A REVIEW OF SAR OBSERVATION REQUIREMENTS FOR GLOBAL AND TARGETED SCIENCE APPLICATIONS

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OVERVIEW

- *Summary* of a first cut review of SAR observation requirements for some key science applications*
  - ***Interferometric phase** the main measurement*
    - *Glaciers & Ice Caps, Solid Earth, Geohazards, Forest AGB (tomo-InSAR)*
  - ***Backscatter intensity** and/or **polarimetric phase** the main measurements*
    - *Land Cover & Forestry, Above-Ground Biomass, Wetlands, Agriculture & Soil Moisture*
    - *Other Hazards (e.g. oil spills, flooding, etc.)*
- *Observation requirements*
  - *Acquisition parameters (e.g. polarisation, radar frequency, observation geometry)*
  - *Sampling strategies (spatial and temporal)*
  - *Identification of challenges and information gaps*
- *Summary/Discussion points for TA sessions @*

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** See IGARSS extended abstract for detailed assessment per application*

Interferometric SAR Applications

(Glaciers & Ice Caps; Solid Earth; Geohazards)

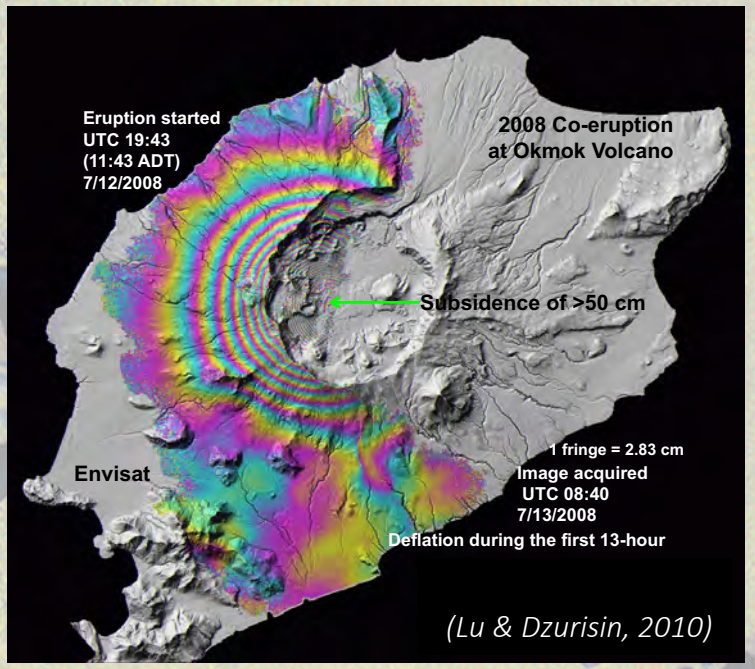
Key application examples

- *Crustal deformation; subsurface magma migration, aquifers*
- *Earthquakes; volcano eruptions, land slides, subsidence*
- *Velocity of glaciers, ice caps and ice sheets*
- *Glacier grounding line mapping*

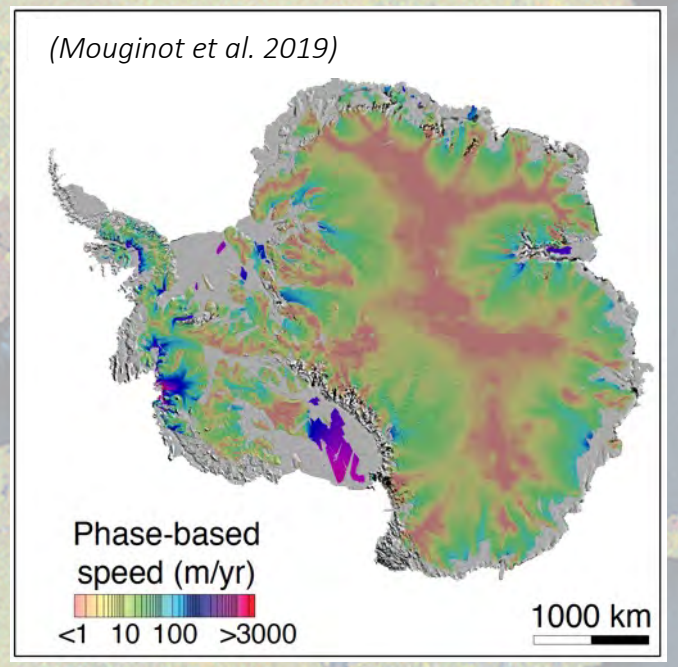
Applications of critical relevance to understanding the impacts of Climate Change (e.g. sea level rise, increased freq. natural disasters)

Challenges

- *Temporal decorrelation*
  - *Current repeat cycles (weeks) do not maintain fringe visibility over fast-flowing ice, vegetated terrain, and are insufficient to understand rapid processes which operate at sub-daily time scales (e.g. ice berg calving, tidal seismic phenomena, land slides).*
  - *Long wavelengths more resilient to temporal decorrelation but lack of high resolution L-band time-series*
- *Ionospheric and tropospheric delay*
  - *Significant sources of noise for InSAR measurements of small signals*



(Lu & Dzurisin, 2010)



Interferometric SAR Applications

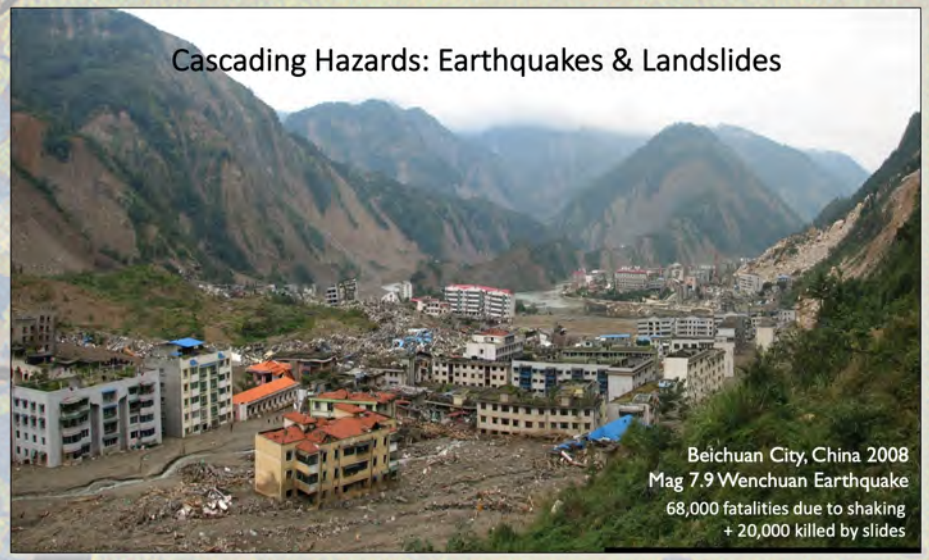
(Glaciers & Ice Caps; Solid Earth; Geohazards)

Challenges (cont'd)

- *Temporal revisit*
  - *Hazards characterised by abrupt initiation – rapid evolution - cascading events – global distribution*
    - ***Sub-daily repeat required** to measure transient and cascading processes*

- *LOS diversity*
  - *Observations from 2 directions only (asc/desc) limits models to 2 D only. Mapping 3D phenomena in 2D - a serious compromise.*
  - *Critical need for 3D mapping for all InSAR applications*

- *Long lead times*
  - *Low latency critical for operational hazard response applications.*
  - *Lack of ground stations for immediate downlink delaying access in certain regions*
  - *Open public access to data*



(Credit: David Wald, USGS NEIC

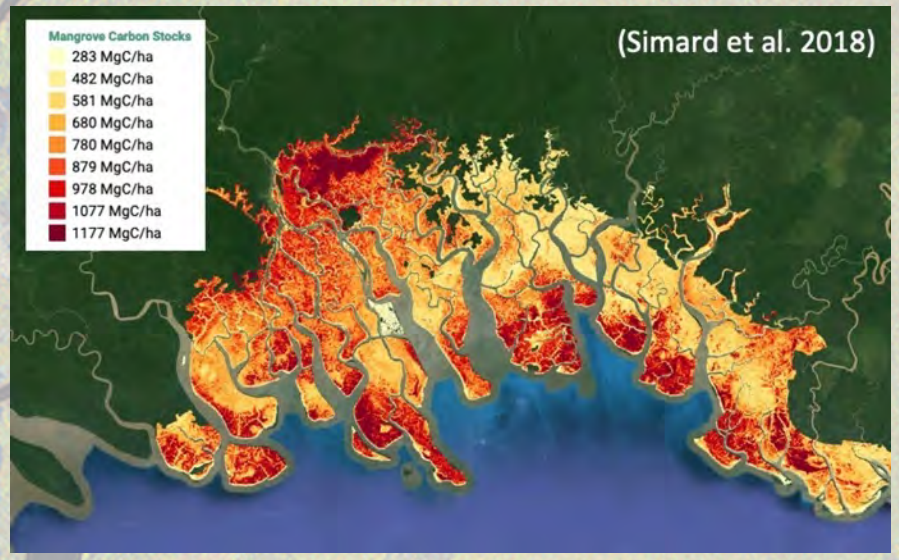
Systematic w2w observations at near global scales provides critical baseline datasets for all InSAR applications (partially fulfilled @ C-band and L-band)

POL & Multi-f SAR Applications

(Land Cover, Forest & Biomass; Wetlands, Agriculture & Soil Moisture)

Key application examples

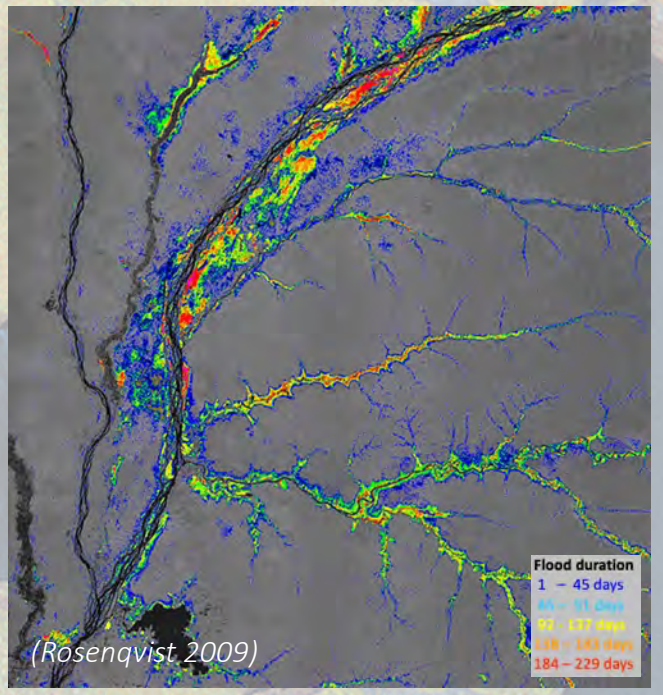
- Forest & Land Cover extent, and change (L-band driver)
- Forest above-ground biomass (L)
- Spatio-temporal mapping of seasonal inundation (L)
- Ag crop mapping (plant cycle, crop health, yield pred.) (C-band)



Close connection with the IPCC AFOLU themes and the UNFCCC Paris Agreement. Strong interest from new, non-expert, user groups.

Challenges

- Seasonality and weather (temporal noise)
  - Seasonal conditions strongly influence SAR backscatter (esp. serious in temporal and boreal zones), and affect e.g. backscatter-based retrieval models
  - Weather effects affecting vegetation moisture contents more subtly
  - Time-series data at monthly repeat or better required to minimise temporal noise.
- QP data scarcity
  - Applications using fully polarimetric data and polarimetric InSAR virtually unexplored due to lack of systematic QP data.



POL & Multi-f SAR Applications

(Land Cover, Forest & Biomass; Wetlands, Agriculture & Soil Moisture)

Forest & AGB

- Challenges
  - Ionospheric conditions, esp. L- & P-band
    → Path delay, Faraday rotation, irregular radiometric artefacts
  - Signal saturation far below high-density tropical & temperate forests
  - DEM spatial resolution affecting RTC
  - Signal saturation for high AGB
  - zero-baseline orbit control inhibits tomo-InSAR
- Near-term actions
  - Full polarimetric scattering matrix to characterise backscatter mechanisms & correct for FR
  - Multi-frequency (P-, L-, C-band) for improved vegetation characterisation
  - Systematic P-band + LIDAR to improve AGB sensitivity
  - Relaxed orbital tube to allow diversity of baselines (multi-pass tomographic InSAR)

Agriculture & Soil Moisture

- Challenges
  - Crop type distinction
  - Sub-daily soil moisture variations
  - NESZ insufficient for bare soil/water distinction
- Near-term actions
  - Coordination of same band missions (e.g. S1 & RCM) to reduce temporal revisit
  - Crop type distinction
    - Polarimetric decomposition
    - Multi-frequency
  - Soil Moisture
    - Full polarimetric time-series

Wetlands

- Challenges
  - Temporal revisit (months) insufficient to capture rapid inundation dynamics
  - Peat sub-surface water table
  - Simultaneous (or daily) water height measurements
- Near-term actions
  - Coordination of same band missions (e.g. NISAR & ALOS-4, SAOCOM) to reduce temporal revisit

SUMMARY (1/2)

Despite the diversity of the applications covered, there are notable similarities in their observation requirements.

- *The most important requirement highlighted in all cases is the* ***need to reduce observation revisit times to the order of days, or less****. For the applications that rely on SAR interferometry, temporal decorrelation constitutes a major limiting factor, preventing e.g. the tracking of fast-moving glacial or seismic events. Temporal decorrelation is also the main obstacle to the use of InSAR for forestry applications.*
- ***For the glacier and solid Earth applications, systematic observations from a variety of different (at least 3) viewing angles*** *is required to characterise the displacement field in three dimensions. Different viewing angles can be obtained from using ascending and descending orbits, alternating right- and left-looking platform roll, observations from a different mission (in a different orbital plane), or potentially by use of forward/backward squinted observations.*
- ***For the glacier and solid Earth applications, systematic observations from a variety of different (at least 3) viewing angles*** *is required to characterise the displacement field in three dimensions. Two angles can be obtained from using ascending and descending orbits. The third angle measurement can be obtained from alternating right- and left-looking platform roll, - or alternatively, use observations from a different mission (in a different orbital plane), or potentially forward/backward squinted observations.*
- ***For forestry applications, a variety of interferometric baselines*** *would enable tomographic retrieval of forest structural parameters. This can be achieved by relaxing the orbit control, which however affects other InSAR applications. Alternatively, via a dedicated bi-static tandem constellation.*

SUMMARY (2/2)

- *For Forestry and Land Cover applications that rely on longer wavelength SAR. Current lack of L-band time-series.*
- ***Polarimetric and Pol-InSAR applications** are **under-developed** due to the lack of global polarimetric time-series data. Basic research in this field should be stimulated.*
- ***Multi-frequency applications** are however also under-developed due to lack of coincident data for research. Simultaneous or near-simultaneous multi-frequency observation campaigns, in particular for land cover related applications, are therefore strongly encouraged.*

Cross cutting issues:

- *Data downlink capacity is a major bottle-neck inhibiting optimal use of SAR payload capacity. Potential for greater inter-agency coordination also on ground segment.*
- *Open data policies and free public access is vital for data democracy and science development.*

CONCLUSIONS

- *No one single SAR system or agency has the capacity to address the full suite of requirements identified, a constellation of missions is consequently required.*
- *In the near term, close agency coordination of current and already planned missions in the 2020's will be essential. From a technical perspective, missions such as Sentinel-1, ALOS-4, SAOCOM, NISAR, BIOMASS, TSX-NG, and CSK-2G, jointly have the potential to address several of the requirements highlighted.*
- *Good potential for synergy between high capacity missions with global observation plans, and missions designed for more targeted focus – including commercial systems.*
- *In the longer perspective, into the 2030's, considering missions still to be defined, there is significant potential for the joint development of an ambitious multi-agency, multi-mission, mega "constellation of constellations", that would fully address the outstanding scientific requirements for temporal revisit, LOS- and baseline-diversity, polarimetry and multi-frequency observations.*
- *System supported by a constellation of Data-Relay Satellites visible from all orbits to optimise observation capacity, streamline downlink, and ensure short lead times.*

→ For further discussion @

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THANK YOU