Potential FCDRs from CGMS Baseline Missions Contributing to the “Architecture for Climate Monitoring from Space”

Joint CEOS-CGMS Working Group on Climate
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- B. Bizzarri completed the whole analysis of FCDRs and missions

- Sources
  - CGMS Baseline (2011)
  - GOSIC (Global Observing System Information Center)
  - GCOS IP Satellite Supplement 2011 update (GCOS-154)
  - ECV inventory
  - OSCAR Space module (www.wmo.int/oscar/space)

Outline

- Background
- CGMS Baseline, Climate Architecture and the ECV inventory
- 1st outcome: Specification of FCDRs
- 2nd outcome: Evaluation of satellite missions
  - A step towards a Gap Analysis
- Discussion

BACKGROUND

CGMS Baseline for long-term mission continuity (operational or «sustained»)

The baseline adopted by CGMS-39 (Oct 2011) includes:

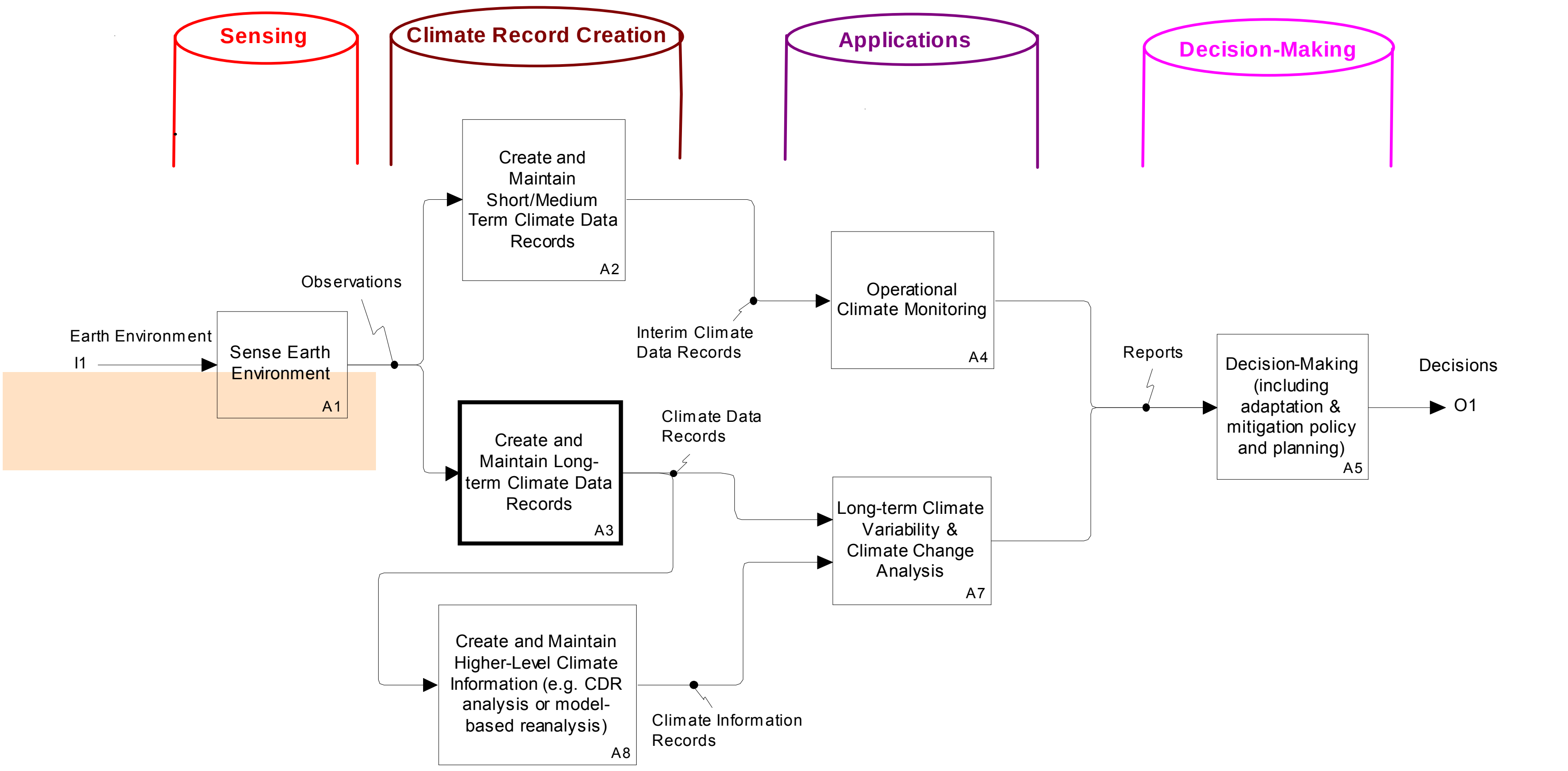
- GEO imagery & IR sounding
- GEO lightning
- LEO SSO imagery VIS, IR & MW
- LEO IR, MW sounding
- Scatterometer missions for ocean surface winds
- Radar altimetry for ocean surface topography (constellation)
- Radio-occultation sounding (T, Q, TEC) (constellation)
- Radiation Budget (Broadband upward radiation and TSI)
- Atmospheric composition (contribution to…)
- High Res and Narrow-band VIS/IR (Vegetation, ocean colour)
- Multi-angle IR radiometry

In the CGMS High-level Priority Plan 2013-2017:

« Advancing the Architecture for Climate Monitoring»

- Take an active role in building up the architecture as a contribution to GFCS
- Evaluate the CGMS baseline against the logical view of the Climate Architecture
- Extend GSICS and SCOPE-CM
- Analyze long-term datasets , impact on climate applications
- Establish priorities for multi-decadal ECV products
- Contribute to creation of key FCDRs supporting many ECVs
- Ensure systematic contribution to the ECV inventory
- Integrated access to climate data records of CGMS members
- Common approach to long-term data preservation
- Work with CEOS

End to end Architecture for Climate Monitoring from Space



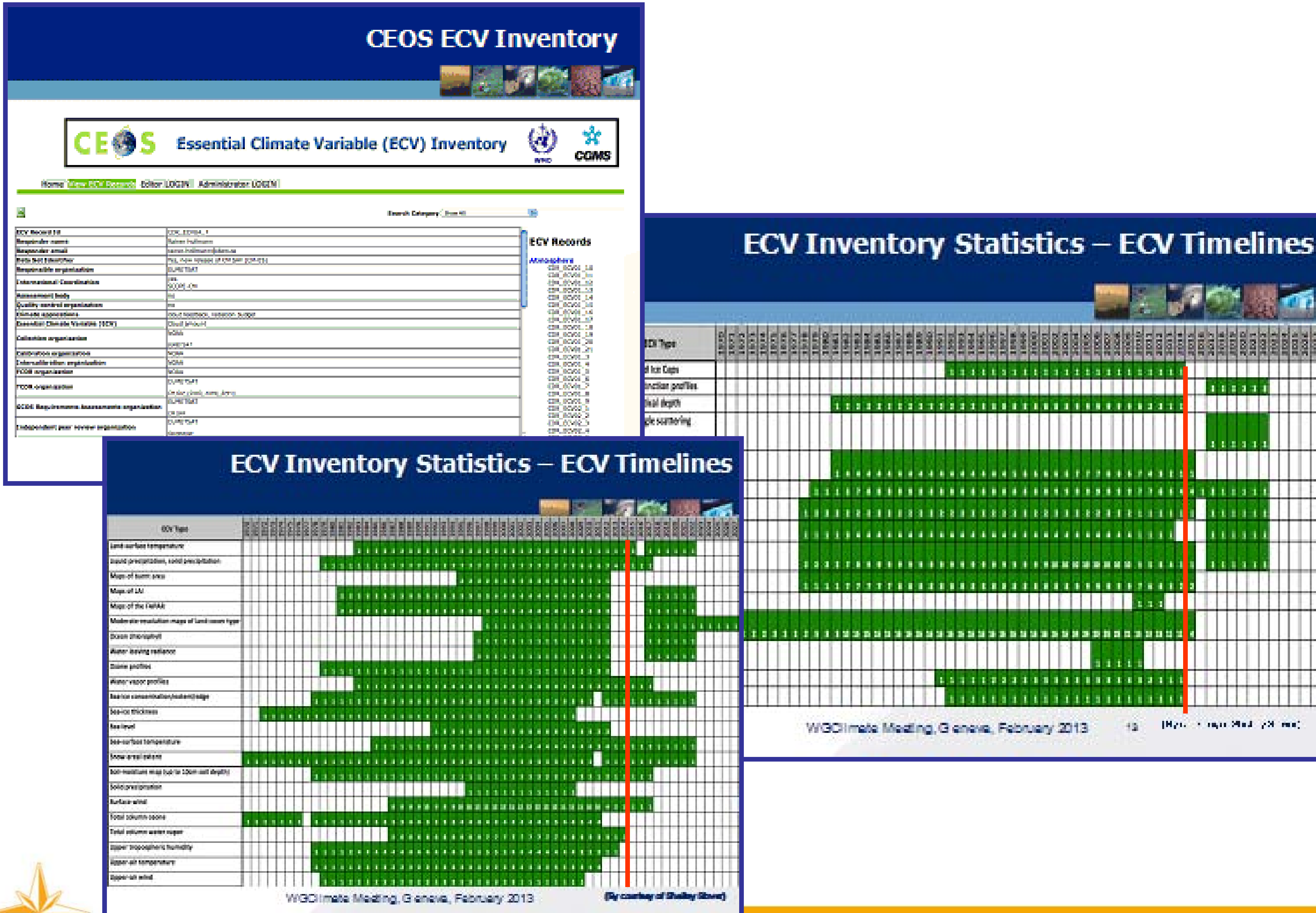
- CGMS Baseline addresses only the sensing level (sensor, orbit, calibration)

Evaluating the CGMS Baseline against the logical view of the Architecture

Can the CGMS Baseline be a building block of the Architecture ?

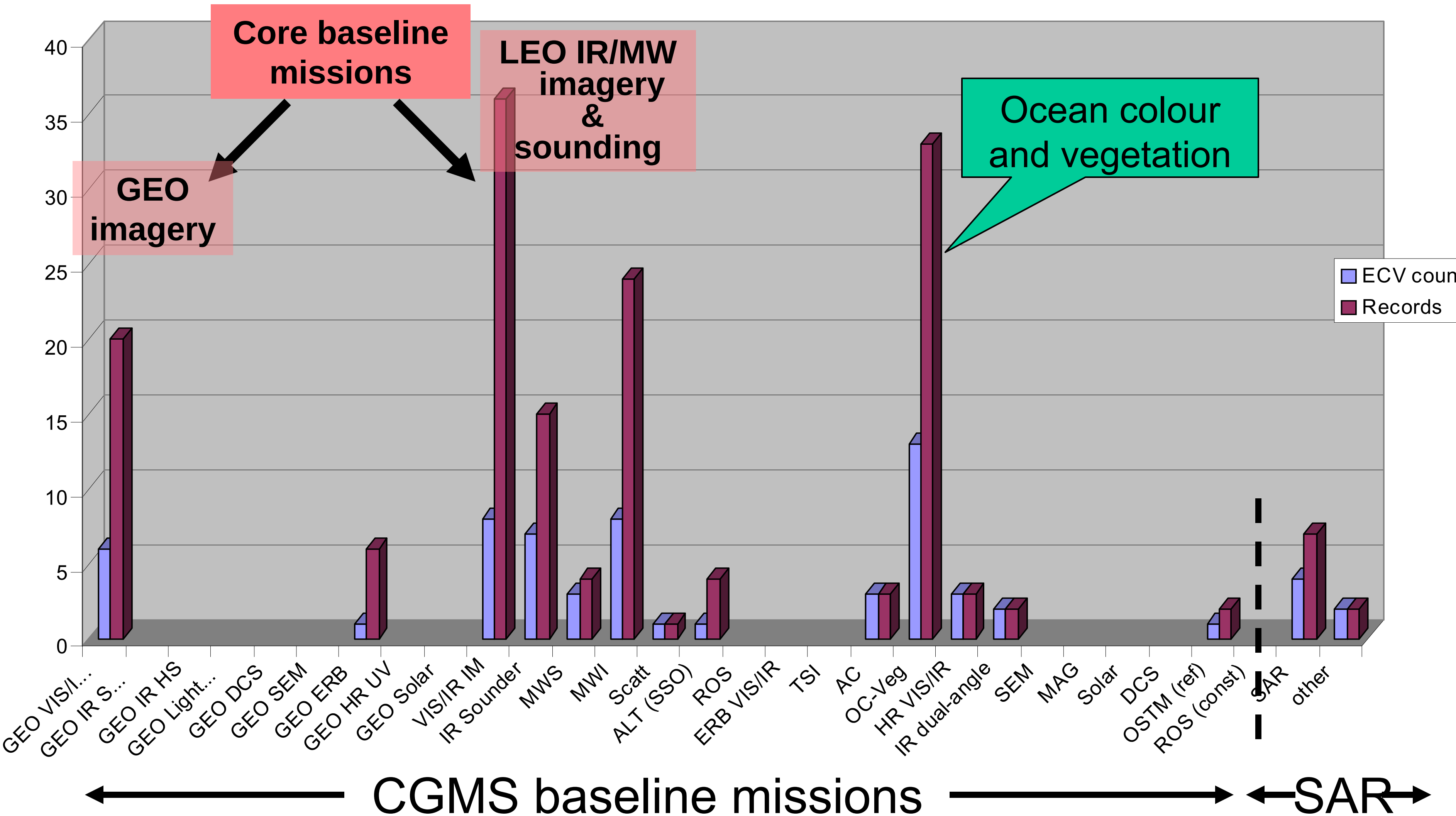
- Discuss relevance/suitability of the «Baseline missions» to support generation of climate products
- Investigate the use of the Baseline to project long-term availability of key climate capabilities
- Derive a preliminary gap analysis at sensor level

CGMS Baseline, Climate Architecture and ECV Product Inventory


CEOS ECV Inventory
CEOS
Essential Climate Variable (ECV) Inventory
CGMS
ECV Records
ECV Inventory Statistics – ECV Timelines
WGClimate Meeting, Geneva, February 2013
ECV Inventory Statistics – ECV Timelines
WGClimate Meeting, Geneva, February 2013

Relevance of CGMS baseline missions for climate

Mapping of the ECV inventory with the CGMS Baseline



CGMS Baseline, FCDRs and ECV Product Inventory

- ECV inventory shows large contribution of CGMS Baseline missions: missions highly relevant for climate (record length)

- However the way the CGMS baseline is defined is too generic to inform the inventory on future capability for ECV production

- Outcome of CGMS-41:

➢ To review the categorisation of missions in the CGMS Baseline (…) (…) to support the high level mapping of future missions with FCDRs *(CGMS Action 41.42)*

➢ To define a list of FCDRs that CGMS Members can commit to provide on a sustained basis building on the CGMS Baseline (…) to communicate to the CEOS-CGMS working group on climate (*CGMS Action 41.43)*

CGMS Baseline, FCDRs and ECV Product Inventory

(Cont.)

- Architecture should give guidance on space segment evolution
- Long-lead programme decisions should be informed by long-term gap analysis
- Product generation plans are not always defined 20 years ahead, potentially involve many players
- Long-term satellite plans better known at sensor level than at product level

- FCDRS (e.g. radiances) often support many different ECV products
- FCDRs have their own value when assimilated in climate models

- (CGMS 41.12) …proposes to establish an inventory of FCDRs in addition to, and in consistency with, the ECV product inventory

Specification of FCDRs

The objective of this part of the study is to specify *Fundamental Climate Data Records (FCDR)* that the CGMS baseline missions can provide in support of the ECVs.

GCOS

GLOBAL CLIMATE OBSERVING SYSTEM

WMO IOC UNEP ICSU

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED DATA PRODUCTS FOR CLIMATE

2011 Update

Supplemental details to the satellite-based component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)"

December 2011

GCOS – 154

UNITED NATIONS ENVIRONMENT PROGRAMME

INTERNATIONAL COUNCIL FOR SCIENCE

GOSIC Global Observing Systems Information Center

GCOS GOOS GTOS

Facilitating Access to Global Observing Systems Data and Information

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GCOS Essential Climate Variable (ECV) Data Access Matrix

The Essential Climate Variable (ECV) Data Access Matrix is in development to provide easy access to ECV data sets and information. The input for the variable descriptions was provided by WMO/GCOS. Essential Climate Variables are required to support the work of the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC). All Essential Climate Variables are technically and economically feasible for systematic observation. It is these variables for which international exchange is required for both current and historical observations. It is emphasized that the ordering within the table is simply for convenience and is not an indicator of relative priority.

An effort is presently underway to identify authoritative data sets for each of the ECVs. These data sets will be made available in this data access matrix. Satellite and in-situ data questionnaires are in development and will be sent to data centers to identify data sets. This effort is in cooperation with the Committee on Earth Observation Satellites (CEOS) Systems Engineering Office/NASA Langley Research Center, the World Meteorological Organization (WMO), the WMO Global Climate Observing System (GCOS), the WCRP Data Advisory Council (WDAC), the Cooperative Institute for Climate and Satellites — NC (CICS-NC), NOAA/NCDC and the GOSIC.

This is a team effort. Suggestions and comments are welcome. Please send them to: christina.lief@noaa.gov

Latest updates:

- The Matrix is being updated with data access information provided by WMO/GCOS and TOPC members.
- Soil moisture ECV information and data links updated per WMO/GCOS input.

Latest Update January 23, 2013

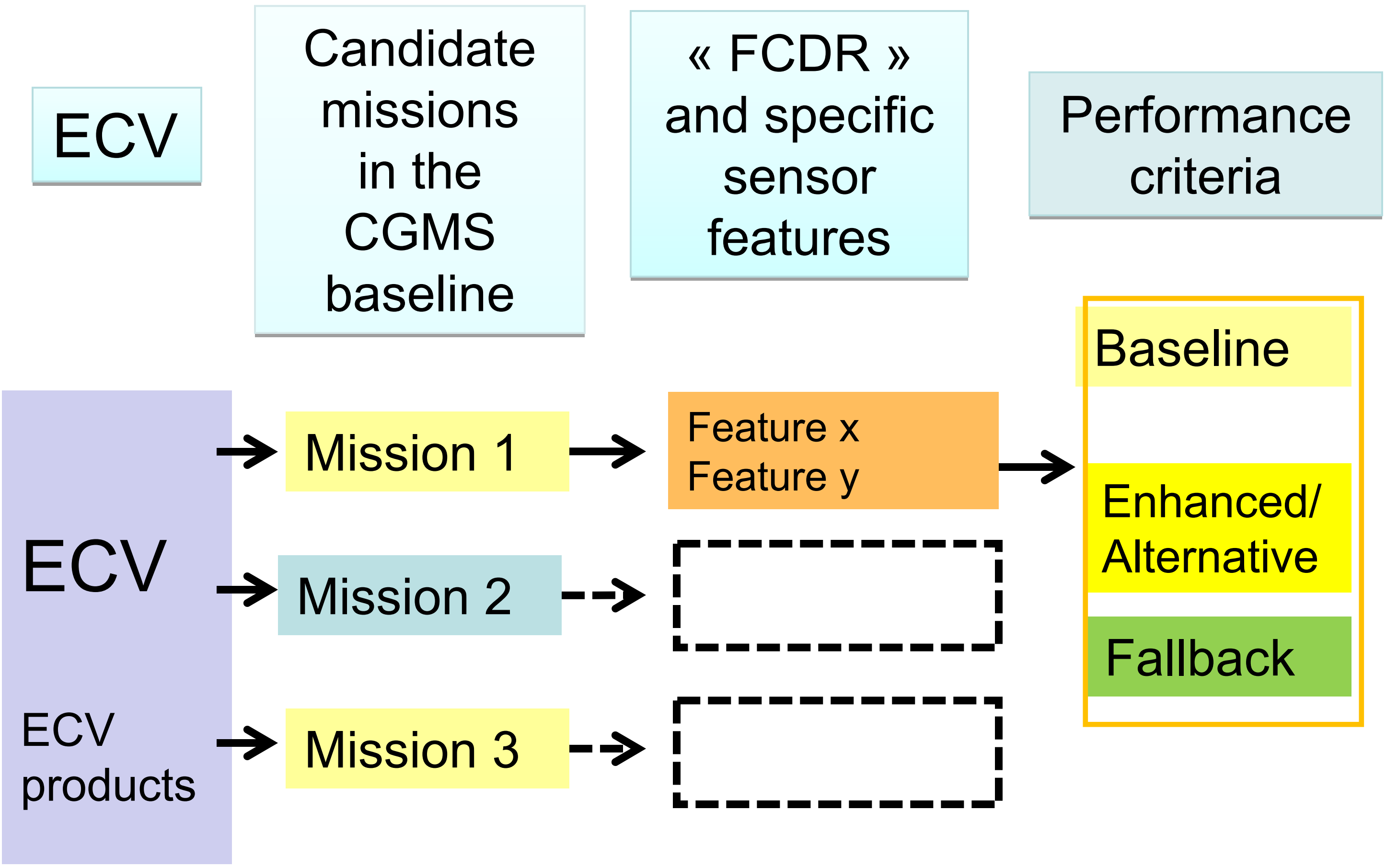
ATMOSPHERIC (over Land, Sea & Ice)	OCEANIC	TERRESTRIAL
Surface	**Surface**	River Discharge
Surface Air Pressure	Carbon Dioxide Partial Pressure	Water Use
Surface Air Temperature	Current	Ground Water
Surface Precipitation	Ocean Acidity *	Lakes (Water level in lakes and reservoirs, water storage) *
Surface Radiation Budget	Ocean Color	Snow Cover
Water Vapour (Surface humidity)	Phytoplankton *	Glaciers and Ice Caps *
Near-Surface Wind Speed and Direction	Sea Ice	Permafrost and seasonally frozen ground
Upper-Air	Sea Level	Albedo and Reflectance Anisotropy *
Cloud Properties	Sea State	Land Cover (including Vegetation Type)
Earth Radiation Budget (including Solar Irradiance) *	Sea Surface Salinity	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
Temperature	Sea Surface Temperature	Leaf Area Index (LAI)
Water Vapor	**Sub-Surface**	Above Ground Biomass *
Wind Speed and Direction	Carbon	Fire Disturbance
Composition	Current	Soil Moisture *
Carbon Dioxide	Nutrients	Soil Carbon *
Methane	Ocean Acidity *	Ice Sheets *
Other Long-Lived Greenhouse Gases	Oxygen *	
Ozone and Aerosols	Salinity	
Precursors (supporting the Aerosols and Ozone ECVs) *	Temperature	
	Tracers	
	Global Ocean Heat Content **	

* Added or modified per 'Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC - August 2010, GCOS-138 (GOOS-184, GTOS-76, WMO-TD/No. 1523)' (pdf)

Table 6: Overview of Products – Atmosphere *(From GCOS-154)*

ECV	Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)	Product Numbers (IP Reference Actions)
Surface Wind Speed and Direction	Surface wind retrievals	Passive microwave radiances and radar backscatter	A.1 (A11)
Precipitation	Estimates of liquid and solid precipitation, derived from specific instruments and provided by composite products	Passive microwave radiances Geostationary VIS/NIR/IR radiances	A.2 (A6, A8, A9, A1
Upper-air Temperature	Upper-air temperature retrievals Temperature of deep atmospheric layers	Passive microwave and IR radiances GNSS radio occultation bending angles	A.3.1 A.3.2 (A20, A21)
Upper-air Wind Speed and Direction	Upper-air wind retrievals	VIS/IR imager radiances Doppler wind lidar	A.4 (A11)
Water Vapour	Total column water vapour Tropospheric and lower-stratospheric profiles of water vapour Upper tropospheric humidity	Passive microwave radiances UV/VIS imager radiances IR and microwave radiances Limb soundings	A.5.1 A.5.2 A.5.3 (A7, A21, A22, A26)
Cloud Properties	Cloud amount, top pressure and temperature, optical depth, water path and effective particle radius	VIS/IR imager radiances IR and microwave radiances Lidar	A.6.1 A.6.2 A.6.3 A.6.4 A.6.5 A.6.6 (A23, A24)
Earth Radiation Budget	Earth radiation budget (top-of-atmosphere and surface) Total and spectrally-resolved solar irradiance	Broadband radiances Spectrally-resolved solar irradiances Geostationary multispectral imager radiances	A.7.1 A.7.2 (A14, A25)
Carbon Dioxide,	Retrievals of greenhouse gases, such as		

Approach followed for each ECV observable from space



Upper air temperature

GCOS-154 ECV & FCDR	Baseline	FCDR and specific sensor feature	Performance criteria	
Uppe… temp… FCD… Pass… and I… radia… GNSS RO bending angles	LEO IR … spectral	IR spectra to cover the CO_2 bands 4-5 μm and 13-15 μm	1.1.1	Baseline: IR spectra to cover the CO_2 bands in MWIR and … provides high vertical …ariable …tive to mid- and high layers …nsitive to the lower
				…the CO_2 band in TIR …er troposphere
				…instead of spectrometer …ue to poor spectral resolution
				…the CO_2 bands in MWIR and … provides high vertical …ariable … temperature (and humidity) …nge monitoring
			1.2.2	Fallback: IR radiometry in about 20 narrow channels including the CO_2 bands in MWIR and TIR - Coarse vertical resolution due to poor spectral resolution
	LEO MW sounder	MW radiances for fine coverage of the O_2 band(s) 50-60 GHz and possibly ~118 GHz - Well over 10 very-narrow channels in the 50-60 GHz band, less in the 118 GHz band - Radiometric accuracy NEΔT < 0.2 K, SNR > 100 - Supporting channels around 23 GHz (water vapour), and 37 and 90 GHz (windows)	1.3.1	Basic: 10 to 15 channels in the O_2 band 50-60 GHz, with supporting channels for water vapour correction (~23 GHz) and in window regions (~37 and ~90 GHz) - For nearly-all-weather temperature sounding
			1.3.2	Alternative: exploitation of the O_2 band around 118 GHz, with supporting water vapour and window channels - More sensitive to the higher atmospheric layers - More affected by clouds, especially ice
			…3.3	Optimum: both O_2 bands 50-60 GHz and ~118 GHz …oited, with supporting water vapour and window channels - Improved vertical resolution of the retrieved variable
			…4.1	Basic: capability to track the satellites of one constellation of the GNSS system during occultation - Capability to capture 200 to 700 events/day, depending on whether tracking is performed both fore- and aft- or only fore- or aft
			…4.2	Enhanced: capability of exploiting more GNSS constellations (GPS, GLONASS, Galileo, Beidou)

MW radiances for fine coverage of the O_2 bands 50-60 GHz and if possible ~118 GHz
- Radiometric accuracy NEΔT < 0.2 K, SNR >100
- Supporting channels around 23 GHZ (water vapour), and 37 and 90 GHz (window)

Optimum: both O_2 bands 50-60 GHz and ~118 GHz with supporting water vapour and window channels
- improved vertical resolution of retrieved variable

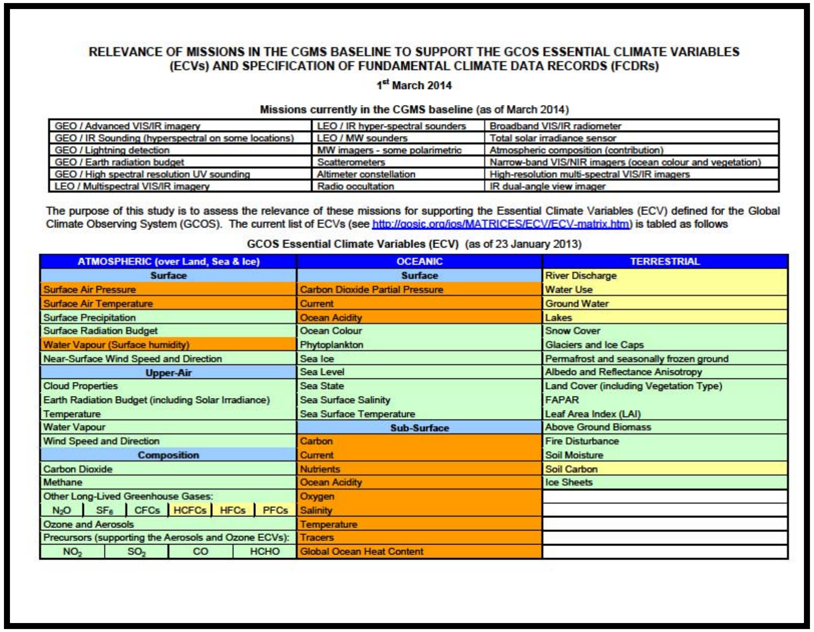
Sea Surface Temperature

baseline	FCDR and specific sensor features	Performance criteria
LEO / Multi-spectral VIS/IR imagery	IR radiances to cover windows at 3.7, 11 and 12 mm -Bandwidths < 1.0 mm at 11 and 12 mm, < 0.2 mm at 3.7 mm -Radiometric accuracy NEDT < 0.1 K @ 300 K	Basic: split TIR window 11/12 mm -Splitting the main TIR window enables correcting for water vapour contamination Enhanced: addition of MWIR window at 3.7 mm -The 3.7 mm window is more transparent and less sensitive to cloud contamination Optimum: addition of split MWIR window 3.7/4.0 mm -Splitting the main MWIR window enables correcting for CO_2 and air temperature contamination
GEO advanced VISIR imagery	Frequent IR radiances to cover windows at 3.7, 11 and 12 mm -Bandwidths < 1.0 mm at 11 and 12 mm, < 0.2 mm at 3.7 mm -Radiometric accuracy NEDT < 0.1 K @ 300 K -Image cycle <	IR radiances for frequent coverage of windows at 3.7, 11 and 12 mm -Spitting the main TIR window enables correcting for water vapour contamination -The 3.7 mm window is more transparent and less sensitive to cloud contamination -Frequent coverage is useful for SST diurnal variations in coastal zone, and filtering from moving clouds Fallback: missing the MWIR window 3.7 mm -Less accurate surface temperature
LEO / IR hyper-spectral sounding	IR spectra to co[illegible] regions around 3.7 and 1[illegible] -Resolving powe[illegible] -Radiometric acc[illegible] 300 K	Baseline: IR spectra to cover window regions around 3.7 and 11 mm -More numerous and more transparent windows available in spectrally resolved radiances -Benefit of stretching the range from 3.7 to over 4 mm for CO_2 and air temperature correction Fallback: IR spectra to cover the window region around 11 mm [illegible]ctral resolution less effective in the TIR window where the water vapour contamination is due to continuum
GEO / IR sounding (hyper-spectral o[illegible] some locations)	[illegible]	[illegible]ing from moving clouds [illegible] [illegible]ent windows
IR dual-angle view imagery	[illegible] and 12 mm.Viewing angles(nadir/45°) Dl < 1.0 at 11 & 12 mm, < 0.3 at 3.7 mm -Radiometric acc.NEDT < 0.1 K @ 300 K	[illegible] 12 mm -Improved corrections for water vapour and other atmospheric effects by differential optical path depth
LEO / MW imagery, some polarimetri[illegible]	MW radiances in the 6.3-7.3 GHz range at 1 to 4 dual-polarised frequencies -Bandwidths Dn < 200 MHz -Radiometyric accuracy NEDT < 0.5 K	Basic: conical scanning, one frequency substantially lower than 7 GHz, 2 polarisations -All-weather capability, maximum sensitivity to SST in C-band, 2 polarisations needed to account for roughness Enhanced: additional frequency / 2-pol slightly above 7 GHz -The additional frequency mitigates the effect of electromagnetic interferences [illegible]

Frequent IR radiances covering windows at 3.7, 11 & 12 µm
- Bandwidths <1.0 µm at 11-12 µm and <0.2 µm at 3.7 µm
- Radiometric accuracy NEDT<0.1 K@300K
- Image cycle <30min

First report in a nutshell

- The 27-page report addresses:
  - 39 ECVs
  - 132 combinations of ECV and « Baseline missions »
  - 173 « FCDR » with specific sensor features
  - 275 classes of sensors to produce these FCDRs
- Indicates which kind of FCDR can be produced from CGMS Baseline missions, and the impact of sensor features on retrieval performance
- Prepares the inventory of FCDRs supported by CGMS baseline missions (CGMS 41.12)



RELEVANCE OF MISSIONS IN THE CGMS BASELINE TO SUPPORT THE GCOS ESSENTIAL CLIMATE VARIABLES (ECVs) AND SPECIFICATION OF FUNDAMENTAL CLIMATE DATA RECORDS (FCDRs)

1st March 2014

Missions currently in the CGMS baseline (as of March 2014)

GEO / Advanced VIS/IR imagery	LEO / IR hyper-spectral sounders	Broadband VIS/IR radiometer
GEO / IR Sounding (hyperspectral on some locations)	LEO / MW sounders	Total solar irradiance sensor
GEO / Lightning detection	MW imagers - some polarimetric	Atmospheric composition (contribution)
GEO / Earth radiation budget	Scatterometers	Narrow-band VIS/NIR imagers (ocean colour and vegetation)
GEO / High spectral resolution UV sounding	Altimeter constellation	High-resolution multi-spectral VIS/IR imagers
LEO / Multispectral VIS/IR imagery	Radio occultation	IR dual-angle view imager

The purpose of this study is to assess the relevance of these missions for supporting the Essential Climate Variables (ECV) defined for the Global Climate Observing System (GCOS). The current list of ECVs (see http://gosic.org/ios/MATRICES/ECV/ECV-matrix.htm) is tabled as follows

GCOS Essential Climate Variables (ECV) (as of 23 January 2013)

ATMOSPHERIC (over Land, Sea & Ice)	OCEANIC	TERRESTRIAL
Surface	**Surface**	River Discharge
Surface Air Pressure	Carbon Dioxide Partial Pressure	Water Use
Surface Air Temperature	Current	Ground Water
Surface Precipitation	Ocean Acidity	Lakes
Surface Radiation Budget	Ocean Colour	Snow Cover
Water Vapour (Surface humidity)	Phytoplankton	Glaciers and Ice Caps
Near-Surface Wind Speed and Direction	Sea Ice	Permafrost and seasonally frozen ground
Upper-Air	Sea Level	Albedo and Reflectance Anisotropy
Cloud Properties	Sea State	Land Cover (including Vegetation Type)
Earth Radiation Budget (including Solar Irradiance)	Sea Surface Salinity	FAPAR
Temperature	Sea Surface Temperature	Leaf Area Index (LAI)
Water Vapour	**Sub-Surface**	Above Ground Biomass
Wind Speed and Direction	Carbon	Fire Disturbance
Composition	Current	Soil Moisture
Carbon Dioxide	Nutrients	Soil Carbon
Methane	Ocean Acidity	Ice Sheets
Other Long-Lived Greenhouse Gases:	Oxygen	
N_2O / SF_6 / CFCs / HCFCs / HFCs / PFCs	Salinity	
Ozone and Aerosols	Temperature	
Precursors (supporting the Aerosols and Ozone ECVs):	Tracers	
NO_2 / SO_2 / CO / HCHO	Global Ocean Heat Content	

Click to open the WORD file

Contribution to Gap Analysis

This second part of the study links the types of FCDR identified in the 1st part with the OSCAR database (www.wmo.int/oscar/space).

It covers past*, current and planned missions, either operational or sustained.

(*) Past missions were included if active in the 1990s and/or there is some continuity between these heritage data and newer series.

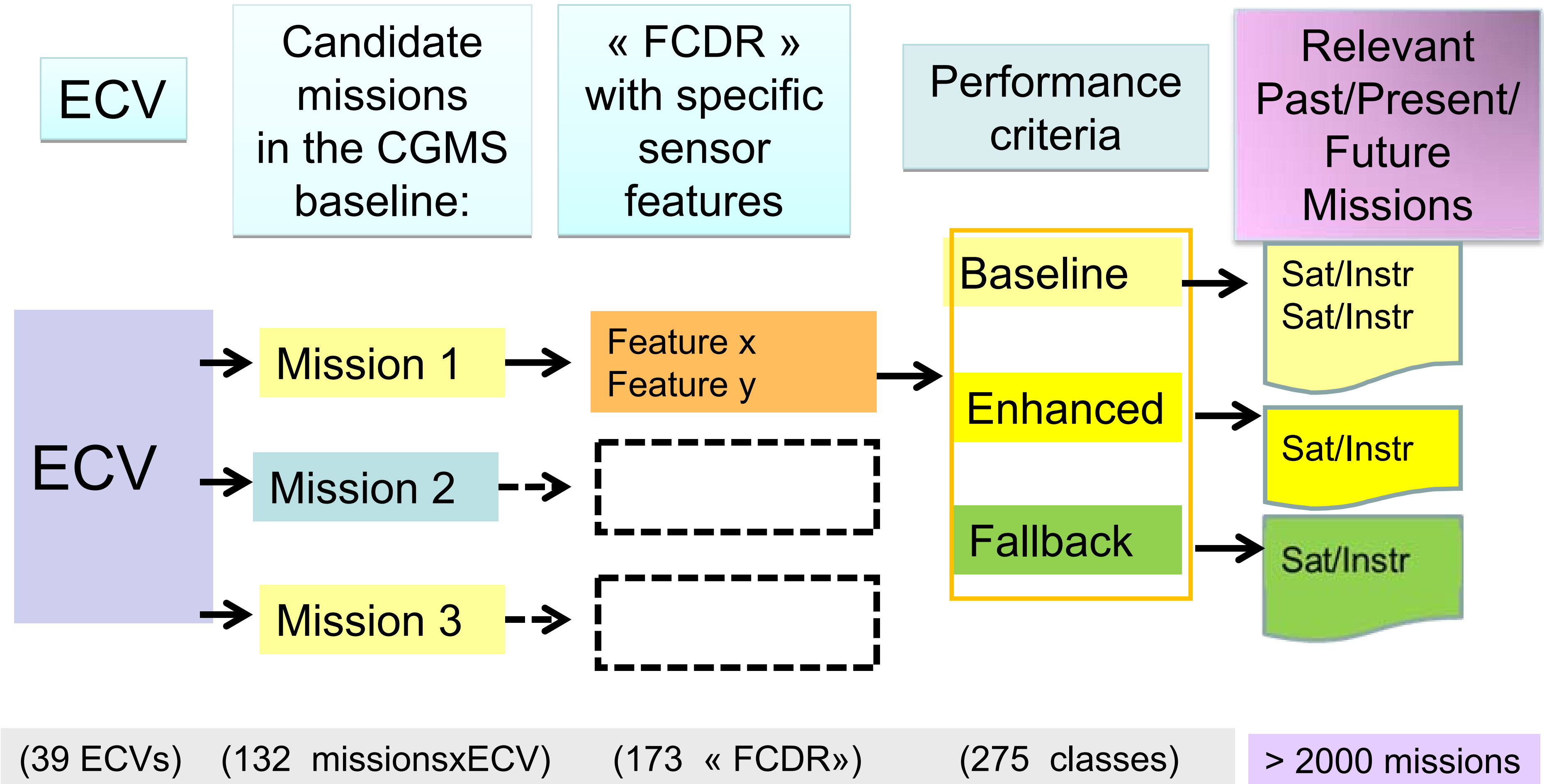
OSCAR timeline of current/planned sensors with potential capability (by design) to support a given variable

Example: sea level observations

Filter by Satellite or Instrument

Instrument	Relevance	Satellite	Orbit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Poseidon-3	1-Primary	JASON-2	66 °	X	X	X	X	X	X															
Poseidon-3B	1-Primary	JASON-3	66 °						X	X	X	X	X	X										
Altimeter	1-Primary	SWOT	78 °											X	X	X	X							
ALT (HY-2A)	1-Primary	HY-2A	06:00 desc		X	X	X	X																
ALT (HY-2A)	1-Primary	HY-2B	06:00 desc					X	X	X	X													
ALT (HY-2A)	1-Primary	HY-2C	06:00 desc							X	X	X	X											
ALT (HY-2A)	1-Primary	HY-2D	06:00 desc										X	X	X	X								
SRAL	2-High	JASON-CS-A	66 °										X	X	X	X	X	X	X	X				
SRAL	2-High	JASON-CS-B	66 °															X	X	X	X	X	X	X
SRAL	2-High	Sentinel-3A	10:00 desc					X	X	X	X	X	X	X	X									
SRAL	2-High	Sentinel-3B	10:00 desc						X	X	X	X	X	X	X	X								
KaRIN	3-Medium	SWOT	78 °											X	X	X	X							
SIRAL	3-Medium	CryoSat-2	92 °	X	X	X	X	X																
ATLAS	3-Medium	ICESat-2	94 °							X	X	X	X	X	X									
AltiKa	3-Medium	SARAL	06:00 asc				X	X	X	X	X	X												
SWIM	3-Medium	CFOSAT	07:00 desc					X	X	X	X													

Approach followed for each ECV observable from space



Missions with potential to provide following FCDR type: Ku-band or Ka-band altimetric data

Specific features	Instrument	Satellite(s)	Agency	Programmatics				Instrument main characteristics		
				Status	Nature	Launch	EOL	Channel	IFOV	Swath
Basic	ALT	HY-2 A to D	NSOAS	Current	Continuous	2011	³ 2022	2	1 km	16 km
	Poseidon-3	JASON-2	CNES	Current	Continuous	2008	³ 2015	2	0 km	30 km
	Poseidon-3B	JASON-3	CNES	Planned	Continuous	³ 2015	³ 2020	2	30 km	30 km
	Alti			Planned	R&D	³ 2020				
				Historical	Continuous	1998				
		GEOSat	DoD	Historical	Continuous	1985				
	NRA		ASA					2	30 km	30 km
	Poseid		NES					2	30 km	30 km
	RA	ERS 1 and 2	ESA					1	20 km	20 km
	RA-2	Envisat	ESA	Historical	Continuous	2002	2012	2	20 km	20 km
	SSALT	TOPEX-Poseidon	CNES	Historical	Continuous	1992	2005	1	25 km	25 km
Enhanced	SIRAL	CryoSat-2	ESA	Current	R&D	2010	³ 2014	1	1.94 km	1.94 km
	SIRAL	JASON-CS A&B,								
	SRAL	Sentinel-3 A&B	ESA	Planned	Operational	³ 2014	³ 2031	2	2.45 km	2.45 km
Alternative	AltiKa	SARAL	CNES	Current	R&D	2013	³ 2018	1	10 km	10 km
Development	SWIM	CFOSAT	CNES	Planned	R&D	³ 2014	³ 2017	1	18 km s.s.p.	180 km
	KaRIN	SWOT	NASA	Considered	R&D	³ 2020	³ 2023	1	0.22 km s.s.p.	120 km

Specific features

Satellite

Channels, IFOV, Swath

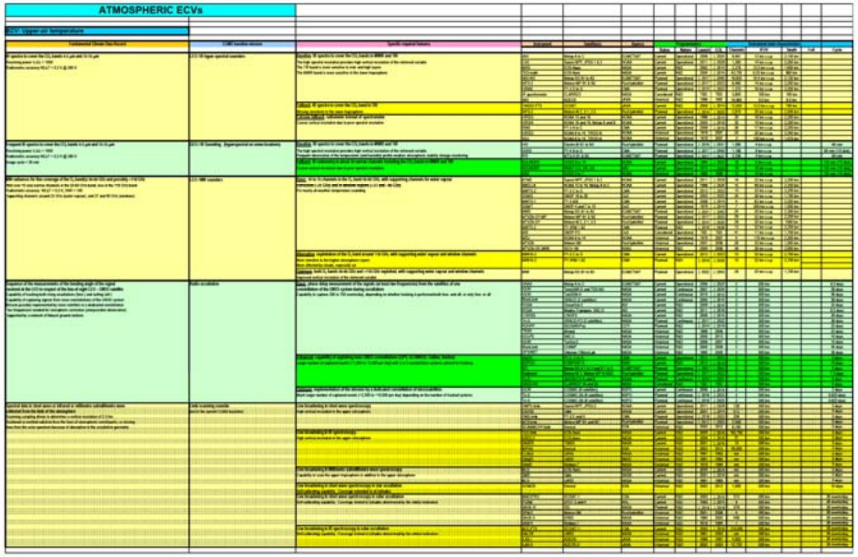
Instrument

Status, launch date & EOL

A snapshot of this second report

- Results consolidated in one EXCEL table per domain:
  - Atmosphere (~ 1100 records)
  - Ocean (~ 260 records)
  - Terrestrial (~ 1200 records)

- Identification of satellite missions with programmatic status, period of availability, and main instrument characteristics
- Sorted by performance class based on instrument design features and orbit type



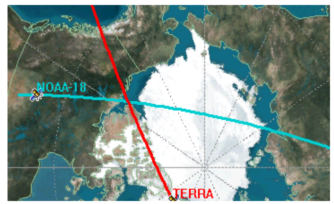
Click to open the EXCEL file

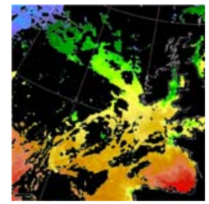
Quality evaluation

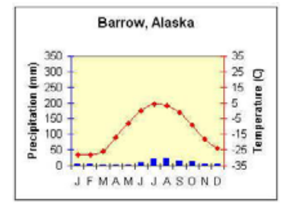
- A tentative quality index can be calculated from sensor design characteristics …however very questionable !
- Quality depends on multiple criteria:
  - Uncertainty (Precision, Bias)
  - Spatial/temporal resolution
  - Data record length
  - Data record completeness
  - Stability over a decade
  - Actual dataset availability, maturity, and accessibility….
- Quality assessment requires dedicated case-by-case analysis
- To be evaluated against user needs: some lower quality can be acceptable depending on how they are used

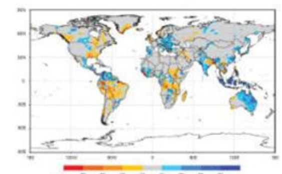
Discussion

Gap analyses at both ends









GAPS ?

Space-based Sensor Inventory

GAPS ?

ECV Product Inventory

Potential
for FCDRs
in support of
ECV product
generation

Actual
ECV product
generation

Conclusion

- This study identifies types of FCDR and the *potential* to deliver such FCDRs from past/present/future missions

- Contribution to the FCDR inventory and Gap Analysis, however:
  - Sensor availability & adequacy are necessary but not sufficient
  - FCDR availability and maturity to be stated by agencies
  - Quality evaluation requires careful assessment

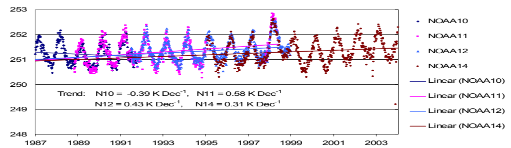
- Long-term continuity:
  - Need to ensure consistency of climate records over time
  - As technology progresses, new generation sensors provide different measurements
  - FCDRs should be evaluated with consideration of their compatibility with relevant heritage instrument data records

Thank you for your attention !

Questions ?

Use of the term « FCDR »

- Fundamental Climate Data Record (FCDR) denotes a well-characterized, long-term data record, usually involving a series of instruments, with potentially changing measurement approaches, but with overlaps and calibrations sufficient to allow the generation of products that are accurate and stable in both space and time to support climate applications
  Example: consistent series of calibrated radiances



- Thematic Climate Data Record (TCDR) denotes the counterpart of the FCDR in geophysical space. It covers one geophysical variable.

- **In this presentation we will also use "FCDR" in a generic way for "*a certain type of FCDRs*"**

Table 7: Overview of Products – Oceans *(From GCOS-154)*

ECV	Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)	Produ Numbers Refere Actio
Sea-surface Temperature	Integrated sea-surface temperature analyses based on satellite and *in situ* data records	Single and multi-view IR and microwave imager radiances	O.1 (O4, O7, O8
Sea-surface Salinity	Datasets for research on identification of changes in sea-surface salinity	Microwave radiances	O.2 (O12)
Sea Level	Sea-level global mean and regional variability	Altimetry	O.3 (O10)
Sea State	Wave height, supported by other measures of sea state (wave direction, wavelength, time period)	Altimetry	O.4 (O16)
Sea Ice	Sea-ice concentration/extent/edge, supported by sea-ice thickness and sea-ice drift	Passive and active microwave and visible imager radiances, supported by Synthetic Aperture Radar (SAR) altimetry	O.5 (O18, O19,
Ocean Colour	Ocean colour radiometry – water leaving radiance Oceanic chlorophyll-a concentration, derived from ocean colour radiometry	Multispectral VIS imager radiances	O.6.1, O.6.2 (O15, O23)

Table 8: Overview of Products – Terrestrial *(From GCOS-154)*

ECV or supporting variable[19]	Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)	Product Numbers (IP-10 Reference Actions)
Lakes	Lake levels and areas of lakes in the Global Terrestrial Network for Lakes (GTN-L)	VIS/NIR imager radiances, and radar imager radiances Altimetry	T.1.1 T.1.2 (T8)
Snow Cover	Snow areal extent, supplemented by snow water equivalent	Moderate-resolution VIS/NIR/IR and passive microwave imager radiances	T.2 (T16)
Glaciers and Ice Caps	2D vector outlines of glaciers and ice caps (delineating glacier area), supplemented by digital elevation models for drainage divides and topographic parameters	High-resolution VIS/NIR/SWIR optical imager radiances, supplemented by microwave InSAR and along-track optical stereo imaging	T.3.1 T.3.2 (T17)
Ice Sheets	Ice-sheet elevation changes, supplemented by fields of ice velocity and ice-mass change	Radar and laser altimetry, supplemented by:SAR, gravity	T.4 (T20)
Albedo	Reflectance anisotropy (BRDF), black-sky and white-sky albedo	Multispectral and multiangular imager radiances	T.5 (T3, T24, T25)
Land Cover	Moderate-resolution maps of land-cover type High-resolution maps of land-cover type, for the detection of land-cover change	Moderate-resolution multispectral VIS/NIR imager radiances High-resolution multispectral VIS/NIR imager radiances, supplemented by radar	T.6.1 T.6.2 (T26, T27, T28)
FAPAR	Maps of the Fraction of Absorbed Photosynthetically Active Radiation	VIS/NIR multispectral imager radiances	T.7 (T3, T29, T31)
LAI	Maps of Leaf Area Index	VIS/NIR multispectral imager radiances	T.8 (T3, T30, T29,T31)
Biomass	Regional and global above-ground forest biomass	Long-wavelength radar and lidar	T.9 (T32)
Fire Disturbance	Maps of burnt area, supplemented by active-fire maps and fire-radiative power	VIS/NIR/SWIR/TIR moderate-resolution multispectral imager radiances	T.10 (T35, T36, T37, T38, T39)
Soil Moisture	Research towards global near-surface soil-moisture map (up to 10cm soil depth)	Active and passive microwave	T.11 (T13, T14)
Land-surface Temperature	Land-surface temperature records to support generation of land ECVs	High-resolution IR radiances from geostationary and polar-orbiting satellites; Microwave radiances from polar-orbiting satellites	T.12 (T5, T13, T23, T27, T28)

Upper air water vapour

GCOS-154 ECV & FCDR	Baseline		FCDR and specific sensor feature		Performance criteria
GCOS-154: - Passive microwave radiances - UV/VIS imager radiances - IR and microwave radiances - Limb soundings	spectral sounders		- Resolving power $\lambda/\Delta\lambda > 1000$ - Radiometric accuracy NEΔT < 0.2 K @ 280 K		- The high spectral resolution provides high vertical resolution of the retrieved variable
				2.1.2	Enhanced: spectral range extended to FIR - The Far Infrared is sensitive to the higher troposphere
				2.1.3	Extreme fallback: radiometer instead of spectrometer - Coarse vertical resolution due to poor spectral resolution
	GEO / IR Sounding (hyperspectral on some locations)	2.2	Frequent IR spectra to cover the H_2O band 5-8 μm - Resolving power $\lambda/\Delta\lambda > 1000$ - Radiometric accuracy NEΔT < 0.2 K @ 280 K - Image cycle < 30 min	2.2.1	Baseline: IR spectra to cover the H_2O band in MWIR/TIR - The high spectral resolution provides high vertical resolution of the retrieved variable - Frequent observation of water-vapour (and temperature) profile enables stability change monitoring
				2.2.2	Fallback: IR radiometry in about 20 narrow channels including the H_2O band in MWIR/TIR - Coarse vertical resolution due to poor spectral resolution
	LEO / MW sounders	2.3	MW radiances for fine coverage of the H_2O band around 183 GHz - 3 to 6 channels in the 183 GHz band, and supporting windows at ~90 and ~160 GHz - Radiometric accuracy NEΔT < 1 K, SNR > 100 - Temperature information from O_2 at ~ 54 or ~118 GHz, either built-in or from a co-flying instrument	2.3.1	Basic: radiometry in the H_2O band around 183 GHz, with supporting window channels - For nearly-all-weather humidity sounding - Temperature information from a co-flying sounder
				2.3.2	Optimum: H_2O band and O_2 band(s) (~ 54 and/or ~118 GHz) in the same instrument - Integrated temperature/humidity sounding
	MW imagers - some polarimetric	2.4	MW radiances to cover the H_2O band around 23 GHz - One channel (1 or 2 polarisations) and at least one nearby window (2 polarisations)	2.4.1	Basic: conical-scanning imaging radiometer including the H_2O band at ~23 GHz - For total-column water vapour over the sea
				2.4.2	Fallback: nadir-viewing channel and a nearby window - Generally designed to support a radar altimeter
	LEO / Multispectral VIS/IR imagery	2.5	NIR radiances in the H_2O $\rho\sigma\tau$ band (~935 nm) and/or ψ band (~1380 nm) - Bandwidths as narrow as ~20 nm ($\rho\sigma\tau$-band) and ~40 nm (ψ-band) - Radiometric accuracy: SNR > 100	2.5.1	Channels in the $\rho\sigma\tau$ and ψ bands of water vapour - For total column and upper troposphere (and cirrus)
				2.5.2	Channels in the $\rho\sigma\tau$ band of water vapour - For total column
				2.5.3	Channels in the ψ band of water vapour - For upper troposphere (and cirrus)
	GEO / Advanced VIS/IR imagery	2.6	Frequent NIR radiances in the H_2O $\rho\sigma\tau$ band (~935 nm) and/or ψ band (~1380 nm) - Bandwidths as narrow as ~20 nm ($\rho\sigma\tau$-band) and ~40 nm (ψ-band) - Radiometric accuracy: SNR > 100 - Image cycle < 15 min	2.6.1	Channels in the $\rho\sigma\tau$ and ψ bands of water vapour - For total column and upper troposphere (and cirrus) - Early detection of instability onset
				2,6,2	Channels in the ψ band of water vapour - For early detection of water vapour growth in the upper troposphere, and cirrus cloud formation