Recent Developments in InSAR Techniques for Monitoring Surface Deformation: Applications in North America*

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Descriptive Statement

Recent advances in the development of algorithms are described for measuring surface deformation from satellite radar data. Focus here is on overcoming vegetation issues and extracting true 3D motion from 1D satellite data, as well as some applications.

AAPG Geosciences Technology Workshop on
"Carbon Capture and Sequestration -- New Developments and Applications, Case Studies, Lessons Learned"

Recent Developments in InSAR techniques for monitoring surface deformation: applications in North America

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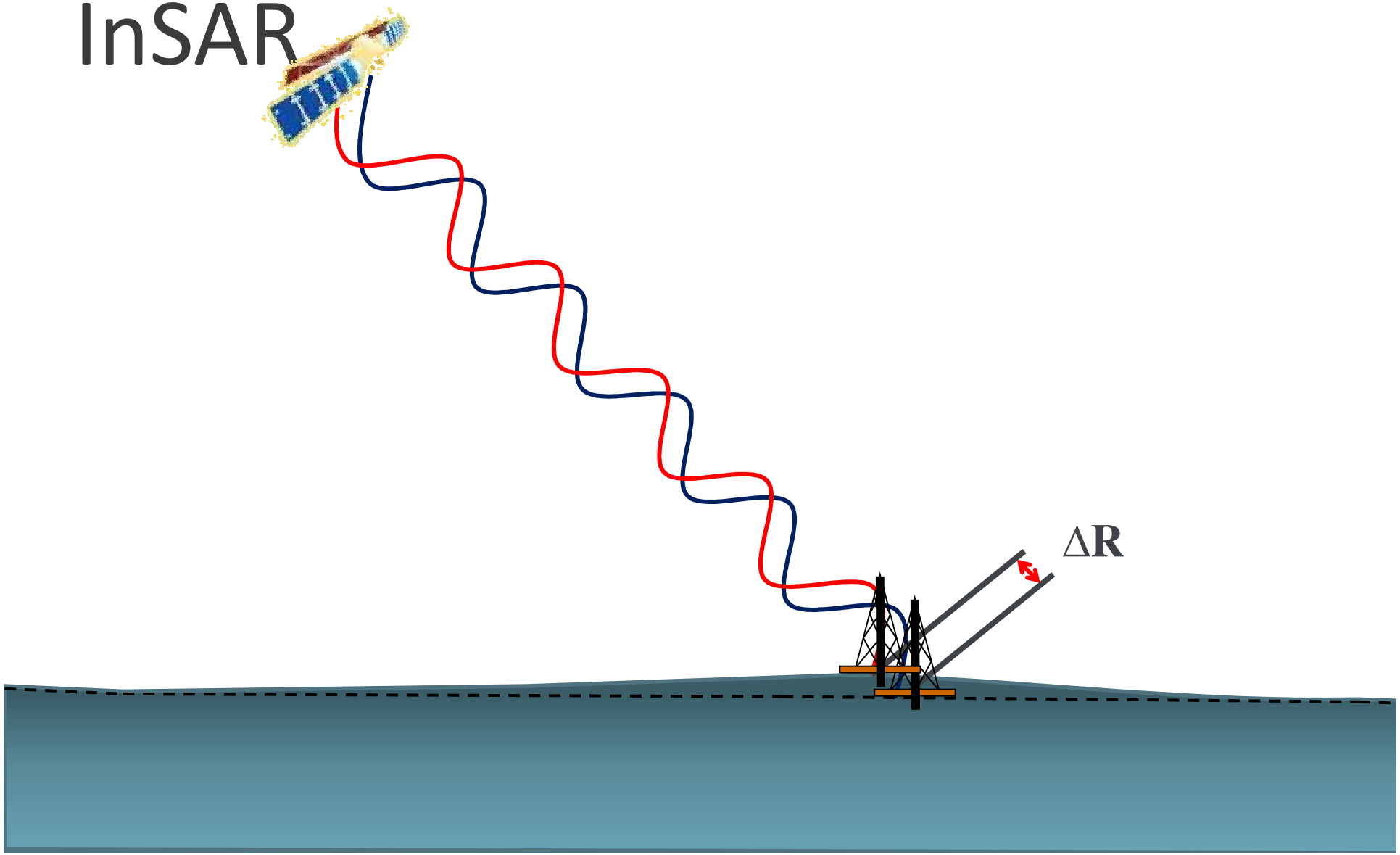
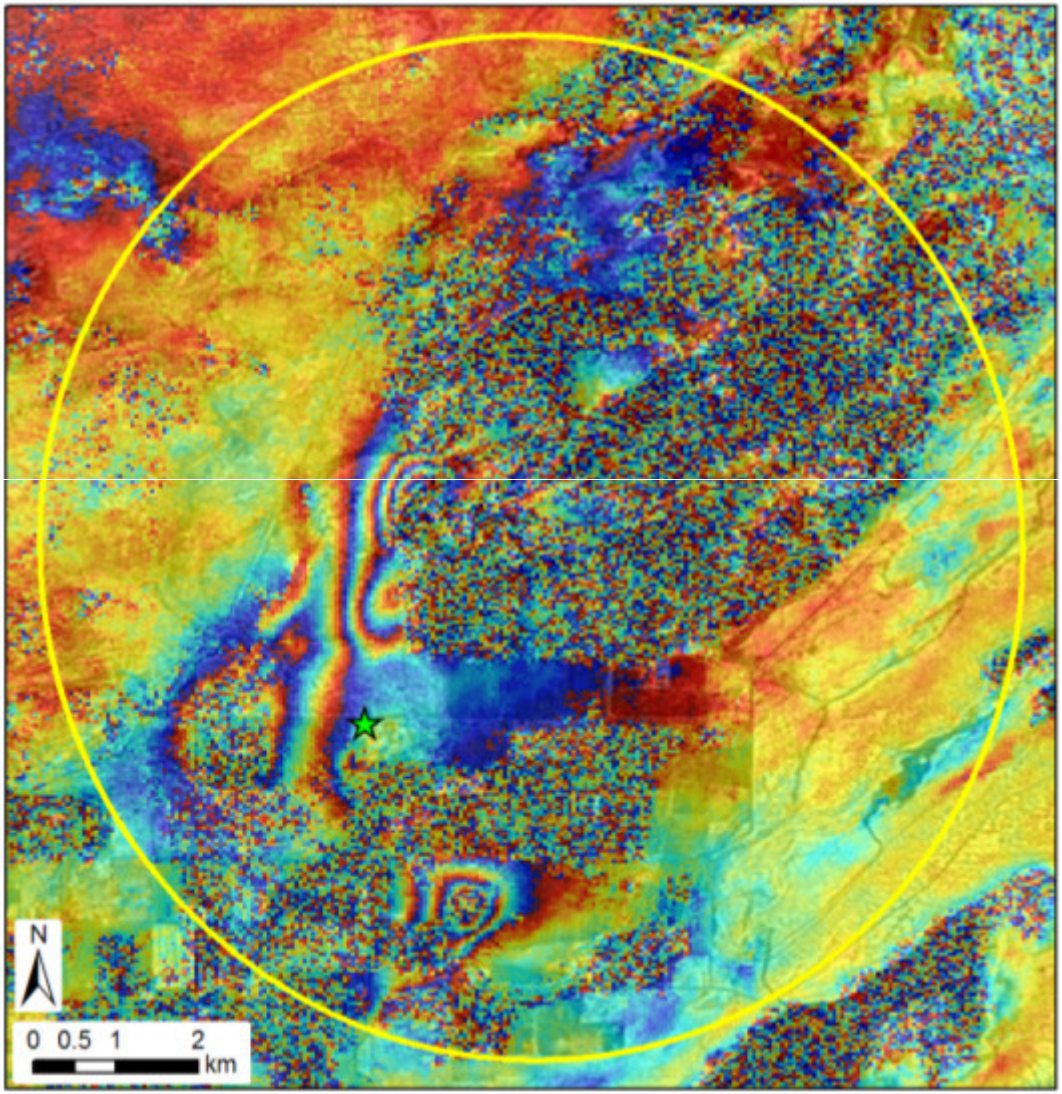
Outline

- Background on InSAR
- New multi-image algorithms
  - PSI
  - SqueeSAR™
- Improved satellite characteristics
  - Improving spatial sampling
  - Improving temporal sampling
- Applications in North America and beyond
- What's in the future?

InSAR

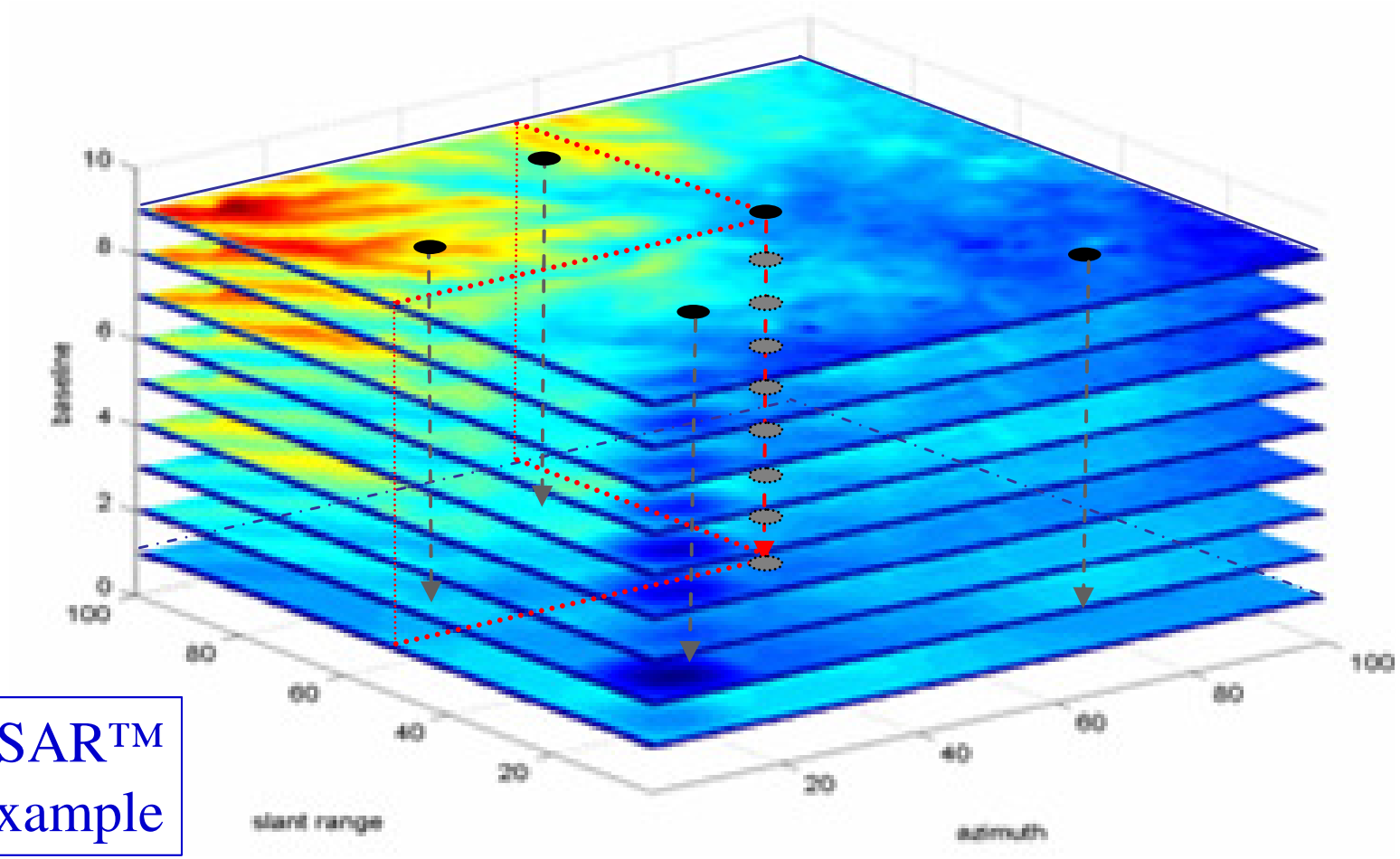


InSAR
Interferogram



Geothermal field, Nevada

PSI techniques are multi-image approaches

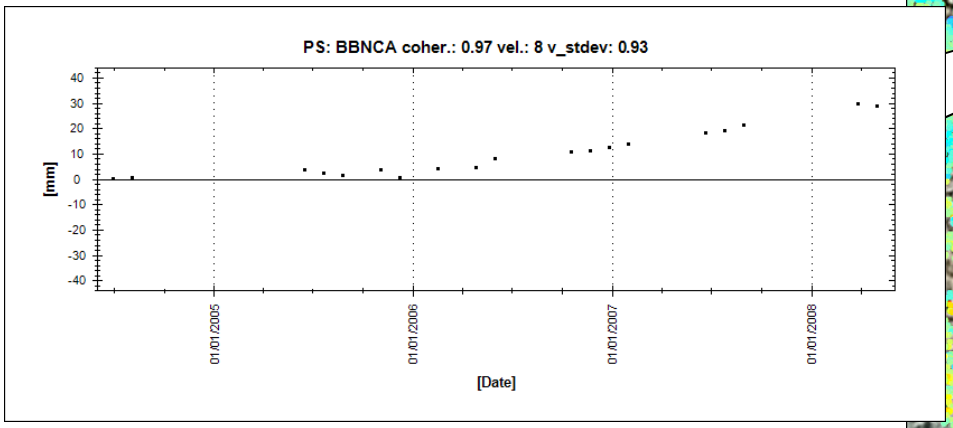


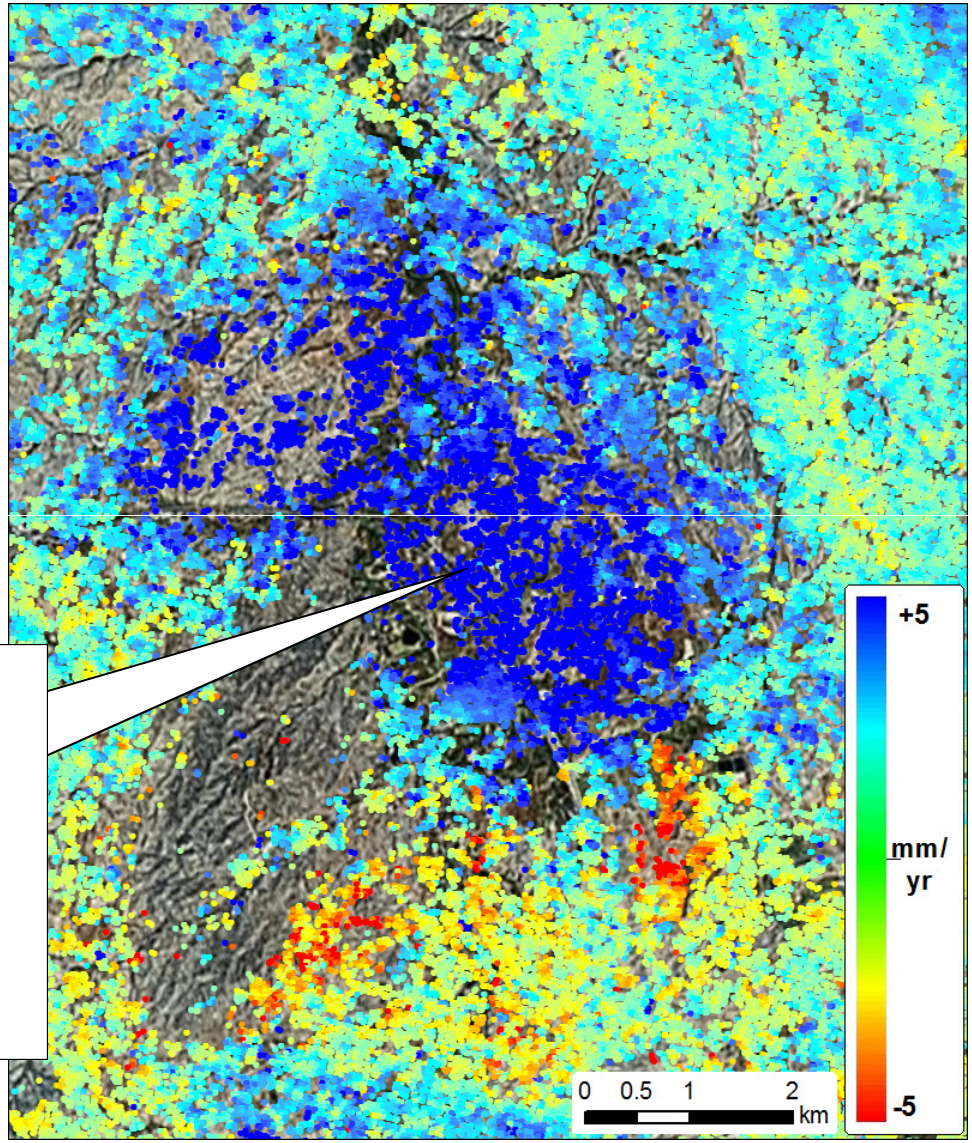
PSInSAR™ example

Output of a PSI analysis

Output consists of point targets corresponding to identified radar targets

Time Series





PSI – pros and cons

Strengths:

- ✓ Covers extensive areas without compromising precision
- ✓ Vertical and E-W horizontal displacement fields can be determined if data from different orbits available
- ✓ Historical data available for many areas
- ✓ Complementary to other monitoring techniques (GPS, tiltmeters, microseismics, optical levelling)

PSI – pros and cons

Limitations:

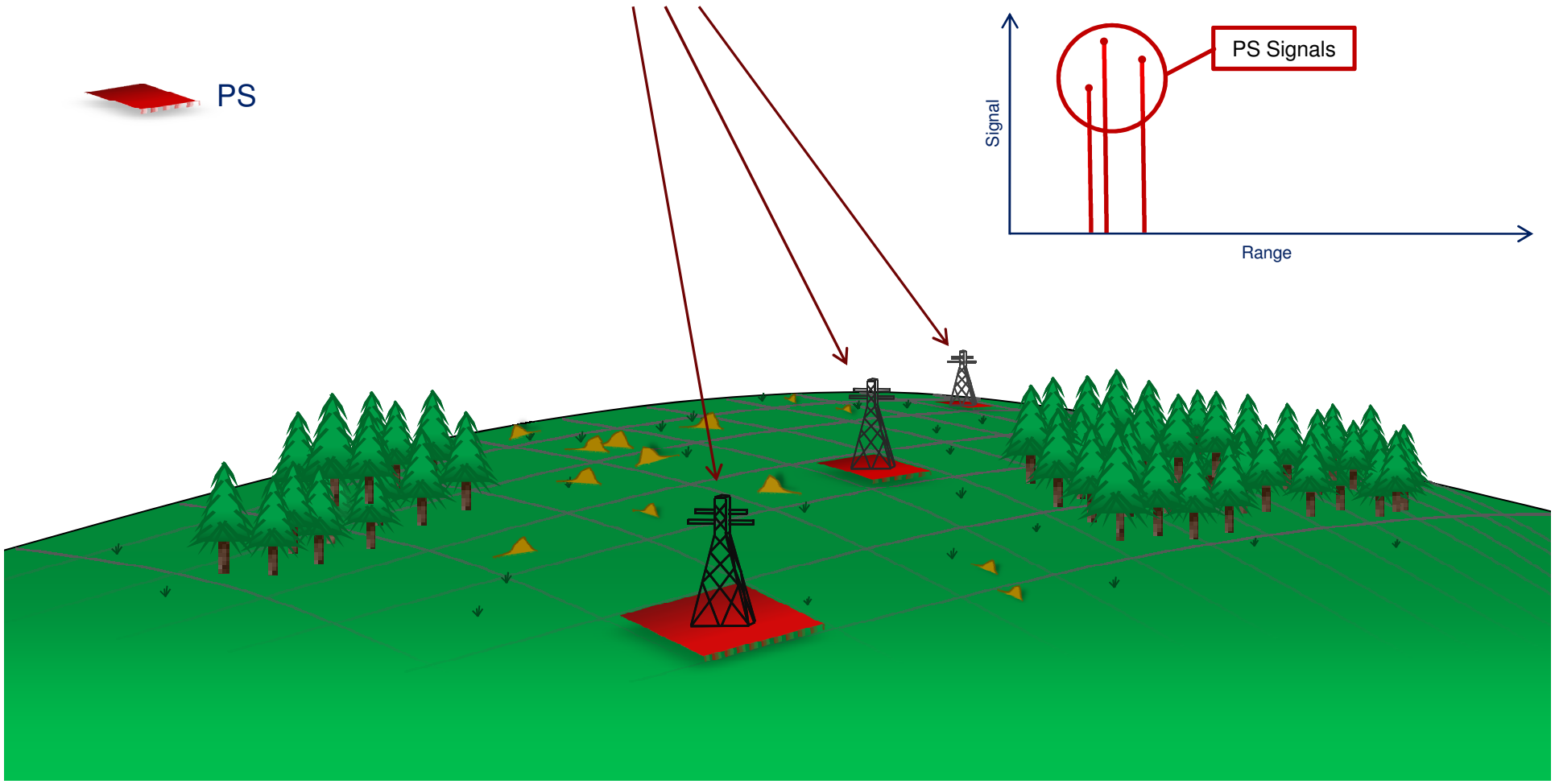
- ✓ Difficulty identifying radar targets in vegetated areas
- ✓ Number and distribution of PS can't be foreseen
- ✓ Artificial reflectors needed in areas with low PS density
- ✓ A minimum number of 15-20 radar images is required
- ✓ Not a real-time technique
- ✓ Not able to measure rapid movements

New generation of algorithms: SqueeSAR™

- ✓ SqueeSAR™ is designed to increase the number of targets in rural environments
- ✓ Detects Distributed Scatterers (DS) ➔ homogeneous areas spread over a group of pixels in a radar image such as rangeland, pasture, shrubs and other low-lying vegetation, bare earth, rock debris
- ✓ Includes PSInSAR™
- ✓ Improves time series quality

SqueeSAR™ concept

- High reflectivity, phase-stable radar targets are identified as PS



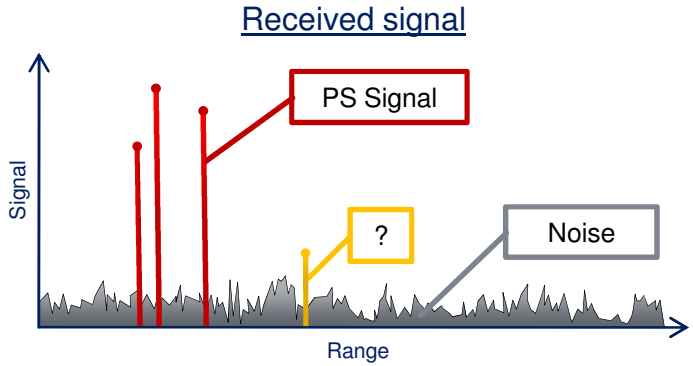
SqueeSAR™ concept

- Vegetated areas do NOT produce PS – no coherence

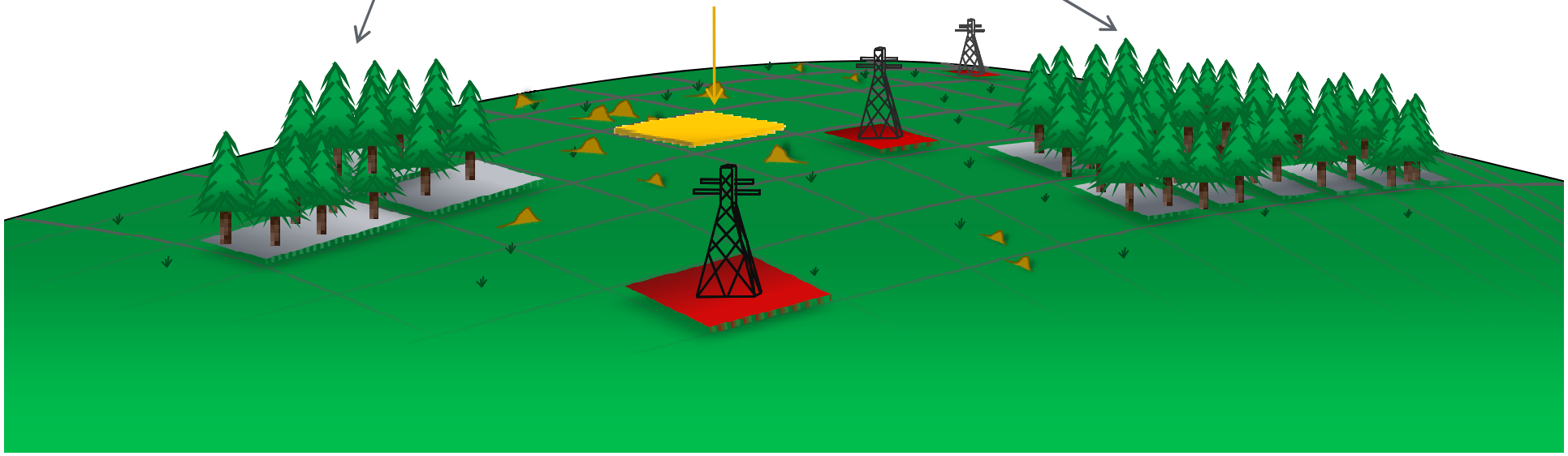
PS

No coherence

?

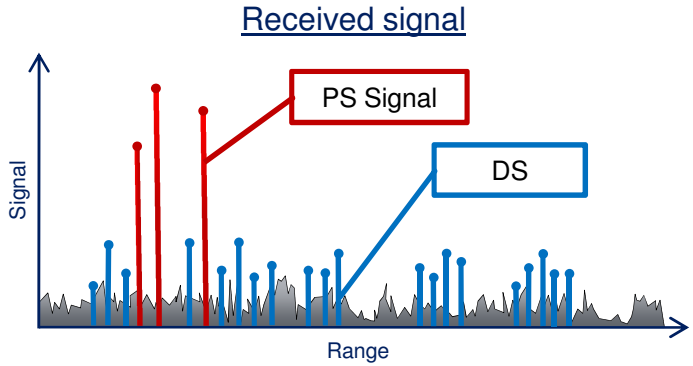


Can more deformation data be extracted?



Identification of Distributed Scatterers (DS)

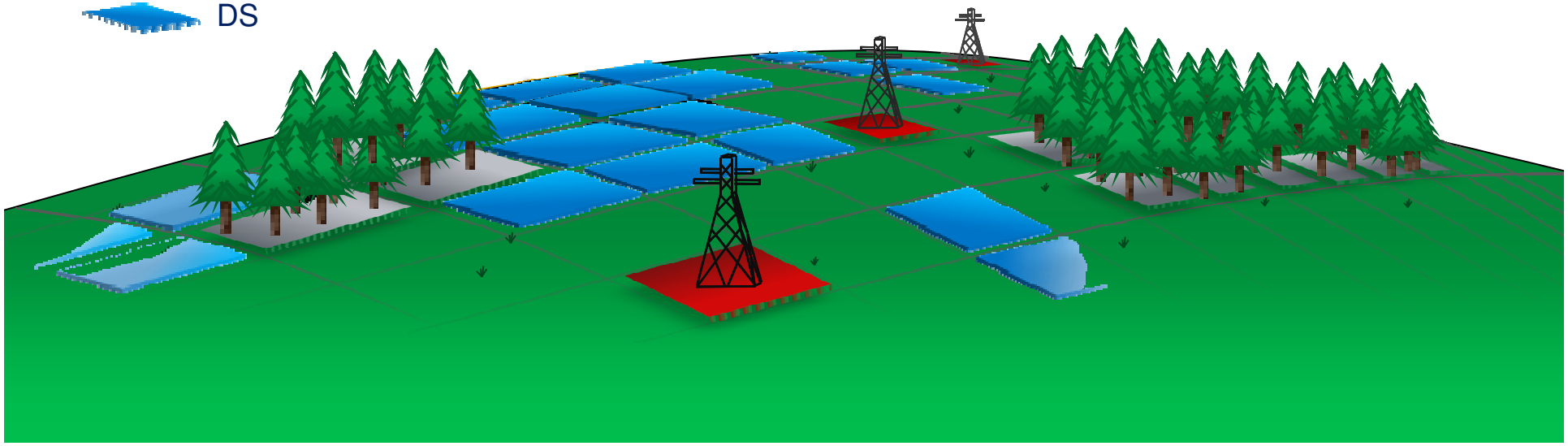
- The process is continued for every pixel



PS

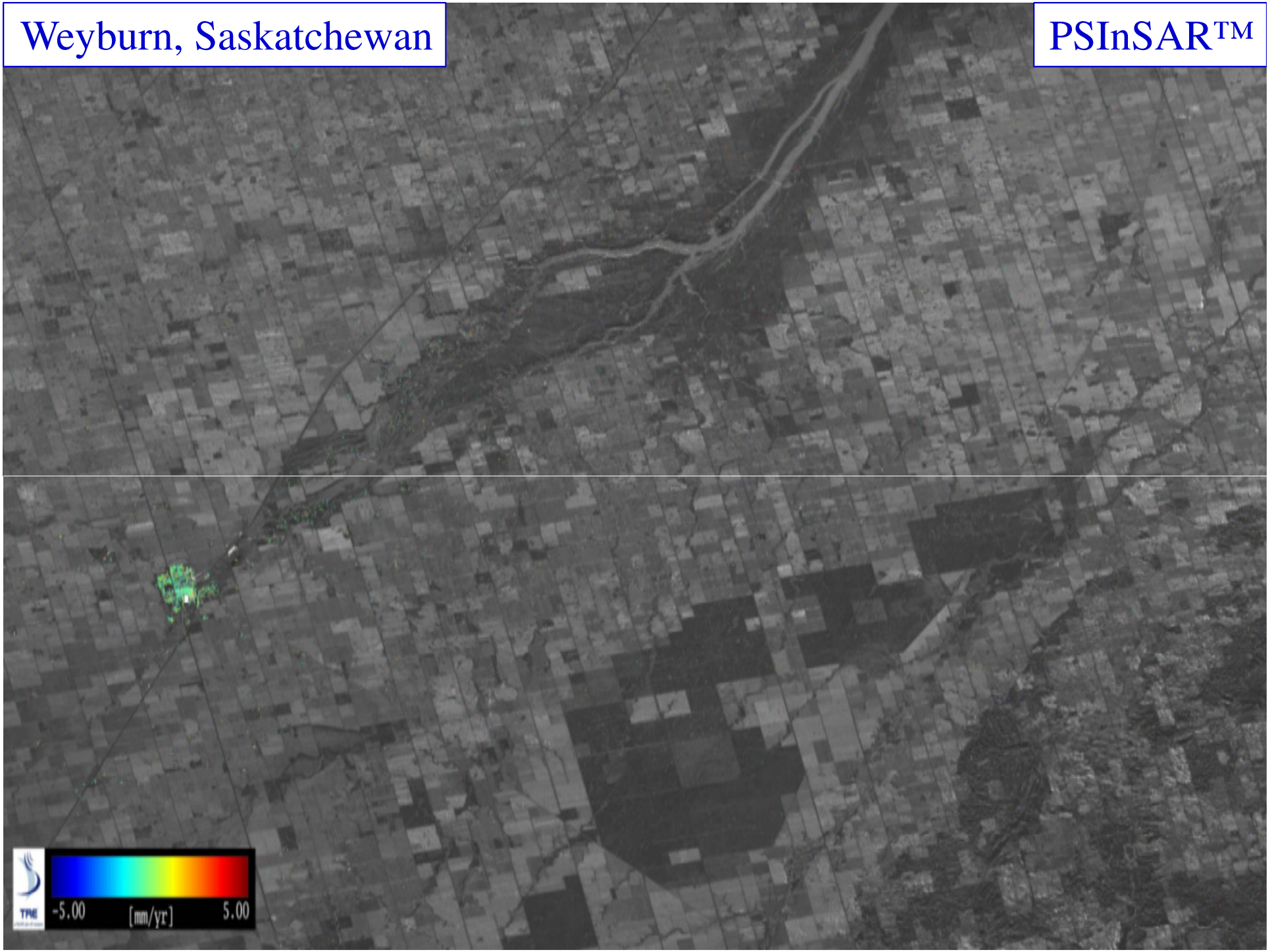
No coherence

DS



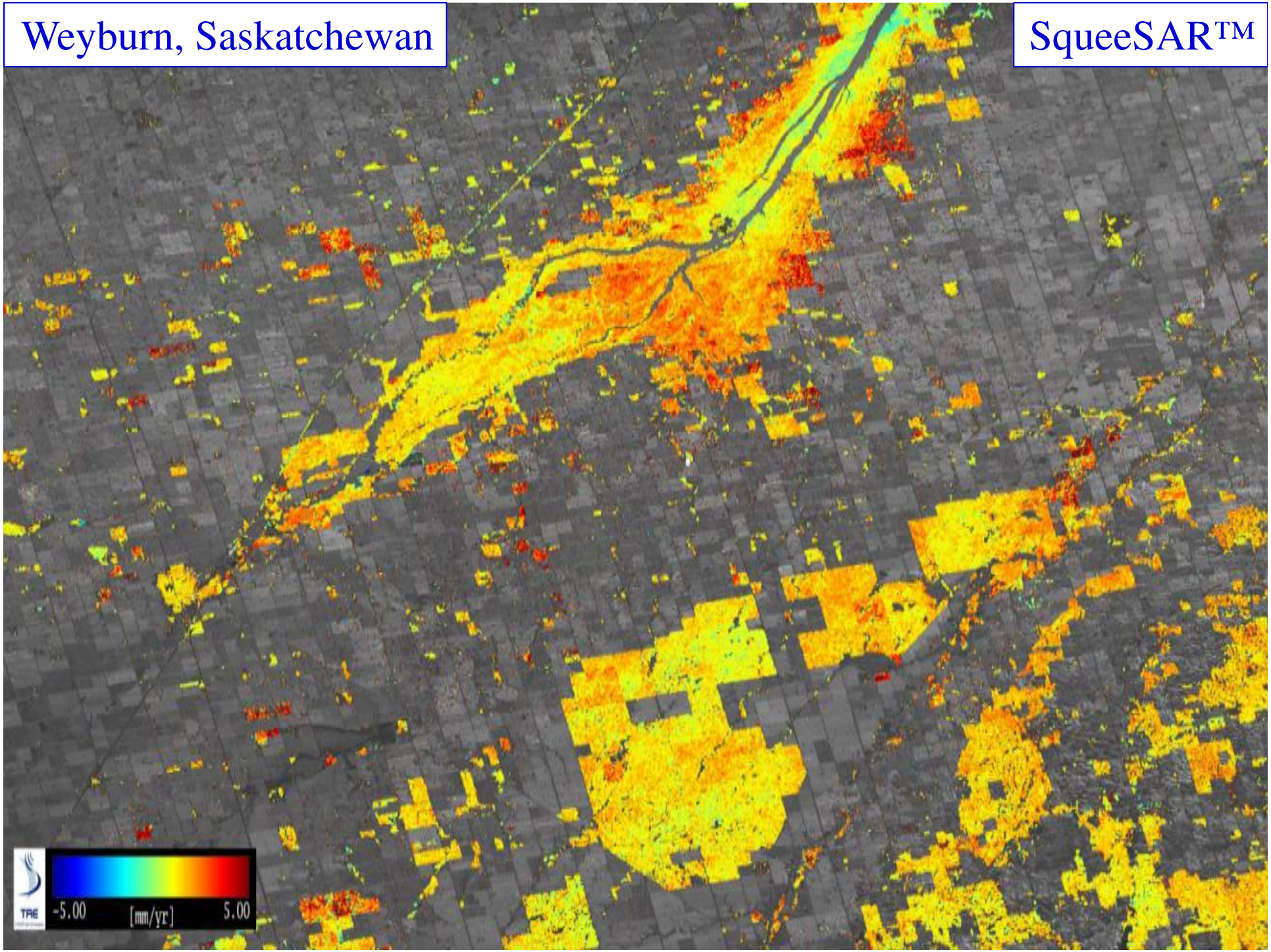
Weyburn, Saskatchewan

PSInSAR™



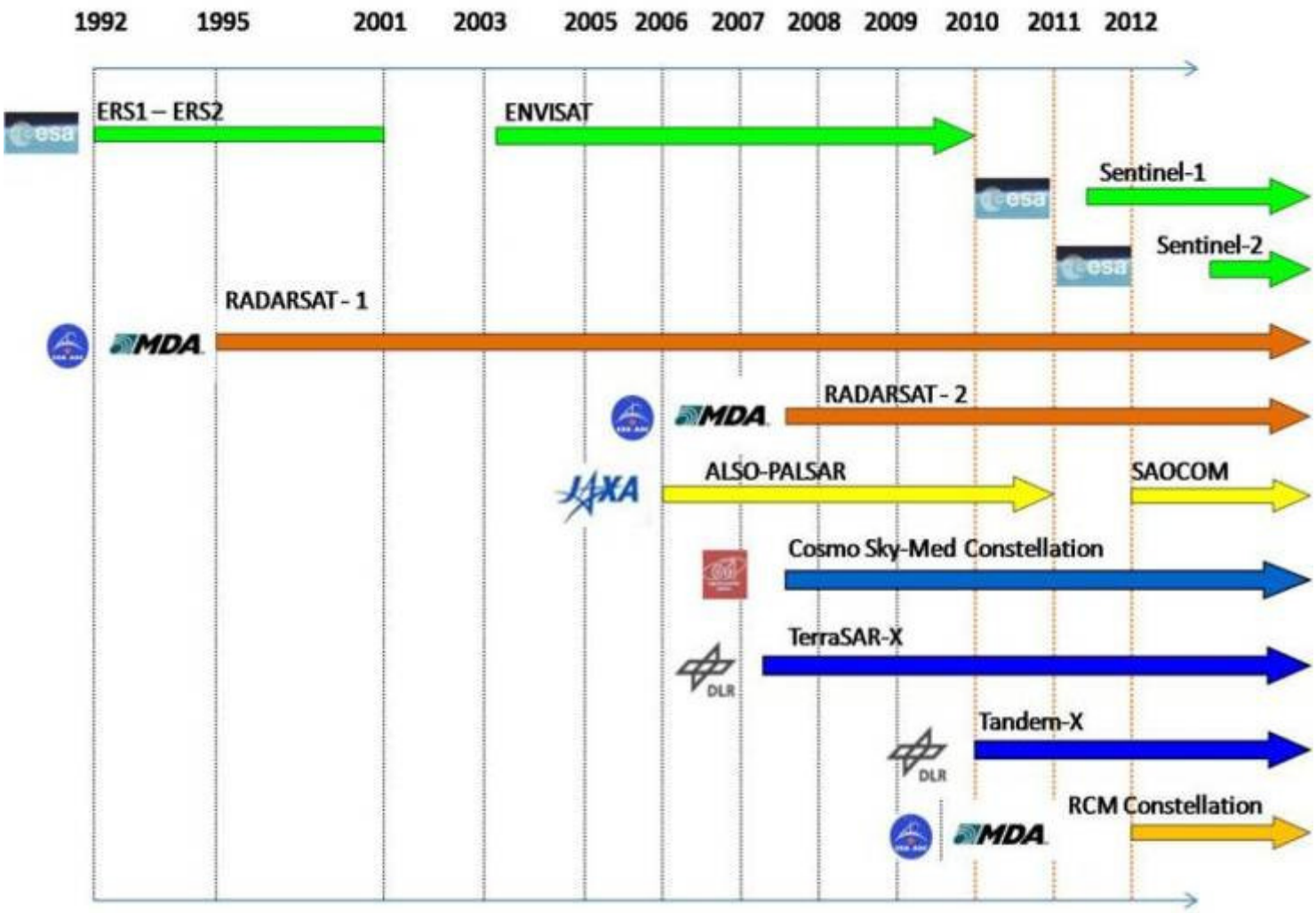
Weyburn, Saskatchewan

SqueeSAR™



New generation of satellites

More, new satellites



New X-band satellites: Increased resolution

ENVISAT
20m x 5m

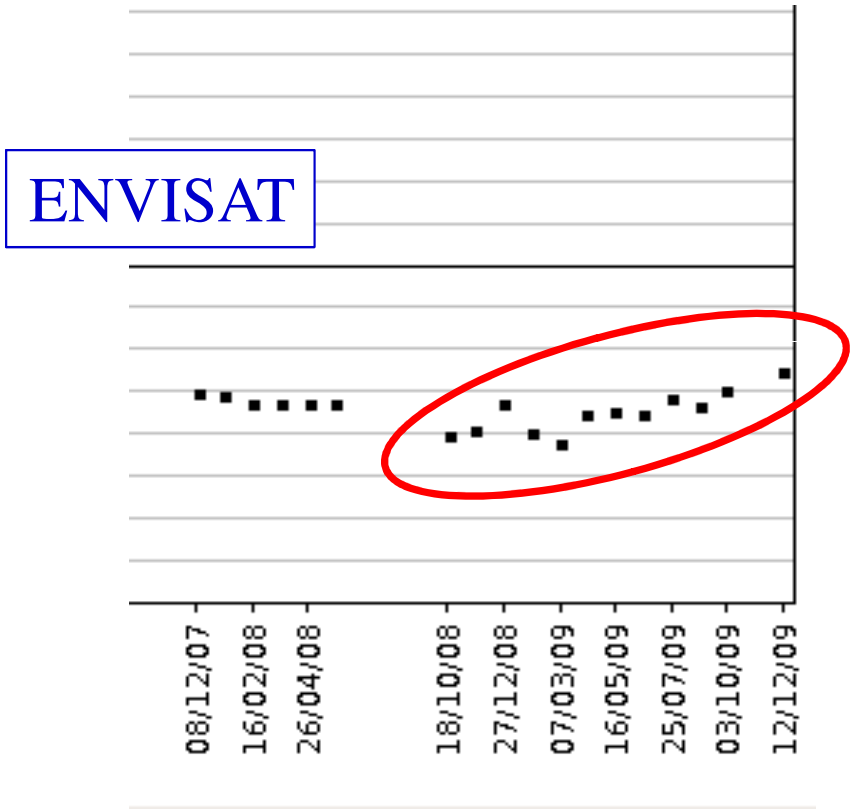
New X-band satellites: Increased resolution

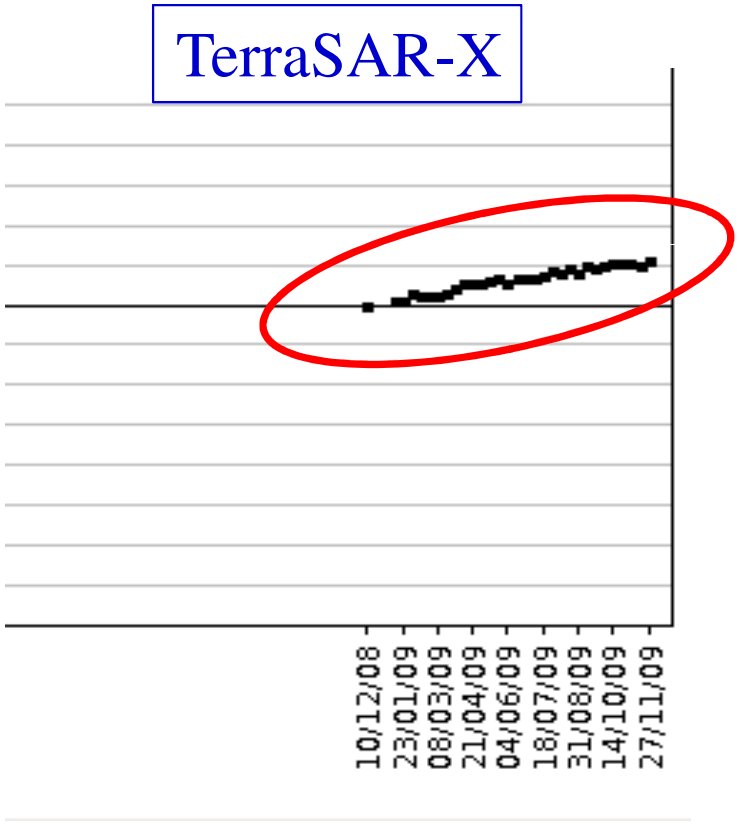
COSMO-SkyMed
2.5m x 2.5m

New satellites: Increased temporal sampling

Satellite	Revisiting time	Operation
ERS	35 days	1992-2000
ENVISAT	35 days	2003-2010
RADARSAT-1	24 days	1995-2011?
RADARSAT-2	24 days	2007-
TerraSAR-X	11 days	2008-
Cosmo-SkyMed	8 (4) days	2008-

Time series comparison

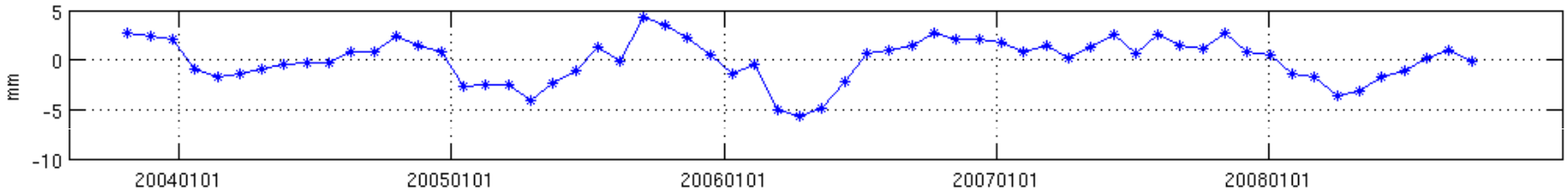


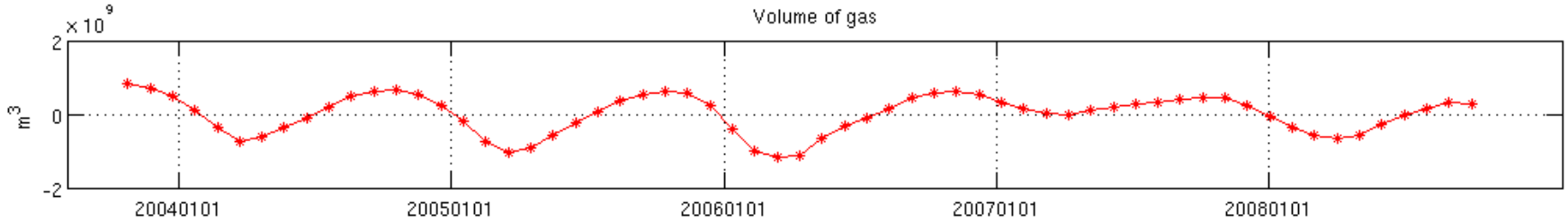


Some Applications

Correlation - surface deformation/ stored volume

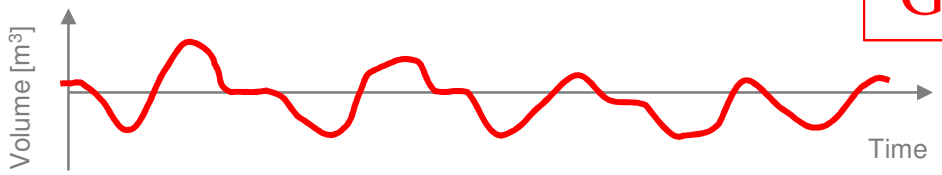
Surface deformation (mm)

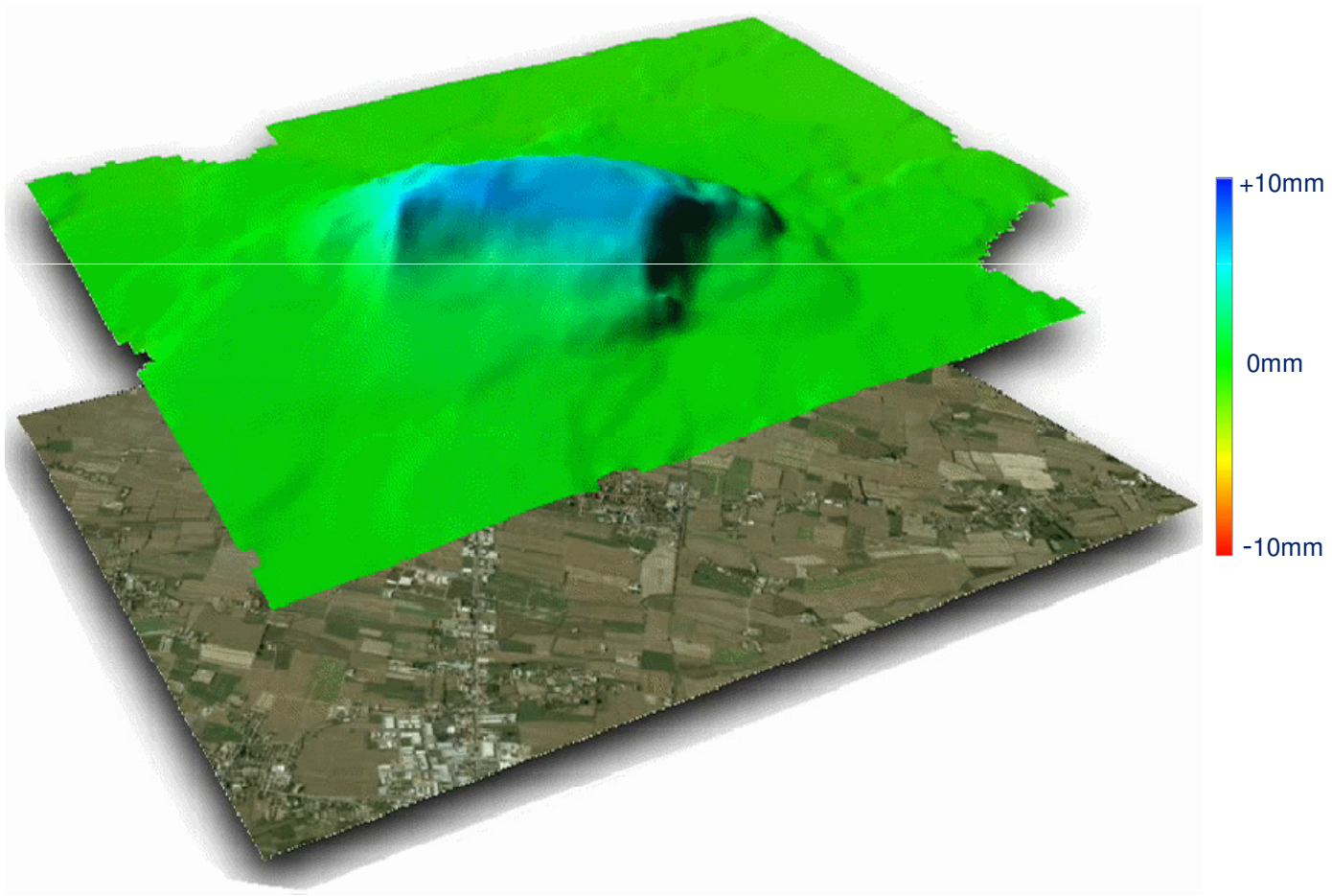




Gas volume (m^3)

Gas volume (m^3)



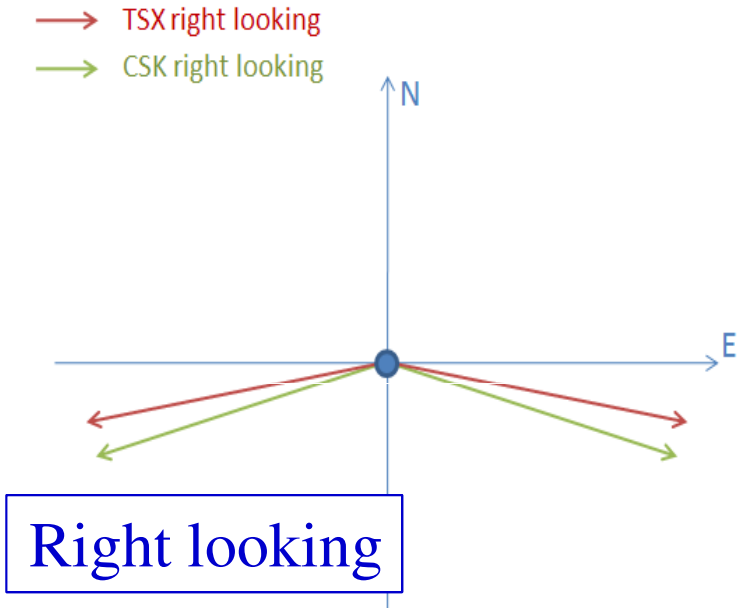


Future developments

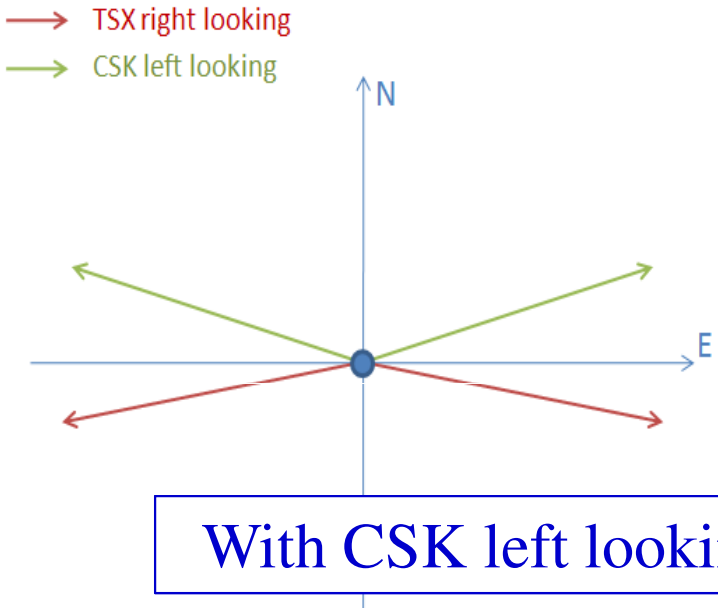
What we'd like to see…

- L-band satellites → longer wavelength = better penetration of vegetation
- More left-looking image acquisitions → reconstruct 3D movement vector

Is it possible to reconstruct full 3D motion?



Right looking



With CSK left looking

component	*Std dev*
LOS	1.0 mm/yr
vertical	0.7 mm/yr
E-W	0.8 mm/yr
N-S	70 mm/yr

component	*Std dev*
LOS	1.0 mm/yr
vertical	0.7 mm/yr
E-W	0.8 mm/yr
N-S	5 mm/yr

Question for you

Transforming data into information requires input from those who require the information. We can provide spatial information on displacement rates, acceleration, cumulative displacement. Time series of displacement for each PS/DS are standard output. We also create time based animations of movement and, using Kriging techniques, we can interpolate motion in the gaps between PS/DS.

What other forms of data transformation would you find helpful?

Another question for you

Most InSAR analyses use data acquired from a single orbit. By analyzing data from two orbits, we can calculate true vertical and East-West horizontal motion. To generate 3-Dimensional measurements will require data from at least three orbits.

Would you see 3-D measurement valuable for CCS applications?

Thank you!

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