CONSIGLIO NAZIONALE DELLE RICERCHE

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

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→ 2nd COASTAL ALTIMETRY WORKSHOP

November 6-7, 2008

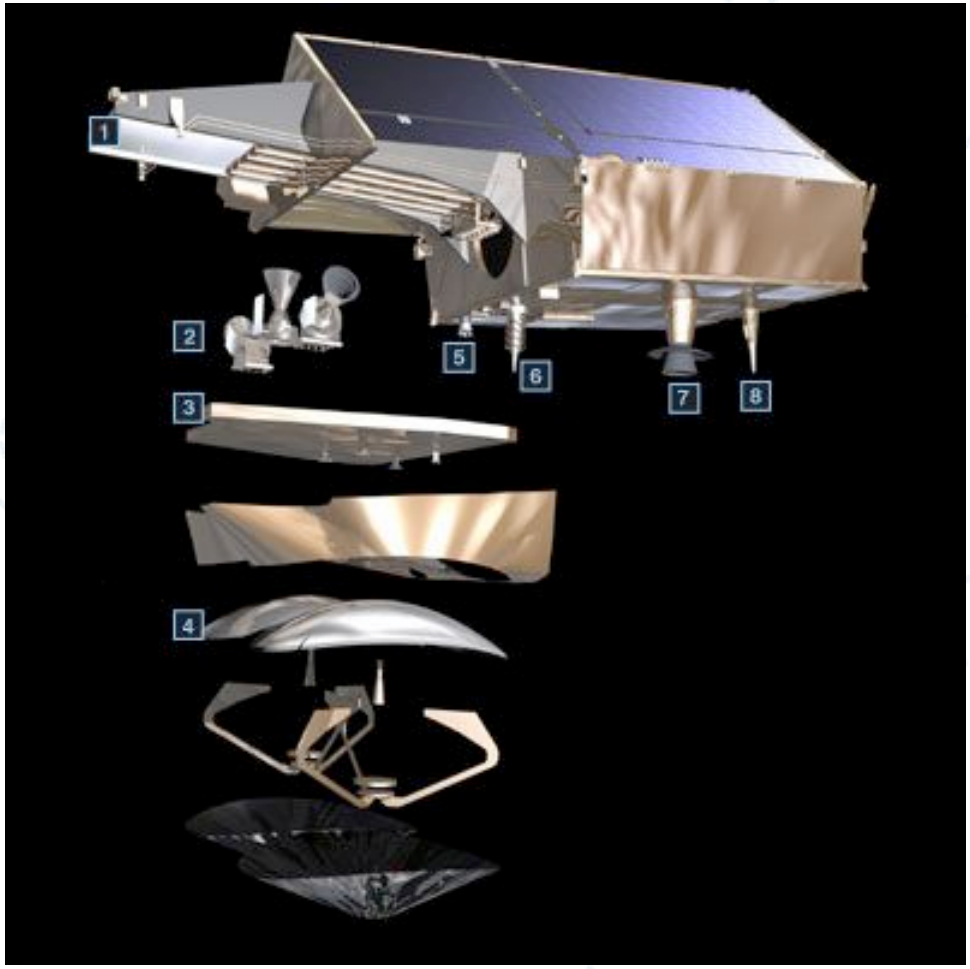
Pisa, Italy

Exploiting Delay/Doppler Altimetry in Coastal Zone with Sentinel-3
&
Sample Datasets from CryoSat-2

Jérôme Benveniste
esa


CryoSat will carry a new generation Altimeter

The satellite and its instruments



1 Radiator: a heat-radiating panel at the top of the nose structure which houses the SIRAL electronics under the solar array.

2 Star tracker

3 Antenna bench: stable and rigid support structure isostatically mounted to satellite nose.

4 SIRAL antennae

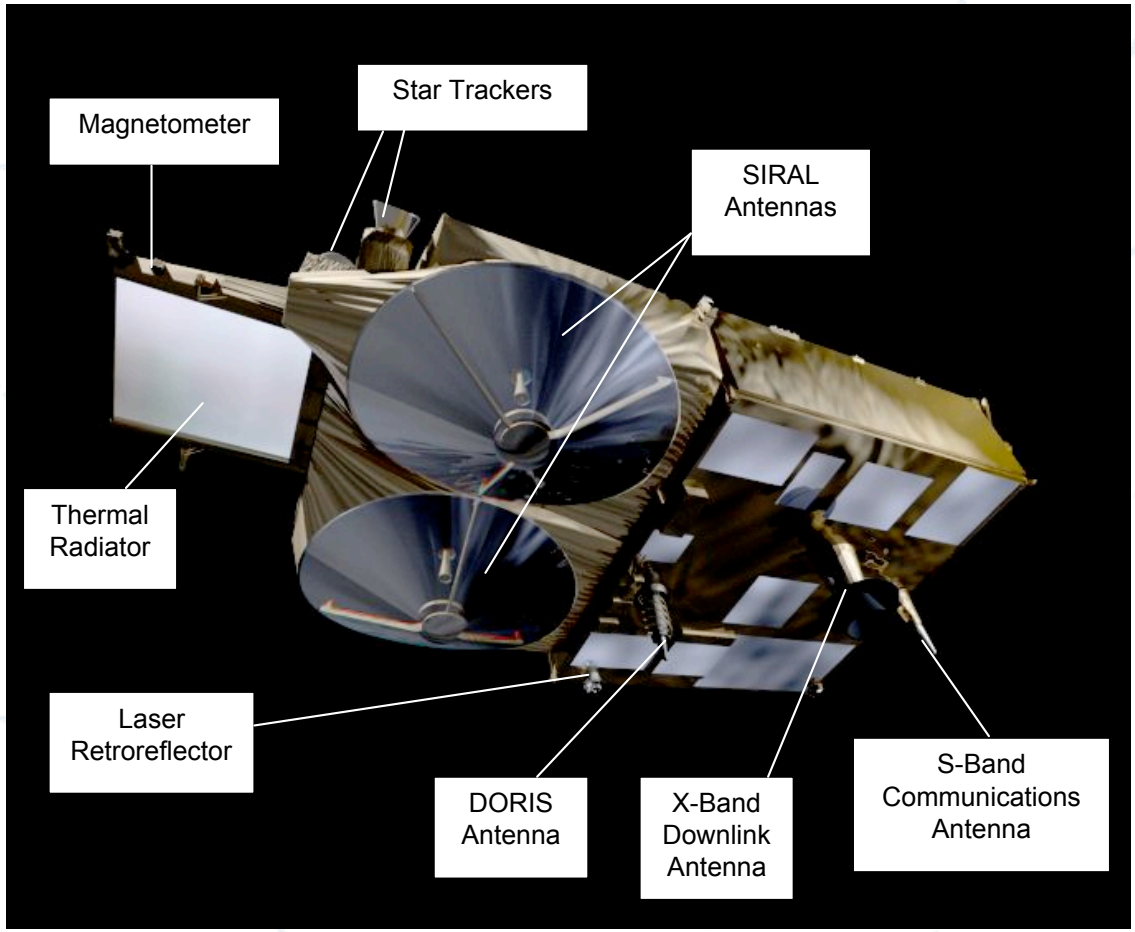
5 Laser retroreflector: reflects tracking pulses back to ground-based laser station.

6 DORIS antenna: receives signals from a global network of radio beacons for orbit determination.

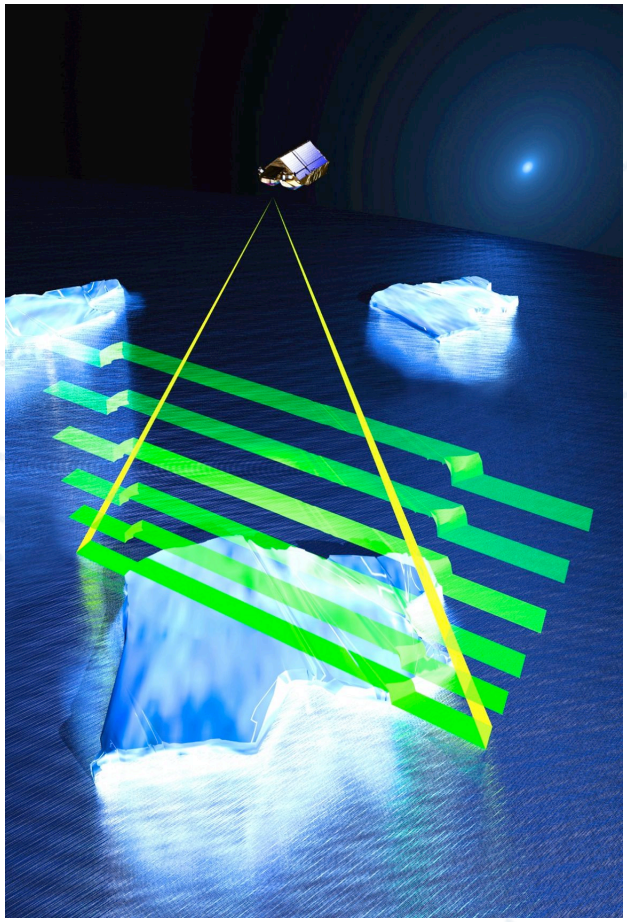
7 X-band antenna: transmits the huge volume of SIRAL measurement.

8 S-band helix antenna: receives telecommands from the ground.

The satellite and its instruments

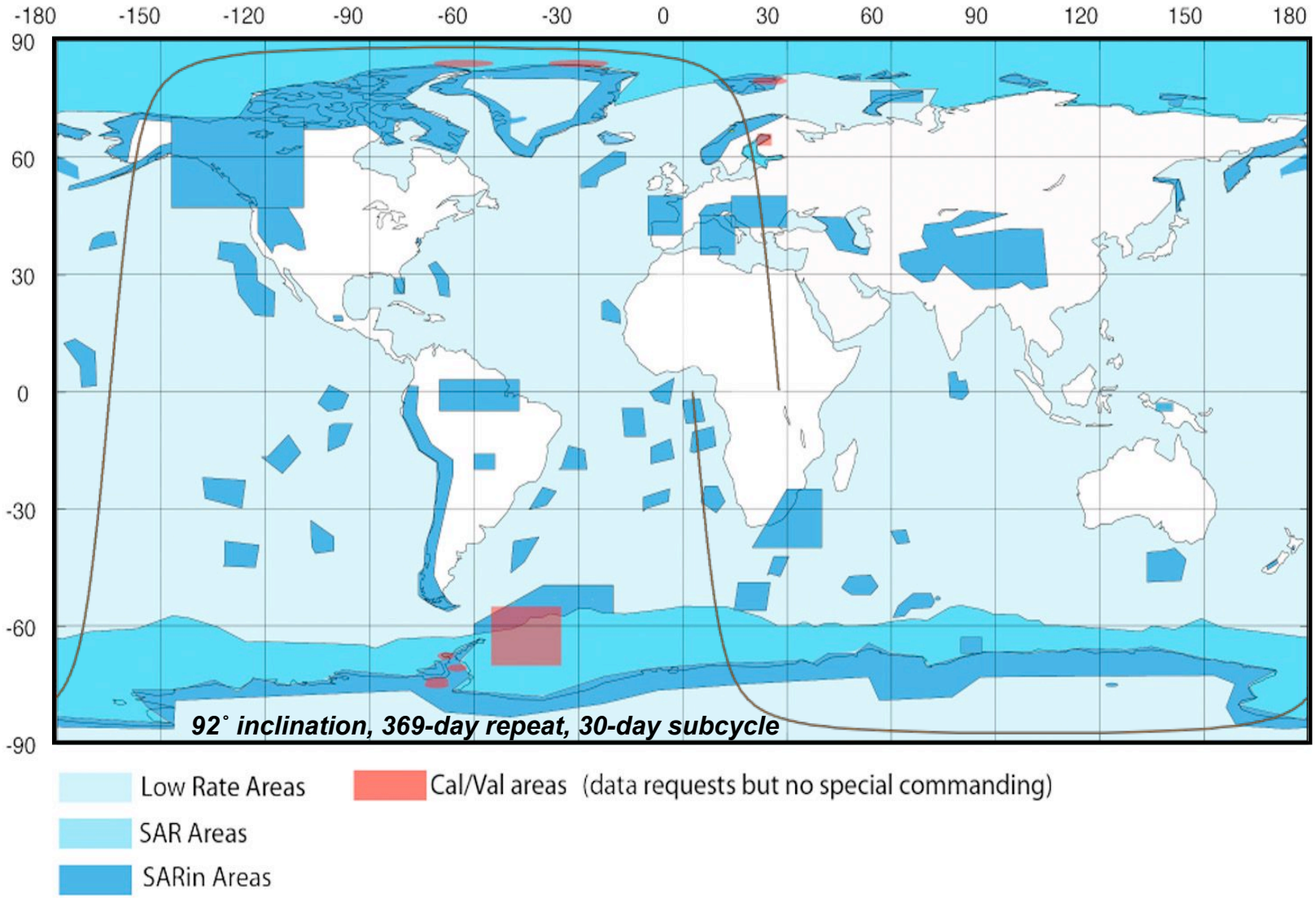


CryoSat's High-Resolution



- Transmits bursts of 64 pulses: sequential echoes are correlated
- Satellite moves 250 m between bursts
- Aperture Synthesis technique gives 250 m along-track resolution, much higher than conventional altimeters (ERS-2, Envisat RA-2)
- SAR Mode used over sea-ice to measure ice-floe freeboards and retrieve thickness

SIRAL Mode Operation



SIRAL Mode Operation

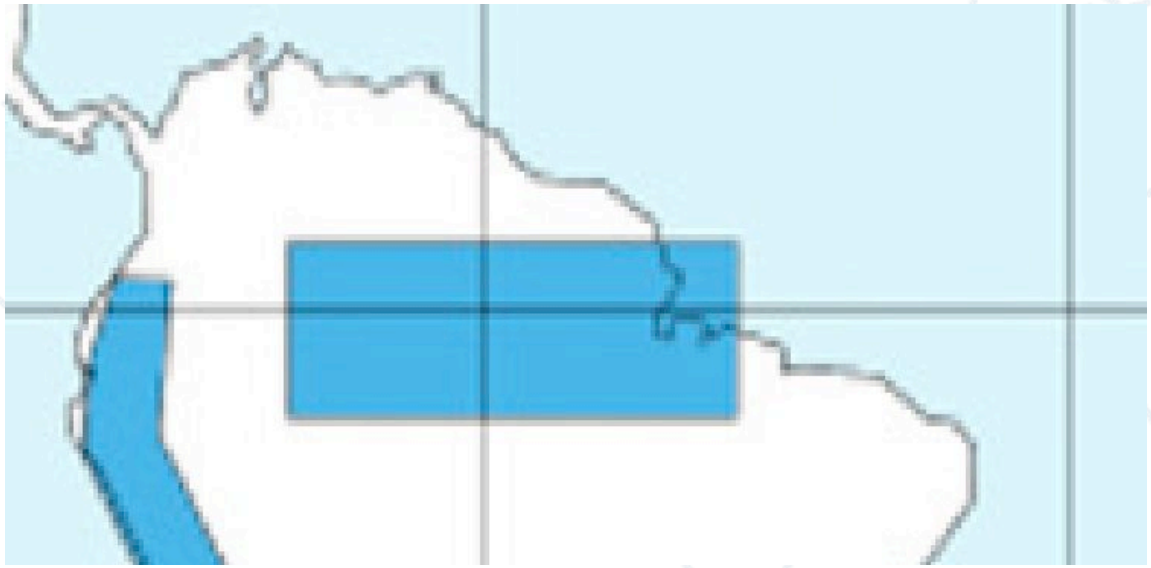
Low Rate Areas

SAR Areas

SARin Areas

Cal/Val areas (data requests but no special commanding)

SIRAL Mode Operation



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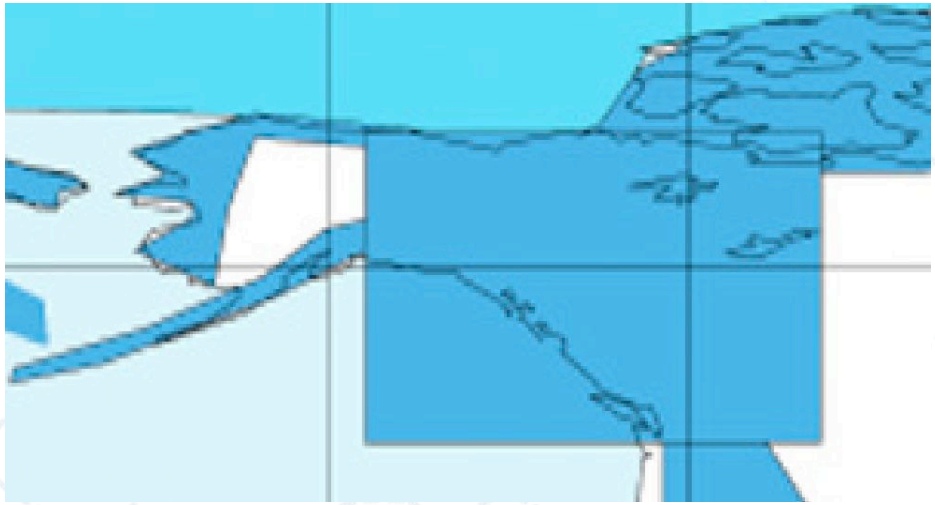
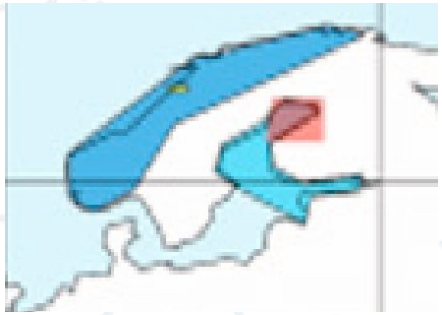
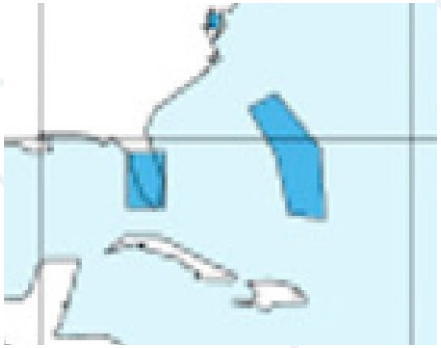
SIRAL Mode Operation







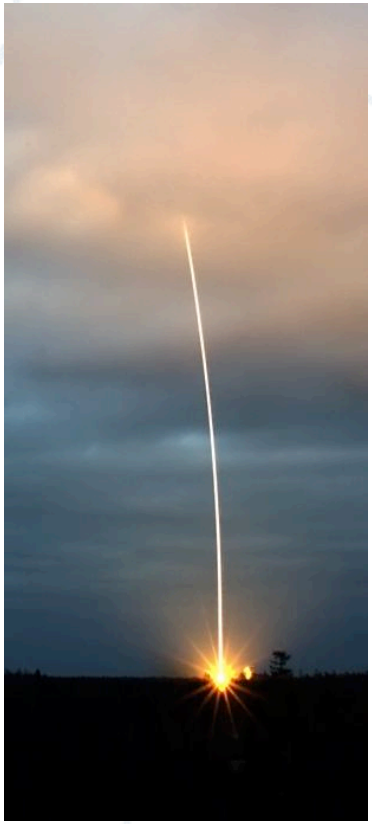
Low Rate Areas

SAR Areas

SARin Areas

Cal/Val areas (data requests but no special commanding)

CryoSat Launch: 8 Oct 2005



CryoSat-2 Launch: 16 Nov 2009

CryoSat-2 Mission Fact Sheet

CryoSat Mission

To determine fluctuations in the mass of the Earth's major land and marine ice fields.

Mission Duration

- 6 months commissioning
- 3 year operational mission.

Mission Orbit

- Type: LEO, non sun-synchronous
- Repeat cycle: 369 days (30 d sub-cycle)
- Mean altitude: 717 km
- Inclination: 92°
- Nodal regression: 0.25°/d

Spacecraft and Payload

Recurrent spacecraft and payload from lost CryoSat 1

Instruments

SIRAL (SAR/Interferometric Radar Altimeter):

- Low-Resolution Mode provides conventional pulse-width limited altimetry over central ice caps and oceans;
- SAR Mode improves along-track resolution (~250 m) over sea ice by significantly increased pulse repetition frequency and complex ground processing;
- -SAR Interferometric Mode adds a second receive chain to measure the cross-track angle of arrival of the echo over topographic surfaces at the margins of ice caps.

Star Trackers (3) measure the interferometric baseline orientation, as well as driving satellite attitude control.

DORIS enables precise orbit determination, as well as providing on-orbit position to the satellite attitude control.

Laser Retroreflector enables tracking by ground-based lasers.

Spacecraft

Simplified rigid structure with no moving parts; all electronics mounted on nadir plate acting as radiator; SIRAL antennas on iso-statically mounted plate with Star Trackers; dedicated SIRAL radiator. 2x GaAs body-mounted solar arrays, with 850 W each at normal solar incidence; 78 Ah Li-ion battery. Attitude: 3-axis stabilised local-normal pointing, with 6° nose-down attitude, using magneto-torquers and 10 mN cold-gas thrusters.

- Dimensions 4.60 m x 2.34 m x 2.20 m
- Mass 720 kg (incl. 37 kg fuel)
- Power 850 W
- Datavolume: 320 Gbit/day
- on-board storage by SSR 256 Gbits

Launch Vehicle

DNEPR

Flight Operations

Mission control from ESOC *via* single ground station at Kiruna. Up to 11 useable downlink passes for science data.

RF Links

- X-band data downlink: 100 Mbps at 8.100 GHz
- S-band TTC link: 2 kbps uplink,16 kbps downlink

Payload Data Processing

Data processing facility at the Kiruna ground station. Local archiving of data with precision processing after one month following delivery of precision orbits from DORIS ground segment (under CNES responsibility). Possibility of quick-look data. Direct dissemination of data from Kiruna.

User Services coordinated *via* ESRIN.

Sentinel-3

will carry a new generation Altimeter, similar to CryoSat but with no interferometry mode

S-3 Observational Requirements

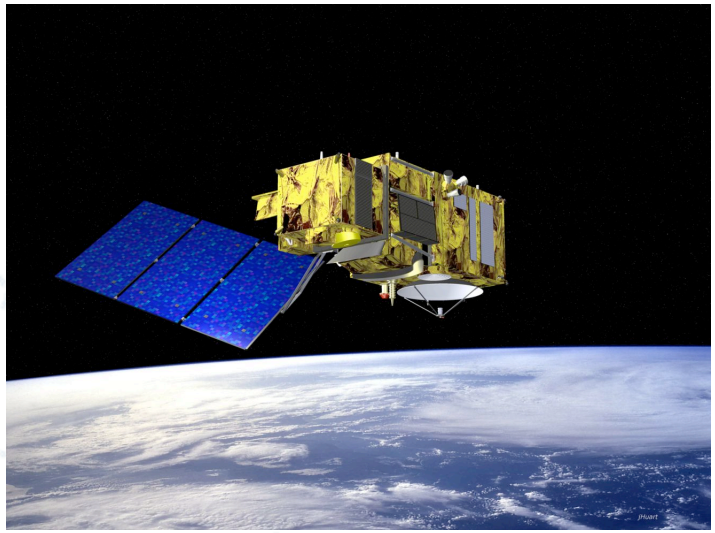
The objectives for a series of Ocean Observer Missions (GMES Sentinel-3) encompass the commitment to consistent, long-term collection of remotely sensed marine data, of uniform quality, for operational ocean state analysis, forecasting and operational service provision, in the context of Global Monitoring for Environment and Security (GMES). A network of global ocean observations is required to provide input data for advanced numerical forecasting models. For the remote sensing variables the following set of observational requirements have been established:

- Sea surface topography (SSH) and, significant wave height (SWH) over the global ocean to an accuracy and precision equivalent to that of Envisat RA-2.
- Sea surface temperature (SST) determined globally to an equivalent accuracy and precision as that presently achieved by A/ATSR (i.e. <0.3 K), at a spatial resolution of 1 km. Coastal zone waters require an increased resolution of < 300 m.
- Visible and Thermal Infrared radiances ("Ocean Colour") for oceanic and coastal waters, determined to an equivalent level of accuracy and precision as MERIS data with complete Earth coverage in 2 to 3 days, and coregistered with SST measurements.

S-3 Observational Requirements

Coastal Zones Monitoring: Demands for information on the state of coastal waters are growing in response to population pressure. Thus, there is a requirement for environmental monitoring of phenomena such as harmful algal blooms (HAB) and habitat assessment in addition to weather and ocean nowcasting and forecasting. The characteristics of the coastal phenomena and the importance of the area for aquaculture, sea-defences, and tourism each justify the observation of coast related parameters with enhanced accuracy and resolution.

GMES Initial Service	S-3 Requirement
Marine and **Coastal** Environment	sea-surface topography mesoscale circulation water quality sea-surface temperature wave height and wind sediment load and transport eutrophication
Polar Environment monitoring	sea-ice thickness ice surface temperature
Maritime Security	ocean-current forecasting water transparency wind and wave height
Global Change Ocean	global sea-level rise global ocean warming ocean CO_2 flux



Surface Topography:
SSH, SWH, Wind, Currents
Sea-ice thickness

Ocean Surface Colour
Cla, PFTs, HAB, Transparency, Sediment loading, Turbidity

Sea Surface Temp.

Global Monitoring for Environment and Security

Sentinel-3 is one element of the overall GMES system providing 2 days global coverage earth observation data for sea and land applications with real-time products delivery in less than 3 hours.

Operational oceanography & global land applications

Acquire data to feed ocean/atmosphere models and to derive global land products and services.

- Sea/land colour data, in continuation of Envisat/Meris.
- Sea/land surface temperature, in continuation of Envisat/AATSR.
- Sea surface and land ice topography, in continuation of Envisat altimetry.
- Along-track SAR for coastal zones, in-land water and sea ice topography.
- Vegetation products by synergy between optical instruments.

Mission duration

A series of satellites, each designed for a lifetime of 7 years, shall be launched to provide an operational service over 15 to 20 years. Furthermore, two satellites shall operate at any time to fulfil the mission requirements.
(Only one satellite is in development at this moment)

Mission orbit

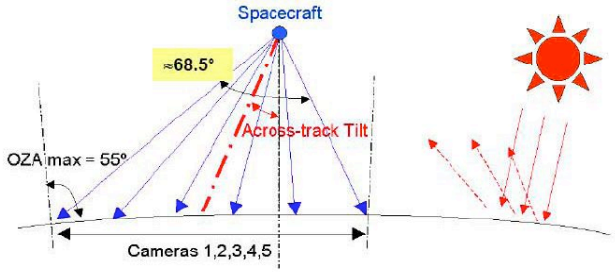
Type:	Frozen, sun-synchronous low earth orbit
Repeat cycle:	27 days (14+7/27 orbits per day).
Average altitude:	814.5km over geoid
Mean solar time:	10h00 at descending node.
Inclination:	98.65°
Launcher:	VEGA/Kourou (Eurockot/Plesetzk backup)

Spacecraft configuration

Launch mass:	1198kg (with maturity margins + 10% system margin, 95kg hydrazine in 130kg tank)
Stowed dimensions:	(H) 3712 mm (W) 2202 mm (L) 2172 mm
Attitude control:	Gyroless, 3 axis stabilised platform with 3 star tracker heads, 4 reaction wheels and magnetic off-loading. Geodetic pointing and yaw sterring
Orbit control:	8x1N hydrazine thrusters for in-plane and out-out plane manoeuvres. 130kg hydrazine tank 3 meter accuracy real-time onboard orbit determination based on GPS and Kalman filtering.
Power:	2.1 kW rotary wing with 10 m^2 triple junction GaAs European solar cells. LiIon battery, 160Ah
Communications:	64kbps uplink, 1Mbps downlink S-band command and control link (with ranging). 2x225Mbps X-band science data downlink. 330Gbit solid state mass memory.
Autonomy:	Position timeline and onboard sun ephemeris for >2 weeks nominal autonomous operations.

OLCI: **Ocean and Land Color instrument**

Swath: 1270km, with 5 tilted cameras



Spatial sampling: 300m @ SSP
Spectrum: 21 bands [400-1020]nm
Radiometric accuracy: 2% absolute, 0.1% relative

SLST: **Sea and Land Surface temperature**

Swath: 180rpm dual view scan, 750km (nadir) and 1675km (backwards)
Spatial sampling: 500m (VIS, SWIR), 1km (MWIR, TIR).
Spectrum: 9 bands [0.55-12]um
Noise equivalent dT: 50mK (TIR)

SRAL: **Synthetic Radar Altimeter**

Operation frequency: dual C and Ku bands
Pulse Repetition Frequency (PRF): 1923.87 Hz
Radar measurement modes: LRM and SAR
Tracking modes: Closed-loop and Open-loop
Total range error: 3cm

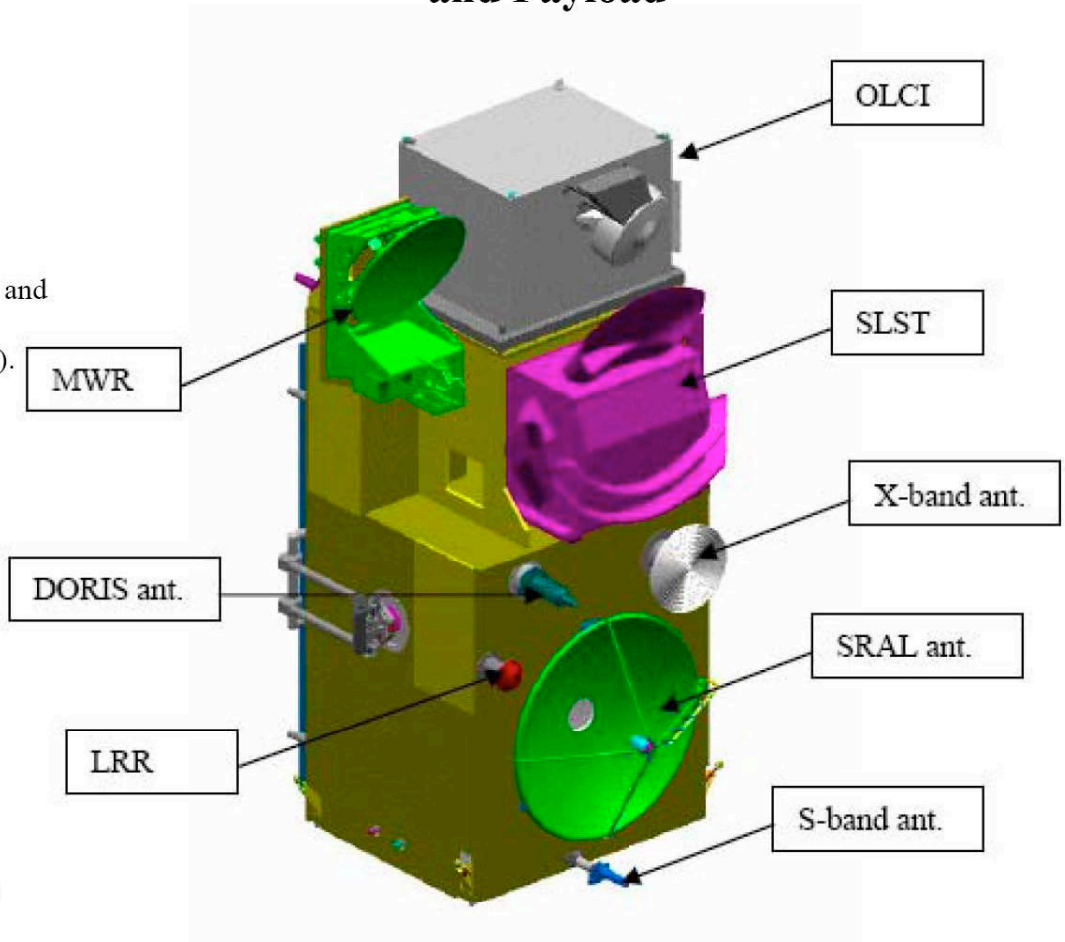
MWR: MicroWave Radiometer (support to SRAL)

Operation frequency: dual 23.8GHz 36.5GHz
Radiometric accuracy: 3K absolute, 0.6K relative

POD: Precise Orbit Determination (support to the whole payload)

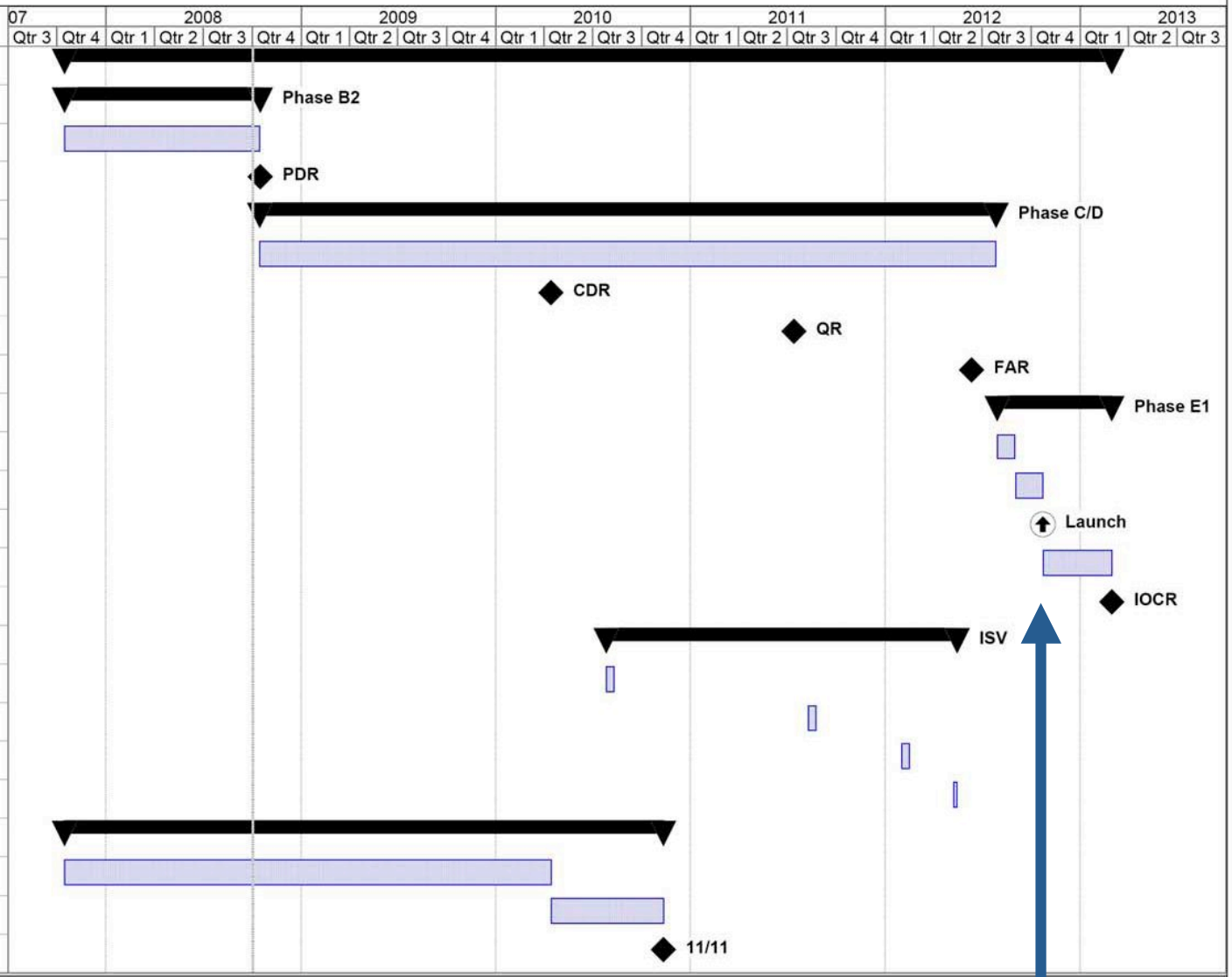
Ground processing of GPS data with enhancement through Laser Retro-Reflector and DORIS (CFI)
Final accuracy: 3cm

Sentinel-3 Configuration and Payload



Earth Observation Programme
Sentinel-3 Project

ID	Task Name
1	**Sentinel-3 Project**
2	**Phase B2**
3	Phase B2 Activities
4	S/L PDR
5	**Phase C/D**
6	Phase C/D Activities
7	S/L CDR
8	S/L QR
9	S/L FAR/FRR
10	**Phase E1**
11	Launch Campaign Preparation
12	Launch Campaign
13	Launch
14	LEOP/Commissioning Phase
15	In Orbit Commissioning Phase
16	**Integrated System Verification (ISV)**
17	SVT-0
18	SVT-1
19	SVT-2
20	SVT-3
21	**Launcher Procurement**
22	Launcher Compatibility Studies
23	Launcher Selection
24	Launcher Contract



Status as of: 30 September 2008

LAUNCH : Q4-2012

SAMOSA

- Exploiting the SAR mode over Ocean, Coastal Zone, Inland water:
- Competitive Tender
  - "Development of SAR Altimetry Mode Studies and Applications over Ocean, Coastal Zones and Inland Water"
- Won by SATOC, NOCS, Starlab,DNSC, DMU
- SAMOSA Start: 31 July 07 for a 15-month duration

SAMOSA

- The development of exploitation of samples of SAR Altimetry mode data over water, aims at making progress in ocean and **coastal zone oceanography**, ocean floor topography (bathymetry), gravity field and inland water monitoring.
- CryoSat-2 will be the first satellite that will provide such data (Q4-2009), followed by Sentinel-3 (Q4-2012).
- This development uses simulated and possibly will use airborne data.
- ENVISAT RA-2 Individual Echoes is also used to test some of the findings of this development.

SAMOSA Work Packages

- WP1a State of the art assessment
- WP1b Ordering, provision and management of simulated data sets
- WP2 Range error as a function of ocean surface
- WP3 Recovery of short wavelength geophysical signals
- WP4 SAR altimeter echo model over water
- WP5 New re-tracking method over water
- WP6 Improvement of coastal zones, estuaries, rivers and lakes
- WP7 Assessment of RA-2 individual echoes over water
- WP8 Validation using ASIRAS data

SAMOSA Deliverables

Deliverable Title		Date
D1.1	State of the art assessment	09/07
D1.2	Data requirements	09/07
D2	Range error as a function of ocean surface	11/07
D3	Recovery of short wavelength signals	12/07
D4	Theoretical echo model development	02/08
D5	Specification of new re-tracking method	07/08
D6	Results over coastal and inland waters	08/08
D7	Assessment of RA-2 individual echoes	10/08
D8	Exploitation of ASIRAS data	11/08

SAMOSA

KR: A request to each of the three key speakers in our session:

In your 15' brief, please include a concise and candid list of

(1) advantageous features, as well as

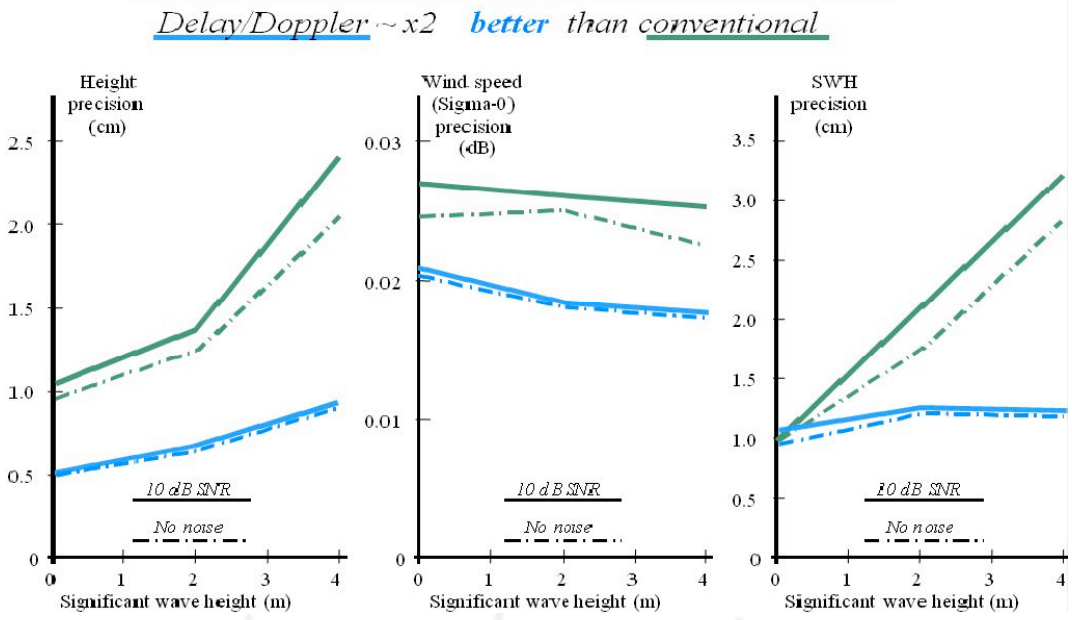
(2) disadvantages and limitations of your respective new technical approach to coastal altimetry.

You may want to be prepared to address how **spatial and/or temporal averaging** requirements and benefits play with respect to your particular technological theme in the coastal environment.

SAMOSA

(1) advantageous features

- High resolution along-track (250 m) to be averaged, at loss of resolution, for better accuracy.
- The expected height precision (based on simulations) of the DDA relative to conventional is approximately 2x better, and shows less degradation to increasing SWH.
- Envisat RA-2 performs at 1.8 cm r.m.s. (7 km, 1Hz) over the global ocean.



Jensen & Raney (1998)

SAMOSA

(2) disadvantages and limitations of your respective new technical approach to coastal altimetry.

Along track data only (nadir)

-> Need Sentinel-3B in orbit to guarantee uninterrupted data supply -- will augment sampling

-> And Jason-3! (Synergy with JA3 is part of the S-3 requirements)

SAMOSA

- Presentation in this Workshop

  Cristina Martin-Puig et al. (Starlab SL, Spain):

  SAMOSA retracker for SAR Altimeter observations over water

- Spatial and/or temporal averaging
  - One data point every 250 m in SAR mode
  - May be averaged to reduce noise
  - Use simulated data from CRYMPS to quantify by the next workshop

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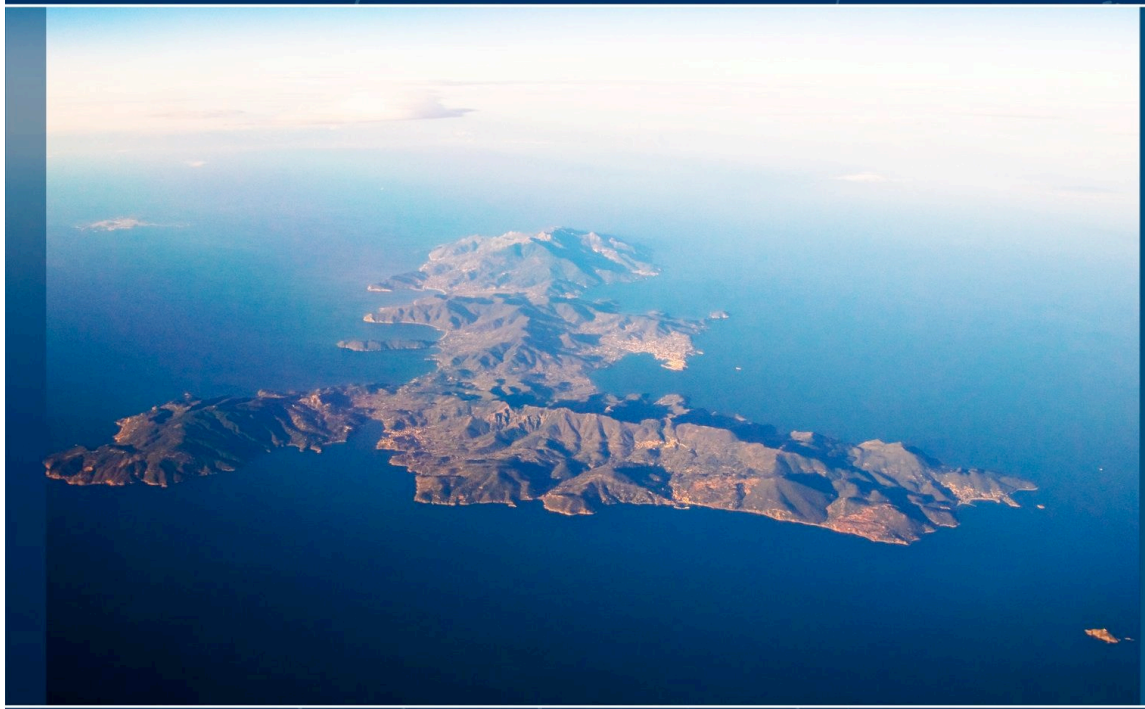
→ 2nd COASTAL ALTIMETRY WORKSHOP



→ TOPICS

1 → User requirements for coastal altimetry
2 → Retracking
3 → Corrections: Dry/Wet Tropospheric, Ionospheric, Tides & HF
4 → SSB & Waves
5 → Data Products, quality and dissemination
6 → Synergy with other data and models
7 → Forthcoming technologies
8 → International Cooperation and Future Programs

→ ORGANIZING COMMITTEE

Jérôme Benveniste - *European Space Agency - ESRIN, Frascati, Italy*
Nicolas Picot - *Centre Nationale d'Etudes Spatiales (CNES), Toulouse, France*
Stefano Vignudelli - *Consiglio Nazionale delle Ricerche (CNR), Pisa, Italy*
Paolo Cipollini - *National Oceanography Centre, Southampton, U.K.*

November 6-7, 2008

Pisa, Italy

→ www.coastalt.eu/pisaworkshop08