



GNSS Remote Sensing and Earth Science Strategic Direction

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and**

11th FORMOSAT-3/COSMIC Data User's Workshop

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Overview of Today's Talk

- The new Decadal Strategy for Earth Observations from Space (and why it matters)
- 2017 versus 2007 (big picture)
- GNSS RO in Decadal Survey 2017
 - Explicitly mentioned
 - Climate panel report
- What about GNSS-R?
 - Barely mentioned, but it's implicitly in there if we can address science questions
 - Programmatic opportunity – **constellation missions/continuity measurements**
 - Case study: SMAP downscaling

*This talk is GNSS-centric (maybe even FORMOSAT/COSMIC centric)
Based on interpretation of DS (we are not committee members)*



Decadal Survey for Earth Science and Applications From Space – January 2018

- Addresses the *statement of task*: generate recommendations from the community for an integrated and sustainable approach to civilian space-based Earth-system science programs
- Steering committee generated the consensus document based on solicited community white papers and study panel reports
- Current NASA Earth science leadership is expected to develop a programmatic/mission roadmap based on the report
 - Michael Freilich, head of the NASA Earth Science Division, did so in 2007
 - Thomas Zurbuchen, associate administrator for the Science Mission Directorate, was co-chair of the last Decadal Survey for Heliophysics (2013)



2017 versus 2007

- **GPSRO was specifically named as a “highest priority” (Tier-1) mission in 2007**
 - Assigned to NOAA (GPSRO = FORMOSAT-3/COSMIC)
 - Also: RO on the Tier-1 CLARREO mission
- **DS 2017 does not specifically recommend missions**

290 community white papers

103 science and applications objectives

24 “most important” objectives

8 targeted observables

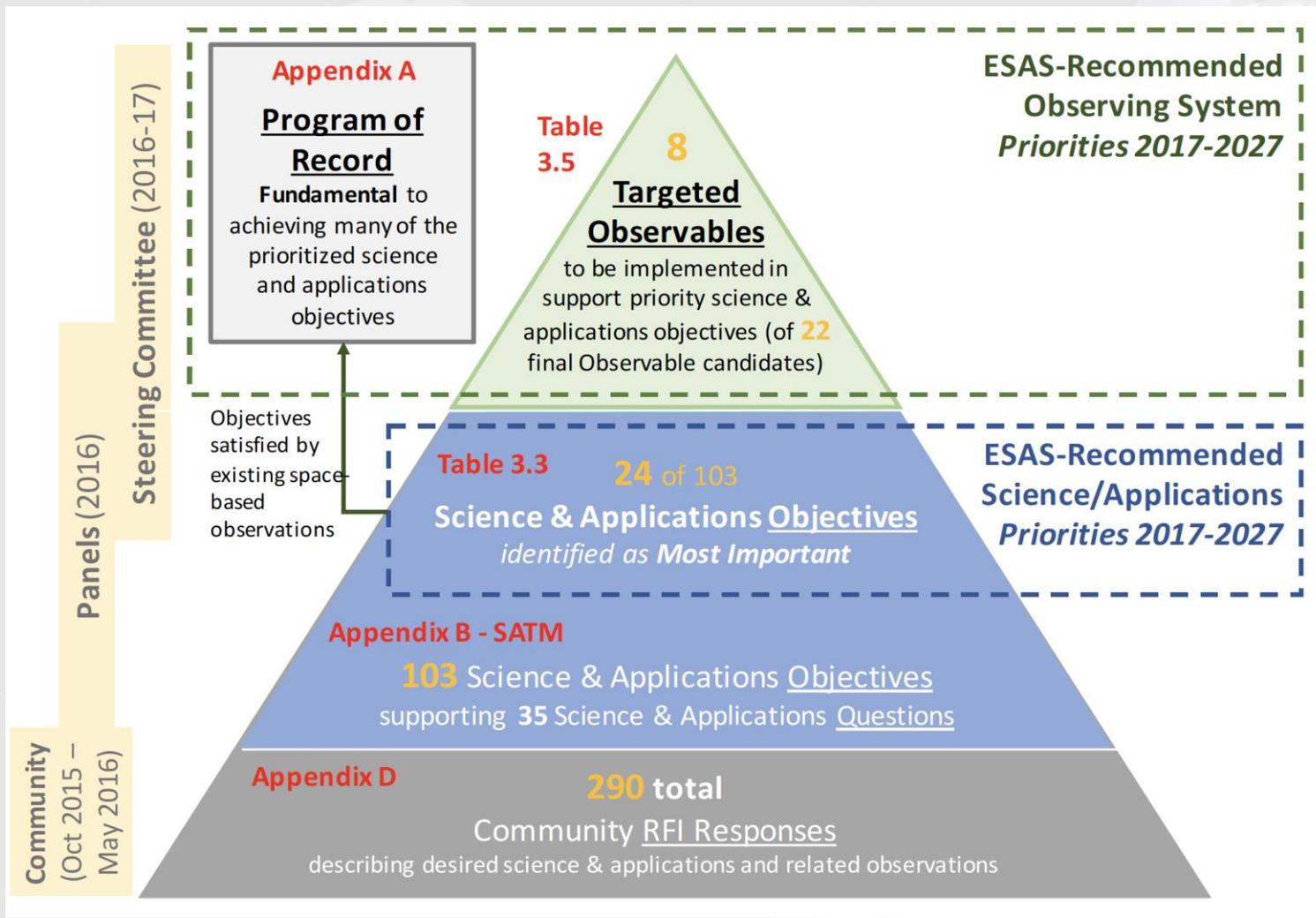
*Informed by
Program of Record:
EU’s Copernicus
FS-3/COSMIC
FS-7/COSMIC-2*

New programmatic elements: “incubator” and “Earth venture continuity”



The 2017 DS Process

Path from Science & Applications to Observational Priorities





Climate Panel Priorities

How much will sea level rise, globally and regionally ... and what will be the role of ice sheets and ocean heat storage?

Most important: Global sea level rise, oceanic heat uptake, ice sheet mass balance.

How can we reduce the uncertainty in the amount of future warming of the Earth as a function of fossil fuel emissions...

Most important: Reduce uncertainty (2x) in low cloud feedback, carbon cycle feedback and total aerosol radiative forcing

Very important: Reduce the uncertainty in water vapor feedback by a factor of 2.

RO provides high-accuracy temperature trends 5-20 km

Improved seasonal-to-decadal predictions, including changes and extremes

High accuracy temperatures for input Integrated Earth System Analysis frameworks

(2007) Testing climate models drove need for RO accuracy

Higher priority observations →

RO, Pol RO

Refl

Refl

Refl

Refl

RO

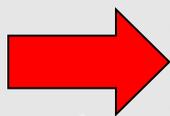
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| Targeted Observable | Science/Applications Summary | Candidate Measurement Approach | Designated | Explorer | Incubation |
|--|---|--|------------|----------|------------|
| Clouds, Convection, and Precipitation | Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes including cloud feedback | Radar(s), with multi-frequency passive microwave and sub-mm radiometer | X | | |
| Surface Biology and Geology | Earth surface geology and biology, ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass | Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR | X | | |
| Ocean Surface Winds and Currents | Coincident high-accuracy currents and vector winds to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift | Doppler scatterometer | | X | |
| Snow Depth and Snow Water Equivalent | Snow depth and snow water equivalent including high spatial resolution in mountain areas | Radar (Ka/Ku band) altimeter; or lidar** | | X | |
| Terrestrial Ecosystem Structure | 3D structure of terrestrial ecosystem including forest canopy and above ground biomass and changes in above ground carbon | Lidar** | | X | |
| | stock from processes such as deforestation and forest degradation | | | | |
| Planetary Boundary Layer | Diurnal 3D PBL thermodynamic properties and 2D PBL structure to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights | Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar** for PBL height | | | X |
| Surface Topography and Vegetation | High-resolution global topography including bare surface land topography ice topography, vegetation structure, and shallow water bathymetry | Radar; or lidar** | | | X |



New Programmatic Element: Earth Venture Continuity

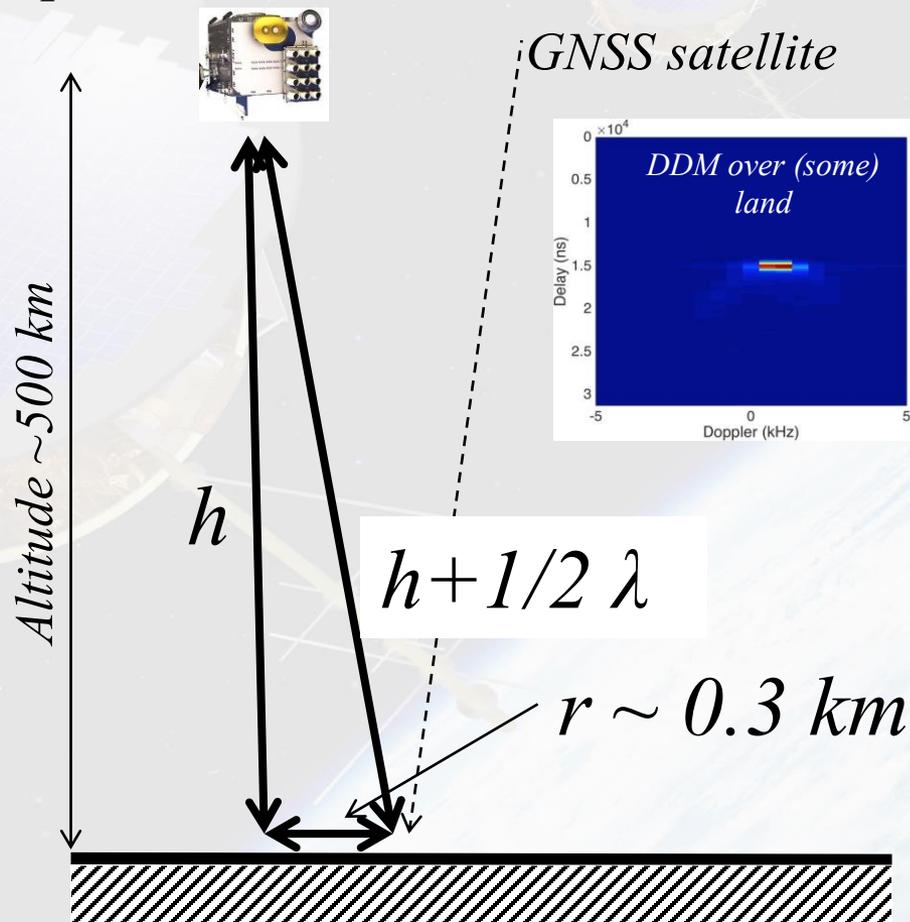
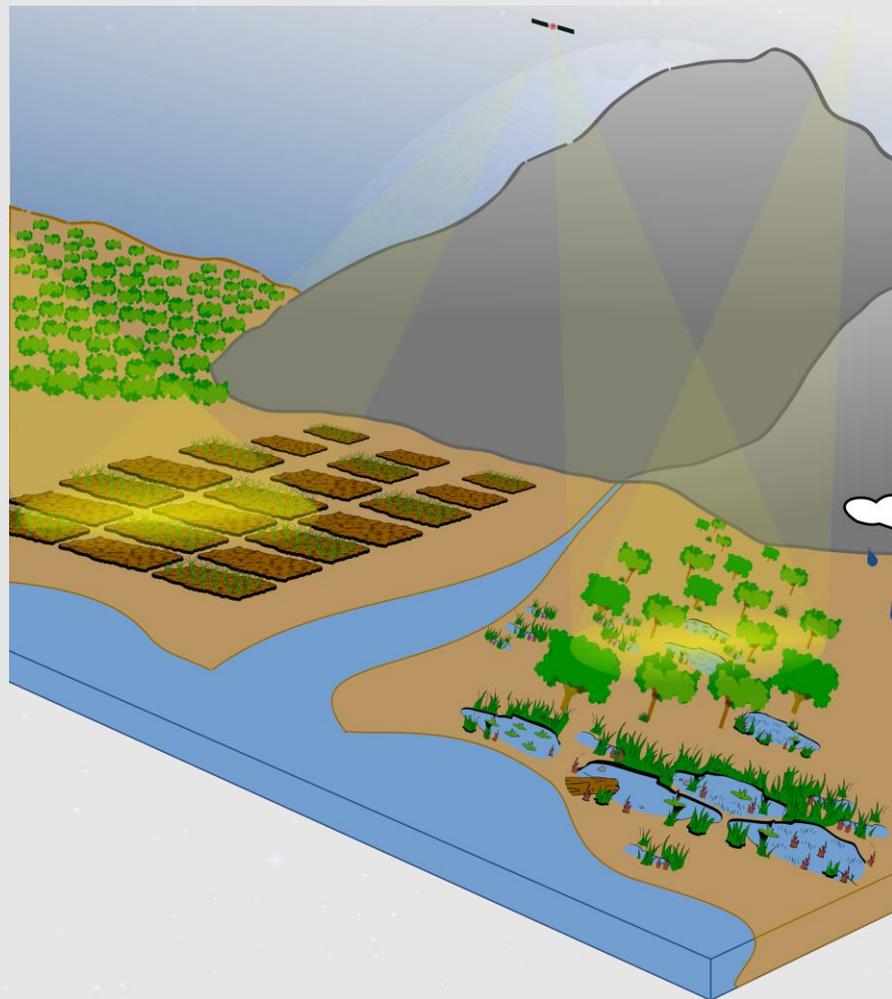
| Program Element | Description | Purpose |
|---|---|---|
| NEWLY RECOMMENDED PROGRAM ELEMENTS | | |
| Designated | Cost-capped core elements of the program specifically recommended for implementation. Could be competed or directed. | Addresses five of the highest-priority Earth observation needs, including three large missions and two medium missions. Elements of this program are considered foundational elements of the decade's observation |
| Earth System Explorer | Each competition seeks to address one of seven pre-specified Targeted Observables with medium sized cost-capped missions (\leq \$350M); three competition opportunities are recommended for the decade | Address three key science and applications needs. The seven candidate Targeted Observables are not prioritized by importance, rather competition is expected to drive innovation (technical and/or programmatic). |
| Incubation | Investments made in three Targeted Observables that are considered very high priorities for the 2027-2037 decade, but that are not currently ready for competition or directed implementation. | Focus investments in key areas that are known to be priorities, that are not sufficiently mature for deployment at this time, but would benefit from targeted investment. This differs from the standard ESTO model in that it is specifically focused in three pre-determined areas. |
| Venture-Continuity | New strand of the Venture program targeted at incentivizing low-cost continuity of existing measurements | Provides opportunities for new and innovative ways to continue existing measurements, and seeks to address the tension between making new measurements vs. continuing existing measurements by bringing forward innovative approaches to sustain measurements at lower costs. |





Unique Remote Sensing Aspects of GNSS-R

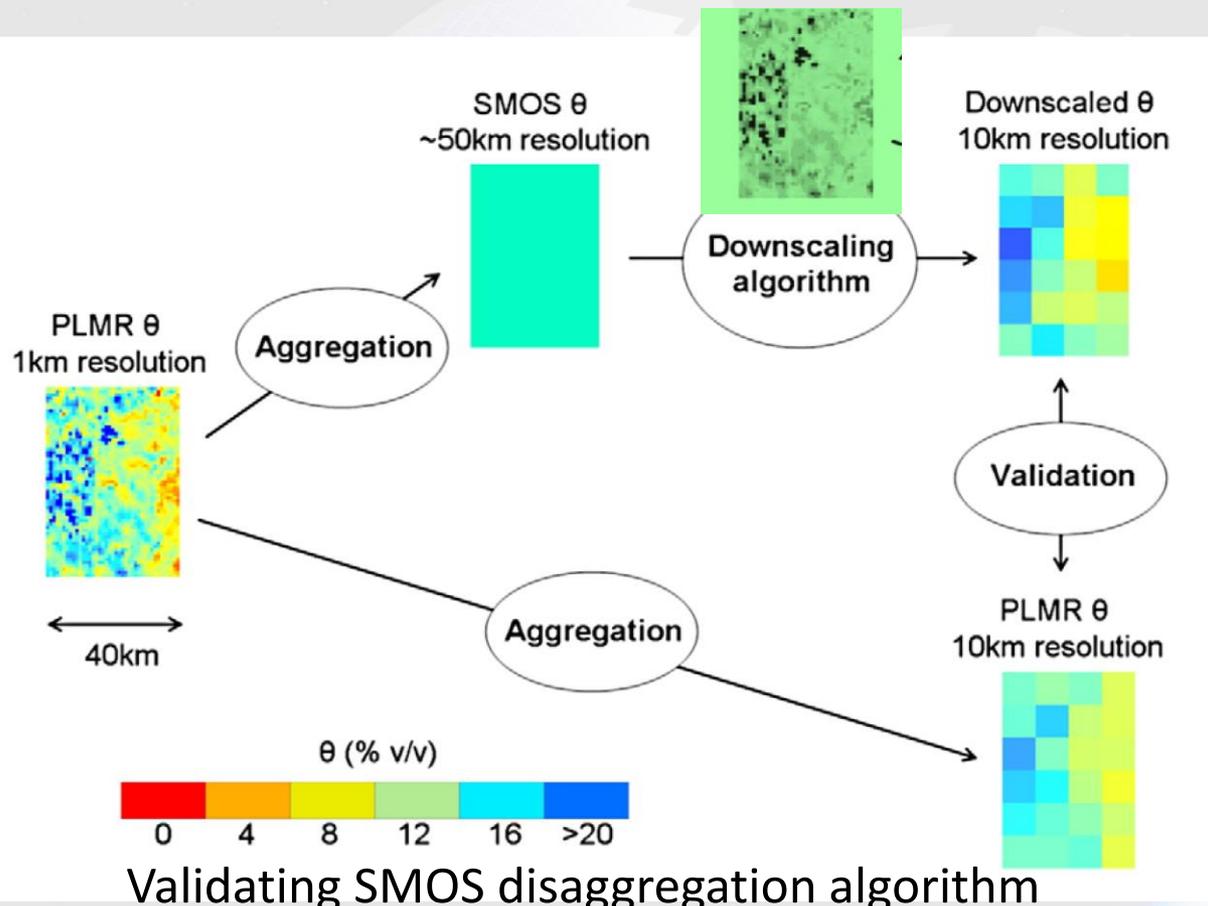
Reflected signal has high degree of coherence. First Fresnel zone is spatial resolution limit





Adapting GNSS-R to Science Objectives: "Upscaling"?

Soil Evaporative Efficiency from MODIS
1 km resolution

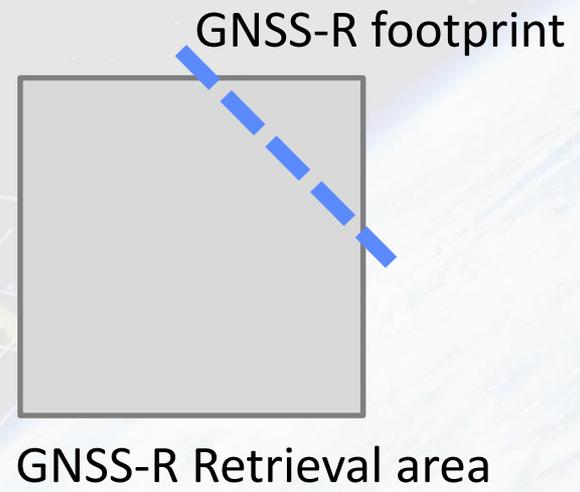


Validating SMOS disaggregation algorithm

Merlin et al., Rem Sens Env 2008

Upscaling required to decrease revisit time

Aggregation approach?





Take Away Points

- The PBL is a high priority observable
 - FORMOSAT-7/COSMIC-2 addresses this directly
 - Other observations needed to address the science
- Highly accurate long-term observations (SI-traceable) are not among the highest priority observations (no CLARREO refresh)
- The cancellation of FORMOSAT-7/COSMIC-2B leaves a gap in the program of record that the committee was not able to address (timing)
- Earth Venture Continuity (cost-effective, long-term observations) represents an enormous opportunity for GNSS RO+R constellation missions
 - *But the argument will need to be made based on the highest priority science objectives*



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Overall Science Priorities

