The Importance of Calibration and Intercalibration for Climate studies

Calibration, Validation and Uncertainties

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Issues for Climate Modelling

Slides extracted from a presentation made by

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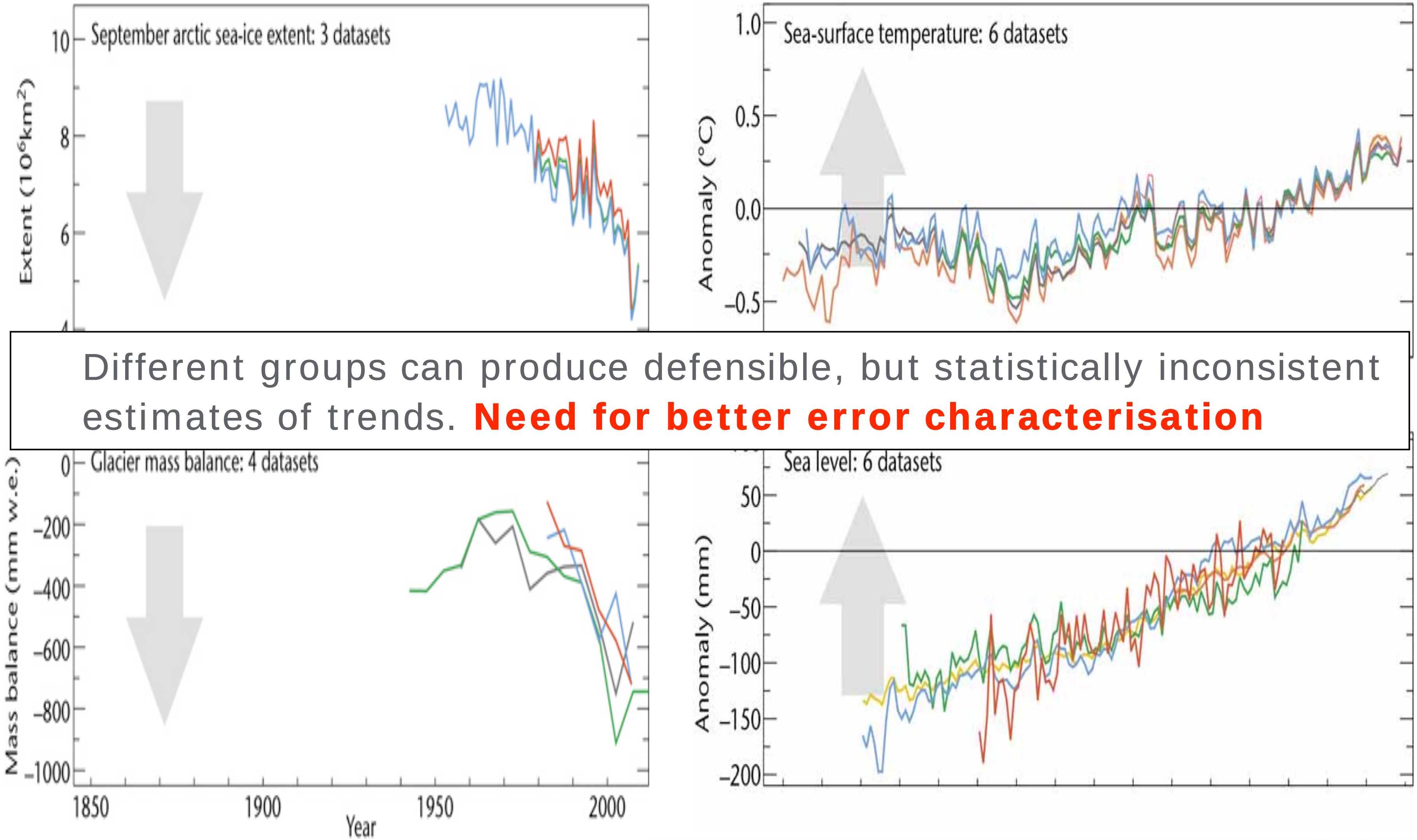
Issues for Climate Modelling

- Higher resolution (horizontal, vertical, time)
- Regional climate prediction (e.g. UKCP)
- More physical processes
- Seasonal to decadal prediction
- Use of reanalyses for climate
- Seamless prediction
  - Weather prediction to climate change using same model
- Metrics developed to evaluate models
  - ESA CCI datasets can help here
- The way observational data is used, is evolving

Climate Monitoring and Attribution



Different groups can produce defensible, but statistically inconsistent estimates of trends. **Need for better error characterisation**

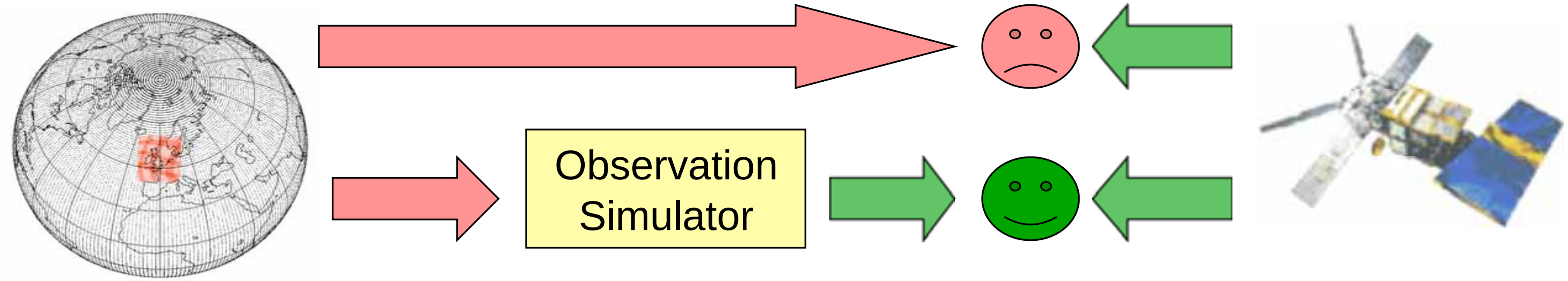
Error Characterisation of CDR

- An estimate of the errors for each CDR produced is ***essential*** for use in climate applications

- The types of errors recently defined by GCOS
  - Accuracy: The rms difference between the single or averaged values of a variable and the truth.
  - Stability: The extent to which accuracy of a time average remains constant over a longer time period (e.g., annual average relative to decadal average).

- 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

The use of Observations is 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
    - ISCCP - International Satellite Cloud Climatology Project

Level 1b products
Fundamental Climate Data Records

The example of Scatterometers

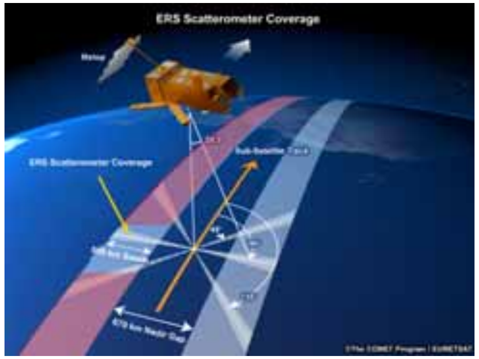
Scatterometers

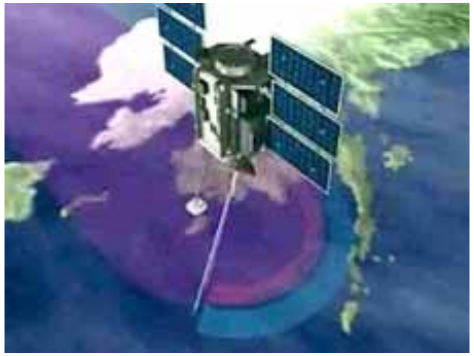
- In Europe,

– ERS-1 - AMI (1991)	C-Band	fan-beam
– ERS-2 - AMI (1995)	C-Band	fan-beam
– Metop - ASCATT (2007)	C-Band	fan-beam

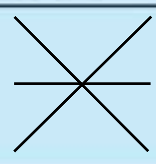
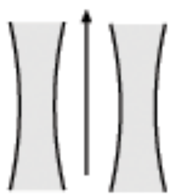
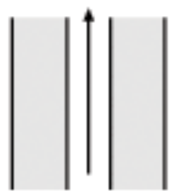
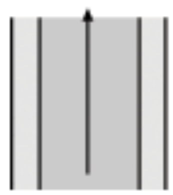
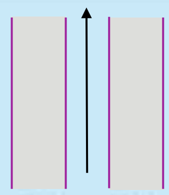
- In US,

– Seasat - SASS (1978)	Ku-band	fan-beam
– NSCAT (1996)	Ku-band	fan-beam
– QuikSCAT - SeaWinds (1999)	Ku-band	scanning
– ADEOS-2 - SeaWinds (2003)	Ku-band	scanning





Scatterometers

	SASS	ESCAT	NSCAT	SeaWinds	ASCAT
FREQUENCY	14.6 GHz	5.3 GHz	14.0 GHz	13.4 GHz	5.255 GHz
ANTENNA AZIMUTH ORIENTATIONS					
POLARIZATIONS	V-H, V-H	V ONLY	V, V-H, V	V-OUTER/H-INNER	V, V, V
BEAM RESOLUTION	FIXED DOPPLER	RANGE GATE	VARIABLE DOPPLER	PENCIL-BEAM	RANGE COMPRES.
MODES	MANY	SAR, WIND	WIND ONLY	WIND/HI-RES	WIND ONLY
RESOLUTION	50/100 km	25/50 km	25/50 km	25 km/6x25 km	12.5/25 km
SWATH, km	 750 750	 500	 600 600	 1400,1800	 500 500
INCIDENCE ANGLES	0° - 70°	18° - 59°	17° - 60°	46° & 54°	25º - 65º
DAILY COVERAGE	VARIABLE	< 41 %	78 %	92 %	82 %
DATES	SEASAT 6/78—10/78	ERS-1 1992—96 ERS-2 1995—	ADEOS I 8/96—6/97	QuikSCAT 6/99— ADEOS II ~02/02	METOP A 10/06

Characteristics of four spaceborne scatterometers flown on Seasat (SASS), ERS-1/2 (ESCAT), ADEOS (NSCAT), and QuikSCAT (SeaWinds or QSCAT).

Long, D. G., M. R. Drinkwater, B. Holt, S. Saatchi, and C. Bertoia (2001), Global ice and land climate studies using scatterometer image data, Eos Trans. AGU, 82(43).

Scatterometer

- Scatterometers measure sea surface roughness
  - The use of a different radar frequency means that the interactions between the sea-surface and the electromagnetic radar pulses are different.

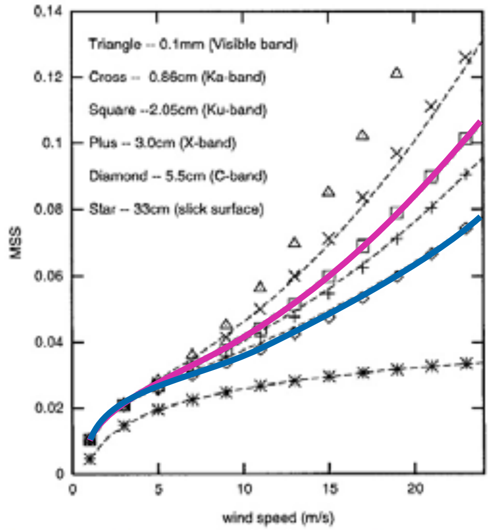


FIG. 2. The MSS of gravity waves and gravity–capillary waves for six different bands.

A variety of Sensors

- Different sensors implies:
  - Different Calibration
  - Different Signal Processing
  - Different Physic

Therefore

  - Different Level-1b products

Therefore

  - The data merging/fusion can only be done after conversion into geophysical products

Input Data Monitoring - Scatterometers

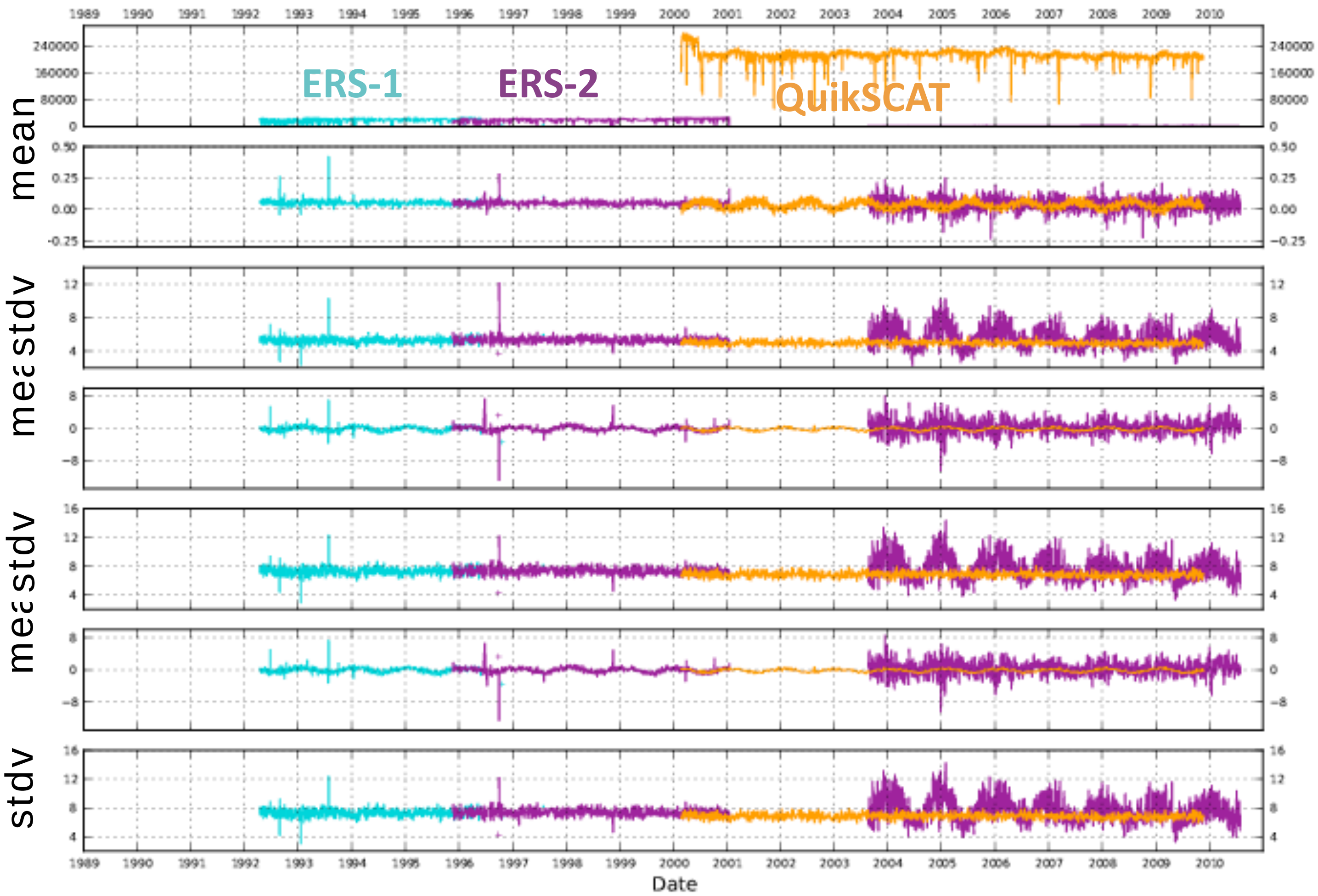
ERA-Interim daily assimilation statistics for scatterometer data (U-wind)

Data counts

Observed values

Background departures

Analysis departures



Dick Dee - ECMWF

From Level-1b to ECV

The example of

A.1 - Surface Vector Wind

GCOS Requirements for ECVs

Product A.1 Surface Vector Wind

Target requirements

The surface wind field is the primary driver of the ocean circulation, which is responsible for the global transport of important amounts of heat, freshwater and carbon. Surface drag and momentum exchanges, fluxes of sensible heat and moisture also depend on wind speed. The surface wind field is a sensitive measure of the state of the global coupled climate system and is very valuable for climate change detection and climate model evaluation. Over land, wind contributes to the surface heat balance influencing advective and turbulent heat fluxes.

- Accuracy: Mean and quadratic statistics to 10% of the mean speed, or ~0.5 ms^{-1} at 10º
- Spatial and temporal resolution: 10 km horizontal resolution, hourly observing cycle
- Stability: ~0.1 ms^{-1}/decade

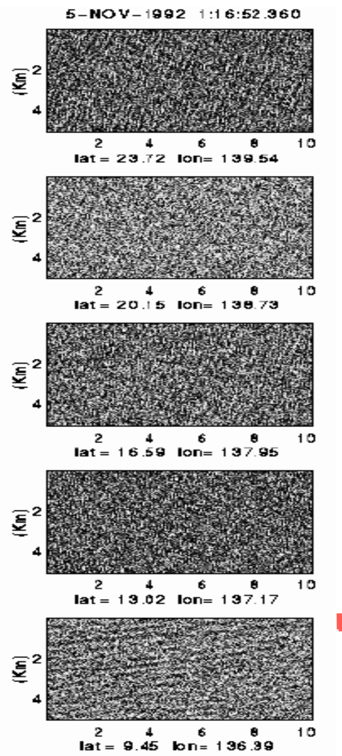
Source: http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf

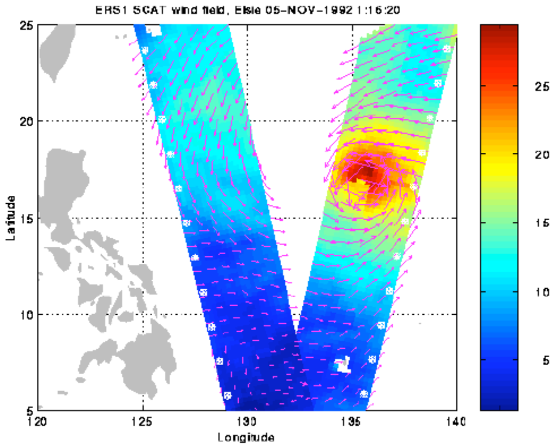
The importance of
Quality Indicators for Climate

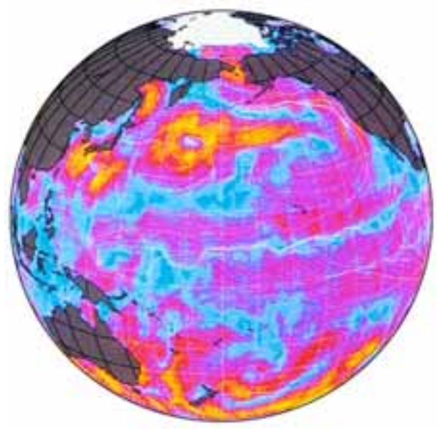
From Sensor to Merged products

From FCDRs to ECVs

The different steps







Level 1b

FCDR

Level 2

ECV

The different Steps - Quality Indicators

- All these steps shall be completely described to allow the production of the ECVs
  - Sensor:
    - Sensor Characteristics
    - Signal Processing
    - Error Characterisation at every level
  - Level-1 B
    - Definition of the parameters
    - Calibration
    - Processing algorithms
    - Assumptions and Hypothesis
    - Error characterisation
  - Level 2
    - Definition of the parameters
    - Validation
    - Processing algorithms
    - Assumptions and Hypothesis
    - Error characterisation
  - Merging / Fusion
    - Definition of the parameters
    - Validation
    - Processing algorithms
    - Assumptions and Hypothesis
    - Error characterisation

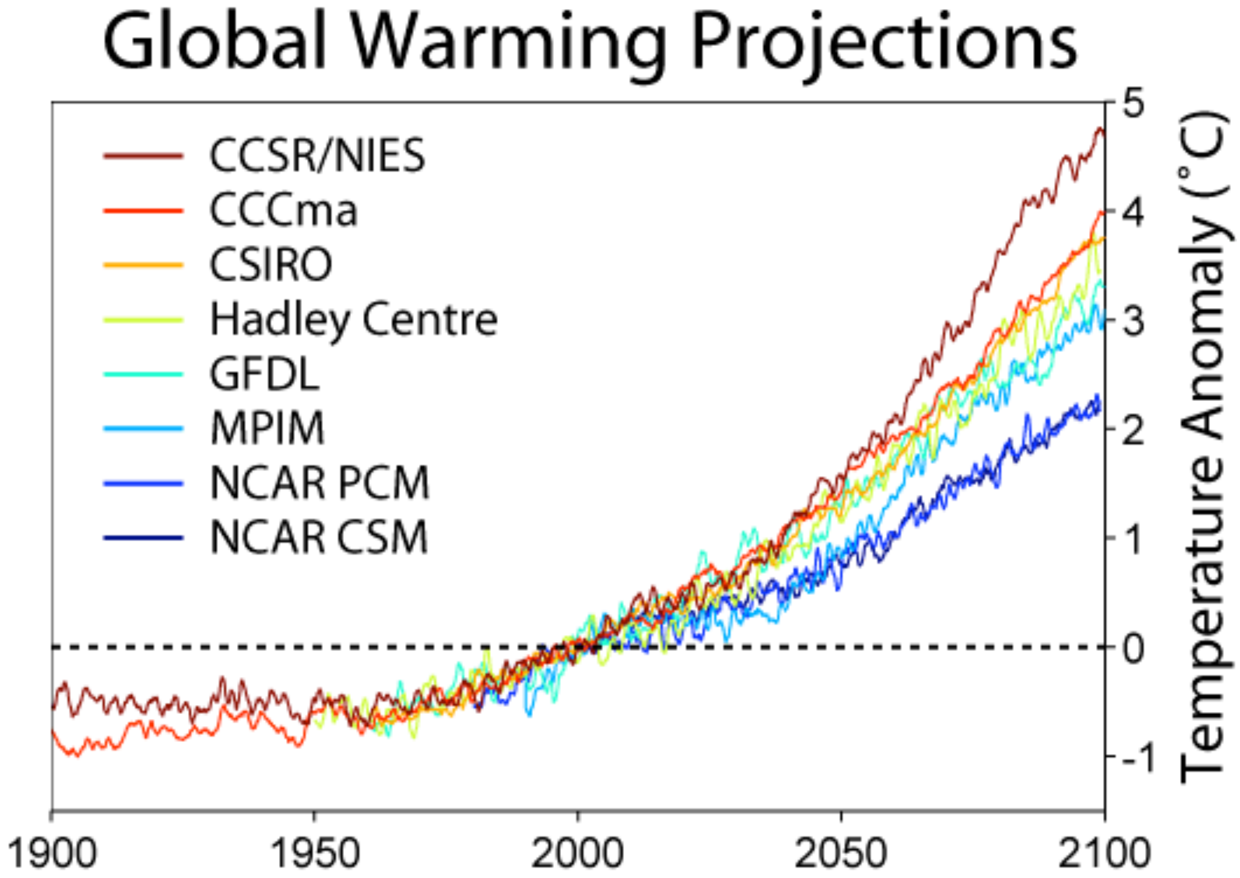
Uncertainties

The estimate of the difference between a measured value and the true value.

Prediction uncertainties

- Predictions are necessarily uncertain
  - Sea Level Rise, SST evolution, Temperature rise, etc…
- This is because:
  - the sensitivity of the climate system is poorly quantified:
    - changing atmospheric greenhouse-gas concentrations,
    - the rate of ocean heat uptake
    - Etc…
  - Future influences on climate of ECVs (e.g. GHG) are difficult to predict
    - anthropogenic as well as natural origin
- Past observations have been used to help constrain the range of uncertainties in future warming rates, but under particular assumptions
  - A particular scenario of GHG future emissions.

Global Warming Projections

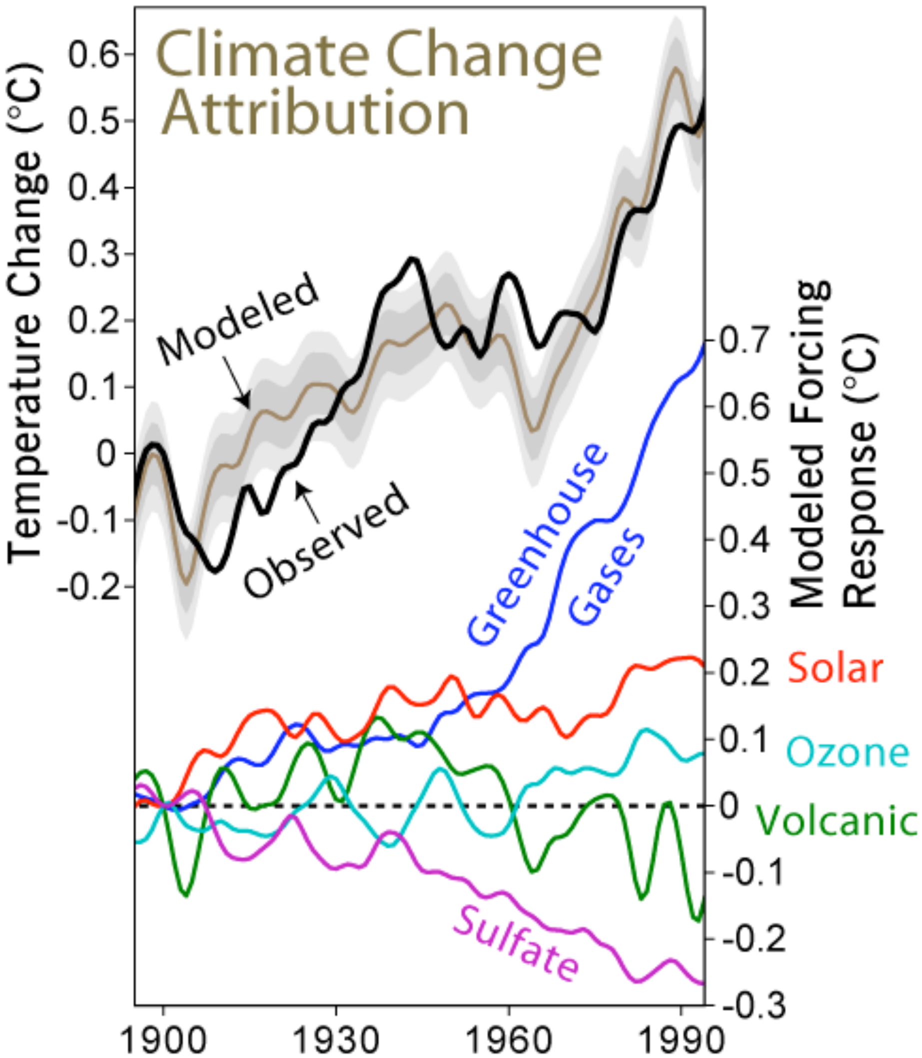


- Calculations of global warming prepared in or before 2001 from a range of climate models under the SRES A2 emissions scenario, which assumes no action is taken to reduce emissions.

Prediction uncertainties

- A reduction of these uncertainties is potentially valuable tool for policy makers and planners.
- Large and difficult-to-quantify uncertainties surround predictions of future demographic changes, economic development and technological change, which will determine future anthropogenic impacts (e.g. pollutant emissions).
- Even with perfect knowledge of these impacts, uncertainties in the representation of atmospheric and oceanic processes by climate models limit the accuracy of any estimate of the climate response.
- Natural variability, generated both internally and from external forcings such as changes in solar output and explosive volcanic eruptions, also contributes to the uncertainty in climate forecasts.

The study of processes



- Reduction of uncertainties is also fundamental to better understand
  - Processes,
  - Feed back mechanisms
  - Interactions between ECVs
  - Climate change attribution

Error Characterisation

- Techniques have been developed to quantify uncertainty in predictions by comparing simulations of past temperature changes with observations.

- The production of consistent ECVs time series over few decades (e.g. the CCI) supports this uncertainty quatification and to the study of processes.

- Comprehensive Error Characterisation is a fundamental element of this work
  - The CCI shall include a complete assessment of the error characteristics that are required to allow the detection of climate change impacts over and above natural variability and a full error budget analysis for the translation of the input baseline datasets to the ECV product. The error budget analysis shall make reference to the error characteristics.

QA4EO Background

- The Global Earth Observation System of Systems (GEOSS) must deliver “timely, quality, long-term, global information ” to meet the needs of its nine “societal benefit areas”.
- This will be achieved through the synergistic use of data derived from a variety of sources (satellite, airborne and surface-based) and the coordination of resources and efforts of the members.
- Accomplishing this vision, starting from a system of disparate systems that were built for a multitude of applications, requires the establishment of an internationally coordinated framework to facilitate interoperability and harmonisation.
- The success of this framework is dependent upon the successful implementation of a single key principle:
  - all EO data and derived products shall have associated with it a documented and fully traceable quality indicator (QI).
- Success also necessitates the means to efficiently communicate this attributes to all stakeholders.

QA4EO Essential Principle

- In order to achieve the vision of GEOSS, Quality Indicators (QIs) should be ascribed to data and products, at each stage of the data processing chain - from collection and processing to delivery.
  - A QI should provide sufficient information to allow all users to readily evaluate a product's suitability for their particular application, i.e. its "fitness for purpose".
  - To ensure that this process is internationally harmonised and consistent, the QI needs to be based on a documented and quantifiable assessment of evidence demonstrating the level of traceability to internationally agreed (where possible SI) reference standards.

Conclusions

Quality Assurance for Climate

- Climate Change is a societal challenge,
- Quality Assurance is a fundamental element of Climate change.

- Examples
  - Offset Market Growing but Quality Assurance Lags: GAO
    - The U.S. Government Accountability Office found that, by and large, a lack of information surrounding carbon offsets leads to problems determining additionality and the existence of quality assurance mechanisms.
  - Environment Canada
    - Quality assurance/quality control (QA/QC) activities should be an integral part of any inventory development processes as they improve transparency, consistency, comparability, completeness and accuracy of greenhouse gas inventories.
  - Green House Gases
    - Lloyd's Register Quality Assurance (LRQA) work with organisations to help them demonstrate their emission reductions and compliance with national requirements.
    - LRQA offers validation and verification services so that clients can demonstrate their emission reductions and compliance with national requirements and the mechanisms originating from the Kyoto Protocol.

- It requires to provide data from a large variety of source and therefore lead to the definition of standards in particular in Products Quality, Quality Control and Cal/Val

- In order to have credibility in the production of ECVs, all the processing steps shall be completely described, characterised with an associated error characterisation process.

- Quality Indicators (the ensemble of parameters needed to understand and exploit FCDRS and to produce ECVs) are essential element of the whole process.