GEOS 639 – INSAR AND ITS APPLICATIONS

GEODETIC IMAGING AND ITS APPLICATIONS IN THE GEOSCIENCES

Lecturer:

Franz J Meyer, Geophysical Institute, University of Alaska Fairbanks, Fairbanks; fjmeyer@alaska.edu

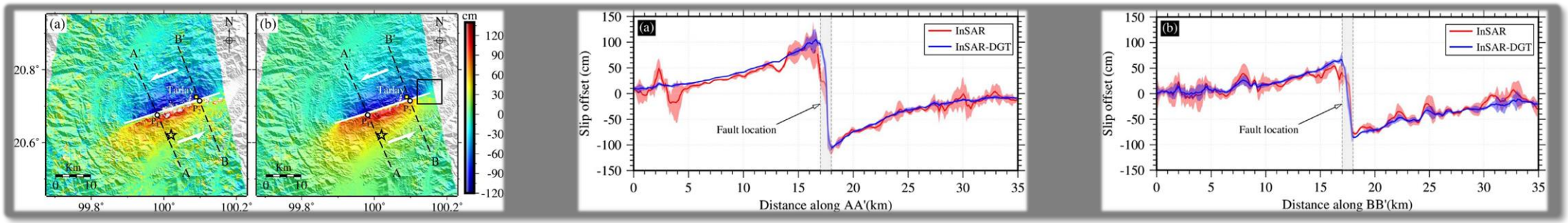
Lecture 1: Introduction to the Course

ASF

UAF UNIVERSITY OF ALASKA FAIRBANKS

GEOPHYSICAL INSTITUTE University of Alaska Fairbanks

UAF COLLEGE OF NATURAL SCIENCE & MATHEMATICS University of Alaska Fairbanks



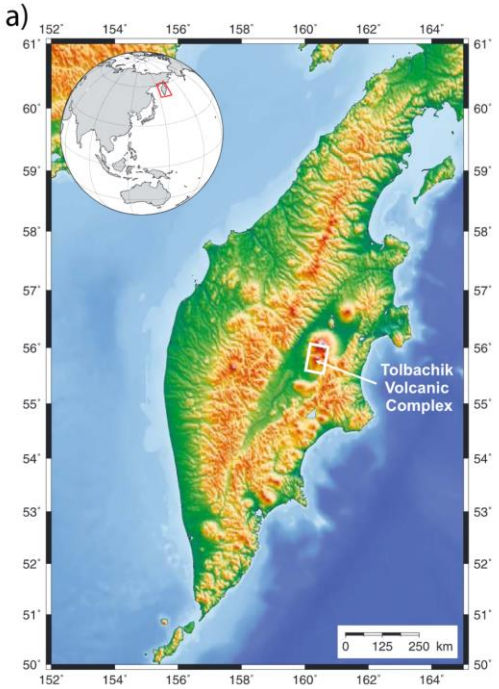
A Look at Some Applications Relevant for this Course

[And at some of the Teaching Tools we will Use]

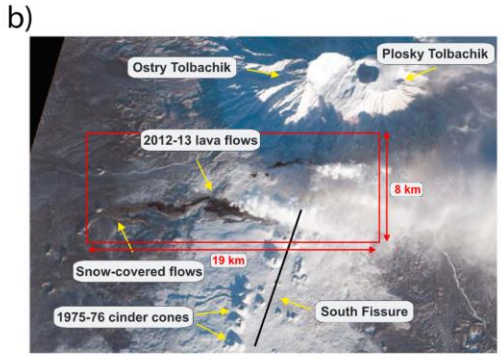
Measuring Shape: Why We Care About DEMs

Effusion Rate Estimation for the 2012-2013 Tolbachik Eruption using TanDEM-X

Location



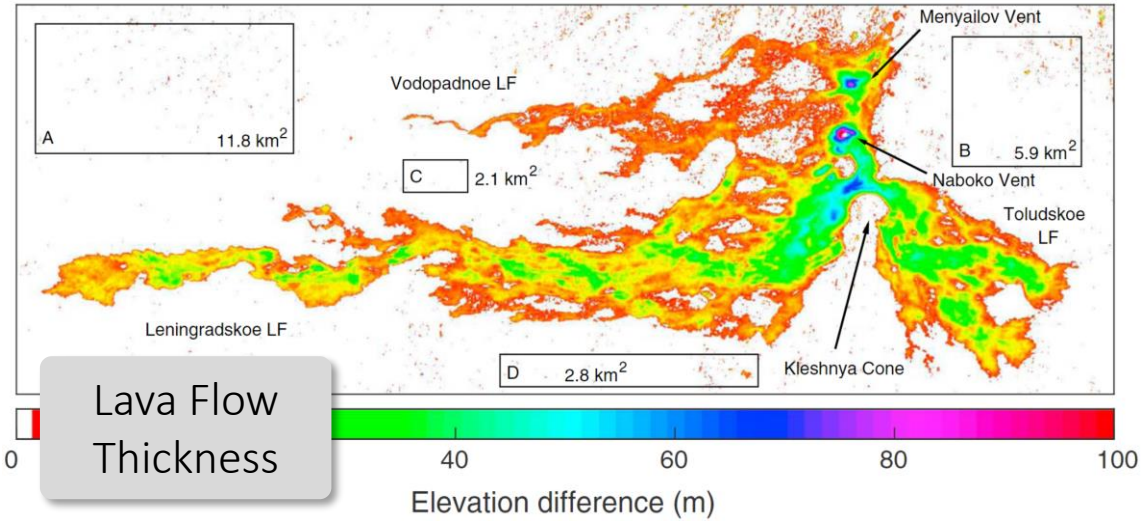
(a) Location of Tolbachik volcano. White rectangle shows footprint of TanDEM-X data; (b) The Tolbachik volcanic complex during the 2012–2013 fissure eruption.

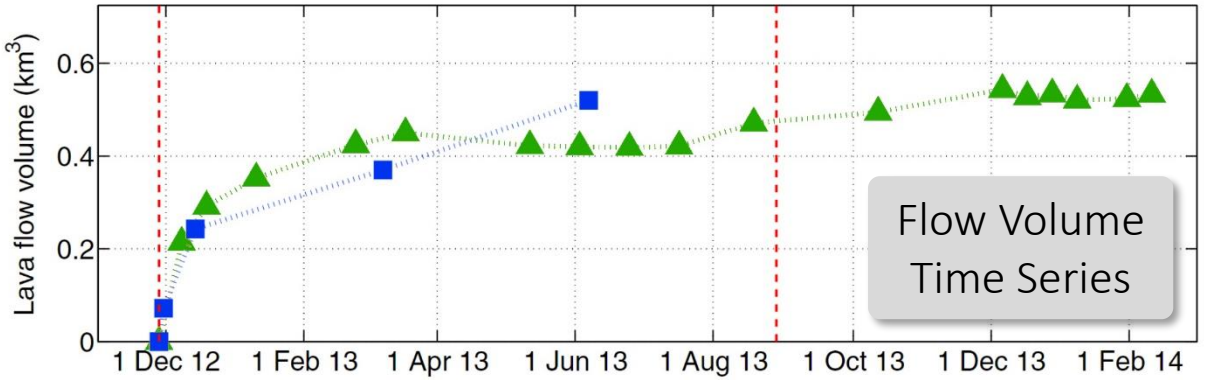


Data

18 DEMs derived from bistatic TanDEM-X InSAR data. TanDEM-X is an X-band, high-resolution X-band SAR constellation built for global DEM generation.

Results





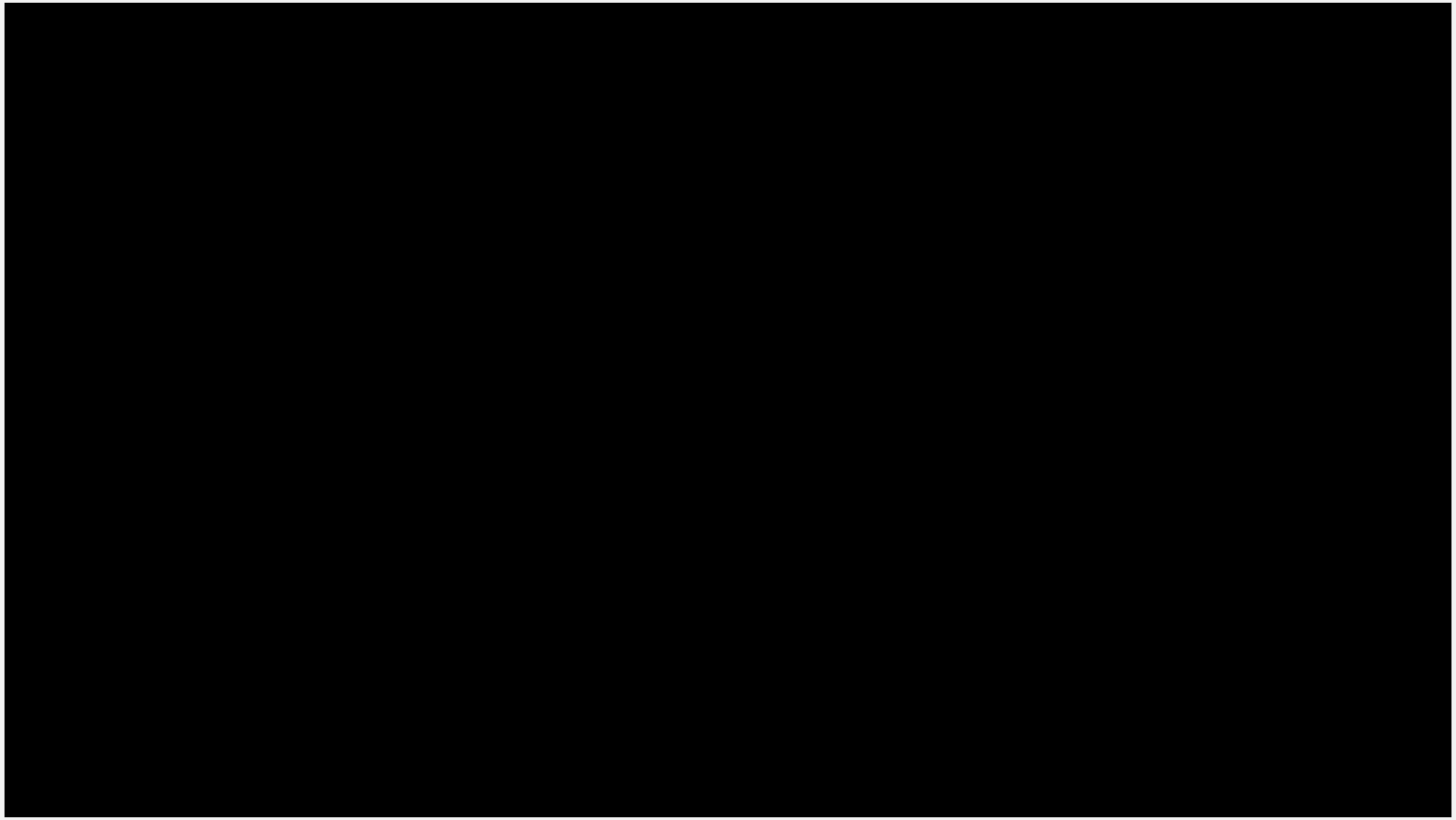
Kubanek, J., Westerhaus, M., & Heck, B. (2017). TanDEM-X time series analysis reveals lava flow volume and effusion rates of the 2012–2013 Tolbachik, Kamchatka fissure eruption. *Journal of Geophysical Research: Solid Earth*, *122*(10), 7754-7774.

Think – Pair – Share

Reconstructing Shape from Images

DEM Reconstruction from Images

- **Q1**: When reconstructing shape information from images, you may encounter three product types: DEM, DSM, and DTM. Define the products behind these acronyms.
- **Q2**: Which methods do you know to derive DEM information from images? [try to come up with at least 4 independent methods]

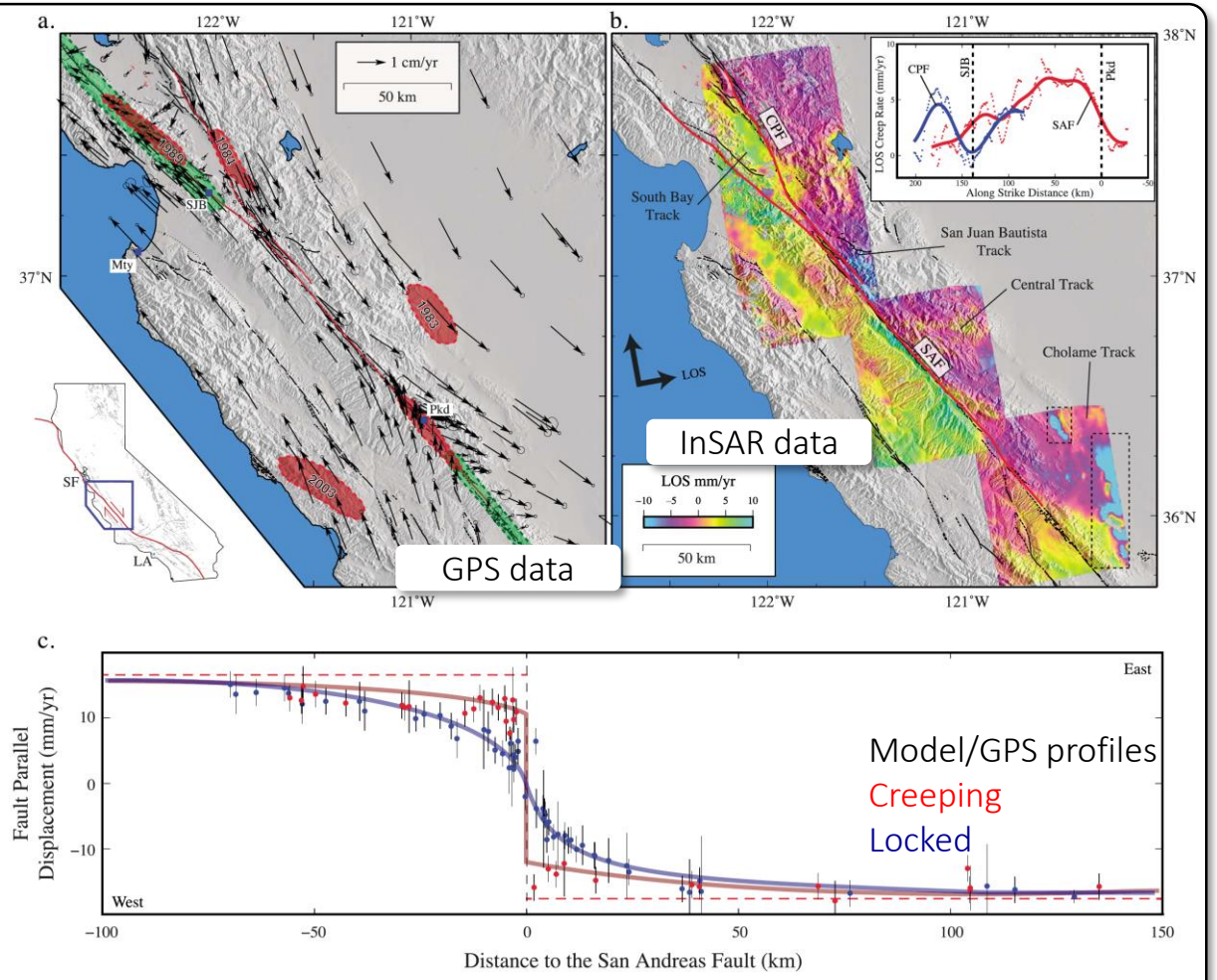


Data acquisition, data processing, and animation by M. Nolan, Fairbanks Fodar; more at https://fairbanksfodar.com/the-first-fodar-map-of-denali-alaska

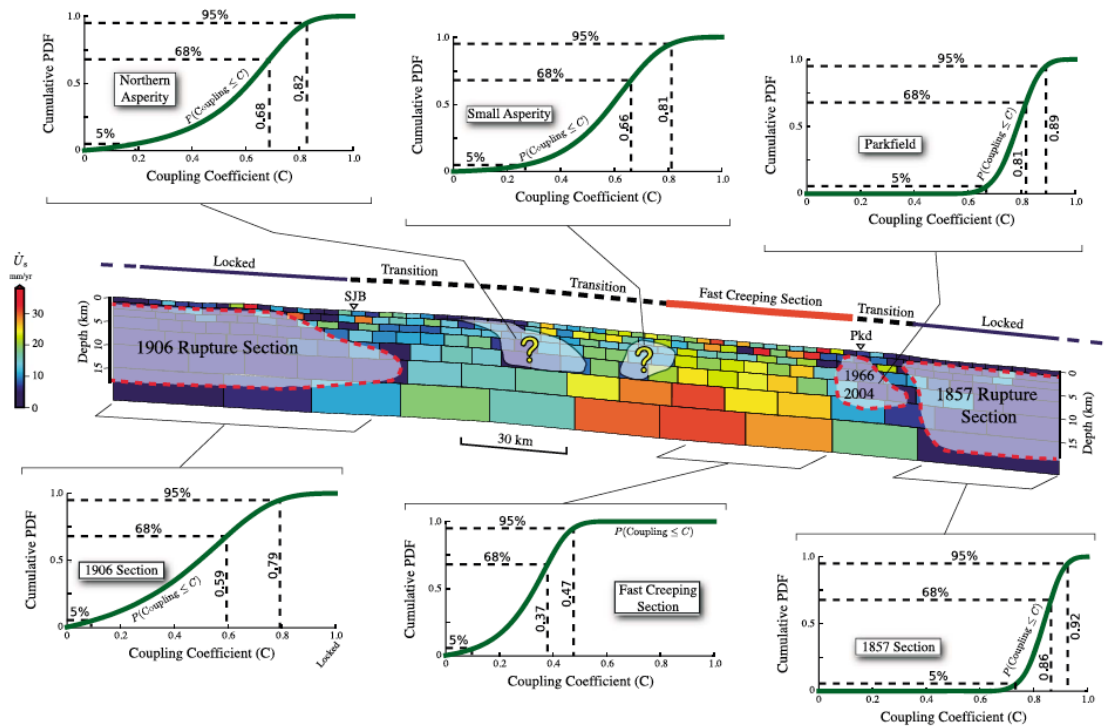
Why We Measure Displacements

Understanding Seismic Coupling / Fault Creep along the San Andreas Fault

InSAR Time Series 2006 -> 2010 --- 30 to 85 interferograms per stack



Jolivet et al., *Geophys. Res. Lett.*, 2014

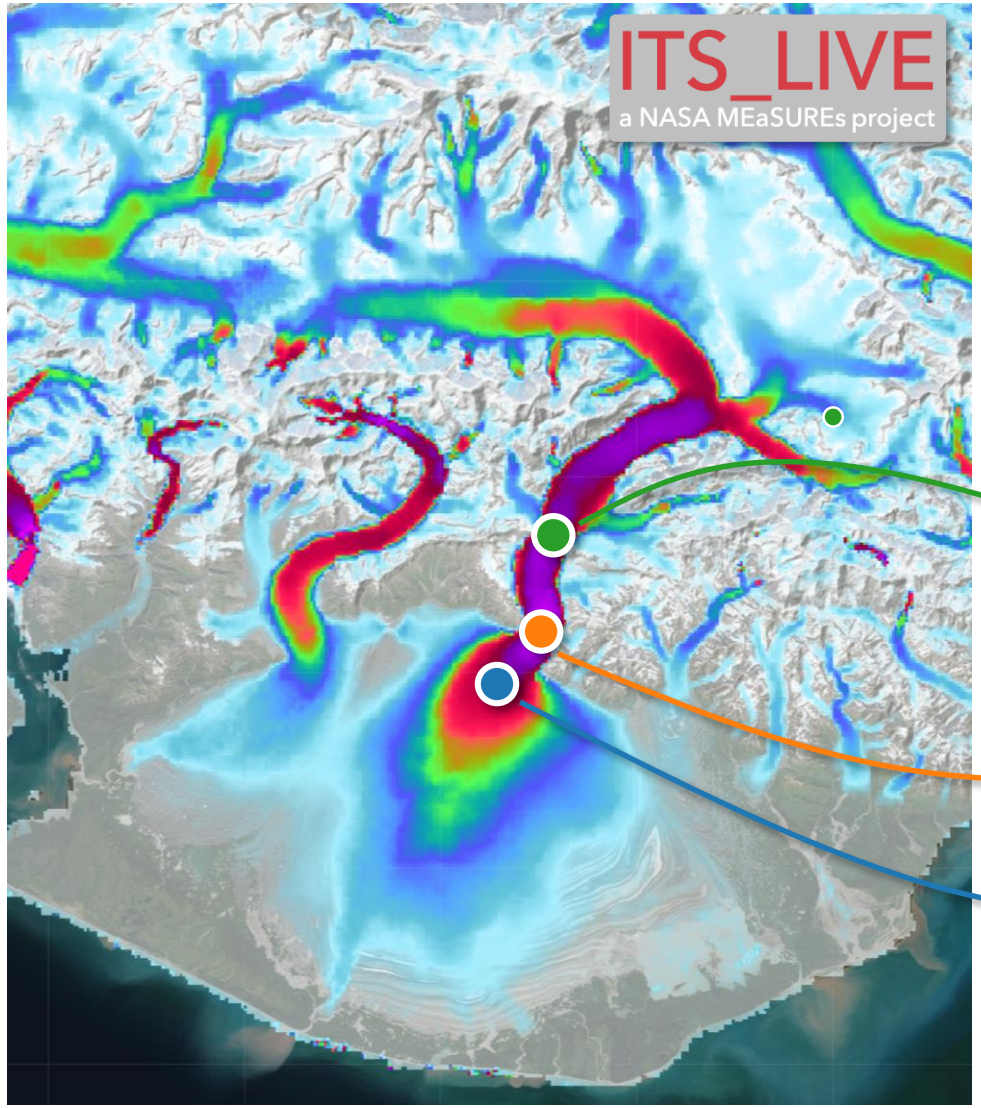


Courtesy: M. Simons, Caltech

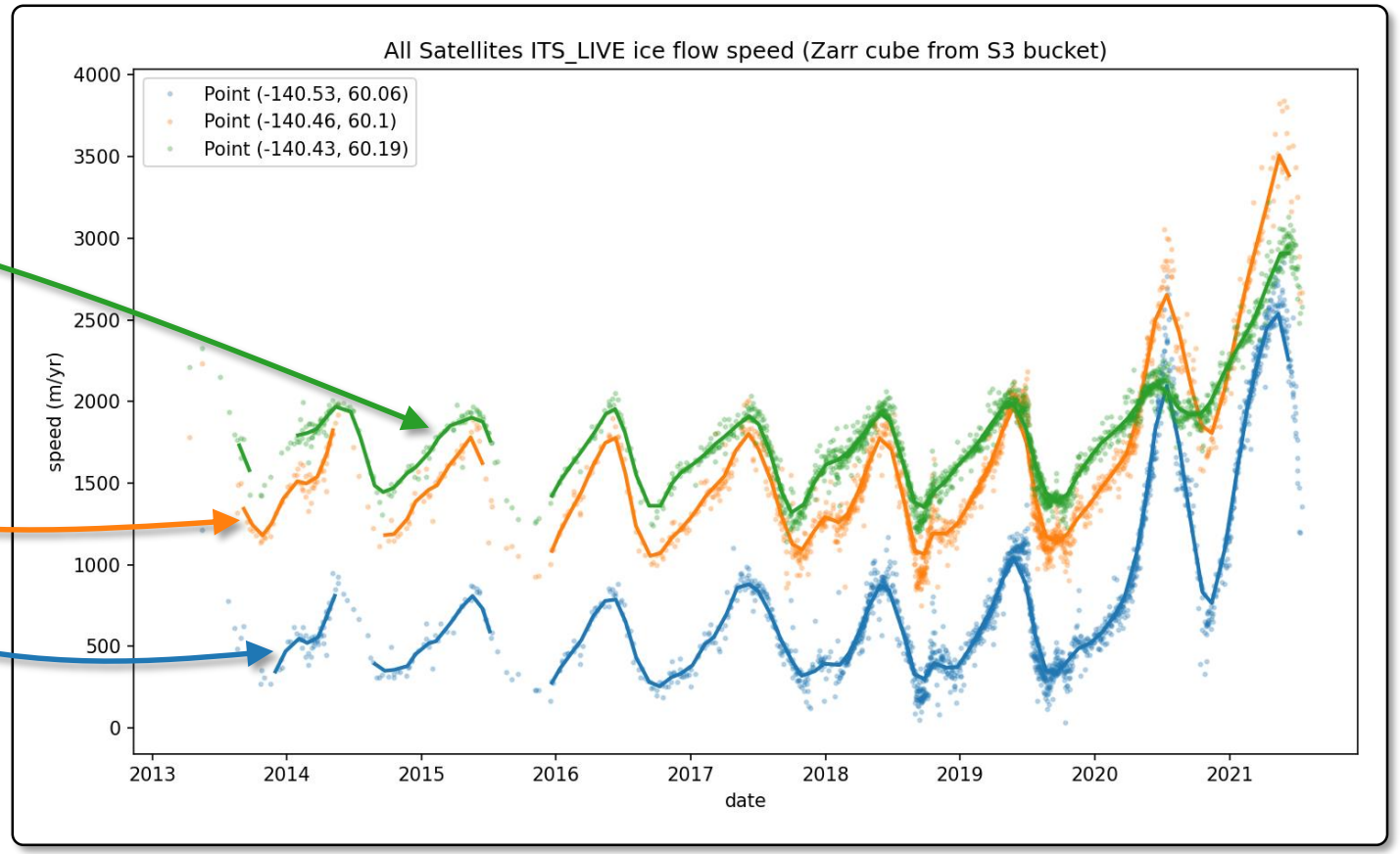
Locked or Creeping: Fully probabilistic Bayesian unsmoothed inference including both data and model prediction covariance

Why We Measure Displacements

Monitoring Surge of Malaspina Glacier, Alaska using Optical and SAR Data



Its_Live is led by Alex Gardner, JPL and includes partners at UAF. The project uses Feature Tracking from Landsat, Sentinel-2, and Sentinel-1 data to monitor velocities at all glaciers in the world!



A Second Interactive Vehicle

Mentimeter Polling

Mentimeter

- Interactive polling with realtime feedback
- Accessible via web browser from any internet-enabled device

- Here is your first Mentimeter poll:

A Look at the Syllabus

A Short Introduction About Myself

MSc & PhD in Engineering, Technische Universitaet Muenchen, Munich Germany

TerraSAR-X Team, German Aerospace Center

Professor of Remote Sensing

Chief Scientist

ALASKA SATELLITE FACILITY
Making remote-sensing data accessible since 1991

University of Alaska Fairbanks, Fairbanks, AK

The Workshop Concept

- **Outline of the Class (https://radar.community.uaf.edu/syllabus/):**

1. Overview	Techniques & applications of Geodetic Imaging
2. Shape	Geodetic Imaging Methods to measure shape
3. Motion	Measuring surface motion from images
4. Limitations Error Sources	Error sources in input data and impact on results
5. Geodesy to Geophysics	Including geodetic data into geophysical models
6. Class Projects	Experience geodetic imaging in mini projects

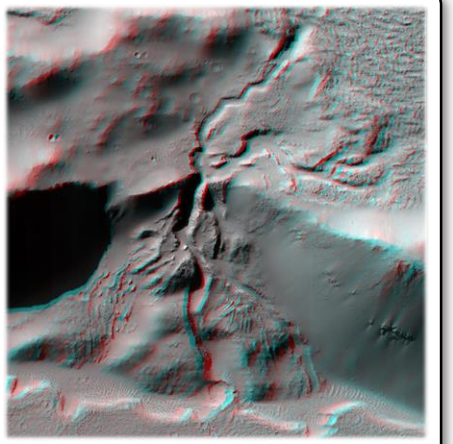
- **Introduction to Cloud-based and Python-based SAR data processing:**
  - No data download and no local compute hardware needed
    → High-performance computing from any internet-connected device
  - Full access to relevant data sets and open-source software
  - Use as you need – only download what you need
  - Jupyter Notebook tools for algorithm development and use

Opensarlab.asf.alaska.edu

- Full performance lab exercises
- End-user processing with moderate local compute & internet infrastructure

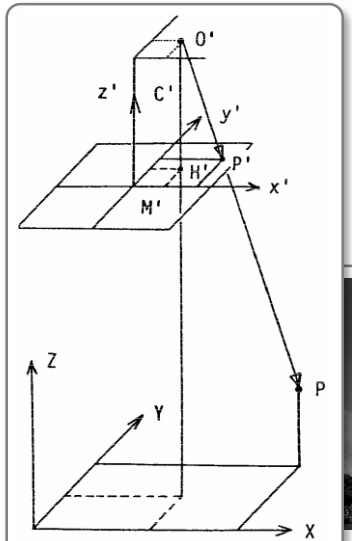
Topic 2: Reconstructing Shape from Images

DEM Reconstruction from Images – Stereo Photogrammetry

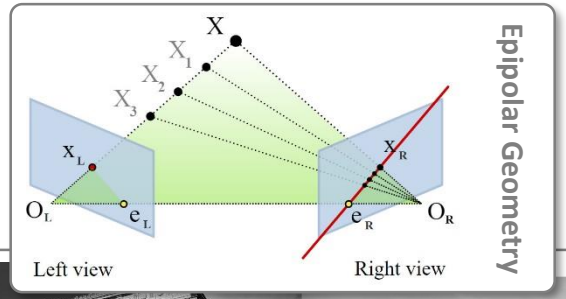


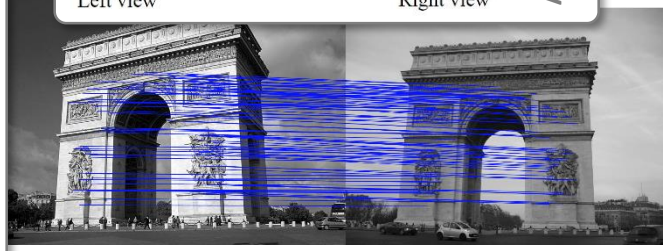
Stereo Image Pair

http://www.uahirise.org/anaglyph/



Collinearity condition

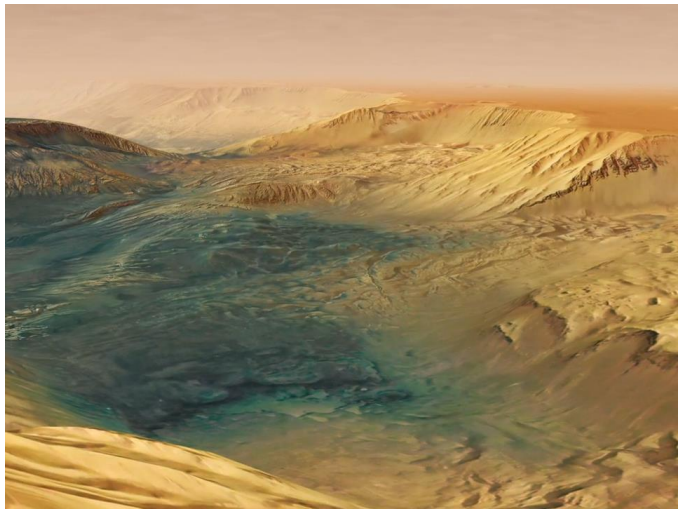




Robust Image Matching

Stereo-Photogrammetry Pipeline

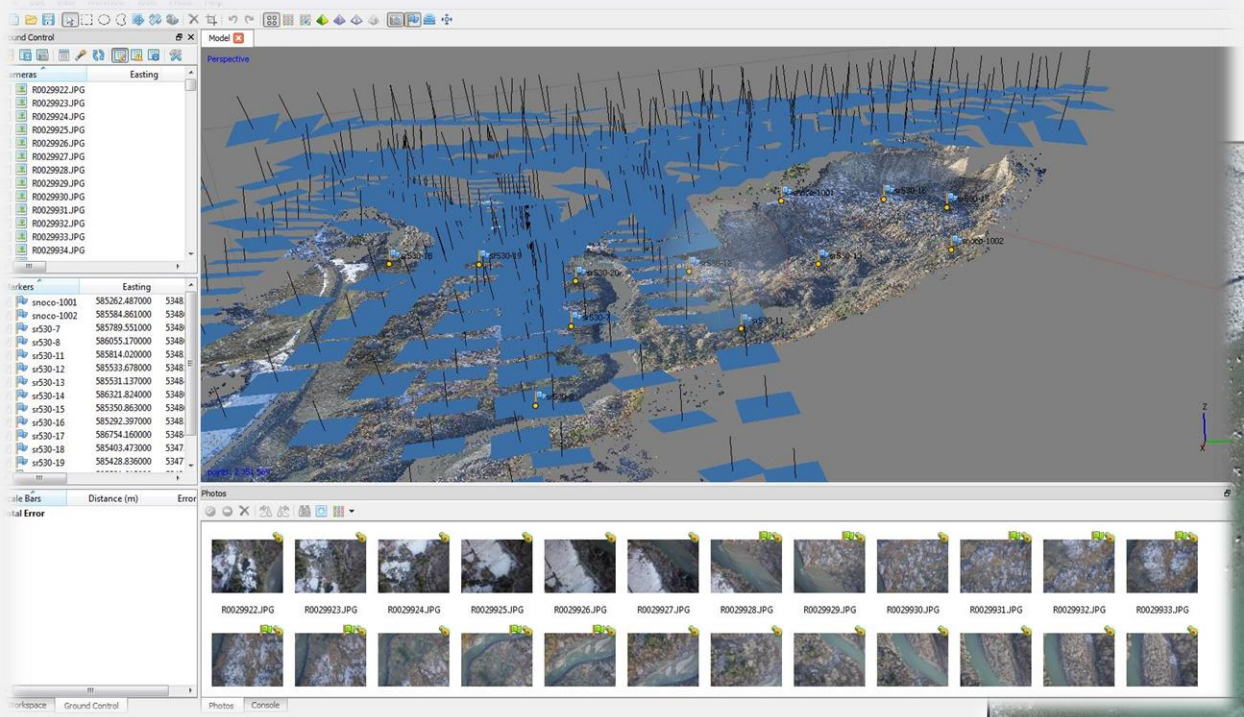
http://www.esa.int/Our_Activities/Space_Science/Fly_through_a_canyon_on_Mars

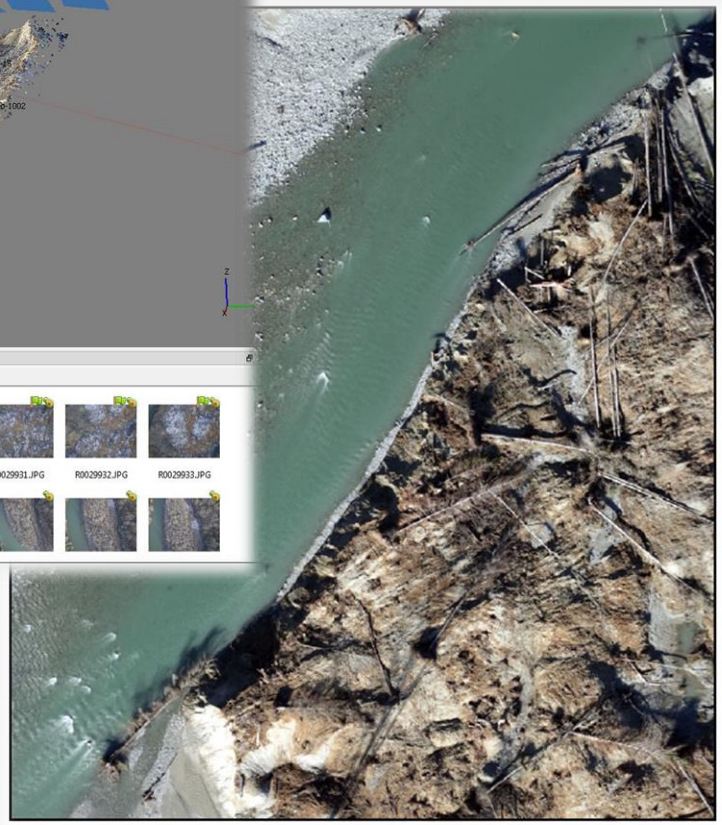


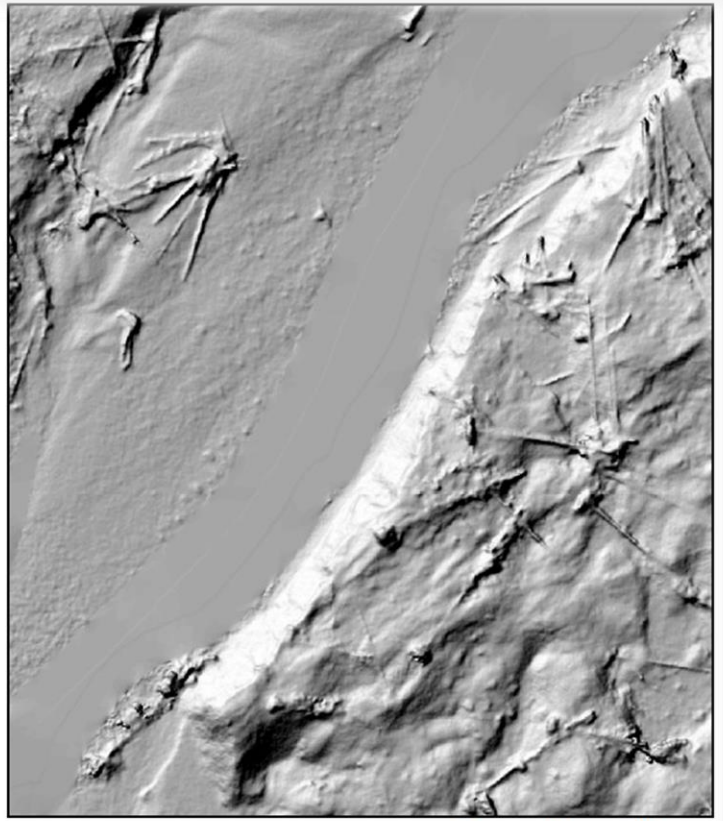
Ortho imagery & 3D Reconstruction

Topic 2: Reconstructing Shape from Images

DEM Reconstruction from Images – Structure from Motion



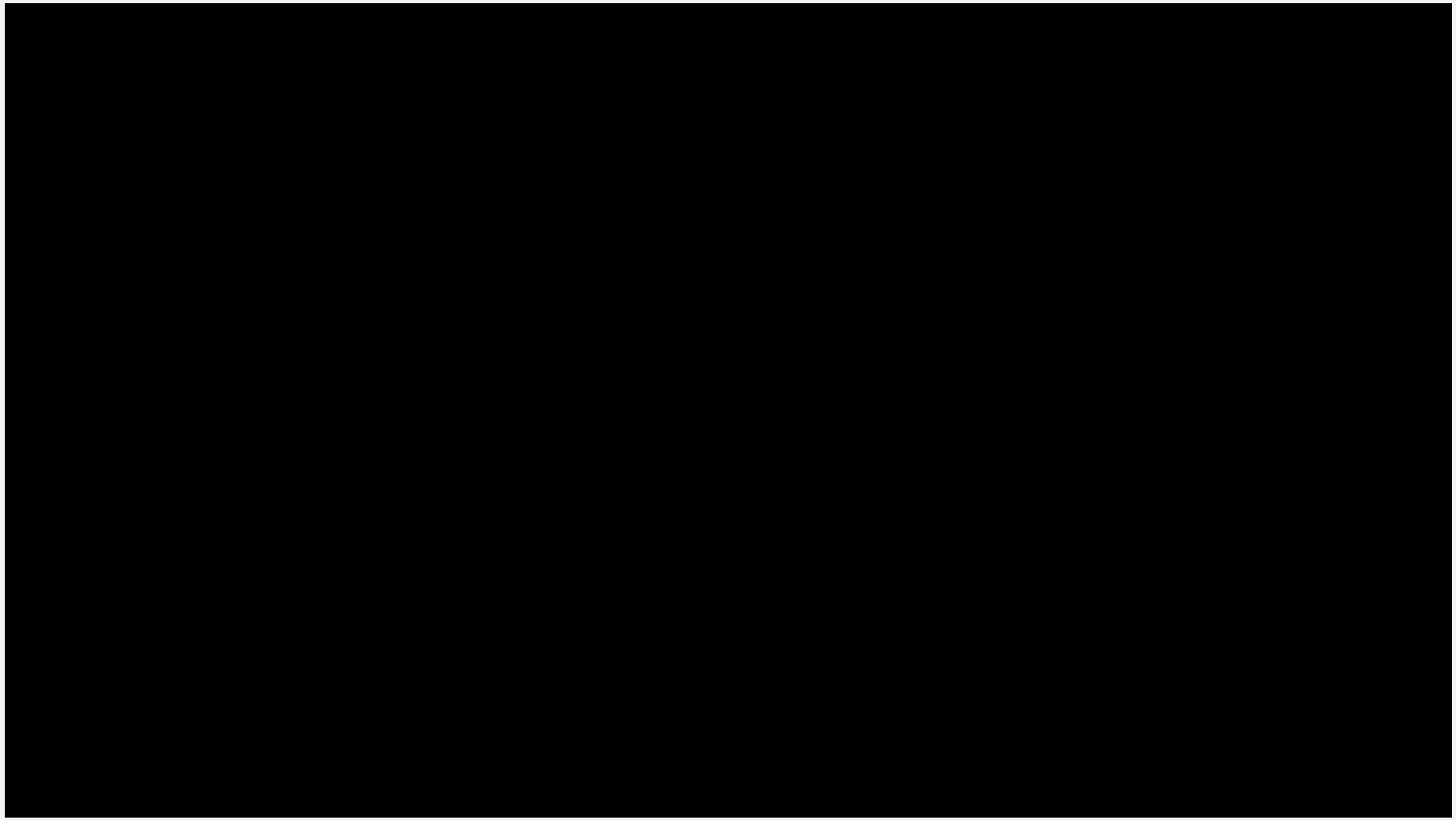




http://wa.water.usgs.gov/projects/sr530/remotesensing.htm

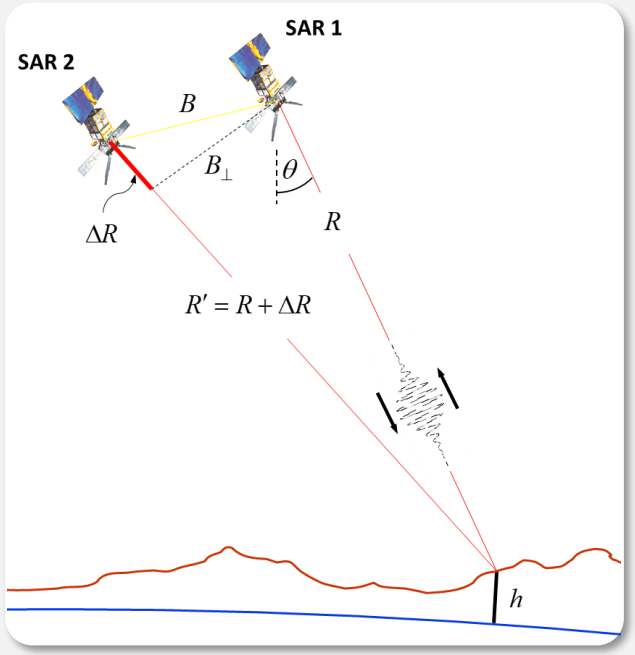
Topic 2: Reconstructing Shape from Images

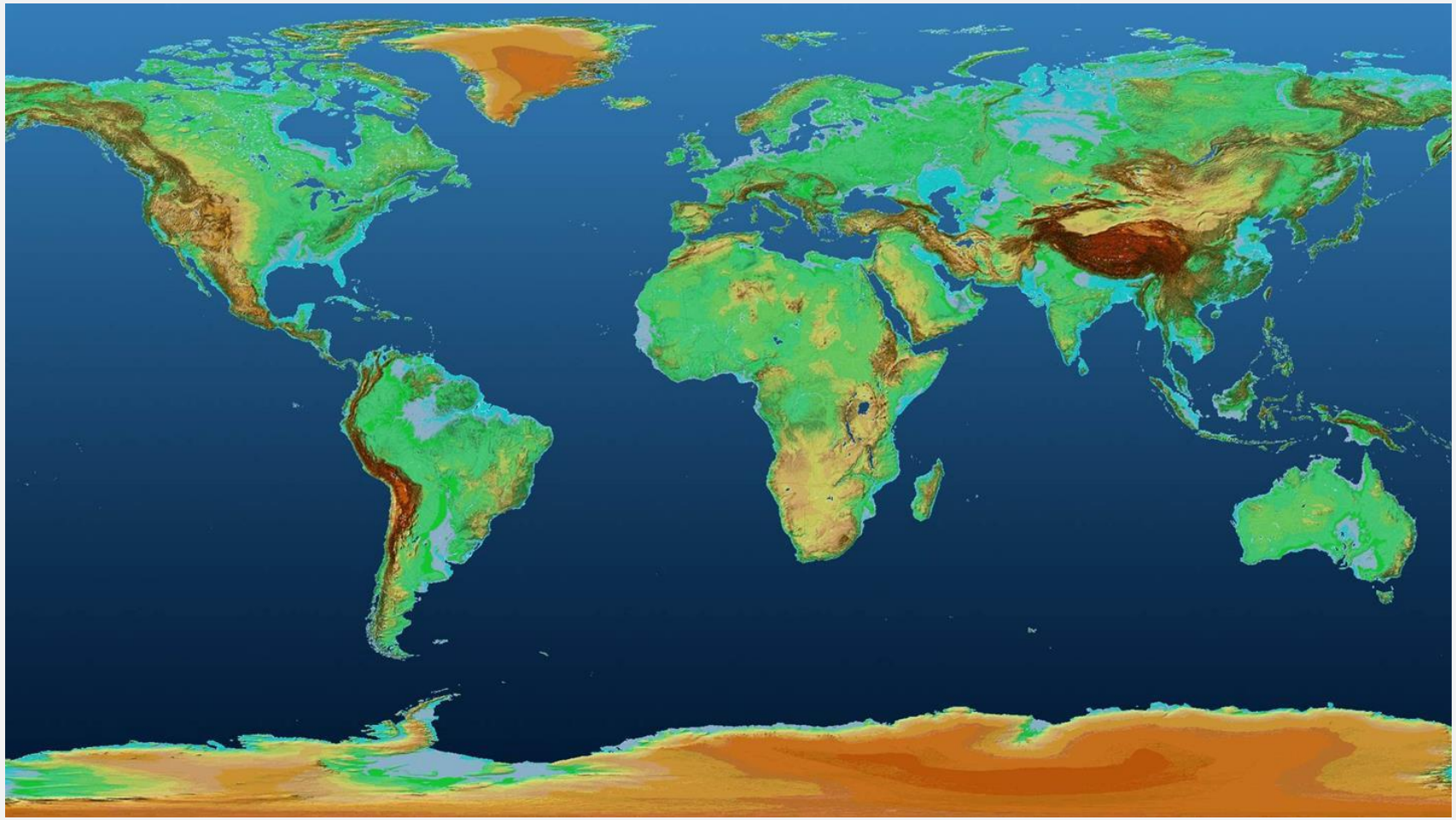
3D Object Reconstruction from Images Blocks



Topic 2: Reconstructing Shape from Images

DEM Reconstruction from Images – InSAR





Topic 2: Reconstructing Shape from Images

3D Reconstruction – Other Methods

- **We will summarize additional methods for 3D reconstruction from images such as**
  - Shape from shading
  - Depth from focus
  - Radarclinometry

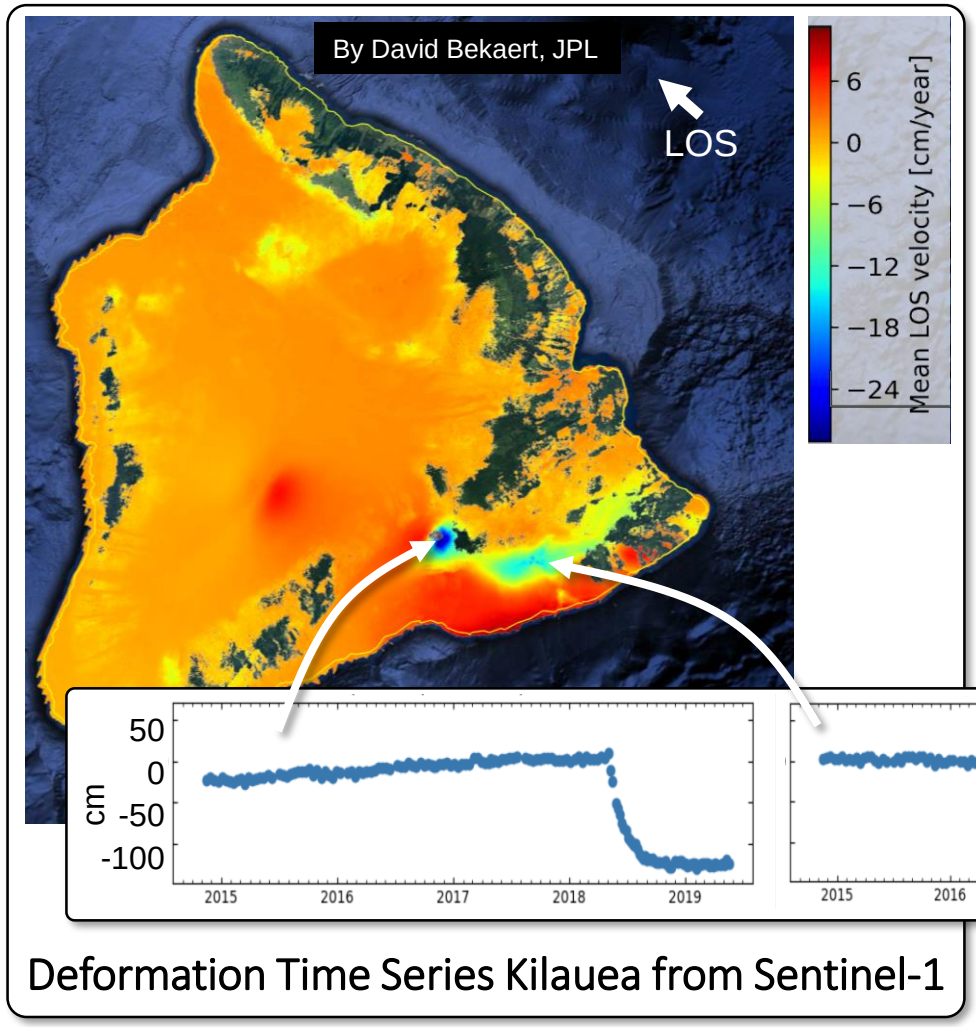
Qualitative results for shape and reflectance estimation from a single image: input image [30], estimated normals and reflectance map, and novel view (from left to right).

[Source: Richter& Roth (2015). Discriminative shape from shading in uncalibrated illumination. IEEE CVPR (pp. 1128-1136)]

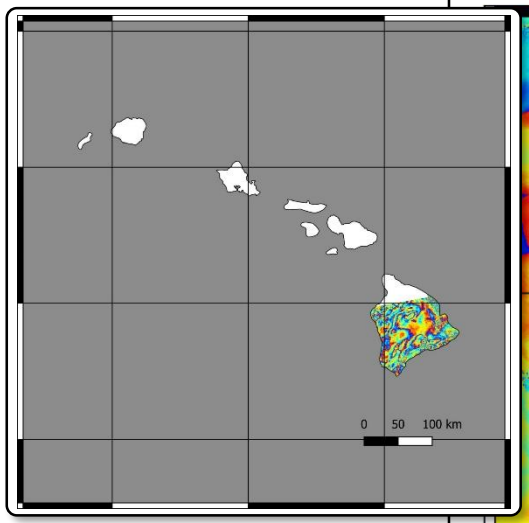
Topic 3: Surface Displacement from Images

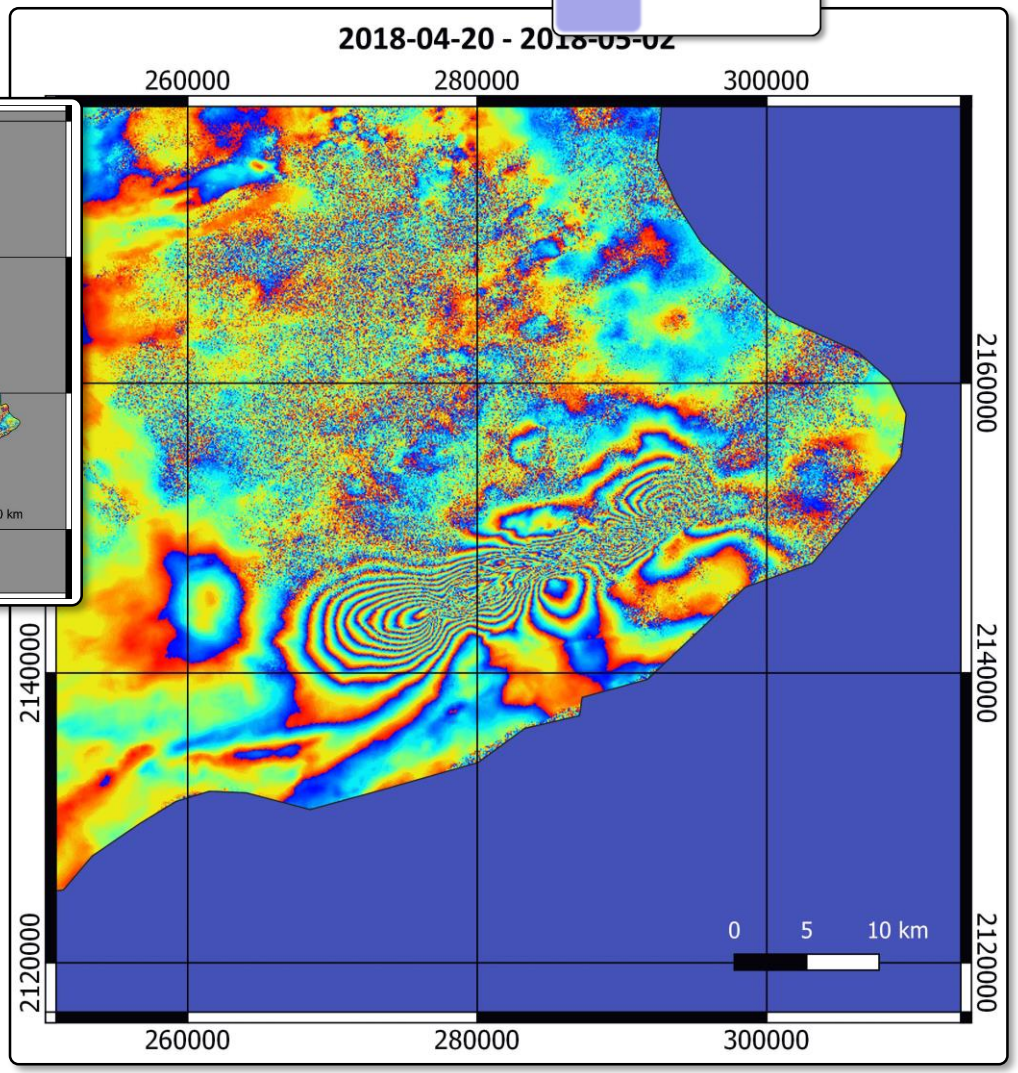
Slow Motion Monitoring [mm/y to m/y] with InSAR

- InSAR Deformation of **Kilauea Event in 2019**



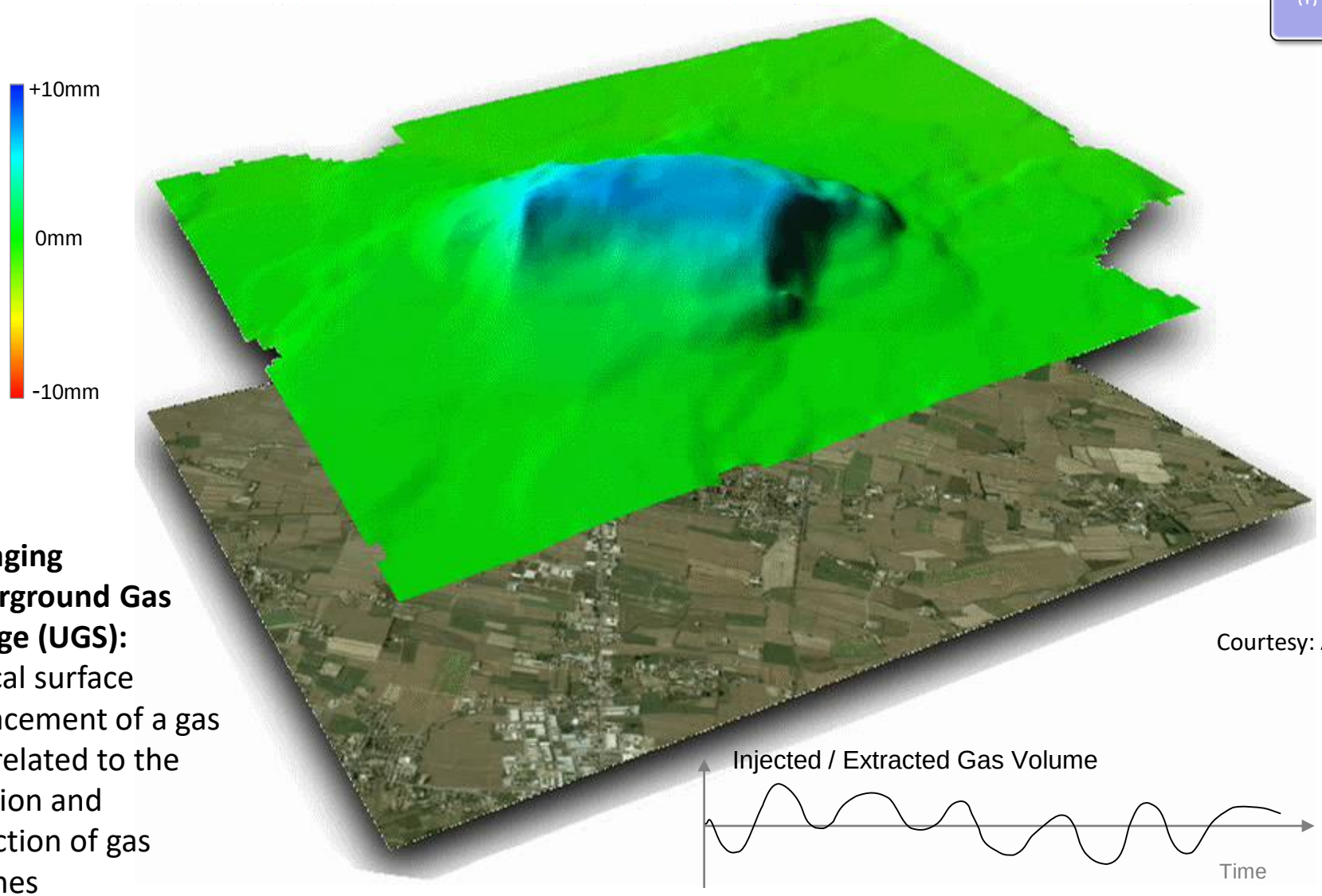
Deformation Time Series Kilauea from Sentinel-1





Topic 3: Surface Displacement from Images

Slow Motion Monitoring [mm/y to m/y] with InSAR



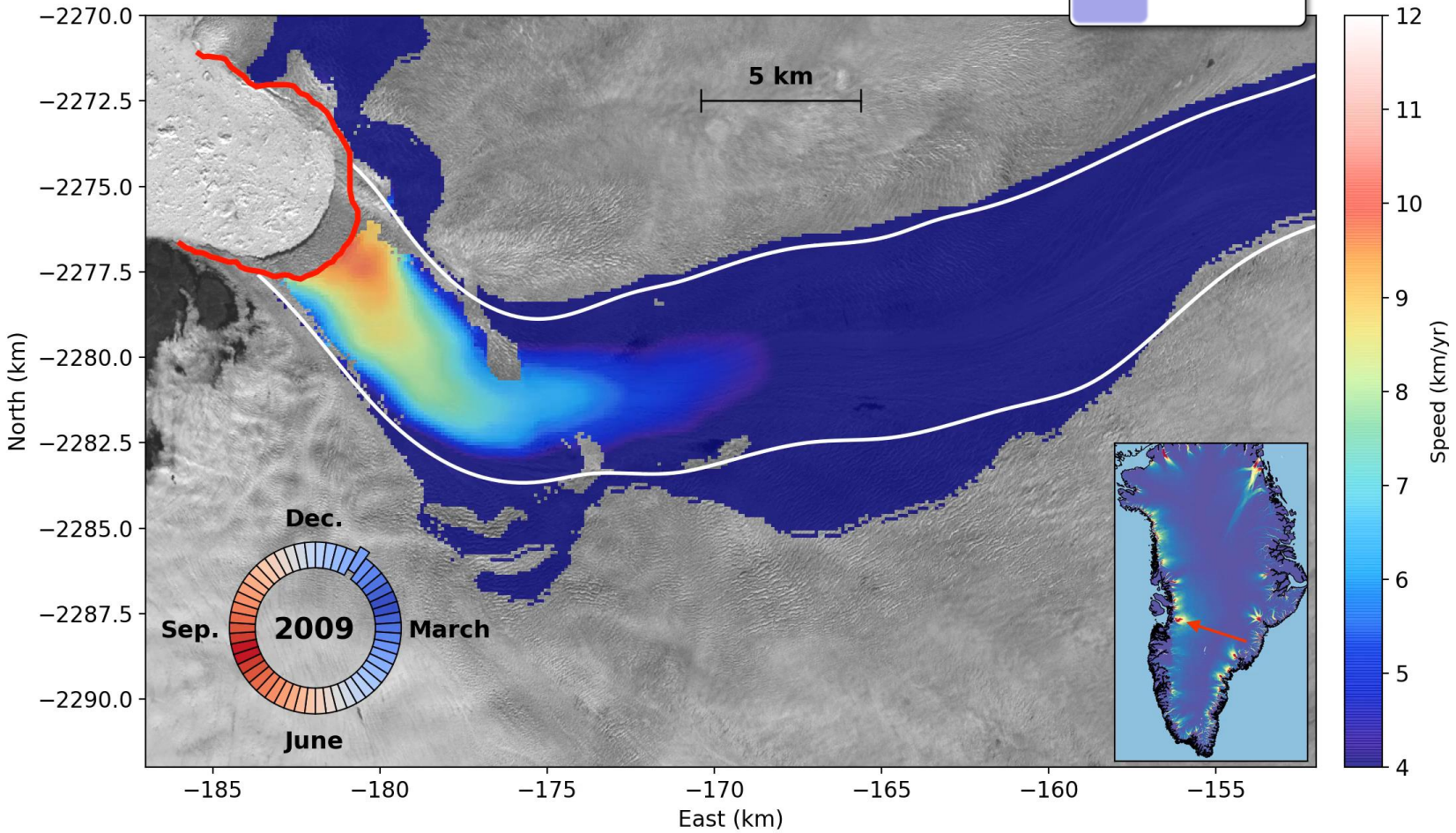
Managing Underground Gas Storage (UGS): Vertical surface displacement of a gas field related to the injection and extraction of gas volumes

Courtesy: A. Ferretti, TRE ALTAMIRA

Topic 3: Surface Displacement from Images

Fast(er) Motion Monitoring [m/y to km/y] Using Feature Tracking and Optical Flow

- **Lot's of surface motions can be too fast for InSAR to work (see lectures later on):**
  - **Glacier motion (and variations thereof)**
  - Sea Ice motion
  - Large earthquake motion
- **We will use feature tracking and optical flow techniques to estimate motion velocities and directions**



Bryan Riel. 2020. Animation of time-dependent velocity magnitudes for Sermeq Kujalleq (Jakobshavn Isbræ) from 2009 - 2019. Arctic Data Center. doi:10.18739/A2W66990B.

Topic 3: Surface Displacement from Images

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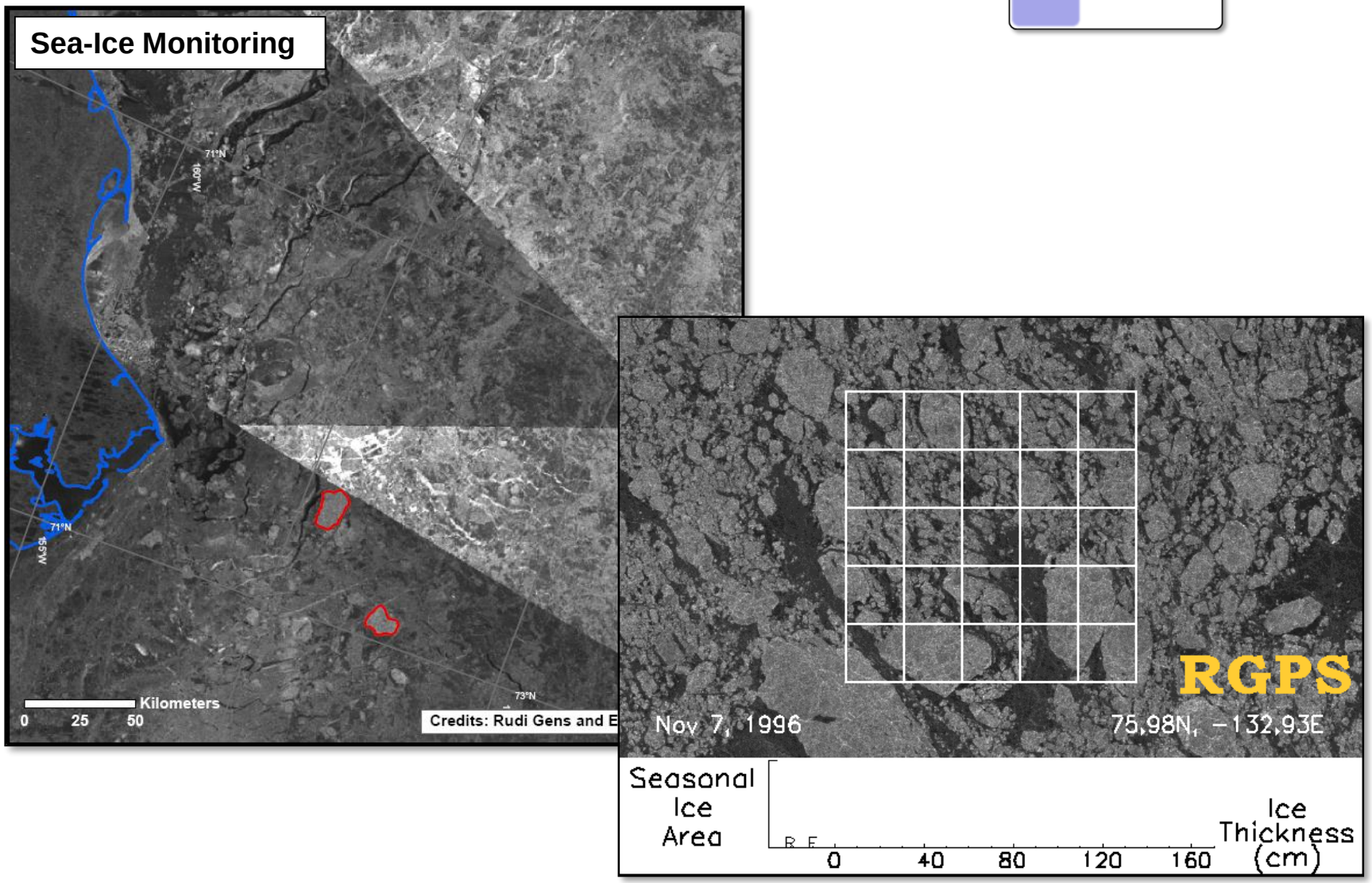
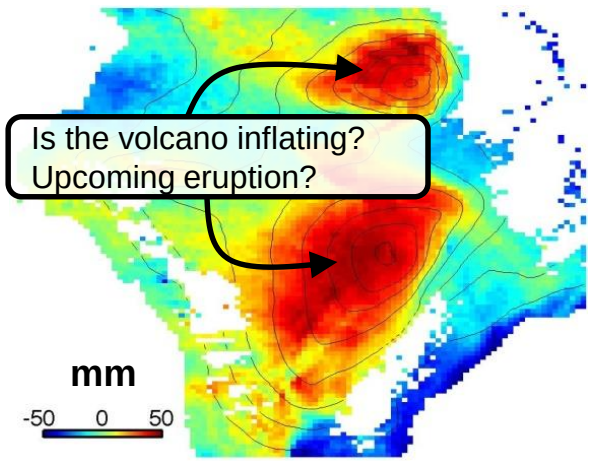


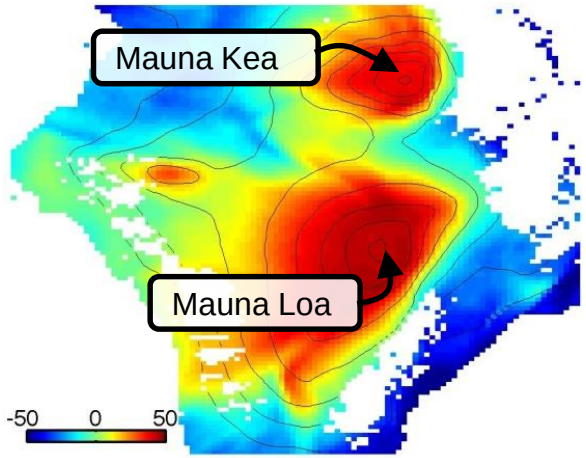
Limitations Of Imaging Geodesy Techniques

Atmospheric Delay / Ionospheric Delay

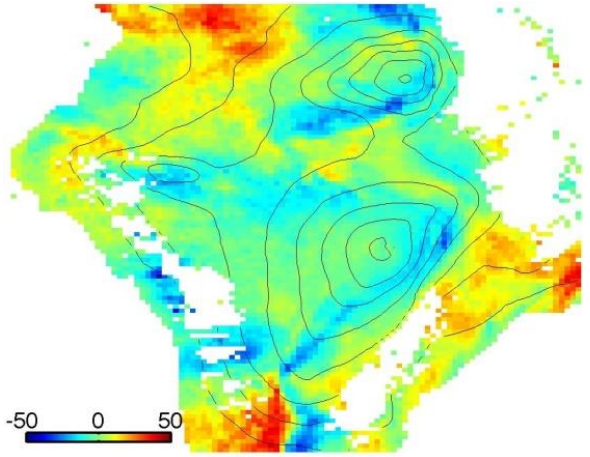
Atmospheric Signals can lead to incorrect interpretation of observations:



d-InSAR Observations, Big Island, Hawaii



Atmospheric Model

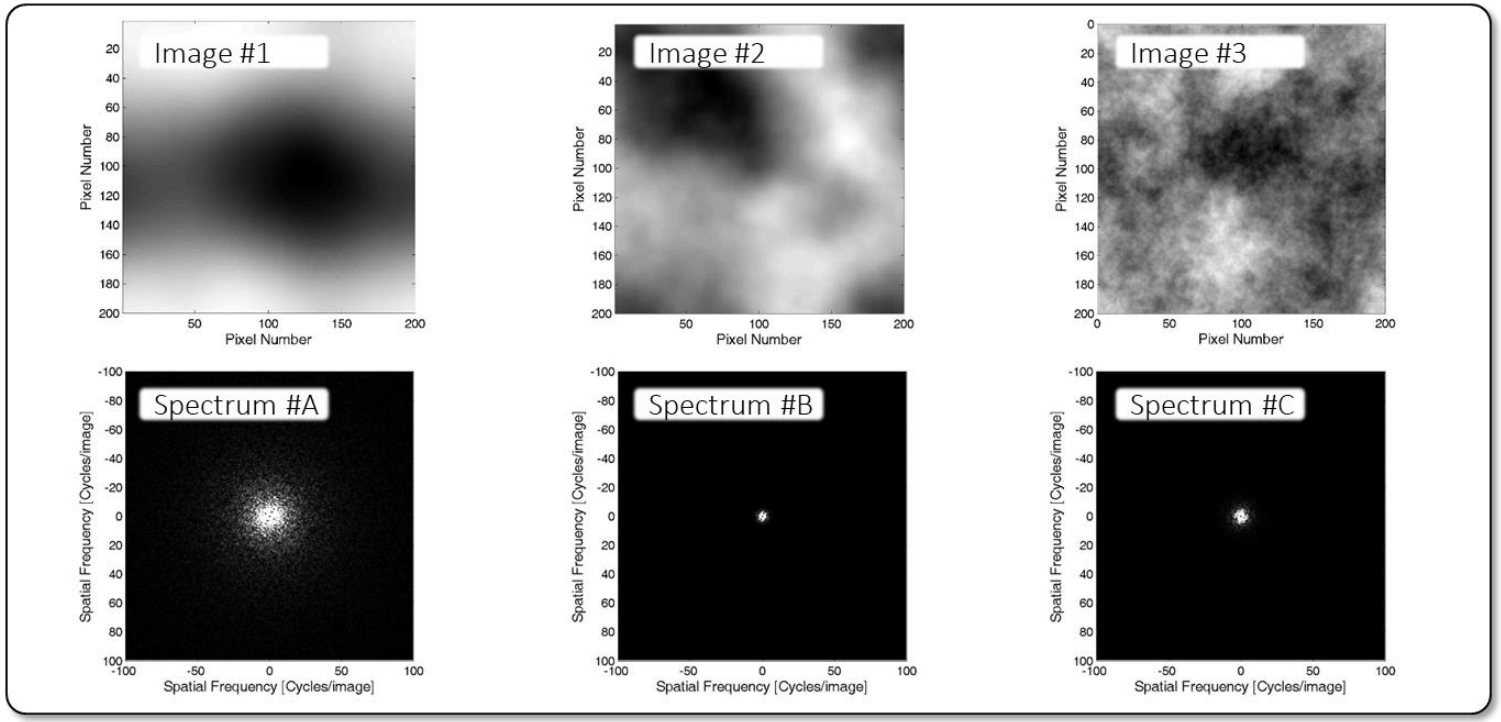


d-InSAR – Atmospheric Model

Limitations Of Imaging Geodesy Techniques

Assessing the Accuracy of Image Matching Algorithms

- **We will analyze the accuracy of image matching techniques used in feature tracking**
  - E.g. we will assess how accurate pixel offsets can be estimated using cross correlation techniques and how this accuracy depends on signal-to-noise, window size, and signal properties



WHY TAKE THIS COURSE NOW?

THE GOLDEN AGE OF REMOTE SENSING

The Golden Age of Remote Sensing

SAR: Free-and-Open, Regularly-Sampled, Global, Cloud-Free Earth Observation Data from Space

Sentinel-1

esa

Frequency: C-band

Launch Date: 2015 & 16

NISAR

NISAR

NASA - ISRO SAR Mission

NASA

Frequency: L-band

Launch Date: Spring 2023

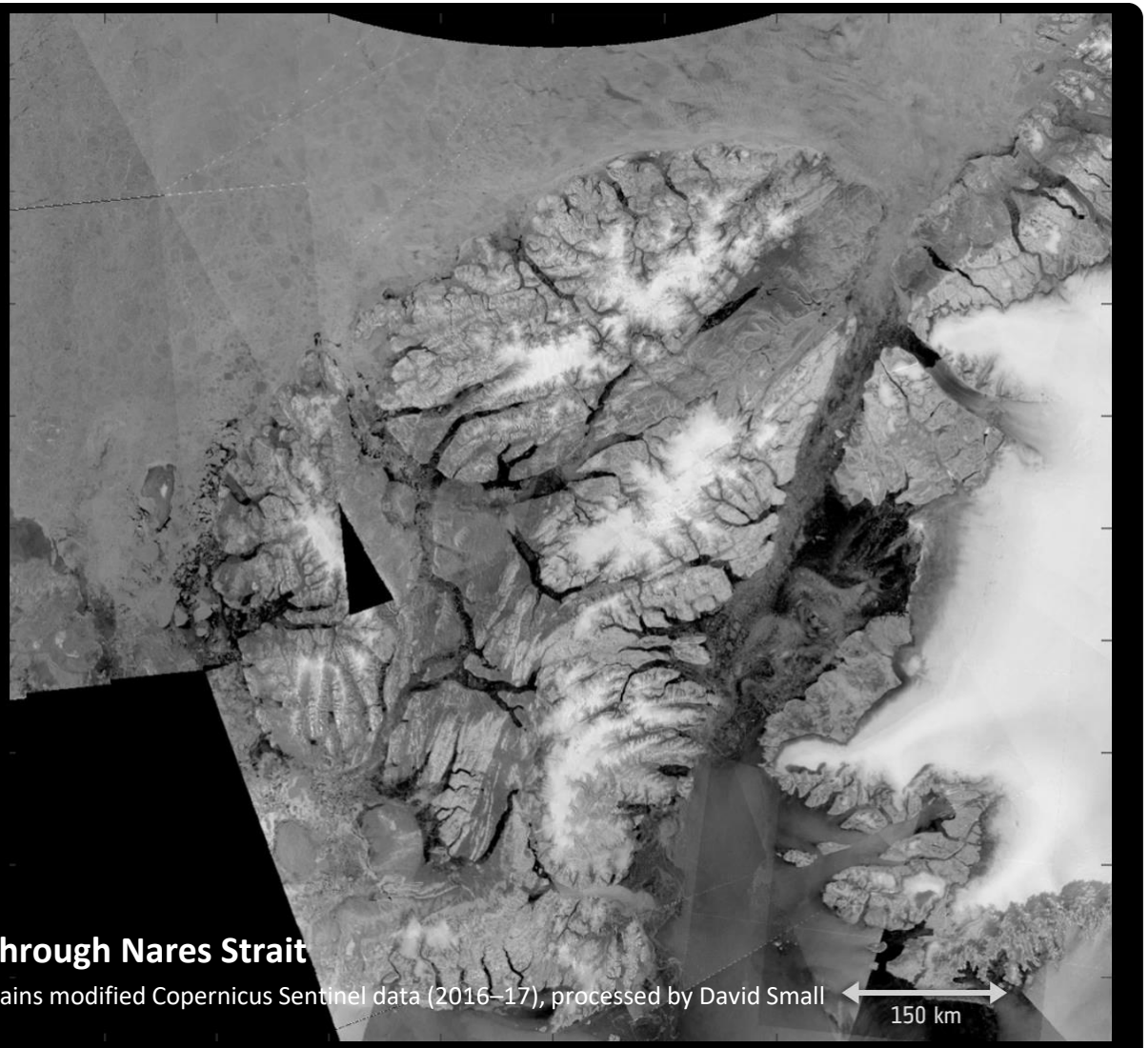
TanDEM-L

DLR

Frequency: L-band

Launch Date: TBD

October 2016
November
December
January 2017
February
March
April
May



Arctic Sea Ice Export through Nares Strait

Copyright contains modified Copernicus Sentinel data (2016–17), processed by David Small

Radar Systems with Operational Character

- **Sentinel-1 (2014 - today): First SAR satellite system with operational mission**
  - Regular reliable observation according to operational requirements
  - Imaging all landmasses, coastal zones and shipping routes every six days
  - Specifically designed for InSAR

FREE AND OPEN DATA!

Preparation for NASA-ISRO SAR (NISAR) Radar Earth Observation Satellite Project

Launch Spring 2023

First spaceborne L- and S-band SAR

Full global coverage in 12 days

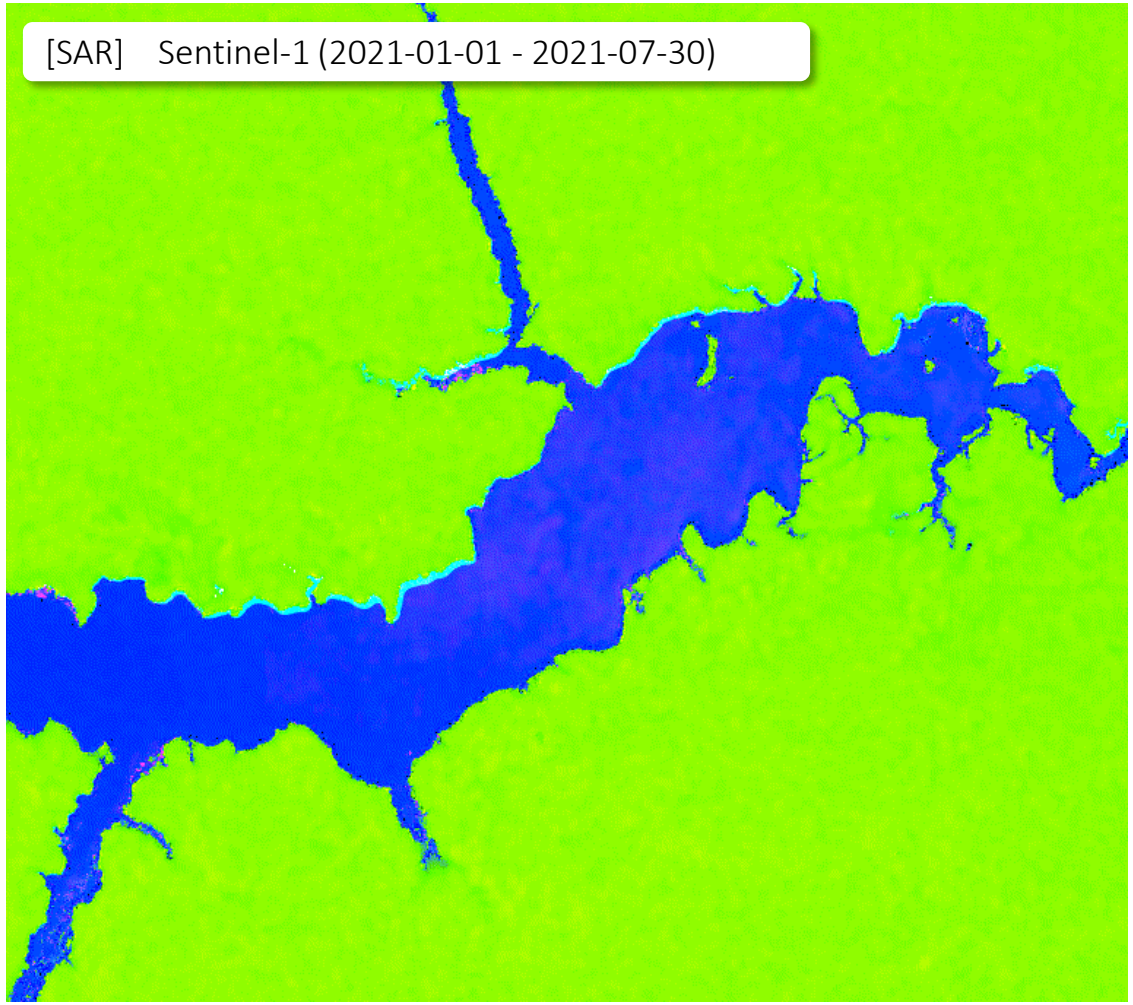
150 Petabyte of Earth Observation data / year

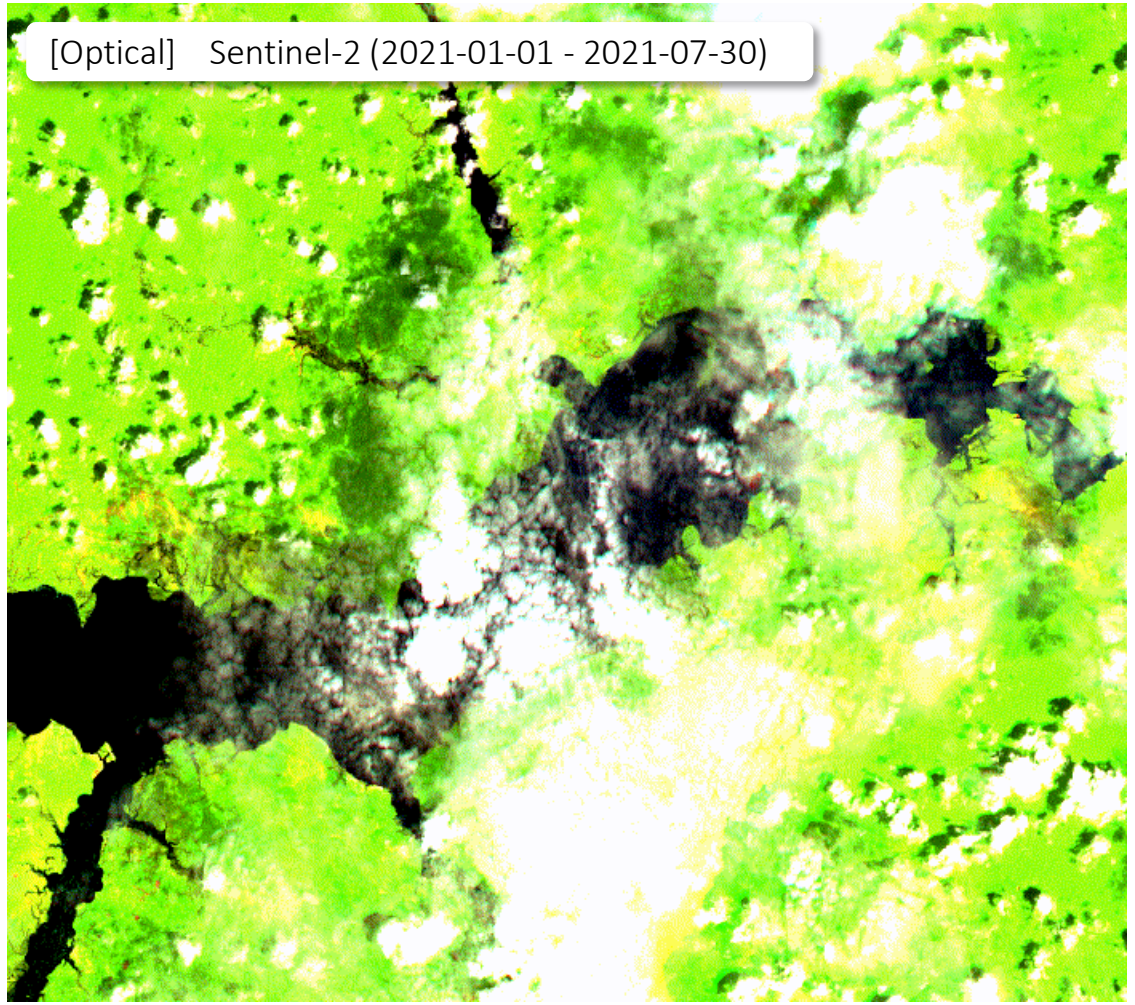
All Data Free and Open!

NISAR Involvement

- NISAR Data Center
- NISAR Ground Station
- NISAR Science Team Member
- NISAR L2 Algorithm Development

Cloud Free? Yes, Really!!

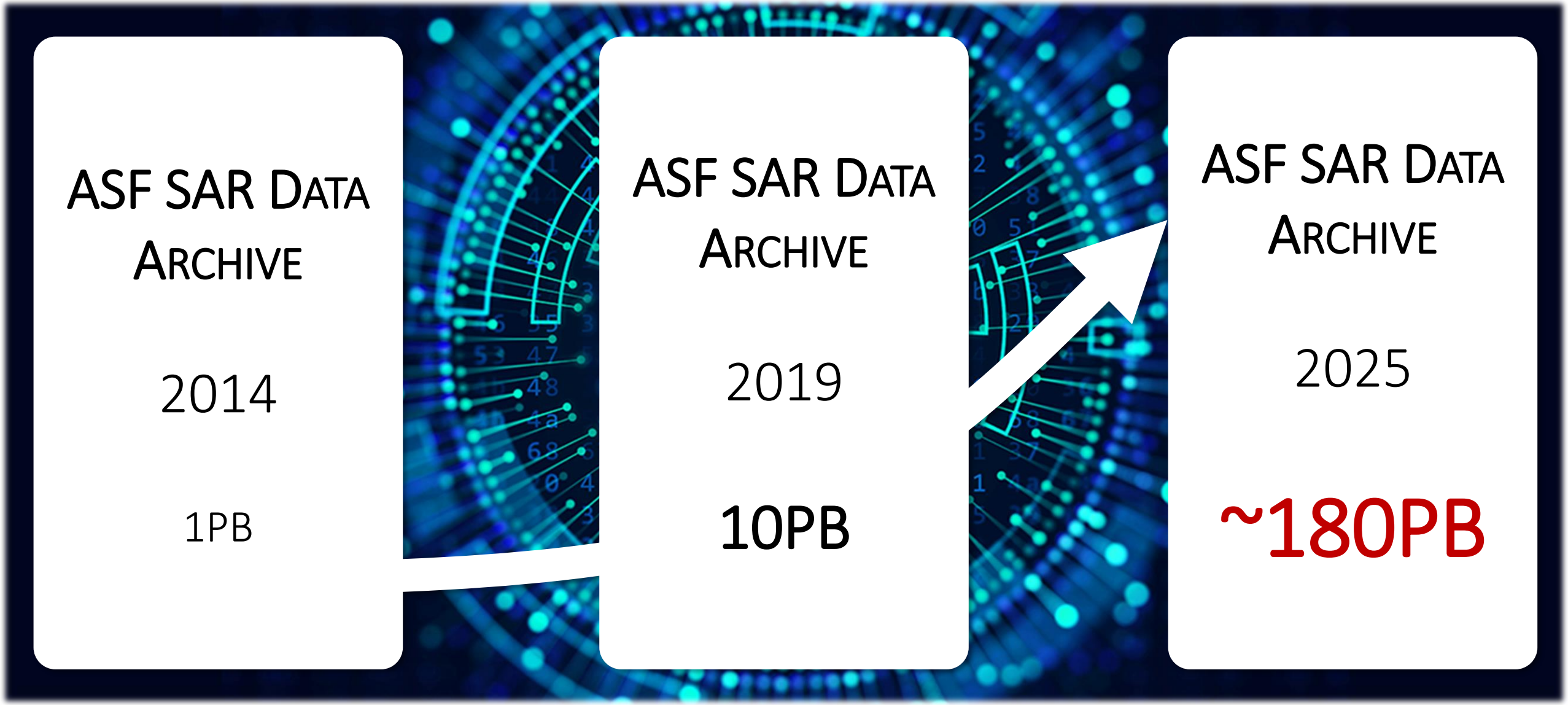




Seasonal Flooding in the Amazon Region

The Golden Age of Remote Sensing

SAR: Unprecedented Earth Observation Data Volumes



The Golden Age of Remote Sensing

Optical: The Landsat Time Series

Landsat:
Consistent Earth Observation Data Since 1972

https://svs.gsfc.nasa.gov/11433

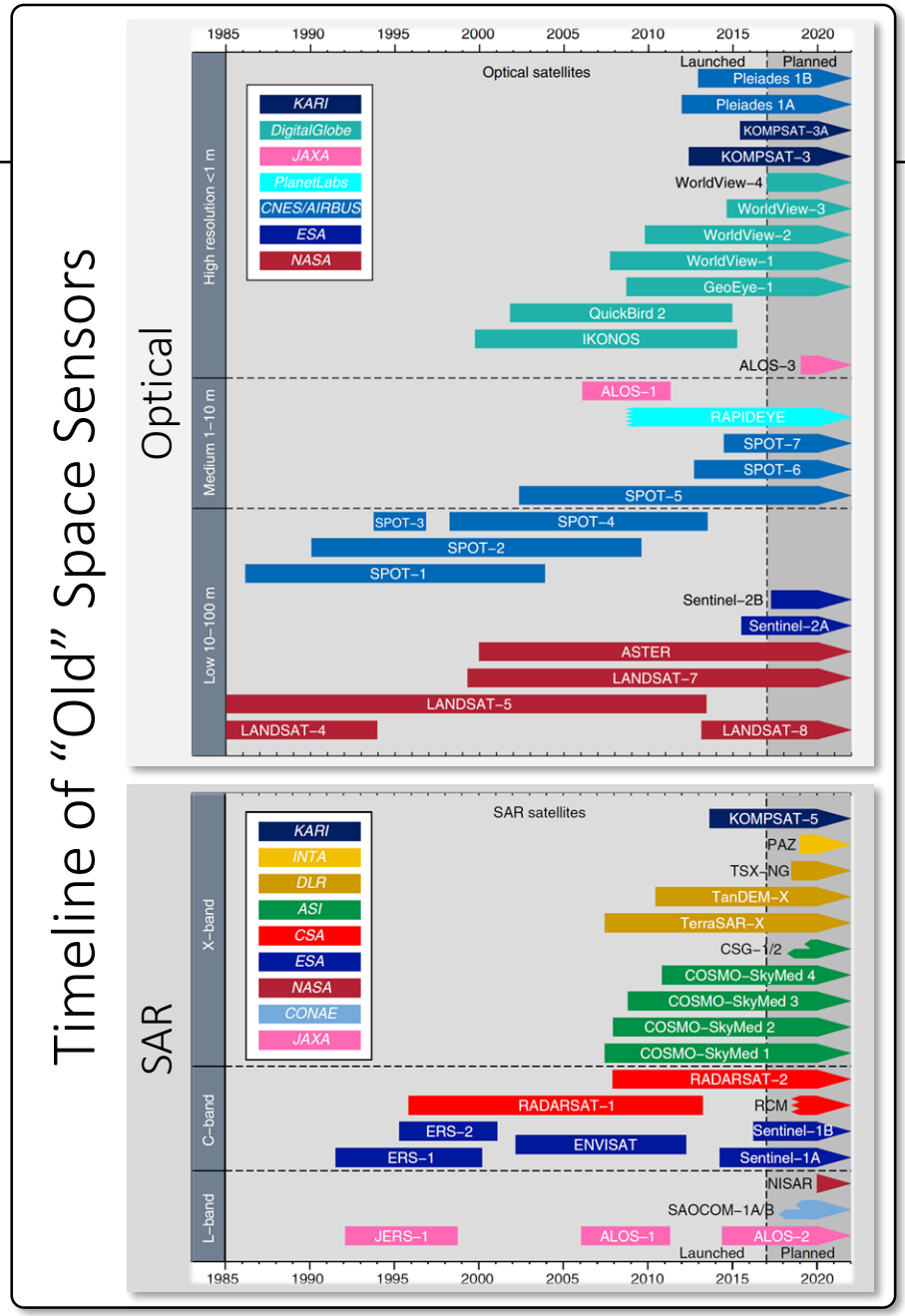
Exploding Constellation of Imaging Earth Observation Sensors

- **Growing constellation of traditional (old space) remote sensing sensors**

- **Additionally a ever growing availability of New Space Earth Observation data:**

Optical
- Planet constellation (RapidEye; Dove; Skysat)
- Blacksky optical sensors
- Satellogic
- …

SAR
- ICEYE
- Capella Space
- Umbra
- …



COURSE TOOLS

Technology to Support the Course

Modern Tools to enable earth-observation data analysis from (almost) anywhere

https://opensarlab.asf.alaska.edu/

Tools to Stay in Touch

Link to Canvas page

Class Project Information

- Students will complete a class project on SAR
- Wide range of options available
- Group work for class project is allowed but should be discussed with me
- Several class projects in recent years led to publications

QUESTIONS?