Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

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

Chris Derksen, Josh King
Climate Research Division, ECCC

Camille Garnaud, Stephane Belair
Meteorological Research Division, ECCC

Yves Crevier, Mélanie Lapointe, Ralph Girard
Canadian Space Agency

Geoff Burbidge, Jose Marquez
Airbus Defence and Space

CSA ASC

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:

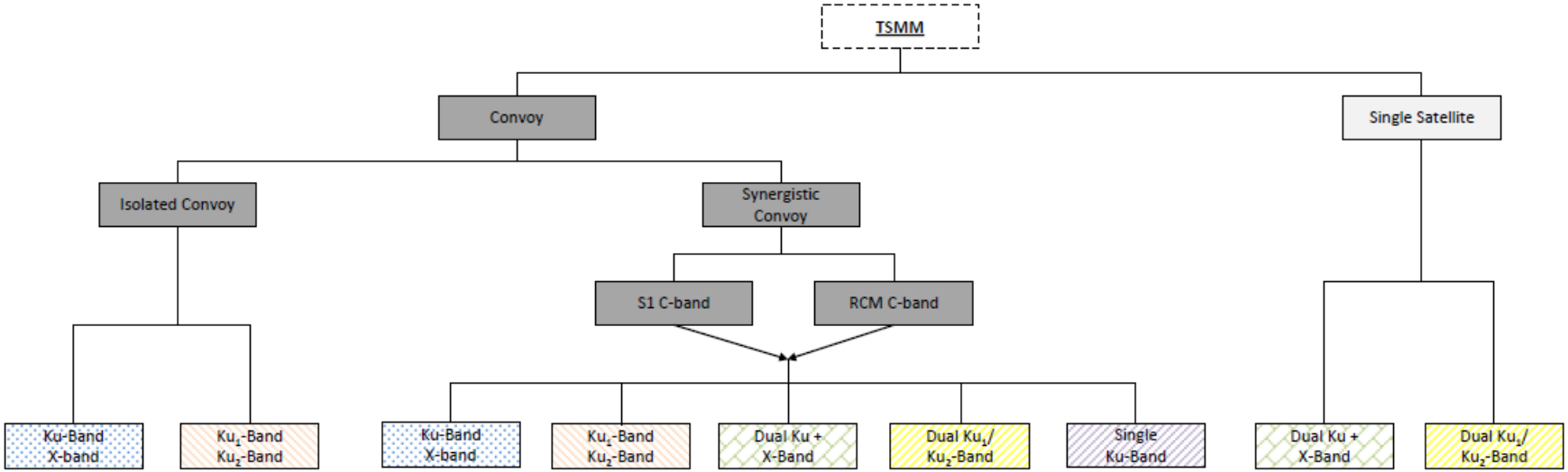
1. Operational environmental prediction
-numerical weather prediction
-hydrological forecasting
-seasonal prediction

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



Isolated Convoys:	
Pros	Cons
Optimised altitude	Separate instrument cost
Platform rebuild cost advantages	No combined measurements

Synergistic Convoys:	
Pros	Cons
Maximal science by leveraging existing missions	Restricts orbital choices to be truly synergistic
Possible tri-band SWE data	Data downlink bandwidth partially consumed by S1/RCM
Single Ku-Band in convoy with C-band is least expensive	

Single Satellite:	
Pros	Cons
Single platform	Challenging dual freq. payload
Zero temporal delay between measurements	No mission convoy redundancy

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:

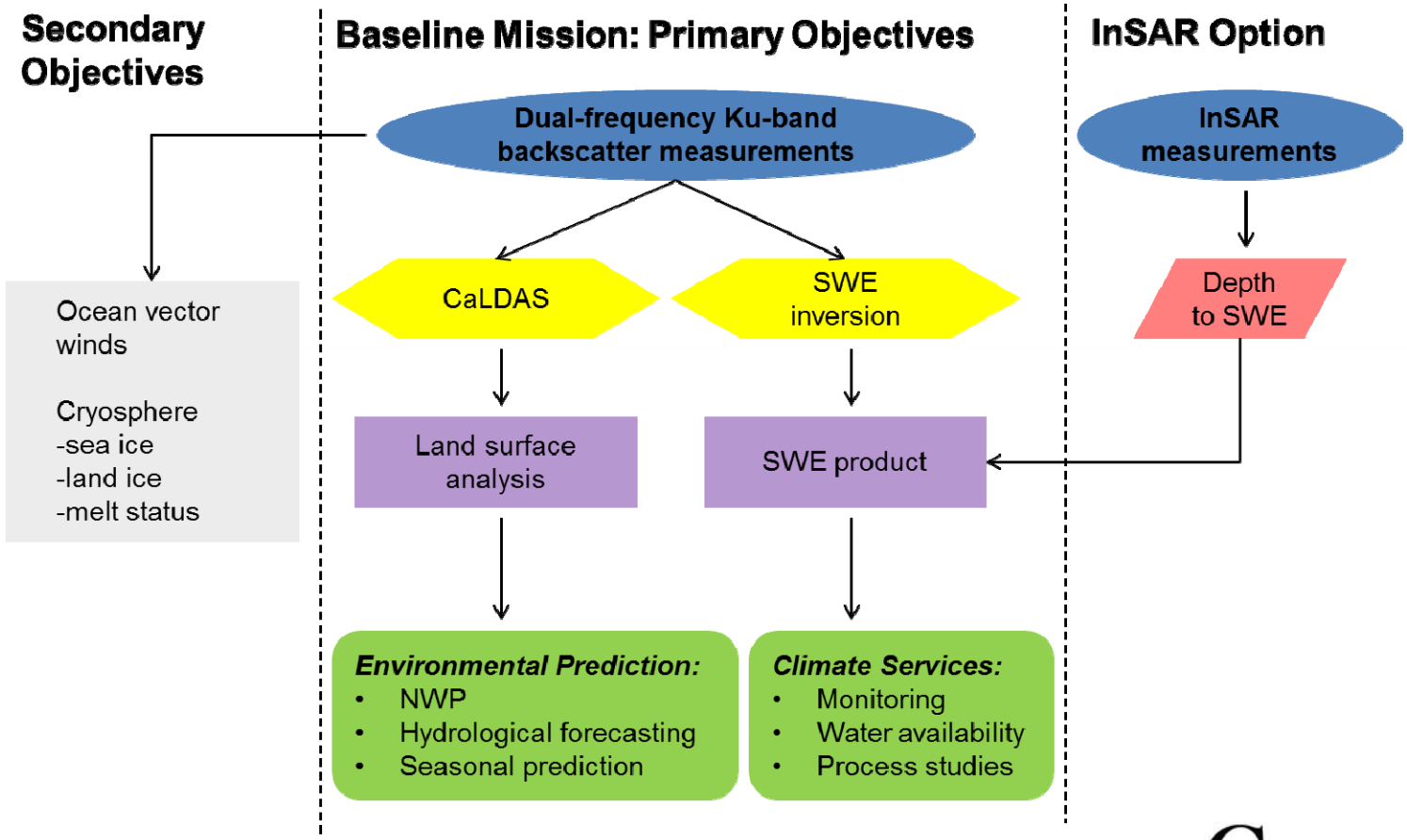
1. Provide observational support for ***prediction*** (via radiance-based data assimilation) of the land surface for NWP, hydrological forecasts, and seasonal prediction
   -well calibrated backscatter with wide swath; moderate spatial resolution (250 m)

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

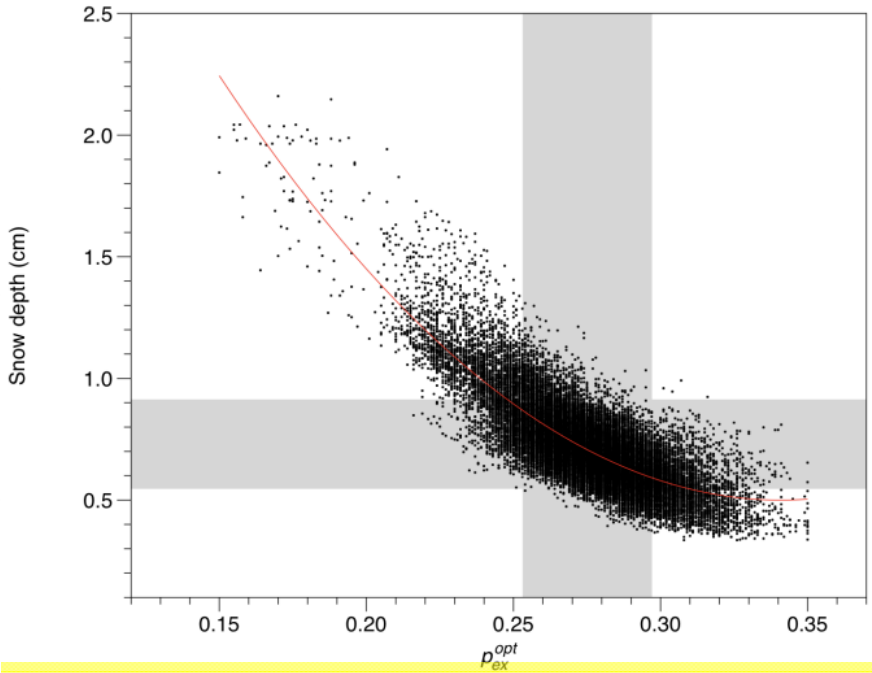
Partnership between CSA and ECCC on a technical study (underpinned by science initiatives) to advance a snow radar mission concept:

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

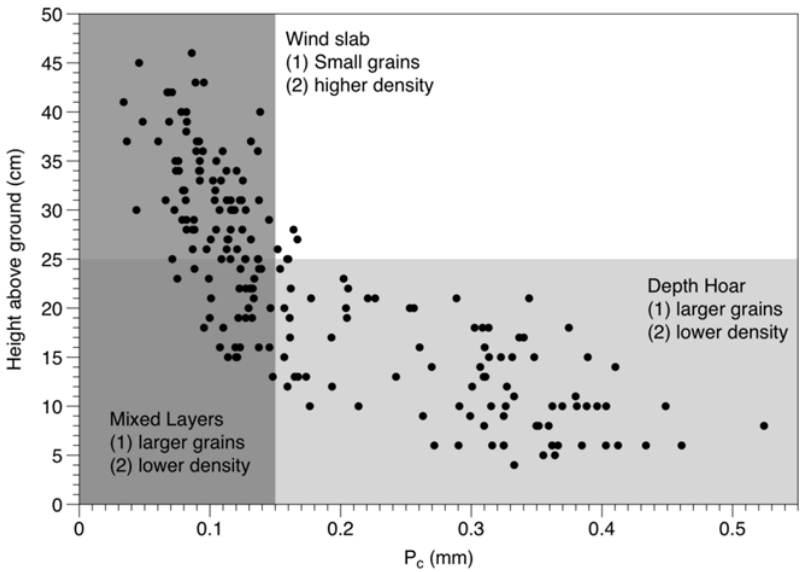
Science Activities: Radar Remote Sensing of Snow

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

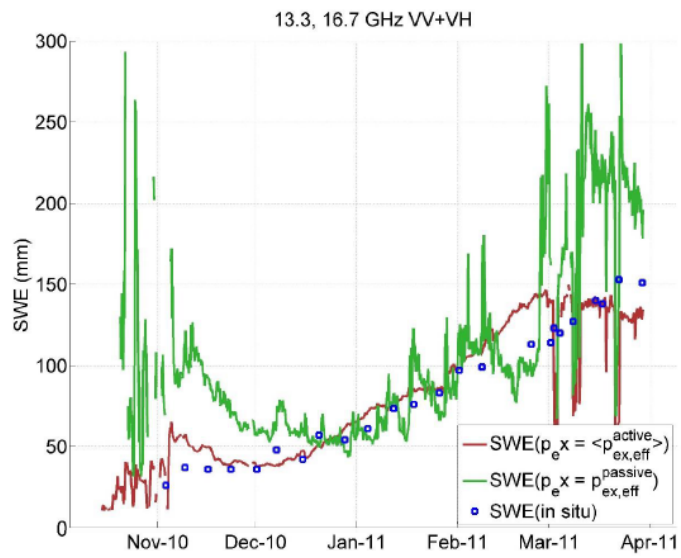
Science Activities: Radar Remote Sensing of Snow

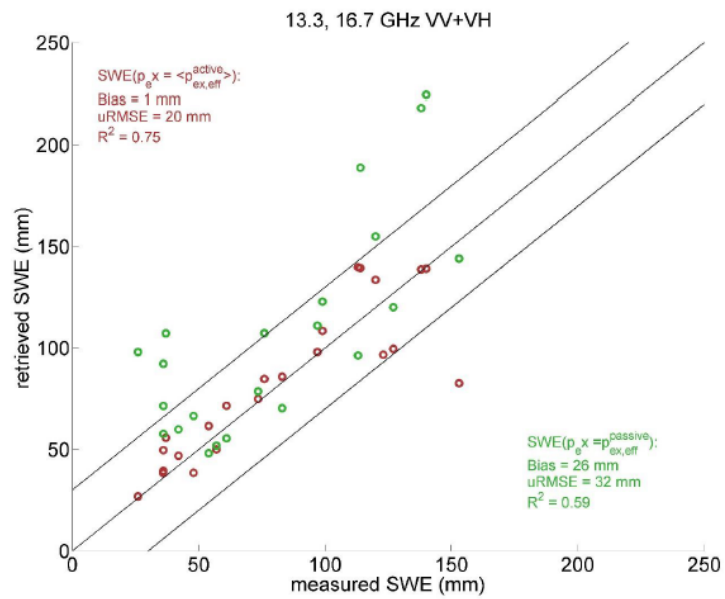
Radar analysis from campaigns in Finland, Austria, and Canada:

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)

NoSREx II

Retrievals of SWE using $p_{ex,eff} = < p^{active}_{ex,eff} >$ and $p_{ex,eff} = p^{passive}_{ex,eff}$



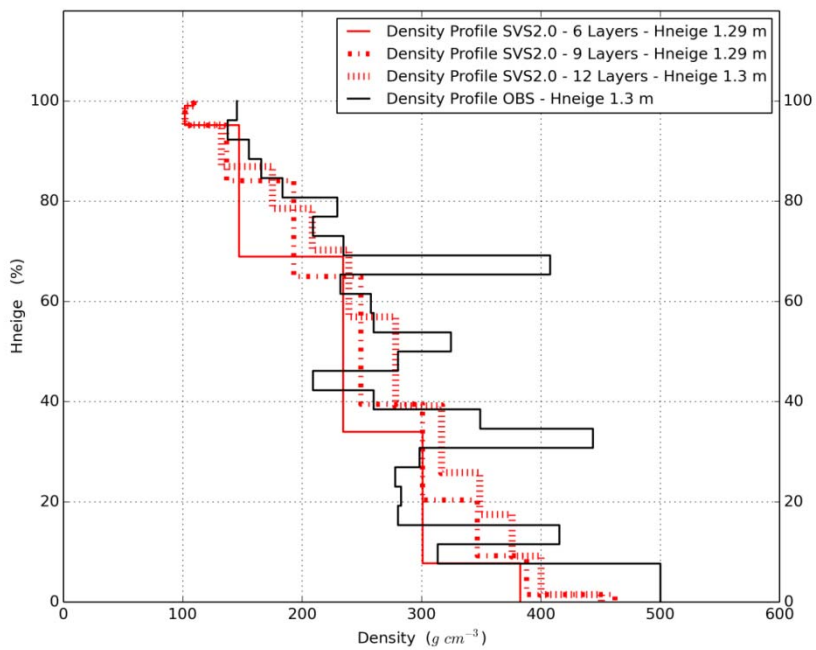


SWE retrieved using seasonal averaged correlation length estimates

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)**



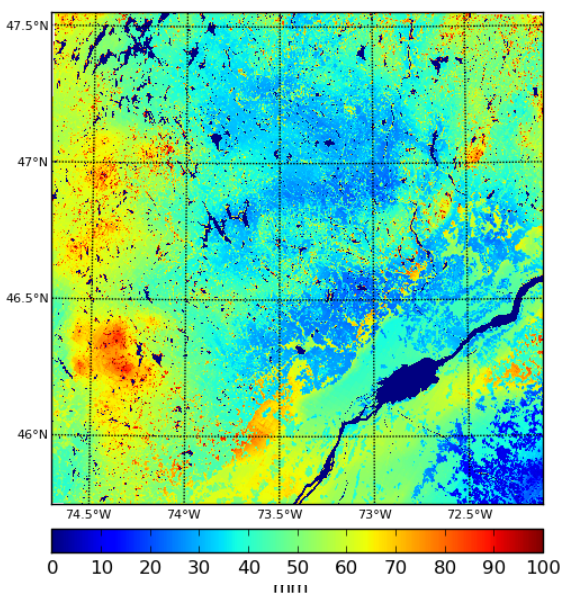
Simulated multi-layer density profiles (SVS2.0) forced by GEM-surf

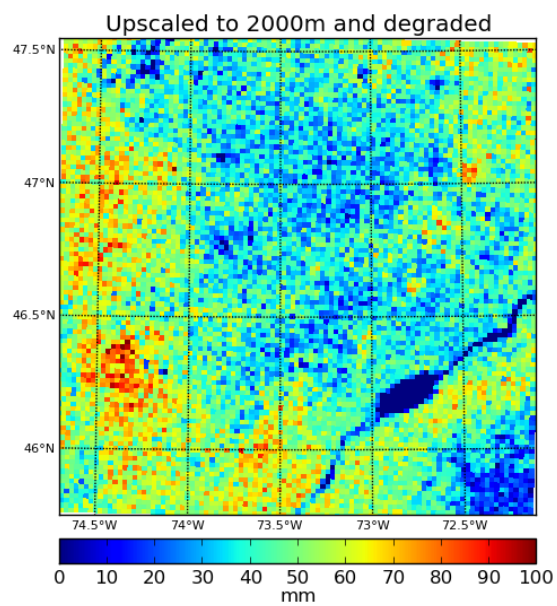
Science Activities: Observing System Simulation Experiment

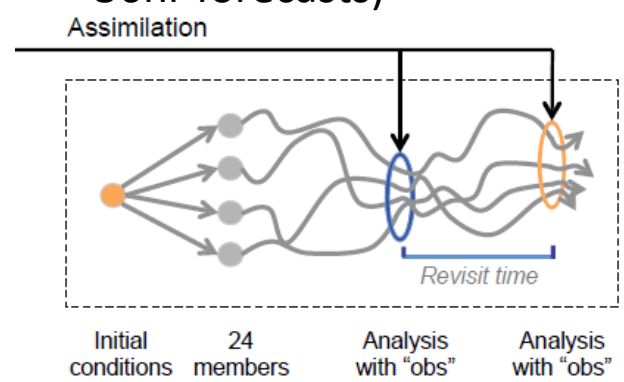
Synthetic truth: 100m-resolution, best land surface and snow model, best geophysical fields and best forcing meteorology

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)
SnowSAR (2011-2013)
SnowEx (2017)

Future Experimental Campaigns

Canada (2018-19)
SnowEx (2019-21)

Technical Study Outcome
Dual-freq Ku
(InSAR option)

Existing experimental datasets to evaluate Ku-band concepts

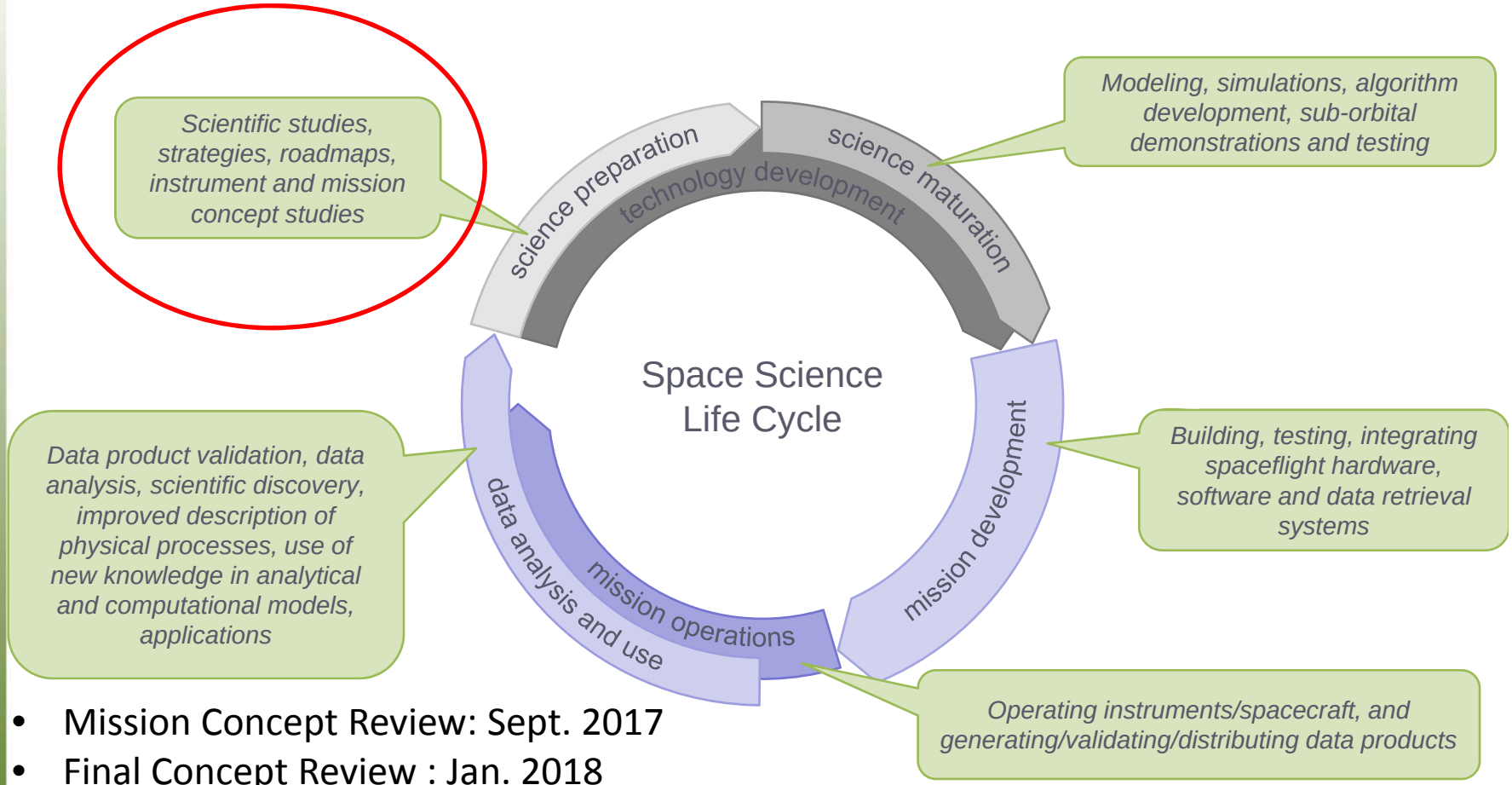
New campaigns required

Appropriate instruments required (WISM)

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



- Mission Concept Review: Sept. 2017
- Final Concept Review : Jan. 2018
- Multi-agency meeting: April 2018
- Transition to Phase 0…

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