GNSS-R: NOT ONLY FOR OCEAN

Examples of water and land GNSS-R applications

Starlab's Space Technologies Team

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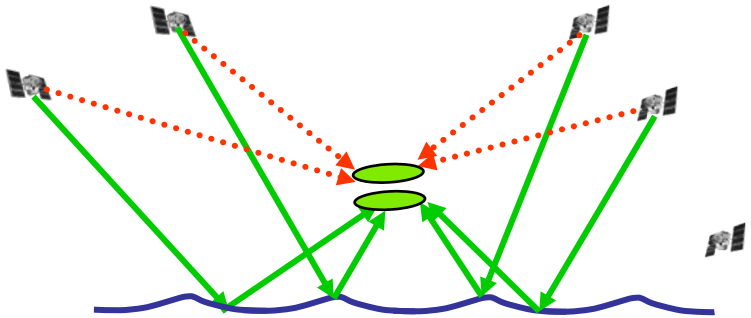
Introduction

The GNSS-R concept and Starlab's activities

The GNSS-R Concept

- Global Navigation Satellite System-Reflections
  - A bistatic (multistatic) radar technique to monitor a reflective surface
- A passive receiver picks up simultaneously direct and the reflected signals emitted by several GNSS satellites
- Sources are: GPS + Augmentation Systems + GIOVEs (now), and GALILEO (future) + GLONASS



- A continuous growing interest on GNSS-R
  1. Global availability and stability of GNSS signals
     - Use of GNSS signals as sources of opportunity
     - Passive nature of instruments (small, and cost effective)
  2. GNSS operation band (L-band): High interaction of L-band with natural medium
- Numerous geophysical parameters to which GNSS signals are sensitive to: significant wave height, tide, lakes level, soil moisture, surface roughness,, vegetation, …
- This increasing interest leads to:
  - Development of scientific applications
  - Creation of new market niches

Starlab's GNSS-R Activities

- Research Lines
  - Sea state monitoring
  - Altimetry applications for sea and in-land waters
  - Soil Moisture and vegetation monitoring

- GNSS-R Instrument development:
  - Fully designed and developed at Starlab Barcelona
  - Originally designed for water applications
  - Modifications done for land applications:
    - calibration chain to compensate for power mismatches among D and R
    - RHCP and LHCP receiving antennas → polarimetric analysis

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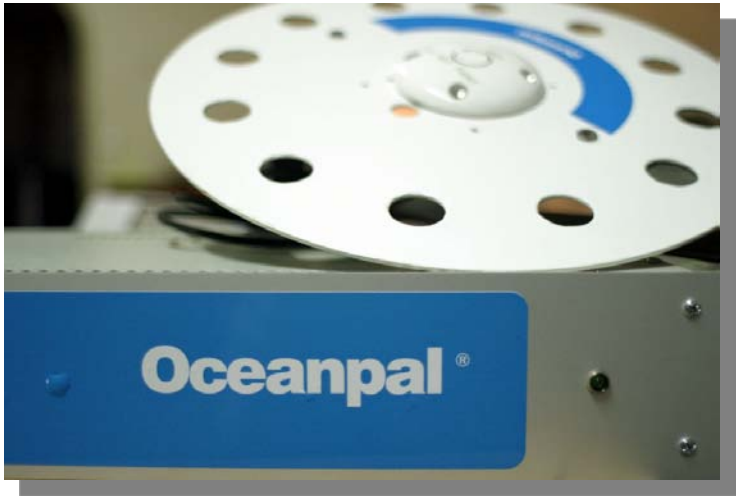

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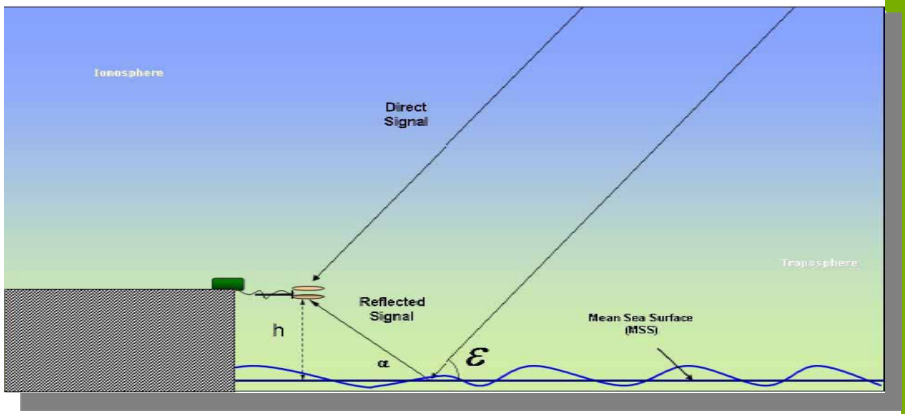
Applications

From Research to Operational Services

Application 1

Sea State Monitoring

- Interferometric Complex Field:
  - Ratio between Reflected, R(t), and Direct, D(t), Waveform peaks
  - Eliminates navigation message and propagation effects
- The algorithm:



Interferometric Complex Field

Sea-surface Coherence time τ_z

Sea-surface model

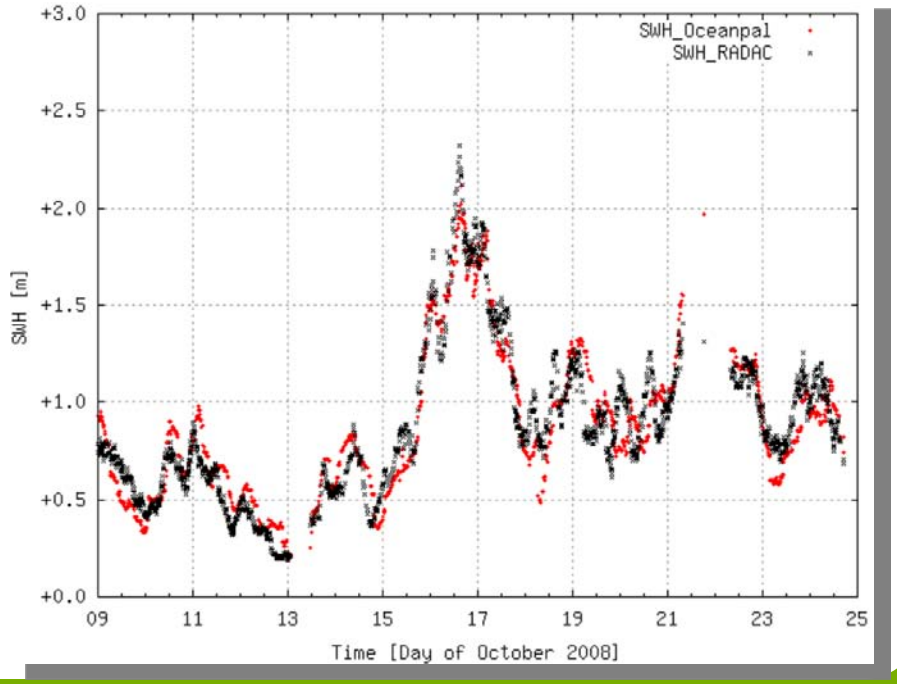
Parameter $SWH = 4.\sigma_z$

$SWH = f(\tau_z, \alpha)$

Semi-empirical model (alpha accounts for on-site calibration parameters)

The Hague Campaign (SWH)

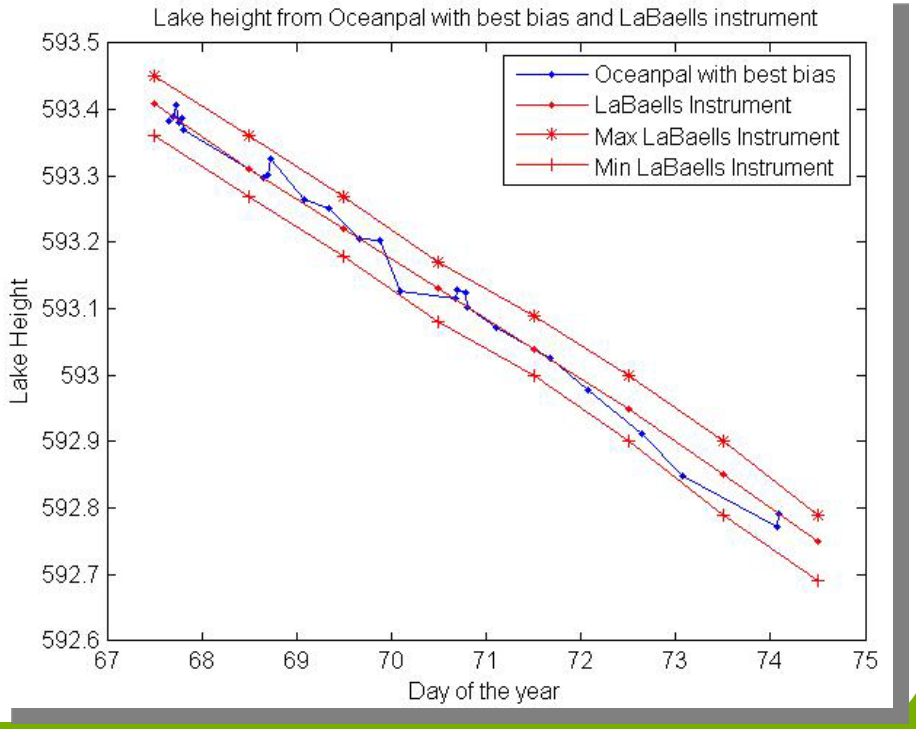
- Scheveningen Pier, the Hague, the Netherlands
- Operational campaign, providing quasi-real time for sea state information
- Long-term comparison of SWH measurements with microwave radar endorsed by **Dutch National Water Agency**
  - rms error < 15 cm, with SWH ranging from 0.5 to 3 m



Application 2

In-Land Waters Level Monitoring

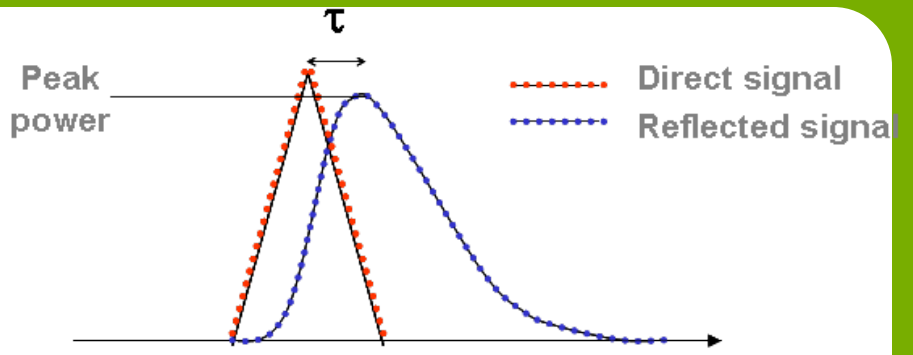
- Phase Altimetry Algorithm:
  - Use of ICF phase to estimate height;
  - Cost function minimization and phase ambiguity method resolution to extract the height information equation:
- La Baells Campaign
  - Water reservoir in Berga, North of Catalonia, Spain (ACA)
  - Offline data delivery
  - Results comparison with in-situ sensor; pressure bubbler with sub-centimetric precision
  - After bias removal, the error standard deviation yields less than 2cm for 5 minutes observation time

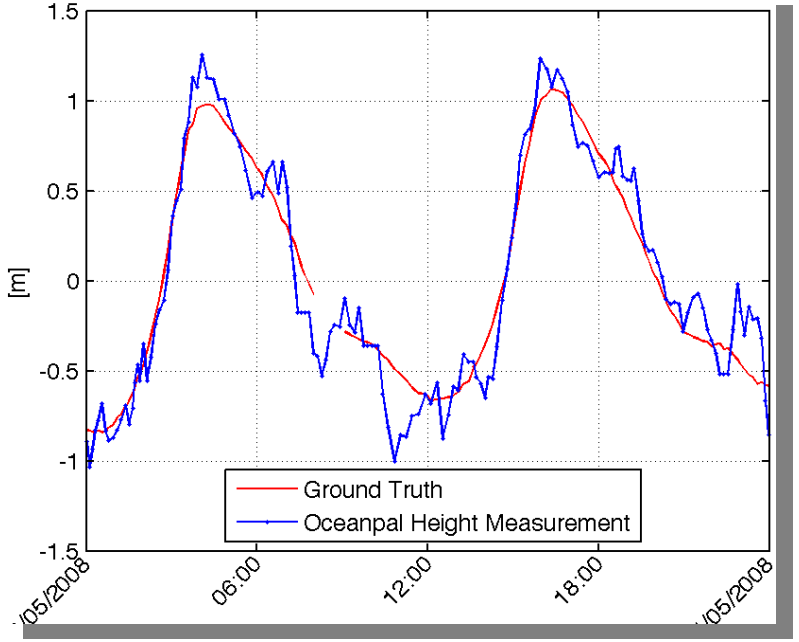


Application 3

Sea Level Monitoring

- Code Altimetry Algorithm
  - Rough surfaces destroy the coherency of the reflected signal
  - Determination of the height information out of the direct and reflected waveform lapse
  - Noisier observables than the phase of the ICF but suitable for sea altimetry applications
- Comparison with RADAC
  - Root mean square error of 12cm with 1 minute integration

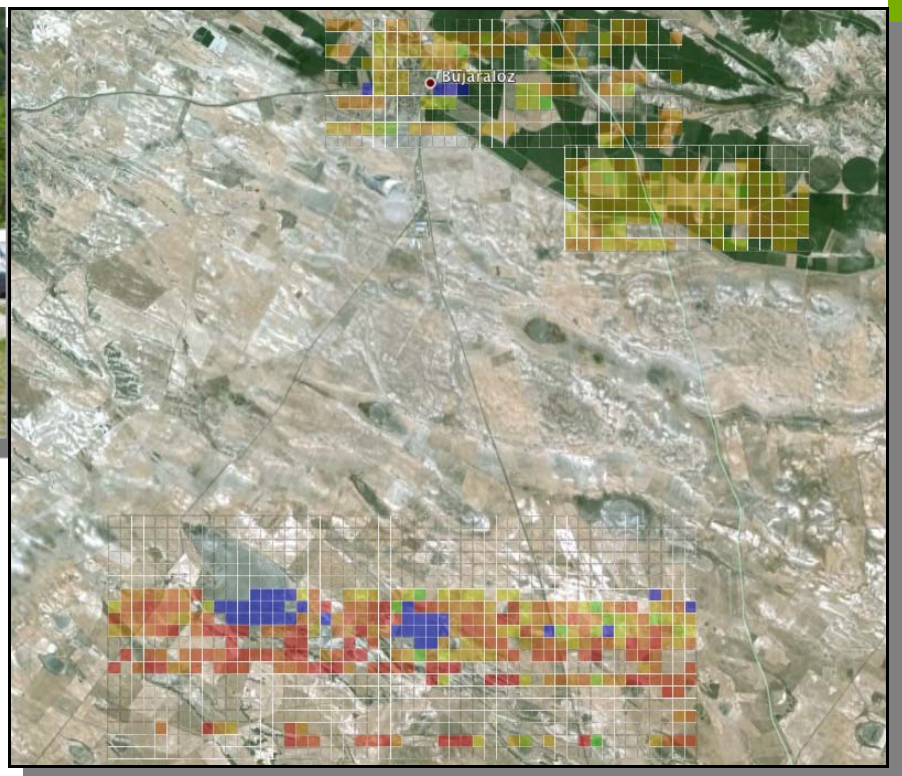




Application 4

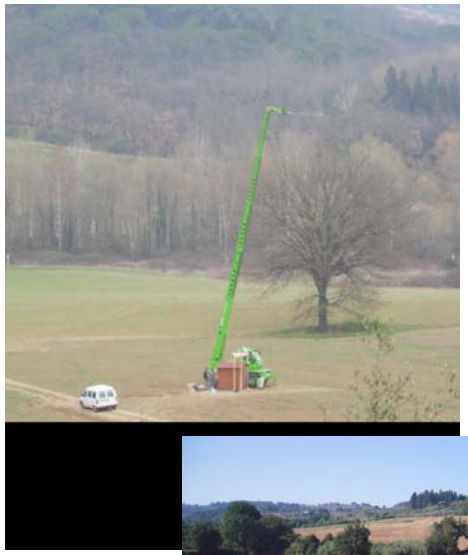
Soil Moisture Applications I

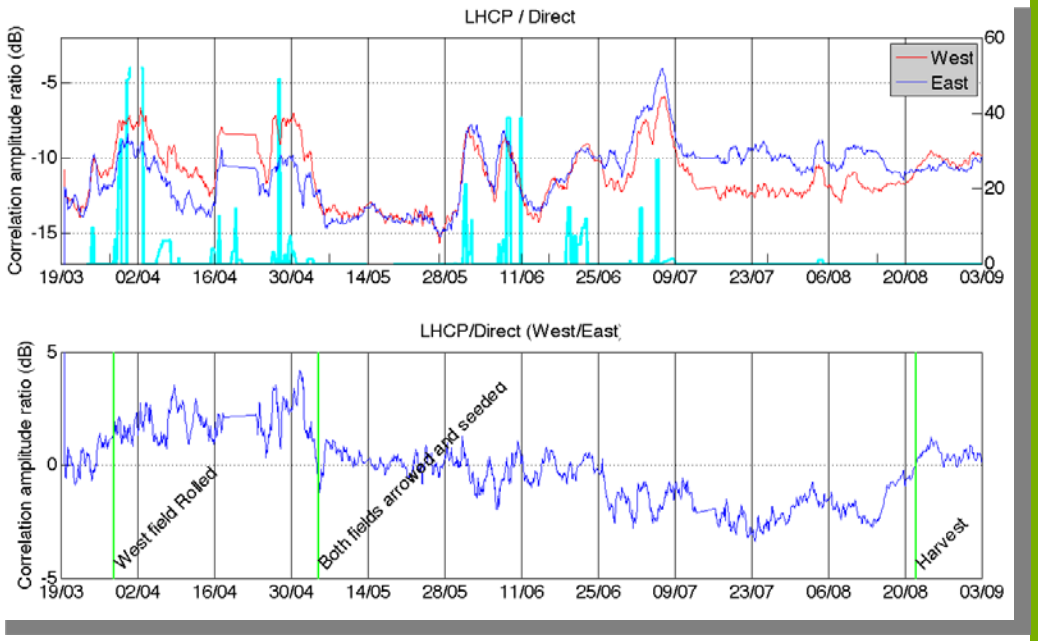
- Soil Moisture determination out of reflected and direct signal power
- SAM ESA (ESTEC) project [from 2007 to 2008]
  - Los Monegros Experiment; Zaragoza (Spain).12th June 2008



Soil Moisture Applications II

- LEIMON ESA (ESTEC) project [from 2008 to 2010]
  - Investigation on combined effects of soil moisture, surface roughness, vegetation
  - Montespertoli Experiment, Florence, Italy (March 2009 - Sept 2009)





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Conclusions

Conclusions

- GNSS-R has become in the last decade a consolidated remote sensing technique
- The increasing interest in GNSS-R contributes to the development of new scientific applications and market niches.
- Starlab has developed several applications
  - Sea State Monitoring (Operational service, quasi-real time SWH data)
    - 15 cm demonstrated precision for wide range SWH
  - In-Land Waters Level Monitoring (towards operational service)
    - demonstrated < 2 cm precision
  - Sea Level Monitoring (towards operational service)
    - demonstrated < 15 cm precision
  - Soil Moisture & Vegetation (research)
- Such local based applications could be path opener to similar global range applications by GNSS-R payloads on-board satellites

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Thank you for your attention