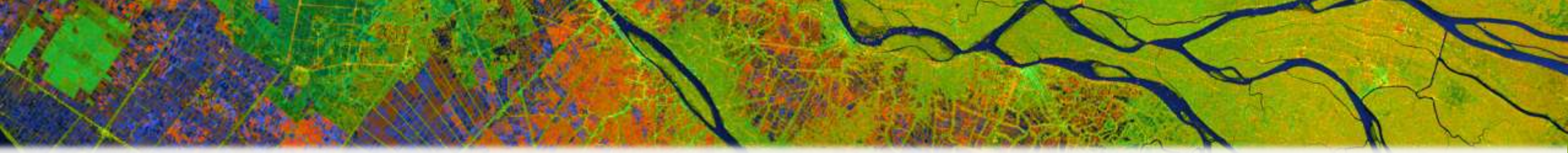


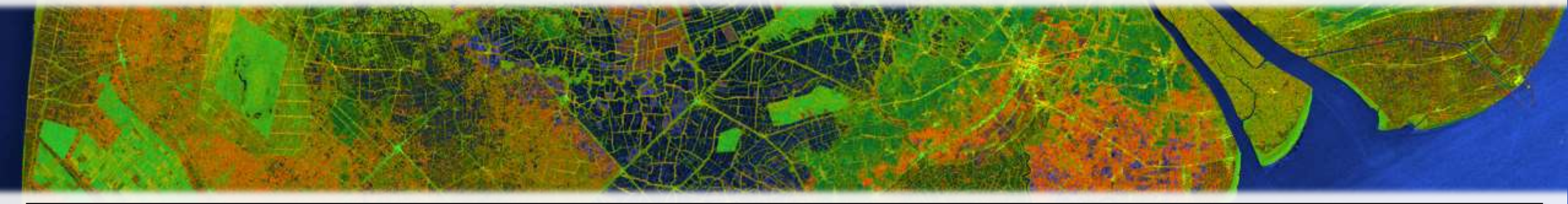
GEOS 639 – INSAR AND ITS APPLICATIONS

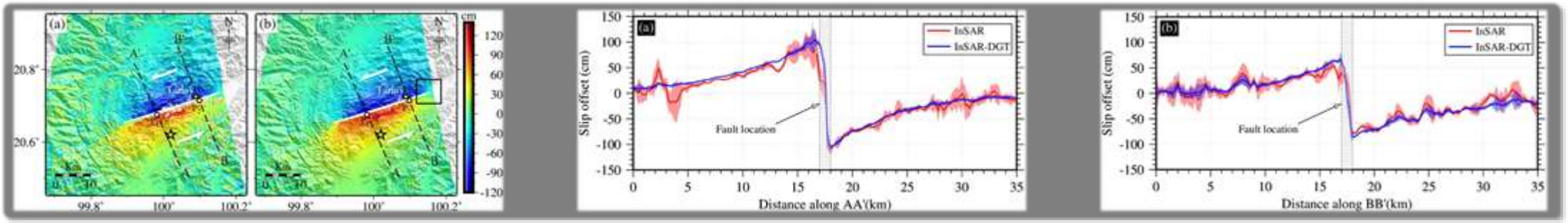
GEODETIC IMAGING AND ITS APPLICATIONS IN THE GEOSCIENCES

Lecturer:

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

Lecture 1: Introduction to the Course





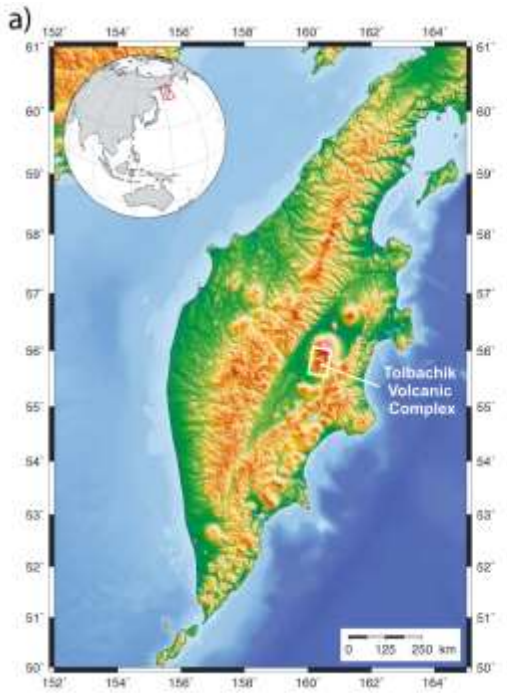
A Look at Some Applications Relevant for this Course

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

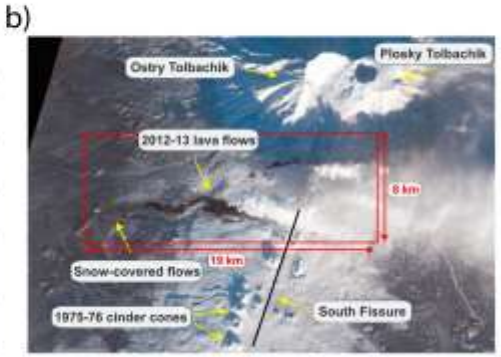
Measuring Shape: Why We Care About DEMs

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

Location



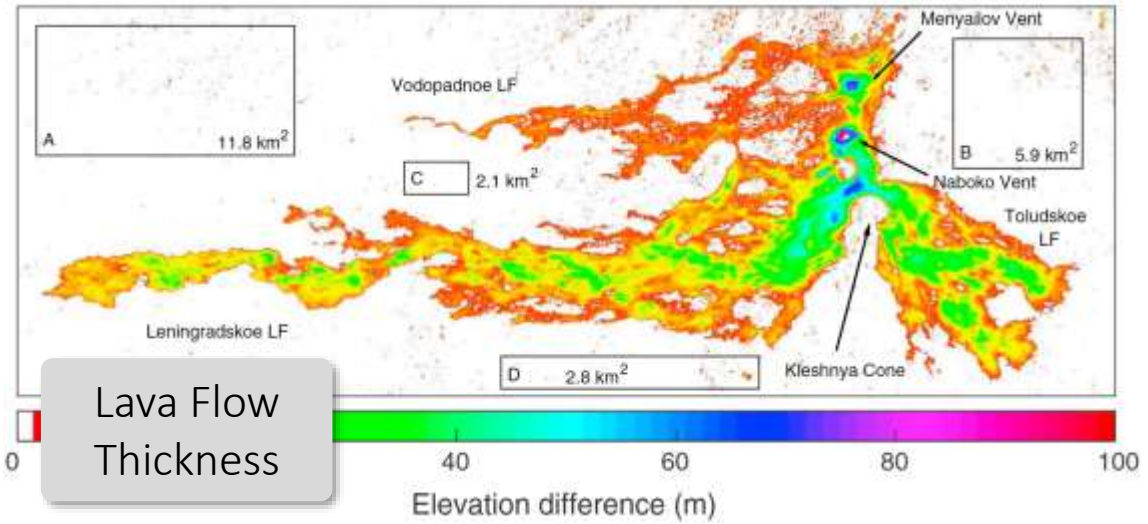
(a) Location of Tolbachik volcano. White rectangle shows footprint of TanDEM-X data; (b) The Tolbachik volcanic complex during the 2012–2013 fissure eruption.

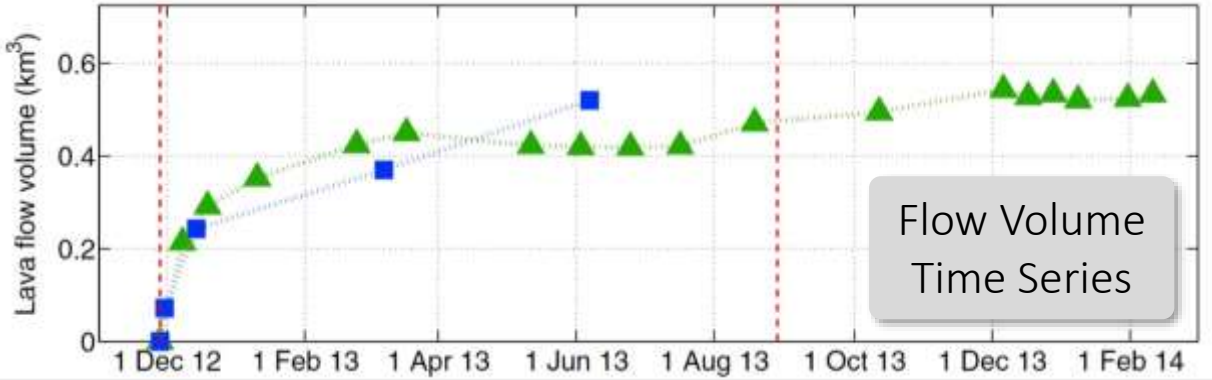


Data

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





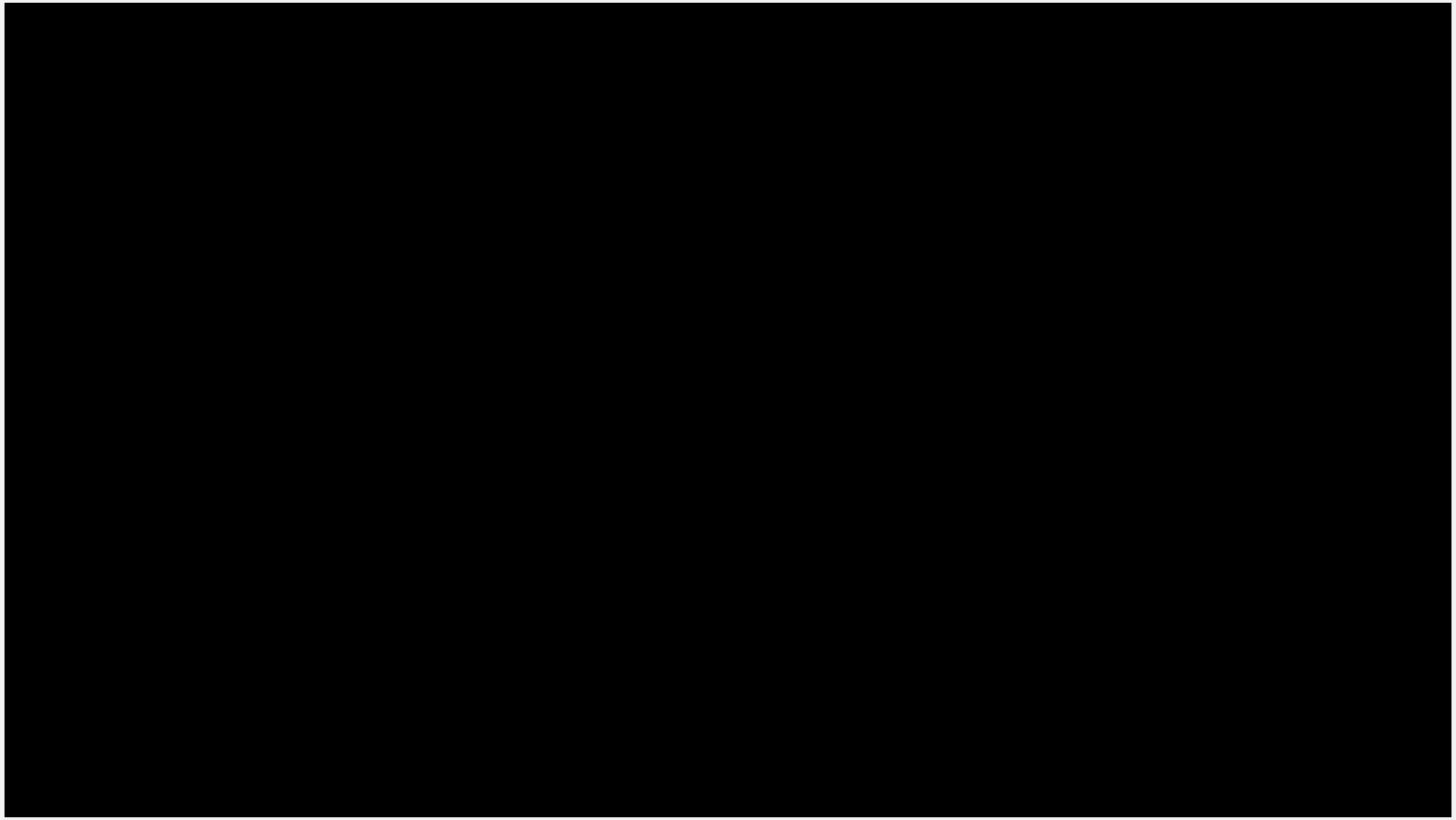
Kubanek, J., Westerhaus, M., & Heck, B. (2017). TanDEM-X time series analysis reveals lava flow volume and effusion rates of the 2012–2013 Tolbachik, Kamchatka fissure eruption. *Journal of Geophysical Research: Solid Earth*, *122*(10), 7754-7774.

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]

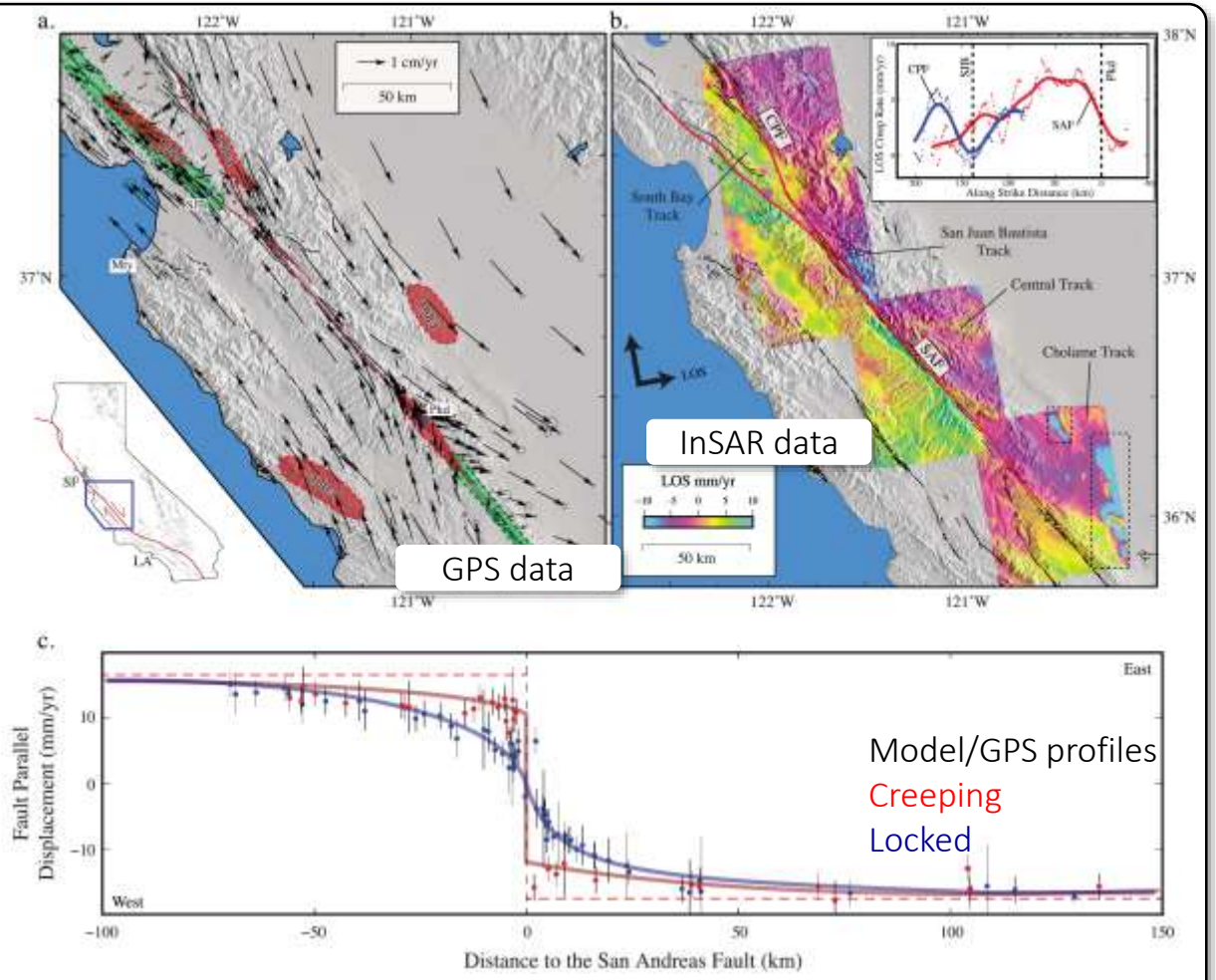


Data acquisition, data processing, and animation by M. Nolan, Fairbanks Fodar; more at https://fairbanksfodar.com/the-first-fodar-map-of-denali-alaska

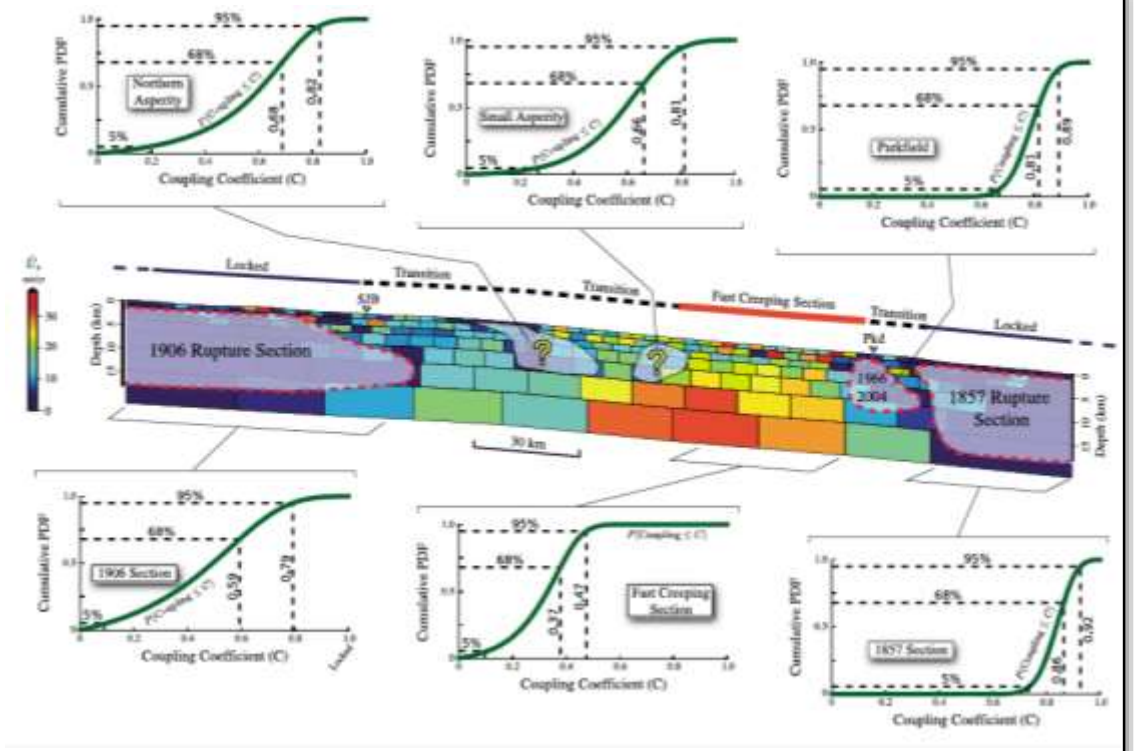
Why We Measure Displacements

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

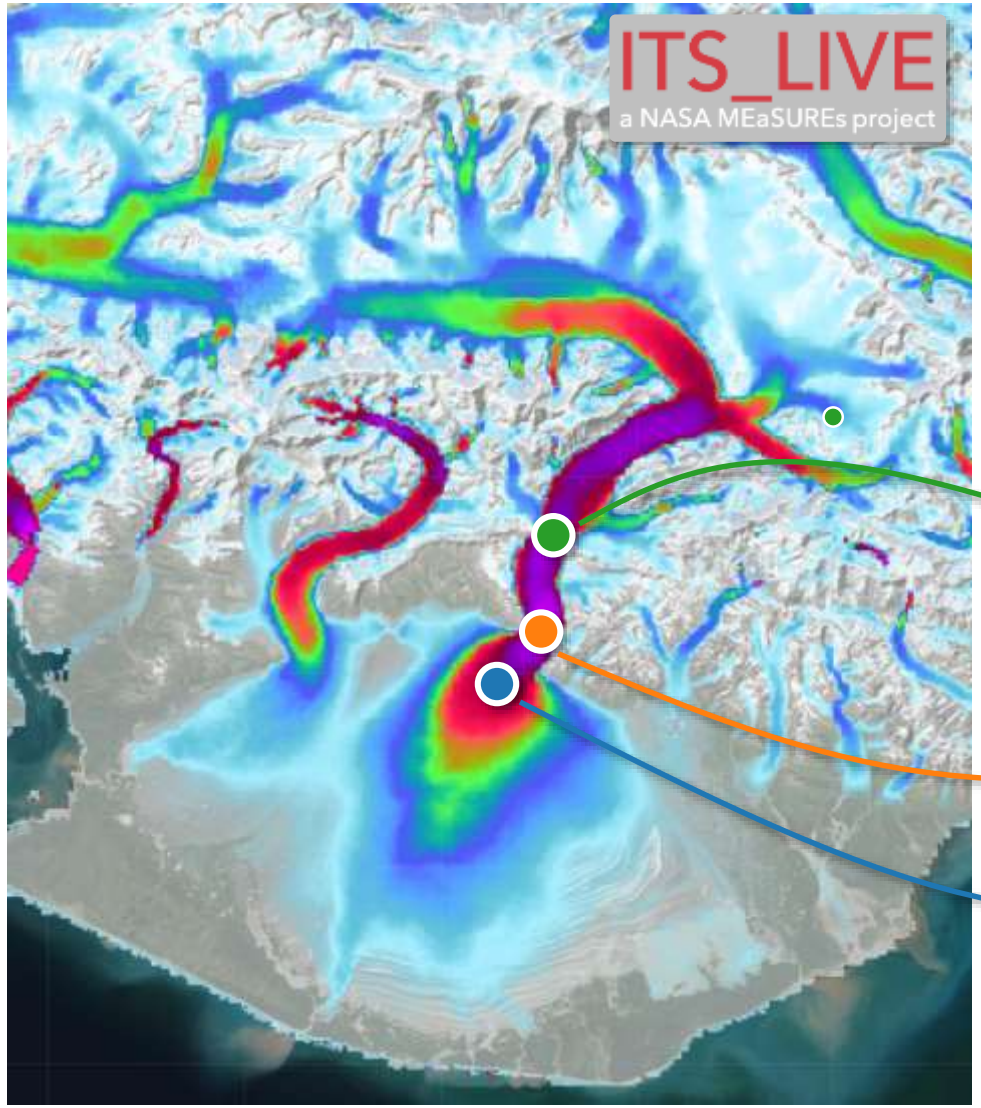


Courtesy: M. Simons, Caltech

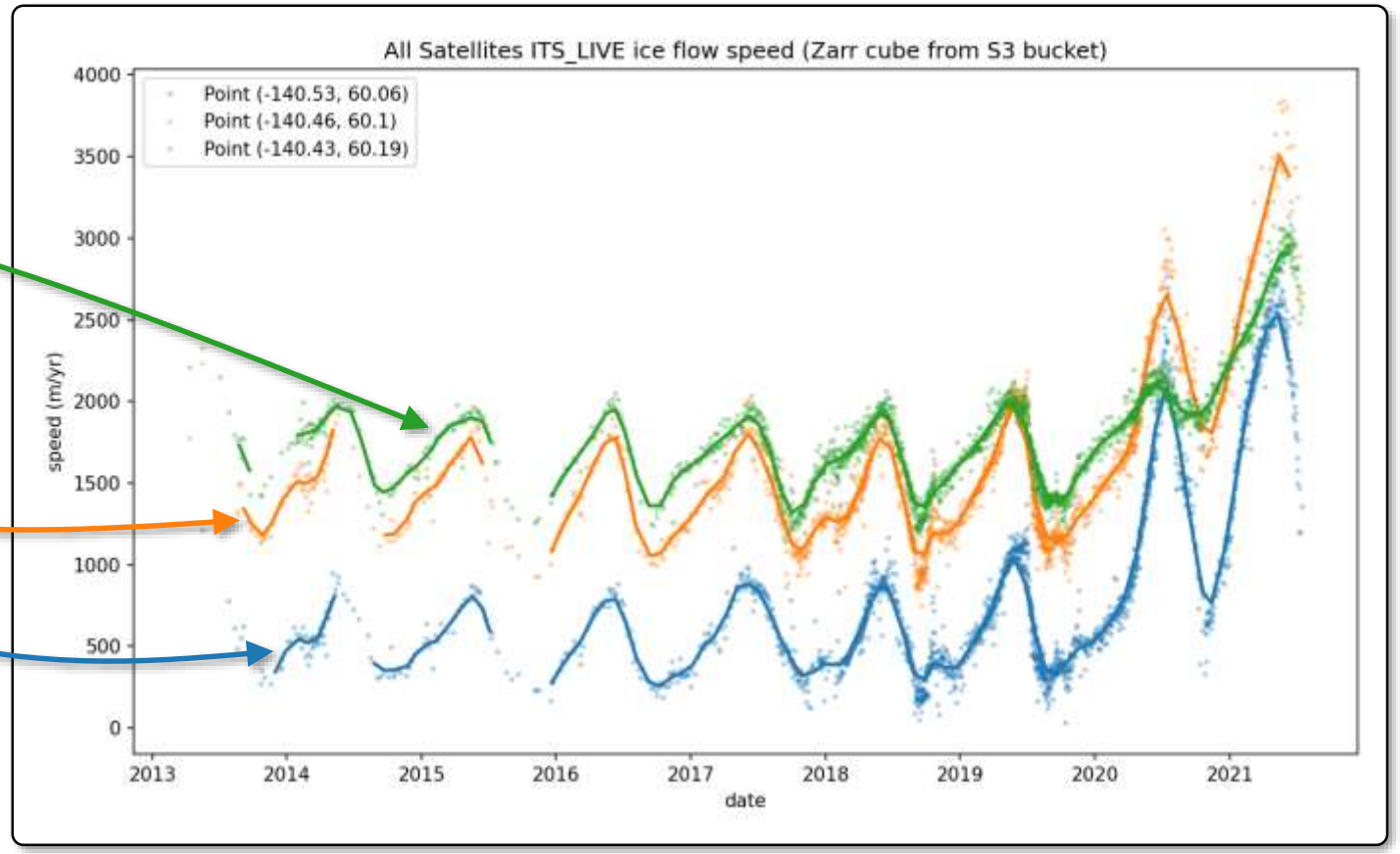
Locked or Creeping: Fully probabilistic Bayesian unsmoothed inference including both data and model prediction covariance

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!



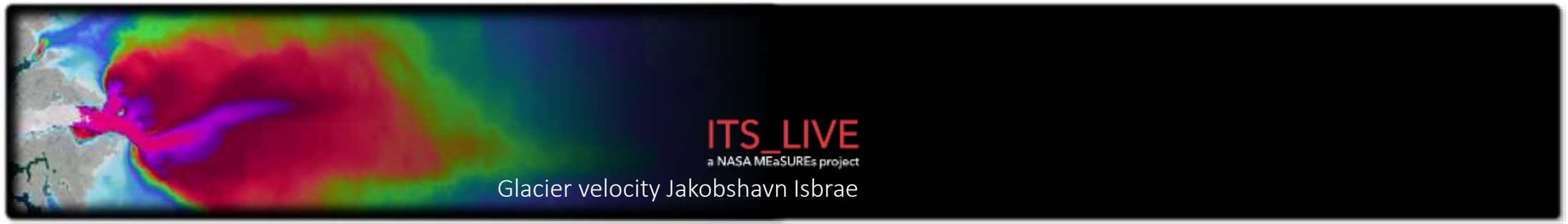
A Second Interactive Vehicle

Mentimeter Polling

Mentimeter

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

- Here is your first Mentimeter poll:



Glacier velocity Jakobshavn Isbrae

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

University of Alaska Fairbanks, Fairbanks, AK

Let’s have a look at the class Canvas Page

The Workshop Concept

- **Outline of the Class (see Syllabus on Canvas):**

1. Overview	Techniques & applications of Geodetic Imaging
2. Shape	Geodetic Imaging Methods to measure shape
3. Motion	Measuring surface motion from images
5. Geodesy to Geophysics	Including geodetic data into geophysical models
6. Class Projects	Experience geodetic imaging in mini projects

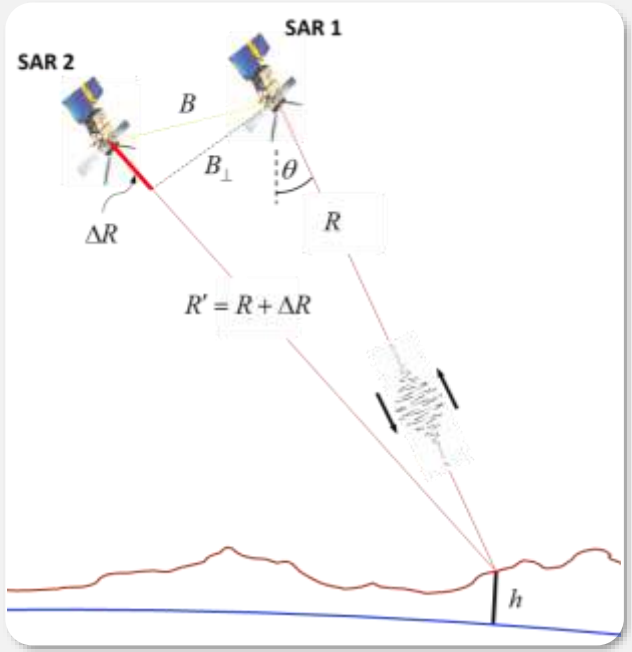
- **Introduction to Cloud-based and Python-based SAR data processing:**
  - No data download and no local compute hardware needed
    → High-performance computing from any internet-connected device
  - Full access to relevant data sets and open-source software
  - Use as you need – only download what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

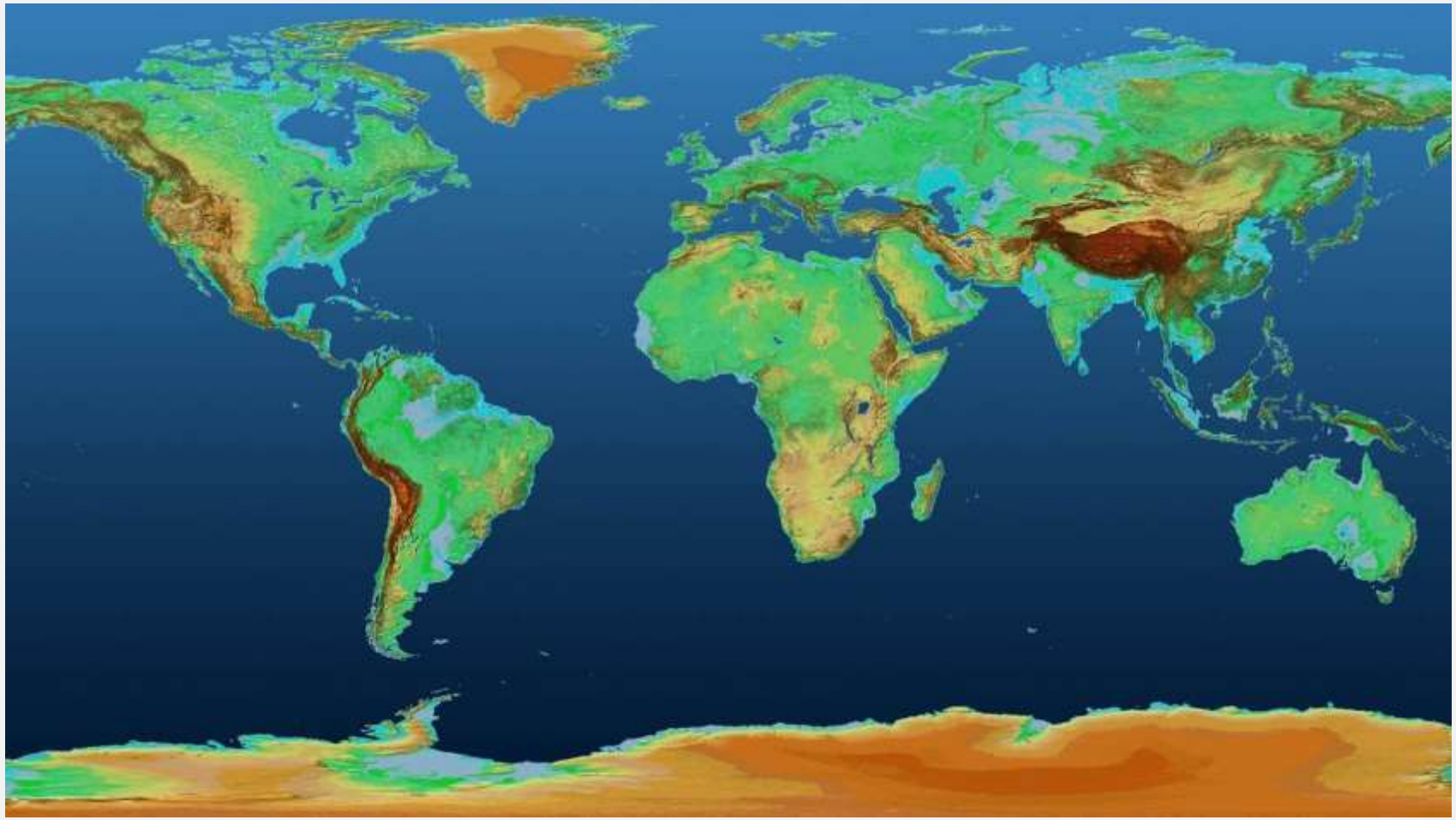
Opensarlab.asf.alaska.edu

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

Topic 2: Reconstructing Shape from Images

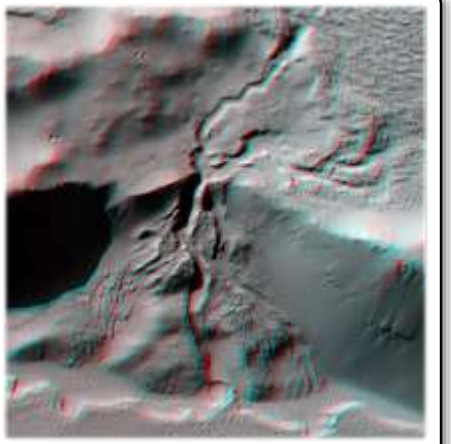
DEM Reconstruction from Images – InSAR





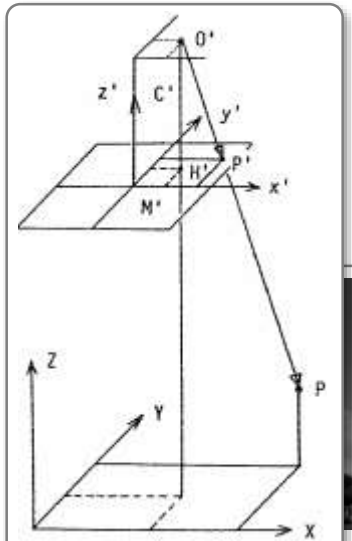
Topic 2: Reconstructing Shape from Images

DEM Reconstruction from Images – Stereo Photogrammetry

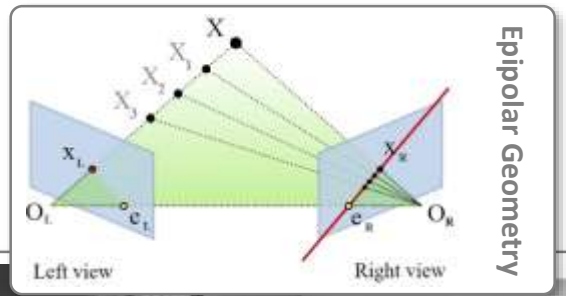


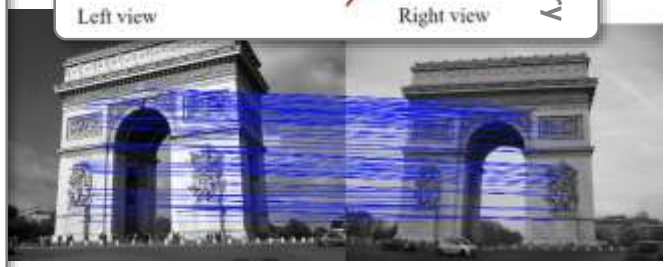
Stereo Image Pair

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



Collinearity condition

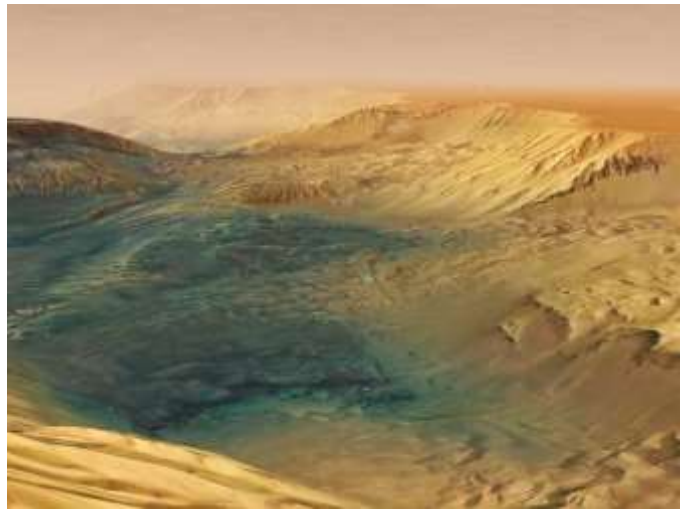




Robust Image Matching

Stereo-Photogrammetry Pipeline

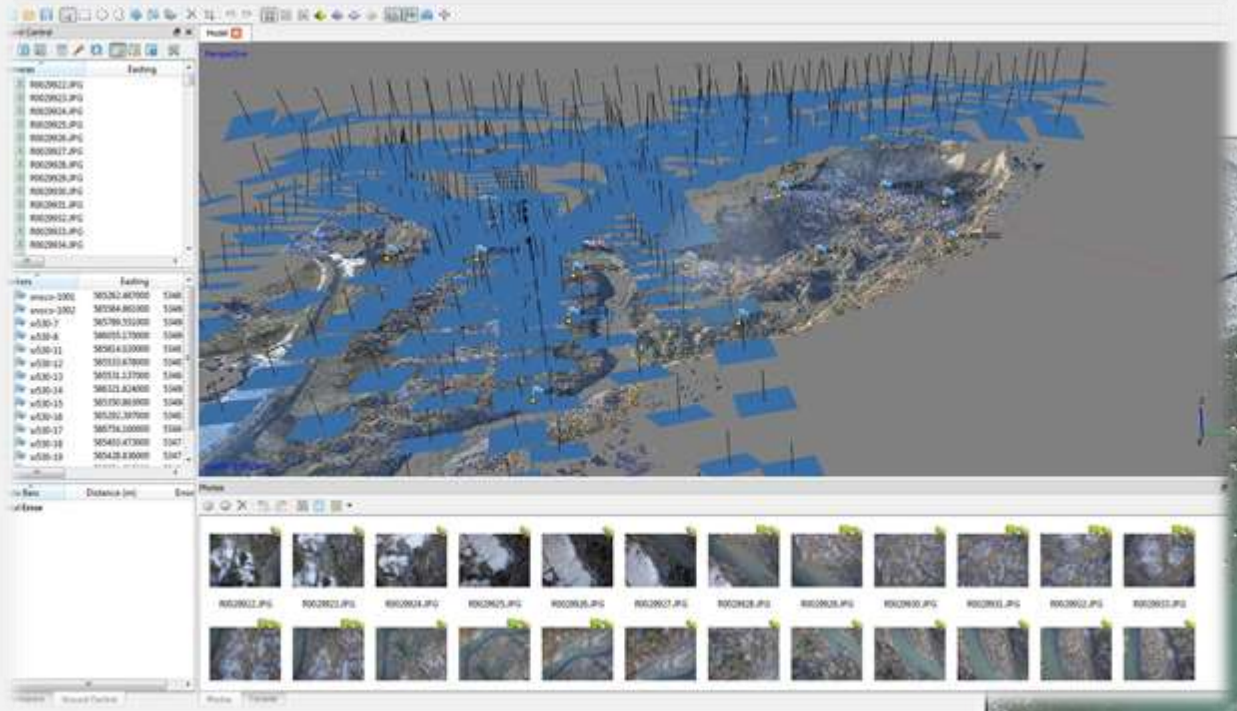
http://www.esa.int/Our_Activities/Space_Science/Fly_through_a_canyon_on_Mars

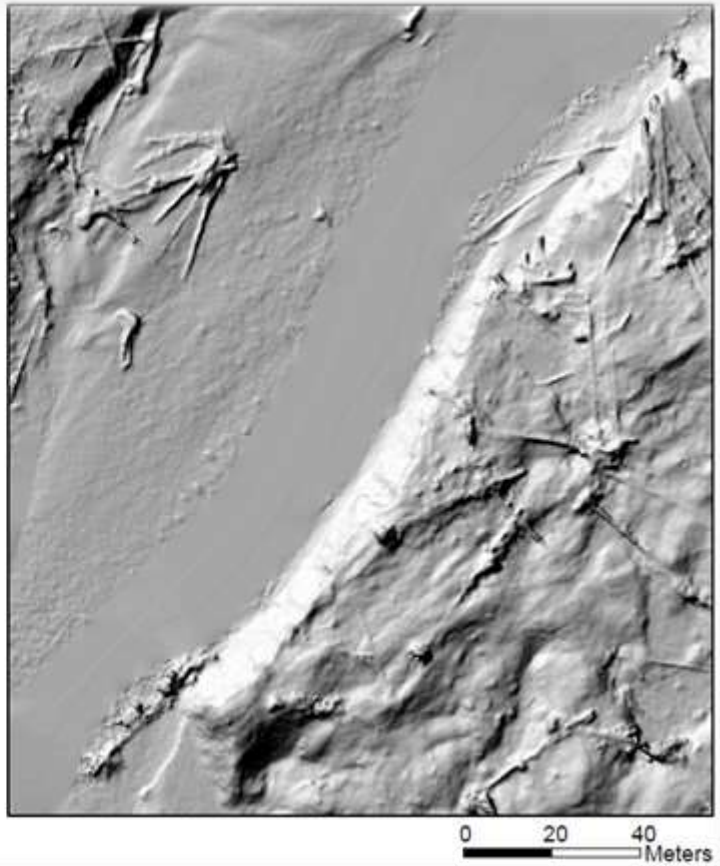


Ortho imagery & 3D Reconstruction

Topic 2: Reconstructing Shape from Images

DEM Reconstruction from Images – Structure from Motion

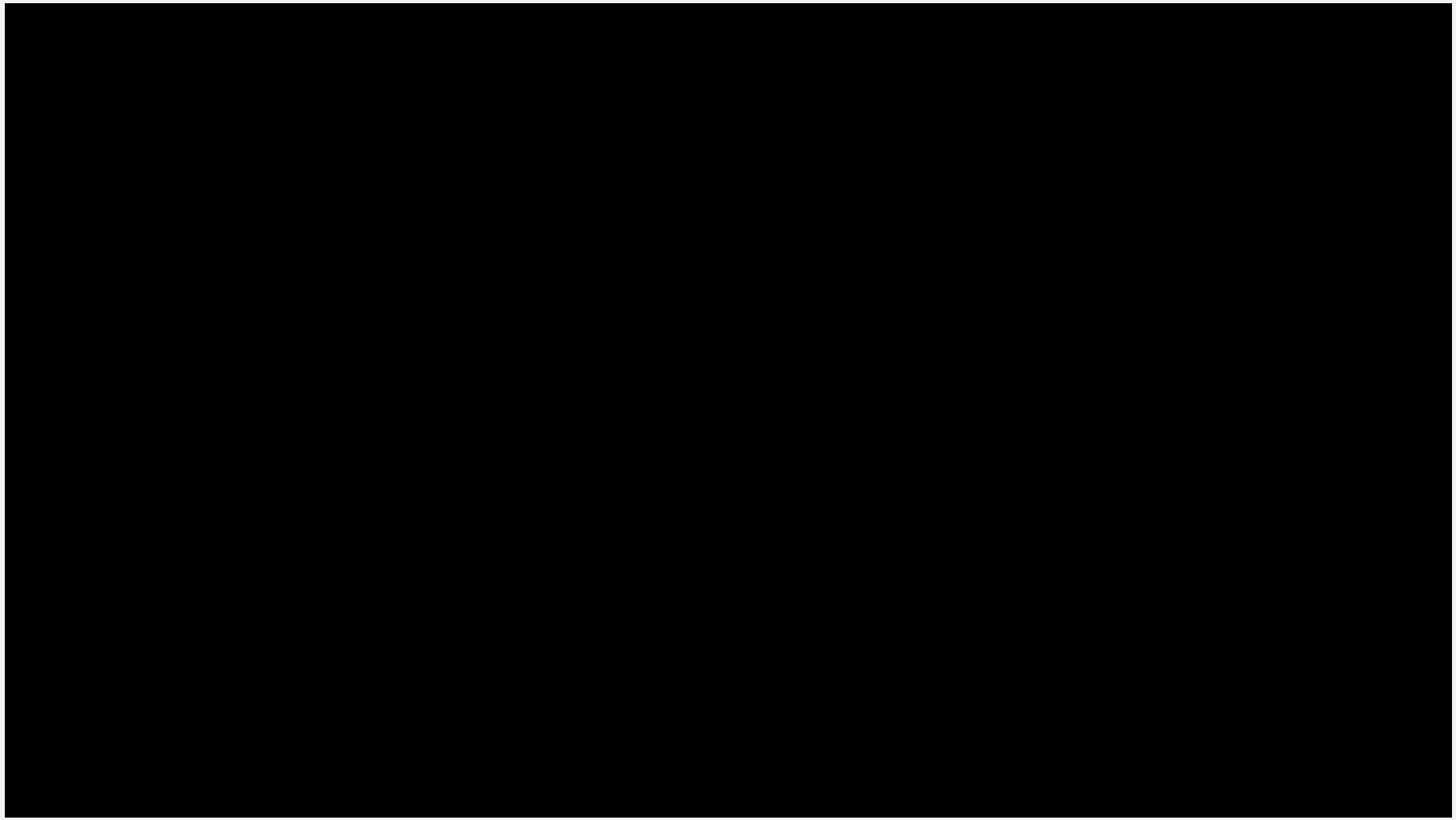




http://wa.water.usgs.gov/projects/sr530/remotesensing.htm

Topic 2: Reconstructing Shape from Images

3D Object Reconstruction from Images Blocks



Topic 2: Reconstructing Shape from Images

3D Reconstruction – Other Methods

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

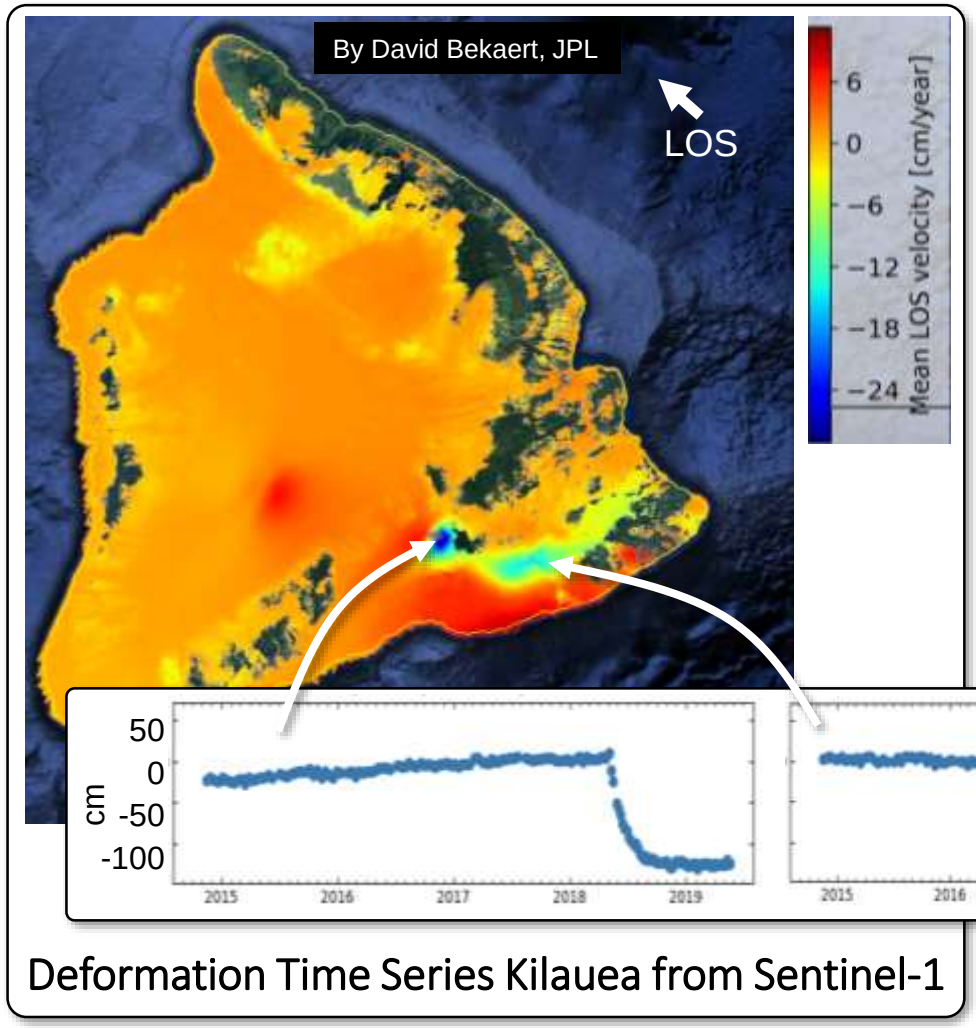
Qualitative results for shape and reflectance estimation from a single image: input image [30], estimated normals and reflectance map, and novel view (from left to right).

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

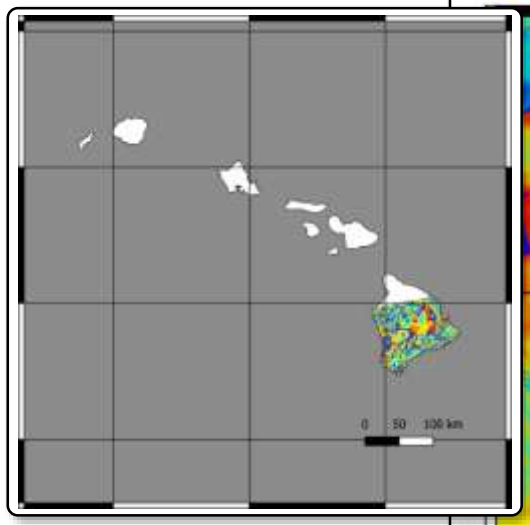
Topic 3: Surface Displacement from Images

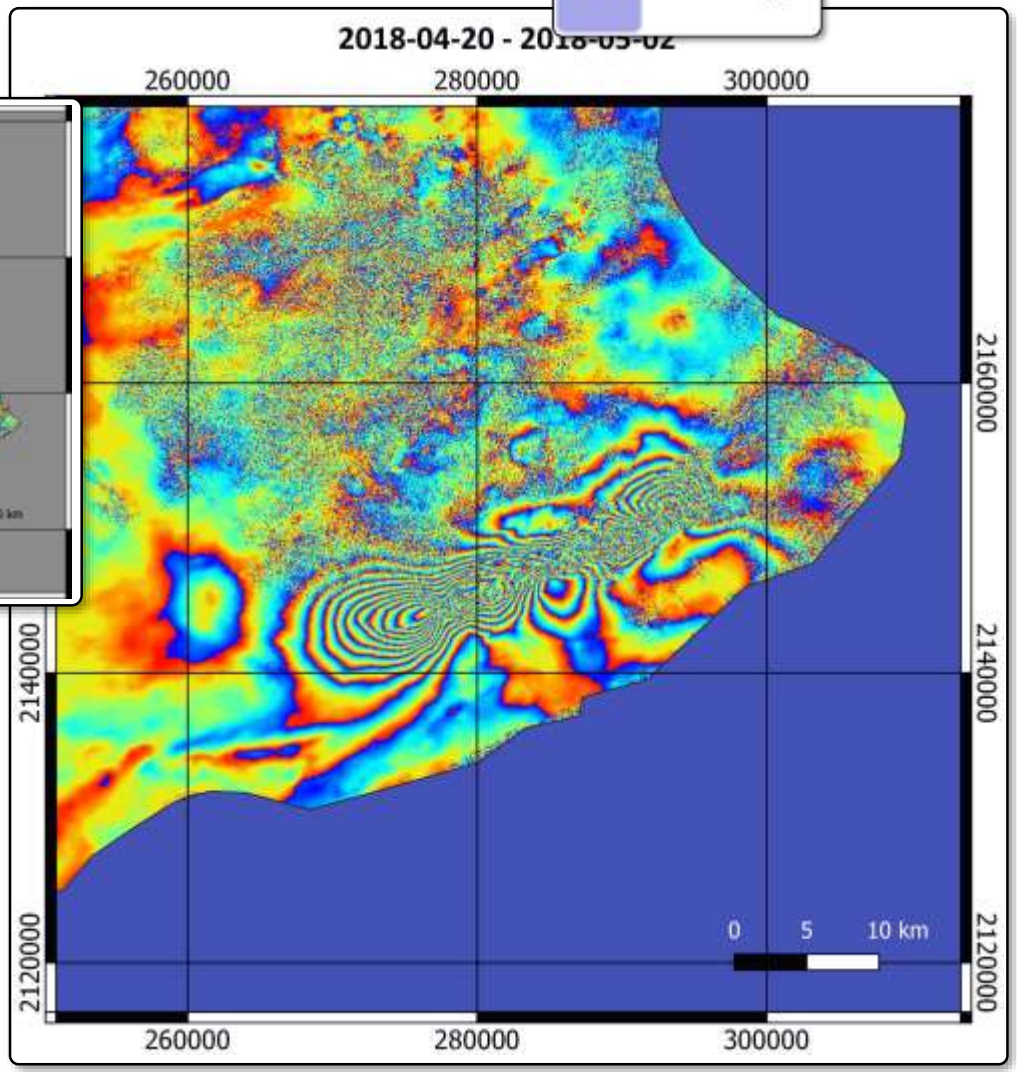
Slow Motion Monitoring [mm/y to m/y] with InSAR

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



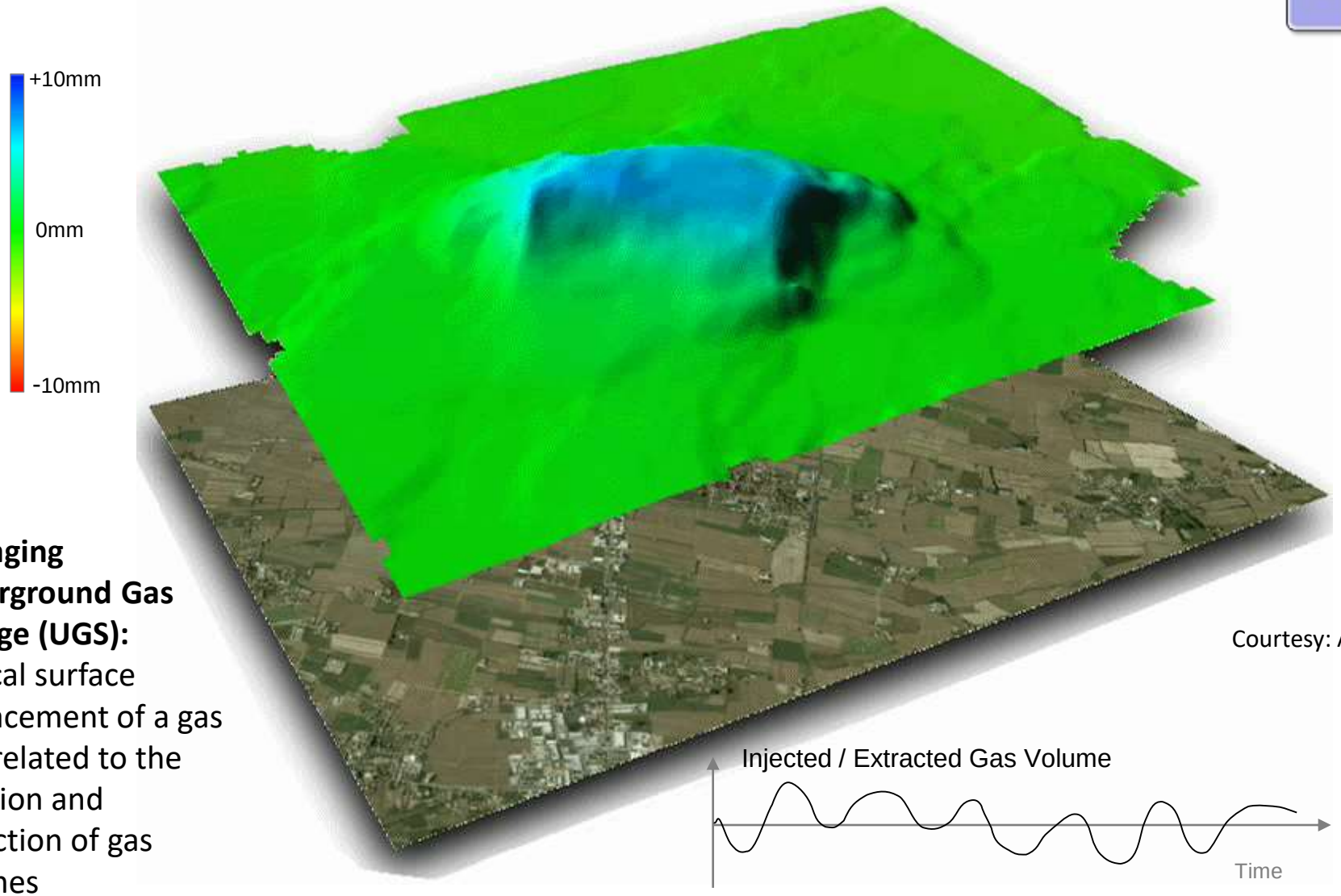
Deformation Time Series Kilauea from Sentinel-1





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

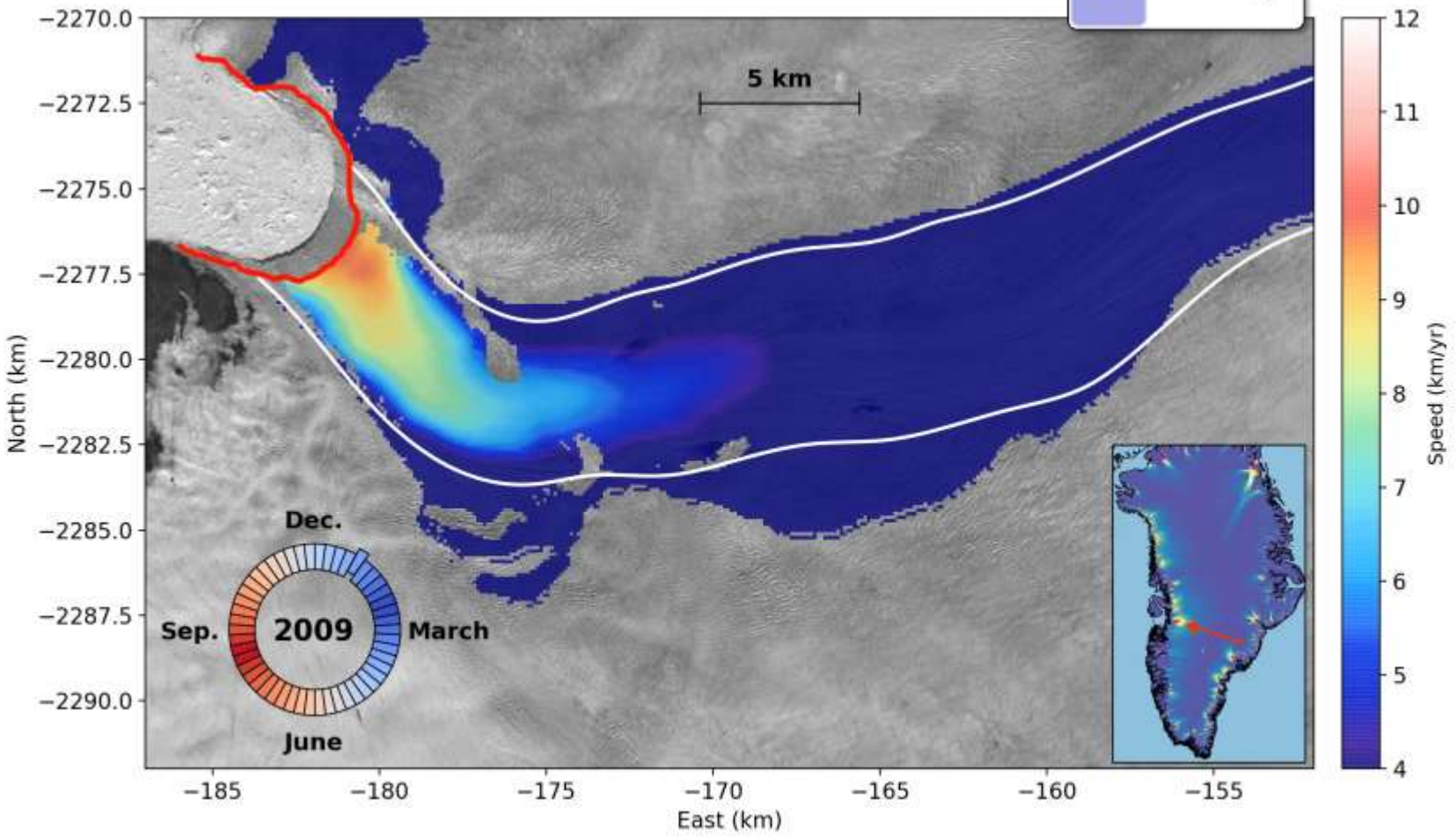
Courtesy: A. Ferretti, TRE ALTAMIRA

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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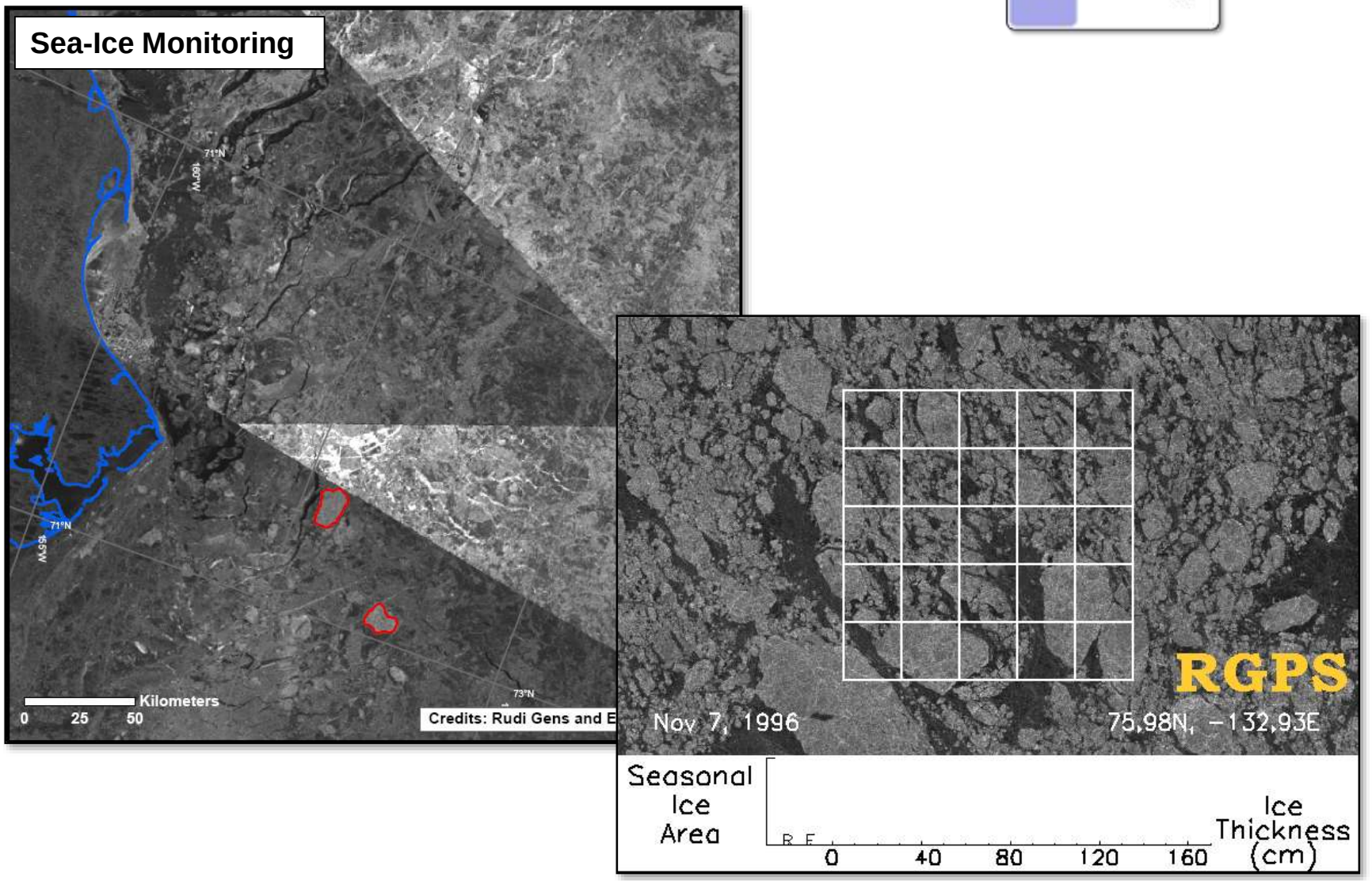
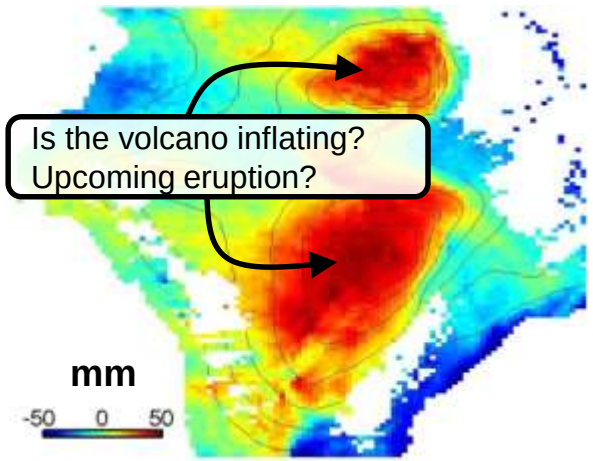


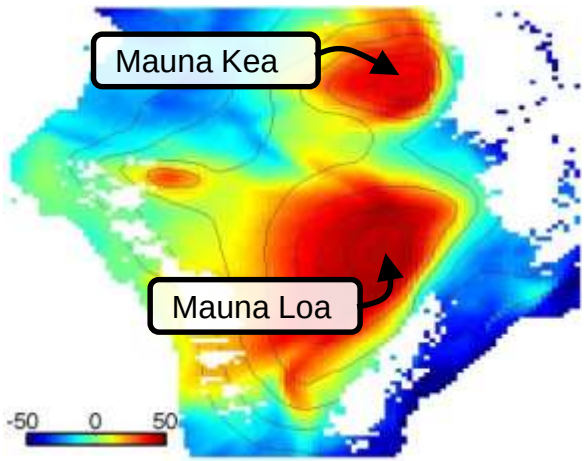
Limitations Of Imaging Geodesy Techniques

Atmospheric Delay / Ionospheric Delay

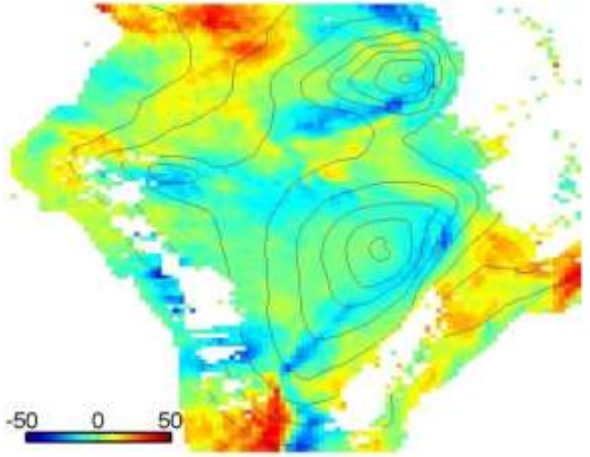
Atmospheric Signals can lead to incorrect interpretation of observations:



d-InSAR Observations, Big Island, Hawaii



Atmospheric Model



d-InSAR – Atmospheric Model

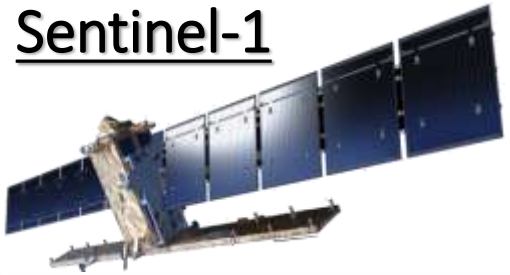
WHY TAKE THIS COURSE NOW?

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 2024

TanDEM-L

DLR

Frequency: L-band

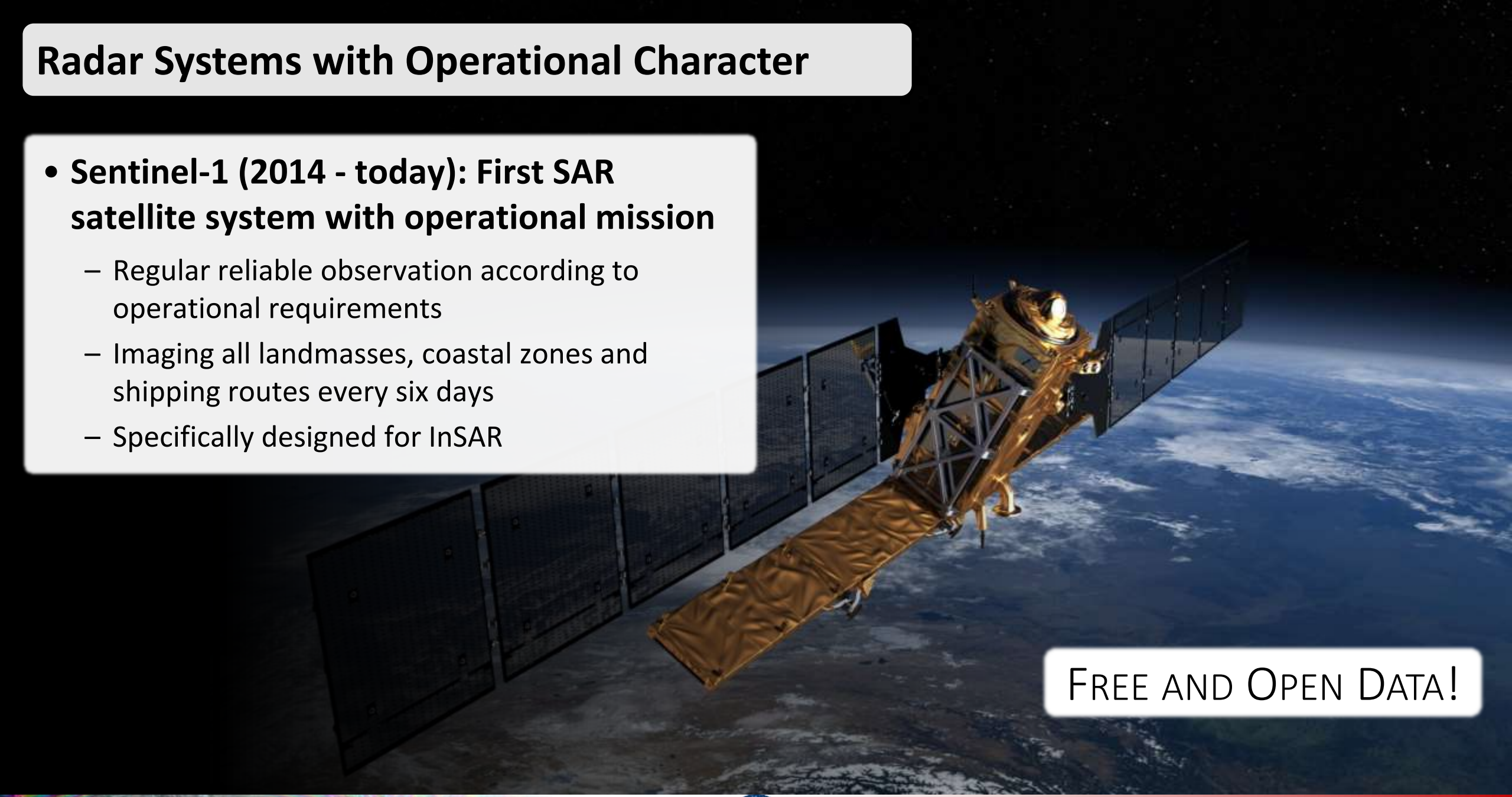
Launch Date: TBD

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 2024

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

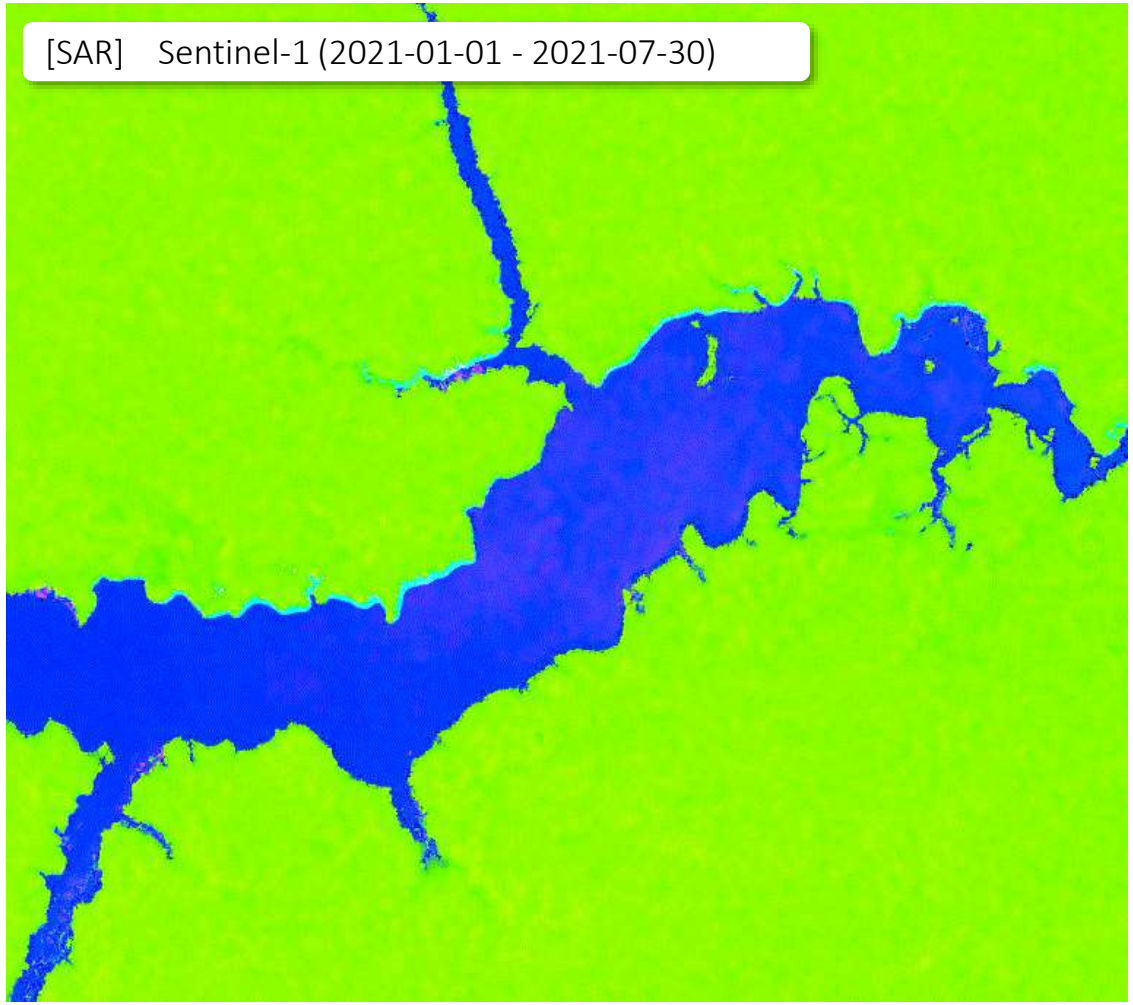
- NISAR Data Center
- NISAR Ground Station
- NISAR Science Team Member
- NISAR L2 Algorithm Development

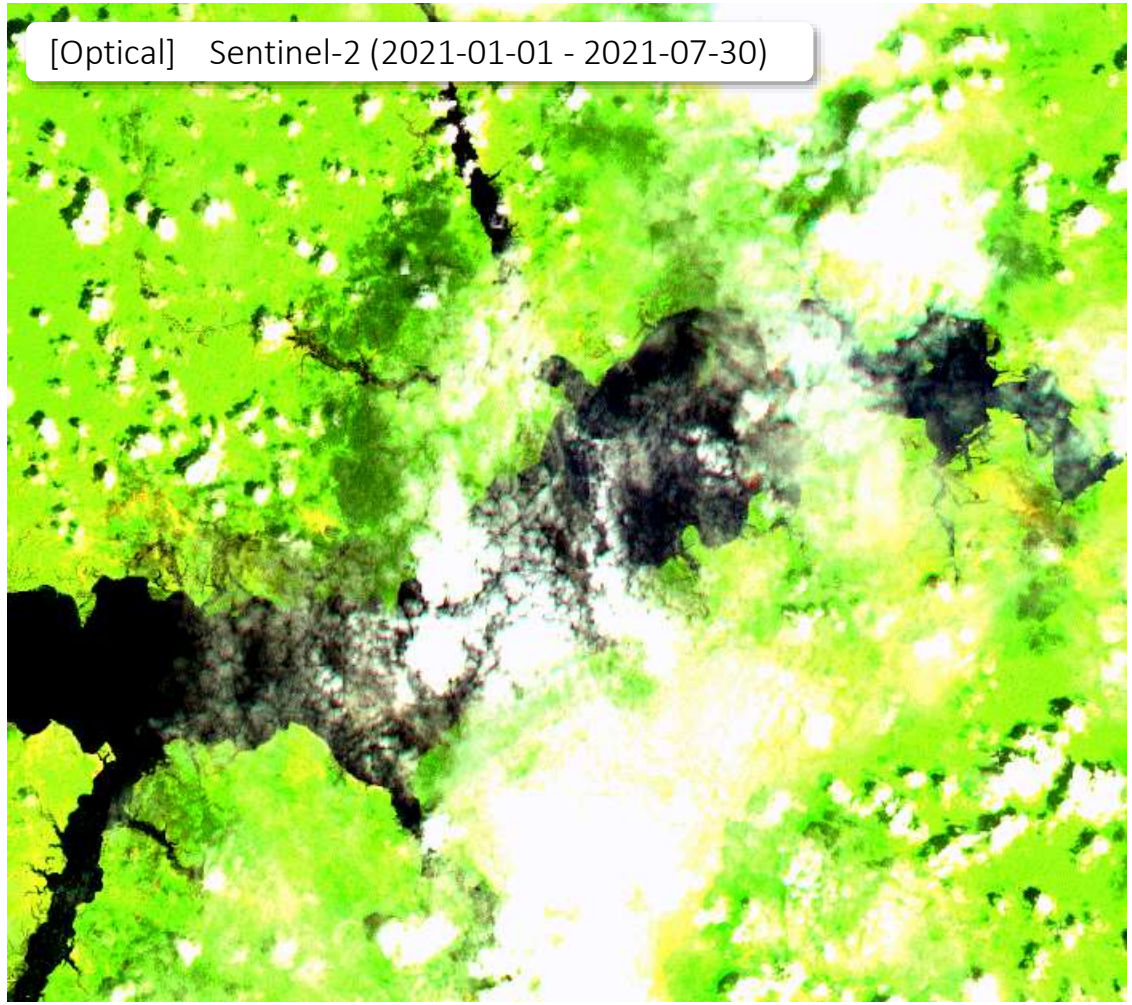
Current launch date:
March 30, 2024

Location & Vehicle:
Sriharikota India;
GSLV MK II

I may miss class for this – sorry ☺

Cloud Free? Yes, Really!!

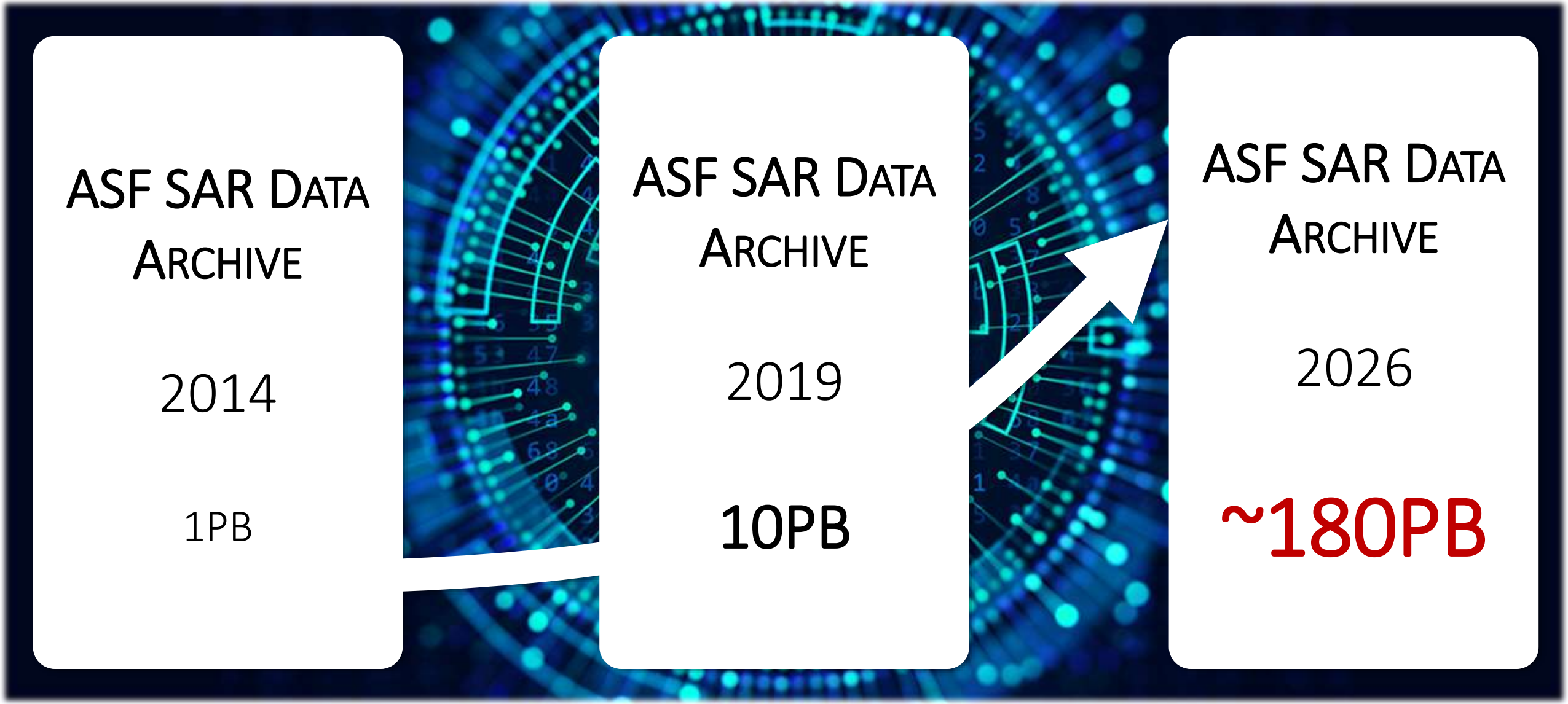




Seasonal Flooding in the Amazon Region

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

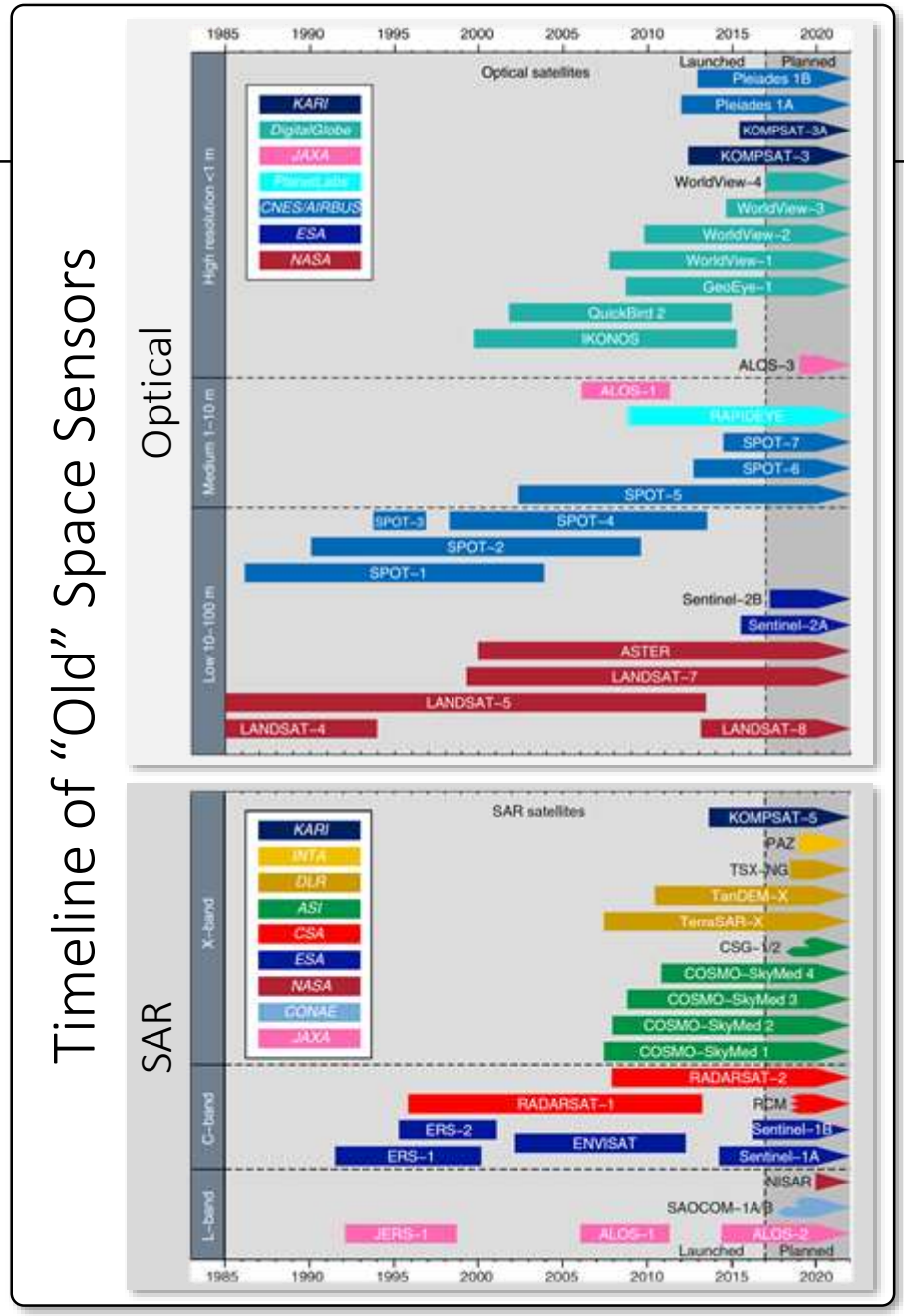
Exploding Constellation of Imaging Earth Observation Sensors

- **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
- …



Modern Commercial SAR Sensor Constellations nowadays provide sub-daily, cloud-free imaging capabilities at cm-resolution

Concept art of ICEYE SAR Satellite Constellation

COURSE TOOLS

Technology to Support the Course

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

https://opensciencelab.asf.alaska.edu/

Tools to Stay in Touch

All Course Information on Canvas

Assignments / Assessment

- **Assignments:**
  - There will be reading assignments for future lectures
    - We will start lectures discussing some of the reading assignments either in a full class or in group discussions
  - There will be graded homework assignments for some of the computational labs

- **Assessment:**
  - Class participation
  - Homework assignments
  - Midterm quiz
  - Class project

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?