



Satellite Oceanography in the context of GMES & GODAE

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- A joint initiative of the EU and ESA
 - Establish (2008) a global monitoring capacity in support of EU objectives :
 - Sustainable development
 - Independence in the provision of data, information, knowledge, indices ...
 - In support of policy making :
 - environment, global change, sustainable development
 - agriculture, fisheries,
 - research,
 - Humanitarian help,
 - Conflict prevention, crisis management, risk evaluation
 - negotiation and monitoring (compliance) of international treaties and conventions

Global Monitoring for Environment and Security

An Intelligence System to provide timely and adequate information delivery

The Goal is to develop operational information services, relying on space infrastructure, in support of public policies, e.g.:

- **Environmental Governance (global and local)**
- **Civil Security**
- **Resources Management**
- **Food and Health Security**

It will rely on:

- **A space-based permanent global monitoring system**
- **Additional in-situ observations**
- **Operational modeling and forecasting centers**
- **A network of users/ customers**

European Commission

*A European Approach to **Global Monitoring for Environment and Security(GMES)**: Towards Meeting User Needs[References: Brussels, 19.6.2001, SEC(2001) 993 and the European Space Agency (ESA/PB-EO(2001)56, rev.1]*

GMES Priority Areas:

- A: Land Cover in Europe
- B: Environmental Stress in Europe
- C: Global Vegetation Monitoring
- D: Global Ocean Monitoring
- E: Global Atmosphere Monitoring

Goal: Expand European capacity to producing global ocean information based upon existing monitoring capabilities; in support to seasonal weather predictions, global change research, commercial oceanography and defence.

Relevance: Existing operational models, climate studies, economic interests, global security.

Potential Users: European Commission; climate research organizations; meteorological services

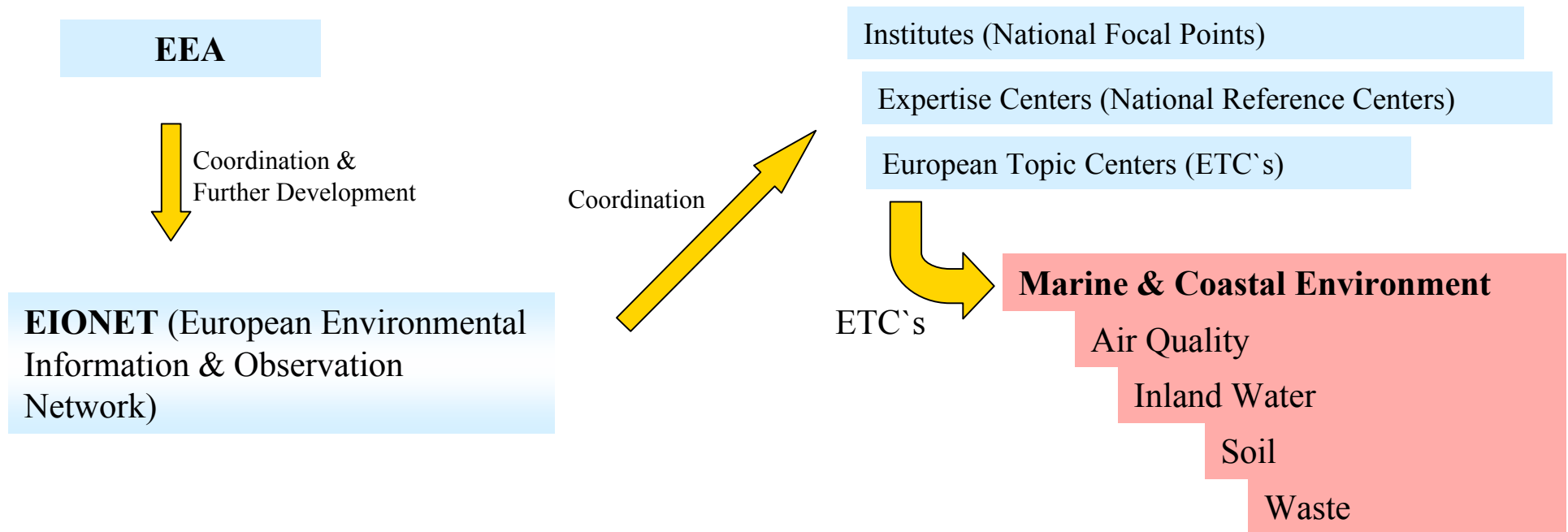
Corresponding on ESA side to GMES Services Element (GSE)

European Environment Agency (EEA)

Main objective is to provide the Community and the Member States with:

⇒ objective, reliable and comparable information at European level enabling them to take the requisite measures to protect the environment, to assess the results of such measures and to ensure that the public is properly informed about the state of the environment

⇒ to that end, the necessary technical and scientific support



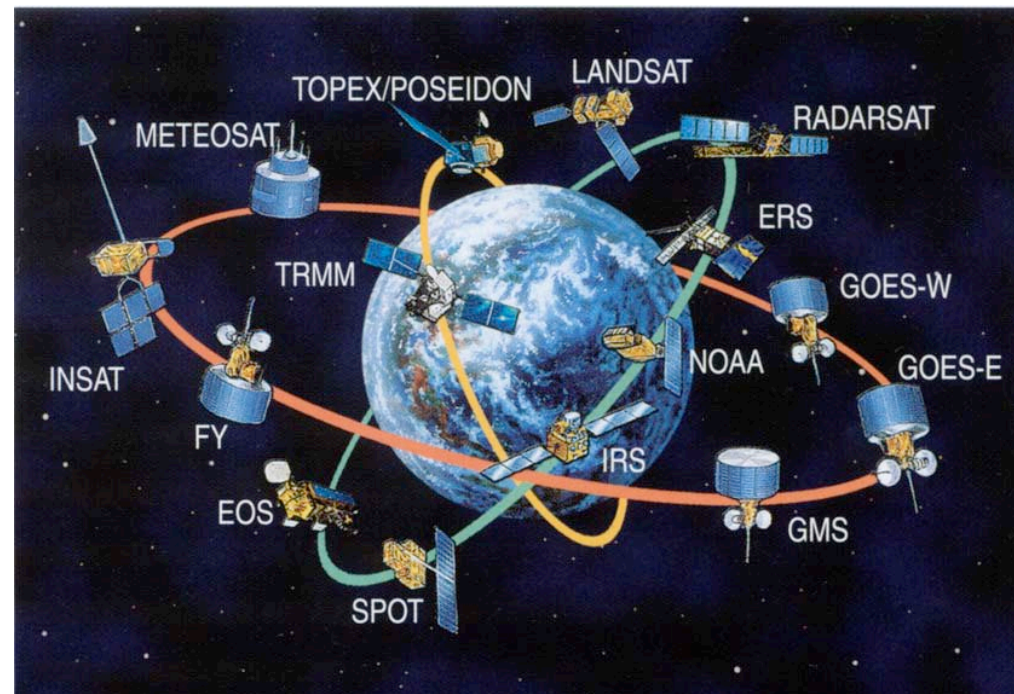
- Satellite Ocean Monitoring forms one of the key elements of Global Monitoring for Environment and Security (GMES)
 - Satellite systems are a unique, globally available data source and facilitate local, regional and global applications and related services.
 - GMES will establish operational capabilities providing information to the user community as specified in the EC Action Plan^[1] (2001-2003).
- The economic and environmental importance of the oceans dictate that ocean and marine GMES applications are initially focused on:
 - fisheries and vessel monitoring
 - maritime traffic and security
 - coastal zones and open ocean environment monitoring
 - sea ice/oil spill monitoring.
- The general objective of the GMES programme is to realise the benefits of EO data for markets and society.

^[1] COM(2001) 609 final GMES: Outline EC GMES Action Plan

- The primary actors in GMES ocean-related projects need to have existing access to the “tools” needed to establish operational services.
- Since these tools must (in most cases) include operational ocean forecasting capability, these groups are logically also participants in MERSEA and the Global Ocean Data Assimilation Experiment (GODAE). Four key ocean modelling efforts are: FOAM, MERCATOR, MFS, and TOPAZ.
- There is an important overlap, in terms of capacity building, between GMES and GODAE, and thus ESA recognises the need to serve the primary data needs of these established users (both operational and scientific).

Series of **OPERATIONAL** and **R&D** satellite sensors for oceanography has been and will be functioning more than ten years till the end of GODAE demonstration phase

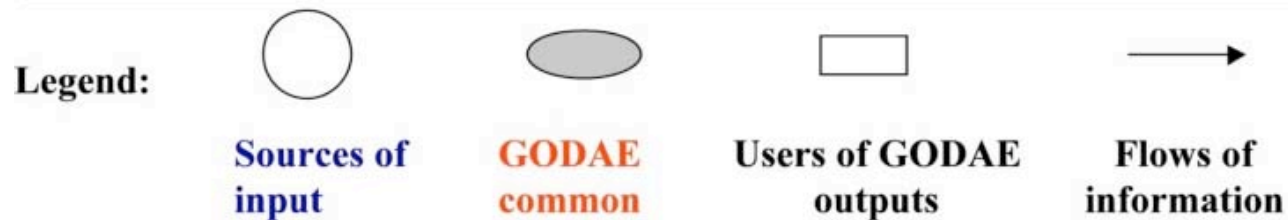
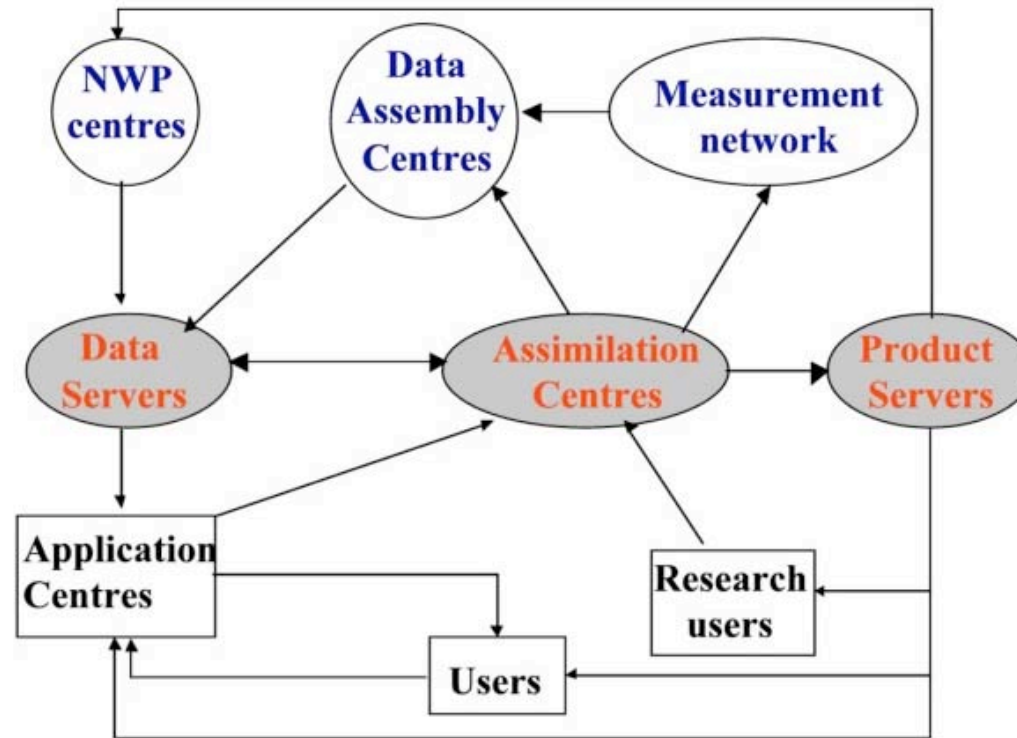
- Altimeter
- Scatterometer
- SST sensor
- Ice sensor
- Ocean Color sensor

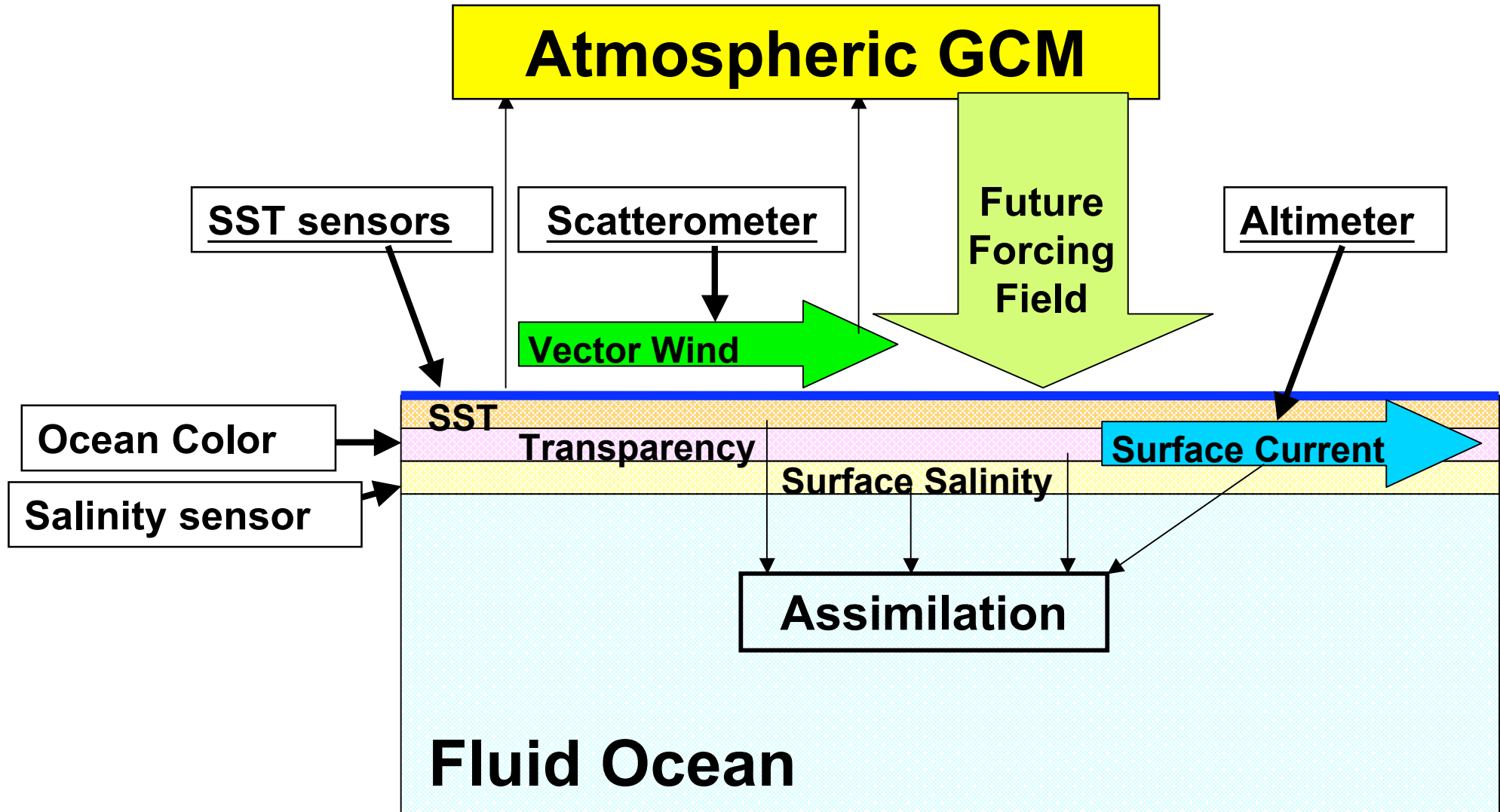


Courtesy IGOS-P

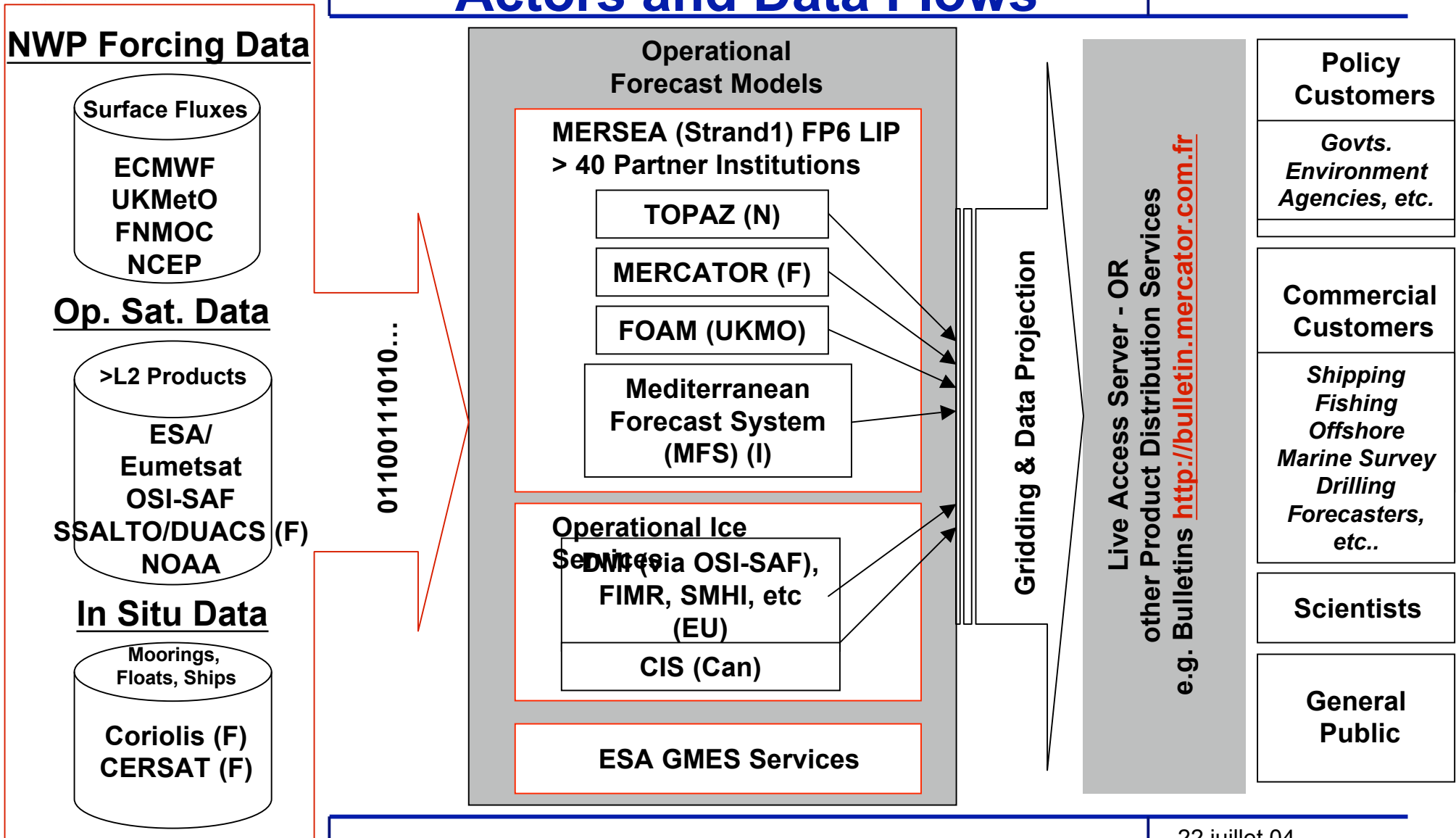
GODAE: Functional Components

GODAE = Global Ocean Data Assimilation Experiment



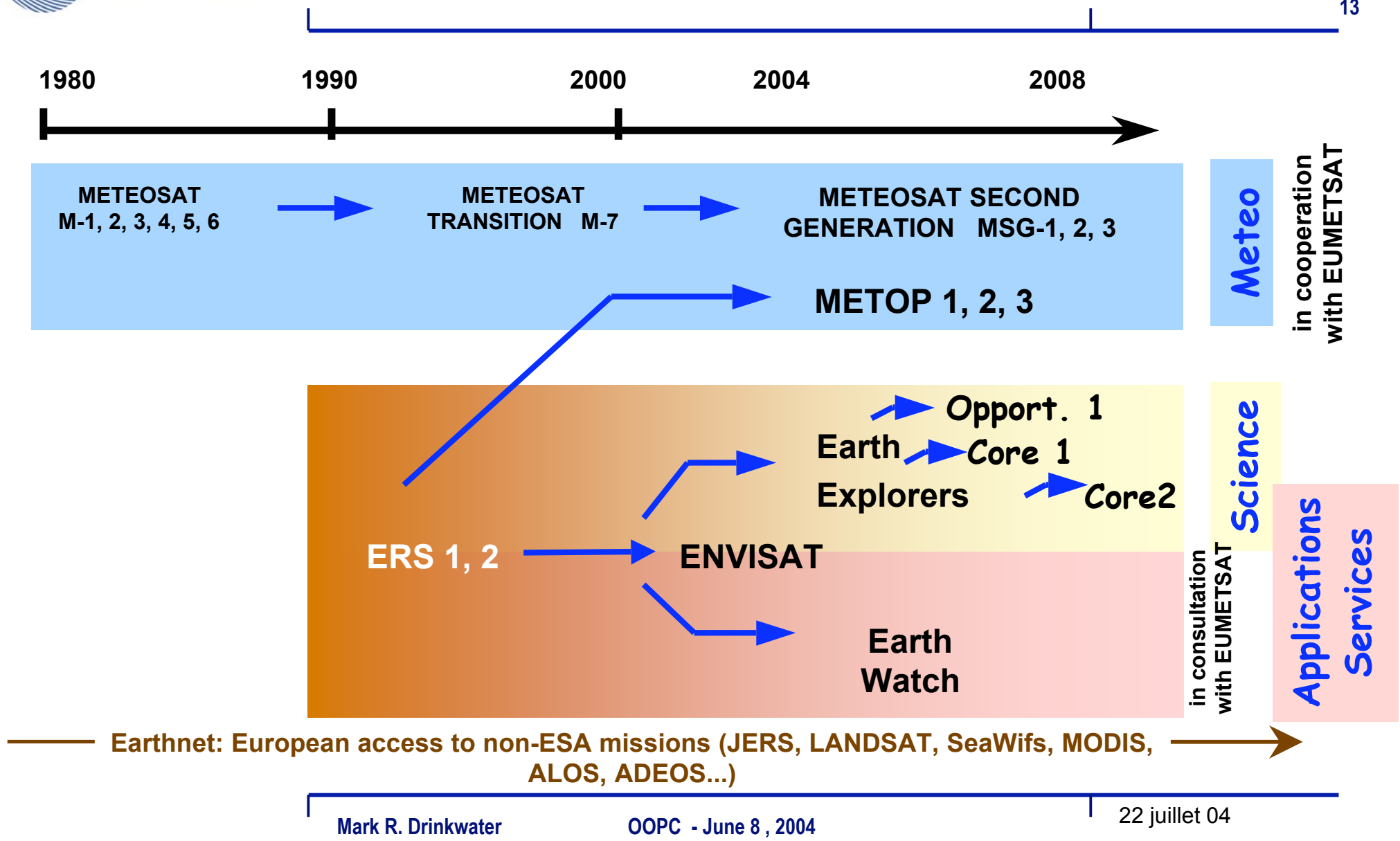


Operational Ocean Forecasting: Actors and Data Flows



- ESA's Living Planet Programme contains two types of missions:
 - Earth Explorers
 - Earth Watch
- Earth Watch missions are operational service-oriented missions of ESA's dual mission strategy
- Earth Watch Missions shall complement the more research-driven Explorers, and provide continuity in observations

ESA's E.O. programme



An Oceans Earth Watch satellite GMES Sentinel 3

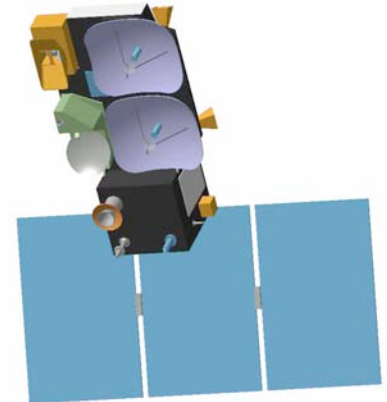
- The human need for global ocean observations
 - better understanding of ocean processes to increase predictability of processes, e.g. NWP, hurricanes, coastal erosion, alga blooms, etc.
- The economic importance of the oceans
 - Commercial, Economic and Social Value
 - 2-5 BEURO /year estimated by EuroGOOS
 - The Environmental Value
 - air, forests, rivers, ocean, soil, represents capital! It is necessary to understand role of the sea better to perceive its true value
 - Sustainable Development
 - Conventions, Kyoto Protocol, Framework Climate Convention, Biodiversity Convention, etc.

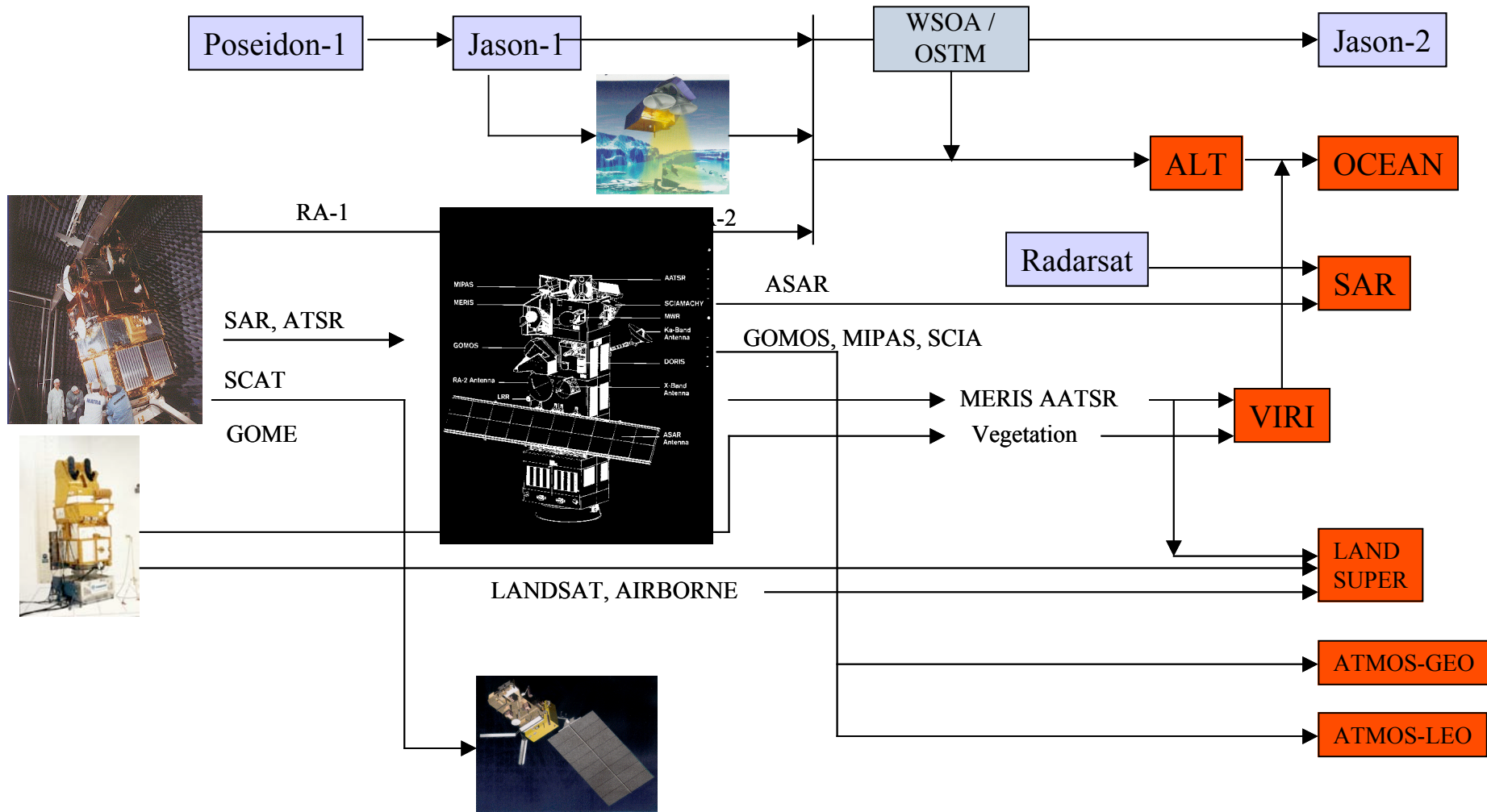
- The capability to observe the ocean and to deliver useful ocean data products is well established
 - Altimetry and ocean topography, ocean colour and biology, wind vector measurements at ocean surface, sea ice, ocean waves
 - Observation techniques and top class instruments: altimeters in ERS, ENVISAT, CRYOSAT, T/P, JASON, ocean colour on IRS and ENVISAT, SST on ERS and ENVISAT, Wind Scatterometers on ERS and MetOp, SAR on ERS, ENVISAT, Radarsat and future EW missions
- The policy justification for a global ocean observing system is well established:
 - GMES, convention monitoring,
 - Support by operational entities in particular Eumetsat (Darmstadt declaration October 2000)
 - Desire to go operational in many federating bodies: WMO, CEOS/ IGOS, EuroGOOS
- Improved knowledge of the ocean is essential for further development of a global ocean observing system
- It is economically, environmentally, strategically and scientifically important, it is mature and politically opportune, it is affordable, it is time to do it.

- The European shelf “environment and food” operational community sectors regard biogeochemical variables as highest priority (also input to ecosystem modelling) - (ROSES GSE Study)
- Accurate NWP requires operational, satellite-derived sea-surface topography, wind-speed, sea-surface temperature data for model data assimilation
- Coastal variables (e.g. sediment transport/biological productivity/sea-level of considerable importance to shipping, waterway and coastal/estuarine resource management)
- Offshore operational community (shipping and platforms) regard wind speed, wave height, mesoscale ocean circulation, SST, and sea-level as high priorities.
- Activity in sea ice (ICEMON & Northern View GSE Studies)

- An Earth Watch oceans mission will provide remote sensing data required to provide operational services for applications related to ocean, coastal zones and possibly ice
- This will endow Europe and Canada with the capability required to satisfy the economic, environmental and strategic interests
- building on past and ongoing investments in science and technology with space missions as ERS, ENVISAT, RADARSAT, T/P, JASON, METOP, etc.
- In the context a world-wide global ocean observing system, taking into account the world-context and in particular the European scenario with the GMES initiative and the role of EUMETSAT

- Broad requirements exist for ocean, ice and coastal waters observation. Considering expectations from existing/planned missions, the needs & potential implementation options include:
 - An altimeter (ALT), with supporting instruments, i.e. Microwave Radiometer, DORIS, and/or GNSS (Galileo, GPS) receiver.
 - A wide-swath coarse resolution sensor working from the visible to the infrared, VIRI, to continue the (A)ATSR – MERIS – VGT missions. This component is also suitable for global land / vegetation monitoring.
- Implementation plan requires results of studies identifying robust operational instrument concepts, platform compatibility issues, etc..



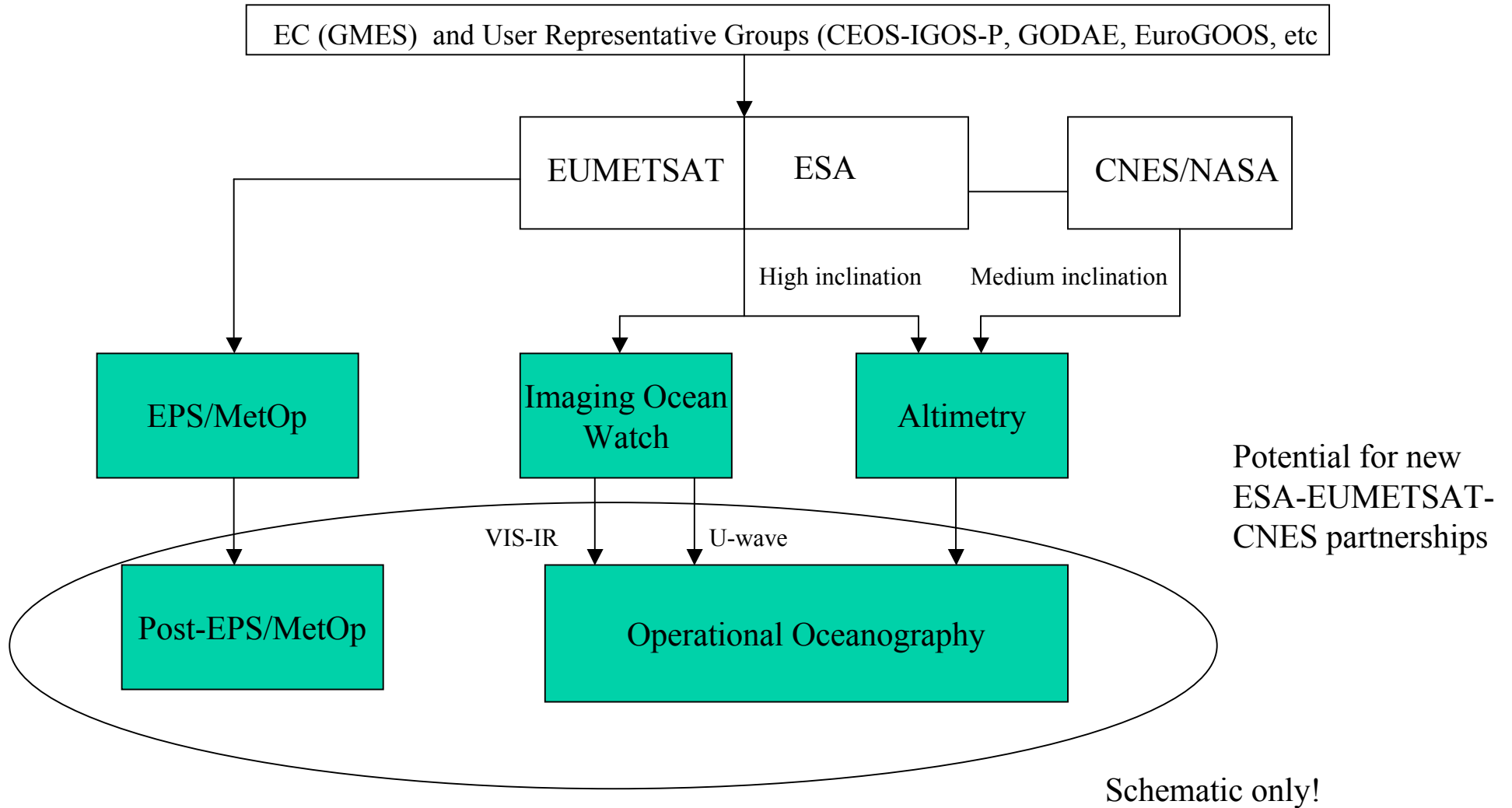


Taking into account the present and planned missions, it is proposed to implement a GMES Earth Watch Operational Oceans Mission exploiting two lines of heritage:

- Altimeter element:
 - Based on ERS-1/2 RA/ENVISAT RA-2/SIRAL heritage and continuation of altimeter development
 - MWR (water vapour content - and tropospheric correction) and a GPS and / or DORIS/Laser reflector (precise positioning for cm accuracy)

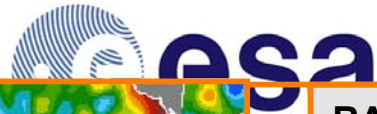
- Optical Element (VIS-IR)
 - Combination of Ocean Colour and SST capabilities (MERIS and A/ATSR), extension to coastal and land applications

- 2000-2001: Preparation of Programme Proposal for EW candidates
- Nov. 2001 Ministerial: Ocean Earth Watch Phase A approved
- 2002: EOEP2 strong fiscal constraints – D/EOP stop on EW activities
- OEW Phase A limbo (2002 – 2003)
 - Internal Design Concept Study
 - Visual Imager (VIRI) concepts studied
 - Future altimeter concepts studied (IRAC)
- GMES: FP6 and GSE ‘foundation’ established as basis for operational services
- Oxygen: Principle of “market pull” to defining EW mission needs
- Today: Translation of GMES operational data needs into monitoring requirements
 - GMES/EW mission concept to complement METOP (2005-2020) sustained metocean observations (EUMETSAT connection)



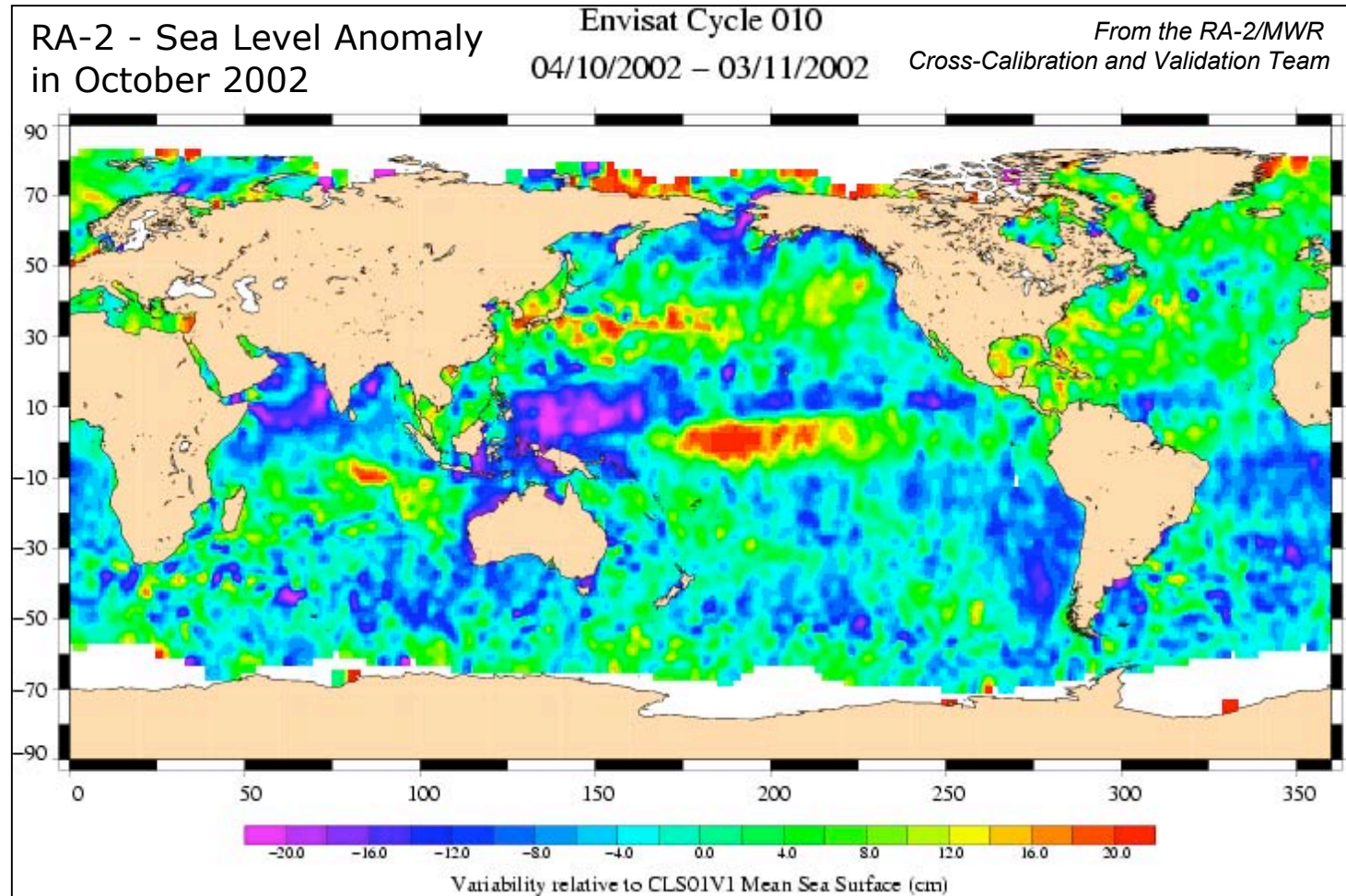
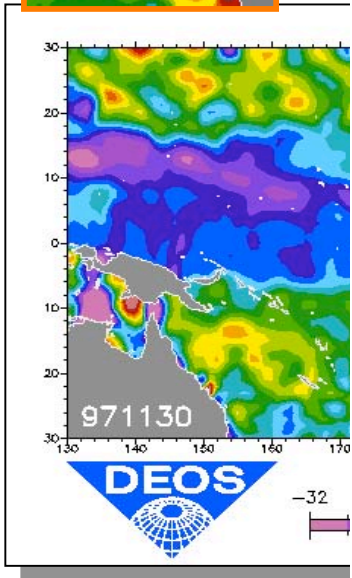
- ESA has provided a high inclination altimetry service since 1991: ERS-1 (1991-2000), ERS-2 (1995 -), ENVISAT (2001 - 2007), CryoSat (2004 - 2007)
- Europe has developed new concepts, CryoSat, Altika, GANDER, MANOLO, PARIS, SWIMSAT, etc.
- Concepts of “Report of High-Resolution Ocean Topography Science Working Group meeting” March 2001, addressed (incl. WSOA, WITTEX, WITTEX-Wide etc..)
- The Ocean Earth Watch has to be conceived in the context of cooperation taking into account the European position for IJPS (i.e. NOAA, Eumetsat, NASA, CNES), planning for post-EPS (i.e. post METOP), and GEO

- Phase A studies on Future Radar Altimeter Concepts concluded:
 - Improved altimeter ocean coverage needed
 - Cross-track ocean slopes needed
 - Existing data assimilation schemes rely on the commitment to complementary Jason and high-inclination RA-2 orbits
 - Better spatial resolution needed to obtain SSH data in near-coastal regions.

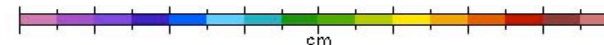


ENVISAT Altimetric Instruments

RA-2, MWR, DORIS: RA-2 measures the satellite's height above the surface to an accuracy of 4.5 cm. When combined with exact orbital tracking data from DORIS, RA-2 measurements yield a profile of the sea surface below. MWR measures amount of water vapour in atmosphere to correct RA-2 radar signals for best accuracy.



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anomalies

<u>Altimeter</u>	Range	Measurement Accuracy	
		Threshold	Goal
SSH	orbit <i>tbd</i>	< 5 cm	< 3 cm
SWH	0.5 - 20 m	< 4% (= 8 cm @ 2 m)	< 1% (= 2 cm @ 2 m)
σ^0	-5 dB — +50 dB	0.5 dB <i>bias</i> , 0.2 dB <i>resid.</i>	0.4 dB <i>bias</i> , 0.1 dB <i>resid.</i>
Windspeed	1 m/s — 20 m/s	< 1.5 m/s	< 1.5 m/s

*Principal SSH data product requirements (GODAE) are;

Global: 100 km res. maps every 10 days to 2 cm accuracy

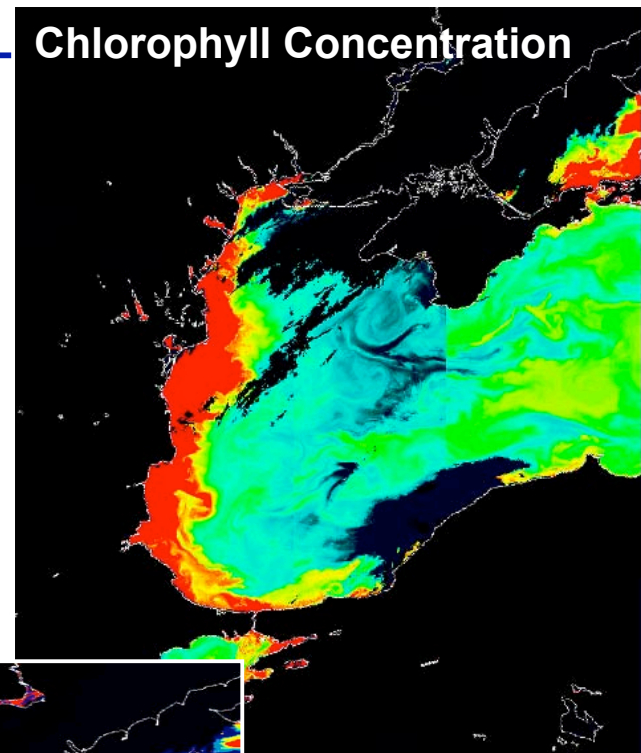
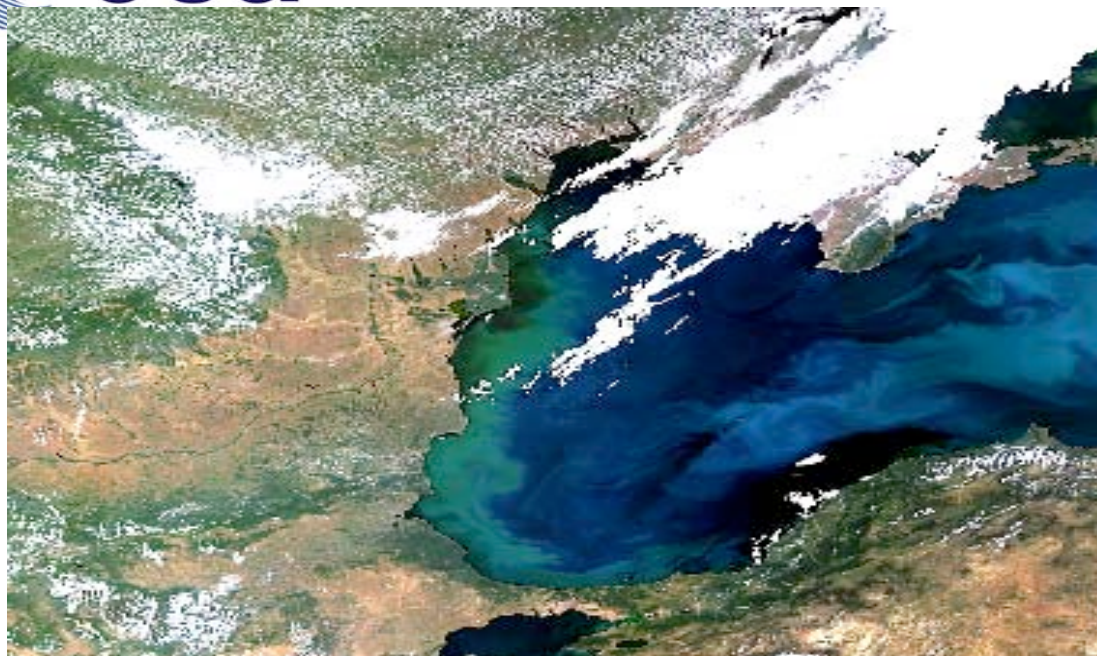
Goal for Mesoscale: 25 km res. maps every 7 days accurate to 2 cm

The above requirements assume at least two altimeters are flying

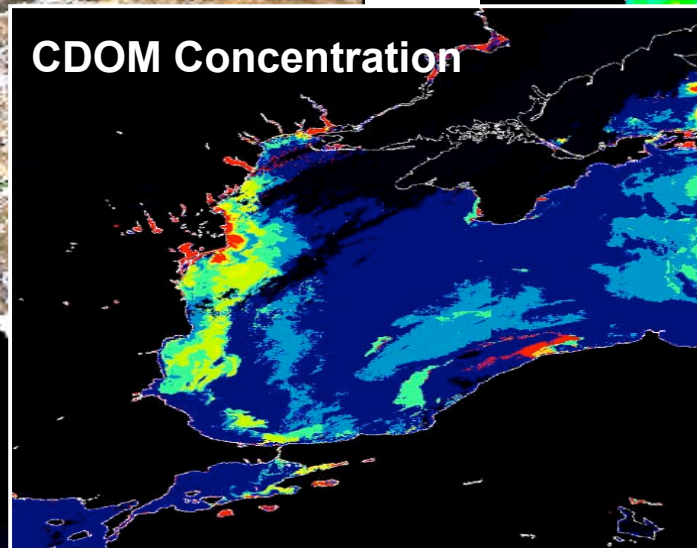
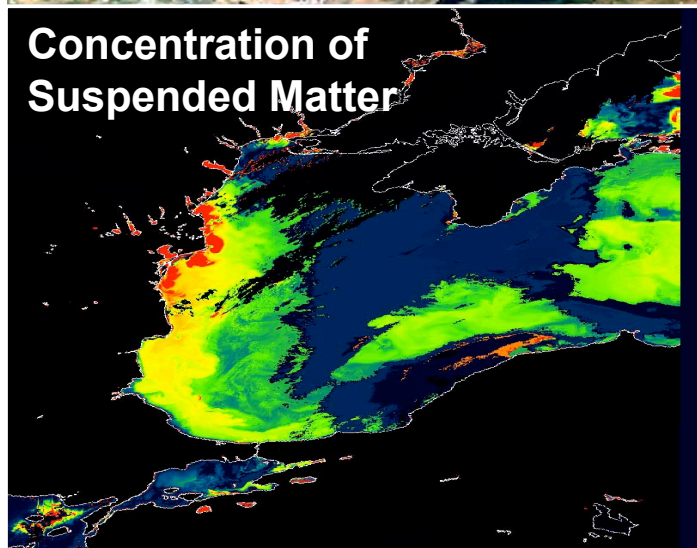
Geophysical Products	Horizontal Resolution	Local evolution	Measurement					
			Range	scale	Resolution		Accuracy	
	(km)				Threshold	Objective	Threshold	Objective
Ocean								
Sea Surface Temperature	1	diurnal	270 - 320K	linear			0.3 K	0.1 K
Ice Surface Temperature	10	diurnal	210 - 290K	linear			1 K	
Ice Cover ⁽¹⁾	2	daily	0.0 - 1.0	linear			0.1	0.02
Ocean Color/Chlorophyll	0.25 - 1	daily	0.03-30 mg/m ³	decimal log	15 classes	30 classes	30 %	
Suspended Matter	0.25	daily	0 - 30 mg/m ³	decimal log	15 classes	30 classes	30 %	
Yellow substance	0.25	daily	0.0 - 1.0 m ⁻¹	decimal log	5 classes	15 classes	30 %	

SST Accuracy will likely require dual view, and split window techniques to meet 0.3°K accuracy

0.25 km res. recommended for coastal zone applications - but may require different modes/swath widths

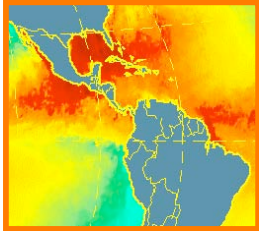


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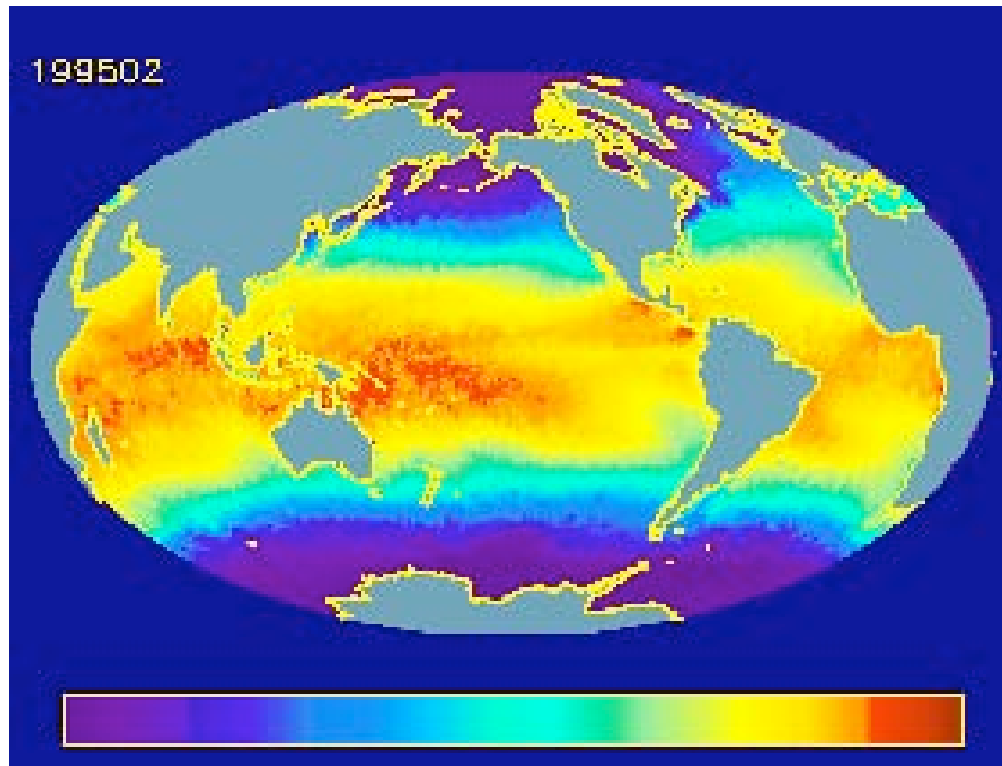


- Parallel Phase A VIRI Studies, and VIRI-M concluded:
 - A/ATSR and MERIS quality SST and OC measurements can be combined in one instrument using today's technology
 - Split window, dual-view sensors (i.e. A/ATSR quality) are the only option for obtaining climate quality SST (<0.3 K)
 - Channels needed for Case 2 waters to be of practical value to coastal management (i.e. beyond standard Case 1 blue ocean channels)
- Space/time collocated SST and OC needed to characterise pCO₂ variability, and gas exchange at the ocean surface
- OC and SST data needed in parallel with global ocean wind data (METOP) to monitor CO₂ sources and sinks effectively

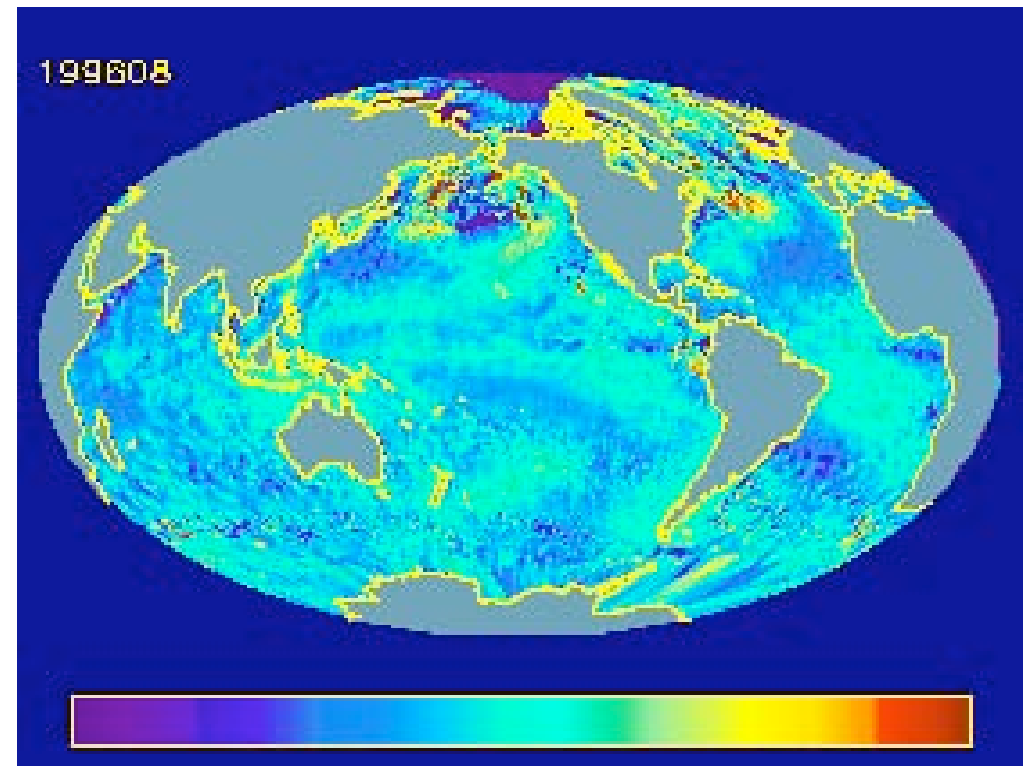
Long Term monitoring of the Sea Surface Temperature



Sea level: AATSR measures sea surface temperature to 0.3 °C accuracy.



Mean Sea Surface Temperature



Sea Surface Temperature Anomaly

Preliminary Requirements

24 spectral bands which could be reduced to 15 for priority 1 products

Center wavelength	Purpose	Spectral width	Priority
Vis/SWIR			
nm		nm	
412	Yellow substance turbidity	10	1
443	Chlorophyll absorption max	10	1
490	Chlorophyll other pigments	10	1
510	turbidity	10	1
560	Chlorophyll ref, ice cover	10	1
620	Suspended sediments	10	1
665	Chlorophyll absorption max, NDVI, cloud properties	10	1
681	Chlorophyll fluorescence	7,5	1
705	Atmpospheric correction	10	1
750	difference with 763 band		2
763	Cloud top height	2.5 or 5	2
870	aerosols, NDVI, cloud properties	20	1
1040 & 1060	Sea surface roughness	20	2
1242 & 1267	radiation flux, net heat flux	20	2
1375	SST improvement	tbd	2
1610	cloud properties, ice cover	60	1
2100	redundance with 1,6 M,		2
TIR channels			
µm		µm	
3,7	SST, ISTcloud properties	0,38	1
8,7	tbd		1
10,9	SST	0,9	1
12,0	SST	1	1
13,0	cloud top height	tbd	2

- Operational Oceanography maturing:
 - GODAE implementation phase began 2003
 - GODAE operational phase > 2007
 - Currently satisfying data assimilation requirements with:
 - ENVISAT RA-2 (SSH; SWH; wind); SAR (wave spectra); A/ATSR (SST); and MERIS (Ocean Colour) – high inclination orbit
 - SeaWifs and MODIS Ocean Colour
 - T/P and Jason low inclination altimetry (< 66 N)
 - NOAA AVHRR SST
 - SeaWinds (QuikScat; ADEOS-II) and METOP wind scatterometry
 - GMES Implementation Phase > 2008
 - Successor to Envisat must be sought as priority 1

- Magnitude of carbon by ocean unknown over large parts of the globe. Sign of uptake/outgassing remains unknown in large parts of the Southern hemisphere ocean.
- Knowledge of pCO₂ requires windspeed, SST, SLP, and Ocean Colour (ocean productivity)
 - Implies concurrent scatterometry, A/ATSR quality SST; MERIS Quality OC

ECMWF committed to atmospheric CO₂ bookkeeping (by combining ADM and OCO data assimilation in models)

- *But it has NO data to constrain lower boundary condition in terms of magnitudes of sources and sinks*
- *It can only watch how integrated column contents are transported and redistributed*

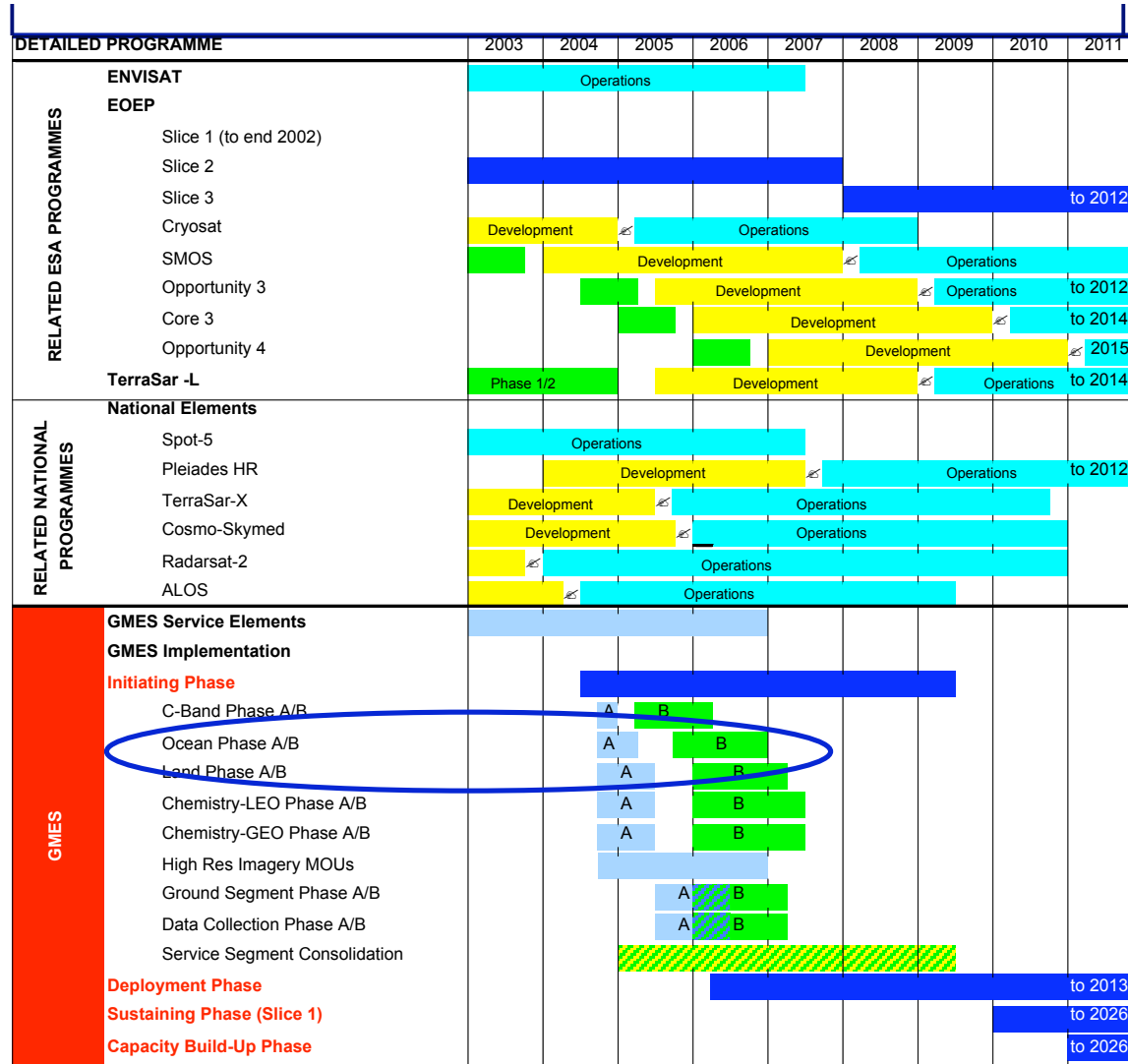
- Future operational oceanography satellites should capitalise on:
 - Instrument products with identified users and services (ECMWF; GMES and FP6 end users; and Eumetsat)
 - well identified, overlapping, yet unsatisfied measurements requirements (IGOS)
 - Existing proven technology which meets existing demanding operational and scientific requirements
 - Sufficiently new technology to ensure long-term performance increment over existing systems

- An Earth Watch oceans mission must be a GMES/Operational Oceanography user-driven mission that will be developed with interagency partnerships in mind.
- ESA shall capitalise on its experience in development of ERS-1/2 (*RA, ATSR*), ENVISAT (*RA-2, AATSR; MERIS*) and CryoSat (*SIRAL*); and ongoing instrument studies
- A future mission concept should try to meet the goal of long-term provision of:
 - High-inclination, high-quality altimeter (SSH, SWH, Wind speed, ice thickness)
 - High-quality SST in replacement of AATSR
 - Ocean Colour data to replace MERIS

And to meet the stringent data delivery timeliness and measurement accuracy requirements

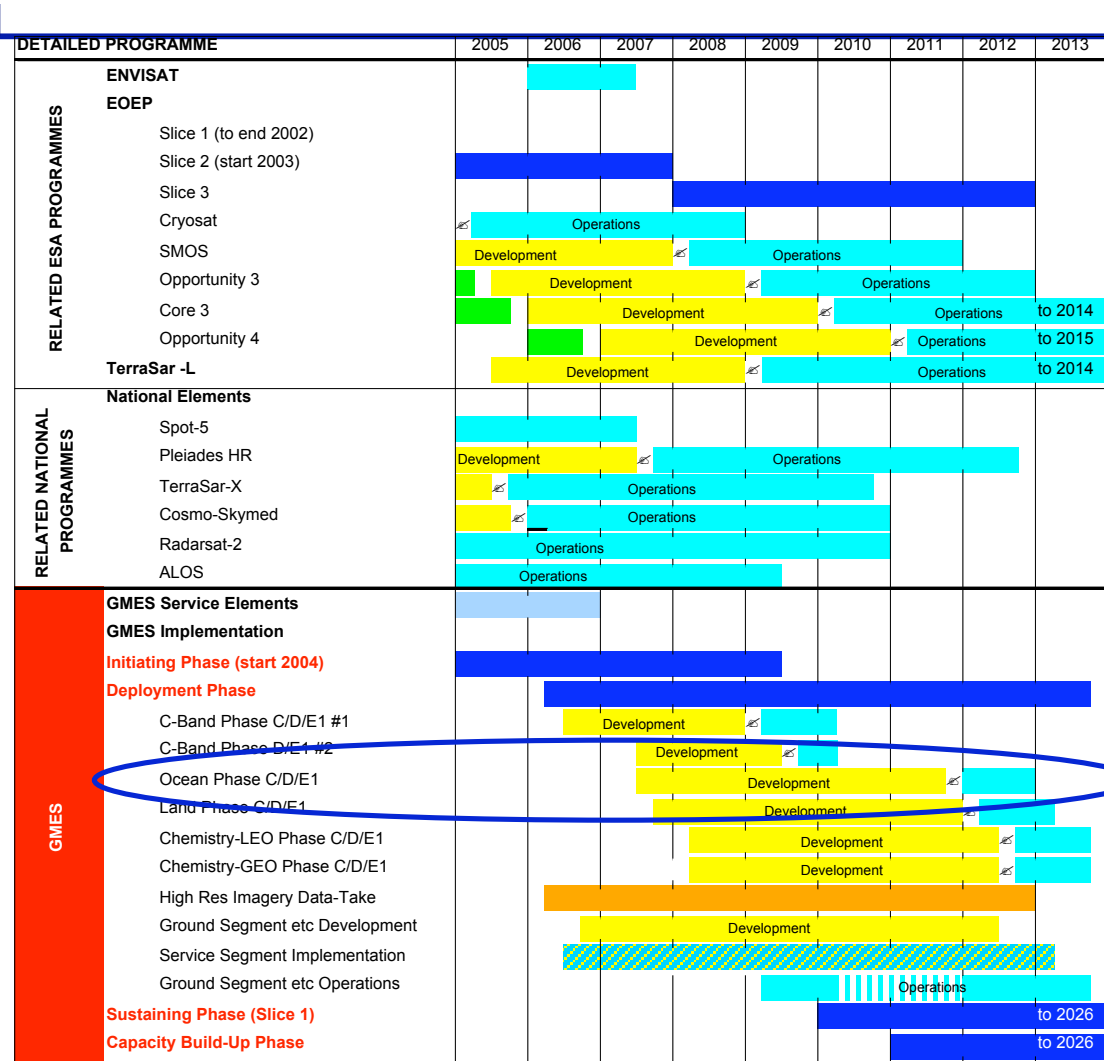
- The present implementation plan assumes a launch in the 2010-11 time frame

GMES Initiating Phase Schedule



Legend: Programme: [Blue] Study: [Light Blue] Pre-Development: [Light Green] Development: [Green] Operations: [Yellow]

GMES Deployment Phase Schedule



Legend: Programme: [Blue] Study: [Light Blue] Pre-Development: [Green] Development: [Yellow] Operations: [Cyan] Data-buy: [Orange]

- GMES Initial Period ('01-'03) Final Report:
Mission definition studies foreseen ('04-'06)
 - Missions justified on basis of key data parameter needs
 - Mission requirements must be derived from these, with due consideration of operational instrument maturity/coverage/delivery timeliness issues
 - System/Ground segment requirements follow
- Nov '04 Deadline for Key inputs to '05 Ministerial
 - Op.parameter needs (GSE; FP5/6; NWP; VACs etc)
 - Justification for a mission measurement suite
 - GMES EW Mission Requirements
 - GMES EW Programme Proposal