Towards operational monitoring of key climate parameters from synthetic aperture radar: perspective and challenges

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Super Science Fellowships (SSF)

- Australian Research Council
- aim: “to attract and retain early-career researchers” → research driven
- 3 years funding

- University of Melbourne / CRC-SI → application driven
- collaborating partners: Monash University, Flinders University, The University of New South Wales → Project Management Group
- aim: development of algorithms (SAR based) for high resolution retrieval of:
  - vegetation properties (type, biomass, etc.)
  - soil moisture
  - microtopography

- simultaneous consideration of vegetation, soil moisture and microtopography
  → 3 SSF fellows working in synergy: Rocco, Mihai, Rocco & Mihai

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Motivation

- large interest in soil moisture and vegetation information
  - weather & climate monitoring and forecast
  - water management and flood forecasting
  - carbon cycling
  - agricultural (growth, yield etc.) and woodlands (water stress) monitoring
- sensitivity of microwaves to
  - water content
  - structural properties (e.g. size, shape, density, etc.)
- increasing number of SAR space borne sensors (L-band: PALSAR, SMAP)
  - global coverage, frequency , night & day acquisitions
- cloud cover does not affect radar acquisitions
- development of new methods for SAR signal processing: interferometry, polarimetry, polarimetric interferometry
Challenges

- Backscatter is the sum of different contributions → have to “separate” them.

- Vegetation scattering mechanism varies greatly with vegetation type:
  - Different models for different vegetation types.
  - Models require testing over diverse areas.
- Need to account for surface roughness.
- Effect of volume scattering in top soil unknown.

Volume f (size, shape, density, water content)
Surface f (moisture, roughness)
Dihedral f (volume, surface properties)
Soil moisture/vegetation retrieval

- **empirical**: relate SAR metrics to ground data through regressed relations → calibrated for certain area, plant type, SAR frequency, polarization and θ.
- **analytical**: predict SAR metrics as a function of physical parameters → large number of variables involved → difficult to implement
- **semi-empirical**: based on functional relationships reflecting the physics of the process → easier to implement operationally, derived from experimental data
Local retrieval

- bare surfaces/low-biomass (< ? Kg/m²)
  - empirical models based on single polarized data (Wang 1986, Dobson 1986)
  - semi-empirical models based on multi-polarized data (Dubois 1995, Oh 2004, Shi 1997) → simultaneous retrieval of soil moisture and roughness
  - analytical models (Fung 1992)
- vegetated areas → correct for the vegetation effect
  - polarimetric decomposition (Hajnsek 2009)
  - time series algorithms (Wagner 1999, Kim 2009)

Global retrieval

- computation of forward models → computationally heavy
- pre-computed “data cubes” → computationally efficient
Image segmentation (classification)

• land use dependant retrieval algorithms require an a priori image classification
  
  *bare surfaces / crops / forests / pastures*

• further classification for main crops types (grouped by dominant scattering mechanism)
  
  *cereals/corn/broadleaf*

• SAR based / Optical based / Multi sensor based classification

Bare soil retrieval

• multi polarization retrieval algorithms (mv, ks)
  
  • Dubois (1995) – based on HH and VV data
  
  • Oh (2004) – based on ratios (HH, VV and HV)

• verify algorithms for the Australian conditions (SMAPEx)

• verify validity range of algorithms

• corrections (?)
Vegetated areas

- backscatter decomposition into main components
  - Water Cloud model (Attema 1978): $\sigma^o = \sigma^o_{\text{veg}} + \sigma^o_{\text{soil}}$
  - MIMICS (Ulaby 1990): $\sigma^o = \sigma^o_{\text{veg}} + \sigma^o_{\text{soil}} + \sigma^o_{\text{gcg}} + \sigma^o_{\text{g-c&c-g}}$
- polarimetric techniques
  - $H/A/\alpha$ – (Hajnsek 2003)
  - surface/volume/dihedral – (Freeman-Durden 1998)
- assessment of the existing models (for the parameterized crop types)
- sensitivity analysis of SAR metrics
  - backscatter metrics: HH, HV, VH, VV, HH/VV, HV/VV, RVI etc
  - polarimetric metrics: $H/A/\alpha$, surface/volume/dihedral, etc.
  - interferometric metrics: coherence, center scattering height
- model formulation and parameterization (vegetation/crop type dependent)
- soil and vegetation parameters retrieval
- validate the models
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Proposed diagram for soil moisture and vegetation retrieval

- RS data
- Ground data
- SAR Backscatter Polarimetric Interferometric
- Mv, Ks, VWC, H, etc.
- Sensitivity analysis
  - Oh (2004)
  - Dubois (1995)
  - Etc.
- Vegetation
- WCM parameterization
  - Pasture
  - Shrub land
  - Forests
  - Crops
  - Cereals
  - Corn
  - Rice
  - Broadleafes

- Bare surface
  - Soil contribution
  - Vegetation contribution
  - Soil moisture
  - Vegetation
  - Validation
SMAPEX 1 / SMAPEX 2 / SMAPEX 3

• Ground data
  • soil moisture: continuous network, spatially intensive
  • roughness: rms height and correlation length
  • vegetation: type, biomass, water content, height, LAI, reflectances
• Airborne data
  • PLIS (L-band SAR, polarimetric/interferometric)
  • PLMR (L-band radiometer)
  • Skye (VIS/NIR/SWIR)
  • Hyperspectral and/or LIDAR (planned for SMAPEX 3)
• Satellite data
  • PALSAR, ASAR, Cosmo-SkyMed (SARs)
  • ASTER, AVNIR 2 (VIS/NIR)
  • Radarsat 2, TerraSAR-X
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- PLIS data
  - new sensor → processing challenges (MOCOM, calibration, geocoding)
  - airborne → large $\theta$ variation across swath → correction needed
- ground data
  - forest ground data collection (SMAPEX 3)
  - sampling of vegetation structure (SMAPEX 3)
  - limited number of samples for some crop types (SMAPEX-1 & SMAPEX-2)
- bare soil surface models: evaluation/selection/correction
- correct classification of crop types by scattering mechanism
- high potential number of models: 3 land use classes + 4 crop types
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