Space-based Essential Climate Variables for lakes

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Lakes as a Climate sentinel

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Lakes as sentinels of climate change

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Abstract

While there is a general sense that lakes can act as sentinels of climate change, their efficacy has not been thoroughly analyzed. We identified the key response variables within a lake that act as indicators of the effects of climate change on both the lake and the catchment. These variables reflect a wide range of physical, chemical, and biological responses to climate. However, the efficacy of the different indicators is affected by regional response to climate change, characteristics of the catchment, and lake mixing regimes. Thus, particular indicators or combinations of indicators are more effective for different lake types and geographic regions. The extraction of climate signals can be further complicated by the influence of other environmental changes, such as eutrophication or acidification, and the equivalent reverse phenomena, in addition to other land-use influences. In many cases, however, confounding factors can be addressed through analytical tools such as detrending or filtering. Lakes are effective sentinels for climate change because they are sensitive to climate, respond rapidly to change, and integrate information about changes in the catchment.

World Climate Conferences

1990 – IPCC – Intergovernmental Panel on Climate Change. **SCIENCE**
2000 – GCOS – Global Climate Observing System. **OBSERVATIONS**
2010 – GFCS- Global Framework for Climate Services. **SERVICES**

These programmes report directly to the United Nations Framework on Climate Change (UNFCCC) and there Parties are expected to support them.

Global Climate Observing System Essential Climate Variables (GCOS ECVs)

European Commission

Table 1: Essential Climate Variables that are both currently feasible for global implementation and have a high impact on UNFCCC requirements

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface:**[8]	Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.
	Upper-air:[9]	Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance).
	Composition:	Carbon dioxide, Methane, and other long-lived greenhouse gases[10], Ozone and Aerosol, supported by their precursors[11]
Oceanic	**Surface:**[12]	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton.
	Sub-surface:	Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
Terrestrial	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.	

Research Centre

GCOS and (other) Lake ECVs

Why should we care?

GCOS provides a process and an explicit set of requirements that space agencies are adopting in implementing their programmes (e.g. ESA CCI)

How could GloboLakes be a catalyst for the definition of Lake ECV requirements?

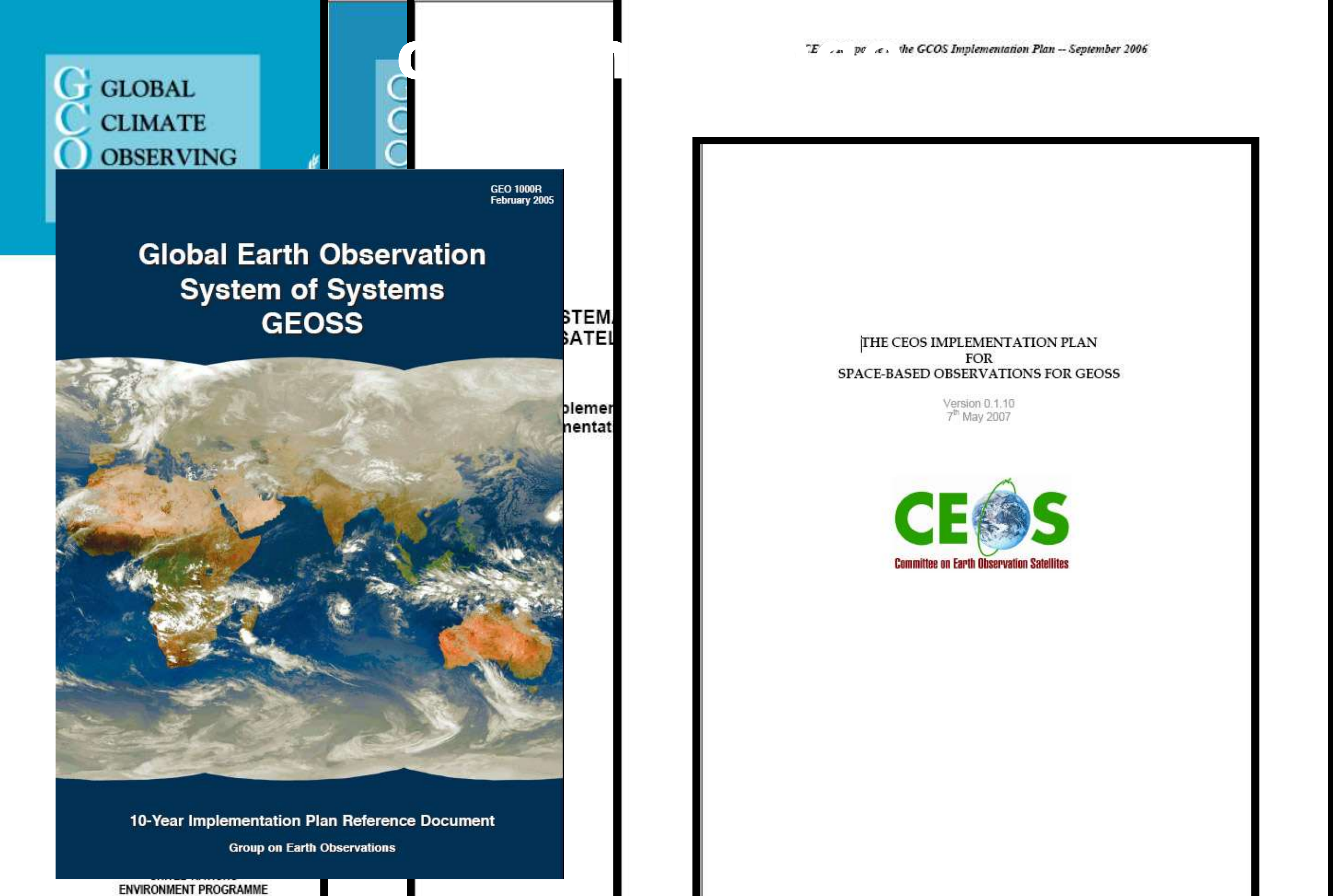
Globolakes can benefit from the iterative capability of user requirement and product definition and implementation

How do we get GCOS to take notice ?

GCOS tends to be (rightly) conservative in admitting new ECVs we need to take advantage of existing references to Lakes in GCOS documentation, and expand/develop from this. (definition of a baseline set of Lake ECV products should be conservative)

On what timescale could GloboLakes contribute to the GCOS process ?

Next cycle of process



global collaborative framework

GCOS Implementation Plan 2010

European Commission

The 2010 edition of the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (IP-10) replaces a similarly titled Plan (IP-04) which was published in 2004. Its purpose is* ***to provide an updated set of Actions required to implement and maintain a comprehensive global observing system for climate that will address the commitments of the Parties under Articles 4 and 5 of the UNFCCC and support their needs for climate observations in fulfilment of the objectives of the Convention.***

This revised Plan updates the Actions in the IP-04, ***taking account of recent progress in science and technology, the increased focus on adaptation, enhanced efforts to optimize mitigation measures, and the need for improved prediction and projection of climate change.*** *It focuses on the timeframe* ***2010-2015***

Joint Research Centre

GCOS Satellite Supplement

... provides supplemental detail to the 2010 Update of the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (GCOS-138, August 2010, hereafter called the ‘GCOS Implementation Plan’ or ’IP-10’) related to the generation of global climate products derived from measurements made from satellites

News

Update of the Satellite Supplement – now open for public review

High-level requirements on the accuracy, stability and resolution of satellite-based datasets and derived products in support of the GCOS ECVs were defined in 2006 and documented in the "Satellite Supplement" (GCOS-107) to the 2004 GCOS Implementation Plan.

An 2011 Update of the Satellite Supplement is currently underway. The draft document is now opened for public review from 9 May to 1 July 2011: Draft Document

GCOS satellite supplement provides

1. Products, Target Requirements, Benefits
2. Rationale
3. Currently Achievable Performance
4. Requirements for satellite instruments and data
5. Calibration, Validation and Archiving Needs
6. Adequacy and Inadequacy of Current Holdings
7. Immediate Actions, Partnerships and International Coordination.

Target Requirements

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
SST	10km	N/A	Daily	0.1K over 100km scales	Less than 0.03K over 100km scales

CEOS Background

European Commission

- Established in 1984 under auspices of G-7 Economic Summit of Industrialized Nations
  - Focal point for international coordination of space-related Earth Observation (EO) activities
  - Optimize benefits through cooperation of members in mission planning and in development of compatible data products, formats, services, applications, and policies
- Operates through best efforts of Members and Associates via voluntary contributions
- 29 Members (Space Agencies), 21 Associates (UN Agencies, Phase A programs or supporting ground facility programs)

- As the space component of the Global Earth Observation System of Systems (GEOSS), CEOS is implementing high priority actions in support of Group on Earth Observation (GEO) Tasks

Primary Objectives of CEOS

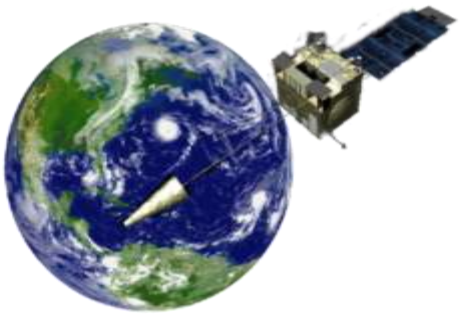
European Commission

1. To optimize benefits of space-borne Earth observations through:
   - Cooperation of its Members in mission planning
   - Development of compatible data products, formats, services, applications, and policies;

2. To serve as a focal point for international coordination of space-related Earth observation activities;

3. To exchange policy and technical information to encourage complementarity and compatibility of observation and data exchange systems.

CEOS
Committee on Earth Observation Satellites



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CEOS Response

- Responds to the GCOS Actions
- Reinforces the needs called out by the GCOS Satellite Supplement
  - Provides more detail on the deliverables, coordination, activities and who will lead the effort.
  - Calls out agency activities
  - Calls out international coordination
- Can include additional activities not called out by GCOS but may be considered important by CEOS.

CCI Rationale & Objective

European Commission

The objective of Climate Change Initiative is to realize the full potential of the **long-term global Earth Observation archives** that **ESA** together with its **Member states** have established over the last thirty years, as a significant **and** timely contribution to the **ECV** databases required by **UNFCCC**.

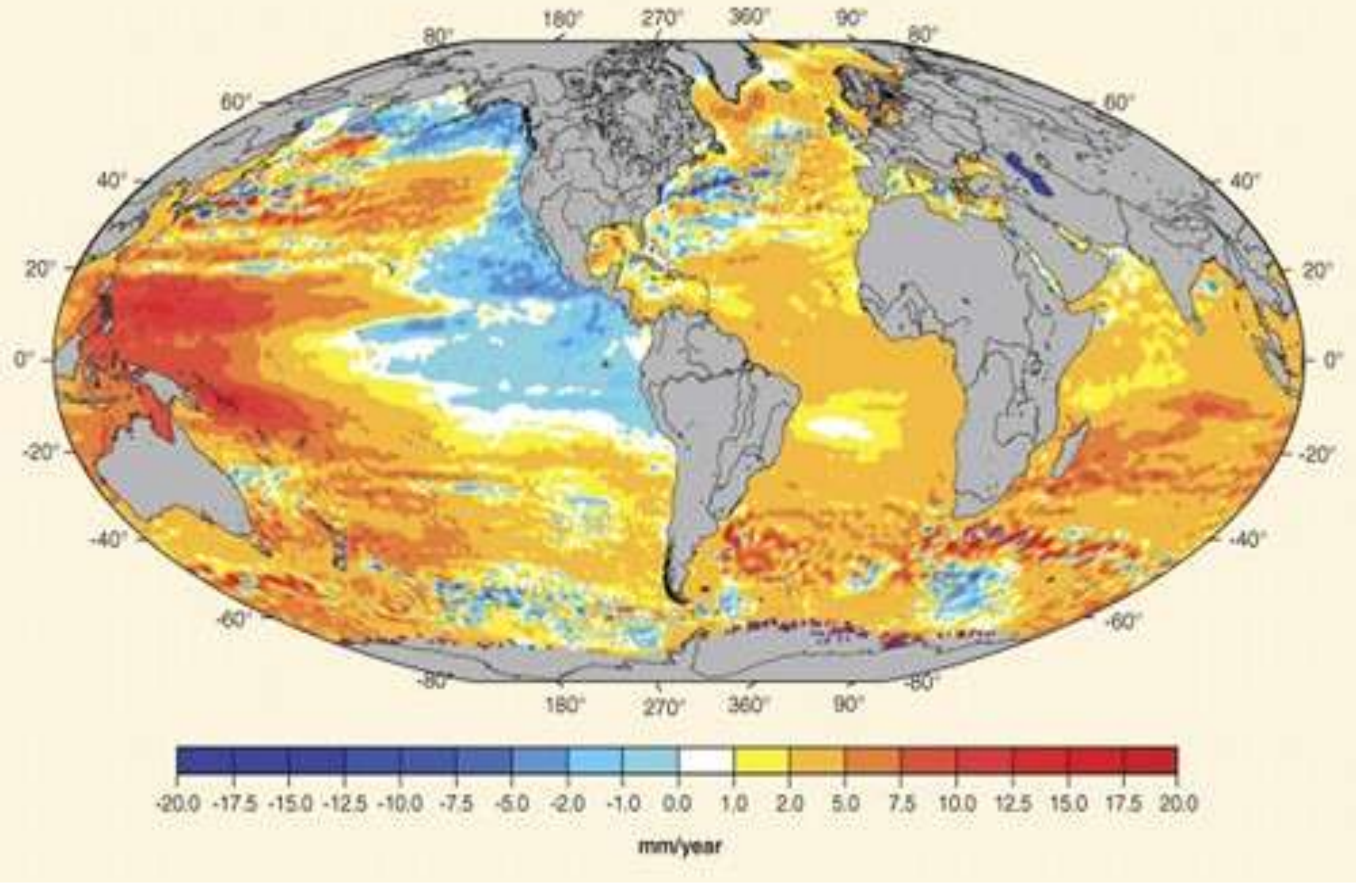
It will ensure that full capital is derived from ongoing and planned ESA missions for climate purposes, including **ERS, Envisat, the Earth Explorer** missions, relevant ESA-managed archives of **Third-Party Mission** data and, in due course, the **GMES Space Component**.

CCI Programme following Ministerial Council in 2008,
about 75MEUR over 6 years for about 20 ECVs
Starting NOW

A Synoptic view of variability

European Commission

Regional sea-level trends from satellite altimetry (Topex/Poseidon, Jason-1&2, GFO, ERS-1&2, and Envisat missions) for the period October 1992 to July 2009.



Sea-Level Rise and Its Impact on Coastal Zones
Robert J. Nicholls, et al. Science 328, 1517 (2010)

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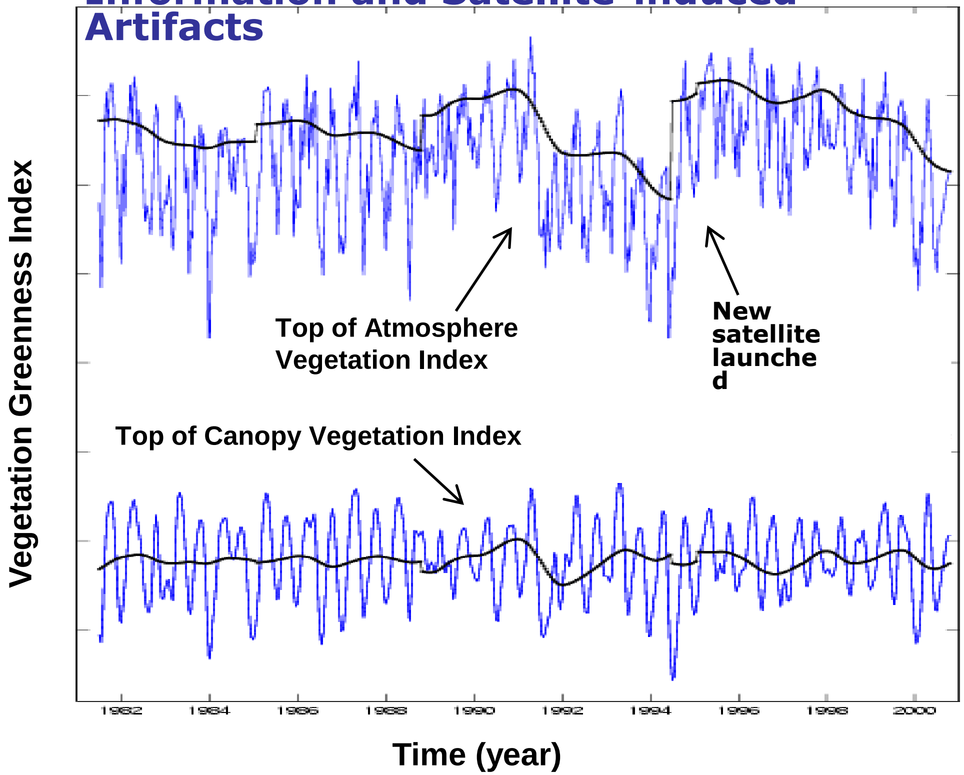
Climate Data Records

The Satellite Era Merging Data From Different Sensors Requires Expert Knowledge and Retrospective Insights

Uncorrected Data Time Series Contain Both Environmental Information and Satellite-induced Artifacts

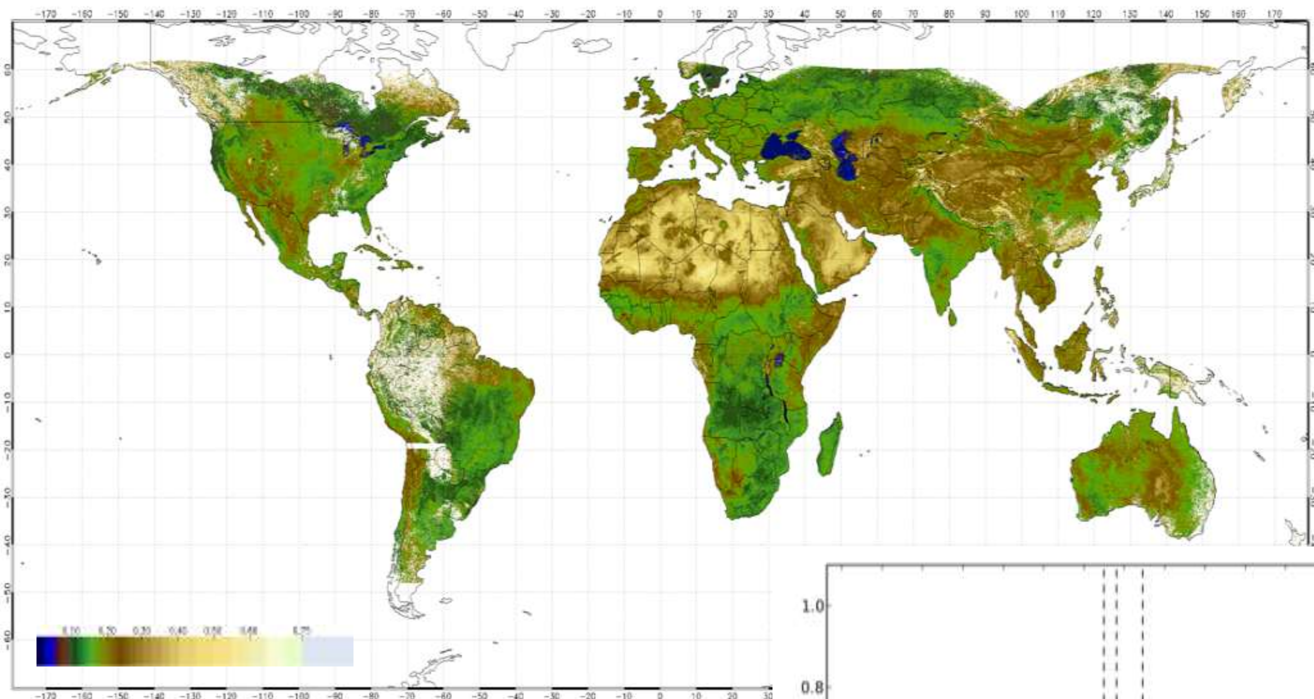


Operational weather and hazard products are produced rapidly to potentially save life and property

Climate Data Records (CDRs) provide long term product consistency through rigorous reprocessing with advanced algorithms, ancillary data and evolved instrument understanding.

Climate Information Records (CIRs) provide specific information about environmental phenomena of particular importance to science and society (*e.g.*, hurricane trends,

Geostationary surface albedo



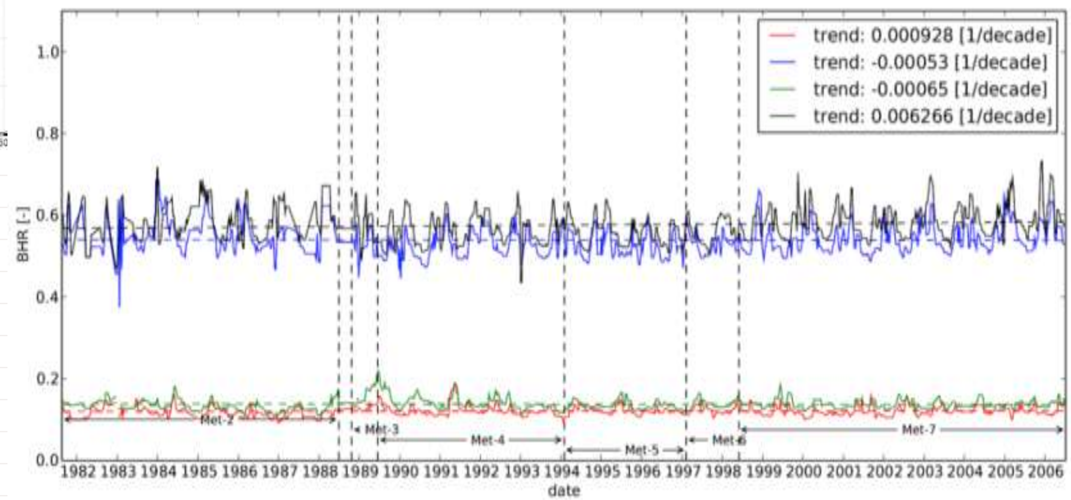
GSA: Broad band (0.3-3.0 µm) surface albedo: 1-10 of May 2001.

From east to west, GMS-5, MET-5,MET-7,GOES-8 and GOES-10.

Products produced within SCOPE-CM initiative.

Validation of GSA time series from 1982 – 2006 at temporally invariant desert sites.

Results are indicating full capability of albedo trend detection.



Source EUMETSAT

Committee on Earth Observing Satellites Working Group on Climate (WGClimate)

European Commission

CEOS

WGClimate was endorsed as a full CEOS WG (joining WGISS, WGCV and WGEdu) and will coordinate and encourage collaborative activities between the world's major space agencies in the area of climate monitoring

The Mission of the Working Group Climate (WGClimate) is to facilitate the implementation and exploitation of Essential Climate Variable (ECV) time-series through coordination of the existing and substantial activities undertaking be CEOS member agencies. This includes the numerous iterative steps involved in the creation of ECVs and ensuring ECV life cycle information is gathered, organized, and preserved for future generations.

Chair of CEOS WGClimate
Mark Dowell (EC/JRC)
Vice Chair John Bates (NOAA/NCDC)

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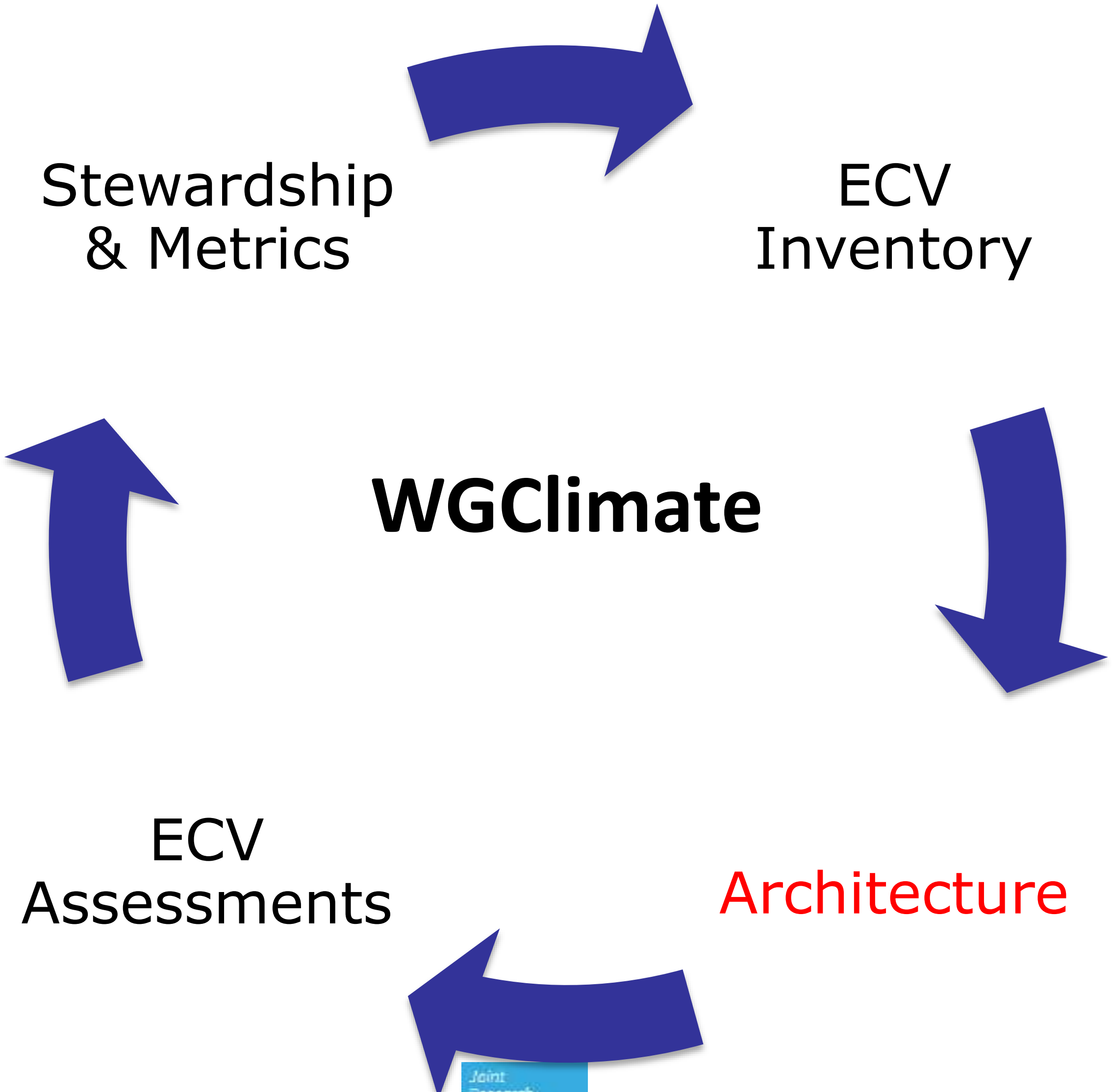
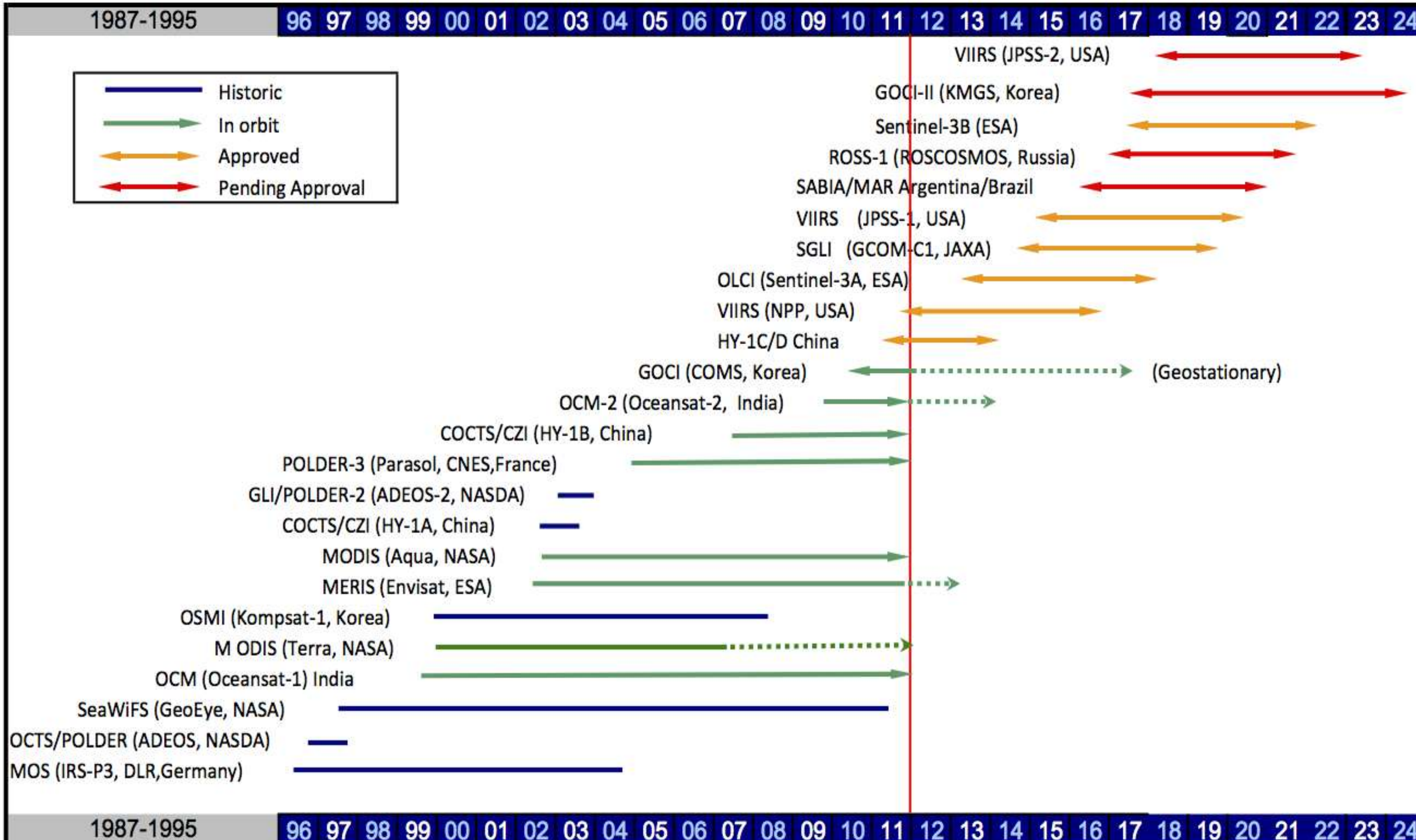

Stewardship
& Metrics
ECV
Inventory
WGClimate
Architecture
ECV
Assessments

Why do we need a Climate Monitoring Architecture?

Three main "needs/usage scenarios" have emerged for a climate monitoring architecture:

- A Assist in promotion of a common understanding of the implementation implications of meeting the various space-related climate monitoring requirements (e.g. from GCOS)
- B To support an assessment of the degree to which the currently implemented systems meet the requirements (and the generation of an action plan to address identified shortfalls/gaps/duplication)
- C To improve our understanding of the end-to-end information flows and dependencies (i.e. from sensing through to decision-making)

State of the Art: Timeline for Ocean Colour ECV



Source IOCCG

Gap Analysis EU

European

8 Gap analysis: Table 5

Essential Climate Variable (mainly Space)			Fundamental Climate Data Record	GCOS Horiz Res. Goal
Atmospheric	1	Precipitation	Passive microwave radiances, High frequency geostationary IR, Active radar (for calibration)	100 km (1 km for extreme events)
	2	Earth Radiation Budget	Broadband radiances, Spectrally resolved solar irradiances, Geostationary multi-spectral imagery	100 km
	3	Upper-air Temperature	Passive microwave radiances, GPS radio occultation, High spectral resolution IR radiances for re-analyses.	100 km
	4	Upper-air Wind	VIS/IR imagery, Doppler wind lidar	100 km
	5	Surface Wind Speed and Direction	Passive microwave radiances and scatterometry	10 km
	6	Water Vapour	Passive microwave radiances, UV/VIS Radiances, IR imagery/soundings in 6.7um band, Microwave soundings in 183 GHz band	10 - 50 km
	7	Cloud Properties	VIS/IR imagery, IR and microwave soundings	99 - 100 km
	8	Carbon Dioxide	NIR/IR radiances	10 - 250 km
	9	Methane	NIR/IR radiances	10 - 50 km
	10	Other GHGs	NIR/IR radiances	
	11	Ozone (tropospheric)	UV/VIS radiances, IR/Microwave radiances	5 - 50 km
	12	Ozone (stratospheric)	UV/VIS radiances, IR/Microwave radiances	50 - 100 km
	13	Aerosol Properties	VIS/NIR /SWIR radiances	1 - 10 km
Oceanic	14	Sea-Surface Temperature	Single & multi-view IR and microwave imagery	1 km
	15	Sea Level	Altimetry	25 km
	16	Sea Ice	Passive Microwave imagery (DMSP, AMSRE), SAR, TIR & VIS imagery	12 - 100 km
	17	Sea State	Altimetry, scatterometer, SAR	25 km
	18	Ocean Salinity	Microwave radiances	15 - 100 km
	19	Ocean Colour (IOP + Chl_a)	Multispectral VIS imagery	1 km
Terrestrial	20	Snow Cover (Extent, Snow Water Equivalent)	VIS/NIR/IR and passive microwave optical imagery	100 m - 100 km
	21	Glaciers and Ice Caps	VIS/NIR/SWIR optical imagery, Altimetry	30 m
	22	Permafrost and seasonally -frozen ground	-	250 m
	23	River Discharge	Altimetry	10 km
	24	Lake level/properties	VIS/NIR imagery radar imagery, Altimetry, IR imagery	1 - 4 km
	25	Albedo	Multispectral and broadband imagery	1 km
	26	Land Cover	multispectral VIS/NIR imagery	250 m
	27	fAPAR	VIS/NIR imagery	250 m
	28	Leaf Area Index	VIS/NIR imagery	250 m
	29	Biomass	L Band / P Band SAR, Laser altimetry	10 m
	30	Fire Disturbance	VIS/NIR/SWIR/TIR multispectral imagery	250 m
	31	Soil Moisture (surface and root zone)	Active and Passive microwave (Scatterometer and SMOS)	50km

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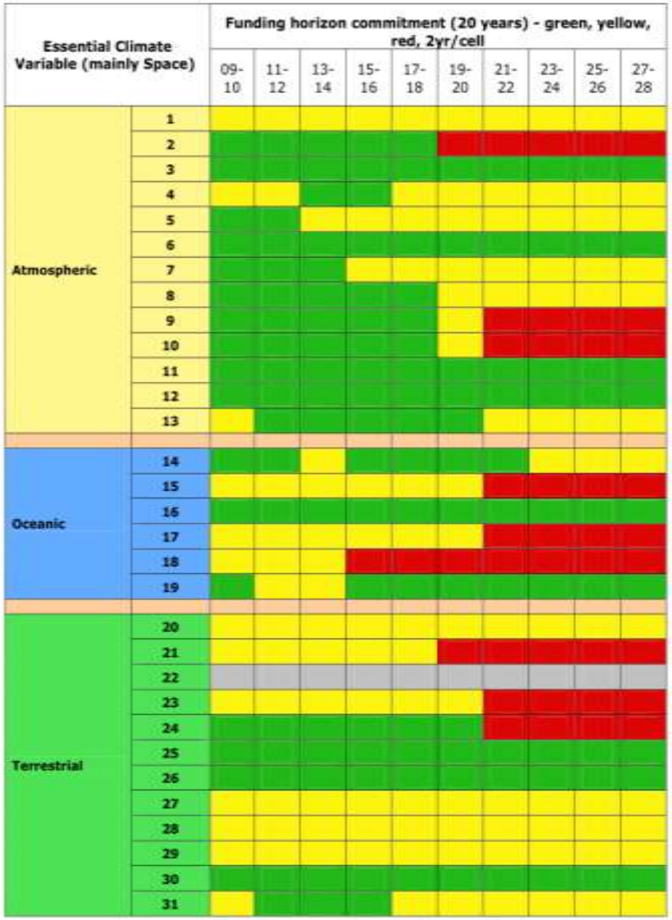

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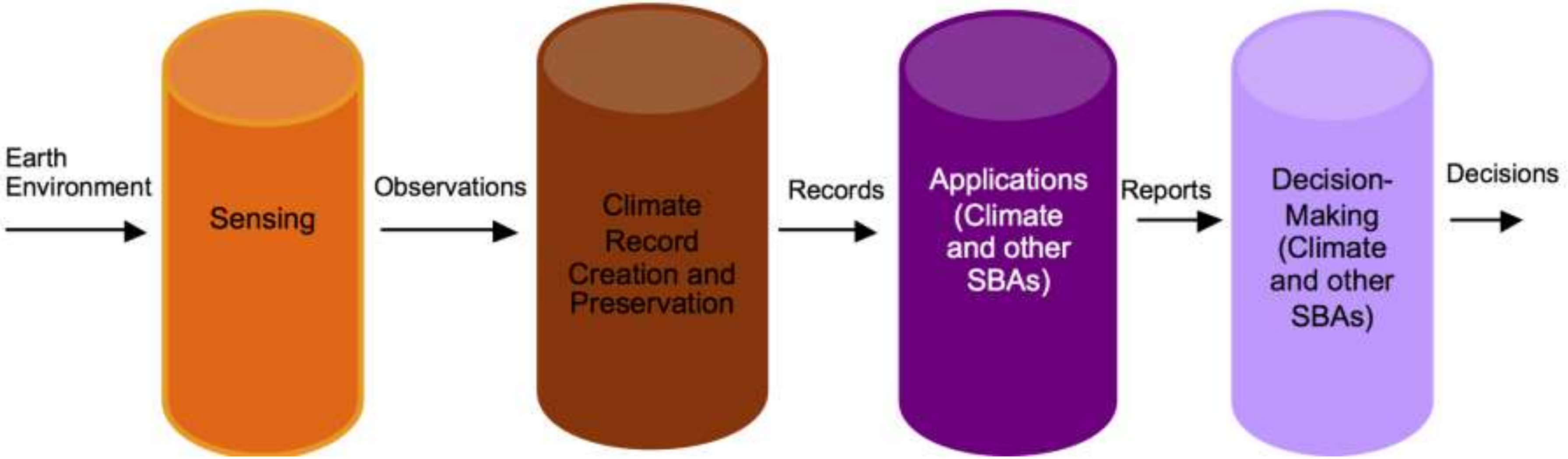
Architecture Pillars

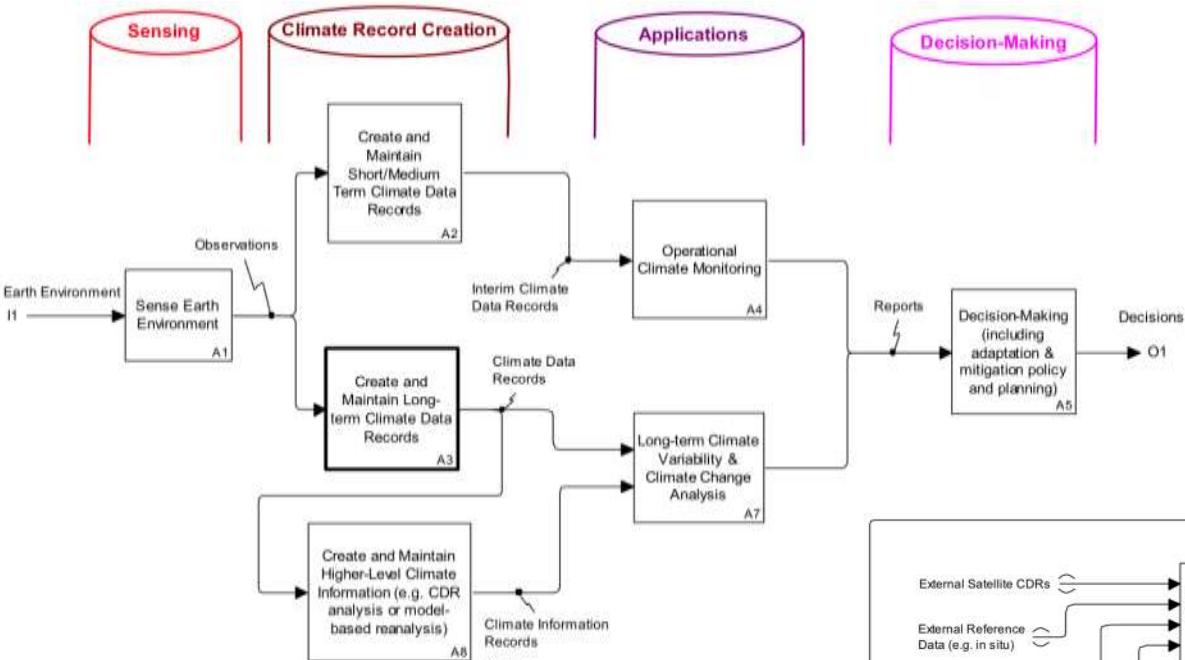


Logical and Physical Architecture

logical view: represents the requirements baseline as a set of interlinked functions and associated dataflows (i.e the target) . Logical view is as stable as the requirements baseline and, once established, should require little maintenance

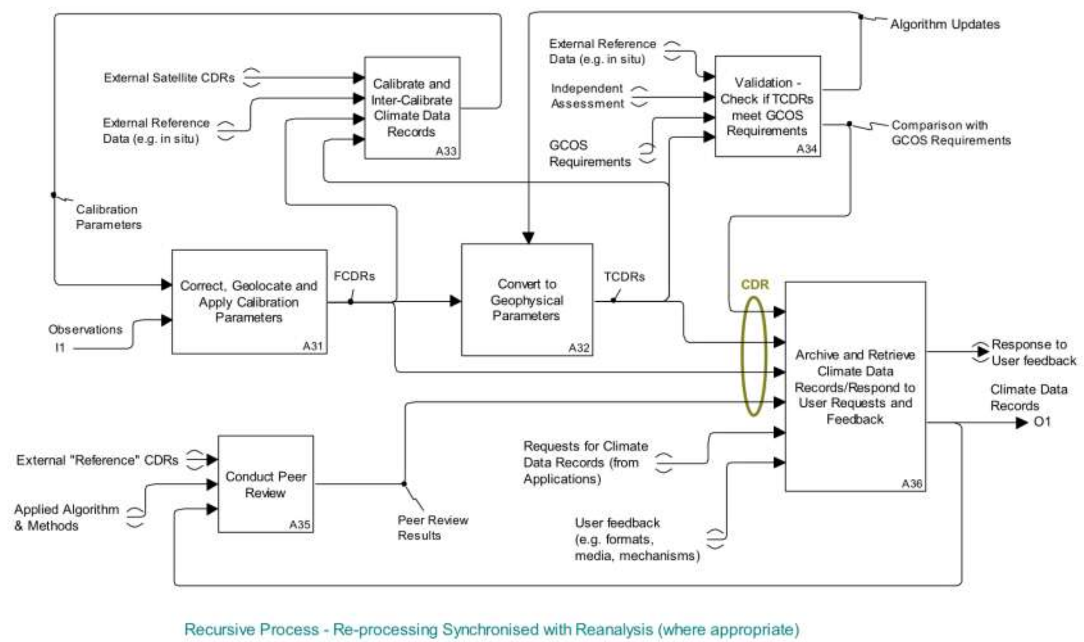
physical view: describes how the logical view is implemented, i.e. how close we are to achieving the target. Needs to maintained on a regular basis to make sure it appropriately reflects the prevailing status (will take longer to determine)

Logical representation



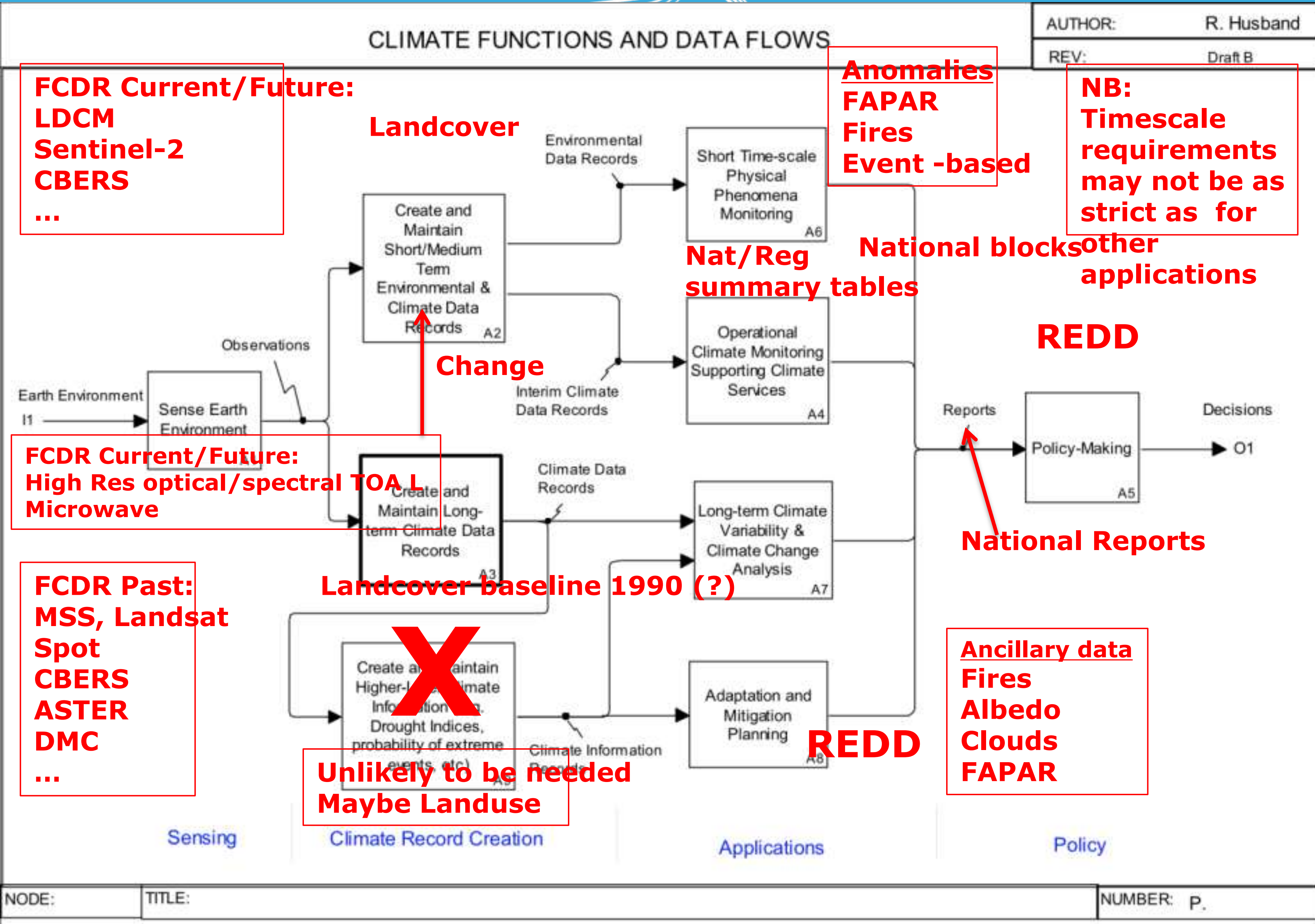
Traceable to GCOS Guidelines and GCOS Climate Monitoring Principles

Traceable from ECV Inventory and physical representation of Climate Monitoring Architecture



Case Studies

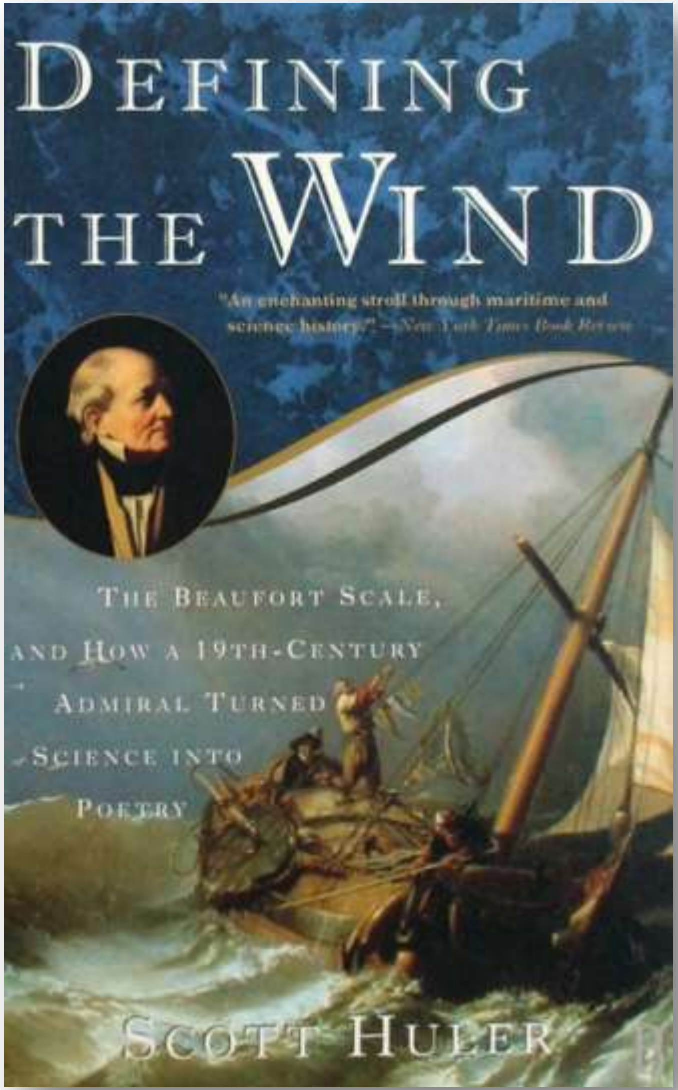
NB: Continuity in change obligation is on reducing rate



Metrics: Motivation

What is at stake?

- History shows that weather observations did not become useful for society until a lexicon was agreed to
  - ✓The Beaufort scale did this for wind climatology and maritime commerce in the 19th century
- For climate services to benefit society, they must adopt a lexicon that sets expectations for openness, process and transparency that are accessible to the public
  - ✓How might we define a climate record lexicon useful to both scientists and the general public in the 21st century?

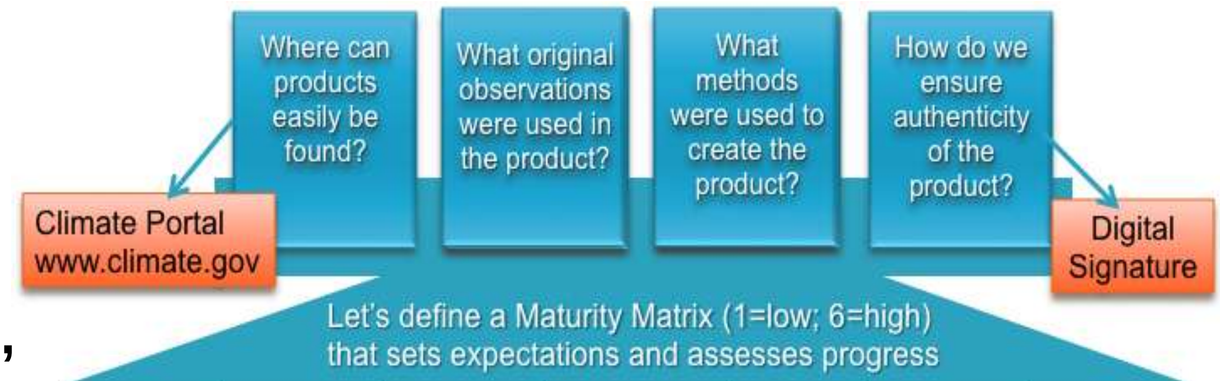


Metrics

Maturity Matrix

European Commission

- **Ultimate ambition – define CEOS “endorsed” Maturity metrics**
- **Starting point - NOAA effort**
- **Task within WGClimate, to review/modify => improve**
- **One size may not fit all**
- **It is as much a tool to monitoring progress as it is to provide a snapshot of current capability**



Collection Methods	Algorithm stability	Metadata & QA	Documentation	Validation	Public Release	Science & Applications
How was the data collected, sensors, surveys, etc.?	Are algorithms under configuration management and how mature?	How full and complete are the metadata and quality assessment?	Is the Operational Algorithm Description full, complete, and peer reviewed?	How complete is the validation?	Are the data, algorithms and software open and available to the Public?	How extensive is the peer reviewed literature and how varied are the applications?

Joint Research Centre

Source J. Bates

GCOS 2010 Lake Actions

Action T8 *[IP-04 T6]*

Action: Submit weekly/monthly lake level/area data to the International Data Centre; submit weekly/monthly altimeter-derived lake levels by space agencies to HYDROLARE. **Who:** National Hydrological Services through WMO CHy, and other institutions and agencies providing and holding data; space agencies; HYDROLARE. **Time-Frame:** 90% coverage of available data from GTN-L by 2012. **Performance Indicator**: Completeness of database. **Annual Cost Implications:** 1-10M US$ (40% in non-Annex-I Parties).

Action T9 *[IP-04 T7]*

Action: Submit weekly/monthly lake level and area data measured during the 19th and 20th centuries for the GTN-L lakes to HYDROLARE. **Who:** National Hydrological Services and other agencies providing and holding data, in cooperation with WMO CHy and HYDROLARE. **Time-Frame:** Completion of archive by 2012. **Performance Indicator:** Completeness of database. **Annual Cost Implications:** <1M US$ (40% in non-Annex-I Parties).

Action T10 *[IP-04 T8]*

Action: Submit weekly surface and sub-surface water temperature, date of freeze-up and date of break-up of lakes in GTN-L to HYDROLARE. **Who:** National Hydrological Services and other institutions and agencies holding and providing data; space agencies. **Time-frame:** Continuous. **Performance Indicator:** Completeness of database **Annual Cost Implications:** <1M US$ (40% in non-Annex-I Parties).

ECVs for which satellites can make a serious contribution

Table 5: Essential Climate Variables for which satellite observations make a significant contribution (cf. Table 3).

Domain	Essential Climate Variables
Atmospheric (over land, sea and ice)	Precipitation, Earth radiation budget (including solar irradiance), Upper-air temperature, Wind speed and direction, Water vapour; Cloud properties, Carbon dioxide, Methane; Ozone and Aerosol, supported by their precursors.
Oceanic	Sea-surface temperature, Sea level, Sea ice, Ocean colour, Sea state, Sea-surface salinity.
Terrestrial	Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Fire disturbance, Soil moisture.

GCOS acknowledged observing networks and systems

Table 13. Observing networks and systems contributing to the Terrestrial Domain

ECV	Contributing Network(s)	Status	Contributing Satellite Data	Status
River Discharge	GCOS/GTOS Baseline GTN-R based on TOPC priority list	Stations selected and partly agreed by host countries, non-contributing stations approached	Research concerning laser/radar altimetry for river levels and flow rates.	Operational laser altimeters not scheduled; EO-based network only research.
Lakes	GCOS/GTOS Baseline Lake Network based on TOPC priority list. To include freeze-up/break-up.	Stations selected, approached by HYDROLARE; GTN-L needs to be established;	Altimetry, high-resolution optical and radar imagery and reprocessing of archived data.	Operational laser altimeters not scheduled. Question mark over high-resolution systems continuity. EO-based network only research.

Inconsistencies with later text

There are a number of other lake-specific variables needed by the climate modelling community (e.g., surface water temperature) or for climate monitoring purposes (e.g., surface and sub-surface water temperature, date of freeze-up, and date of lake ice break-up). Whenever possible, these variables should be measured by National Hydrological Services and other responsible agencies holding data, in association with measurements of lake level and area, and be submitted to HYDROLARE.

Action T10 *[IP-04 T8]*

Action: Submit weekly surface and sub-surface water temperature, date of freeze-up and date of break-up of lakes in GTN-L to HYDROLARE. **Who:** National Hydrological Services and other institutions and agencies holding and providing data; space agencies. **Time-frame:** Continuous. **Performance Indicator:** Completeness of database **Annual Cost Implications:** <1M US$ (40% in non-Annex-I Parties).

What to do next?

European Commission

User defined – product specification (LST, Chl, CDOC ??, Turbidity ??)

User ECV product requirements (spatial/temporal res, uncertainty, stability)

Satellite WP leads implement a processing architecture that is consistent with GCOS Guidelines and GCOS Climate Monitoring Principles

Next revision of GCOS Implementation plan 2015 (draft will start in 2014) – can GloboLakes be ready to contribute to this process for the next revision?

Target Requirements

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
SST	10km	N/A	Daily	0.1K over 100km scales	Less than 0.03K over 100km scales

Conclusions & Points for discussion

1. This may seem premature… but it is to the community's advantage if GloboLake implements a "GCOS compliant" product generation system from the project's inception.
2. Ultimately this will only work if multiple space agencies agree to start generating these products – although having a "champion agency" is useful.
3. Therefore it is imperative to standardize baseline products and their requirements
4. There are a lot of "chicken and egg" issues
5. Ultimately the a clear definition of a user requirement – product definition/implementation iterative loop is the key to success