Towards Sentinel-1 Soil Moisture Data Services: The Approach taken by the Earth Observation Data Centre for Water Resources Monitoring

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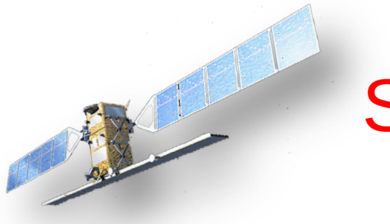
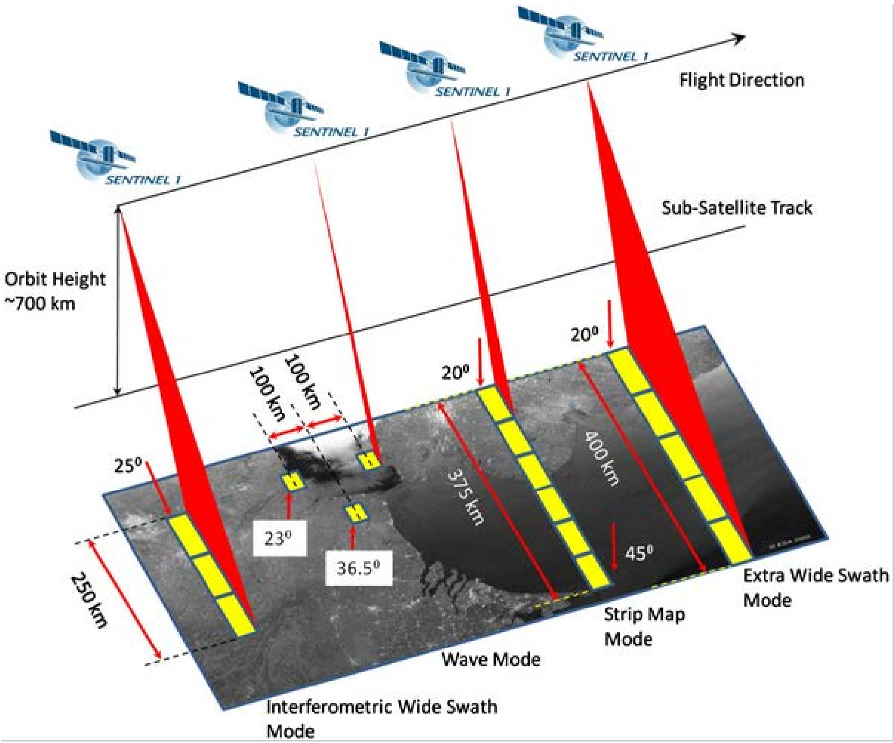


Sentinel-1

- Sentinel-1 launched on 3 April

Credit: ESA

- Sun-synchronous, near-polar, circular orbit
  - 693 km orbit height
  - 98.18° inclination
  - 12 day repeat cycle at Equator with one satellite, 175 orbits/cycle.
- SAR Instrument
  - C-band (5.405 GHz)
  - Dual polarisation (HH+HV, VV+VH)
  - 4 exclusive acquisition modes:
    - Stripmap (SM)
    - Interferometric Wide swath (IW)
    - Extra-Wide swath (EW)
    - Wave mode (WV)
- Fixed acquisition plan
  - Unique spatio-temporal coverage



Sentinel-1 Data Volume

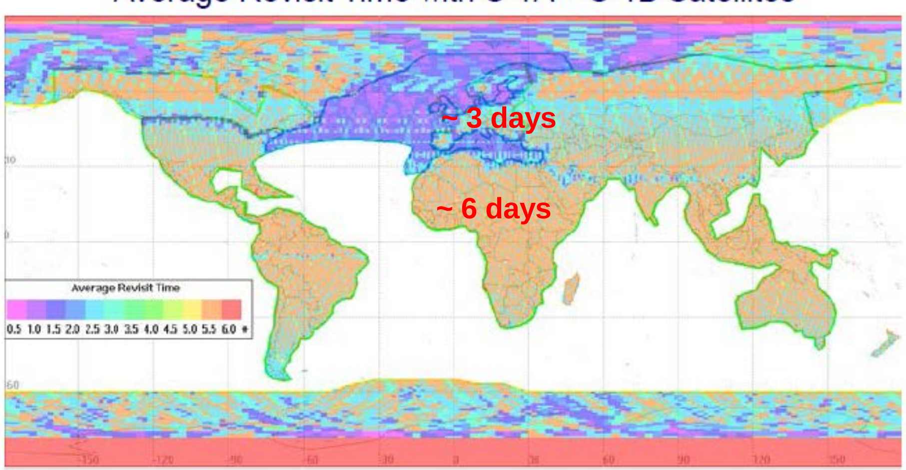
- Sentinel-1 Interferometric Wide swath (IW) mode
  - One satellite, over landmasses (IW, 15 minutes duty cycle per orbit)
  - SLC data acquisitions only 3,75 minutes during each duty cycle

Data-volume estimates (Single Polarization, raw format, excl. annotation)

Product Type	Data rate [MB/s]	Data acq. per orbit	Data volume per orbit	Data volume per day	Data volume per year	Data volume 7.5 years	Data volume 20 years
IW L1 SLC	127.554	**3.75 min**	**28.7 GB**	**419.0 GB**	**152.9 TB**	**1.1 PB**	**3.1 PB**
IW L1 GRD-HR	32.418	**15 min**	**29.2 GB**	**426.0 GB**	**156.0 TB**	**1.2 PB**	**3.1 PB**
IW L1 GRD-MR	5.190	**15 min**	**4.7 GB**	**68.2 GB**	**25.0 TB**	**186.7 TB**	**497.8 TB**
IW L1 BRW	0.007	**15 min**	**6.3 MB**	**92.0 MB**	**33.6 GB**	**251.8 GB**	**671.5 GB**
Total	-	**-**	**62.6 GB**	**913.3 GB**	**333.9 TB**	**2.5 PB**	**6.7 PB**

Comparable in size to the complete ASAR data volume

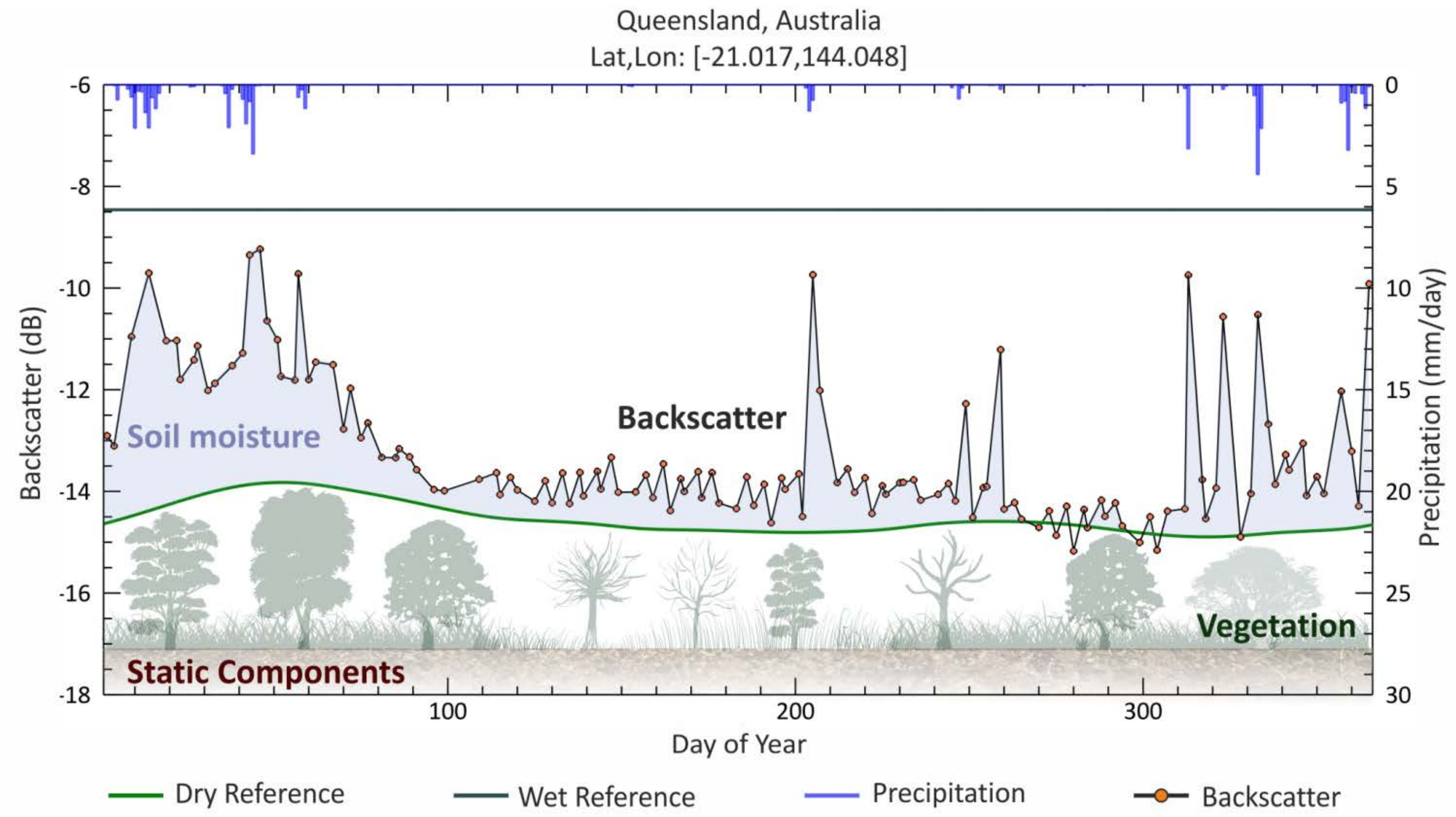
Average Revisit Time with S-1A + S-1B Satellites



Average Revisit time for two Sentinel-1 satellites © ESA

TU Wien Change Detection Method

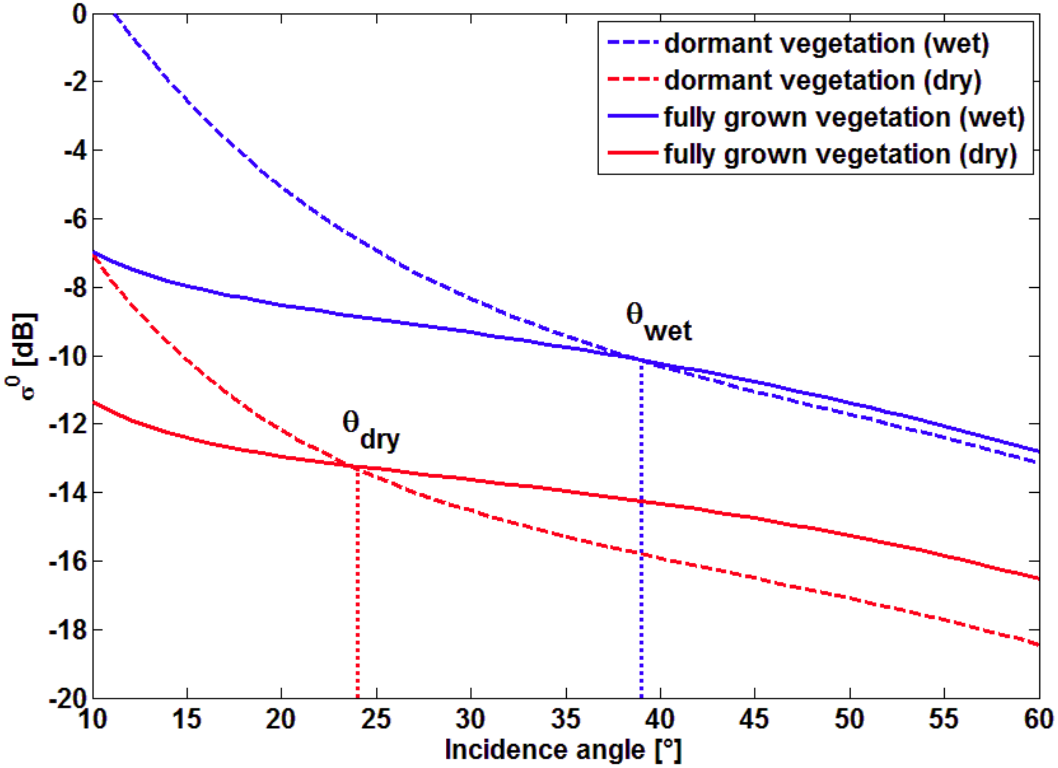
- Soil moisture retrieval method was developed for ERS scatterometer and later adopted to METOP ASCAT and ENVISAT ASAR



Functional Behaviour

- Mimics a semi-empirical backscatter model with a strong surface-volume interaction term

$$\sigma^0 = (1 - f_{nt})\left[\frac{\omega_{tr}\cos\theta}{2}\left(1 - e^{-\frac{2\tau_{tr}}{\cos\theta}}\right) + \sigma_s^0(\theta)e^{-\frac{2\tau_{tr}}{\cos\theta}} + 2\chi R_0\,\omega_{tr}\,\tau_{tr}\,e^{-\frac{2\tau_{tr}}{\cos\theta}}\right] + f_{nt}\,\frac{\omega_{nt}\cos\theta}{2}$$



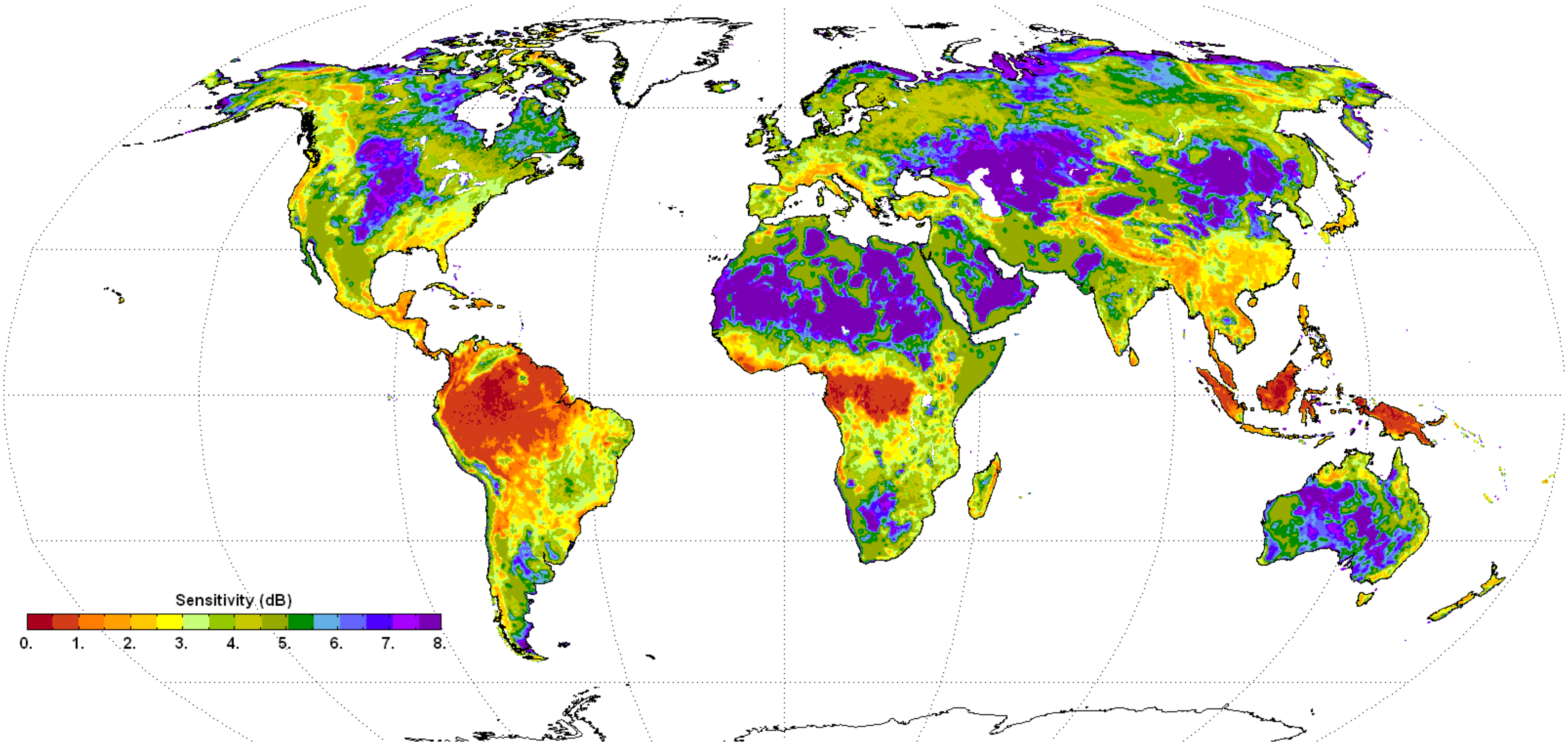
Mixing model with fraction of non-transparent (*nt*) and transparent (*tr*) vegetation

Bare soil scattering $\sigma_s^0(\theta)$ modelled with Improved Integral Equation Method I^{2}EM

Interaction term enhanced soil moisture contributions

Sensitivity to Soil Moisture

- The sensitivity describes the signal response to soil moisture changes and depends strongly on land cover

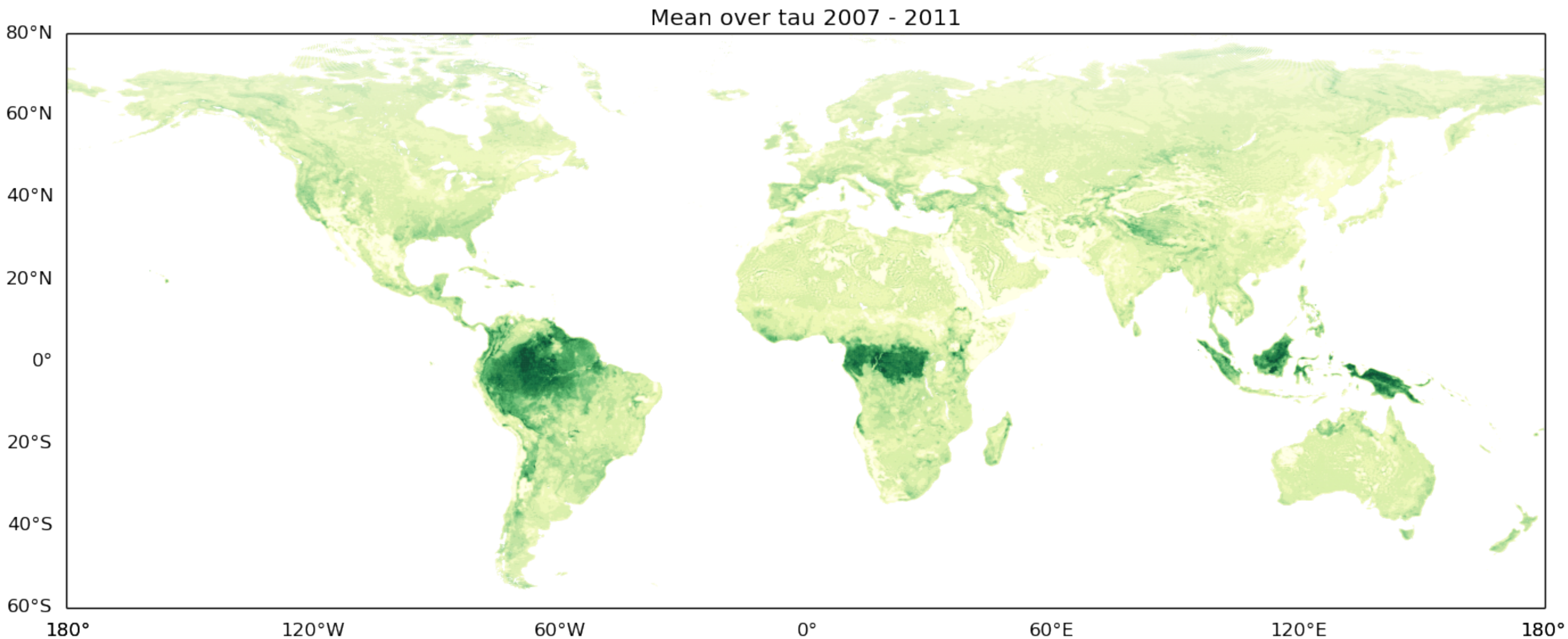


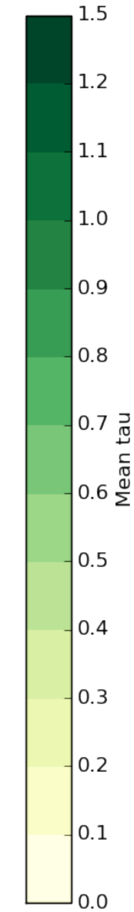
Optical Depth Estimated from Sensitivity

$$\tau \approx \frac{\cos\theta}{2} \ln \frac{\Delta\sigma_s^0}{\Delta\sigma^0}$$

← Theoretical sensitivity for a bare soil

← Observed sensitivity



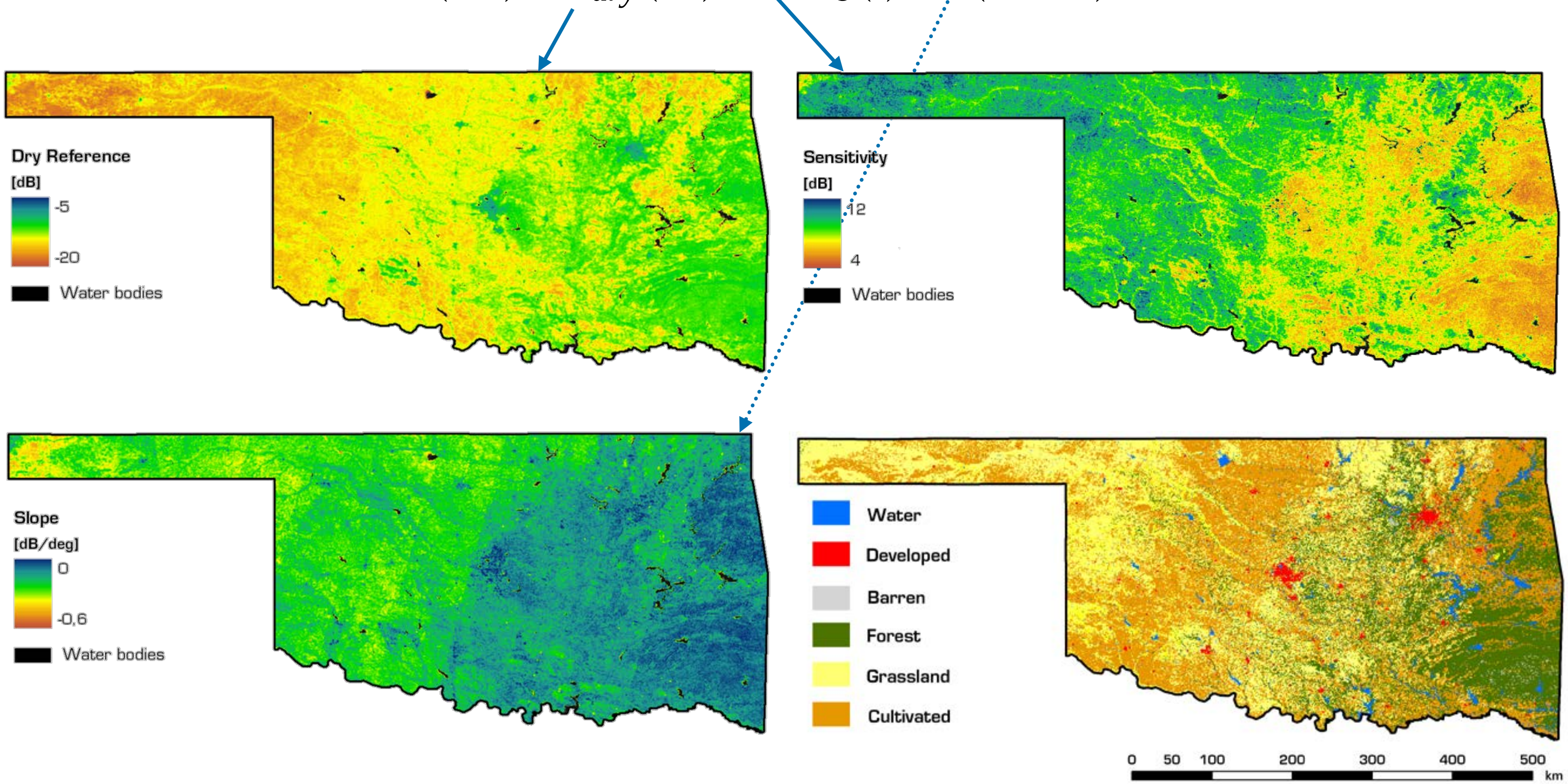


See the poster of Mariette Vreugdenhil
"Linking vegetation parameters derived from active and passive microwave observations"

SAR Backscatter Model

- Simplified version of the SCAT backscatter model

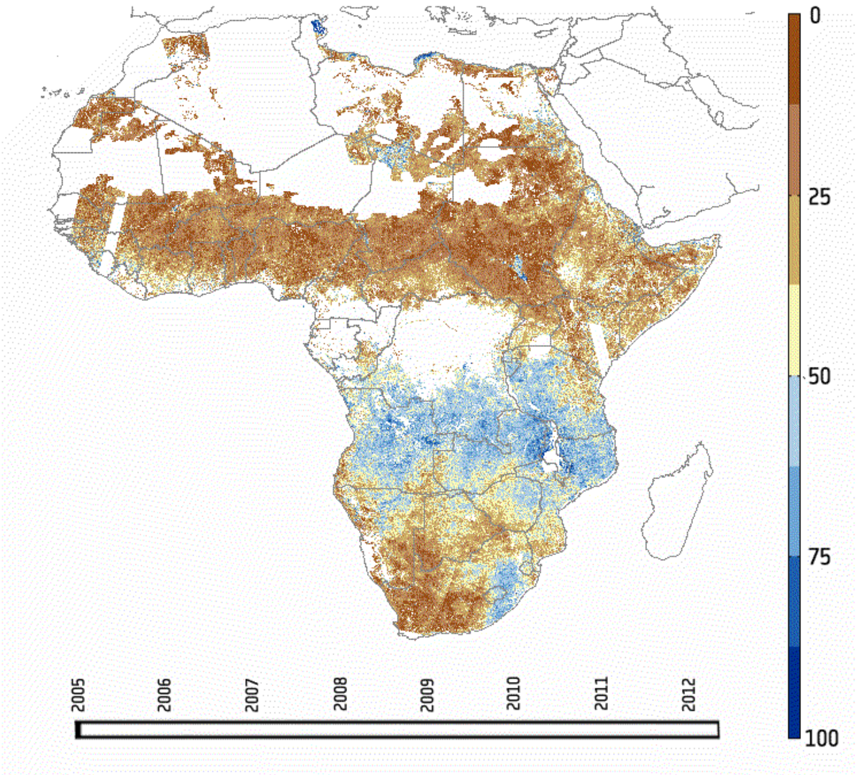
$$\sigma^0(t,\theta) = \sigma^0_{dry}(30) + S \cdot m_s(t) + \beta(\theta - 30)$$



ASAR backscatter model parameters and land cover map of Oklahoma, USA.

ENVISAT ASAR Soil Moisture

- Change detection model has been extensively tested for ENVISAT ASAR Global Monitoring (GM) data
  - Full continents (Australia, Africa) have been processed
  - NRT capabilities demonstrated
- Weaknesses
  - Poor temporal coverage
  - High radiometric noise
  - No seasonal vegetation correction
- Strengths
  - High consistence with ASCAT and other global soil moisture products
  - Spatial details not contained in ASCAT and passive sensors



1km ASCAT soil moisture over Africa produced by TU Wien in the ESA funded SHARE & Tigernet projects

eodc TU WIEN GEO

From ASCAT and ASAR to Sentinel-1

- Initial Implementation
  - Implementation of ASAR algorithm for Sentinel-1
  - Straight forward from algorithmic point of view
  - Challenging due to high data volume
- Continuous Development & Operations
  - Step-wise improvement of retrieval algorithm
  - Expected challenges
    - Roughness changes at finer scales (e.g. agricultural practices)
    - Higher complexity of vegetation characterisation at finer scale (e.g. wheat versus sugar beet)
  - Comparison with other retrieval algorithms
    - Algorithm ensembles?

Costs & Tasks are too much for one single organisation to stem!

Earth Observation Data Centre for Water Resources Monitoring

eodc

An open & international Cooperation

TU WIEN

ZAMG

GeoVille Group

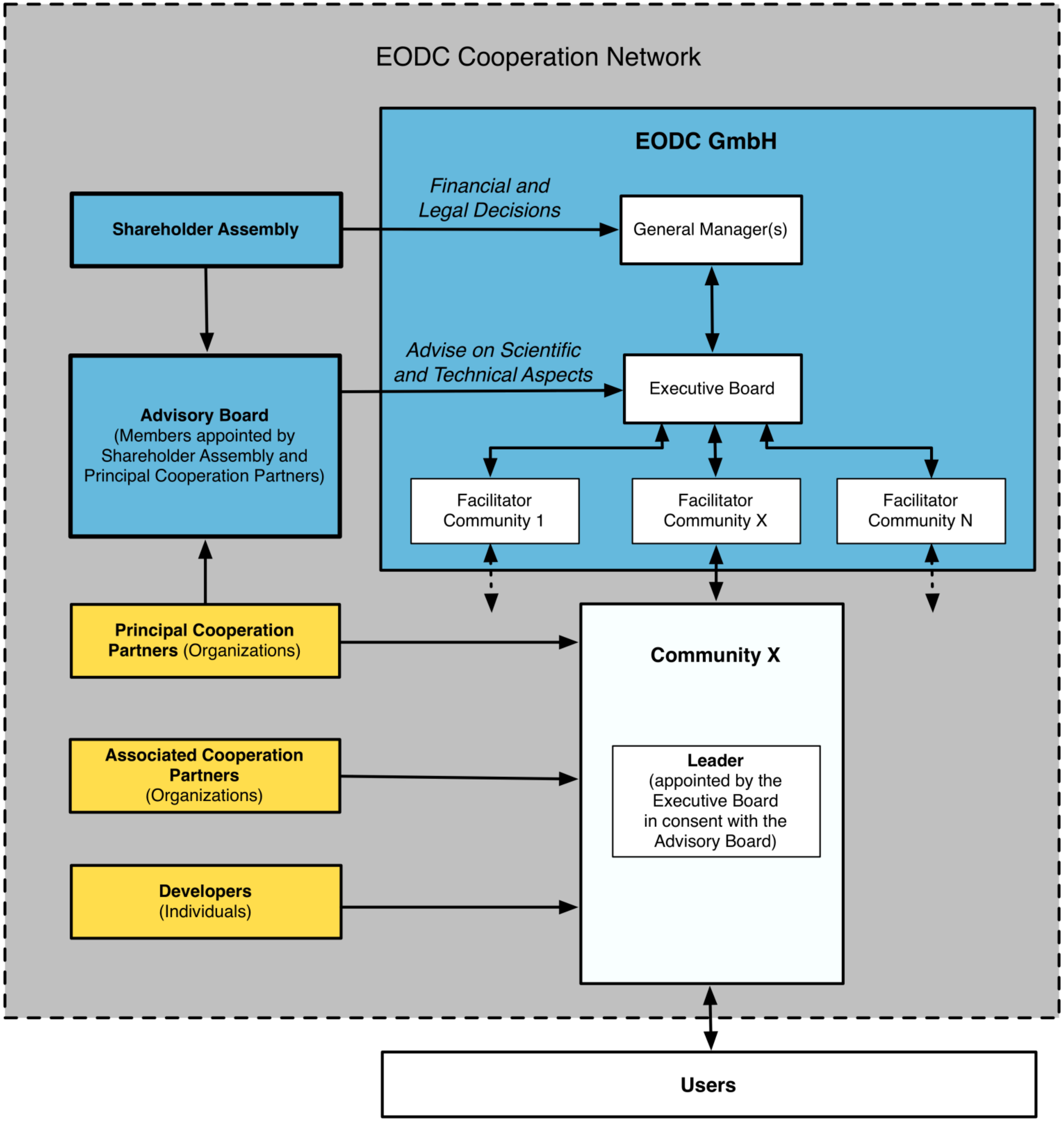
Catalysts software is your passion

BOKU

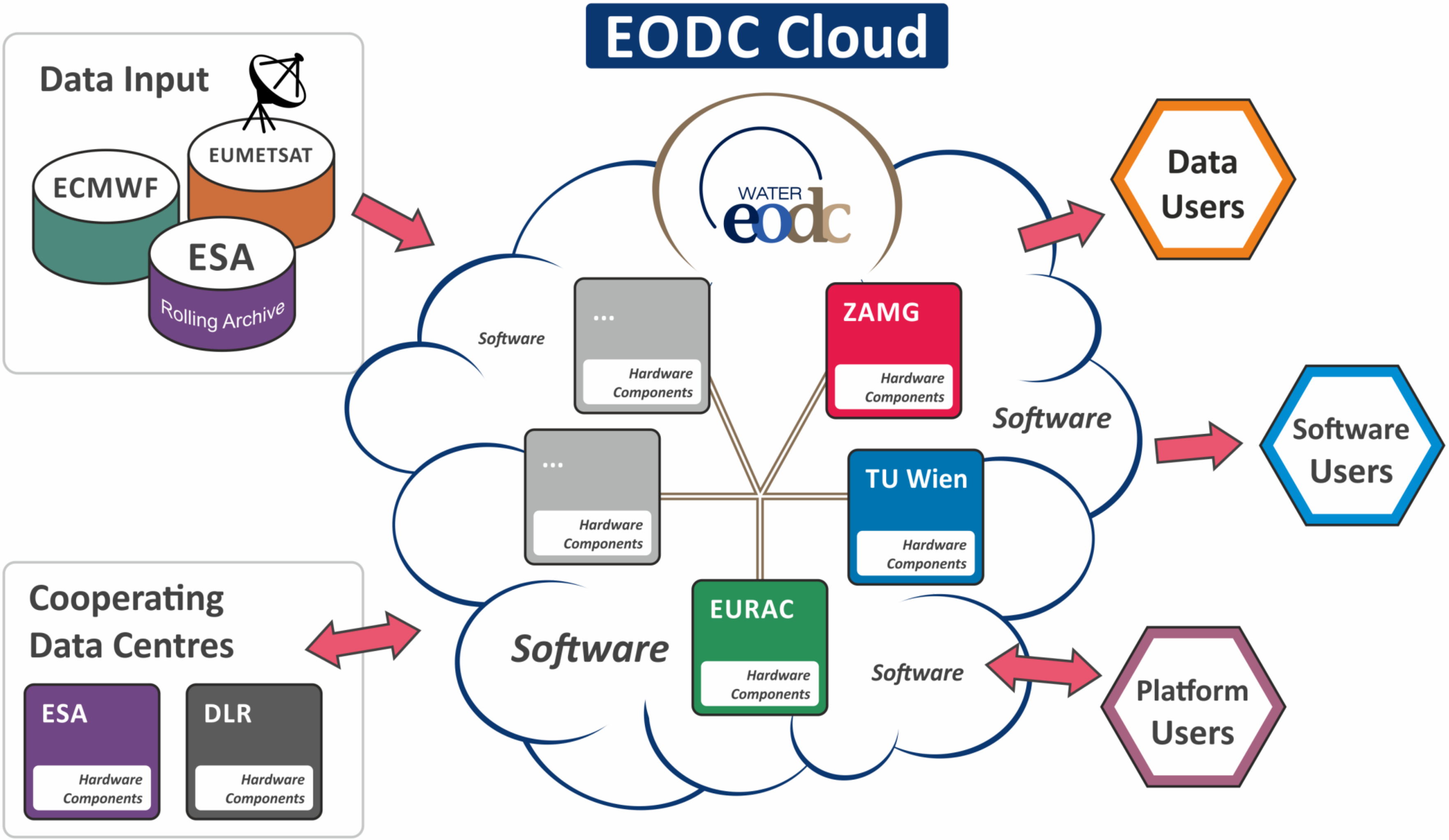
EURAC research

AWST

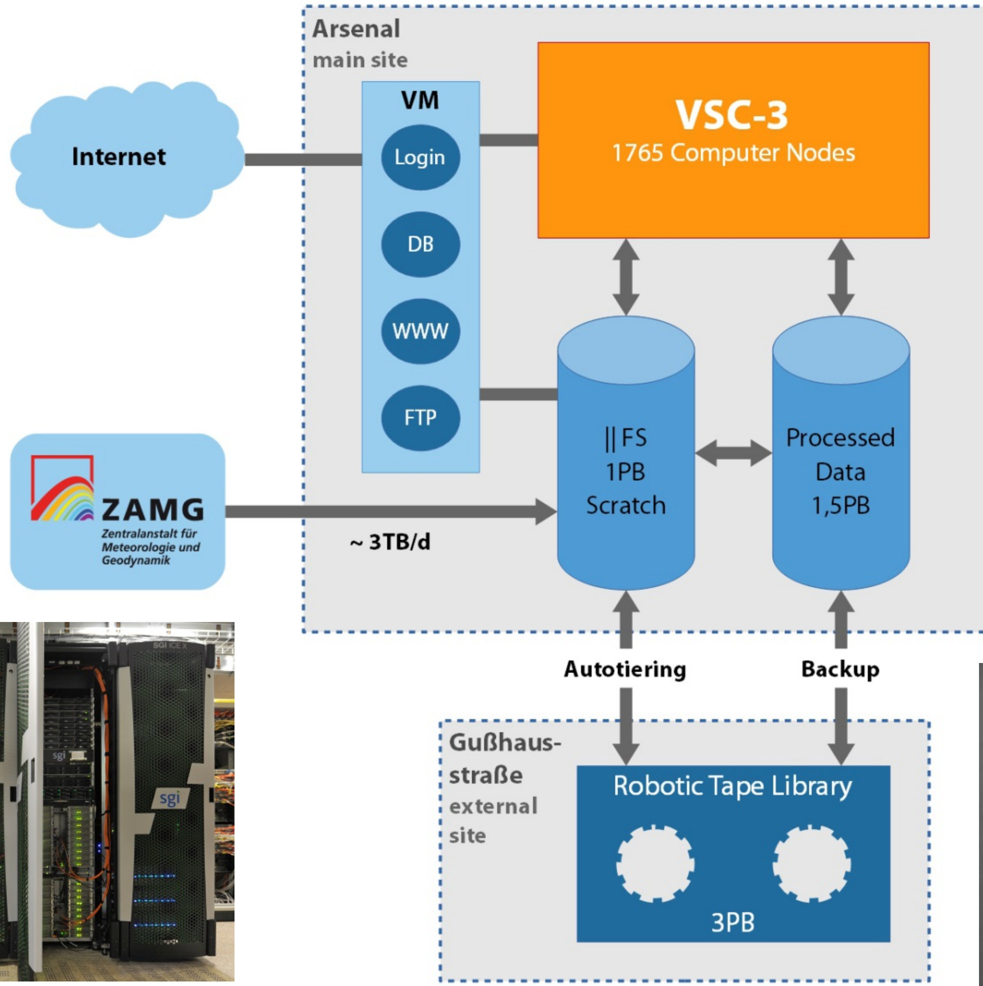
Cooperation Model



Collaborative Infrastructure



Initial IT Infrastructure hosted by TU Wien & ZAMG



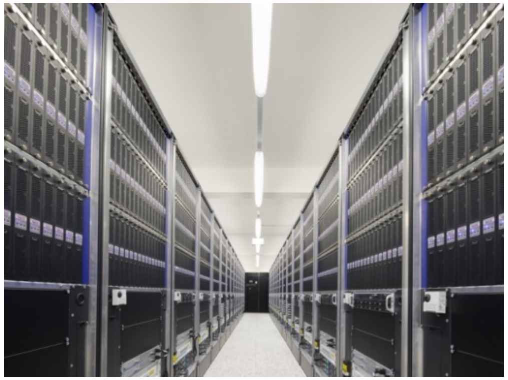
File storage
& Supercomputing

24/7 Operations
& Rolling Archive

Vienna Scientific Cluster

- The VSC-3 is an HPC system consist of 1756 nodes
- Each node is equipped with 2 processors (Intel Xeon 2.6 GHz, 8 cores), 64 GB RAM
- Connected with an Intel QDR-80 dual link high speed infiniband fabric
- Energy efficient cooling will be provided by the oil based
- Amongst the TOP 100-150 supercomputers worldwide

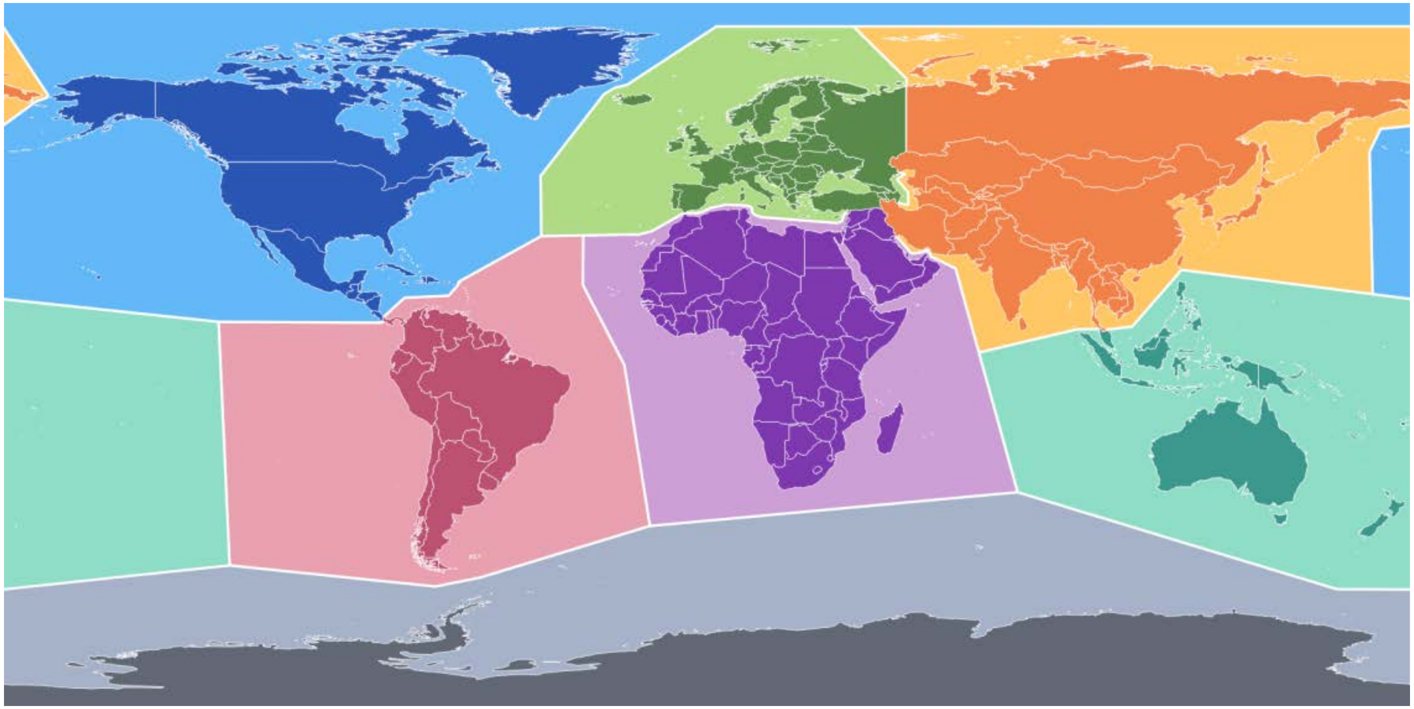
VSC-3



VSC-2

Re-engineering of SAR Processing Line for S1

- Open source code
- Fast parallel processing & efficient data storage
- Fast access in time and spatial domain



7 Continental Grids
2 % Oversampling

Bauer-Marschallinger, B., D. Sabel, W. Wagner (2014) Optimisation of Global Grids for High-Resolution Remote Sensing Data, Computers & Geosciences, in press.

Outlook

- Get EODC started
  - Initial focus will be on community services (EODC Connect/Connect+)
- Open or deepen discussions with potential Cooperation Partners
  - International outreach has started: Germany, Italy, France, Netherlands, Luxemburg, Czech Republic, Morocco, …
- Set up initial IT infrastructure (October 2014 - April 2015)

- Establish a Collaborative Ground Segment to ensure
  - Timely access to Sentinel data
  - Be clear on data policy

- Strive to become the Thematic Exploitation Platform for Hydrology
  - Implementation of models on the EODC platform is considered