Examples of the use of MERIS data in marine and land applications

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Examples of the use of MERIS data

European Service for Ocean Colour

Marine & Coastal Monitoring Services

MERIS Global Land Cover Map

ESA Grid Processing on Demand

Credit: GlobColour Team

Background of GlobColour

Context

- Initiated in 2005 and funded by the ESA DUE Programme
- Driven by the global ocean colour user community: IOCCG, IOCCP, UK Met-Office, …

Objectives

- Satisfy emerging demand for validated merged ocean colour derived information
- Develop a satellite based ocean colour data service to support global carbon-cycle research and operational oceanography
- Provide a long time-series (10 years) of ocean-colour information by merging together data streams from different ocean-colour sensors:
  MERIS (ESA), SeaWiFS (NASA), MODIS-AQUA (NASA)
- Put in place the capacity to continue production of such time series in the future

Ocean Colour Data Merging

Algorithm inter-comparison and trade-off analysis against in situ data

Merging recommendations:

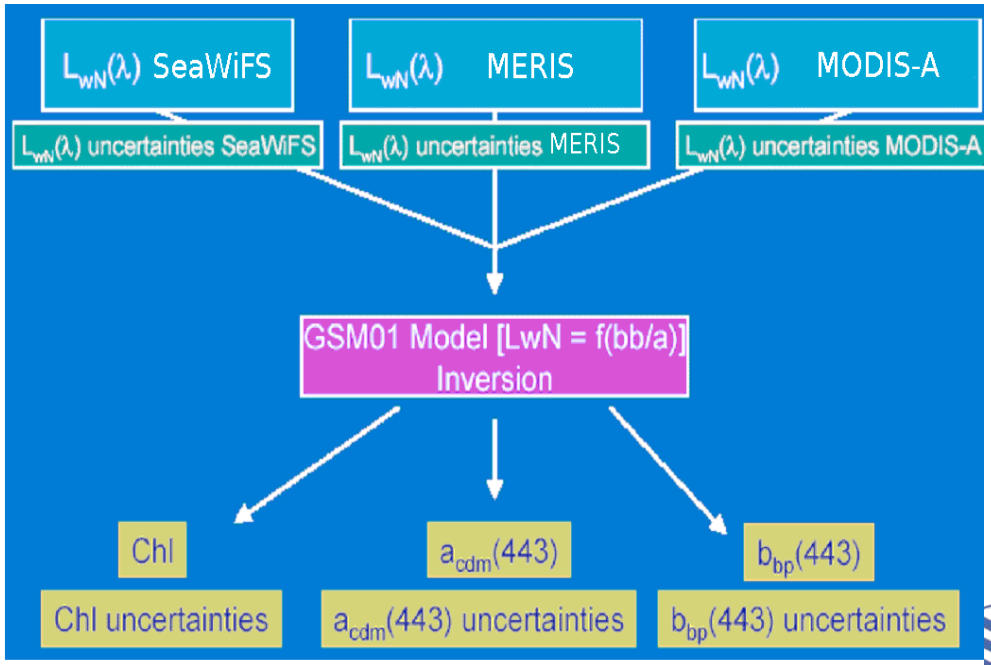
– **Weighted averaging** of bio-optical properties (chl-a)

– **GSM01model** (Maritorena et al., 2002)

• Input
Lw_n (λ) from all available sensors
+ sensor specific error estimates

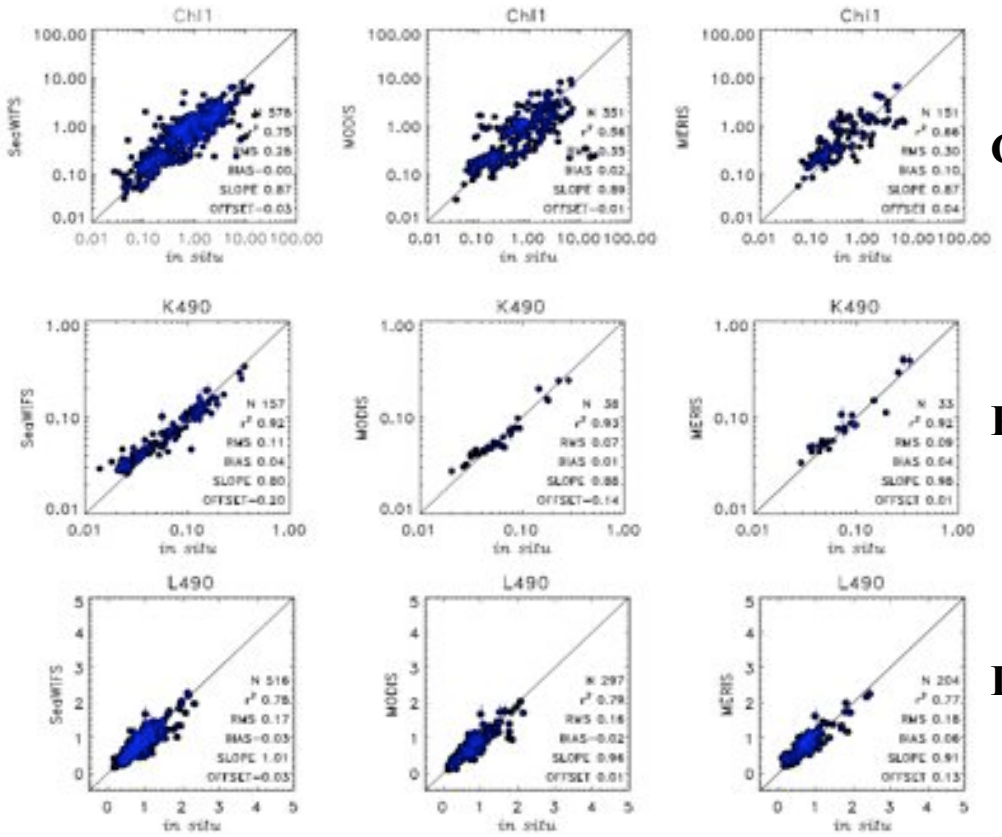
• Model
Inversion procedure of a bio-optical merging model

• Output
Several bio-geochemical products
+ error estimates per pixel



Sensor characterization

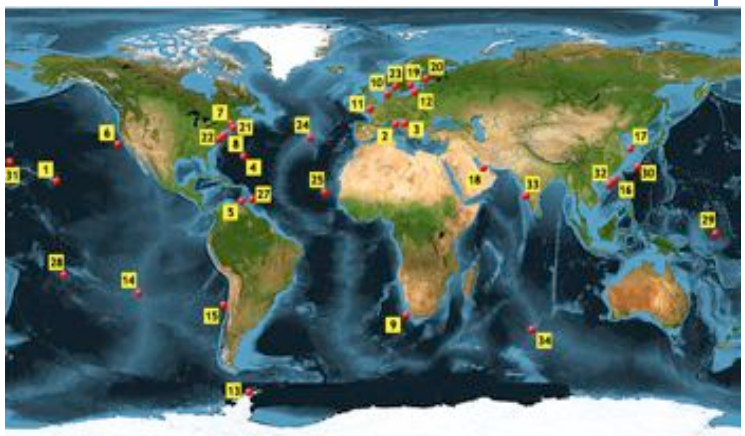
SeaWiFS **MODIS** **MERIS**



CHL

K490

L490



In-situ Diagnostic Data Set for characterization and validation

Achievement:
Statistical uncertainties have been derived and are used for the data merging

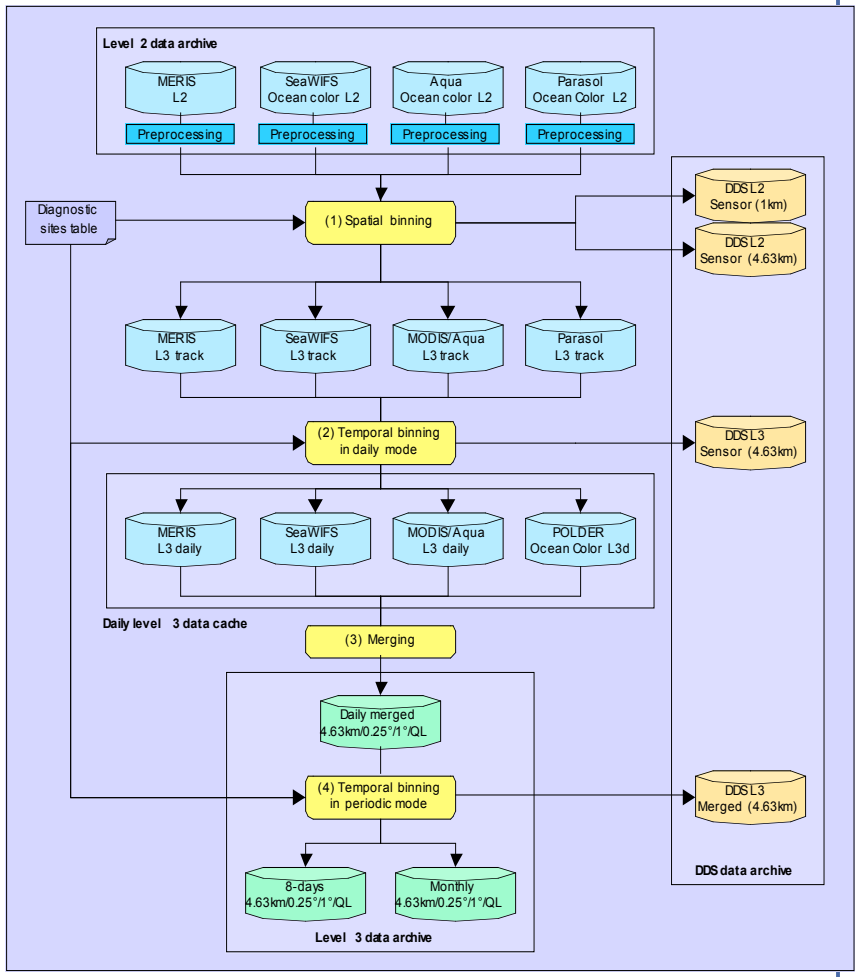
GlobColour processor

Main modules

- Data acquisition
- Pre-processing
- Spatial binning
- Temporal binning
- Merging
- Formatting (netCDF, JPG/PNG)

Data Volumes

– More than 25 Tb of input data (level 2)
– 14 Tb of intermediate products
– 4.5 Tb of distributed data



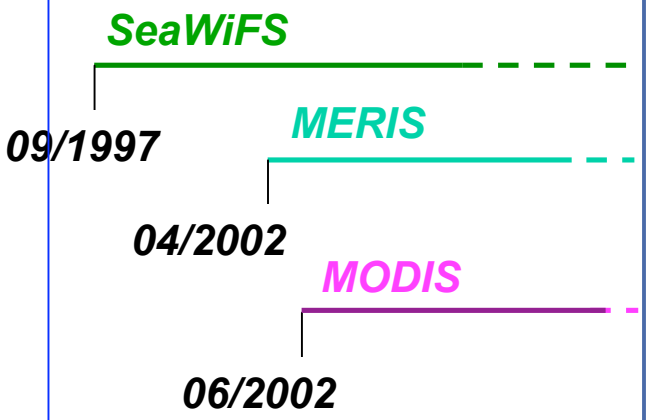
GlobColour products

Daily, 8-days, monthly products at 4.6 km res.

http://www.globcolour.info

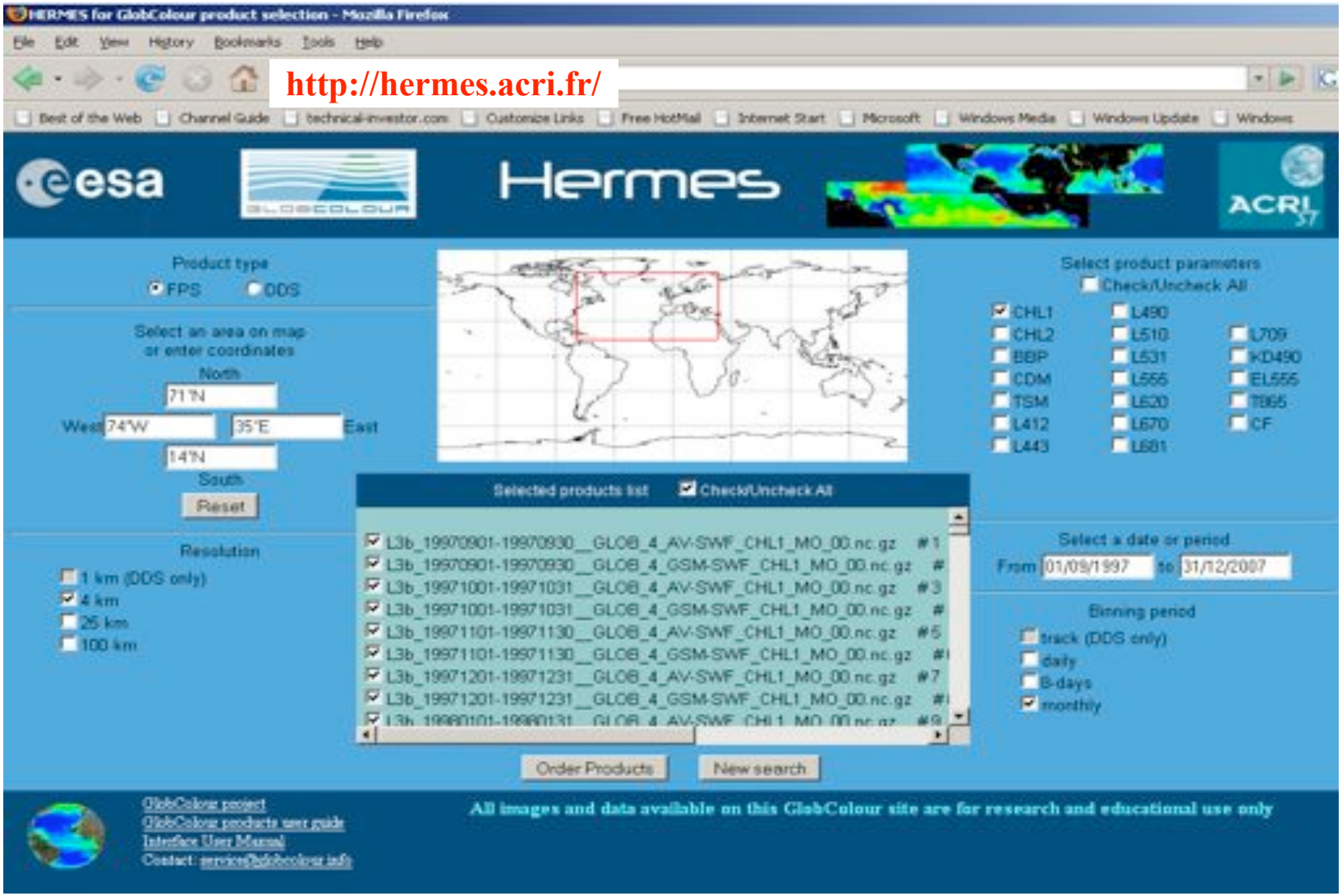
- Normalised water-leaving radiance @ 412, 443, 490, 510, 531, 555, 620 nm
- Water-leaving radiance @ 670, 681, 709 nm
- Particle backscattering coefficient (bbp443)
- CDM absorption (aCDM443)
- Chlorophyll concentration (Chla)
- Total Suspended Matter
- Diffuse attenuation coefficient @ 490nm (K_d490)
- Aerosol Optical Thickness (T865)
- Data quality flags
- Cloud fraction
- Excess of radiance at ~ 555 nm (turbidity index) (EL555)
- GSM01 error estimates per pixel for each layer

MODIS-only, MERIS-only

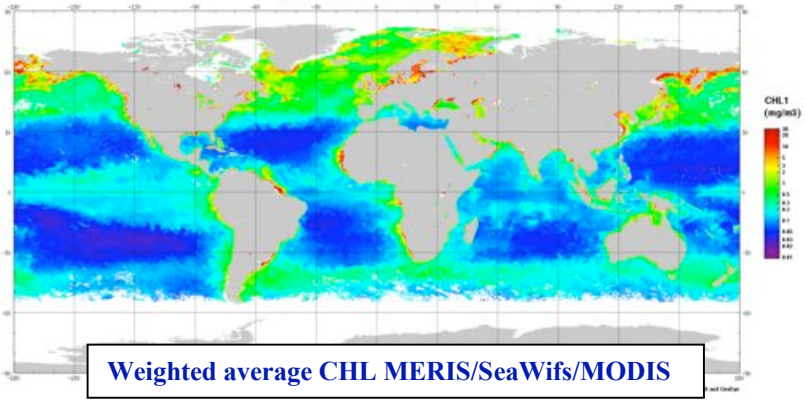


HERMES Web portal

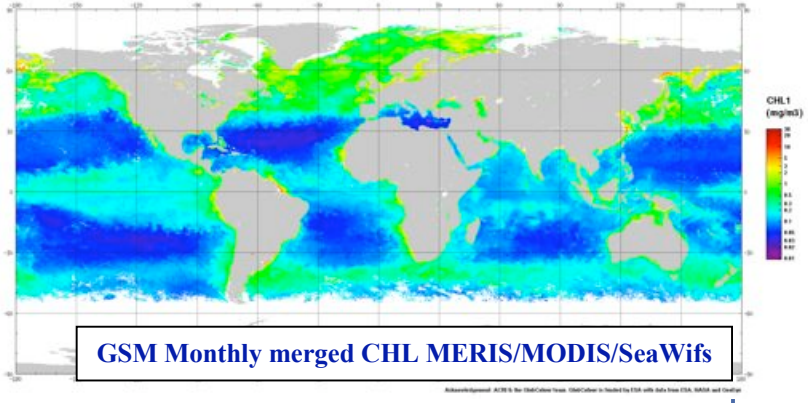
to access GlobColour data sets



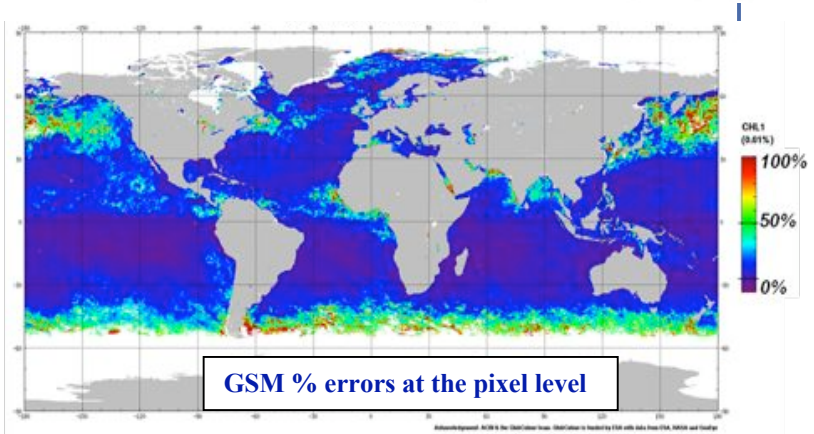
Product examples



Weighted average CHL MERIS/SeaWifs/MODIS



GSM Monthly merged CHL MERIS/MODIS/SeaWifs

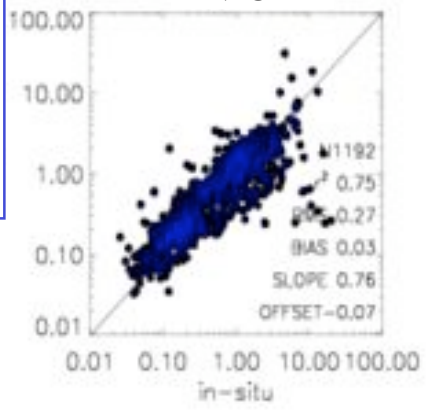


GSM % errors at the pixel level

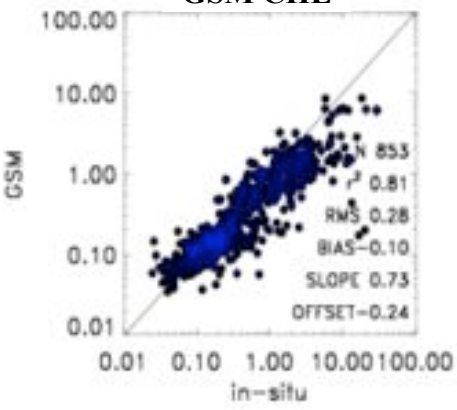
Match-up analyses (OBPG/NOMAD/BOUSSOLE) & product inter-comparison show:

- Error statistics of the merged data are in general better than data from the tree individual sensors
- The normalized water-leaving radiance at 490 nm is by far the most homogeneous product among the 3 sensors
- GlobColour GSM01 merging algorithm shows to be quite robust over coastal waters

AV CHL

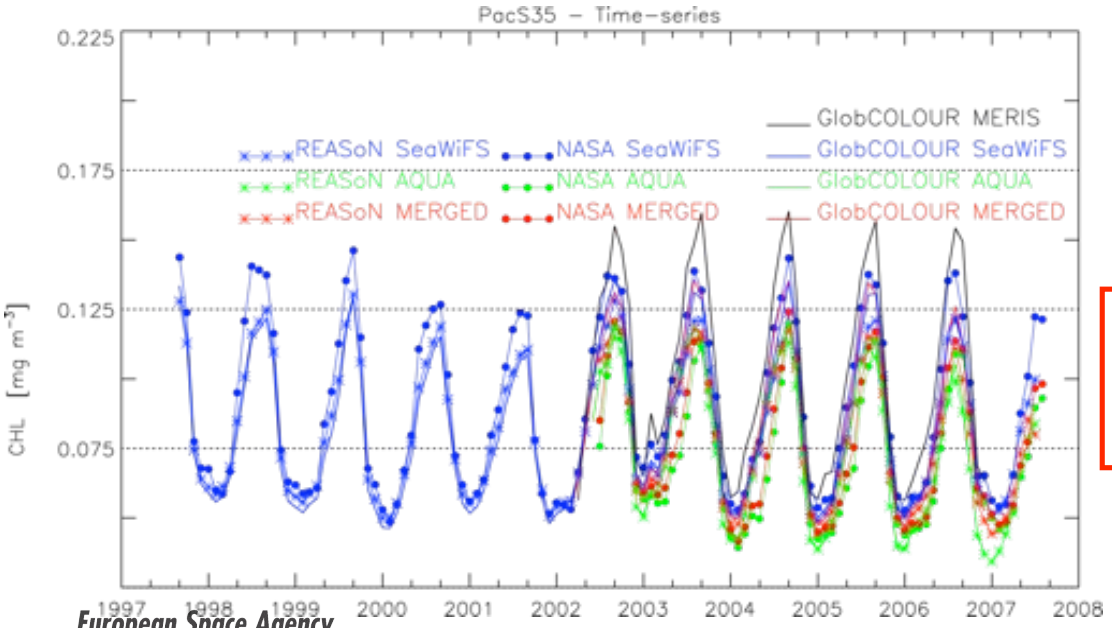


GSM CHL



Inter-comparison with other initiatives

	REASoN	NASA OBPG	GlobColour
Input Data	•SeaWiFS •MODIS-AQUA	•SeaWiFS •MODIS-AQUA	•MERIS •SeaWiFS •MODIS-AQUA
Merging method	•GSM01 model (merges the Lwn(λ))	•Weighted average	•GSM01 model (with Lwn(λ) weighting) •Weighted average
Products	• CHL • CDM • BBP • (uncertainties for daily products)	• CHL	• 19 products (+ uncertainties for some)
Spatial, temporal resolution	9 km Daily, 4-Day, 8-Day, Monthly	9 km Daily, 8-Day, Monthly, Seasonally, Yearly	4.5 km, 1/4°, 1° Daily, 8-Day, Monthly



- **The CHL products, merged or from only the individual sensors are very consistent and agree very well**
- **MERIS alone tends to produce higher CHL values than SeaWiFS or AQUA**
- **AQUA alone tends to produce lower CHL values than SeaWiFS or MERIS**

Validation results presented at the 2nd user workshop in Oslo, Nov 2007
www.enviport.org/globcolour/validation/

Conclusion

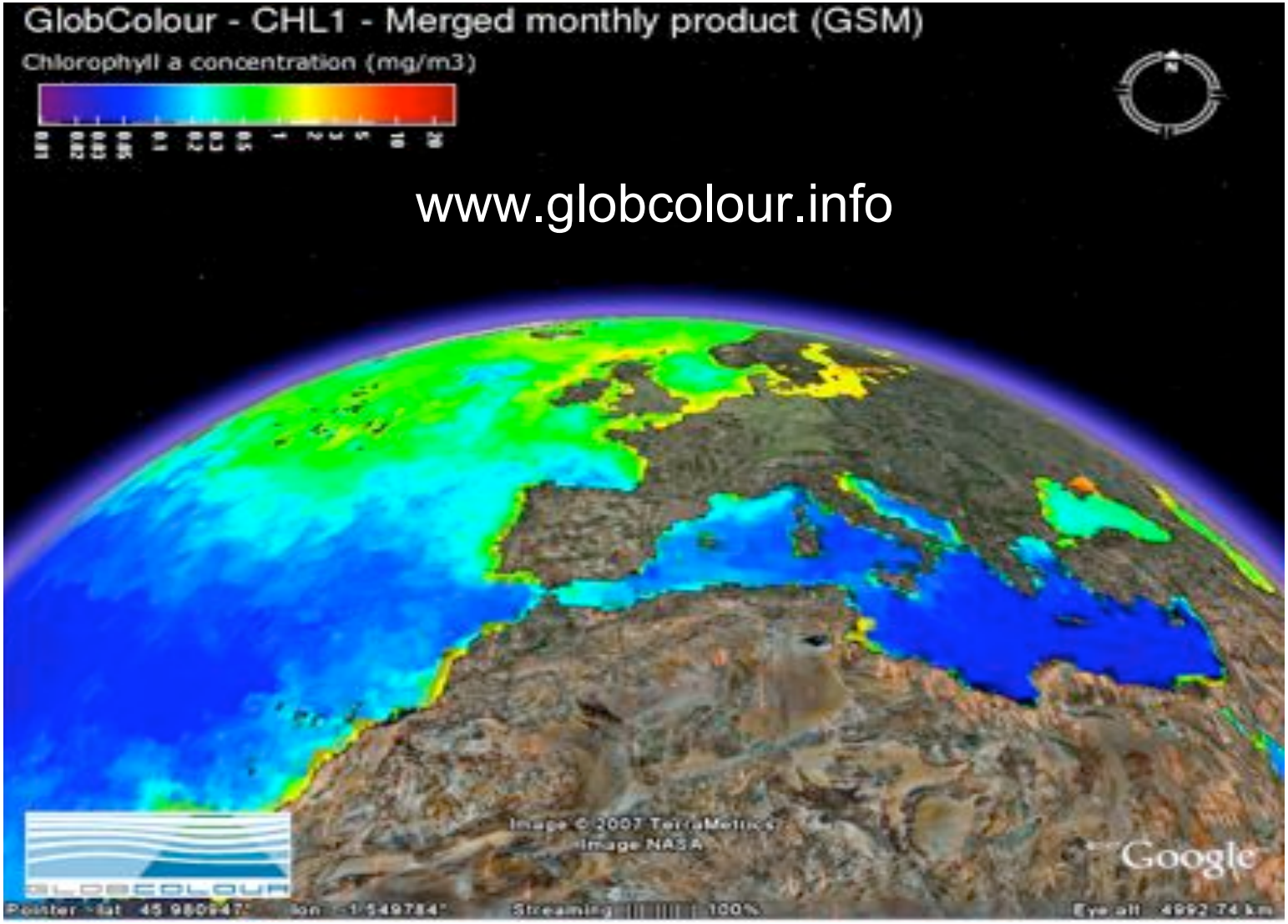
- GlobColour products are at least as accurate as the individual sensor products. In most cases they are better. User feedback is very positive.

- Globcolour brings several benefits over existing products:
  - better sampling of the daily variability
  - smaller errors because of larger amount of data
  - reduced instrumental biases
  - inclusion of error statistics

- GlobColour is a step towards meeting the requirements for an ocean colour Essential Climate Variable, but more work needs to be done !

- Users want a coastal version of GlobColour => GlobColour 2 (?)

- GlobColour time-series production will continue as part of the EC GMES Marine Core Service from 2009 onwards


GlobColour - CHL1 - Merged monthly product (GSM)
Chlorophyll a concentration (mg/m3)
www.globcolour.info
Google

MarCoast
a GMES Services Network

A European service network providing coastal information services to operational users

Credit: MarCoast Project Team

MARCOAST Overview

- **Background**
  - Initiated in 2005 as part of the GMES Service Element Programme managed and funded by ESA
- **Objective**
  - Establish a technical and organizational framework at European level for marine & coastal information services by making best use of EO data, in-situ observations, and models
  - Provide information services tailored to the needs of international, regional and national end users in charge of the marine environment (e.g. EEA, EMSA, German Federal & Maritime Hydrographic Agency, etc.)
- **Key Requirements**
  - Address all European waters
  - Reliable products and services
  - Cost effectiveness
  - Sustainability

MarCoast
a GMES Services Network

MARCOAST Context

GMES: joint ESA/EU initiative aiming at providing operational geo-spatial information services to operational users and policy makers

- **European Space Policy (adopted in 2007)**
  - ESA responsible for GMES Space Component
    - New European satellites ensuring continuity of operational ocean colour measurements
    - Coherent access to data from contributing missions (Member States, Eumetsat, 3d Party)
  - EU responsible for implementation of services
    - European Commission R&D Budgets and Member States operational budgets

Maritime Context

User interest driven by **European Legislation**

- Convention on the Protection of the Marine Environment of the Baltic Sea
- Integrated Maritime Policy for the EU
- Marine Strategy Directive
- Water Framework Directive

MARCOAST Service Portfolio

The MARCOAST service network is delivering a wide array of products to support the monitoring of the European Seas

- **Oil spill service chain**
  - Oil spill alert and polluter identification
  - Oil spill drift forecast
- **Water quality service chain**
  - Water quality monitoring service
  - Algae bloom monitoring, evolution and forecasting service
  - Water quality indicators

Service Provision

- **Service network:** 32 Service Providers (coordianted by Alcatel Aleniaspace)
- **Users:** Operational environmental agencies from 11 European coastal states
- **Service Level Agreements (45):** Formal agreements between Users and Service Providers

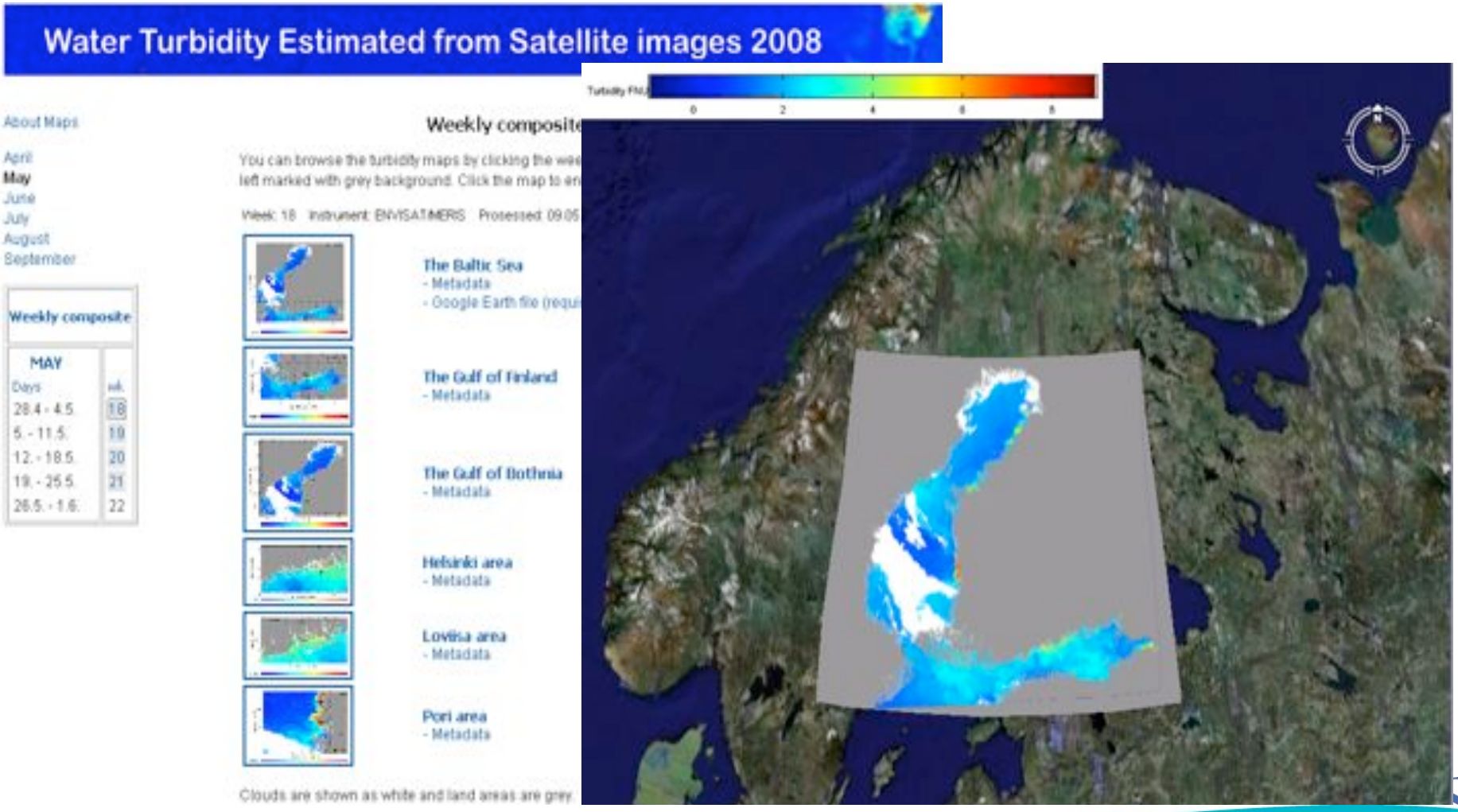
Service Portal

http://serviceportal.marcoast.eu

MarCoast
a GMES Services Network

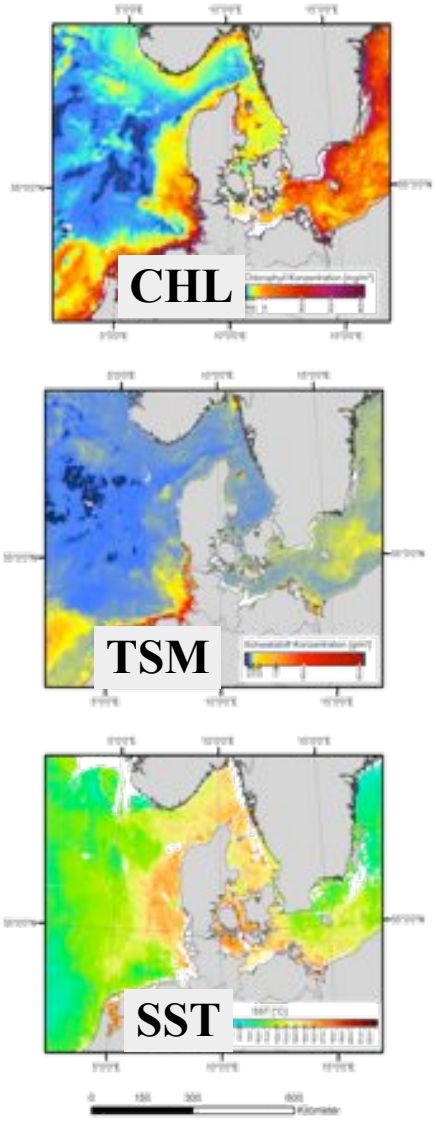
Service Example 1

Finnish Environment Institute (SYKE)

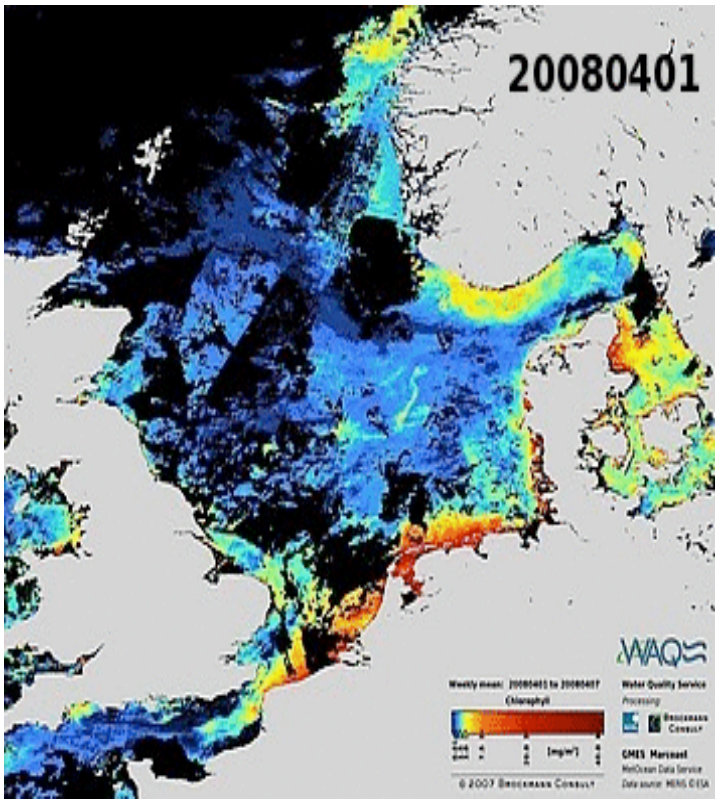


Service Example 2

Water Quality Products to local monitoring authorities in Germany



BROCKMANN CONSULT



Algal bloom in the North Sea

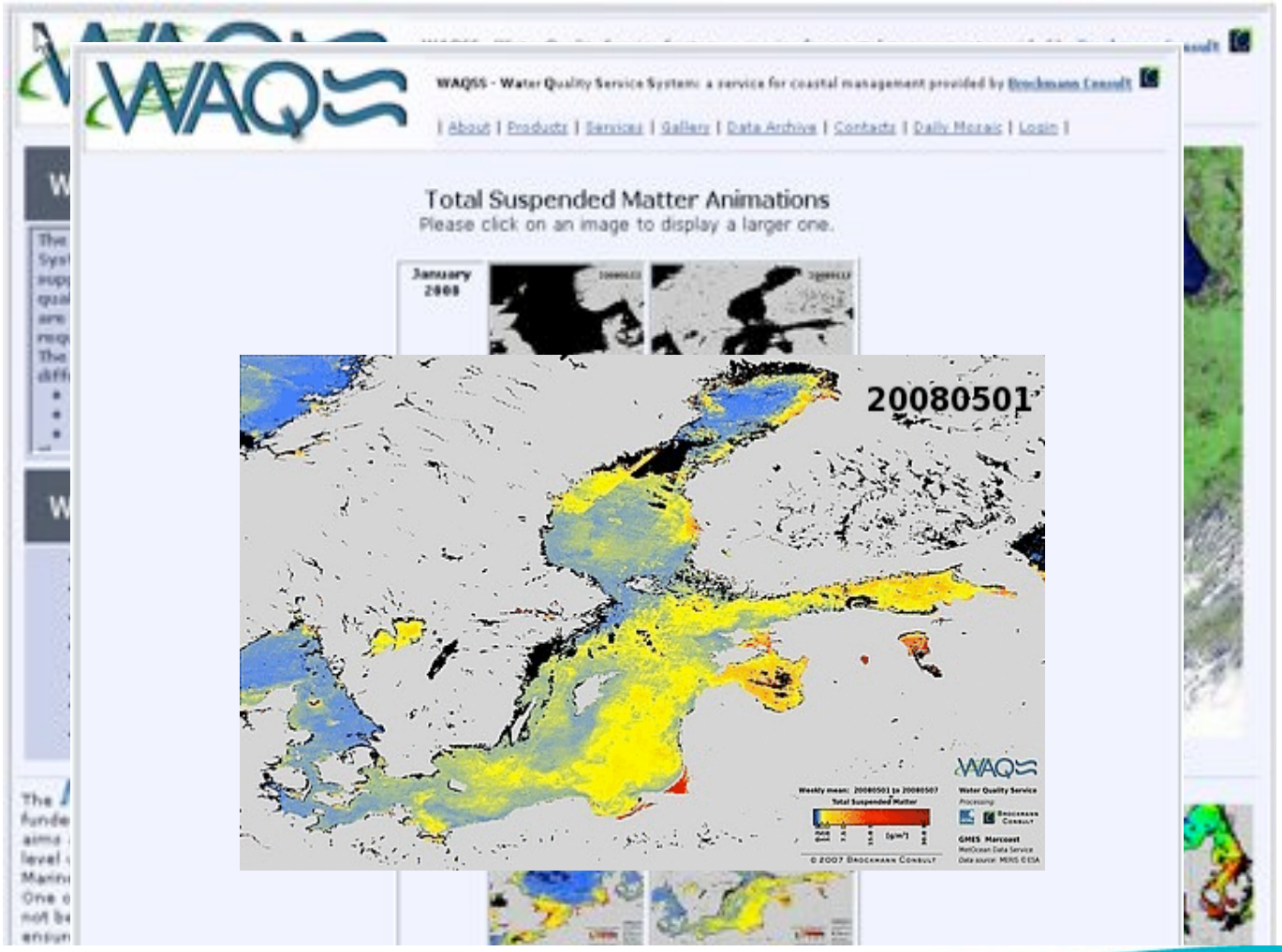
MarCoast
a GMES Services Network

Service Example 3

TSM distribution in the Baltic Sea

www.waqss.de

BROCKMANN CONSULT



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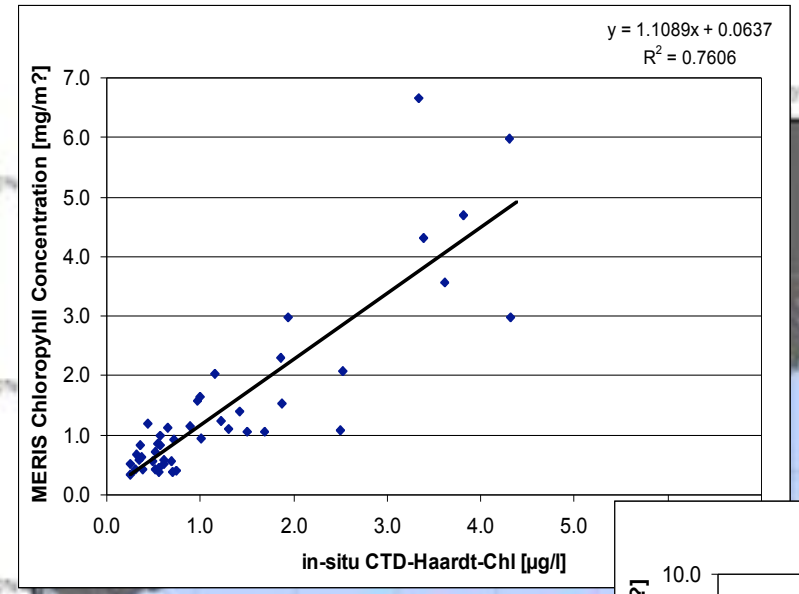
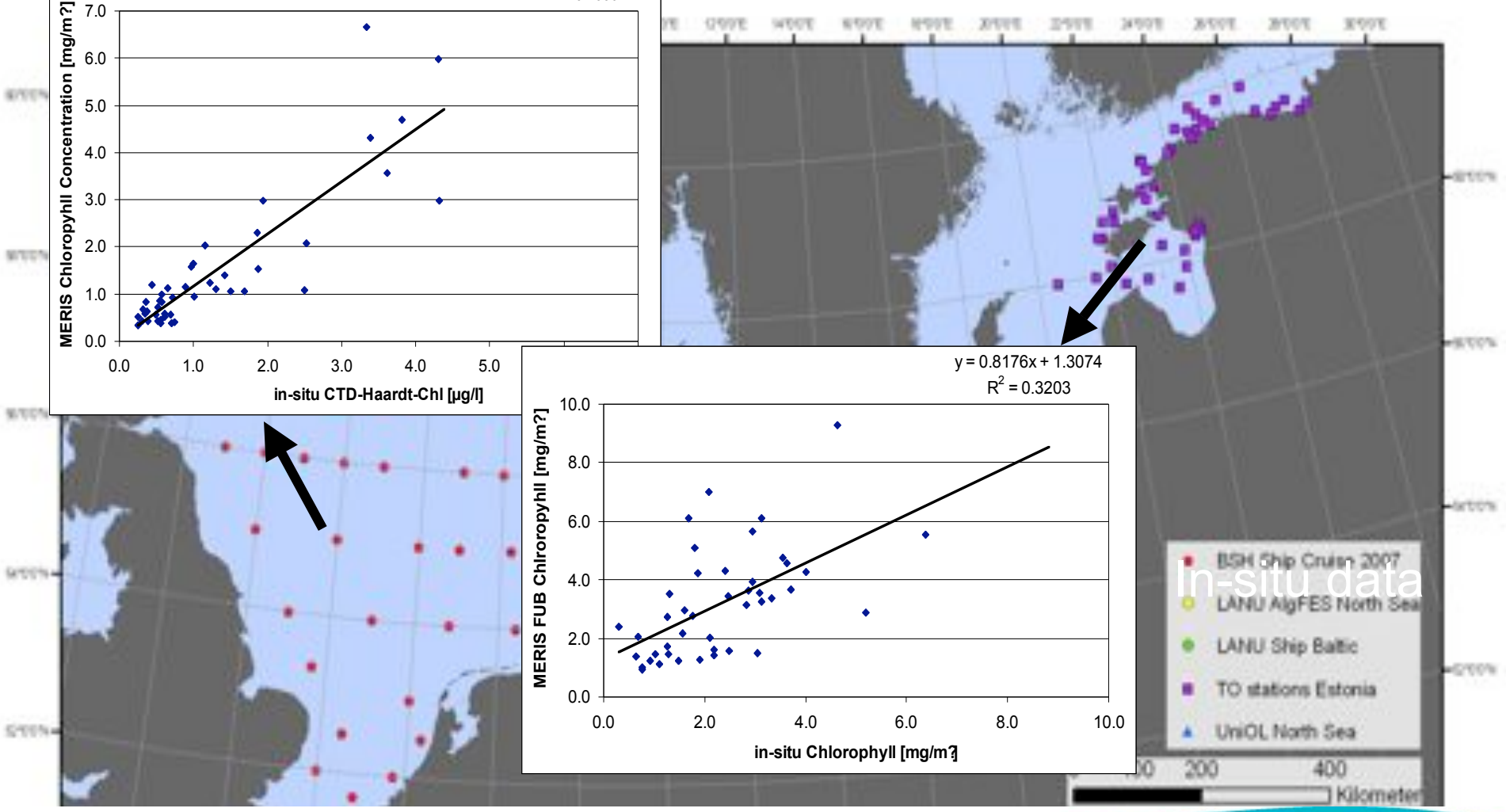
a GMES Services Network

Validation

- **Validation Bureau:** ensures high quality of products & services
  - Independent from service providers
  - Validation process development & service quality assessment
- **Validation Procedure**
  - Validation Protocol
    - Product Validation: Comparison against in-situ (user) data
    - Service Validation guided by SLA
      - Documentation, timeliness, reliability, completeness, user information
  - Service Provider Validation Report evaluated by end user
  - Final assessment by Validation Bureau & feedback to users and service providers
- **Validation Workshops**
  - Open to external experts & review of individual services
  - Scientific discussion & recommendations

Validation Example

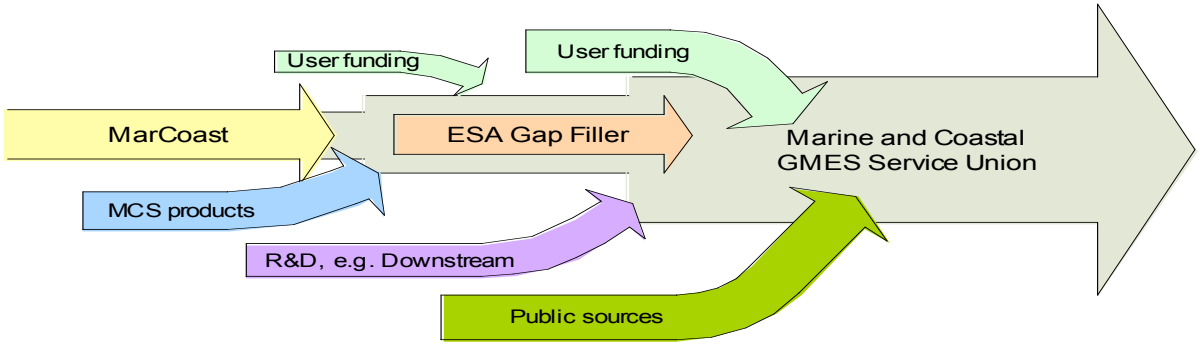




MarCoast
a GMES Services Network

Summary & Perspective

- **Outlook for MARCOAST services is very encouraging**
  - Evolution in policy is creating demand for operational marine services
  - Well coordinated service network providing policy relevant information services
  - Very positive user feedback; users are going to contribute to service costs
- **Consolidation of water quality services required**
  - better regional algorithms & extension of FR MERIS based services
  - new services (indicators, oxygen depletion, forecasting)
- **Maintaining service continuity is critical**
  - data continuity ensured through new operational missions (ESA Sentinels)
  - continued ESA funding and progressive transfer to operational funding lines (EC, national) ➔EC GMES Marine Core Services



ESA GlobCover Project

GlobCover Overview

Objectives:

- Global Land Cover Map Dec 2004/Jun 2006 using MERIS data at 300m
- Update, complement, improve other existing comparable global products (e.g. GLC-2000, EC-JRC, 1km resolution)

Accuracy goal:

- 70%; (GLC 2000: 68%)

Partnership:

- DUE project led by international network of partners: ESA – EC JRC - UN FAO - UNEP - EEA – IGBP
- Defining user requirements and providing feedback on product quality

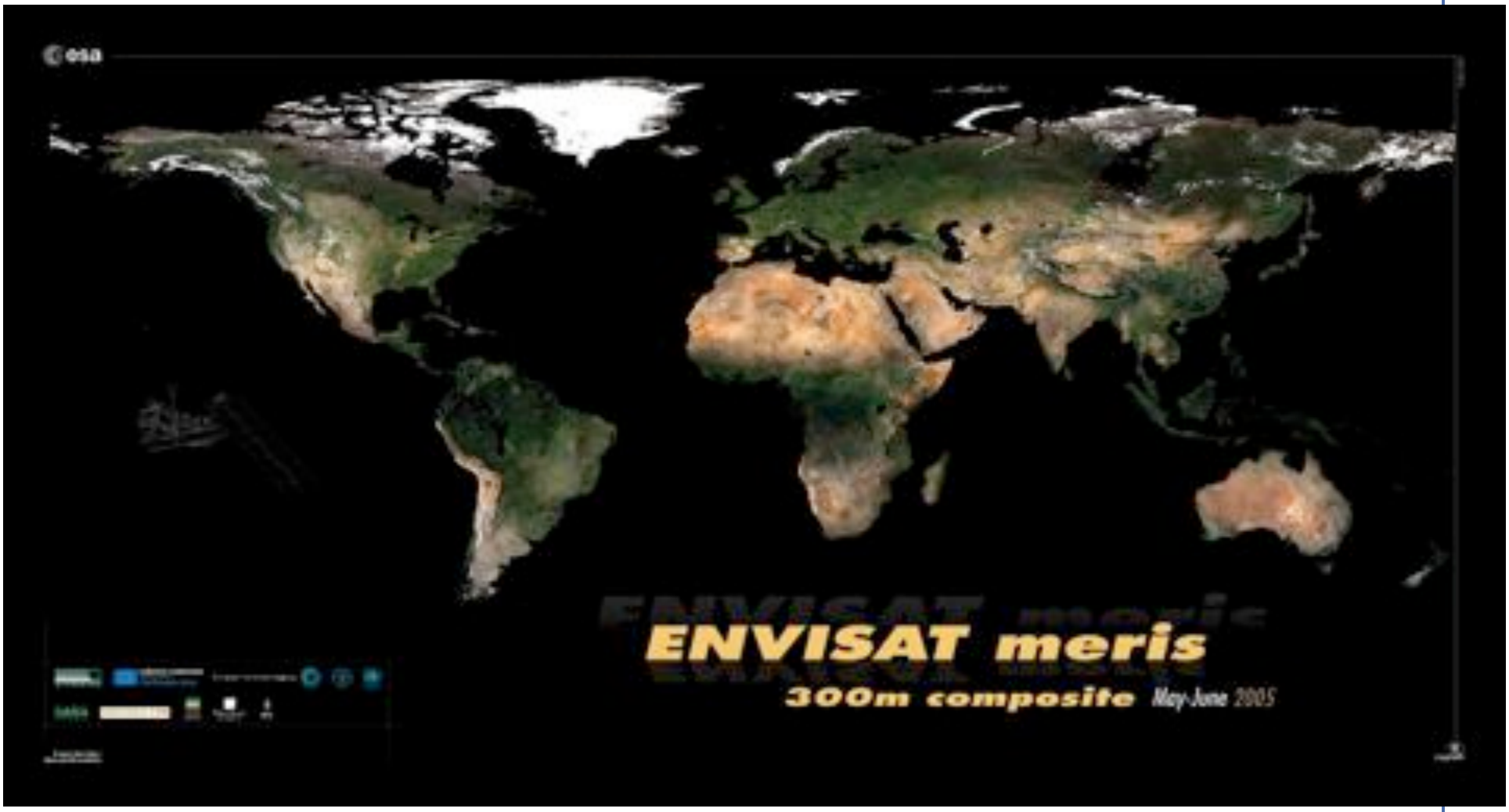
Implementation:

- Kick-off April 2005
- ESA, ACRI, UK PAC, MEDIAS, Brockmann, UCL

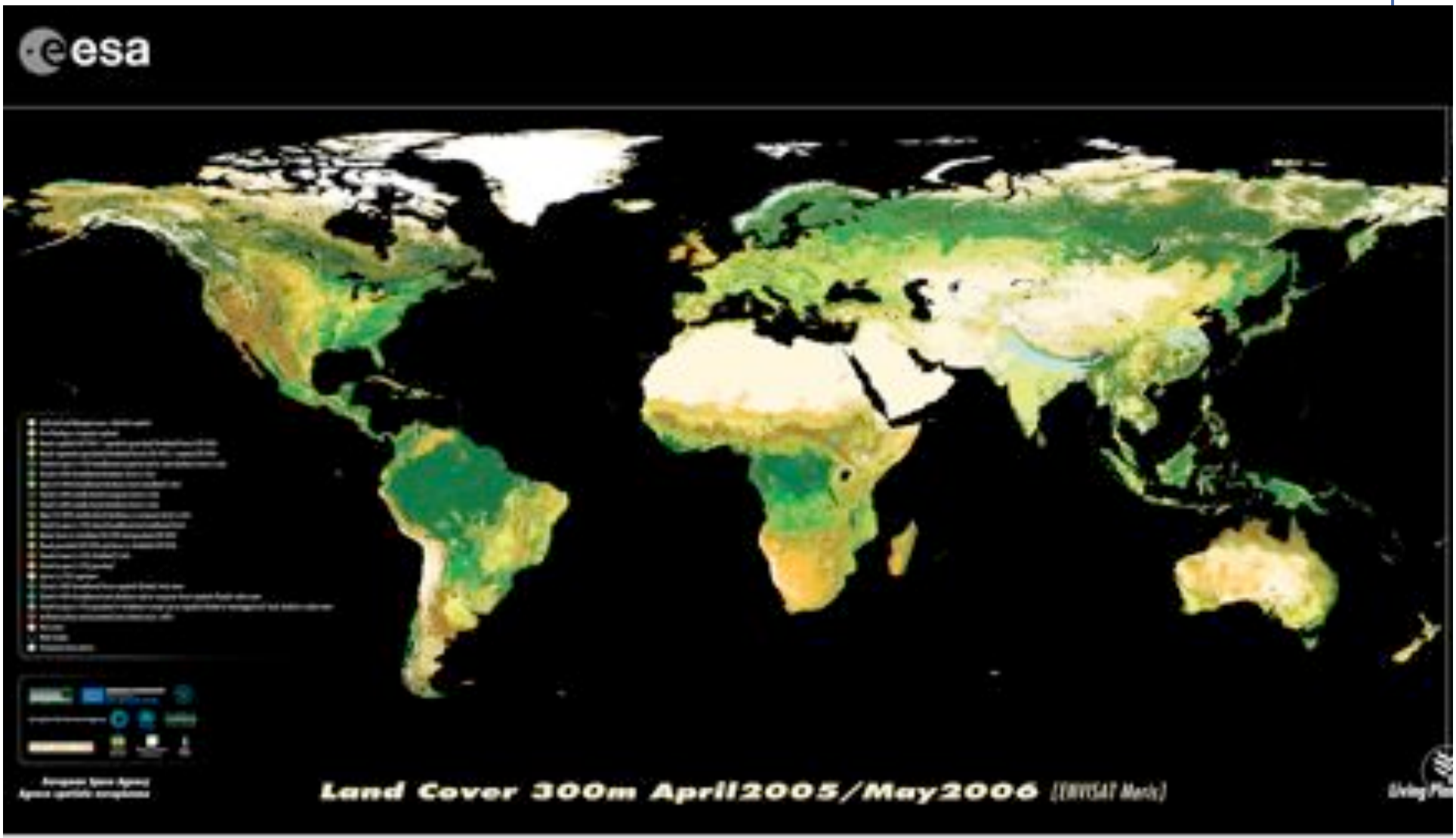
Outputs:

- Bi-monthly MERIS FR surface refl. composite
- GlobCover Land Classification Map V1 (Feb 2008)

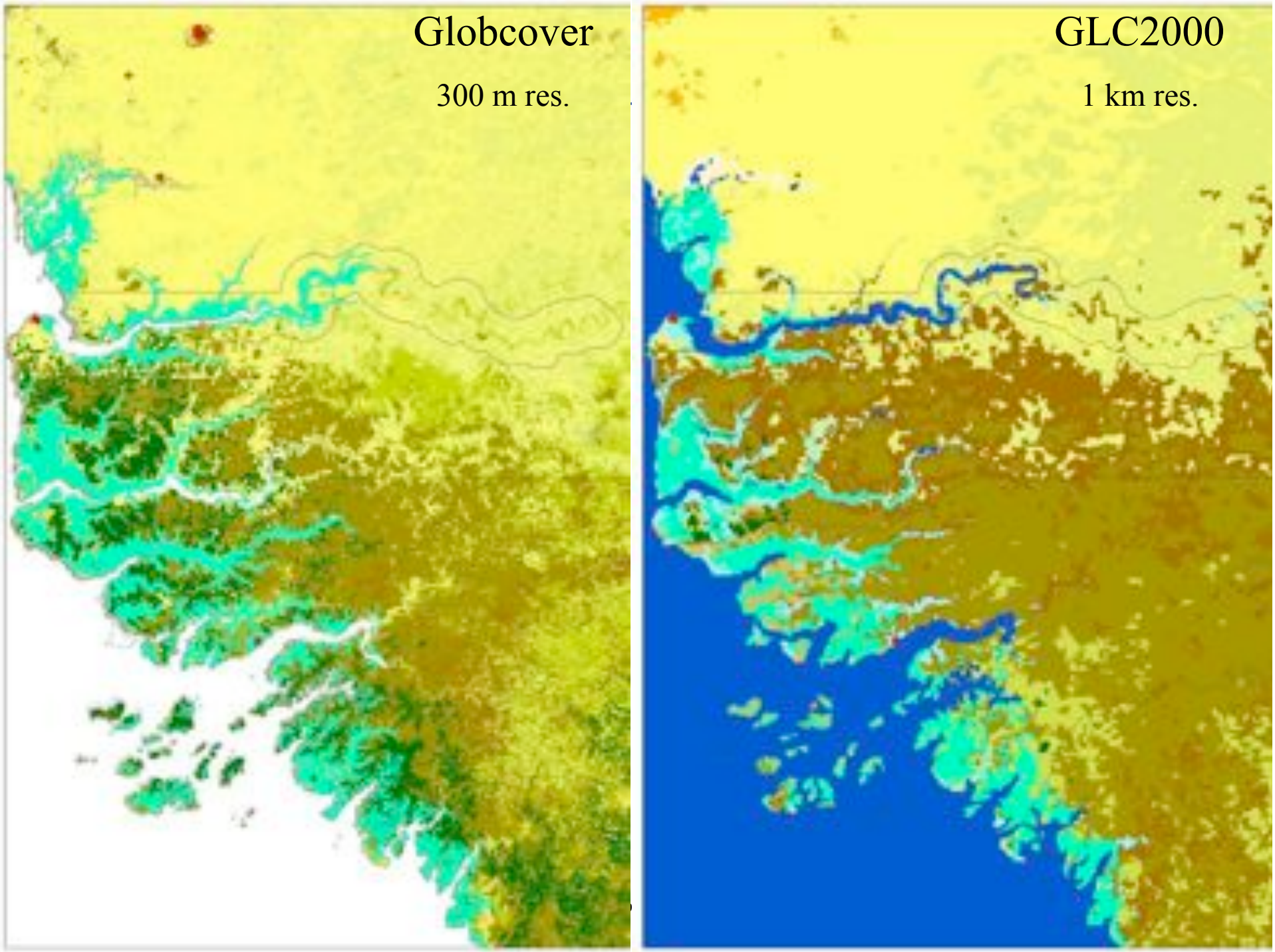
GlobCover MERIS FR composite



GlobCover Land Cover Map



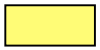
Land cover map at 300m over Europe

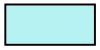

Globcover
300 m res.
GLC2000
1 km res.

GlobCover classification system

Classification system compatible with the GCL 2000

22 land cover types compatible with the FAO-UNEP LCCS


Cultivated and Managed areas


Post-flooding or irrigated croplands

Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)

Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)

Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m)

Closed (>40%) broadleaved deciduous forest (>5m)

Open (15-40%) broadleaved deciduous forest/woodland (>5m)

Closed (>40%) needle-leaved evergreen forest (>5m)

Closed (>40%) needle-leaved deciduous forest (>5m)

Open (15-40%) needle-leaved deciduous or evergreen forest (>5m)

Closed to open (>15%) mixed broadleaved and needleaved forest

Mosaic forest or shrubland (50-70%) and grassland (20-50%)

Mosaic grassland (50-70%) and forest or shrubland (20-50%)

Closed to open (>15%) shrubland (<5m)

Closed to open (>15%) grassland

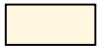
Sparse (<15%) vegetation

Closed (>40%) broadleaved forest regularly flooded, fresh water

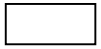
Closed (>40%) broadleaved semi-deciduous and/or evergreen forest regularly flooded, saline water

Closed to open (>15%) grassland or shrubland or woody vgt on regularly flooded or waterlogged soil, fresh, brakish or saline water

Artificial surfaces and associated areas (Urban areas >50%)


Bare Areas

Water Bodies


Permanent Snow and Ice

European Space Agency
Agence spatiale européenne

the Living Planet

Validation

- GlobCover V1 released to team of 12 external experts for validation
- Comparison of GlobCover classification with "ground truth" data
- Results presented to users at 2nd User Consultation Workshop (Mar 2008):
  - Product does not reach yet the envisaged accuracy level of 70%
  - Overall accuracy ranked 66.5 % according to land cover types; several artefacts
  - Need for improved cloud detection, aerosol correction, snow processing, water/forest discrimination
  - Need for regionally-tuned approach to the data

➔ **Consolidated GlobCover V2**

soon available at:

http://www.esa.int/due/ionia/globcover

ESA Grid Processing on Demand (G-POD)

Why G-POD at ESA for EO ?

- **Scientists have the processing algorithms**
  What they need is Data!
  Near-real-time data, decades of data, multi-source data

- **Operational issues**
  - Space missions generate large data volumes (Envisat > 500 GB/day)
  - EO data archive is "scattered"
  - Algorithms evolve → need for recurrent reprocessing (→ re-distribution)
  - Moving the data to the users is "costly"
  - Significant investments required to handle the data at the scientist's lab

- **Using GRID can solve the problem**
  - Move processors close to the data in a flexible and controlled way
  - Resources can be shared/re-used (data, tools, computing resources)
  - Providing a common shared platform → Collaborative Environment

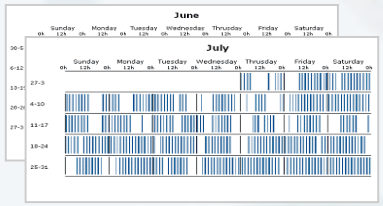
ESA G-POD Environment

➢ A User-Segment data processing environment

- Over 200 CPUs, 120 Tbytes online (ESA & 3d party) , tools (IDL, Matlab, compilers, image processing utilities…), catalogue queries & data provision functions
- Hosts user processors: "production" lab / "collaboration" environment
- Open and sizeable: Able to host "any" processor
- Simple engineering model and instructions, clear interfaces (no G-POD expertise needed)
- Engineering and production phases fully supported by ESA

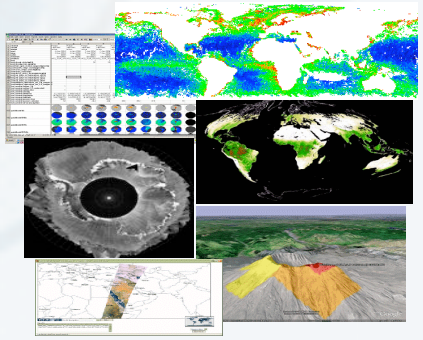
➢ Systematic / On-demand processing of large data volumes

- Wide ranging applications supported



on-line data archives

User controls from the web portal his own processor running on G-POD computers



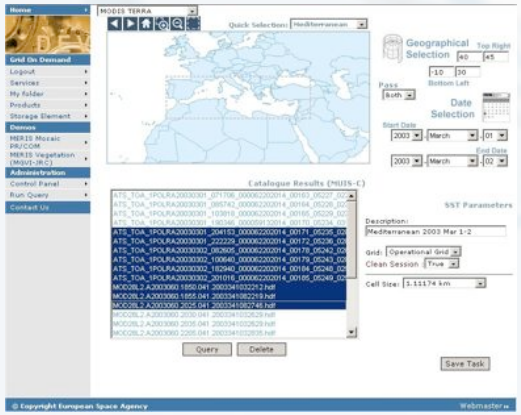
high-level products

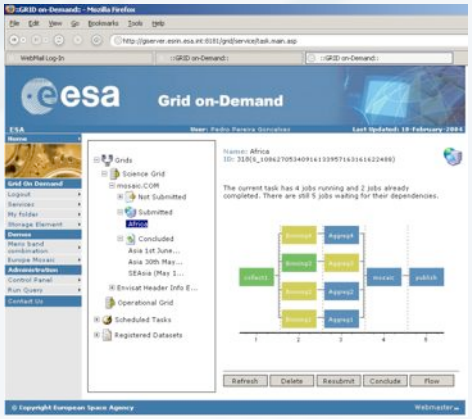
G-POD Web Portal

Flexible, secure, generic and distributed multi-functional platform:

- Temporal/spatial selection of EO products for the Grid processing
- set up the processing script and monitor the actual processing
- Tools for result visualization
- Access to output products and related documentation

http://gpod.eo.esa.int
http://eopi.esa.int/G-POD



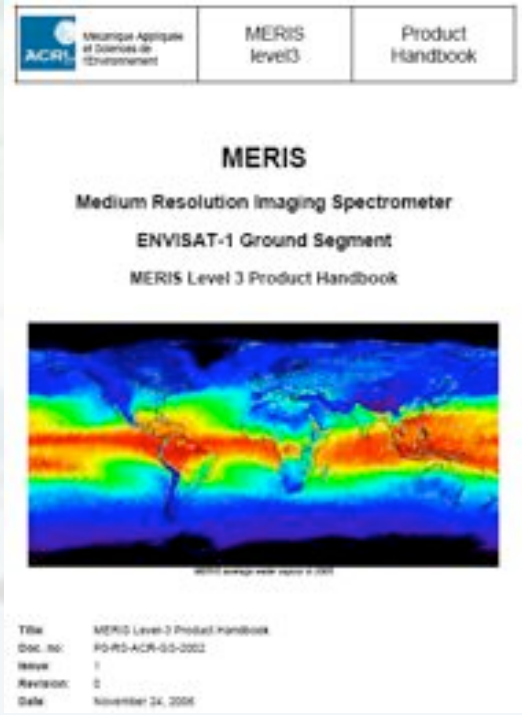


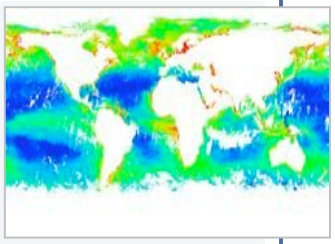
MERIS Level-3 Products

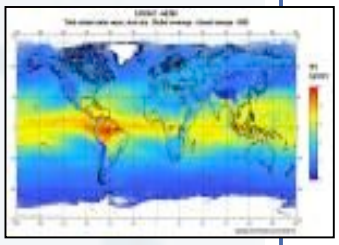
- Monthly at 9 km resolution, sinusoidal grid (2002-2008)
- Daily at 4.6 km resolution grid (2007, 2008)

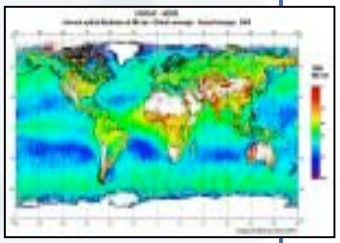
http://envisat.esa.int/level3/meris/

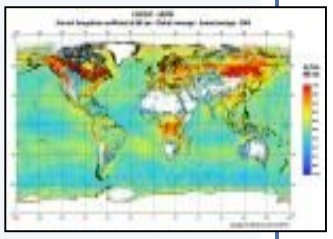
Normalised water leaving radiance at 412, 443, 490, 510, 560 nm
Chlorophyll-a, case-1 water (chl1)
Angstrom alpha coefficient over water at 865 nm
Aerosols optical thickness over water at 865 nm
Angstrom alpha coefficient over land and water at 550 nm
Aerosols optical thickness over land and water at 550 nm
Total water vapor column, clear sky
ABSOA_DUST flag statistics
MERIS Global Vegetation Index
Aerosols optical thickness over land at 443 nm





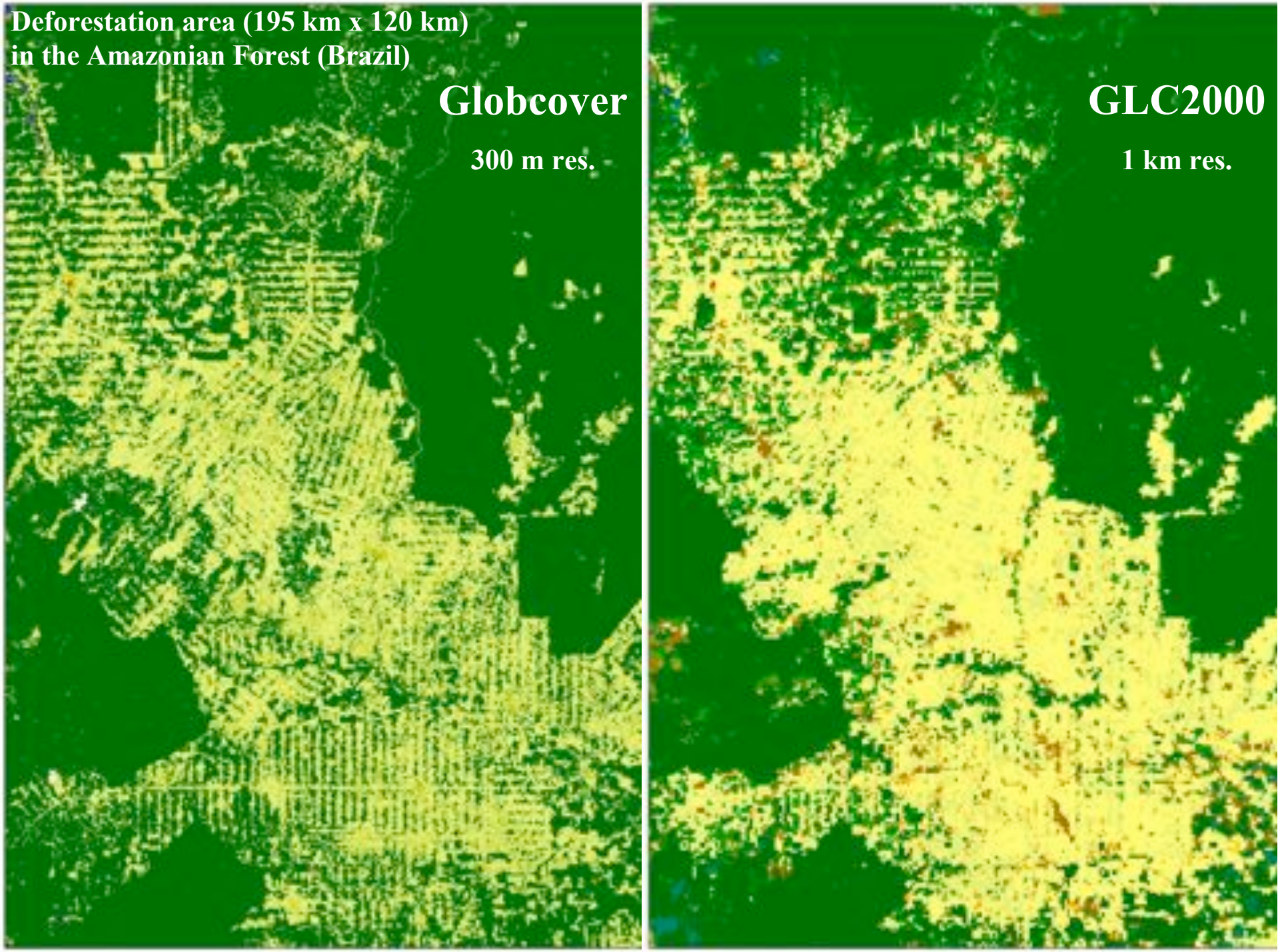




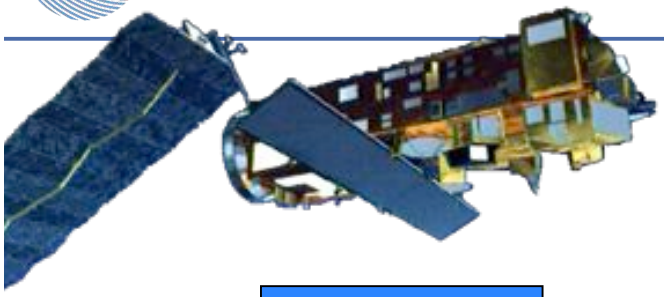


Conclusion & Perspective

- **Growing demand for G-POD on-demand processing capabilities**
- **Cost Effective Solution**
  - One Infrastructure investment for shared use
  - No need for large volume data movement
  - Simple integration of a new G-POD application
- **Extend G-POD to other ESA facilities e.g. Kiruna, PACs, 3d party facilities**
- **Promote the G-POD concept e.g. for future GMES Ground Segment**


Deforestation area (195 km x 120 km)
in the Amazonian Forest (Brazil)
Globcover
300 m res.
GLC2000
1 km res.

Water quality service chain



EO

MetOcean Data

Surface currents
Sea Height
SST
Ocean Color data
Ocean state forecast
Winds

Physical products

EO

In Situ

Water Quality Monitoring

WQ Parameters

EO

In Situ

Algae bloom
Risks mapping
Propagation
Alert assessment

Blooms
Propagation forecast
Risk Maps

EO

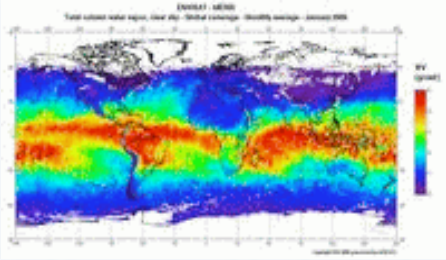
Water Quality Assessment

Indicators

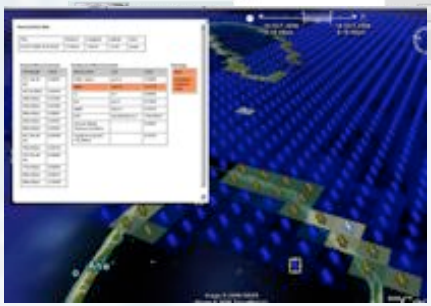
U S E R S

G-POD in Operations

- **MERIS Level-3 Products**
  - Daily/monthly L3 products available on-line http://envisat.esa.int/level3/meris/



- **MIRAVI Geo-toolbox**
  - Geo-coding of MERIS full resolution images produced by MIRAVI real-time service



- **AeroMeris**
  - Fast pixel extraction over user-area and statistics from the complete MERIS level-2 product archive

- **Global & Regional True Colour Mosaics**

GlobColour products

Daily, 8-days, monthly products at 4.6 km res.

http://www.globcolour.info

Parameter	Description	L3 merging method	M
CHL_1	chlorophyll-a concentration (mg/m^3) for case 1 water	GSM model	
CHL_2	chlorophyll-a concentration (mg/m^3) for case 2 water	weighted averaging method	✪
TSM	total suspended matter concentration (g/m^3)	weighted averaging method	✪
CDM	Coloured dissolved and detrital organic materials (m^{-1})	GSM model	
b_{bp}	particulate back-scattering coefficient at 443 nm (m^{-1})	GSM model	
Kd(490)	diffuse attenuation coefficient at 490 nm (m^{-1})	analytical from merged CHL_1	
Lxxx	fully normalised water leaving radiances at xxx nm (mW/cm/m/sr) where xxx= 412, 443, 490, 510, 531, 550-565, 620, 665-670, 681 and 709 nm	weighted averaging method	
L555	inter-calibrated fully normalised water leaving radiances at 555 nm (mW/cm/m/sr)	weighted averaging methods (1)	
EL555	relative excess of radiance at 555 nm (%)	analytical from merged L555 & CHL_1	
T865	aerosol optical thickness over water (-)	weighted averaging methods	
CF	cloud fraction (%)	classification & statistical methods	

SeaWiFS 09/1997 – 04/2002

MERIS 04/2002 – 06/2002

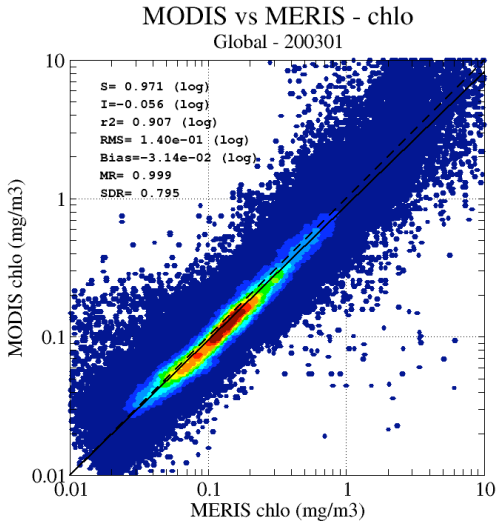
MODIS 06/2002 –

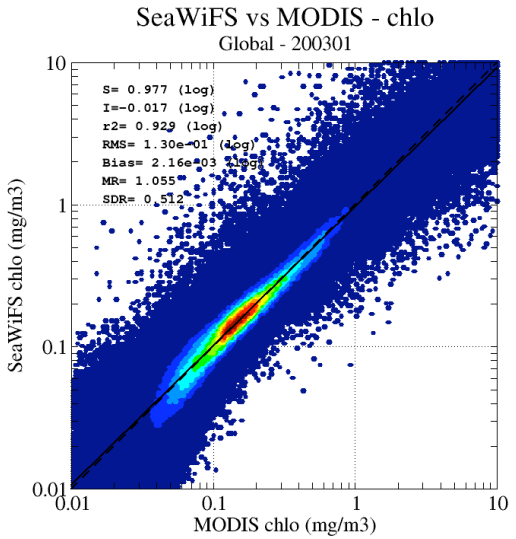
+ error estimates for the output merged products

End 2008 start of NRT service demonstration ?

Difficulties

- Different sensor design, calibration, sensitivity, algorithms, accuracies,….
- Large volumes of data to deal with
- Merging procedure should not create biases, discontinuities, artifacts,…





Schematic Production Chain

EO

Input Data	Value Adding	Packaging, Formatting, Delivery	Validation
L2 raw MERIS MODIS AATSR AVHRR Averaged Merged Prods From S6	Regional processing Derived variables Merging Averaging Projecting Combination with In-situ Data Extraction Modelling Bulletins	Images Data tables DIMAP netCDF HDF GeoTIFF GIS layer ftp Email	Statistics Compare with in-situ, models, .. Time series analysis

Reporting

from user to SP

U S E R S

In situ networks

MarCoast
a GMES Services Network

GlobCover Products

GlobCover V1 (Feb 2008)

- released to the project team members
- assessed at 2nd User Consultation (Mar 2008)

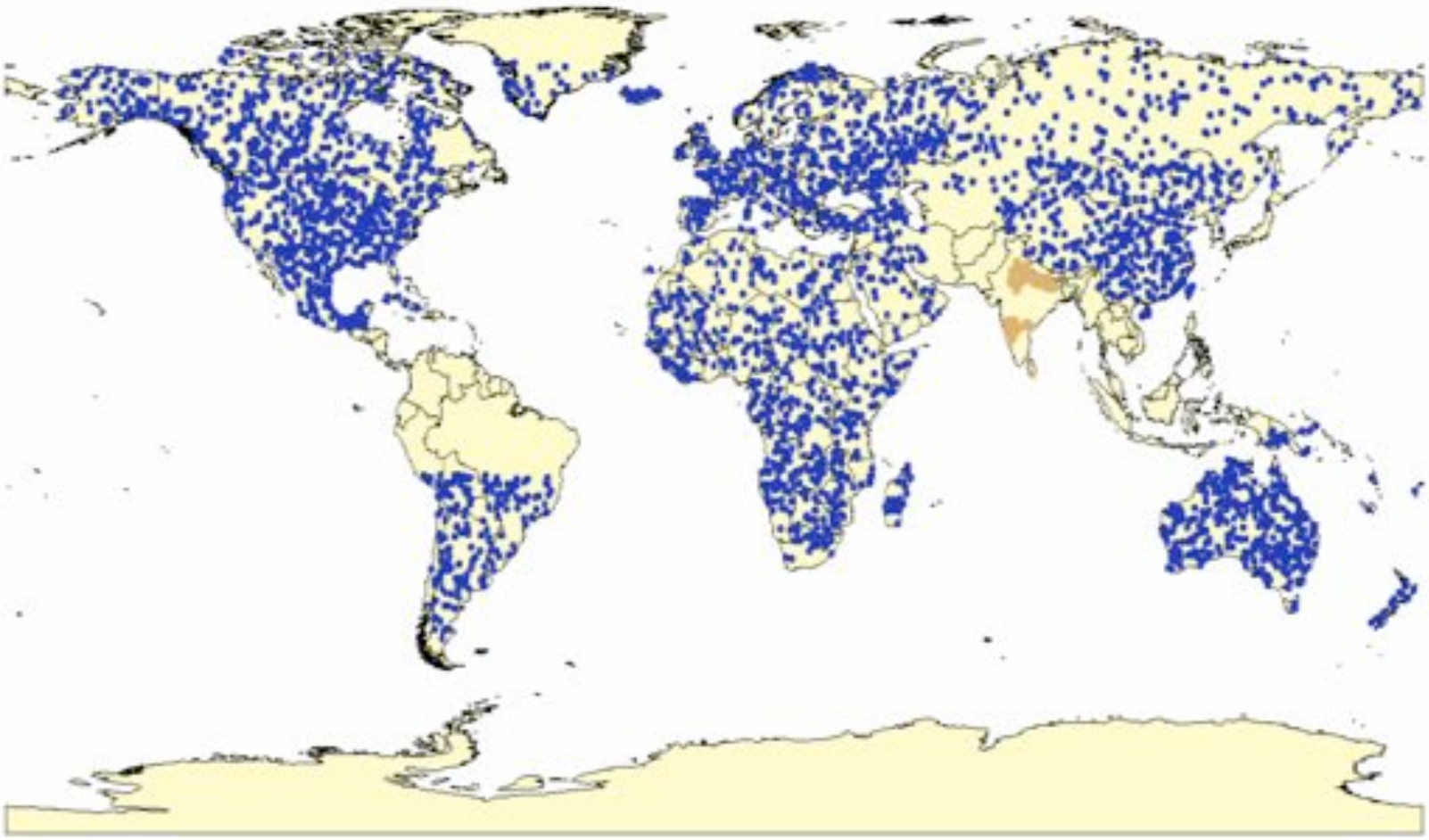
=>

- overall accuracy ranked 73% according to land cover types, however several artefacts

GlobCover V2 (Aug 2008)

- consolidated version
- regionally-tuned approach to the data
- improved cloud detection, snow processing, aerosol correction

Globcover V2 soon available at:
http://www.esa.int/due/ionia/globcover



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