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→ 4th ESA ADVANCED TRAINING
ON OCEAN REMOTE SENSING

The Marine Component of ESA´s Ocean Climate Change Initiative

7–11 September 2015 | IFREMER | Brest, France

Input to this presentation has been received from

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DOSTAG 84, 2/3 September 2015

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Objectives of the CCI

Realise 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

Within the scope of the CCI as presented in 2009

Atmosphere	Ocean	Terrestrial
Composition	**Surface**	
Aerosols Properties	Sea Surface Temperature	Land Cover
Carbon Dioxide & Methane	Sea Level	Fire Disturbance
Ozone	Sea Ice	Soil Moisture
Long-Lived GHGs	Ocean Color	Glacier and Ice Caps
Precursors (for Aerosols and O3)	Sea State	Ice Sheets
Upper Air	Current	Snow Cover
Cloud Properties	Sea Surface Salinity	Albedo
Temperature	Carbon Dioxide Partial Pressure	Leaf Area Index (LAI)
Water Vapor	Phytoplankton	(FAPAR)
Wind Speed and Direction	Ocean Acidity	Lakes
Earth Radiation Budget	**Sub Surface**	Above Ground Biomass
Surface	Carbon	Permafrost
Surface Air Pressure	Current	Ground Water
Surface Air Temperature	Nutrients	River Discharge
Surface Precipitation	Ocean Acidity	Soil Carbon
Surface Radiation Budget	Oxygen	
Water Vapour (Surface humidity)	Salinity	
Near-Surface Wind Speed, Dir	Temperature	
	Tracers	
	Global Ocean Heat Content	

CCI Scope	

Implemented by the CCI

Atmosphere	Ocean	Terrestrial
Composition	**Surface**	
Aerosols Properties	Sea Surface Temperature	Land Cover
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	Tracers	
	Global Ocean Heat Content	

CCI Scope	Started in CCI	

ESA Climate Change Initiative

INPUT FROM

Long Term Archiving Programmes
Multi-mission infrastructure

Re-processing ex archive (e.g. calibration)

"Gather"

ECV generation (e.g. validation & bias)

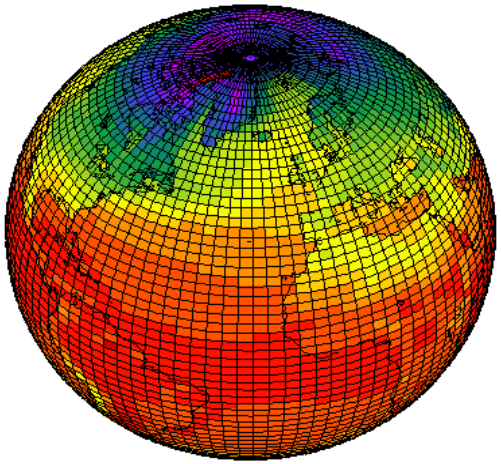
"Deliver"

ECV assimilation & assessment

"Exploit"

FEEDBACK LOOP:

6 year programme for 3 cycles



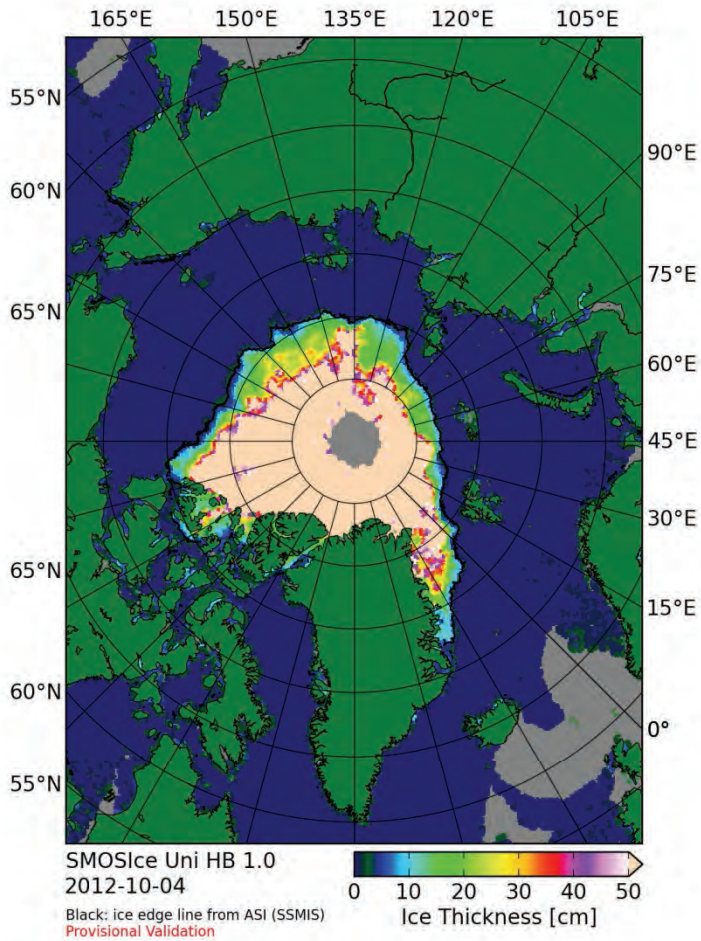
OUTPUT TO

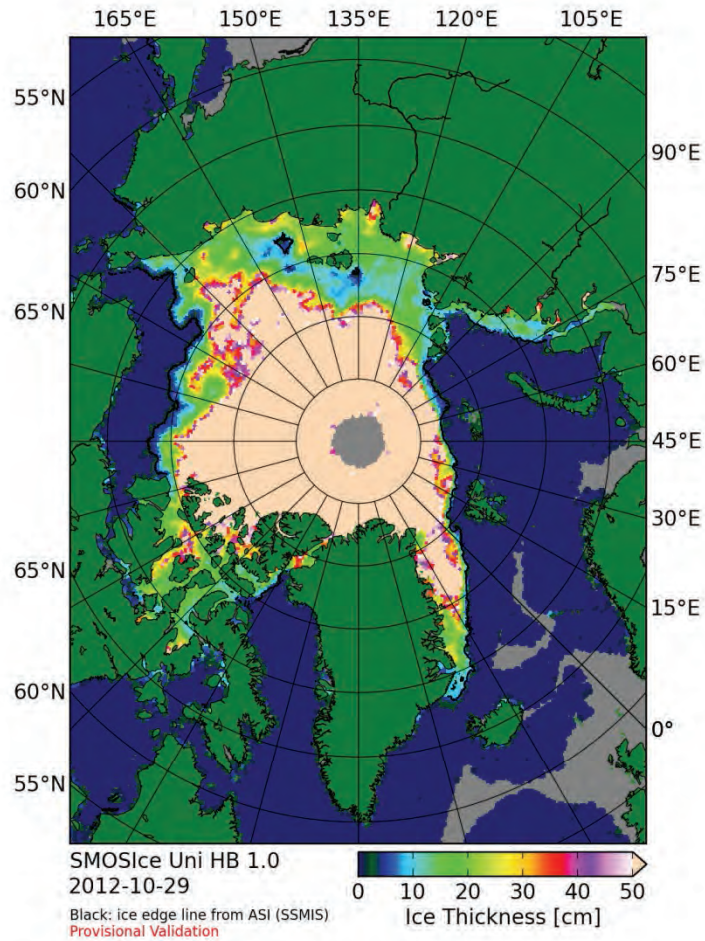
International Climate Programmes
EC & MS R&D Programmes
IPCC Process, UNFCCC

"Show"

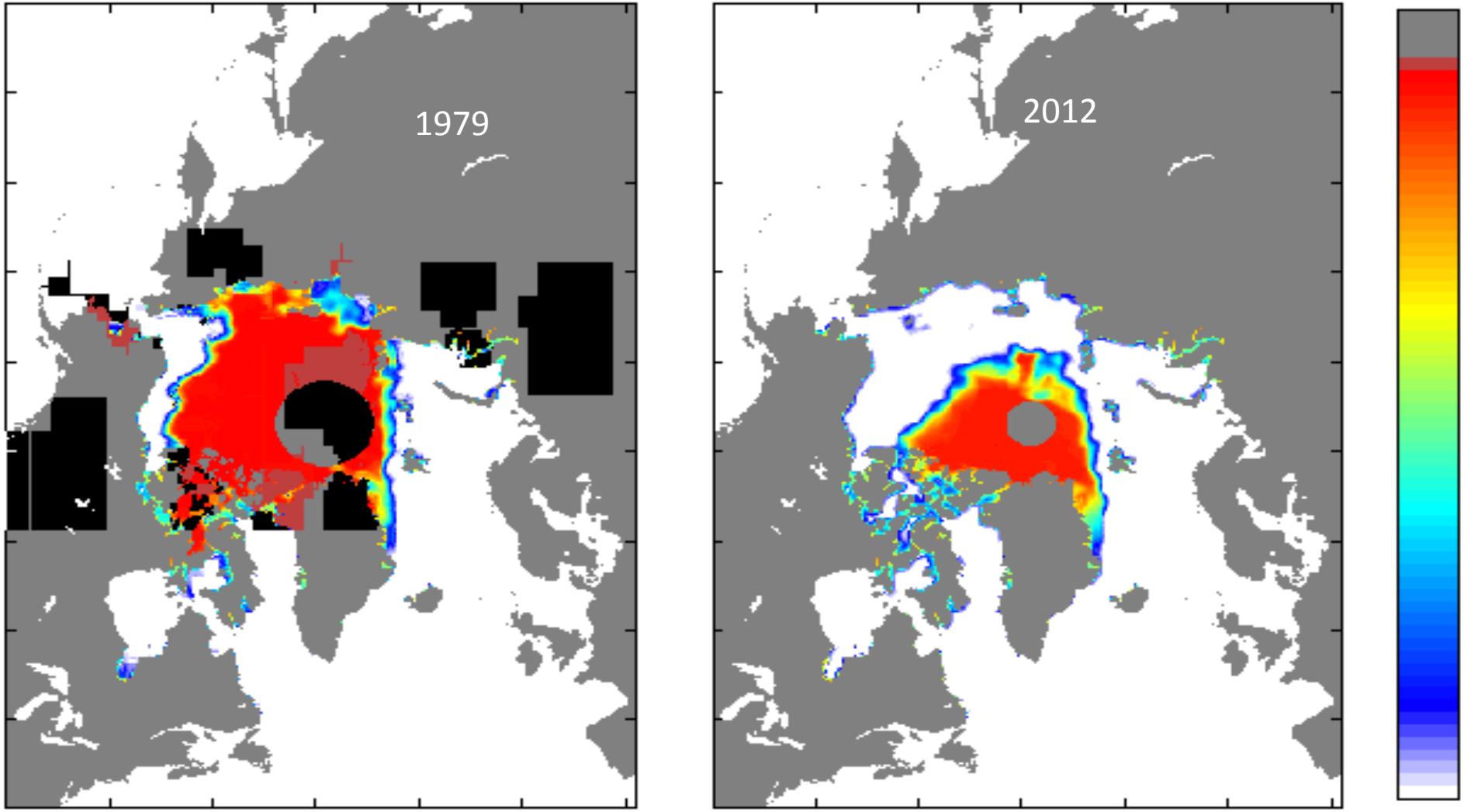
Education & Awareness

Use SMOS-ice product to identify extensive areas of thin ice (2012)

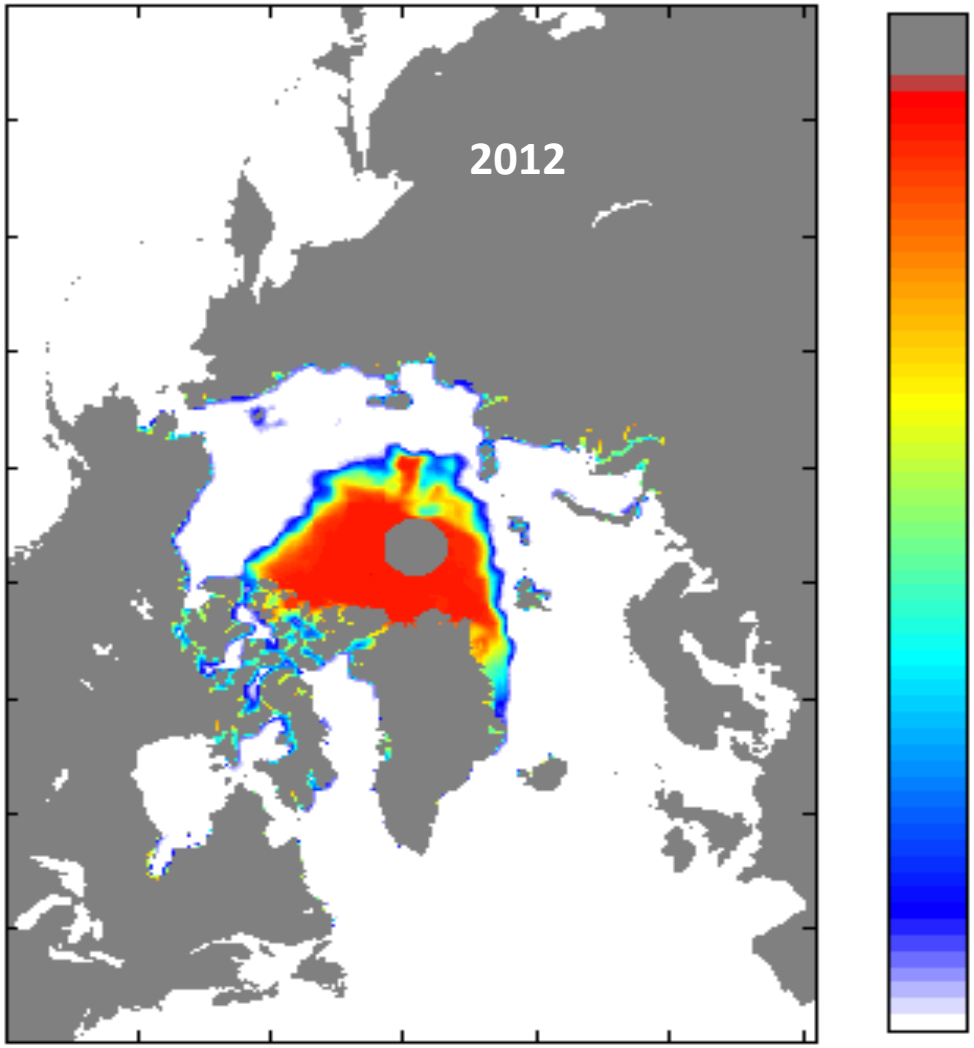


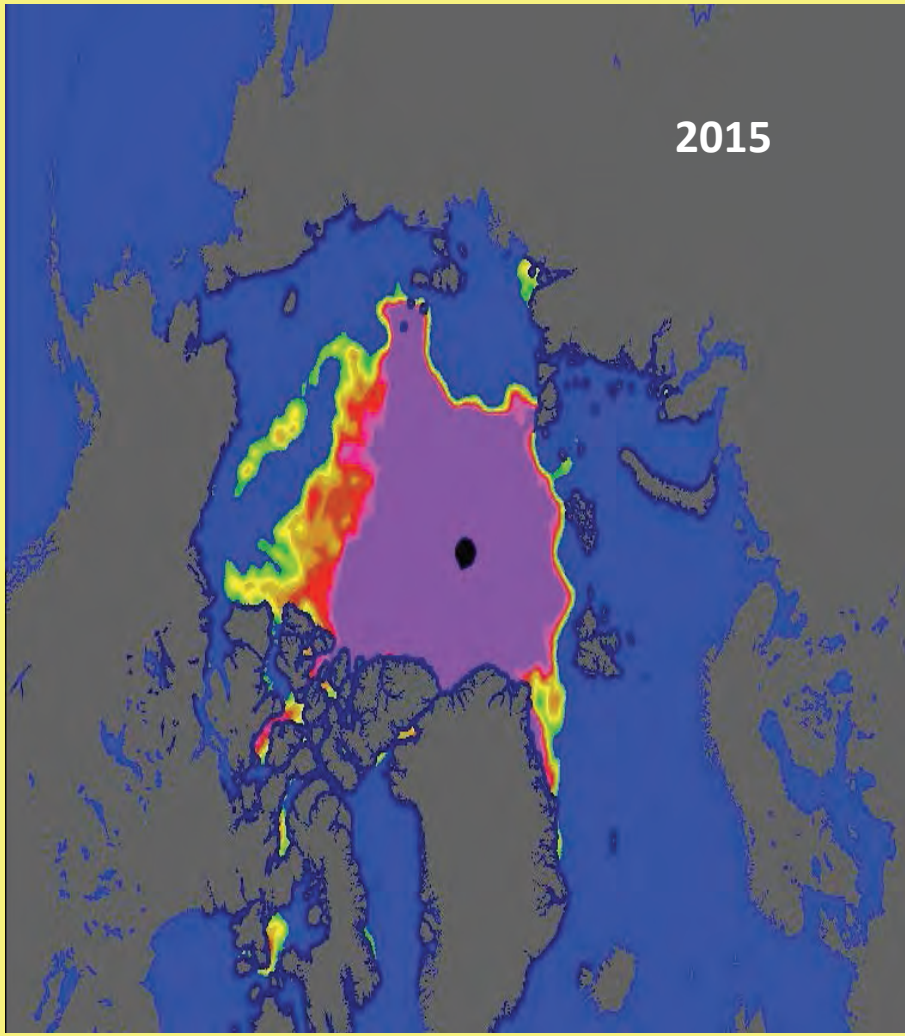


September 1979 versus September 2012

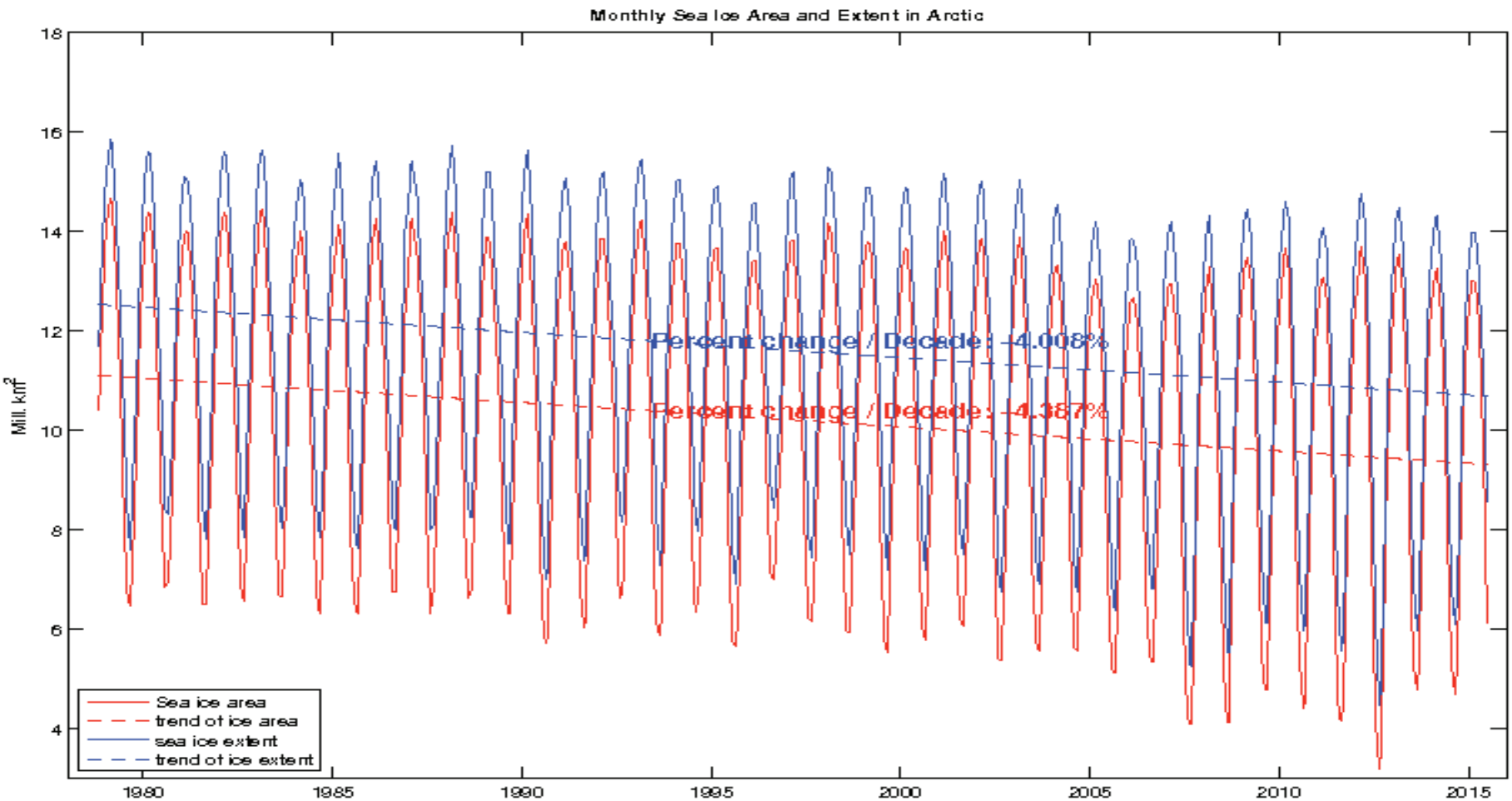


September 2012 versus 2015





Monthly sea ice area and extent



The latest month is: 2015–7

The Algorithms

- A total of 25+ algorithms were implemented and tested
- Most were algorithms published over the last 30 years
- Some were very simple
- Some were combinations (such as averages) of others

Algorithm	Channels
Near90_lin	90HV
Near90GHz	90HV
P90	90HV
ASI_NoWeather	90HV
combo3	(NRL+N90)/2
Bootstrap_p	37HV
combo7	(CF+N90)/2
P37/NRL	37HV
combo4	(NRL+N90+CF)/3
combo2	(CF+NT+N90)/3
PR	37HV+19HV
P18	19HV
P10	10HV
combo8	(CF+N90*CF)/(1+CF)
NASA_Team	37V+19HV
Bristol	37HV+19V
combo5	(CF+N90*CF**2)/(1+CF**2)
osisaf	37HV+19V
Bootstrap_f	37V+19V
CalVal	37V+19V
UMass_AES	37V+19V
TUD	90HV+37V+19V
NORSEX	37V+19V
combo1	(CF+NT)/2
combo6	(CF+N90*CF**3)/(1+CF**3)
One_channel	6H

Sea Level ECV

Project objectives

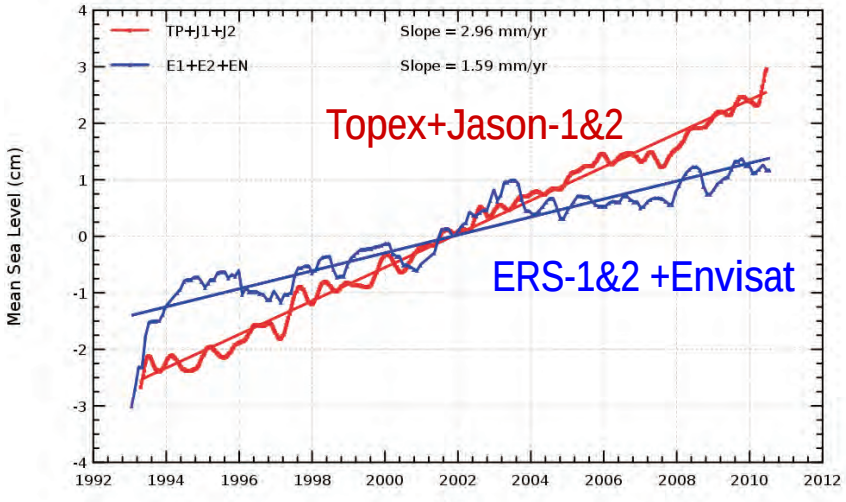
⇨ Provide a long, accurate space-based sea level record

Specific requirements:

- Reduce errors on the global mean sea level trend to <0.3 mm/yr
- Reduce errors on the interannual variability to <1 mm
- Reduce errors on regional sea level trends to <1 mm/yr

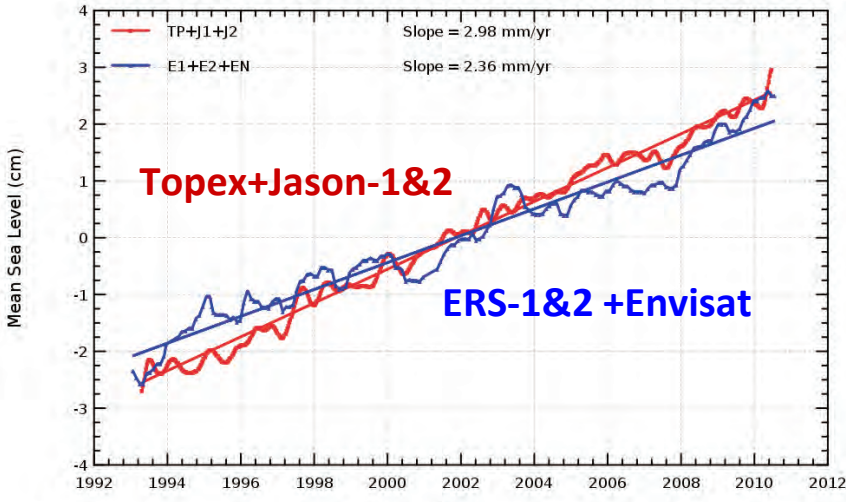
Sea Level ECV

Improvements from the Sea_Level_CCI project for the ERS-1&2 + Envisat-based global mean sea level time series



1992 2012

Before the Sea_Level_CCI project



1992 2012

After the Sea_Level_CCI project

Phase 1 Achievements:

- Developed improved and homogeneous reprocessing of altimetry data from ERS-1, ERS-2, Envisat, TOPEX/Poseidon, Jason-1, Jason-2, GeoSat and GFO (1985-2015)
- Investigated specific technical issues, such as Arctic sea-level during sea-ice minima, coastal sea-level change, etc.
- By combining the Sea-Level_cci products with other CCI ECVs (glaciers, ice sheets, sea surface temperature, etc.), initial sea level budget studies performed at global and regional scales.

Phase 2 Objectives:

- Improve accuracy in coastal areas and the Arctic, and employ new altimeter corrections
- Refine uncertainty estimates at interannual timescales
- Reprocess and extend time series to 2015, bringing in new missions (CryoSat, AltiKa, Sentinel-3)
- Produce regional sea-level trend uncertainty maps
- Organise an international intercomparison exercise

GCOS Requirements

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Global mean sea level	50km	N/A	10 days	2-4mm (global mean); 1 cm over a grid mesh	<0.3mm/yr (global mean)
Regional Sea Level	25km	N/A	Weekly	1cm (over grid mesh of 50-100km)	<1mm/yr (for grid mesh of 50-100km)

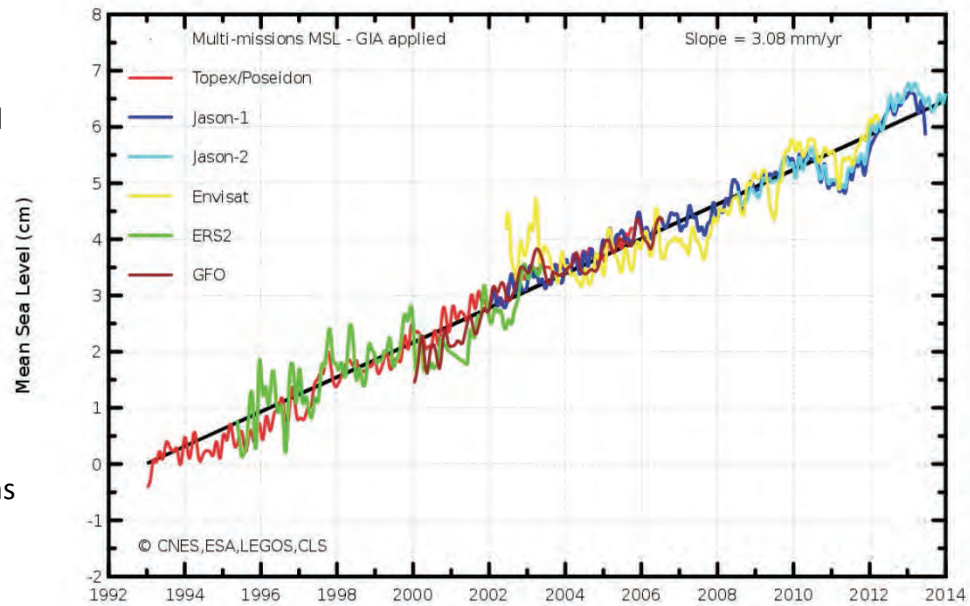
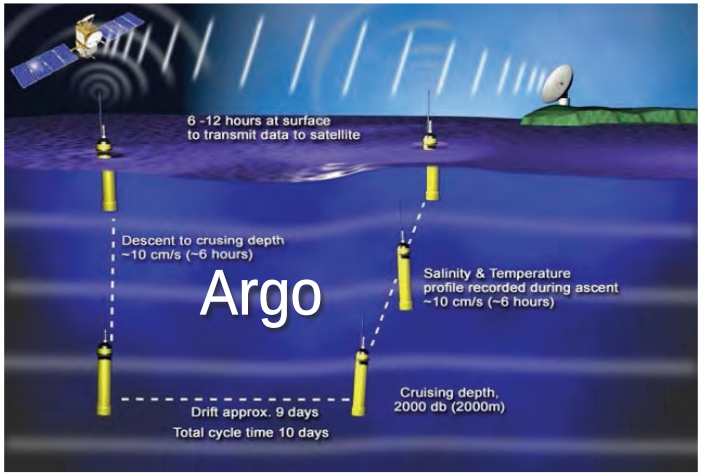
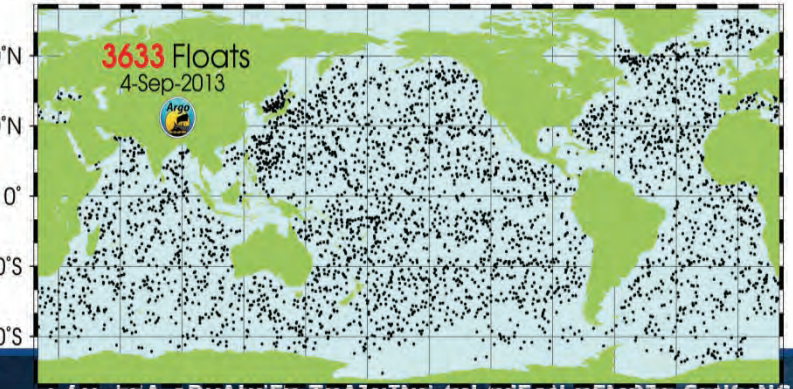


Figure: Multi-mission global sea level trend from altimetry. This figure includes all the CCI satellite time series overlaid after being adjusted for biases (1993-2013)

Since ~ 2003, Argo + GRACE → upper ocean thermal expansion + ocean mass

Thermal expansion of the upper ocean (0-1500 m)

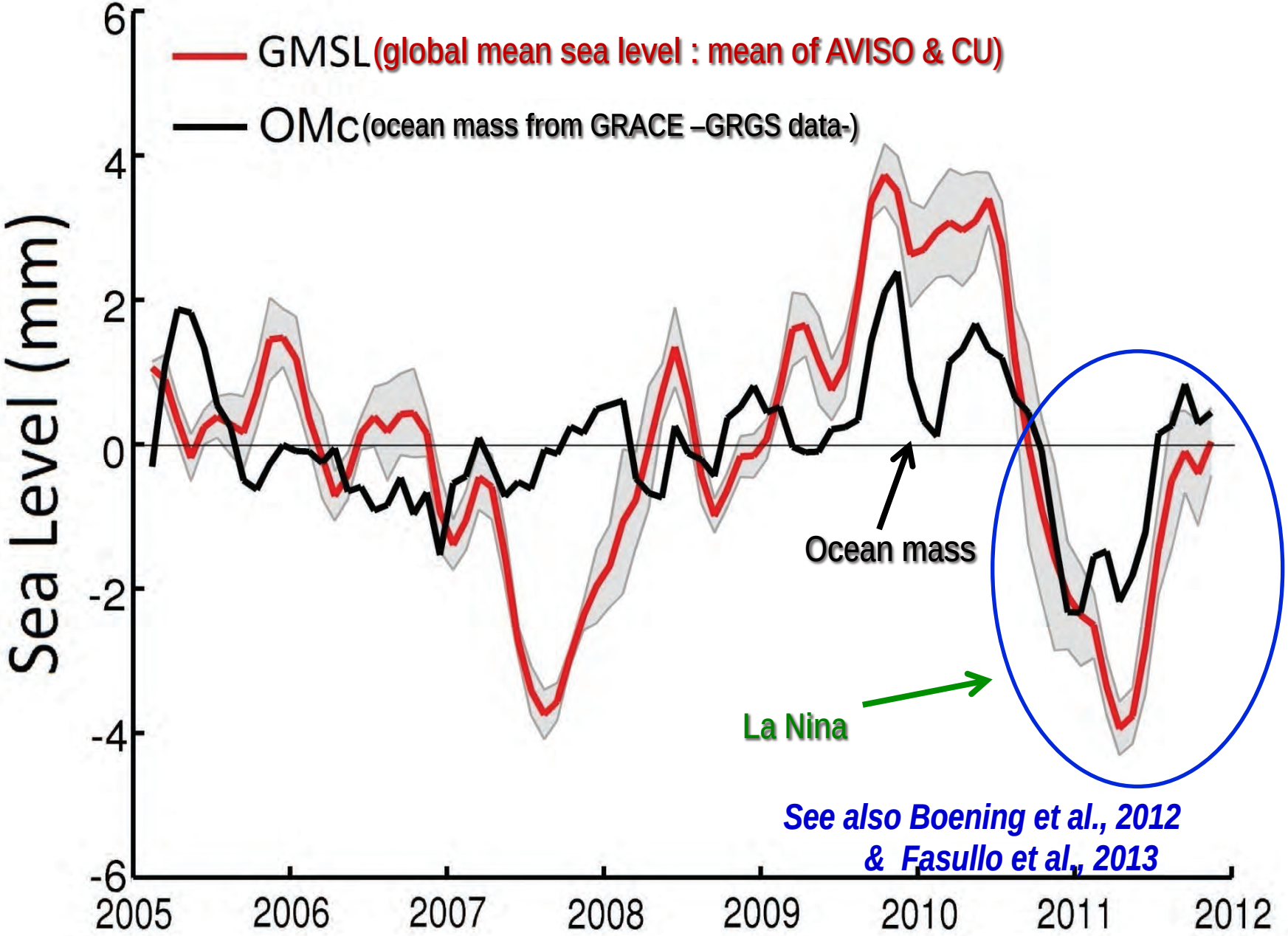


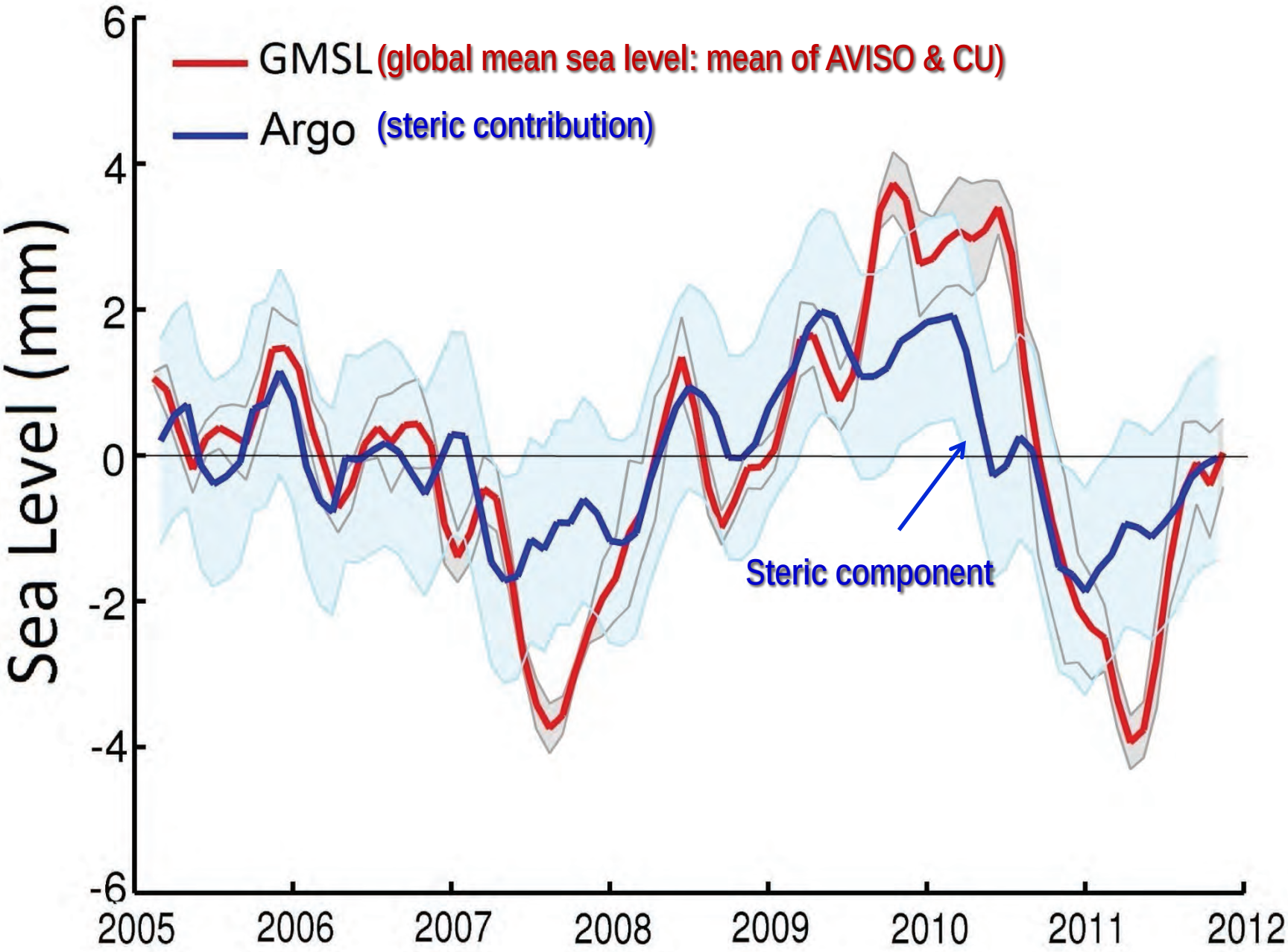


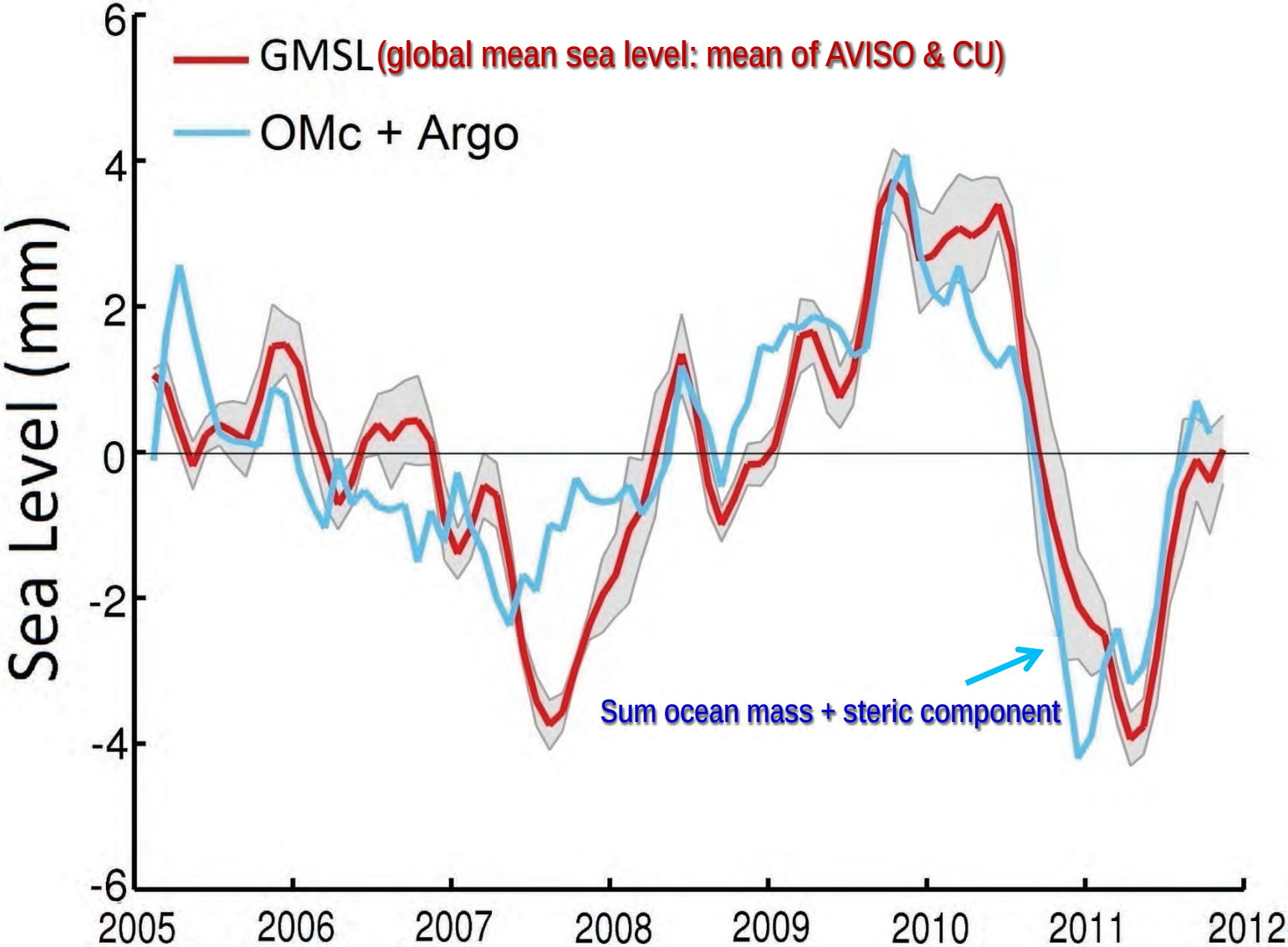
mass changes

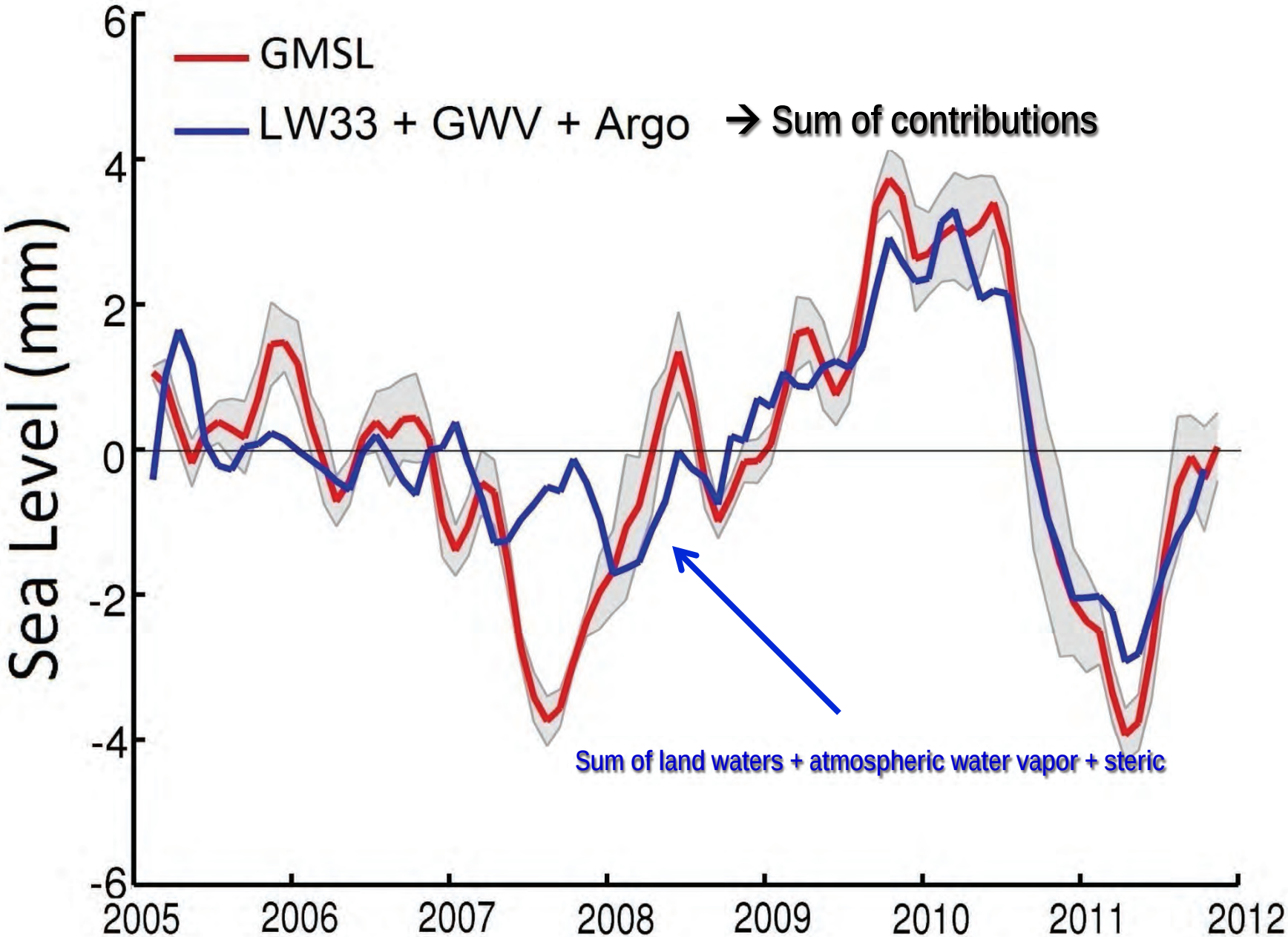
ocean mass

Glaciers, ice sheets, land waters


GMSL (global mean sea level : mean of AVISO & CU)
OMc (ocean mass from GRACE –GRGS data-)
Sea Level (mm)
6
4
2
0
-2
-4
-6
2005
2006
2007
2008
2009
2010
2011
2012
Ocean mass
La Nina
See also Boening et al., 2012
& Fasullo et al., 2013


GMSL (global mean sea level: mean of AVISO & CU)
Argo (steric contribution)
Sea Level (mm)
6
4
2
0
-2
-4
-6
2005
2006
2007
2008
2009
2010
2011
2012
Steric component


GMSL (global mean sea level: mean of AVISO & CU)
OMc + Argo
Sea Level (mm)
6
4
2
0
-2
-4
-6
2005
2006
2007
2008
2009
2010
2011
2012
Sum ocean mass + steric component


GMSL
LW33 + GWV + Argo
→ Sum of contributions
Sea Level (mm)
6
4
2
0
-2
-4
-6
2005
2006
2007
2008
2009
2010
2011
2012
Sum of land waters + atmospheric water vapor + steric

Phase 1 Achievements:

- Developed SST ECV data sets for 1991-2010:
  - ATSR-1, ATSR-2 and AATSR
  - AVHRR
  - Level-4 analysed SST products combining the above IR plus AMSR-E and AMSR-2 microwave records
- Integrated SEVIRI for diurnal modelling
- Products are independent from in-situ measurements, homogeneous and stable throughout the time series, and accompanied by context-specific uncertainty estimates.

Phase 2 Objectives:

- Multiple algorithm improvements – sea-ice, aerosols, high-latitudes, inter-instrument cross-calibrations, specific ATSR-1 issues, uncertainty estimates, ...
- Extend SST_cci data record beyond the (A)ATSR era back to 1981 with AVHRR data and forward to 2016 with a target accuracy of 0.1K (reference sensor period) and 0.2K (AVHRR's only period).
- Develop and implement an approach to bridge and fill the gap between Envisat AATSR and Sentinel-3 SLSTR

GCOS 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

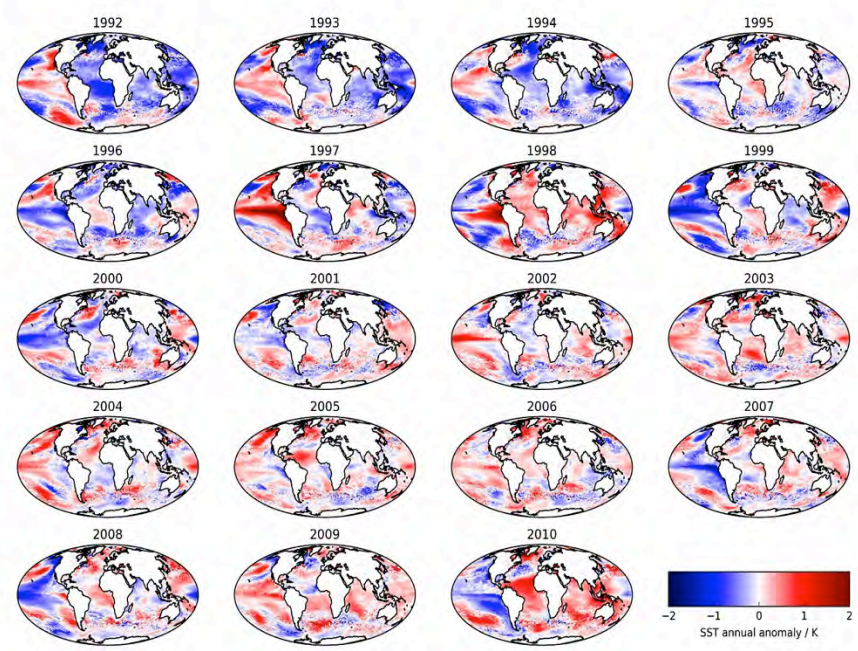
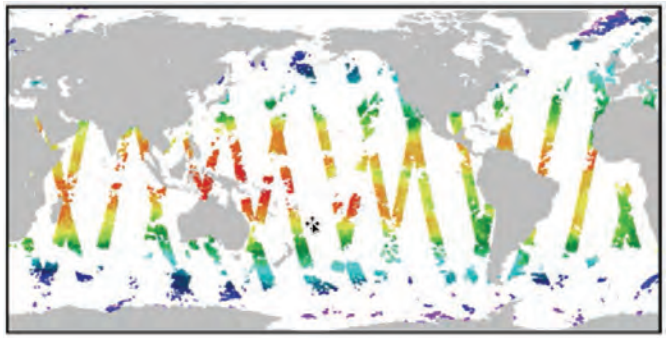


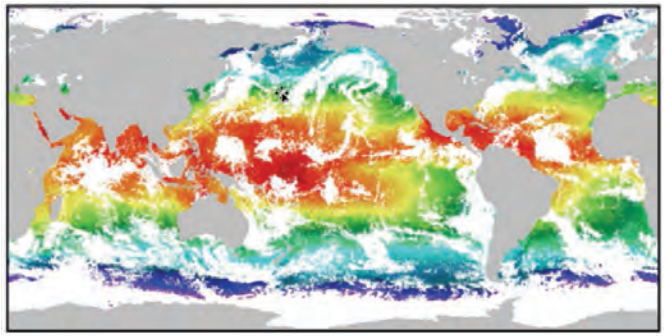
Figure: CCI annual mean sea surface temperature (SST) anomaly maps for 1992 - 2010

SST CCI climate data record

- Involves
  - New AVHRR retrieval algorithm (optimal est.)
  - Tie AVHRR SSTs to ATSRs (cross-referencing)



Dual-view reference SST coverage

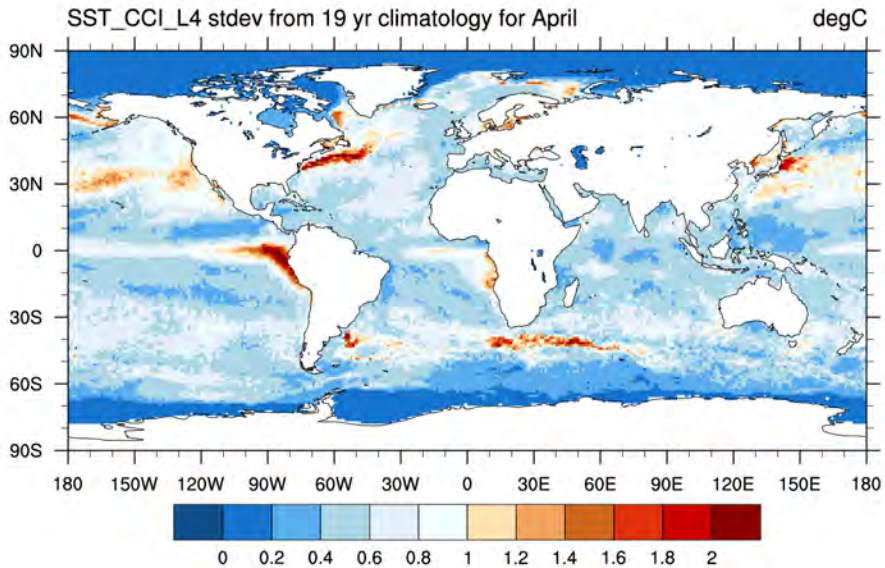


Tied AVHRR SST coverage

Consistent AVHRR and ATSR L2/L3 → improved L4

ESA SST CCI
European Space Agency
Sea Surface Temperature
Climate Change Initiative

Retrieval accuracy

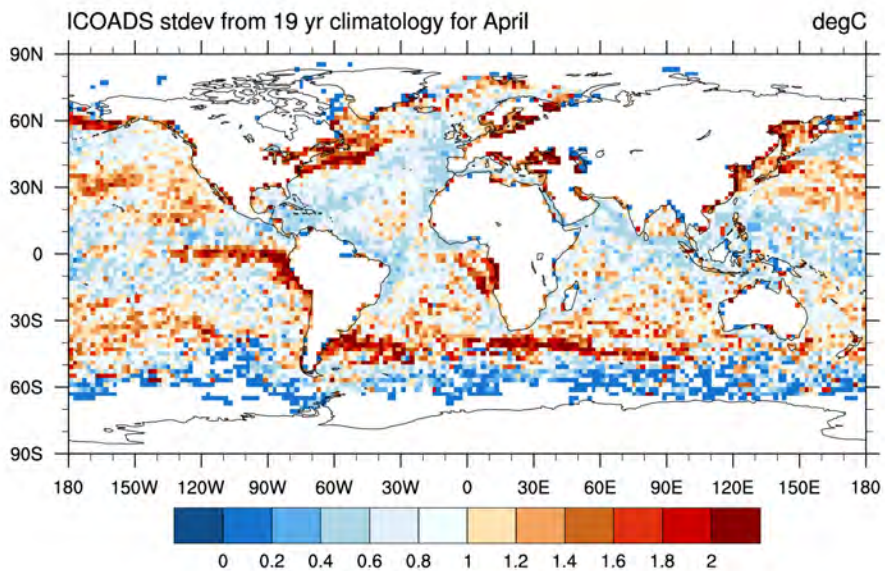


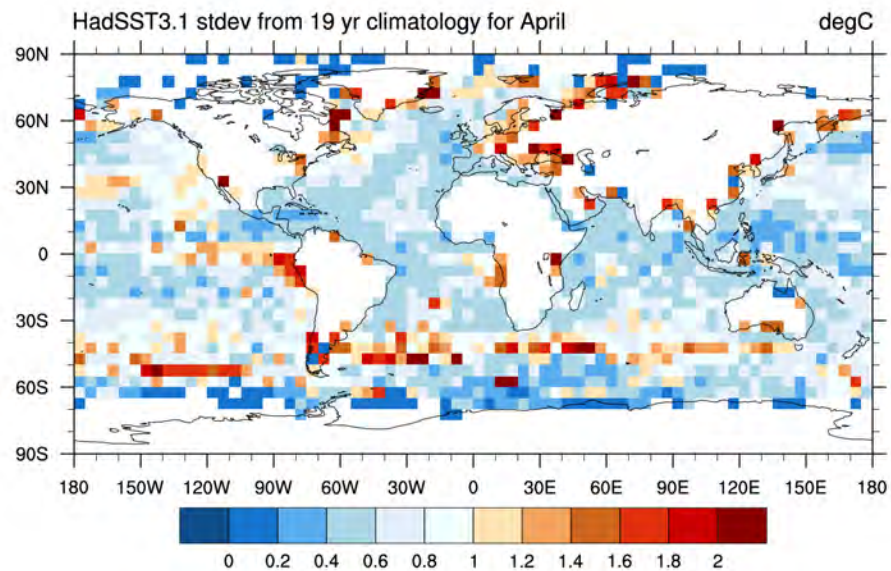
Std Dev of April-mean SSTs over same 19 yrs

Satellite data gives more subtle and plausible picture of inter-annual variability

Good quantitative agreement where in situ datasets have many observations (e.g. tracks)

Variability from SST CCI being used as basis for historical reconstruction in HOSTACE





Phase 1 Achievements:

- ECV products from a multi-mission combination of SeaWiFS, MODIS/Aqua and MERIS (1997-2015):
  - Water-leaving radiances (412-670 nm)
  - Chlorophyll-a, Kd490, and IOPs (412-670 nm).
- Additional tests were performed on earlier CZCS data from 1978-1986. The products cover Case 1 waters (oceanic) and plans are underway to develop prototype ECV products for Case 2 (coastal) waters.
- Close cooperation with the International Ocean Colour Coordinating Group, the OCR Virtual Constellation, the NASA Ocean Biology Processing Group and NASA MEaSURES project has been maintained throughout.

Phase 2 Objectives:

- Implement cyclical annual reprocessing to rapidly exploit algorithm improvements.
- Develop prototype products with new algorithms to cover optically complex and highly productive coastal waters (Case 2)
- Integrate VIIRS and Sentinel-3 OLCI data
- Investigate use of VIIRS and OCM-2, to fill Envisat to S-3 gap.

GCOS Requirements

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Water Leaving Radiance	4km	N/A	Daily	5%*	0.5%
Chlorophyll-a concentration	30km	N/A	Weekly averages	30%	3%

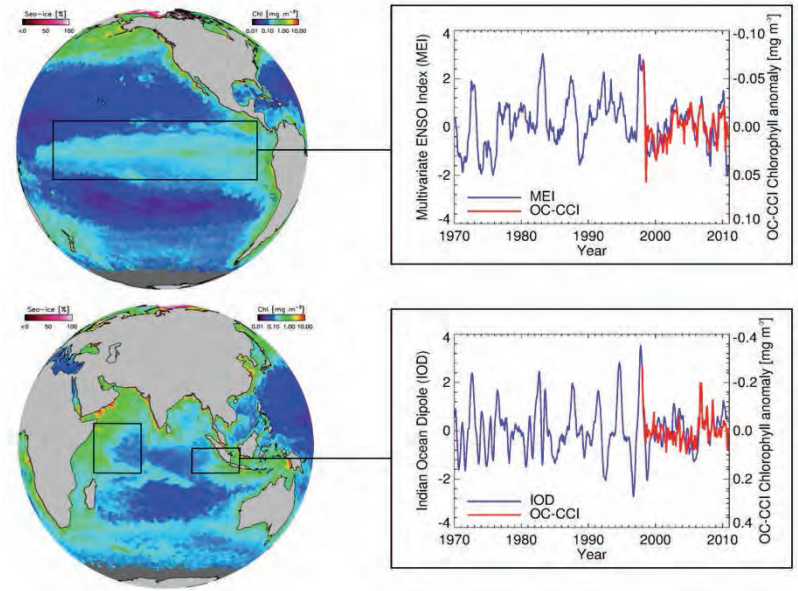
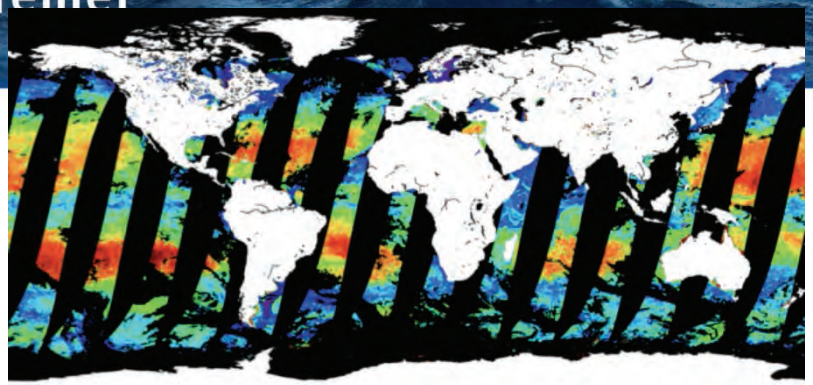
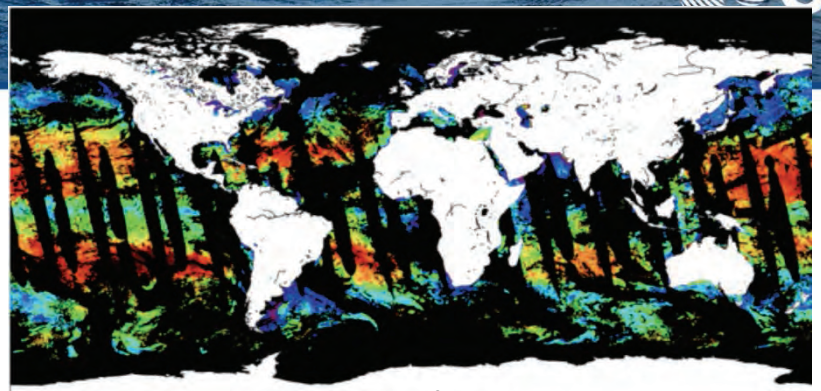


Figure: A time-series of the chlorophyll anomaly in the equatorial Pacific compared with the ENSO index, and also the chlorophyll anomaly in the Indian Ocean and the Indian Ocean Dipole. This image shows how well chlorophyll tracks two climate indices.

Ocean Colour ECV

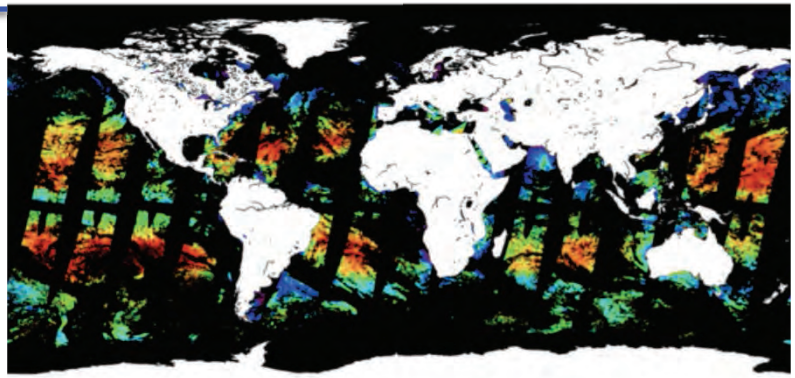


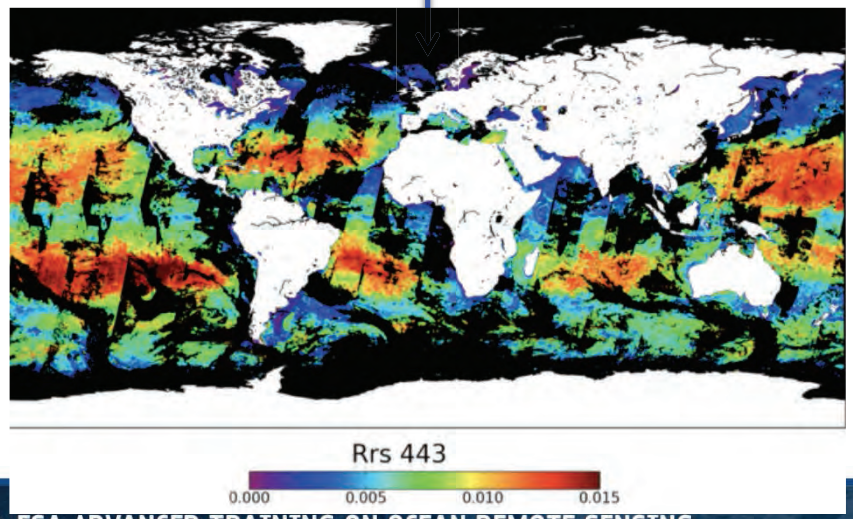
MERIS Radiance



MODIS-A Radiance

Band-shifting, bias correction,
Merged product





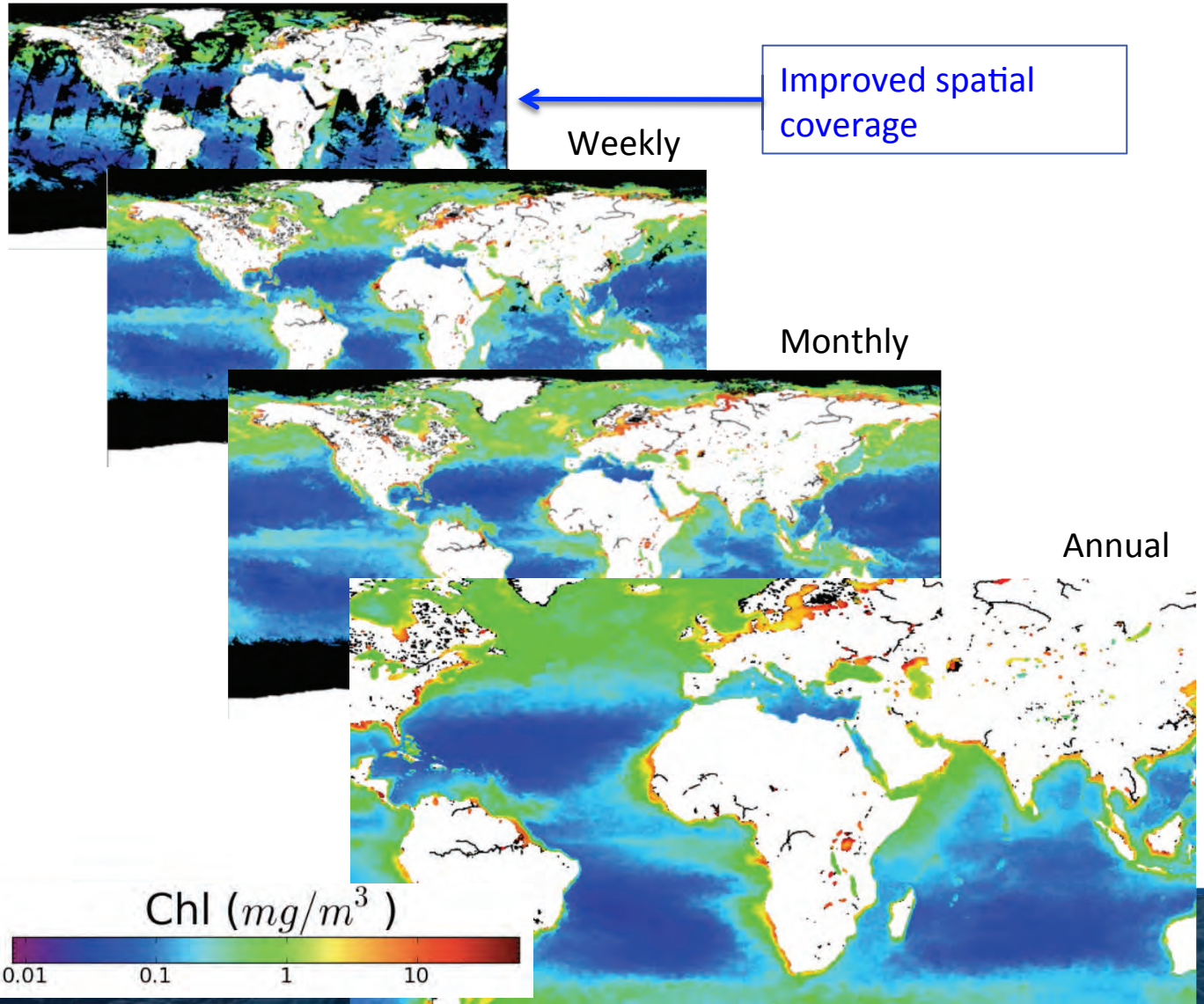
Ocean Colour CCI Products

Daily

Weekly

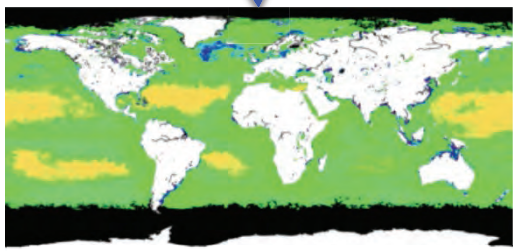
Monthly

Annual

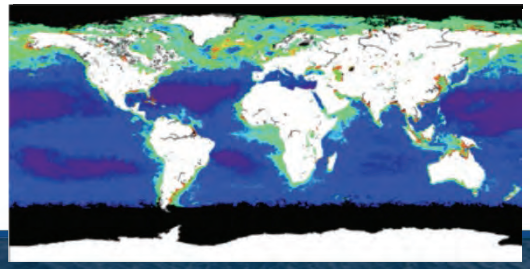


Improved spatial coverage

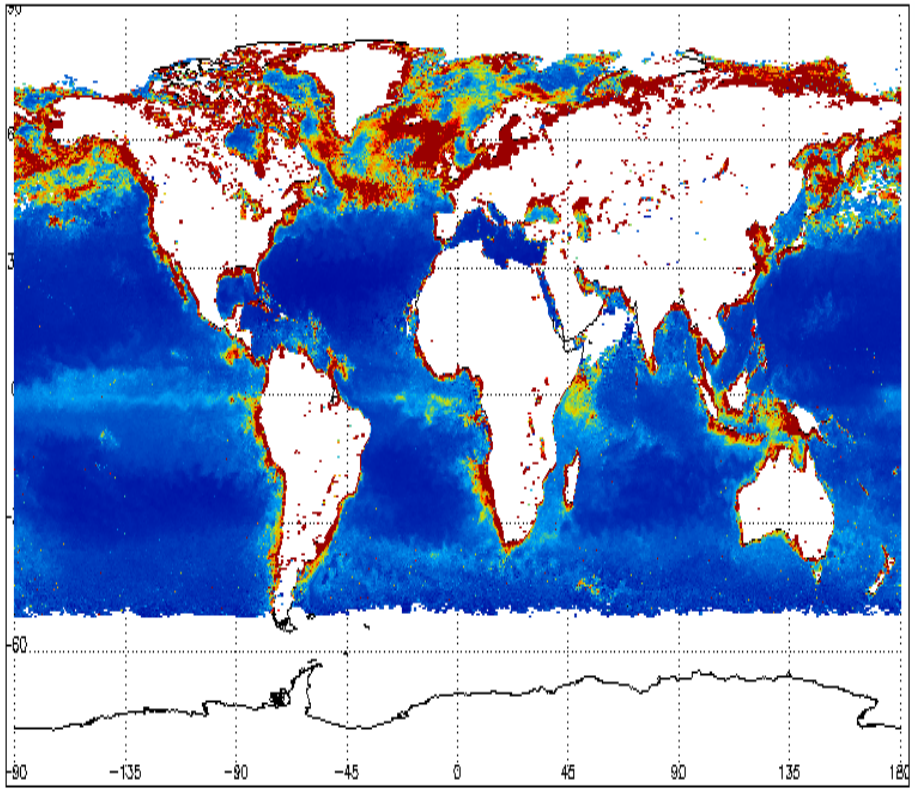
Error specification (RMSE and bias) based on comparison with match-up in situ data & extrapolation to global ocean

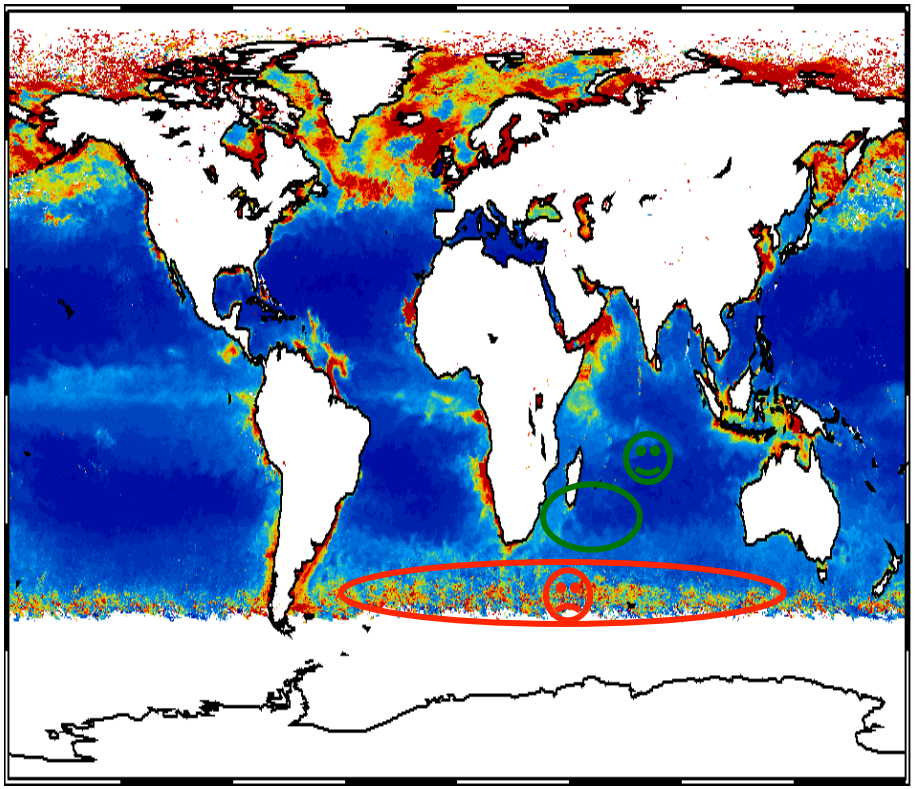


Error-characterisation



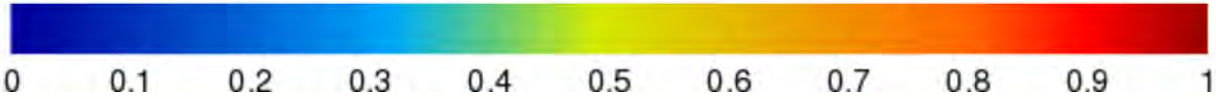
July 2003 mean chlorophyll





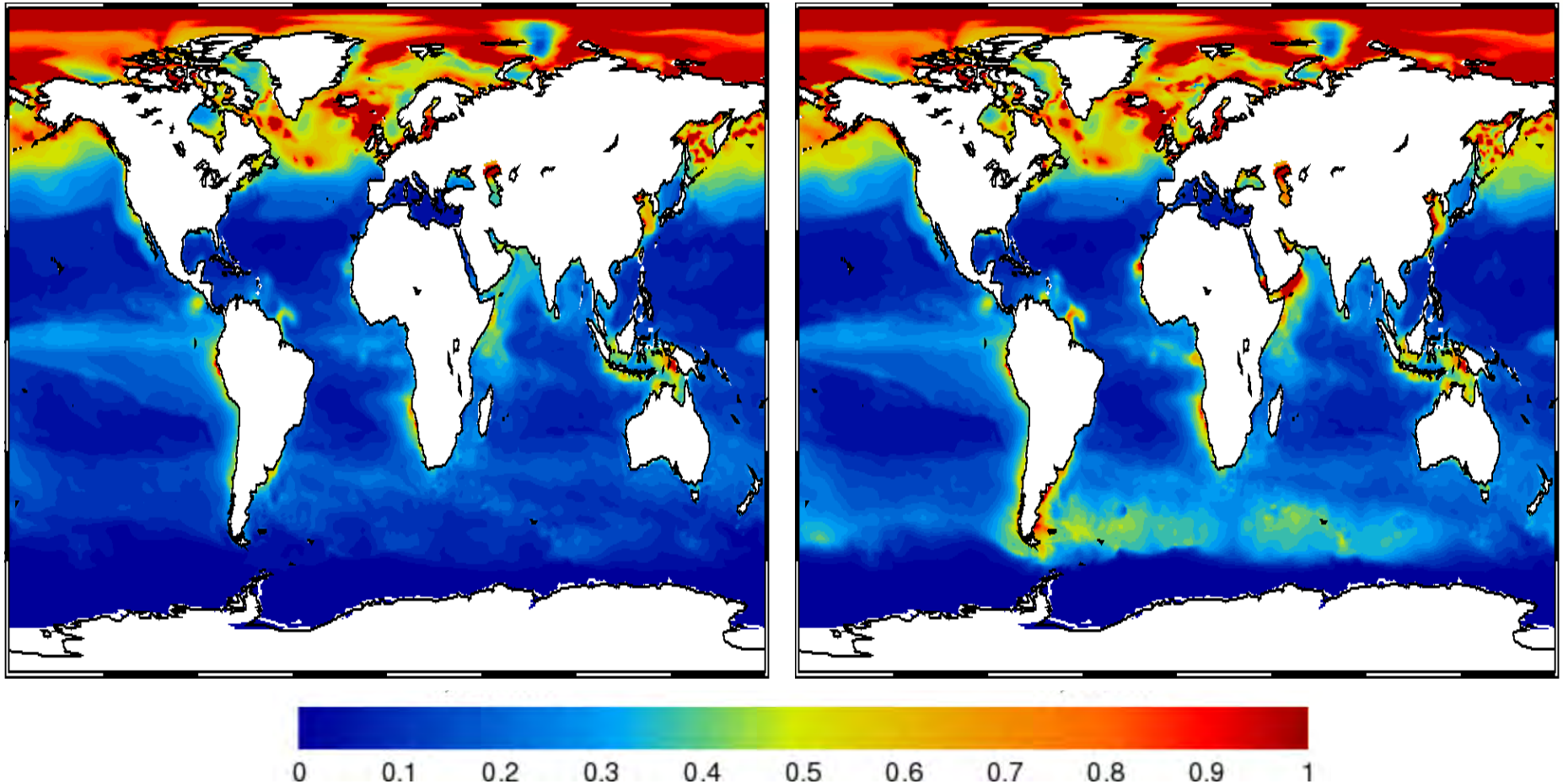
GlobColor

CCI



mg/m^3

July 2003 mean chlorophyll



GlobColor Assimilation

CCI Assimilation

mg/m^3

CCI Programme (2010-2015)

Horizontal Supporting Activities

- System Engineering WG
- Data Standards WG
- Colocation Meetings
- Integration Meetings

CCI ECV Projects

- Cloud
- Aerosol
- Greenhouse Gases
- Ozone

- SST
- Sea Level
- Sea Ice
- Ocean Colour

- Glaciers
- Ice Sheets

- Land Cover
- Fire
- Soil Moisture

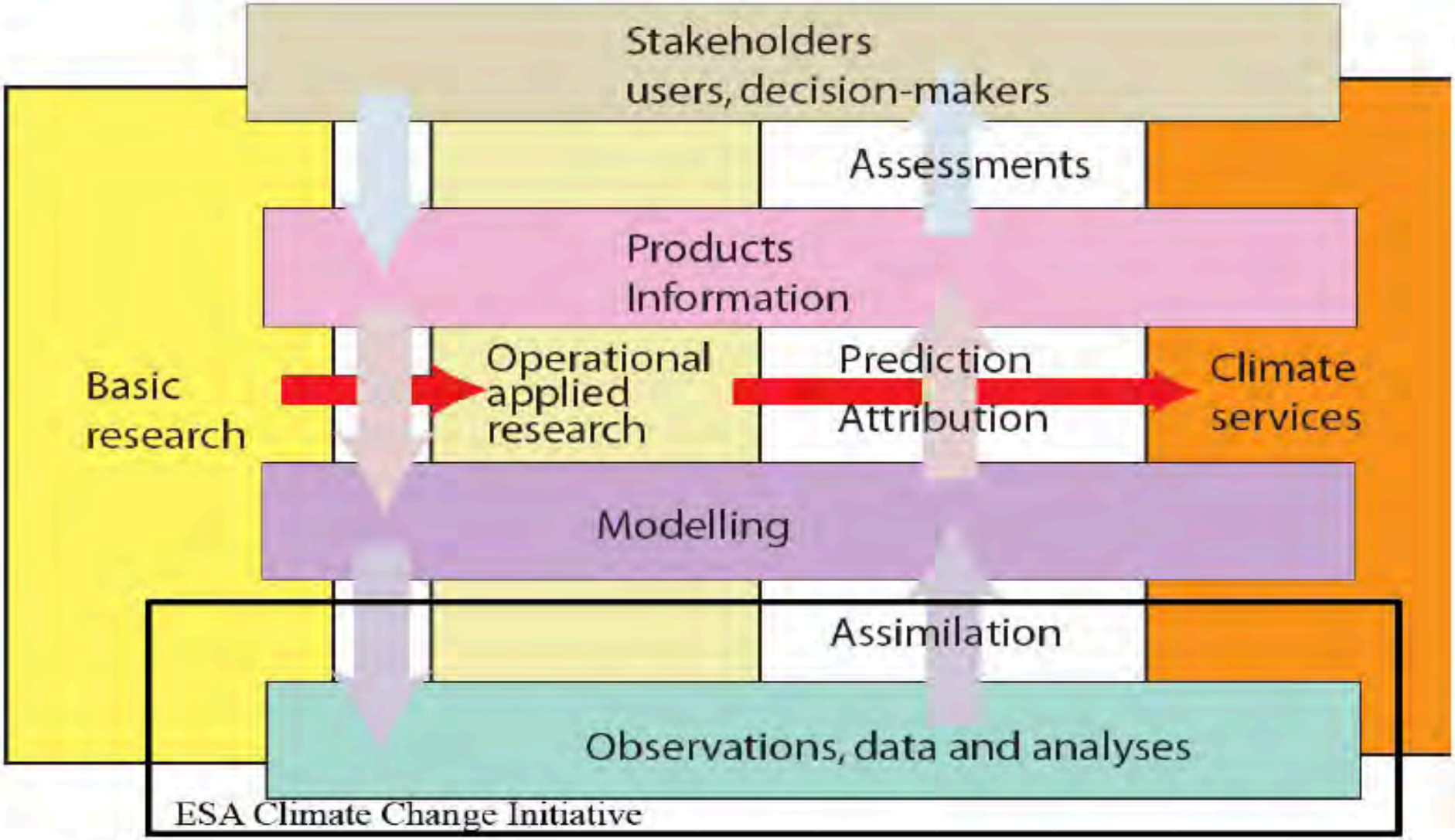
Cross-ECV & Exploitation

- Climate Modeller User Group
- Research Fellowships
- Ice Sheet Mass Balance Intercomparison Exercise
- Cross-ECV Workpackages

Communication and User Support

- CCI Visualisation Tool
- CCI Open Data Portal
- CCI Toolbox

Research to Service



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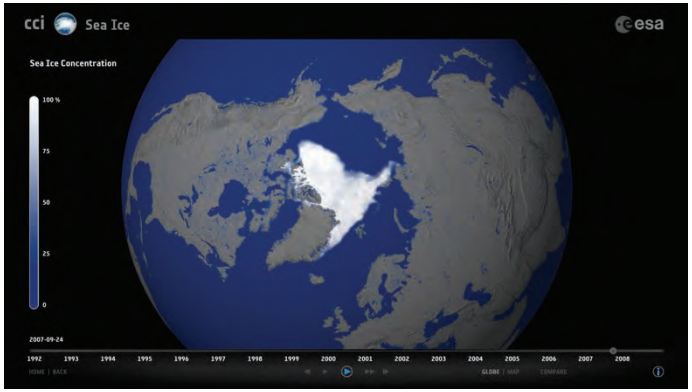
CCI Visualisation Tool

Interactive visualisations of the CCI data sets have been developed to help show the type of information satellites can provide on climate.

- *CCI Visualisation Exhibition Tool*: detailed animations of *all* products within the CCI. Zoom in, speed up and slow down the time series, and compare variables where feasible. Aimed at conferences and exhibitions.
- *A CCI free public App* of these visualisations, with further explanation and context is in development, aimed for launch in autumn 2015.
- *Animations* of key climate processes and concepts, such as the contributions to sea level rise, shown in multiple CCI data sets, explained step by step.

Team:
Planetary Visions Ltd (IRL)



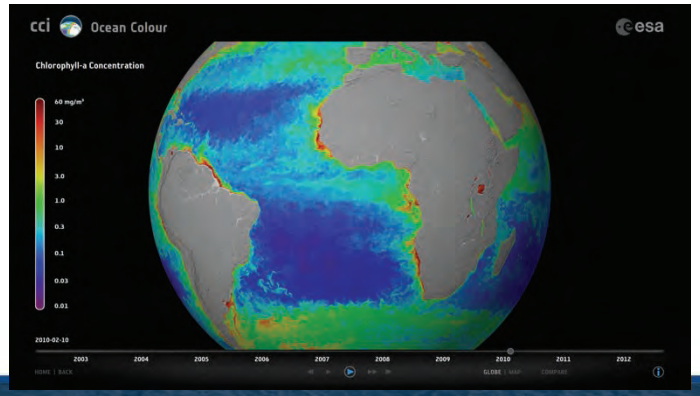


Figure: Screenshots from the CCI Visualisation Tool

CCI Postdoctoral

Support for ten 2-year postdoctoral positions to undertake research activities relevant to the Climate Change Initiative (cci.esa.int).

Focus on projects dedicated to:

- Exploiting Essential Climate Variable (ECV) products from CCI for improved understanding of the Earth System;
- Examining Cross-ECV consistency and multiple ECV use (those under the CCI Programme in particular).
- Enhancing interactions between CCI members and other Earth science laboratories, research centres and universities.

Funding available: 40kEuro/year for two years

In view of the success a new call has been made for another 6 positions, closed on 30 Aug 2015.

1. CryoSat measurements of Antarctic Ice Shelf thickness change (U. Leeds)
2. Climate Impact on MARine ECOsystem State (PML)
3. Exploring thE cArboN CyclE through atmospheric GreenHouse Gas variability (U. Leicester)
4. CARBOn dioxide emissions from FIRES (U. Bremen)
5. The Environmental Response to Aerosols observed in CCI ECVs (U. Oxf)
6. Does Increasing Temperature Increase Carbonaceous Aerosol Direct Radiative Effect over Boreal Forests? (FMI)
7. Ocean Colour at low sun and high waves (HZG)
8. Surface water and climate variability from a high-resolution GIEMS-SAR merged product (Estellus)
9. VERification of high-resolution climate forecasts on Intraseasonal-to-interannual Timescales with Advanced Satellite datasets of the Climate Change Initiative (Barcelona SCC)
10. Harmonization of soil moisture and fire CCI products for permafrost research (ECO, Harwell)

CCI Open Data

The **CCI Open Data Portal** project was started in April 2015:

- To satisfy climate users' needs for a single point of harmonised reliable access to the mature and validated ECV data products and information delivered by the CCI programme.
- To ensure the ECV data products and other results of the CCI programme are provided to users in a consistent and complementary way to other key climate initiatives – e.g. integration with Earth System Grid Federation and CMIP/ obs4MIPs.
- To provide the primary communication and promotion web site for the ESA CCI programme.
- To survey if there are user requirements for a potential Thematic Exploitation Platform for Climate.
- Team: TVUK, STFC, CGI, U. Reading, BC

CCI Toolbox: KO expected in the coming weeks (in September 2015)

- To provide software tools to inspect, display, process and analyse CCI ECV data products
- To facilitate cross-ECV analysis, including both CCI and non-CCI climate data sets
- To seamlessly interface with ECV data sets hosted on the CCI Open Data Portal
- To follow an open source software approach so that users can add in their own functionality

Achievements

- Creation of a European EO Climate Science community
- Facilitate the scientific cooperation between the Climate Observing and Modelling Communities
- Develop a protocol for Climate Quality Algorithms Evaluation in an international context.
- Delivered fully Error Characterised Climate Data sets, first for many ECVs
- Provided up to date validated scientific data sets to support International Climate Policy and decision making.

Further Achievements

- Generate peer reviewed publications in high impact scientific journals by European Scientific Community (>215 publications)
- Pave the way for the ECV component of the Copernicus Climate Change Services,
- Facilitate the Sea Level Closure Budget by strengthen dialogue between Glaciers, Ice Sheets and Sea Level research communities,

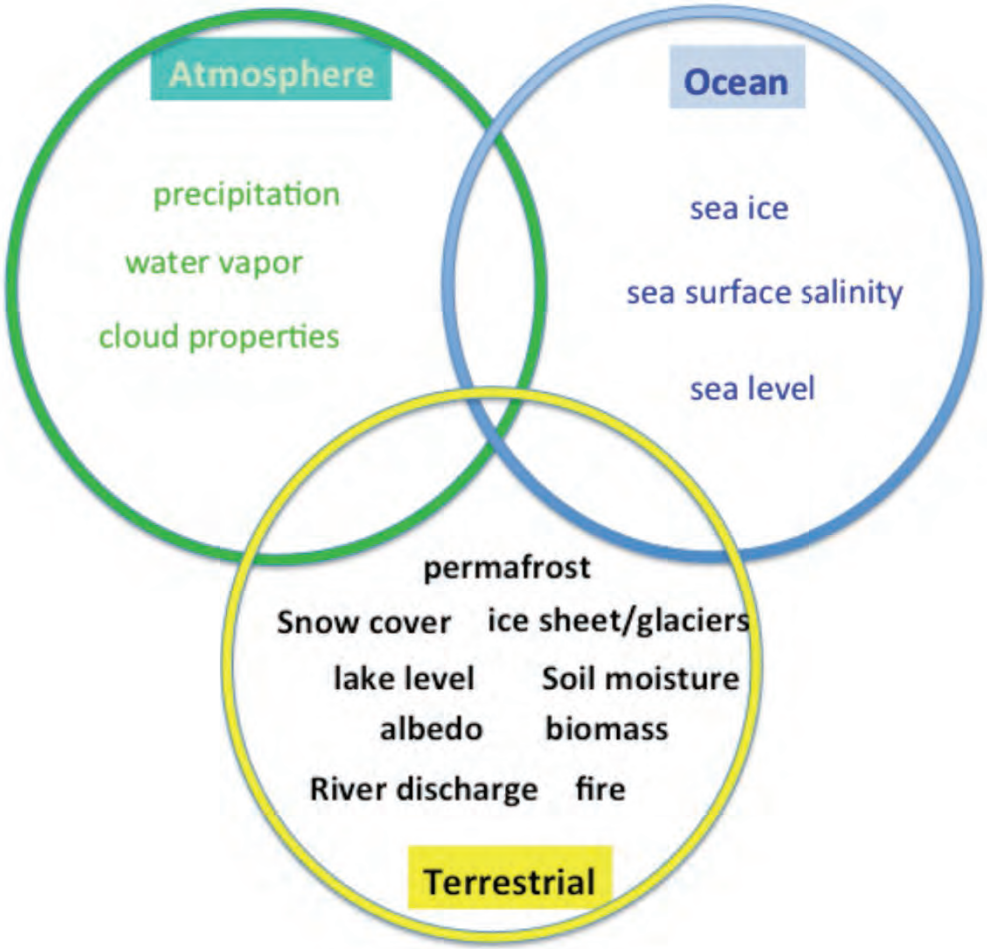
Proposed within CCI Extension

Atmosphere	Ocean	Terrestrial
Composition	**Surface**	
Aerosols Properties	Sea Surface Temperature	Land Cover - High Resolution
Carbon Dioxide & Methane	Sea Level	Fire Disturbance
Ozone	Sea Ice	Soil Moisture
Long-Lived GHGs	Ocean Color	Glacier and Ice Caps
Precursors (for Aerosols and O3)	Sea State	Ice Sheets
Upper Air	Current	Snow Cover
Cloud Properties	Sea Surface Salinity	Albedo
Temperature	Carbon Dioxide Partial Pressure	Leaf Area Index (LAI)
Water Vapor	Phytoplankton	(FAPAR)
Wind Speed and Direction	Ocean Acidity	Lakes
Earth Radiation Budget	**Sub Surface**	Above Ground Biomass
Surface	Carbon	Permafrost
Surface Air Pressure	Current	Ground Water
Surface Air Temperature	Nutrients	River Discharge
Surface Precipitation	Ocean Acidity	Soil Carbon
Surface Radiation Budget	Oxygen	Land Surface Temperature
Water Vapour (Surface humidity)	Salinity	
Near-Surface Wind Speed, Dir	Temperature	
	Tracers	
	Global Ocean Heat Content	

CCI Scope	Implemented in CCI	Proposed in CCI Extension

ECVs and Cycles

Hydrological Cycle



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http://lps16.esa.int