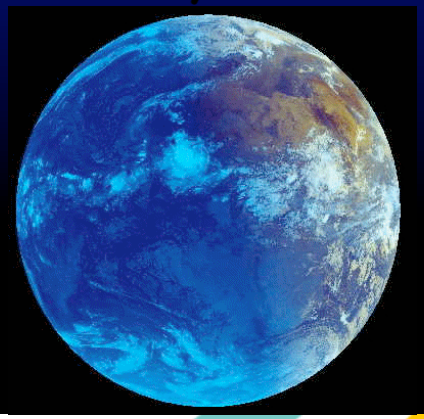
Challenges of a sustained climate observing system

Kevin E Trenberth

NCAR

with

Alan Belward, Otis Brown, Edward Haberman,
Thomas R. Karl, Steve Running, Barbara Ryan,
Michael Tanner, and Bruce Wielicki



WCRP World Climate Research Programme

Open Science Conference

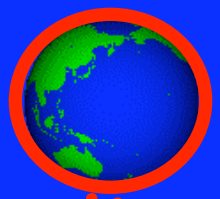
WMO IOC ICSU International Council for Science

The challenge

"Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future, is one of the greatest intellectual challenges facing humanity.

It is also one of the most important challenges for society as it seeks to achieve prosperity, health and sustainability."

National imperatives for the next decade and beyond (NRC 2007).



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.

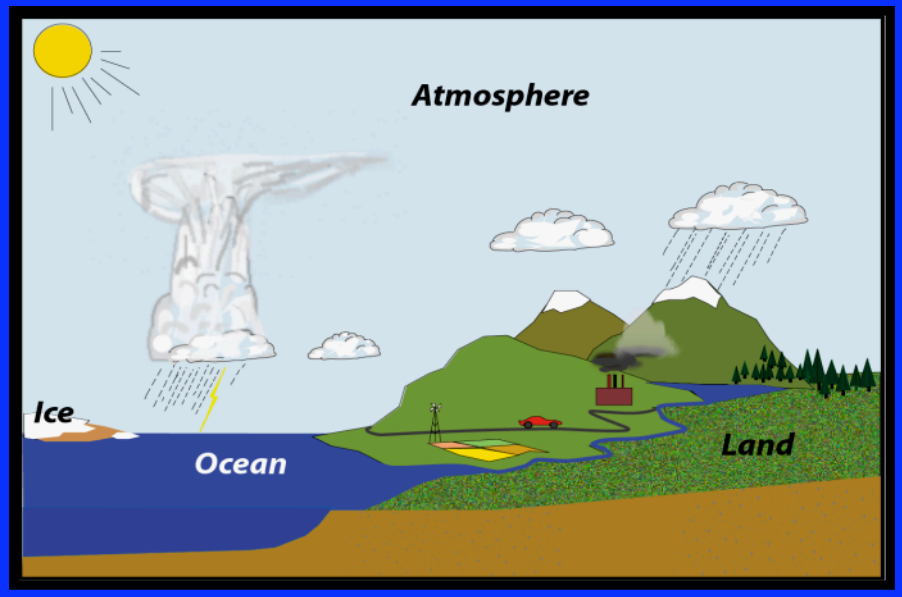
Climate change from human activities adds a whole new dimension and an **imperative**:

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"



The climate system:

Atmosphere
Land
Ocean
Cryosphere

Observations:

Atmosphere

Land

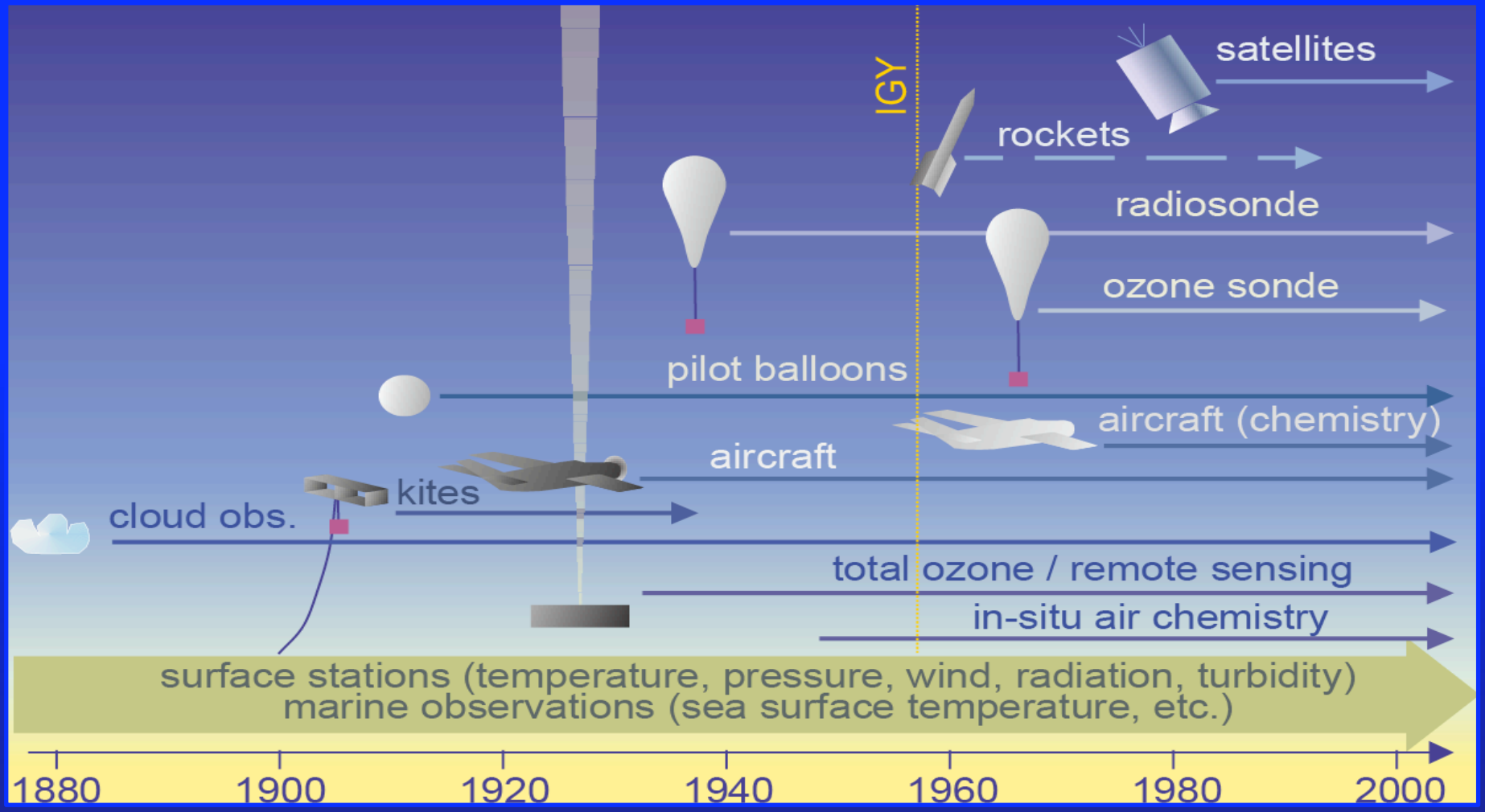
Oceans

Space

Courtesy: Tom Karl

A challenge:

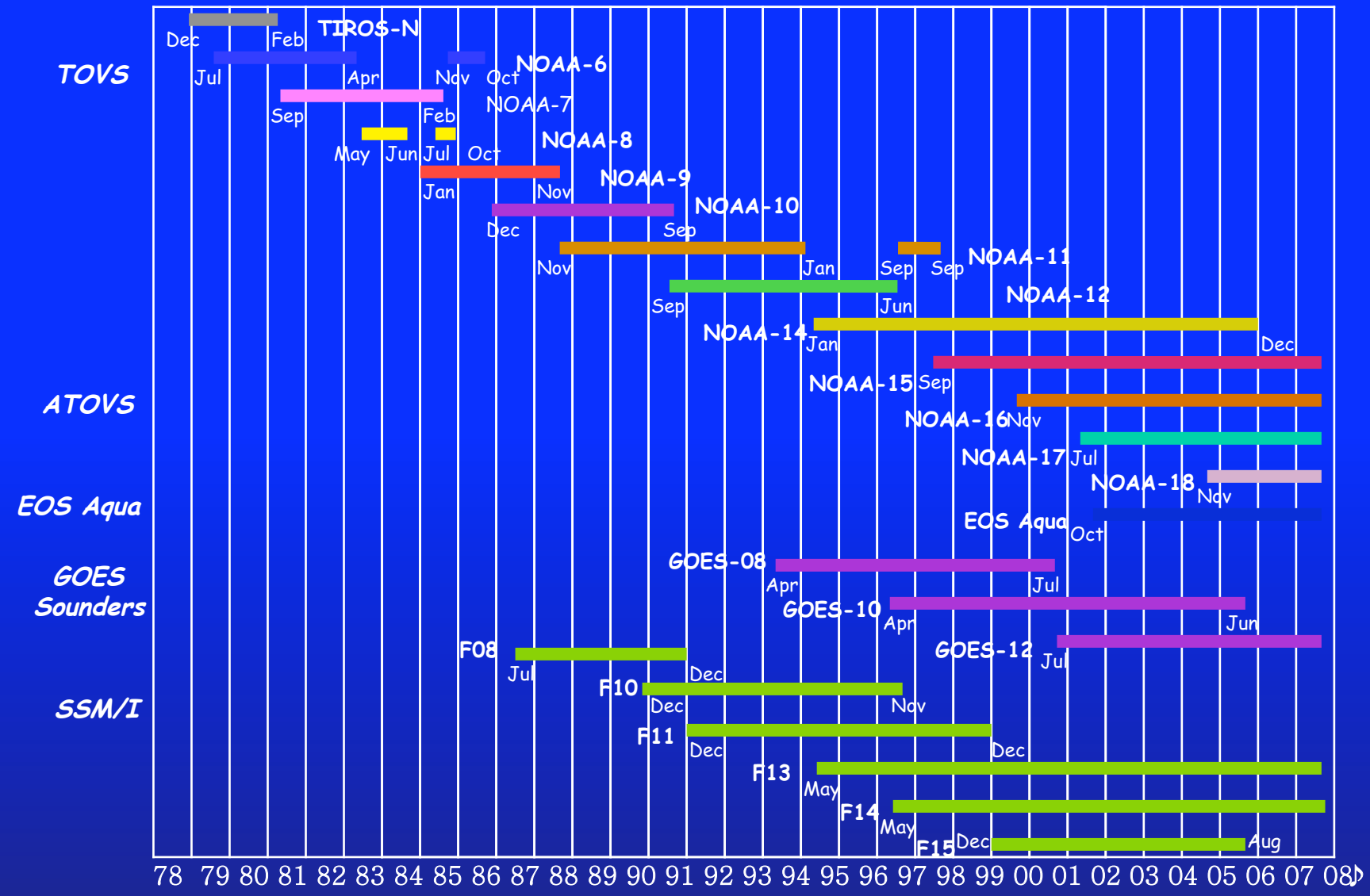
The changing observing system



The continuing changing observing system

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 i… of…
  interannual varia…
  - but not for de…

See our Poster T195A, session C23; **Schneider et al.** this morning

Needed:

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

Informed Guide

http://climatedataguide.ucar.edu/

See our Poster T195A, session C23; **Schneider et al.** this morning

UCAR ▾ NCAR ▾

NCAR

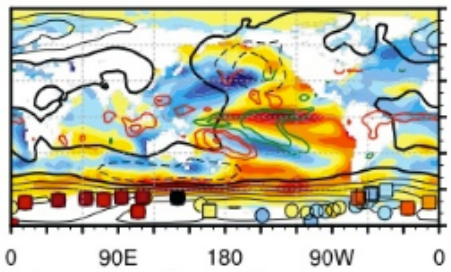
CAS Climate Analysis Section

ClimateDat

an informed guide to climate data sets featuring communit

About ClimateDataGuide ▾ Data Sets ▾ Search Data Data Proc

Community Generated Expert Guidance



A growing community resource established in 2011, **climatedataguide.ucar.edu** is an interactive website that enables researchers and students to identify and make effective use of climate data sets by providing a focal point for expert-user guidance, commentary, and questions on the strengths and limitations of selected observational datasets and their applicability to model evaluations.

...read more

***ClimateDataGuide* at World Climate Research Program's Open Science Conference, Denver, Colorado, 24-28 October, 2011**

Please visit our poster session on Tuesday, October 25th, 2011 in Session C23, 10:30 AM – 12 noon. We will be on hand to answer your questions about the *Climate Data Guide* and provide a live website demonstration on our laptop or yours. Poster #T195A.

We will also be at the AGU Fall Meeting, presenting at the Thursday morning poster session, GC41 in Moscone South.

...ays to participate in the *Climate Data Guide*:

- Register or Log In
- Contribute expert-user guidance
- Post comments/questions to a page
- Post an "in-brief" link to an article of interest
- Post to the "Which data set?" forum

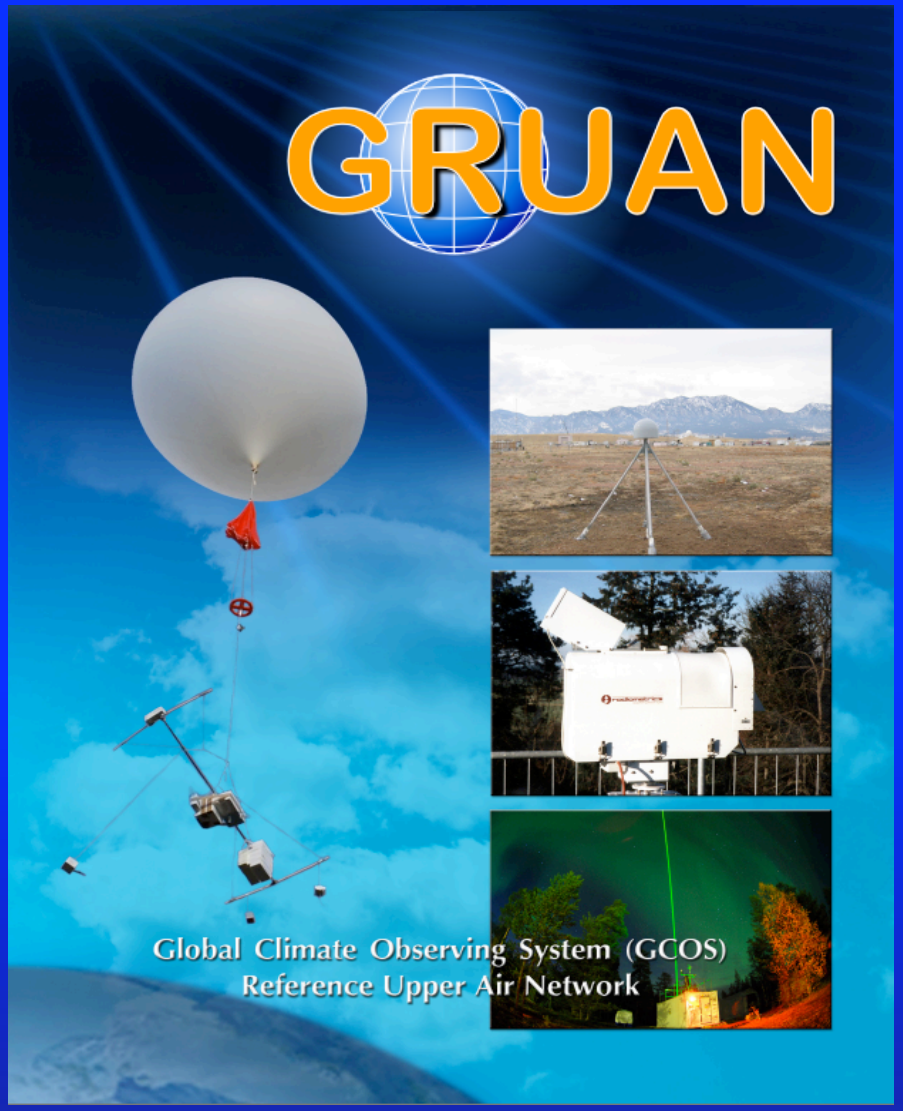
in brief

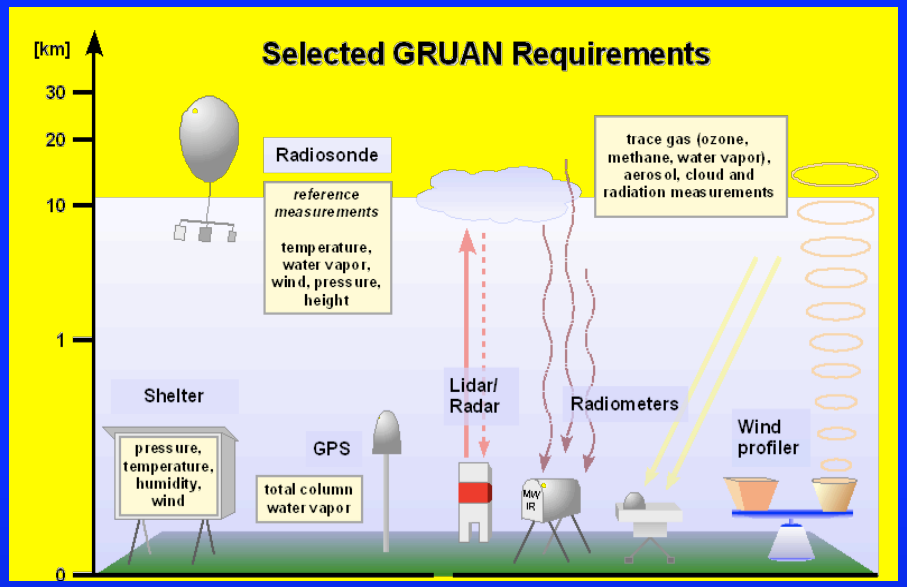
User-submitted external links about data set news and issues.

Scholarly study on the use of Web 2.0 in scholarly research [link]

CryoSat-2 is mapping sea ice thickness [link]

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

Space-based Global Observing System Schematic

Information Value Chain

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

contingency plan

GSICS Global Space-based Inter-Calibration System

SCOPE•CM

INTERNET Internet WMO IGDDS

GEONETCast Delivering Environmental Data to Users Worldwide

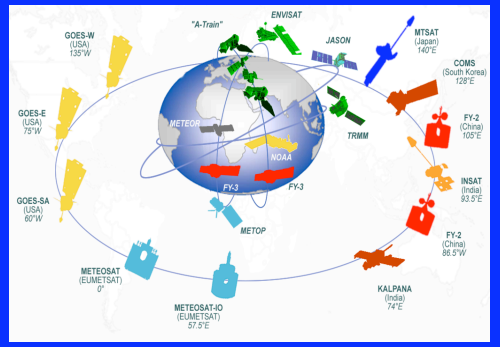
VLab

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.



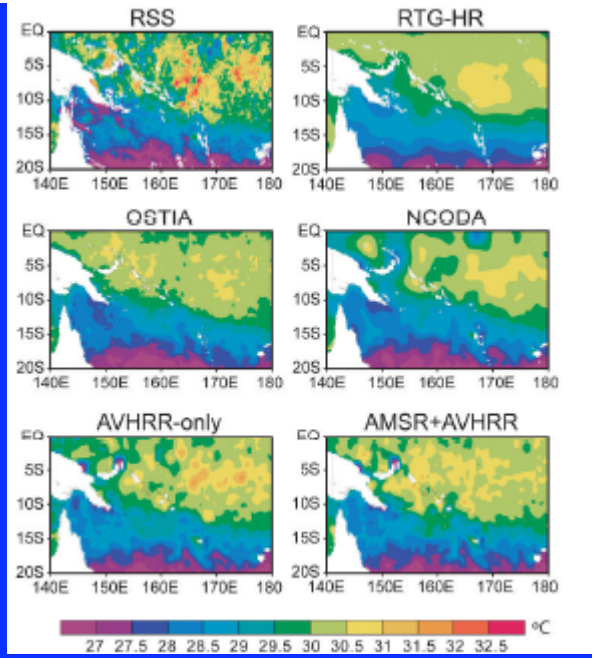
Volumes of data continue to grow and the challenge is to distill **information** out of the increasing **numbers**.

Known issues

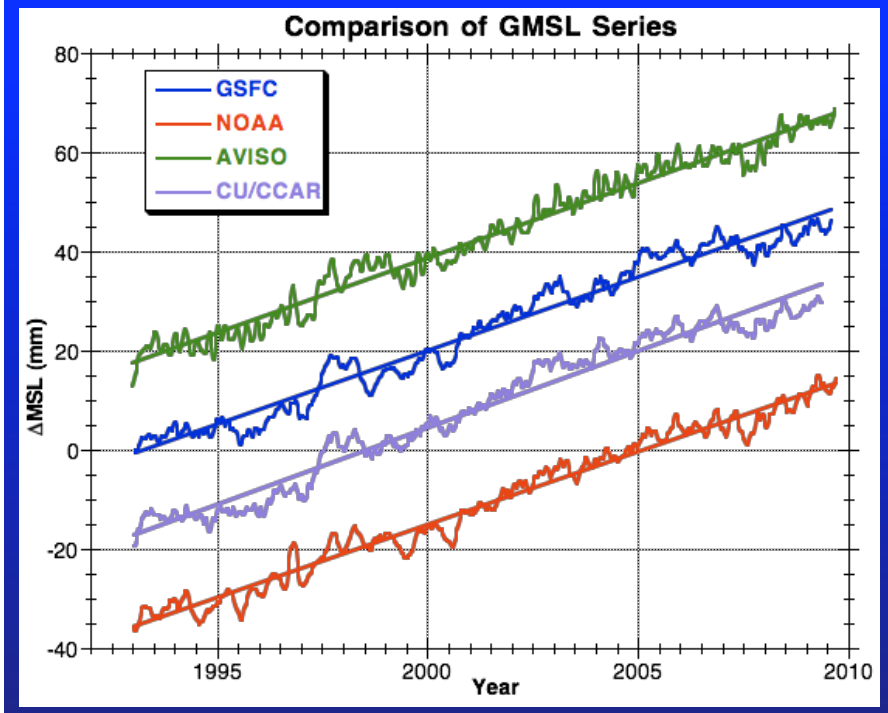
- Nearly all satellite datasets contain large spurious variability associated with changing instruments/satellites, orbital decay and drift, calibration, and changing methods of analysis
- Only 2 datasets (SSM/I water vapor; MSU T) were used in AR4 IPCC to examine trends
- Once, the issue was getting 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

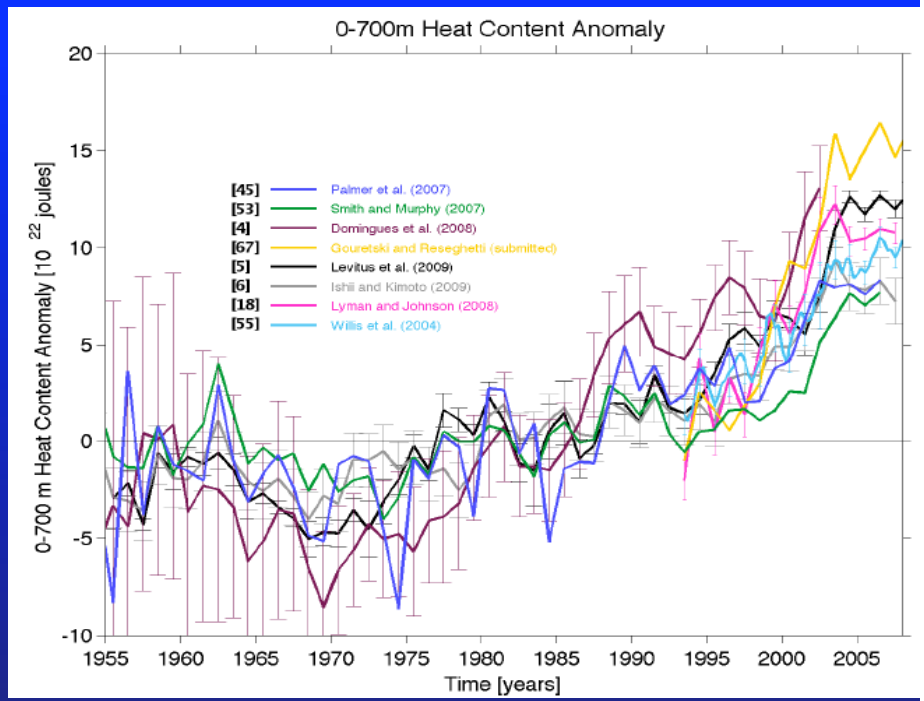
Daily SST (1 Jan 2007)
Reynolds and Chelton 2010 JC



Sea Level
w. offsets

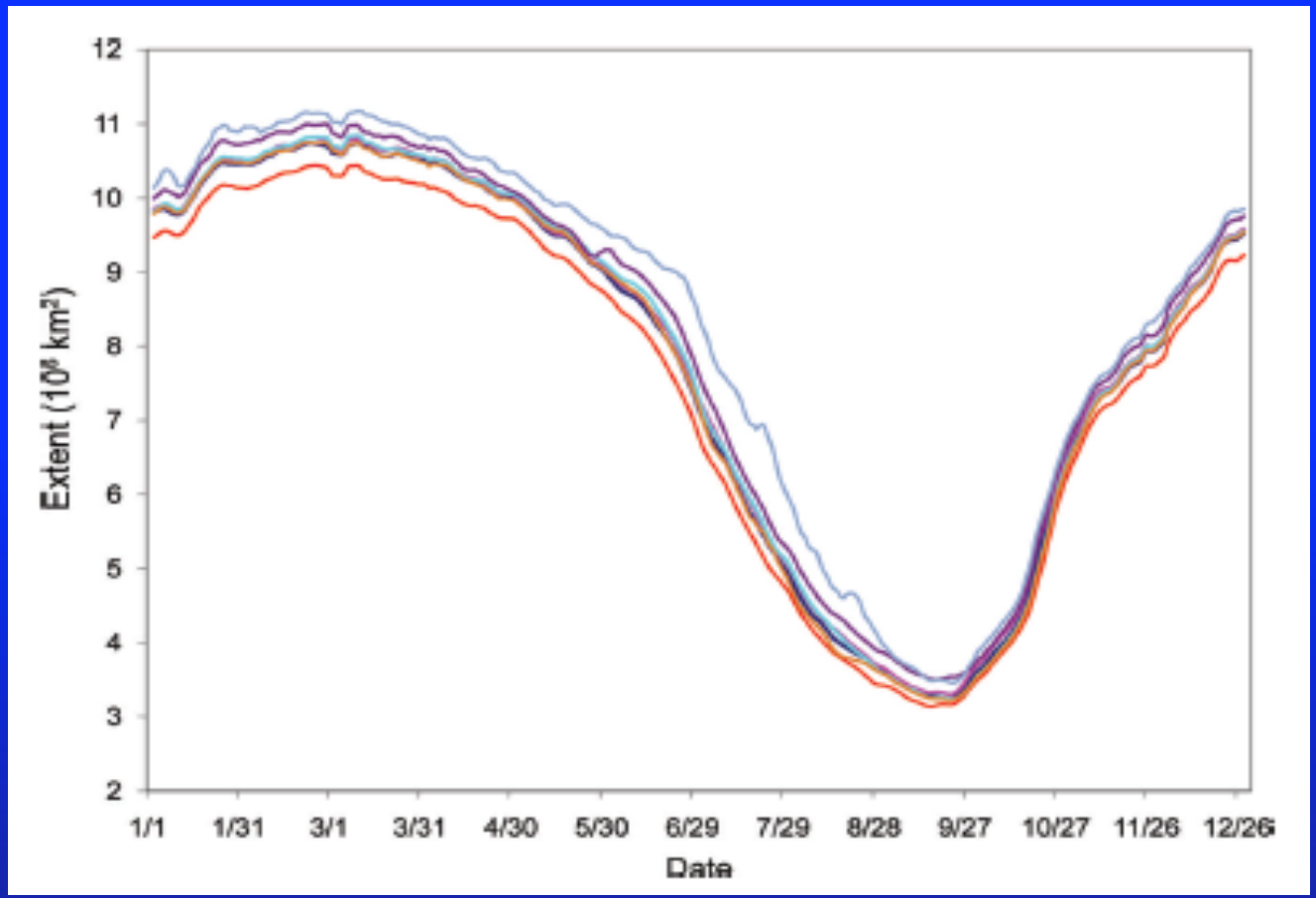


OHC
Palmer et al 2010
OceanObs'09



Total sea ice area: 2007

Arctic sea-ice extent for 2007 from seven algorithm products: Kattsov et al 2011 (Courtesy W. Meyer)



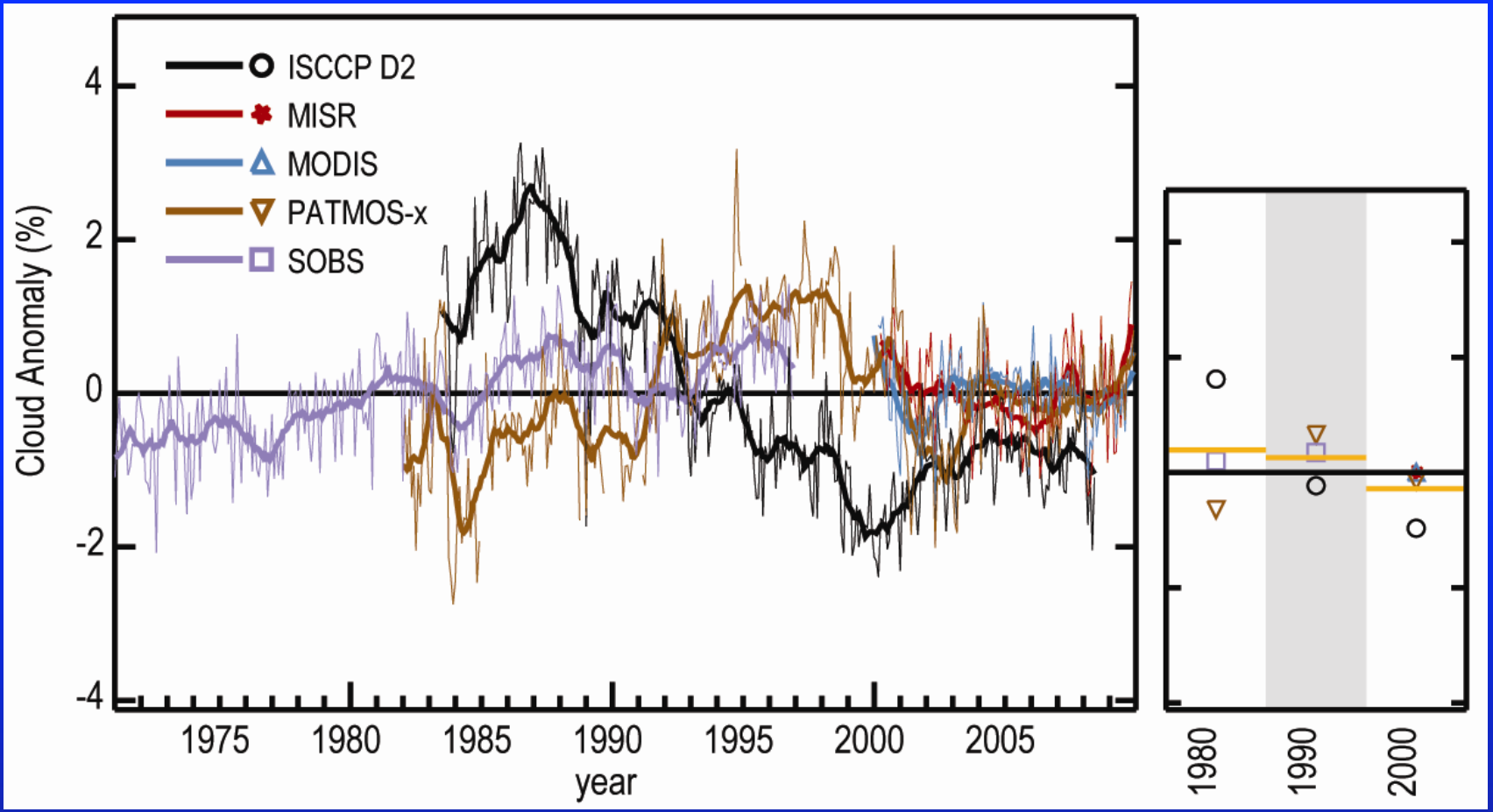
No single algorithm clearly superior.

Even bigger issues for ice thickness/ volume

The largest factor for ice concentration/extent consistency is intercalibration of the products through transitions through different generations of satellite-borne sensors.

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

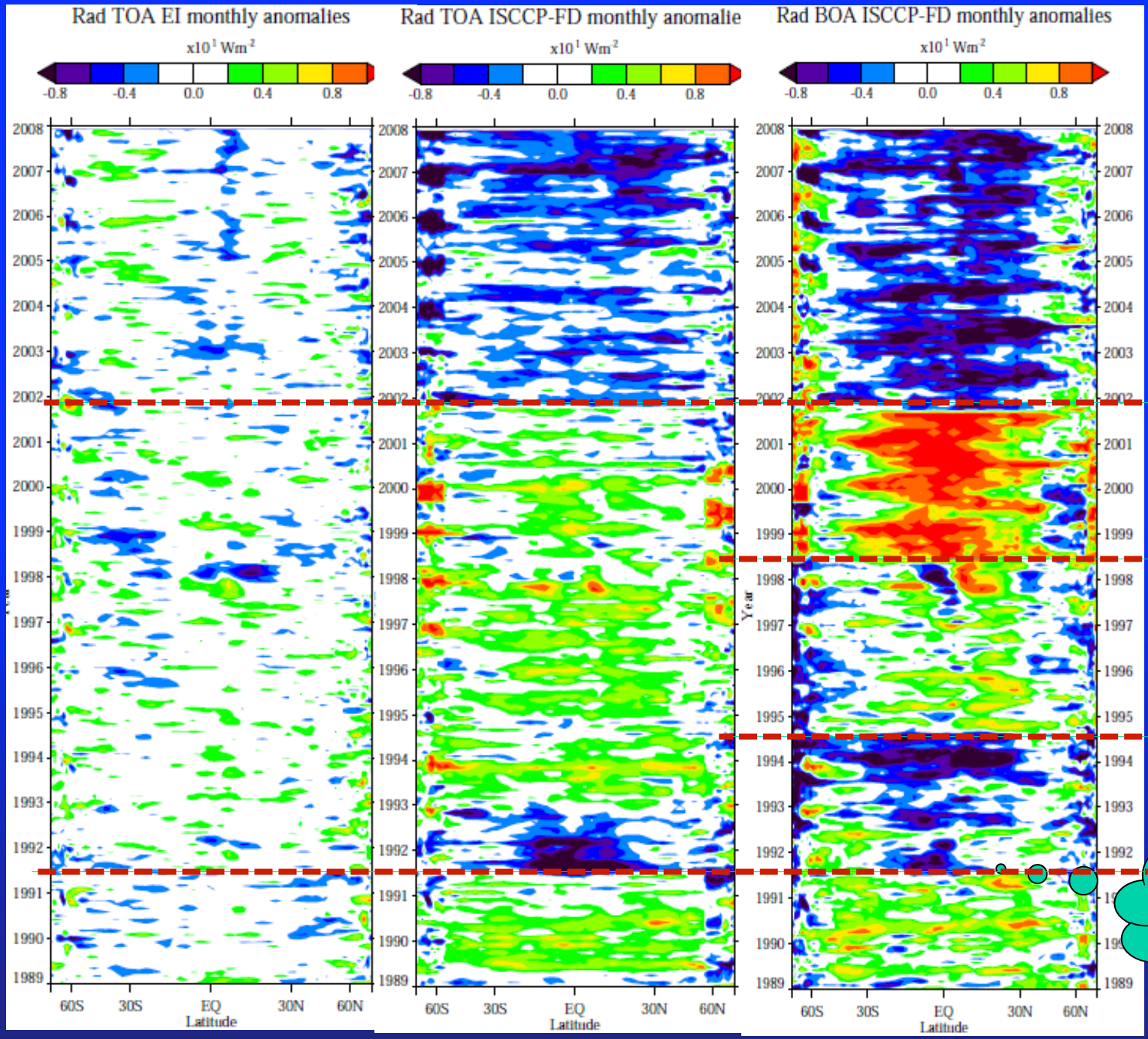
Clouds are not well defined:

- 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



Radiation TOA, Sfc

Major spurious changes in ISCCP-FD

NOAA 16

ATOVS↑

NOAA 15

TOVS ↓

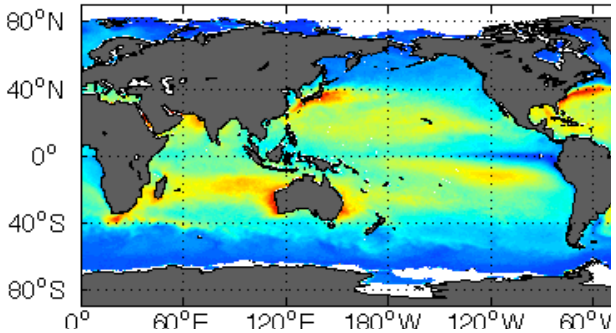
NOAA 14

Pinatubo effects

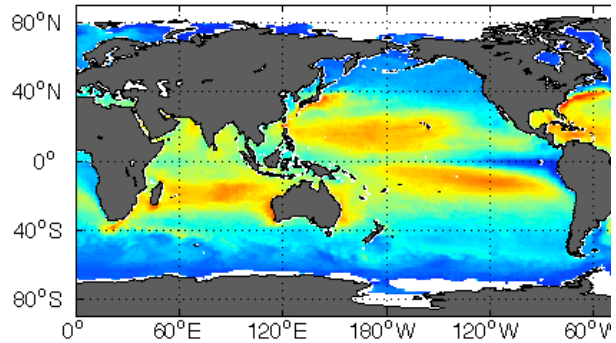
Michael Mayer

Latent Heat Flux: 1999-2005

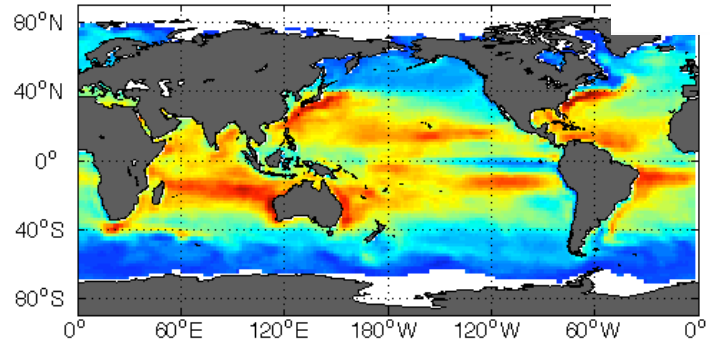
SeaFlux v1.0



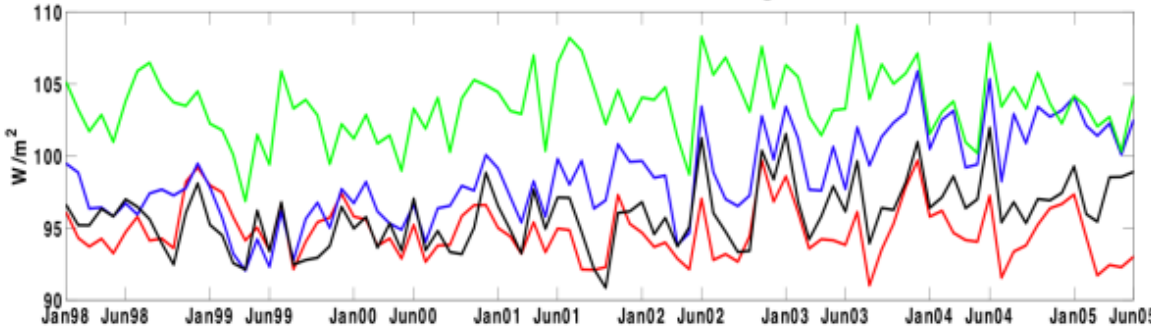
HOAPS v3



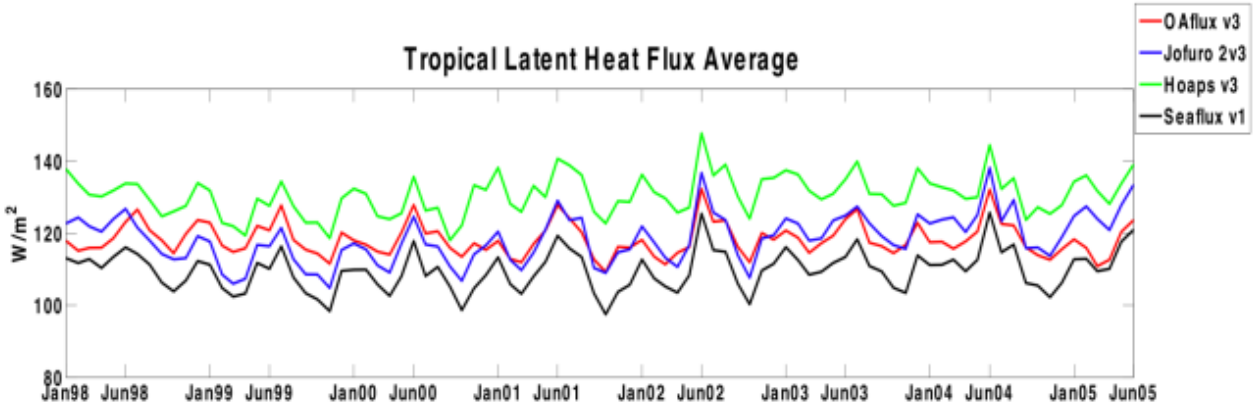
NCEP2

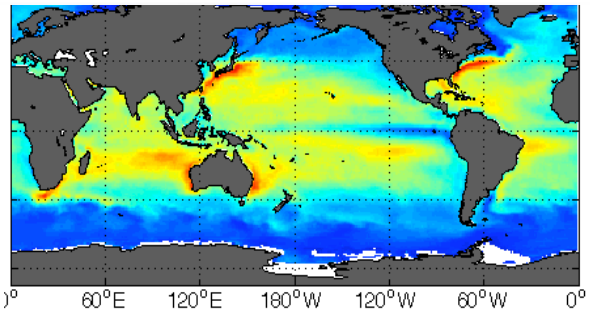


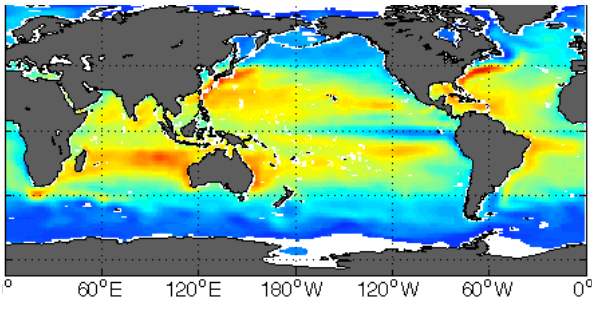
Global Latent Heat Flux Average



Tropical Latent Heat Flux Average

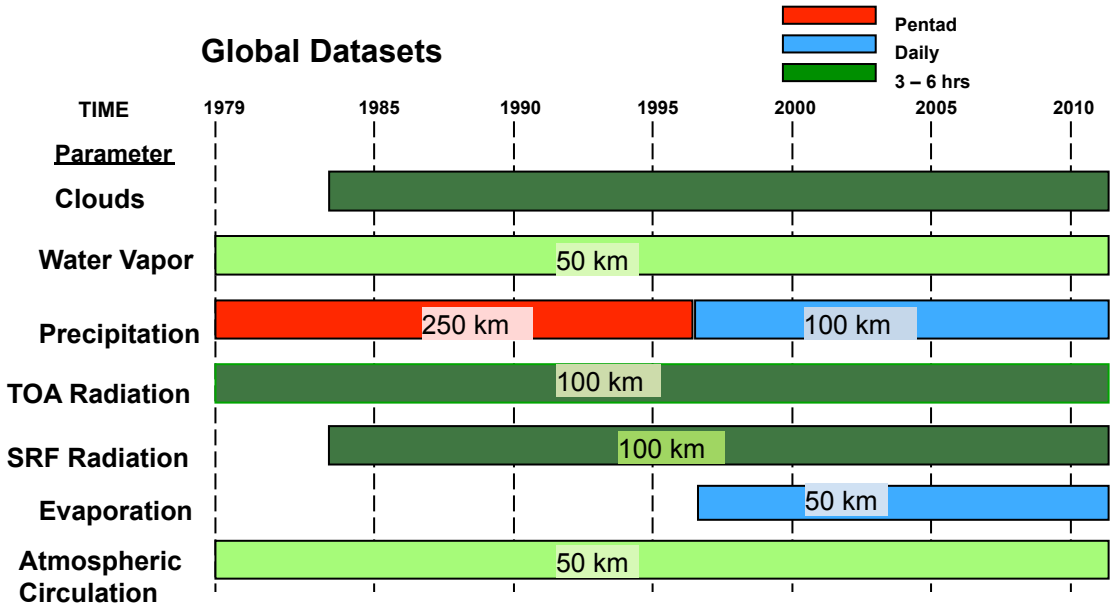






GEWEX Radiation Panel develops climate data records of water and energy variables, complete with metadata and error bars.

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



A GRP product is endorsed by GEWEX/GRP 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.

➡ **GEWEX Data and Assessments Panel**

GEWEX Reprocessing

The **proliferation** of datasets that are all different, with different strengths and weaknesses, demands assessment: Enormous need to evaluate and reprocess the data!

So the objectives are:

Reprocess *all GRP products with common ancillary data and assumptions. Plan to reprocess approx. every 5 years.*

Publish state of the "Observed" Water and Energy budgets

Expand accessibility to multi-variable products.

Facilitate research to interpret global and regional covariance among Water & Energy variables.

Assess all products of the same variable for strengths and weaknesses. *Each agency wants to only reprocess their product.*

Help move products to operations; share experience

(SCOPE-CM)

Atmospheric Reanalyses

*Current **atmospheric reanalyses**, with the horizontal resolution (latitude; T159 is equivalent to about 0.8°), the starting and ending dates, the approximate vintage of the model and analysis system, and current status.*

Reanalysis	Horiz.Res	Dates	Vintage	Status
NCEP/NCAR R1	T62	1948-present	1995	ongoing
NCEP-DOE R2	T62	1979-present	2001	ongoing
CFSR (NCEP)	T382	1979-present	2009	thru 2010, ongoing
C20r (NOAA)	T62	1875-2008	2009	Complete, in progress
ERA-40	T159	1957-2002	2004	done
ERA-Interim	T255	1989-present	2009	ongoing
JRA-25	T106	1979-present	2006	ongoing
JRA-55	T319	1958-2012	2009	underway
MERRA (NASA)	0.5°	1979-present	2009	thru 2010, ongoing

Atmospheric Reanalyses

- **Reanalyze** all observations with improved state-of-art system held constant.
- Improves basic observations (QC)
- Improves data processing, automation (monitoring system)
- Improves understanding and models
- **Potential to improve further.**
- Very useful for examining anomalous atmospheric circulation
- Getting better for decadal variations and trends, but further improvement needed:
- Main spurious variations are from observing system changes
- Many users, many citations
- But many misuses!
- Reanalysis in other domains: ocean, land, polar…

ECMWF

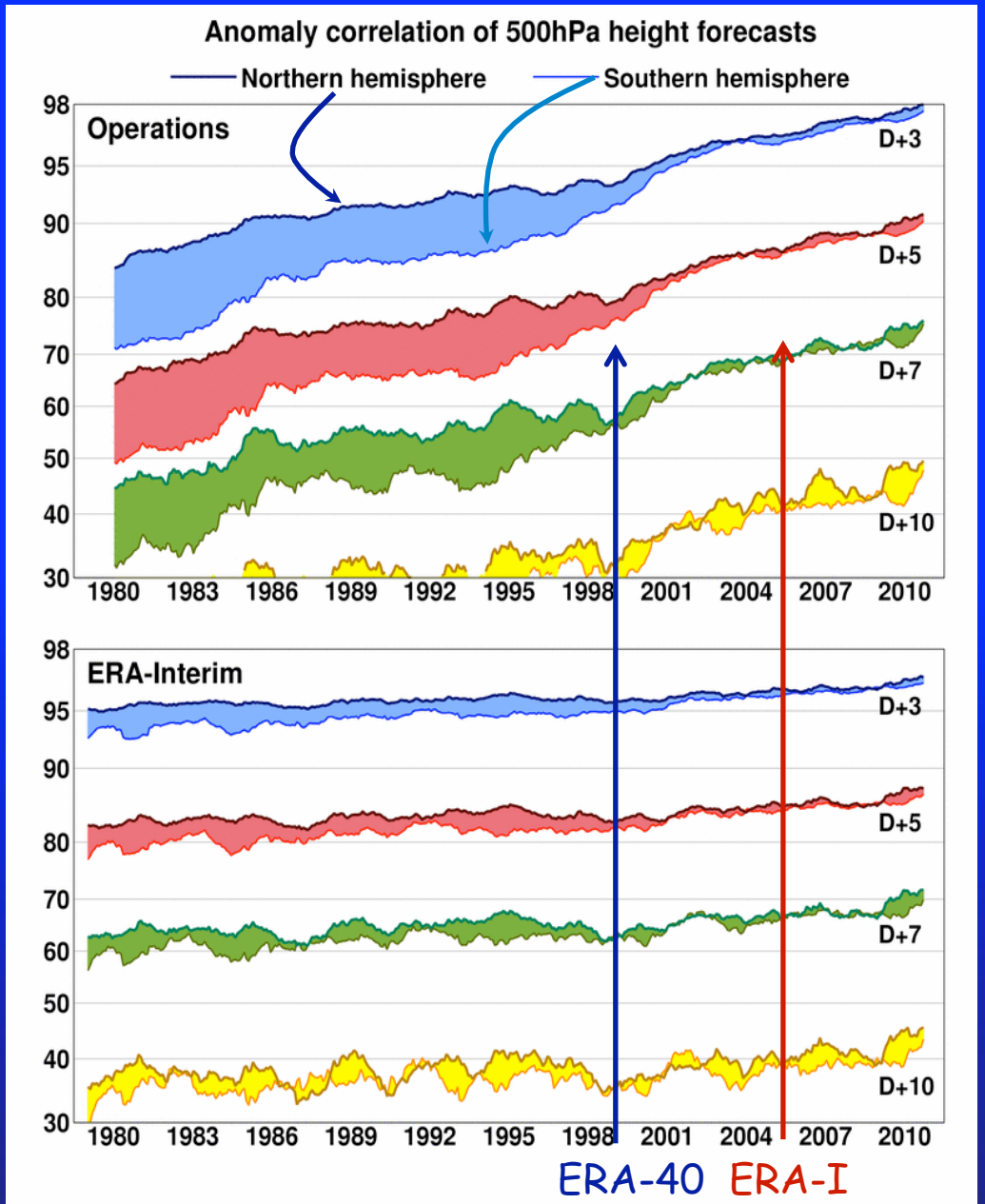
Improvement in forecasts:

From 1980 to 2000 comes mostly from improvement to forecasting system

Correlation (%) of actual and predicted 500hPa height anomalies (12-month running means).

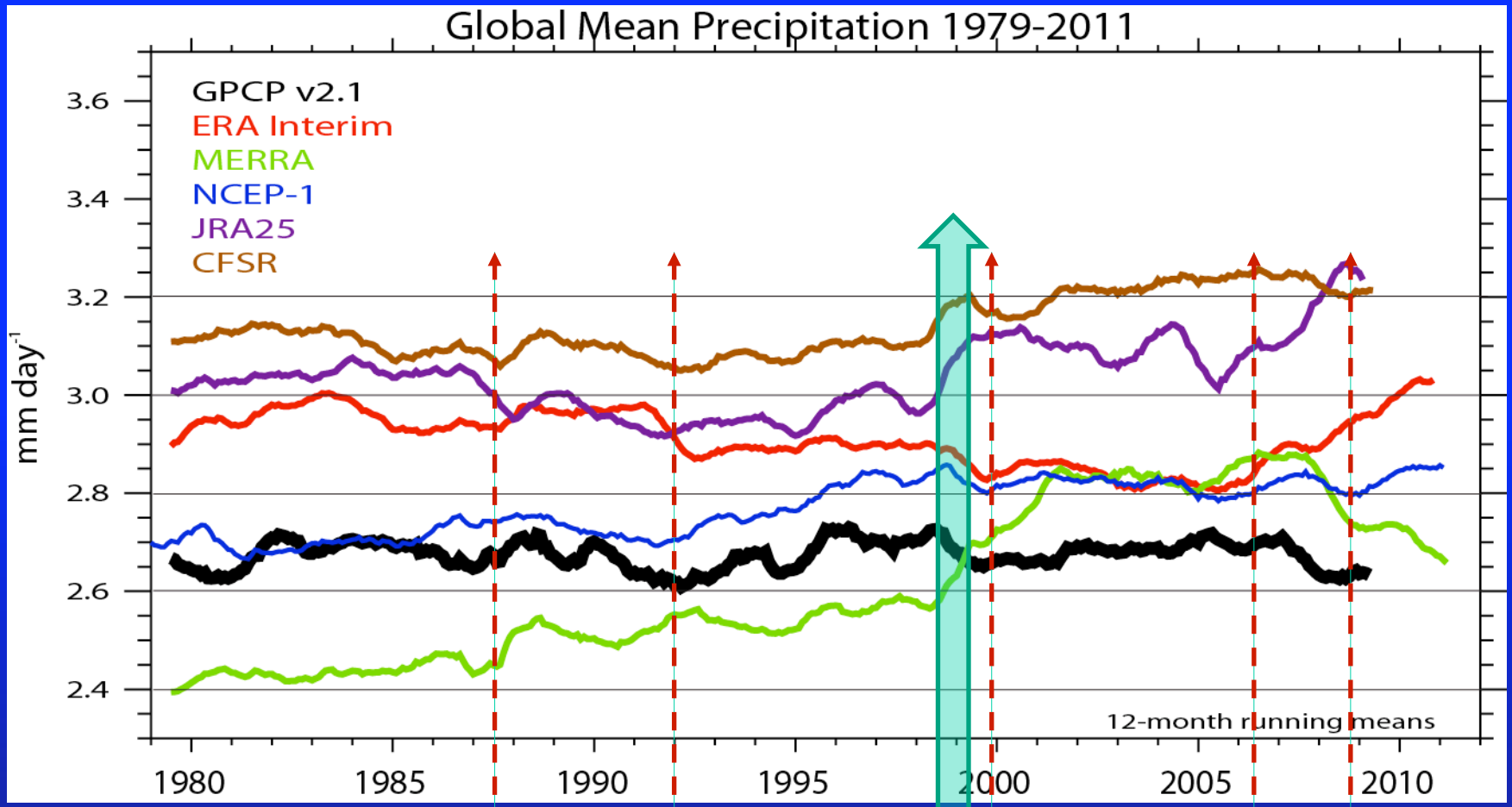
Reanalysis

Improvement since 2000 comes from both forecasting system and observations



Courtesy Adrian Simmons

Global mean precipitation



12-mo running means

TOVS to ATOVs Nov 1998

Changes in SSM/I

Courtesy J Fasullo

TOA Radiation

CCSM4

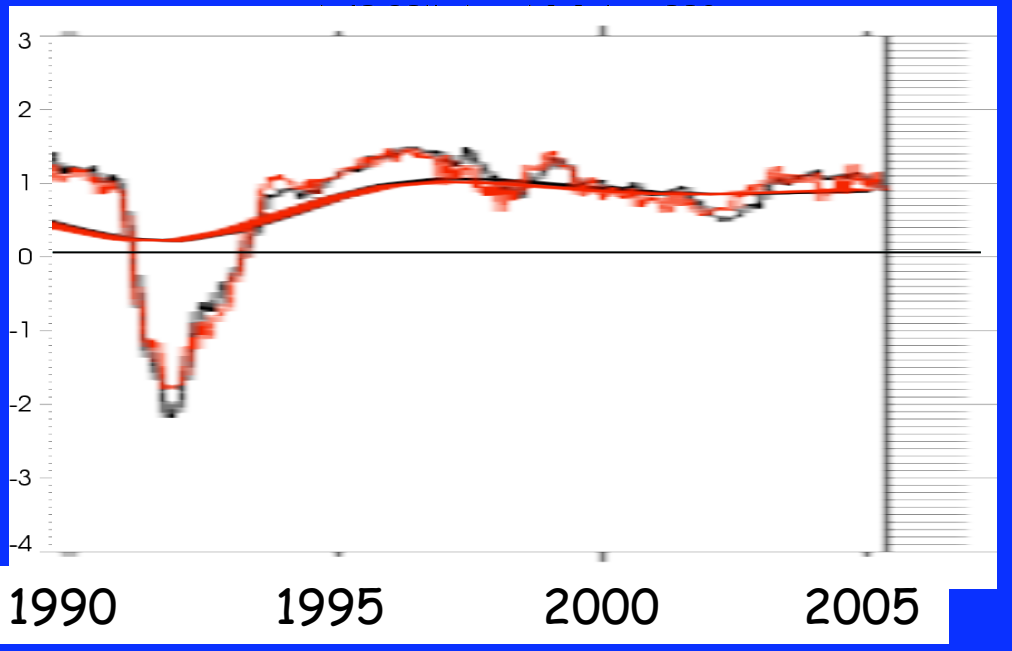
TOA radiation and surface flux over ocean;

Net 1990s 0.6 W m^{-2}

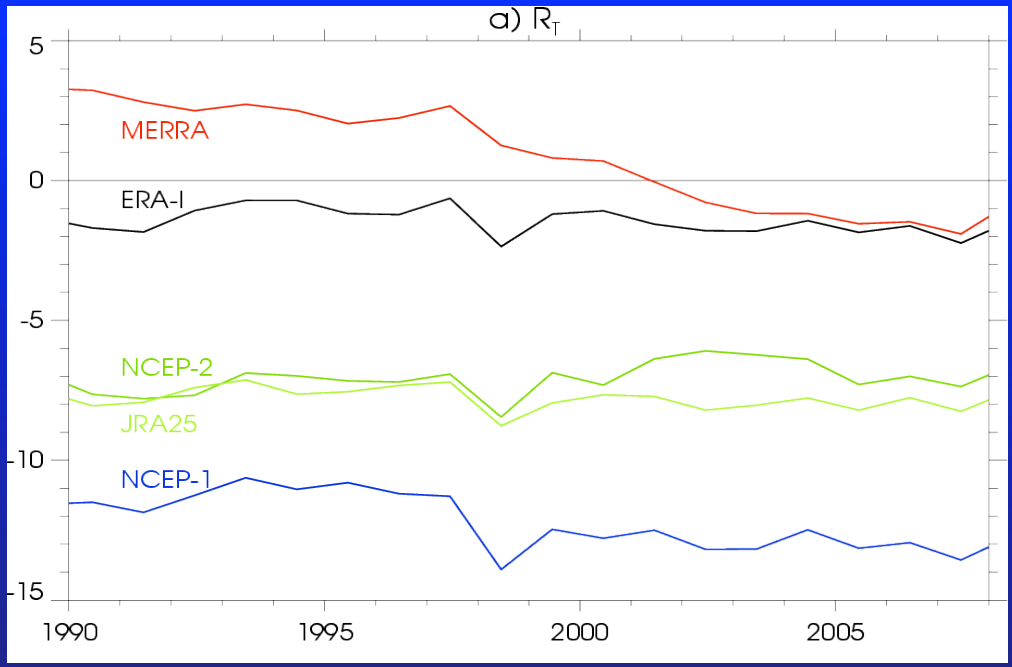
(Pinatubo knock down)

Net 2000s 0.9 W m^{-2}

In a good model, the water and energy are conserved.

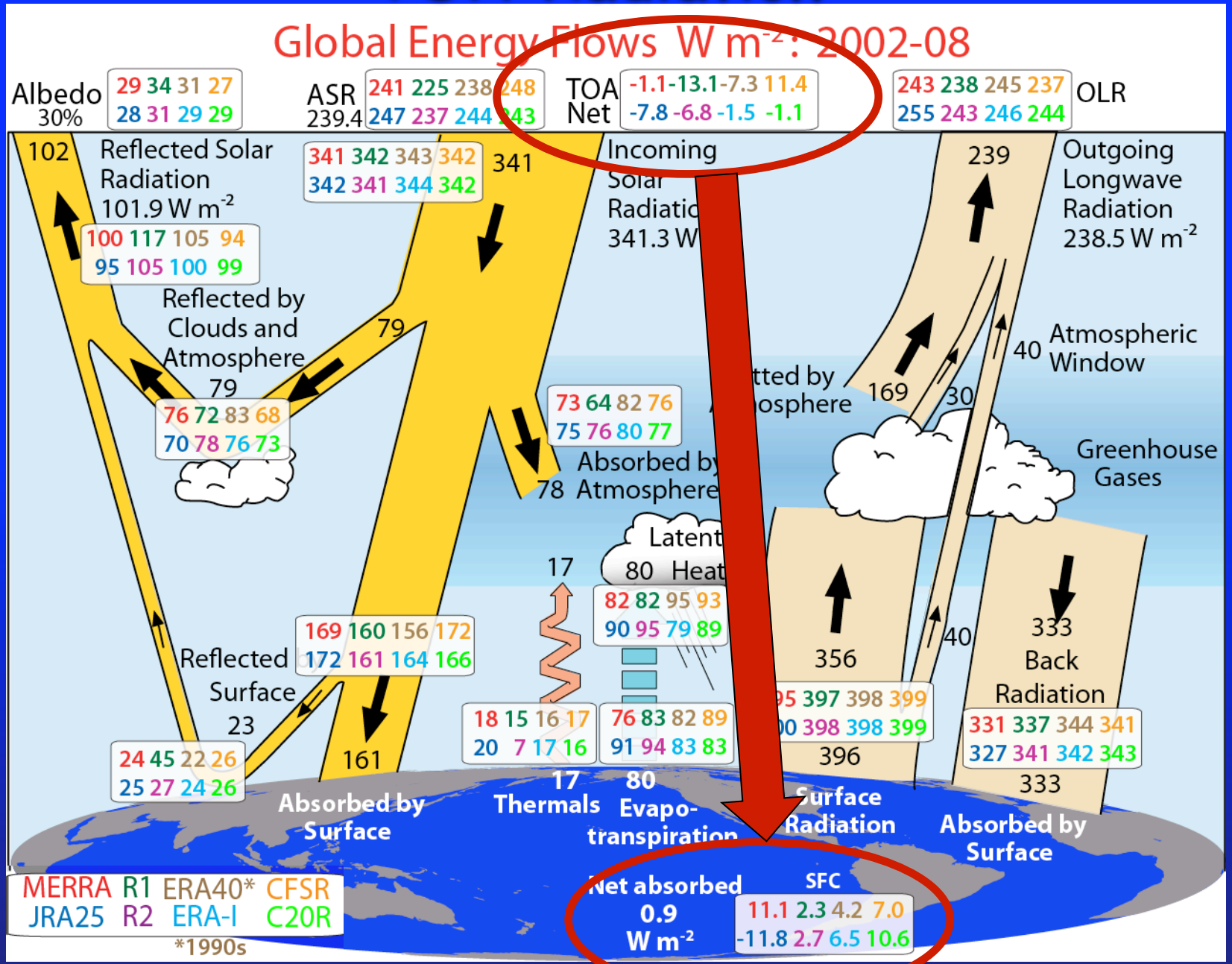


Reanalyses: TOA 1990-2008 Net radiation



Trenberth et al 2009:
0.9 W m^{-2} for 2000s

TOA Radiation

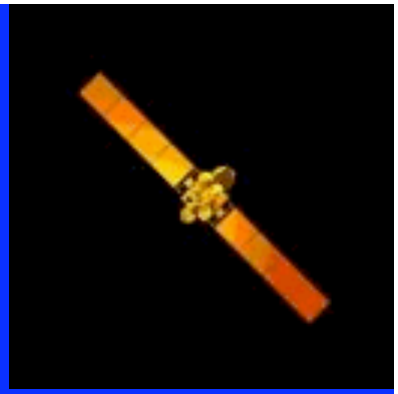


Trenberth et al 2011 J Climate

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…)
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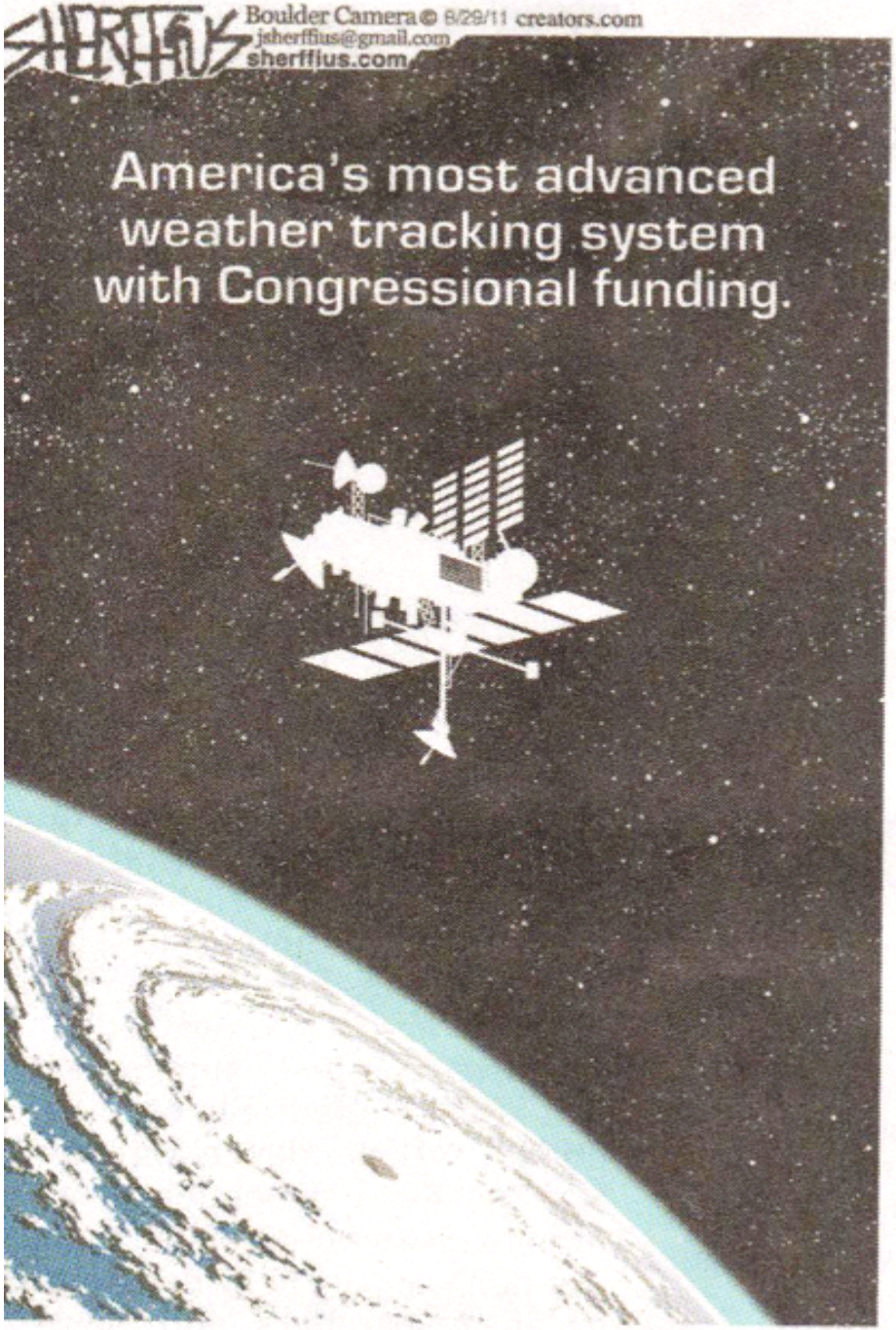
- There is inadequate overlap and dual operation of observing systems
- Need continued priority for key reference observing systems such as GRUAN and CLARREO
- Major risk of gaps in the satellite records over the next 10-20 years
- **Observation continuity:** key to climate record is in jeopardy;
  - 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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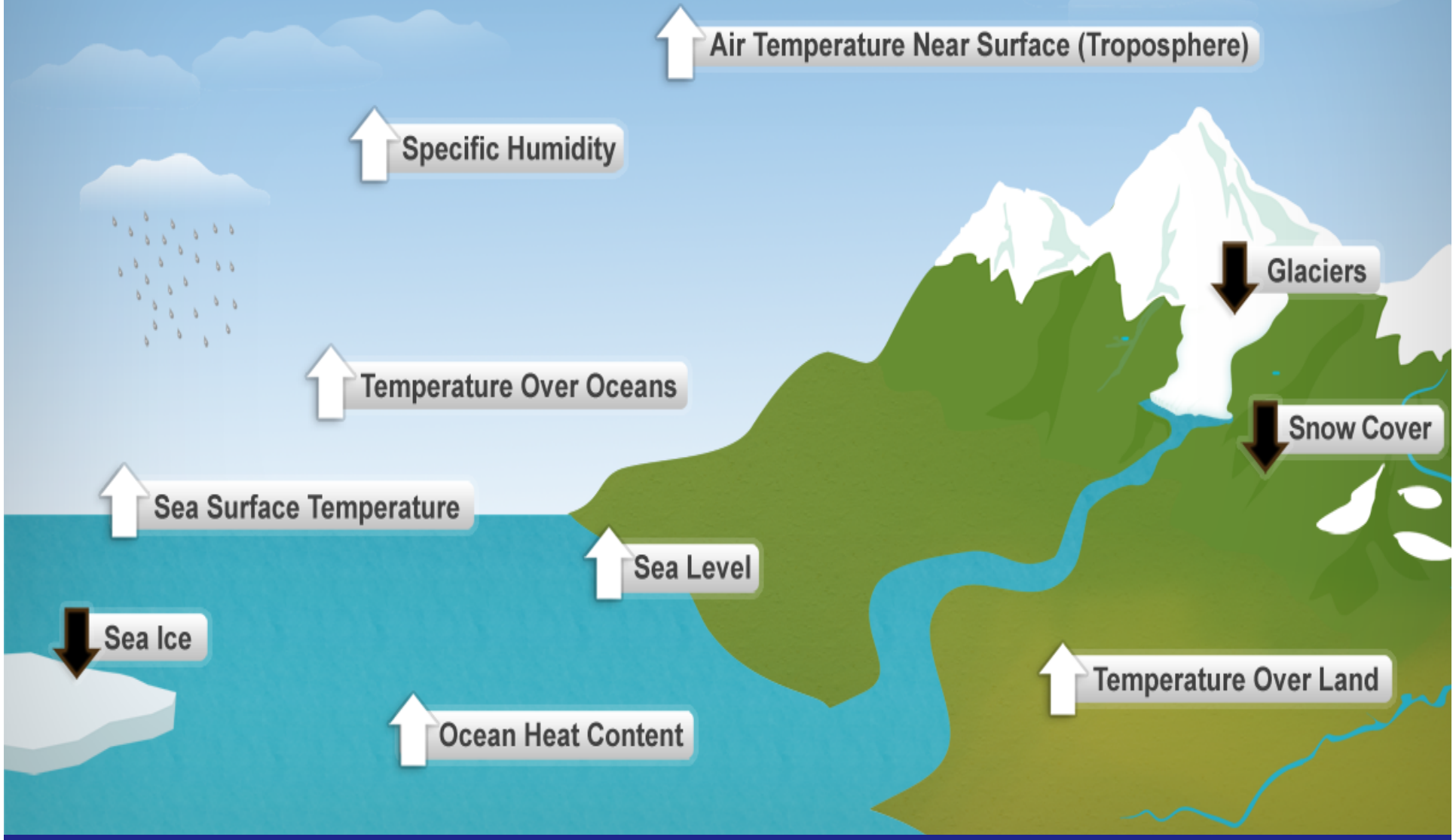
There is a LOT of potential:
10 Essential Climate Variable Indicators



2009 State of the Climate report

Long-term needs?

Where is this from?

"To advance our understanding of the causes and effects of global change, we need new observations of the Earth. These measurements must be global and synoptic, they must be long-term, and different processes must be measured simultaneously.

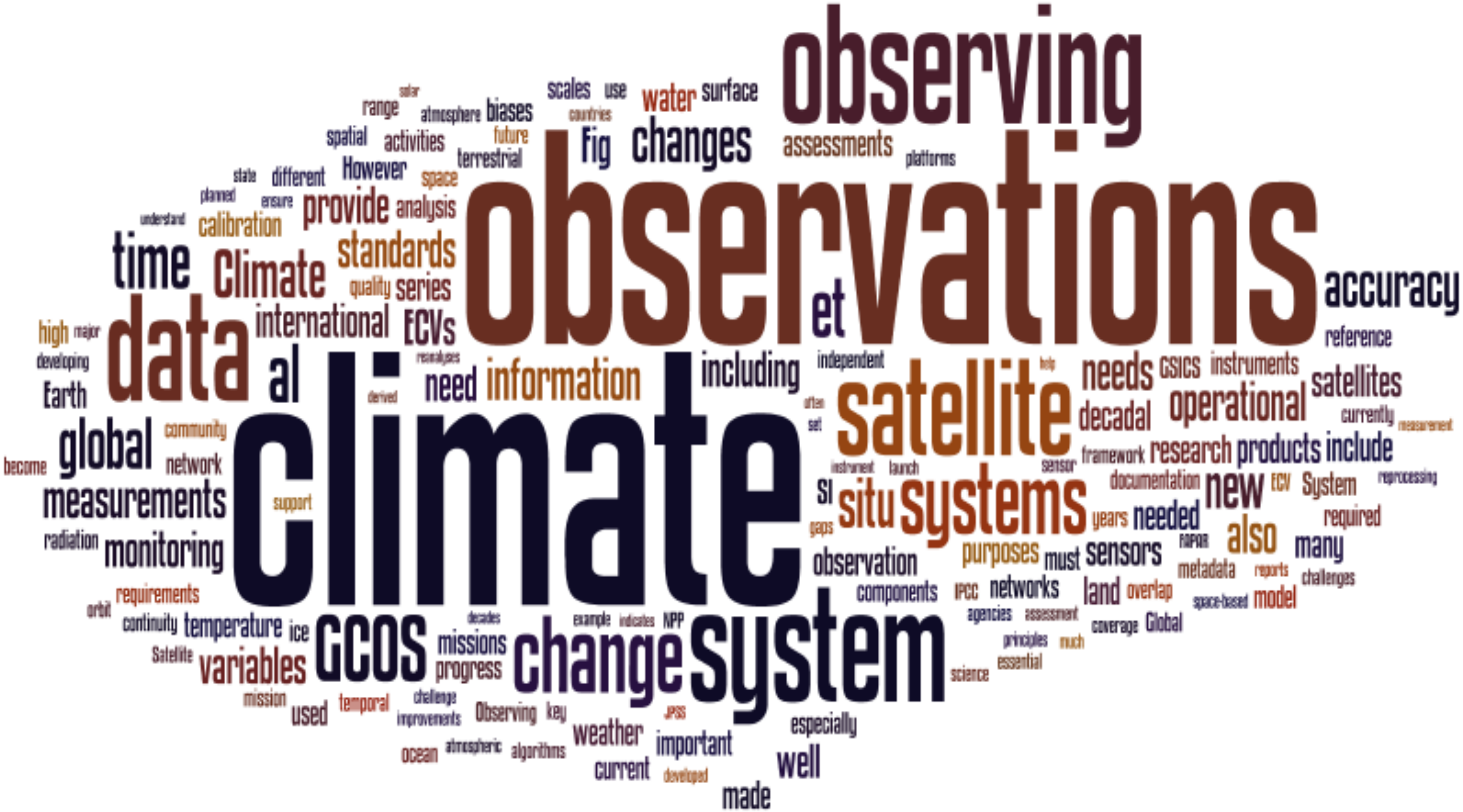
* **Long-term continuity is crucial.** A 20-year time series of the crucial variables would provide a significant improvement in our understanding.
* Now we are on the verge of establishing a global system of remote sensing instruments and Earth-based calibration and validation programs. Together, these space- and Earth-based measurements can provide the necessary data"

Earth System Science Committee, 1985

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


observing
observations
climate
data
time
Climate
satellite
system
systems
change
GCOS
accuracy
changes
global
measurements
monitoring
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series
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analysis
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different
activities
terrestrial
spatial
range
atmosphere
biases
scales
use
water
surface
assessments
platforms
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Earth
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developing
become
network
community
radiation
requirements
continuity
ice
Satellite
mission
used
temporal
Observing
key
ocean
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algorithms
reference
instruments
GSICS
framework
documentation
System
required
metadata
model
challenges
coverage
Global
components
agencies
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SI
independent
years
needed
must
overlap
IPCC
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