Environment Canada/Canadian Space Agency Terrestrial Snow Mass Mission Concept Study

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Terrestrial Snow Mass Mission Concept Study

Through engagement with the Canadian Space Agency (CSA), Environment and Climate Change Canada (ECCC) identified enhanced information on seasonal terrestrial snow mass as a key observation gap that could be addressed via new spaceborne measurements.

Snow mass is a priority issue at ECCC because of impacts on:

1. **Operational environmental prediction**
   - numerical weather prediction
   - hydrological forecasting
   - seasonal prediction

2. **Climate services**
   - freshwater availability
   - snow monitoring
   - process studies

**Measurement requirements** were identified:
- sensitivity to dry snow mass (radiance-based data assimilation; SWE retrievals)
- frequent revisit (1-5 days)
- moderate spatial resolution (~250 m)
- consideration of wet snow
Terrestrial Snow Mass Mission Concept Study

Competitive contract awarded to Airbus Defence and Space in early 2017; Payload Trade-off Review completed in April 2017
Mission Science Drivers

Selected concept for further study:
- dual-frequency Ku-band radar (13.5 & 17.2 GHz)
- InSAR option (wet snow depth retrievals)
- examine convoy orbit for active/passive synergy

Scientific objectives for moderate resolution Ku-band measurements:
1. Provide observational support for prediction (via radiance-based data assimilation) of the land surface for NWP, hydrological forecasts, and seasonal prediction
   - well calibrated backscatter with wide swath; moderate spatial resolution (250 m)

2. Quantify the spatially and temporally dynamic amount of freshwater stored in seasonal snow for determination of freshwater availability
   - derived SWE product with wide swath; moderate spatial resolution (250 m)

3. Support secondary science drivers related to the cryosphere (sea ice; land ice; freeze/thaw state) and ocean vector winds
Mission Concept Overview

- Single-aperture multi-frequency Ku-band antenna (13.5/17.2 GHz)
- Single pass interferometry options being explored to allow wet snow depth retrievals
- Synergistic use of MetOp-SG Sat B (Microwave Imaging Radiometer) for active/passive synergy
Terrestrial Snow Mass Mission Concept Study Components

Partnership between CSA and ECCC on a technical study (underpinned by science initiatives) to advance a snow radar mission concept:

1. **Refine mission objectives:**
   - consultation with partners to build a business case

2. **Science development:**
   - analysis of experimental radar datasets
     - land surface modeling studies: OSSE, snow microstructure, hydrology

3. **Technical study:**
   - payload analysis and trade-off
   - mission concept development
   - identification of Canadian industrial capabilities

4. **International liaison:**
   - science steering group
   - participation in ESA ‘SnowConcepts’ Project (led by Finnish Met. Institute)
   - participation in NASA SnowEx and other initiatives with U.S. partners
Science Activities: Radar Remote Sensing of Snow

Radar analysis from campaigns in Finland, Austria, and Canada:

1. current forward models are performing well (good news for radiance assimilation)
2. snow microstructure first guess is required for SWE retrieval (requires physical modeling tools)

Ku-band backscatter retrieved exponential correlation length vs. LiDAR snow depth

Snow pit exponential correlation length vs. height above ground
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Juha Lemmettyinen, FMI
Science Activities: Land Surface Modeling

Radar analysis from campaigns in Finland, Austria, and Canada:
1. current forward models are performing well (good news for radiance assimilation)
2. snow microstructure first guess is required for SWE retrieval (requires physical modeling tools)

Simulated multi-layer density profiles (SVS2.0) forced by GEM-surf
Science Activities: Observing System Simulation Experiment

**Synthetic truth:** 100m-resolution, best land surface and snow model, best geophysical fields and best forcing meteorology

**Upscaling and degrading:** different resolutions (500m, 1000m, and 2000m); degrading in line with the threshold and goal accuracies

**CaLDAS:** 2.5km-resolution, operational land surface and snow model, lower resolution geophysical fields and low-quality forcing meteorology (30-36hr forecasts)

Focus now on radiance assimilation using SMRT as forward model
Technical Concepts and Experimental Data

**Completed Experimental Campaigns**
- SnowScat (2009-2017)

**Future Experimental Campaigns**
- Canada (2018-19)
- SnowEx (2019-21)

**Technical Study Outcome**
- Dual-freq Ku (InSAR option)

- New campaigns required
- Appropriate instruments required (WISM)

Existing experimental datasets to evaluate Ku-band concepts
Summary

- Partnership between CSA, ECCC, and Airbus in developing the science and technical components of a Ku-band radar mission concept
- Significant potential scientific value in both Ku-band backscatter (radiance assimilation; sea ice motion; ocean vector winds) and derived products (SWE)
- Ongoing analysis of experimental radar data show the importance of quantifying snow microstructure for forward and inverse modeling, potential for SWE retrievals using snow grain first guess from multi-frequency radar, passive microwave measurements, and/or physical snow models
- Physical snow model in development at ECCC is multi-layer, performs well when driven by forecast meteorology, and includes snow microstructure parameters
- OSSE work to continue, including focus on backscatter assimilation (SMRT as forward model, consistent with plans at ECMWF)
- Plans to deploy Wideband Instrument for Snow Measurements (WISM) in Canada in 2018
- Identifying international partnership opportunities are a priority: ESA ‘SnowConcepts’ project, ESA Earth Explorer 10
Space Science Life Cycle at CSA

- Final Concept Review: Jan. 2018
- Multi-agency meeting: April 2018
- Transition to Phase 0...

Thomas Piekutowski, CSA
Final Thoughts...

- Concept study is in a very early phase – some flexibility remains
- We may eventually de-emphasize the snow aspect of the mission even as these requirements currently drive the concept study
- We are aware that this mission concept will not please everybody, but we seek broad engagement and all feedback is welcome
- To be successful, we require a partner or partners: the Canadian perspective is that this cannot be a single agency mission