

Application of Synthetic Aperture Radar (SAR) remote sensing in flood disaster management (Module 1)

Space based Disaster Management

Prepared by

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Introduction to flood disasters

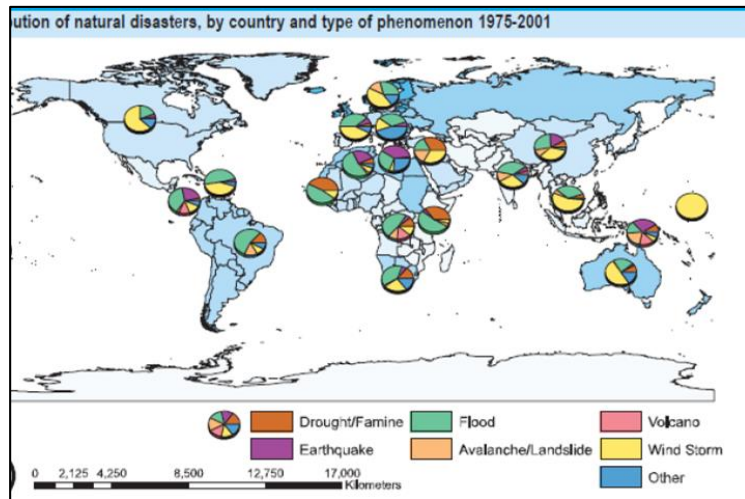


Disaster

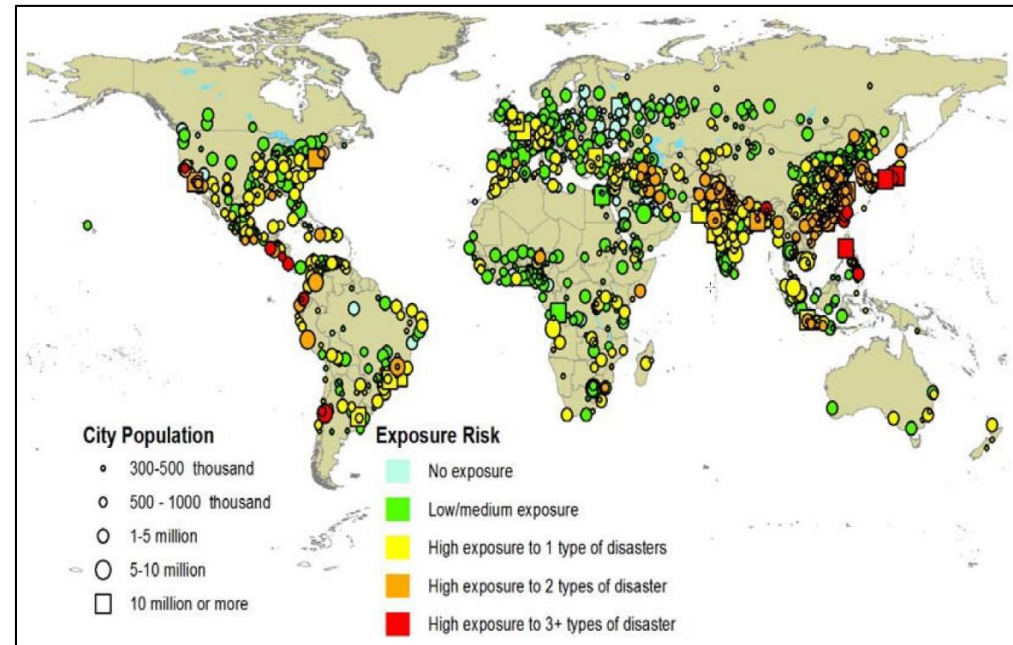
“A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.” Source: United Nations Office for Disaster Risk Reduction ([UNDRR](#))

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Source: EM-DAT International Disaster database



Distribution of cities by population size and risk of exposure to natural disasters (Source: WUP 2014)

Floods

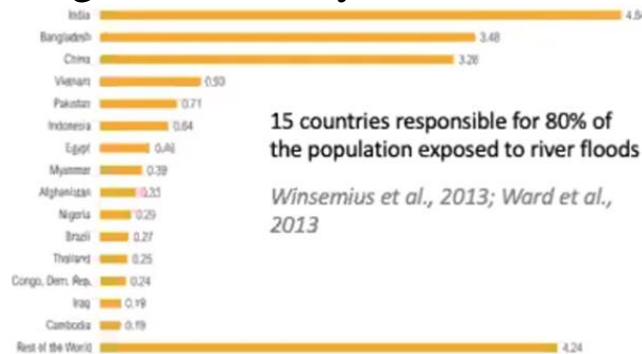
A flood is an overflow of water that submerges land that is usually dry

- According to the European Environment Agency, 37 European countries have reported 3,563 flood events between 1980 and 2010.
- Flooding is the most common natural hazard worldwide and often devastating.
- Impacts 21 million people every year
- Affects global GDP by \$100 billion every year

Floods

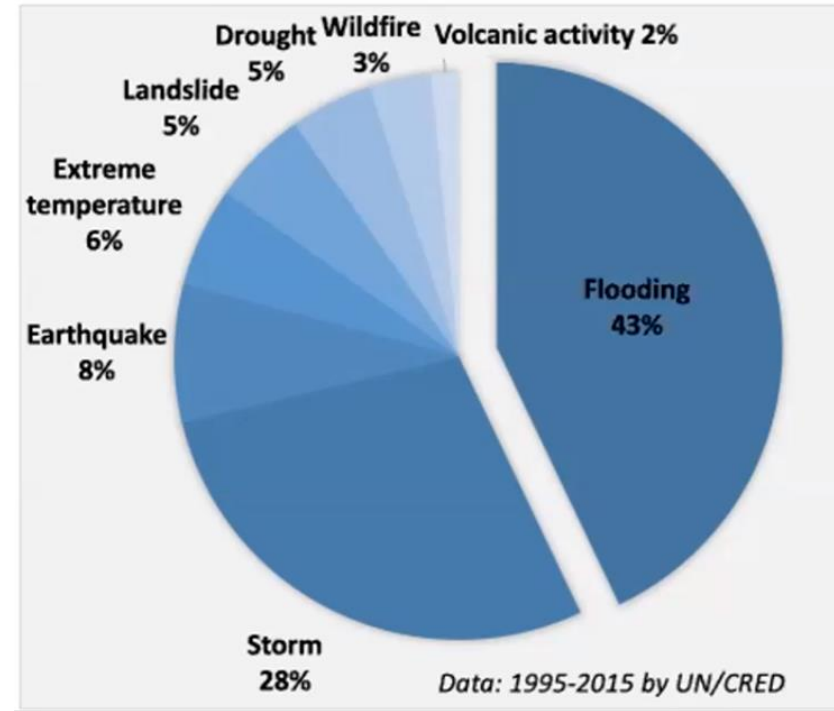
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15 countries responsible for 80% of the population exposed to river floods

Winsemius et al., 2013; Ward et al., 2013



Floods

Floods can be caused by:

- Heavy rainfall
- River overflow
- Storm surge
- Cyclone induced floods
- Dam burst induced floods, etc.
- Combination of any of the above factors

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The recent devastating floods in Chennai (coastal city) in 2015 is a result of

“Heavy rainfall + River overflow + Storm surge”

The recent devastating floods in Hyderabad (Inland city) in 2020 is a result of

“Heavy rainfall + improper urban planning + encroachments of water bodies”

The recent devastating floods in West Bengal state in 2020 is a result of

“Cyclone + River overflow”

Application of Remote sensing in flood management

- Based on type of flood event, a proper remote sensing technique that helps in accurate monitoring has to be chosen.
- **Optical** Remote Sensing (RS) is often obstructed by **cloud cover**. Therefore, flood events like “Dam burst induced floods” etc., can be monitored more accurately with optical RS provided that cloud free images are available.
- Microwave Remote Sensing (MRS) technique, especially **Synthetic Aperture Radar (SAR)** images monitor any type of flood event due to its ability to **penetrate** through **clouds**.
 - Passive MRS data (AMSR-E, AMSR-2, GPM IMERG, TRMM etc.) is used to monitor the regional level flooding.

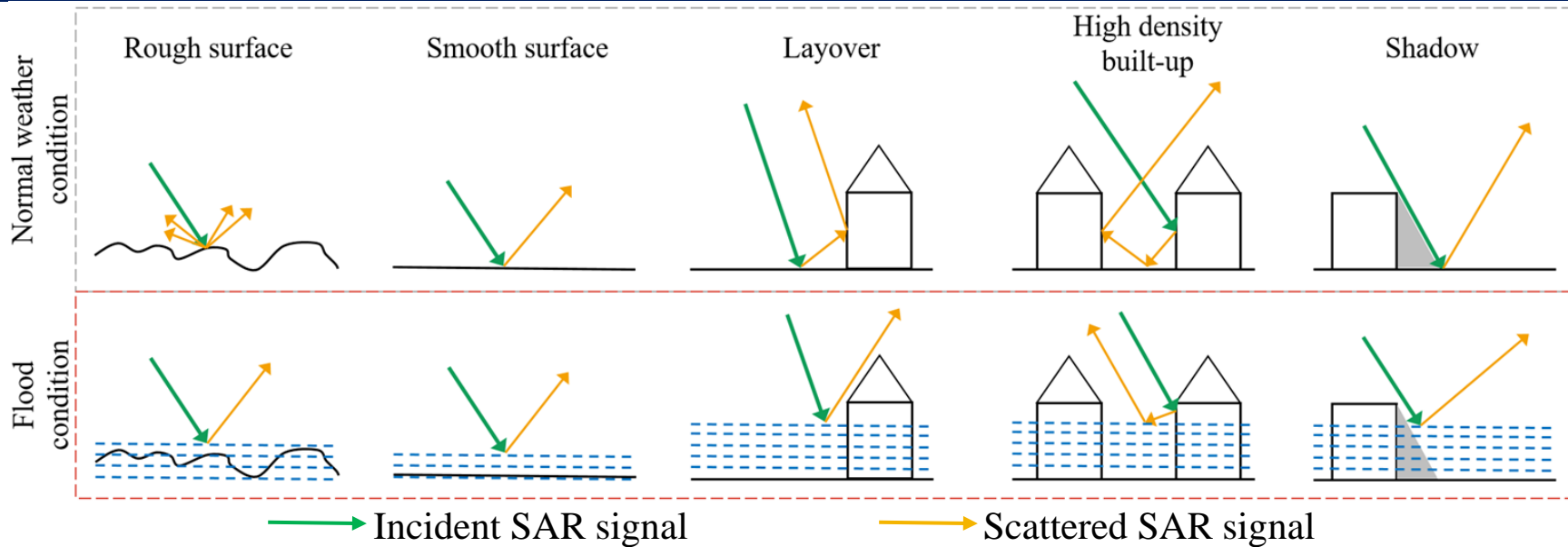
Synthetic Aperture Radar (SAR) technique for flood monitoring

Some of operational SAR satellites for flood monitoring

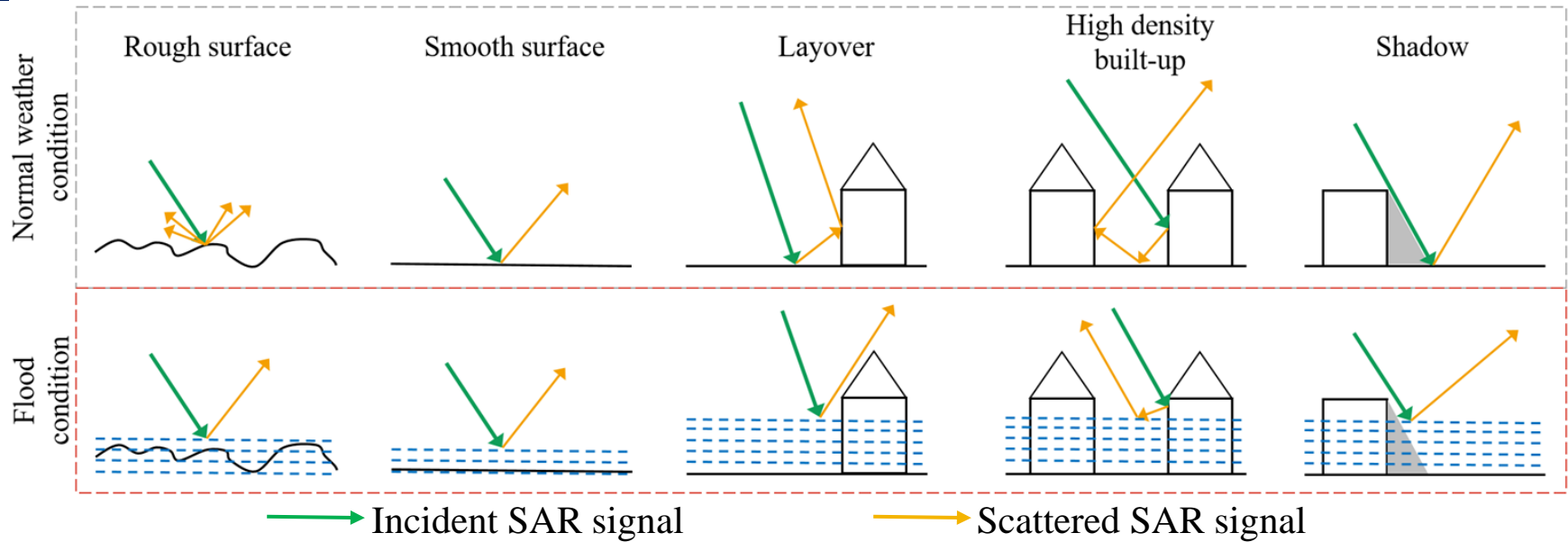
- ALOS -2 (L-band)
- Sentinel-1 (C-band)
- Radarsat (C-band)
- Cosmos Skymed (X-band) etc.,

Sentinel data is freely available to the end users, and most of the other satellites are commercial. Some space agency provide the data to research communities through peer-reviewed proposals.

SAR Signal Scattering over flooded areas



SAR Signal Scattering over flooded areas



- Water surfaces are generally smooth at radar wavelengths
 - Specular reflection yields **low** backscatter σ^0 values and appears as dark in the image
- Therefore, water is regarded as low intensity area in the SAR image comparing to surrounding Land Use Land Cover (LULC) regions.

Challenges in SAR based flood mapping

- Water-like reflecting surfaces
 - Airport runways, highways, flat roof structure
 - Shadow regions, layover, wind
- Underdetection
 - Flooded built-up surrounding by vegetation canopy
 - High density built-up
- Overdetection
 - Wide flat regions (parking lots)
 - Inclined rooftops

Methods for SAR based flood mapping

In case, the single SAR image acquisition happens during the floods (non-availability of pre and post flood images)

- **Thresholding (global, local)**

- Manual thresholding,
- Otsu's,
- Tasi's,
- Kapur's,
- Kittler and Illingworth (KI)
- Split-window approach, etc.,

- **Machine learning methods**

- ANN,
- SVM,
- Random forest,
- Fuzzy logic,
- Neuro-fuzzy, etc.,

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The input parameters* for these methods are

- Intensity images (HH/VV/HH+HV/VV+VH/HH+HV+VV)
- Polarimetric parameters
 - Surface scattering (P_S)
 - Double bounce scattering (P_D)
 - Volume scattering (P_V)
 - Helix scattering (P_C)
 - Eigenvalues (λ_i)
 - Scatter types (α)
 - Entropy (H)
 - Mean scatter type ($\bar{\alpha}$)

Note: * input parameters completely depends on image acquisition characteristics

Methods for SAR based flood mapping

- If SAR images are acquired continuously i.e., before, during and after-flood, it is possible to monitor the temporal dynamics of flood events.
- Apart from the methods applicable to single SAR image, the following methods are useful in case of availability of temporal SAR images.
 - Change detection (CD) methods*
 - Difference Index (DI)
 - Ratio Index (RI)
 - Normalize Change Index (NCI)
 - Normalize Difference Flood Index (NDFI)
 - Hierarchical split based approach (HSBA)
 - Region growing (RG) algorithms

Methods for SAR based flood mapping

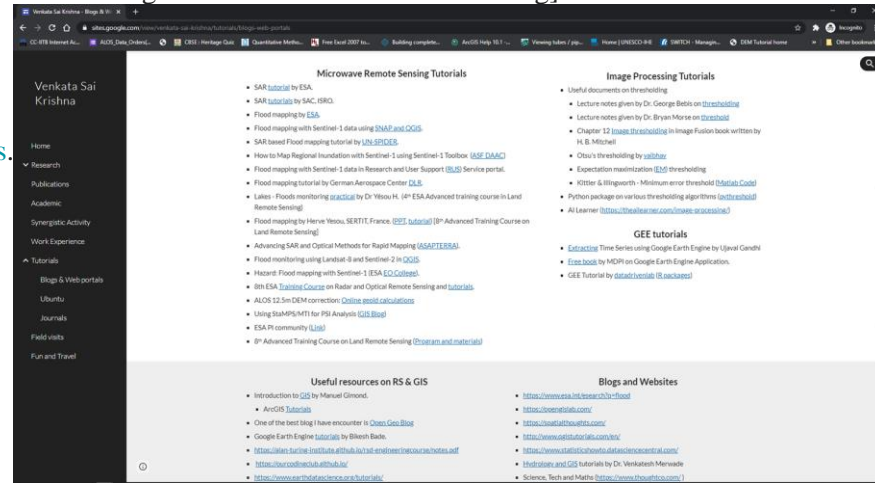
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- The extra input parameters* for these methods are
- Interferometric Coherence
 - Interferometric Phase
 - Phase Standard Deviation (PSD)
 - Phase Vector Sum (PVS)
 - Phase Range (PR)

Note: * CD methods are possible to implement only if the temporal SAR image acquisition characteristics are same

* some of these input parameters can only be generated with quad pol data

Useful Resources

- Global Exposure Analysis on Floods/Drought and Poverty ([Slides](#))
- Flood mapping by [ESA](#).
- Flood mapping with Sentinel-1 data using [SNAP](#) and [QGIS](#).
- SAR based Flood mapping tutorial by [UN-SPIDER](#).
- How to Map Regional Inundation with Sentinel-1 using Sentinel-1 Toolbox ([ASF DAAC](#))
- Flood mapping with Sentinel-1 data in Research and User Support ([RUS](#)) Service portal.
- Flood mapping tutorial by German Aerospace Center [DLR](#).
- Lakes - Floods monitoring [practical](#) by Dr Yésou H. (4th ESA Advanced training course in Land Remote Sensing)
- Flood mapping by Herve Yesou, SERTIT, France. ([PPT](#), [tutorial](#)) [8th Advanced Training Course on Land Remote Sensing]
- Advancing SAR and Optical Methods for Rapid Mapping ([ASAPTERRA](#)).
- Flood monitoring using Landsat-8 and Sentinel-2 in [QGIS](#).
- Hazard: Flood mapping with Sentinel-1 (ESA [EO College](#)).
- 8th ESA [Training Course](#) on Radar and Optical Remote Sensing and [tutorials](#).



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Thank you