

Validating Precipitable Water Vapor from Shipborne GNSS Observation using Ground-based and Spaceborne Data

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IGS Workshop

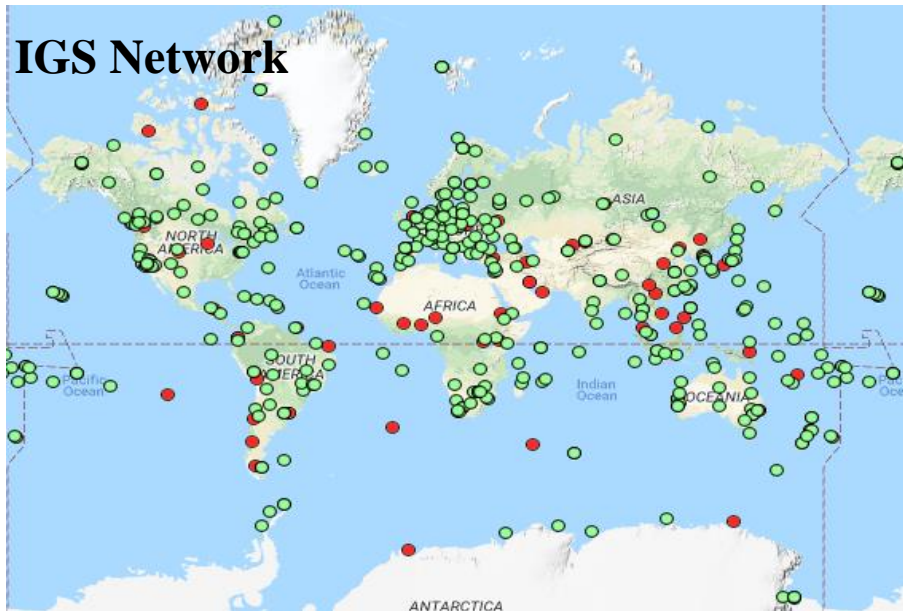
29.10-02.11, 2018, Wuhan, China

Overview

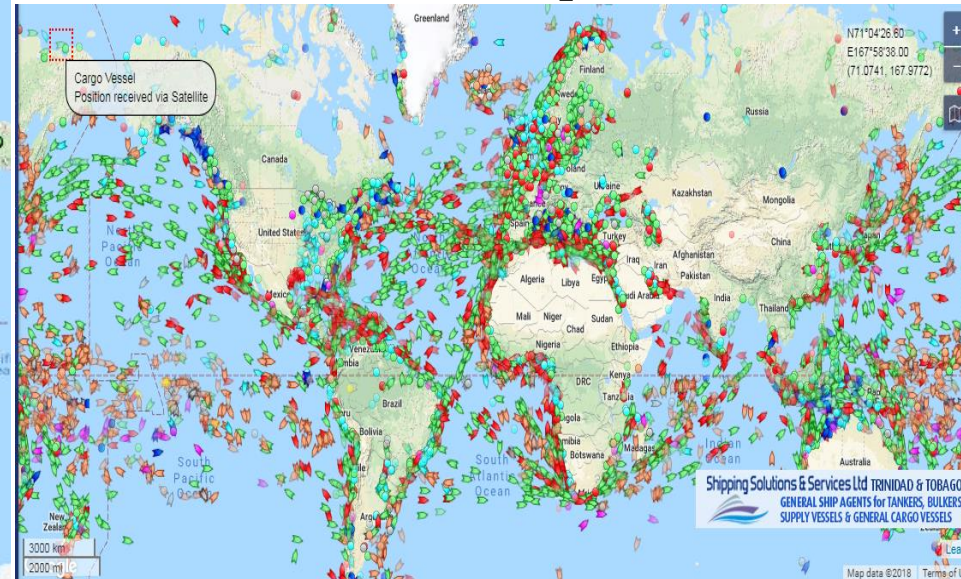
- **Background**
- **The Fram Strait Experiment**
- **GNSS Data Processing**
- **Results**
 - ZTD validation using ground GNSS stations
 - PWV validation using NWP model and radiosonde profiles
 - PWV comparison with WVR onboard altimetry satellites
- **Summary**

Background : GNSS Meteorology

- **Ground-based GNSS atmosphere sounding**
 - GNSS ZTD/PWV: with 6 mm /1 mm accuracy
 - GNSS stations limited to mainland, islands
- **Shipborne GNSS atmosphere sounding**
 - Chadwell, 2001; Rocken, 2005; M. Fujita, 2008
 - To Extend GNSS Meteorology to Ocean



~170,000 ships via AIS



Background: *Shipborne GNSS Applications*

- **To Retrieve Tropospheric Delays Over Ocean**
 - To Improve Weather Forecast
- **To Calibrate ZWD of Onboard WVR for Altimetry Satellites**
 - **SARAL** a joint French-Indian altimetry satellite
 - **HY-2A** an ocean obs./monitoring satellite of China, launched in 2011
- **To Estimate Sea Surface Height**
- **What accuracy could be achieved?**

<https://www.flickr.com/photos/eumetsat/17391300405>

The Fram Strait Experiment in 2016

- **GNSS-Reflectometry Experiment**

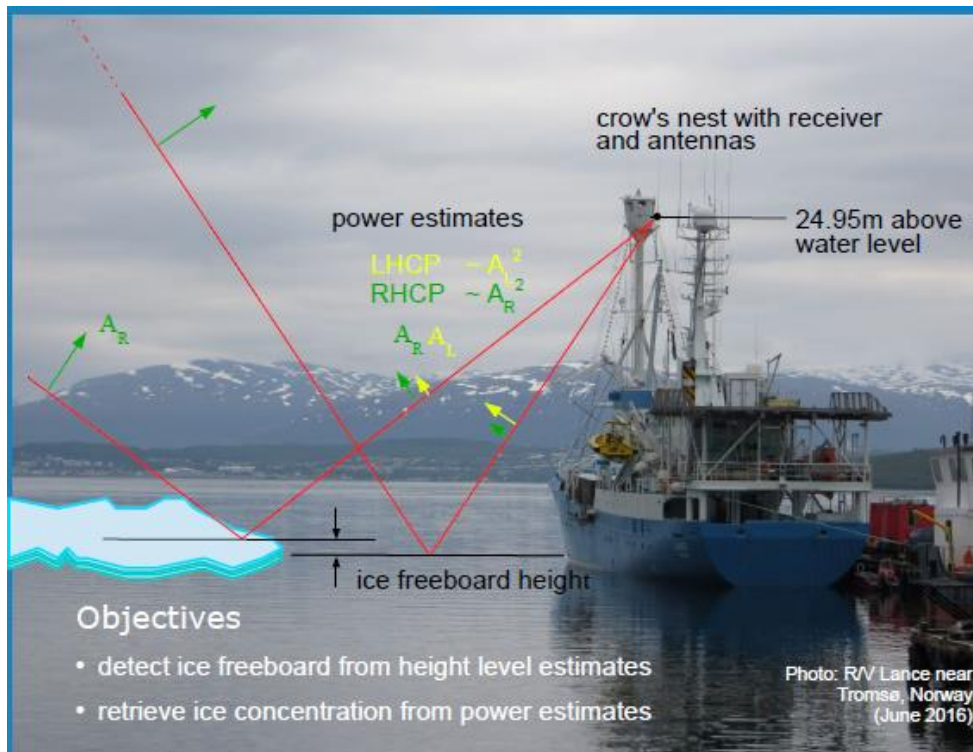
- GNSS-R antenna on ship mast
- Detect ice freeboard height
- Retrieve ice concentration

- **Location : Fram Strait**

- Between Greenland and Svalbard

- **Carrier : RV Lance (~60 m)**

- **Cruise from DOY 238-257**

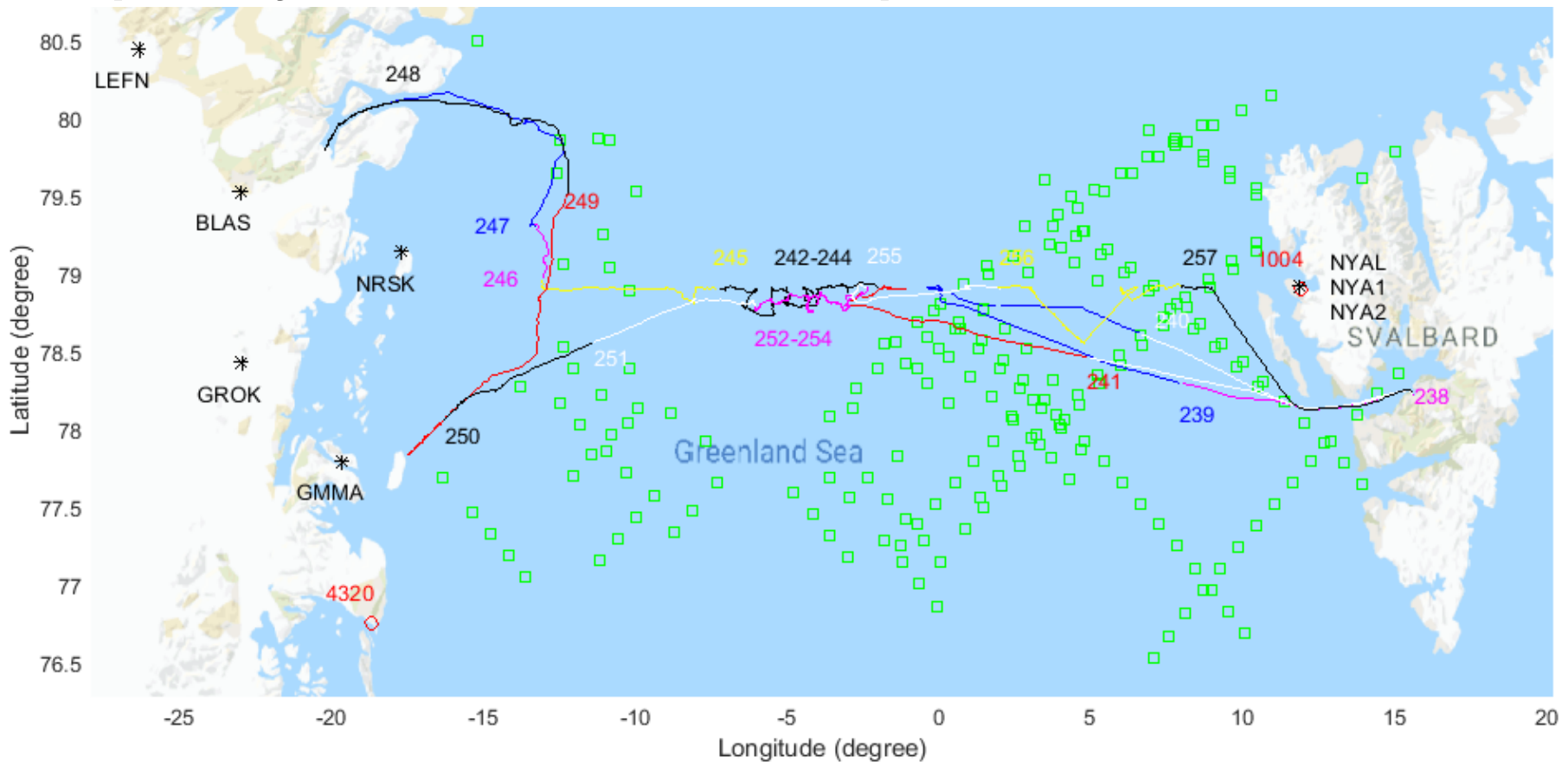


Cruise Trajectory

- **Cruise from DOY 238-257**

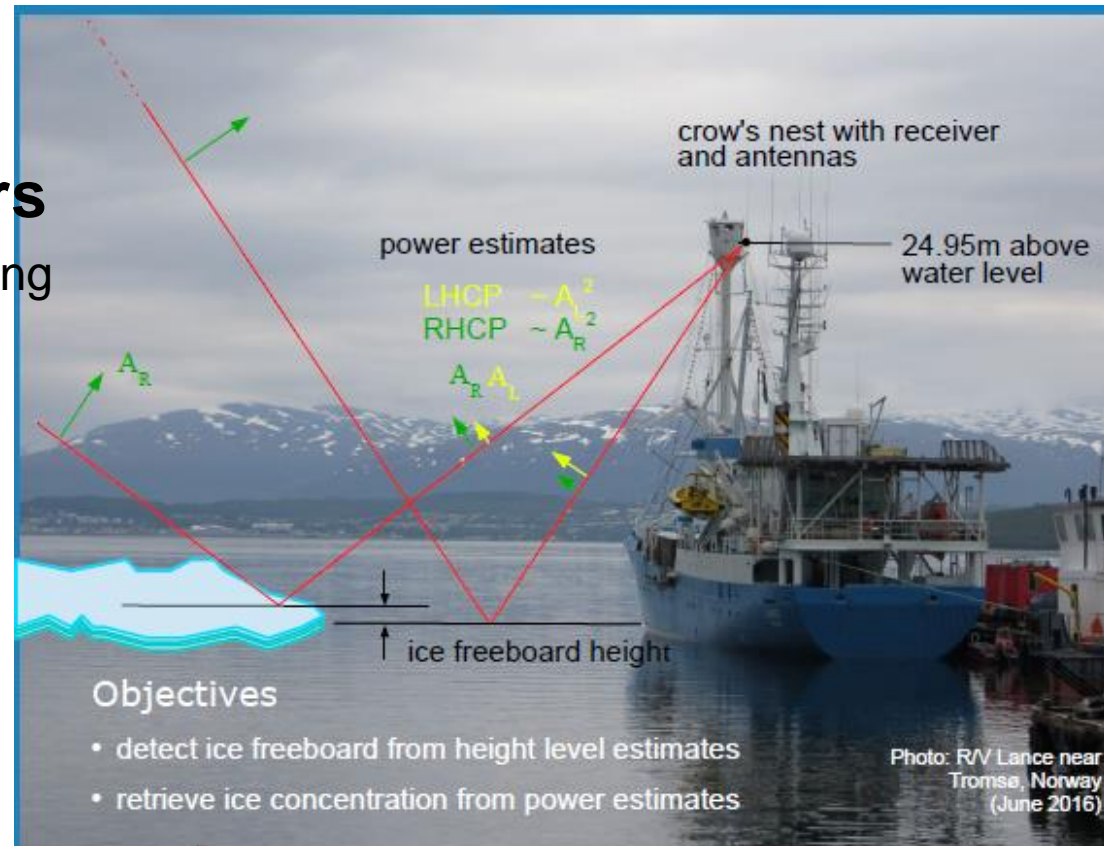
- Svalbard to Greenland: 238 to 249
- Greenland to Svalbard: 250 to 257

- **Repetivity & Crossover for Comparison**



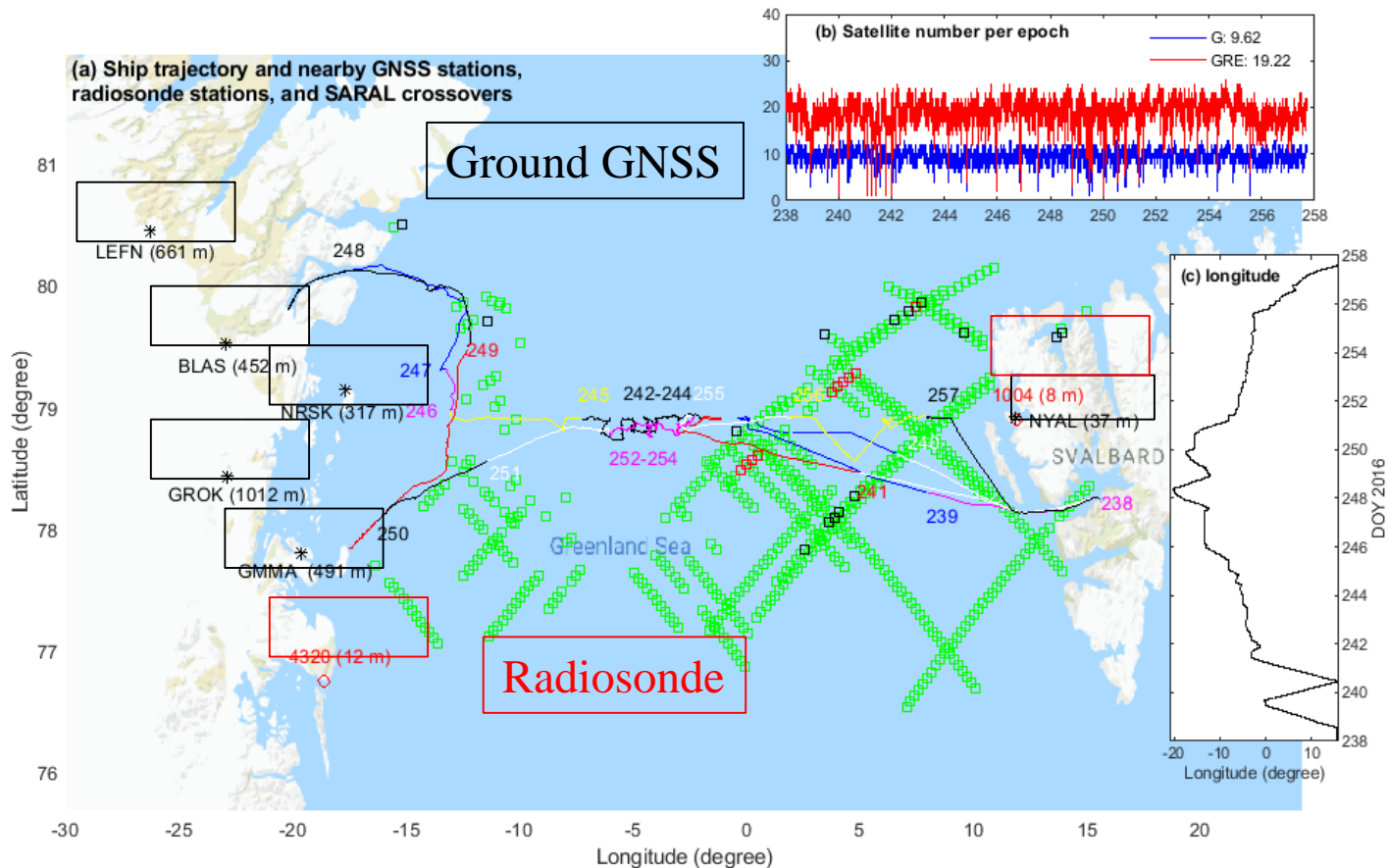
Experimental Sensors

- GNSS-R antenna on ship nest
- **GNSS geodetic antenna for precise positioning**
 - 1-Hz GPS/GLONASS/Galileo observations
- **Meteorological sensors**
 - Pressure, temperature
 - Wind speed
- **Ship motion sensors**
 - Heave, pitch, roll, heading



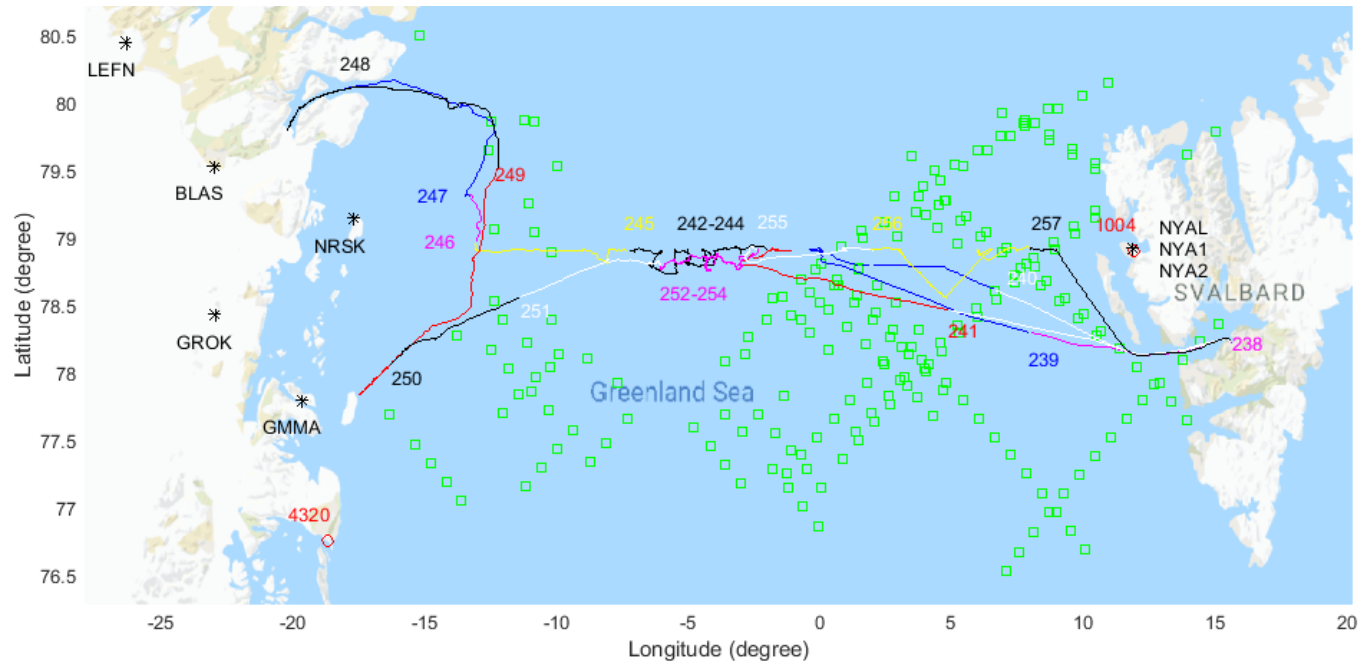
Data Collected

- GNSS obs. for Positioning
- GNSS stations along coast
- Ship Attitude / Wind Speed
- Radiosonde Data
- WVR onboard SARAL a joint French-Indian altimetry satellite
- Numerical Weather Model



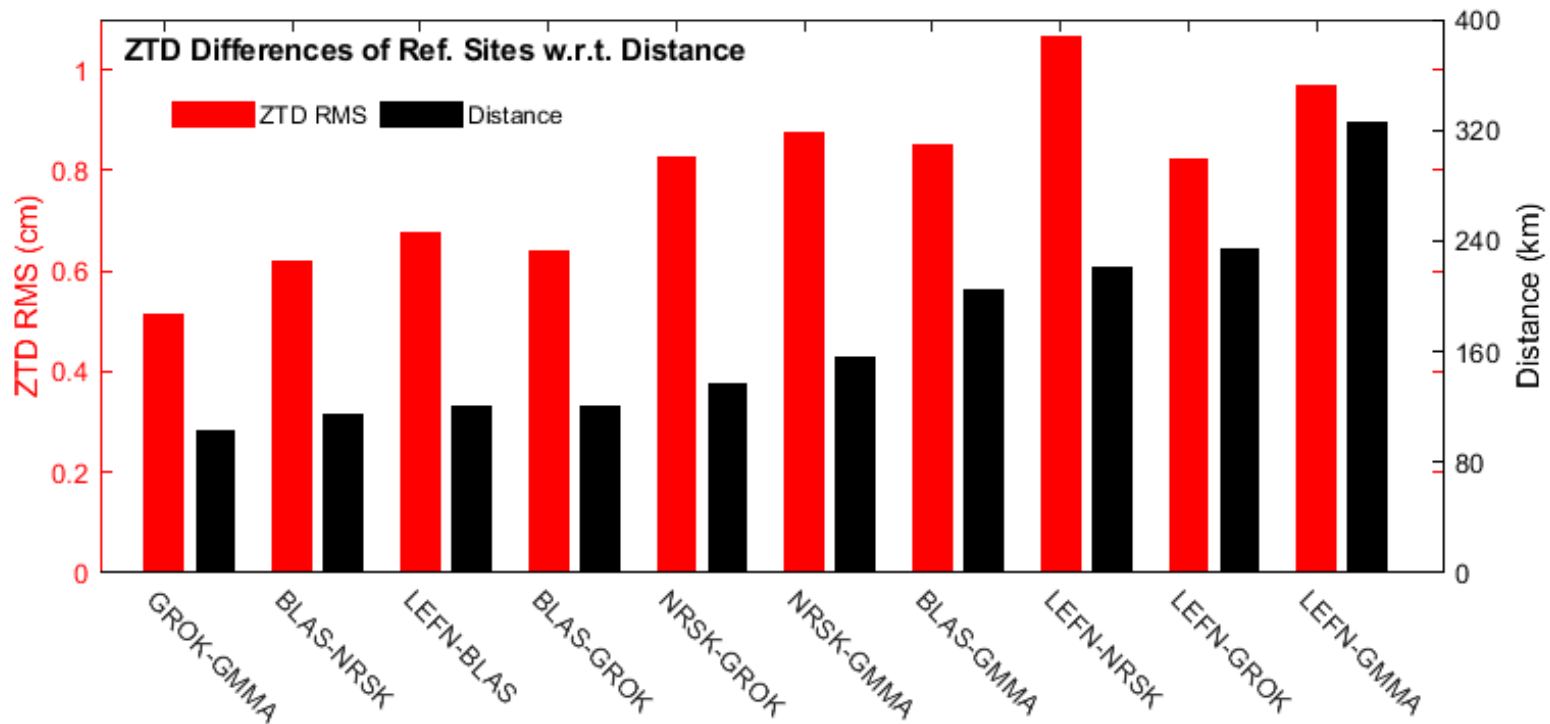
GNSS Data Processing

- **GNSS Observations at Ground Stations**
- **Shipborne GNSS Observations**
 - GPS-only and Multi-GNSS G/R/E PPP in kinematic mode
 - ZWD estimated as random walk process
 - 30s sampling rate, daily post-processing
- **Positioning And Navigation Data Analyst (PANDA)**



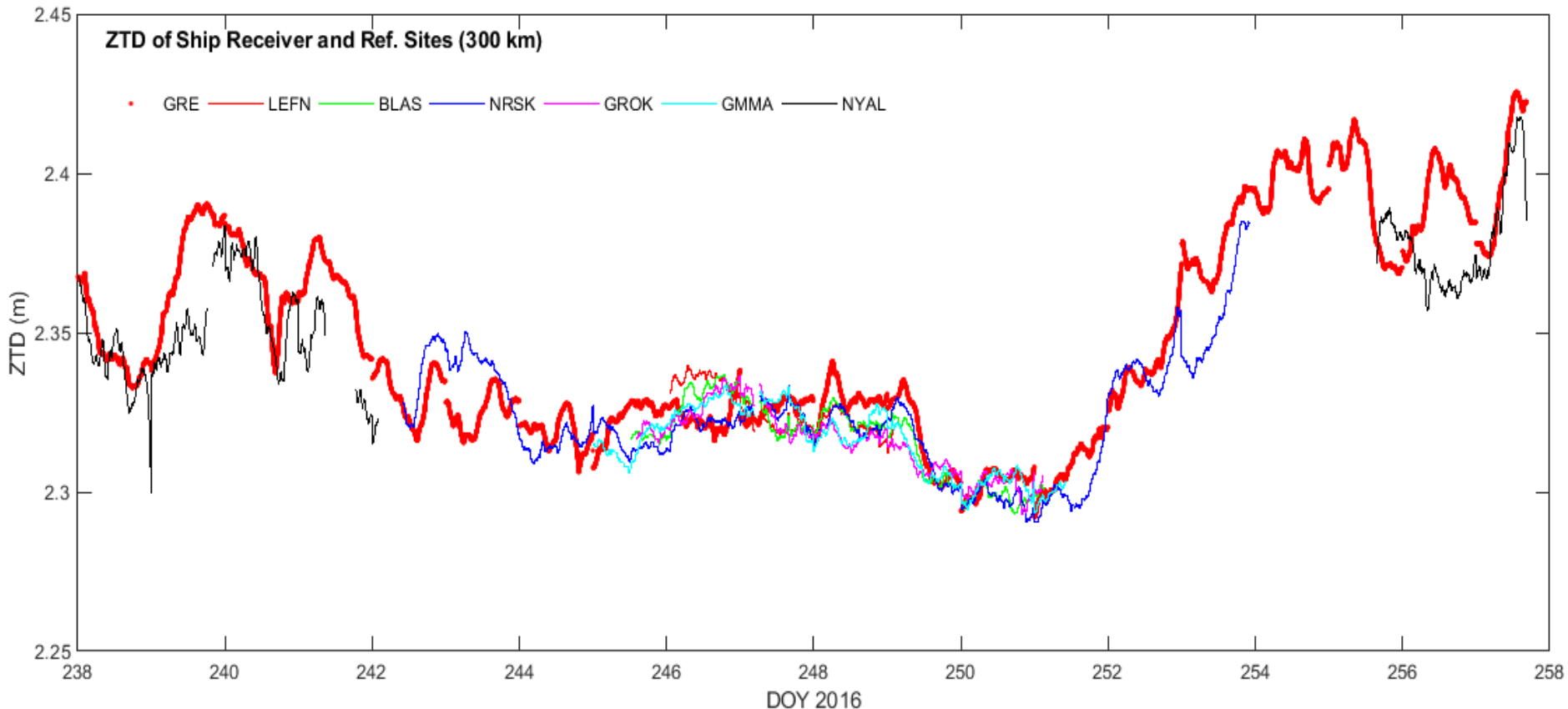
GNSS ZTD at Ground Stations

- **Daily static PPP ZTD**
 - RMS 0.40 cm Compared to IGS final
- **Aligned to Shipborne Antenna Elevation**
 - Elevation (height above sea level) from 37 m to 1012 m
- **ZTD Correlation Along With Inter-station Distances**



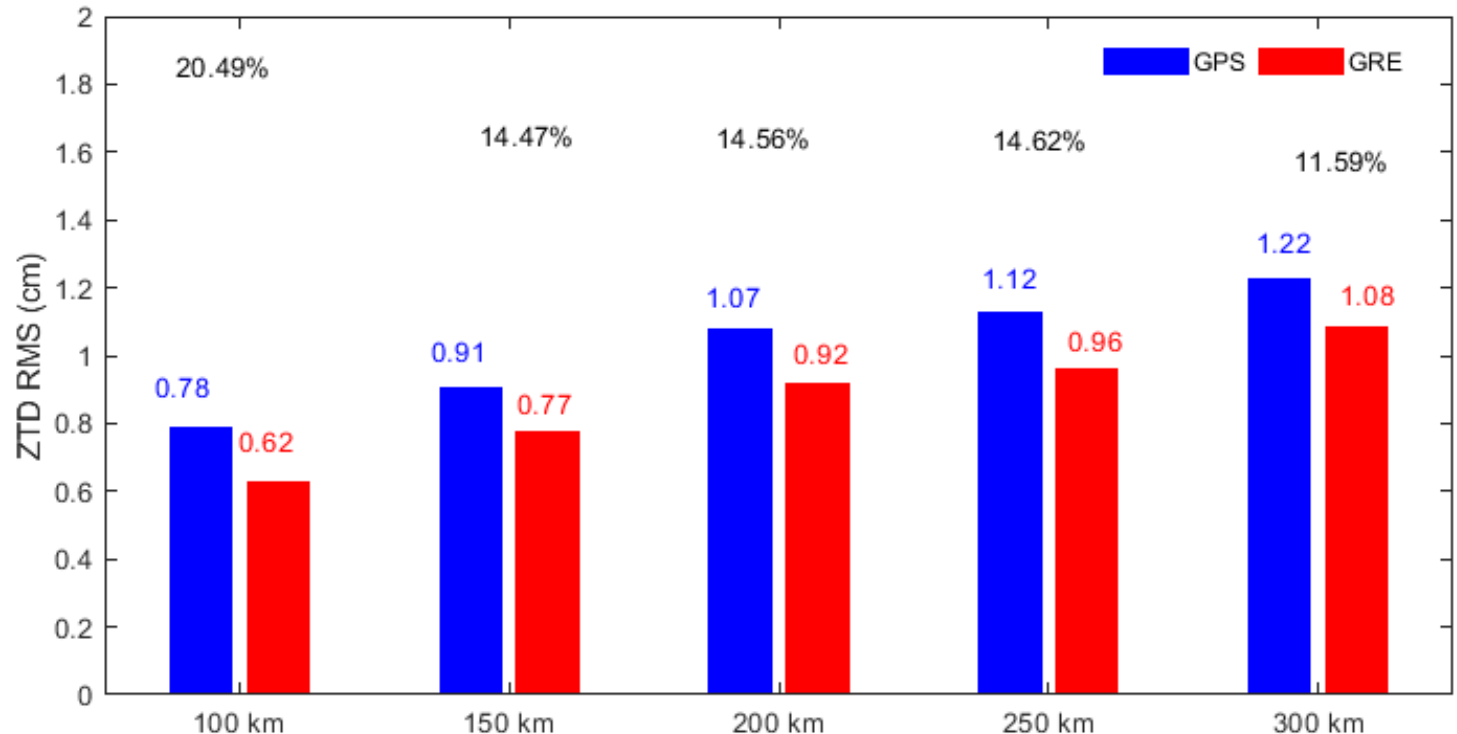
Results – Shipborne vs Ground Stations

- ZTD comparison with ground GNSS stations within 300 km
- Good agreement with ground reference GNSS stations



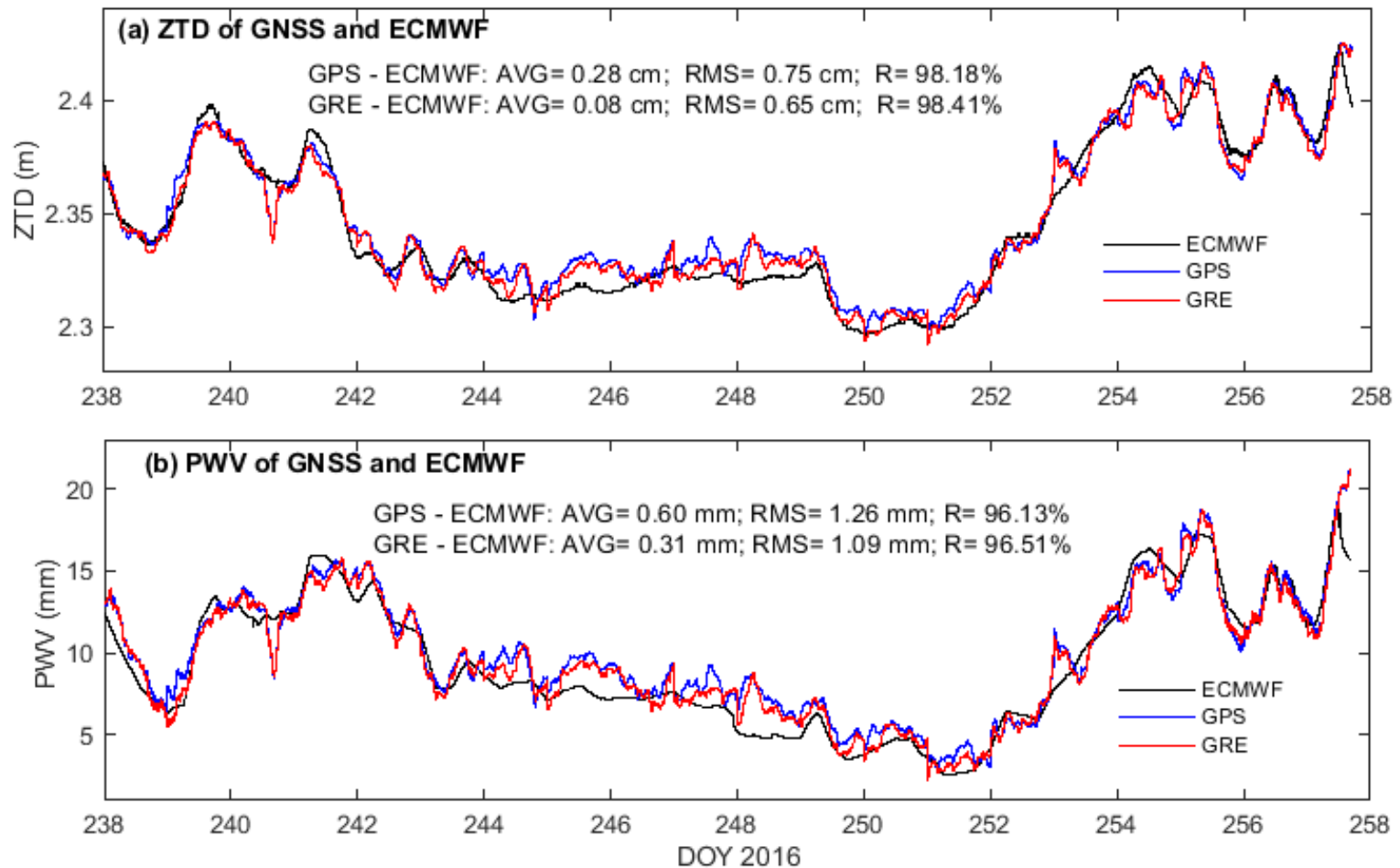
Results – Shipborne vs Ground Stations

- **Multi-GNSS ~0.6 cm RMS within 100 km**
- **Multi-GNSS ~1.1 cm RMS within 300 km**
- **Multi-GNSS Improvement**
 - ~12% (300 km), ~20% (100 km)



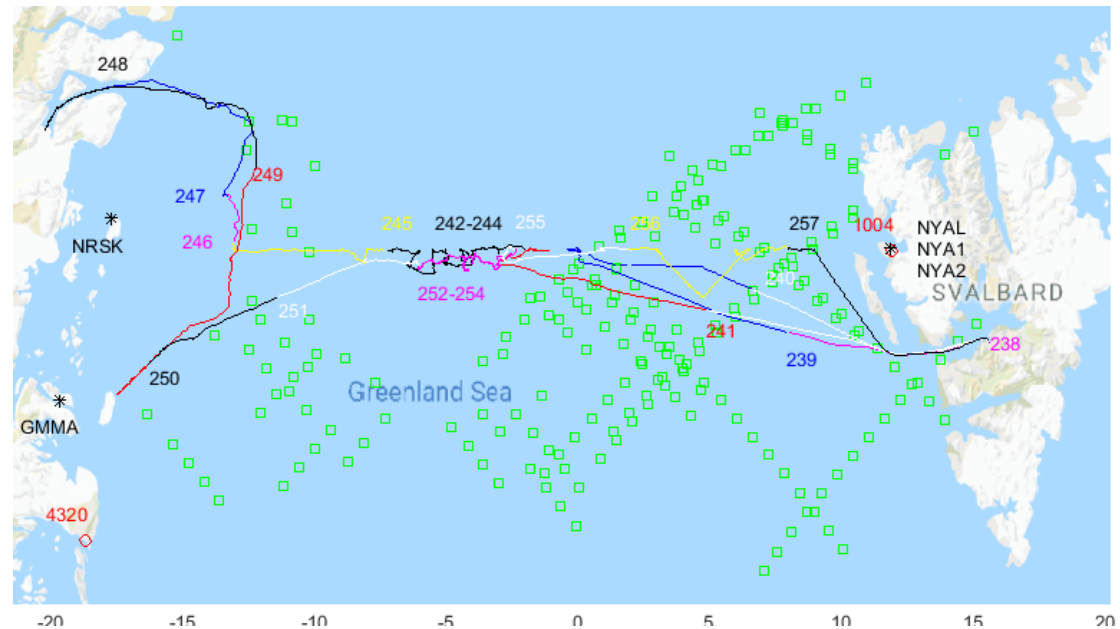
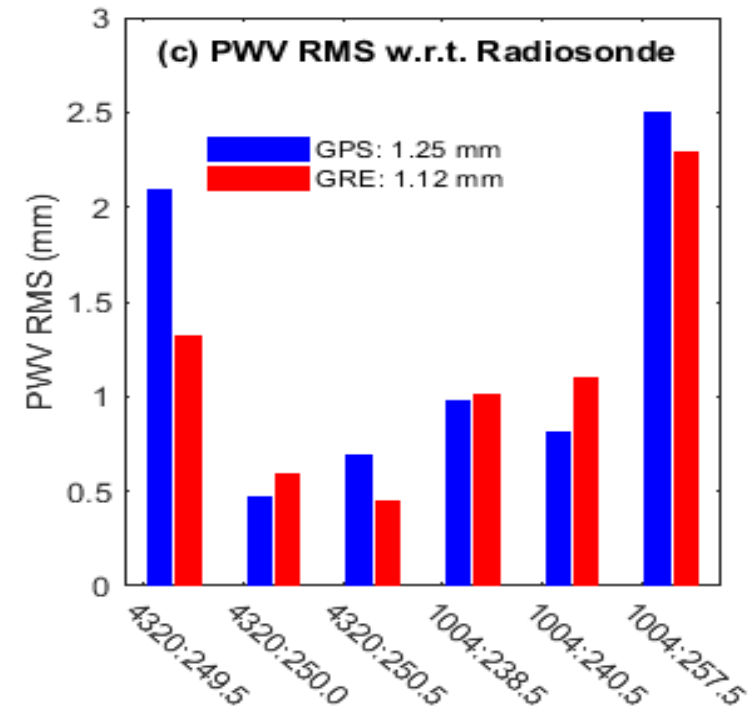
Results – Shipborne vs ECMWF

- Multi-GNSS ZTD : 0.65 cm, correlation 98.4%
- Multi-GNSS PWV :1.09 mm, correlation. 96.5%
- Multi-GNSS vs GPS : ~10% improvement



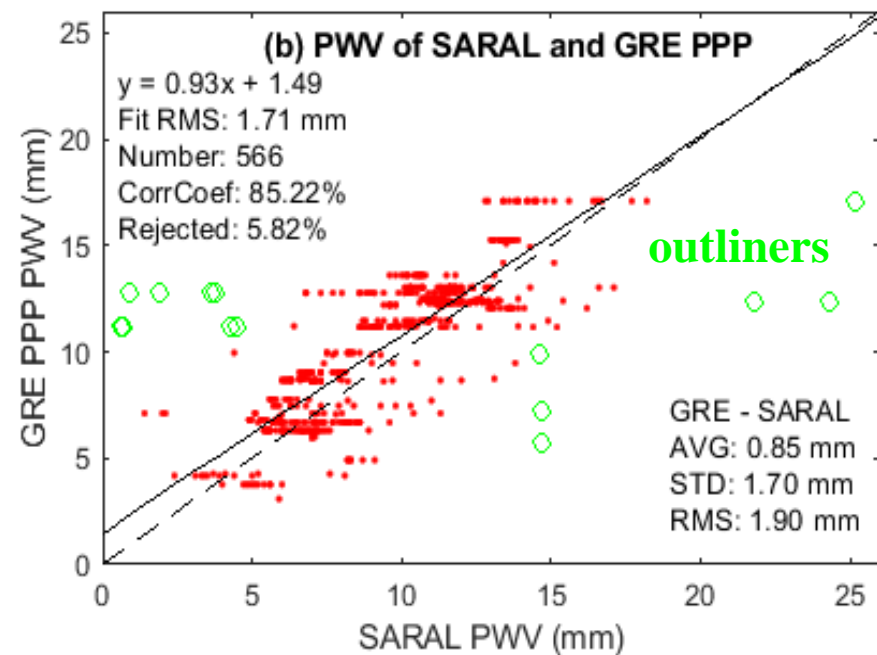
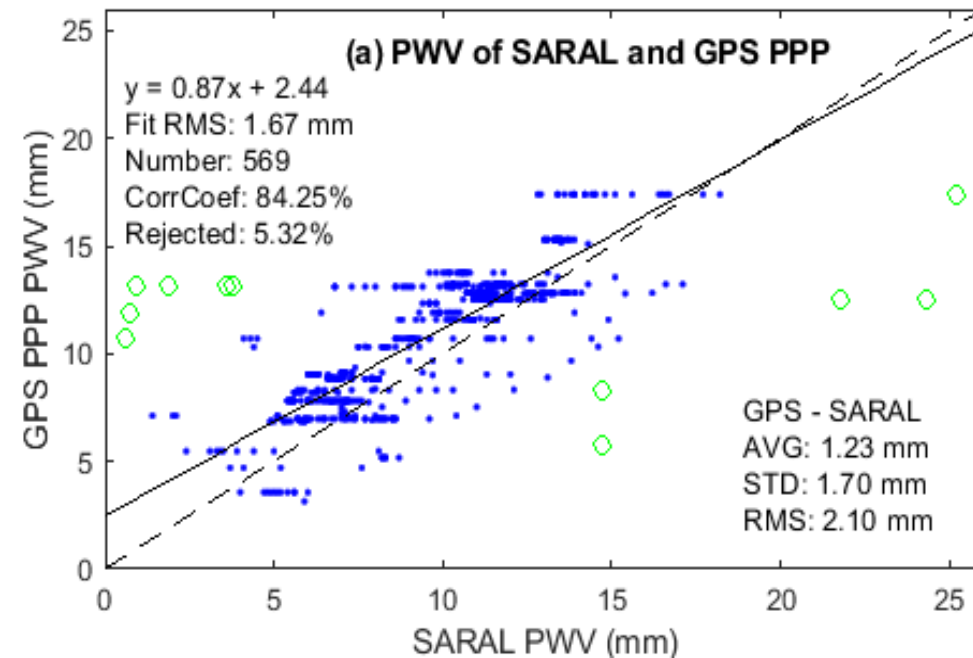
Results – Shipborne vs Radiosonde

- Six Radiosonde Profiles within 2 hour & 200 km
- Multi-GNSS PWV RMS 1.1 mm



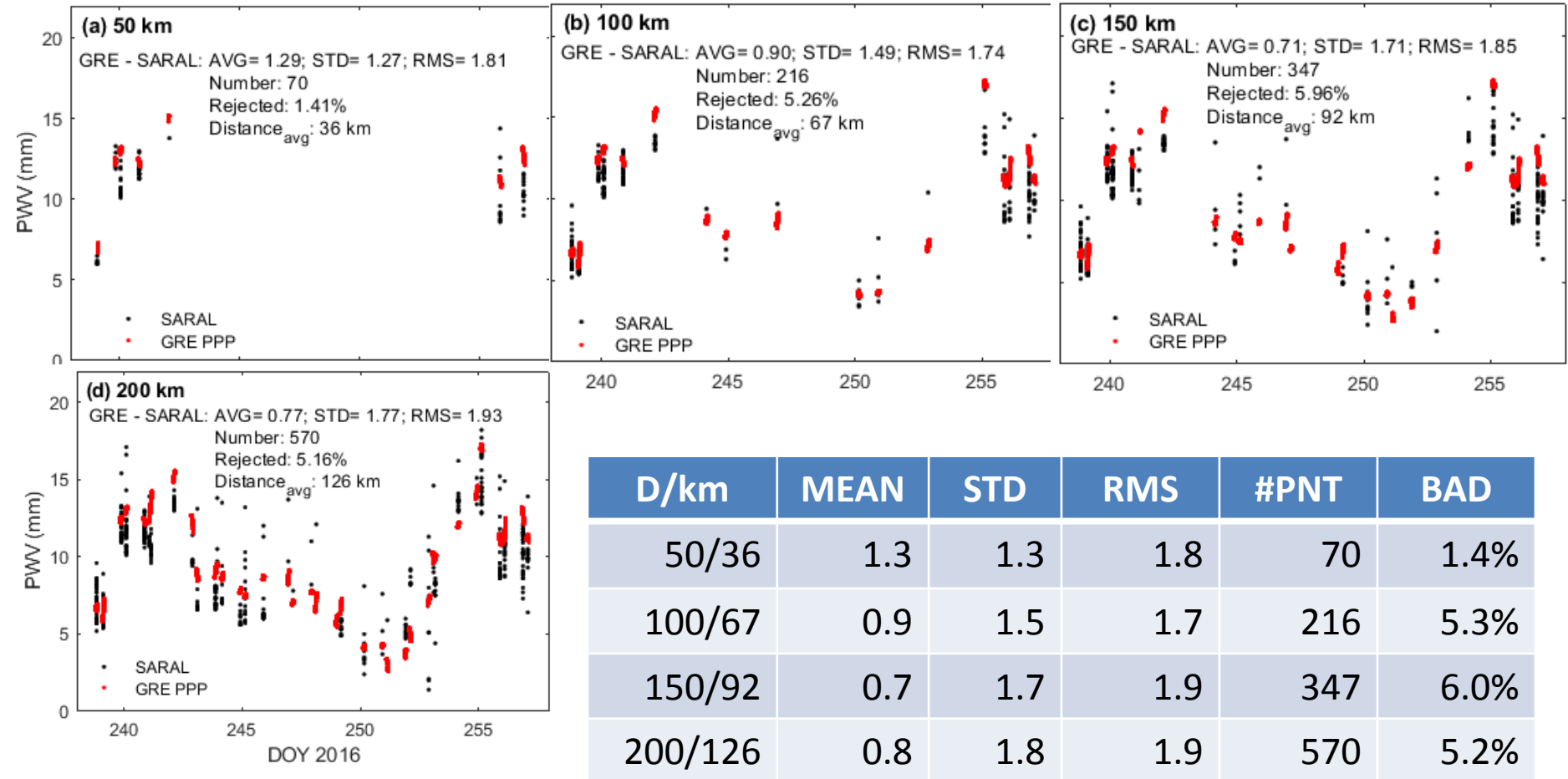
Results – Shipborne vs Spaceborne

- Number of Crossover Points ~566 (within 2 h & 200 km)
- Fit RMS ~1.7 mm, Correlation coefficient: ~85%
- SARAL PWV outliers detected: ~5% (green dots)
- **Very Small PWV**



Results – Shipborne vs Spaceborne

- PWV comparison with SARAL PWV observations
- Within 2h, 50/100/150/200 Km



Ongoing Work

- **HY-2A (Altimetry) Satellite PWV**

- Detect sea surface wind field, sea surface height, sea surface temperature
- Altitude: 971 km
- Inclination: 99.3°
- Repetitivity: 14/168 days
- Instruments:
 - Dual-frequency (Ku/C) altimeter
 - Doris
 - Scatterometer
 - **Microwave Radiometer Imager**

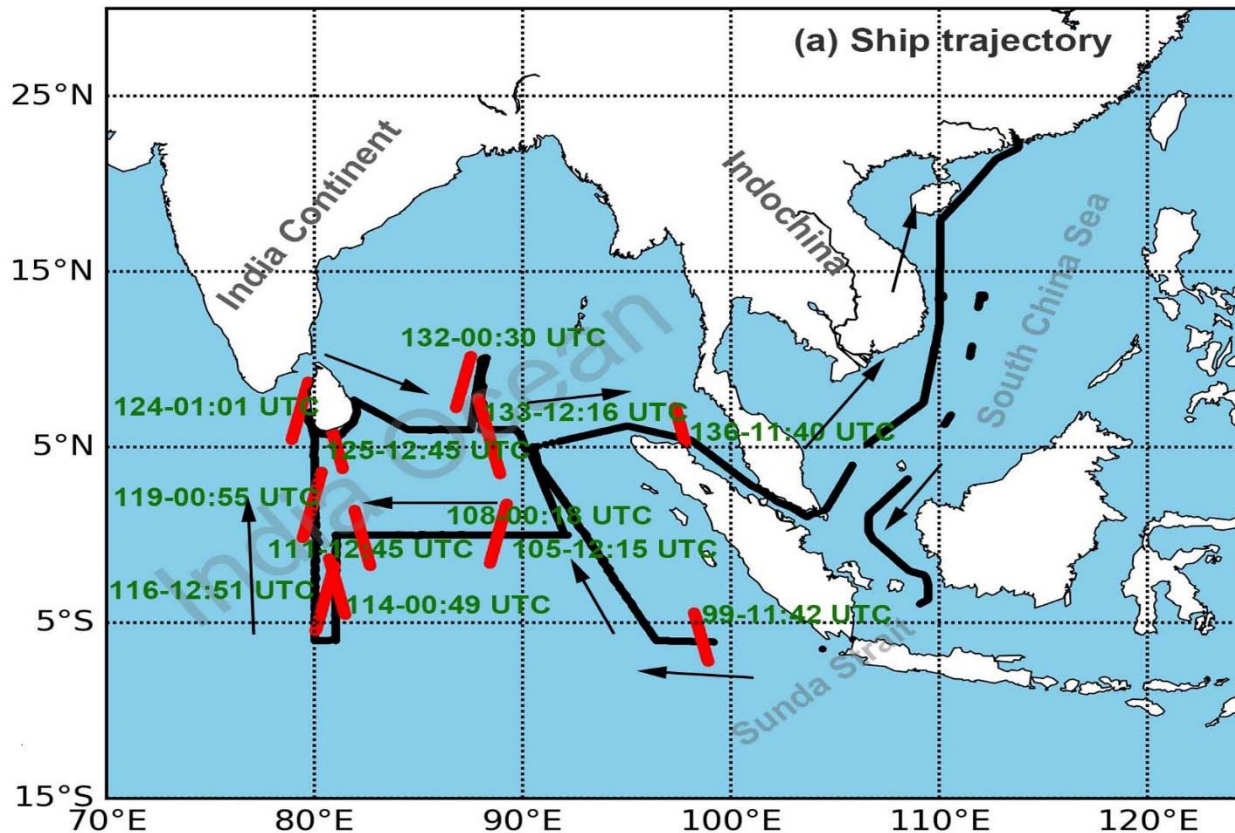


<https://directory.eoportal.org/web/eoportal/satellite-missions/h/hy-2a>

Ongoing Work

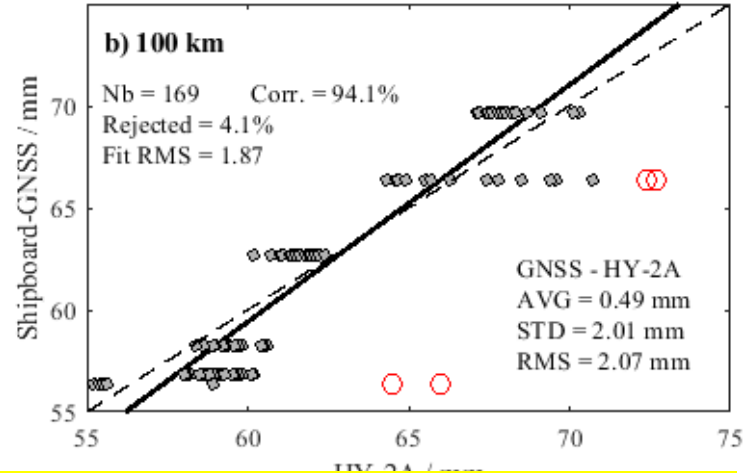
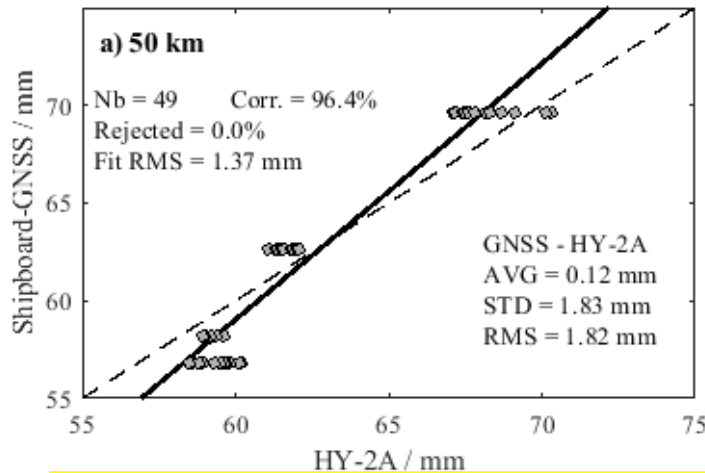
- **Shipborne GNSS**

- Scientific survey 2014 dedicated for HY-2A WVR calibration
- About Two Months 1-Hz GPS/GLONASS observation
- Similar GNSS data processing procedure

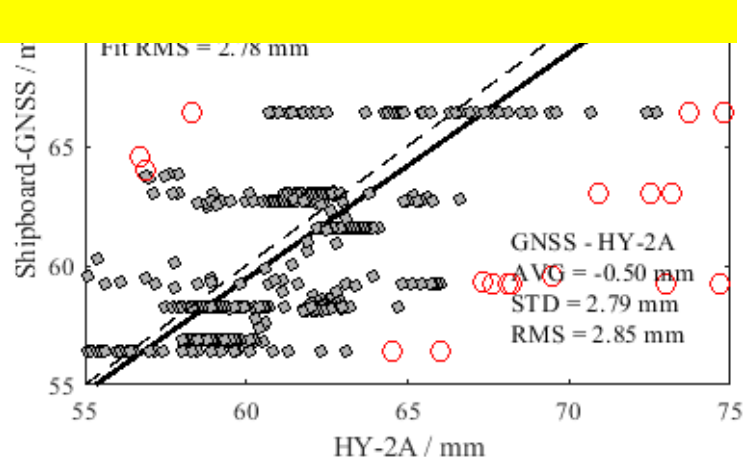
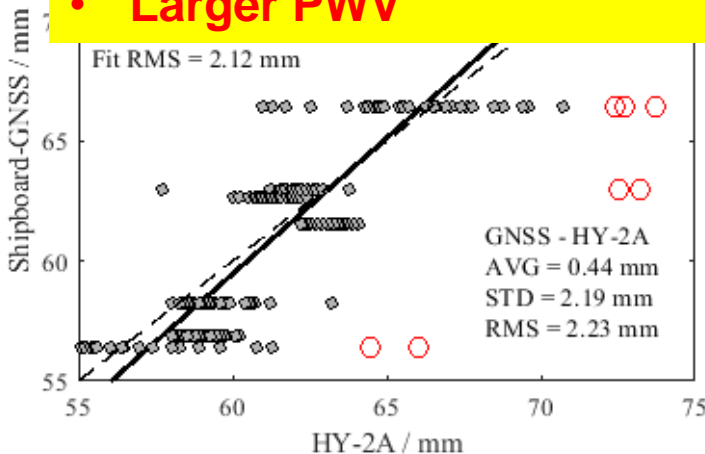


Ongoing Work

- Validating HY-2A PWV with shipborne GNSS



- Bias: <0.5mm, STD: 1.8-2.8mm RMS: <3mm,
- Distance Related RMS
- Larger PWV



Summary

- **Shipborne GNSS PWV with 1~2 mm accuracy**
- **Shipborne GNSS PWV potential applications**
 - Contribution to NWP models
 - Validation/calibration of onboard WVR of altimetry satellites
- **Further Work**
 - HY-2A Onboard PWV calibration
 - Sea Surface Height Estimation

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Thanks a lot
Questions?