SAR and InSAR for disaster response and precursors

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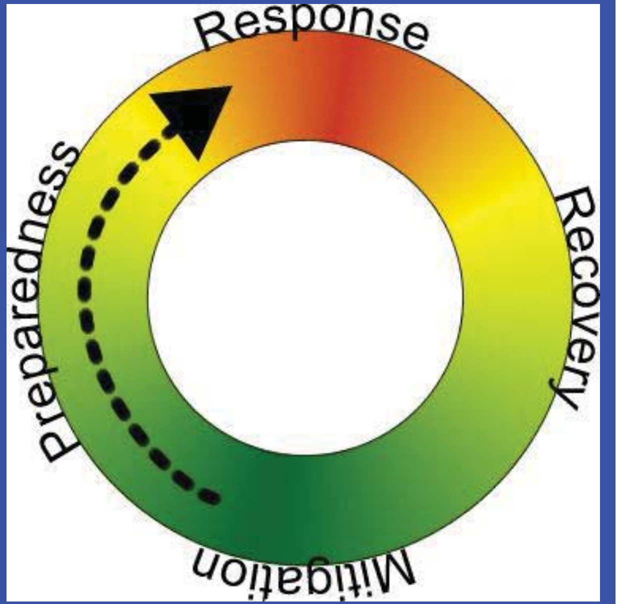
Disaster Management Cycle



Lewis, 2009

SAR and InSAR provide multiple observations useful
For hazard assessment and response

1) Phase change
2) Coherence change
3) Amplitude change (also use optical images)
4) Polarimetry
5) Topographic mapping (also use optical images)

Case studies:

1) Sinkholes, floods, wildfires, permafrost

2) Using coherence change as a proxy for damage

3) Glacier change in Patagonia

Many InSAR applications already discussed

Landslides (but precursory deformation before landslides is an open question)

Inter-seismic strain: where will future earthquakes occur?

Rapid calculation of co-seismic deformation
Which fault ruptured?
For Coloumb stress change on nearby faults (e.g., Haiti, Neena Mountain, etc.)

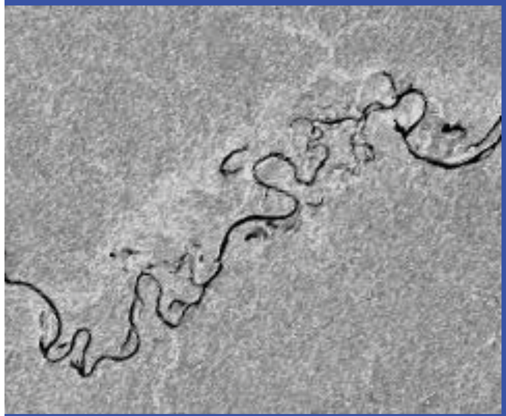
Precursory deformation before volcanic eruptions (not always)

Land subsidence: coastal areas, damage to infrastructure

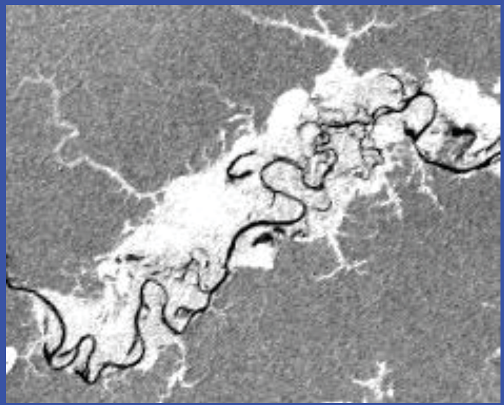
InSAR and SAR to measure floods

Varzea (Amazon) Dry Season

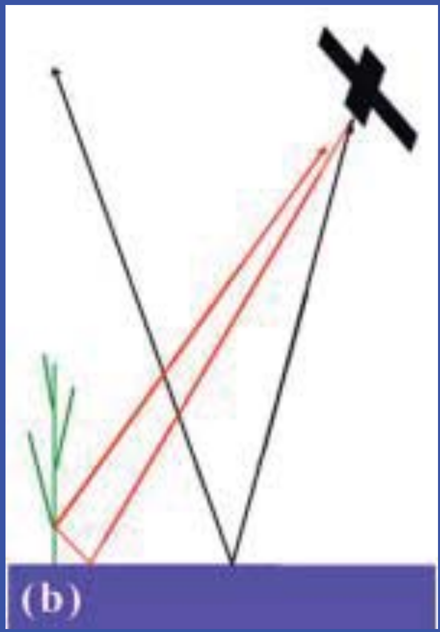
Varzea (Amazon) Wet Season



JERS-1 Dry Season



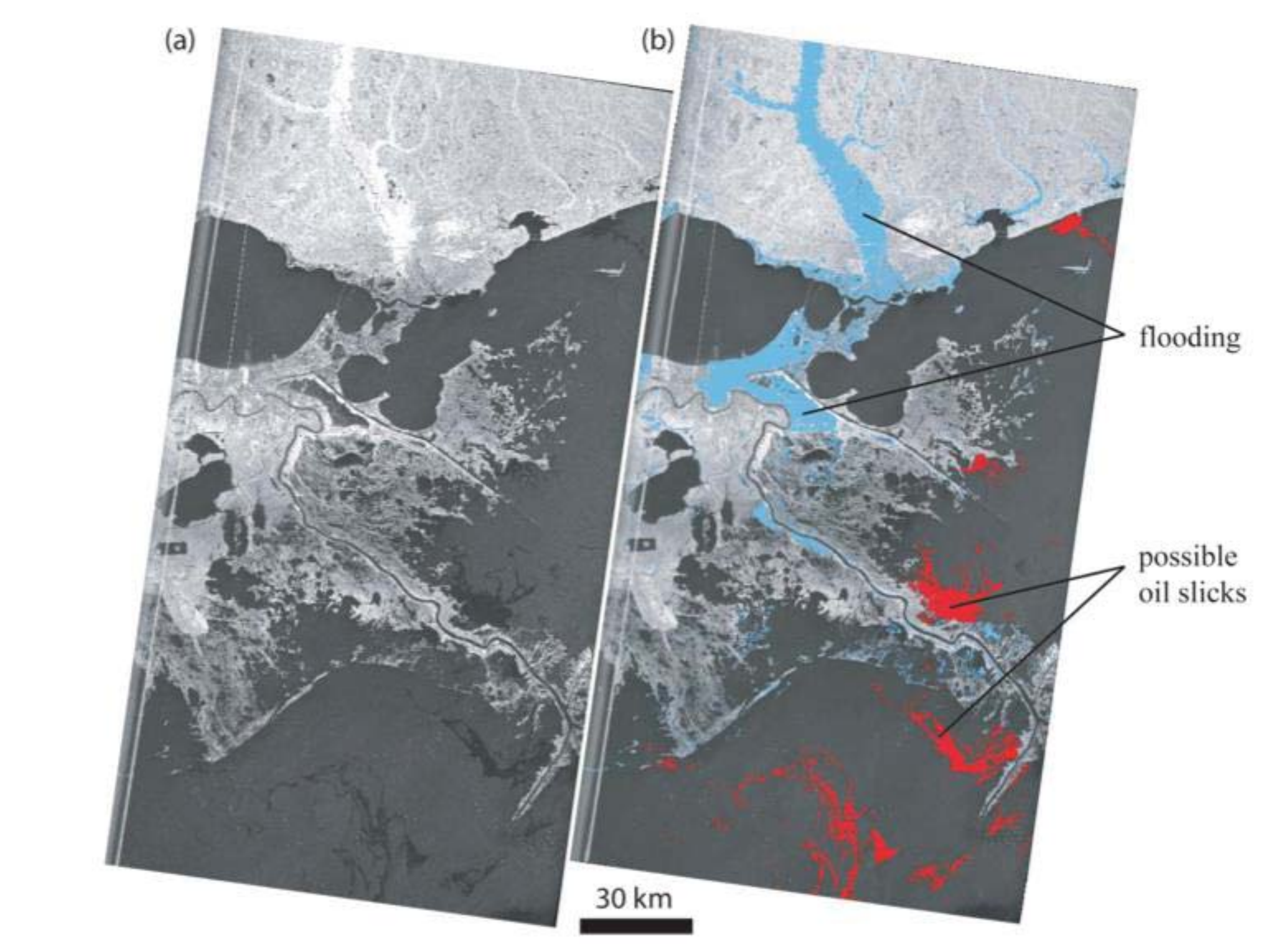
JERS-1 Wet Season



Double bounce of inundated areas increases signal amplitude and changes the phase signal (causing "fringes")

Courtesy DESDynI Science Team and Shimon Wdowinski

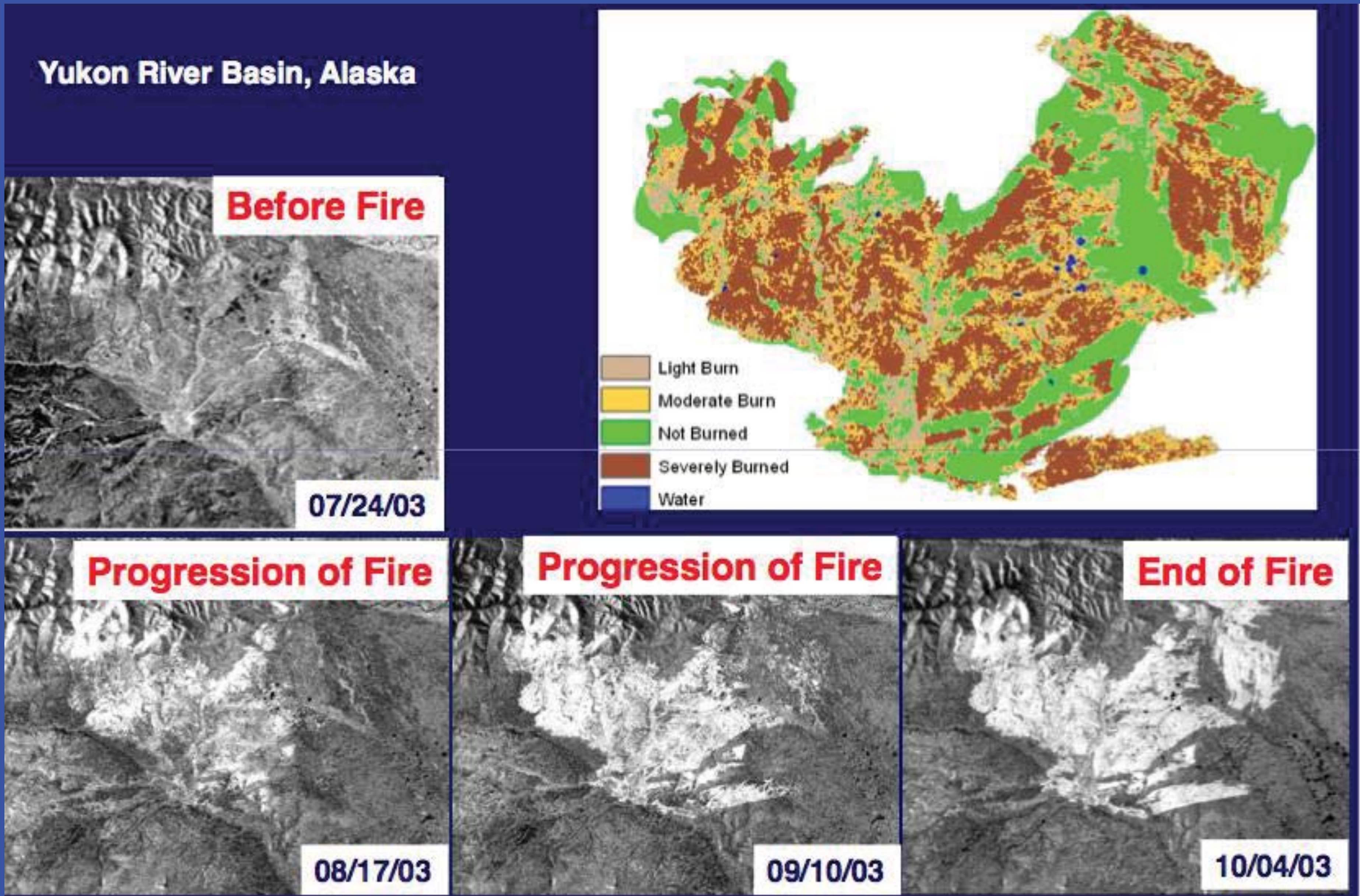
Example following hurricane Katrina



Radarsat-1 image from 2 Sept. 2005 compared with Landsat ETM+ mosaic

Lu et al., 2010

Mapping wildfire severity and extent



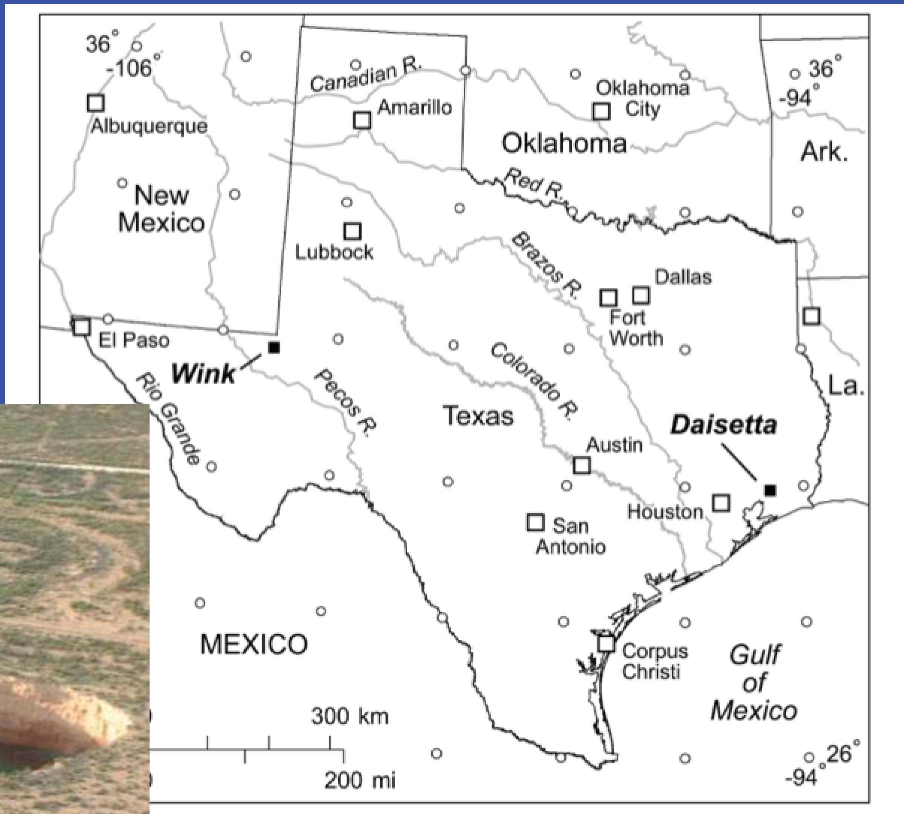
Rykhus and Lu, 2011

Sinkholes in Texas

Wink sinkholes:
Hendrick oil field with salt deposits

1980: Caused by seepage or fractures near oil well?

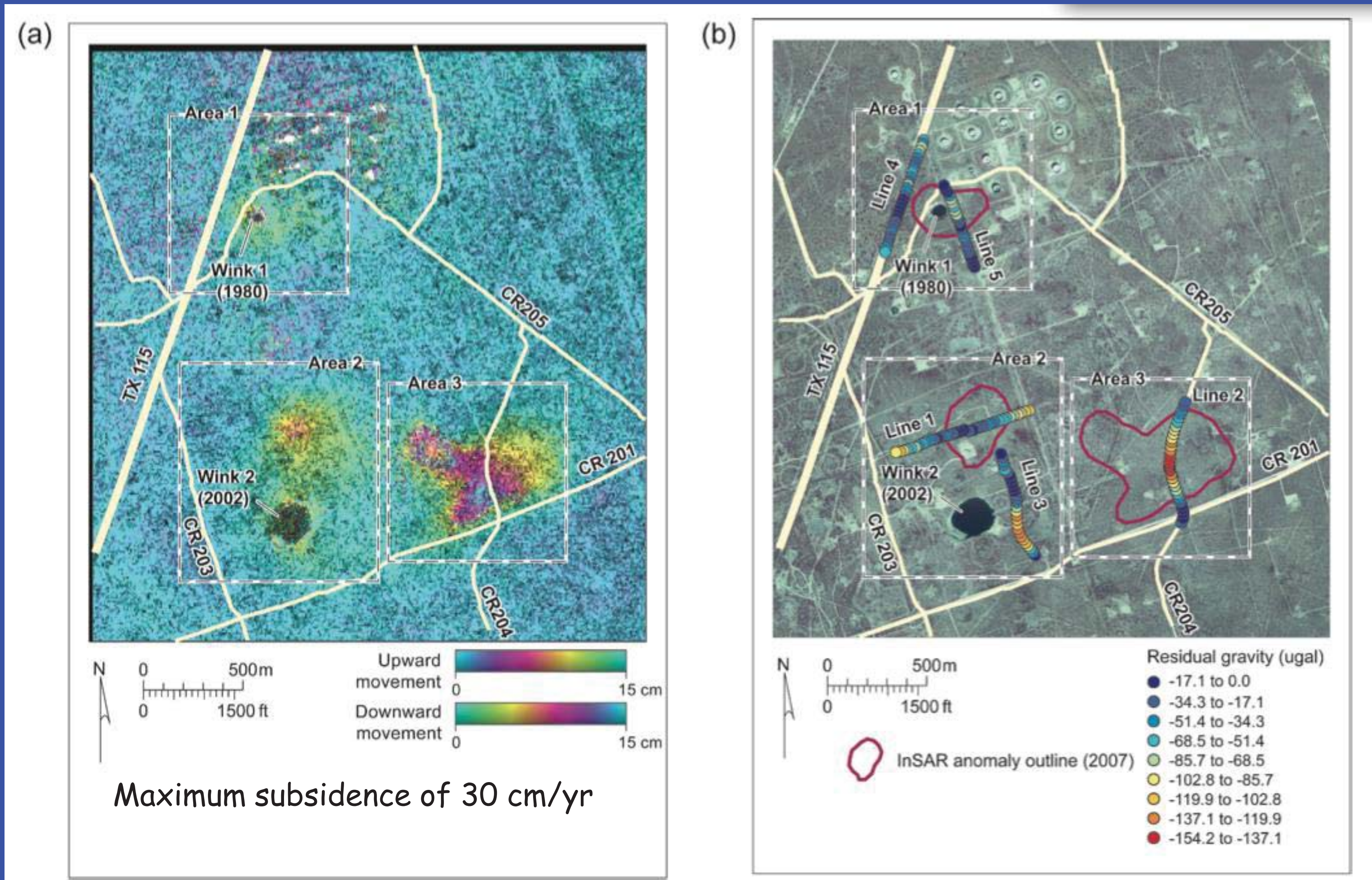
2002: Cause unknown, but maybe related to water well



Daisetta 2008 sinkhole had no precursory deformation

Paine et al., 2012

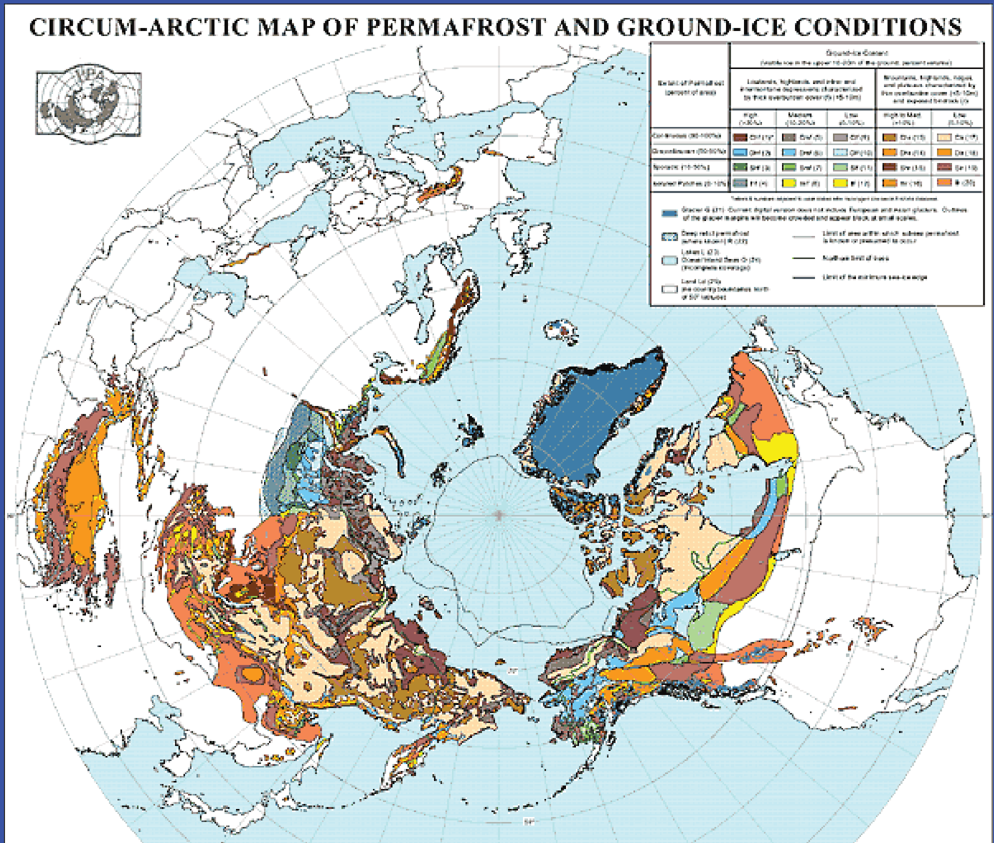
Expansion of old sinkholes and potential new ones



Maximum subsidence of 30 cm/yr

Paine et al., 2012

Permafrost change



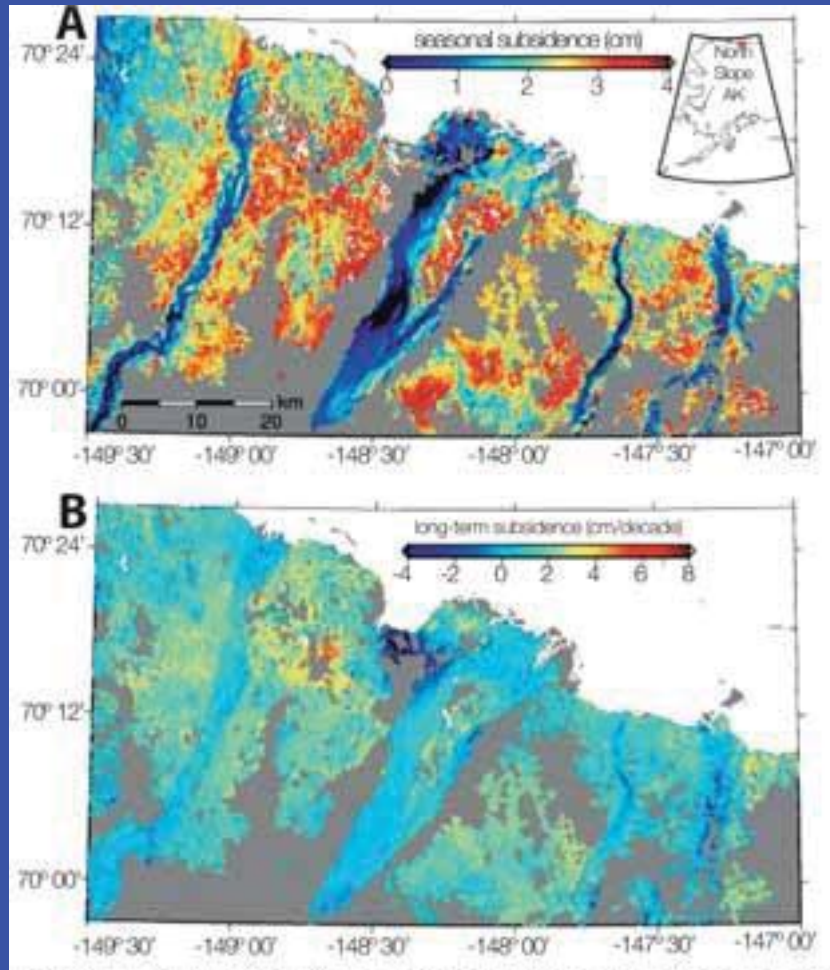


Figure 2: (a) Long-term average seasonal subsidence occuring between June and September based on InSAR measurements. The inset map shows the location of the study area as a red box on the North Slope of Alaska. (b) Long-term trends in surface subsidence between 1992 and 2000. The Arctic Ocean in the northeast is in white. Gray areas indicate regions where no robust InSAR measurements could be made. Figures are adapted from Liu, et al. [2010].

Seasonal signal related to active layer thickness
Long term trend from climate change

Impact on local infrastructure & global impact on methane

Liu et al., 2010

Disaster response: InSAR coherence to rapidly produce damage proxy maps

Synopsis:

•All-weather, day/night radar with automatic algorithm (no human intervention)

•More effective than other satellite sensors and crowdsourcing?)

•Need for validation:

Haiti example: only ~10% of the most damaged buildings were identified in 0.8 m/pixel imagery. Vertical collapse not easy to detect in nadir imagery (e.g., Booth et al., 2012)

The Aria project of Caltech/JPL

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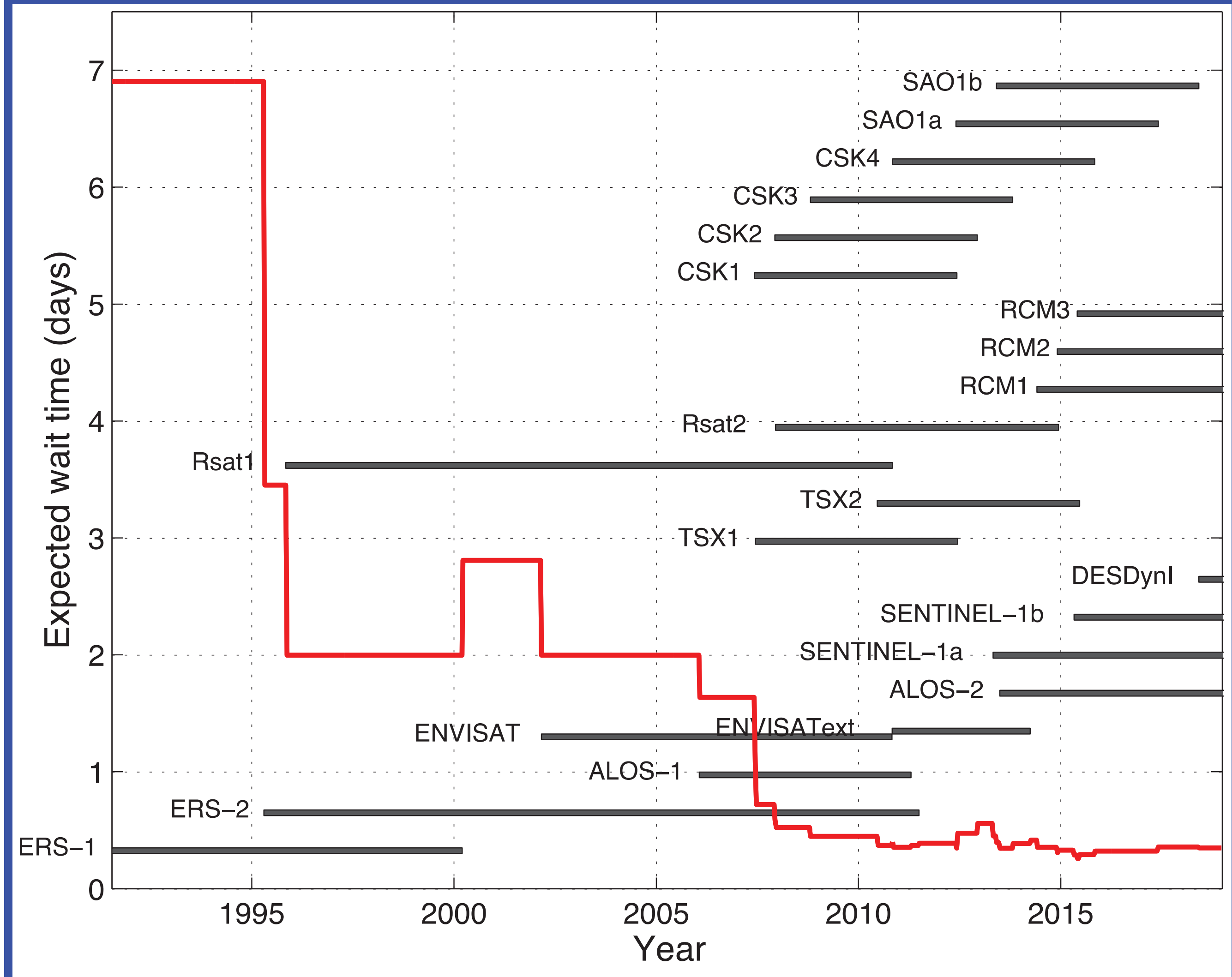
2. California Institute of Technology
3. Geological Survey of Japan, AIST, Tsukuba, Japan

Data Acquisition Latency (all InSAR missions)



Expected wait time until the first SAR satellite to visit after an event

Ascending + descending orbit

Right-looking mode

Latitude of 38° N/S

Present: 9 hours

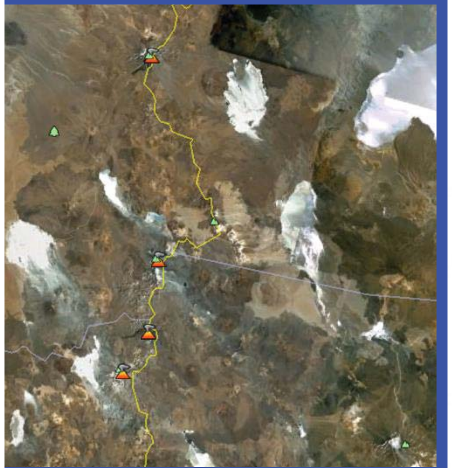
2020: 8 hours

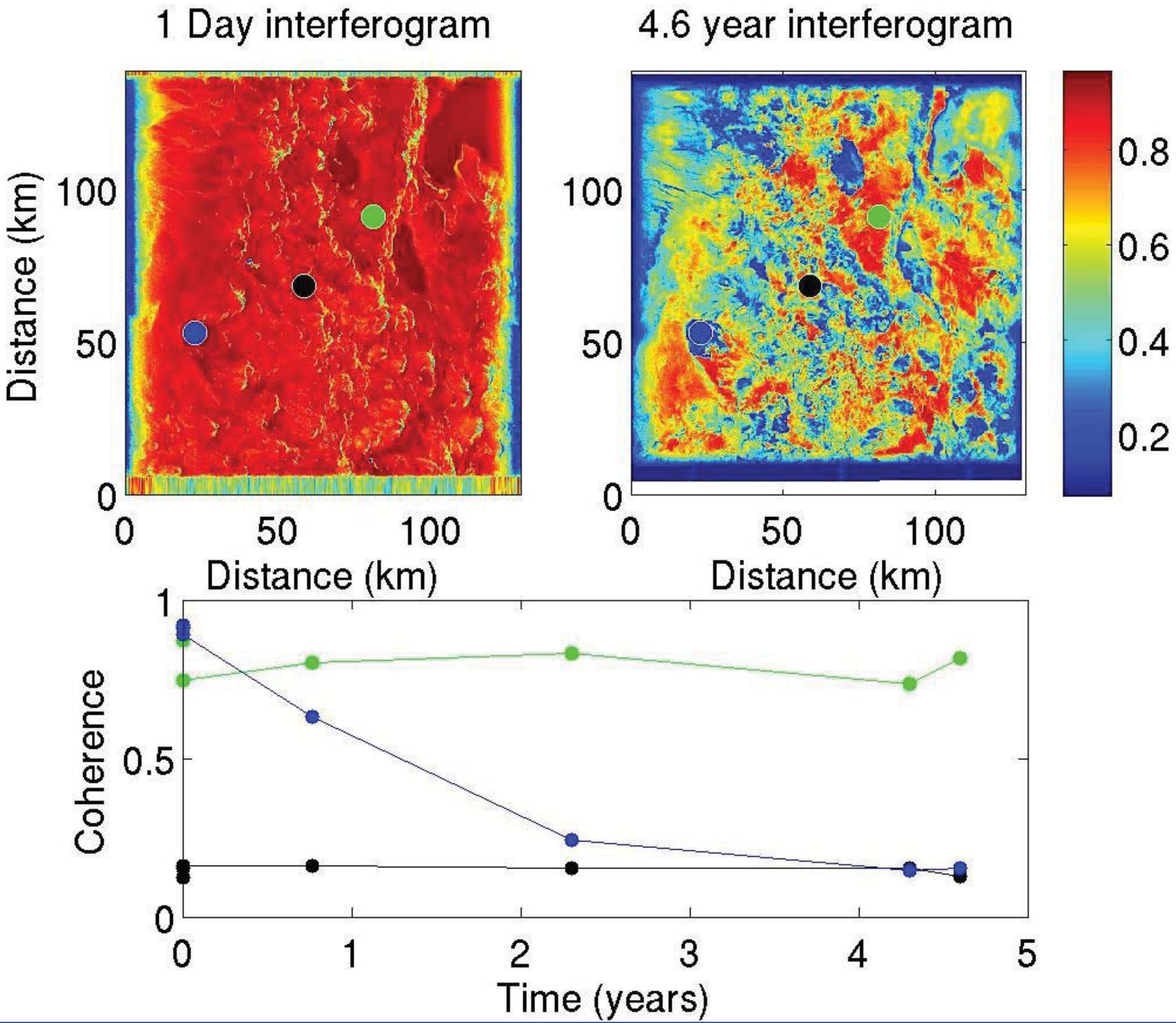
(Yun et al, 2011)

Problem:

- Sufficient pre-event imagery?

Natural coherence change with time





Multiple image analysis of arid Andes (Chile/Argentina)

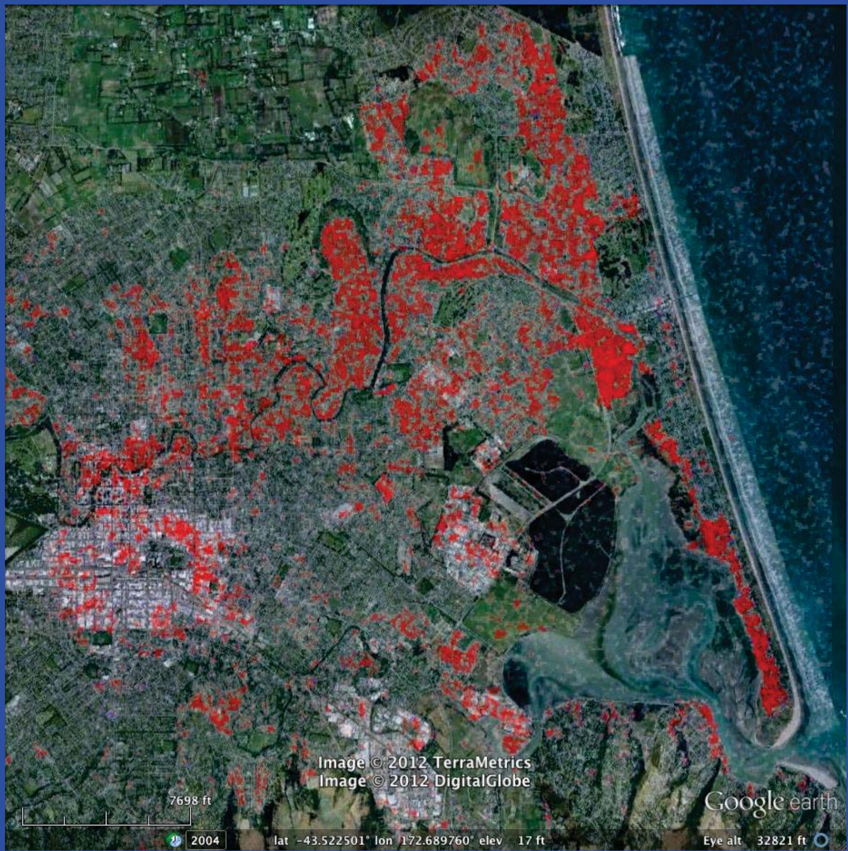
Black pixel = water

Green = unchanging volcanic deposit

Blue = windblown salt flat

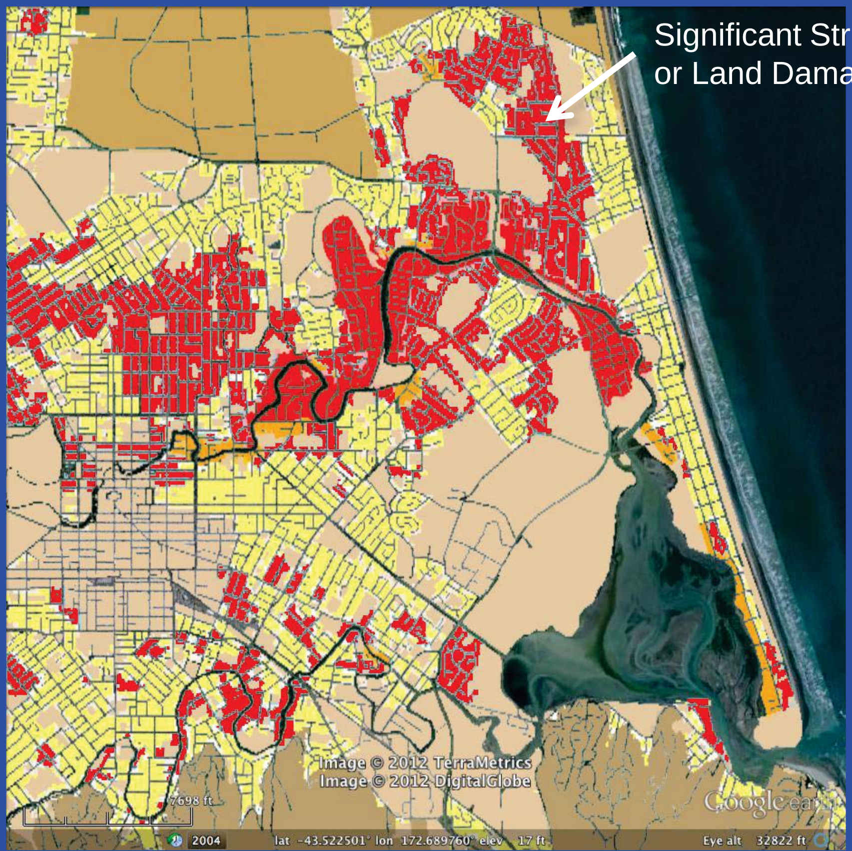
February 2011 Christchurch Earthquake Damage

From radar data acquired **3 days** after EQ



Damage Proxy Map (ALOS PALSAR):
2010.10.10 – 2011.01.10 – 2011.02.25
ARIA – JPL/Caltech

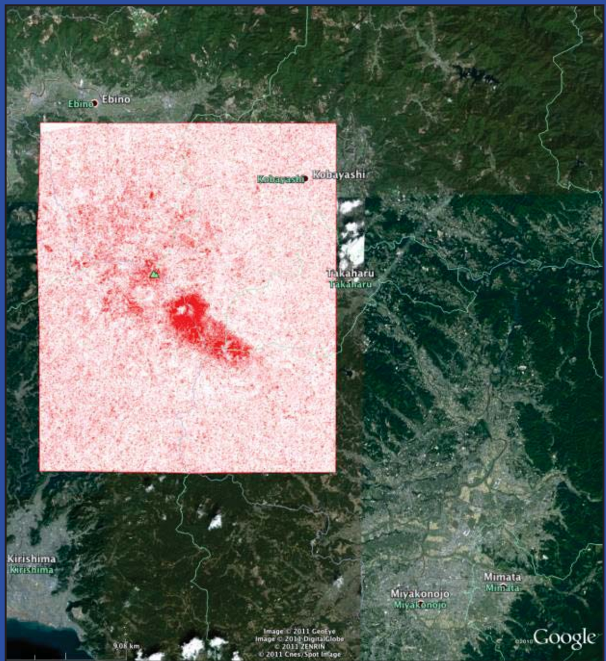
Ground Truth Map released **8 months** after EQ



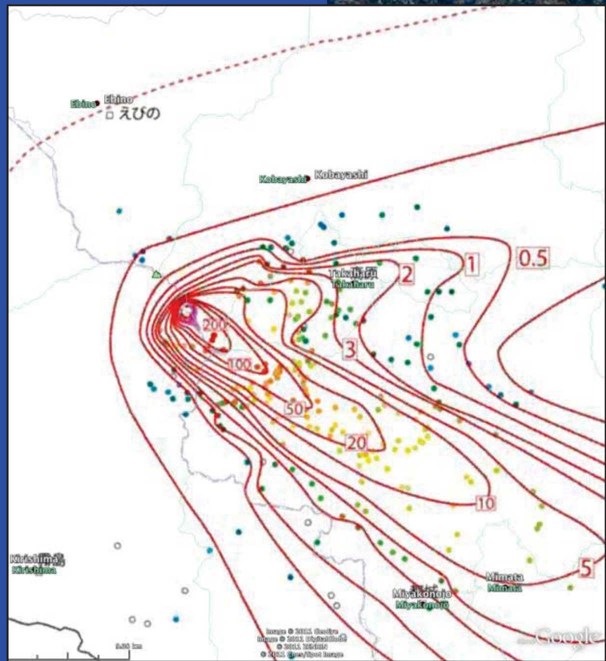
2011.08.28 version
Data provided by the New Zealand Government
http://data.govt.nz

2011 Kirishima Volcano Eruption Ash Fall Damage

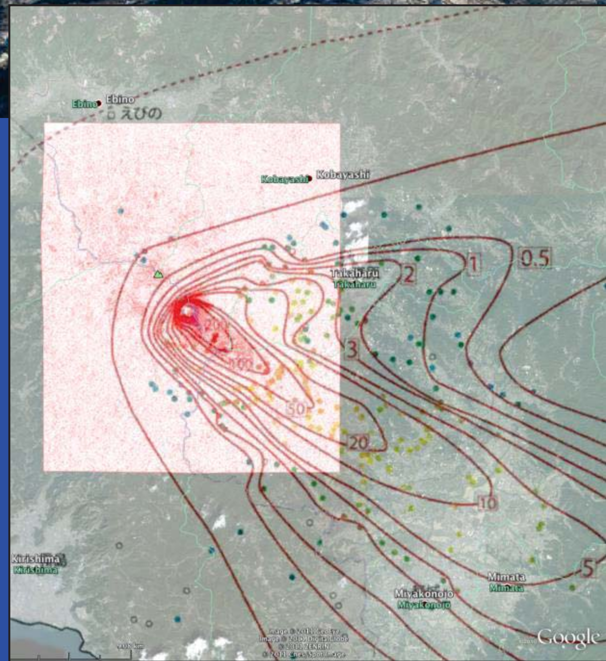
ALOS PALSAR 2010/05/20 – 2010/11/20 – 2011/02/20



Damage Proxy Map
ARIA – JPL/Caltech



Ground Truth: Contour lines that indicate the amount of ash deposits in kg/m^2 - Geological Survey of Japan (AIST)



With 99 percentile anomaly threshold, the detection boundary corresponds to 100 kg/m2 curve (~10 cm deep)

Remote sensing of Patagonia glacier change

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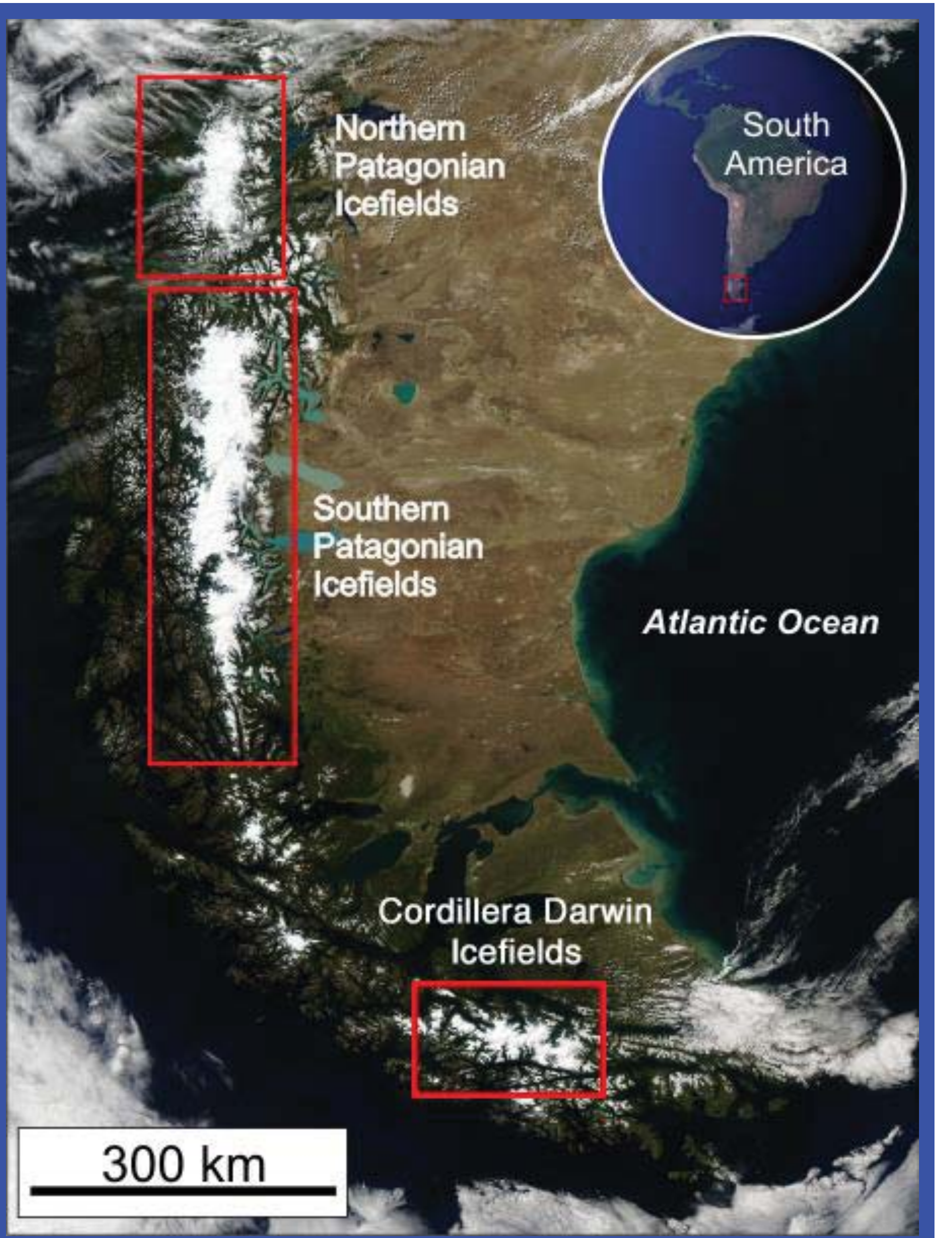
Cornell Andes Project

Despite being 0.6% of all ice, Patagonia & Alaska contribute ~20% of all eustatic sea level rise (Jacob et al., 2012)

They are more responsive to change and produce glacial outburst floods

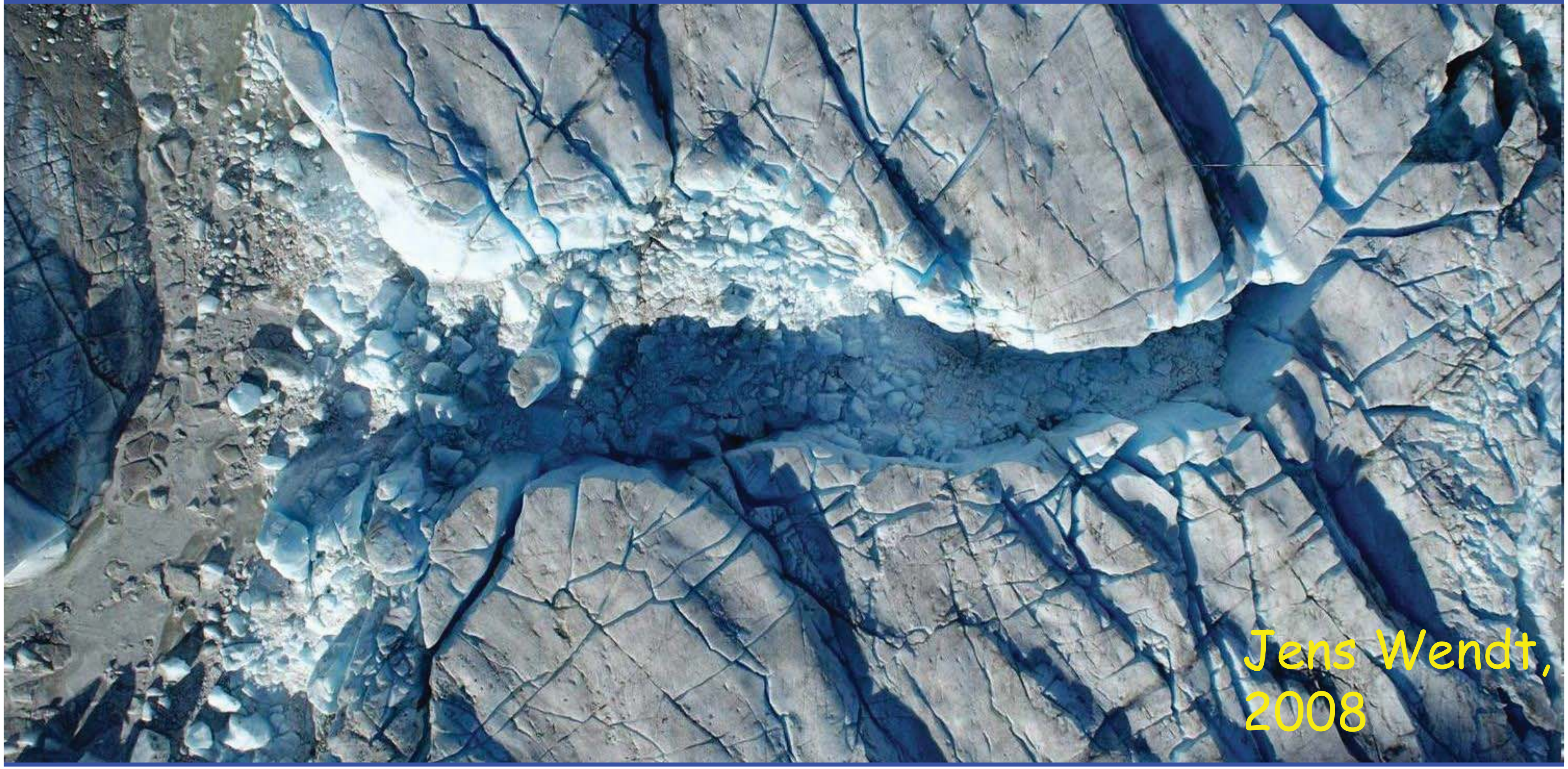


MODIS image

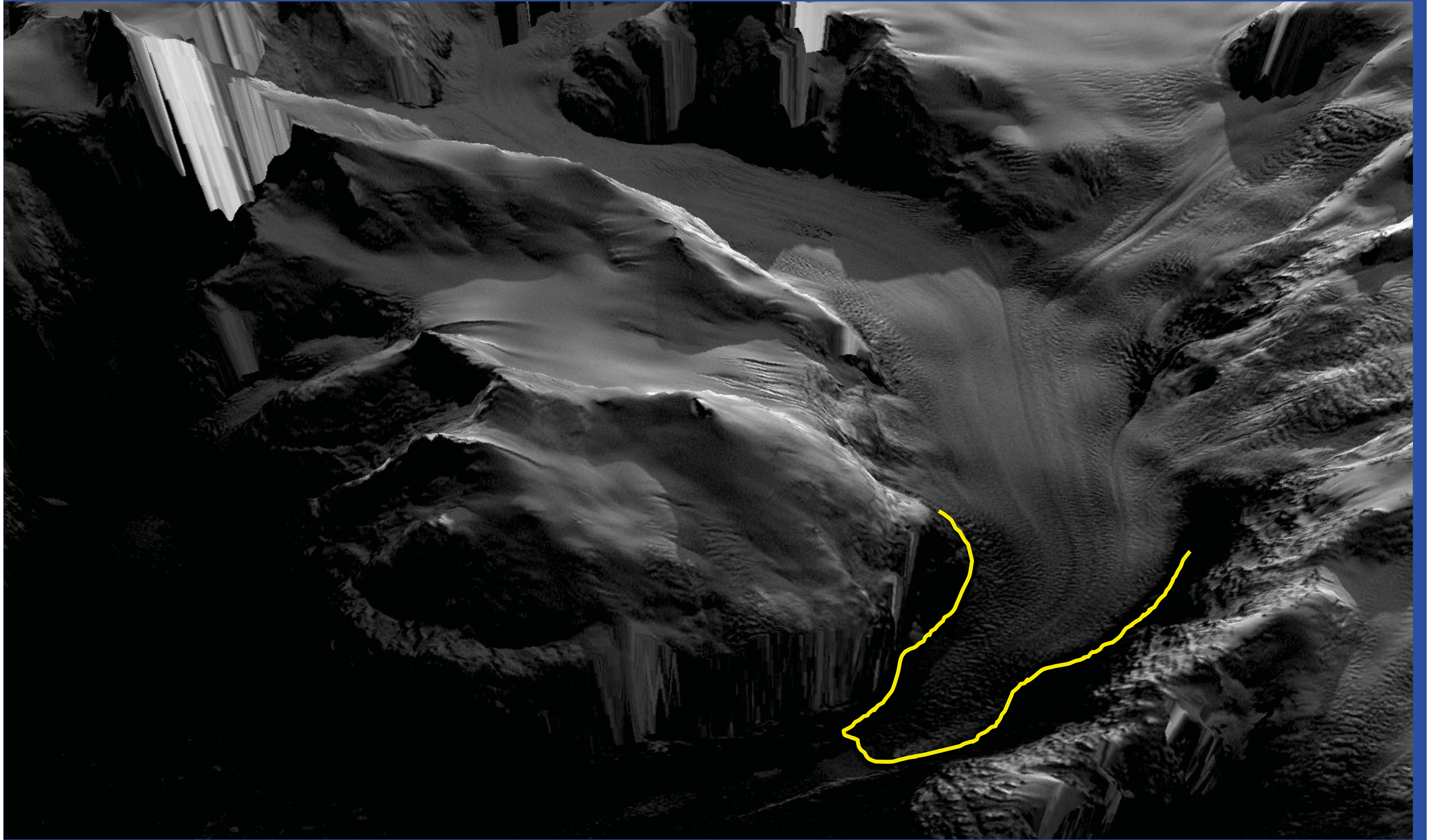
Glacial Lake Outburst Floods

Colonia glacier, Northern Patagonia Icefield: near proposed dam-site

5 floods in 2008-2009, each 200 million m^3 – potential for bigger ones unprecedented since monitoring started in 1963 (Dussaillant et al., 2009)

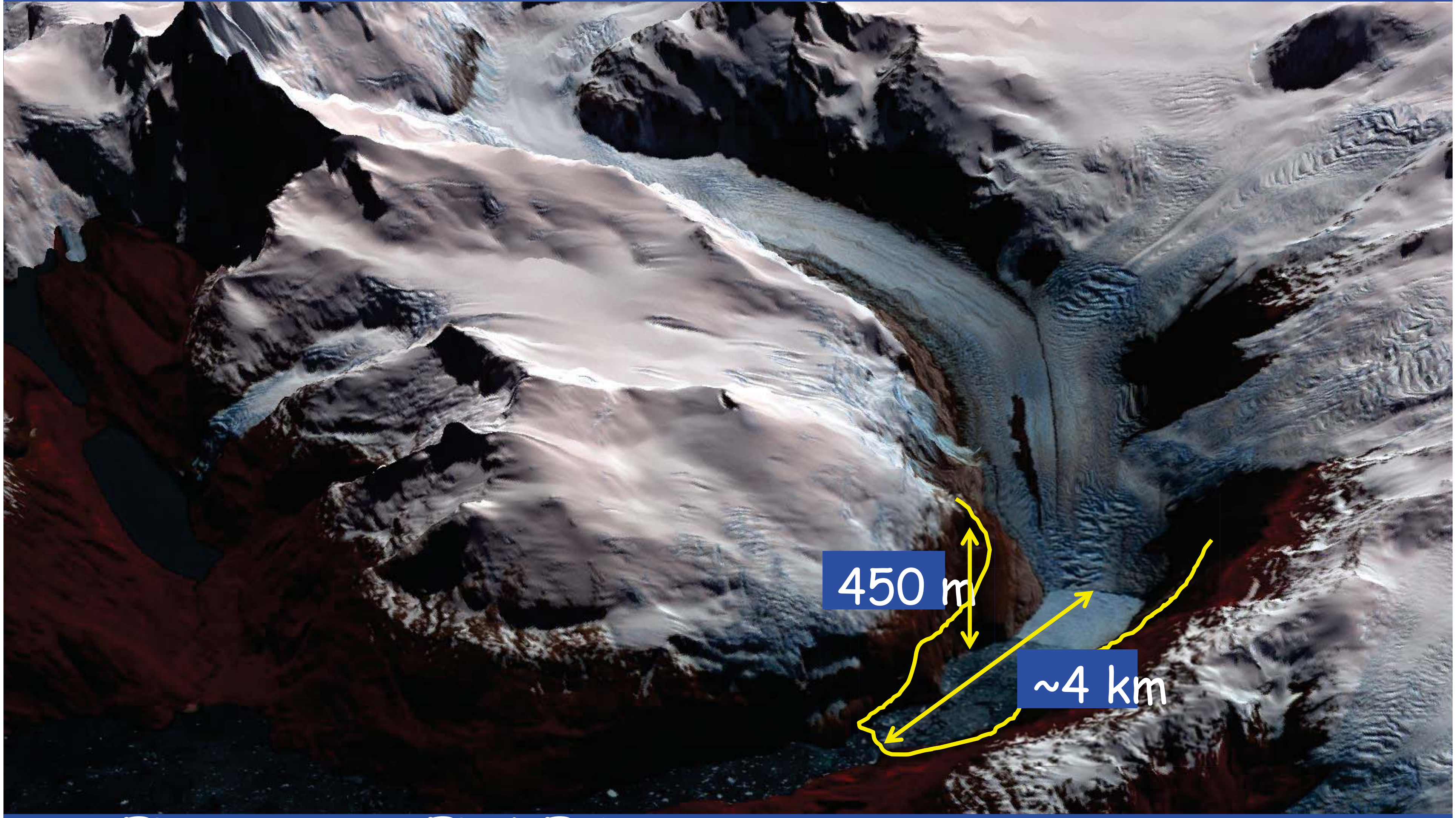


HPS 12 glacier, southern Patagonia: Oct. 2001

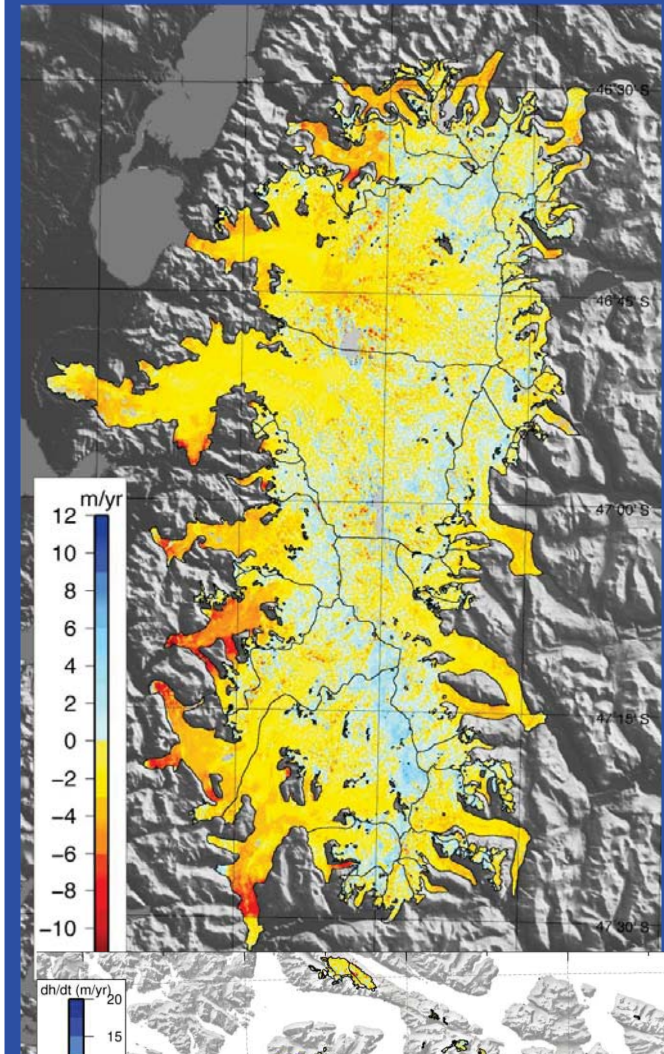


Landsat over SRTM DEM.

HPS 12 glacier, southern Patagonia: Feb. 2010

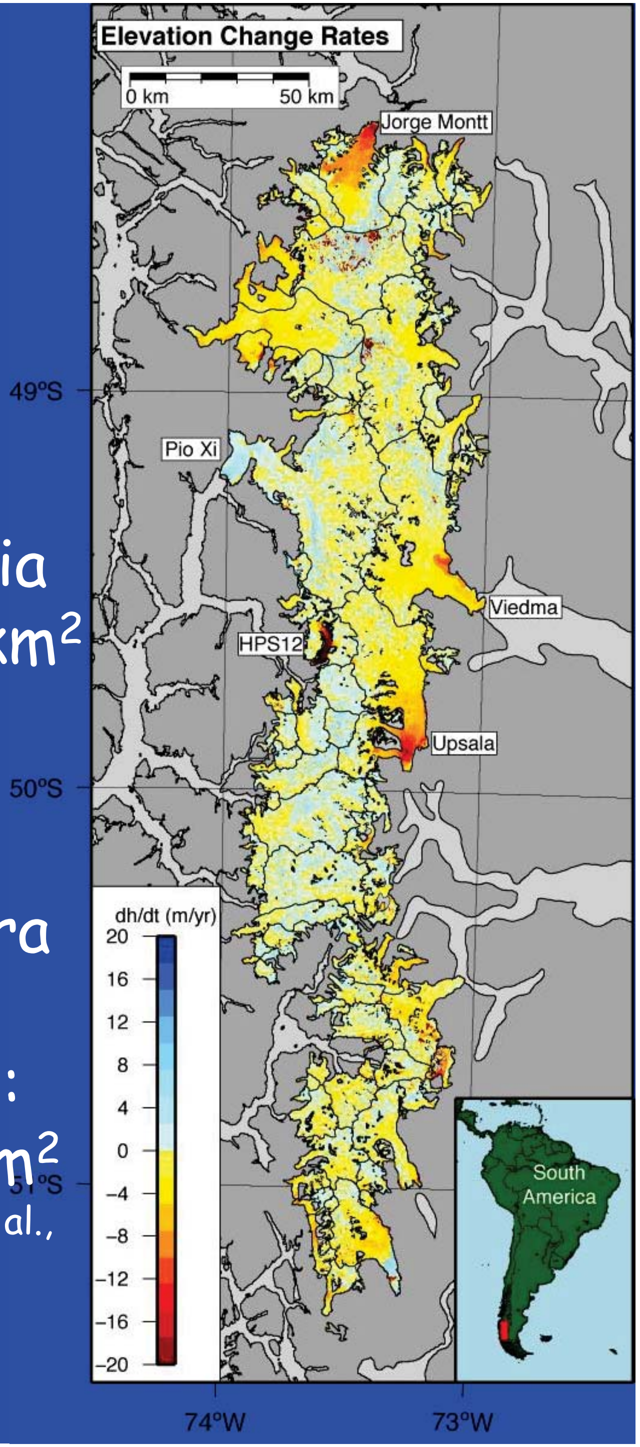


ASTER over ASTER DEM
Lost thickness = Empire State Building

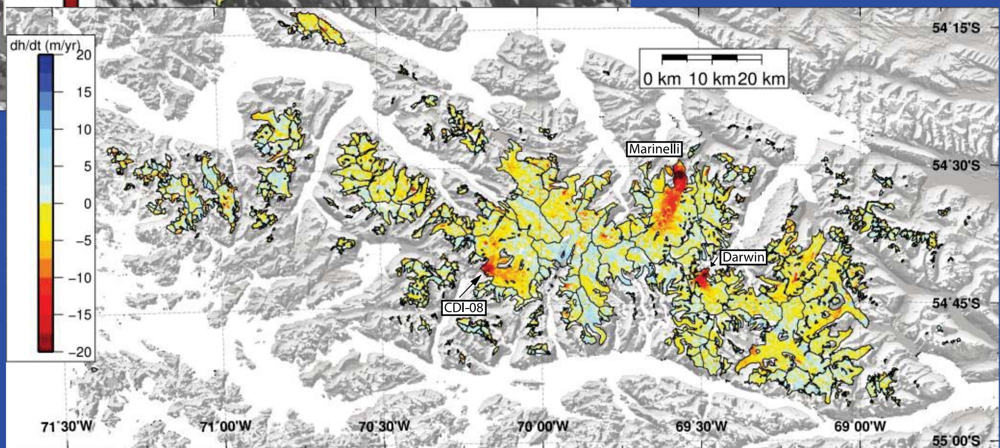


Northern Patagonia Icefield: 4,000 km^2
(Willis et al., 2012)

Southern Patagonia Icefield: 12,000 km^2
(Willis et al., 2012b)



Cordillera Darwin Icefield: 2,500 km^2
(Melkonian et al., 2013)



Summary

• Satellite radar is a versatile & underutilized complement to optical sensors for disaster response

• While some applications for hazard assessment are well developed (earthquakes, inter-seismic, volcanoes, landslides, subsidence, etc.) others that could be more widely used

• Advantages:

- All-weather, Day-night capability
- Derived products are routine, uniform, and fast

1) Phase change: ground movement
2) Coherence change: damage
3) Amplitude change: Ground movement & damage
4) Polarimetry
5) Topographic change

Taking full advantage of the temporal coverage from the constellation of international sensors is a challenge