The GNSS-R Eddy Experiment

Airborne Sea-Surface Altimetry with GPS Reflections

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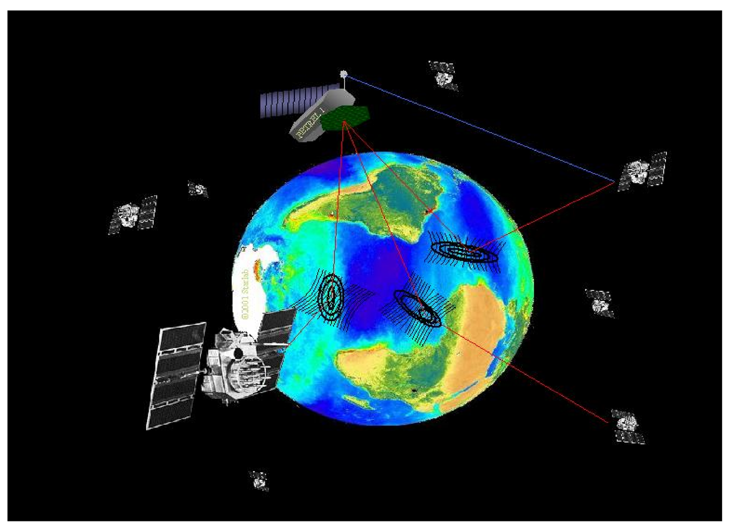
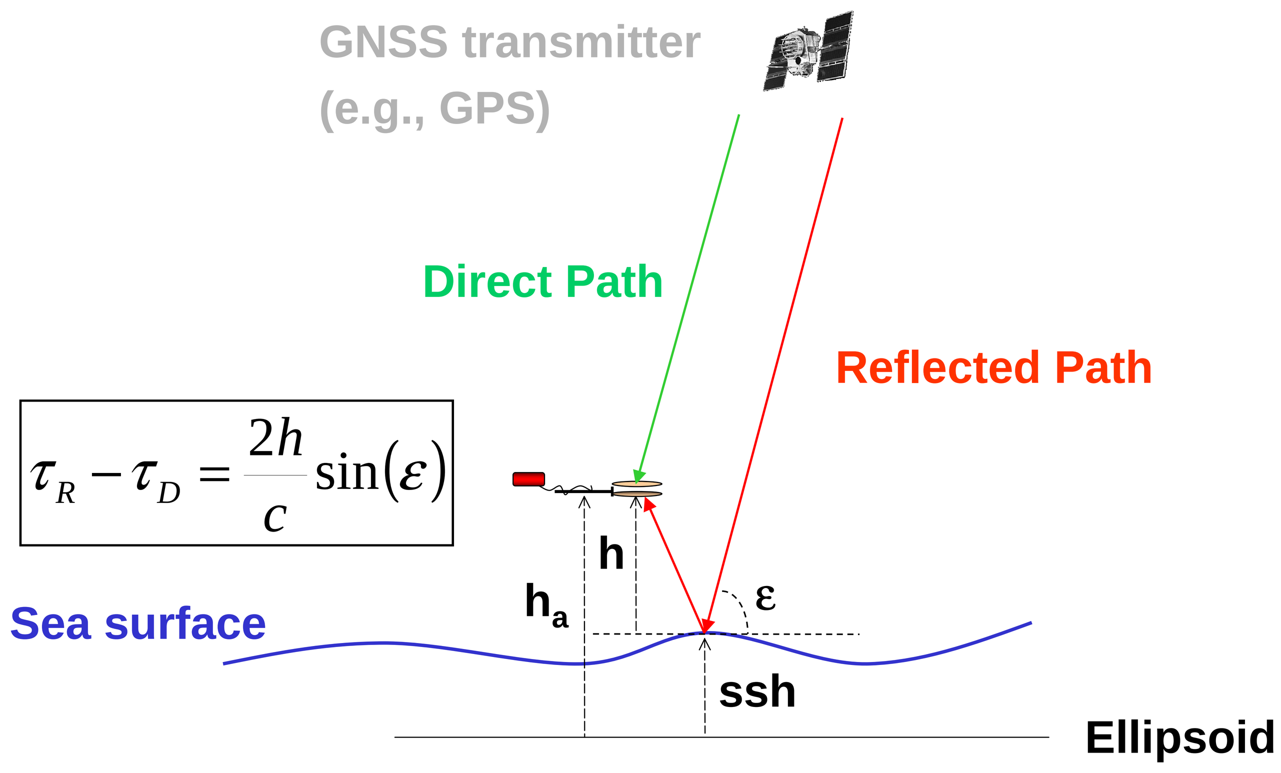
Context and Concept

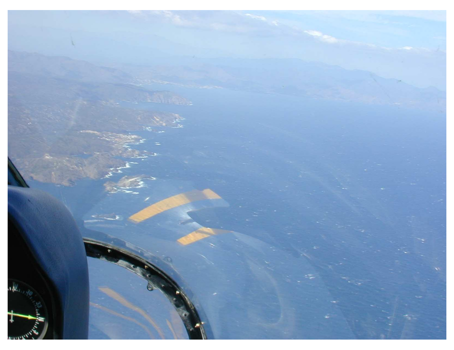
- Under ESA contract PARIS-GAMMA Phase-1 (TRP ETP 137.A)
- Development of technologies for sea-surface mesoscale altimetry with GNSS reflected signals (GNSS-R)
- Demonstrate GNSS-R airborne C/A code altimetry
- Provide a precise reference for a potential future space mission

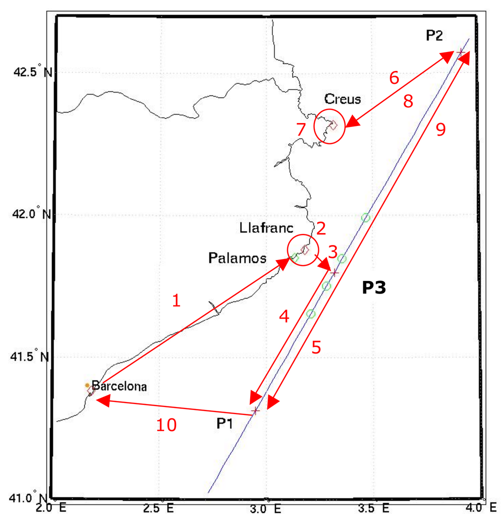


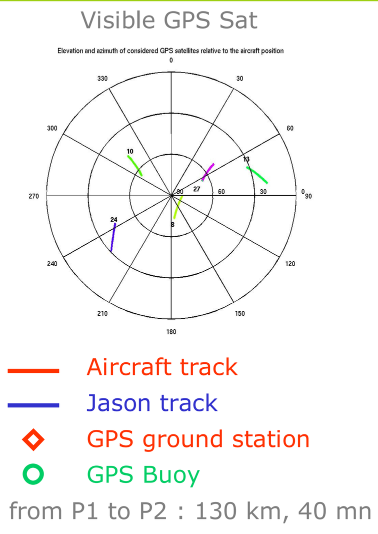


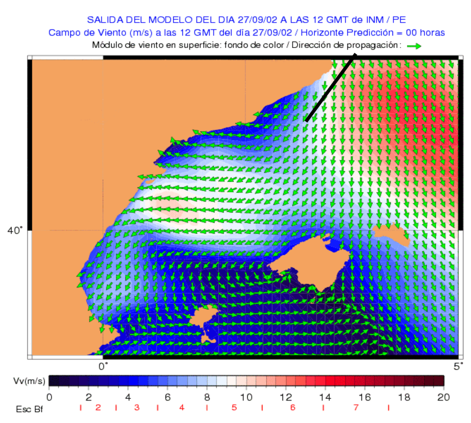
The Experiment

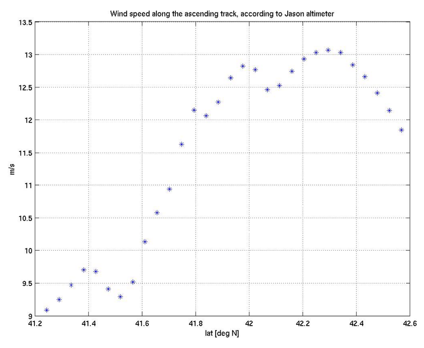
- Catalunya coast, 27th September 2002
- Aircraft @ 1 km altitude, 50 m/s speed
- Acquisition of raw direct/reflected L1 GPS data
- GPS station network + INS for precise kinematics
- Ground truth: JASON + buoys data



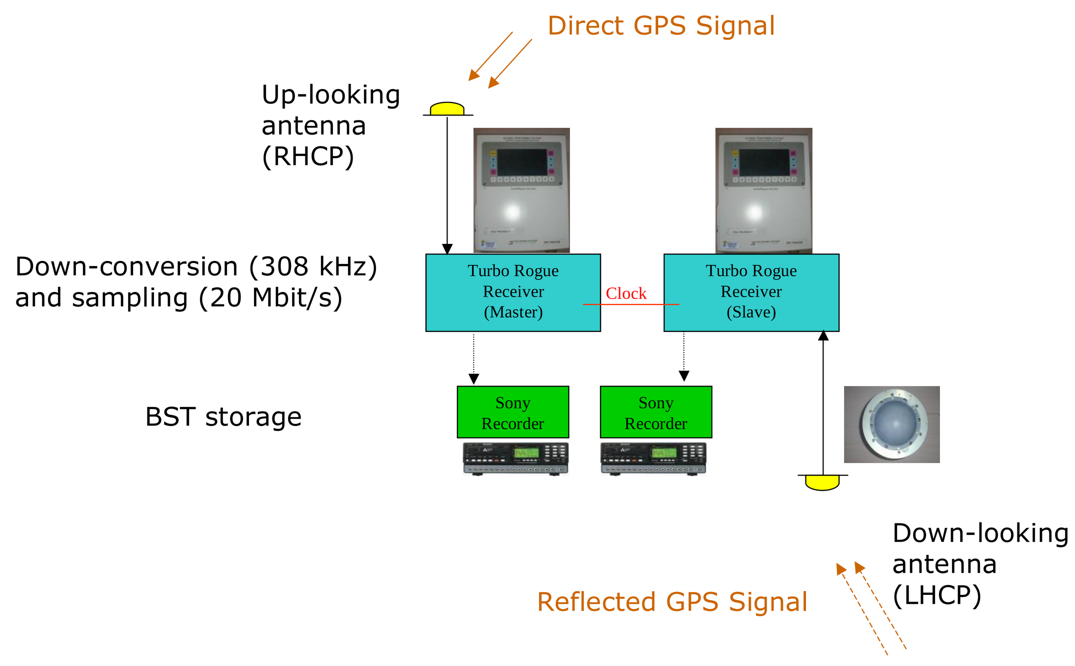




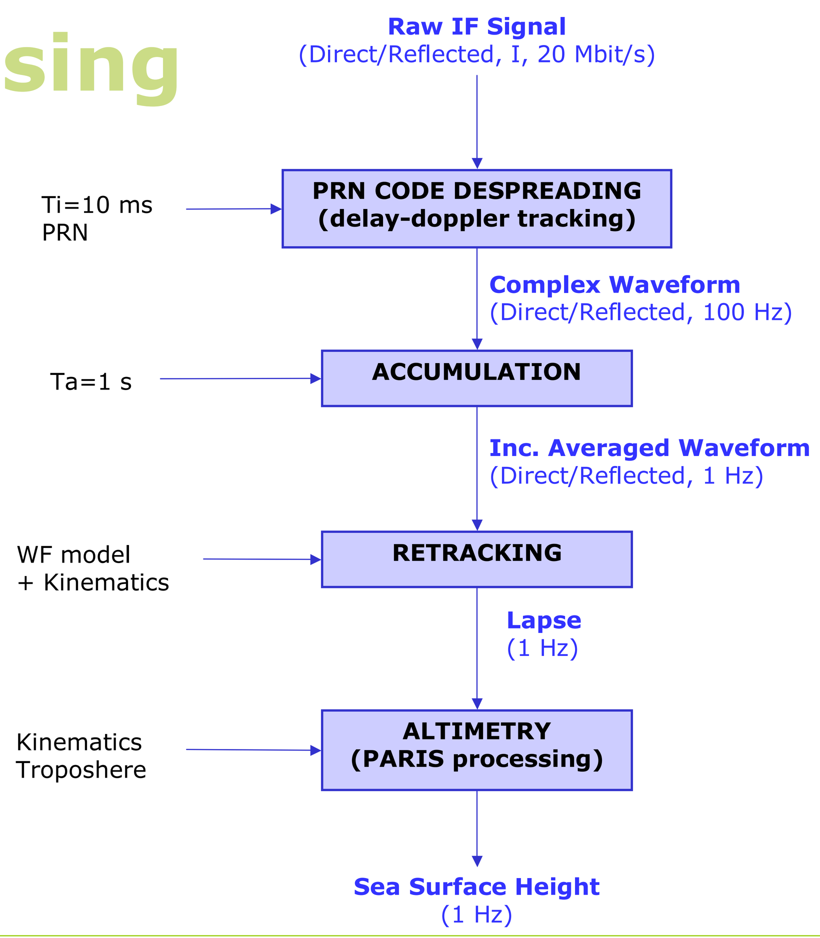


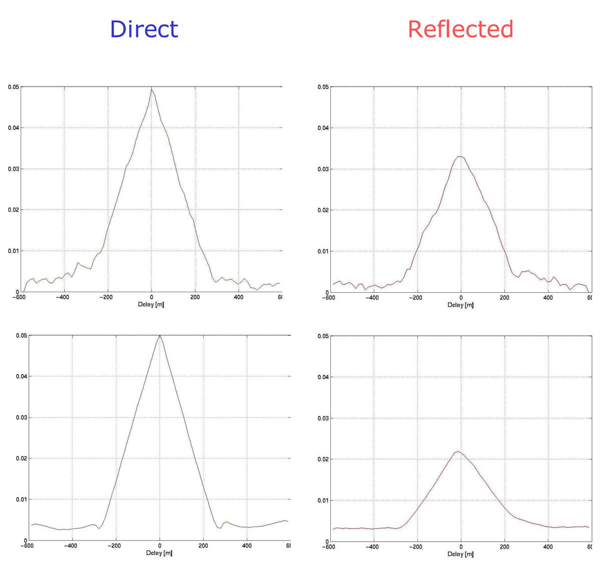


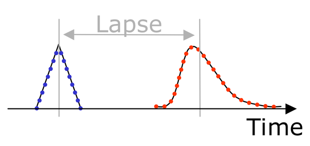
Rough sea conditions...



Processing

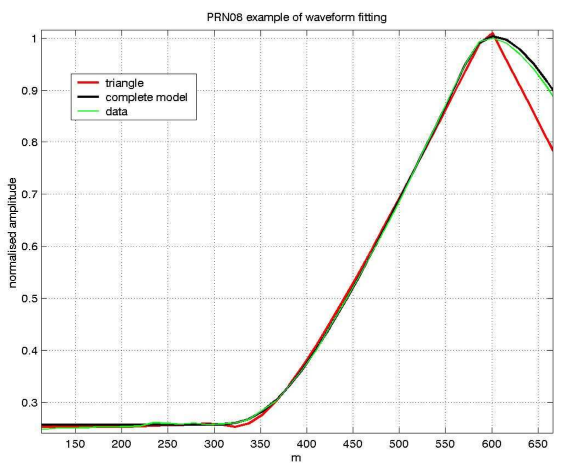






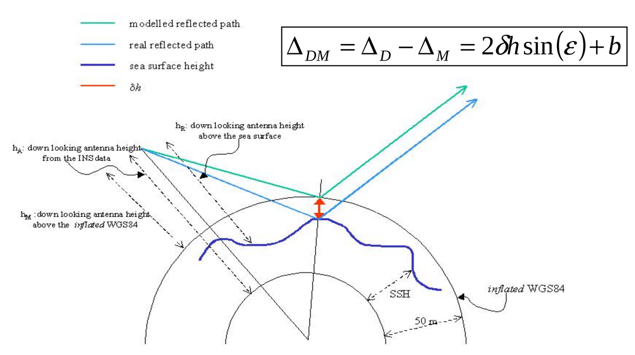
RETRACKING

- Waveform model:
  - Direct: PRN autocorrelation
  - Reflected: Bistatic Radar Equation (Kirchoff+GO)
- Numerical Optimization:
  - Steepest slope descent algorithm
- Parameters:
  - delay, scaling factor
  - SWH (but irrelevant)
  - directional sea-roughness (3 DMSS)
  - antenna rotation (known up to some degrees)



ALTIMETRY

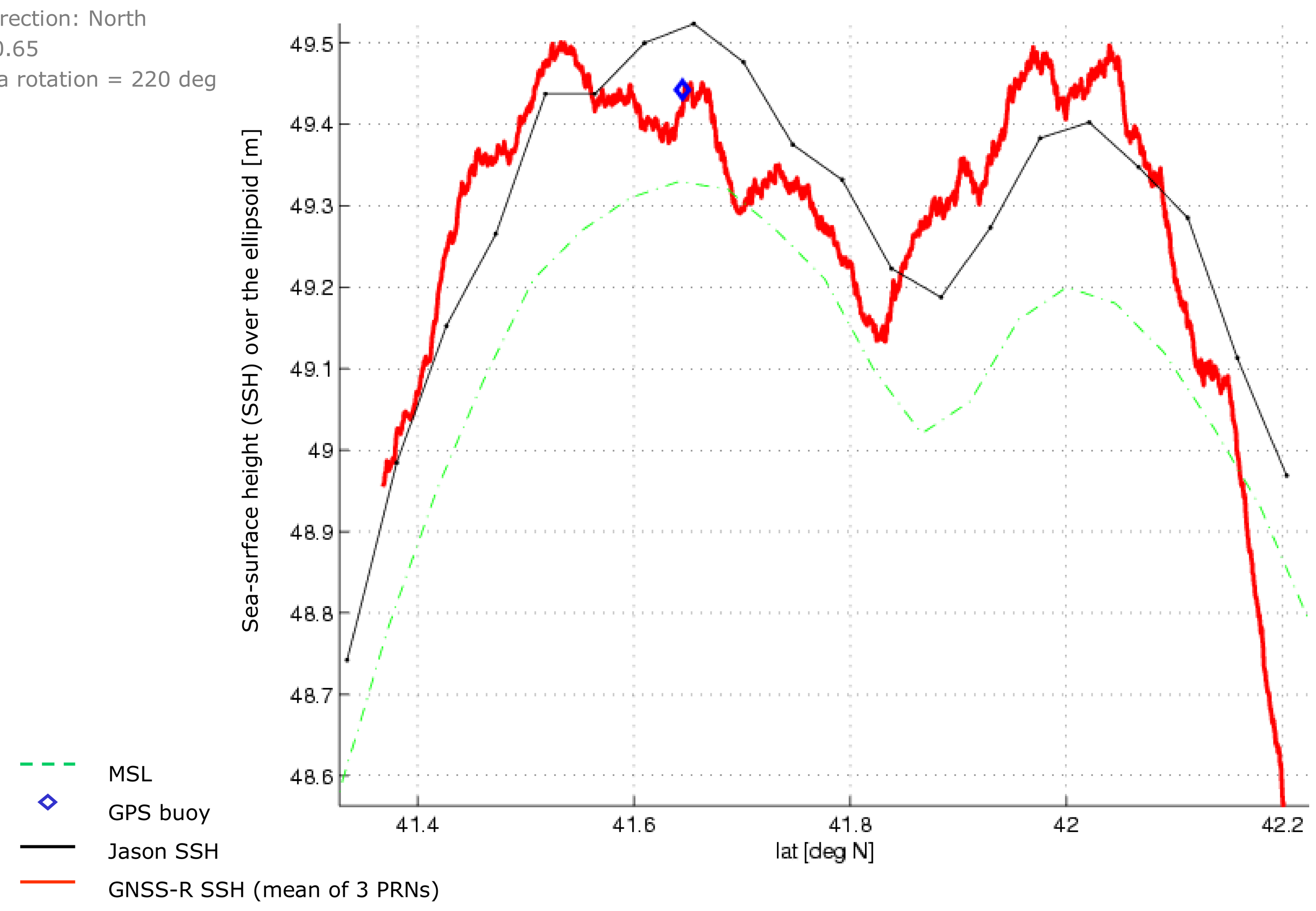
- Differential version of the PARIS equation
- Atmospherics:
  - Ionosphere delay cancels out in airborne GNSS-R
  - Troposphere does not. Components are dry and wet
    - Dry easily estimated using surface level pressure (1024 mb)
    - Wet estimated from SSM/I data, agrees with GPS
    - Correction applied to the lapse: 60 cm/sin(elev) (±5 cm)



Results

Altimetric results filtered @ 200 s (10 km) obtained with the following assumptions:

- wind speed 10 m/s
- wind direction: North
- SPI = 0.65
- antenna rotation = 220 deg



CONCLUSION

- The Eddy Experiment can be considered a success:
  - Precision after one-second: around **3 m** (lapse RMS for each PRN)
  - Accuracy w.r.t. Jason SSH: around **10 cm** (mean of 3 PRNs)
- We believe this represents a significant step along the GNSS-R road.

RECOMMENDATIONS AND PERSPECTIVES:

- Future experiments needed at higher altitudes (5 to 10 km). Low altitude flights represent the worst case scenario:
  - severe sea-roughness (DMSS) impact
  - multipath in reflected signal
- Sensitivity to antenna pattern. Needs to be precisely calibrated
- A PARIS Aircraft Demonstrator (PAD) is now being built (PARIS-GAMMA Phase-2).
  - multi-beam system with on-board signal processing
  - design seeks to minimize the space risk.

* All Starlab authors have contributed signifcantly; the Starlab author list has been ordered randomly

N.B. Full papers available online: http://arxiv.org/physics/0310092 and http://arxiv.org/physics/0310093