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Committee on Earth Science and Applications from Space

Presented by:

Joe Carroll, Director of Business Development – Spire Federal

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Spire Market Sectors & Product Verticals

Satellite-driven global data products & space services

Maritime

Spire provides continuously refreshed information on the state of the global waterways by leveraging the International Maritime Organization (IMO) Automatic Identification System (AIS) standard

Aviation

Spire collects near real-time information on the movements of civilian aircrafts across the globe, following the International Civil Aviation Organization (ICAO)-backed Automatic Dependent Surveillance-Broadcast (ADS-B) standard

Weather

Spire models global space-based weather data at various vertical levels, with critical implications for severe weather events forecasting, preparation, and management

Earth Intelligence

Spire generates unique data sets of Earth's surface and atmospheric layers using GNSS remote sensing techniques such as radio occultation and reflectometry

Space Services

Spire offers access to its proven LEMUR CubeSat platform and infrastructure for a wide range of customer- driven missions. Standard APIs enable customer access to Spire's cloud-based constellation management and ground station network

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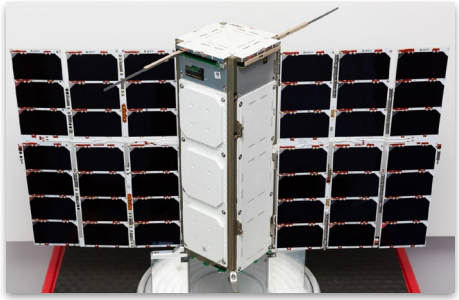
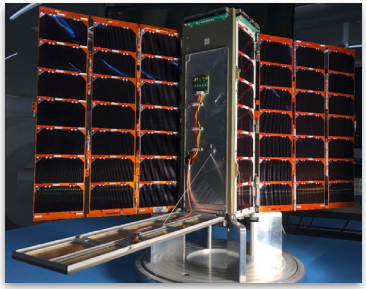
Spire GNSS Earth Observation Infrastructure

Spire GNSS-RO Satellites

- 3U form factor
- Moderate gain, dual antennas for rising / setting Radio Occultation
- Multi-GNSS signals tracked
- Rapid on-orbit innovation





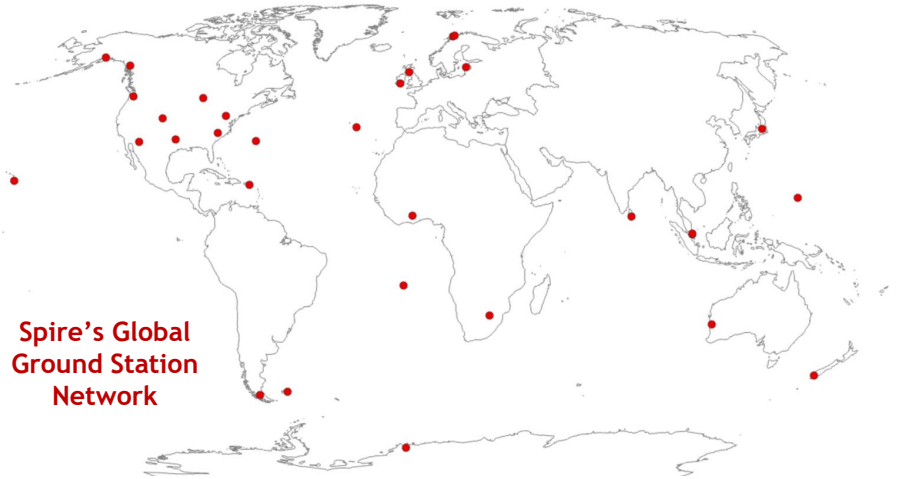
Spire GNSS-R Batch 1

- Dual nadir antennas
- Multi-GNSS signals tracked
- **30 simultaneous reflections**
- Launched in Dec 2019

Spire GNSS-R Batch 2

- Three GNSS-R antennas
- Multi-GNSS signals tracked
- **45 simultaneous reflections**
- Launched in Jan 2021

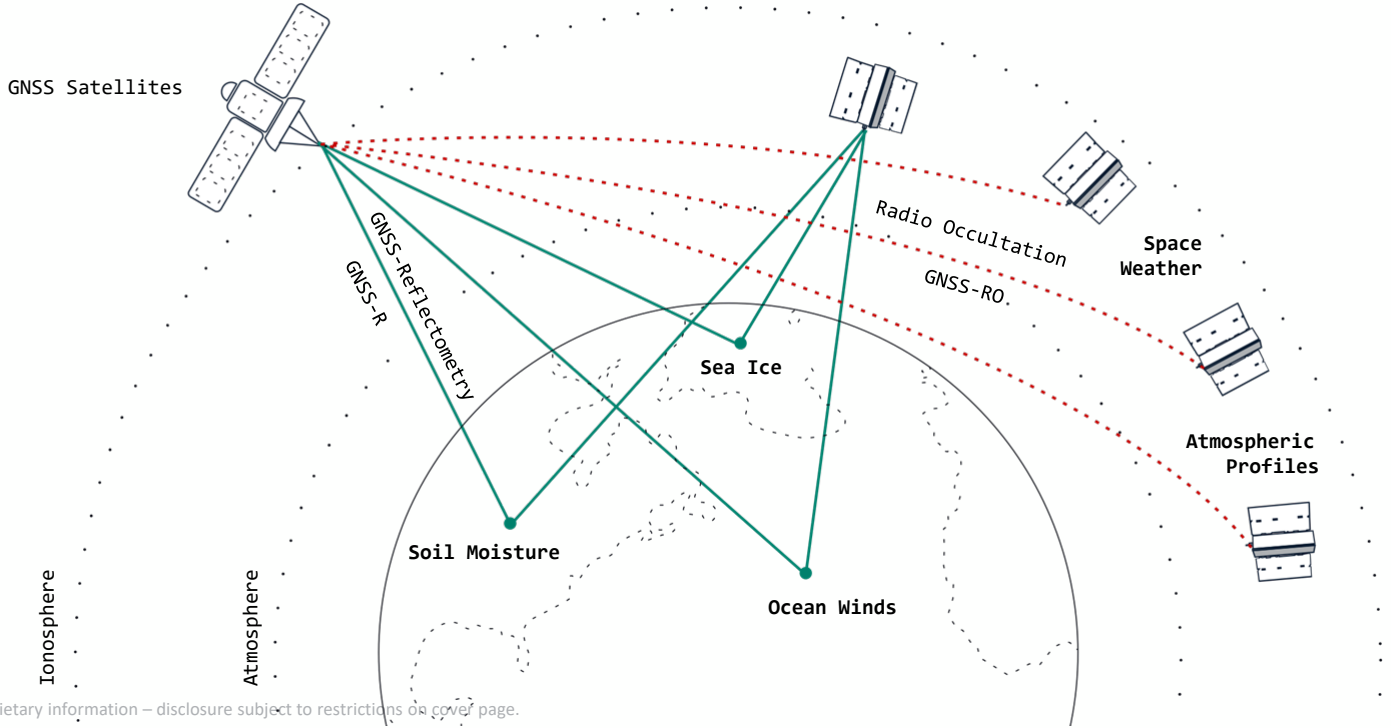
- 20+ on-orbit GNSS EO satellites
- GNSS-R sats in 37 deg and SSO orbits with Nadir oriented antennas
- Global ground station network with **over 32 locations** for low-latency data downlink



Spire's Global Ground Station Network

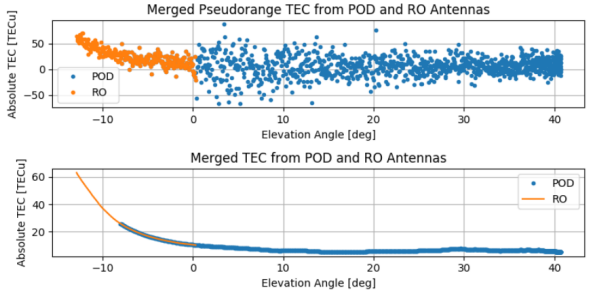
Spire Earth Intelligence Data

Our satellites capture data relevant for NWP modeling, space weather monitoring, Ionosphere corrections for navigation, and Thermospheric density



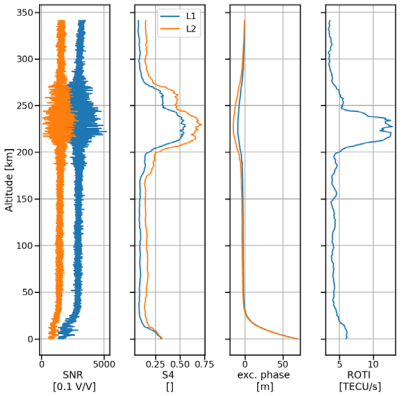
Growing GNSS-RO Volume and Coverage

- Radio Occultation Profiles
- Space Weather Total Electron Content (TEC) estimates and scintillation

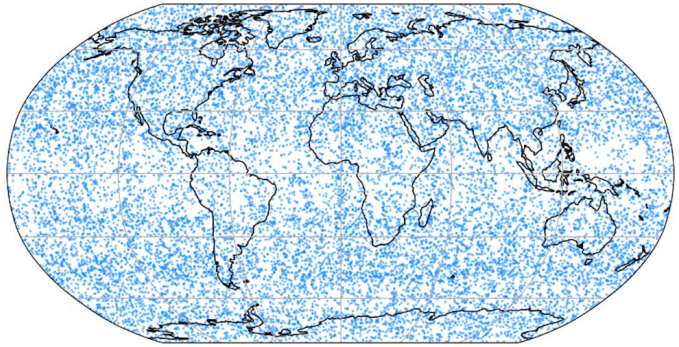


F-region 50 Hz Data and Scintillation Indices

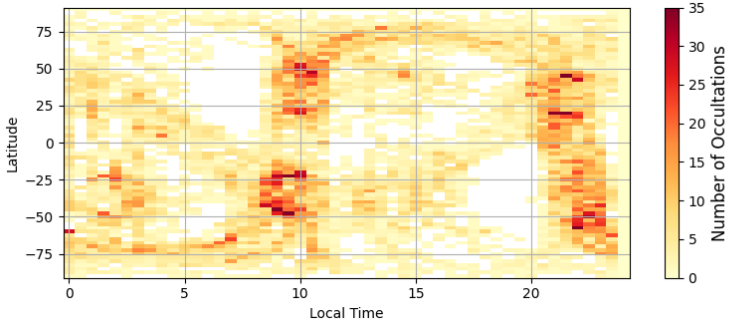
Example of combining TEC across multiple antennas



World's largest producer of RO profiles
(24 hr coverage shown below)



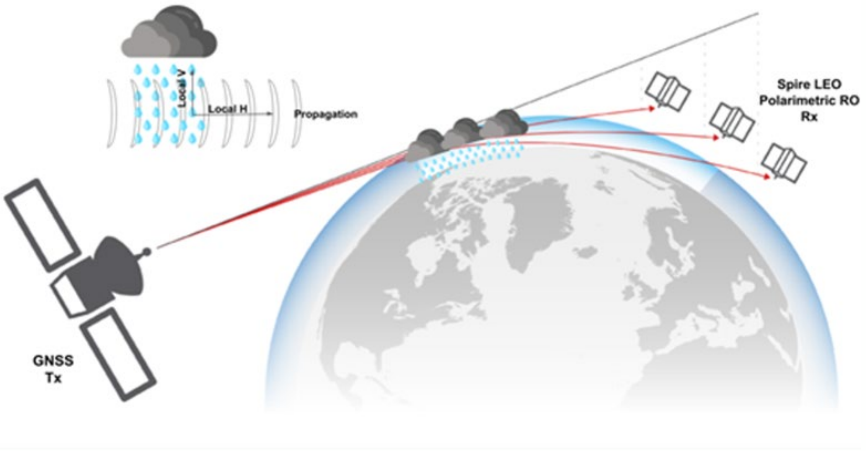
Diverse local time coverage



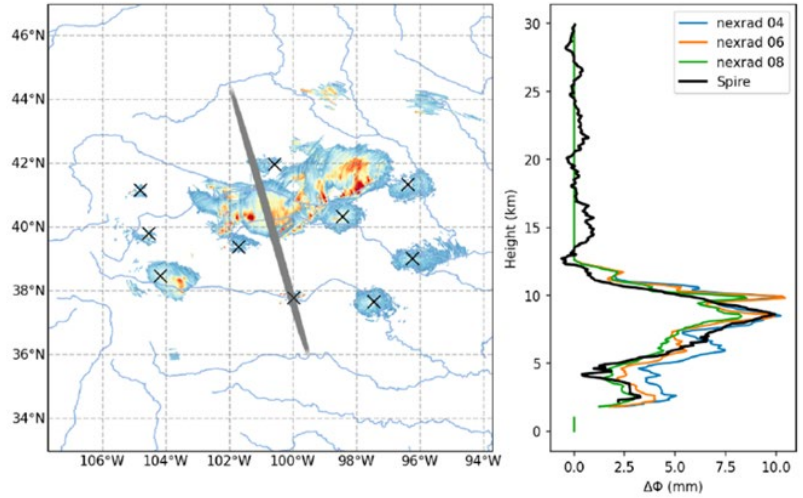
EI Polarimetric RO

- The polarimetric RO technique derives information about precipitation rate by measuring the phase shift between linearly polarized occulted signals
- 3 PRO-capable satellites launched in 2023 (ESA-funded PROGRESLux mission) and produced 10X amount of available PRO data
- PRO polarization phase shifts demonstrate clear sensitivity to precipitation. Additionally, RO profiles (bending angle) can be derived from PRO data with quality similar to Spire's operational RO

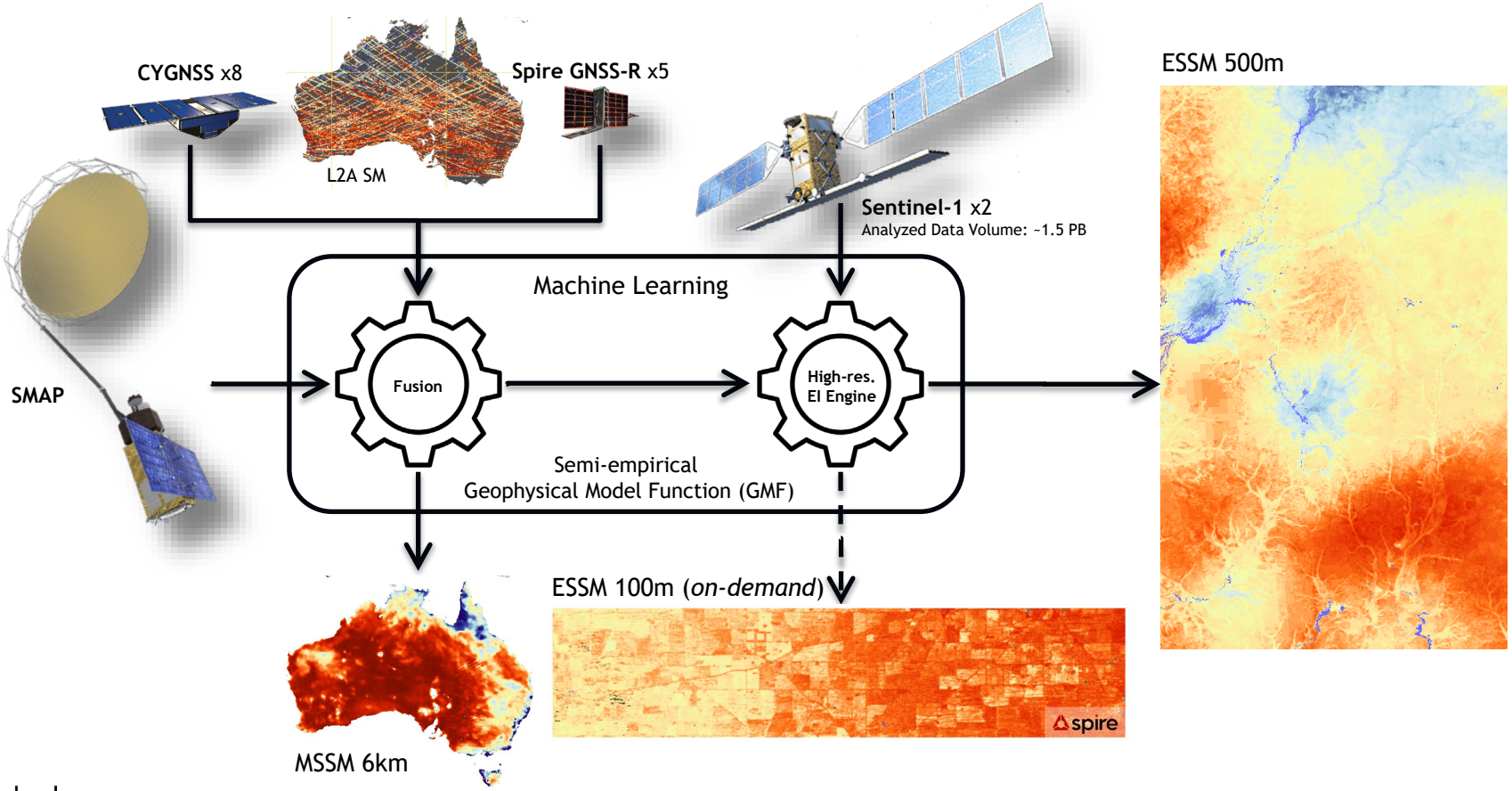
Spire satellites with PRO antennas sense precipitation along with traditional RO variables along ray path



PRO Data Match Well with Ground-based Radars (NEXRAD)

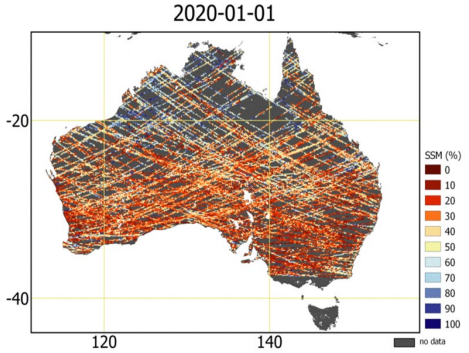


Spire SM Monitoring System

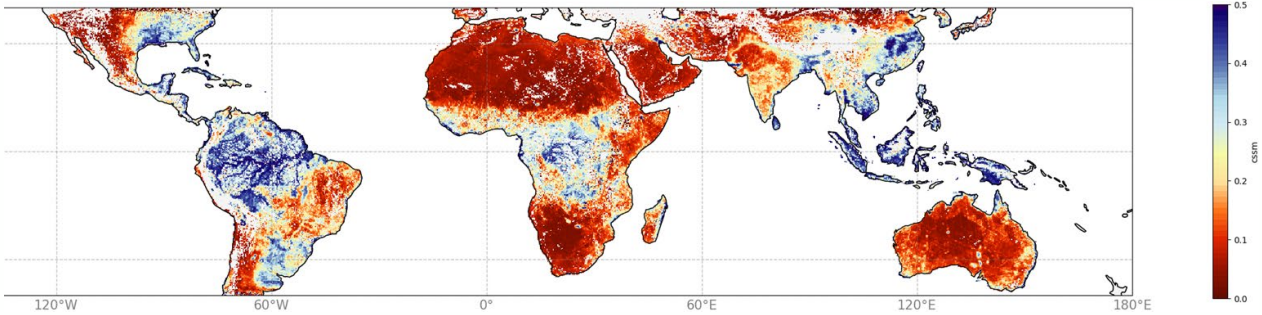


Spire's Operational L2A SM Products

- The surface reflectivity of the L-band GNSS signals, measured by GNSS-R receivers on board the Spire satellites, are used to monitor changes in soil moisture.
- The Spire's SM retrieval algorithm is a semi-empirical change detection method. The relative measure of reflectivity is calibrated to volumetric units using historical NASA's SMAP observations.
- The Level 2A product contains trackwise GNSS-R measurements of SM in volumetric units (cm^3/cm^3), Quality Flags, and observations' geometry information.

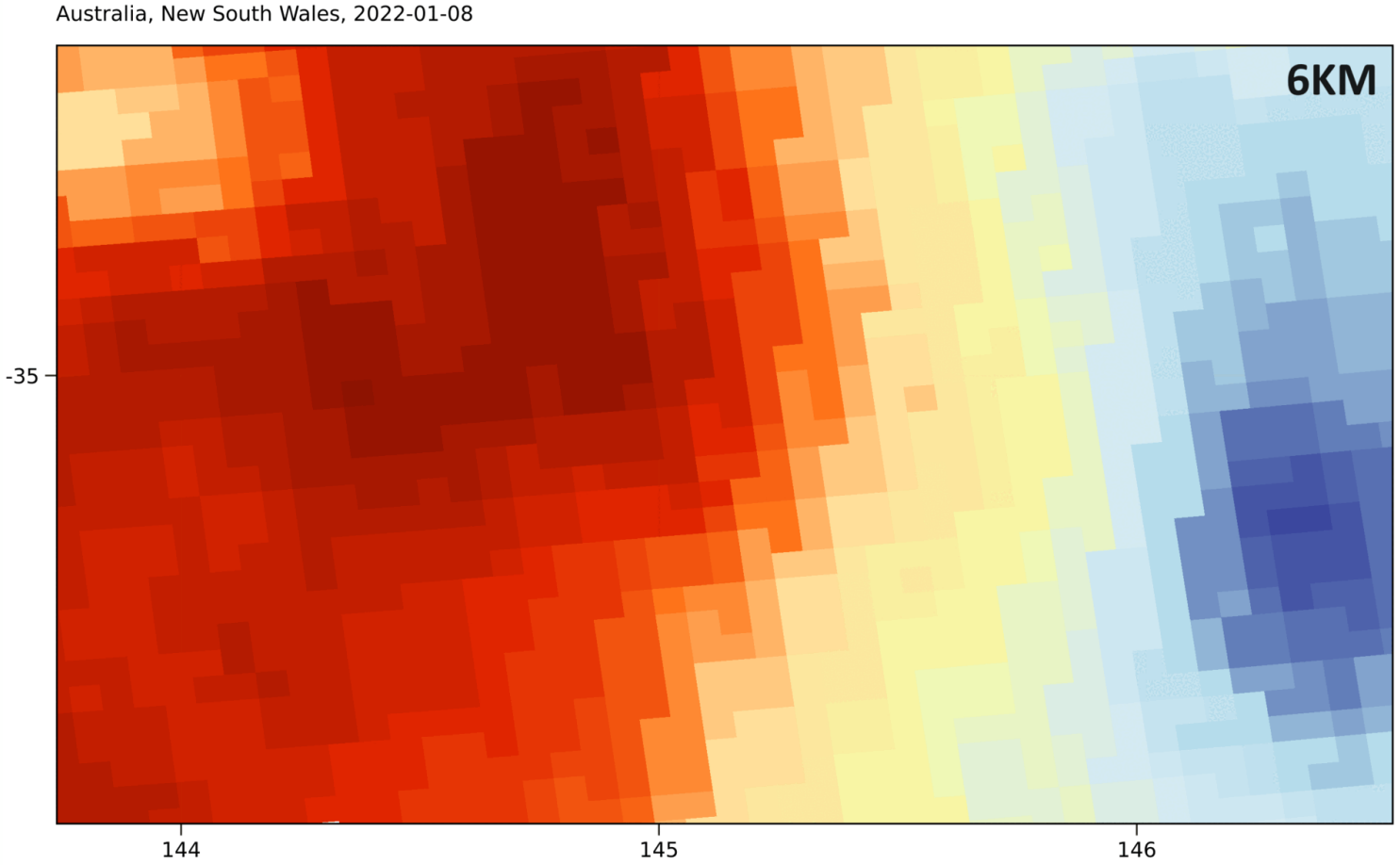


Daily average of the relative Surface Soil Moisture measured by GNSS-Reflectometry technique



Monthly averaged L2A SSM averaged to a lower (25 km) resolution grid (caution: no masks have been applied).

A detailed SM product with tailored resolutions



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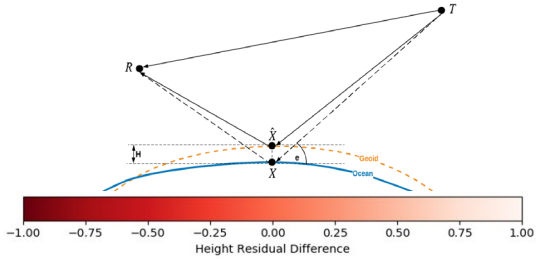
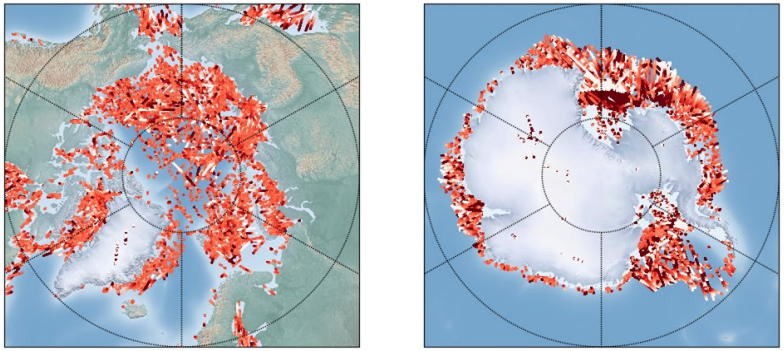
Grazing Angle GNSS-R Sea Ice

Spire produces two L2 sea ice products from grazing angle GNSS-R techniques derived from Spire GNSS-RO satellites

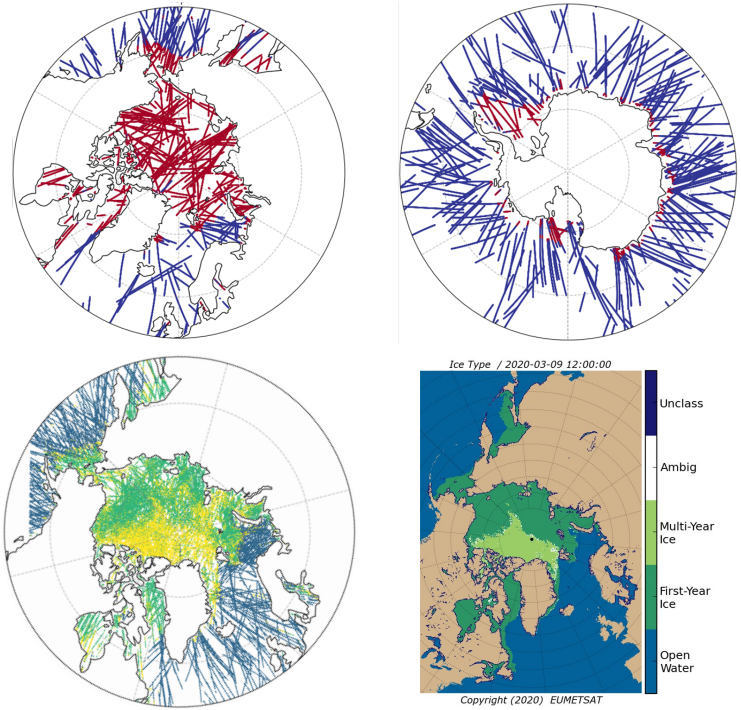
Sea Ice Altimetry





Altimetric Height Coverage over 1 Week

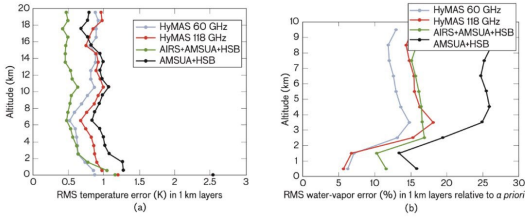
Sea Ice Detection and Classification



Benefits of HyMS Data

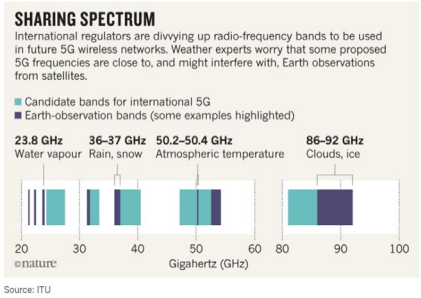
Channel volume and vertical resolution improve value of HyMS data

Retrieval Accuracy



- In simulation studies, using HyMS to sample more channels improves retrieval accuracy of water vapor, temperature profiles
- *Studies currently agree* found 0.5K temperature, 5% humidity improvements
- *Boukabara and Garrett* found temperature and water vapour improvements compared to AMSU/MHS

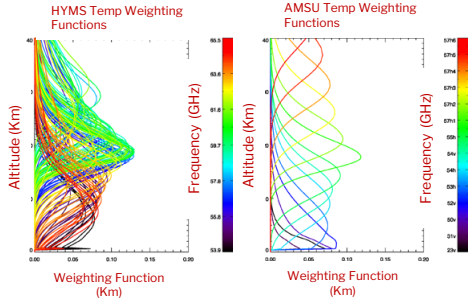
RFI Mitigation



Source: ITU

- Digital channel formation supports time-frequency domain methods and statistical methods to be applied to remove RFIs

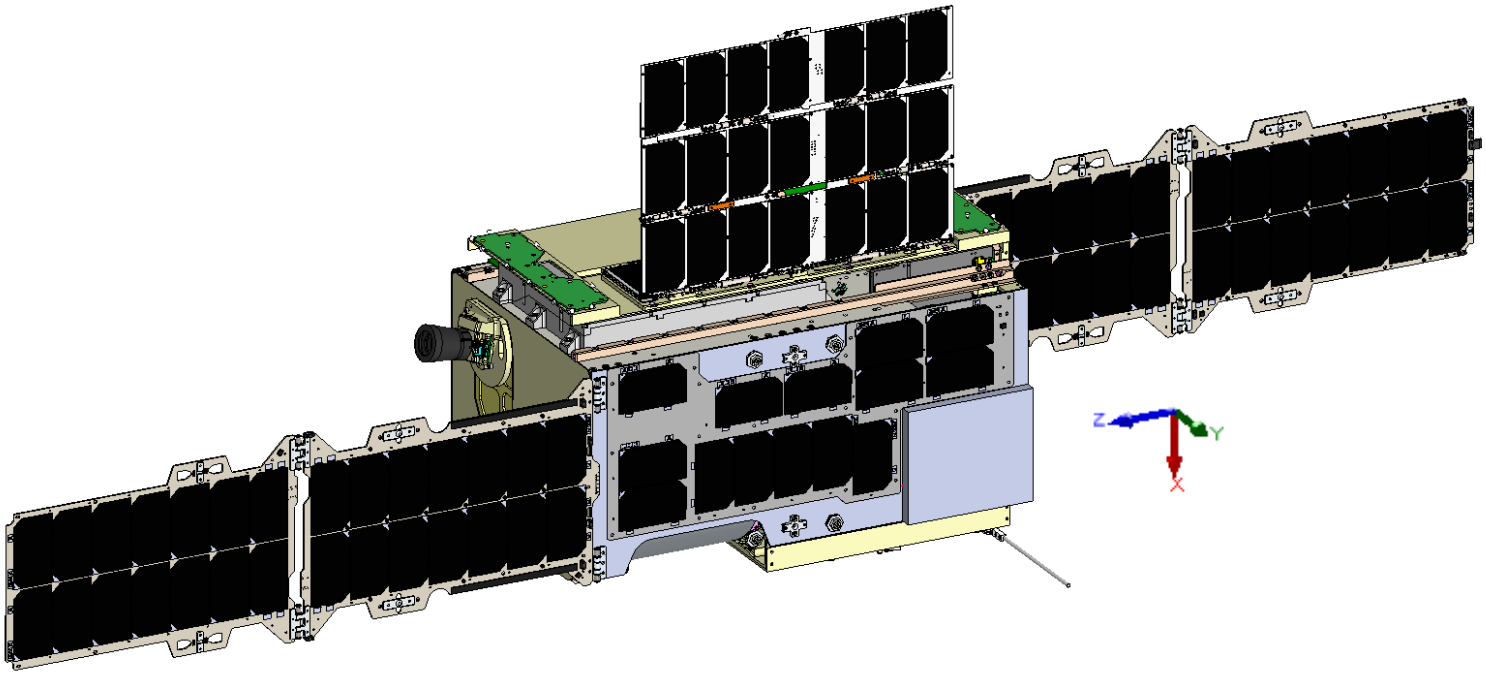
Vertical Resolution



- Provides atmospheric layer mean temperature, and moisture profiles over geographic point
- Each sounder channel is sensitive to temperature and humidity at different atmospheric layers
- Weighting functions indicate the distribution of radiances from various atmospheric levels across frequencies.

External 16U Views| Mission Design

System at Critical Design Review, ongoing Build Readiness activities



Better Nowcasts and Forecasts

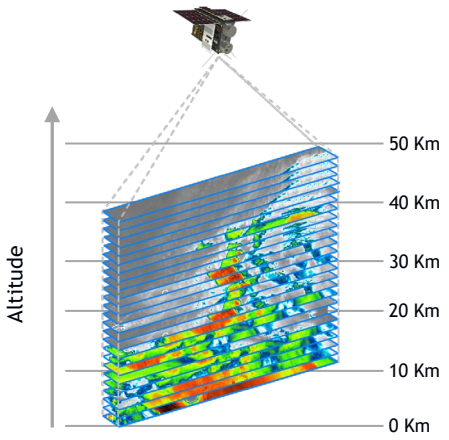
Hyperspectral Microwave Sounder (HyMS) vs. Microwave Sensors

HyMS

<40 kg Dedicated Platform

>1000 Channels

Updated every 3 Years



Benefits

1 Improved **Accuracy**

2 Better **RFI Noise Mitigation**

3 Higher **Vertical Resolution**

4 Increased **Hydrometeor Characterization**

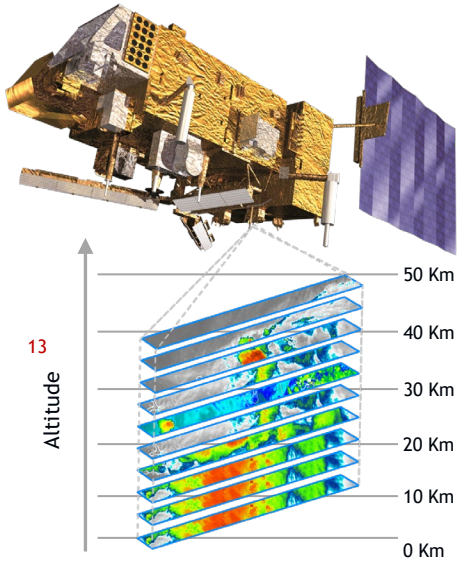
5 Additional Expected Benefits

MetOP SG MWS Instrument

>4000 Kg Multi-sensor Platform

24 Channels

Updated every 20 Years



Discussion Questions

- Which data sets available now, or anticipated in the near future, from non-government (e.g., commercial) providers could be of interest to NASA, NOAA, and USGS?
  - GNSS-R, GNSS-RO, High-Resolution Soil Moisture, Hyperspectral Microwave Soundings, Space Weather
- What are the advantages to the government and science/operational communities of using non-government data?
  - Speed, Scalability, Cost, Coverage Diversity, resiliency.
  - Spire has been the first to add GNSS-RO/PRO, GNSS-R capabilities on a CubeSat, beam forming, relative calibration, and others
- How well does current contracting work? How should it?
  - Path from pilot programs to operational deliveries unclear. Length of contracts doesn't align with spacecraft lifetime and makes planning difficult.
  - Improved industry/government communications to better understand planning factors and data demands.

Discussion Questions

- What are the incentives and disincentives to provide data to NASA/NOAA/USGS?
  - NASA put a man on the moon with less computing power than is in our phones. These are the people who are going to change our world for the better and commercial companies can give them more and better data to do that.

- Should NASA/NOAA/USGS play roles beyond buyers, such as centralized validation?
  - NASA/NOAA have not just played roles as buyers, they are the validators of the data we provide.

Thank you

From our team, to yours.

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