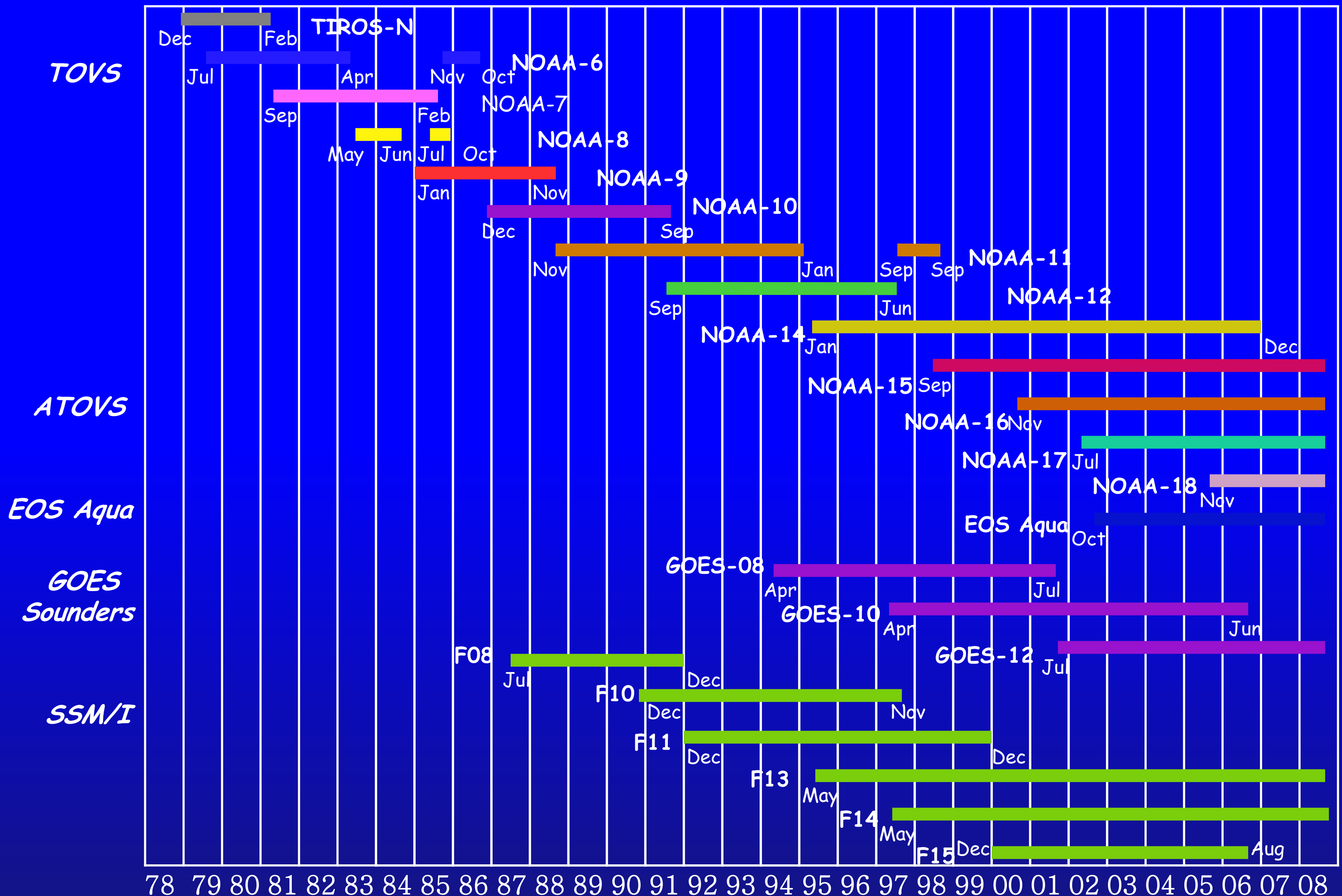
The changing observing system



The continually changing observing system

Adapted/ Courtesy, S. Brönnimann

Satellite Data Streams



New satellites, instruments: continuity?

New technology

New observing systems and data processing systems are wonderful.

But can cause havoc for climate because they destroy continuity unless properly managed.

They aren't properly managed!

Calibration, Accuracy, Benchmarks

Climate Data Records (CDRs)

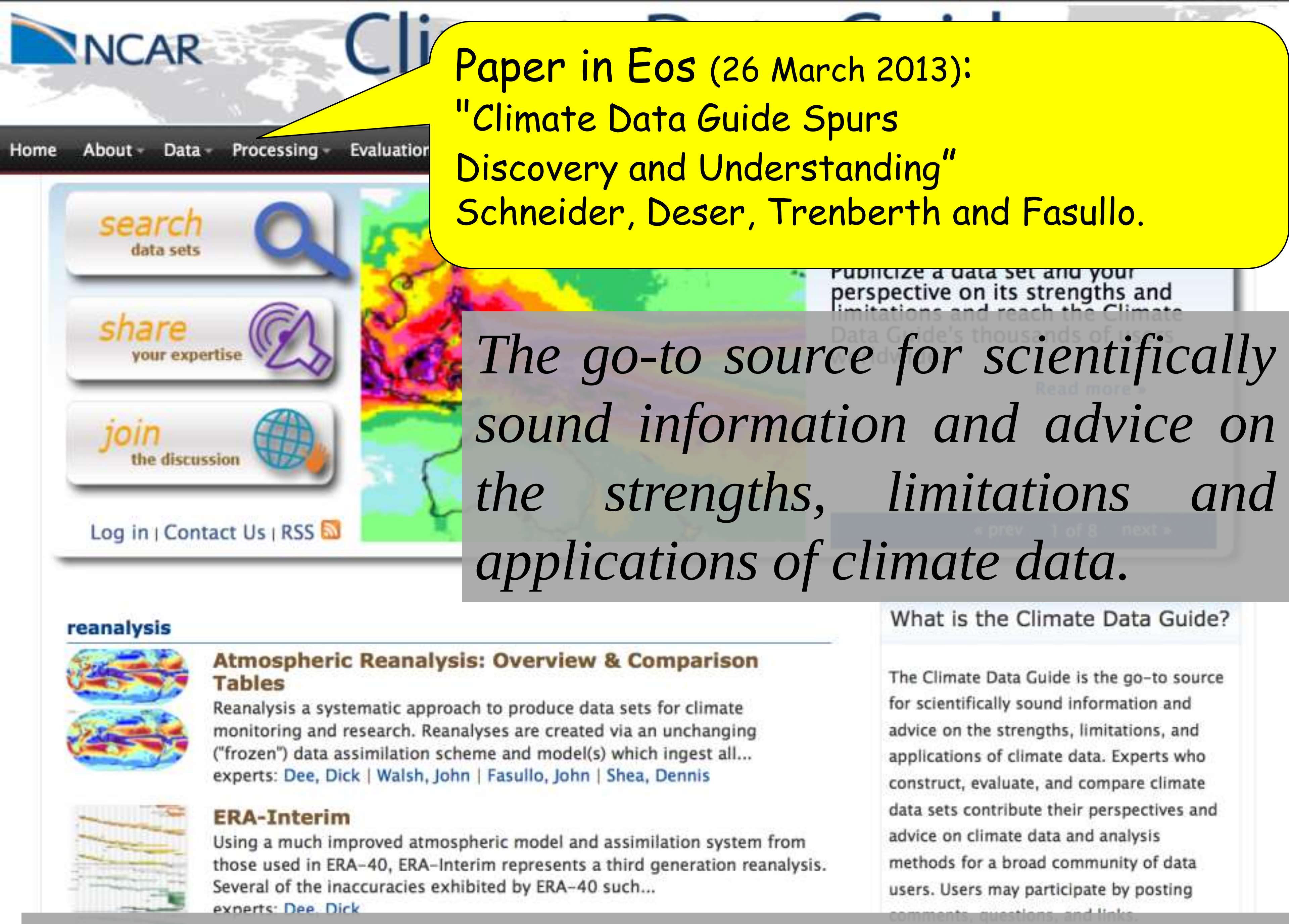
- Calibration is essential
- In the absence of adequate accuracy, continuity (overlap) is essential
- One need is to develop and foster benchmark observations:
  - In situ: GRUAN, GRN
  - Space: GPS RO
  - Space: C[illegible]REO
- Cross calibration and reprocessing

Needed: CDRs for diagnostic studies

- Data of **known quality**
- The signal to noise is often adequate for interannual variability
  - but not for **decades or trends**

Needed:

- An ongoing **assessment** process
- A **physical framework** that accounts, e.g. for mass, water and energy constraints
- An **informed guide** for datasets: on their strengths and shortcomings
- **Reprocessing** to produce CDRs
- **Reanalysis** to synthesize



Paper in Eos (26 March 2013):
"Climate Data Guide Spurs Discovery and Understanding"
Schneider, Deser, Trenberth and Fasullo.

The go-to source for scientifically sound information and advice on the strengths, limitations and applications of climate data.

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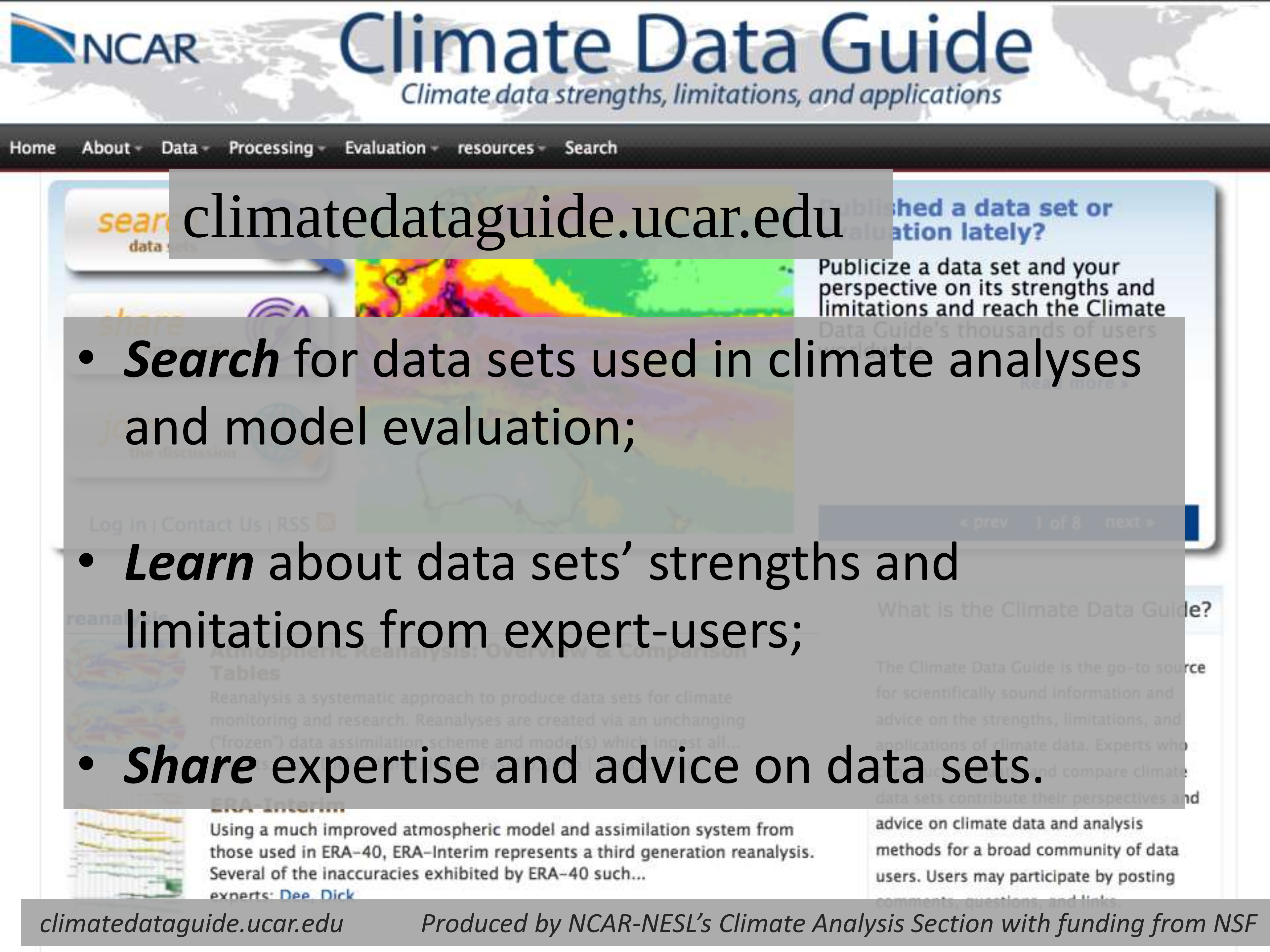

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- ***Search*** for data sets used in climate analyses and model evaluation;
- ***Learn*** about data sets' strengths and limitations from expert-users;
- ***Share*** expertise and advice on data sets.

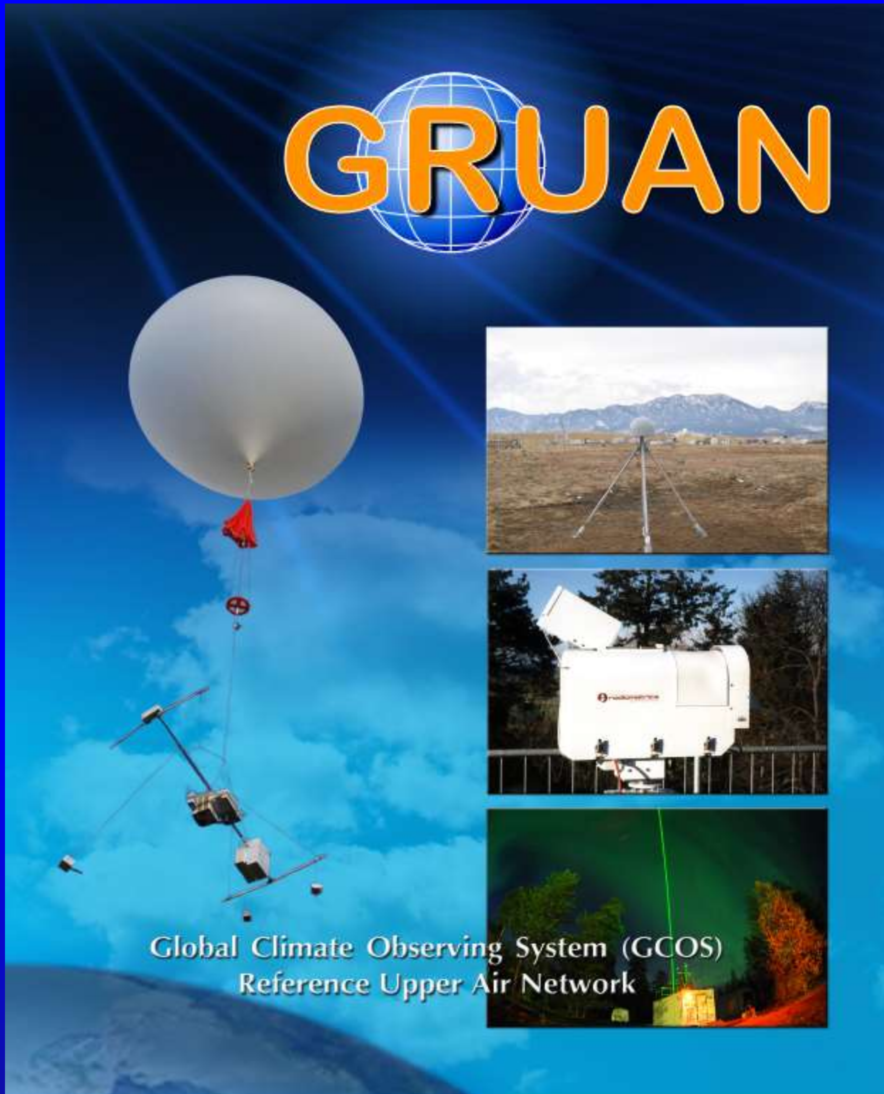
Reference Observations

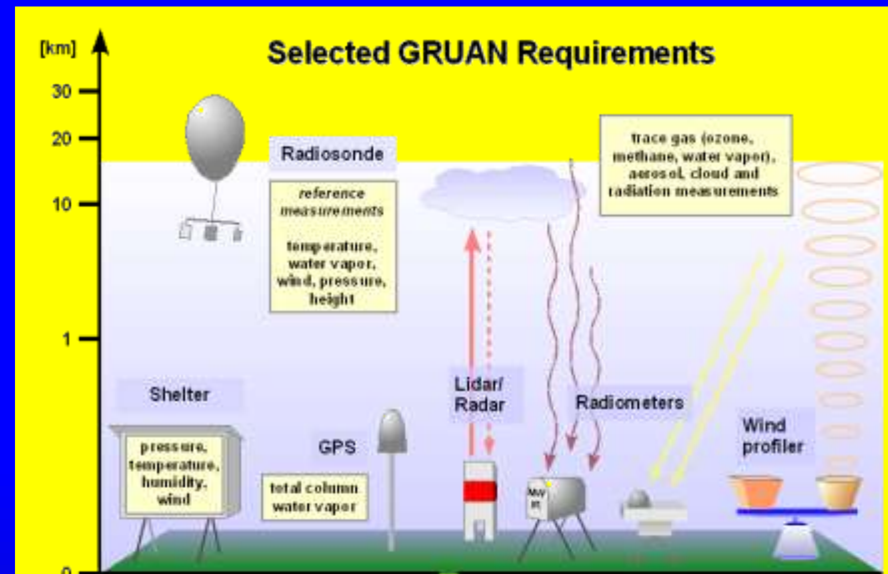

- Increasing emphasis has been placed on reference quality networks for detecting climate trends.
- They provide anchor points for existing networks, for calibrating satellite data, and validating data products.
- Reference quality in-situ networks are critical to fill in the inevitable gaps in the climate record caused by lack of overlapping satellite missions
- Must be able to answer the question 50 years from now on how global climate has changed.

Status

- GCOS Reference Upper Air Network (GRUAN) is spinning up but resources still inadequate.
- Climate Absolute Radiance and Refractivity Observatory (CLARREO) is a climate-focused mission that could be a key element of the climate observing system, but now on hold.
- GPS RO lacks full funding to continue

GCOS Reference Upper Air Network



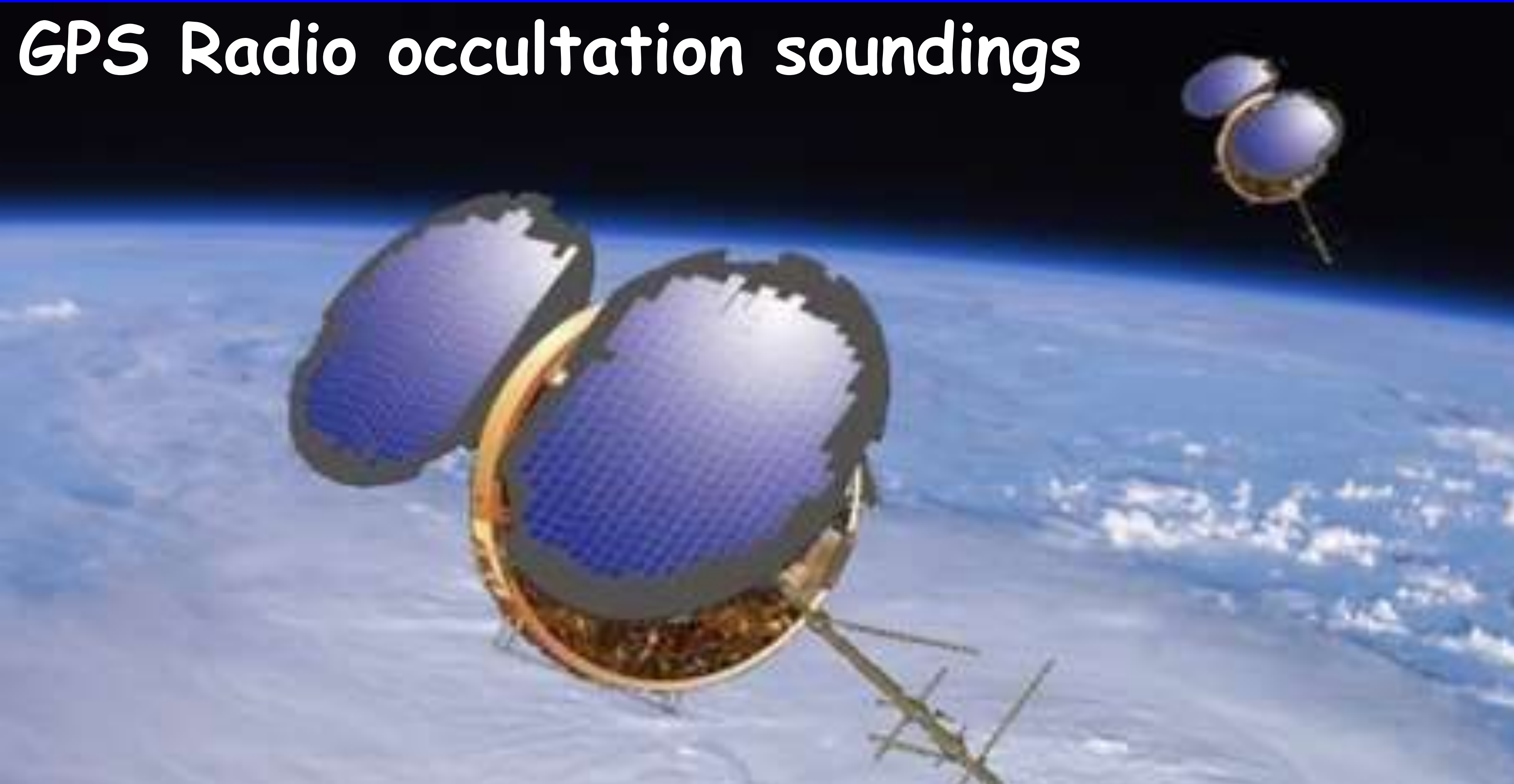


Priority 1: Water vapor, temperature, (pressure and wind)

Priority 2: Ozone, clouds, …

- Provide long-term high-quality upper-air climate records
- Constrain and calibrate data
- Fully characterize the properties of the atmospheric column

GPS Radio occultation soundings



Based on measurement of time of radio waves to transit from a GPS satellite to a LEO receiver, measures refraction (bending angles) f(T,q).

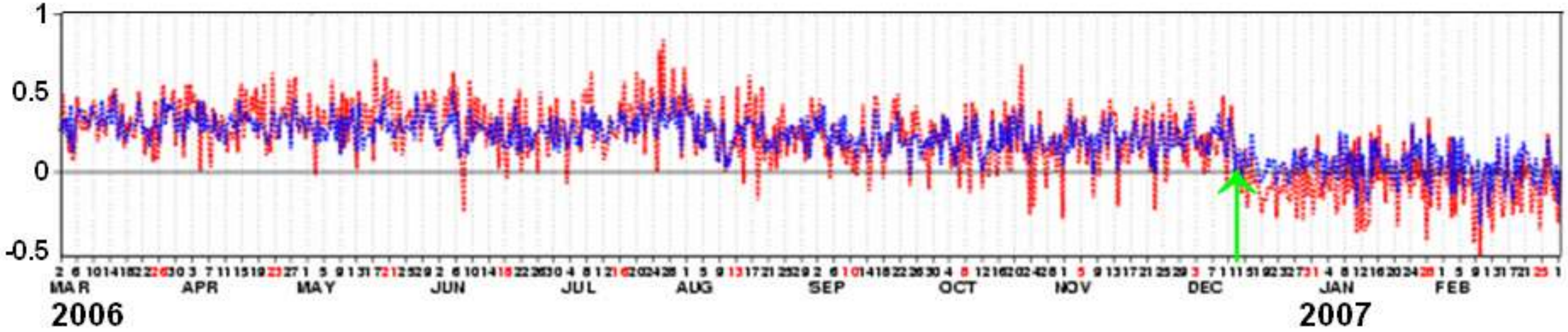
GNSS (Global Navigation Satellite System) radio occultation is self calibrating.

COSMIC (2006-), and other radio occultation missions such as GPS/MET (1993-1995), CHAMP (2001-2010) SAC-C (2000-) and METOP-A (2006-) have demonstrated the value of radio occultation in producing precise, accurate, climate quality observations in all weather (Anthes, 2011).

(COSMIC-2) has been proposed (but funding has been declined by NOAA from sequestration)http://space.skyrocket.de/doc_sdat/formosat-7-cosmic-2.htm)

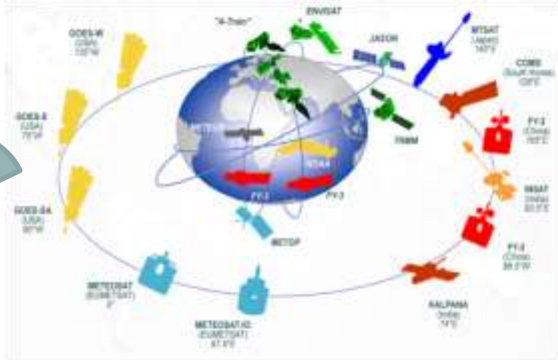
ECMWF Operational implementation of GPS RO on 12 December 2006

Mean departures of analysis (blue) and background (red) from southern hemisphere radiosonde temperatures (K) at 100 hPa



Anthes 2011

Information Value Chain



Satellites & sensors → Calibrated data sets → Quality-controlled products → Dissemination & access → Awareness & training → Users

GSICS Global Space-based Inter-Calibration System

SCOPE-CM

Internet

WMO IGDDS

GEONETCast

VLab

Components

GSICS: Global **S**pace-based **I**ntercalibration **S**ystem
IGDDS: WMO Integrated Global Data Dissemination Service
SCOPE-CM: Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring
Vlab: Virtual Laboratory for Training in Satellite Meteorology

Given the observations:

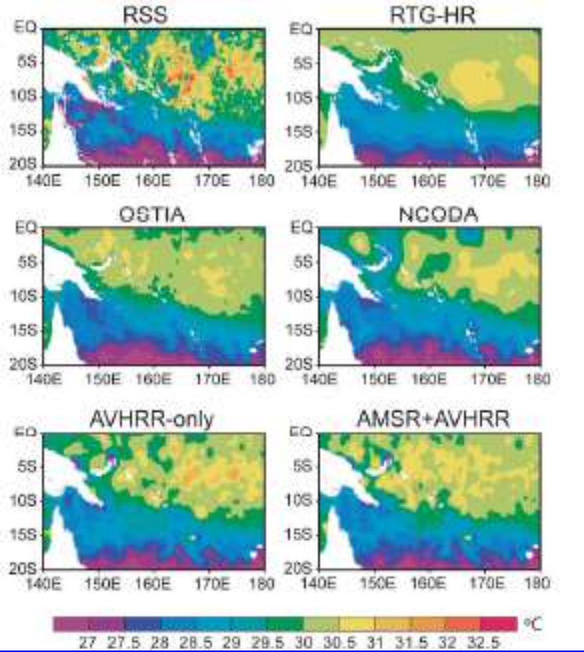
Adequate **analysis**, **processing**, **meta-data**, **archival**, **access**, and **management** of the resulting data and the data products create further challenges in spite of the new computational tools.

Volumes of data continue to grow and the challenge is to distill **information** out of the increasing **numbers**.

Known issues

- Nearly all satellite datasets contain large spurious variability associated with changing instruments/satellites, orbital decay and drift, calibration, and changing methods of analysis
- Only 2 datasets (SSM/I water vapor; MSU T) were used in AR4 IPCC to examine trends
- Once, the issue was getting a single time series. Now there is a proliferation and multiple datasets purporting to be the "one". All differ, often substantially.

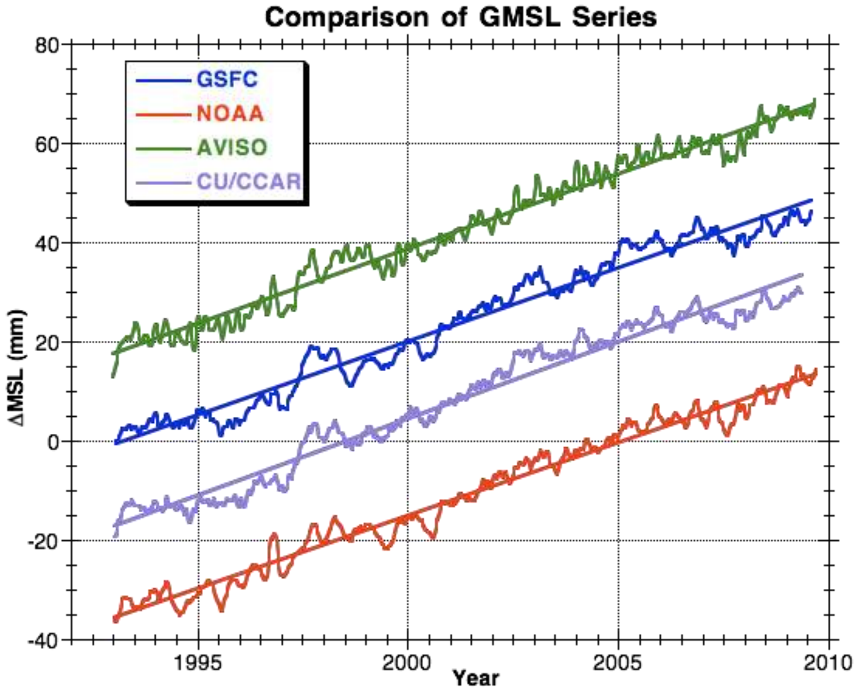
Large disparities among different analyses

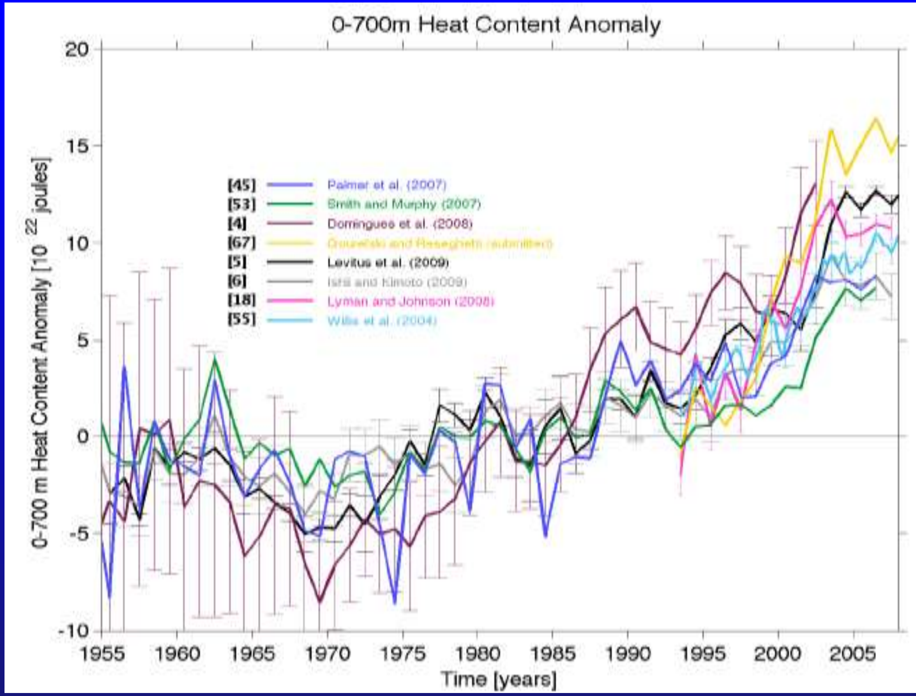


Daily SST (1 Jan 2007)
Reynolds and Chelton 2010 JC

OHC
Palmer et al 2010
OceanObs'09

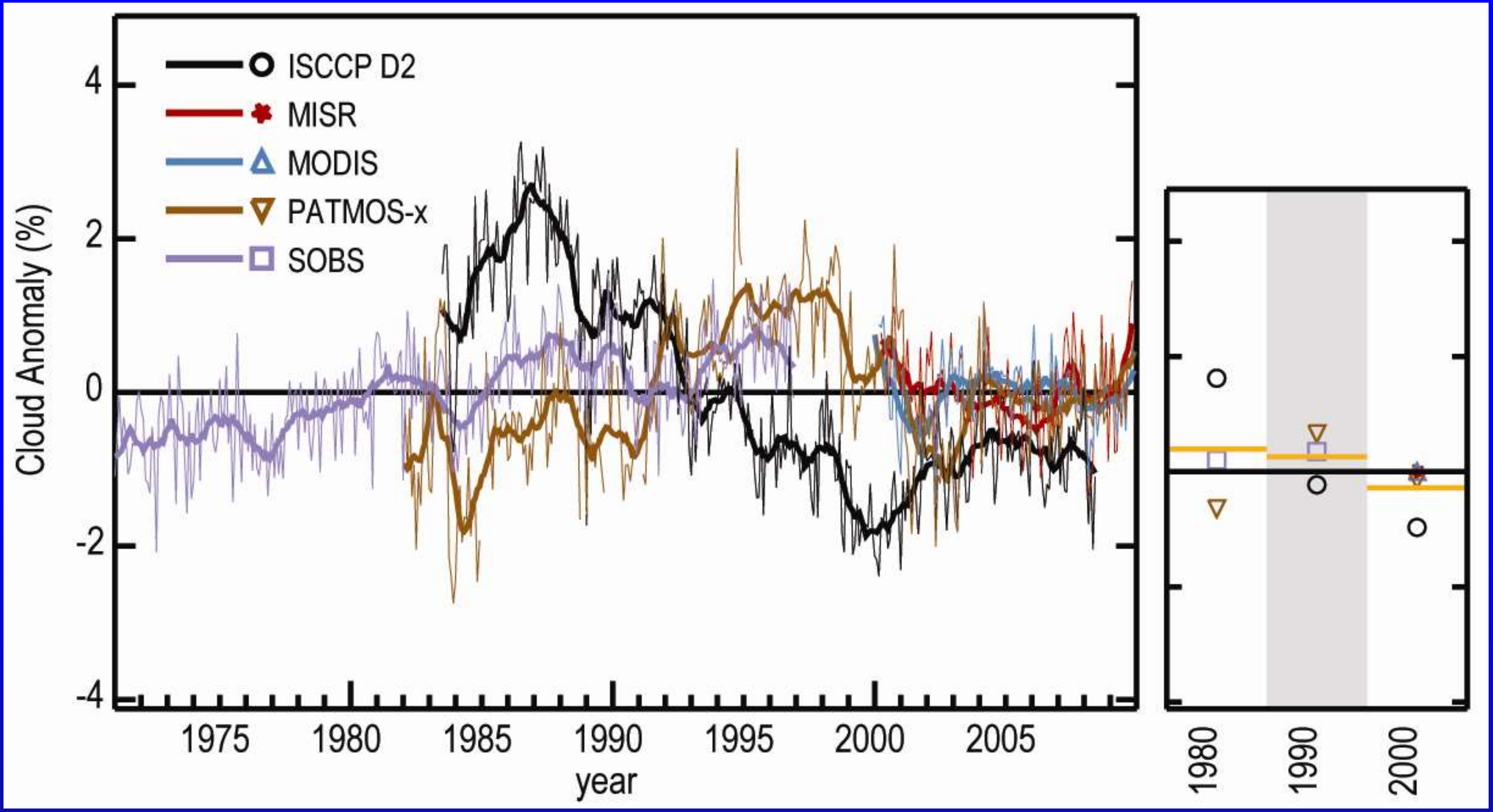
Sea Level
w. offsets





Cloud 1979 to 2009

A 1% increase in clouds is about $-0.5\ W\ m^{-2}$



State of Climate Report 2009: Foster et al.
SOB: sfc obs to 1996, MODIS, MISR, ISCCP, PATMOS-x
Issues: Sensor viewing angle, pixel footprint size, spectral channels, diurnal satellite drift, and sensor calibration.

Clouds remain a major issue

Clouds are not well defined:

- fn of sensitivity of instrument
- compounded by aerosols
- defn of clear sky includes aerosols??????
- partitioning into clear sky and cloudy murky

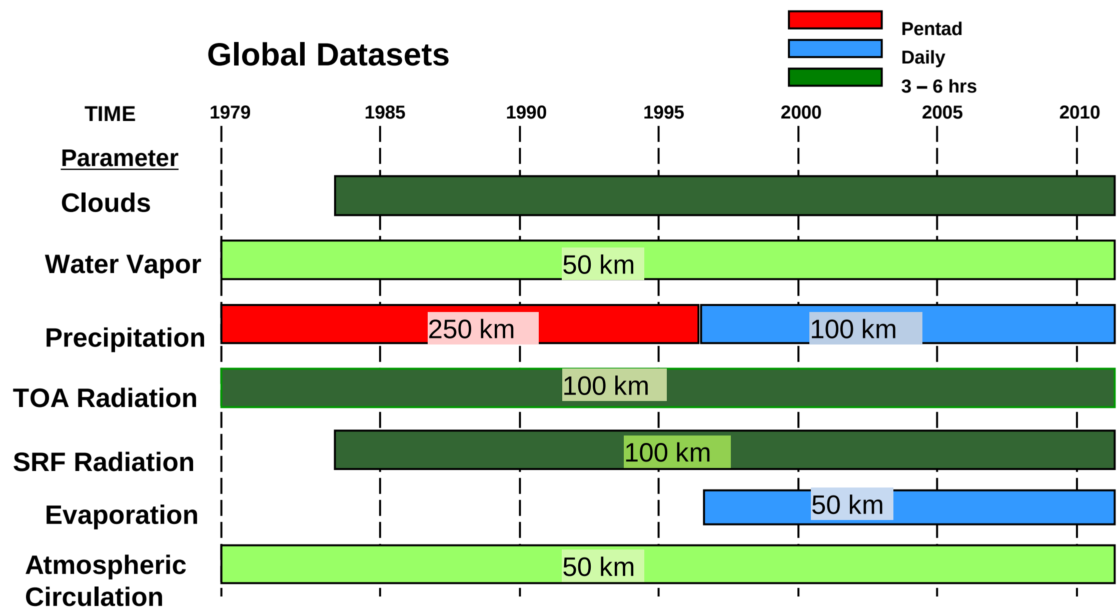
The radiative properties of clouds matter most:

Cloud amount
Optical thickness, microphysical properties
Cloud top temperature
Cloud base temperature

Water vapor: (invisible cloud) large radiative effects

GEWEX Data and Assessments Panel develops **climate data records** of water and energy variables, complete with metadata and error bars.

Clouds - ISCCP
Radiation - SRB
    Surface ref. obs - BSRN
Aerosols - GACP
Precipitation - GPCP
    Sfc gauge obs GPCC
Turbulent Fluxes
    SeaFlux
    LandFLux
    - Soil Moisture
Water Vapor- GVAP

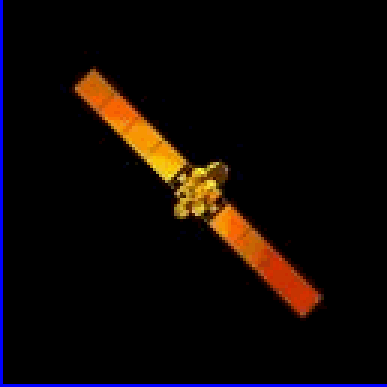


A GDAP product is endorsed by GEWEX/GDAP to conform to a high standard of production and documentation. It consists of a blend of available satellite and in-situ observations and is periodically compared and assessed against other products in an open and transparent fashion. It is openly available to everyone without restrictions.

Major Concerns

- Difficult to anticipate problems in satellite observing
  - On-Orbit failures (ADEOS, Cryosat...)
  - Inadequate funding and delays: NPP, JPSS
  - Launch failures (OCO, Glory)

Orbiting (?) Carbon Observatory



Major Concerns

- Difficult to anticipate problems in satellite observing
  - On-Orbit failures (ADEOS, Cryosat...)
  - Inadequate funding and delays: NPP, JPSS
  - Launch failures (OCO, Glory)
- There is inadequate overlap and dual operation of observing systems

- Need continued priority for key reference observing systems such as GRUAN , CLARREO, GPSRO
- Major risk of gaps in the satellite records over the next 10-20 years
- **Observation continuity:** key to climate record is in jeopardy;
  - Planned redundancy is critical
- These have greatly **increased the risk of us going blindly into the future** wrt many aspects of climate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America's most advanced weather tracking system with Congressional funding.
America's most advanced weather tracking system without Congressional funding.
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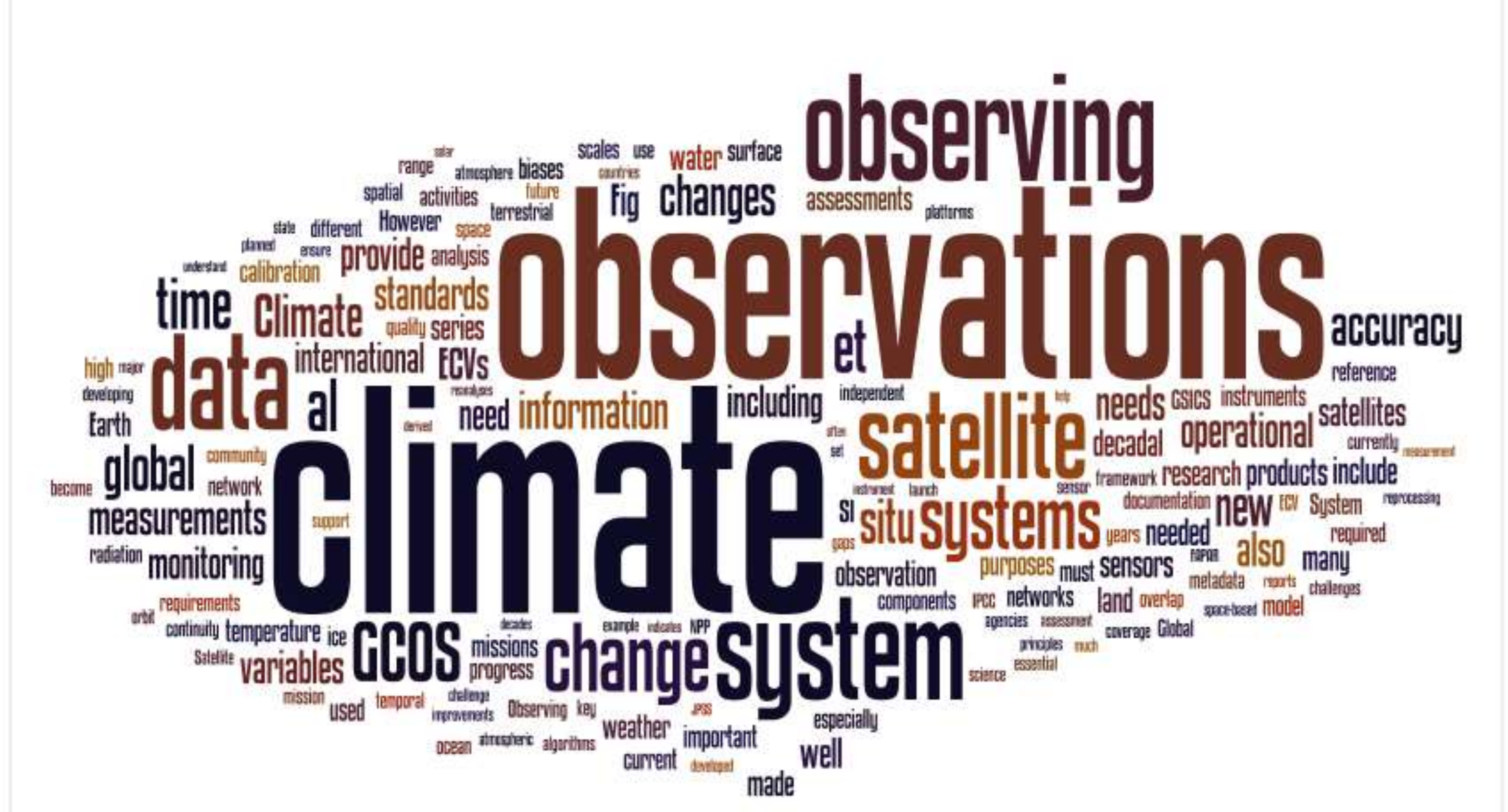
Future challenges

1) The Earth is observed more completely today than at any other time but many of the observations are not **"climate quality"** and useful for monitoring long-term climate.
2) Because the climate is changing from human influences, there is an **imperative** to document what is happening, understand those changes and their causes, sort out the human contribution (because it has implications for the future), and make projections and predictions on various time horizons into the future.
3) "**You can't manage what you can't measure**" applies to Earth's climate system and affects adaptation to climate change and application of climate services.
4) The needs are compelling and enormous, but also feasible with **international cooperation.**

Summary

Trenberth, K. E., R. A. Anthes, A. Belward, O. Brown, E. Haberman, T. R. Karl, S. Running, B. Ryan, M. Tanner, and B. Wielicki 2012: Challenges of a sustained climate observing system. In *Climate Science for Serving Society: Research, Modelling and Prediction Priorities, G. R. Asrar and J. W. Hurrell, Eds.* Springer; 484 pp, 13-50.



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