Observing Flash Flood in Arid and Semi-Arid Regions from Space: Wadi Watier in Sinai of Egypt as a Case Study

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Traditional observing methods are not able to capture the flash flood events especially in arid and semi-arid areas, where the development of these events take place on both space and time scales. There is a need for monitoring these events using remote sensing (RS) techniques to permit the assessment of flash flood severity. This contribution aims at identifying flash flood potential areas by RS and Geographic Information System (GIS) techniques by taking the watershed of Wadi Watier in Sinai of Egypt as a case study. Different sets of information from satellite data, namely Tropical Rainfall Measuring Mission (TRMM), Shuttle Radar Topography Mission (SRTM), and Landsat 8 (L8) Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images, are collected for pre-, during and post- flash flood event in 2015. The SRTM data is used as input for topography processing using Topographic Parameterization (TOPAZ) program under Watershed Modeling System (WMS 10) software. The TRMM product is used to observe the spatial variability of rainy event. Detecting the locations of water storage areas and flooded sub-catchments are performed by applying Automated Water Extraction Index (AWEI) index and evaporative fraction (EF) using Surface Energy Balance Algorithms for Land (SEBAL) model, respectively, on Landsat 8 satellite image after the flash flood event on 12/09/2015. Availability of spatial land characteristics and precipitation data of a watershed are tested by plotting the EF over each pixel respectively against the TRMM. EF and TRMM are positively correlated, R2 = 0.66, $p < 0.0001$, which, in general, indicates a satisfactory spatial relationship between the two datasets. The results indicate also the location of water storage structure where flood water has retained and this was confirmed during a field visit. A map identifying the most active streams is developed. In conclusion, these information of such an event could be used for improving hydrologic models. Many water management solutions can be proposed from satellite image perspective for areas where data are scarce.

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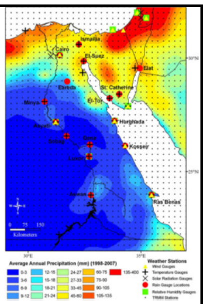
Outlines:

1. Introduction
2. Study area
3. Methods and Materials
4. Results
5. Conclusions and Recommendations

1. Introduction:

- Flash flood hazards in Sinai Peninsula and Red sea of Egypt.
- Understanding the hydrological behavior of the occurred flash floods is essential for future development plans
- Lack of data and hydrological process
- The potentiality of using remote sensing (RS)
- This research aims at identifying flash flood potential areas by RS and Geographic Information System (GIS) techniques by taking the watershed of Wadi Watier in Egypt as a case study.

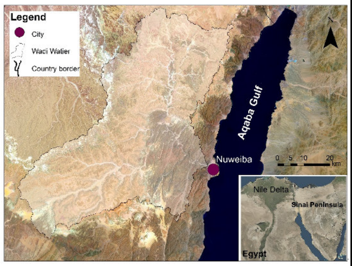


Average annual precipitation over Egypt (1998–2007) from Tropical Rainfall Measuring Mission (TRMM). Source: Milewski et al. (2009)

2. Study area:

Sinai Peninsula
- Important region for settlement
- Local residence (Bedouin)
- Arid area
- Water Shortages
- Flash flood

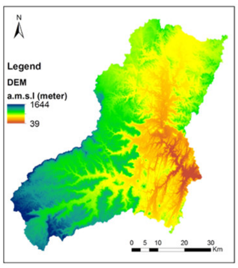
Wadi Watier
Most active watershed
North-eastern part
Area 3,500 km^2 and length 70 km
Nuweiba city



3. Methods and materials:

3.1 Watershed representation

- Digital Elevation Model (DEM) of the Shuttle Radar Topography Mission (SRTM) (90m cell size in the study area) is used.
- Topographic Parameterization (TOPAZ) program in Watershed Modeling System (WMS 10) was applied to identify:
  - Water accumulation patterns,
  - Stream networks and
  - Geometric properties (areas, slope, length).



3. Methods and materials:

3.2 Rainfall spatial distribution

- Rainfall is the main driving force in the hydrology, where the rain gauge network is sparse.
- The coverage provided by satellite is essential as its precisions affect the accuracy of hydrological model simulations.
- There are several products of rainfall based on RS data (e.g. Tropical Rainfall Measuring Mission (TRMM) and Global Satellite Mapping of Precipitation (GSMaP)
- Daily TRMM data was used in the current research since is better at determining rain occurrence (Li et al., 2012)

3. Methods and materials:

3.3 Identify water storage structure

- Detention and attenuation of a hydrograph caused by a reservoir should be accounted (Chow et al., 1988; Al Zayed, 2010)
- Automated Water Extraction Index (AWEI) by Feyisa et al. (2014) is utilized for recognizing water structures after the flash flood event.

$$AWEI_{sh} = \rho_{band1} + 2.5 \times \rho_{band2} - 1.5 \times (\rho_{band4} + \rho_{band5}) - 0.25 \times \rho_{band7}$$

3. Methods and materials:

3.4 Active sub-catchments

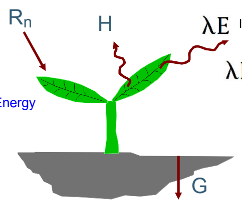
- The active channels of a wadi are not necessarily the same in different flood events.
- Soil moisture is the most influential factor to identify active streams after a rainy event in a dry river; the greater is the antecedent soil moisture the larger amount of fallen precipitation reaches the streams (Critchley et al., 1991).
- Surface Energy Balance Algorithms for Land (SEBAL) model is used to estimate actual Evapotranspiration which is an indication to the soil moisture
- Landsat 8 satellite image after the flash flood event on 12/09/2015.

3. Methods and materials:

3.4 Active sub-catchments

ET is calculated as a "residual" of the energy balance

Basic Truth:
Evaporation consumes Energy



latent heat flux

$$\lambda E = R_n - G - H$$

R_n = Net Radiation
G = Soil Heat Flux
H = Sensible Heat Flux

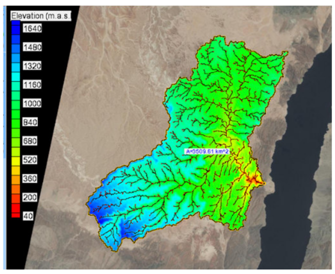
3. Methods and materials:

3.5 Data sources

- Shuttle Radar Topography Mission (SRTM) DEM data (90 m)
- Landsat 8 image (path 170/row 40—Worldwide Reference System) was used in this research with spatial resolution of 30 m and a 16-day repeat cycle.
- Two images on 11/08/2015 and 28/09/2015 were used to reveal the occurrence of the flash flood event of September 2015.
- Daily TRMM 2B42 product was obtained from NASA website

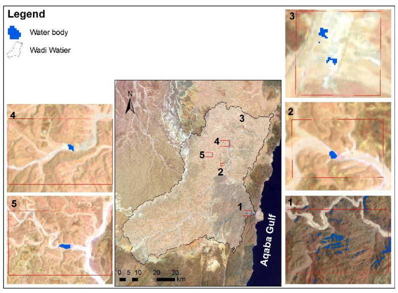
4. Results:

4.1 Watershed characteristics



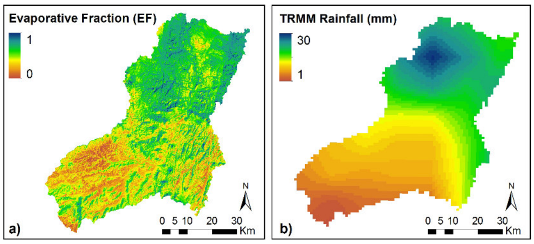
4. Results:

4.2 Water structures of the wadi



4. Results:

4.3 Active wadies from space



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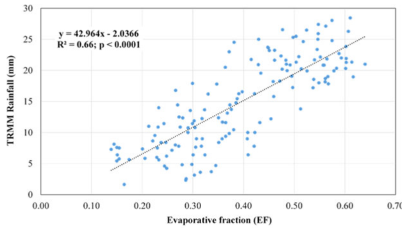
4. Results:

4.3 Active wadies from space



Relationship between Evaporative fraction and rainfall from TRMM based on pixel-by-pixel (resampled to 5 km) of Wadi Watier.

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5. Conclusion and recommendations:

- Documentation of flash flood event is needed to understand in arid and semi-arid regions.
- ability to predict sites most prone to flooding would help mitigate against future damage and substantially aid regional development.
- help direct the planning of drainage constructions such as ditches and culverts along roads to minimize damage and limit flood impacts on the transport system.
- Many water management solutions can be proposed from satellite image perspective for areas where data are scarce.

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