UN-COSPAR Symposium
Space-Observation Contributions Supporting Climate Action

Sponsored by the United Nations Office for Outer Space Affairs (UNOOSA) during STSC 60 and as part of the UN Agenda for Sustainable Development

SATELLITE GEODESY AS THE SENTINEL FOR CLIMATE-INDUCED HAZARDS MONITORING

C K Shum
Division of Geodetic Science, School of Earth Sciences, The Ohio State University, Columbus, Ohio, USA, ckshum@osu.edu

UN-COSPAR Symposium
14 February 2023
(15:00–17:00 CET; @16:15–16:30 CET)
Multi-mission Radar Altimeter Generated Virtual Water Level Stations Over Dams, Lakes, Rivers, via Google Earth Visualization

Legend
- ERS-1/-2/Env/SARAL
- GFO
- Sentinel-3A
- Sentinel-3B
- TOPEX/Jason-1/-2/-3

Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus

Krishan River
Jason-2 Pass218, Krishna River
Year
280 300 320 340
Height [m]

Krishan River
ENVISAT/ALTIIKA Pass109, Krishna River
Year
230 240 250 260 270 280
Height [m]

Rihand Dam
ENVIATS Pass223, Rihand Dam
Year
250 260 270 280
Height [m]
Radar Altimetry Sensing of Land Subsidence: Central Valley, CA

(Left) Central Valley, CA, multi-mission radar altimeter tracks (1991-present), ground wells (green dots), and GPS sites (red triangles)

2-D vertical land deformation sensed by CryoSat-2 LRM

Future Work
Detrended radar altimetry deformation compared with GPS time series at Jason-2/Envisat crossover near Corcoran, CA, 2008–2020

Updated from Yang [2020]

GPS Station: CRCN | Dist.: 9.8 km

• Long-term altimetry observed deformation time series is sensitive to drought and flood episodes
• Satellite altimetry plausibly could be an effective solid Earth deformation tool to monitor land subsidence
• Latency for monitoring subsidence using satellite radar altimetry is estimated to be ~days to 1 week
Interferometric SAR (InSAR)

Land deformation rate over Bangladesh coastal polders (polder 13-15, 35) estimated from ALOS-PALSAR (2008-2011) [Credit: Y.Y. Jia].

MTInSAR (Multi-temporal InSAR)

Active layer thickening rate estimates over study regions along the Qinghai-Tibetan Railway from ALOS InSAR (2007-2010) [Credit: Y.Y. Jia].

TCPInSAR for pavement surface monitoring: Hong Kong International Airport (2013–2016) using COSMOS X-SAR [Credit: Lei Zhang, Tonji Univ., 2021].

* PSInSAR: Permanent Scatterer InSAR
  * TCPInSAR: Temporal Coherent Point InSAR
  * SBSInSAR: Small Baseline Subset InSAR
Ground-based GNSS-Reflectometry (Potential International Great Lakes Datum Maintenance, Sea-/Lake-Level, Wind, Wave, Sea/Lake Ice Cover/Freeboard)

- SNR technique for geocentric Lake water level observations: vertical datum monitoring

(Top Right) GPS station (HBCH, red star) at Harbor Beach, MI, Lake Huron; (Bottom) comparison between in situ water level time series and GNSS-R retrieved water level time series around the station
2020 Atlantic Hurricanes: SNR GNSS-Reflectometry

2020 Gulf of Mexico Hurricanes

CALC, AMER, TXPO, SBCH NOAA/NGS GPS stations in the northern Gulf of Mexico

In Situ GNSS-R SNR sea-level
[Sun, 2017]
GNSS-R Offshore Hurricane Sensing

CALC (Calcasieu Pass, LA), RMS = 0.74 cm

- GNSS-R
- Tide Gauge
- Wind Speed

Hurricane Laura
Hurricane Delta
Hurricane Hanna
Tropical Storm Beta

Non-detided sea level observations

Month of Year, 2020 - 2021

GNSS-R SNR sea-level

Correlation Coefficient = 0.972
R² = 0.997

NASA
NASA CYGNSS 8-CubeSat Constellation, Orbital inclinations at 35° – Spaceborne GNSS-Reflectometry

- High temporal sampled GNSS-R wind speed to study tropical cyclone evolutions
- Potential CYGNSS GNSS-R altimetry: code range (DDM only) at 4 m accuracy; phase altimetry ~decimeter accuracy, requires raw IF data, and with coherency, or at glazing angles

All-weather high spatiotemporal resolution cyclone wind speed evolutions

**Improved Energy Balance Approach (iEBA)**

\[ V_{12}^E = V_2^E - V_1^E = \frac{1}{2} |\mathbf{\dot{r}}_{12}|^2 + \mathbf{\dot{r}}_1 \cdot \mathbf{\dot{r}}_{12} + \int_{t_0}^{t} \frac{\partial V_{12}}{\partial t} dt - \int_{t_0}^{t} (\mathbf{f}_2 \cdot \mathbf{\dot{r}}_2 - \mathbf{f}_1 \cdot \mathbf{\dot{r}}_1) dt - V_{12}^R - E_{12}^0 \]

\[ \delta V_{12} (L1C) = V_{12} - V_{12}^0 \]

**L1C residual disturbance Geopotential Difference**

Guo et al. [2015], Shang et al [2015], Zeng et al. [2015], Zhang [2020]
Surface water storage (soil moisture, etc) removed from GRACE TWS: averaged values predicted by 6 models: CPC, ERA-Interim, MOS, VIC, CLM, NOAH.
A devastating flood occurred in the Indian state of Maharashtra in July 22–August 2021. Thirteen districts were affected in western Maharashtra. Over 300 casualties due to floods and landslides.

GRACE-FO gravimetry solutions at 11-day solution span, with daily steps, detected the genesis and evolutions of the Maharashtra flood. Animation shows multiple episodes of flood and drought.

HV: Hydrometeorological (ERA-5 L & Other) models
TWSA: Farrell loading based terrestrial water storage anomaly

Preliminary results

Preliminary results
Hurricane track: 6-hour sampling
Note: no direct GRACE/GRACE-FO data

Preliminary results

Hurricane track: 6-hour sampling