Outline

- Why do we need airborne campaigns?
- First airborne demonstration of Pol-InSAR
- What is the status of application development with Pol-InSAR?
  - Forest Application
  - Agricultural Application
  - Ice and Snow Application
  - Urban Area Application
- Contribution of airborne campaigns to spaceborne
Why do we need airborne campaigns?

Innovation
- Specifications needed for future satellite sensors
- Test advanced imaging modes (Pol-InSAR, digital beamforming, etc.)

Development
- Development of algorithm for quantitative parameter estimation
- Development of new application products
- Observations to with which to calibrate or validate satellite retrievals

Data Availability
- Detailed information’s in critical areas
- Key information that cannot currently be measured from space
- Young researcher education and preparation to satellite SAR sensors

First airborne Pol-InSAR campaigns

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**AIRSAR’s first Pol-InSAR campaign @ JPL, USA**

Objectives: To measure attenuation at different frequencies in the canopy
Understand temporal decorrelation in the canopy
See how the interferometric phase varied with polarimetric decompositions

Summary: Airborne InSAR experiments have shown good correlation at L-band

GeoSAR: Dual Pol-InSAR @ P-band – Campaign in Camp Lejune NC USA 2000

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**First airborne Pol-InSAR campaigns**

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**EMISAR's first Pol-InSAR campaign @ DNSC, Denmark**

**Test site:** Foulum, Denmark  
**Campaign purpose:** Crop classification  
**Acquisition date:** May 3, 1995  
**Acquisition/processing:** Technical University of Denmark  
**Frequency:** C-band

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**First airborne Pol-InSAR campaigns**

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E-SAR’s first Pol-InSAR campaign @ DLR, Germany

First airborne Pol-InSAR campaigns

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**RAMSES’s first Pol-InSAR campaign @ ONERA, France**

- Date: Sep 1999
- Campaign: ORANGE
- Objective: Polarimetry studies
- Test site: Bretigny, France
- Frequency: X band
- Imaging mode: Single pass

**First airborne Pol-InSAR campaigns**

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**PI-SAR's first Pol-InSAR campaign @ JAXA, Japan**

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<th>First experiments</th>
<th>Oct. 8, 2000</th>
<th>Nov. 21, 2006</th>
</tr>
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<tr>
<td>Objective</td>
<td>Tree height, InSAR capability (~90m Bp)</td>
<td>Surface deformation with control flight (5m tube)</td>
</tr>
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<td>Test site</td>
<td>Tottori, Tsukuba</td>
<td>Mt. Fuji</td>
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<tr>
<td>Frequency</td>
<td>1.27GHz</td>
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TopoSAR first Pol-InSAR campaign @ Intermap, Germany

TopoSAR (formerly AeS-1)
- Simultaneous X-band HH and quad-pol P-band
- P-band bandwidth: 70 MHz @ 415 MHz centre frequency
- First Pol-InSAR demonstration in 2000
- First operational Pol-InSAR campaign in July 2002: Capitol Forest (Washington State, USA) for the purpose of bald-earth DTM generation beneath forest canopy

Gulfstream Commander with X- and P-band antennas

Capitol Forest example:
P-band Magnitude (HH) Aerial Photograph Pol-InSAR derived DTM

Forest Vegetation
- Forest Height
- Forest Biomass
- Canopy Extinction
- Forest Structure
- Underlying Topography

Agricultural Vegetation
- Soil Moisture Content
- Soil Roughness
- Height of Vegetation Layer
- Extinction of Vegetation Layer
- Moisture of Vegetation Layer

Ice and Snow
- Topography
- Penetration Depth
- Depth of Snow-Ice Layer
- Extinction
- Density of Ice Bodies

Urban Areas
- Geometric Properties
- Dielectric Properties

- Forest Ecology
- Forest Management
- Ecosystem Change
- Carbon Cycle

- Farming Management
- Water Cycle
- Desertification

- Ecosystem Change
- Water Cycle
- Water Management

- Urban Monitoring
1994: SIR-C / X-SAR acquires the first POL-InSAR data.
1996: First publication on Pol-InSAR.
1998: First Pol-InSAR forest height estimation.
Three main forest types have been investigated:
- Temperate forest
- Boreal forest
- Mediterranean forest

Airborne Campaigns with E-SAR @ Forest applications

Campaign Objectives:
- E-SAR campaigns over different forest types in Europe for forest height retrieval:
  1. Algorithm improvement
  2. Model validity
  3. Validation
  4. Product development

Airborne Campaigns @ Forest applications
**Tropical forest applications**

**Campaign Objectives:**

1. Investigation of L- and P-band over tropical forest for forest height estimation (visibility of the ground, validity of the RVoGM etc.)
2. Is there a relation of forest height and forest biomass over tropical forest?
3. Is there an empirical relation between the radar backscatter and the forest biomass using L- and/or P-band?

**MAWAS: Tropical forest height**

RGB Image X/L/P Band

Tropical Forest Height from Pol-InSAR

Forest height over tropical forest in Indonesia
**Preliminary results: Tropical forest applications**

1. Both frequencies L- & P-band are suitable for forest height estimation
2. Research is still ongoing and a definite answer is pending – relation between height/biomass
3. Six different definitions of biomass have been found in the literature and have been used for comparison. No significant relation between biomass and radar backscatter were found (270-390 t/ha)

---

**Boreal Forest 2003 @ Helsinki Area**

**Campaign Objectives:**

1. Investigation of Pol-InSAR in L-band over boreal forest areas.
2. Comparison of Pol-InSAR derived forest heights with HUT-SCAT data

---

**HUT-SCAT Profile**

Cooperation with HUT
**Forest height @ different frequencies ...**

Short summary:

1. Significant correlation between L-band & HUTSCAT derived forest heights
2. Significant correlation between X-band & HUTSCAT derived forest heights

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E-SAR / Test Site: Helsinki, Finland
**E-SAR’s Agricultural Campaign in Tunesia 2005**

**Airborne Campaign: AQUIFEREX within AQUIFER**

- support the national authorities and international institutions with Earth Observation (EO) based technology to better manage internationally shared water resources and aquifers
- strengthen overall and integrated water management practices
- build-up of an independent service provision capacity to ensure local service delivery after the project cycle to achieve the longer-term goal of service sustainability

**Campaign Execution**

- November 2005
- South Tunesia (Ben Gardane, Gabes Region)

**Important observation Parameter:**
- Land-cover and use & soil moisture

**Bare Surfaces: Soil Moisture Estimation @ AQUIFEREX**

![Diagram showing radar data and soil moisture estimation](image)

- X-Bragg
- Bragg
- Roughness

Pol. Coherence Matrix:

\[
\begin{bmatrix}
T_{11} & T_{12} & T_{21} & T_{22} & T_{33}
\end{bmatrix}
\]

**E-SAR / Test Site: Aquiferex, Tunisia**

- L-band / Pauli RGB
- Dielectric Constant
- Vol. Soil Moisture
Agriculture Vegetation @ Alling/Germany 2000

AGRISAR: Soil Surface and Crop Parameter (April-Aug.2006)

1. Building up a data base for agricultural parameter estimation over a whole vegetation growth period - has been started mid April 2006
2. support the space segment activities at ESA with respect to the Sentinel Program
   - answering open questions concerning system constellation (single, dual, qual polarisation, revisit time, etc)

- 16 Radar data acquisition flights during three months
  - Polarimetry
  - Frequency
  - X-band interferometry

Interferometric Coherence:
Test Site: Kuettighoffen, Switzerland
E-SAR / Test Site: Alling, Germany
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- Forest Height
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**Urban Monitoring**
First Pol-InSAR Snow Experiment in Austria 2004

E-SAR: Kuehtai / Austria 2004
Cooperation with University of Innsbruck

Snow appears as a Volume Scatterer @ L-band

Campaign Objectives:
Investigation of Pol-InSAR for snow characterisation

Snow depth can be potentially estimated

Baseline 1 (20M): Δφ=17° -> Δz=1.48m
Baseline 2 (40M): Δφ=28° -> Δz=1.22m
**SVALEX 2005 – Svalbard Airborne Experiment**

**DLR-HR (Microwaves and Radar Institute)**
- Pol-InSAR measurements over land ice
- penetration depth at different frequencies
- retrieval of glacier topography
- mapping of internal ice structures

**AWI-Potsdam (Alfred-Wegner Institute)**
- measurements of optical, chemical, and physical properties of Arctic aerosols, in particular Arctic haze

**AWI-Bremerhaven (Alfred-Wegner Institute)**
- boundary layer meteorology
- transfer of atmospheric momentum to sea ice
- use of radar imagery to quantify ice $k_s$

**Sensors:**
1. E-SAR Radar System
2. Meteopod (wind velocity, humidity, temp.)
3. Laser Altimeter
4. KT15 (surface temp.)
5. Linescan camera

Airborne Radar Campaign at Spitzbergen
- over Sea Ice in X- & L-band quad pol
- over Land Ice (Glacier) in Pol-InSAR L- and P-band

**Sea/Land ice SAR data acquisition**
Preliminary Summary

• Investigation of penetration depth at different frequencies, where the corner reflector are used as a reference point. First results show that lower penetration occurs as expected in X-band, L-band and P-band.

• Implementation and modification of coherent scattering models for the characterisation of the ice volume and Pol-InSAR analysis at different frequencies showed good agreement with the observables.
**Campaigns over Urban Area over Munich 2005/6**

**Campaign Objective:**

1. Identification of Coherent Scatterers at different Frequencies
2. Characterisation of Coherent Scatterer (dielectric and geometric properties)

**Dihedral Size:**
- Vertical: 80 x 80 cm
- Horizontal: 80 x 80 cm

**Orientation:**
- 1st dihedral: 0°
- 2nd dihedral: 5°

**Acquisition:**
- 13. Oktober 2005

**Tracks:**
- 0, 30, 90, 270m
- 3 independent

**Urban Areas: Coherent Scatterers @ Munich 2005/6**

2005-6: First CS’s dedicated experiment

E-SAR / Test Site: Munich, Germany

- R: HH-VV
- G: HV
- B: HH+VV

- R: L-band
- G: C-band
- B: X-band
Coherent Scatterers

Red: Dihedrals
Green: Dipoles
Blue: Flat Plates

Amplitude
Entropy
Alpha angle

06.2006

See presentation by Kostas Papathanassiou & Luca Marotti

Looking Forward …

- Development of parameter estimation methodology / algorithms: Snow / Ice / Agriculture …
- Information product definition and validation / Projection of product spec’s onto system design.
- Exploration of new and innovative observation spaces:
  - From E to F (SAR)
  - From S to Q (Pol)
  - From R to S (Pass)
  - From M to B (Static)

ALOS / Pal-SAR  TerraSAR-X  RadarSAT-2  Tandem-X