Sea Surface Topography with CyGNSS and SMAP: Preliminary Assessment

GNSS+R 2017 Workshop
Ann Arbor, MI, May 23-25 2017

Cinzia Zuffada*, Rashmi Shah*, Hugo Carreno-Luengo*, Zhijin Li*, Stephen Lowe*, Tong Lee*, Maria Paola Clarizia^, Paolo Cipollini^^, Chris Ruf^*

*Jet Propulsion Laboratory/Caltech
^ University of Michigan
^^ NOC, Southampton, UK
Outline

• Motivation and relevant recent work
• A look at available space datasets
  – TDS-1, SMAP, CyGNSS
• Plans for future activities
Altimetry with GNSS-R

• Characteristics
  – Measurement relies on the time difference between the peak of the direct signal and the maximum derivative of LE of the reflected signal
  – SNR of ocean reflections expected to limit measurement accuracy in most practical cases, requiring antenna gains far higher than those used for scatterometry DDMs
  – Proof-of-concept demonstration of altimetry with TDS-1 data shows SSH RMS error of 7-8 m compared to DTU maps (Clarizia et al., GRL, 2016)
Altimetry with GNSS-R

• Assessing ability of 1-2m RMS SSH to resolve ocean mesoscale applied to synthetic data (Li et al, IEEE JSTARS, 2016)
  – Simple averaging would require huge measurement number to beat the error down (√N)
  – Mapping SSH fields with an efficient optimal interpolation algorithm (2Dvar) filters out some of the error (better than √N)
  • Chosen decorrelation length scale is related to the measurement footprint, and affects the spatial scales resolved/suppresses by the filter
Simulation Results
Li et al, *IEEE JSTARS*, 2016

From ground truth, a first guess field is generated by filtering out the dynamic signal of mesoscale variability.

Synthetic fields correspond to hypothetical receivers on COSMIC 2B, for two days worth of reflections, assuming both GPS and GLONASS.

Power spectral densities for 3 ocean regions in case a)

Mapped fields realistically represent mesoscale features down to 100 km.
SMAP Geometry

Source: Carreno et al, MDPI Remote Sensing, in press
GNSS Reflectometry with SMAP

• After radar transmitter ceased to function in mid 2015, JPL had the opportunity to retune the receiver (1.25 MHz bandwidth) to the GPS L2C frequency for a reflectometry research experiment

• 1.5 year-long data set, dual polarization (H&V)

• Antenna gain ~36 dB, rotating at ~4 sec period, captures direct GPS signal as leakage

• SMAP has no GPS for POD, orbits are good to ~100-300 m
SMAP Ocean Reflections

SMAP Signal-to-Noise Ratio H-Pol [dB]
Evidence of Coherence

SMAP TE/LE Ratio H-Pol [dB]

Zoom over Indonesia
CyGNSS Ocean Reflections

Indonesia is chosen as a case study region
Indonesian Throughflow (ITF)

- The low-latitude pathway for warm, fresh water to move from the Pacific to the Indian Ocean
- The water transports of 15. Sv, in comparison to the Gulf Stream of 30 Sv in the Florida Current
- Carry with it the eggs and larvae of the marine life of the Indo-Pacific, which is a diverse area containing over 4000 identified species, compared to around 1000 in the Red Sea and 400 in the Caribbean

SSH Signals: 15 cm above average in the Pacific to the northwest of the Indonesian archipelago; 15 cm below average in the Indian Ocean to the south

1 Sv = 1 million cubic metres per second. The entire global input of fresh water from rivers to the ocean is about 1.2 Sv
Sea Surface Height Anomaly Variability

- Great temporal and spatial variability, with an amplitude of as large as 30 cm
- Need of higher temporal and spatial resolution

Jason 2 Product
Significant Wave Height Variability

- Great temporal and spatial variability
- Need of higher temporal and spatial resolution

Jason 2 Product
Wind Speed Variability

WS Jul. 15 – Aug. 5, 2015
WS Feb. 18 – Mar. 8, 2016

Jason Product
Spatial Coverage of Data

Spatial location of:
- SMAP (one year of data)
- Jason-2 (traditional altimetry orbit)
- Jason-3 (traditional altimetry orbit)

Spatial location of:
- CyGNSS (20 days of data, antenna gain > 10 dB)
- Jason-2 (interleaved orbit)
- Jason-3 (traditional altimetry orbit)

It is observed that CyGNSS already has more data than SMAP GPS reflections.
SMAP SNR and Jason 2/3 SWH
Collocated data spatially (within 3 km) and temporally (36 hours)

Relationship between Jason 2/3 SWH and SMAP SNR suggests the possibility of coherent component
SMAP SNR and Jason 2/3 Wind Speed

Collocated data spatially (within 3 km) and temporally (36 hours)

Relationship between Jason 2/3 WS and SMAP SNR suggests the possibility of coherent component
Relationship between Jason 2/3 SWH and CyGNSS SNR suggests the possibility of coherent component

CYGNSS SNR and Jason 2/3 SWH

Collocated data spatially (within 3 km) and temporally (36 hours)
CYGNSS SNR and Jason 2/3 Wind Speed

Collocated data spatially (within 3 km) and temporally (36 hours)

Relationship between Jason 2/3 WS and CyGNSS SNR suggests the possibility of coherent component
Hitting a Snag ...

• Unable to duplicate SSH result obtained by Clarizia et al, GRL 2016, with CyGNSS data
  – Implementation of the exact same algorithm shows 5 km error over WGS84
  – Currently examining the CyGNSS variables and metadata, suspecting an error

• SMAP dataset currently not usable for altimetry
  – Orbit error could be reduced considerably
Next Steps

• Obtain SSH from CyGNSS data
  – Might require cross comparison with TDS-1 metadata?

• Assimilate SSH in ROMS
  – Assess ability to resolve dynamics of ITF

• Assess expected altimetry error of SMAP reflectometry as a function of improved orbits