The Global L-band Active/Passive Observatory for Water Cycle Studies (GLOWS): High Resolution L-band Wind Speeds

David Long[1], Rajat Bindlish[2], Jeffrey Piepmeier[2], and Mark Bailey[3]
[1]NASA Goddard Space Flight Center, [2]Brigham Young University, [3]MMA Design

Abstract

The NASA Instrument Incubator Program has funded the initial development of the Global L-band active/passive Observatory for Water cycle Studies (GLOWS) as a NASA Soil Moisture Active Passive (SMAP) data continuity mission. SMAP, launched in 2015, collected L□band radiometer and radar measurements over land and ocean [1,2]. SMAP observations have demonstrated utility in measuring sea surface salinity and ocean vector winds over the ocean, as well as sea ice thickness. Unfortunately, the SMAP quad-polarization radar failed soon after launch after collecting only 100 days data. The SMAP polarimetric radiometer continues to provide high quality radiometer measurements to the present.

To address the need for L-band radiometer data continuity, as well as provide radar measurements to support improved soil moisture estimates and L-band wind speed measurements, we have been developing the GLOWS mission which will continue the science observations of SMAP at the same resolution and accuracy at substantially lower cost, size, and weight [3].

SMAP employed a complicated 6 m offset-fed reflector antenna that rotated at 14 rpm. In order to reduce the cost of GLOWS, we are using a new deployable meta-material lens antenna [4]. This antenna is lightweight and rotationally symmetric (flat), which greatly simplifies spacecraft accommodation issues. At launch the antenna is densely packed into a small volume which enables a much smaller support spacecraft. Advancements in electronics further enable us to minimize the size, weight, and power (SWaP) of the radar and radiometer components of the GLOWS instrument system. The rotating antenna beam provides two azimuth looks of each point of the swath for wind observation.

GLOWS measurements will support critical ocean measurements such as sea surface salinity (SSS), sea ice, and ocean vector winds using a quad-polarization, multi-azimuth radar. While L-band measurements only enable wind speed measurements, they are much less affected by rain than higher frequency measurements, which makes them particularly valuable for wind measurement in tropical cyclones and hurricanes [4]. The GLOWS radar will have ~250 m resolution that will be averaged onto a 1 km resolution reporting grid. This will support global high resolution wind retrieval, particularly near-coastal regions. The cross-polarization measurements from the radar will ameliorate the need for additional incidence angles in solving for the wind speed.

L-band Science

Soil Moisture
- High-resolution and frequent-revisit
- Understand the impact of climate change on the water cycle
- Understand processes that link the terrestrial water, energy and carbon cycles
- Enhance agriculture, weather, flood and drought prediction

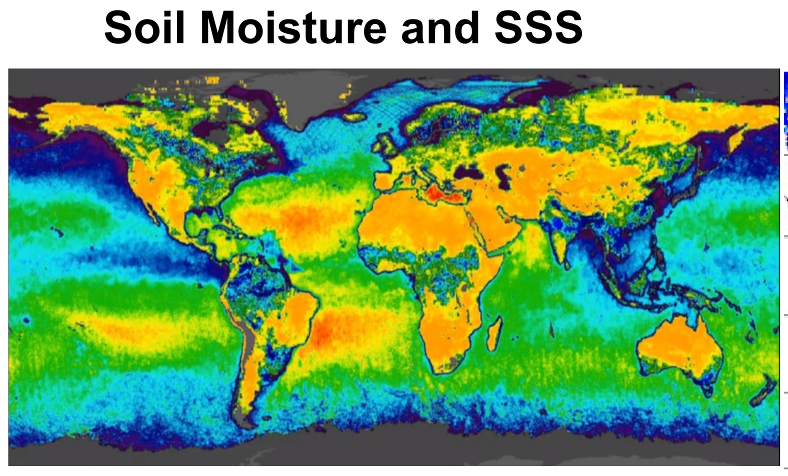
Ocean Surface Salinity
- Ocean circulation governed by salinity + temperature
- Global water cycle: Salinity reflects balance between precipitation and evaporation
- Freshening due to ice melt in Arctic
- Balance between Atlantic and Pacific
- Changes in coastal salinity due to increased run off

Ocean Surface Wind
- Polarimetric backscatter observations
- Effective in intense tropical cyclones
- L-band not affected by rain or clouds
- L-band does not saturate with wind speed

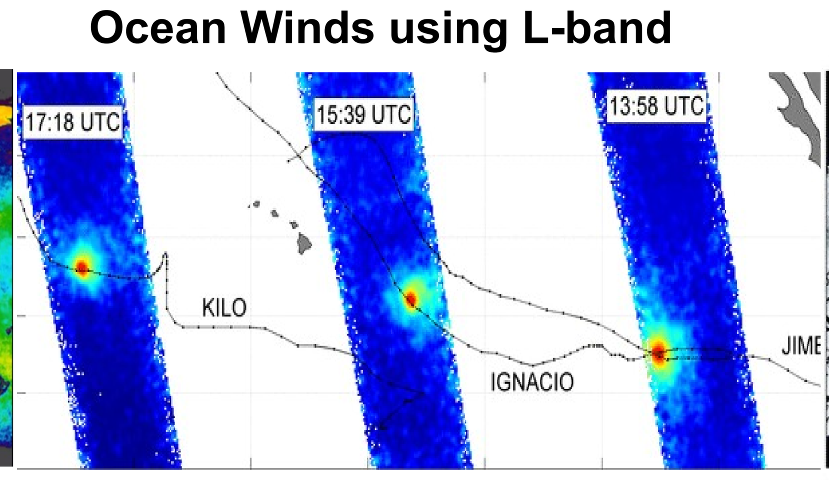
Vegetation Biomass
- Radar observations provide all-weather vegetation biomass
- Microwaves observations saturate at higher biomass
- Food security and agriculture
- Quantify net carbon flux in boreal landscapes

Thin Sea Ice
- Sea ice thickness up to 0.5 m
- Complementary observations to altimeter - thin sea ice
- Summer melt of sea ice and ice sheets can cause fresh water lenses

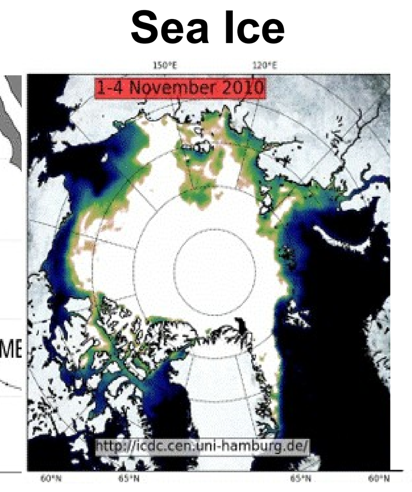
Soil Moisture and SSS



Ocean Winds using L-band

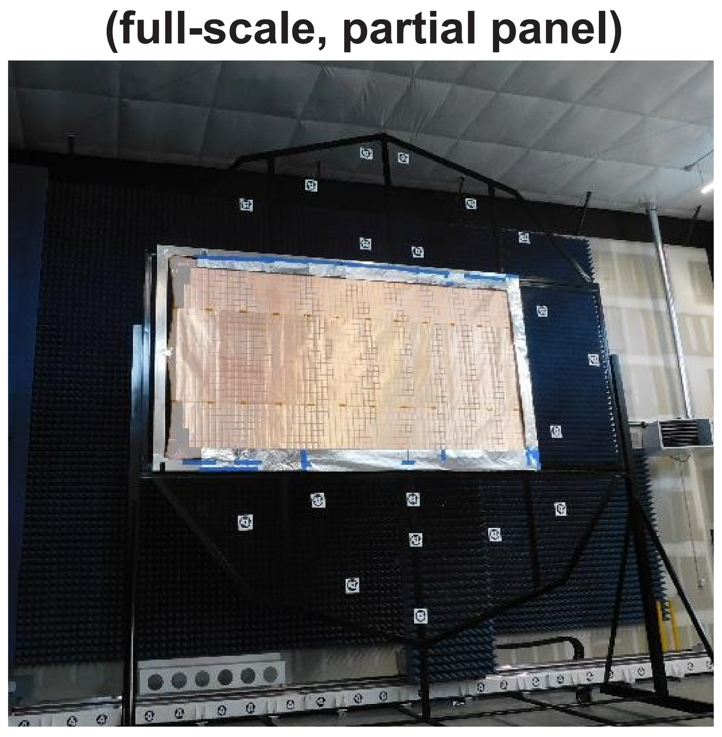


Sea Ice



Design updates

Lens Antenna Validation (full-scale, partial panel)



Lens RF design:
- Membrane L-band waveguide transmissivity and pattern
- Lens design and model validation – 2 m x 4 m full scale antenna slice
- Antenna feed

Lens structural design
- 6 m prototype deployment demonstration
- 6 m positional deployment stability

SMAP diplexer redesign

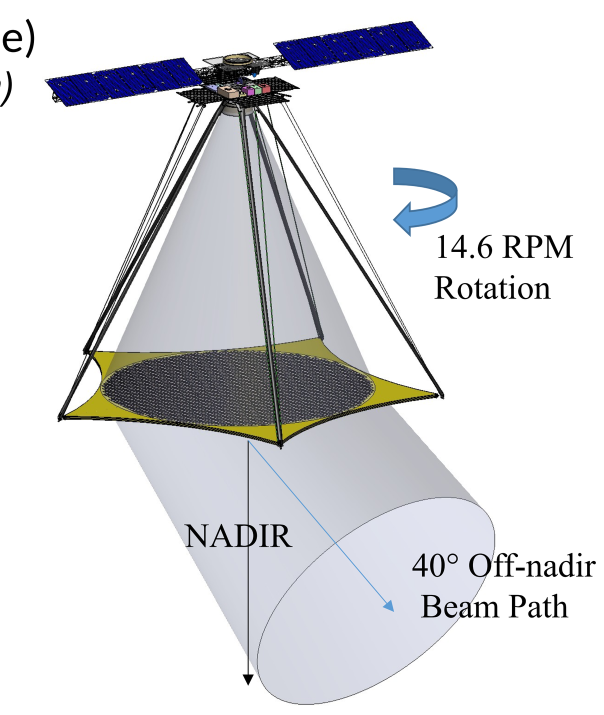
Radiometer Front-end Design with updated digital receiver Digital Receiver

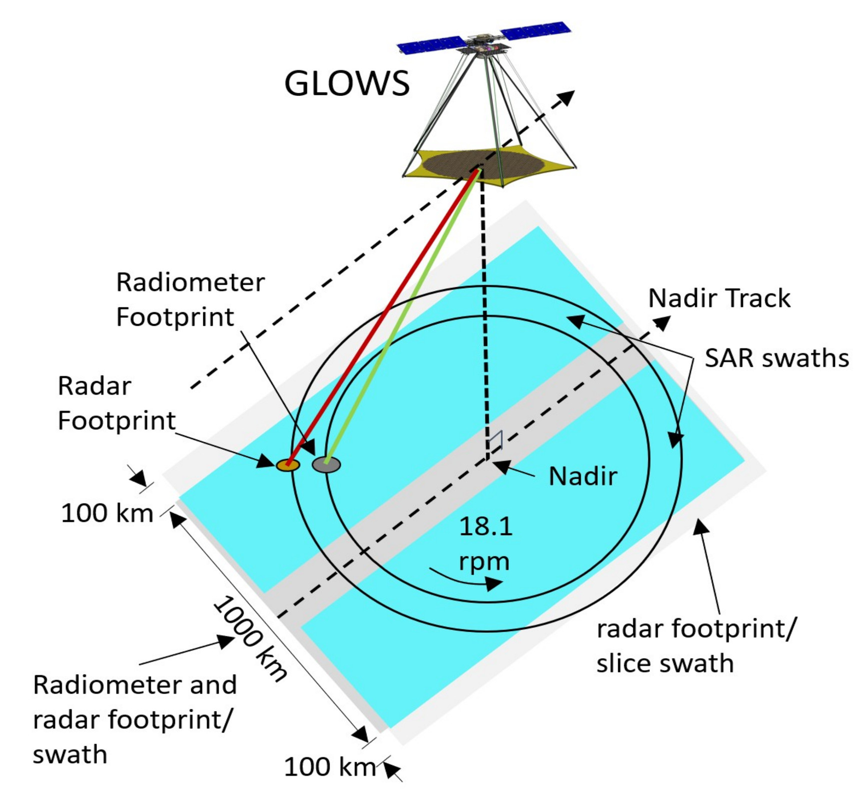
References

[1] D. Entekhabi, et al., "The Soil Moisture Active Passive (SMAP) mission," Proc. IEEE, vol. 98, no. 5, pp. 704–716, May 2010.
[2] J.R. Piepmeier et al., "SMAP L-Band Microwave Radiometer: Instrument Design and First Year on Orbit," IEEE Trans. Geosci. Remote Sensing, vol. 55, no. 4, pp. 1954–1966, 2017.
[3] D. Long et al., "Status Update: The Global L-band Observatory for Water Cycle Studies (GLOWS)," Proceedings of the International Geoscience and Remote Sensing Symposium, Pasadena, CA, July 2023.
[4] F. Ulaby and D.G. Long, Microwave Radar and Radiometric Remote Sensing, University of Michigan Press, Ann Arbor, MI, 2013.

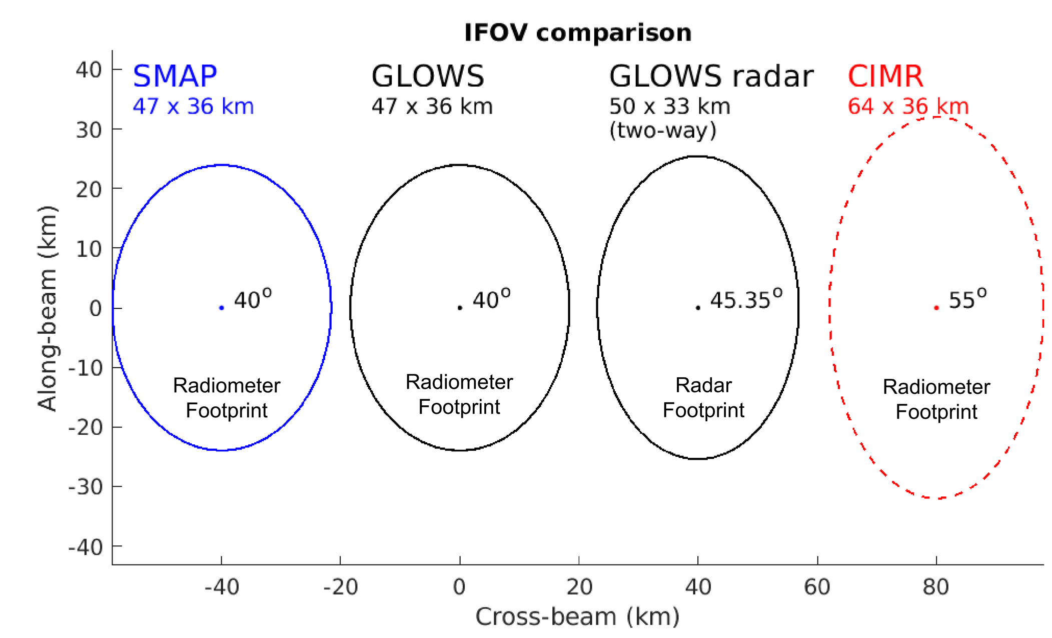
GLOWS Characteristics

- GLOWS is similar to SMAP with similar science but at much lower cost
- Create SMAP-like capability at lower cost
  - Science (resolution/swath/etc.)
  - Radar and radiometer (1000 km wide swath, 40° Incidence angle)
    - *L-band radiometer operating at 1.4 GHz (spatial resolution < 40 km)*
    - *L-band radar operating at 1.2 GHz (spatial resolution 1-3 km)*
  - Same CONOPS
- Low cost achieved by
  - Small size: stow within a rideshare volume
  - Use deployable high gain meta-material lens as a refractor
  - Lens steers beam off nadir to scan swath as lens rotates
  - Use multi-element patch array feed
  - Reduce mass and volume
  - Leverage SOA commercial radar technologies
  - Low cost, small size/weight
- Easier to deploy and rotate
- Meta-material lens used as antenna rather than reflector
- Aperture below the spacecraft enables unrestricted use of solar panels, GPS



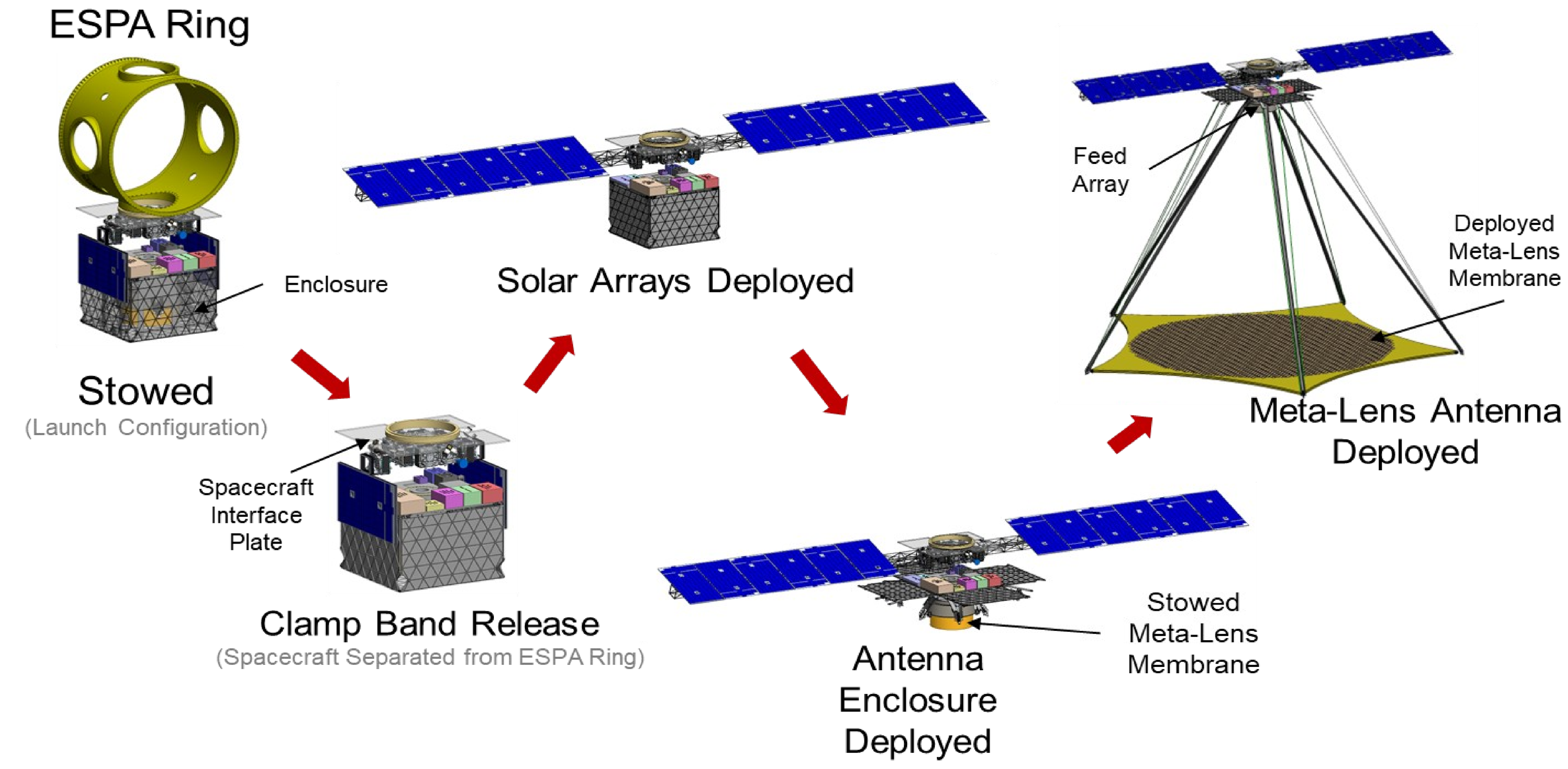


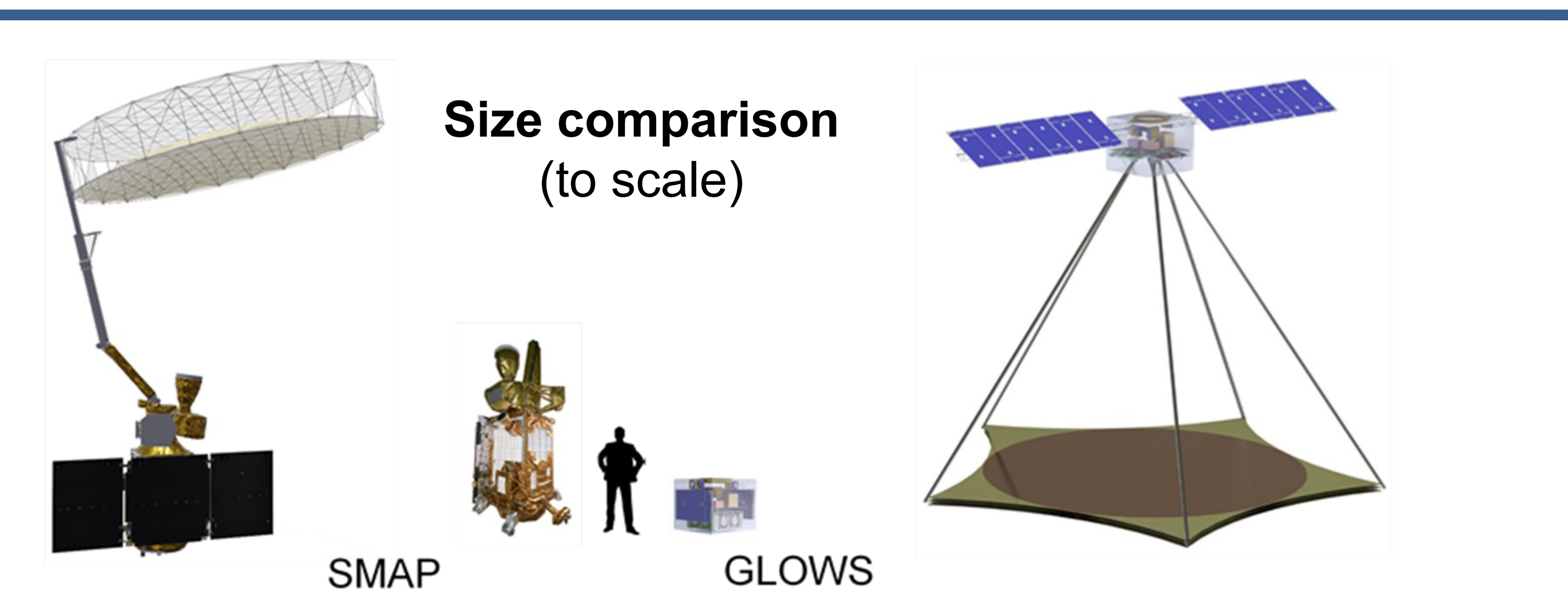
Radiometer swath 1000 km (same as SMAP)
Radar swath 1200 km (200 km wider than SMAP)



- GLOWS radar resolution of 1-3 km after SAR processing
  - 3 km resolution over the middle third of the swath
  - 1 km resolution over the outer thirds of the swath
- GLOWS radar slice resolution: 6 km x 33 km

GLOWS deployment





Summary

A low-cost MAP smallsat follow-on is now possible due advances in antenna technology needed for L-Band to reduce mass & volume and thus cust
- 60% reduction in mass
- 90% reduction in volume

GLOWS mission concept facilitates an active/passive SMAP follow-on mission
- Will enable global wind speed wind speed measurement with 90% daily coverage

E-mail: David Long <long@byu.edu>