New opportunities in satellite remote sensing for hydrological and environmental applications

ESA perspective

Radoslaw Guzinski
About me

• 2010 – 2014: PhD from the University of Copenhagen
  • Remote sensing and evapotranspiration

• 2012 – 2015: Working in a remote sensing consulting company
  • Software development and physically based models

• 2016 – 2018: Research Fellow at ESA
  • Evapotranspiration
  • Agricultural applications
ESA facts and figures

- Over 50 years of experience
- 22 Member States
- Eight sites/facilities in Europe, about 2300 staff
- 5.75 billion Euro budget (2017)
- Over 80 satellites designed, tested and operated in flight
Sensors
Copernicus Space Component: the dedicated Sentinels …

<table>
<thead>
<tr>
<th>Mission Type</th>
<th>Launch Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1A/B: Radar Mission</td>
<td>3 Apr 2014/25 Apr 2016</td>
</tr>
<tr>
<td>S2A/B: High Resolution Optical Mission</td>
<td>23 June 2015/7 March 2017</td>
</tr>
<tr>
<td>S3A/B: Medium Resolution Imaging and Altimetry Mission</td>
<td>16 Feb 2016/2018</td>
</tr>
<tr>
<td>S4A/B: Geostationary Atmospheric Chemistry Mission</td>
<td>2021/2027</td>
</tr>
<tr>
<td>S5P: Low Earth Orbit Atmospheric Chemistry Mission</td>
<td>2017</td>
</tr>
<tr>
<td>S5A/B/C: Low Earth Orbit Atmospheric Chemistry Mission</td>
<td>2021/2027</td>
</tr>
<tr>
<td>S6A/B: Altimetry Mission</td>
<td>2020/2025</td>
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Sentinel-1: Copernicus radar imaging mission for ocean, land, emergency

• Part of the Copernicus Programme led by the European Union
• Mission based on 2 identical satellites (S1A & S1B) and a highly performing ground segment

Main satellites characteristics:
• C-band Radar instrument
  • Instrument duty cycle of 25 min/orbit in HBR modes and 75 min/orbit in LBR (Wave)
  • Sun-synchronous orbit at 693 km altitude
  • Inclination: 98.18°
• 7 years lifetime, consumables for 12 years
• Mean LST: 18:00h at ascending node
• 12-day repeat cycle at Equator (6 days with 2 satellites)
• Instrument operations based on a predefined observation scenario
• Systematic data processing with open & free data access
• Gradual increase of the mission operational capacity from the S1A launch up to the mission constellation routine operations
Sentinel-1 applications

- Maritime surveillance: oil spill monitoring, ship detection, illegal fisheries, etc.
- Ice sheets, glaciers, climate change
- Sea ice and iceberg monitoring
- Sea state: wind, wave
- Ground deformation: subsidence, landslides, earthquakes, volcanoes, infrastructure monitoring
- Sea ice and iceberg monitoring
- Soil moisture, wetland
- Emergency management
- Maritime surveillance: oil spill monitoring, ship detection, illegal fisheries, etc.
Sentinel-2: General Features

- Optical **high resolution multispectral** mission
- Twin satellite constellation with wide imaging swath: fast repetition, systematic “carpet mapping” image acquisition
- **5 days revisit time** at equator (with two satellites)
- **13 spectral bands** VIS-NIR-SWIR
Sentinel-2 applications

- **Forests & Carbon, Vegetation monitoring**
- **European land cover, human impact, high resolution layers**
- **Regional to Urban Applications**
- **Agriculture, fluorescence & biophysical parameters**
- **Water quality, Wetlands**
- **Coastal zones/bathymetry**
- **Emergency management**
- **Glaciers & ice**
- **Geology & geomorphology**
SENTINEL-3 mission overview

- Operational mission in high-inclination, low Earth orbit
- Full performance achieved with 2 satellites in orbit (S-3A,-3B)

**Optical Mission Payload providing**
- Sea and land color data, through OLCI (Ocean and Land Color Instrument)
- Sea and land surface temperature, through the SLSTR (Sea and Land Surface Temperature Radiometer)

**Topography Mission Payload providing**
- Sea surface topography data, through a Topo P/L including a Ku-/C-band Synthetic Aperture Radar Altimeter (SRAL), a bi-frequency MicroWave Radiometer (MWR), and a Precise Orbit Determination (POD) including:
  - GNSS Receiver
  - DORIS
  - Laser Retro-Reflector

In addition, the payload design will allow:
- Data continuity of the Vegetation instrument (on SPOT4/5),
- Enhanced fire monitoring capabilities, river and lake height, atmospheric products
Sentinel-3 applications

- Agriculture, vegetation monitoring
- Climate monitoring, numerical modelling and mesoscale analysis
- Water resource management
- Inland water quality
- Ship routing: maritime safety
- Fisheries: Harmful algal bloom/marine biology/global ocean primary production
- Weather forecasting & NWP
- Snow and Ice
- Mesoscale ocean circulation, currents, tides
- Fire monitoring
- Agriculture, vegetation monitoring
- Climate research
- Inland water quality
- Weather forecasting & NWP
- Snow and Ice
- Mesoscale ocean circulation, currents, tides
- Fire monitoring
Copernicus – higher temporal resolution

Data capture from Sentinel-2 (left) and Sentinel 1 (right) over a three-month period - July, August and September, in 2017.
Copernicus – higher spatial resolution

Sentinel-1

<table>
<thead>
<tr>
<th>GRD Level 1 product resolution</th>
<th>Swath Width</th>
<th>Polarisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>50m (3 ENL)</td>
<td>&gt; 400 km</td>
<td>HH+HV or VV+VH</td>
</tr>
<tr>
<td>20m (5 ENL)</td>
<td>&gt; 250 km</td>
<td>HH+HV or VV+VH</td>
</tr>
<tr>
<td>9m (4 ENL)</td>
<td>&gt; 80 km</td>
<td>HH+HV or VV+VH</td>
</tr>
<tr>
<td>50m (140 ENL)</td>
<td>20 x 20 km² at 100 km spacing</td>
<td>HH or VV</td>
</tr>
</tbody>
</table>

EW: main mode over land and coastal areas
Copernicus – higher spatial resolution

Sentinel-2

10 m

20 m

60 m
Etna eruption (March-April 2017)

Images generated using EO Browser ➞ http://apps.sentinel-hub.com eo-browser
Copernicus – higher spectral variety

- Sentinel-1
  - Dual polarisation: HH+HV or VV+VH

- Sentinel-2
  - 13 spectral bands
  - 3 in red edge

- Sentinel-3
  - OLIC – 21 spectral bands
  - SLSTR – 3 thermal channels – including for fire detection
Complementarity between sensors

Optical

SAR

Oberpfaffenhofen Airfield
(L-Band, representation of Pauli)
Complementarity between sensors

Fort McMurray wildfires - 2016

Sentinel-3 Optical and Thermal data

Contains modified Copernicus Sentinel data (2016)/processed by ESA/STFC–RAL Space, CC BY-SA 3.0 IGO
Copernicus – other features

• Free and open access data policy

• High quality
  • Accurate geolocation
  • Improved signal to noise ratio
  • Higher radiometric resolution

• Long-term planning
  • At least until 2030 in current configuration
  • Followed by second generation Sentinels
Copernicus Space Component Expansion

- Six potential missions:
  - High Spatio-Temporal Resolution Land Surface Temperature (LST) Monitoring Mission
  - HyperSpectral Imaging Mission
  - Anthropogenic CO2 Monitoring Mission
  - Polar Ice and Snow Topographic Mission
  - Passive Microwave Imaging Mission
  - L-Band SAR Mission

- Timeline:
  - 2017 – 2018: Mission requirements finalized and feasibility studies
  - 2019: Mission selection
  - 2025-2026: Launch
High spatio-temporal resolution thermal mission

- Objectives:
  - To support monitoring evapotranspiration (ET) rate at European field scale
    - Water use efficiency
  - To support mapping and monitoring the soil composition
    - Mineralogy (silica) and organic matter
  - To support a range of additional services benefitting from TIR observations
    - Urban heat island, high-temperature events, permafrost monitoring

- Preliminary specifications:
  - 30 – 50 m spatial resolution
  - 1 – 5 days temporal resolution
  - Land surface temperature uncertainty below 1 – 1.5 K
  - Early afternoon overpass
Earth Explorers

- Soil Moisture and Ocean Salinity (SMOS)
  - Soil moisture

- CryoSat-2
  - Ice thickness

- Fluorescence Explorer (FLEX)
  - Fluorescence, photosynthesis

- Biomass
  - Biomass in forests
Applications
Flood/water extent mapping – Sentinel-1

Sentinel-1 Flood Monitoring of Caprivi Flood Plain, Namibia

Caprivi floodplain, April 2014

Malawi/Mozambique January 2015

Legend
- Country border
- Derived HARD Index > 10 m
- Flooded areas

Description:
This map shows the flooding situation in the Caprivi flood plain of Zambezi River on 13th of April 2014. The flood was determined with the Water Observation and Information System (WOKS) based on SENTINEL-1A satellite data. The flood map is overlaid on the World Topographic layer.

Source data:
SENTINEL-1A 90 mode, 20 m resolution; acquired on 13th of April, 2014 at 23:31.

Cartographic Reference:
Projection: EPSG:4326
Datum: WGS 84

Legend
- International borders
- Pre-flood waters (4th Jan 2015)
- Flooded areas (22rd Jan 2015)

This map shows the flooding situation in the Lower Shire Basin on the 22nd of January 2015. The flooded areas was delineated with the Water Observation and Information System (WOKS) and based on Sentinel-1A satellite data.
Soil moisture – Sentinel-1

Gao et al. (2017), Synergetic Use of Sentinel-1 and Sentinel-2 Data for Soil Moisture Mapping at 100 m Resolution

Dabrowska-Zielinska et al. (2016), Assessment of Carbon Flux and Soil Moisture in Wetlands Applying Sentinel-1 Data
Rice growth monitoring – Sentinel-1

Contains modified Copernicus Sentinel data (2015–16)/CESBIO/ESA DUE GEO-Rice Innovator project
Agricultural monitoring – Sentinel-2

Contains modified Copernicus Sentinel data (2016), processed by ESA, CC BY-SA 3.0 IGO
Crop type mapping – Sentinel-2

http://www.esa-sen2agri.org

DUE Sentinel-2 for Agriculture project; contains modified Copernicus Sentinel data (2015), CC BY-SA 3.0 IGO
Biophysical parameters – Sentinel-2

Contains modified Copernicus Sentinel data (2017)
Lake water quality – Sentinel-2

Furesø - 2017-06-19

Chlorophyll Concentration

\[ \text{mg/m}^3 \]

- 0
- 0.2
- 0.4
- 0.6
- 0.8

Contains modified Copernicus Sentinel data (2015), CC BY-SA 3.0 IGO
Inland water quality – Sentinel-3
CyanoLakes: http://eonemp.cyanolakes.com

- CyanoLakes: winner of Copernicus Masters Ideas Challenge in 2014
- Integration of Earth Observation into the National Eutrophication Monitoring Service (EONEMP) provided by CyanoLakes (Pty) Ltd, funded by the Water Research Commission of South Africa.
- Service based on MERIS data (10 year archive) and OLCI data (live since April 2017)
- Monitoring and reporting on eutrophication (via chlorophyll-a estimates) and cyanobacteria blooms in lakes/reservoirs in South Africa.
Evapotranspiration modelling – Sentinel-2 & -3

Evaporation - Po Valley - 2017.05.17 10:30 AM

Contains modified Copernicus Sentinel data (2017)
OLCI Terrestrial Chlorophyll Index (global mean, 20-23 September 2016). Credit: Sentinel-3 MPC

SLSTR Land Surface Temperature monthly composite for September 2016. Credit: D. Ghent, University of Leicester.
Water level – Sentinel-3

Jiang et al. (2016), CryoSat-2 Altimetry Applications over Rivers and Lakes
Tools
EO Browser

http://apps.sentinel-hub.com/eo-browser/
Open Sentinel Data Access @ ESA

- ESA offers free access for all users to Sentinel products: most recent as well as complete long term archive
- ESA delivers on 24/7 basis **Near Real Time** products (3 hours from sensing) as well as Non Time Critical products (24 hours from sensing)

**ESA Data Hub provides an OPEN SOURCE Web interface**

Users can set own scripts to automatically search, filter and download products
Sentinel Application Platform (SNAP)

- Toolboxes for Sentinels 1, 2 and 3
  - Sentinel-1:
    - Radar pre-processing
    - Radar image stacking
  - Sentinel-2:
    - Atmospheric correction (Sen2Cor)
    - Radiometric Indices
    - Biophysical parameters retrieval
  - Sentinel-3:
    - Water quality retrieval
DIAS: Data Information Access Service
The Copernicus Cloud

DIAS Provider: In charge of DIAS Back-Office Services & Interfaces operations

Data Sources:
Copernicus Data & Information, Sentinels Core Products, ...

Interface for storage access & processing and management
Scalable storage hosted on cloud environment
End user: User of the third-parties services

DIAS

DIAS Provider

DIAS
Front-office

Third-Party user interface

Third-Party resources

Third-Party

User of the third-parties services

Third-Party user interface

Third-Party resources
DIAS

- Ready for operations (KO + 6months) not later than Q2-2018 assuming successful negotiation
- 3.5 years of operations, with the aim to reach the service self-sustainability by the end of the contract
- IPRs & confidentiality protection

For now...

- IPT Cloud Poland
- ESA Open Science Earth Observation Call - https://earth.esa.int/aos/oseo
- Supported until May 2018
Mapping Water Bodies From Space conference

- Mostly water body mapping
- Also other applications – water quality, etc.
- http://mwbs2018.esa.int/
Thank you

Questions?