European Snow Activities – ESA Perspective

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Overview and status of on-going and planned ESA activities in relation to snow

- Satellite Snow Product Intercomparison and Evaluation Experiment (**SnowPex**)
- Microstructural origin of electromagnetic signatures in remote sensing of snow
- **SnowLab** campaign
- SnowSAR campaign data analysis study (**SCADAS**)
- Scientific evaluation of mission concepts for snow mass and other cryospheric parameters
- Other initiatives and activities
- Summary

Where do we stand?

Analysis of problems / Analysis of experimental data

Why do we want to observe? What do we want to observe? How do want to measure? Do we meet requirements? What is the delta provided? What is the (scientific) maturity?

Satellite Snow Product Intercomparison and Evaluation Experiment (SnowPex)

Objectives:

- Intercompare and evaluate global / hemispheric (pre) operational snow products derived from different EO sensors and generated by means of different algorithms, assessing the product quality by objective means.
- Evaluate and intercompare temporal trends of seasonal snow parameters from various EO based products in order to achieve well-founded uncertainty estimates for climate change monitoring.
- Elaborate recommendations and needs for further improvements in monitoring seasonal snow parameters from EO data.

Status: Ongoing

The project will support the setup of a consolidated operational satellite snow observation system for the Global Cryosphere Watch Initiative of the WMO and help to improve the snow cover data base for climate monitoring, as addressed by the WCRP-CliC programme.

Study logic

PROGRESS

Review of SE / SWE Algorithms and Products

Identification of reference data

ISSPI WS-1
July 2014

Methods and Protocols for Validation & Intercomparison of SE / SWE Products

Compilation of Reference Data Set

Validation and Intercomparison of Products (1st results)

Trend Analysis of SE / SWE products (1st results)

ISSPI WS-2
Sep 2015

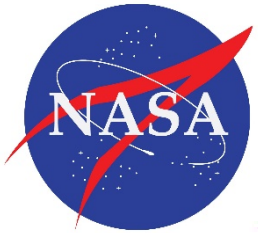
Validation and Intercomparison of Products (Final Results)

Trend Analysis (Final)

SE & SWE Synergy Products

Publication of Project Results, Conclusions, Recommendations for satellite snow monitoring

Organisations providing Snow Extent and SWE Products to SnowPEx

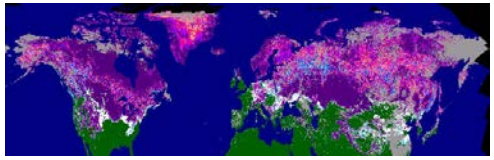


SnowPEx – Snow Extent Products

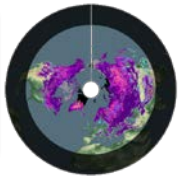
SnowPEx PROD. ID	Product Name	Thematic Parameter	Frequency	Period	Pixel Sp.	Contact
ASNOW	View, Autosnow	Binary, Global	daily	2006 – present	4 km	P. Romanov / NESDIS
CRCLIM	Ground CryoClim	Binary, Global	daily	1982 – present	5km	R. Solberg / NR
CRYOL	Ground, CryoLand	Fractional, PanEU	daily	2000 – present	0.5 km	T. Nagler / ENVEO
EURAC	Snow On the ground EURACSnow	Binary, Alps	daily	2002 – present	0.25 km	C. Notarnicola / EURAC
GLSSE	Ground GlobSnow v2.1	Fractional, NH	daily - monthly	1996 – 2012	1 km	S. Metsämäki / SYKE
HSAF10	HSAF H10	Binary, PanEU	daily	2009 – present	5 km	M. Takala / FMI
IMS01	Ground, IMS	Binary, NH	daily	2014 – present	1 km	S. Helfrich / NOAA
IMS04	Ground, NOAA IMS	Binary, NH	daily	2004 – present	4 km	S. Helfrich / NOAA
IMS24	Grround. NOAA IMS	Binary, NH	daily	1997 – 2004	24 km	S. Helfrich / NOAA
JXAM5	View, JASMES GHRM5C	Binary, Global	daily, weekly half-monthly	1979 – 2013	5 km	M. Hori / JAXA
JXM10	View, JASMES MDS10C	Binary, Global	daily, weekly half-monthly	2000 – 2013	5 km	M. Hori / JAXA
M10C05	View, MOD10_C5	Fractional, Global	daily	2000 – present	0.5 km	D. Hall, G. Riggs / NASA
MEASU	Ground, MEaSUREs	Binary, Global	daily	1999 – 2012	25 km	D. Hall / NASA D. Robinson / U. Rudgers
PATHF	Ground, AVHRR Pathfinder	Fractional, NH	daily	1985 – 2004	5 km	R. Fernandes / NRCAN
SCAG	View; SCAG	Fractional, NH	daily	2000 - 2013	0.5 km	T. Painter / NASA K. Rittger / NSIDC

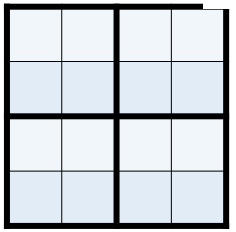
Concept for Intercomparison for SE Products

Data stack of SE products



Transformation to common projection (EASE-GRID 2.0)





Aggregate SE to intercomparison grid sizes 5 km & 25 km

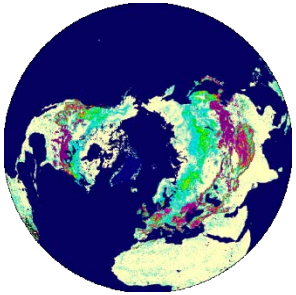
Generate valid pixel mask by applying common mask of non-valid areas (e.g. sea)

Generate maximum SE map from all products

Deviation of SE products from maximum SE map

Intercomparison of valid pixels of SE products
- Pixel by pixel
- spatial difference maps

Spatial Difference Map



- Number of snow pixels & intercompared pixels
- RMSE, Bias, Mean Absolute Difference
- Correlation Coefficient
- Fraction of total SE
- Time series of parameters
- Separate statistic analysis for forest / non-forest / plain areas / mountains / SCF classes

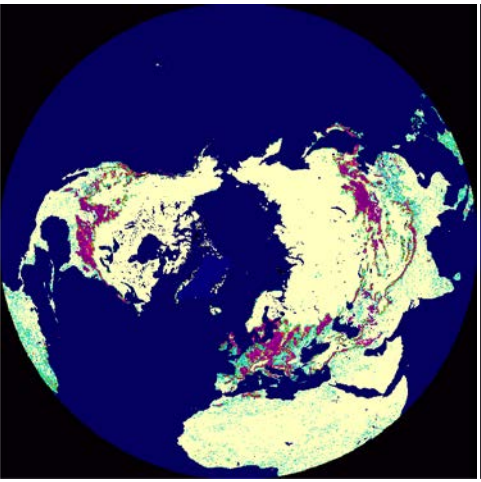
Snow Difference Maps:
max SE – SE products, March 2008, total area

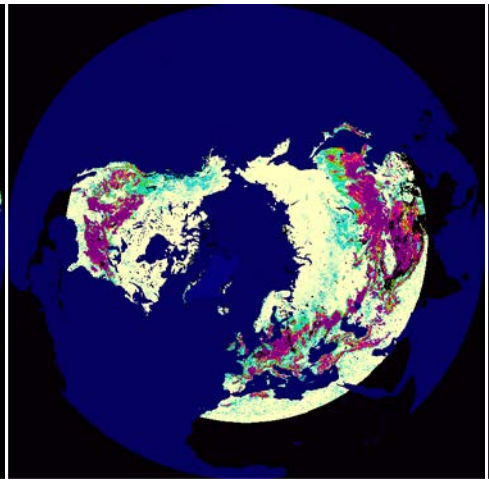
CryoClim
Binary, 5 km

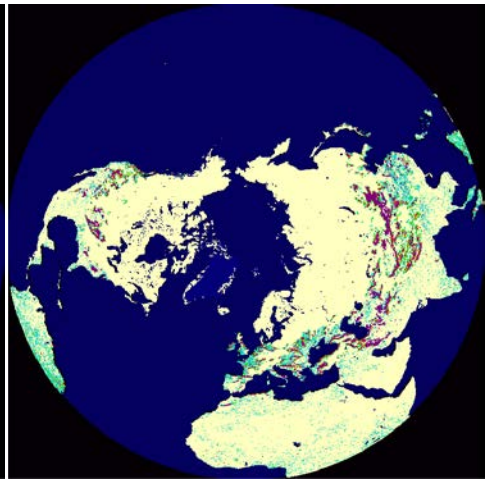
GlobSnow
Fractional, 1 km

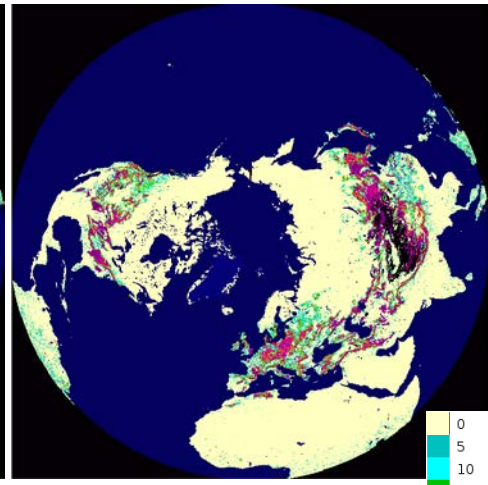
NOAA IMS
Binary, 24 km

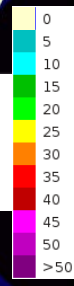
JASMES GHRM5C
Binary, 5 km









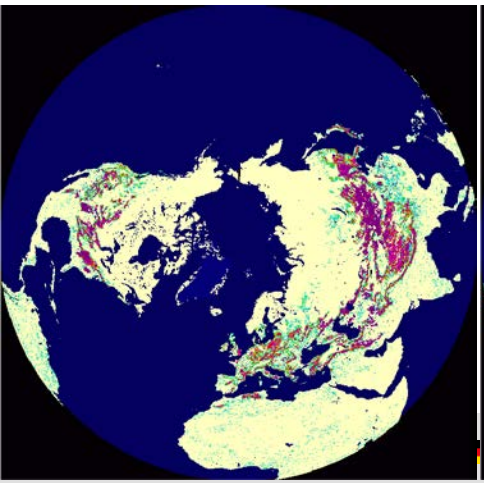


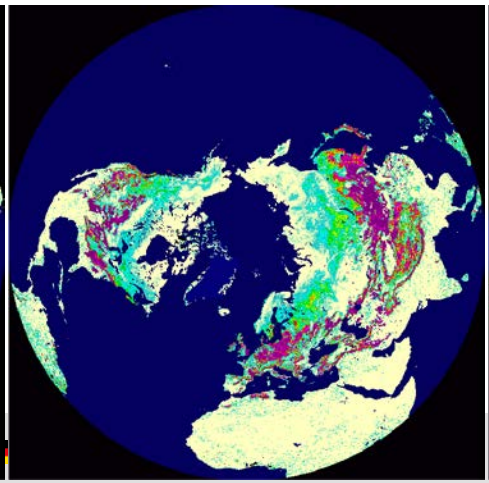
JASMES MDS10C
Binary, 5 km

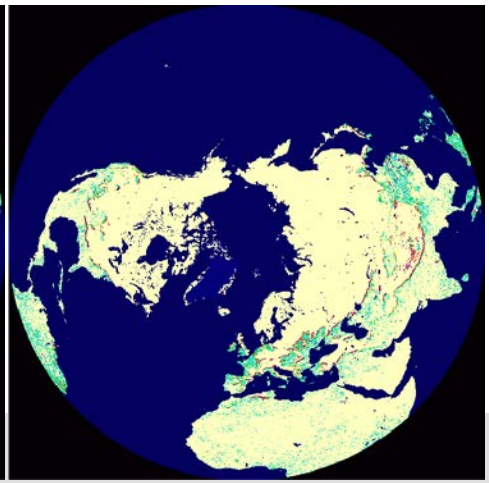
MOD10_C5
Fractional, 0.5 km

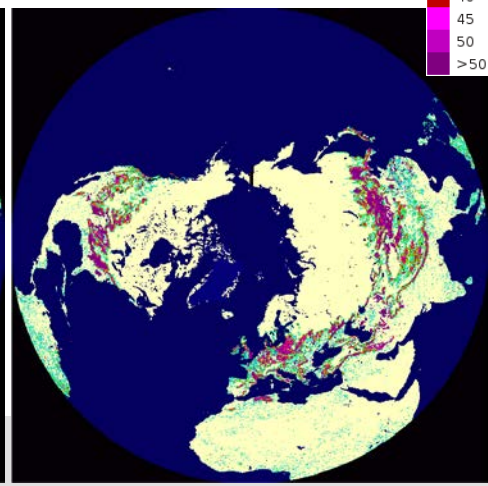
MEaSUREs
Binary, 25 km

AutoSnow
Binary, 4 km







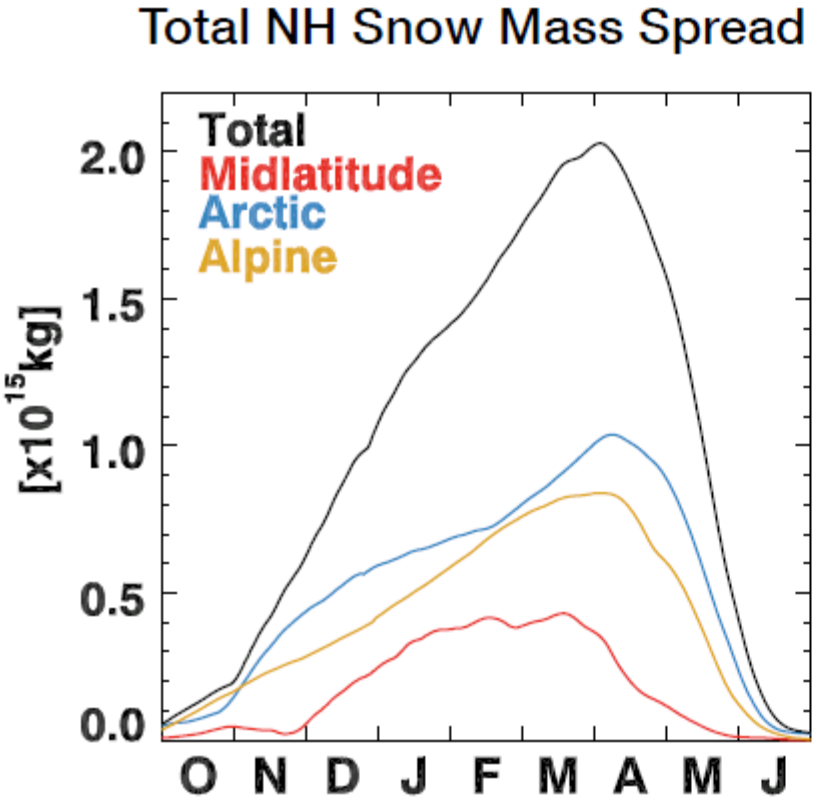


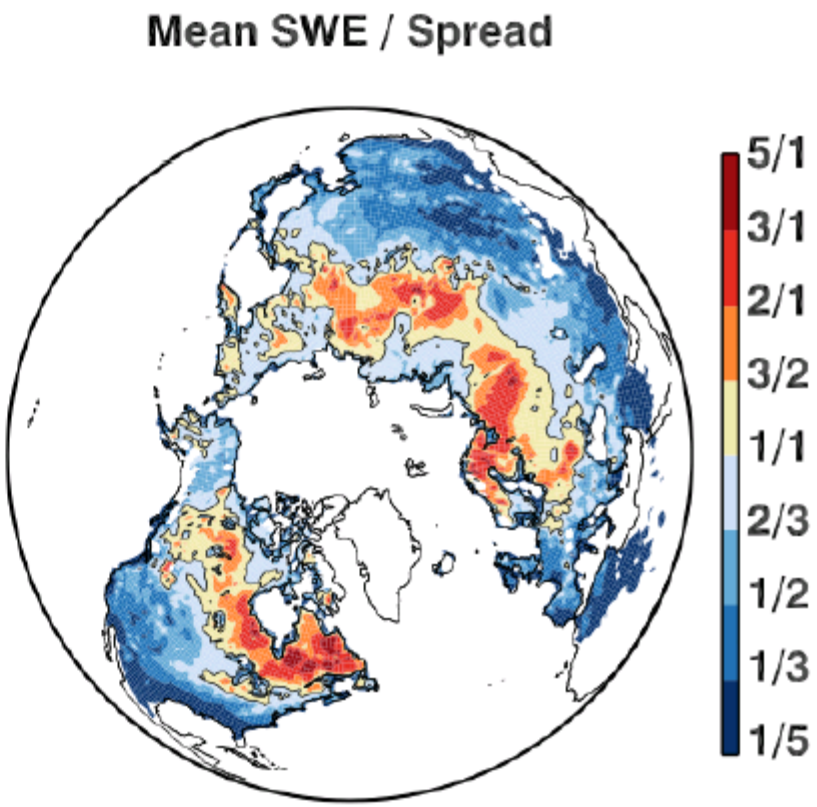
SnowPEx SWE Datasets

Dataset	Method	Ancillary / Forcing Data	Resolution	Time Series	Reference
GlobSnow	Passive microwave + in situ	Weather station snow depth measurements	25 km	1979-2015	Takala et al (2011)
NASA AMSR-E standard	Standalone passive microwave	none	25 km	2002-2011	Kelly (2009)
NASA AMSR-E prototype	Microwave + ground station climatology	Weather station snow depth climatology	25 km	2002-2011	TBD
ERAint-Land	HTESSEL land surface model	ERA-interim	0.75° x 0.75°	1981-2010	Balsamo et al (2013)
MERRA	Catchment land surface model	MERRA	0.5° x 0.67°	1981-2010	Rienecker et al (2011)
Crocus	ISBA land surface + Crocus snow model	ERA-interim	1° x 1°	1981-2010	Brun et al (2013)
GLDAS-2	Noah 3.3 land surface model	Princeton Met.	1° x 1°	1981-2010	Rodell et al (2004)

Snow Mass Spread

EC

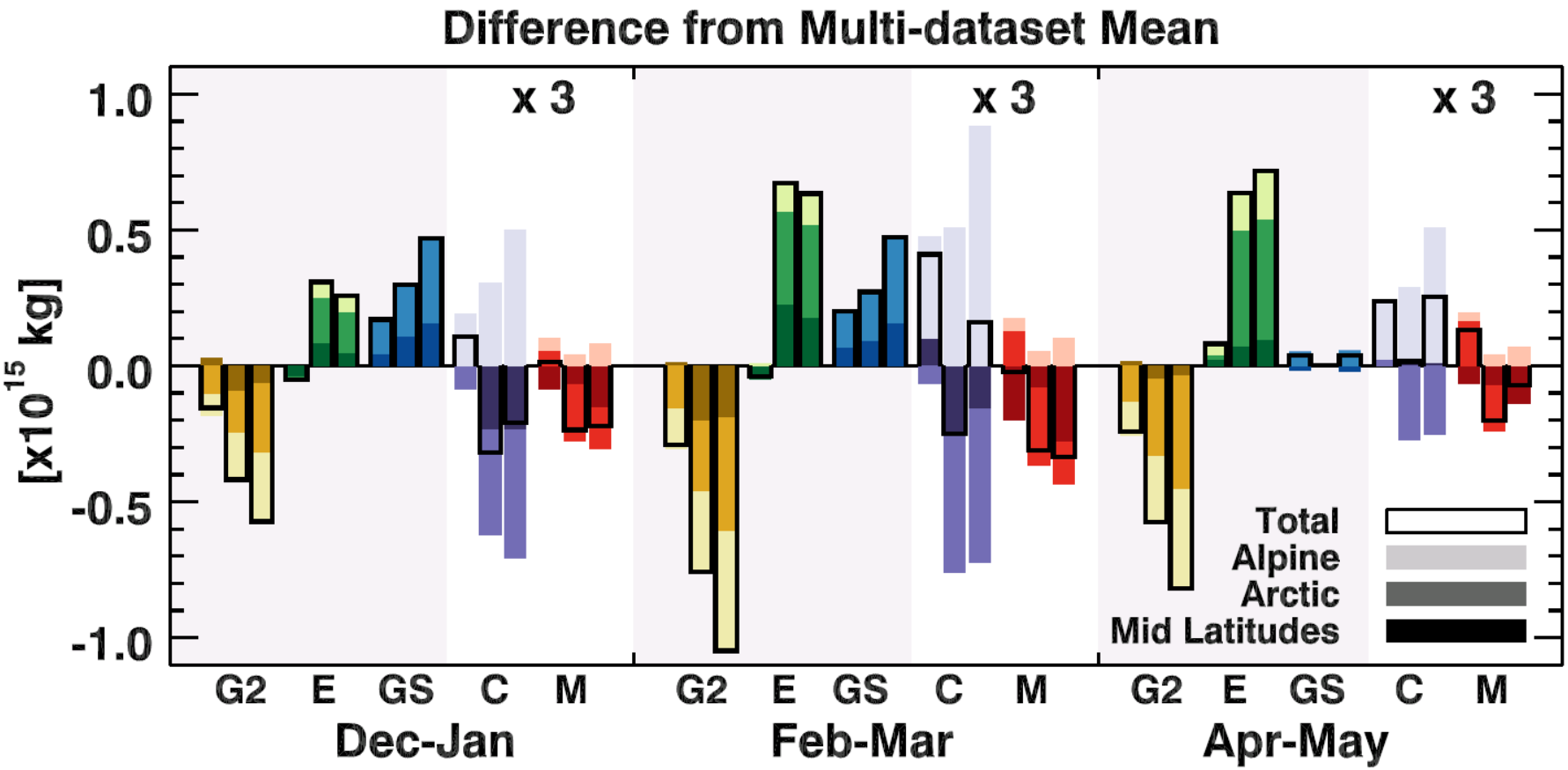




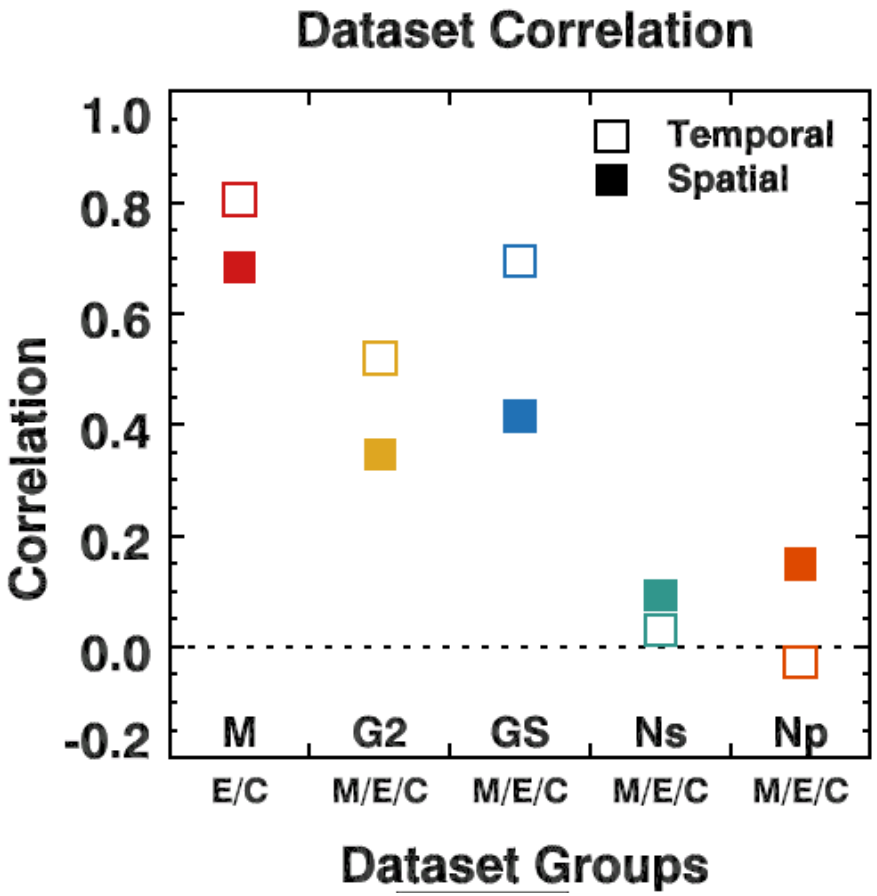
Mudryk et al., J. Climate, 2015

Difference From Multi-Dataset Mean

EC



Inter-Dataset Correlations



EC

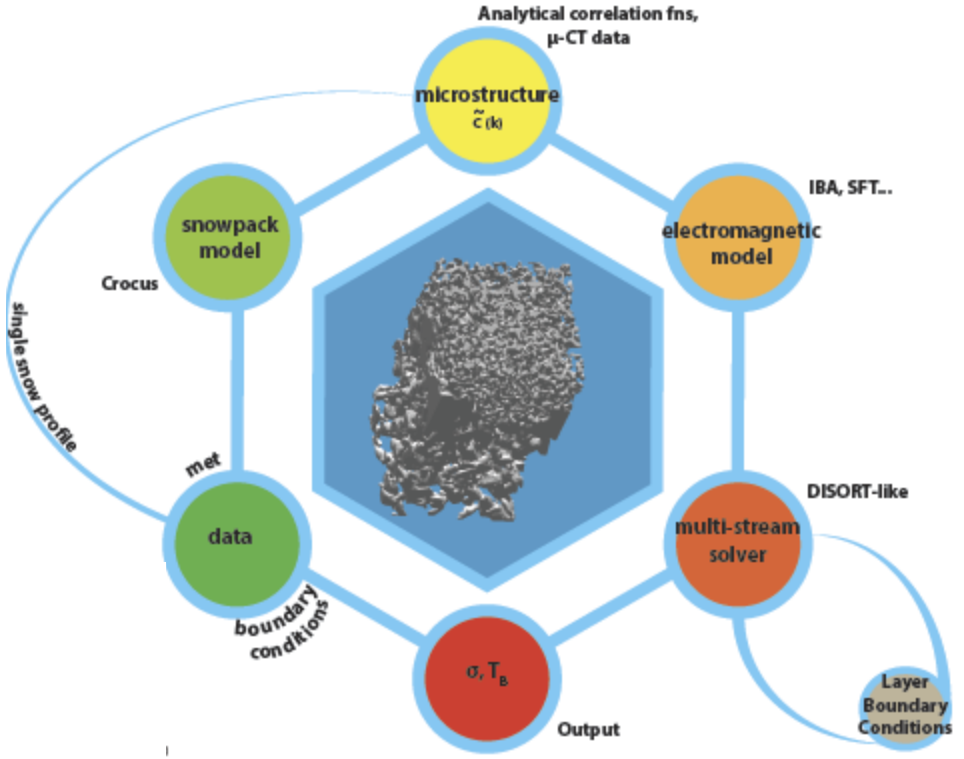
Correlation of daily anomalies, (NDJFMA = 180 d x 30 y)

Microstructural origin of electromagnetic signatures in remote sensing of snow

Objectives

The overarching objective of this activity is to consolidate the understanding of the impact of snowpack structure on the microwave remote sensing signal, with a main focus on active (radar) sensing. In practice, this study shall combine several elements:

- propose a description of the land snowpack that includes both macro- and microphysical components.
- develop a microwave emission/scattering model of the snowpack that can make use of the proposed snowpack description as input
- validate the proposed approach, relying on recent experimental data



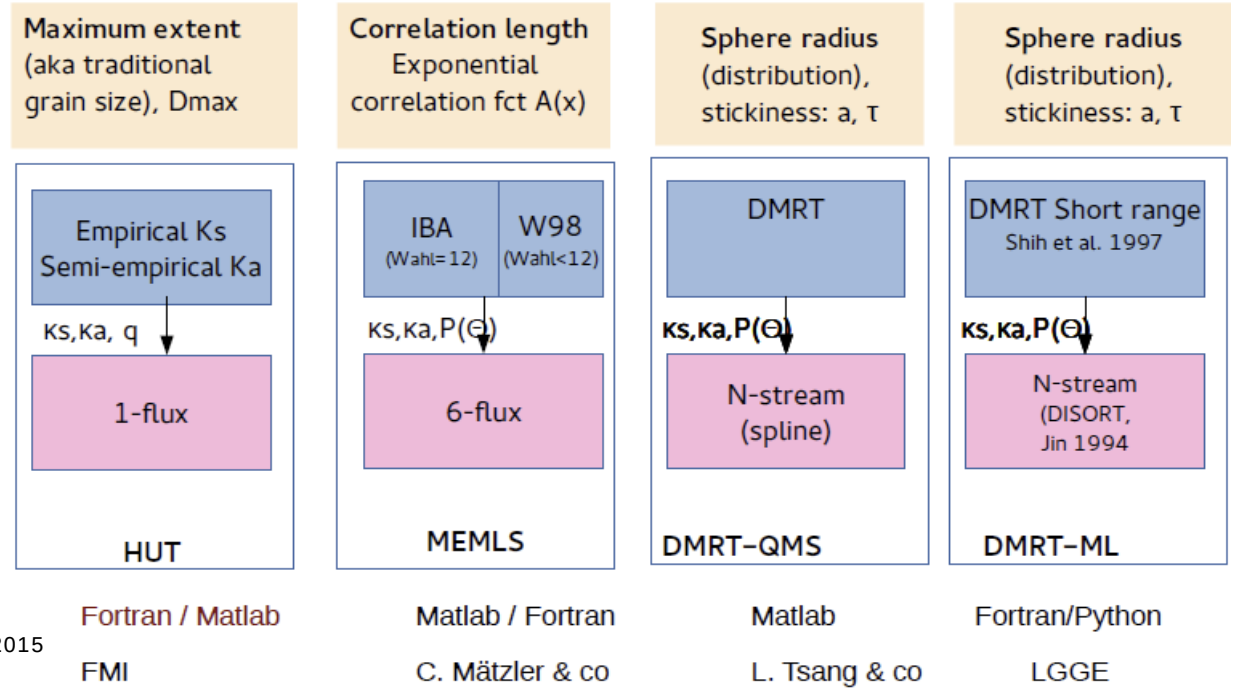
Sandells et al 2015

Duration: 18 months
Status: ongoing

Model development

Several snow microwave emission models have been developed and used by the community over the last 20-30 years in order to:

- Retrieve snow depth or snow mass on the ground for space.
- Consolidate the case for a future satellite mission dedicated to snow



Picard et al 2015

- Many open issues: snow micro-structure, dense media, coherency,...
- Numerical comparisons show none of the models is significantly/always better than the others.

-> Development of a new active/passive microwave model within 2016

SnowLab

Objectives:

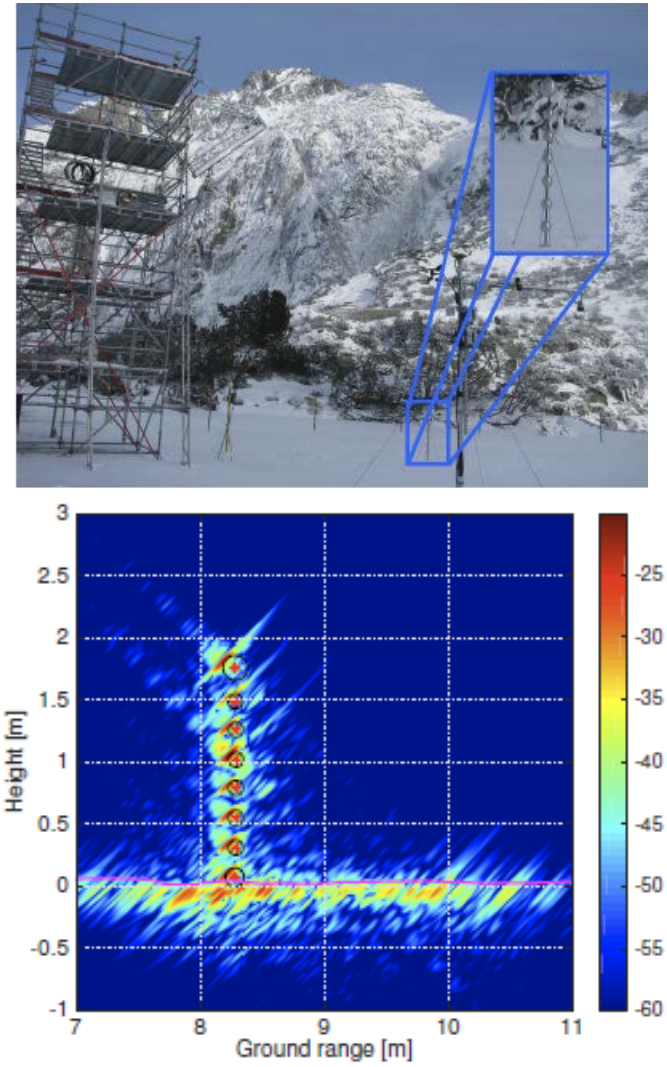
The overall objective of the activity is to provide a comprehensive multi-frequency, multi-polarisation, multitemporal dataset of active and passive microwave measurements over snow-covered grounds to investigate the relationship between effective snow- and ground parameters and the resultant signals detected by microwave radars and radiometers. The experiment will focus on the following topics:

- effects of snow accumulation (SWE) and temporal evolution of snow morphology on multi-frequency and polarimetric backscatter signatures, starting from the first snowfall.
- Temporal variability of the polarimetric and interferometric radar signatures as a function of environmental conditions
- Characteristics and information content of x to Ku-Band tomograms during the winter season
- Contribution of microwaves to the description and understanding of the snow-ground compartment.

Status: The experiment is being executed in the Swiss Alps and is planned to last for 3 winters starting in 2015/2016

SnowLab

SnowLab experimental setup at the testsite Gerstenegg, Switzerland, in January, 2016. For tomographic profiling measurements, the SnowScat device is moved along the rail taking 50 measurements at intervals of 4cm).



Example of a tomographic profile (HH channel) as obtained from 50 measurements along the rail after processing.

SnowSAR campaign data analysis study (SCADAS)

Objective: Scientific analysis and further suitability of the SnowSAR data to

- Determine the temporal and spatial variability of the snow cover over the three campaign areas by means of in-situ data, and compare with the SnowSAR data, snow process models driven by meteorological data, output of numerical weather prediction models and passive microwave data (where reasonable).
- Analyse the sensitivity and relationship of the acquired SnowSAR data (X-band and Ku-band) to the main snowpack parameters (Snow Extent, Snow Water Equivalent (SWE), Snow accumulation over glaciers) over three different snow regimes and background media as acquired during SnowSAR-2, TVCExp, and AlpSAR.
- Derive empirical or parametric relationships between SnowSAR data and snowpack physical parameters using the result of the sensitivity analysis.
- Provide recommendations on the way forward for a development of retrieval algorithm(s).

Duration: 15 months

Status: ITT released since end of March http://emits.esa.int

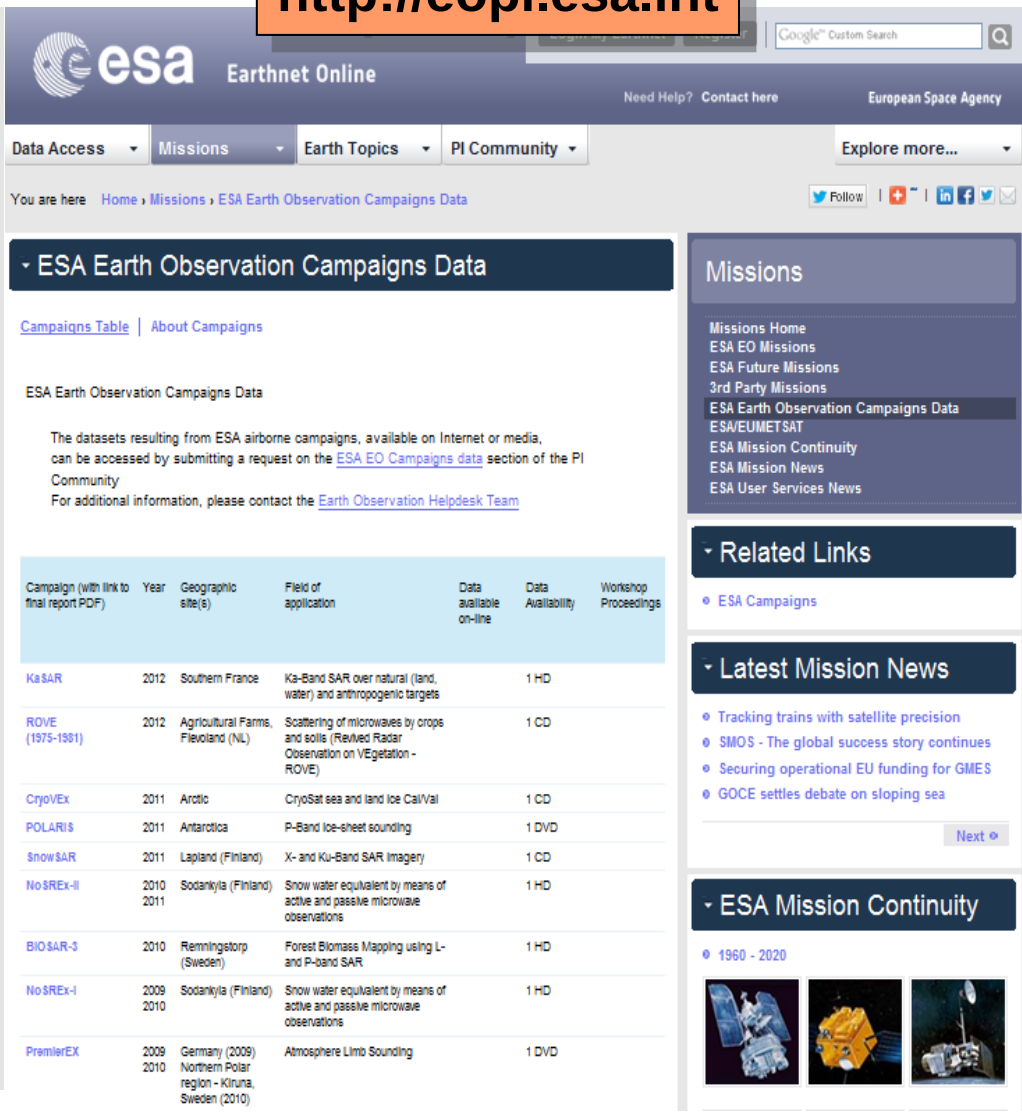
ESA Campaigns covering main snow regimes

(Near-)Coincident Ku-band and X-band scatterometers and airborne SARs used including very detailed in-situ measurements

Access to ESA Campaign Data

- All ESA campaign datasets formatted and documented are available through the ESA EOPI Portal
- Data inventory includes final reports with full description of campaign activity and analyses
- Access to datasets is provided through Category 1 mechanism (short proposal incl. identification of desired datasets)
- Data archive continuously increase in number and variety of campaign datasets
- Currently 43 campaign datasets available

http://eopi.esa.int



Scientific evaluation of mission concepts for snow mass and other cryospheric parameters

Objectives: The overarching objective of this activity is to **study and develop the needs and scientific requirements for a new satellite mission concept** with focus on global scale retrieval of snow mass and secondary cryosphere parameters taking full account of the recent and emerging experimental data sets and theoretical model developments.

Duration: 18 months

Status: Proposal in evaluation

Study initiated as a result of the ESA workshop in 2014

Summary for:

"Workshop on Novel Mission Concepts for Snow and Cryosphere Research"

held on 16+17 September 2014
at ESA-ESTEC, The Netherlands

Compiled in October 2014

European Space Agency
Agence spatiale européenne

Other initiatives and activities

- **Future EO Mission Concepts for the Polar Region – POLARIS**
  - Pre-Phase O studies ongoing

- **Call for Proposals for Earth Explorer 9 – overview:**
    - excellent science / societal benefits
    - SRL, TRL > 4
    - 120 ME industrial costs
    - Launch 2024

  - EE-9 **ISE-PAC (Letter of Intent)**
    - Ku-band imaging radar, operated in convoy with MetOp SG Sat-B
    - Provides an integrated and flexible ***multi-frequency active/passive*** observing system with MetOp-SG B MWI and SCA

- **CSA snow mission concepts study to start in Spring 2016**

Summary

- ESA supports the scientific community through studies and campaigns in order to advance modelling and (future) measurement of snow cover properties from space

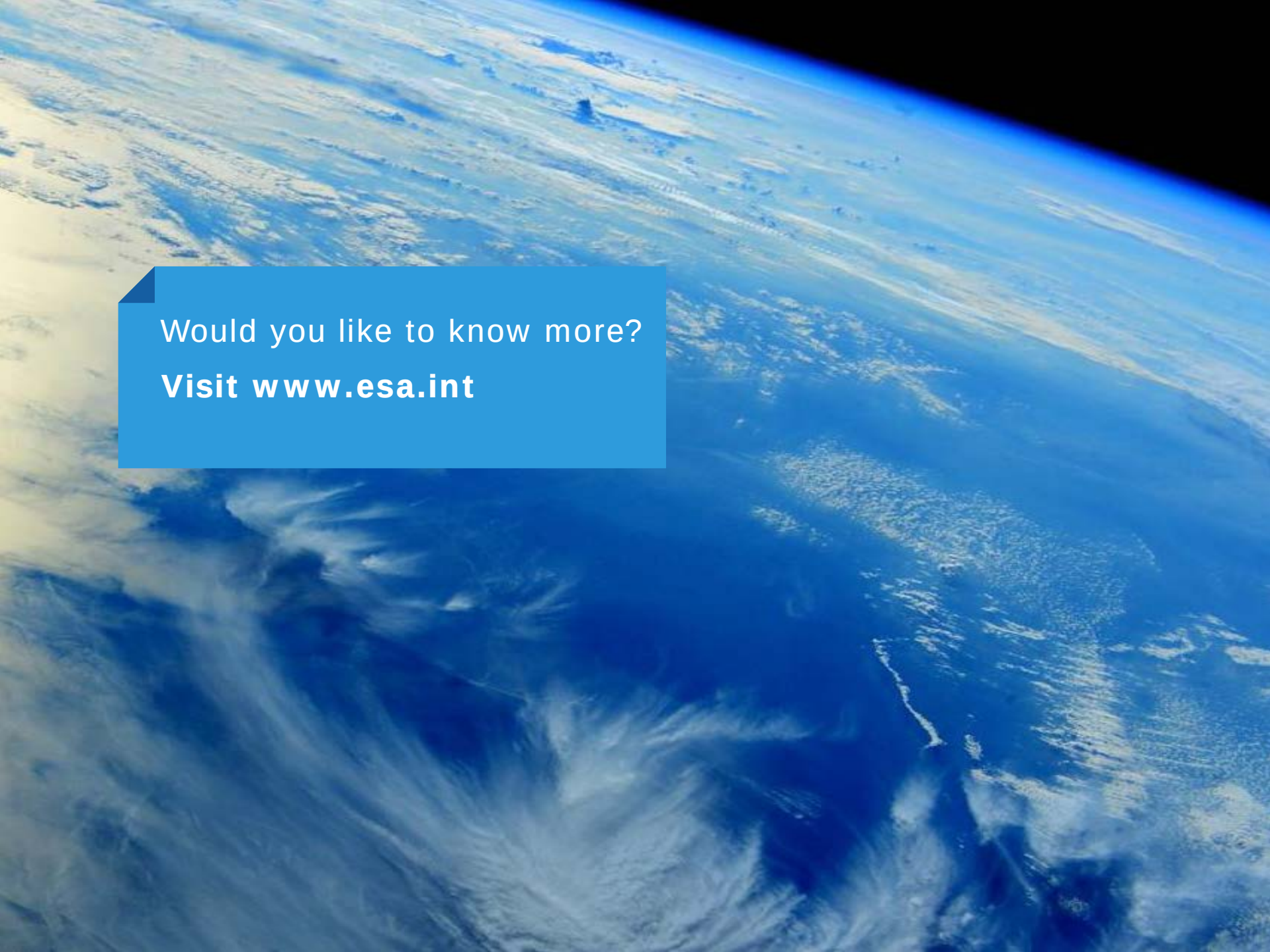
- Significant advances made in understanding and modelling snow and microwave interactions

- Further experimental data collections and (SnowSAR and other campaign) data analysis needed to define and consolidate future snow mission concepts

- 'Snow research' is highly relevant in view of ESA's EO strategy and addresses scientific questions and challenges with a direct bearing on societal issues

- International cooperation, coordination is key to mature science and development and satellite technology needed for a (potential) future snow mission

Thank you!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