A flood index based on EO big data for an improved flood mapping, depth estimation and impact assessment in a changing climate

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Floods are the greatest sources of losses in the globe. Impacts are constantly increasing with climate change and socio-economic change as main drivers.

Floods happen!
Inserire immagine inondazione
Fabio Cian, 2/5/2016

grafico munich re su incremento di flood damage
Fabio Cian, 2/5/2016
Floods (riverine, flash and coastal floods) are the greatest sources of losses in the globe.

Impacts are constantly increasing with climate change and socio-economic change as main drivers.

Flood risk is not sufficiently understood.

Data from satellites show potential for supporting decision making processes in order to reduce losses and increase adapting and coping capacity.

Knowledge gap between stakeholders and RS.

Sources:
Inserire immagine inondazione
Fabio Cian, 2/5/2016

grafico munich re su incremento di flood damage
Fabio Cian, 2/5/2016
Need of a better flood risk assessment?

Institutions demand better understanding of flood risk:

– support climate change adaptation policies
– develop robust public disaster relief funds
– develop risk profile for financial institutes
– risk portfolio for re-insurance companies
– risk in supply chain for multinational companies

Increasing need of global flood risk assessment

Sources:
New Sentinels, new opportunities

Exploitation of **EO Big Data**: Sentinel-1

**More precise flood mapping** for emergency response and economic impact assessment

**Evolution** of flood events

Derivation of **Flood Depth**
Assess the **extent** of a **flood event**

**Compute the Normalized Difference Flood Index**

\[ NDFI = \frac{\text{mean pixel intensity (reference)} - \text{min pixel intensity (flood)}}{\text{mean pixel intensity (reference)} + \text{min pixel intensity (flood)}} \]

- Stack of reference images
  (selection of images in the same weather season)

- Stack with flood images
Normalized Difference Flood Index

Flood index > 0

Flood index < 0
Normalized Difference Flood Index

1 – unlikely values
2 – permanent water bodies
3 – flooded areas
Compute the Normalized Difference Flood in Vegetated Areas Index

$$NDFVI = \frac{\text{max pixel intensity (flood)} - \text{mean pixel intensity (reference)}}{\text{max pixel intensity (flood)} + \text{mean pixel intensity (reference)}}$$
Shallow Water in Short Vegetation

Flood index > 0

Flood index < 0
From beginning of January 2015 heavy rain caused a big flood in south Malawi, which lasted until the end of March.

276 deaths
174,000 displaced
1 million affected

Overcrowded displacement sites
Concern for rape, cholera, diarrhea, malaria
Flood in Malawi 2015 – Sentinel 1 Data

January 22nd, 2015

Sentinel 1 Data

Descending Orbit
VV Polarization

Reference Images
11 November 2014
05 December 2014
29 December 2014
Flood in Malawi 2015 – Sentinel 1 Data

January 22nd, 2015

NDFI (inverted grayscale)

Descending Orbit
VV Polarization

Reference Images
11 November 2014
05 December 2014
29 December 2014
Flood in Malawi 2015 – Sentinel 1 Data

January 22nd, 2015

NDFVI

Descending Orbit
VV Polarization

Reference Images
11 November 2014
05 December 2014
29 December 2014
Flood in Malawi 2015 – Sentinel 1 Data

January 22\textsuperscript{nd}, 2015

\textbf{Flood Map}

NDFI > 0.7
NDFVI > 0.75

Filtered:
Area < 1000 m\textsuperscript{2}
Elevation --> Slope > 5°

\begin{itemize}
  \item Flood
  \item Shallow Water
  \item in Short Vegetation
\end{itemize}
Flood in Malawi 2015 – Sentinel 1 Data

Flood Map

NDFI > 0.7
NDFVI > 0.75

Filtered:
Area < 1000 m²
Elevation --> Slope > 5°

- Flood
- Shallow Water in Short Vegetation
Flood in Malawi 2015 – Sentinel 1 Data

February 3rd, 2015

Flood Map

NDFI > 0.7
NDFVI > 0.75

Filtered:
Area < 1000 m²
Elevation --> Slope > 5°

- Flood
- Shallow Water in Short Vegetation
Flood in Malawi 2015 – Sentinel 1 Data

February 15th, 2015

Flood Map

NDFI > 0.7
NDFVI > 0.75

Filtered:
Area < 1000 m²
Elevation --> Slope > 5°

- Flood
- Shallow Water in Short Vegetation
Flood in Malawi 2015 – Sentinel 1 Data

February 21st, 2015 (Ascending Orbit)

Flood Map

NDFI > 0.7
NDFVI > 0.75

Filtered:
Area < 1000 m²
Elevation --> Slope > 5°

- Flood
- Shallow Water in Short Vegetation
Flood in Malawi 2015 – Sentinel 1 Data

March 23rd, 2015

Flood Map

NDFI > 0.7
NDFVI > 0.75

Filtered:
Area < 1000 m²
Elevation --> Slope > 5°

- Flood
- Shallow Water in Short Vegetation
Flood in Malawi 2015 – Sentinel 1 Data

Overall Flood from January until March

Flood Map

NDFI > 0.7
NDFVI > 0.75

Filtered:
Area < 1000 m²
Elevation --> Slope > 5°

- Flood
- Shallow Water in Short Vegetation
22 January – Comparison with Copernicus Products

Flood Map
(Detail, Bangula)

NDFI > 0.7
NDFVI > 0.75

Filtered:
Area < 1000 m²
Elevation --> Slope > 5°

- Flood
- Shallow Water
  in Short Vegetation
- Flood - Copernicus
Flood in Venice 2010
Early snow in late October led to excessive runoff from the pre-alpine region.

Heavy rain over urban areas.

Wind to the south prevent rivers to discharge properly in the Venetian lagoon.
Flood in Venice 2010

November 1st 2010
CSK
3 meters

Few hours before the event
Flood in Venice 2010

November 2^{nd} 2010, RADARSAT 2
25 meters

First Image after the flood peak
Flood in Venice 2010

November 3rd, 2010, CSK
3 meters
Flood in Venice 2010

November 5th, 2010, RADARSAT 2
25 meters
November 6th
2010, CSK
3 meters
Flood in Venice 2010

November 6th, 2010, TSX
3 meters
Flood in Venice 2010

November 7th
2010, CSK
3 meters
Flood in Venice 2010

November 12th, 2010, ENVISAT ASAR
150 meters
Flood in Venice 2010

November 3rd 2010
CSK 3 meters
(Detail, Saletto)

Comparison with maps produced by CIMA Foundation for the Italian civic protection (red)
Flood in Venice 2010

November 3rd 2010
CSK 3 meters
(Detail, South of Vicenza)

Comparison with maps produced by CIMA Foundation for the Italian civic protection (red)
Synthetic Aperture Radar Image Stack
Normalize Difference Flood Index

Flood in Venice 2010 – Flood Depth Estimation

Value
High: 5
Low: 0

Flood Depth

Flood Depth

Flood Depth

living planet symposium 2016 9–13 May 2016 | Congress Centre | Prague | Czech Republic
Hypothesis: water surface is a plane (true almost always)

If flood map is accurate, the elevation along the contour of each flooded area should be the same (there are exceptions)

Detect the maximum elevation (95th percentile) along the contour to compute flood depth
Flood in Venice 2010 – Flood Depth Estimation

Profile Graph Title

Flood Depth - Ospedaletto Euganeo - 4th November 2010

Flood depth along the red profile line

Value
High: 5
Low: 0

Flood Depth
Conclusions

Easy and precise flood mapping
  • Thanks to EO Big Data: Sentinels

Fast mapping good for **emergency response** thanks to the methodology developed

Precise **Flood Depth estimation** possible when a high resolution DEM is available

Flood dynamics/evolution thank to frequent acquisition

Improvement for **economic impact assessment**