Towards integrated European marine research strategy and programmes

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INFRASTRUCTURES

Marine Research Infrastructures updated overview, European integration and vision of the future

Annex 5 : **Satellites for seas and oceans observation**

WP4-D4.1_Annex5

Milestone M4.1.1

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WP 4: **Infrastructures**

Task 4.1: A strategic vision for marine research infrastructures

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Milestone N°: M 4.1.1

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1. Introduction

1.1 The first satellites for meteorological purpose

In the sixties (first : Tiros 1 on 1960), based on optical sensors in the visible spectra for the clouds observation.

1.2 The first satellites for the earth observation

In the seventies ; in Europe, it is the SPOT program decided in 1978 (France, Belgium, Sweden):

From SPOT 1 (1986 - resolution 20 m) to SPOT 5 (2002 - resolution 2,5 m)

Requirements covered mostly are :

- cartography, landscape
- spatial planning,
- vegetation,
- anthropogenic impact,

For marine sciences => river mouths and coastline cartography, vegetation and anthropogenic impact

1.3 The first satellites specifically dedicated to the Ocean observation

In the 90's : Topex-Poseidon (1992), a joint satellite mission between NASA, the U.S. and CNES.

This satellite carried on board a radar altimeter allowing an accurate measure of the distance satellite / ocean surface. Combined with the Doris system allowing itself an accurate position of the satellite in the earth reference, it allowed to make a mapping of the seas level with an unequalled "cm" accuracy. It was a revolution for the oceanographic research, revealing an unexpected and spectacular vision of the ocean :

- Fine mapping of the waves of tide, revelation of internal waves associated with the sea bed landscape,
- Fine mapping of the oceanic currents, revelation of mesoscales vortex (few tens km in diameter), in the margins of the big oceanic currents, also influenced by sea bed,
- Confirmation of the sea level rise, an average 2-3 mm / year but with strong disparities from a place to another.

Topex-Poseidon 1992 => operational oceanography birth

2. Overview of satellites for seas and oceans observation

2.1 Coastal land and waters observation

The European satellites more specifically focused on the land coverage, and so including the shore line, are the SPOT family :

SPOT-4 (launched in 1998) and **SPOT-5** (launched in 2002) are still in operation, SPOT-5 is foreseen to be under nominal operations up to 2014 as a minimum.

SPOT-5 mission includes :

- two HRG (High Geometric Resolution) optical instruments,
- a HRS (High-Resolution Stereoscopic) stereo viewing instrument for relief mapping,
- a low-resolution instrument (VEGETATION2) which provides continuity of environmental monitoring around the globe,

SPOT-5 provides a balance between high resolution and wide-area coverage :

- 5-metre and 2.5-metre resolution,
- wide imaging swath, which covers 60 x 60 km or 60 km x 120 km in twin-instrument mode,

http://smsc.cnes.fr/SPOT/

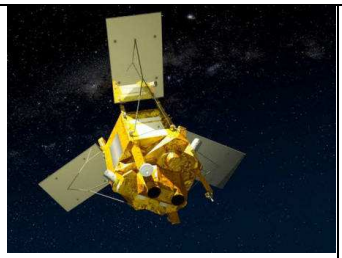
Penbé – Images Spot 5

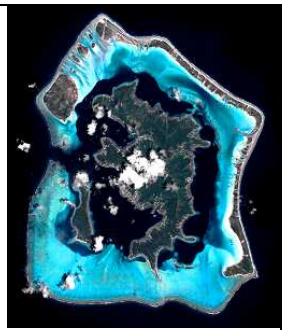
A follow-up, **SPOT 6** (launched in Sept. 2012) and **SPOT 7** (scheduled for 2014) was decided by ASTRIUM in 2009.

SPOT 6 and SPOT 7 High-resolution, wide-area imagery

- Ortho 1.5 m natural-colour products, orthorectified as standard
- On-line ordering of area of interest plus fast delivery
- Daily global revisits
- Ability to accept last-minute tasking requests

SPOT 6 and SPOT 7 are phased 180° on the same orbit as the Pleiades constellation (see here after) , thus combining wide-area collection with the ability to image and revisit point targets the same day. http://www.astrium-geo.com/en/147-spot-6-7





Spot 6 first image : Bora Bora Atoll

Spot Image, an Astrium subsidiary, support the total investment and is the owner of the entire system (satellites and ground segments). http://www.astrium-geo.com/

ORFEO Programme : Drawing on the heritage of the SPOT satellites, the Orfeo programme is composed of 6 next-generation, high-resolution satellites : 4 Cosmo-Skymed X-band satellites from Italy (ASI), 2 Pleiades optical satellites from France (CNES). It is an European cooperation between France / CNES, Italy / ASI, Austria / ASA, Belgium / Belspo, Spain / INTA and Sweden / SNSB :

- **Cosmo-Skymed** : ***4 Cosmo-Skymed satellites were launched between 2007 and 2010.*** They are planned for sun-synchronous polar orbits, phased at 90° and at an altitude of 619 km, with revisit time less than 12 hours. The expected operating life of each satellite is estimate in 5 years. Main equipment for earth observation : Synthetic aperture radar working in X band.

  ⇨ ***Control of oceans and seacoasts :*** COSMO-SkyMed satellites can provide continuous and accurate information about conditions of seacoasts, seas and inland waters, so as to evaluate phenomena of coast erosion and pollution. Furthermore, the system represents a precious help for sea traffic control.

- **Pleiades :** the Pleiades constellation is composed of two very-high-resolution optical Earth-imaging satellites.

Pleiades-HR 1A was launched 17 Dec. 2011

Pleiades-HR 1B is scheduled for Dec. 2012

Pleiades-HR 1A and Pleiades-HR 1B will provide coverage of Earth's surface with revisit time less than 24 hours.

The two satellites will operate in the same phased orbit and will be offset at 180° to offer a daily revisit capability over any point on the globe.

Orbit : sun-synchronous, phased, near-circular.

Mean altitude : 694 km.

Dubai coast

They are designed as a dual civil/military system. The Pleiades system is designed for a range of very-high-resolution (VHR) remote sensing applications. Several elementary images of 20 km x 20 km can be quasi-simultaneously acquired to realize mosaics of more than 100 km x 100 km, or acquire stereoscopic doublets or triplets. Metric resolution (with 20 km swath).

Lifetime: 5 years

http://smsc.cnes.fr/PLEIADES/index.htm

Pleiades constellation is particularly adapted to the study of the coastal strip both natural and artificial (built by men) because of its very high-resolution (70 cm) and of the use of an infrared ray. It is then possible to make a precise follow-up of the urbanization and of the coastal arrangements, whatever they permanent or seasonal.

The need of knowledge of the topography evolution due to the marine and/or wind erosion and accretion effects was also taken into account by the working group. Works are still to be done in order to make a significant methodological contribution to the monitoring of the topographic evolution of dunes, foreshores and shallow waters.

As regards the sea observation itself, very high-resolution spatial stays of a rather marginal usage. However, we can mention the monitoring of dirty waters extensions (pollutants, rivers plumes), the waters quality monitoring in fish farming areas and the detection of floating objects (small boats, containers).

The Pleiades spectral blue ray, which does not exist on SPOT satellites, is a real novelty which allows the possibility of spatial high-resolution submarine penetration, and opens the way to the study (classification and follow-up) of shallow waters sea bed, even for bathymetric studies.

Some other European satellites focused on imagery :

Germany :

TerraSAR-X (2008) and TanDEM-X (2010) German Earth Observation satellites (TanDEM is a TerraSAR-X add-on for Digital Elevation Measurement). Applications of the high-resolution TerraSAR-X radar imagery include ***Land Cover and Land Use Mapping***, and further applications like ***vegetation monitoring***. The scientific use of the data can be divided into 3 areas: new quality Digital Elevation Models (e.g. for hydrology), along-track interferometry (***e.g. measurement of ocean currents***) and new bi-static applications (e.g. polarimetric SAR interferometry). The scientific use of the data are coordinated through the TerraSAR-X Science Service System by the DLR (German Aeospace Center). http://www.dlr.de/eo/en/desktopdefault.aspx/tabid-5725/9296_read-15979/	 http://www.astrium-geo.com/terrasar-x/

EnMAP, planned for launch in 2015 : EnMAP (Environmental Mapping and Analysis Program) is a German mission to deliver high-quality hyperspectral image data with a swath width of 30 km, spatial resolution of 30×30 m and an off-nadir (30°) pointing feature for fast revisit (4 days). The mission will offer data on a wide range of ***ecosystem parameters*** encompassing agriculture, forestry, soil and geological environments, ***coastal zones*** and inland waters.

EnMAP applications for coastal zones The high spectral resolution of EnMAP in the visible and near-infrared (VNIR) region will allow the assessment of the proposed optically visible parameters including chlorophyll-a content for determination of the phytoplankton-biomass, algae composition and blooms, emerse and submerse macrophytes as well as the secchi-depth and the structure of littoral. Additionally, other important water quality parameters such as suspended matter and dissolved organic carbon concentration can be monitored with the EnMAP sensor.	 http://www.enmap.org/coast

Spain :

DEIMOS-1 (launched in 2009) , DEIMOS-2 (scheduled for 2013)
Elecnor spanish private high resolution satellites. Products include land use and land cover maps, spills and river mouth cleanliness control.

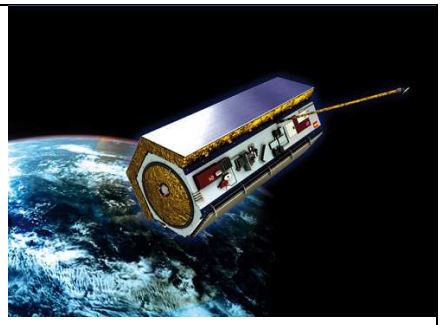
http://www.elecnor.es/en/news/deimos-1-the-first-spanish-earth-observation-satellite-celebrates-its-third-anniversary

PAZ (scheduled 2013, radar sat.) and INGENIO (scheduled 2014, optical sat)
Within the Spanish Earth Observation Satellites programme PNOTS. System financed and owned by the Spanish Government and operated by HISDESAT(Spanish private company with public share) and INTA(Spanish Aerospace National Institute).
Current mission definition: ***carpet mapping of Spain*** and acquisition over the main areas of interest, and "on-demand" for other products. System could become ***a candidate national mission contributing to GMES*** and to participate to the ESA third party mission scheme, within the EO multi-mission environment.
PAZ (Spanish for "peace") satellite is intended primarily to address security and defense needs. HISDESAT is the owner and operator of the PAZ satellite, which will offer precise information for multiple applications from its polar orbit around the Earth.

http://www.hisdesat.es/eng/satelites_observ-paz.html

INGENIO (Spanish for "ingenuity") optical-technology satellite is intended primarily to address the needs of civilian users. The project is led by the Ministry of Industry and by the CDTI. The European Space Agency (ESA) is handling the construction contract. It is scheduled for launch in 2014.

http://www.hisdesat.es/eng/satelites_observ-ingenio.html



Paz

Ingenio

UK :

DMC : the **Disaster Monitoring Constellation** (**DMC**)

Consists of a number of remote sensing satellites constructed by Surrey Satellite Technology Ltd (SSTL) and operated by DMC International Imaging. The DMC provides emergency Earth imaging for disaster relief under the International Charter for Space and Major Disasters, which the DMC formally joined in November 2005. The DMC has monitored the effects and aftermath of the Indian Ocean Tsunami (December 2004) and Hurricane Katrina (August 2005). Other DMC Earth imagery is used for a variety of civil applications by a variety of governments. Spare available imaging capacity is sold under contract.

http://www.dmcii.com/index.html

Some other international satellites focused on imagery :

Quickbird (2001), **WorldView 1** (2007) and **WorldView 2** (2009) : DigitalGlobe owns and operates the most agile and sophisticated constellation of high-resolution commercial earth imaging satellites (resolution < 0,6 m). QuickBird, WorldView-1 and WorldView-2 together are capable of collecting over 500 million km^2 of quality imagery per year and offering intraday revisit around the globe. Digital Globe constellation :

http://www.digitalglobe.com/index.php/82/Content+Collection+Systems

GeoEye-1 : owns and exploits by the GeoEye company, GeoEye-1 can collect images with a ground resolution of 0.41-meters in the panchromatic or black and white mode. It collects multispectral or color imagery at 1.65-meter resolution.
http://launch.geoeye.com/LaunchSite/about/

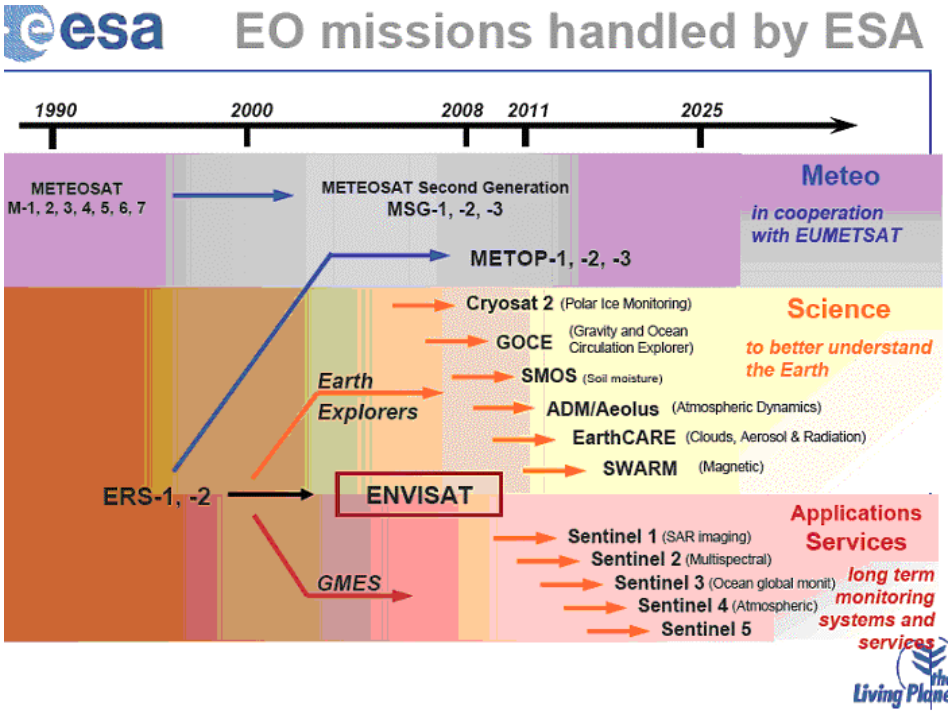
USA / NOAA Coastwatch :

Within NOAA :

- NESDIS (National Environmental Satellite, Data, and Information Service)
    - STAR (Center for Satellite Applications and research, the science arm of NESDIS)
        - SOCD (Satellite Oceanography and Climatology Division)
            - NOAA Coastwatch : http://coastwatch.noaa.gov/

2.2 Satellites for seas and ocean observation

European satellites handled by the European Space Agency ESA and involved in My Ocean :



ESA Earth observation missions : https://earth.esa.int/web/guest/missions/esa-operational-eo-missions

ENVISAT (ESA, launched 2002, ***out of service since April 2012***) : a polar-orbiting Earth observation satellite, focused on environment, which provides ***a large spectra of measurements for*** atmosphere, ***ocean***, land, and ***ice***. The orbit selected for ENVISAT will provide a 35-day repeat cycle. ENVISAT data supports earth science research and allows monitoring of the evolution of environmental and climatic changes.

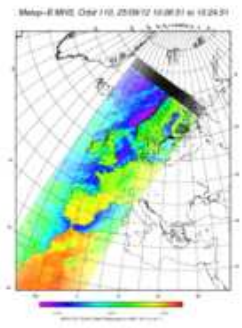
http://envisat.esa.int/earth/www/category/index.cfm?fcategoryid=60

METOP (ESA-EUMETSAT) : 3 satellites METOP-A launched in 2006, METOP-B launched on 17 September 2012 and METOP-C in 2016. The prime objective of the EUMETSAT Polar System (EPS) METOP mission series is to provide continuous, long-term data sets in support of operational meteorological and environmental forecasting and global climate monitoring. METOP carries a set of 'heritage' instruments provided by the United States and a new generation of European instruments that offer improved remote sensing capabilities to both meteorologists and climatologists, including wind speed and direction, sea surface temperature and sea ice concentration.

http://www.eumetsat.int/Home/Main/Satellites/Metop/index.htm?l=en

METOP-B , 28 Sept. 2012 :

Four of the instruments on the Metop-B weather satellite (AMSU-A, ASCAT, MHS, GRAS) have been activated this week and are delivering data. The Advanced Scatterometer (ASCAT) and Microwave Humidity Sounder (MHS) are innovative European instruments. ASCAT delivers information on near-surface wind speed and direction over the global oceans and soil moisture over land, while the MHS delivers information on atmospheric humidity in all weather conditions.



Parameters and Instruments :

Ocean Ocean surface winds: AMSU-A, ASCAT

Surface temperature (ocean) : AVHRR/3, HIRS/4, IASI

Multi-purpose imagery (ocean) : AVHRR/3

Snow & Ice Snow cover, edge and depth: AMSU-A, AVHRR/3

Sea ice cover, edge and thickness : AMSU-A, ASCAT, AVHRR/3

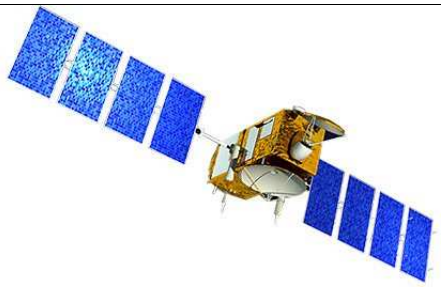
http://www.esa.int/esaLP/LPmetop.html

METEOSAT (ESA-EUMETSAT) : Meteosat Second Generation (MSG) consists of a series of four geostationary meteorological satellites, along with ground-based infrastructure, that will operate consecutively until 2020. Meteosat-8 (MSG-1) was launched on 2002, Meteosat-9 (MSG-2) on 2005. The MSG satellites carry instruments for operational forecasting needs and climate studies, incl. ***sea surface temperature***. Permanent visible and infrared imaging of the Earth's disc are provided with a baseline repeat cycle of 15 minutes. http://www.eumetsat.int/Home/Main/Satellites/MeteosatSecondGeneration/index.htm?l=en

JASON (CNES, EUMETSAT, NASA, NOAA) : a series of three satellites as a follow-up of Topex-Poseidon with as main mission the sea level measurement.

- Jason-1 was launched on 2001
- Jason-2 on 2008
- Jason-3 is scheduled on April 2013

Measurement capabilities : sea-surface height (2 cm accuracy), wave height, ocean surface wind speed, sea ice, in line with the request of international programs about oceans observation and climate change, to have high-precision altimetric measurements in near-real time for integration into ocean forecasting models (operational oceanography), to continue Topex/Poseidon - Jason-1 time series in order to benefit from data over a period long enough to study ocean long-term variations, to have quality data nearer to the coasts (tide models improvements), and over lakes and rivers. http://smsc.cnes.fr/JASON2/index.htm

Jason-3, to be launched in April 2014 Mini satellite of the CNES's Proteus series Instruments: Poseidon-3B altimeter, AMR radiometer, DORIS, LRA, GPSP (GPS location) and two passengers (LPT, CARMEN-3) Measurement of ocean surface topography, surface wind speed, wave height High inclination orbit at 1336 km altitude Lifetime 5 years http://smsc.cnes.fr/JASON3/index.htm	

SENTINEL (ESA, within GMES programme) : ESA is developing five new missions called Sentinels specifically for the operational needs of the GMES programme. The Sentinel missions are based on a constellation of 5 satellites to fulfil revist and coverage requirements, providing robust datasets for GMES Services :

- **Sentinel-1** is a polar-orbiting, all-weather, ***day-and-night radar imaging mission for*** land and ***ocean*** services. The first Sentinel-1 satellite is planned for launch in 2013.
- **Sentinel-2** is a polar-orbiting, multispectral ***high-resolution imaging mission for*** land monitoring providing, for example, ***imagery of vegetation***, soil and water cover, inland waterways and ***coastal areas***. Sentinel-2 will also deliver information for emergency services. The first Sentinel-2 satellite is planned for launch in 2014.
- **Sentinel-3** is polar-orbiting, multi-instrument mission to measure variables such as ***sea-surface topography, sea- and land-surface temperature, ocean colour and land colour*** with high-end accuracy and reliability. The first Sentinel-3 satellite is expected to launch in 2014, followed by the second to provide the required level of coverage for GMES services. http://www.esa.int/esaLP/SEMTST4KXMF_LPgmes_0.html

- **Sentinel 4 and 5** are for atmospheric monitoring purposes (scheduled in 2019 & 2020).

Sentinel-3 parameters and sensors
Sea- and land-surface temperature : A Sea and Land Surface Temperature Radiometer (SLSTR), which is based on Envisat's Advanced Along Track Scanning Radiometer (AATSR), to determine global sea-surface temperatures to an accuracy of better than 0.3 K.

Ocean colour and land colour : An Ocean and Land Colour Instrument (OLCI) is based on heritage from Envisat's Medium Resolution Imaging Spectrometer (MERIS).

Sea-surface topography : A dual-frequency (Ku and C band) advanced Synthetic Aperture Radar Altimeter (SRAL) is based CryoSat heritage and provides measurements at a resolution of ~300m in SAR mode along track. SRAL is supported by a microwave radiometer for atmospheric correction and a DORIS receiver for orbit positioning. The combined topography package will provide exact measurements of sea -surface height, which are essential for ocean forecasting systems and climate monitoring. SRAL will also provide accurate topography measurements over sea ice, ice sheets, rivers and lakes.

http://www.esa.int/esaLP/SEMTST4KXMF_LPgmes_0.html

Other International satellites involved in My Ocean :

AQUA (2002) : a NASA Earth Science satellite mission named for the large amount of information that the mission will be collecting about the Earth's water cycle, including ***evaporation from the oceans***, water vapor in the atmosphere, clouds, precipitation, soil moisture, ***sea ice***, land ice, and snow cover on the land and ice. Additional variables also being measured by Aqua include ***radiative energy fluxes***, aerosols, vegetation cover on the land, ***phytoplankton and dissolved organic matter in the oceans***, and air, land, and ***water temperatures***. http://aqua.nasa.gov/

DMSP satellites : The DMSP (Defense Meteorological Satellite Program) is a Department of Defense (DoD) program. DMSP designs, builds, launches, and maintains 4 satellites monitoring the meteorological, ***oceanographic***, and solar-terrestrial physics environments.
http://www.ngdc.noaa.gov/dmsp/

Radarsat-1 and Radarsat-2 (2007, Canadian Space Agency) : The RADARSAT program was born out the need for effective monitoring of Canada's icy waters, operational use of space radar for sea ice monitoring.

http://www.asc-csa.gc.ca/eng/satellites/radarsat2/applications.asp#ice

Saral/Altika (scheduled 12 dec. 2012) France/CNES + India/ISRO
AltiKa is an innovating Ka-band altimeter system, dedicated to accurate measurement of *ocean surface topography*. It is envisioned as a successor of RA-2 instrument on board ESA's satellite ENVISAT. The AltiKa project is part of a French program of operational oceanography.
Measurements of :
- ocean surface topography,
- surface wind speed,
- surface wave height

Contribution to ARGOS system continuity for collect and distribution of environmental data.
http://smsc.cnes.fr/SARAL/index.htm

Some other satellites focused on seas and oceans observation :

Cryosat-2 (2010, ESA) : CryoSat-2 carries sophisticated technologies to measure changes at the margins of the vast ice sheets that overlay Greenland and Antarctica and ***marine ice floating in the polar oceans***. By accurately measuring thickness change in both types of ice, CryoSat-2 will provide information to complete the picture and lead to a better understanding of the role ice plays in the Earth system.
http://www.esa.int/SPECIALS/Cryosat/SEMFJ4908BE_0.html

GOCE (2009, ESA) : **G**ravity field and steady-state **O**cean **C**irculation **E**xplorer. After just two years in orbit, ESA's GOCE satellite has gathered enough data to map Earth's gravity with unrivalled precision. Scientists now have access to the most accurate model of the 'geoid' ever produced. The geoid is the surface of an ideal global ocean in the absence of tides and currents, shaped only by gravity. It is a crucial reference for measuring ocean circulation, sea-level change and ice dynamics. GOCE gives dynamic topography and circulation patterns of the oceans with unprecedented quality and resolution, these results will help improve our understanding of the dynamics of world oceans.
http://www.esa.int/SPECIALS/GOCE/SEM1AK6UPLG_0.html

SMOS (2009, ESA) : ESA's **S**oil **M**oisture and **O**cean **S**alinity (SMOS) mission has been designed to observe soil moisture over the Earth's landmasses and ***salinity over the oceans***.
http://www.esa.int/esaLP/ESAMBA2VMOC_LPsmos_0.html

USA / NOAA for Oceans :

Within NOAA :

- NESDIS (National Environmental Satellite, Data, and Information Service)
    - STAR (Center for Satellite Applications and research, the science arm of NESDIS)
        - SOCD (Satellite Oceanography and Climatology Division) :
            - Marine Ecosystems & Climate Branch (MEB) : http://www.star.nesdis.noaa.gov/star/meb_index.php
            - Ocean Physics Branch (OPB) : http://www.star.nesdis.noaa.gov/star/opb_index.php
            - Coral Reef Watch : http://coralreefwatch.noaa.gov/satellite/index.html

3. Overview of instruments and ocean parameters measured

3.1 Spectro radiometer

Instrument type	Ocean parameters measured	Instrument name	Satellite
Spectro radiometer	•Chlorophyll content •Organic and mineral content •Sea surface temperature •Sea Ice Cover	MODIS MERIS	Aqua (NASA, USA) Envisat (ESA, Europe)

Reminder : visible light : 0,7 to 0,7 µm wavelength, near-infrared : 0,8-2,5 µm, mid-infrared : 2.5–25 µm, far-infrared : 25–1000 µm.

MODIS instrument provides high radiometric sensitivity (12 bit) in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm. The responses are custom tailored to the individual needs of the user community.

MERIS is a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range. Fifteen spectral bands can be selected by ground command. 15 bands selectable across range: 0,39 µm to 1,04 µm.

3.2 Infrared radiometer

Instrument type	Ocean parameters measured	Instrument name	Satellite
Infrared radiometer	•Sea surface temperature (SST)	AVHRR AATSR MODIS SEVIRI GOES	(NOAA, USA) + METOP (Eumetsat, Europe) Envisat (ESA, Europe) Aqua, Terra (NASA, USA) MeteoSat (Eumetsat, Europe) (NOAA, USA) DMSP (NASA, USA)

AVHRR/3 : The AVHRR is a radiation-detection imager that can be used for remotely determining cloud cover and the surface temperature (note that the term *surface* can mean the surface of the Earth, the upper surfaces of clouds, or the surface of a body of water). The latest instrument version is AVHRR/3, with 6 channels, including channel 5 : 11.50 - 12.50 µm, for Sea surface temperature.

AASTR (Advanced Along-Track Scanning Radiometer). It is the most recent in a series of instruments designed primarily to measure Sea Surface Temperature (SST), following on from ATSR-1 and ATSR-2 on board ERS-1 and ERS-2. AATSR data have a resolution of 1 km at nadir, and are derived from measurements

of reflected and emitted radiation taken at the following wavelengths: 0.55 µm, 0.66 µm, 0.87 µm, 1.6 µm, 3.7 µm, 11 µm and 12 µm.

SEVIRI (Spinning Enhanced Visible and Infrared Imager) : The Imaging Radiometer SEVIRI is a 50 cm diameter aperture, line by line scanning radiometer, which provides image data in four Visible and Near InfraRed (VNIR) channels and eight InfraRed (IR) channels. http://www.esa.int/msg/FT/FT4a.html

GOES : The GOES I-M Imager is a five channel (one visible, four infrared) imaging radiometer designed to sense radiant and solar reflected energy from sampled areas of the earth. 5 channels, from 0,5 to 12,5 µm. http://noaasis.noaa.gov/NOAASIS/ml/imager.html

3.3 Microwave radiometer

Instrument type	Ocean parameters measured	Instrument name	Satellite
Microwave radiometer	•Atmospheric water vapor content •Atmoshperic water liquid content (cloud) •Rain rates •Sea-ice concentration, type, extent •SST •Salinity	SSM/I TMI AMSR-E MWR JMR, AMR	DMSP (NASA, USA) TRMM (NASA, USA) Aqua (NASA, USA) + (developed by JAXA, Japan) Envisat (ESA, Europe) Jason-1, Jason-2 (Cnes, France + NASA, USA)

A **microwave radiometer** measures energy emitted at sub-millimetre-to-centimetre wavelengths known as microwaves. Their primary application has been measuring atmospheric and terrestrial radiation, mostly used for meteorological or oceanographic remote-sensing.

SSM/I : Sensor Microwave/Imager (SSM/I) is a seven channel passive microwave radiometer. SSM/I products include precipitation, cloud liquid water, total precipitable water, snow cover, and sea-ice extent. http://www.ncdc.noaa.gov/oa/rsad/ssmi/gridded/index.php

TMI : Microwave Imager (TMI) is a passive microwave sensor designed to provide quantitative rainfall information. By carefully measuring the minute amounts of microwave energy emitted by the Earth and its atmosphere, TMI is able to quantify the water vapor, the cloud water, and the rainfall intensity in the atmosphere.

AMSR-E : The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) is a twelve-channel, six-frequency, total power passive-microwave radiometer system. Measures precipitation rate, cloud water, water vapor, sea surface winds, sea surface temperature, ice, snow, and soil moisture.

MWR : The MWR design concept derives from the experimental radiometers embarked on ERS-1 satellite. It is a two channels passive Dicke microwave radiometer, operating at 23.8 GHz and 36.5 GHz, and devoted to measure the amount of water content in the atmosphere beneath the satellite's track (Nadir pointing). Its output products includes correction of atmospheric propagation data. A secondary objective is the direct evaluation of brightness temperature to characterise polar ice, land surface properties.

http://envisat.esa.int/handbooks/ra2-mwr/CNTR1-1-6.htm

JMR/AMR:

- JMR (Jason-1 Microwave Radiometer) instrument measures radiation from the Earth's surface at three frequencies (18, 21 and 37 GHz). Measurements acquired at each frequency are combined to determine atmospheric water vapour and liquid water content.

- AMR (OSTM/Jason-2) is an enhanced version of the JMR. The instrument measures total water vapor along the path viewed by the altimeter. In addition to measuring total water vapor, it is used for range correction and to measure brightness temperatures. Resembling the JMR, the AMR combines the measurements acquired at three different frequencies, and from this, scientists can extract the water vapor signal.

http://sealevel.jpl.nasa.gov/newsroom/spotlights/index.cfm?FuseAction=ShowNews&NewsID=304

3.4 Altimeter

Instrument type	Ocean parameters measured	Instrument name	Satellite
Altimeter	•Sea-surface height •Ocean surface wind speed •Wave height •Sea ice	Poseidon-2 RA-2 Poseidon-3	Jason-1 (CNES, France + NASA, USA) Envisat (ESA, Europe) Jason-2 (CNES, France + NASA, NOAA, USA + Eumetsat, Europe)

Altimetry satellites basically determine the distance from the satellite to a target surface by measuring the satellite-to-surface round-trip time of a radar pulse. The principle is that the altimeter emits a radar wave and analyses the return signal that bounces off the surface. ***Surface height*** is the difference between the satellite's position on orbit with respect to an arbitrary reference surface (the Earth's centre or a rough approximation of the Earth's surface: the reference ellipsoid) and the satellite-to-surface range (calculated by measuring the time taken for the signal to make the round trip). Besides surface height, by looking at the return signal's amplitude and waveform, ***we can also measure wave height and wind speed*** over the oceans, and more generally, backscatter coefficient and surface roughness for most surfaces off which the signal is reflected. If the altimeter emits in two frequencies, the comparison between the signals, with respect to the frequencies used, can also generate interesting results (rain rate over the oceans, detection of crevasses over ice shelves, etc). To obtain measurements accurate to within a few centimetres over a range of several hundred kilometres requires an extremely precise knowledge of the satellite's orbital position. Thus several locating systems are usually carried onboard altimetry satellites.

Poseidon-2 and Poseidon–3 : The Poseidon-2 and –3 altimeters are the main instrument on respectively Jason-1 and Jason-2 missions. Derived from the Poseidon-1 altimeter on Topex/Poseidon, it measures ***sea level, wave heights and wind speed.*** It operates at two frequencies and is also able to estimate atmospheric electron content.

RA-2 : Radar Altimeter 2 (RA-2) is an instrument for determining the two-way delay of the radar echo from the Earth's surface to a very high precision: less than a nanosecond.

3.5 Scatterometer

Instrument type	Ocean parameters measured	Instrument name	Satellite
Scatterometer	•Wind speed and heading (10 m above ocean surface) •Rain •Sea ice concentration	ASCAT	Metop (Eumetsat, Europe)

Scatterometer : disturbance of the sea surface caused by winds affects radar backscattering characteristics in a particular way. These backscattering properties are well known and are dependent on both the wind speed over the sea and the direction of the wind with respect to the point from which the surface is observed. Besides conventional use in wind vector determination, scatterometers are also used in applications to monitor land and ice.

ASCAT : ASCAT uses radar to measure these backscatter coefficients. ASCAT provides two swaths of wind vectors simultaneously at a resolution of 50 km and, on an experimental basis at 25 km resolution.

3.6 Synthetic Aperture Radar (SAR)

Instrument type	Ocean parameters measured	Instrument name	Satellite
Synthetic Aperture Radar (SAR)	•Wind •Surface wave field •Sea ice monitoring	ASAR	Radarsat-1, Radarsat-2, Canada Envisat, Europe

Environmental monitoring, earth-resource mapping, and military systems require broad-area imaging at high resolutions. Many times the imagery must be acquired in inclement weather or during night as well as day. Synthetic Aperture Radar (SAR) provides such a capability. Signal processing uses magnitude and phase of the received signals over successive pulses from elements of a synthetic aperture (i.e. a virtual antenna) to create an image. Synthetic aperture radar complements photographic and other optical imaging capabilities because of the minimum constraints on time-of-day and atmospheric conditions and because of the unique responses of terrain and cultural targets to radar frequencies.

ASAR : The Advanced Synthetic Aperture Radar (ASAR) instrument onboard the Envisat satellite. ASAR uses an active phased-array-antenna with incidence angles between 15 and 45 degrees. Applications for this sensor will include the study of ocean waves, sea ice extent and motion, and land surface studies such as deforestation and desertification, to name a few.

http://envisat.esa.int/handbooks/asar/CNTR1.htm#eph.asar.ug

4. Scientific coverage / area coverage

4.1 Scientific coverage overview

Scientific challenges	Satellites contribution , Adequacy, Major gaps
Understanding the Ocean	Physical/biological oceanography : ocean circulation (meso-scale vortex, ocean currents), wind and waves, sea surface temperature and salinity, ocean reservoir of heat, phytoplankton and algae blooms. Some satellites/instruments are 100% oriented ocean observation Adequacy : High, for all these sea surface parameters ; Gaps : ?
New frontiers	Polar research : sea ice extent and thickness, some satellites are 100% oriented on this issue. Adequacy : High for polar research ; Gaps : Ice thickness accuracy ?
Climate Change and the Marine Environment	Climate change assessment : sea level change (thanks to altimetry accuracy), sea ice extent Adequacy : High for these issues; Gaps : CO2 uptake by the Ocean ?
Ocean Technologies	Contribution to remote sensing improvement
Energy	Contribution to the mapping of ocean and coastal winds and waves
Food	Contribution through a real time monitoring of the algal blooms events and extension
Oceans and Health (Human)	
Safe and sustainable use of marine and coastal spaces	Coastal waters : cartography, spatial planning, contaminants from land and rivers
Policy Support (Governance and Regulation)	Coastal waters : cartography, spatial planning, contaminants from land and rivers
Maritime Transport	Maritime surveillance, waves information, storm warning

4.2 Utility of every parameter versus scientific challenges

(from My Ocean web site)

Temperature : Sea surface temperature (SST) is the temperature of the ocean near the surface. Knowing the temperature of this part of the ocean is absolutely essential for many reasons. For oceanographers, meteorologists and climatologists, it is one of the signs/results of the exchange of energy between the ocean and the atmosphere. For marine biologists, it is the parameter that determines the development of different biological organisms. For fishermen, important temperature variations as seen on a map (thermal fronts) indicate prolific fishing zones. For the diver or swimmer, sea surface temperature can make or break a vacation!

Meteorological phenomena such as El Niño or tropical hurricanes/cyclones are the direct consequences of specific temperature variations at the sea-surface.

Sea surface temperature varies between -1,8°C, temperature at which sea water freezes, and +30°C near/below the Equator.

Currents : By transporting heat and energy, ocean currents play a major role in shaping the climate of Earth's many regions.

Surface currents (restricted to the upper 400 m of the ocean) are generally wind-driven and develop their typical clockwise spirals in the northern hemisphere and counter-clockwise rotation in the southern hemisphere (for warm currents).

Deep ocean circulation is the result of a number of factors including temperature and salinity variations in water masses, shorelines, subsurface topography, tides, etc.

Some of the most well-known currents include the Gulf Stream in the Atlantic and the Kuroshio in the Pacific. Warm surface currents invariably flow from the tropics to the higher latitudes, driven mainly by atmospheric winds, as well as the earth's rotation. Subtropical western boundary currents, such as the Gulf Stream and Kuroshio, are warm, fast surface currents that transport a lot of water and heat of tropical origin to subpolar regions. This process is extremely important for maintaining the earth's heat balance.

Currents known as upwelling also bring bring cold, nutrient-rich water from the depths up to the surface. Earth's rotation and strong seasonal winds push surface water away from some western coasts, so water rises on the western edges of continents to replace it. Marine life thrives in these nutrient-rich waters.

Salinity : Sea Surface Salinity is a key parameter to estimate the influence of oceans on climate. Along with temperature, salinity is a key factor that determines the density of ocean water and thus determines the convection and re-emergence of water masses.

The thermohaline circulation crosses all the oceans in surface and at depth, driven by temperature and salinity.

A global "conveyor belt" is a simple model of the large-scale thermohaline circulation. Deep-water forms in the North Atlantic, sinks, moves south, circulates around Antarctica, and finally enters the Indian, Pacific, and Atlantic basins. Currents bring cold water masses from North to South and vice versa.

This thermohaline circulation greatly influences the formation of sea ice at the world's poles, and carries ocean food sources and sea life around the planet, as well as affects rainfall patterns, wind patterns, hurricanes and monsoons.

Sea ice : At the center stage for climate change are the Earth's poles and their sea ice. While the sea ice surface area at the North Pole has shrunk continuously since measurements began in 1979, sea ice surface area has remained constant in Antarctica, and has even increased slightly with time. Given its importance as a climatic, economic and geopolitical issue, it is crucial to measure, monitor and forecast polar sea ice today.

The North and South pole are very different: the North Pole is an Ocean surrounded by land, while the South Pole is a vast continent surrounded by ocean. The sea ice in the South Pole is open onto the ocean and free to move. In this way, it is almost entirely replaced each year, except in rare places such as the Ross or Weddel Seas. South Pole sea ice is therefore never very thick (1 metre on average).

At the North Pole, ocean dynamics are quite different. While the Transpolar Drift, which flows from Siberia to Greenland via the Fram Strait allows ice to pass to the South and melt, the Arctic basin is a closed basin that traps the ice. In certain places, like Northern Canada, or in the Beaufort Gyre, ice gets stuck and can go several years without melting. This is ice is known as multiyear ice and can last two, three, seven or even nine years. Its average thickness is three metres.

Sea level : The sea surface is anything but flat. There are bumps and troughs , all due to different physical characteristics such as gravity, currents, temperature and salinity… Since we do not know much about the ocean's bottom, it is easier to refer to "sea height" instead of sea depth. Sea level is measured with reference to a fixed surface height. By analyzing variations from this reference point, scientists determine ocean circulation (currents and eddies at the edges of holes and bumps), seasonal or inter-annual variations, or even longer periods (long-term rise in sea level).

Wind : Surface winds, combined with other atmospheric forces (solar energy, precipitation rate, evaporation rate) are all responsible for the movement of water masses in the ocean, and are thus responsible for ocean currents.

Marine winds shape the ocean, and can cause waves as high as a mountain to swell during a storm. They are the source of many legends and color the moods of seafarers around the world.

Biogeochemistry : Phytoplankton (vegetable plankton) is the first link in the ocean's food chain, and is the main source of food for most fish. Phytoplankton contains chlorophyll, which instigates photosynthesis in the ocean, absorbs atmospheric CO2 and releases oxygen in sunlight. More than any land-based plant, phytoplankton is the biggest producer of oxygen on Earth.

Sustainable management of marine resources has become a major preoccupation for today's society, and knowing the chlorophyll content of the ocean's surface levels is an important way to measure primary production, as well as of global ocean health

Area coverage

All European marine regions are potentially covered by every European satellite.

A lot of satellites have ***the agility capability to focus*** on a given area at each orbit passage, an user can "order" an acquisition request on a specific region. Example :

- SPOT 6 and SPOT 7 constellation's performance makes it possible to collect a maximum amount of imagery and deliver products as quickly as possible:
  - The tasking plan is revised every 4 hours to be able to accept urgent requests.
  - The satellites' agility keeps acquisition conflicts to a minimum and allows them to switch targets in record time.
  - Automatic production and electronic delivery ensure products are rapidly available.

5. Satellites data access / data acquisition specific request

5.1 My Ocean data service

All products are detailed in the MyOcean catalogue. They are of 3 kinds:

- **Observations**
  In Situ measurements (from Argo buoys, gliders, Ferryboxes, …)
  Space measurements (from spaceborne sensors)
- **Model Outputs**
  Analysis (Hindcast and Nowcast)
  Forecasts
- **Re-analysis** (of Observations or Model Outputs)

They cover the 7 following geographical areas:

Mediterranean Sea, Black Sea, Atlantic European North West Shelf Ocean, Atlantic Iberian, Biscay Irish Ocean, Baltic Sea, Arctic Ocean, Global Ocean

And contain the following parameters:

Temperature, Sea Surface Temperature, Salinity, Currents, Sea Surface Height, Sea Ice (several parameters), Wind, Biogeochemistry (several parameters)

All products are available in an electronic form. ***All the costs (production and service) are fully covered by MyOcean consortium*** with the financial support of the EC, through the FP7 program, until the end of the MyOcean Project (planned on 31st March 2012).Thus, MyOcean services and products are free of charge for the User until this date. Technical upgrades and service commitment updates will be done on regular basis. The next release (new version of service) is scheduled by December 2011. http://www.myocean.eu/web/26-catalogue-of-services.php

5.2 Other Eurpean satellites data service

ESA ESRIN : ESRIN is the ESA Centre for Earth Observation. It is ESRIN's responsibility to make its data available to scientists, to liaise with the scientific community and to harness their input into future satellite missions, sensors and products :

- ***At cost price :*** Researchers can apply to receive Earth Observation data at cost price through the ESRIN-hosted Earth Observation Principal Investigator Portal. They are expected to report on project progress at least twice a year through this Portal, and also to publish intermediate results in this way. http://eopi.esa.int/esa/esa .
- ***Or free of charge :*** Regular Announcements of Opportunity are also accessed through the Portal. These give researchers the opportunity to make use of Earth Observation data completely free of charge within particular designated fields.

- http://eopi.esa.int/esa/esa?topSelectedNavigationNodeId=HOME&sideNavigationType=HOME&aoid=104&ts=1311936345689&cmd=aodetail
- Browse products by :
    - Application => ***Ocean and Coast***
    - Satellites,
    - Instruments,
    - Processing level,

SPOT Image, *incl. for coast watch* : Spot Image is a worldwide distributor of geographic information products and services derived from the Spot Earth observation satellites, including the Vegetation instrument flown on SPOT 4 and 5. Spot Image also distributes complementary optical and radar data acquired by other satellites offering low to very high resolution images. Spot Image acquires the SPOT data through a receiving station at its premises in Toulouse and via a network of partner stations around the world.

Data access : within the SPOT catalogue, search of data by : area, resolution, dates of acquisition (start, end), cloud cover (more or less in %), angle of incidence (vertical, near-vertical, any angle). http://catalog.spotimage.com/PageSearch.aspx

Programming request : Spot Image can directly program the SPOT satellites and their revisit observation frequency for any given point on the globe which means it can acquire images of your geographic area of interest at any time.

http://www.spotimage.com/web/en/180-programming.php

- How Pleiades and SPOT will operate together in orbit, see video :

  http://videos-en.astrium.eads.net/#/video/bba506fb3d1s

CERSAT (Ifremer, France) : The Center for Satellite Exploitation and Research (CERSAT) is one of the major world data centers ***for oceanography***. It processes, archives and distributes a large amount of data products obtained from satellite remote-sensing, mostly intended to support research activity in various fields (oceanography, meteorology, climatology,...) and operational applications based on space data (weather prediction, ocean circulation, environment monitoring,...). Data access by : project, satellite mission, product type, parameter (***ocean wind, sea ice, altimetry, waves, sea surface temperature***) : http://projets.ifremer.fr/cersat/Data/Discovery

Germany :

The TanDEM-X Science Service System is a web interface for the submission and evaluation of scientific proposals, **incl. for oceanography** (see TanDEM-X science plan). The portal is the main interface for Principal Investigators to define their acquisition requests. It is further used to monitor and track the status of submitted proposals and is a tool for the science coordination team to help organize the science user community of TanDEM-X. https://tandemx-science.dlr.de/

5.3 Other International satellites data service

NASA / Oceancolor :

Level 1 and 2 Browser : Visually search the ocean color data archive. Directly download or order data from a single file to an entire mission. Simulated data from the upcoming Aquarius mission can be found here

Level 3 Browser : Browse the entire global ocean color, sea surface temperature and sea surface salinity data sets for many parameters and time periods and download PNG images or digital data in HDF format.

Global Time Series : Time series plots of selected SeaWiFS, MODIS and OCTS Standard Mapped Images for a set of selected regions or the entire globe.

Data Archive : Access to the complete data archive via an 'FTP-like' directory structure. Retrieval of data in bulk is possible with this new server.

Ocean Productivity : Ocean Net Primary Productivity data products derived from MODIS and/or SeaWiFS data available from Oregon State University.

NOAA / STAR (Center for Satellite Applications and Research) : The mission of STAR is to create satellite-based observations of the land, atmosphere, and *ocean*, and transfer them from scientific research and development into routine operations. In addition, STAR offers state-of-the-art data, products, and services to decision-makers. http://www.star.nesdis.noaa.gov/star/products.php

6. Vision of the future

Two very different types of earth observation satellites :

- The « **Coast watch »** type : actually satellites designed for landscape observation are based mainly on optical sensors (visible + infra red to observe despite clouds coverage) which could of course be used for the coast strip. On-board sensors, being focused on landscape observation, are more or less pertinent for some marine waters specific parameters. The very high resolution (< 1 m) which is worth for landscape fine description can be also useful for the coastal cartography and vegetation (including the foreshore areas at low tides), but no longer a real requirement as long as we consider water areas away from the coastline strictly speaking : then the less expensive average resolution < 2,5 to 5 m is sufficient.
- The « **Ocean watch »** type : satellites focused on ocean observation and which can also of some use for coastal waters, which have not the very high spatial resolution as first priority a priori. : it is each parameter resolution which matters instead.

A very active domain with recent and planned satellites launches :

Launched satellites between 2007 and Sept. 2012 : 12

Satellite(s)	Launch date	Coast watch	Ocean watch
Cosmo-Skymed (4)	2007 - 2010	X	
GOCE	2009		X
SMOS	2009	X	X
Cryosat 2	2010		X
TanDEM X (2)	2010	X	
Pleiades-HR 1A	Dec. 2011	X	
SPOT 6	Sept. 2012	X	
METOP-B	Sept. 2012		X

Satellites planned to be launched between Dec. 2012 and 2016 : 12

Satellite(s)	Launch date	Coast watch	Ocean watch
Saral-Altika	Dec. 2012		X
Pleiades-HR 1B	Dec. 2012	X	
Jason 3	April 2013		X
PAZ	2013	X	
SPOT 7	2014	X	
INGENIO	2014	X	
Sentinel 2 (2)	2014	X	
Sentinel 3 (2)	2014		X
EnMAP	2015	X	
METOP-C	2016		X

"Coast watch" issue :
Driven by land environmentalist scientists.

But for the Pleiades satellites, a working group was dedicated on Sea and Coast :

GT1 – Thematic Group on Sea and coastal areas :

http://smsc.cnes.fr/PLEIADES/Fr/PDF/reu_080610/1-SeaAndCoastline.pdf

"Ocean watch" and operational oceanography issues :
Driven by scientists involved in meteorology, climate and ocean circulation, and by operational oceanography people (mix of scientists and engineers), focused on quasi real time release of data & forecasts

GMES Marine service issues (My Ocean) :

- Which perimeter extension (and limitation) for the My Ocean service as a provider of marine data ?
- Which articulation with all RI involved in *in-situ* data acquisition on which it relies on ?
- Which articulation with EMODNET ?, with SeaDataNet (=> an MoU exists between these two projects)

GMES Climate service : the (6th) new GMES base service which includes an Earth system re-analysis (with interactions between Atmosphere, ***Ocean***, Land, etc)

http://ec.europa.eu/enterprise/policies/space/files/gmes/climate-change-conf-helsinki-june-2011/presentations/presentation_report_cuvelier_uppala_and_al_en.pdf

Other :

General studies programme (GSP) : Think tank for ESA, scientific aspect, technology aspect

Annexe : references

Web sites of all mentioned projects and satellites.

ITC's database of Satellites and Sensors :

http://www.itc.nl/research/products/sensordb/searchsat.aspx

Earth Observation Portal :

http://catalogues.eoportal.org/

CNES-SPOT :

http://smsc.cnes.fr/SPOT/

Digital Globe constellation :

http://www.digitalglobe.com/index.php/82/Content+Collection+Systems

GeoEye-1 :

http://launch.geoeye.com/LaunchSite/about/

Towards integrated European marine research strategy and programmes

Seas-era

EUFP7ERA-NET

http://www.seas-era.eu

Project Beneficiaries

Project Third Parties