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

Rocco Panciera

Mihai Tanase

Kim Lowell Jeff Walker

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

  } Australian conditions

- simultaneous consideration of vegetation, soil moisture and microtopography

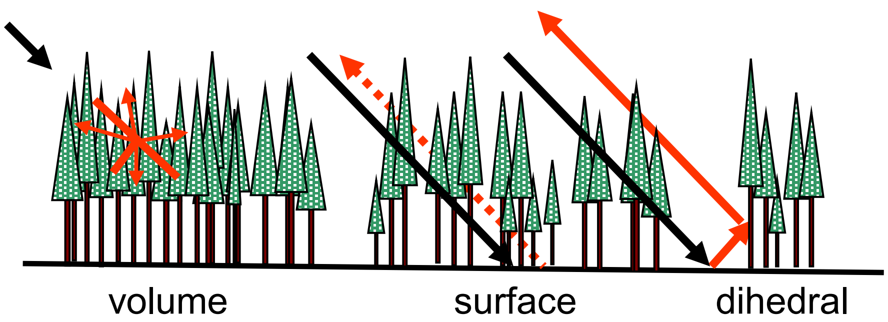
  → 3 SSF fellows working in synergy: Rocco, Mihai, Rocco & Mihai

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

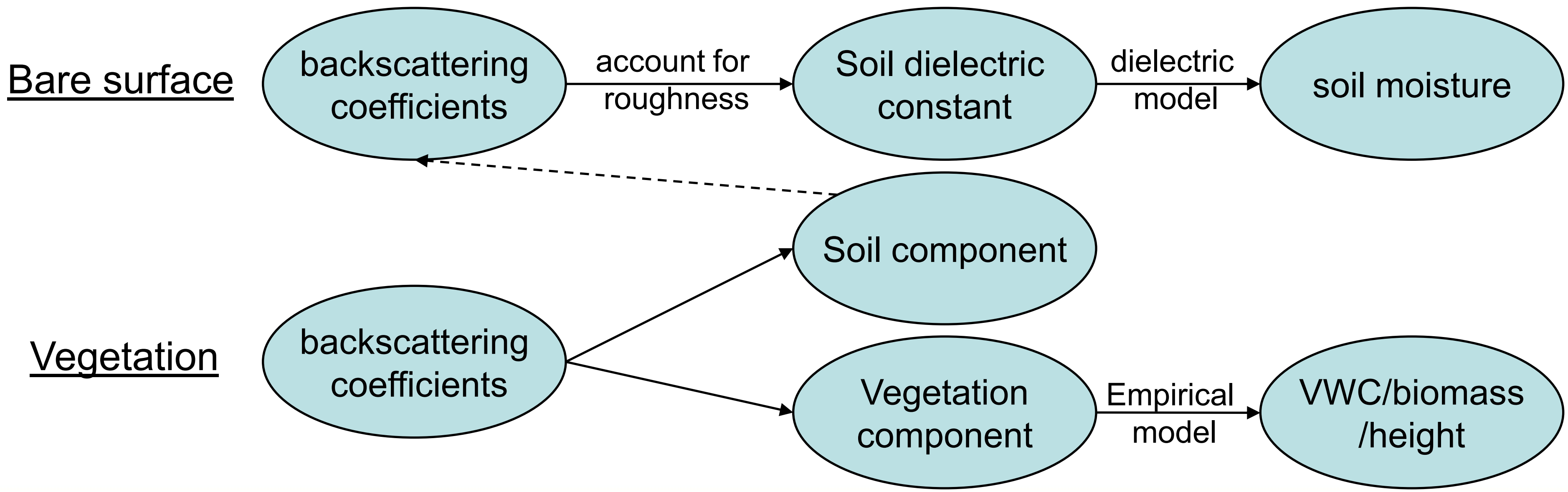


Volume f (size, shape, density, water content)
Surface f (moisture, roughness)
Dihedral f (volume, surface properties)

- 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

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/m^2)
  - 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
  - water cloud models (Attema 1978, *Bindlish 2001, Gherboudj 2011, Joseph 2008)*
  - 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

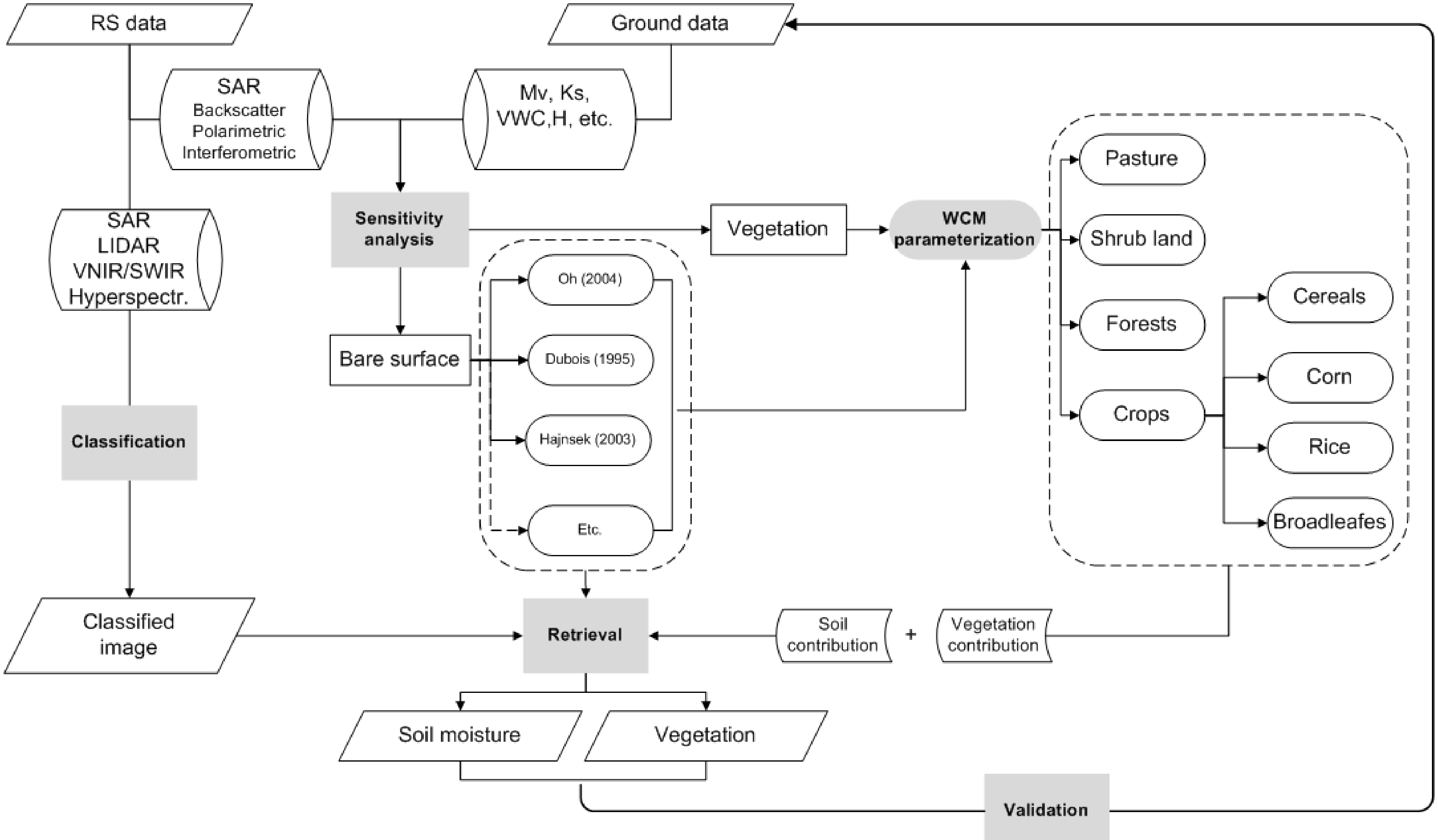
Bare soil retrieval

- 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): $\sigma° = \sigma°_{veg} + \sigma°_{soil}$
  - MIMICS (Ulaby1990) : $\sigma° = \sigma°_{veg} + \sigma°_{soil} + \sigma°_{gcg} + \sigma°_{g\text{-}c\&c\text{-}g}$
  - polarimetric techniques
    - H/A/α – (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/α, 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

Proposed diagram for soil moisture and vegetation retrieval



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

- PLIS data
  - new sensor → processing challenges (MOCOM, calibration, geocoding)
  - airborne → large θ 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
- …………
- …………