National Environmental Satellite, Data, and Information Service

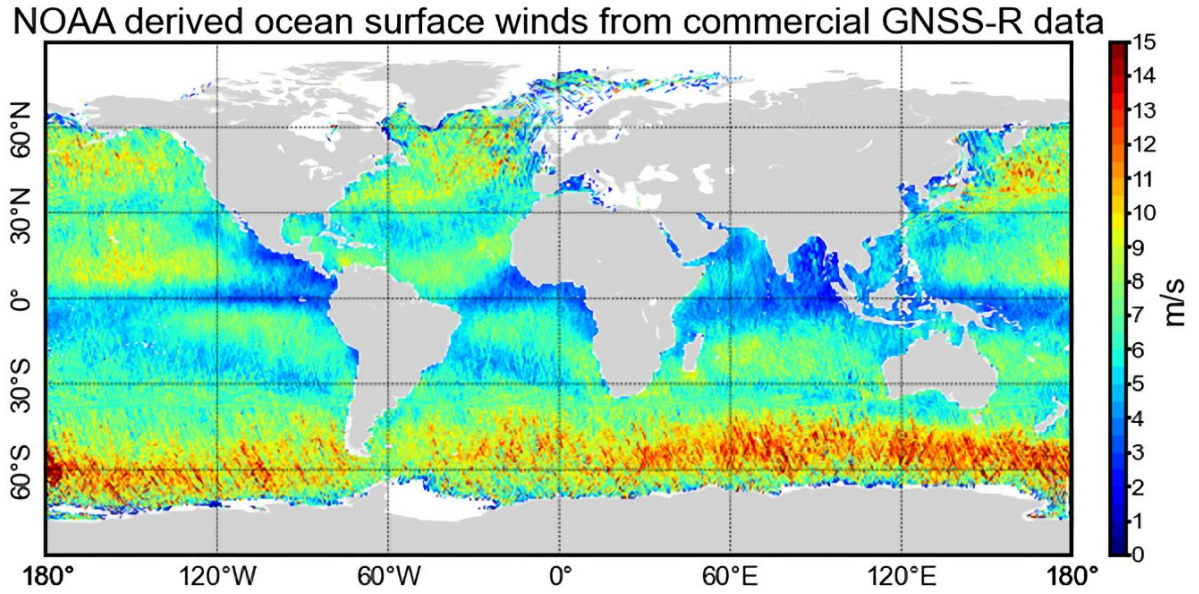
Sept. 13, 2024

The NOAA/NESDIS Commercial Data Program GNSS-R Ocean Surface Winds Pilot

Gerard Peltzer, NOAA/NESDIS Office of Systems Architecture and Engineering - Commercial Data Program

2023-2024 NESDIS Commercial Weather Data Pilots

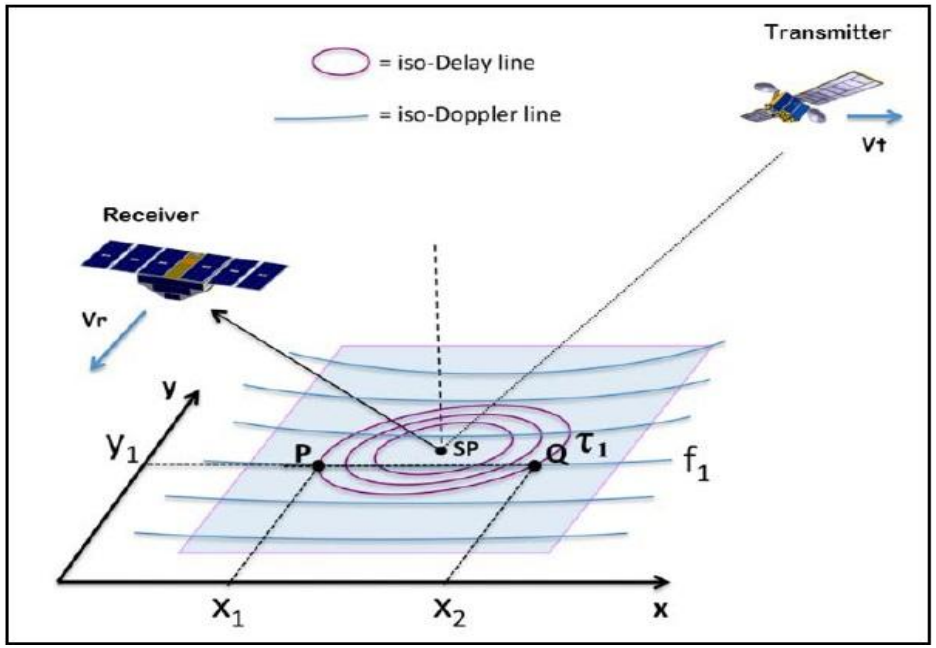
- **Space Weather Pilot (ended in 2024):** NESDIS CDP conducted a successful pilot study of exploiting commercial GNSS-RO data for space weather parameters. ***Final report available.***
- **Ocean Surface Winds (OSW) GNSS Reflectometry Pilot (ongoing):** NESDIS CDP is executing a pilot study to use commercial reflectometry data to derive ***ocean surface wind speeds*** and additional environmental measurements.



Through a Commercial Weather Data Pilot, NOAA is developing methods for determining ocean surface wind speeds globally using commercial GNSS-R (reflectometry) satellite data.

The NOAA GNSS-R OSW Pilot

- In January 2024, The NOAA NESDIS Commercial Data Program (CDP) began a **pilot study on GNSS satellite reflectometry (GNSS-R) data for ocean surface winds (OSW) and other environmental observations**. Key activities include:
  - Adapting OSW products previously developed by NOAA to commercial GNSS-R observations and assessing their utility.
  - Evaluating vendor-derived OSW products.
  - Assessing commercial GNSS-R measurements for environmental applications including ***soil moisture monitoring, soil inundation, inland water body mapping, freeze/thaw event detection, and sea ice detection and characterization***.
  - The Pilot will also leverage past reflectometry research with the NASA-led Cyclone GNSS (CYGNSS) mission.

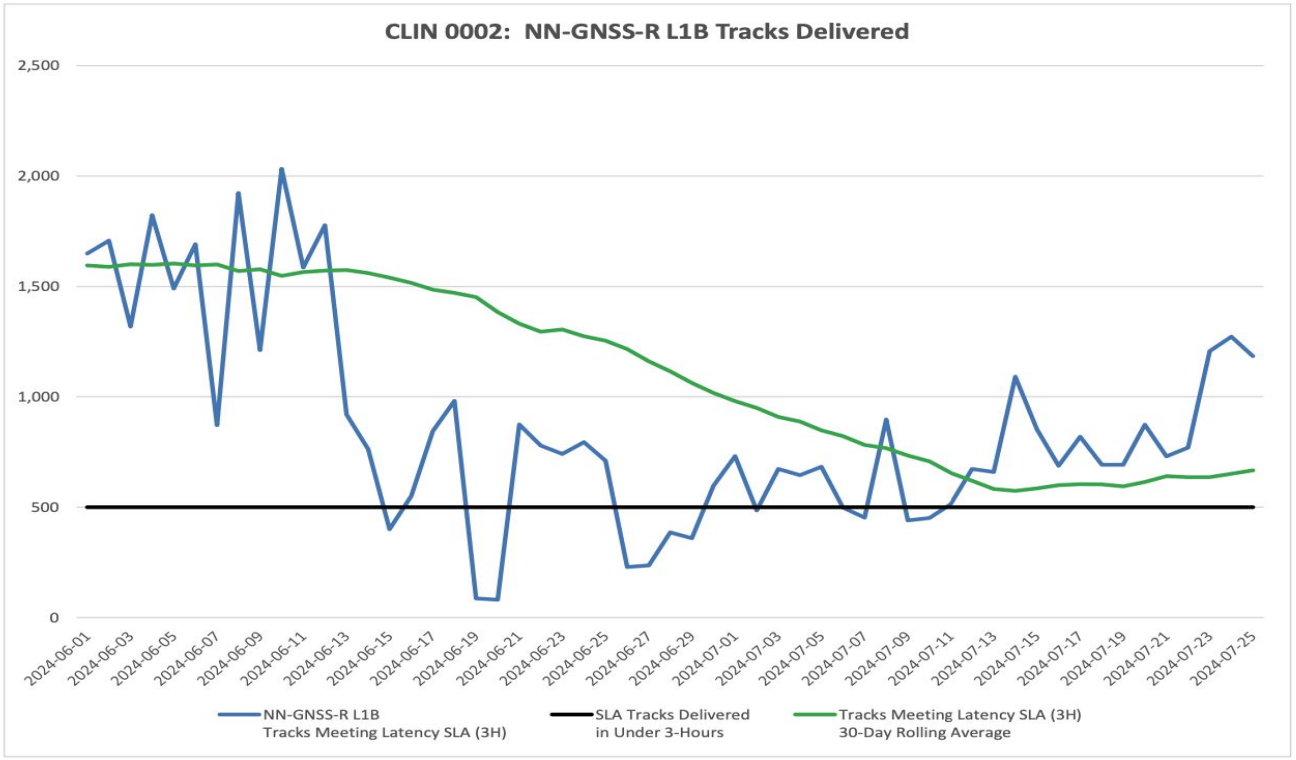


NOAA GNSS-R OSW Pilot Member Organizations

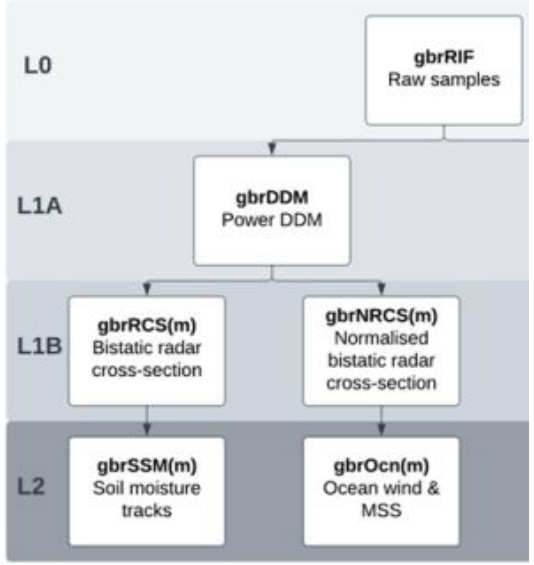
Agency	*Role*
• **NOAA/NESDIS Commercial Data Program**	• Pilot project management.
• **NOAA Center for Satellite Applications and Research (STAR)**	• Statistically analyze and characterize pilot GNSS-R data including OSW products in comparison to satellite and numerical model data. • Quantify the impacts of pilot GNSS-R derived OSW and GNSS RO Data for topical cyclone prediction. • Assess ancillary GNSSR Level 2 products generated by UCAR.
• **UCAR and University of Colorado**	• Develop, improve, and validate data products including soil inundation, detection and mapping of inland water body boundaries, detection and characterization of sea ice, precision altimetry over calm ocean, sea ice, and inland water bodies. • Utilize correlative datasets to validate and compare GNSS-R pilot datasets.
• **NOAA Quantitative Observing System Assessment Program (QOSAP)**	• Conduct impact assessment and optimization for the assimilation of Ocean Surface Winds (OSW) data. • Evaluate OSW vendor data quality against CYGNSS products.
• **Joint Center for Satellite Data Assimilation**	• Determine methods for ocean surface wind product ingest and assimilation. • Determine OSW data impact on global numerical weather prediction using JEDI Skylab system. • Quality control, error assignment, and systematic bias examination for vendor GNSS-R data.
• NWS NCEP	• Data assessment, impact analysis & data assimilation plan, timeline development for utilization.
• OSPO	• Evaluation of GNSS-R products.
• NCCF and NCEI	• Data ingest, dissemination, and archive.
• EUMETSAT, ESA, ECMWF, IEEC and ICE-CSIS (Spain), UKMET and UKNOC	• International participants • Pilot data evaluation and data product development

GNSS-R Vendor Data Delivery

- The pilot included 6 months of data delivery (Jan – July 2024) and 3 months vendor evaluation support (ongoing).
- Additional Spire data from the NASA CSDA Program is also available for research.



Spire data delivery mainly exceeded requirements aside from a brief data drop due to satellite loss and SpaceX launch delays.



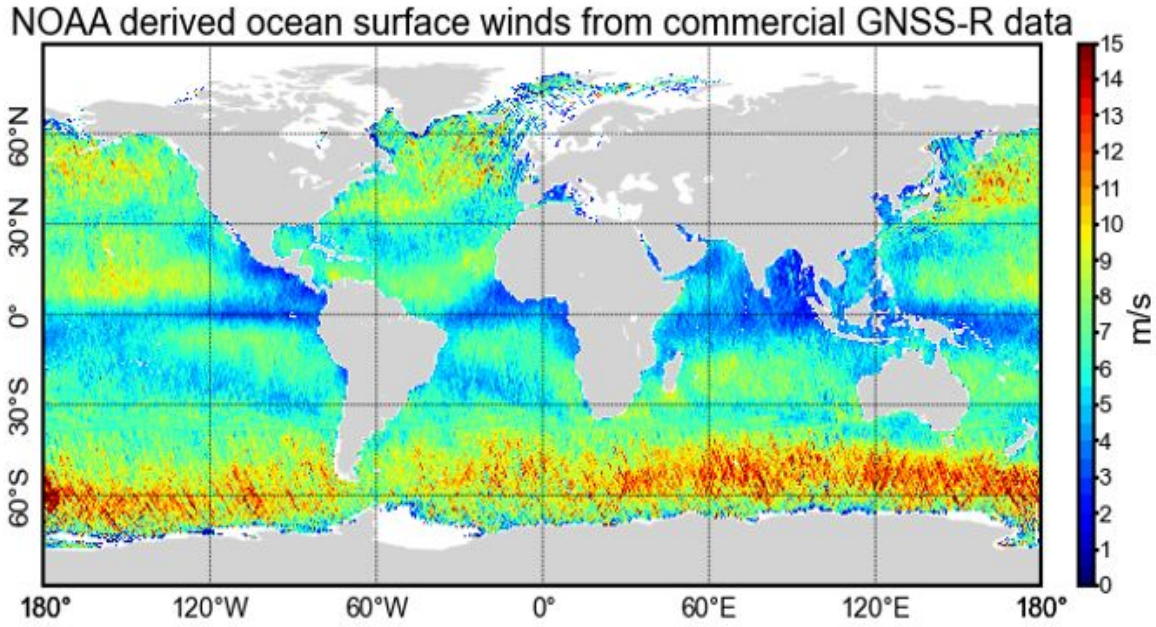
Spire data includes L1 and L2 products

STAR Activities

STAR's Pilot activities include assessing vendor data, adapting STAR-developed GNSS-R ocean wind speed products to Spire data, and investigating the utility of the Spire-developed wind speed products.

STAR achievements to-date include:

- **Fully characterized the Spire-provided L1 data**
  - Identified calibration, statistical, and geographical errors.
- **Fully characterized the Spire-provided L2 wind speed product**
  - Validated against other satellite and model wind data for consistency and accuracy.
- **Defined GNSS-R data sets for use in data assimilation (DA) impact studies**
- **Developed and released NOAA L2 Spire wind product**
  - Released v1.0 wind product based on Spire L1 data on 9/16/24.
  - NOAA L2 Spire winds dataset provides precision geolocated average wind speed with 25x25Km cells and daily global coverage from all available Spire spacecraft.

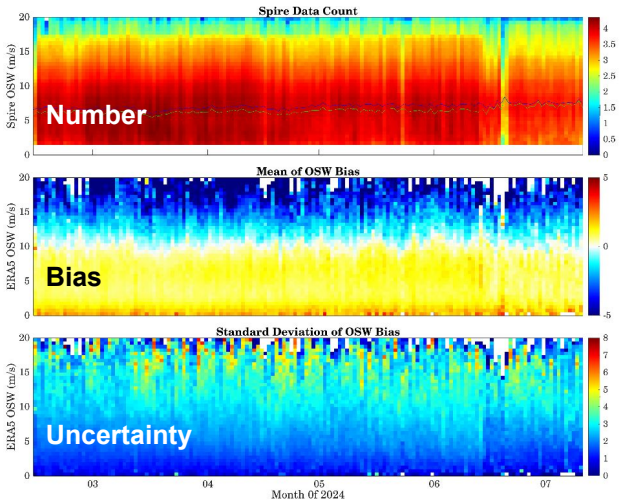


https://manati.star.nesdis.noaa.gov/spire/NOAA/L2/

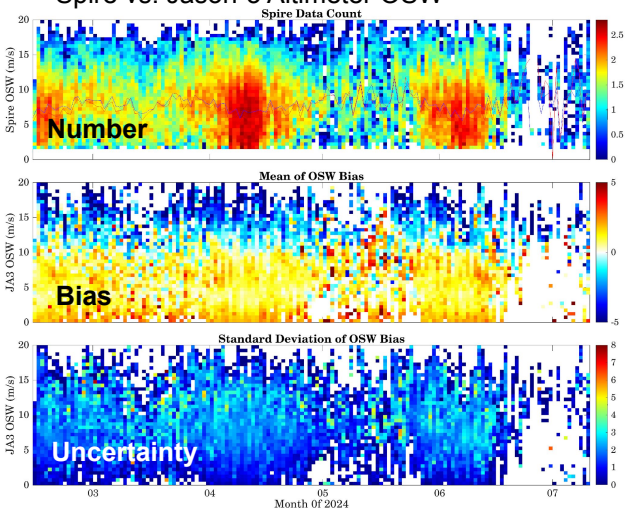
STAR Activities, continued

- **Evaluated the accuracy, uncertainty and stability of Spire OSW data.**
  - Through comparison with co-located ERA5 and Jason-3 altimeter OSW speed data.

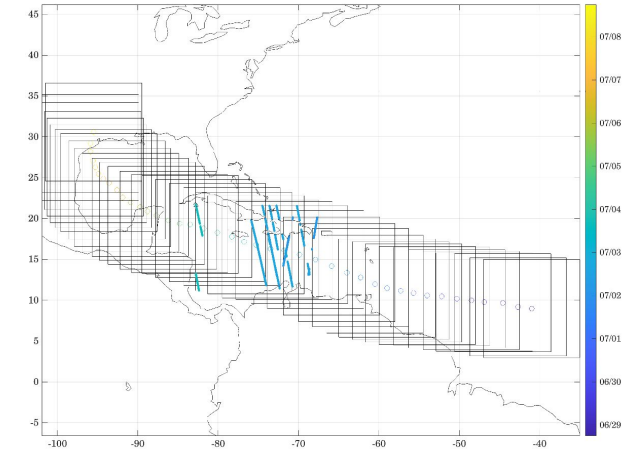
Spire vs. ERA5 OSW



Spire vs. Jason-3 Altimeter OSW



- **Studying assimilated GNSS-R OSW speed impacts on regional model forecasts of a Tropical Cyclone (TC) event.**
  - Completed HAFS Control runs of Hurricane Beryl (2024) without GNSS-R; test runs adding NOAA CYGNSS and Spire OSW speed are in progress.
  - Impacts of assimilated GNSS-R data on HAFS forecast TC intensity and inner-core structure will be evaluated.



Map of DA Impact study on Hurricane Beryl (2024) HAFS TC forecasts. Extracted Spire OSW profiles falling into the 12° × 12° HAFS inner storm-following nest that assimilates observations.

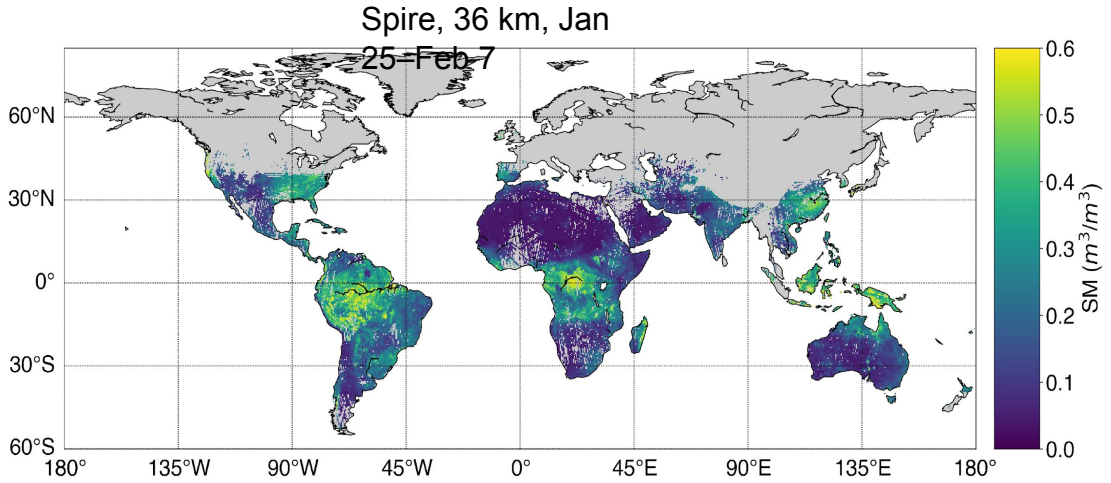
For more information, see poster: Liu et al., *Evaluation of Spire GNSS-R Ocean Surface Wind through Comparison with ERA5 Reanalysis and Jason-3 Altimeter Wind Data*

UCAR Activities

UCAR's Pilot activities include data assessment and environmental GNSS-R applications.

UCAR achievements to-date include:

- **Data assessments** including:
  - Data volume, spatial sampling coverage, quality flag analysis, and reflectivity evaluation
- **Developing Soil Moisture (SM) products**
  - Developed a linear regression method using Spire reflectivity observations and SMAP SM.
  - **Generating daily & weekly 36 km SM using Spire reflectivity, based on a linear regression method.** Overall RMSD of daily Spire SM is comparable to other research using CYGNSS reflectivity.
  - Implemented a forward model of reflectivity to semi-physically invert SM. Conducted an initial experiment using data in Australia.

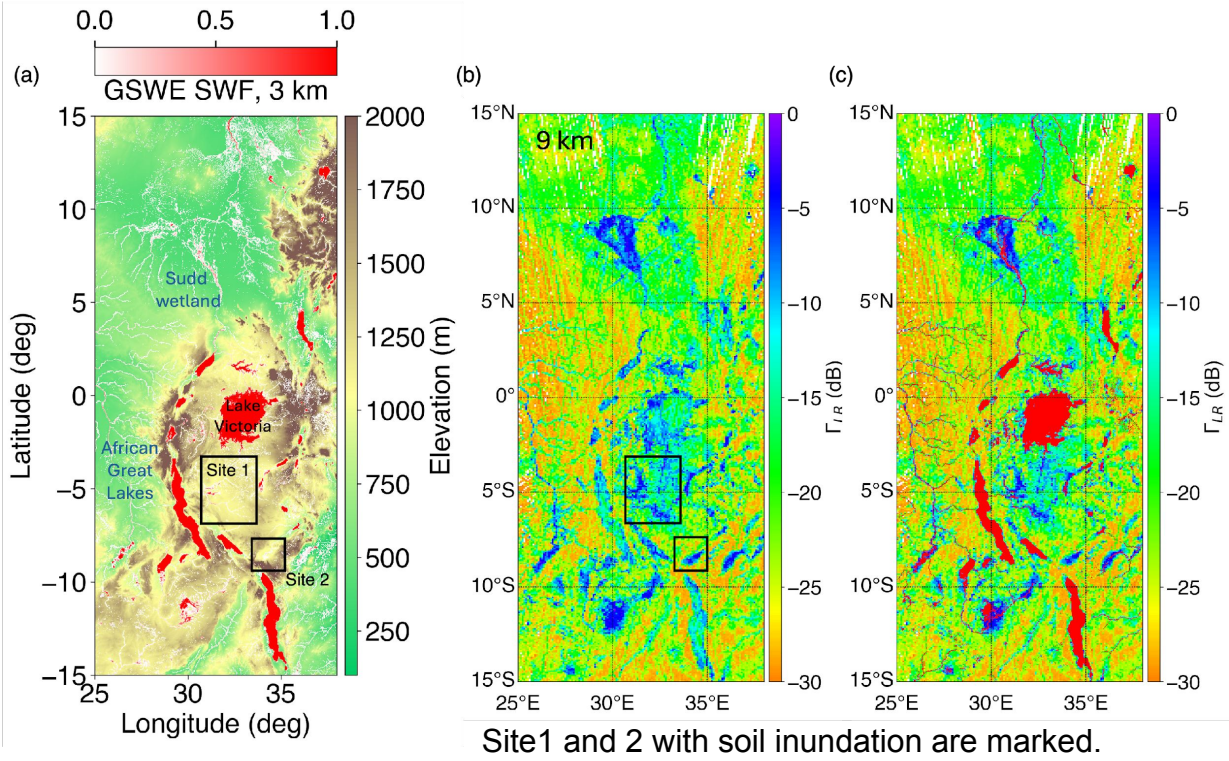


UCAR Soil Moisture Using Spire GNSS-Reflectometry Observations

For more information, see presentation on Monday afternoon (9/16): *Global Monitoring of Soil Moisture Using Spire GNSS-Reflectometry Observations*

UCAR Activities, continued

- **Developed a method to map Ground Surface Water (GSW) and its temporal changes**
  - A first-order reflectivity-based detector for a binary classification of water and ground.
  - A simple case study was conducted using reflectivity to reveal temporal variations in soil inundation drainage events in East Africa.



UCAR GNSS-R Ground Surface Water (GSW) mapping

- **For more information, see poster: *Mapping Inland Surface Water Using Spire GNSS Reflection Data***

UCAR Activities, continued

- **The University of Colorado is working with UCAR on environmental applications using Pilot GNSS-R data.** Work to-date includes:
  - **Remote sensing of ice shelf surface characteristics.**
    - **For more information, see presentation on Monday (9/16): Anderson, Sophie, *GNSS-Reflectometry Based Mapping of Antarctic Ice Shelf Surface Characteristics***
  - **Grazing angle GNSS-R carrier phase measurements for studying IWB surface height variations and flow direction.**
    - **For more information, see presentation on Monday (9/16): Scott, Margaret, *Studying the Tonle Sap Lake Surface using GNSS-Reflectometry and ICESat-2***

QOSAP Activities Detailed

QOSAP Pilot activities include conducting impact assessments and optimization for assimilation of Pilot OSW data:

- **Develop algorithms for the assimilation of Spire Pilot data.** Quantify the impact in NWP as a function of the number of satellites.
- **Tune assimilation algorithms for Pilot data** (forward operator, observation error and quality control).
- **Evaluate the impact of CDP Pilot OSW data on global NWP and on hurricane forecasting for a selected case**.

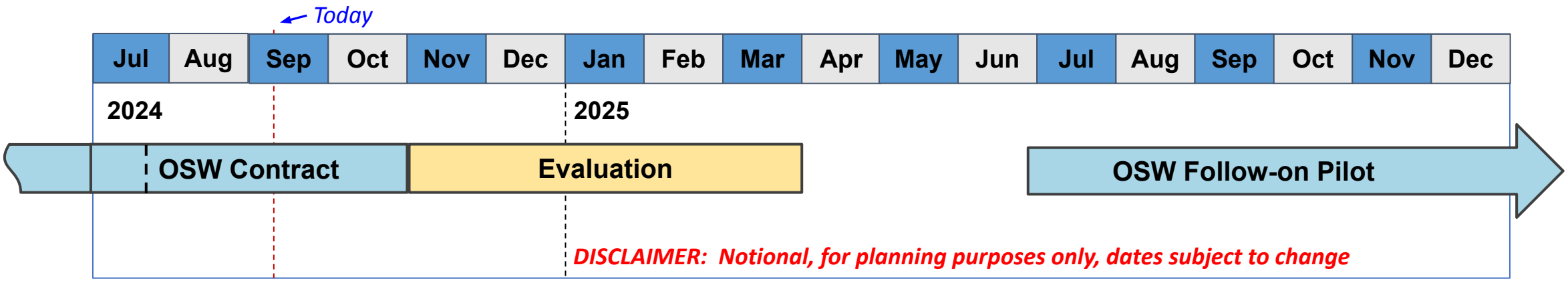
Activities to-date include:

- **Conducted preliminary CYGNSS OSW data assimilation tests** in preparation for the Spire Observing System Experiments (OSEs).
- **Obtained Spire OSW retrievals for preliminary data assimilation tests as well as a Spire forward operator.**
- **Conducted a preliminary 4-cycle test using the QOSAP original modified forward operator** without tuning of quality control parameters or error modification.

Ongoing work and next steps include:

- Work to better understand CYGNSS results and optimize impact on global weather forecasting.
- Develop assimilation algorithms for Spire data, including testing a Spire-developed forward operator.
- Quantify impact of Spire data in global weather forecasting, including tropical cyclone evaluation.
- Quantify impact of Spire data in hurricane forecasting (HAFS) for a selected case.

Next Steps



- The NOAA NESDIS OSW pilot study has completed its data collection phase and is now in a 3-month technical support phase with vendor Spire.
- CDP anticipates evaluation will continue through Q1 2025, at which time a report will be issued to the NESDIS AA with results and recommendations on proceeding with a second pilot in the late 2025 timeframe.
- Factors influencing a second pilot include:
  - Obtaining data during the North American hurricane season (August – November)
  - Ability to conduct assessments and comparisons for a variety of GNSS-R datasets.

Questions?

NESDIS CDP Organizational Email: nesdiscdp@noaa.gov
Gerry Peltzer, NESDIS OSW PM: gerard.peltzer@noaa.gov
Natalie Laudier, NESDIS CDP PM: natalie.laudier@noaa.gov