

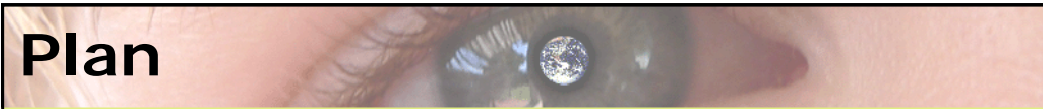


Oceanpal Experiments

Starlab Oceanpal Team

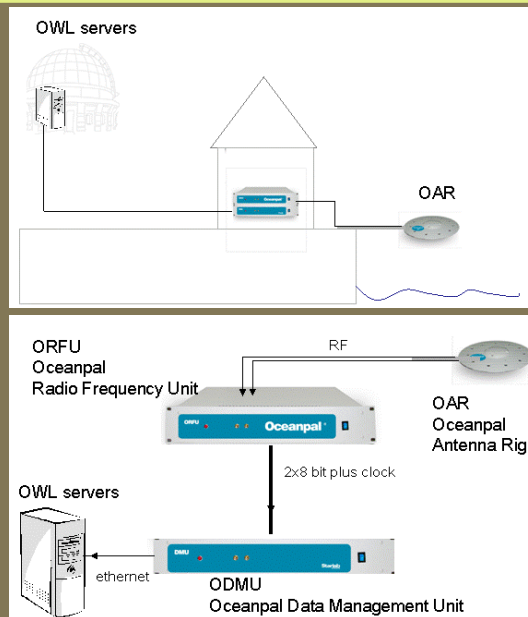
GNSSR'06 Workshop - ESTEC

Plan



- Instrument Overview
- Barcelona Permanent Station
- Brest Experiment
- PARIS Ice Retrievals Campaign

System Architecture



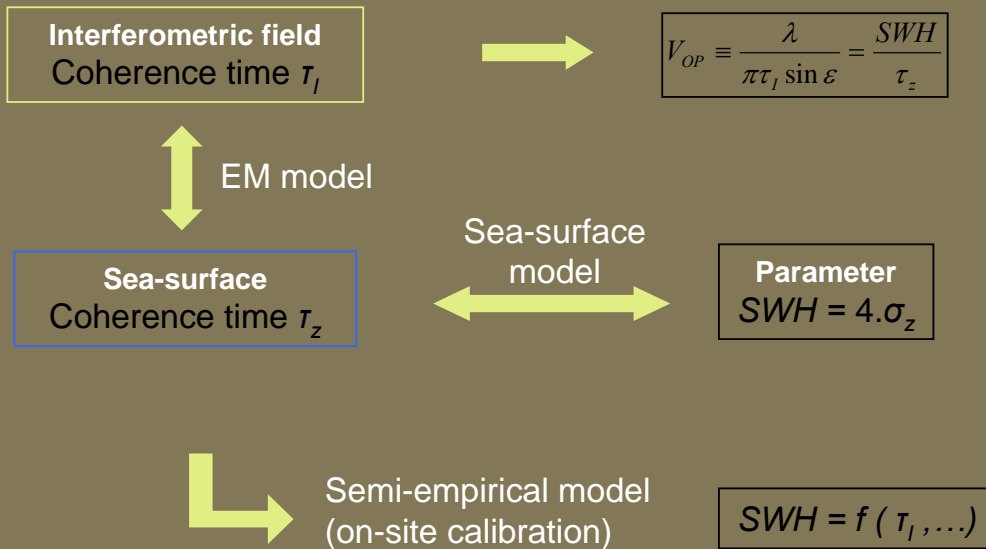
System Functions

- Stores (temporally) the RAW data
- Data Processing and storage
 - L0 : complex waveforms
 - L1 : field coherence time, direct/reflected lapses
 - L2 : geophysical products (SWH and H)

- L2 data (XML): Download from ODMU, store to MySQL database
- User remote access to the L2 database



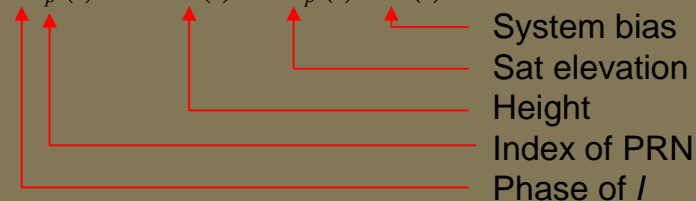
Coastal Sea-State Algorithm



Coastal Altimetry Algorithm

- Phase Altimetry possible on calm-water surface (e.g. inside a harbour)
- Use of the interferometric field $I(t)$, the ratio of the reflected $R(t)$ and the direct $D(t)$ signals (eliminates the navigation message and all errors common to both signals)
- Fundamental equation:

$$\Phi_p(t) = 2k h(t) \sin \varepsilon_p(t) + \theta(t)$$

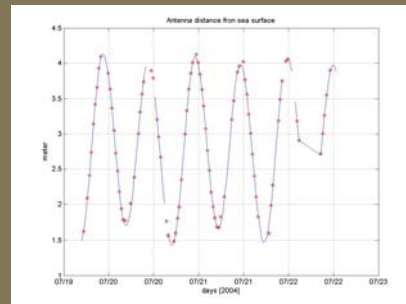


Coastal Altimetry Campaign

- 3-day campaign at the Port of Villagarcía (Galicia, Spain), July 2004.
- Collaboration with Puertos del Estado.
- Ground truth: Radar tide gauge.
- Tide of 2.5 m approx.



- One take of 2 mn every 30 min.
- Error vs. ground truth: 3.1 cm RMS.



Barcelona Port Station

- **Starlab Oceanpal project.**
 - Collaboration with the Environmental Department of the port.
- **First deployment 2004.**
- **Objectives:**
 - Development and validation of L0 to L2 algorithms for coastal monitoring.
 - Focus on altimetry and sea-state (SWH).
 - Implementation of a permanent station.
 - Real time web-based data provision to Port Authority.

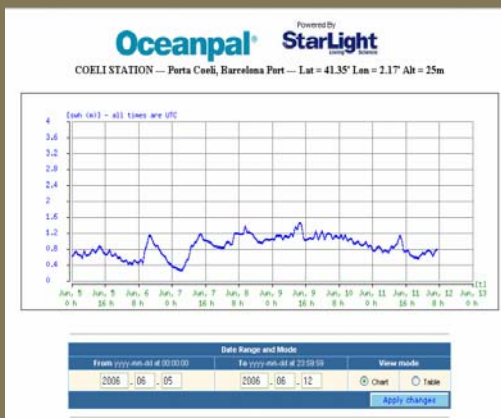
Deployment

- At Coeli Meteo Station
- Altitude ~25 m.



User Interface

- Real time access
 - Graphics
 - Table
- Customized to Port requirements (hourly provision).



Date	Time	SWH
2006-06-12	00:07	0.70
2006-06-12	01:02	0.67
2006-06-12	02:10	0.74
2006-06-12	03:03	0.75
2006-06-12	04:04	0.71
2006-06-12	05:04	0.61
2006-06-12	06:05	0.74
2006-06-12	07:00	0.70
2006-06-12	08:02	0.79

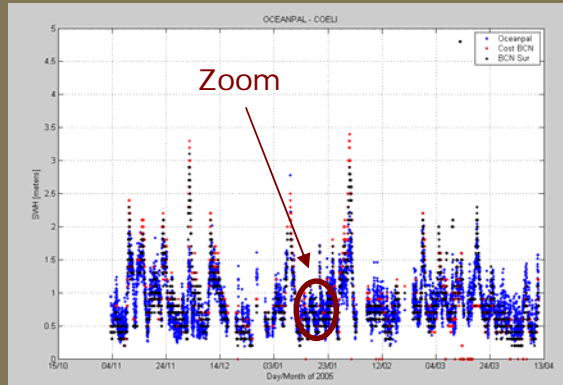
Analysis and Validation (I)



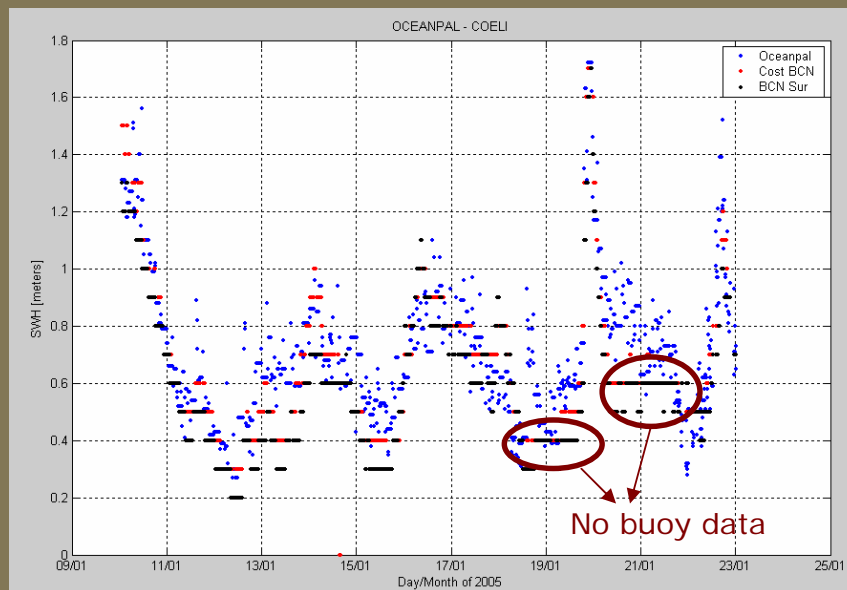
Buoy "Cost Barcelona"



Buoy "Barcelona Sur"



Analysis and Validation (II)



Barcelona Port Conclusions

- SWH delivery is satisfactory to the Port User (18 cm precision after 1 minute)
- Regular SWH provision for the last 1.5 years.
- Much less data missing with respect to buoy data.
- Phase Altimetry possible on calm-water surface (e.g. inside a harbour).

Brest Experiment (OPIF)

- Ifremer Contract.
 - Collaboration with CETMEF, SHOM.
- Experimental Campaign carried out September 2005.
- Objectives:
 - Validate Oceanpal L2 algorithms, developed at the Barcelona Port, on a site with significant tide and sea-state variability.

Deployments

- Oceanpal installation

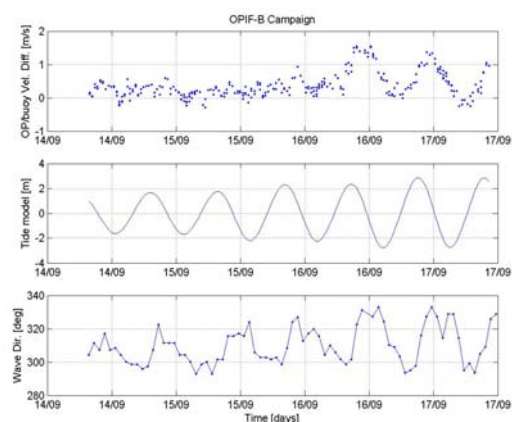
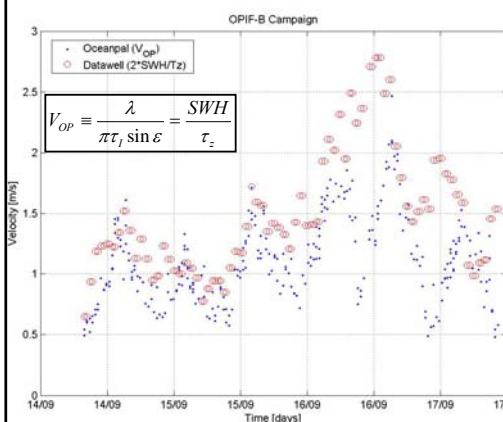


- Datawell buoy from French Ministry of Equipment (CETMEF)



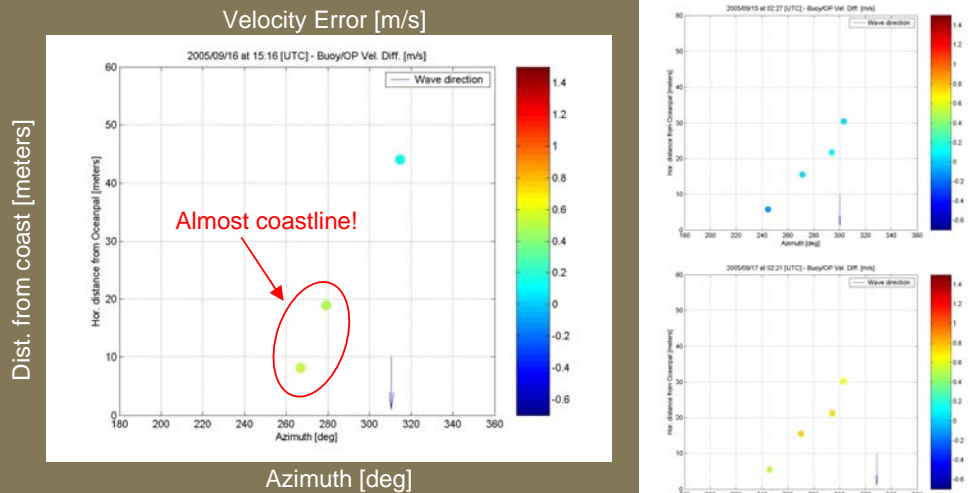
Analysis: Sea State: Velocity

- For the first 2 days, very good agreement with buoy measurements.
- Periodic error, varies with wave direction (Northly waves), sea level and tide gradient.



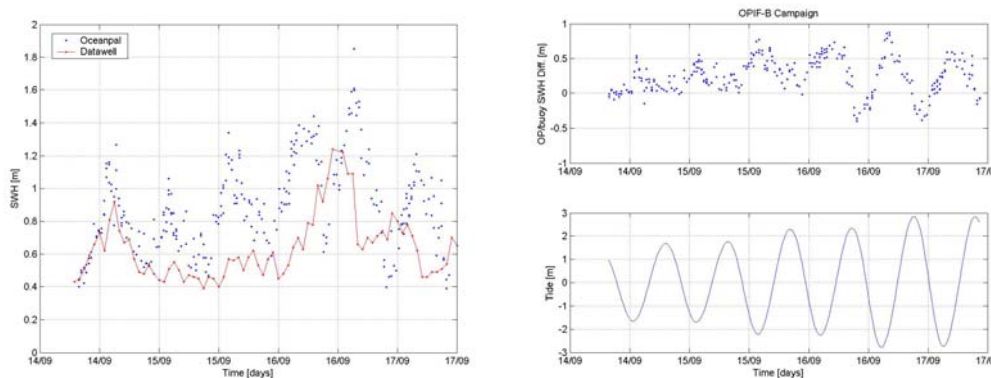
Analysis: Sea State: 2D Map

- Coastal GNSS-R detects spatial variations of the sea-surface roughness.



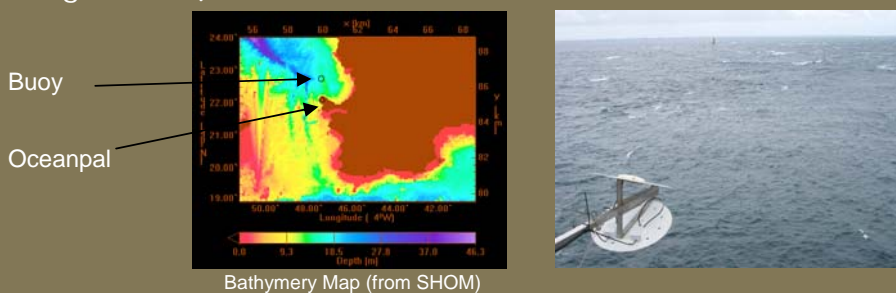
Analysis: Sea State: SWH

- Stronger departures are observed at low tides with strong tidal coefficients.
- Error is periodic and clearly in phase with the tide variations.
- Discrepancies due to the complex signature of the strong tidal currents (associated to the maximum tidal flow gradients) together with the local bathymetry.



OPIF Conclusions

- Successful demonstration of coastal GNSS-R observations for sea-state monitoring applications.
- Surface vertical velocity appears to be a relevant sea-state parameter. Error < 0.5 m/s.
- Strong impact of the local bathymetry on SWH.
- Coastal GNSS-R can depict very local un-homogeneity in sea surface roughness (here due to the strong bathymetric gradients).



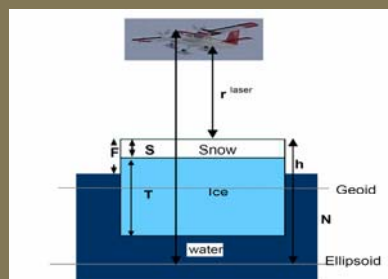
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PARIS Ice Retrievals

- **ESA Contract**
 - Opportunity to gather GNSS reflections over Artic snow/ice regions (ESA project) within the Cryosat Validation Experiment.
 - Collaboration with M. Davidson, C. Buck and DNSC.
- **First Test Campaign carried out May 2006.**
- **Potential future opportunities to fly with ESA.**
- **Objectives:**
 - GNSS-R Data collection together with Interferometric Radar Altimeter (ASIRAS) and laser scanner measurements.
 - Focus on altimetric and scatterometric applications.



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Campaign


- Bad weather conditions.
- Campaign agenda reduced for Svalbard flights.



Flight Plan

Conclusions

- Oceanpal, a GNSS-R instrument for coastal sea-surface monitoring with two initial applications:
 - tide measurements inside a harbour
 - sea-state in open sea
- Campaigns have demonstrated precisions of (after 1 min.)
 - 3 cm for the tide measurements
 - 18 cm for the *SWH* measurements
- Code altimetry (rough-surface) to be implemented soon.
- More flights for ice detection.




Thank you for your attention

<http://starlab.es>


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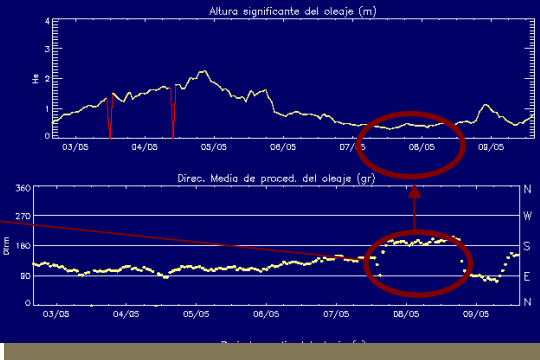


Validation

Oceanpal



Boya Cost Barcelona



Diferencias por periodos especiales

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Coastal Sea-state Algorithm (I)

Ref: Soulat *et al.*, *Geophys. Res. Lett.*, Vol. 31, 2004

Autocorrelation of the interferometric field:

$$\Gamma(\Delta t) \approx A(\sigma_z, l_z, \varepsilon, G_r) \cdot e^{-4k^2 \sigma_z^2 \frac{\Delta t^2}{2\tau_z^2} \sin^2 \varepsilon}$$

$$\Rightarrow \tau_l = \frac{\tau_z}{2k\sigma_z \sin \varepsilon} = \frac{\lambda}{\pi \sin \varepsilon} \frac{\tau_z}{SWH}$$

To first order, τ_l is inverse-proportional to the surface “effective velocity” σ_z / τ_z

Coastal Sea-state Algorithm (II)

Further, a linear relationship is assumed between σ_z and τ_z

So that finally:

$$SWH = SWH_0 + \frac{\alpha}{k\tau_l \sin \varepsilon - \beta}$$

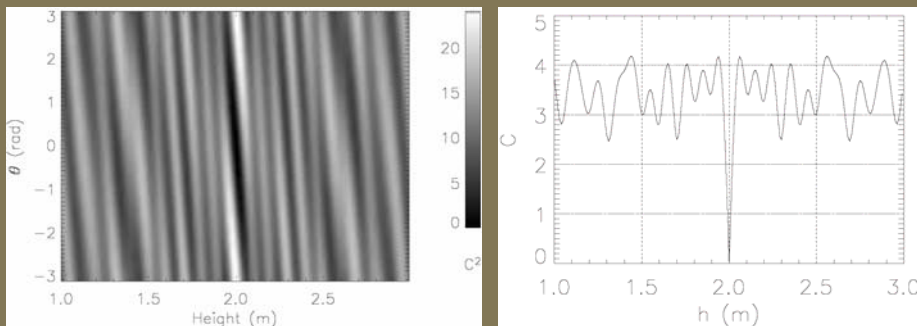
Semi-empirical model where the coefficients SWH_0 , α , β must be calibrated on site.

Coastal Altimetry Algorithm

- System bias assumed constant during the take
- Non-linear cost function:

$$C(h, \theta) = \sum_{p,t} \left| e^{i\tilde{\phi}_p(t)} - e^{i\phi_p(t)} \right|^2$$

- Difficult to minimize jointly for h and θ due to 2π phase wrapping ambiguities (here 6 PRNs from 15 to 78 deg)

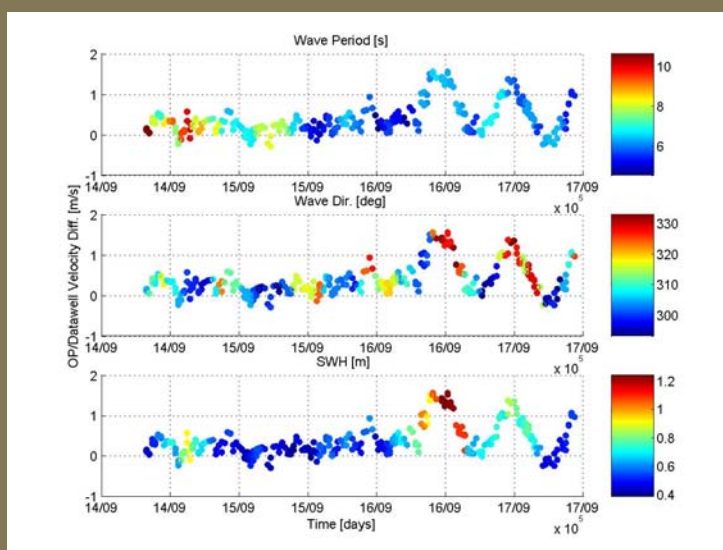


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Velocity Error



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