UN-COSPAR Symposium

Space-Observation Contributions Supporting Climate Action

UNOOSA

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

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The Ohio State University, Columbus, Ohio, USA, ckshum@osu.edu

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UN-COSPAR Symposium
14 February 2023
(15:00–17:00 CET; @16:15–16:30 CET)

NSF NASA NOAA İTÜAKADEMİ GEODETIC SCIENCE A DIVISION OF THE SCHOOL OF EARTH SCIENCES THE OHIO STATE UNIVERSITY

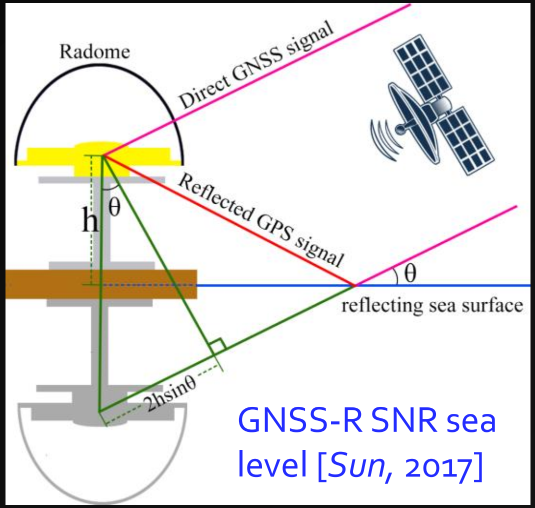
ESA

NASA/CNES TOPEX/Poseidon

GPS-III (DoD)

GNSS

Spaceborne GNSS-Reflectometry

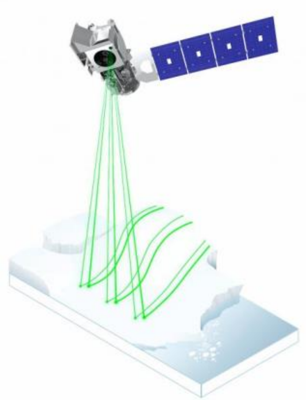


GNSS-R SNR sea level [*Sun*, 2017]

Planet, Inc Dove
Over 200 3U CubeSats

ESA Sentinel-2 Optical Imagery

Satellite Altimetry



NASA ICESat-2

Satellite Geodetic/Remote Sensing Climate & Hazards Monitoring System

Machine-/Deep-Learning or AI-Aided Satellite Data Downscaling

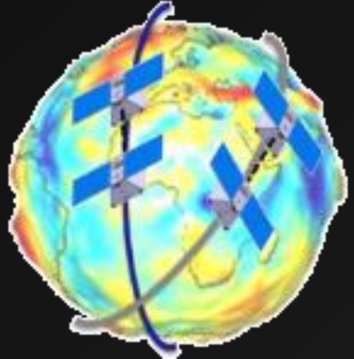
Satellite Gravimetry

NASA/DLR GRACE

Interferometric Synthetic Aperture Radar (InSAR)

JAXA ALOS-/ALOS-2 InSAR

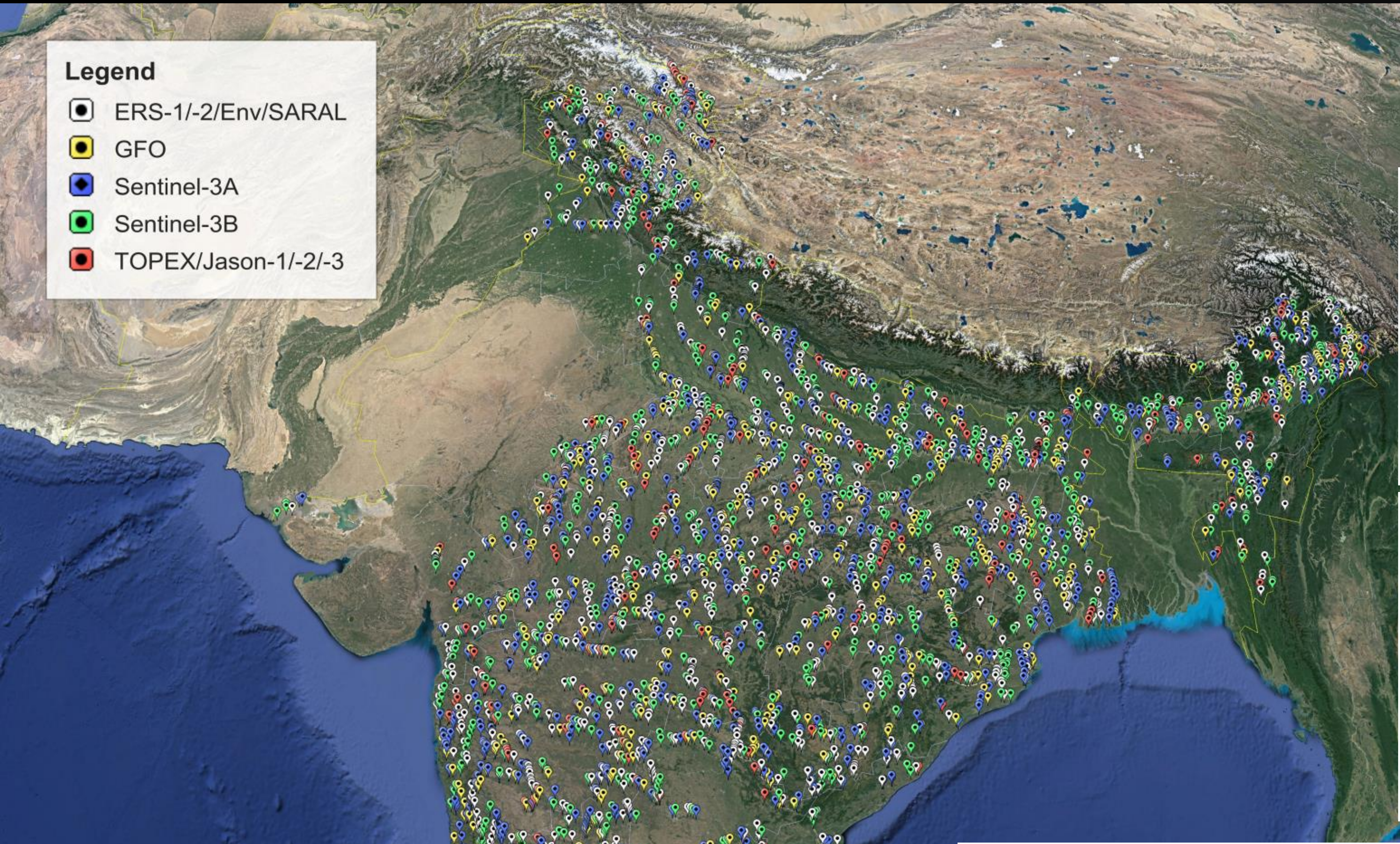
ESA Sentinel-3 InSAR

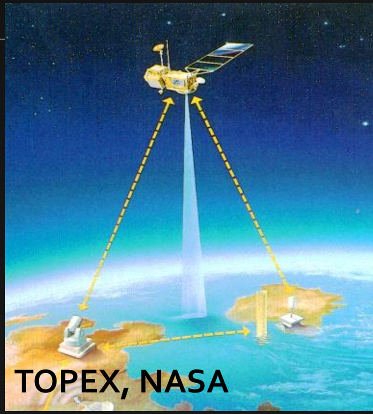


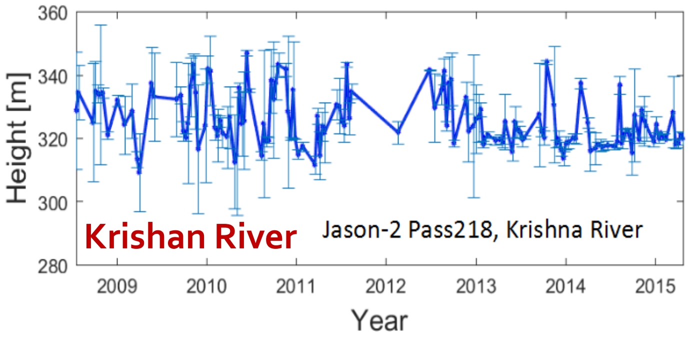
ESA NGGM

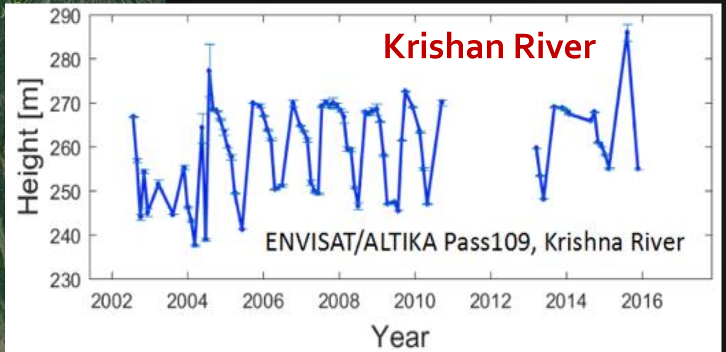
NASA/GFZ GRACE-FO

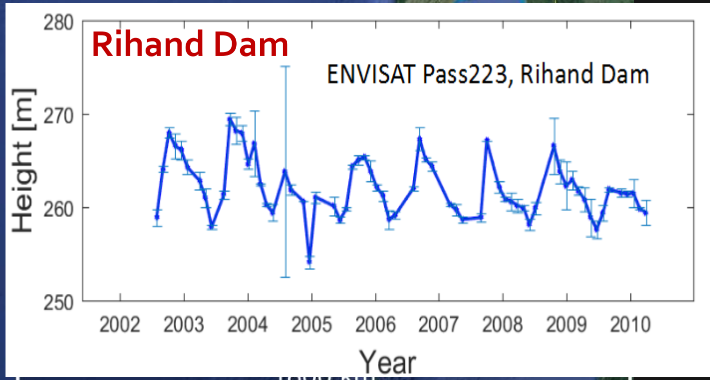
Multi-mission Radar Altimeter Generated Virtual Water Level Stations Over Dams, Lakes, Rivers, via Google Earth Visualization











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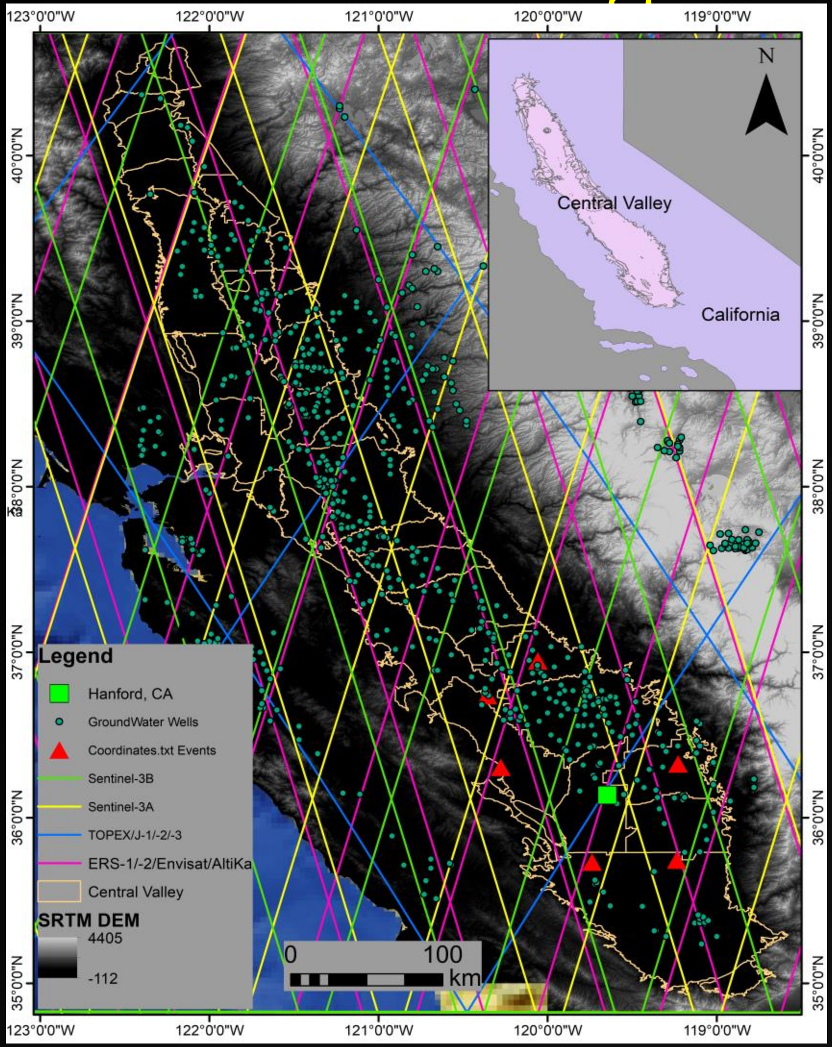
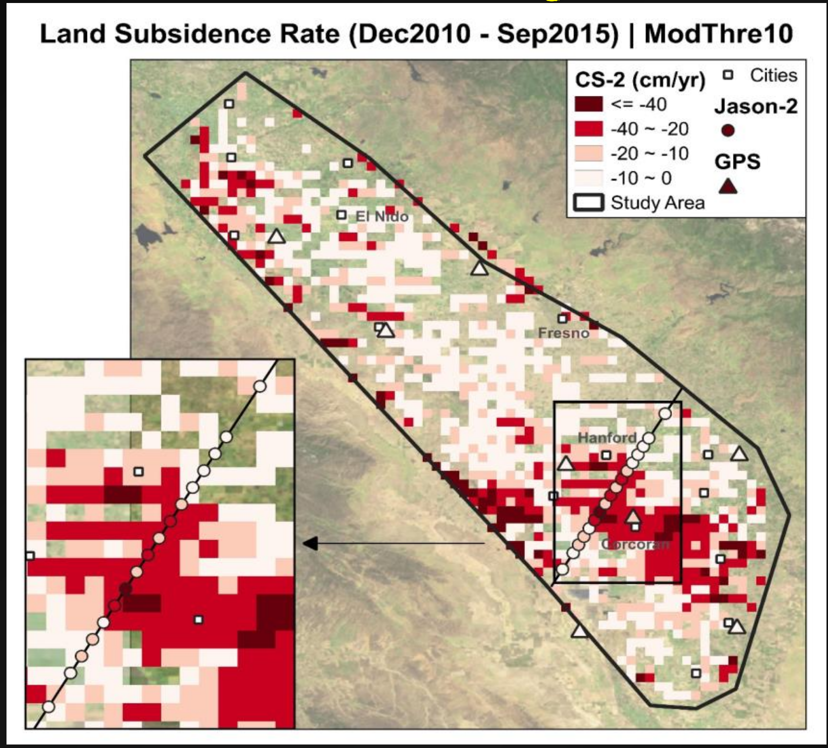
Radar Altimetry Sensing of Land Subsidence: Central Valley, CA



(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

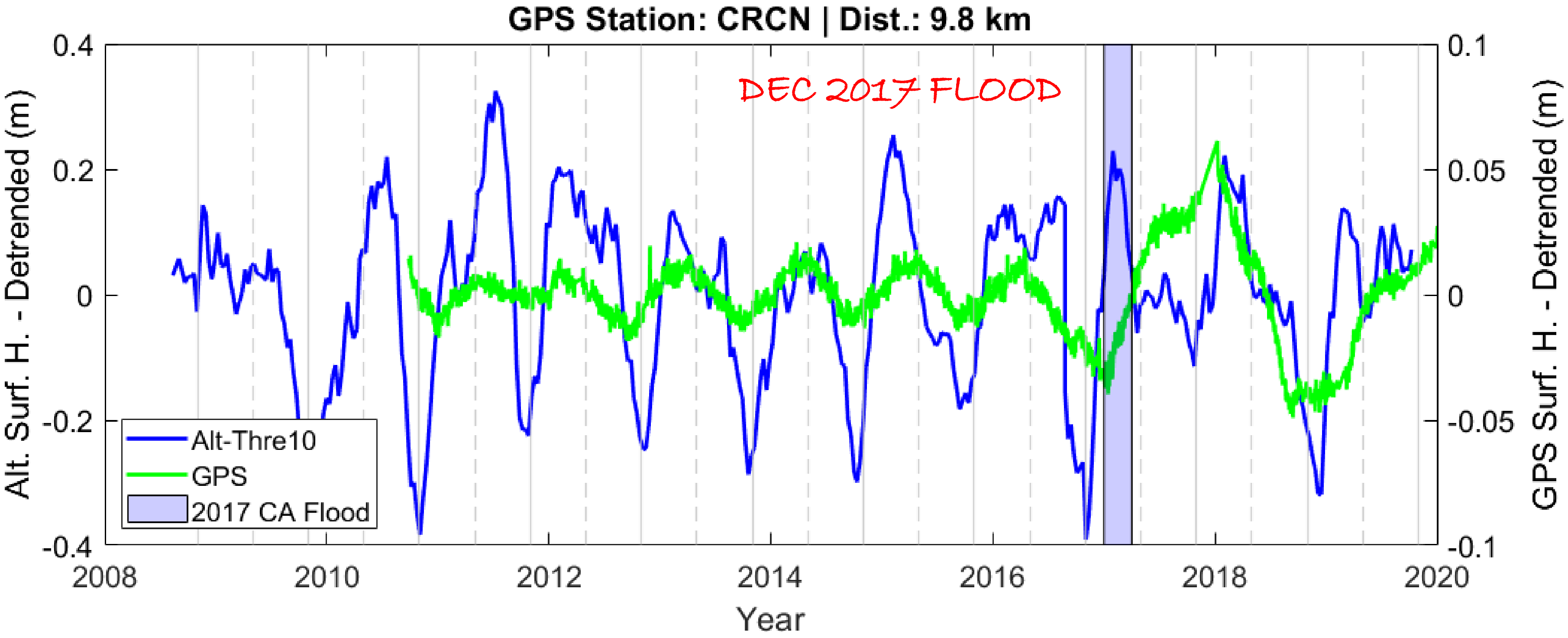


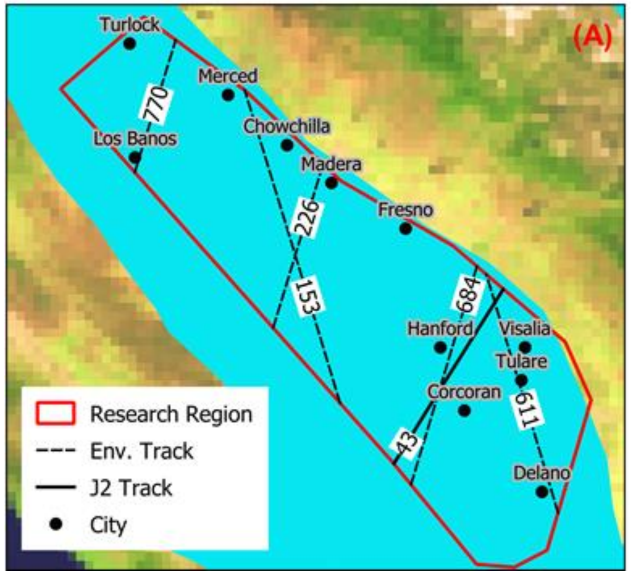
Future Work

NASA ESI

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

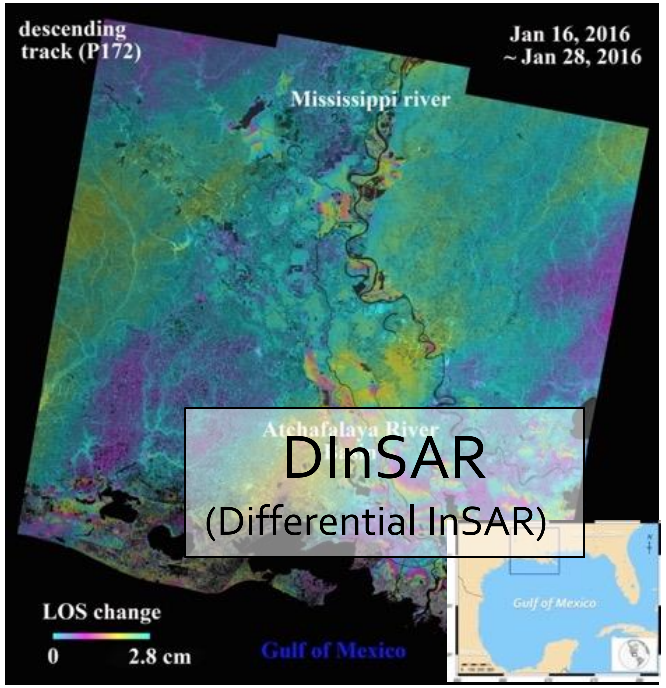
Updated from *Yang* [2020]





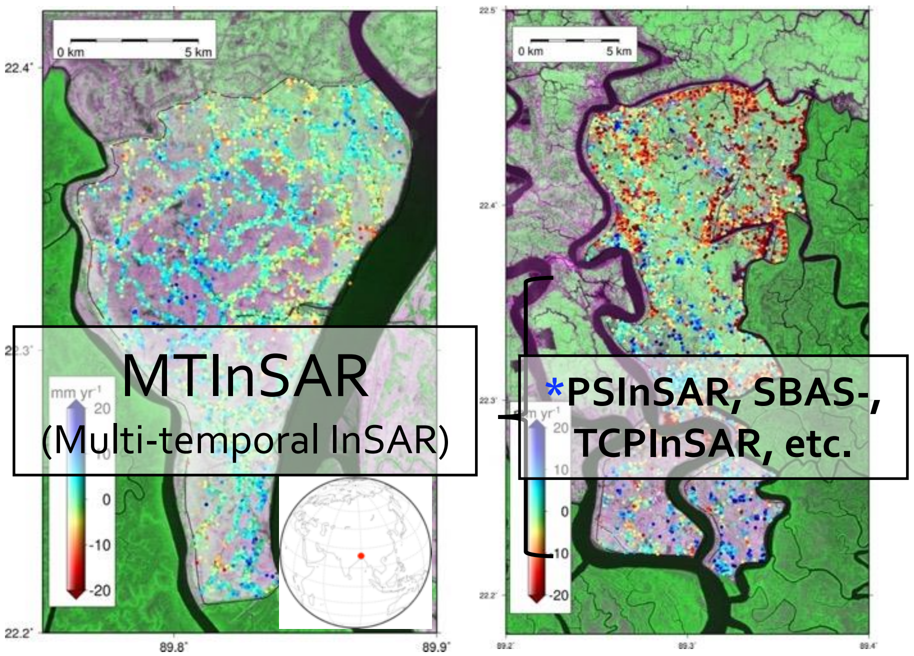
- Long-term altimetry observed deformation time series is sensitive to ***drought*** **and** ***flood*** **episodes**
- Satellite altimetry plausibly could be an effective solid Earth deformation tool to monitor ***land subsidence***
- Latency for monitoring subsidence using satellite radar altimetry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

Interferometric SAR (InSAR)



DInSAR
(Differential InSAR)

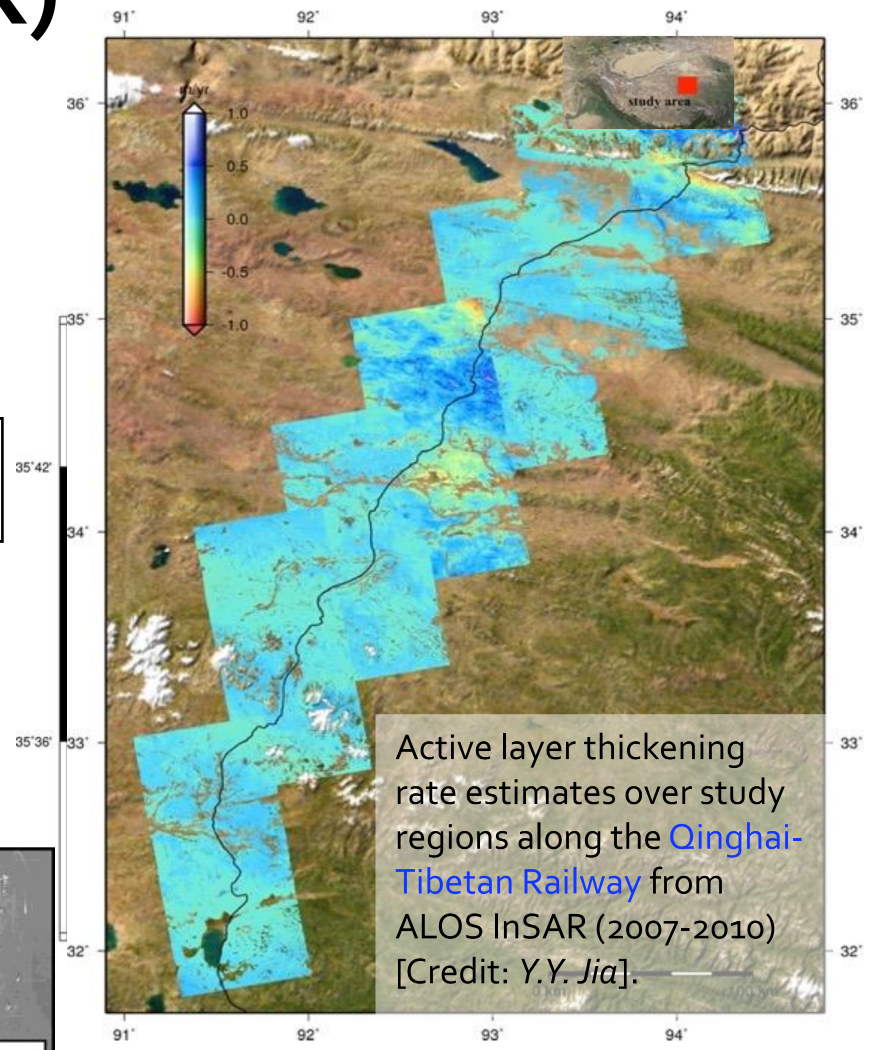
Wrapped interferogram from Sentinel-1A descending data (2016/01/16-2016/01/28) in coastal Louisiana [Credit: *J.W. Kim*].



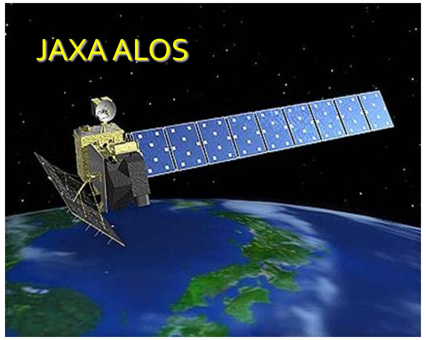
MTInSAR
(Multi-temporal InSAR)

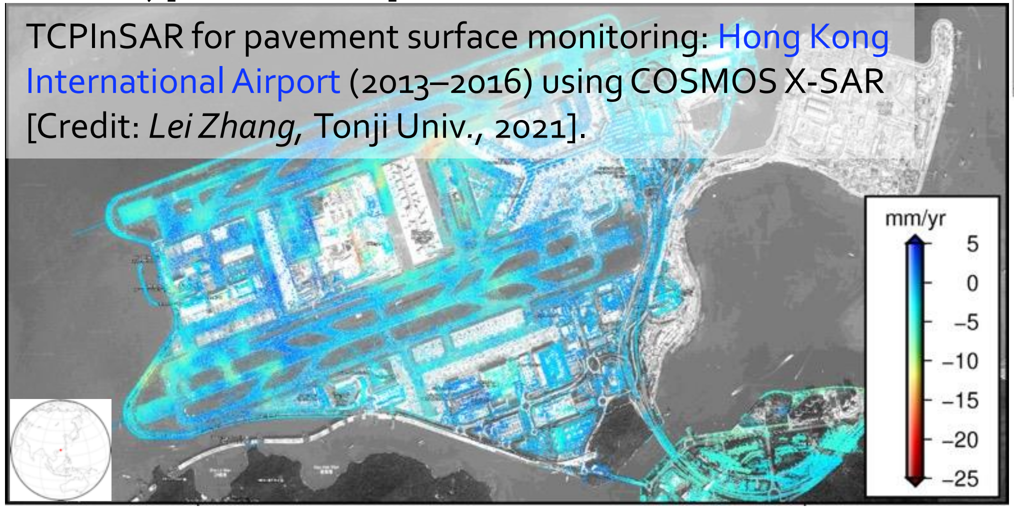
***PSInSAR, SBAS-, TCPInSAR, etc.**

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



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

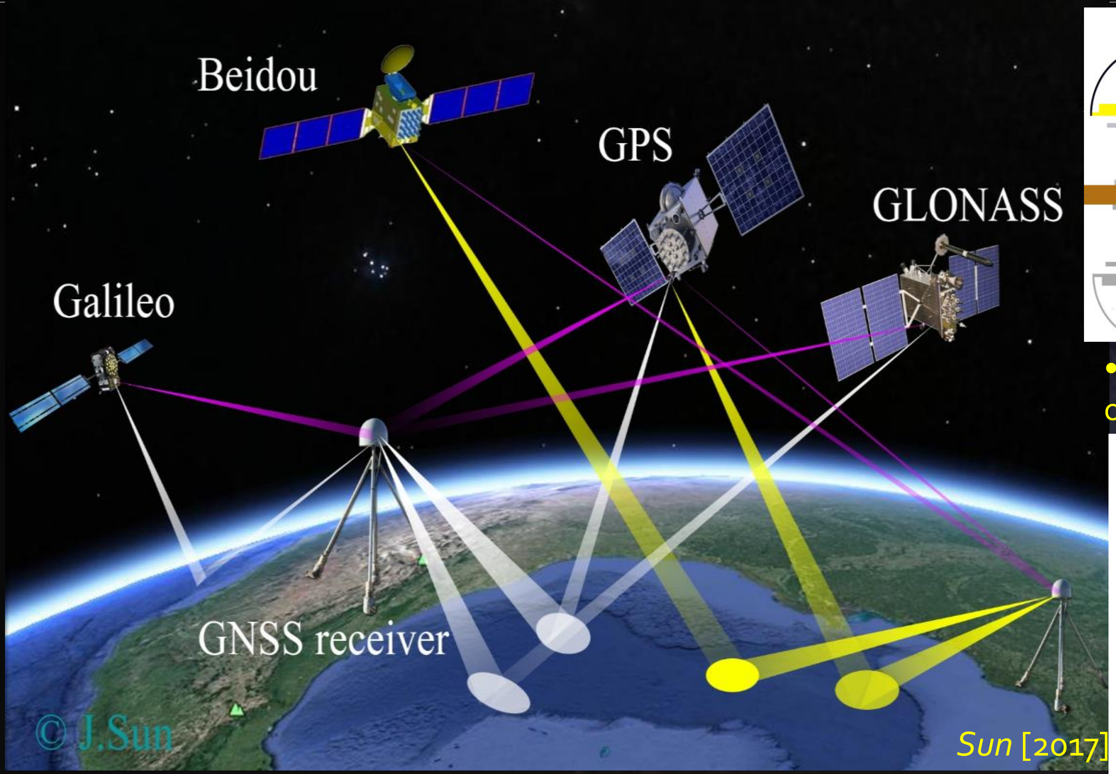




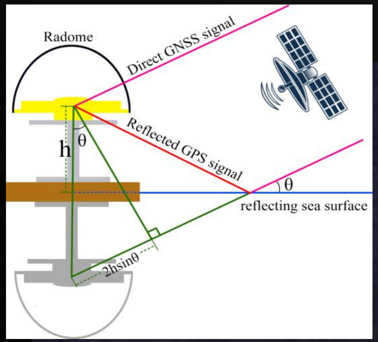
TCPInSAR for pavement surface monitoring: Hong Kong International Airport (2013–2016) using COSMOS X-SAR [Credit: *Lei Zhang*, Tonji Univ., 2021].

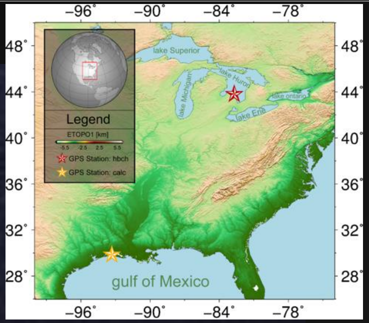
* • PSInSAR: Permanent Scatterer InSAR
• TCPInSAR: Temporal Coherent Point InSAR
• SBSInSAR: Small Baseline Subset InSAR

Ground-based GNSS-Reflectometry (Potential International Great Lakes Datum Maintenance, Sea-/Lake-Level, Wind, Wave, Sea/Lake Ice Cover/Freeboard)

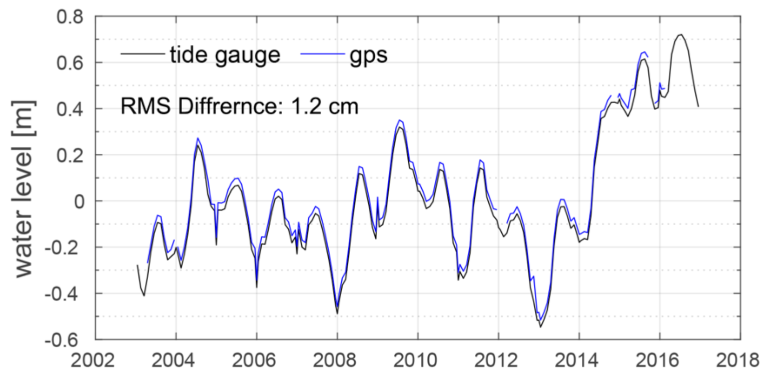


Sun [2017]





- 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

Cooperative Institute for Great Lakes Research CIGLR Great Lakes Science for Society

National Geodetic Survey

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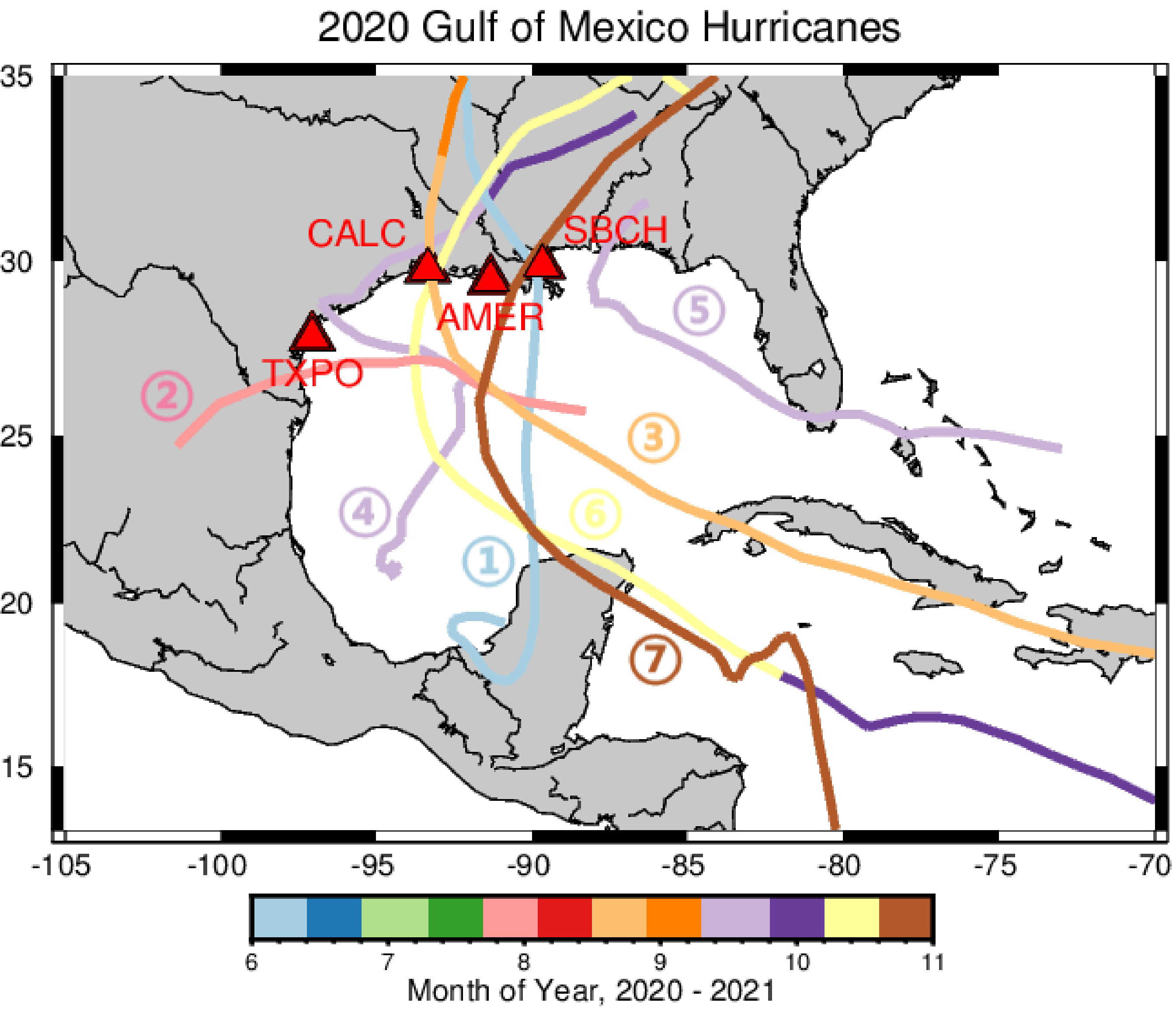
2020 Atlantic Hurricanes: SNR GNSS-Reflectometry



Legend

▲ GPS station

① Storm Cristobal, Jun 01 - 12

② Hurricane Hanna, Jul 23 - 27, Cat 1

③ Hurricane Laura, Aug 20 - 29, Cat 4

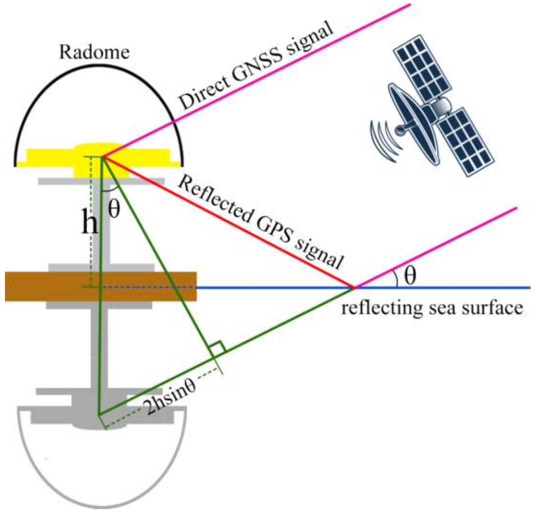
④ Storm Beta, Sep 16 - 25

⑤ Hurricane Sally, Sep 10 - 17, Cat 2

⑥ Hurricane Delta, Oct 02 - 12, Cat 4

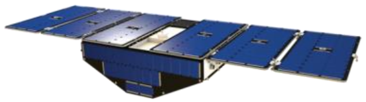
⑦ Hurricane Zeta, Oct 20 - 30, Cat 2

From: National Hurricane Center



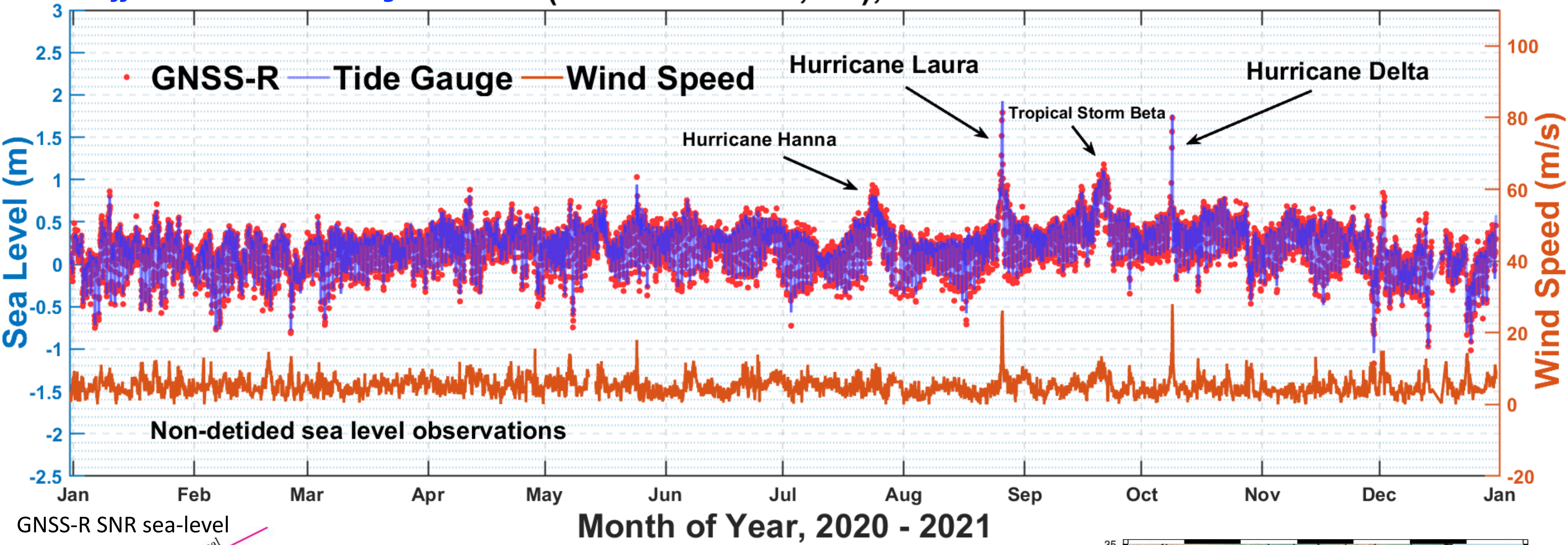
***In Situ* GNSS-R SNR sea-level**
[*Sun*, 2017]

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

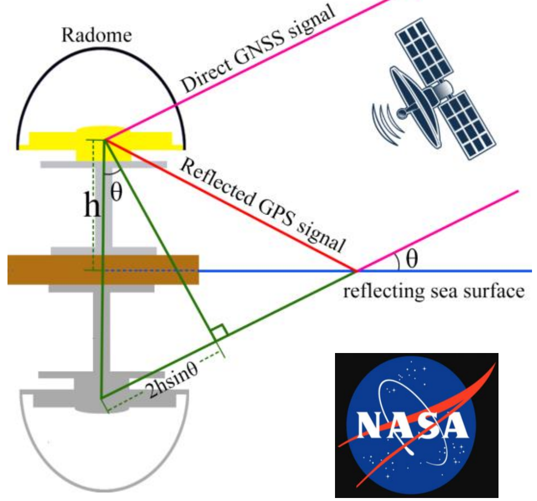


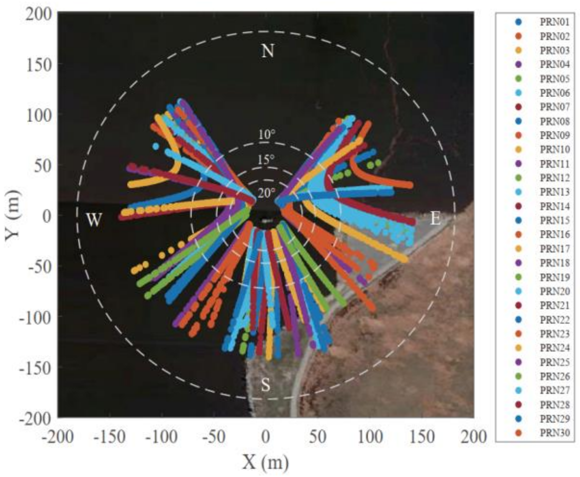
GNSS-R Offshore Hurricane Sensing

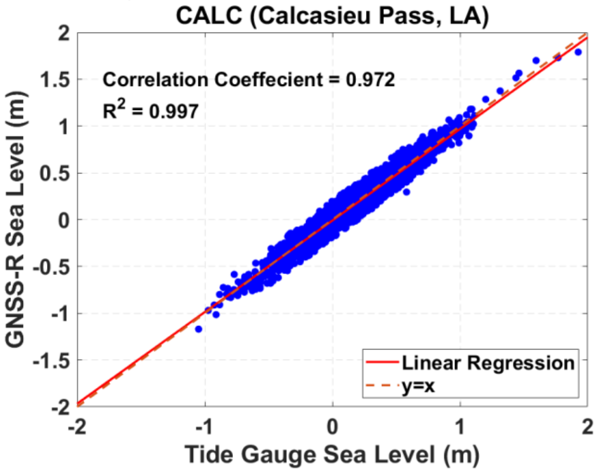
CALC (Calcasieu Pass, LA), RMS = 0.74 cm

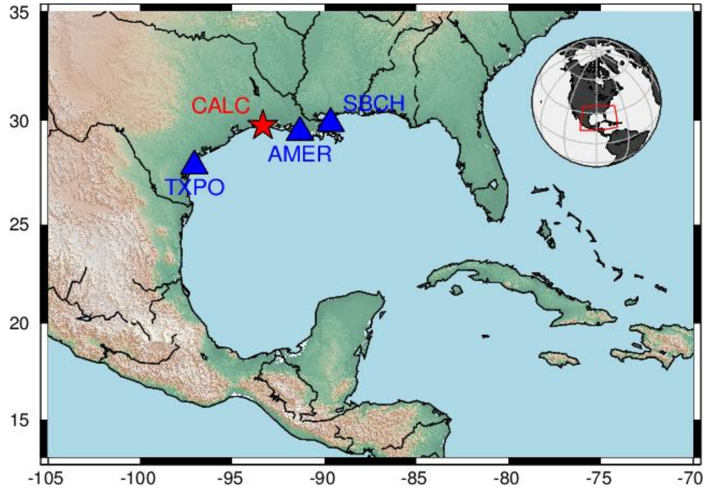


GNSS-R SNR sea-level

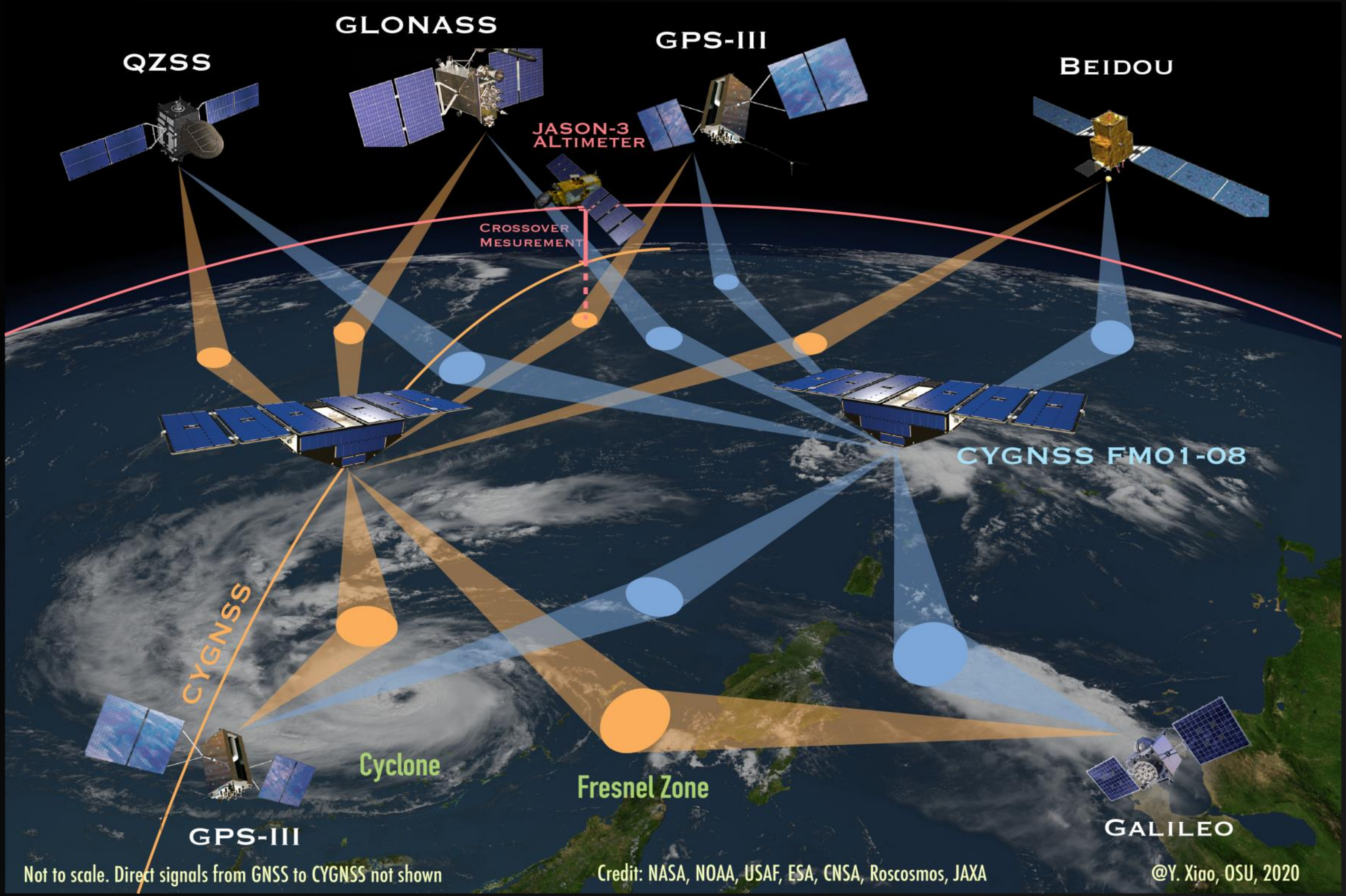








NASA CYGNSS 8-CubeSat Constellation, Orbital inclinations at 35° – Spaceborne GNSS-Reflectometry



- 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

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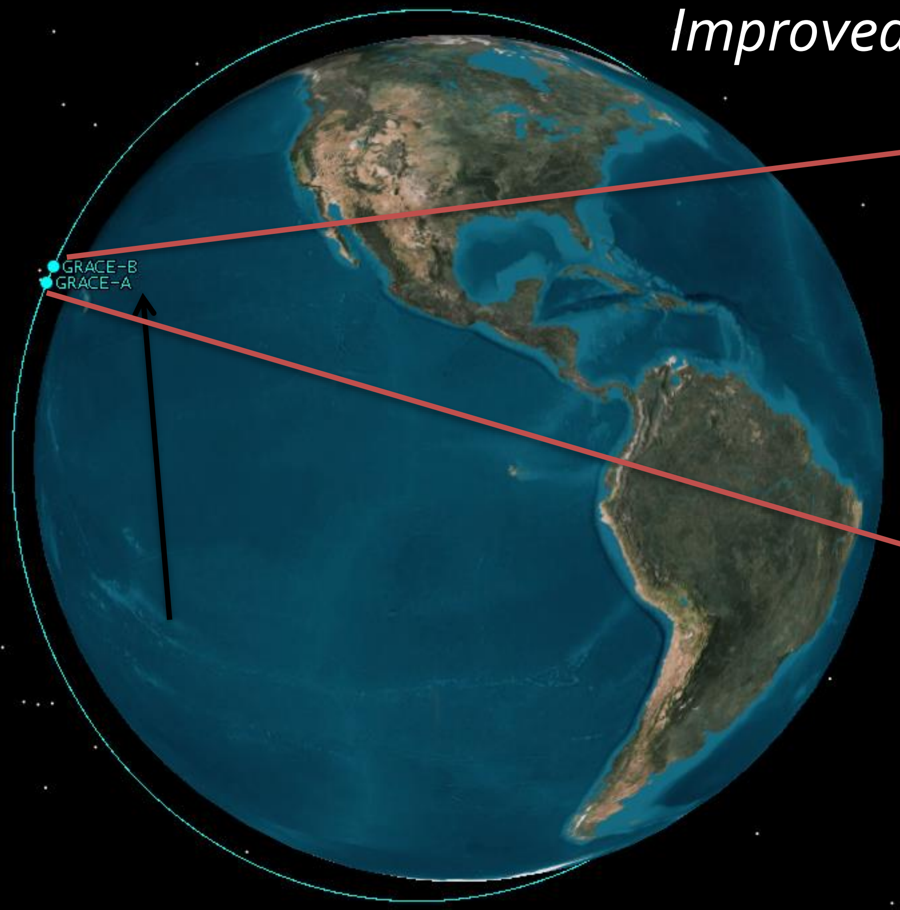
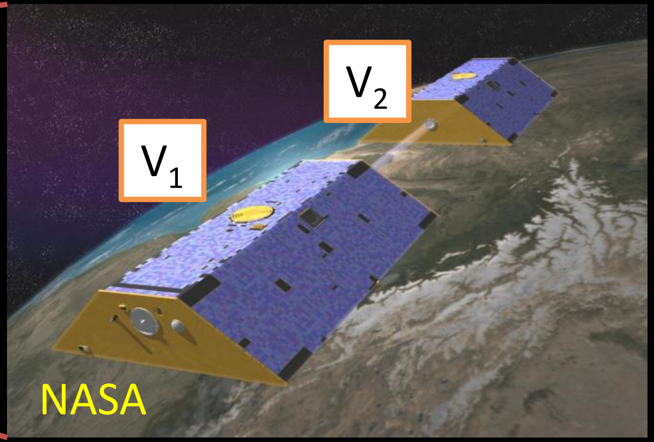
NASA/DLR GRACE

Gravity Recovery And Climate Experiment (GRACE), 2002–2017, and GRACE-FO Satellite Missions, 2018–

Improved Energy Balance Approach (iEBA)





$V_{12} = V_2 - V_1$

L1C (at sat. altitude)

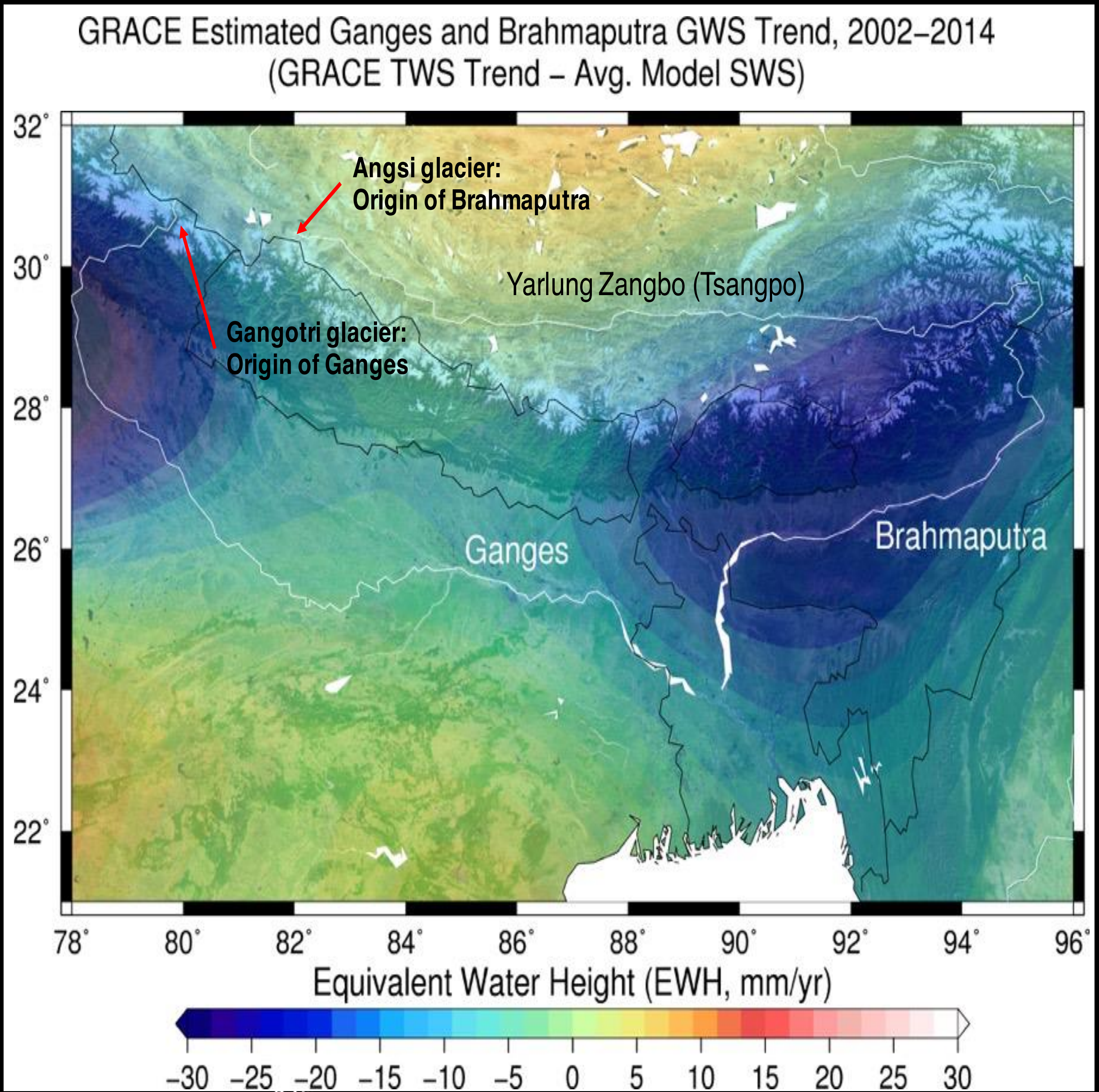
$\delta V_{12}\,(\mathrm{L1C}) = V_{12} - V_{12}^{0}$

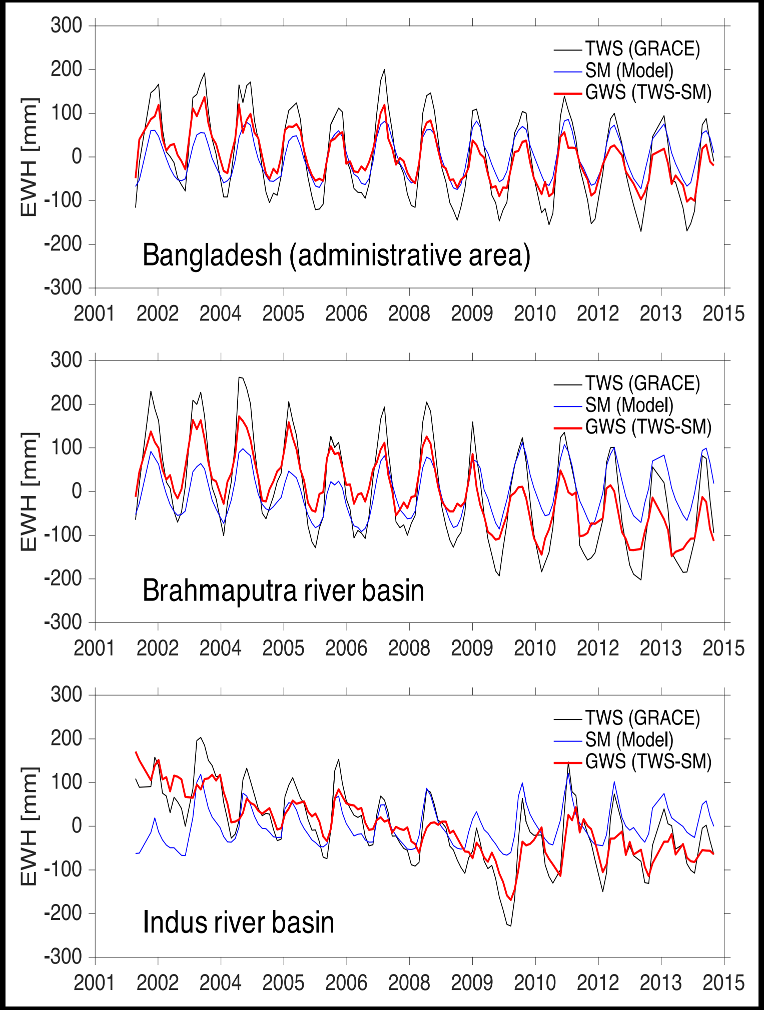
L1C residual
disturbance Geopotential Difference

$$V_{12}^{E} = V_{2}^{E} - V_{1}^{E} = \frac{1}{2}\left|\dot{\mathbf{r}}_{12}\right|^{2} + \dot{\mathbf{r}}_{1}\cdot\dot{\mathbf{r}}_{12} + \int_{t_0}^{t}\frac{\partial V_{12}}{\partial t}dt - \int_{t_0}^{t}\left(\mathbf{f}_{2}\cdot\dot{\mathbf{r}}_{2} - \mathbf{f}_{1}\cdot\dot{\mathbf{r}}_{1}\right)dt - V_{12}^{R} - E_{12}^{0}$$

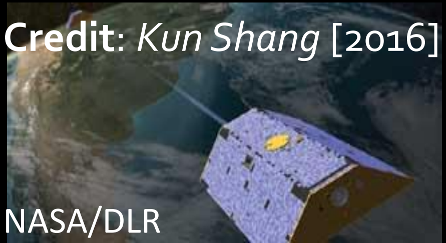
Guo et al. [2015], *Shang et al* [2015], *Zeng et al.* [2015], *Zhang* [2020]

GRACE Groundwater: Granges-Brahmaputra-Meghna Basin

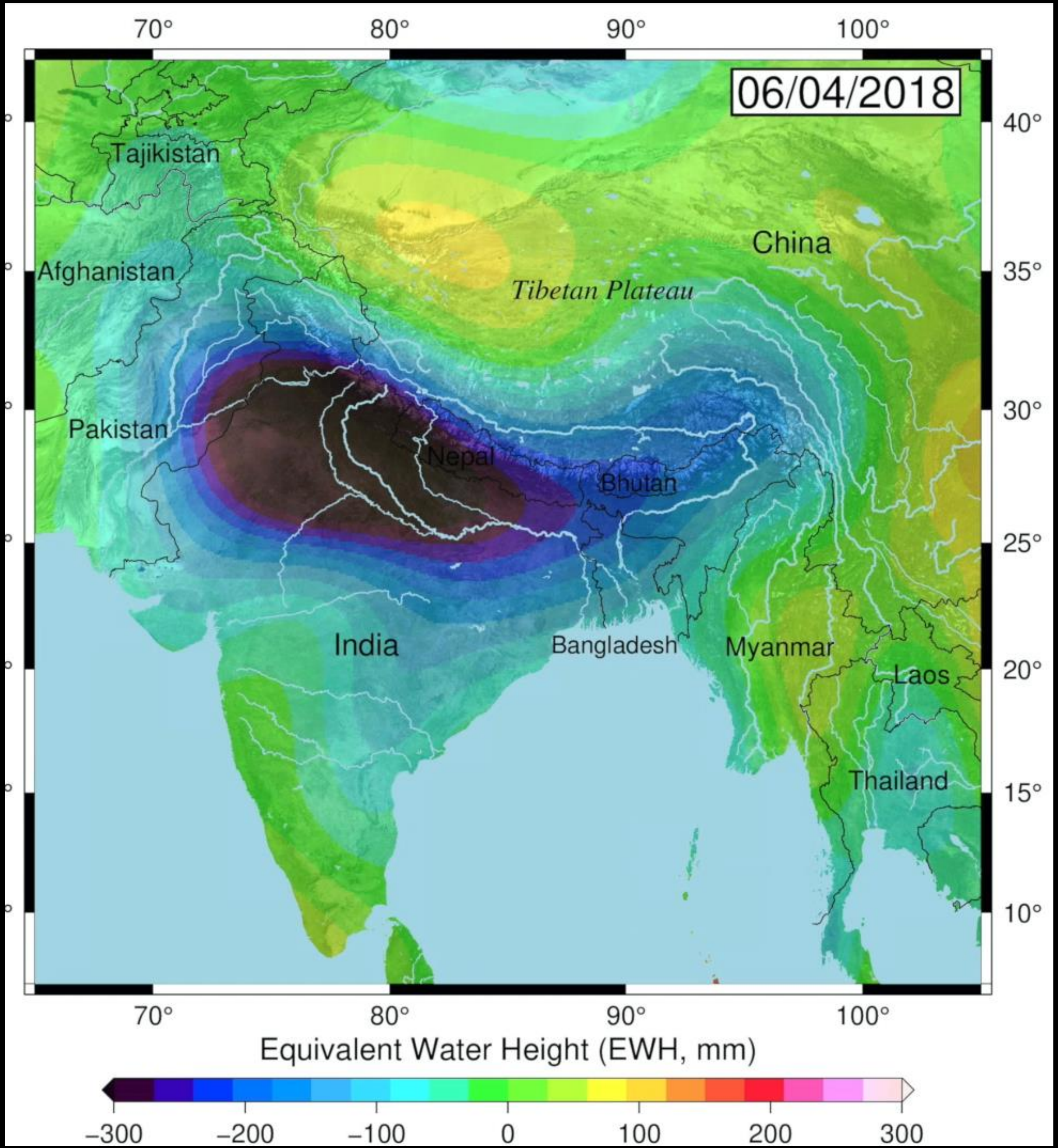




Credit: *Kun Shang* [2016]

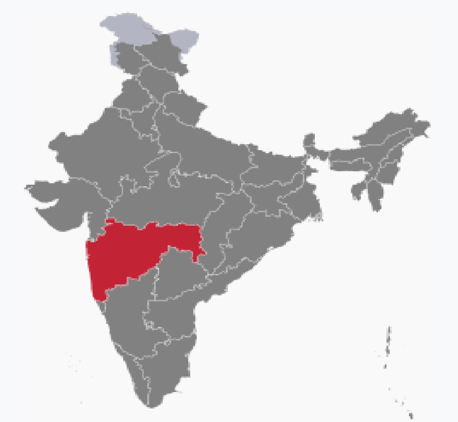


Surface water storage (soil moisture, etc) removed from GRACE TWS: averaged values predicted by 6 models: CPC, ERA-Interim, MOS, VIC, CLM, NOAH



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.

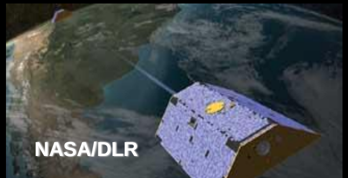
2021 Maharashtra floods



The state of Maharashtra within India

Date	22 July 2021 – August 2021
Cause	Heavy rainfall
Deaths	209[1]
Missing	8

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



Animation: South Asia droughts and floods, 04/06/2008 – 26/08/2021

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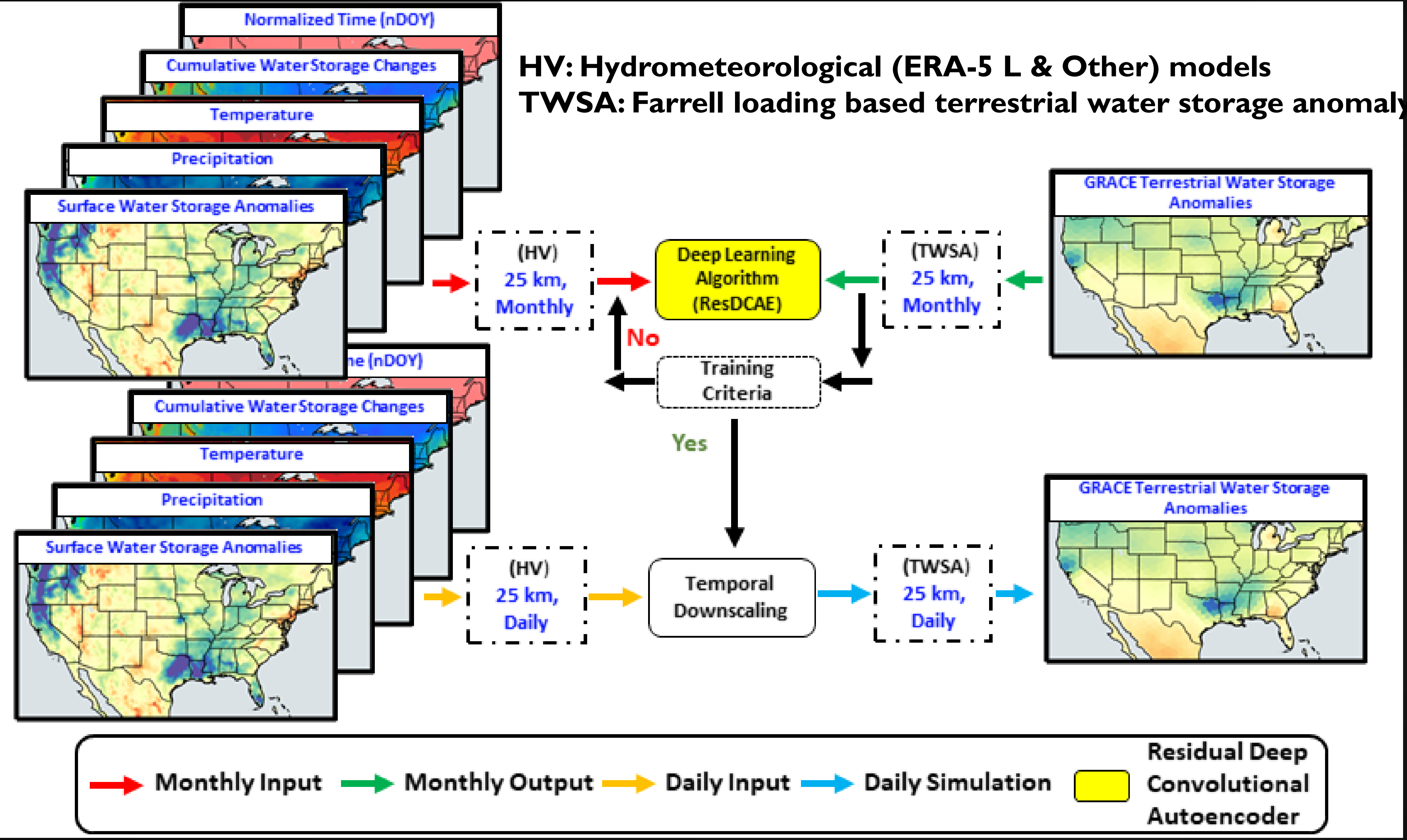
Residual Deep Convolutional Auto-Encoder (ResDCAE): Deep-Learning Downscaled GRACE/GRACE-FO Satellite Gravimetry: North America (25 km, Daily TWSA, 2003–)

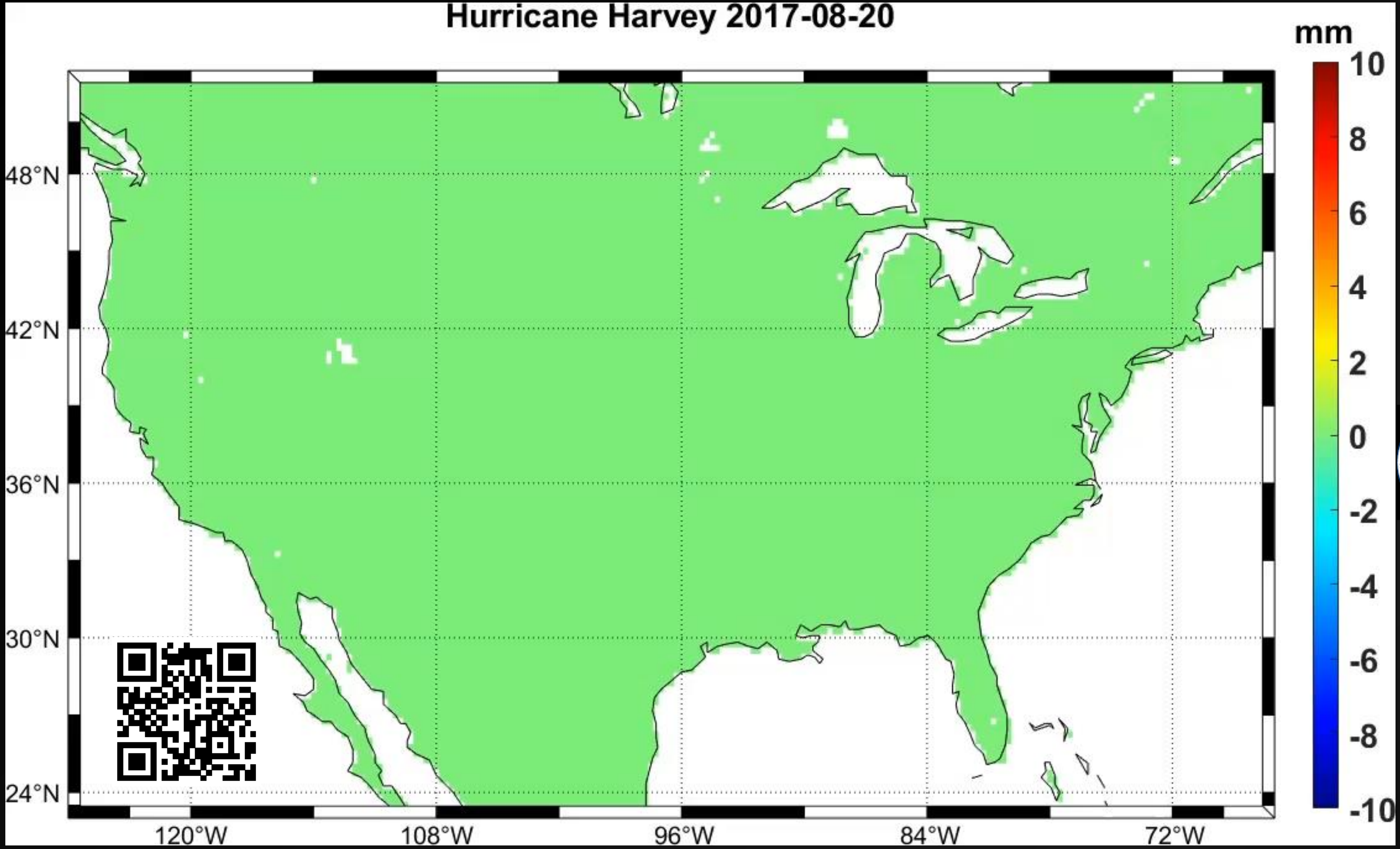
HV: Hydrometeorological (ERA-5 L & Other) models
TWSA: Farrell loading based terrestrial water storage anomaly



Preliminary results

Updated Uz et al. [2022]

ResDCAE Deep-Learning Downscaled Satellite Gravimetry TWSA (daily, 25 km) : Category 4 Hurricane Harvey South Texas Landfall, August 25–29, 2017



Preliminary results

Hurricane track: 6-hour sampling

Note: no direct GRACE/GRACE-FO data

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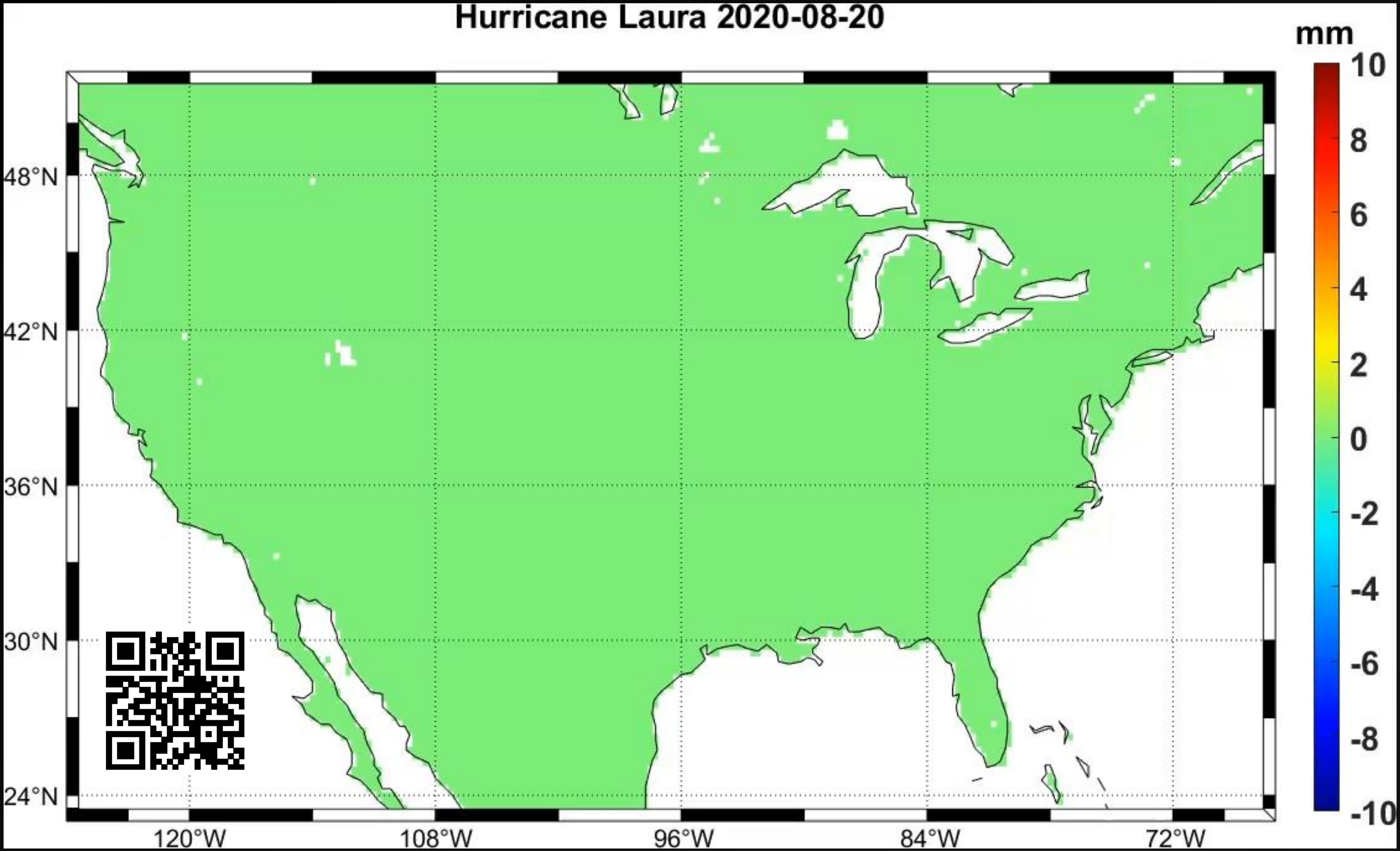
ResDCAE Deep-Learning Downscaled Satellite Gravimetry TWSA (daily, 25 km) : Category 4 Hurricane Laura Louisiana Landfall, August 20–29, 2020



Preliminary results

Hurricane track: 6-hour sampling

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