How Earth Observation can Support Agrometeorological Services?

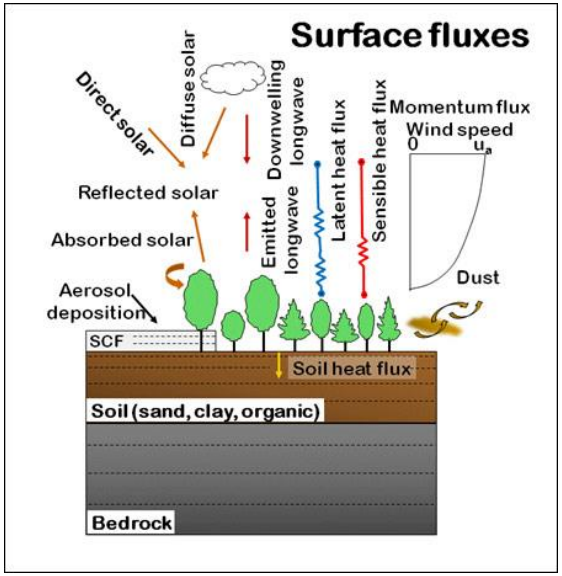
Wolfgang Wagner
wolfgang.wagner@geo.tuwien.ac.at

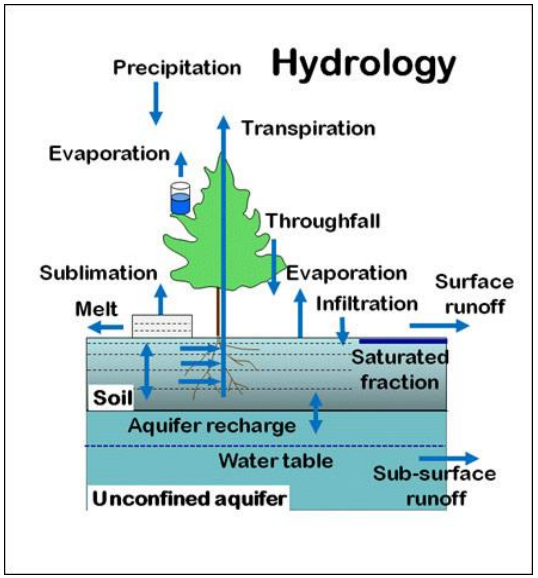
Department of Geodesy and Geoinformation (GEO)
Vienna University of Technology (TU Wien)

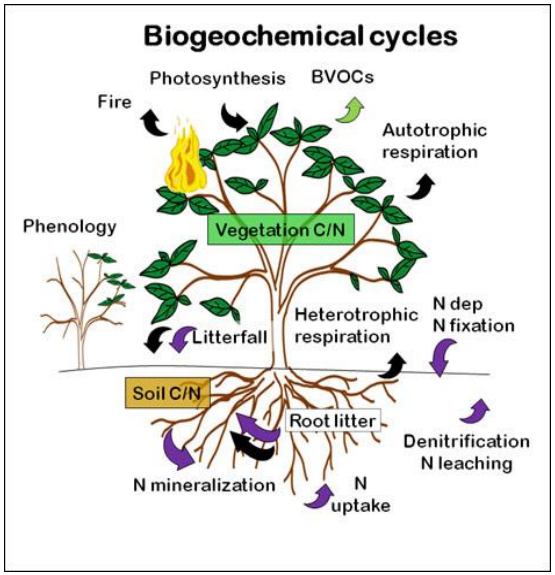
Earth Observation Data Centre for Water Resources Monitoring (EODC)

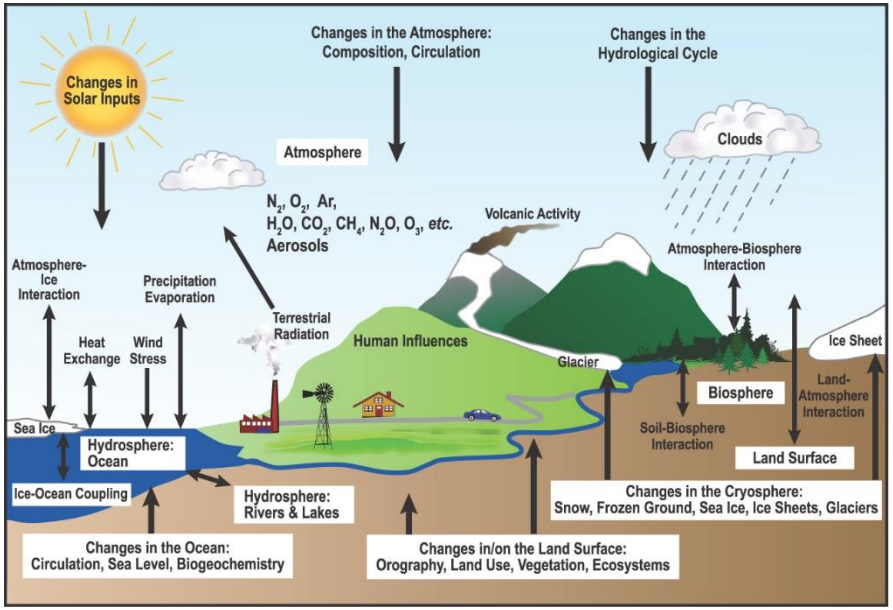
Maize field in Upper Austria end of August 2015

Agricultural Monitoring Requires a Holistic View







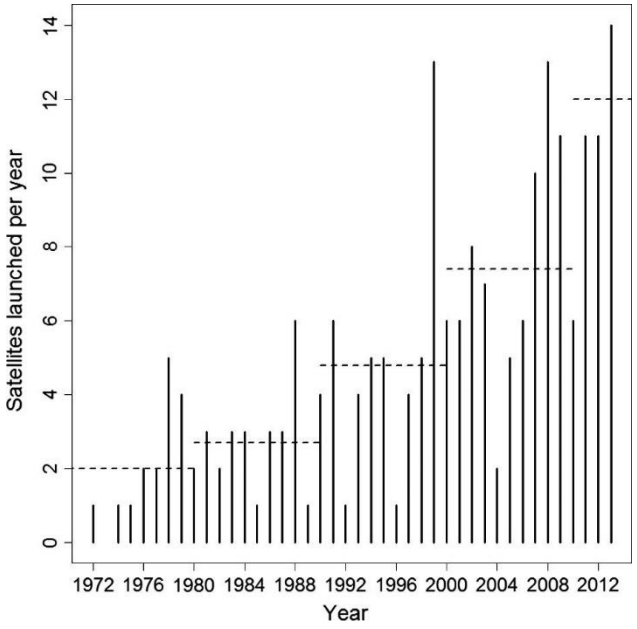


Schematic diagram depicting processes represented in the Community Land Model (http://www.cesm.ucar.edu/models/clm/)

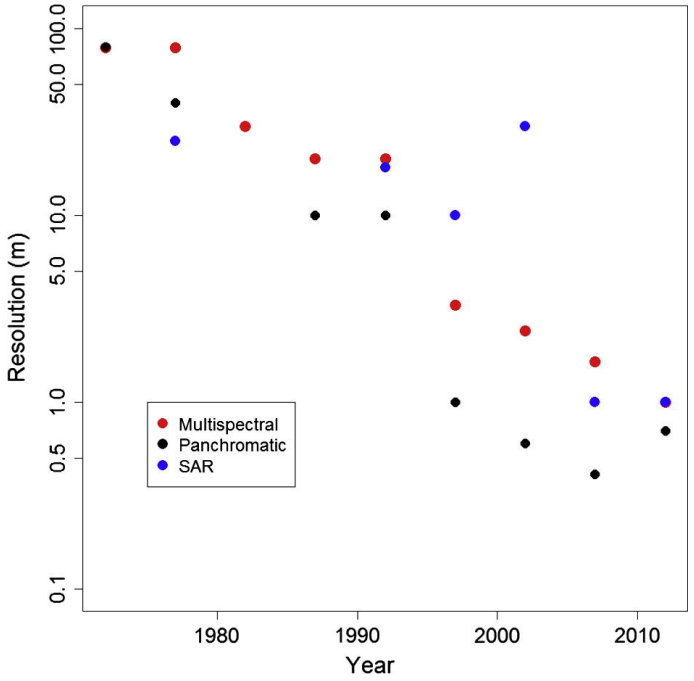
Lawrence and Fisher (2013) The Community Land Model Philosophy: model development and science applications. iLEAPS Newsletter, 13, 16-19.

Earth Observation

- More satellites than ever and better than ever



Number of individual near-polar orbiting, land imaging civilian satellites launched per year



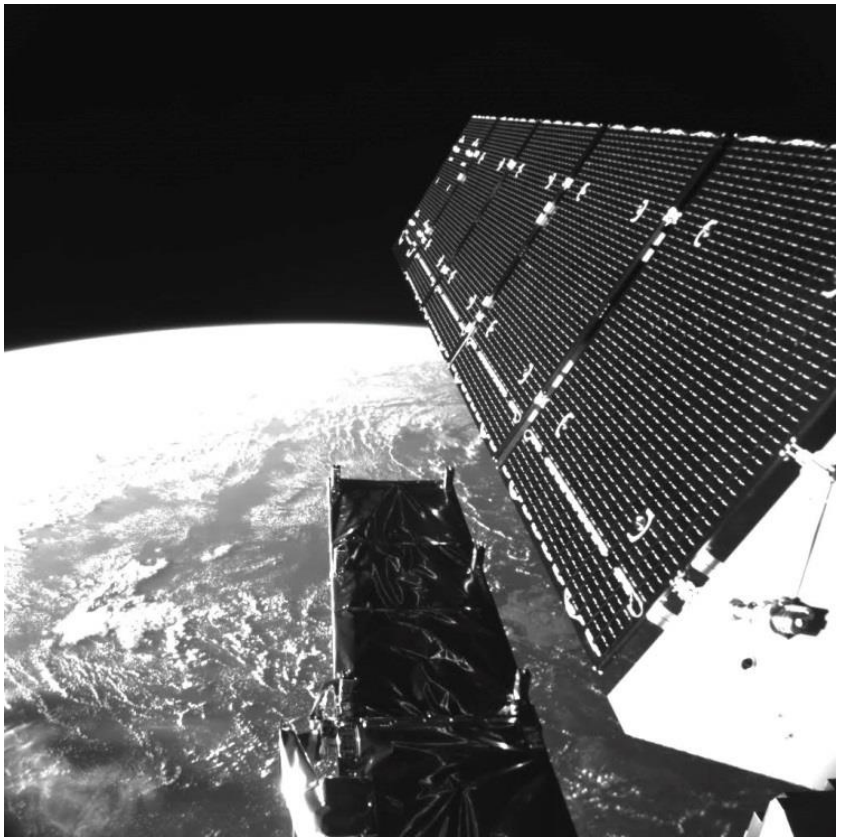
The highest resolution (meters) achieved from any panchromatic, multispectral and/or SAR sensor onboard a near-polar orbing, land imaging civilian satellite

Belward and Skøien (2015) Who launched what, when and why; trends in global land-cover observation capacity from civilian earth observation satellites. ISPRS Journal of Photogrammetry and Remote Sensing, 103, 115-128.

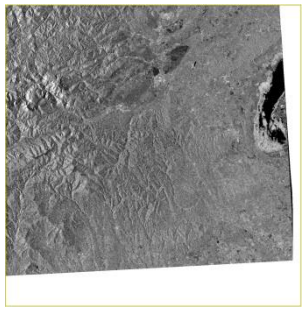
Sentinel-1 – A Game Changer

- C-band SAR satellite in continuation of ERS-1/2 and ENVISAT
- High spatio-temporal coverage
  - Spatial resolution 20-80 m
  - Temporal resolution < 3 days over Europe and Canada
    - with 2 satellites
- Excellent data quality
- Highly dynamic land surface processes can be captured
  - Impact on water management, health and other applications could be high if the challenges in the ground segment can be overcome

Solar panel and SAR antenna of Sentinel-1 launched 3 April 2014. Image was acquired by the satellite's onboard camera. © ESA



Sentinel-1 Time Series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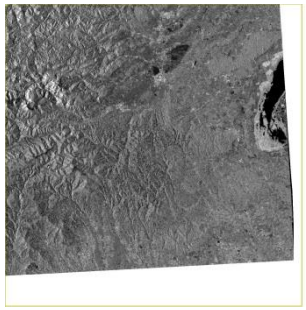
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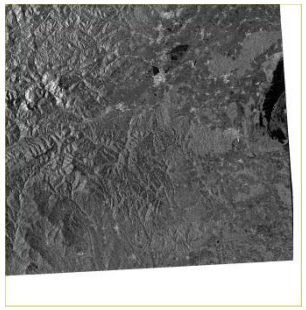
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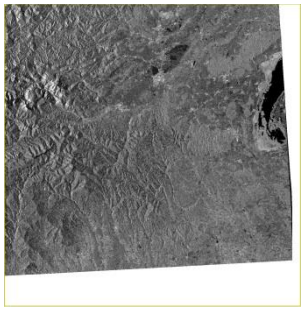
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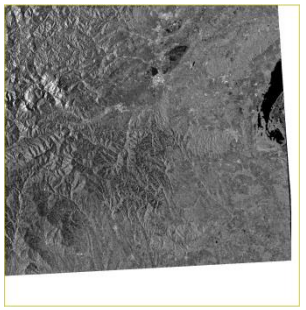
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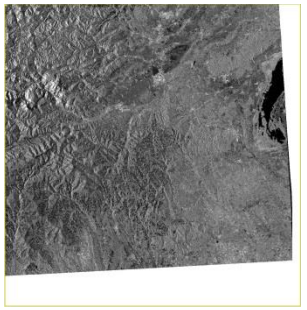
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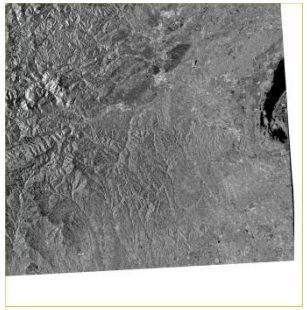
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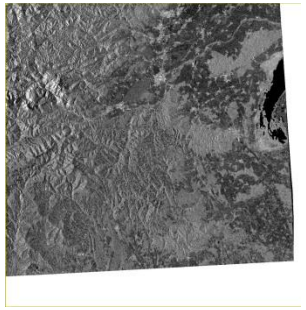
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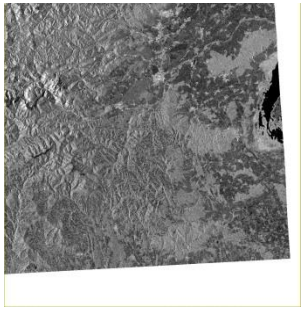
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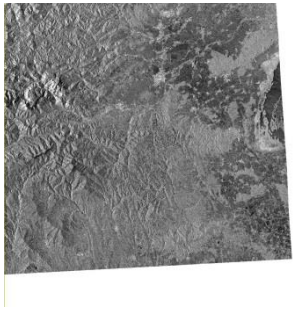
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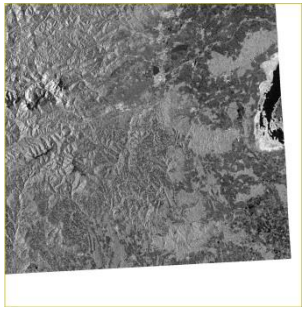
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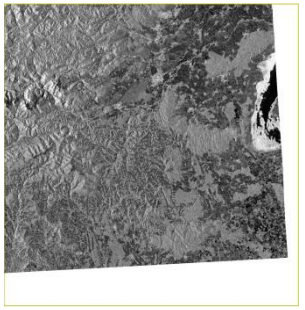
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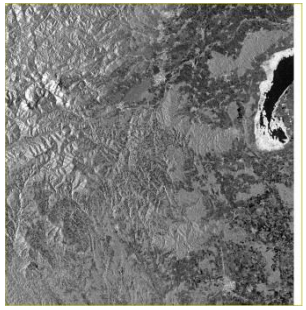
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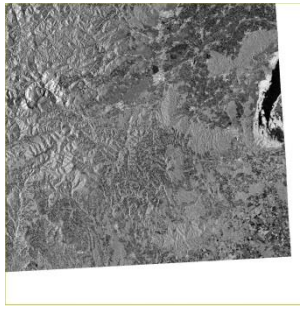
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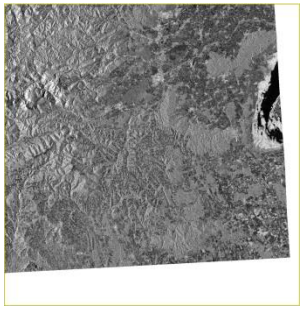
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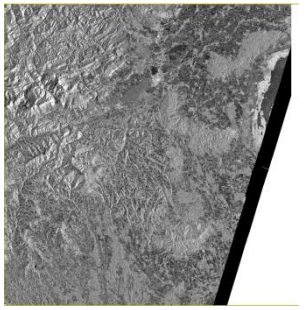
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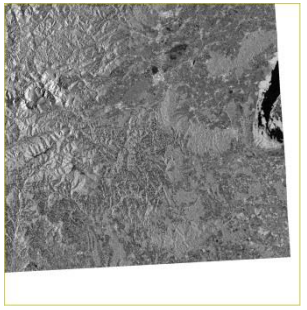
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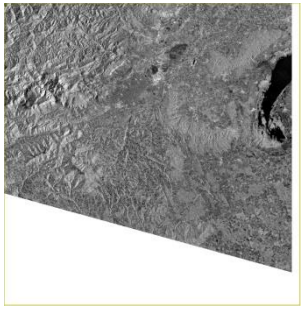
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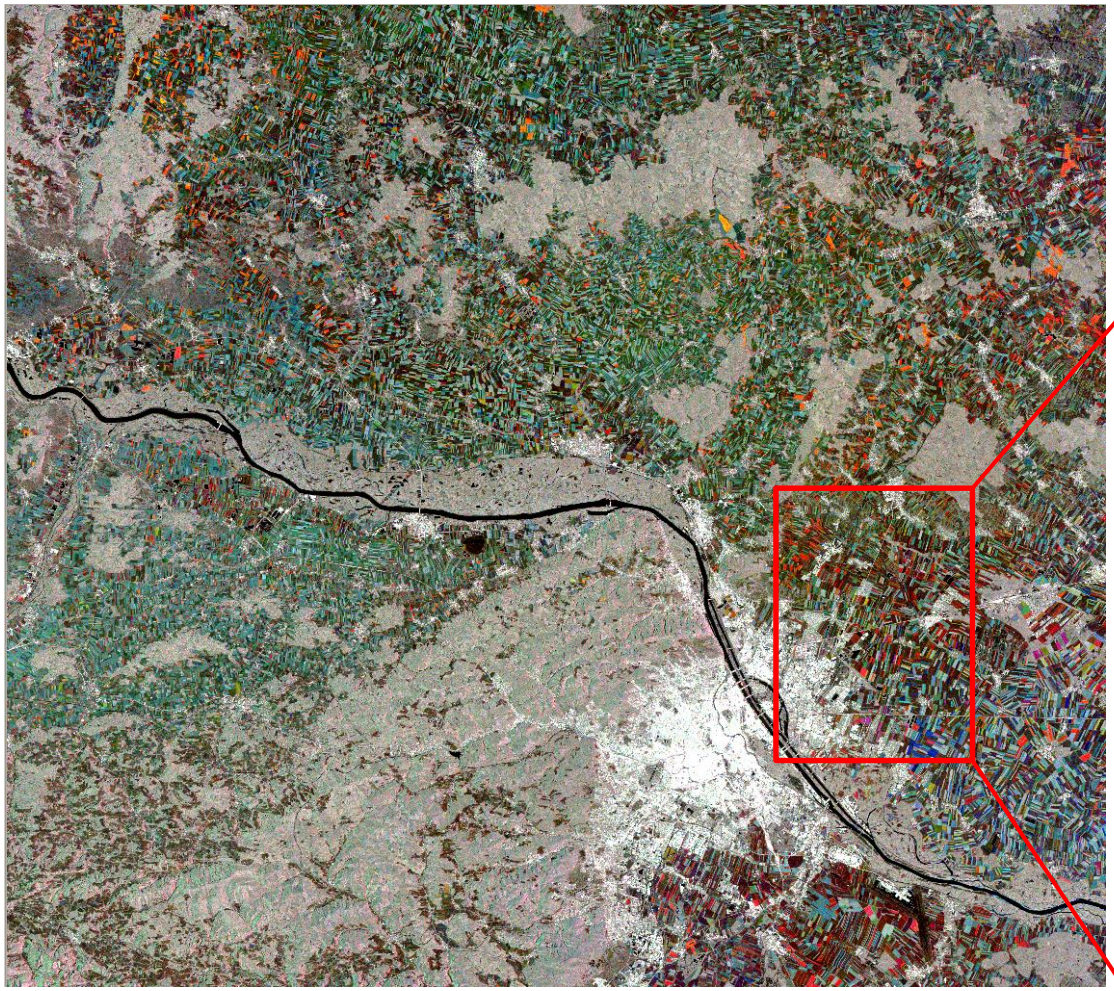
Sentinel-1 Cross-Pol (VH) Images

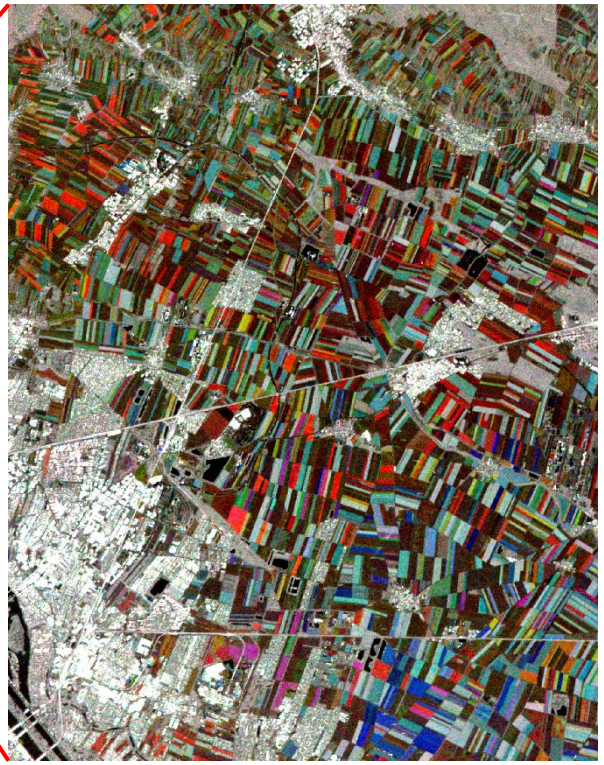


False-colour image of Sentinel-1
VH monthly image mosaics

Red – June

Green – July

Blue – August



Operational EO Data Services

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TU Wien's Soil Moisture Data Services

- **Hydrology SAF**
  - Cooperation with EUMETSAT, ZAMG and ECMWF to deliver
    - 25 km ASCAT surface soil moisture data in near-real-time
    - Assimilated ASCAT soil moisture profile
    - Disaggregated 1 km ASCAT/ASAR soil moisture maps
- **Copernicus Global Land**
  - Cooperation with ZAMG and VITO to deliver
    - Daily 25 km Soil Water Index (SWI) product based on H-SAF soil moisture data
    - Evolution activity to produce 1km ASCAT/Sentinel-1 SWI data
- **CCI Soil Moisture**
  - Cooperation with Vandersat and many others to deliver
    - Long-term (1978 up to present) 0.25° merged active/passive microwave soil moisture product
- **International Soil Moisture Network**
  - Global data hosting facility for in situ soil moisture data

ESA CCI Soil Moisture

- Merging active and passive microwave Level 2 soil moisture data sets
  - ASCAT Level 2 data provided by H-SAF
  - Passive data processing supported by NASA

- Latest release: v02.2 in 2015
  - 3 datasets: Merged active, merged passive, and combined active-passive data
  - Longer time period: 1978/11-2014/12

- New release cycle
  - February: Internal for project team
  - August: Early release for key users
  - December: Public release

soil moisture cci

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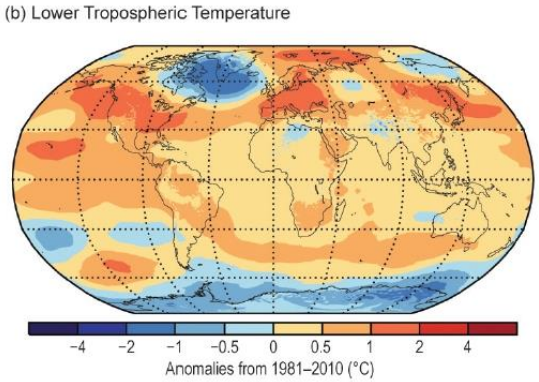
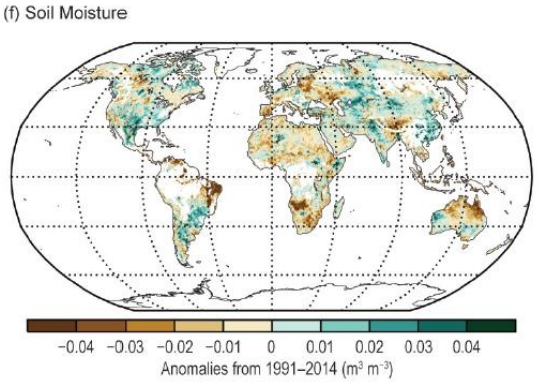
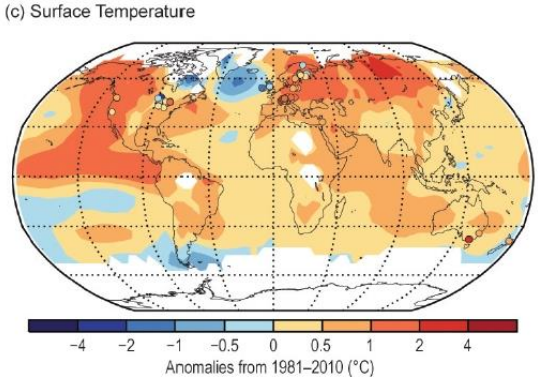
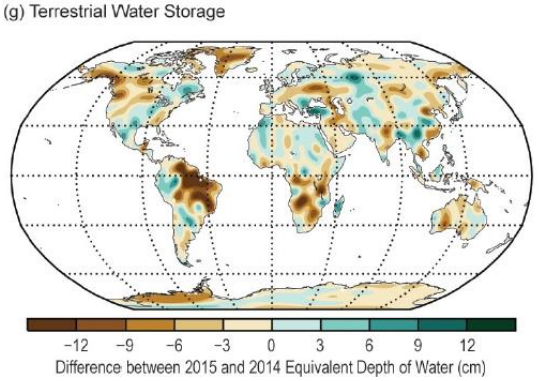
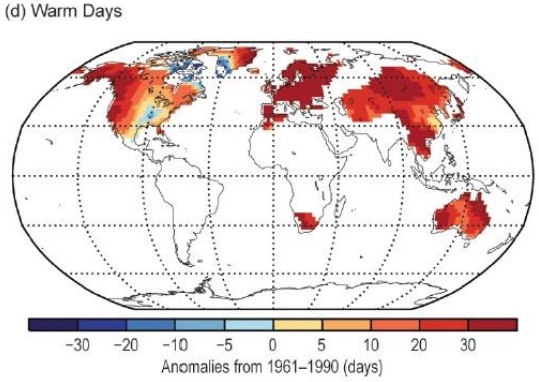
BAMS State of the Climate in 2015

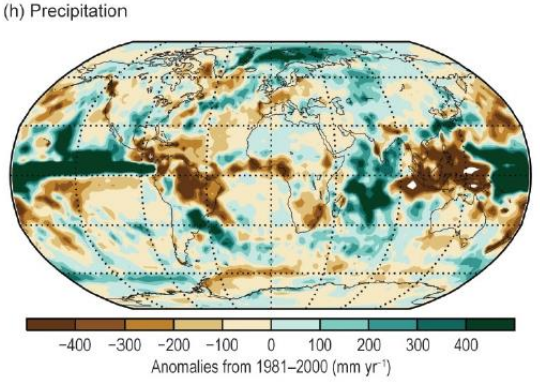










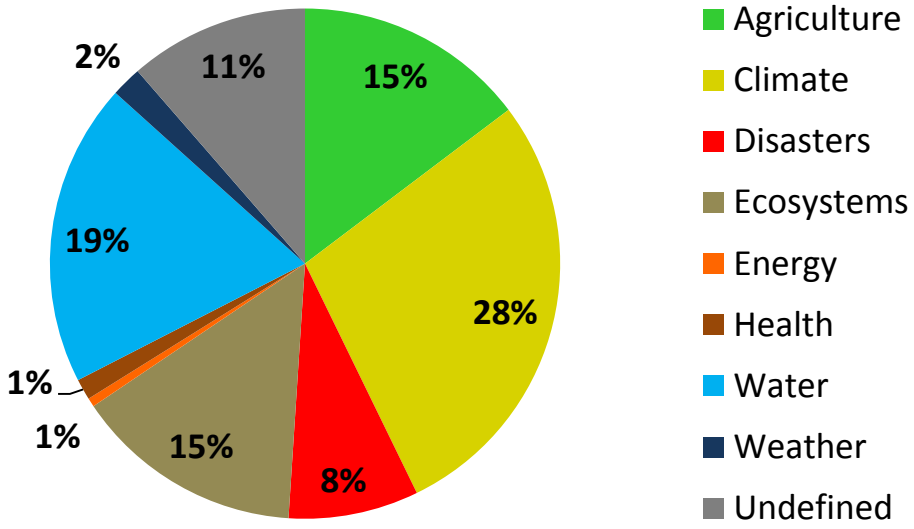


"Drier-than-average conditions were also evident over the global landmass. Soil moisture was below average for the entire year, and terrestrial groundwater storage was lower than at any other time during the record, which began in 2002. Areas in "severe" drought greatly increased, from 8% at the end of 2014 to 14% by the end of 2015."

Yearly anomalies for selected variables in 2015. Extract of Plate 2.1 of BAMS State of the Climate 2015 report. Figure f shows soil moisture anomalies derived from ESA CCI soil moisture data set.

CCI Soil Moisture Data Users

- Already over 2600 users
- Scientific users dominate, but already 20 % of all users come from public and commercial sector

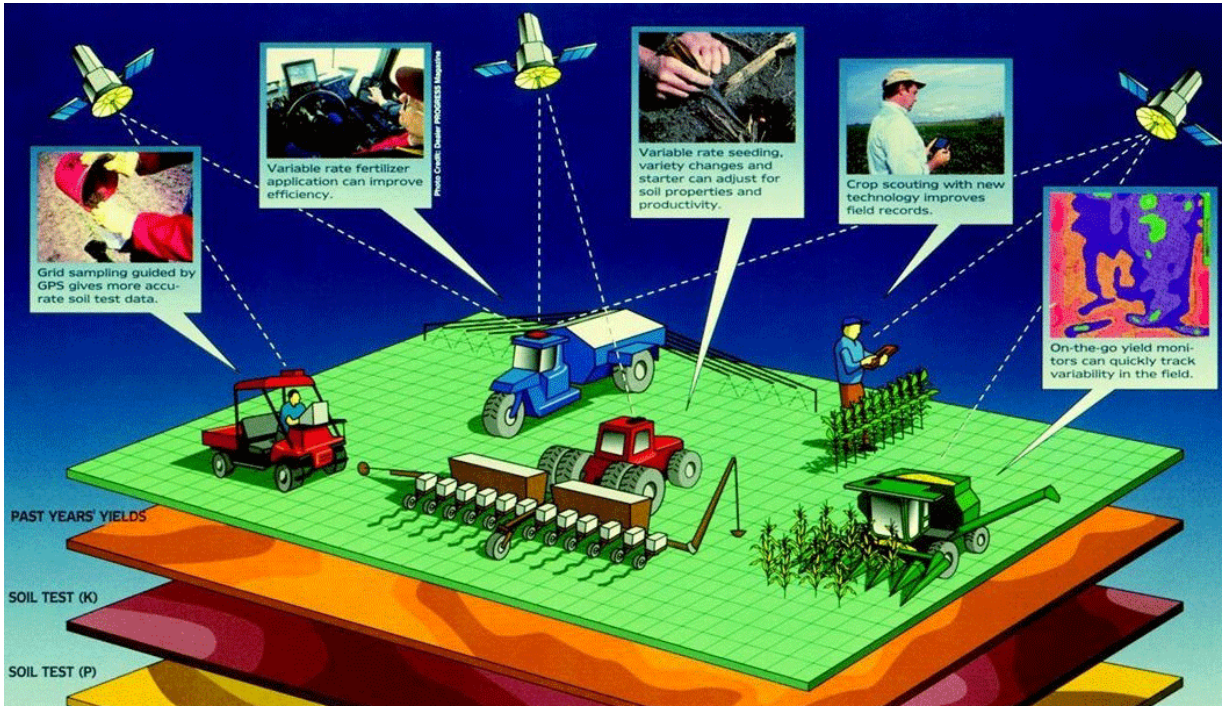


Application Domains

Agriculture has grown by 2% in the past years

Impact on Agrometeorological Applications

- Remarkably, the proliferation of earth observation technology has had only modest impacts on agrometeorological applications yet
- Simple indices such as the Normalised Difference Vegetation Index (NDVI) continue to be the main EO data type
  - Quantitative applications (e.g. assimilation of biogeophysical variables in crop yield models) still rare



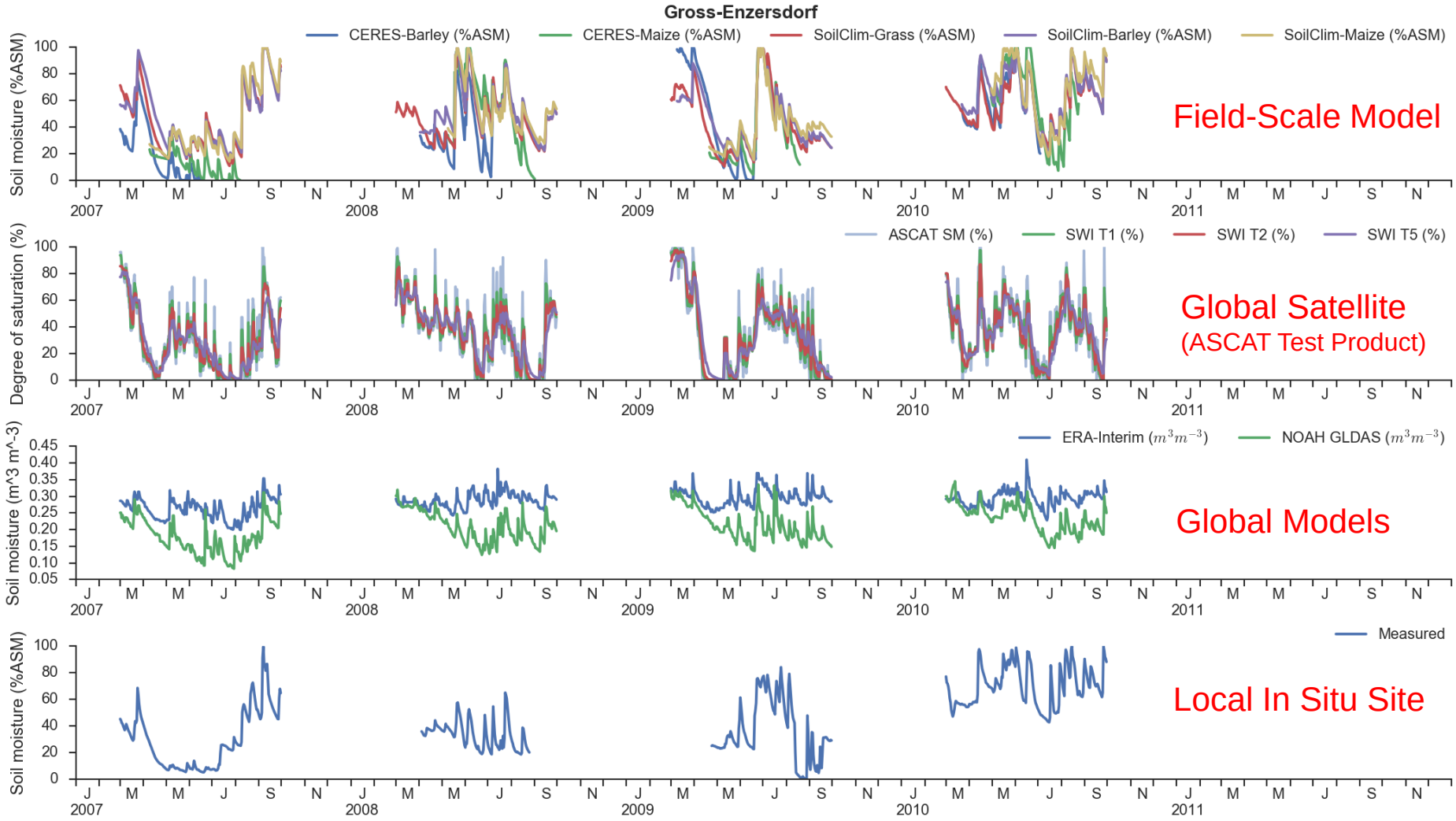
What has become of the dream of EO-powered *Precision Agriculture*?

Rodericks Oisebe (2012) Geospatial Technologies in Precision Agriculture, GIS Lounge, https://www.gislounge.com/geospatial-technologies-in-precision-agriculture/

Hurdles to Using EO Data

- Added value of using EO data in agrometeorological applications often difficult to demonstrate
  - What is the unique information provided by the EO data? For whom?
- EO data services are often not fit for purpose
  - Using EO data should be simple, not requiring expert knowledge
  - Consistency between near-real-time and historic off-line data
  - Parallel data streams for operations and testing
  - Spatiotemporal uncertainty estimates and quality flags
- Complexity of problem
  - Relationship between EO data and crop yield not straight forward
  - Existing agrometeorological models have not been built for using EO data
  - Data assimilation schemes are complex and costly
  - Lack of high quality reference data
  - Understanding scaling and representation problems

Soil Moisture from Models, In Situ and Satellites



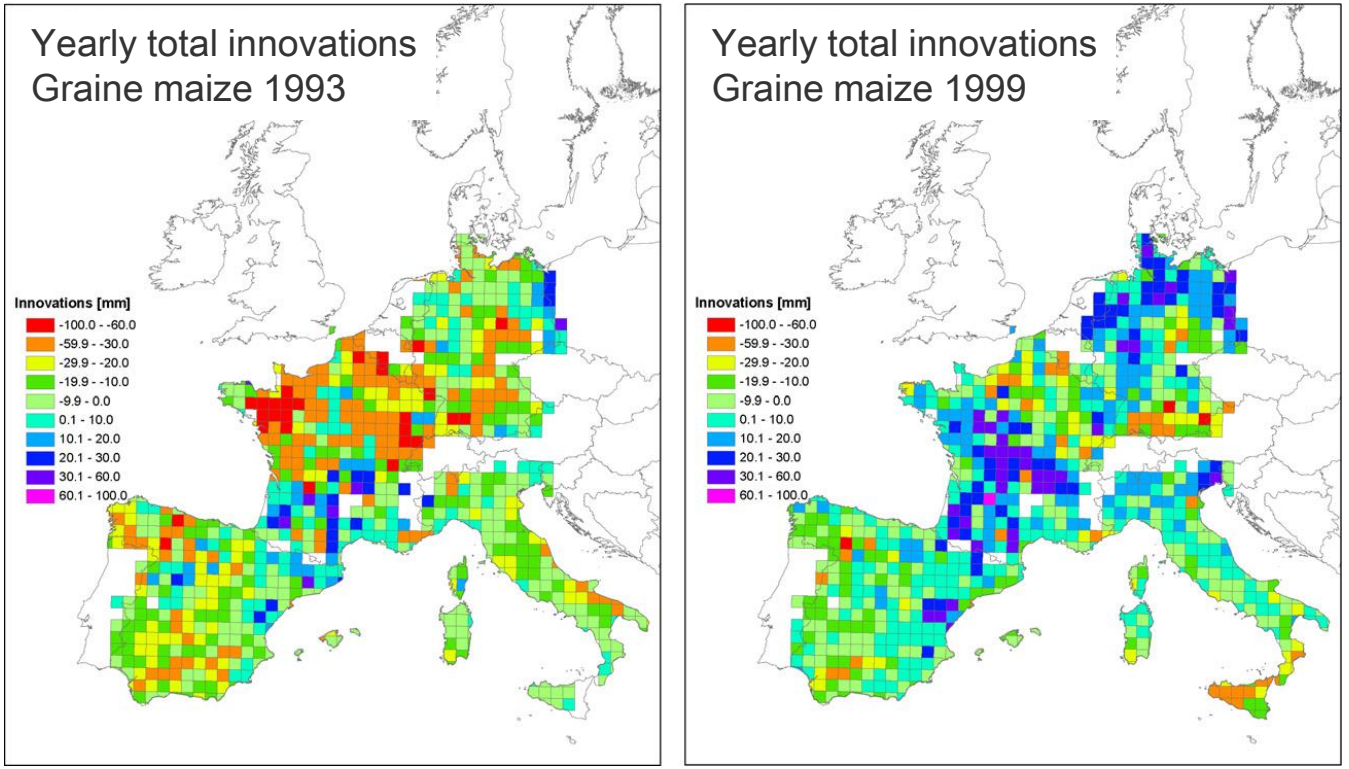
Comparison of different soil moisture data sets over an agricultural region east of Vienna.
S. Thaler, S. Hahn (manuscript in preparation)

Yield Modelling using Scatterometer SWI Data

- Assimilation of SWI in crop model WOFOST
  - Crop model data assimilation with the Ensemble Kalman filter with the goal of improving regional crop yield forecasts

Model was wetter than SWI

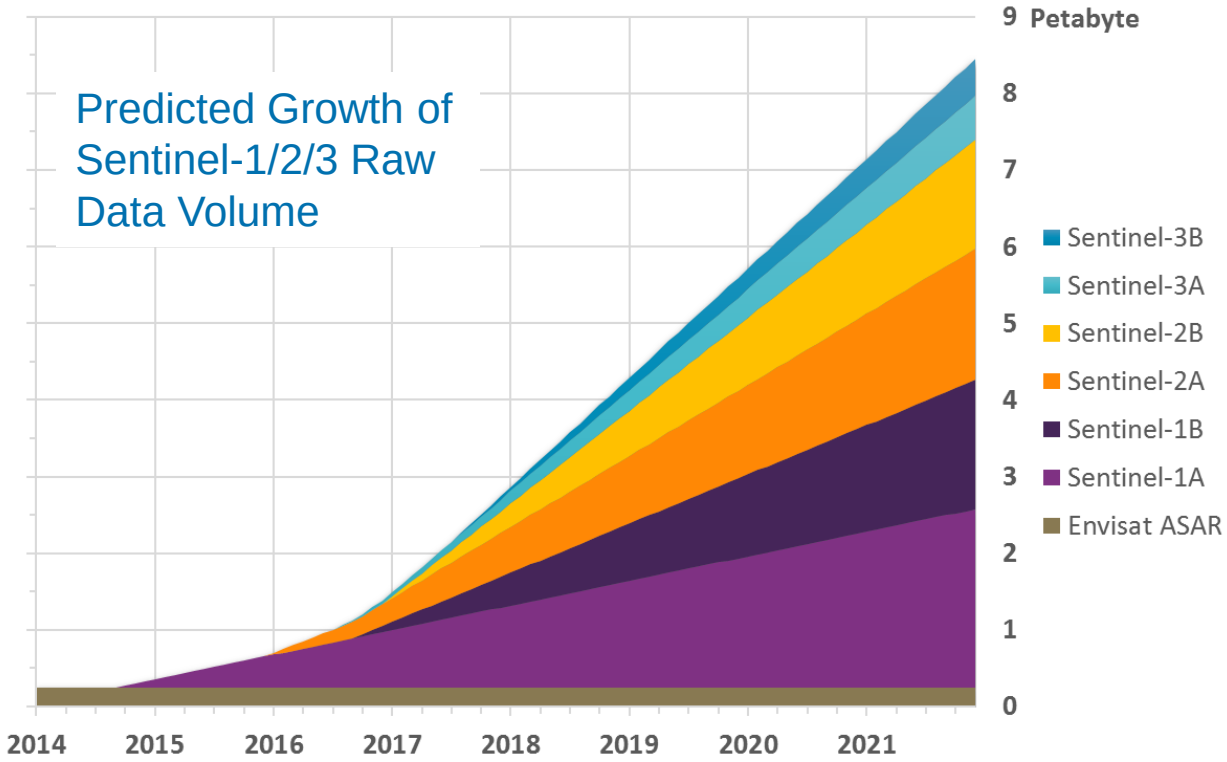
Model was drier than SWI



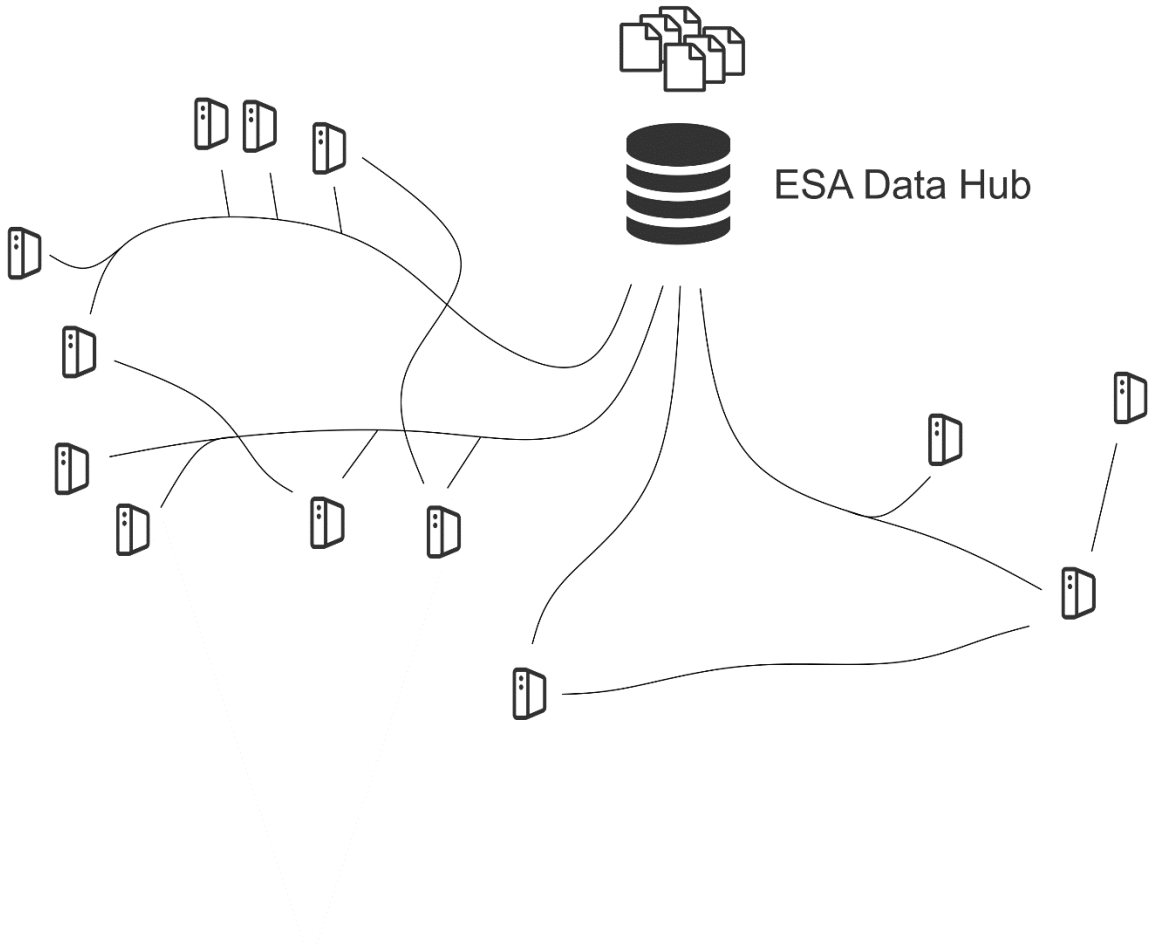
de Wit and van Diepen (2007) Crop model data assimilation with the Ensemble Kalman filter for improving regional crop yield forecasts, Agricultural and Forest Meteorology, 146(1-2), 38-56.

Towards a New Era in Earth Observation

- Volume and diversity of EO data is growing fast
- Bringing the users and their software to the data rather than vice versa becomes inevitable

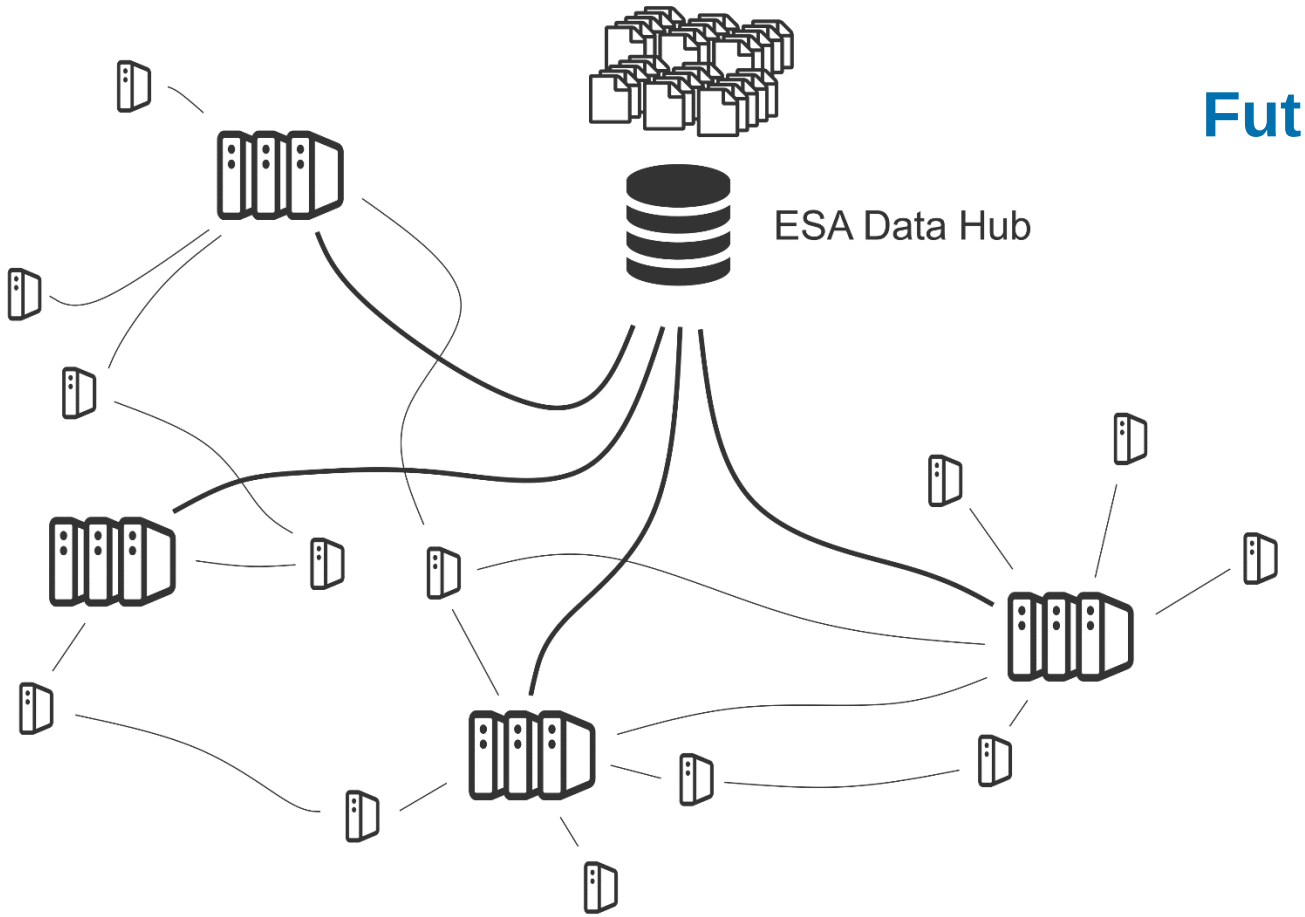


Earth Observation Ground Segment



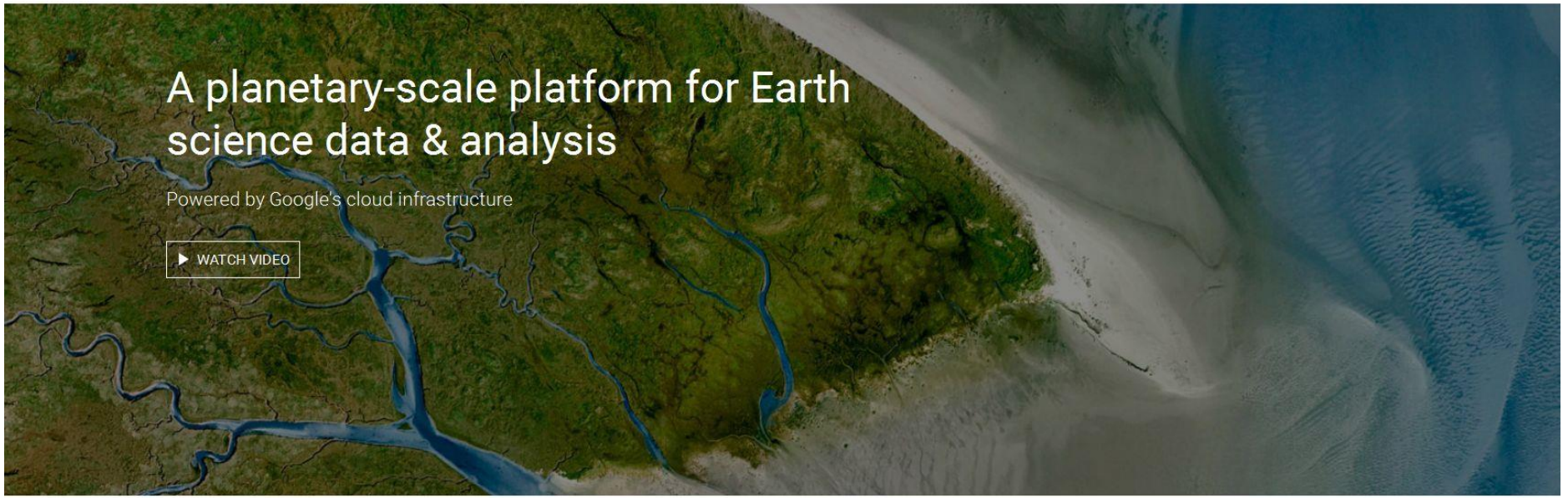
Present

Earth Observation Ground Segment



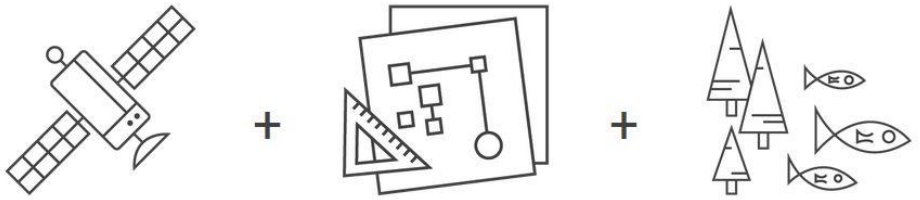
Google Earth Engine

FAQ TIMELAPSE DATASETS CASE STUDIES PLATFORM SIGN UP



Meet Earth Engine

Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities and makes it available for scientists, researchers, and developers to detect changes, map trends, and quantify differences on the Earth's surface.



https://earthengine.google.com/

Earth Observation Data Centre

- 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
- Central Goals
  - Bring users and their software to the data
  - Organise cooperation & enable specialisation
- Facilitate Joint Developments
  - Cloud infrastructure, platform services, data services, software, etc.
- Processing of Big Data
  - From satellite raw data to biogeophysical data products up to model forecasts
    - Sentinel-1, Sentinel-2, etc.
- Organisation
  - The EODC GmbH was founded in May 2014 as Public Private Partnership
  - Interested organisations can join the EODC Partner Network by becoming Principal- or Associated Cooperation Partners

EODC Infrastructure @ TU Wien's Science Centre

- Shared, multi-owner infrastructure

TOP 500 The List.

Rank 165
(June 2016)

Science Integration and Development Cloud Platform

SIDP
Cloud Plattform
>40 VMs in OpenStack
2.25 TB RAM
122 TB Private Storage
200 vCPUs

VSC-3
Supercomputer
>2'000 Nodes
>128 TB RAM
600 TB Parallel FS

Ethernet
2 x 10 GBit

Infiniband Fabric
4 x 56 GBit

EO-Compute
Compute Cluster
30 CPUs
3.5 TB RAM
1.1 PB Object Storage
3.2 TB SSD

EO-Storage
Hard Drive Disks
2 PB Parallel FS
+ 1 PB Tape Storage
2 Drives / 100 Tapes

Dedicated EO Data Processing Cluster

Petabyte-Scale Disk Storage (Disks & Tapes)

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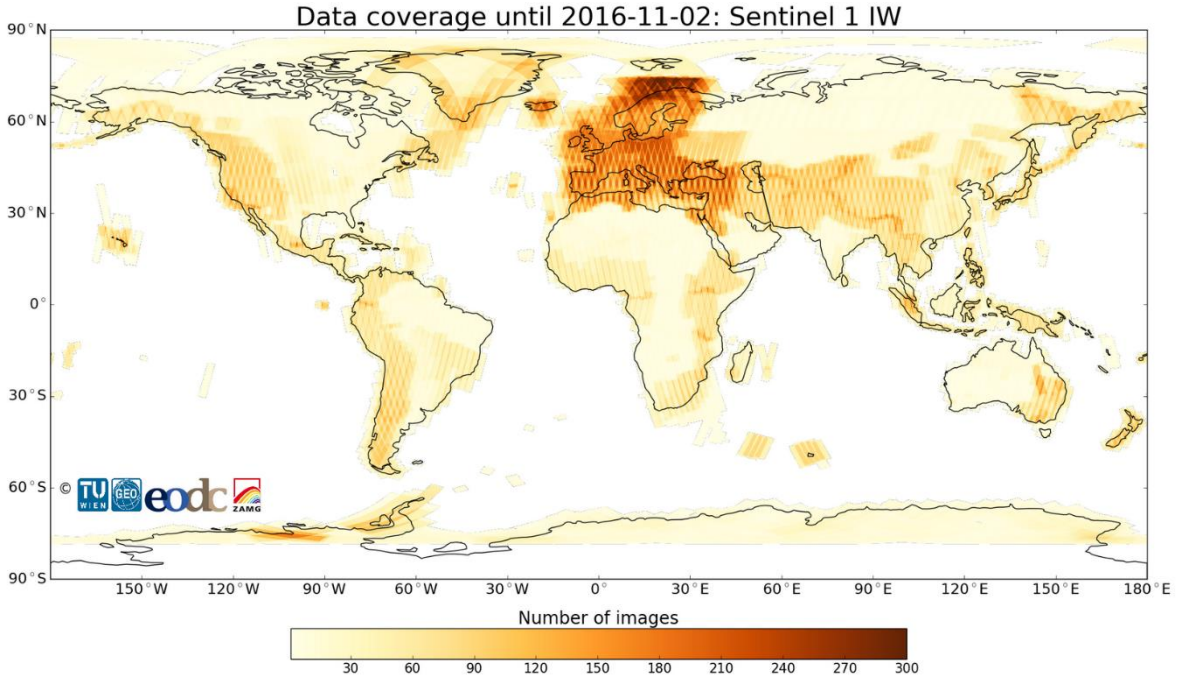
Data Availability @ EODC

- Data are received via the Sentinel National Mirror Austria
- EODC aims to store complete Sentinel data record
  - Sentinel-1
    - GRDH: 212.569 scenes
    - SLC: 10.936 scenes
  - Sentinel-2: 151.616 scenes
  - Sentinel-3: 1600 scenes

> 650 TB of Raw Data
(Status October 2016)



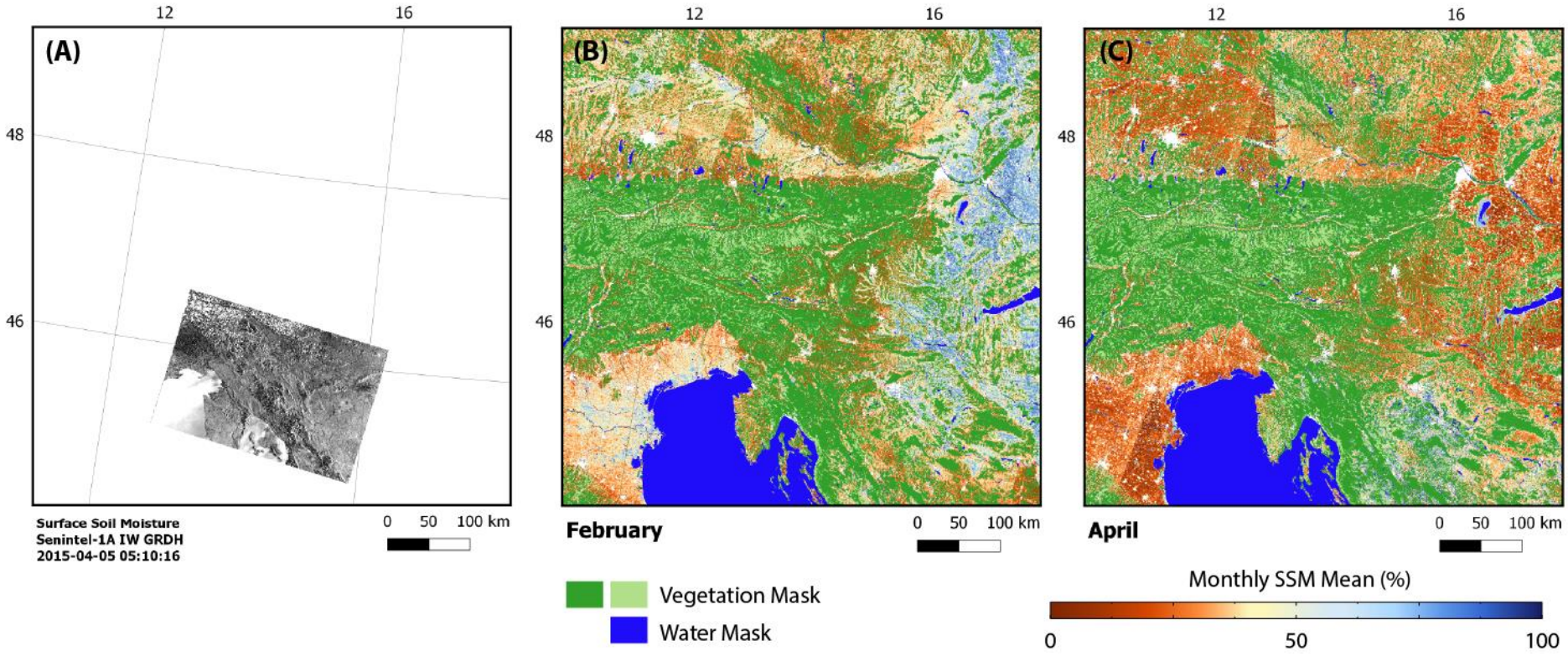
Up-to-date coverage maps:
https://www.eodc.eu/
sentinel-1a-coverage-maps/

Supercomputing Experiment: SAR Geocoding

Test	n. 1	n. 2	n. 3	n. 4
SAR product mode	ASAR GM	ASAR WS	ASAR WS	S-1 IW GRDH
Spatial resolution	1 km	150 m	150 m	20 m
Total number of data files	189,621	31,199	31,199	1,075
Number of images for job / Total Number of jobs	8 / 23,703	2 / 15,600	2 / 15,600	1 / 1,075
Input data file size range	1 - 73 MB	12 - 692 MB	12 - 692 MB	0.8 – 1.7 GB
Total input data files size	1.579 TB	5.401 TB	5.401 TB	1.2 TB
Max. number of simultaneous running nodes	417	454	612	396
Number of cores used by Sentinel-1 Toolbox	4	8	8	8
Input data caching on node	False	False	True	True
Output data caching on node	True	True	True	True
Averaged processing time (seconds/MB)	9.18	5.65	2.39	2.69
Elapsed time including SLURM queueing	**≈ 3.5 days**	**≈ 4 days**	**≈ 8 hours**	**≈ 3.5 hours**
Estimated elapsed time using only 1 node	**≈ 167 days**	**≈ 353 days**	**≈ 353 days**	**≈ 37 days**

Elefante et al. (2016) High-performance computing for soil moisture estimation, BiDS'2016, EUR 27775 EN, 95-98.

Sentinel-1 Surface Soil Moisture



A) Sentinel-1 SSM product, 2015-04-05 05:1:15
B) Monthly average of SSM, February
C) Monthly average of SSM, April.

Conclusions & Outlook

- Scientific, technical and organisational challenges for building EO-based agrometeorological services are often underestimated
- Cooperation is essential
  - if one wants to avoid becoming dependent on a handful of big commercial ITC companies
  - to build processing chains covering all steps from raw EO data to final app interface for agrometeorological users
- EODC offers not just the infrastructure but also the framework within which joint EO-based service can be developed
  - E.g. agricultural drought apps based upon multi-sensor soil moisture and vegetation data products

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EUMETSAT: H-SAF CDOP2