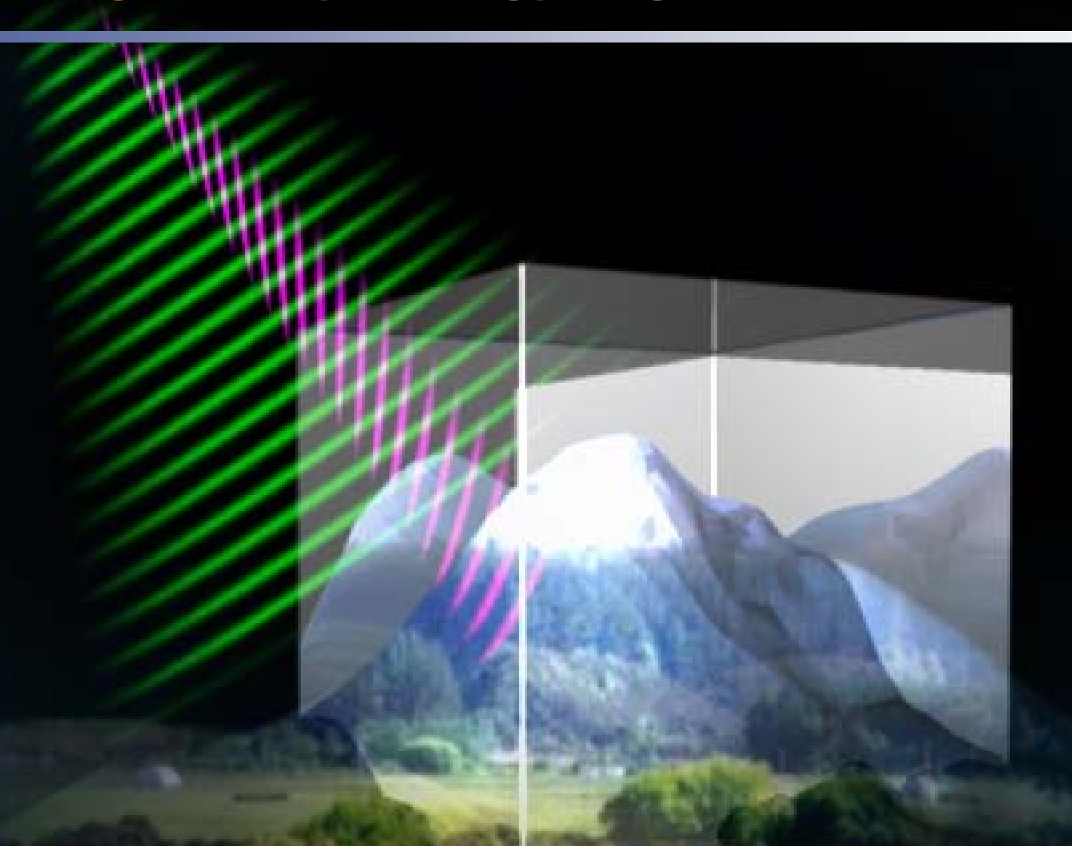
Cold Regions Hydrology High-resolution Observatory



A dual-frequency SAR Mission for Hydrology and Climate Research in Cold Environment

Claude Duguay & other MAG members of CoRe-H_2O

COREH2O

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Outline of Presentation

- Background
- Mission objectives
- Observational requirements
- Preliminary system concept
- Field experiments/science studies

Background

- Science Team of the CoReH$_2$O Proposal -

Proposal submitted in response to the Call for Ideas for the next Earth Explorer Core Missions, 2005

Monique Bernier - CAN
Robert G. Brakenridge - USA
Donald Cline - USA
Robert E. Davis -USA
Jean-Pierre Dedieu - F
Wolfgang Dierking - DE
Matthias Drusch - ECMWF
Richard Essery - UK
Pierre Etchevers - F
Martti Hallikainen - SF
Svein-Erik Hamran - N
Stefan Kern - DE
Ron Kwok - USA
Peter Lemke - DE
Eirik Malnes - N
Kyle McDonald - USA
Heinz Miller - DE

Keith Morrison - UK
Thomas Nagler - AT
Son Nghiem – USA
Johannes Oerlemans – NL
Paolo Pampaloni - IT
Kim Partington - UK
Shaun Quegan - UK
Walter L. Randeu - AT
Helmut Rott – AT (Chair)
Mathias Schardt - AT
Jiancheng Shi - USA
Detlef Stammer - DE
Rasmus T. Tonboe - DK
Wolfgang Wagner - AT
Anne Walker - CAN
Urs Wegmüller - CH
Simon Yueh - USA

Industrial Partner: EADS Astrium GmbH Friedrichshafen

Background

- Mission Assessment Group (MAG) -

- Helmut Rott, Austria
- Claude Duguay, Canada
- Richard Essery, UK
- Christian Haas, Germany
- Giovanni Macelloni, Italy
- Eirik Malnes, Sweden
- Jouni Pulliainen, Finland
- Helge Rebhan, The Netherlands

US-Observers:

Simon Yueh, JPL

Don Cline, NOAA

- **Technical and scientific studies over a 12-month period.**
- **“Report for Assessment” to be finalised by spring 2008.**

Mission Objectives

- Contributions to the Study of Cryospheric Processes -

CoReH$_2$O addresses all main (surface) components of the cryosphere with an emphasis on snow cover

LAND SURFACES

Land cover, Water cycle, Albedo, Surface temperature, Wet lands, Eco-systems, Carbon cycle

ATMOSPHERE

Temperature, Pressure, Motion, Composition (clouds, precipitation, trace gases, etc.)

OCEAN

Temperature, Salinity, Circulation, Sea level

Frozen Ground Permafrost

Heat exchange
Gas exchange
Carbon cycle

Snow Cover

Accumulation
Melt
Runoff
Water supply
Exchange of heat, moisture momentum
Avalanches

Glaciers Ice Caps

Mass balance
Atmospheric forcing
Runoff
Water supply

Ice Sheets Ice Shelves

Mass balance
Accumulation
Exchange of heat, momentum and water

River and Lake Ice

Extent
Thickness
Energy exchange
Runoff routing

Sea Ice

Thickness
Growth
Snow accumulat.
Melt
Exchange of heat, momentum

Source: IGOS Cryosphere Theme, 2007

Primary Mission Objectives (1)

For hydrology ***CoReH$_2$O aims at closing the gaps in spatially detailed information on snow, glaciers, and surface water, in order to serve the following objectives:***

- Improving the modelling and prediction of water balance and stream flow for snow covered and glacierised basins (including ungauged basins).
- Understanding and modelling the water and energy cycles in high latitudes.
- Assessing and forecasting water supply from snow cover and glaciers, including the assessment of effects of climate change.
- Monitoring land surface water extent in high latitudes and studying its relation to climate variability.

Primary Mission Objectives (2)

CoReH$_2$O will contribute to <u>weather and climate research</u> by:

- Providing new observation types for advanced data assimilation systems for the initialization of numerical models.
- Improving parameterization of snow and ice processes in NWP and climate models.
- Improving the understanding and modelling of land-cryosphere-atmosphere exchange processes.
- Providing data for the validation of GCMs and meso-scale meteorological models.
- Improving the estimates of glacier and ice sheet mass balances.

Secondary Mission Objectives (2)

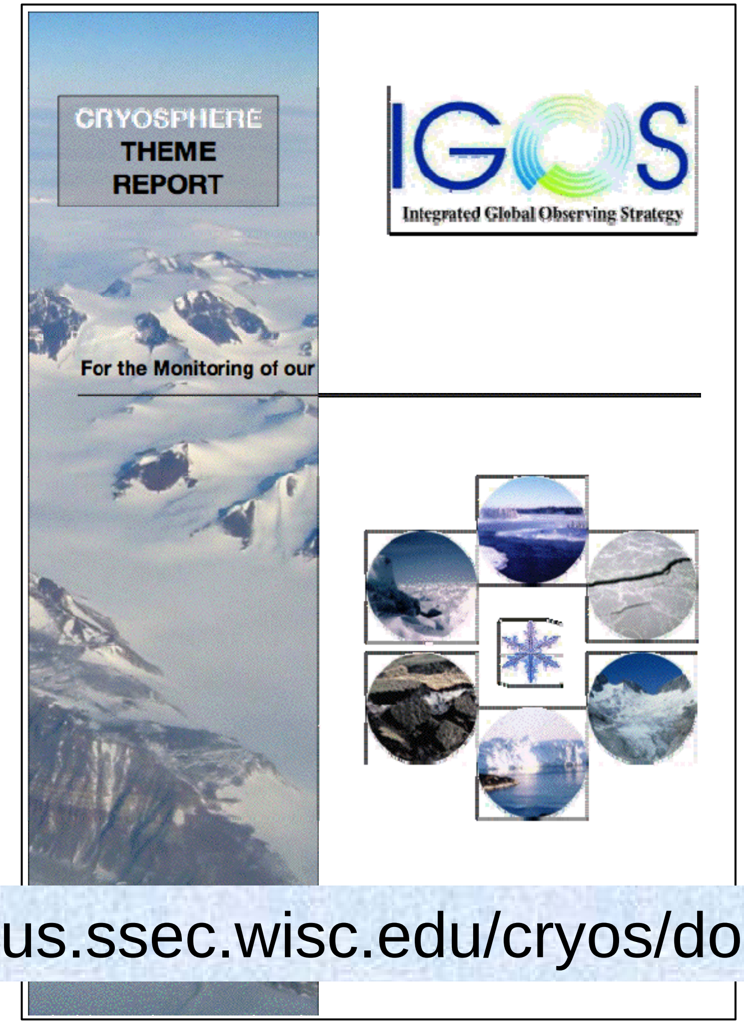
CoReH$_2$O will contribute to the characterisation of marine and freshwater ice parameters:

- Monitoring surface melt and melt season length for studies of seasonal sea ice albedo evolution and energy flux partitioning.
- Contributing to understanding of regional ice kinematics and dynamics in marginal ice zones.
- Improving estimates of surface heat fluxes and mass balance and their variability by retrieving properties of snow cover on the ice.
- Mapping thin ice types and polynyas and their temporal evolution for heat flux estimations.
- Improving understanding of coastal ocean wind effects on sea ice extent, polynyas, and leads.
- Observing freezing state and properties of lake (and river) ice covers.

Key Observational Requirements (1)

Variable	Spatial scale [m] -Threshold -Goal Global	Regional	Repeat interval	Accuracy (RMS) -Threshold -Goal
1. Primary Parameters				
Snow				
Snow extent	500 100	250 100	3-15 d	5% of hydrological unit (HU) ?
Water equivalent	500 300	250 100	15 d	20% for WE < 20 cm 10% for WE > 20 cm; else 3 cm
2.) Secondary Parameters				
Snow				
Extent of melting snow	500 100	250 100	3 d	5% of HU
Snow depth	500 100	250 100	3-15 d	10% at HU
Glaciers				
Facies type	200	100	15 d	2% of glacier area
Winter snow accumulation	500	200	15 d	10% of maximum
Terminus position, lakes	N/A	50	15 d	50 m
Freshwater Ice				
Ice area	N/A	50	3 d	5% of overall ice area
Sea Ice				
Snow Depth	N/A	200	3 -15d	ca. 10 cm
Ice Type	N/A	100	3 d	5% classification error
Ice Motion	N/A	1000	3 d	ca. 200m/day
Ice Melt	N/A	100	3 d	5% of overall sea ice area
Surface Water				
Extent of open water areas	100	50	3-15 d	0.02 km^2 capability

Key Observational Requirements (2)



http://stratus.ssec.wisc.edu/cryos/documents.html

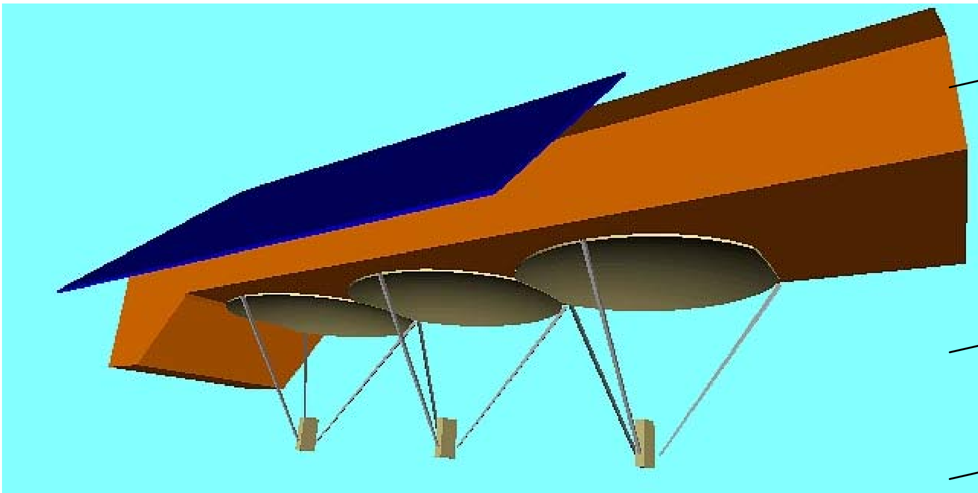
Preliminary System Concept (1)

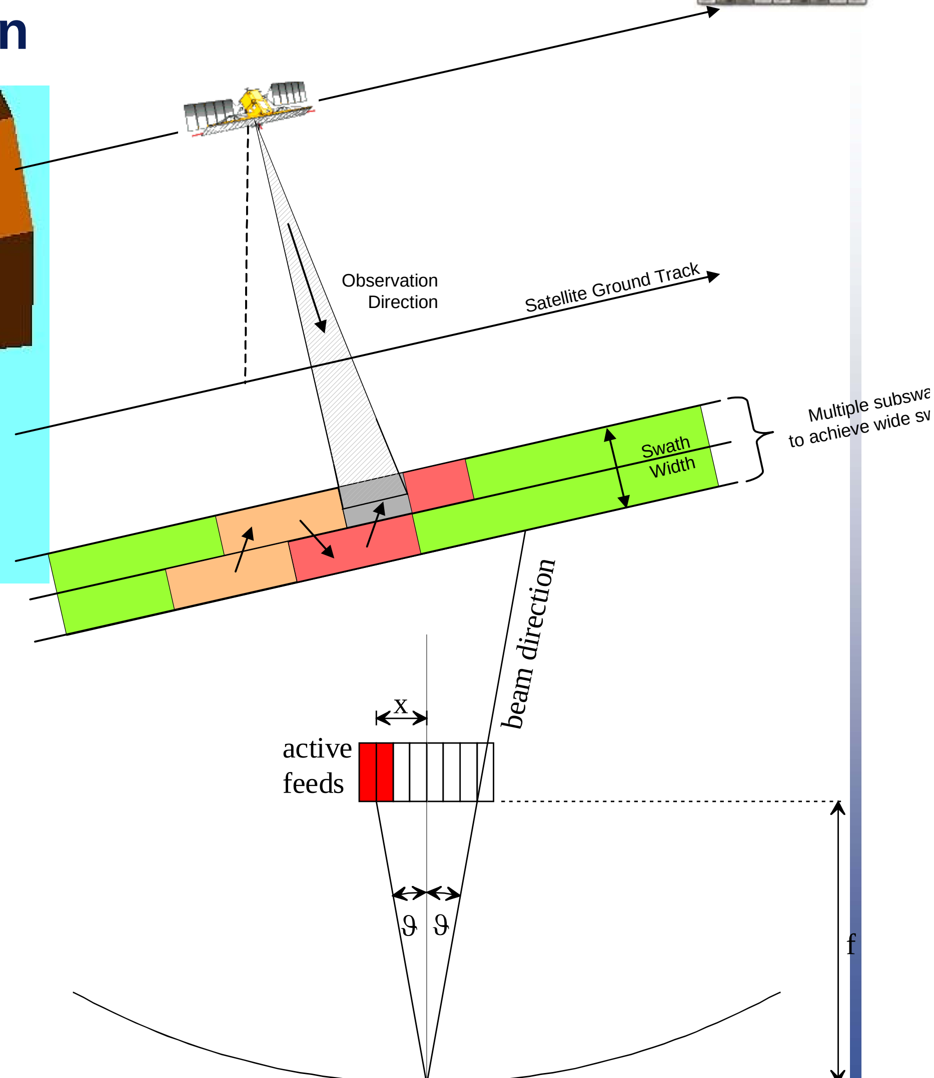
General Mission Configuration

Mission duration	4 years min., target 5 years
Sensors	Ku-band (17GHz) SAR, X-band (9.6GHz) SAR
Polarisation	VV and VH
Incidence angle	30 Š 40 deg.
Swath	> 100 km (ScanSAR)
Spatial resolution	50 m (multi look with # of looks >5)
Temporal co-registration (X-Ku)	30 Š 60 min
Spatial co-registration (X-Ku)	0.5 pixel
Orbit	Polar dawn/dusk, 98 deg. inclination LTAN: 06:00 +- 30 min

Preliminary System Concept (2)

Potential SAR Satellite Configuration





SAR Instrument:

- 2 frequencies 9.6 and 17.2 GHz
- VV and VH Polarisation

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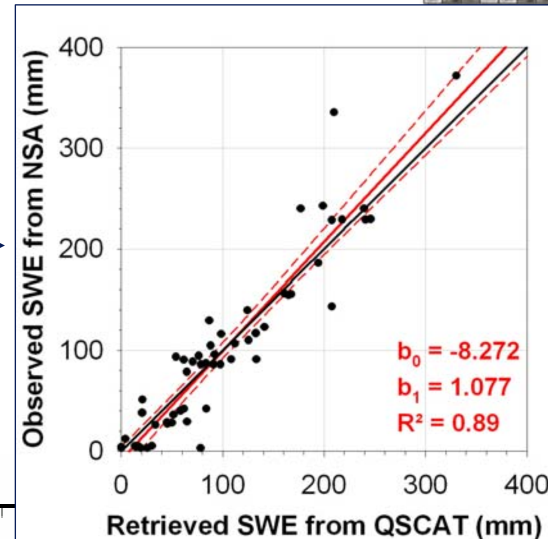
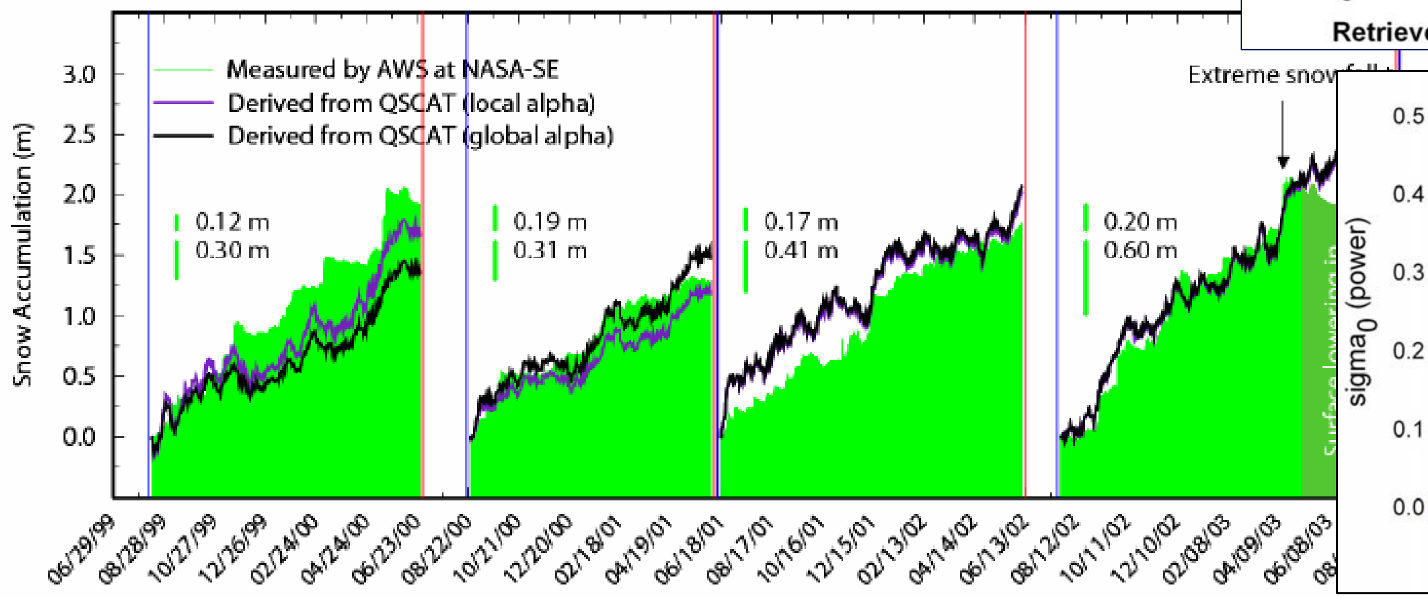
Preliminary System Concept (3)

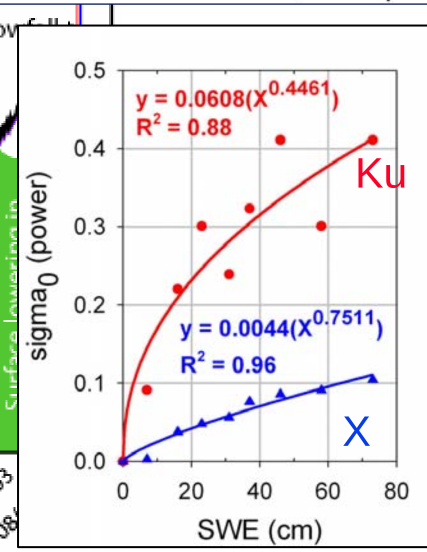
Results from Scatterometer Data

SWE retrieved from QuikSCAT Ku-band data using a radiative transfer model function compared to observations (Cline, 2004).



Snow accumulation at NASA-SW station in Greenland and QSCAT retrieval (S. Nghiem)





Ulaby, 1984

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Preliminary System Concept (4)

Requirements for Different Mission Phases

	Phase 1	Phase 2
Repeat cycle	3 days	12-15 days
Orbit	dawn/dusk, sun syncr.	dawn/dusk, sun syncr.
Spatial coverage	constrained by swath width with emphasis to cover selected test areas	global, permanent gaps (up to 5%) are acceptable
Coverage to be optimised for latitudes	n.a.	Northern hem.: 40 Š 88 Southern hem. 40 Š 82
Data latency	3-6h for special experiments 1-3 d nominally	7 d

Phase 1: Years 1 and 2 Phase 2: Years 3+

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Field Experiments/Science Studies (1)

Objectives:

- To identify the capabilities and limitations of microwave scattering models.
- To give first guidance on observational strategies and algorithms.
- To assess the maturity of algorithms.

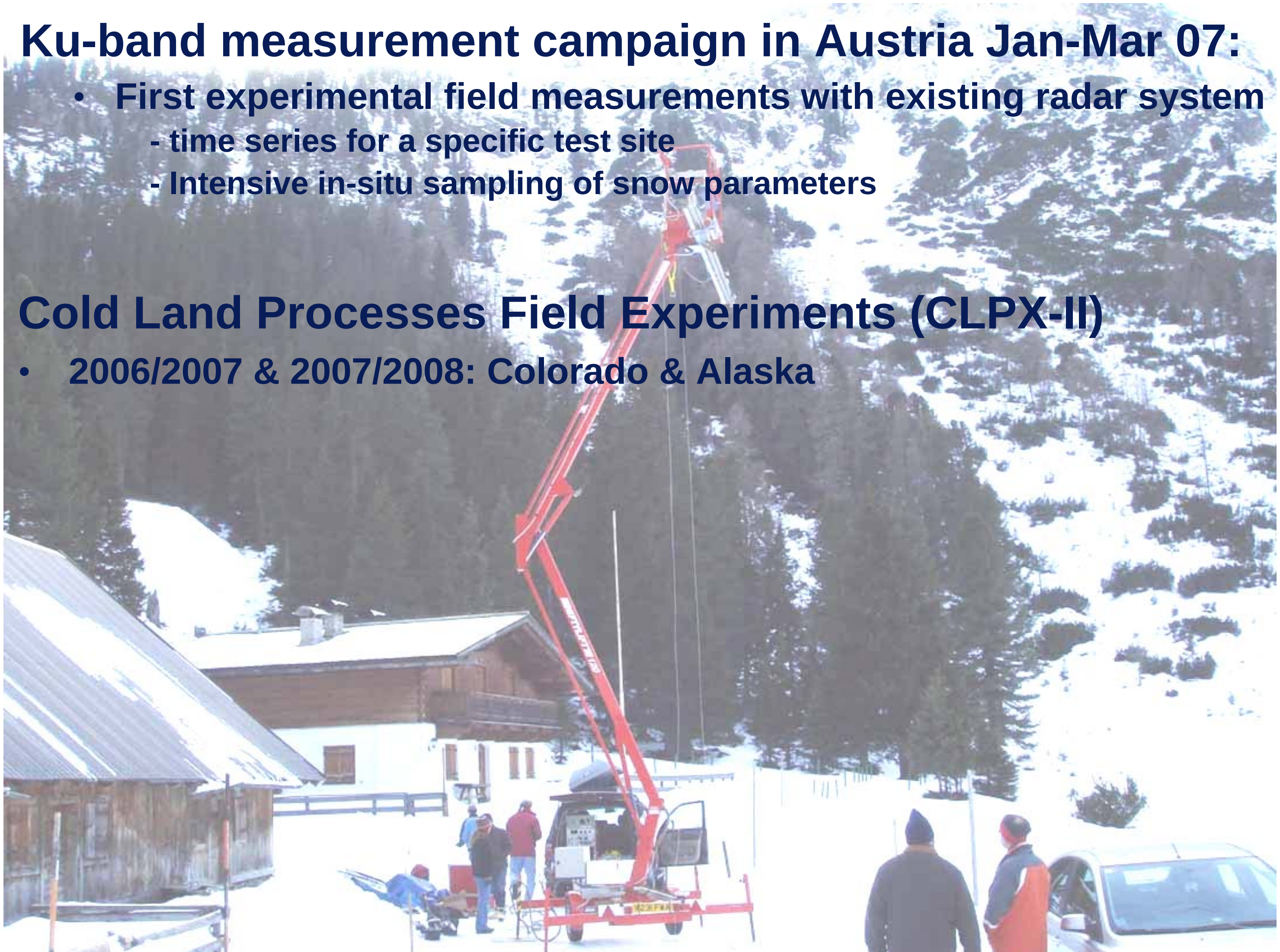
Field Experiments/Science Studies (2)

Ku-band measurement campaign in Austria Jan-Mar 07:

- **First experimental field measurements with existing radar system**
  - **- time series for a specific test site**
  - **- Intensive in-situ sampling of snow parameters**

Cold Land Processes Field Experiments (CLPX-II)

- **2006/2007 & 2007/2008: Colorado & Alaska**



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Merci / Thank you

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Backup Slides

Work Plan and Schedule (1)

WP No.	WP TITLE	INSTITUTION	WP MANAGER
100	**Project Management**	ENVEO	H. Rott
200	**Review of Models, Methods, and Experimental data**		
210	Review of Backscatter Models and Retrieval Algorithms	FMI	J. Pulliainen
220	Review of Experimental Work and Compilation of Data Sets	NORUT	E. Malnes
300	**Assessment of Critical Issues**		
310	Atmospheric Propagation Effects	FMI	J. Pulliainen
320	Effects of Snow Physical Properties	FMI or NORUT or ENVEO	
330	Effects of Vegetation and Topography	IFAC	G. Macelloni
340	Physical Properties of Sea Ice, Lake Ice, and Glaciers	AWI	C. Haas
400	**Retrieval Algorithms**		
410	Specifications for Level-1 Satellite Products	NORUT	E. Malnes
420	Snow Retrieval Algorithms over Land Surfaces and Glacier Ice	ENVEO	H. Rott
430	Retrieval Algorithms for Sea and Lake Ice	AWI	C. Haas
500	**Impact of Satellite Snow Products for Process Models**		
510	Use of CoReH2O Products for Snow Process Models	U. Wales	R. Essery
520	Impact of CoReH2O Products for Sea Ice and Lake ice Models	U-WAT	C. Duguay
600	**Conclusions and Recommendations**	ENVEO	H. Rott

Work Plan and Schedule (2)

Time Schedule
(started 1 May 2007)

Month	1	2	3	4	5	6	7	8	9	10	11	12
WP100	X	X	X	X	X	X	X	X	X	X	X	X
WP200	X	X										
WP300		X	X	X	X							
WP400				X	X	X	X	X	X	X		
WP500									X	X	X	
WP600											X	X
Meetings			X			X			X			X

Innsbruck
16-20 July 2007

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Models for Snow Scattering and SWE Retrieval

1.) Discrete dipole approximation (DDA)

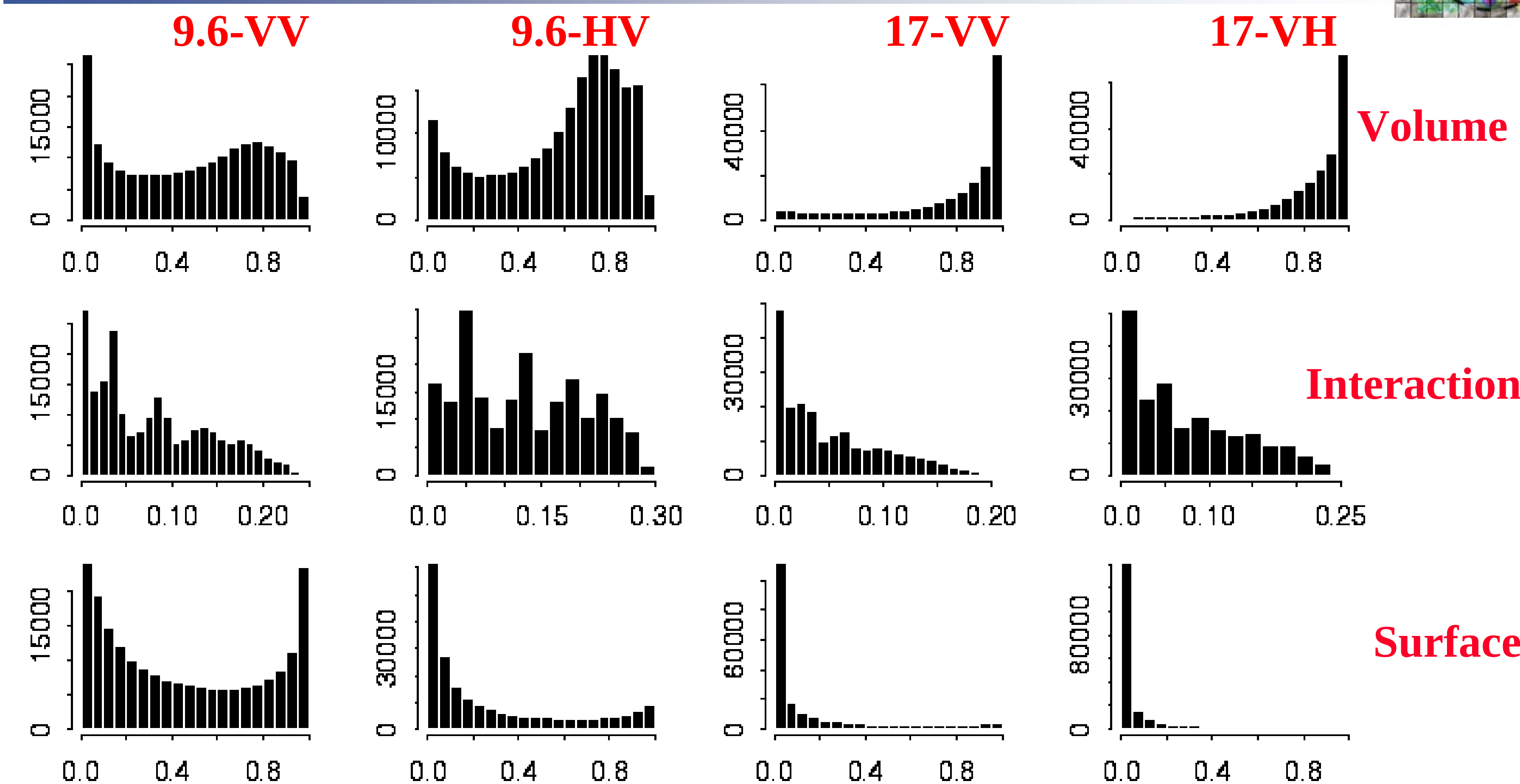
- computing scattering of radiation by particles of arbitrary shape. (Purcell, Pennyacker, 1973)
- adopted for snow scattering models (Pulliainen, Hallikainen)

2.) Dense Medium Radiative Transfer (DMRT)

- Applied for numerical simulation of $\sigma°$ for a wide range of snow conditions.
- Algorithm developed for SWE estimation with dual-frequency (9.6 & 17 GHz) & polarization (VV and HV) SAR by scattering decomposition (J.C. Shi, UCSB)
- Depolarization factor for dry snow proportional to the scattering contribution in co-polarization signals; used to decompose surface and volume scattering

With the estimations of scattering albedo and optical thickness at two frequencies, SWE can be retrieved.

Scattering at different frequencies and polarisation



Each Scattering Contribution in % for 3 Components

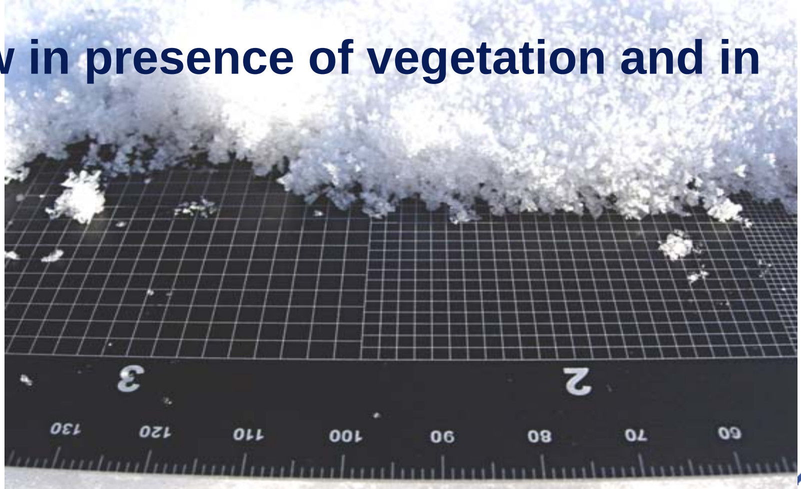
Scientific Issues

CoRe-H2O very ambitious in claimed accuracies

-> Dedicated scientific studies together with in-situ campaigns

Particular issues to assess:

- **Feasibility of required observation accuracy using X- and Ku-band (17.2 GHz) SAR data (e.g. ambiguity between snow depth and water equivalent)**
- **Decomposition of grain size effects and snow mass (SWE) in backscattering signatures.**
- **Layover in mountain terrain, snow in presence of vegetation and in forested areas**
- **Atmospheric effects**



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Technical Studies

Technical Design Phase-0 study with industry to assess implementation concepts

- Status: start foreseen May/June 2007

Ku-band Scatterometer development

- Objectives:

  To develop a scatterometer at Ku-band for ground-based campaigns;

  To perform an initial proof-of-concept campaign for demonstrating its functionality and performance.

- Status: start foreseen mid 2007