The development of a dynamic web mapping service for vegetation productivity using remote sensing and in situ sensors in a sensor web based approach

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Why combine in situ and remote sensing sensors?

Opportunities for sensor web based approaches:
- Multi-sensor
- Interoperability
- Requirement for scaling in space and time
- Autonomy

In Situ Sensor Measurement Assimilation Program (ISSMAP) (Teillet, 2002)
Scaling between user requirements

Time
- decade
- year
- quarter
- month
- week
- day
- hour

Space
- local
- regional
- state/country
- continental
- global

Up-Down-Scaling

Climate change: carbon accounting (national government)
- Invasive species
- River catchments: flood protection (river & water board)
- Nature reserves: fire protection (forest service)

Agricultural parcel: precision agriculture (farmer)
- Nature reserve: nature management (nature service)

Drought monitoring
- Biodiversity

Source images: ecocast.arc.nasa.gov

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Scaling between user requirements

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Up/Down-Scaling

Operational earth observation systems
- Climate change
- Land use
- Drought monitoring
- River catchments
- Nature reserves
- Agricultural parcel
- Invasive species
- Drought monitoring

Geo-sensor networks operated by one organization
- e.g., MODIS products

Agricultural parcel: precision agriculture (farmer)
Nature reserves: nature management (nature service)
River catchments: flood protection (river & water board)
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Climate change: carbon accounting (national government)
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Objectives of activities in RGI-project

- Develop a sensor web based approach which combines earth observation and *in situ* sensor data to derive daily maps of vegetation productivity for regional to national scale.

- Implementation in dynamic Web Mapping Service.

- Evaluate current limitations and future research requirements.
At the global scale, terrestrial plant productivity (GPP, NPP) is one of the most-modeled ecological parameters.

8-day MODIS product (MOD17A2) is available which models GPP at a 1 km resolution.

For regional applications (e.g., monitoring crop productivity), both spatial and temporal resolution are too coarse.

Products developed for a global scale; not taking into account the regional heterogeneity of land use and meteorological parameters.

MODIS land use schematization (left) and high-resolution image (right) with detail of LGN database of area around Gendt.
Requirements for service

- Real time information provision
- Easy access to broad range of end-users: from farmers to river managers to scientists
- Automated processing
- Opportunities for scaling
- Use available OGC standards and protocols
Calculation of vegetation productivity

- \( \text{GPP} = \downarrow \text{PAR} \times \text{FPAR} \times (\varepsilon_{\text{g-max}} \times S_{\text{Tmin}} \times S_{\text{VPD}}) \)
- \( \text{GPP} = \) gross primary production (g C m\(^{-2}\) day\(^{-1}\))
- \( \downarrow \text{PAR} = \) incoming photosynthetically active radiation
- \( \text{FPAR} = \) fraction of \( \downarrow \text{PAR} \) absorbed by the plant canopy
- \( \varepsilon_{\text{g-max}} = \) maximum light use efficiency (land use specific)
- \( S_{\text{Tmin}} = \) minimum temperature scalar
- \( S_{\text{VPD}} = \) vapor pressure deficit scalar
Calculation of vegetation productivity

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يدة data
remote sensing
Implementation: automated processing chain

MODIS surface reflectance

End user

NASA MODIS FTP

Automated download & processing

MODIS surface reflectance

Potential LUE

download most actual LU & processing

SDI-NL

LUE static p. year

LUT

Calculation of GPP per 250 m pixel (python)

Web Mapping Service (pmapper)

Get Observation & processing

meteo time-series

interpolated PAR

FPAR

FPAR time-series

Get Observation & processing

FTP

Automated download & processing

End user

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RS data - MODIS sensor

- Operated by NASA (start 2000)
- Daily over-flight; spatial res.: 250–1000 m; 36 bands
- Completely automated pre-processing chain
- Daily download MODIS surface reflectance product (MOD09) from MODIS ftp download facility
- Simple cloud screening algorithm
- Calculation of FPAR (≈ NDVI = (NIR-RED)/(NIR+RED))

1 Source: http://edcdaac.usgs.gov/modis/mod09gqv5.asp
SWE – KNMI set-up

- 16 stations (KMDS)
- WMO set-up
- Prec; temp; rel hum; glob sol rad; wind dir & speed;
- 10 minute data
- OGC-SWE implementation

- Calculation of daily mean

Source: KNMI, Wiel Wauben
Web Mapping Service Vegetation Productivity

Source: http://webgrs.wur.nl/cgi/projects/sensorweb/pmapper/pmapper_gpp/map.phtml
Functionality WMS Vegetation Productivity

- Standard: panning, zooming, selection of layers, download as geotiff etc.
- Information on most recent vegetation productivity
- Time-series of vegetation productivity

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Functionality WMS KNMI Meteo Data

- Query most recent meteo data using KNMI SOS server using GetObservation request
- Example:
  - Tuesday October 14, 14:00:
    - Leeuwarden (13:30): 14.1 °C
    - Maastricht (13:30): 16.0 °C
- Additional functionality:
  - trajectories
  - other parameters
  - geographic selection
  - Etc.

Source: http://webgrs.wur.nl/cgi/projects/sensorweb/pmapper/pmapper_gpp/map.phtml
Limitations and opportunities

- Time delay remote sensing data (5-10 days)
  - Direct broadcast (including facility for processing: NL organization)
  - SWE standards not used yet
- Limited revisit frequency of RS data (incl. clouds)
  - Multi-sensor approach: specific tasking
- Limited spatial resolution of RS data
  - Sensor data fusion: combine high (25 m) and low (250 m) resolution sources: e.g., Landsat and MODIS
  - Multi-sensor approach: specific tasking
- Limited number of point stations available as SOS
  - Plug and play services required to include other stations
  - However, KNMI evaluation shows not yet the case: incomplete, redundant information, security, tools for exploration and finding data
- Interoperability will be key to combine (multi-source) sensors in space and time: use of common standards and protocols
Developments in field of Earth Observation

- OGC - Open Web Service phase 4 - Demonstration
  - Service discovery
  - EO1 tasking (NASA)
  - SPOT Tasking (ESA)
  - Web processing:
    - threshold filter
    - workflow

Example 1: Datafed online EO processing

Example 2: Wildfire monitoring through EO sensor tasking


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Conclusions and outlook

- Proof of concept shown
- Combined use of in situ sensor and remote sensing data: dynamic continuous maps (as input for SDI)
- Multi-sensor data: extent use of (OGC) standards
- Further research & implementation to reduce limitations

Outlook

- Extent to other products and applications: e.g., actual evapotranspiration