

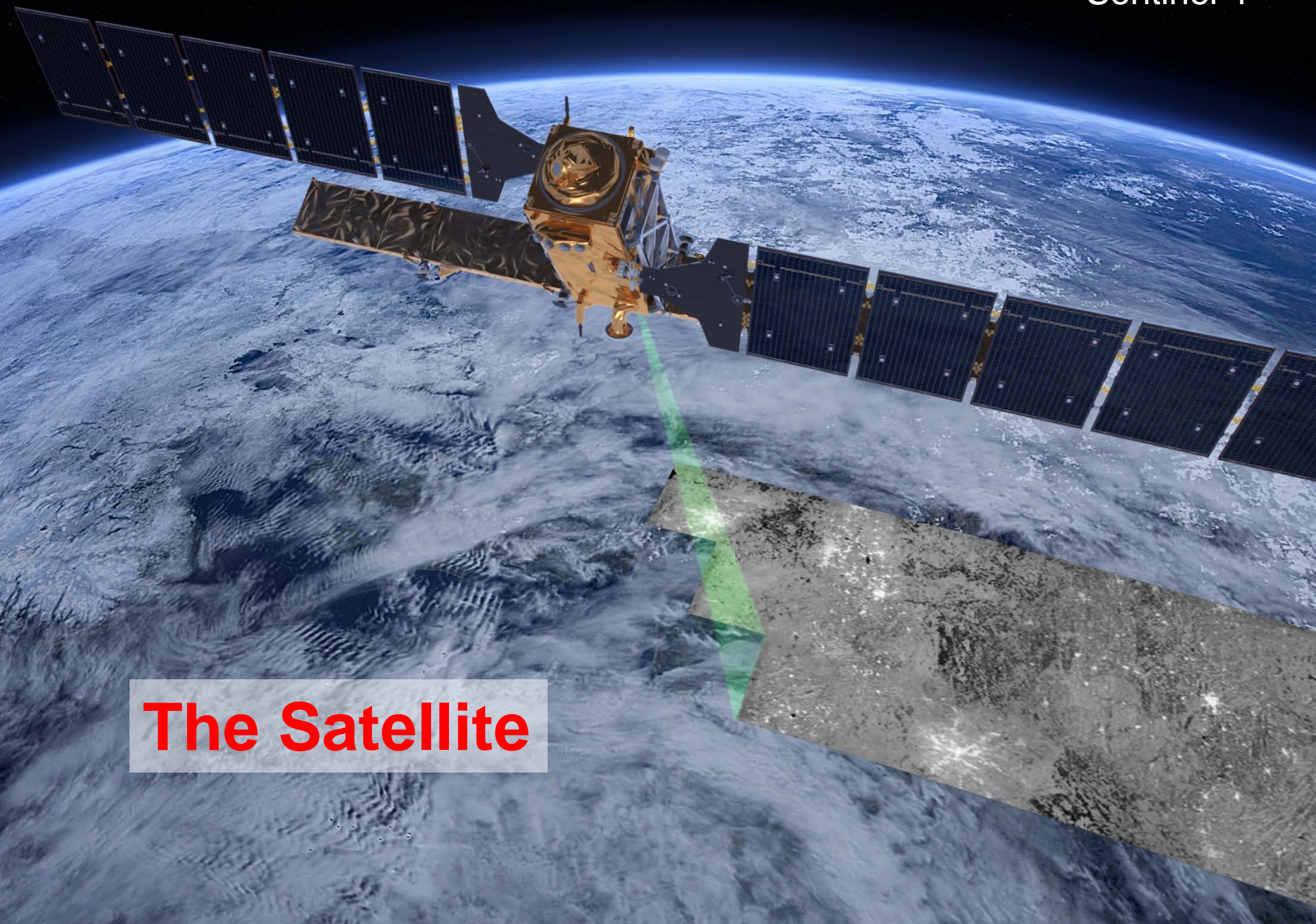


# Sentinel-1: Chancen und Herausforderungen für die Wissenschaft

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Vienna University of Technology (TU Wien)  
<http://www.geo.tuwien.ac.at/>

Sentinel-1



**The Satellite**



Sentinel-1 Image of Vienna  
15/03/2015 Orbit 5045





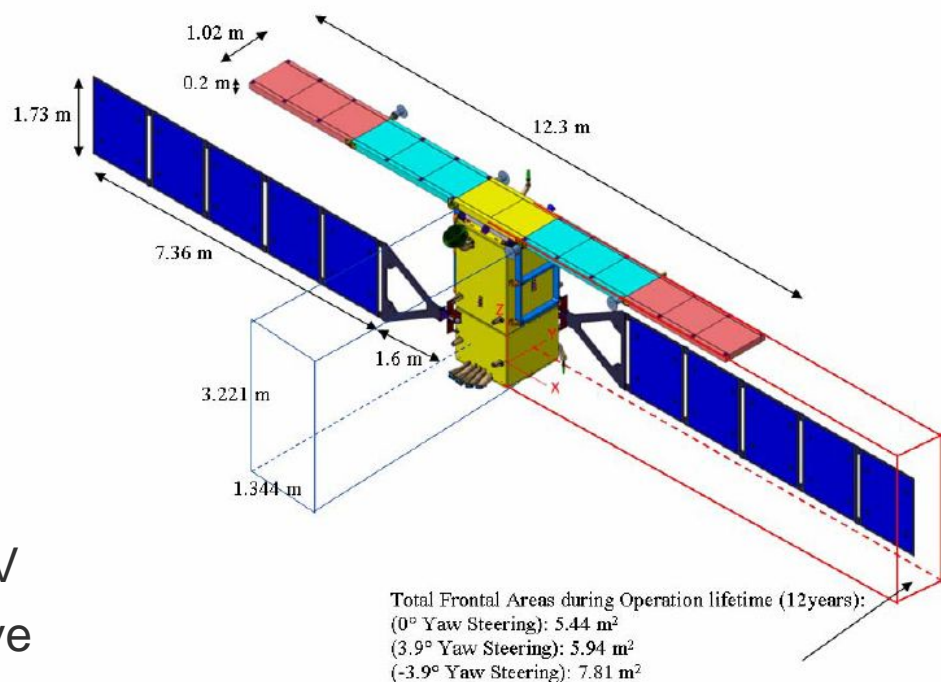
# Sentinel-1 – Just Another C-Band SAR Mission?

- European C-band SAR satellite in continuation of ERS-1/2 and ENVISAT

## What's New?

- Operational monitoring concept
  - Fixed acquisition scenario
  - Optimum use of SAR duty cycle (25 min/orbit)
- Two-satellite constellation
  - 1A launched on 3/4/2014
  - 1B launch in spring 2016
- Improved technical specifications
  - Dual polarisation: VV+VH or HH+HV
  - Terrain Observation with Progressive Scans SAR (TOPSAR)
    - beam steering in the azimuth direction for each burst

## “Simplify & Focus”

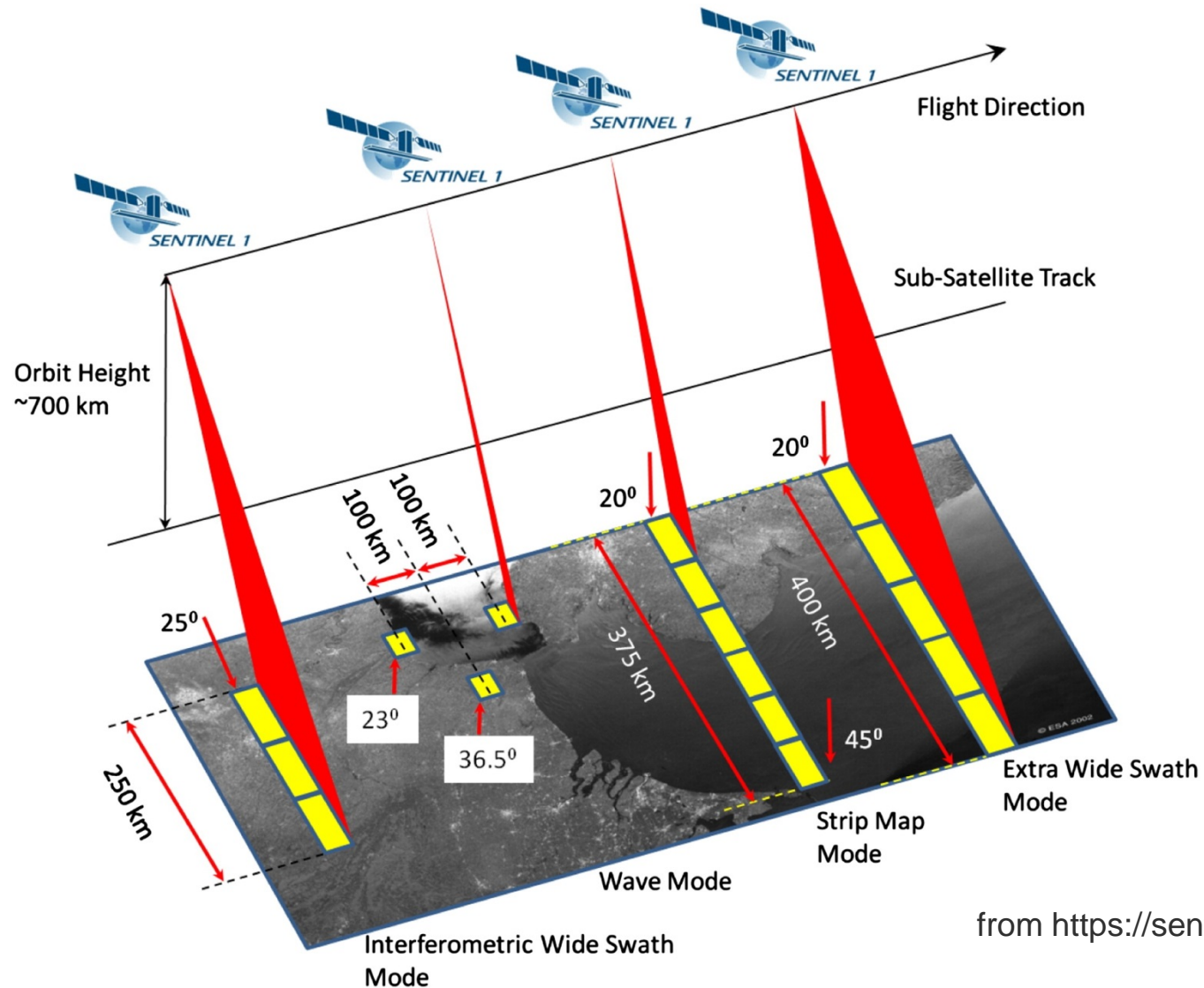


Total Frontal Areas during Operation lifetime (12 years):  
(0° Yaw Steering): 5.44 m<sup>2</sup>  
(3.9° Yaw Steering): 5.94 m<sup>2</sup>  
(-3.9° Yaw Steering): 7.81 m<sup>2</sup>

Mean frontal area during operational lifetime: 6.2 m<sup>2</sup>

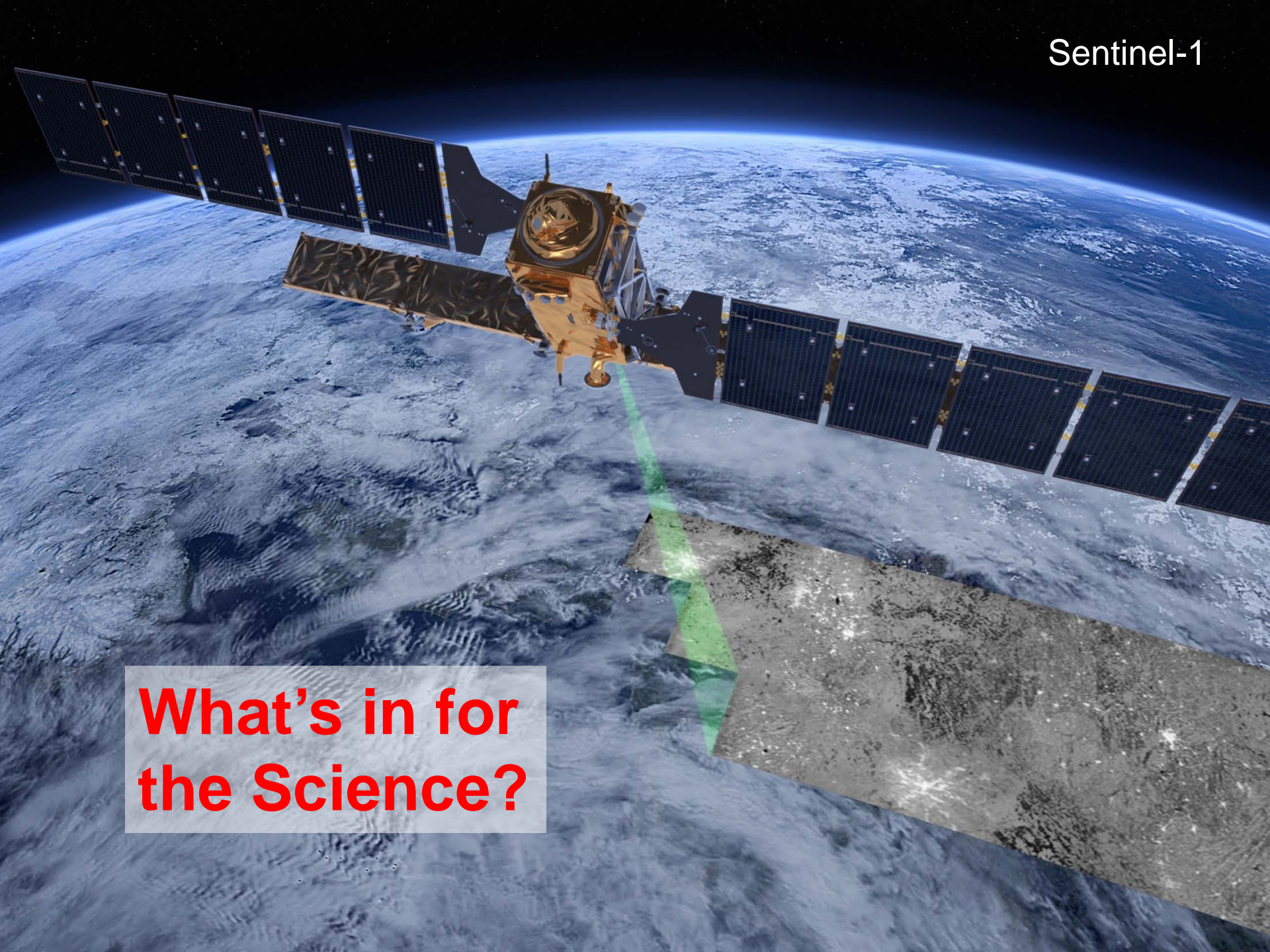


# Sentinel-1 Observation Geometry



from <https://sentinel.esa.int/>





**What's in for  
the Science?**



# ESA's Earth Observation Satellite Programme



**Earthnet:** European access to non-ESA missions: Landsat, SeaWifs, NOAA, JERS, MODIS, ALOS, Proba, Bird, Scisat... **European users**

**Meteo**

METEOSAT M-1, 2, 3, 4, 5, 6, 7 → METEOSAT Second Generation MSG-1, -2, -3

METOP-A, -B -C

*in cooperation with EUMETSAT*

**Science**

*to better understand the Earth System*

Earth Explorers → GOCE (Gravity and Ocean Circulation Explorer)

SMOS (Soil Moisture and Ocean Salinity)

ADM/Aeolus

CryoSat 2 (Polar Ice Monitoring)

Earthcare

SWARM EE7

**Applications Services**

*to initiate long term monitoring systems and services*

ERS-1, -2 → ENVISAT

Earth Watch → Copernicus in cooperation with EC

Sentinel 1

Sentinel 2/3

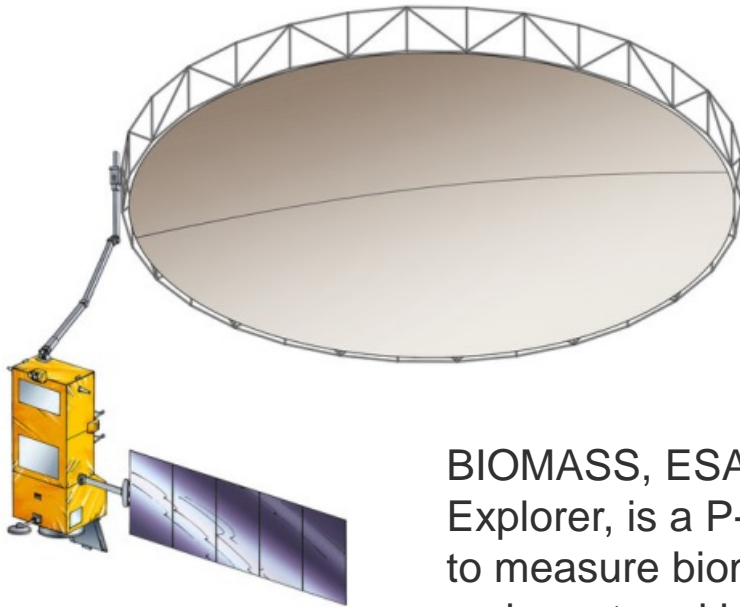
Sentinel 5 pre

Sentinel 4/5

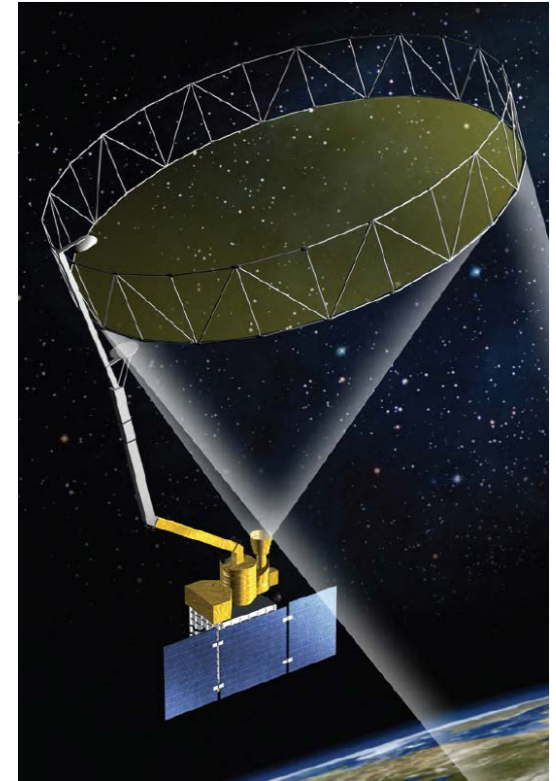


# Scientific Trends in Microwave Remote Sensing

- Scientific remote sensing community is keen on
  - Novel sensor technologies
  - Moving to longer wavelengths
  - Adding more and more information layer

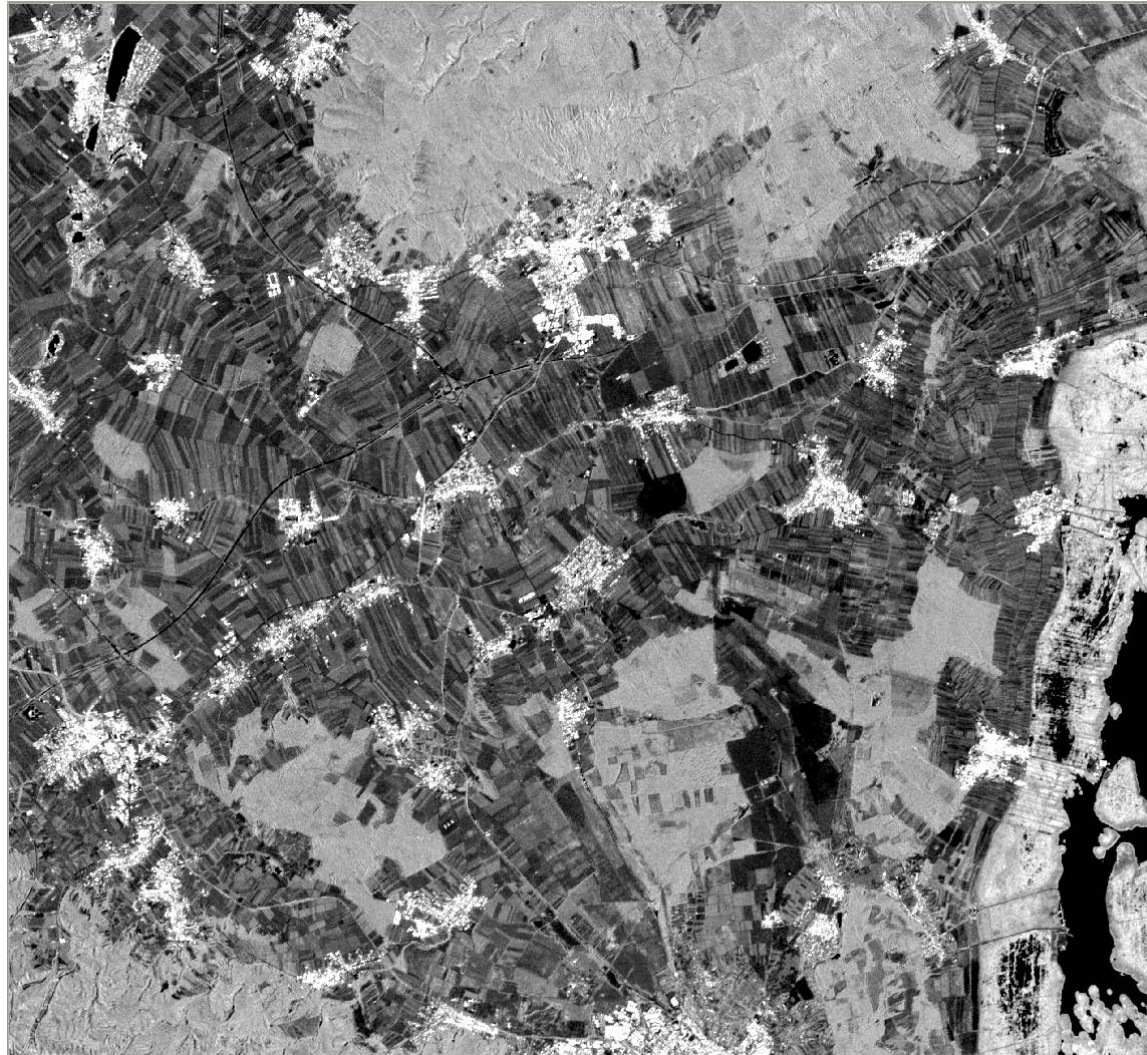


BIOMASS, ESA's 7<sup>th</sup> Earth Explorer, is a P-band SAR to measure biomass and carbon stored in forests.



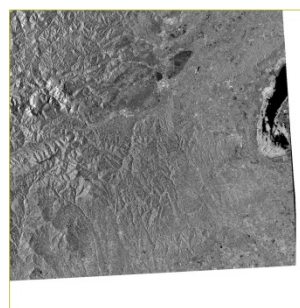
SMAP, an active-passive L-band sensor for measuring soil moisture, launched by NASA on 31 January 2015

# From 150 km ASAR to 20 m Sentinel 1

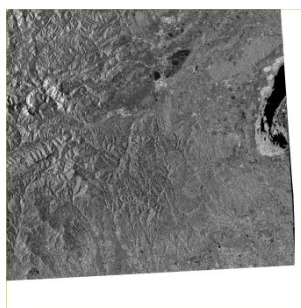




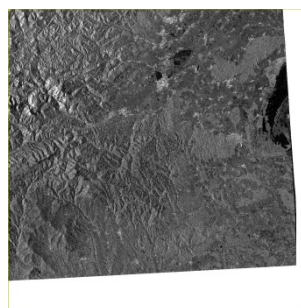
# Sentinel-1 Time Series



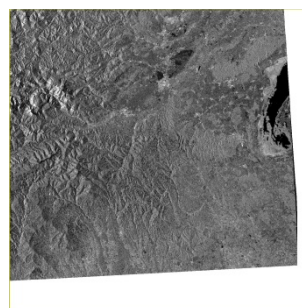
2014-11-08



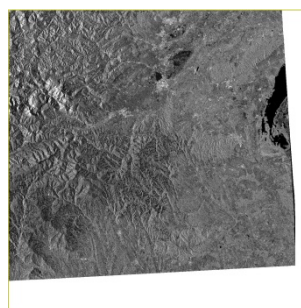
2014-12-14



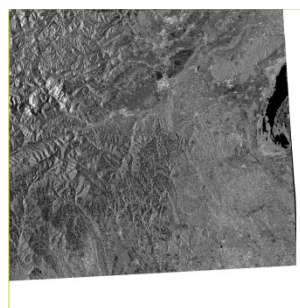
2015-01-07



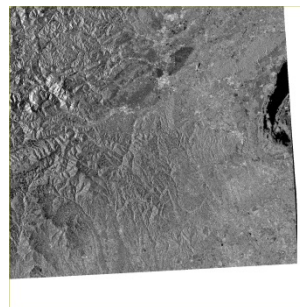
2015-01-19



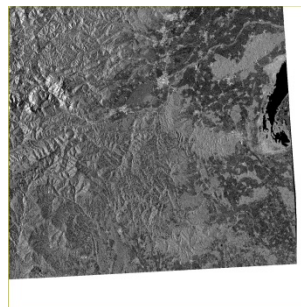
2015-01-31



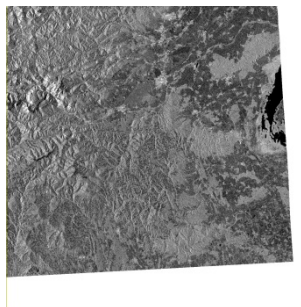
2015-02-12



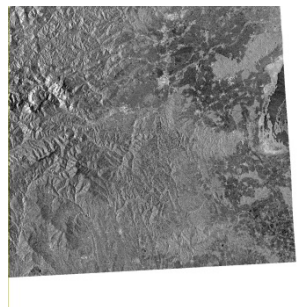
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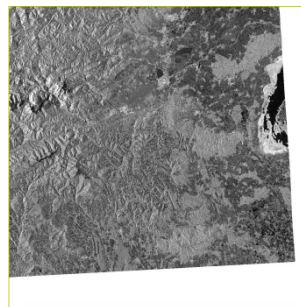
2015-03-08



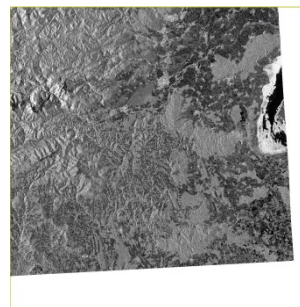
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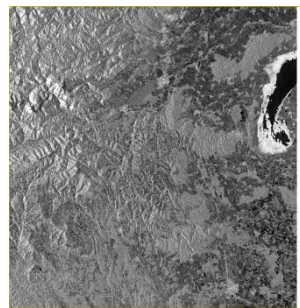
2015-04-01



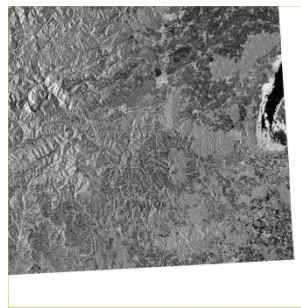
2015-04-13



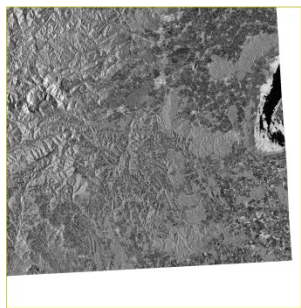
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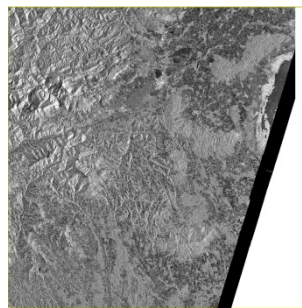
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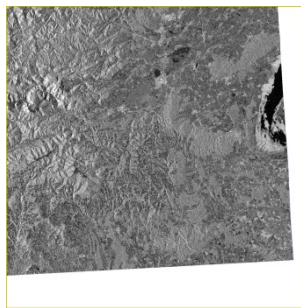
2015-05-19



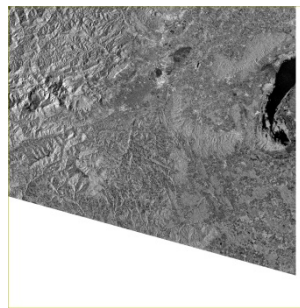
2015-05-31



2015-06-04



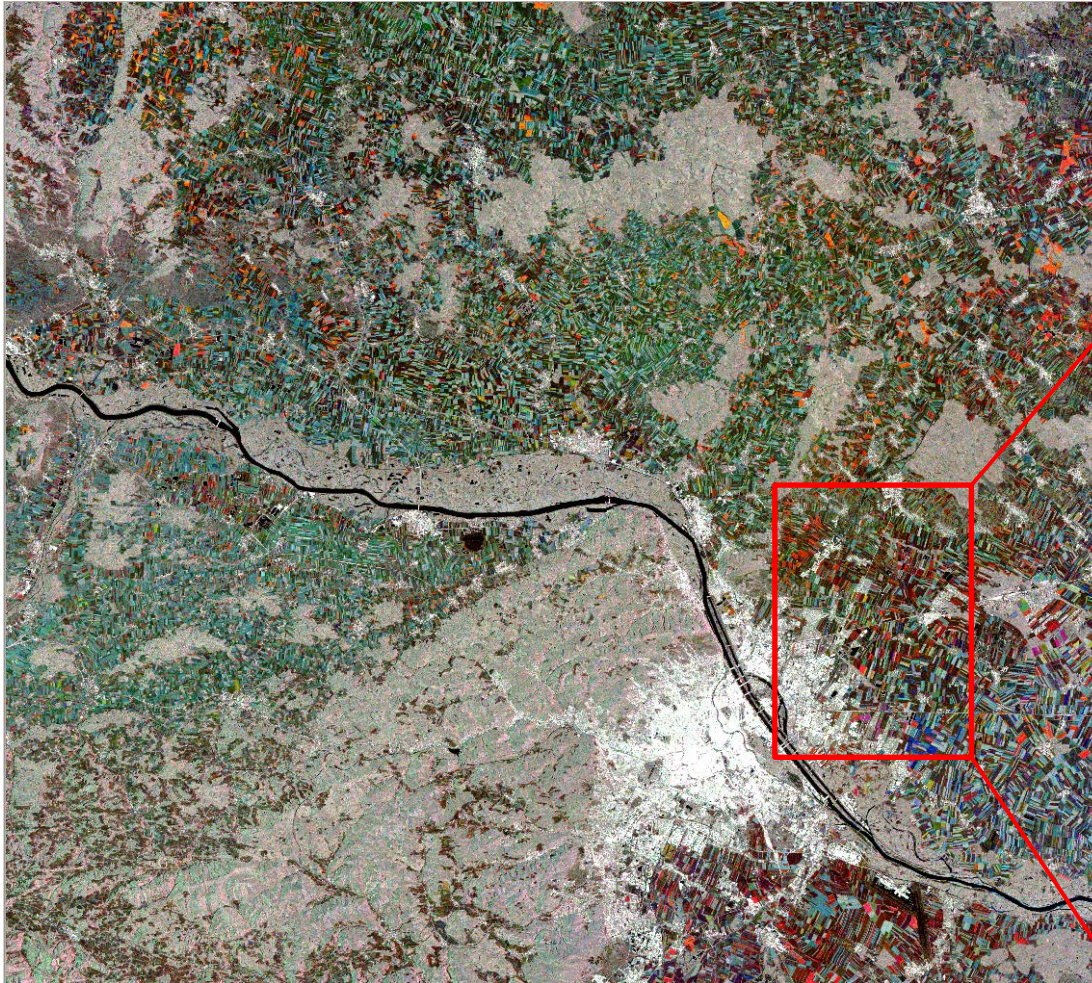
2015-06-12



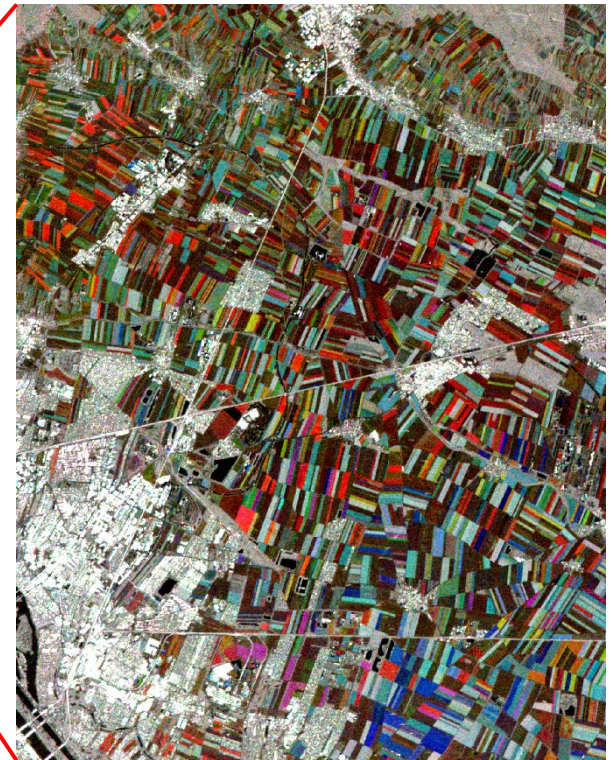
2015-06-23



# Sentinel-1 Cross-Pol (VH) Images



Red – June  
Green – July  
Blue – August



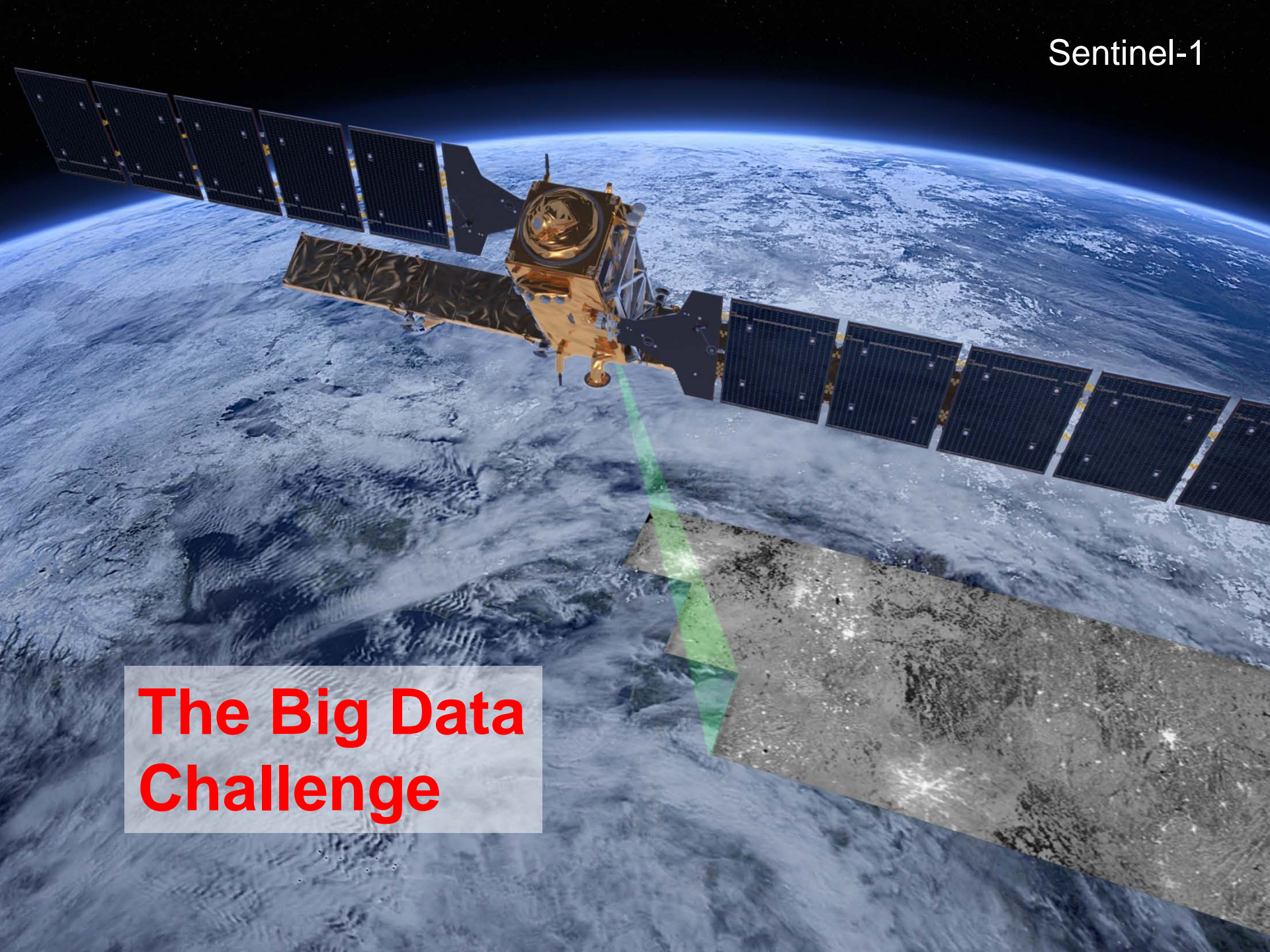
False-colour image of Sentinel-1  
VH monthly image mosaics



# Sentinel-1 for Science

- Remote Sensing Science
    - Due to its high spatio-temporal coverage, Sentinel-1 will allow to observe more physical phenomena than other SAR/scatterometer missions
    - Cross-polarisation data of this quality have never been available before
    - Also at C-band the interaction of microwaves with the land surface is yet only partly understood
  - Earth Sciences
    - Start from long, consistent, and complete data records
    - Need value-added geophysical data products
    - Good understanding of error characteristics more important than high accuracy
- ⇒ Sentinel-1 will have a much bigger scientific user community than experimental microwave missions!

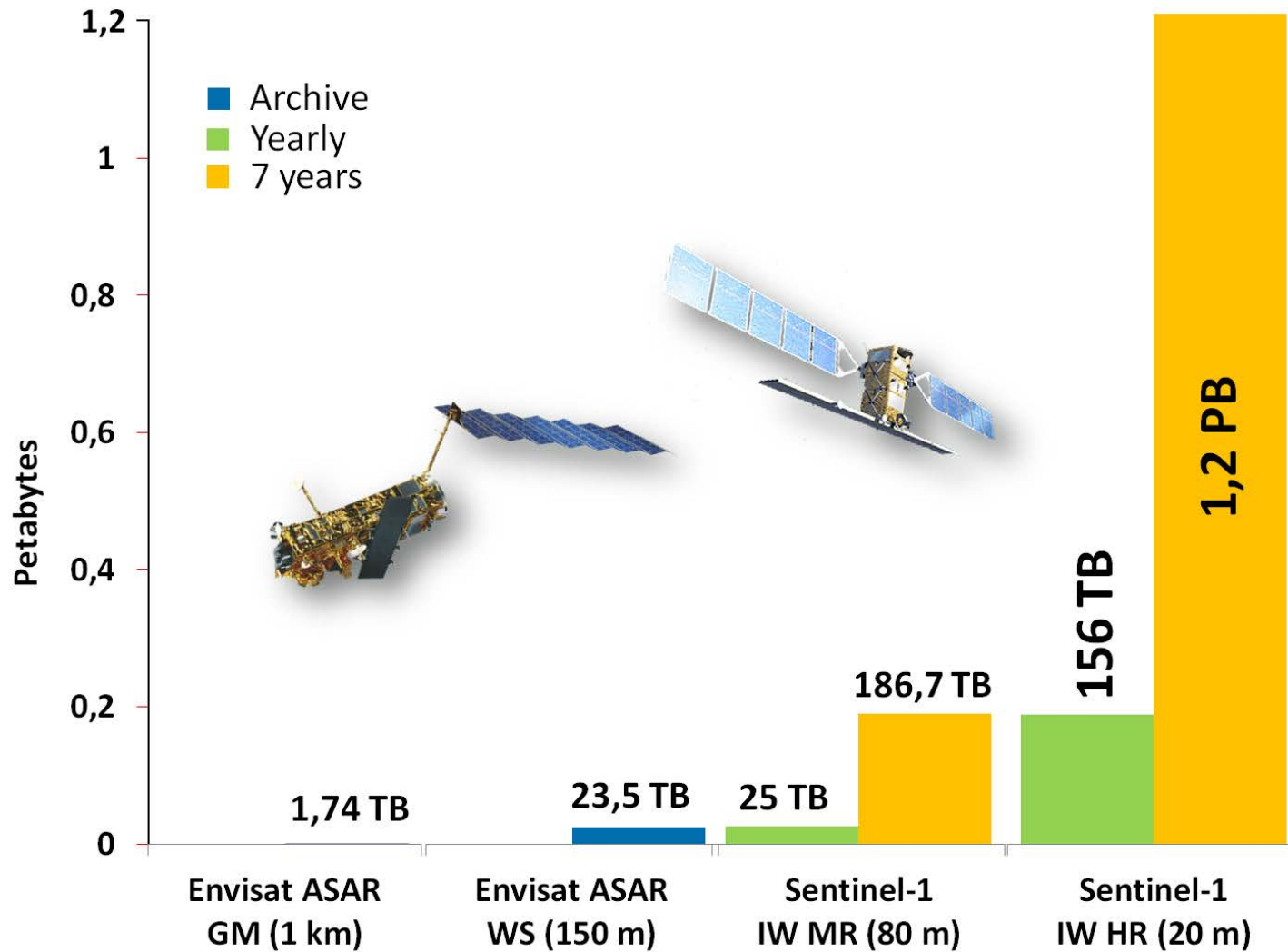
Sentinel-1



**The Big Data  
Challenge**



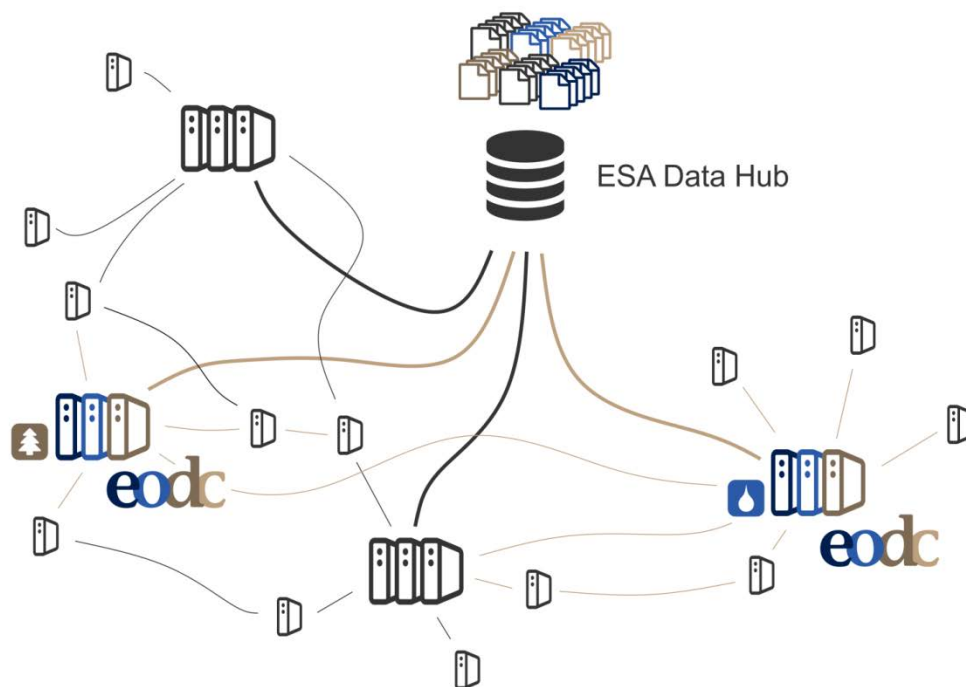
# Sentinel-1 Data Volume



# Earth Observation Data Centre (EODC)

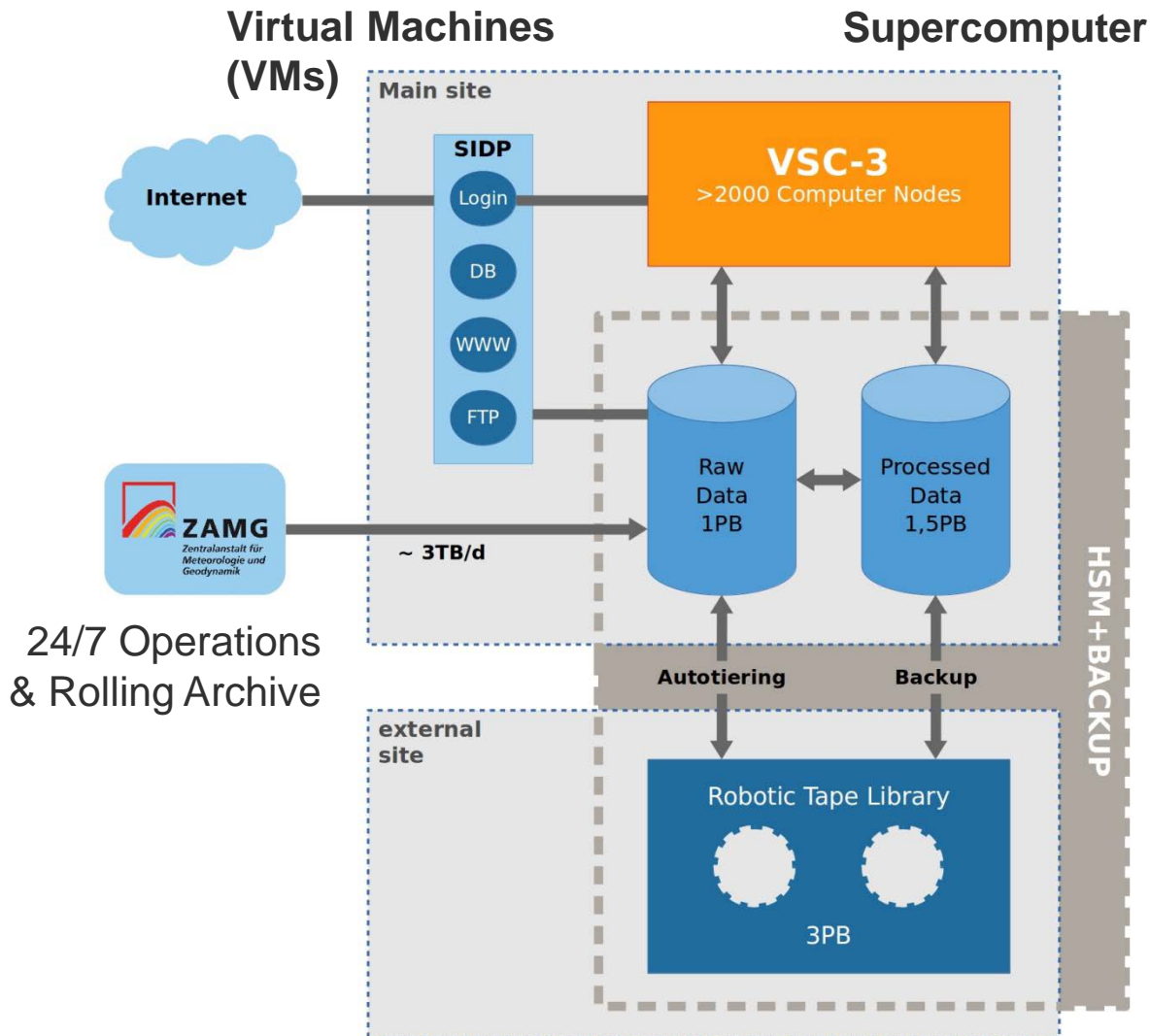
- Founded in May 2014 as a Public-Private Partnership
- Mission
  - EODC works together with its partners from **science**, the **public**- and the **private** sectors in order to foster the use of EO data for monitoring of water and land
- EODC acts as a **community facilitator**
- Joint developments
  - Cloud infrastructure
  - Operational data services
  - Software
    - Open Source

EODC works towards  
a federation of data  
centres





# EODC Infrastructure in Vienna



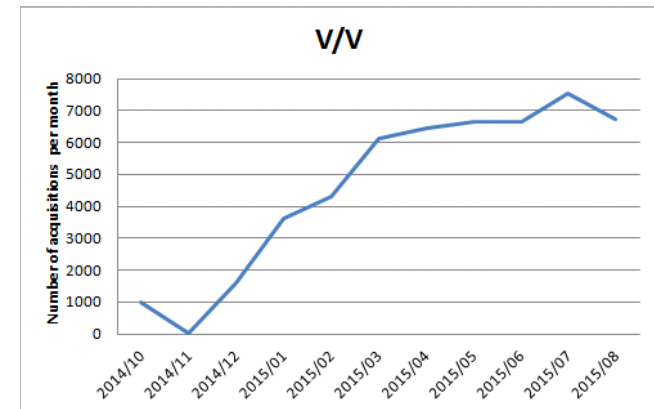
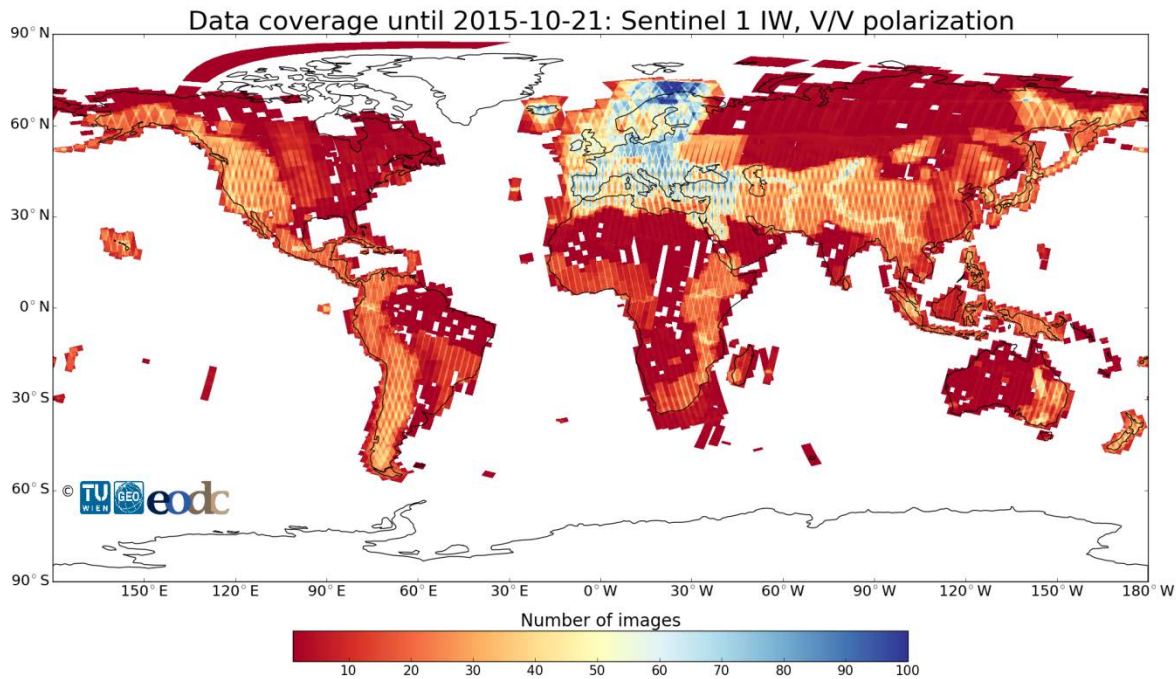
VSC-3 Rank 85 of the World's most powerful computers (11/2014)

**Petabyte-Scale Disk Storage**  
20 Petabyte until 2018

Tape Storage

# Sentinel-1 Data Availability @ EODC

- Sentinel-1 data are currently available ~2,5 hours after its processing time and 6,25 hours after acquisition time
- Already more than 60 TB (>2,5 times our 10-year ENVISAT ASAR archive)



Ramp-up of Sentinel-1 acquisition scenario to full operational status

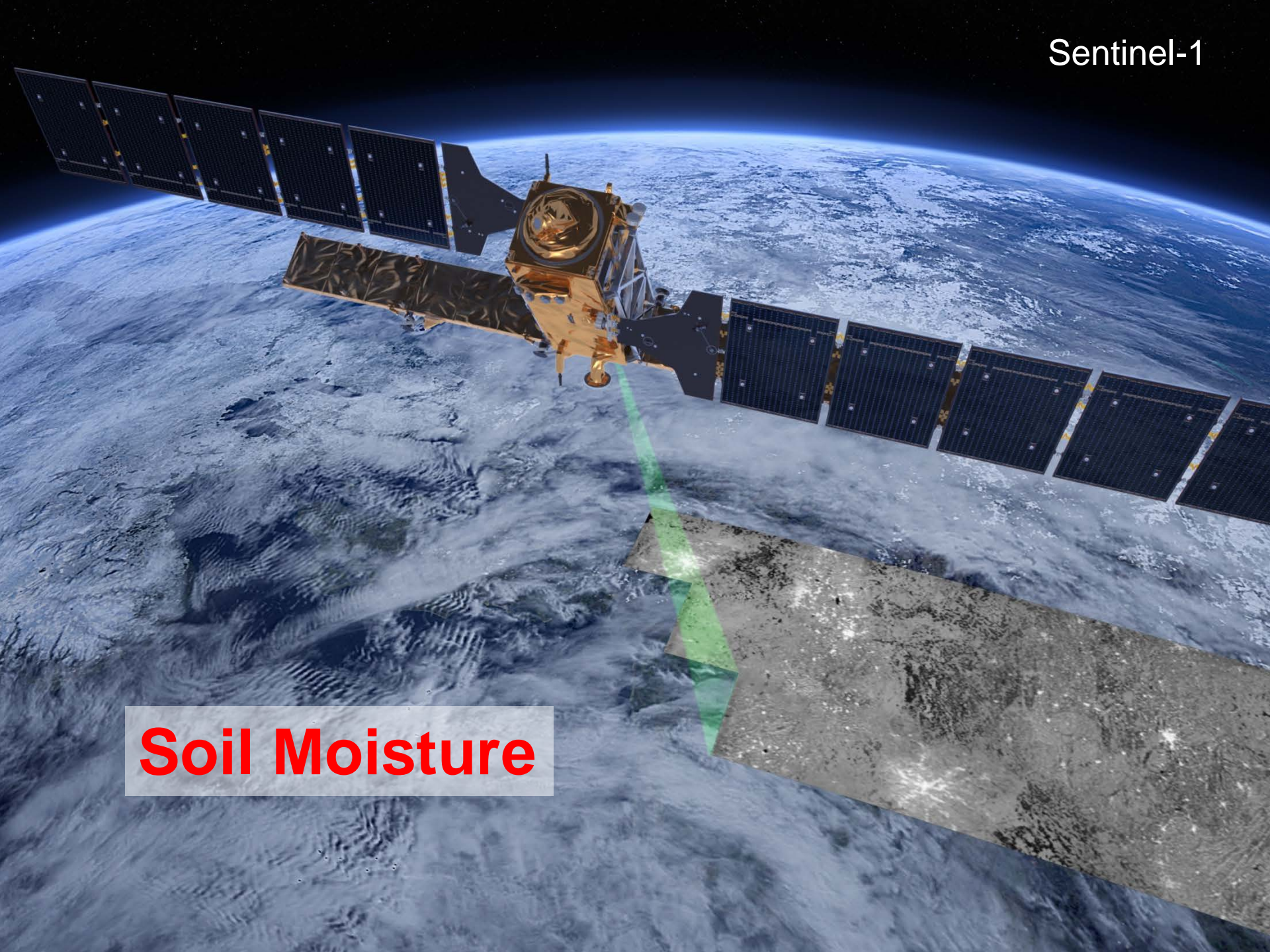
Up-to-date coverage maps available from <https://www.eodc.eu/sentinel-1a-coverage-maps/>



# Supercomputing Experiment

- Vienna Scientific Cluster 3
  - High-performance computing (HPC) system with 2020 nodes
  - Each node has 2 processors Intel Xeon E5-2650v2, 2.6 GHz, and 64 Gbytes of RAM
  - Simple Linux Utility for Resource Management (SLURM)
- Experiment
  - Geocoding of 624 Sentinel-1 images from Austria, Sudan and Zambia with Sentinel-1 toolbox
  - Each image is about 1 Gbyte in size
  - Serial processing with one processor would take about two weeks
- Approach
  - Parallel processing on 312 nodes whereas 2 images were simultaneously launched on a single computing node
- Results
  - Processing was completed within 45 min (without queuing)

Sentinel-1

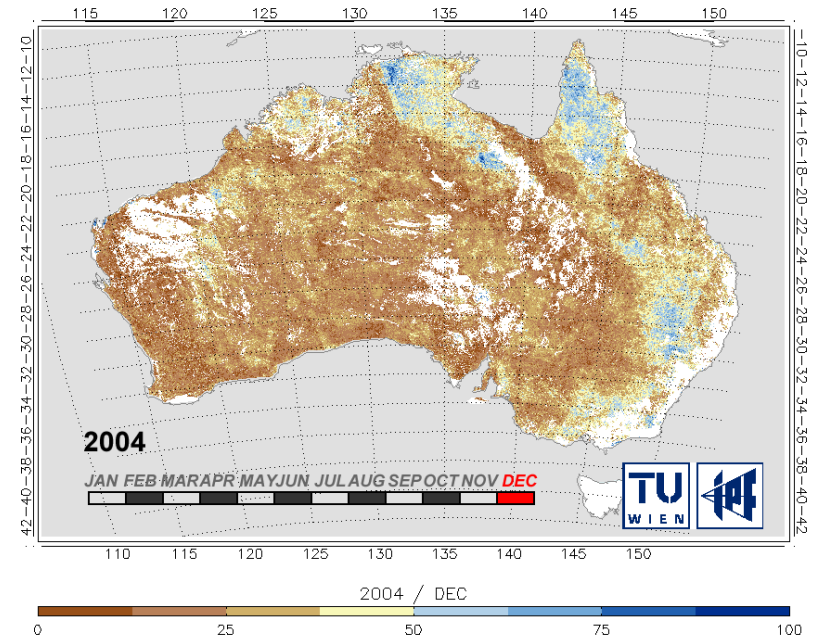


**Soil Moisture**

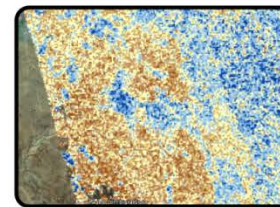
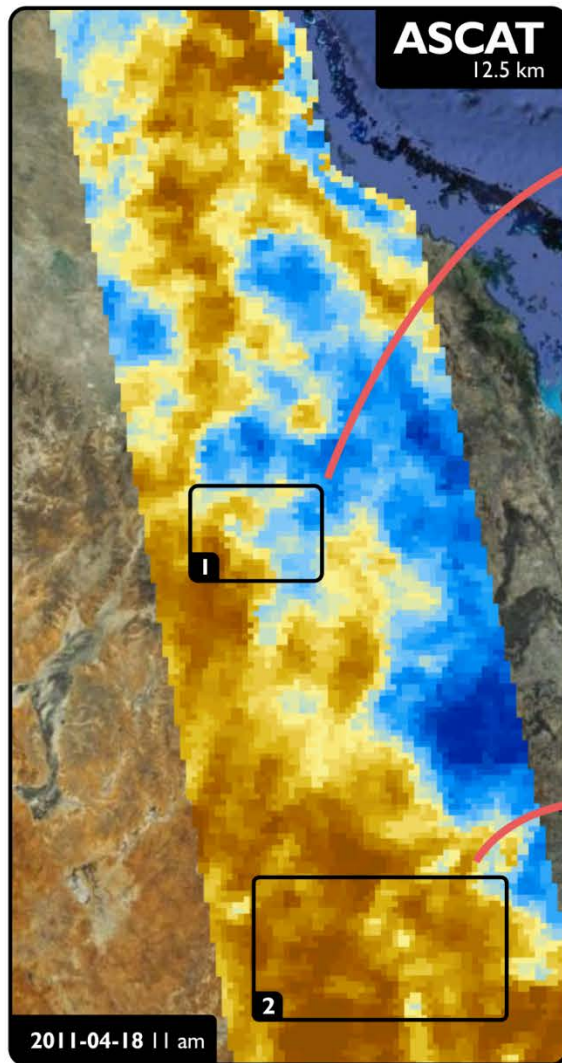
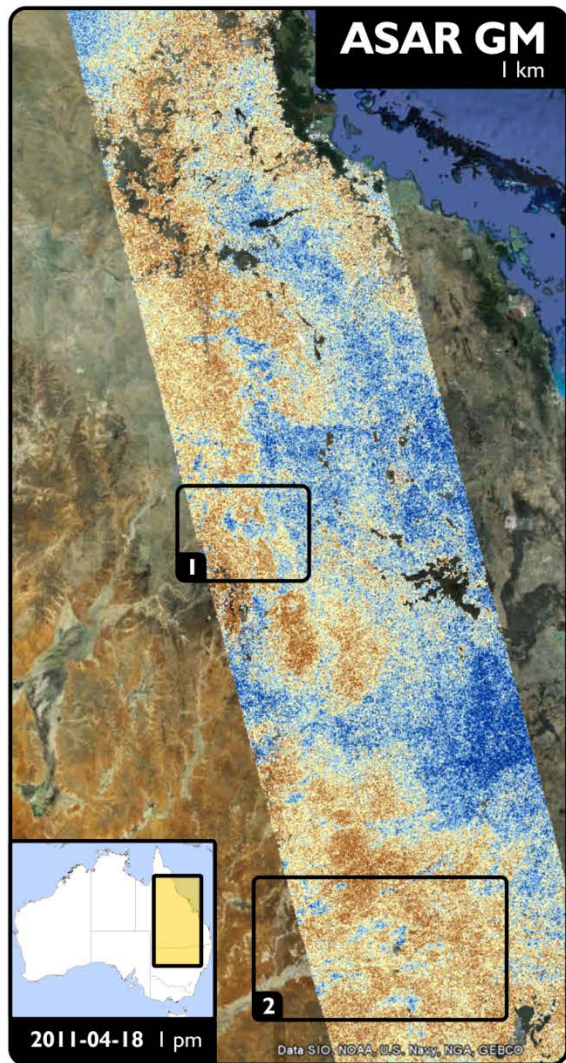


# ASAR Soil Moisture (2002-2012)

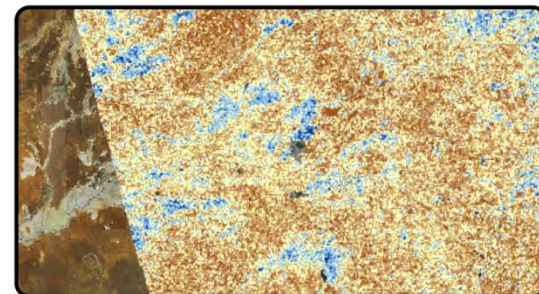
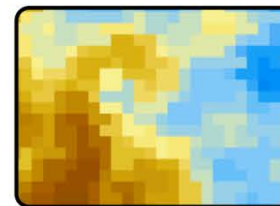
- ENVISAT ASAR Global Monitoring (GM) mode served as test bed for demonstrating soil moisture monitoring capabilities
  - Full continents (Australia, Africa) have been processed
  - NRT capabilities demonstrated
- Weaknesses
  - Poor temporal coverage
  - High radiometric noise
- Strengths
  - High consistence with ASCAT and other global soil moisture products
  - Spatial details not contained in ASCAT and passive sensors



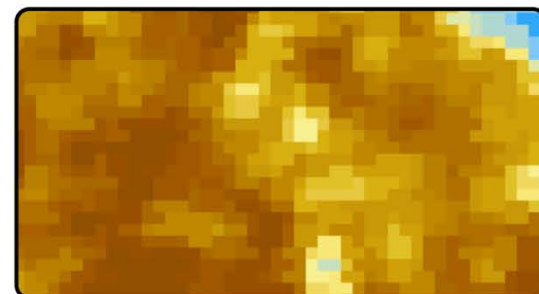
First continental-scale 1km soil moisture product produced by TU Wien in the ESA funded SHARE project



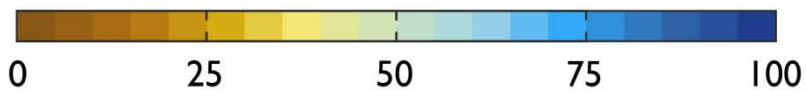
**1**



**2**



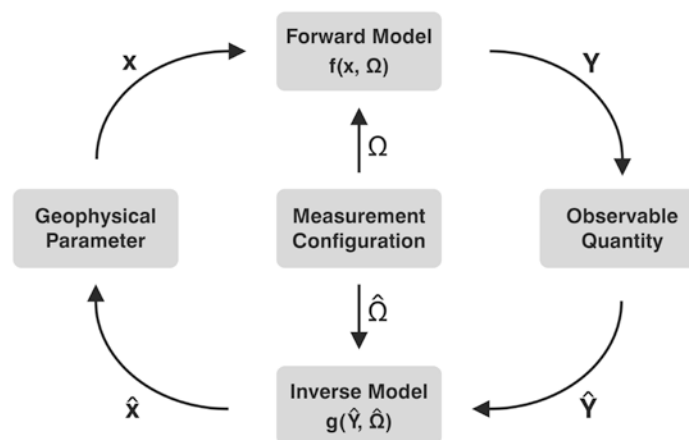
**Surface Soil Moisture (%)**



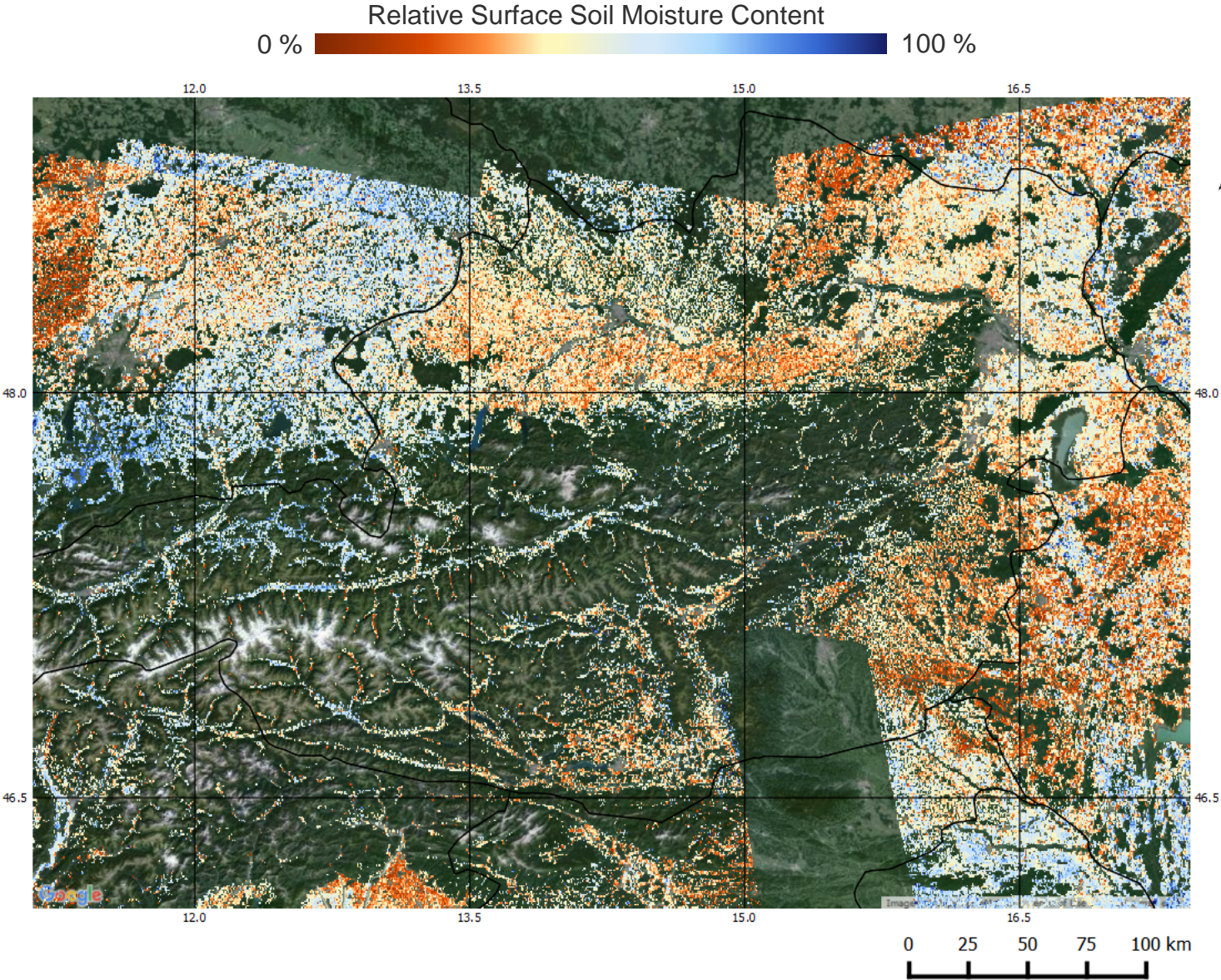


# Soil Moisture Retrieval for Sentinel-1

- Baseline algorithm
  - Change detection approach as developed for ERS SCAT and METOP ASCAT and later adopted to ENVISAR ASAR
- Science questions
  - Impact of VV polarisation for Sentinel-1 versus HH for ENVISAT ASAR?
  - Value of VH polarisation for improving soil moisture retrieval?
  - How to improve the vegetation parameterisation?
- Benefit from alternative modelling/retrieval approaches
  - Theoretical backscatter models
  - Semi-empirical models
  - Statistical approaches
    - Artificial Neural Networks
    - Support Vector Regression
    - Bayesian models



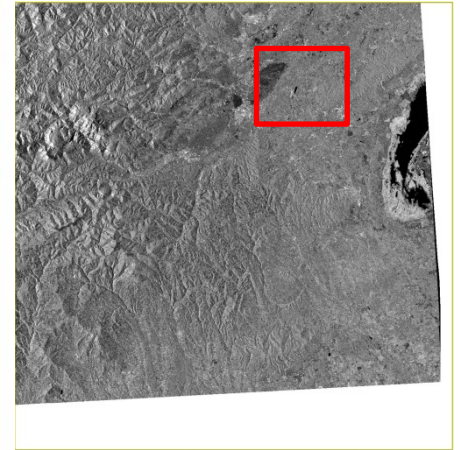
# First 1 km Sentinel-1 Soil Moisture Images



Monthly SSM  
image mosaic  
for June 2015  
over Austria



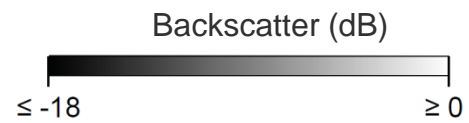
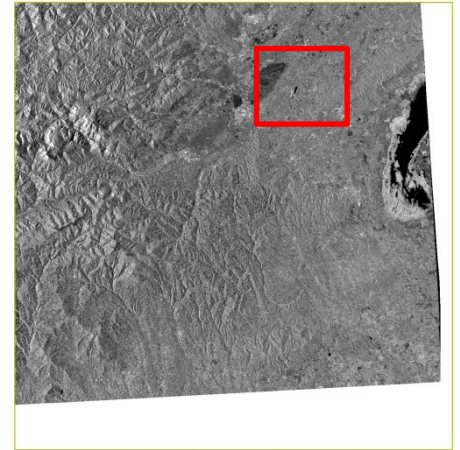
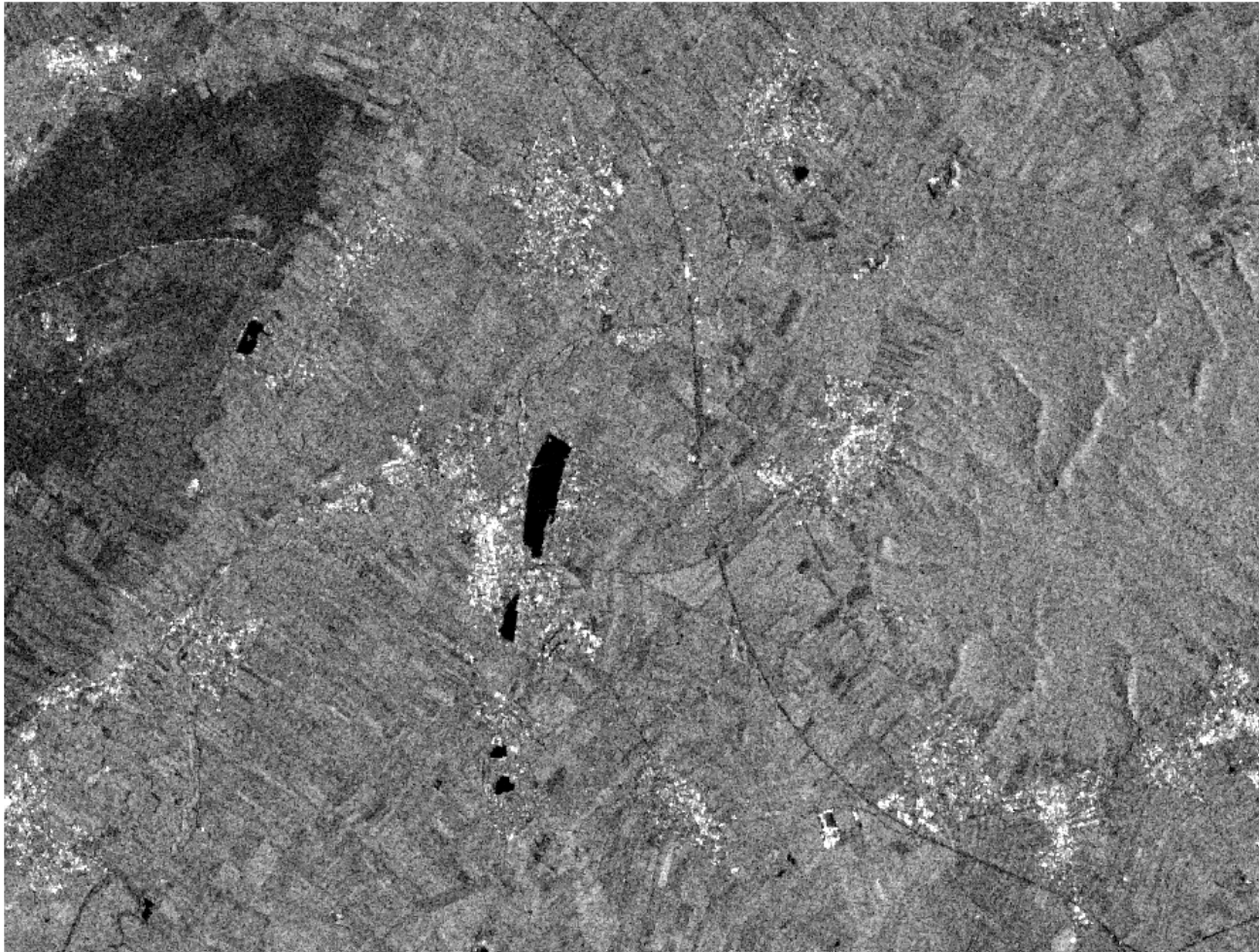
# First Sentinel-1 Soil Moisture Experiments at 20 m



Landsat image  
Credit: google.com

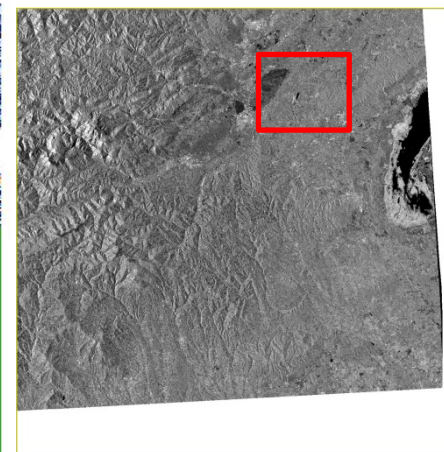
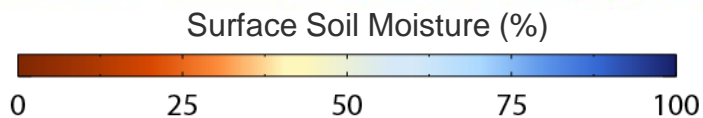
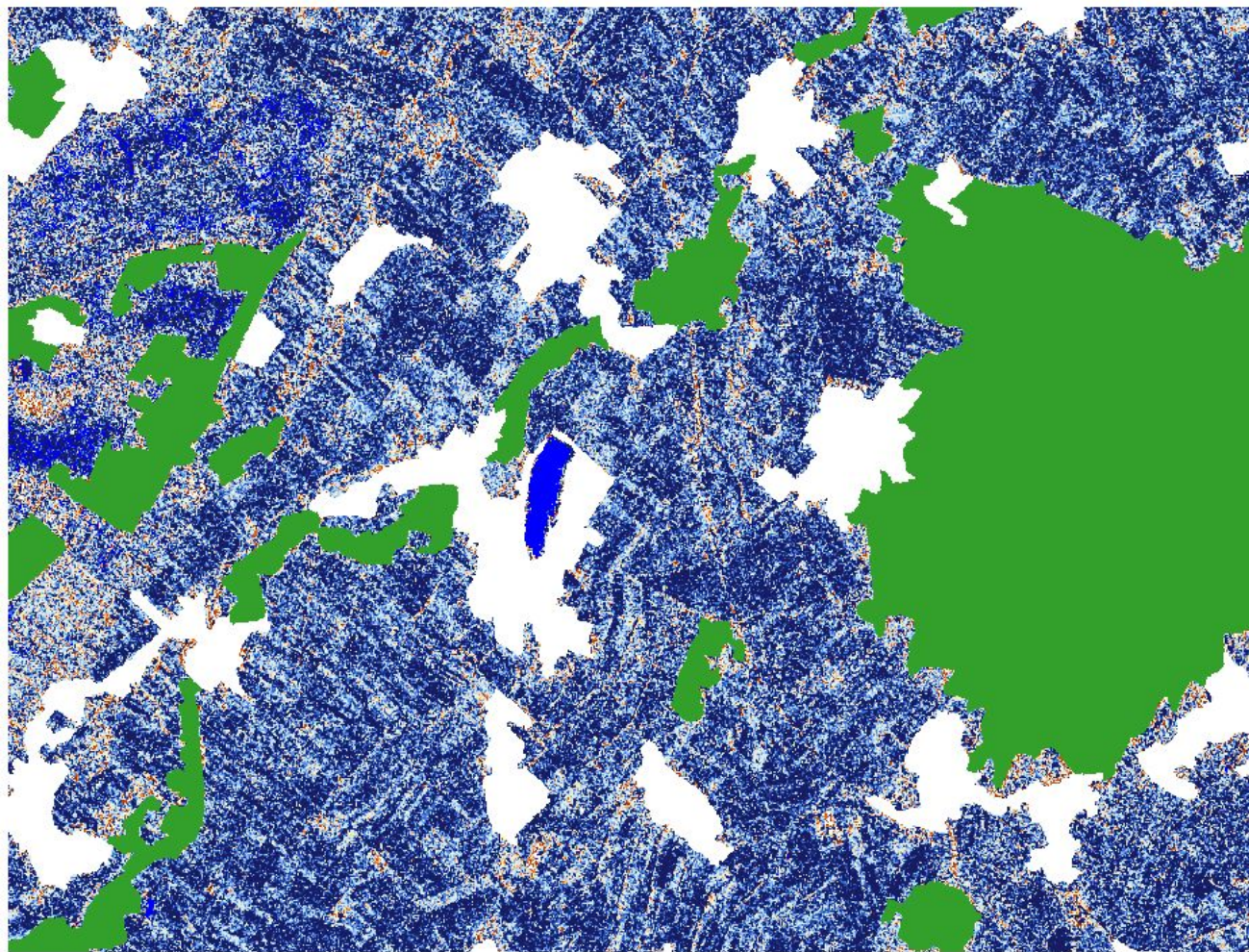


2014-11-08







# 20 m Sentinel-1 Soil Moisture Index on 2014-11-08

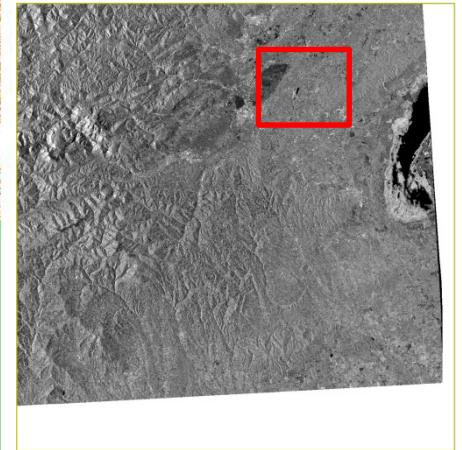
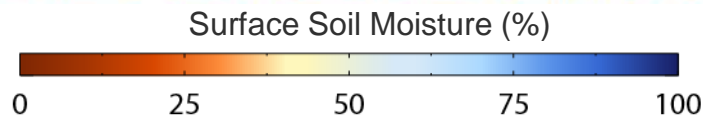
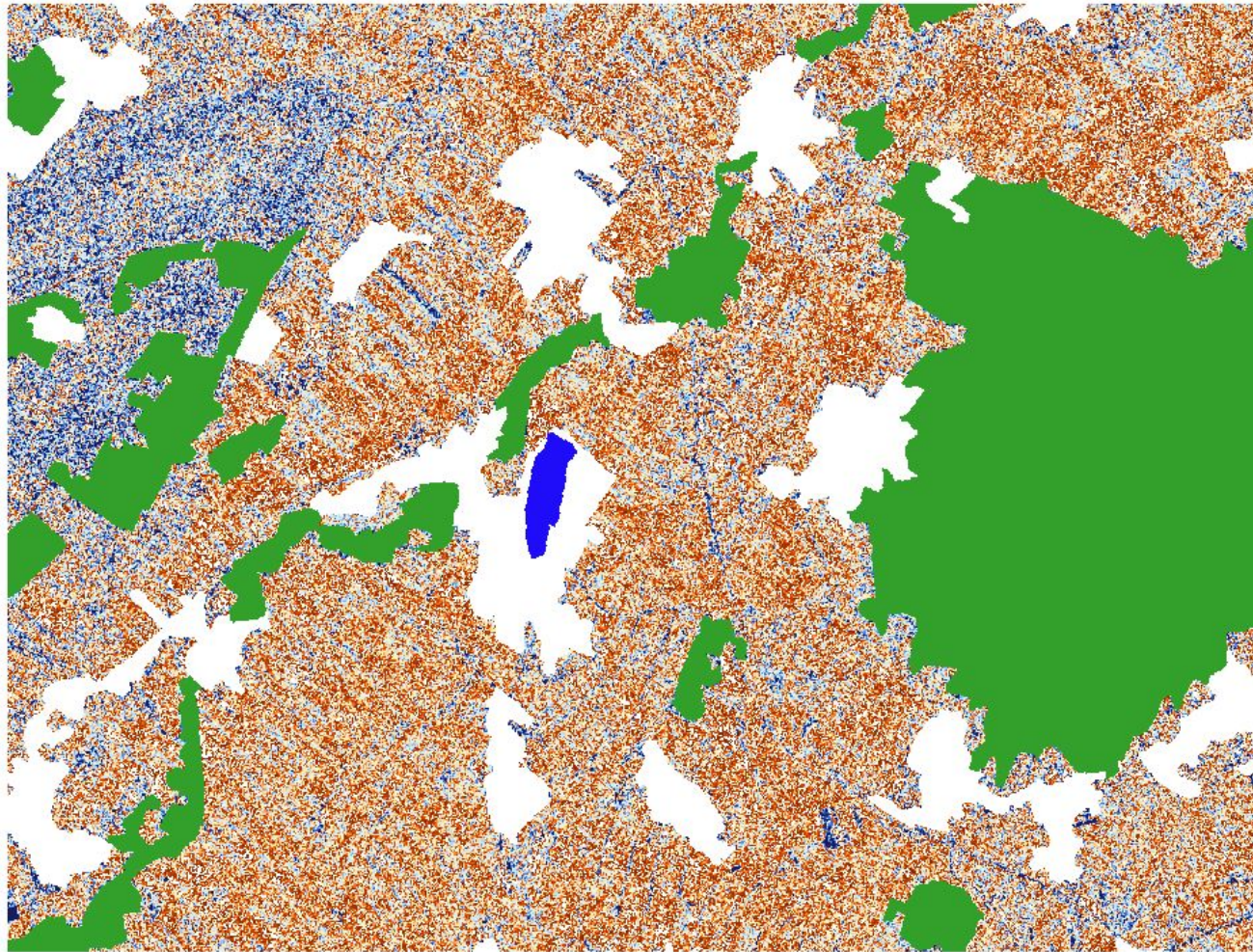


Precipitation map 16:45 UTC  
<http://www.meteox.com>



-  Water bodies
-  Dense vegetation



# 20 m Sentinel-1 Soil Moisture Index on 2015-05-02



Precipitation map 16:45 UTC  
<http://www.meteox.com>

-  Water bodies
-  Dense vegetation



# Conclusions

Sentinel-1 (like the other Sentinels) will be highly beneficial for science!

but

Scientific challenges are underestimated

Apart from few exceptions, there are no Big Data infrastructures that allow dealing with the vast volume and variety of the Sentinel data

- Closer cooperation between public and private organisations needed
- Gaps in the funding programmes need to be covered

## Acknowledgements

My colleagues at TU Wien and EODC: Vahid Naeimi, Senmao Cao, Alena Dostalova, Bernhard Bauer-Marschallinger, Stefano Elefante, Thomas Mistelbauer, Christian Briese

Austrian Space Application Programme: Projects 844350 "Prepare4EODC" and 88001 "WetMon"

European Community's 7th Framework Programme: Grant agreement no 606971 "AdvancedSAR"

European Commission Joint Research Centre: Framework contract 388533 "Copernicus Global Land"

European Space Agency: Contract No. 4000105732/12/I-NB "TIGER NET"