Systematic Observation Requirements for Climate

GCOS and ESA's approach

mark doherty

esa

based on material provided by

science teams of the esa climate change initaitive

overview

- **Global Climate Observing System**
- **esa climate change initiative (CCI)**
- **ECV examples**
- **what do climate modellers want ?**
- **the big picture…**

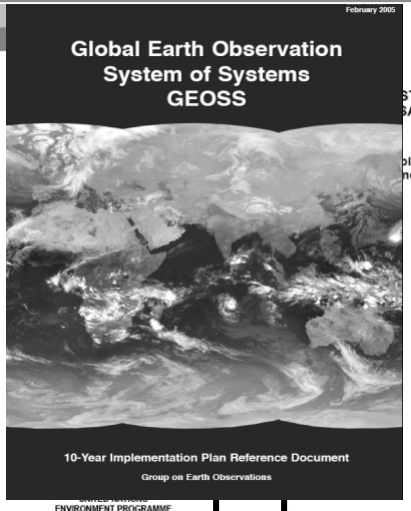
(observations, science and public policy)

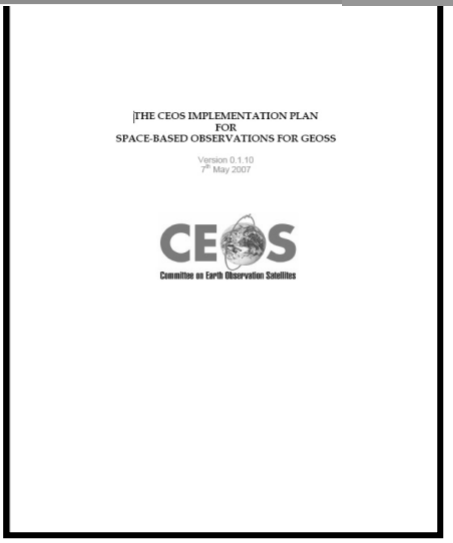
a global political framework

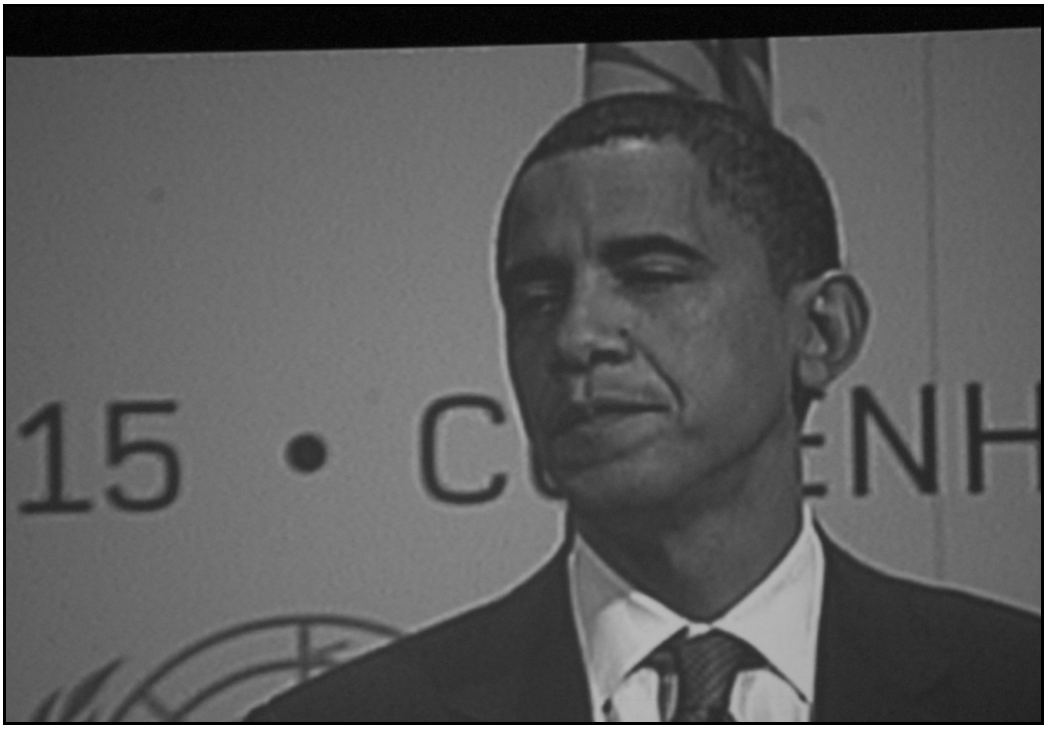
- GEOSS
  - coordinated global earth observations
  - data sharing principles
- CEOS
  - satellite component
  - virtual constellations
- GCOS
  - authoritative requirements for climate
  - climate monitoring principles

for global earth observations

GCOS requirements <=> CEOS response






15 •

CCI objectives

Realize the full potential of the long-term global EO archives that ESA, together with its Member states, has established over the last thirty years.....

….. as a significant and timely contribution to the ECV databases required by the United Nations Framework Convention on Climate Change

6 Years / 75 M

GCOS Essential Climate Variables (ECVs)

OCEANS	O.1	Sea Ice
	O.2	Sea Level
	O.3	Sea Surface Temperature
	O.4	Ocean Colour
	O.5	Sea State
	O.6	Ocean Reanalysis
	O.7	Ocean Salinity

TERRESTRIAL	T.1	Lakes
	T.2	Glaciers & Ice Caps, and Ice Sheets
	T.3	Snow Cover
	T.4	Albedo
	T.5	Land Cover
	T.6	fAPAR
	T.7	LAI
	T.8	Biomass
	T.9	Fire Disturbance
	T.10	Soil moisture

ATMOSPHERE	A.1	Surface Wind Speed and Direction
	A.2	Upper-air Temperature
	A.3	Water Vapour
	A.4	Cloud Properties
	A.5	Precipitation
	A.6	Earth Radiation Budget
	A.7	Ozone
	A.8	Atmospheric reanalysis (multiple ECVs)
	A.9	Aerosols
	A.10	Carbon Dioxide, Methane and other Greenhouse Gases
	A.11	Upper-air Wind

CCI First Steps (11 + 2ECVs)
Later in CCI (8 ECVs)

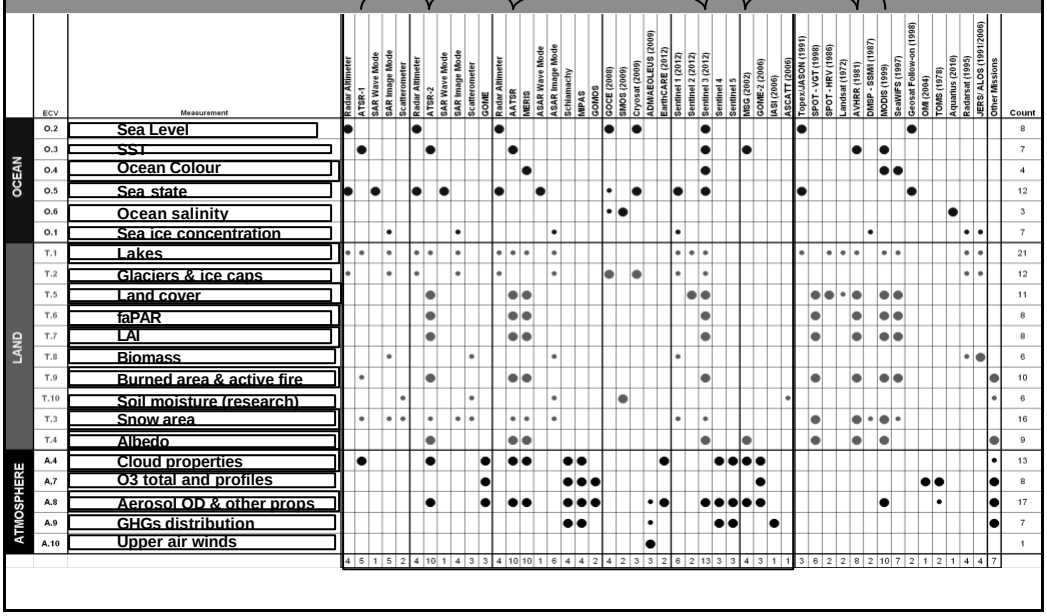
GCOS – 107 Systematic Observation Requirements for Satellite -Based Product for Climate Page 12 and 13

a major scientific challenge

e.g. sea level ECV

GCOS Requirement		Current Status
Accuracy	1 cm	2 cm
Stability	0.5 mm/decade	10 mm/decade (*1 mm/yr*)

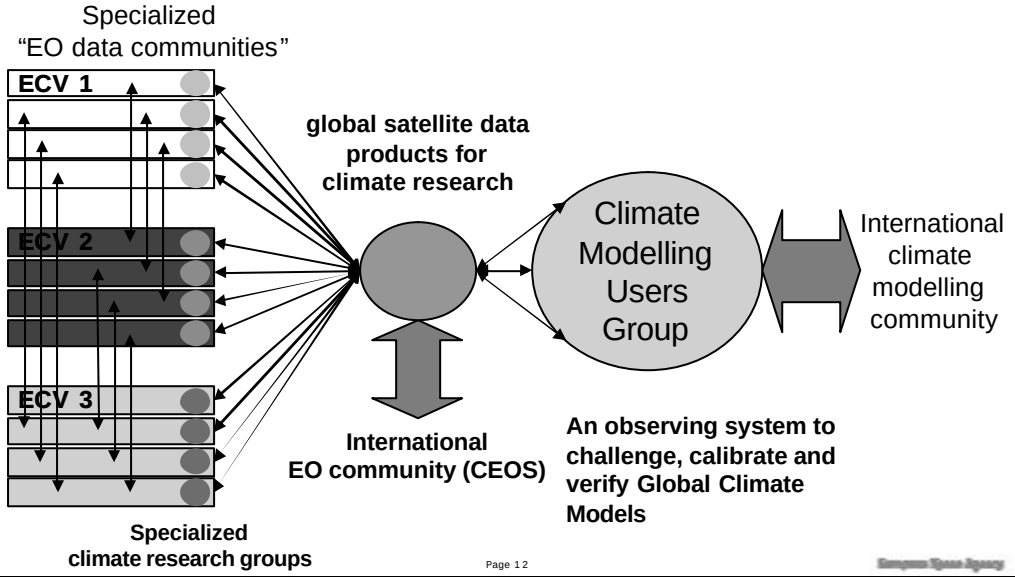
multiple sensors….consistency…..



CCI: International coordination

- **UNFCCC which coordinates the interests and decisions of its Parties on Climate Policy,**
- **GCOS which represents the scientific and technical requirements of the Global Climate Observing System on behalf of UNFCCC,**
- **CEOS which serves as a focal point for Earth Observation related activities of Space Agencies (e.g NOAA, NASA, JAXA, EUMETSAT)**
- **Individual Partner Space Agencies with whom ESA cooperates bilaterally (e.g. EUMETSAT)**
- **International Climate Research Programmes, which represent the collective interests and priorities of the worldwide climate research,**
- **EC and National Research Programmes which establish research priorities and provide resources for climate research community within Europe (e.g. DG Research, DG-JRC)**
- **GMES Partners: DG Enterprise and Industry, user DGs ENV, EEA…**

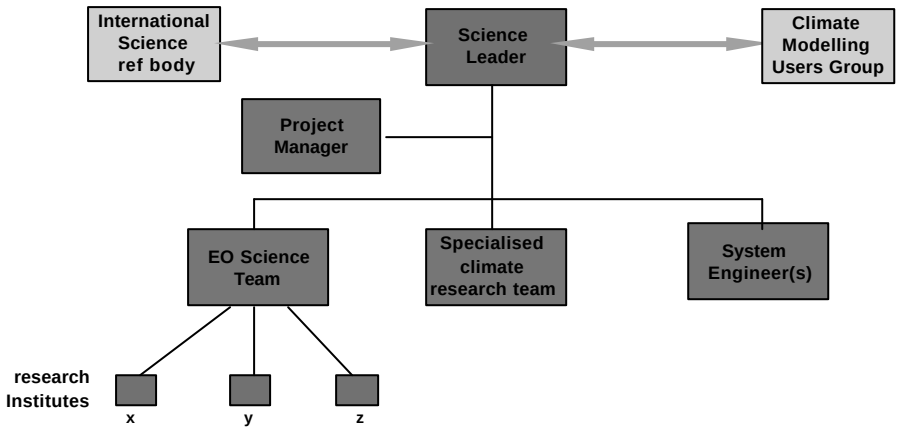
where we want to go…



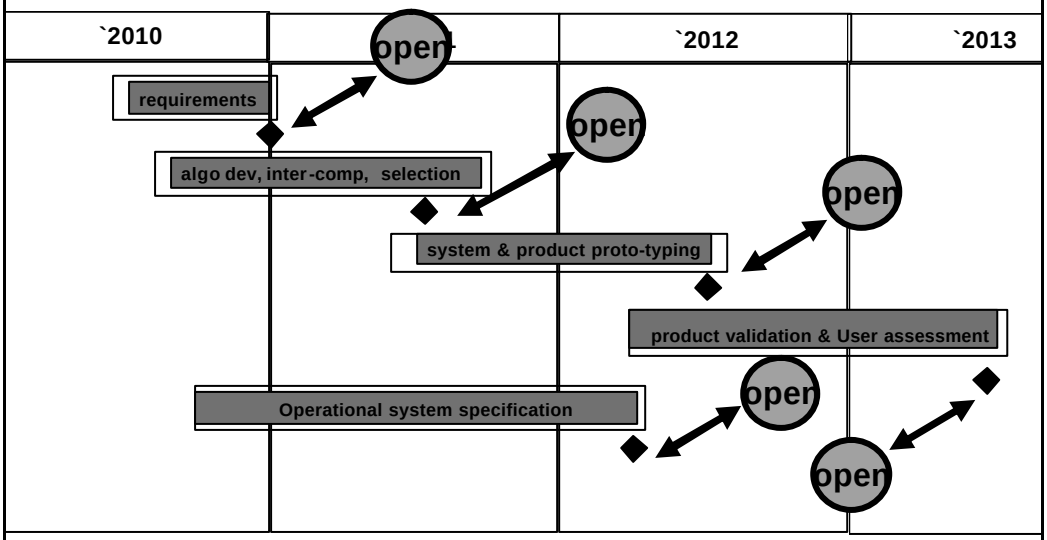
next 3 years => CCI phase 1 Cardinal Requirements

- Develop and validate algorithms to meet GCOS ECV requirements for (consistent, stable, error-characterized) global satellite data products from multi-sensor data archives
- Optimize impact of ESA EO missions data on climate data records
- Produce, within R&D context, most complete and consistent possible multi-sensor global satellite data products for climate research and modelling
- Generate complete specifications for an operational production system
- Strengthen inter-disciplinary cooperation between international earth observation, climate research and modelling communities, in pursuit of scientific excellence

CCI project teams



CCI projects x 11

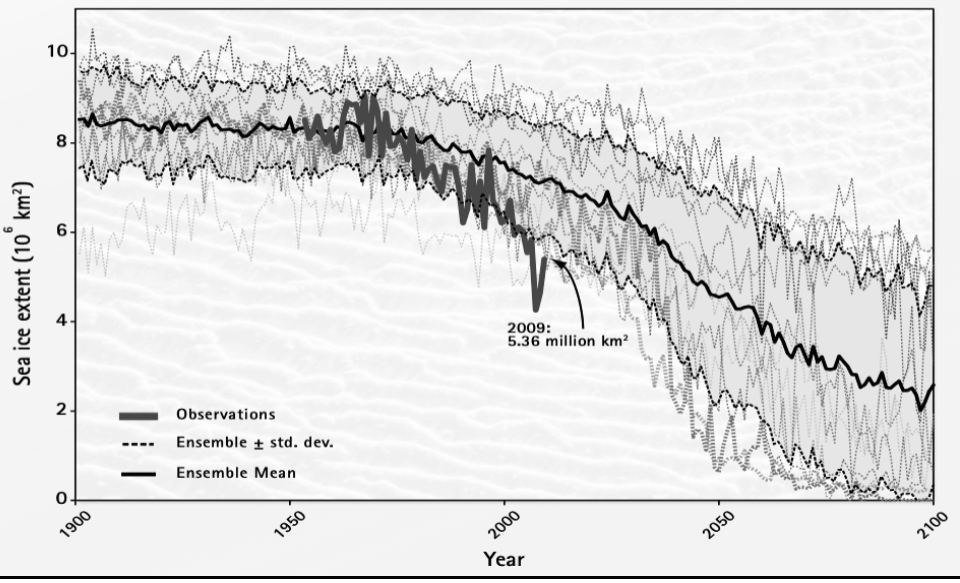


ECV Teams

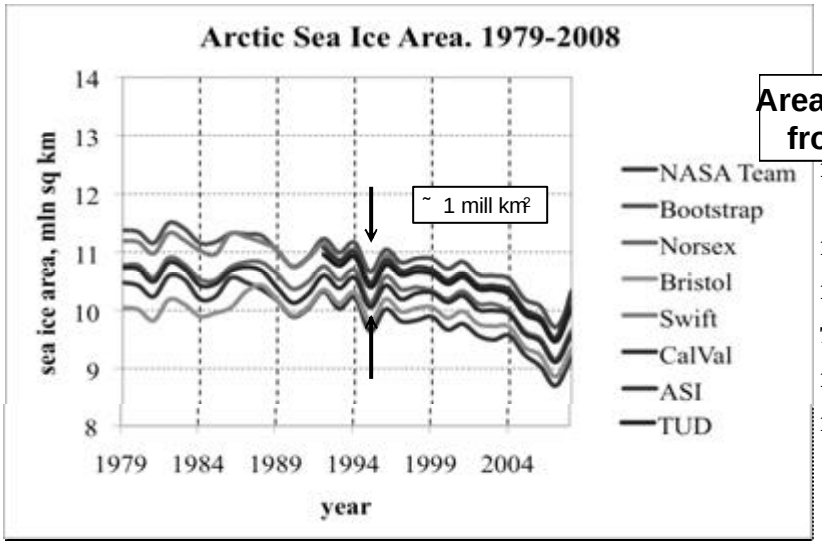
ECV	Science Leader
Cloud	*DWD*
Ozone	*BIRA*
Aerosol	*DLR/FMI*
GHGs	*U Bremen*
SST	*U Edinburgh*
Global Land Cover	*UCL*
Sea level	*CLS*
Ocean Colour	*PML*
Glaciers	*U. Zurich*
Fire Disturbance	*U.Alcala*

Sea ice

discrepancy between sea ice extent models (IPCC) and satellite observations...



Discrepancy between PMW sea ice concentration algortihms



Area decreas from 1979
13.7%
11.0%
11.1%
7.2%
12.0%
10.9%

Ivanova and Johannessen, 2010

sea_level_cci

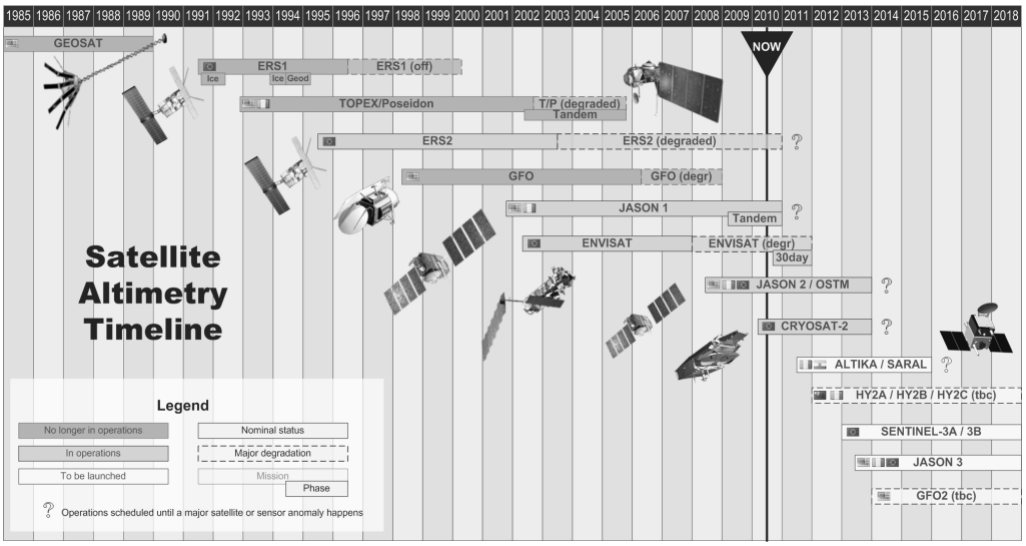
Sea_Level_CCI Team

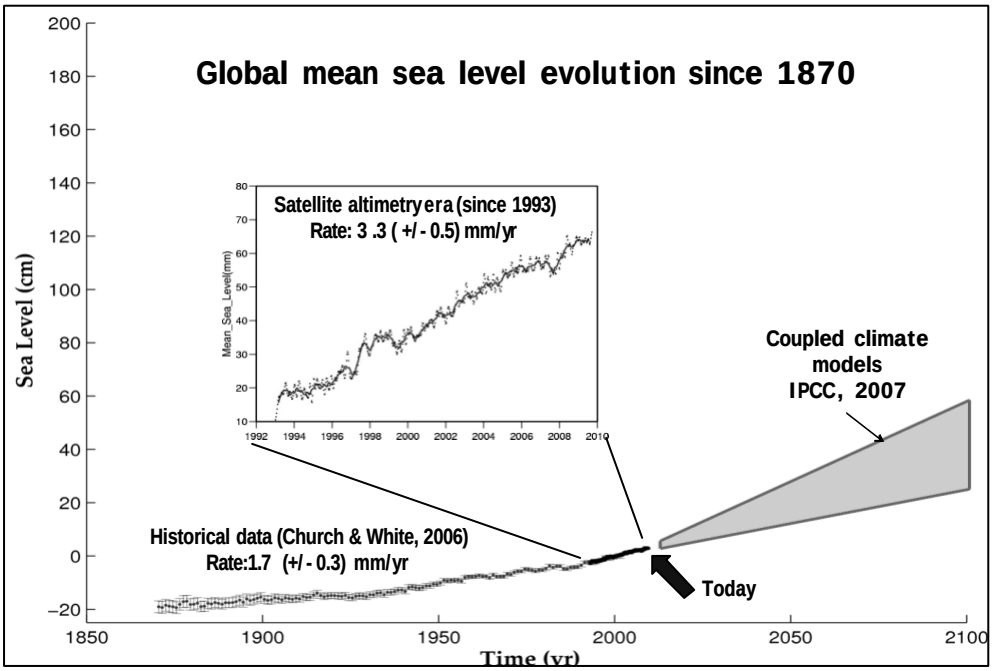
represented by Anny Cazenave (LEGOS, Toulouse)

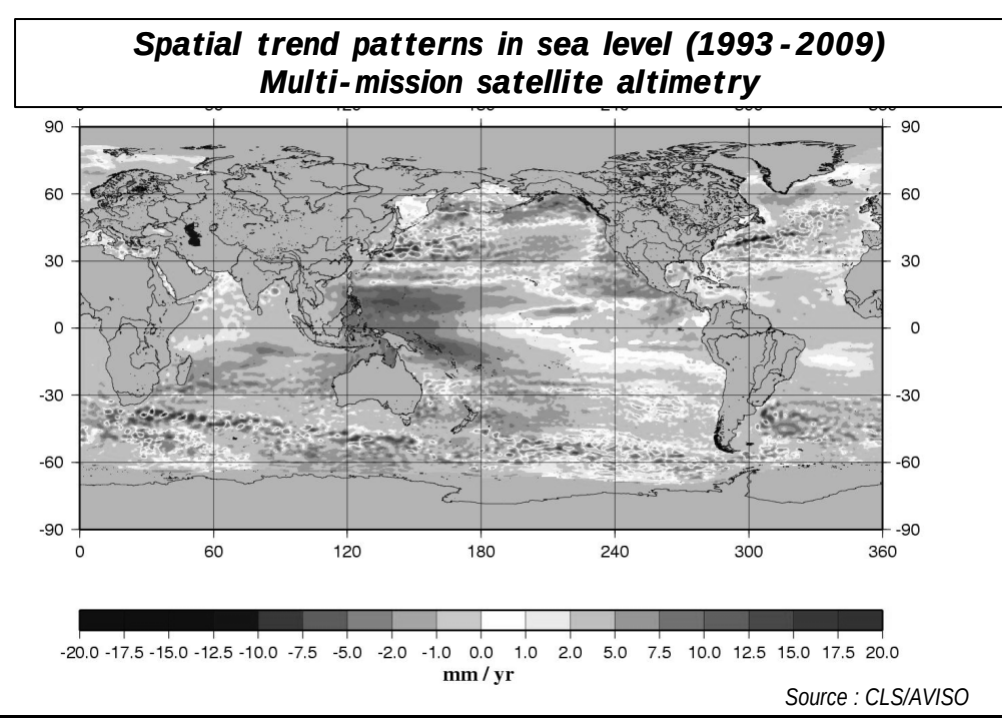
Sea Level: a sensitive index of climate change and variability

- it responds to change of ALL components of the climate system (ocean, atmosphere, cryosphere, hydrosphere) and even to solid Earth processes (GIA)
- Satellite and in situ observations indicate that sea level is currently rising
- It will continue to rise in the future decades
- But how much? We don't know.....
- Coastal impacts of sea level rise are among the most threatened consequences of global warming
- Coupled climate models neither provide yet reliable sea level projections nor reproduce adequately 20th Century sea level rise
- Accurate monitoring of sea level change (globally and regionally) by (multi-missions) satellite altimetry is a high-priority objective

ALTIMETRY MISSIONS




Global mean sea level evolution since 1870
Sea Level (cm)
Time (yr)
Satellite altimetry era (since 1993)
Rate: 3 .3 (+/ - 0.5) mm/yr
Mean_Sea_Level(mm)
Historical data (Church & White, 2006)
Rate:1.7 (+/ - 0.3) mm/yr
Coupled climate models
IPCC, 2007
Today

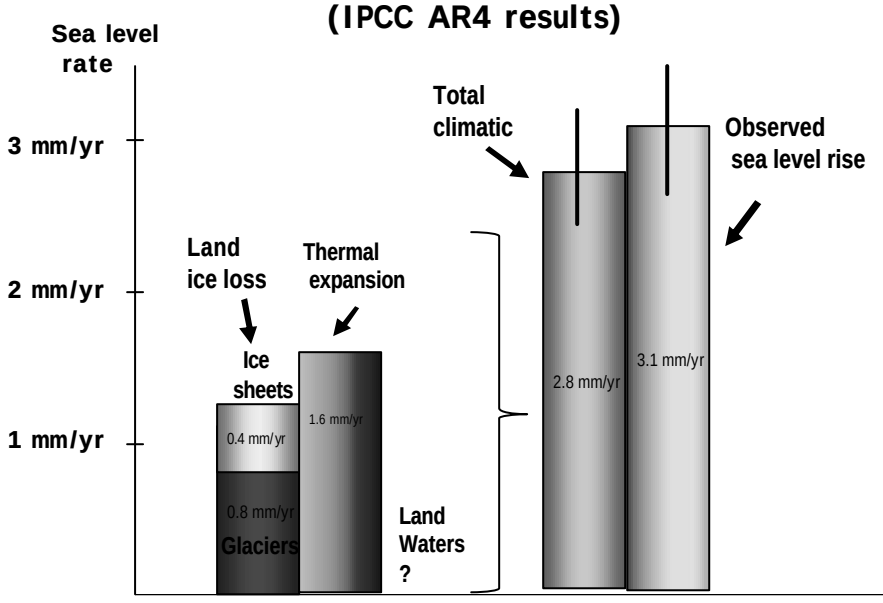

Spatial trend patterns in sea level (1993 - 2009)
Multi-mission satellite altimetry
mm / yr
Source : CLS/AVISO

The contributions:

-Ocean thermal expansion
-Glaciers
-Ice sheets
-Land waters

Sea Level Budget *1993-2003*

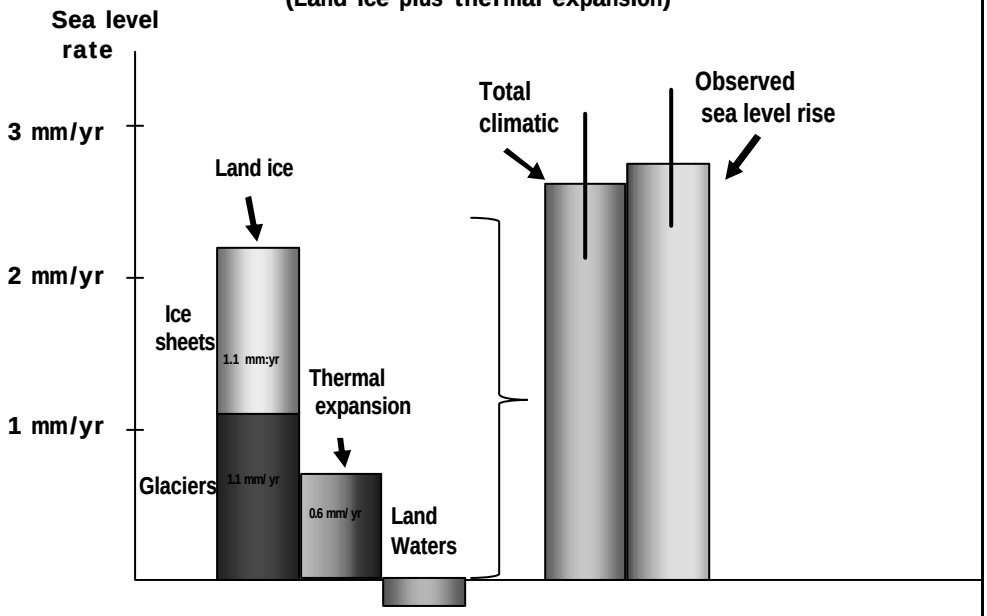
(IPCC AR4 results)



IPCC, 2007

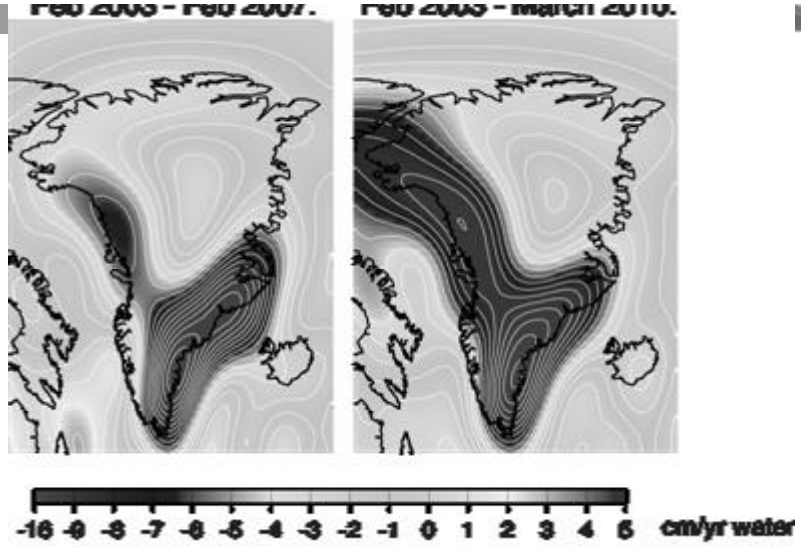
Sea Level Budget *2003-2009*

(Land ice plus thermal expansion)



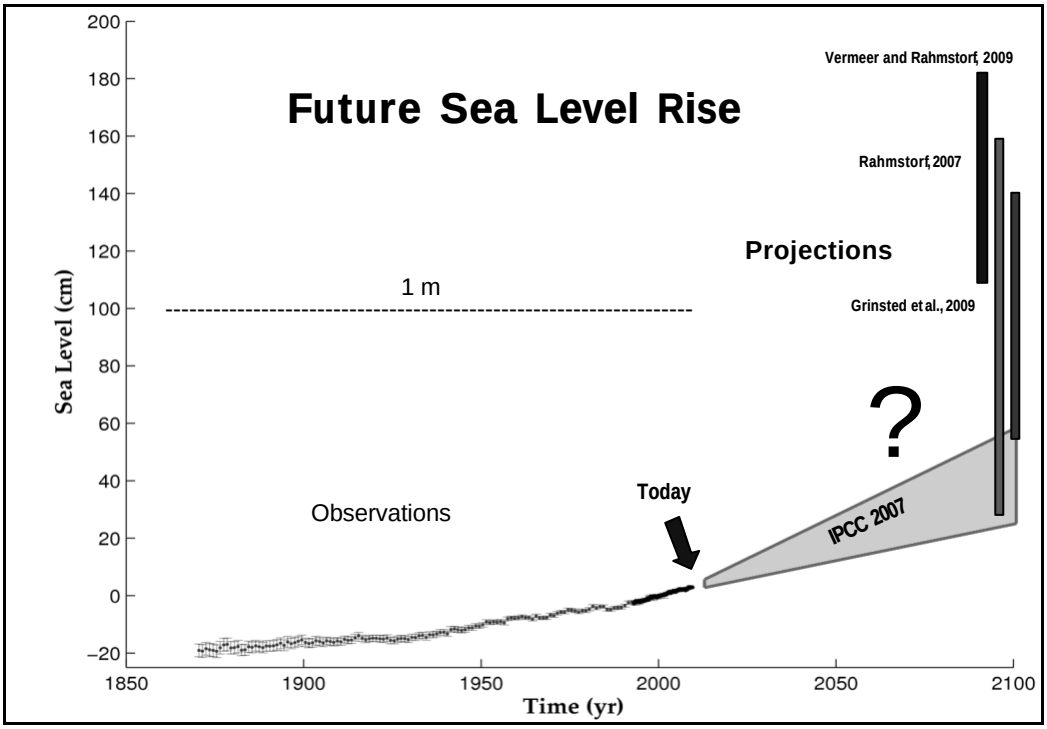
Cazenave & Llovel (2010)

Greenland: Rate of Mass Change from GRACE

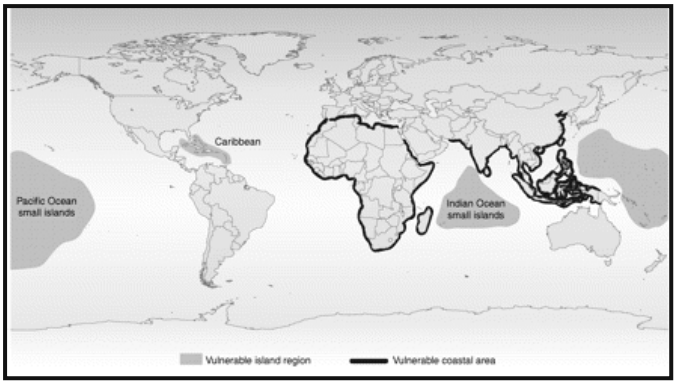


The mass loss has been spreading up the northwest coast the last 2-3 years.

J. Wahr, I. Velicogna (Courtesy of K. Steffen)



Regions most vulnerable to sea level rise



Nicholls and Cazenave, 2010

Global mean sea level trend: current error budget

Source	Trend error (mm/yr)
Orbit (Beckley et al., 2007; Ablain et al., 2009)	0.3
Wet atmos. (radiometer drift) (Ablain et al.)	0.3
Mission bias (Ablain et al.)	0.25
Dry atmos. (pressure fields) (Ablain et al.)	0.1
Sea state bias (Ablain et al.)	0.1
Quadratic sum (1 sigma)	***~ 0.5***
Tide gauge calibration (Micthum and Nerem; Beckley et al.; Ablain et al.)	0.4

GCOS requirements for the « Sea Level » ECV

Accuracy : **1 cm** (single sea surface height measurement)
Spatial resolution: **25 km**
Temporal resolution: **daily**
Stability: **0.5 mm/decade (sea level change)**

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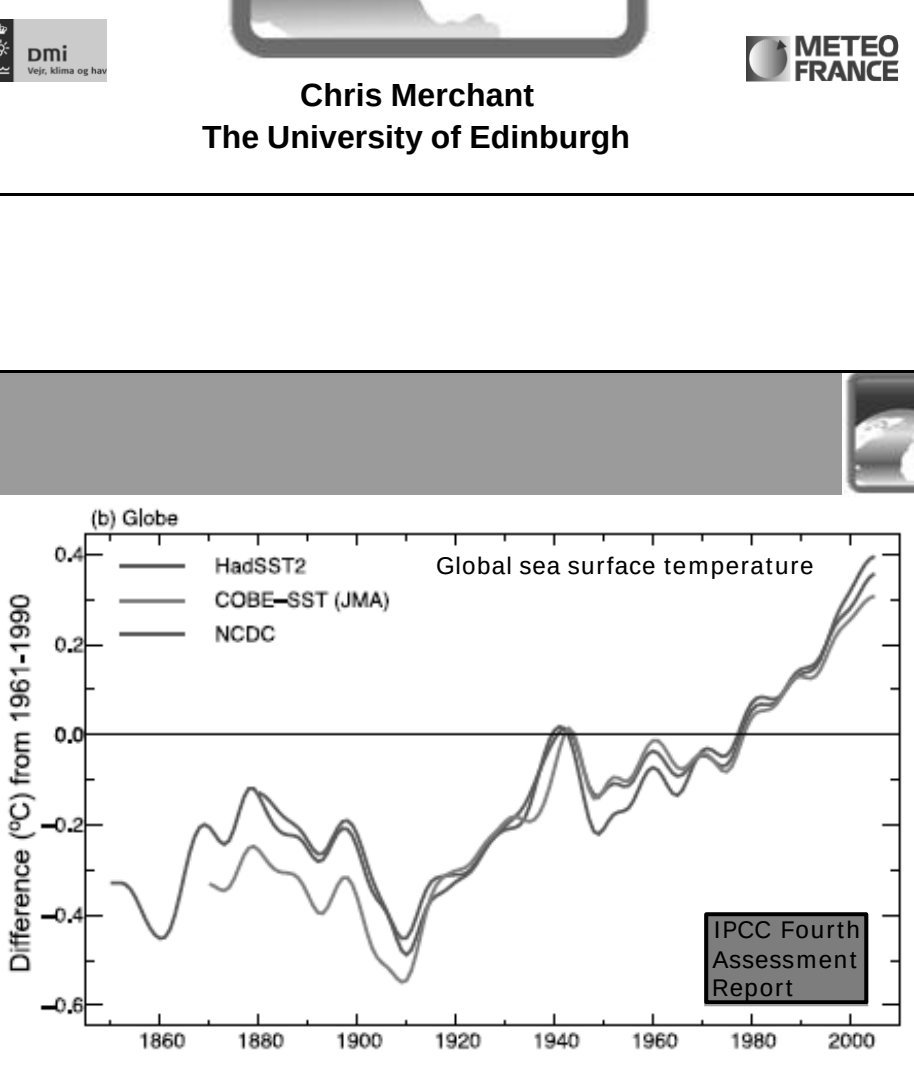
•Current status of altimeter error budget is far from the GCOS requirements (see Ablain et al. 2009)

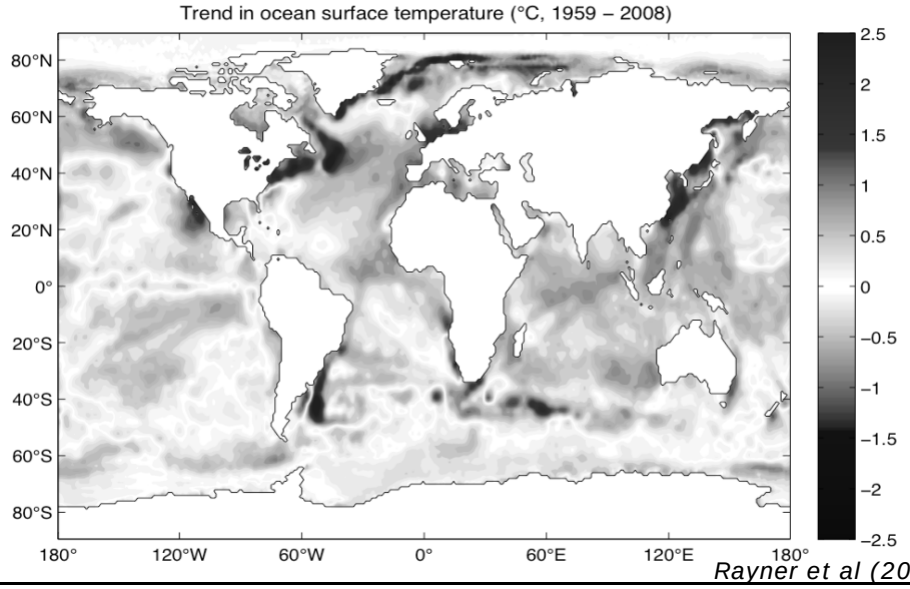
→ Error budget will be refined during the Sea_Level_CCI project

sst_cci

Chris Merchant
The University of Edinburgh



Trend in ocean surface temperature
^{o}C 1959-2008

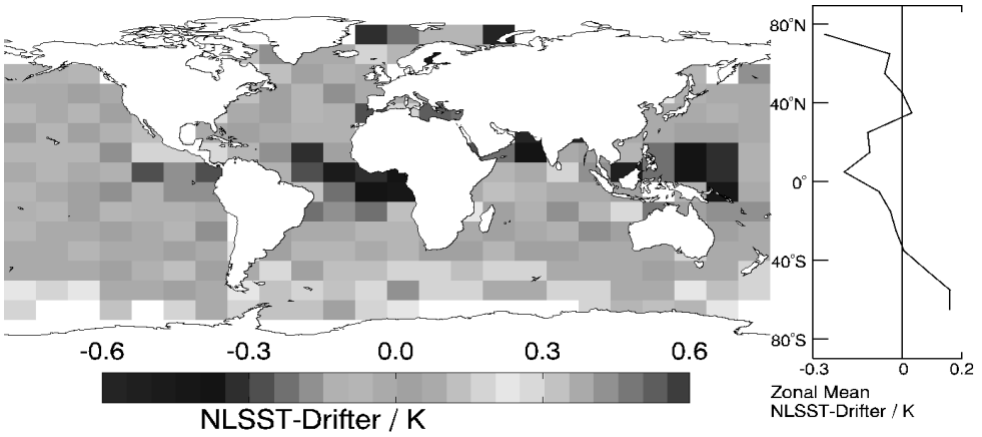


Rayner et al (2009)

GCOS requirements

- **Accuracy (absence of bias): 0.25 K**
- **Stability (constancy of bias): 0.1 K decade^{-1}**
- **1 km resolution**
- **3 hourly observing cycle (no aliasing of diurnal cycle into longer term)**

Accuracy in Pathfinder AVHRR



National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

THE UNIVERSITY OF EDINBURGH

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L17604, doi:10.1029/2009GL039843, 2009

Retrieval characteristics of non-linear sea surface temperature from the Advanced Very High Resolution Radiometer

C. J. Merchant,[1] A. R. Harris,[2] H. Roquet,[3] and P. Le Borgne[3]

ATSR Reprocessing for Climate

- **Independence of in situ observations**
- **Accuracy: 0.1 K over regional scales**
- **Stability: 0.05 K / decade**
  - **Homogeneous, corrected for diurnal cycle**
- **0.1 deg resolution, >15 year record**
- **Detailed uncertainty characterisation**

Merchant C J, D Llewellyn-Jones, R W Saunders, N A Rayner, E C Kent, et al. (2008) , Deriving a sea surface temperature record suitable for climate change research from the along-track scanning radiometers, Adv. Sp. Res, 41 (1), 1-11. doi:10.1016/j.asr.2007.07.041

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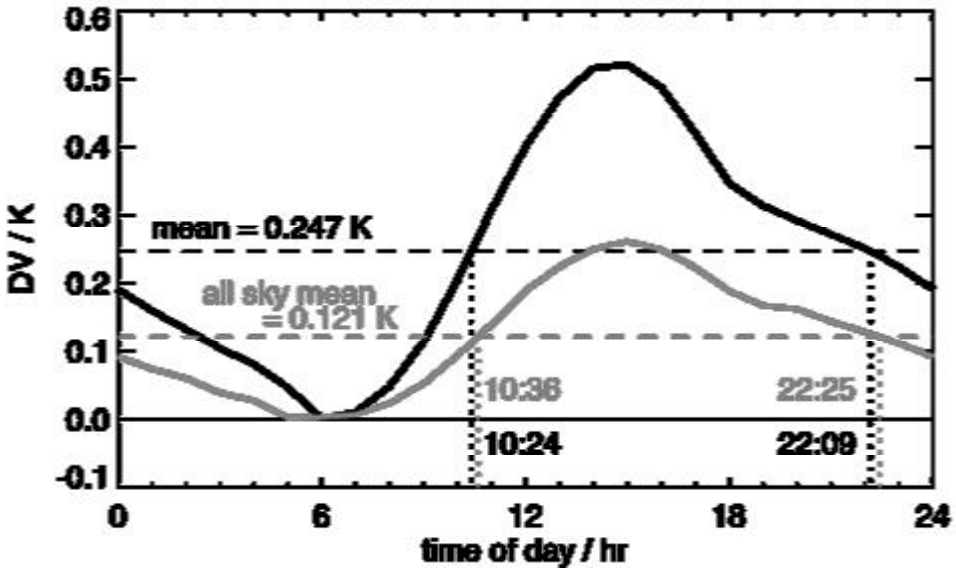
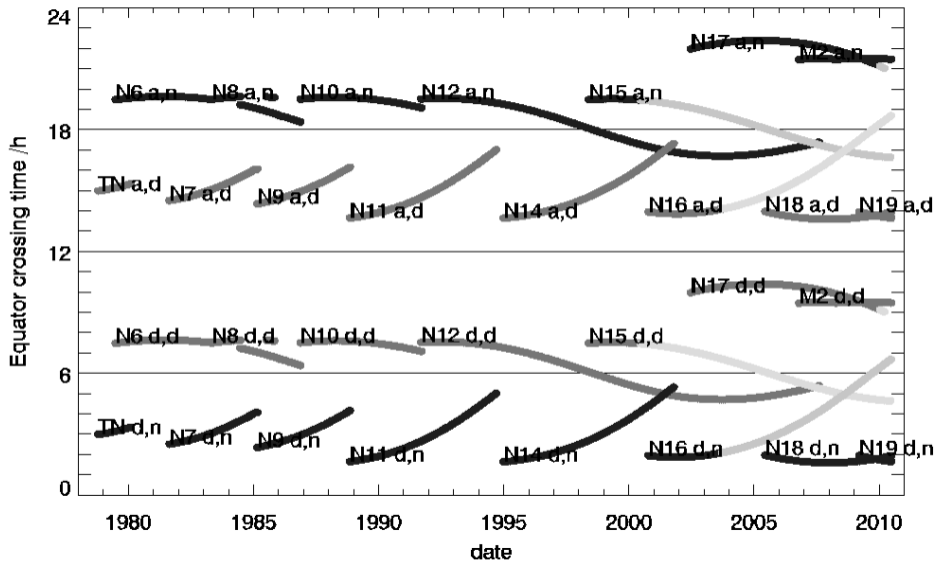
ENERGY & CLIMATE CHANGE

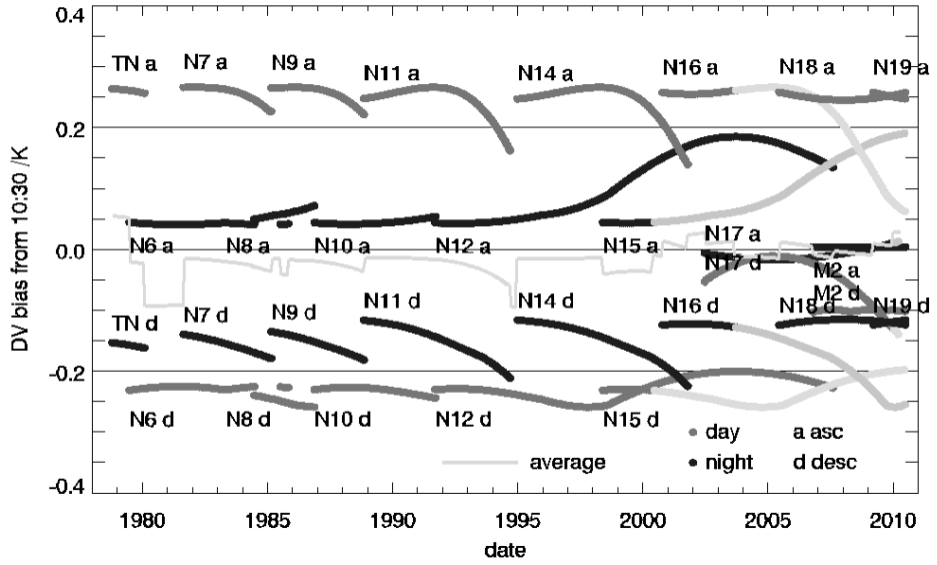
Mean diurnal cycle



AVHRR orbit drift



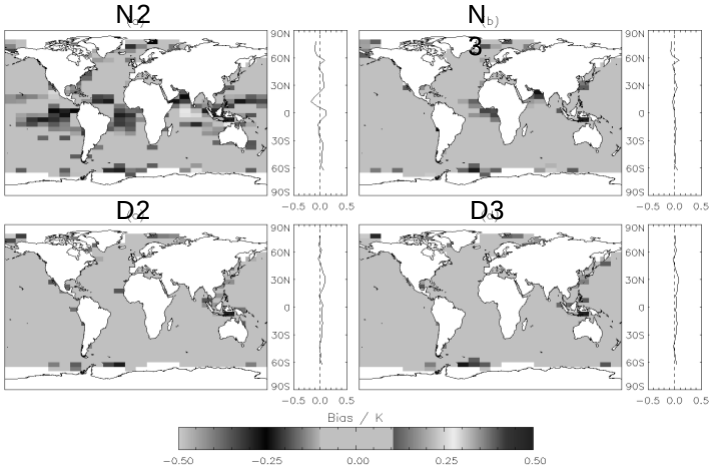
AVHRR orbit drift



Characteristics of Long Term CCI SST

	PATHFINDE	ARC	CCI SST
Sensors	AVHRR	ATSR	AVHRR + ATSR
Tied to	Drifting	Independent	Independent
Homogenized	No	Yes	Yes
Accounting for diurnal effects	No	Yes	Yes
Meets GCOS accuracy (0.25 K)	No	Yes	Yes
Meets ARC target accuracy (0.1	No	Mostly	Yes/mostly
Retrieval method	Coefficients	Coefficients	Optimal
Meets GCOS stability	No	Likely	Likely
Stability quantified	No	Yes	Yes
Clearly defined SST	No	SST-skin, depth	SST-skin, sub-skin, depth
Stable during strat. aerosol	No	Yes	Yes
Quantified uncertainties	No	Yes	Yes
Spatial resolution	4 km	0.1^{o}	1 km to 0.05^{o}
GHRSST & netCDF compliant	No	No	Yes

ARC SST bias cf. drifting buoys



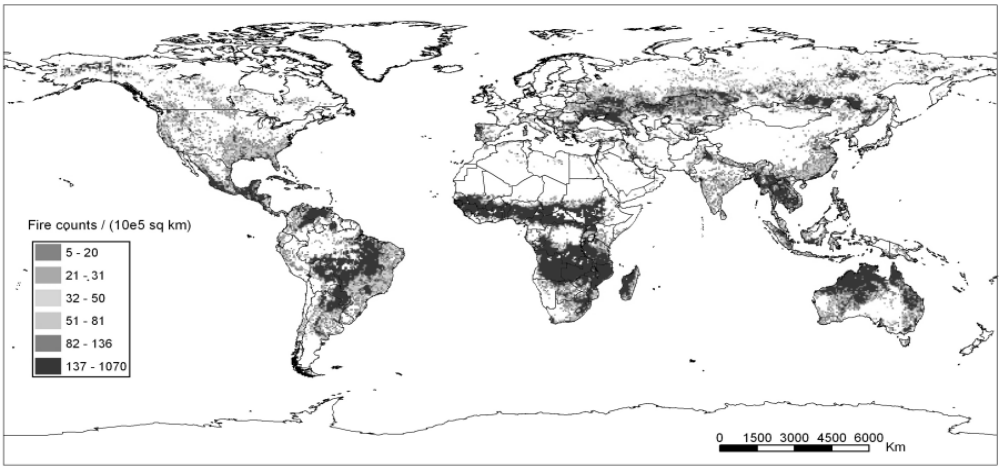
Merchant C J, P Le Borgne, A Marsouin and H Roquet (2008), Optimal estimation of sea surface temperature from split-window observations, Rem. Sens. Env., 112 (5), 2469-2484. doi:10.1016/j.rse.2007.11.011

Embury, O., C. J. Merchant and G. K. Corlett (submitted), A Reprocessing for Climate of Sea Surface Temperature from the Along-Track Scanning Radiometers: Preliminary validation, accounting for skin and diurnal variability, Rem. Sens. Env.

Fire Disturbance

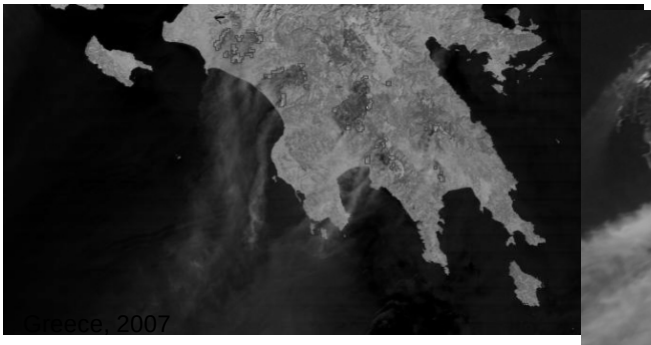
Emilio Chuvieco
University of Alcalá (Spain)

Fire is a global phenomenon…

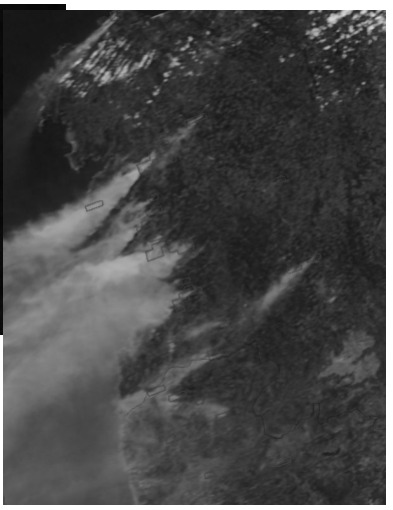


Around 30% of the emerged world has some relevant fire activity (Chuvieco et al., 2008, GCB)

With critical regional implications…



Greece, 2007



Spain, 2006

Fire and Global change

- **Biomass burning has significant effects on:**
  - **Land use / cover change, carbon budgets**
  - **Global GHG emissions**
  - **Biodiversity**
- **Fires are also affected by climate change. Changes in fire regimes:**
  - **Longer season.**
  - **Greater severity.**
  - **Fires in new areas (Rainforest)**
- **Impacts of fires depend on whether they are adapted to "natural" fire regimes.**

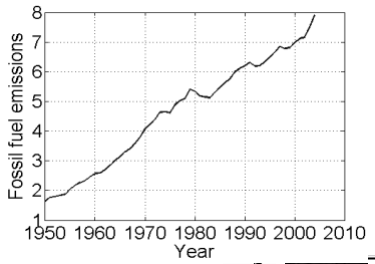
Fires and CO2 emissions

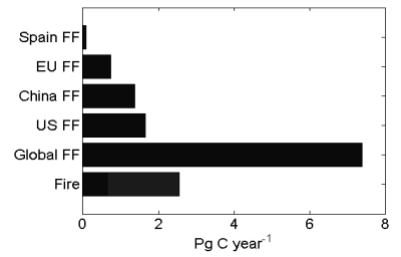
Temperate & boreal forest:	0.25 Pg C / year
Savanna & grassland:	1.35 Pg C / year
Tropical rainforest:	0.65 Pg C / year
Shrubland:	0.10 Pg C / year
Agriculture:	0.20 Pg C / year
Total:	2.55 Pg C / year

(!! highly uncertain !!)

Van der Werf, 2008

Fossil fuels 7.2
Deforestación 1.5

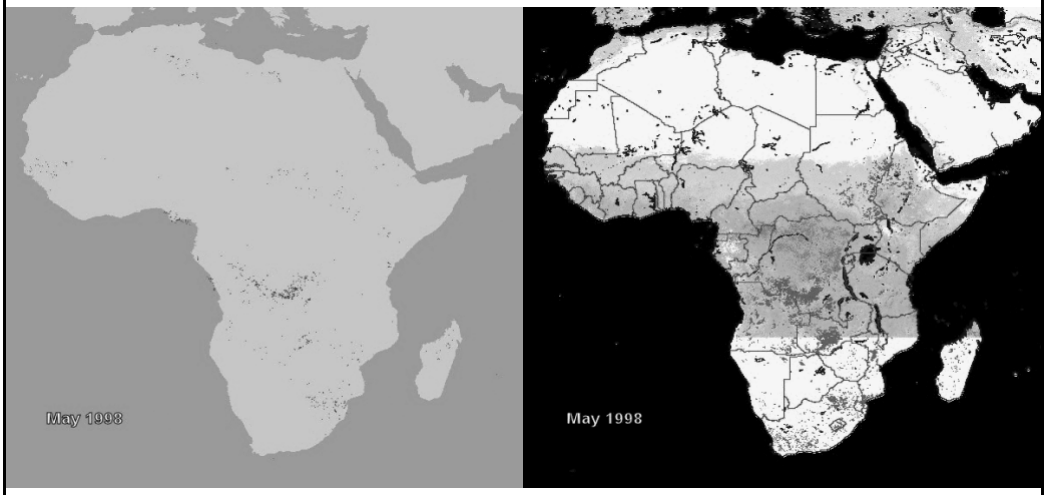




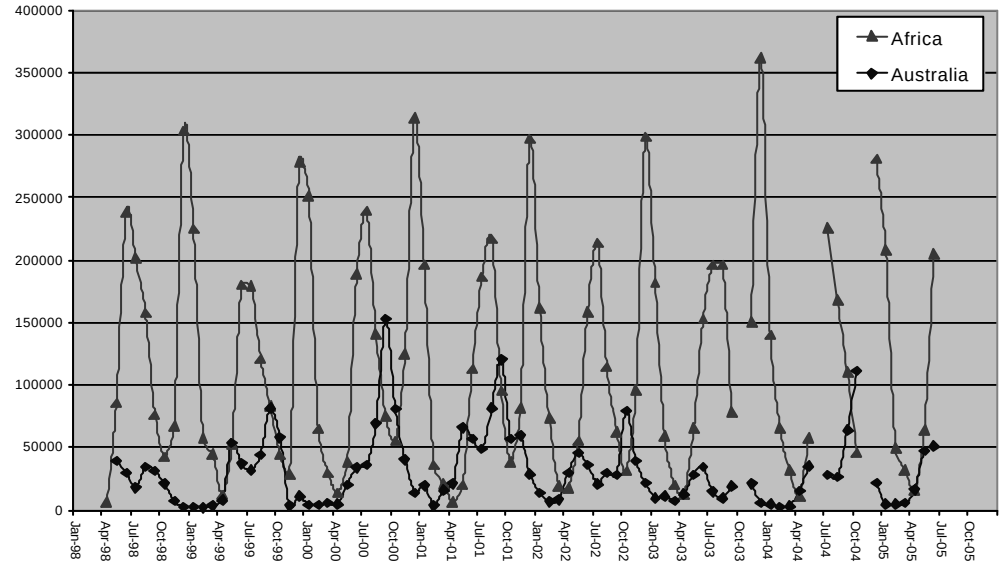
Critical Questions

- **What is the actual magnitude of fire impacts?**
  - **How much area is burned annually?**
  - **How much biomass is actually consumed?**
  - **What is the combustion efficiency?**
  - **Solve uncertainties.**
- **What are the recent trends in fire activity?**
  - **Long time series.**
  - **Consistent outputs.**

Africa 1998-1999 BAE



GLOBCARBON BA Yearly Variation

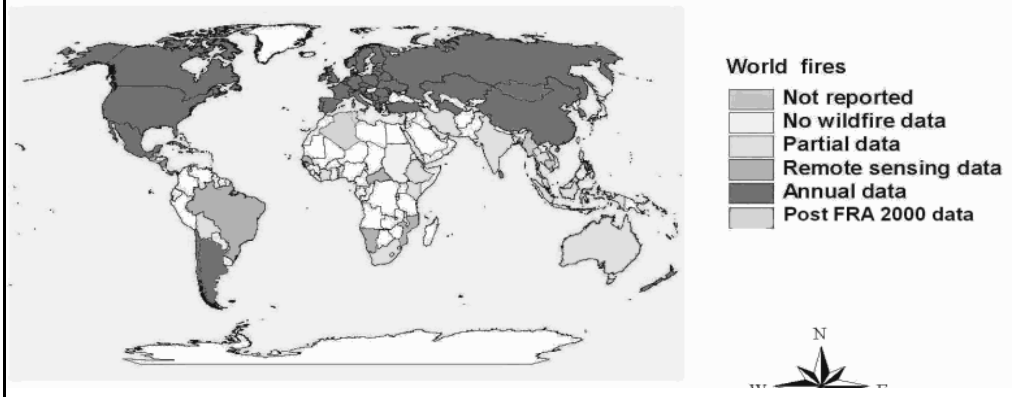


Temporal variation in continental burning

GCOS Fire requirements (GCOS, 2006)

- **Relative calibration of VIS, NIR and SWIR channels to within 2% over the full lifetime of each instrument**
- **BA Product:**
  - **Accuracy: 5% (maximum error of omission and commission)**
  - **Spatial resolution: 250 m**
  - **Temporal resolution: daily observing cycle**
  - **Stability: 5%**
- **can not be met with current data…**

Quality of World Fire Statistics



(FAO 2000)

Fire databases: spatial and Temporal inconsistencies

Figure 3. Locations of fires (red symbols) flagged with an identifiable problem from the original federal fire occurrence database.

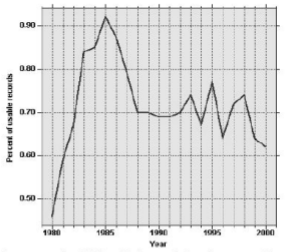


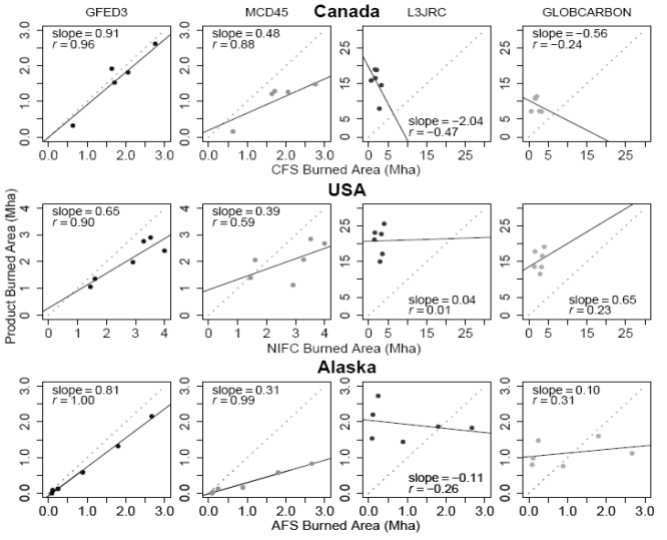
Figure 5. Annual percent number of BIA usable fire records from the coarse quality controlled U.S. federal wildland fire database for the period 1970-2000.

Figure 6. Annual percent number of BLM usable fire records from the coarse quality controlled U.S. federal wildland fire database for the period 1970-2000.

Need for Product validation and assessment

- **Current global BA products:**
  - **MCD45**
  - **GFED v3**
  - **GLOBCARBON**
  - **L3JRC**
- **Total burned area: 3.7 MKm².**
- **However:**
  - **Systematic validation not performed.**
  - **Preliminary analysis shows many uncertainties and inconsistencies.**

Uncertainty: Comparison of global products



(Giglio et al., 2010).

Inconsistencies

- **Slopes of regression line: from 0.85 to 0.33 depending on the algorithms.**

LOGICAL OR	Number of Hexes	Correlation gradient	Correlation intercept	Correlation standard deviation
Global	454	0.8517	5.4424	10.1576
North America	106	2.4785	6.9787	9.1000
South America	85	0.9359	0.6062	3.3052
Europe	46	1.1753	4.4405	9.2483
Africa	76	0.9350	4.0309	10.0727
Asia	20	1.4278	11.5742	17.1363
Australia	121	0.7653	4.6500	8.5929

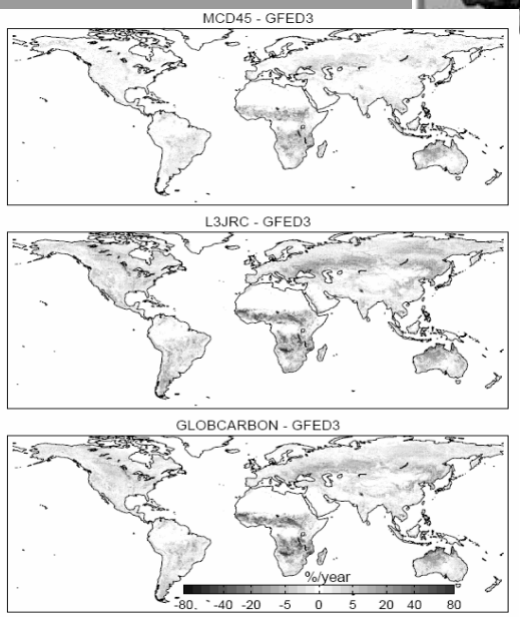
GLOBCARBON DPQRv4.2 Demonstration Products and Qualification Report version 4.2 December 2007

GLOBCARBON

Global comparison

Red: over estimation
Blue: under estimation

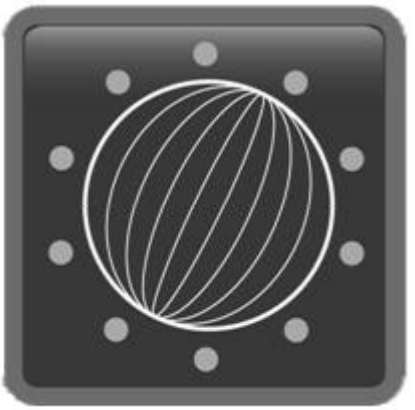
(Giglio et al., 2010).



BA Production targets

- **Temporal series over 10 selected areas (500x500 km) (1995-2009):**
  - **Assure temporal consistency and stability.**
  - **Demonstrate full-time series available.**
- **Global coverage for five years:**
  - **Demonstrate the semi-operational processing.**
  - **Ensemble chain, bulk processing of data.**

what do climate modellers say ?



Roger Saunders
Met Office Hadley Centre

Climate Modelling User Group

- Sea-ice
- Sea-level
- Sea surface temperature
- Ocean Colour
- Glaciers and ice caps
- Land Cover
- Fire disturbance
- Cloud properties
- Ozone
- Aerosols
- Greenhouse Gases

Met Office Hadley Centre
Climate Modelling
NWP
HadGEM3, FOAM, HadSST

Climate Modellers

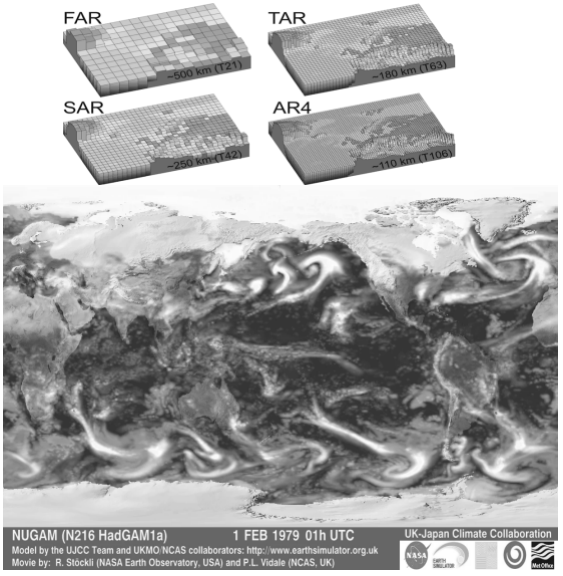
Reanalyses

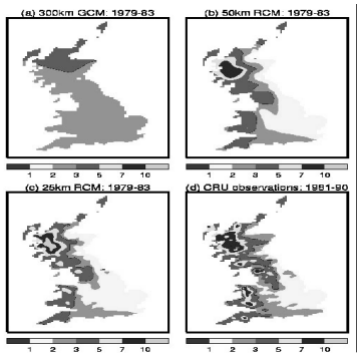
ECMWF
Reanalyses
NWP
IFS (ERA-Interim)
MACC

MPI-Hamburg
Climate Modelling
MPI-M/ESM, JSBACH

MétéoFrance
Climate Modelling
NWP
Arpege, MERCATOR
CNRM-CM, MOCAGE

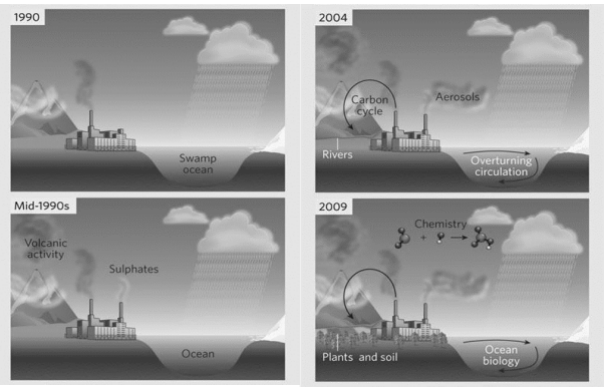
Model resolutions are increasing…





E.g. the new Met Office model, HadGEM3, will have a horizontal resolution of ~ 60 km and 85 vertical levels

Climate models are becoming increasingly complex…

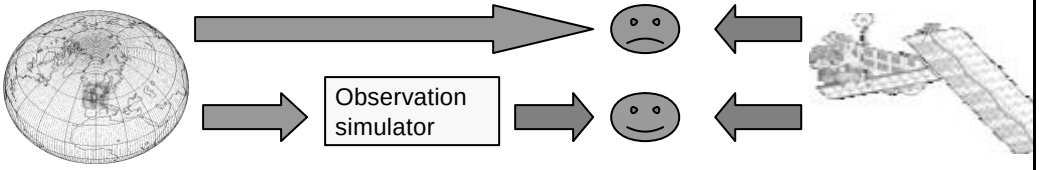


W. Collins et al., 2008

A fully coupled Earth System Model includes:

- **Atmosphere, ocean, sea-ice, land surface**
- **Land ecosystems: vegetation, soils**
- **Ocean ecosystems: plankton**
- **Aerosols: sulphate, black carbon, organic carbon, dust, sea salt**
- **Tropospheric chemistry: ozone, methane, oxidants**

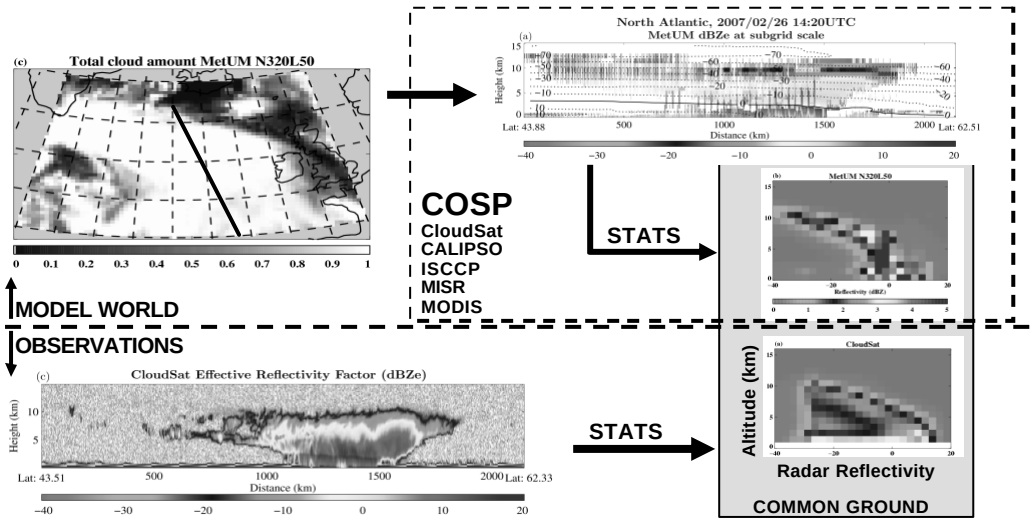
Use of observations evolving..



- **Forward modelling of measured quantities (radiances, skin SST, radar reflectivities) rather than high-level products (profile retrievals, bulk SST, cloud properties)**
- **Ensures more direct comparison of equivalent model variable with observations**
- **This was the key for use of ISCCP clouds**

COSP

CFMIP Observational Simulator Package



Implications for requirements

- **The new ECV datasets must have *added value* over existing ones and *future proof* for model evolutions**
- **Datasets should have global coverage and for some applications >15 years**
- **Be clear about applications for specific dataset as this drives the required accuracy:**
  - **Climate monitoring** — **high stability, precision and accuracy**
  - **Change detection** — **high stability, precision**
  - **Evaluate processes in model** — **high precision and accuracy**
  - **Model validation** — **high stability, precision**
  - **Assimilation** — **high precision**
- **Uncertainty estimates are as important as product itself for all applications. Correlation of errors in space / time also important**

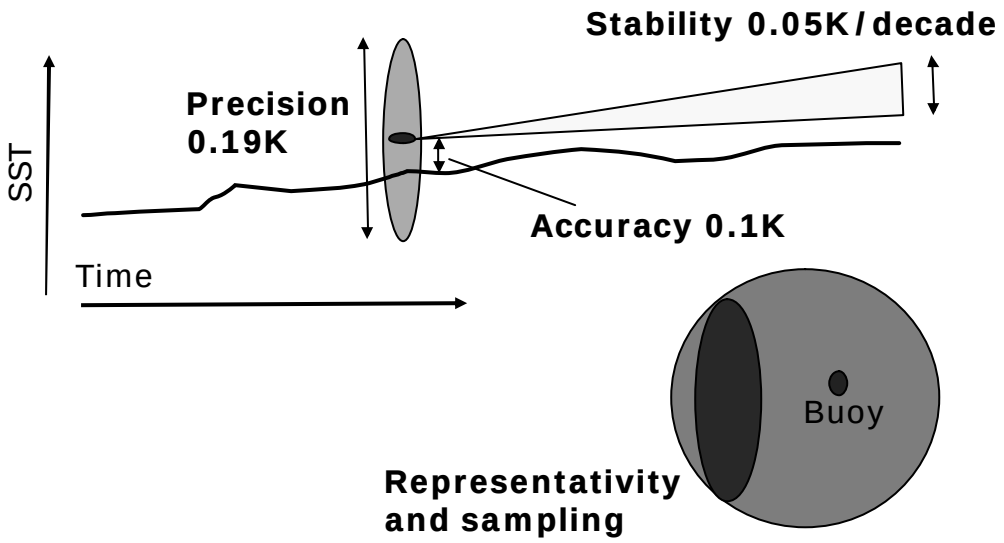
Error characterisation of CDRs

- **An estimate of the errors for each CDR produced is *essential* for use in climate applications**
- **There are several types of errors**
  - **Precision**
  - **Accuracy**
  - **Stability**
  - **Representativeness**

See next slide for definitions

- **The importance of specifying each depends on the application**
- **Errors should be specified on *a FOV basis.* Aggregated error estimates are not sufficient**
- **Single sensor products are simpler than merged products**
- **Error correlations are also important to document**

Example of different errors

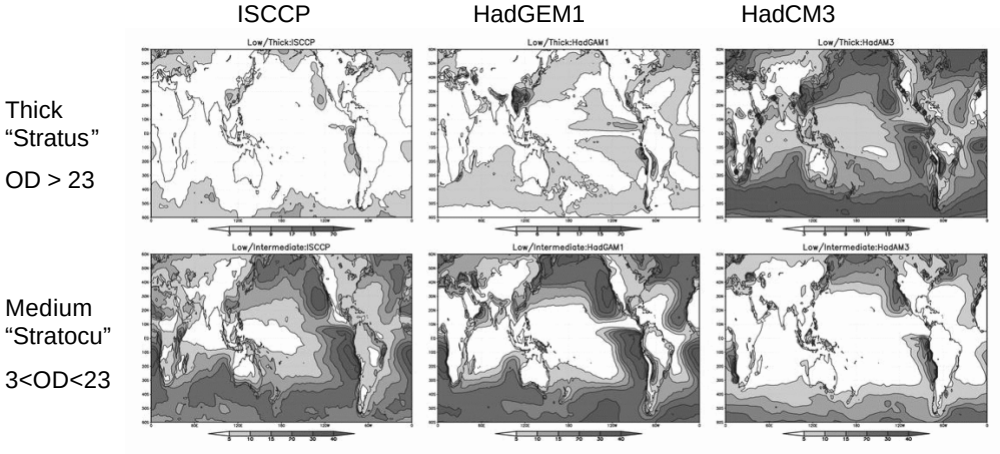


Errors associated with CDRs (from BIPM meeting)

- ***Accuracy*** **is the measure of the non-random, systematic error, or bias, that defines the offset between the measured value and the true value that constitutes the SI absolute standard**
- ***Precision*** **is the measure of reproducibility or repeatability of the measurement without reference to an international standard so that precision is a measure of the random and not the systematic error. Suitable averaging of the random error can improve the precision of the measurement but does not establish the systematic error of the observation.**
- ***Stability*** **is a term often invoked with respect to long-term records when no absolute standard is available to quantitatively establish the systematic error - the bias defining the time-dependent (or instrument-dependent) difference between the observed quantity and the true value.**
- ***Representativity*** **is important when comparing with or assimilating in models. Measurements are typically averaged over different horizontal and vertical scales compared to model fields. If the measurements are smaller scale than the model it is important. The sampling strategy can also affect this term.**

Use of ISCCP to evaluate models

Low level cloud: CTP < 680 hPa



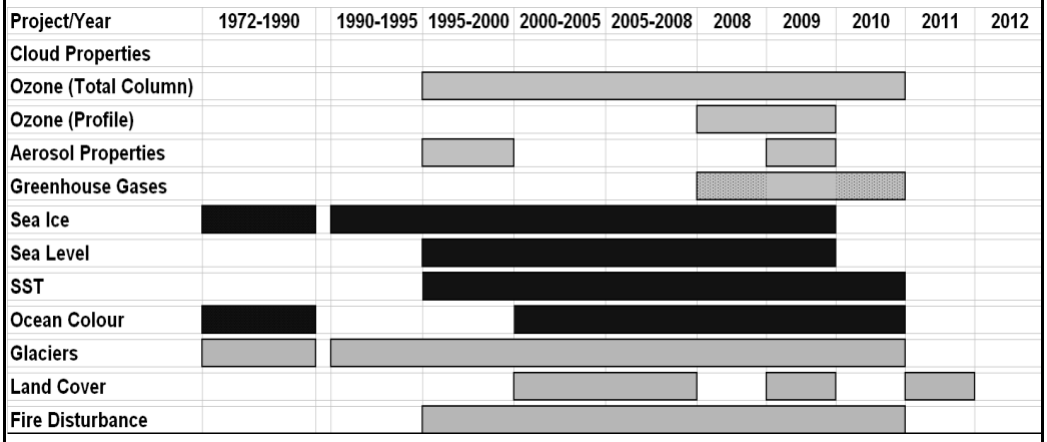
Martin et al. (2006)

Lessons learnt from past

- **Recognise move of modellers to using lower level of products (e.g. level 1 or 2).** ***This is especially true for reanalyses***
- **It took more than 15 years to get ISCCP cloud a ATSR SST datasets used for climate**
- **Observation simulators are important for some satellite products to compare apples with apples (e.g. clouds ..)**
- **Essential to include error characteristics**
- **Easy access to data and simple format to read**

- **integrated and consistent approach**
- **to generating space-based climate records**

“baseline” requirement per ECV



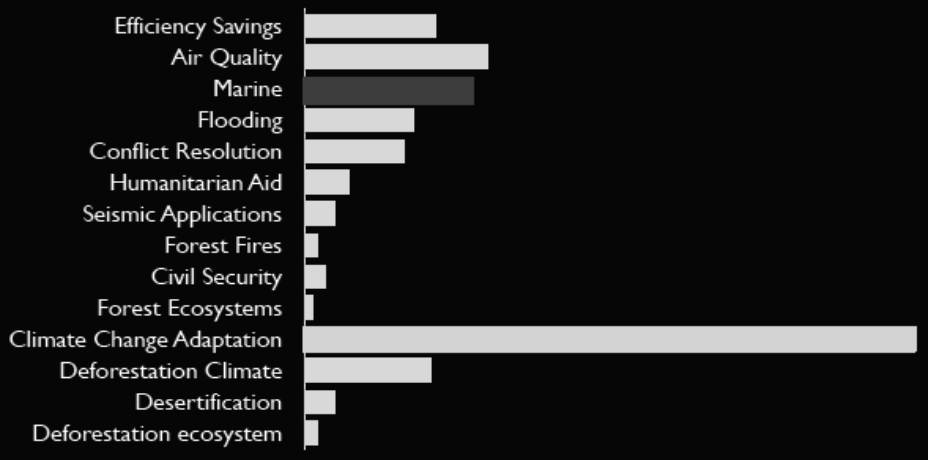
key issues for climate records

- **error-characterization**
- **openness, traceability, repeatability**
- **scientific cooperation**

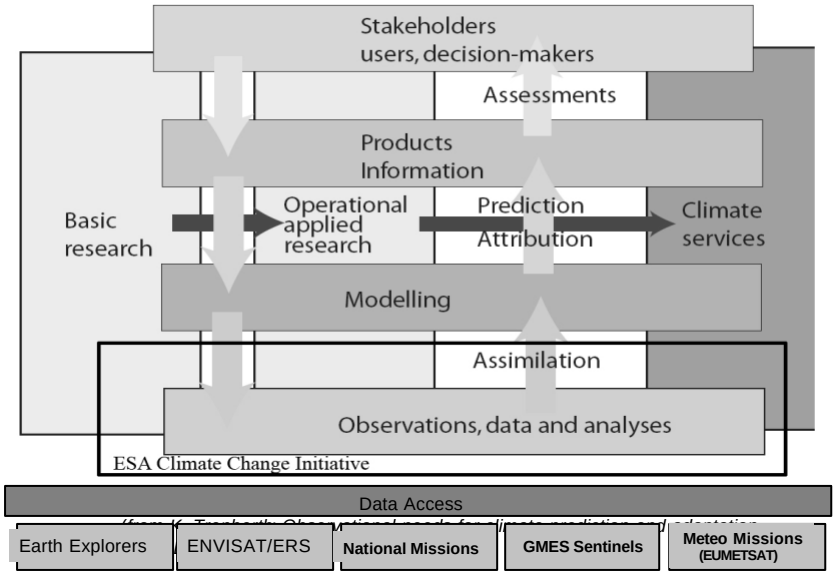
the big picture...

socio-economic benefits

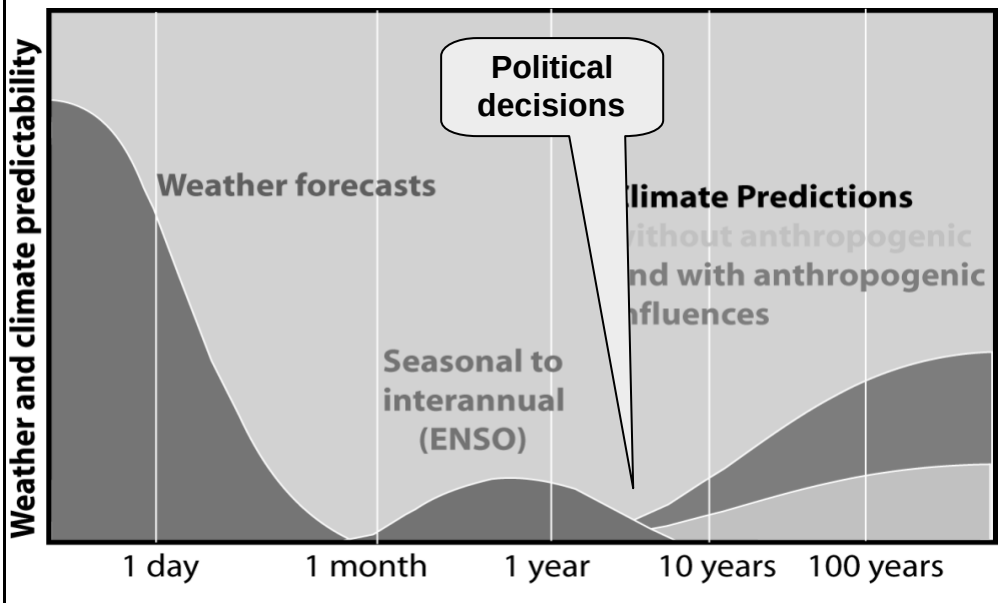
(GMES 25 years)



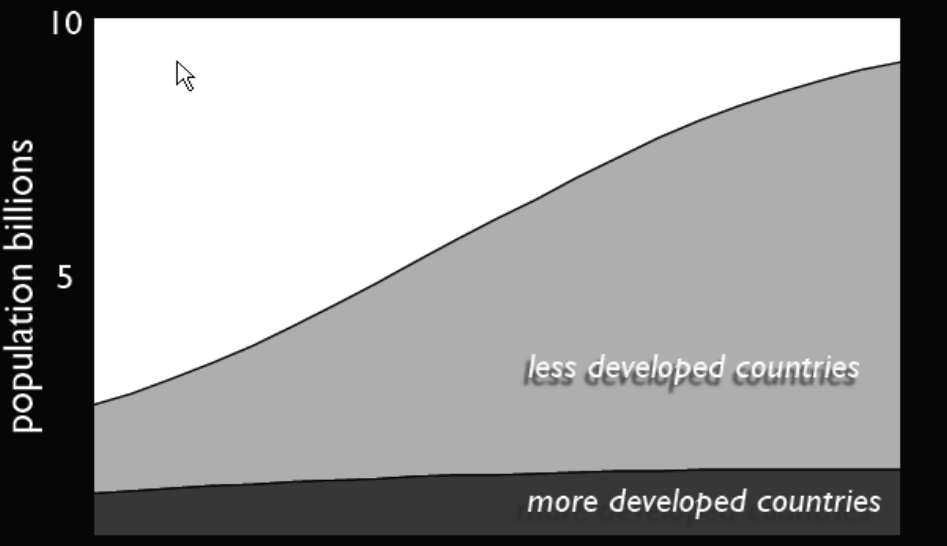
the big picture…



Predictability of weather and climate (K Trenberth)



benefits? who? where? when?



esa

thank you…