Role of Remote Sensing in Flood Management

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Flood in a global context

- Floods account for 40% of all natural disasters worldwide
- Globally US$24 billion per year in the period 2001–2011 due to flood losses
- The map illustrates 3713 events over the period 1985–2010

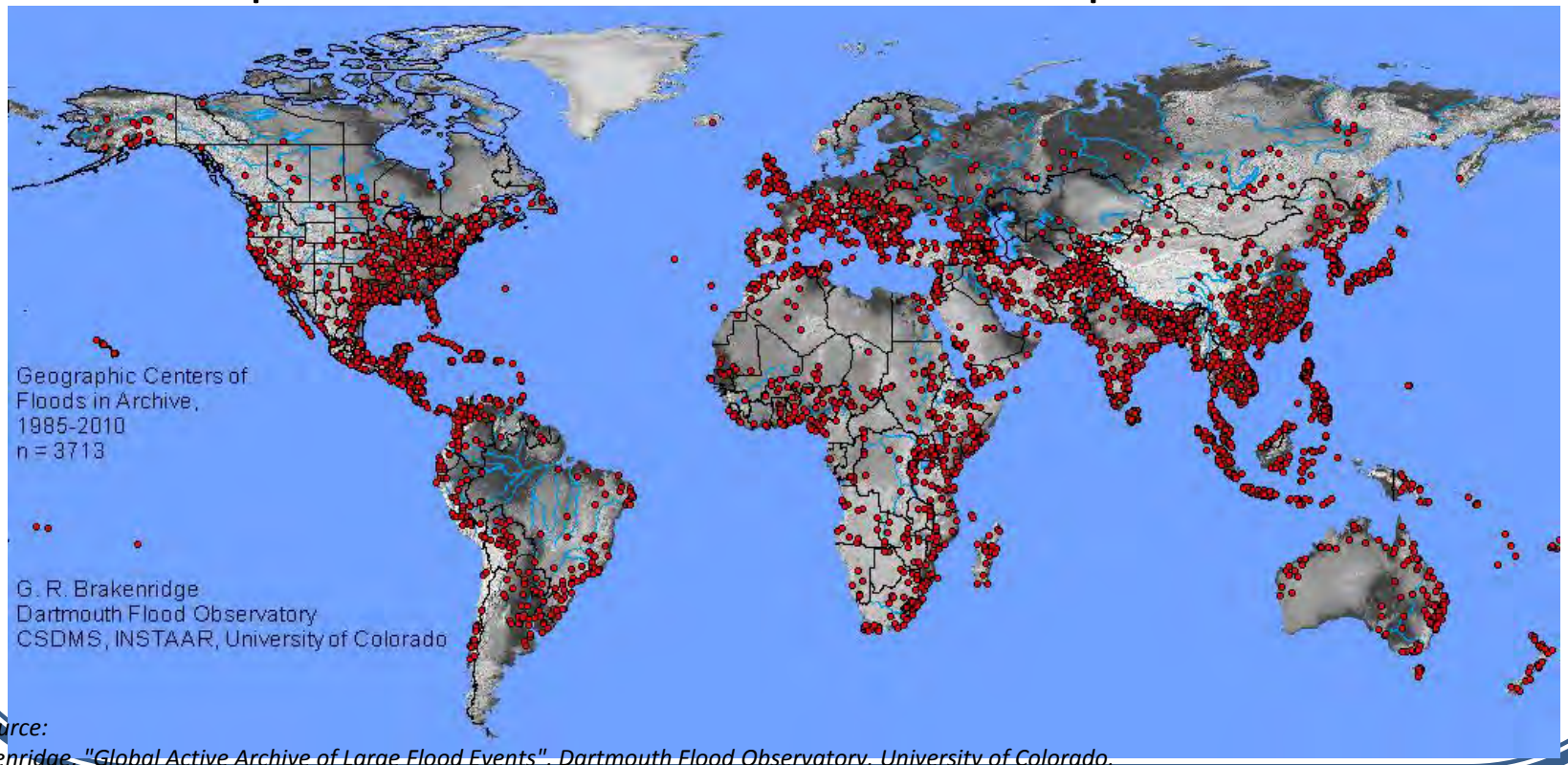


Image source:
G.R.Brakenridge, "Global Active Archive of Large Flood Events", Dartmouth Flood Observatory, University of Colorado, http://floodobservatory.colorado.edu/Archives/index.html

Flood Management

Flood management = strategy to minimize potential harm and loss

Importance flood management:

- Mitigation strategy (protection of people & property from damaging impacts of floods)
- Emergency responses
- City Planning

Remote Sensing in Flood Management

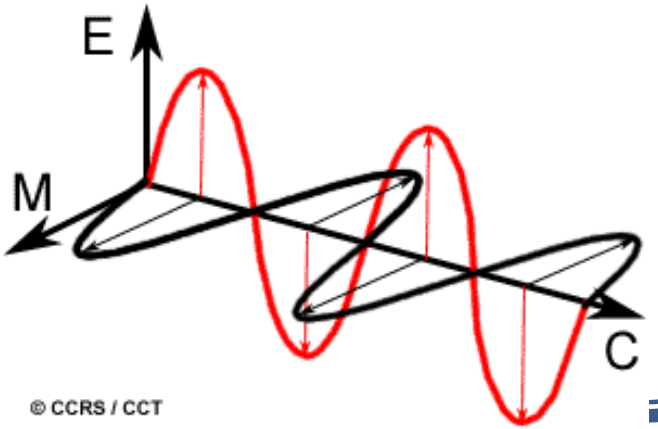
- Remote Sensing's main contribution towards flood management:
  - Derivation of flood extent and depth! (also known as flood monitoring)

- Subsequent Remote Sensing products for flood management all depend flood extent and depth

  Example:
  - Evacuation Route
  - Identifying flood Shelter (refuge) locations
  - Vulnerability/Damage Assessment
  - Risk mapping

What is Remote Sensing (RS)?

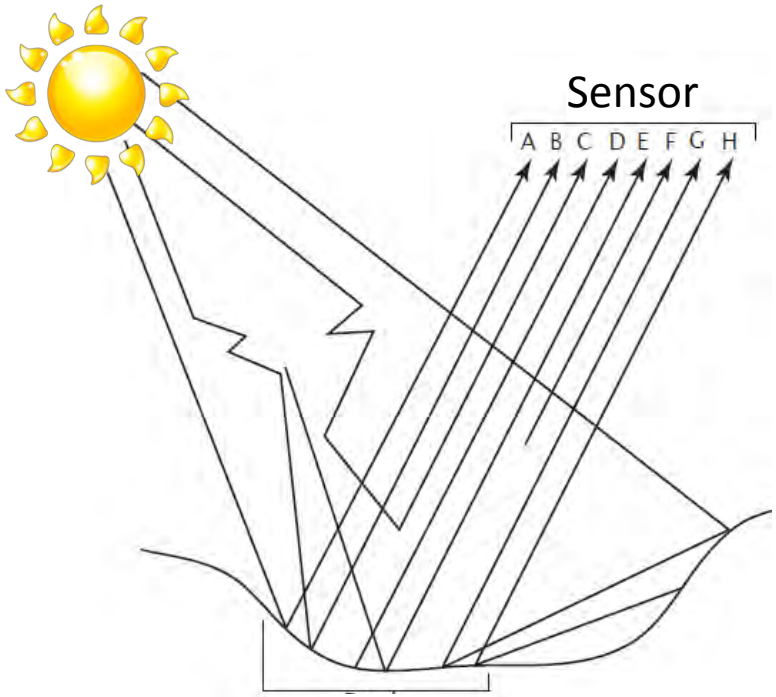
- Remote sensing = acquiring information about the Earth's surface without actually being in contact with it
- satellite remote sensing measure the electromagnetic (EM) energy that is reflected or emitted, by objects on Earth’s surface to create an image.



Passive Remote Sensing

- Passive sensors on satellite - respond to the interaction of existing and naturally occurring energy.

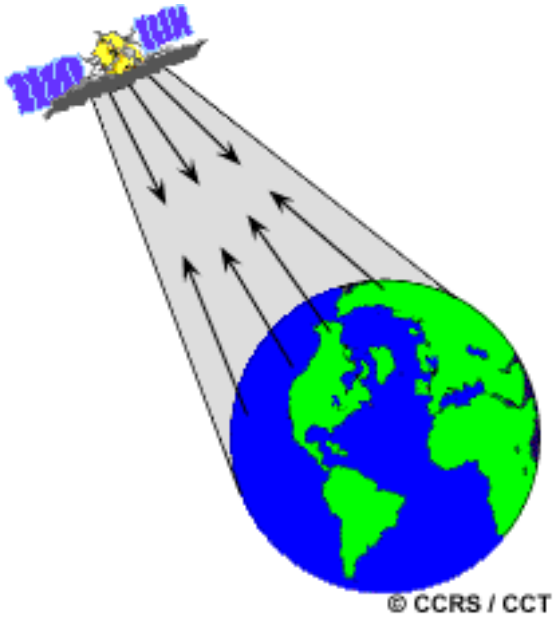
Passive sensors depend on solar radiation



Active Remote Sensing

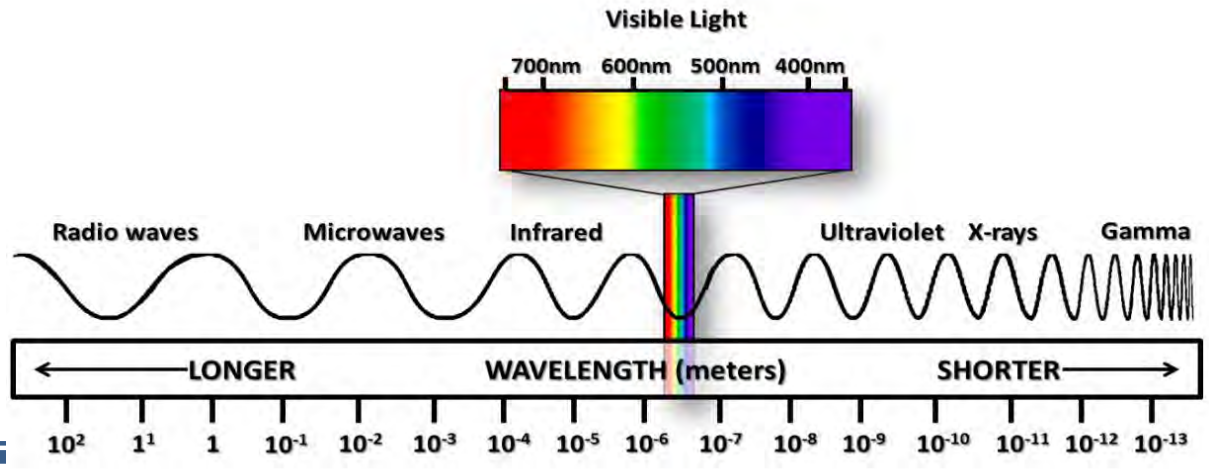
- Active sensors on satellite - sensors transmit its own energy and then measure the reflected signal

Active sensors depend on their own EM energy source



Microwave & Optical RS

- The names refer to the wavelength used.
- Optical remote captures EM in the wavelengths:
  - visible (0.4 - 0.7µm)
  - near infrared (0.75–1.4 µm)
  - short-wave infrared (1.4-3 µm)
- Microwave remote sensing captures EM in 1cm to 1m wavelength



Advantages of RS in Flood Management?

- Provides spatially continuous data (gauges or field measurements only provide point measurements).
- Data can be constantly updated based on the temporal resolution (satellite revisit time)
- Inexpensive (compared to using a field crew)
- Quick and practical (easy to download)
- Captures data where water gauges are not present or locations that are difficult to access

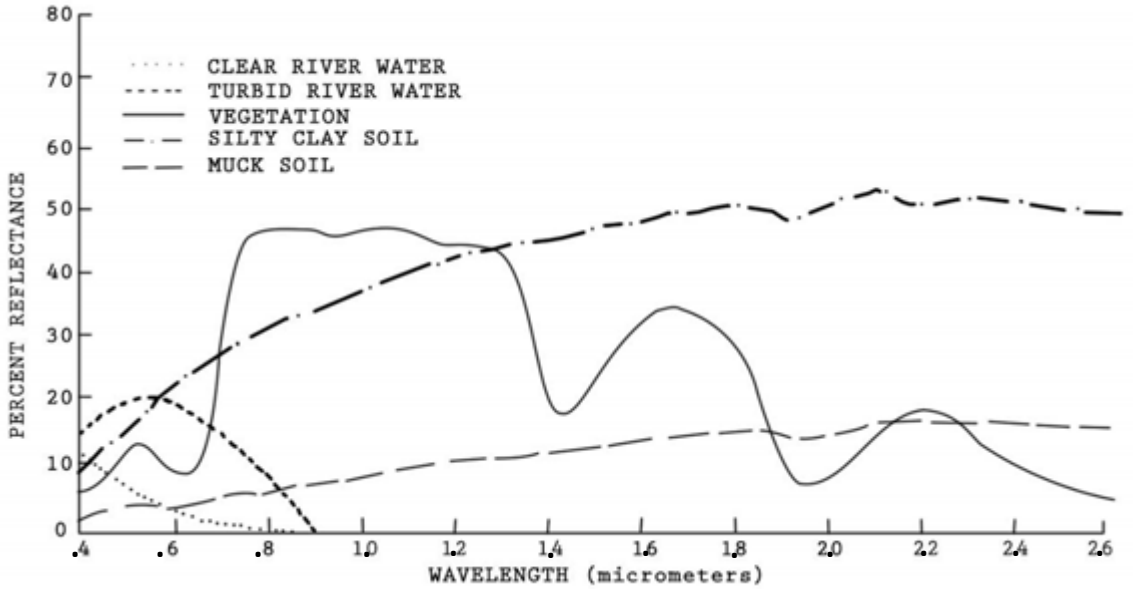
Limitations of RS in Flood Management?

- Not as accurate as gauges
- Measurements do not occur as often as gauges (limited by satellite revisit time).

Optical RS in Flood Management

- Optical RS is passive
- Optical RS uses spectral signatures to identify features in the Earth's surface
- Objective is to classify flooded and non-flooded image pixel
- dry surfaces and wet surfaces have different reflectance different spectral signatures

figure source
http://www.gisdevelopment.net/technology/rs/techrs0020a.htm



Optical RS in Flood Management

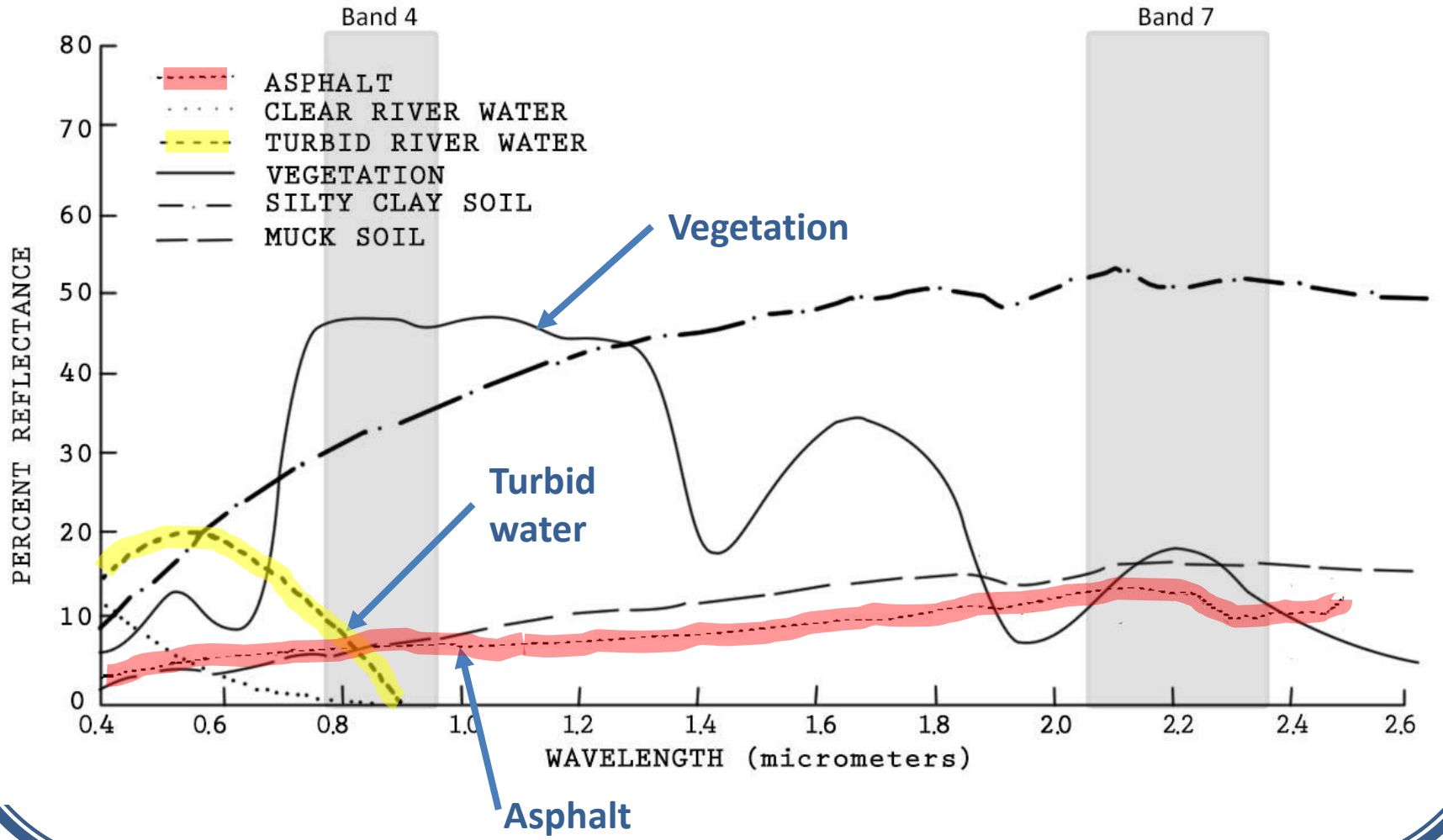
- The higher the spectral resolution (I.e.: how many times a satellite can divide a wavelength range into separate images) the easier it is to distinguish between features on the Earth's surface

- In flood events, it can be difficult to separate dry and wet surface because of high load of suspended sediments. This, alters the spectral signature of water, and making it close to dry surface

- Different techniques must be used to separate flooded pixel from non-flooded pixels.

Optical RS in Flood Management

Example



Optical RS in Flood Management

Advantages:

- Spectral Resolution – allows the use of bands and spectral signatures to classify flooded pixels
- Free or low cost imagery

Optical RS in Flood Management

Limitations:

- Satellite Revisit time
- Spatial Resolution
- Cannot detect floods under cloudy conditions
- Cannot detect floods under canopy cover

Microwave RS in Flood Management

- Passive Microwave RS not suitable for flood detection because of large spatial resolution
- Synthetic Aperture Radar (SAR) most prevalent in flood detection
  - High spatial resolution
- Only emits and receives in one band

Microwave RS in Flood Management

current satellite missions with SAR sensors useful for floodplain mapping

Mission (year of launch)	Sensor Frequency (Band , λ)	Spatial Resolution (m)	Revisit Time (days)
ERS-2 (1995)	5.3Ghz (C, 5.6cm)	25	35
RADARSAT-1 (1995)	5.3 GHz (C, 5.6 cm)	8-100	24
ENVISAT (2002)	5.3 GHz (C, 5.6 cm)	12.5-1000	35
ALOS (2006)	1.3 GHz (L, 23.6 cm)	7-100	46
COSMO-SkyMed (207)	9.6 GHz (X, 3.1 cm)	15-100	16
TerraSAR-X (2007)	9.6 GHz (X, 3.1cm)	42370	11
RADARSAT-2 (2007)	5.3 GHz (C, 5.6 cm)	3-100	24

Schumann, G., Bates, P. D., Horritt, M. S., Matgen, P., & Pappenberger, F. (2009). Progress in integration of remote sensing–derived flood extent and stage data and hydraulic models.*Reviews of Geophysics*, *47*(4), RG4001. doi:10.1029/2008RG000274

Microwave RS in Flood Management

- Advantages:
  - Can penetrate cloud cover
  - Can penetrate canopy cover
  - Day or night measurements (own energy source)

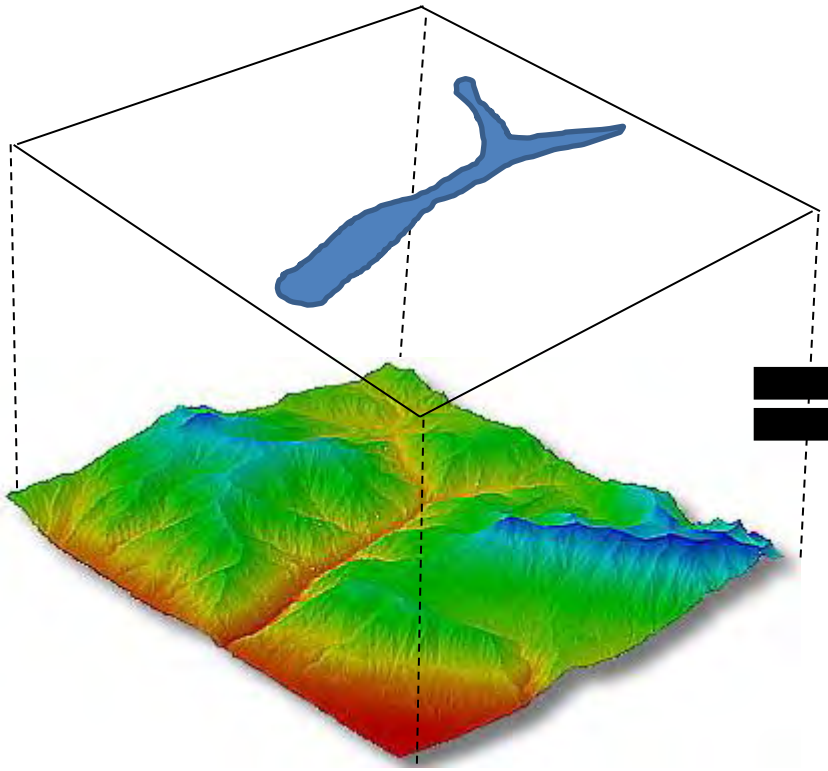
- Limitations:
  - Expensive (no free data)
  - Long revisit times

RS derived products for Flood Management

- By overlaying the extracted flood extent onto existing:
  - images,
  - maps, and
  - Digital Elevation Models (DEMs)
- different products can be derived

Flood Level Calculation

Flood extent



Digital Elevation Model (DEM)

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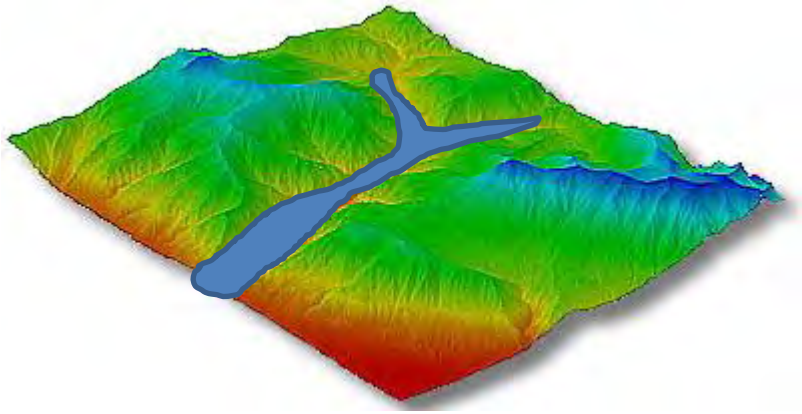
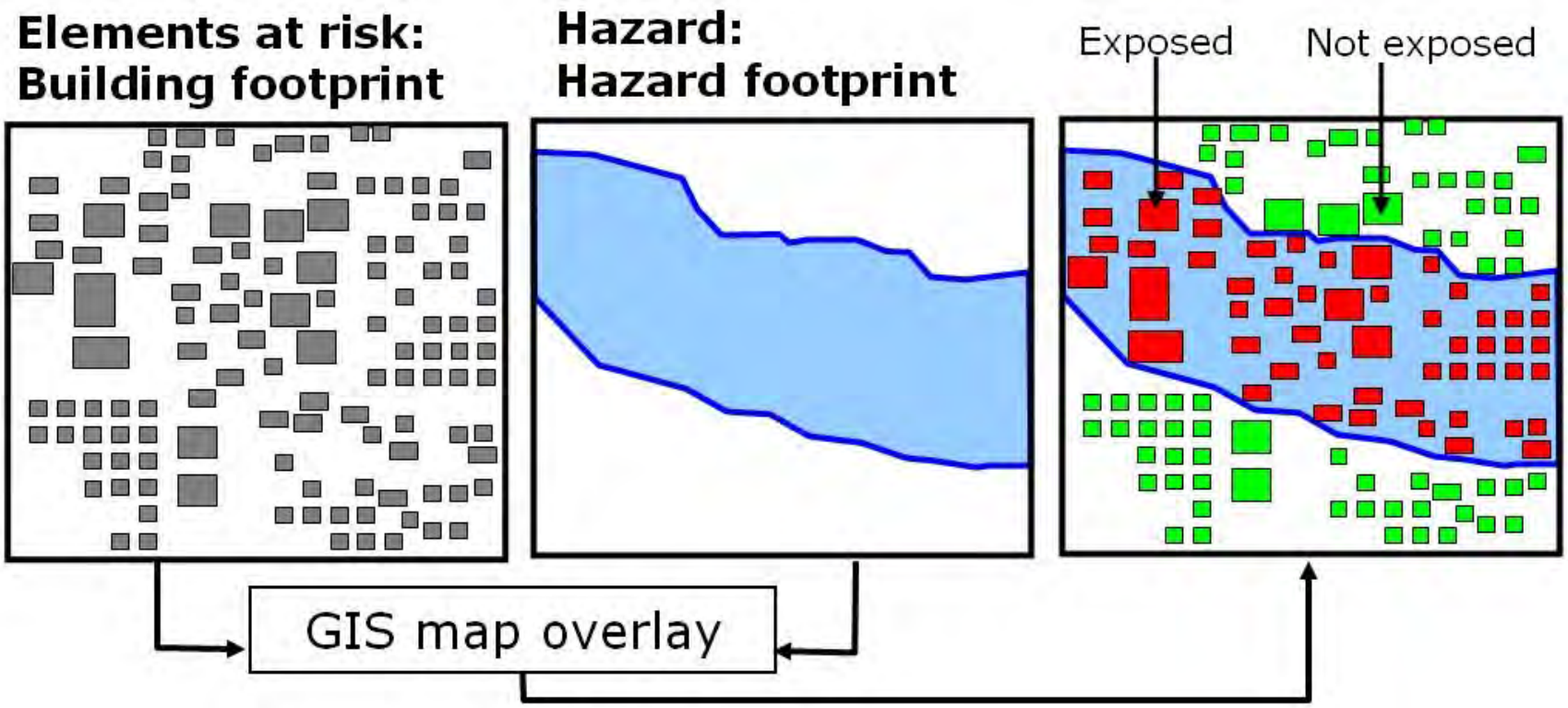
Where flood extent edges and DEM intersect, the flood (water) level is known



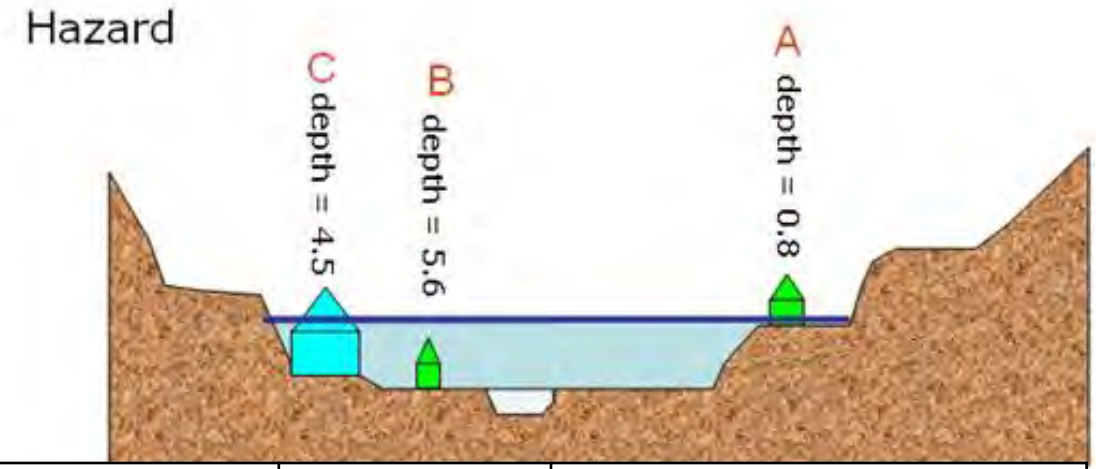
Flood Vulnerability Assessment

- Vulnerability = potential exposure (or damage) and (loss) susceptibility
- Exposure analysis = “Who or what will be affected by floods?” (Flood extent)
- Susceptibility analysis = “How will the affected elements be damaged?” (Flood depth)
- Damage assessments are needed to derive vulnerability

Vulnerability Assessment: Extent



Vulnerability Assessment: Depth



Location	Water depth	Vulnerability (damage) percentage
A	0.8	10%
B	5.6	100%
C	4.5	50%

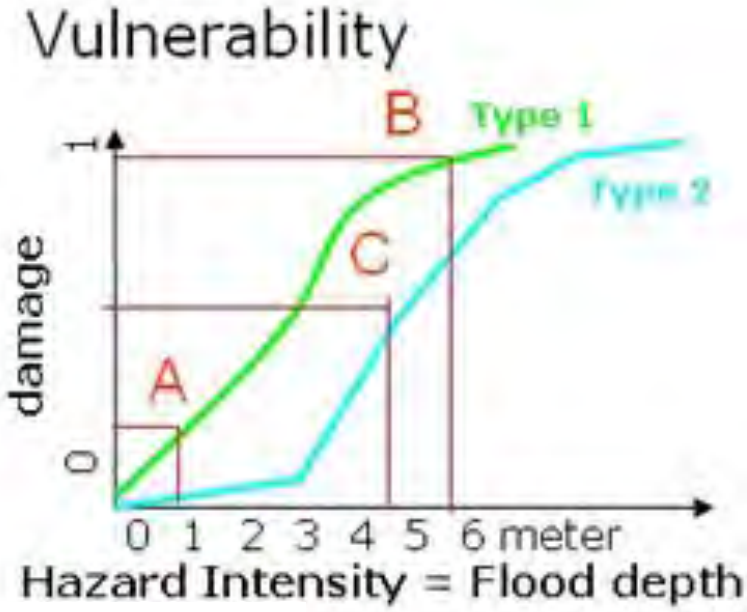
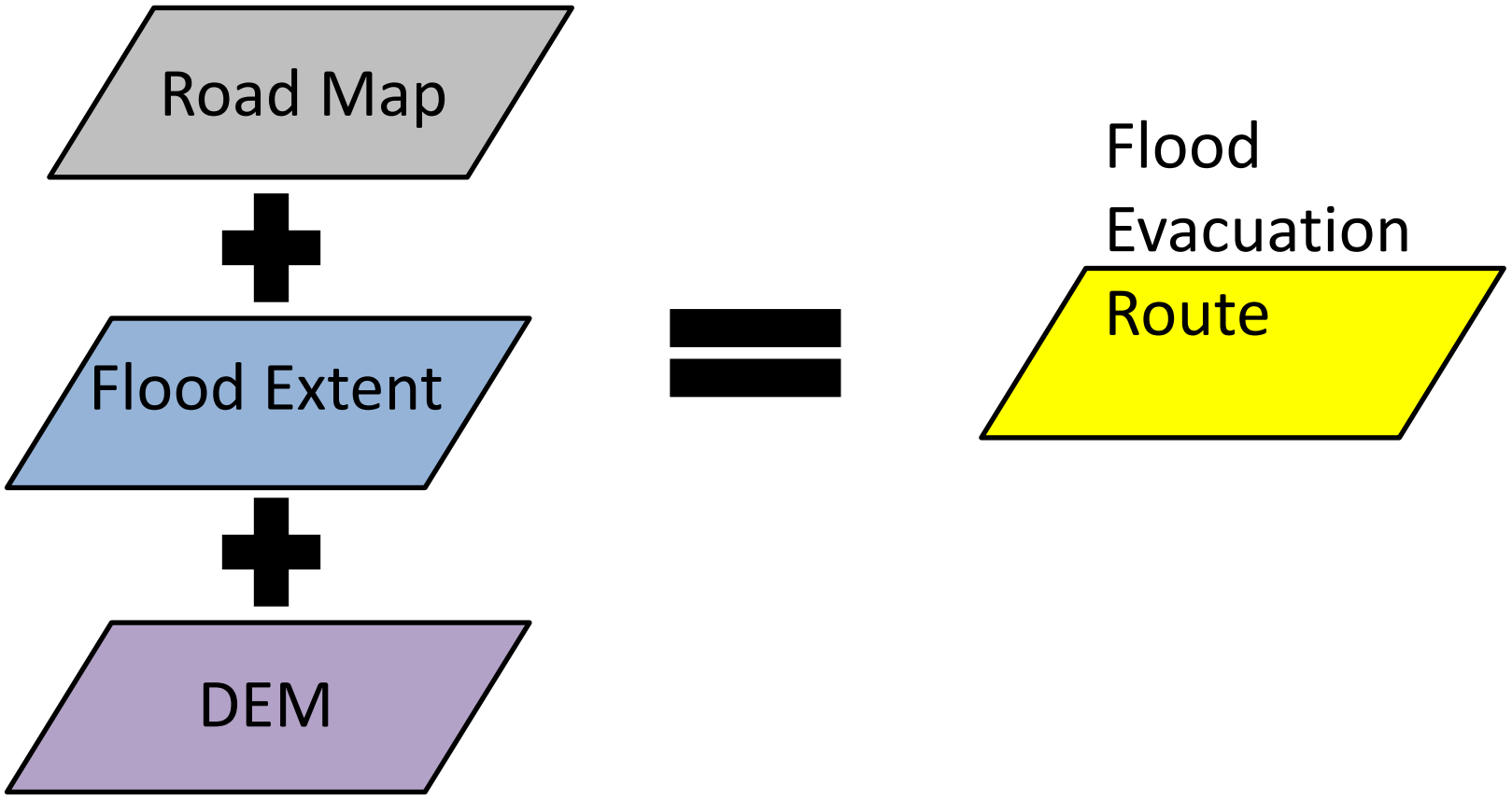


Image source:
ftp://ftp.itc.nl/pub/westen/Multi_hazard_risk_course/Powerpoints/Lecture%2008%20Multi%20hazard%20Risk%20Assessment.ppt

Other Flood Management Products: Flood Evacuation Route



Other Flood Management Products: Flood Shelter Analysis

Image modified from: Uddin et al. 2013

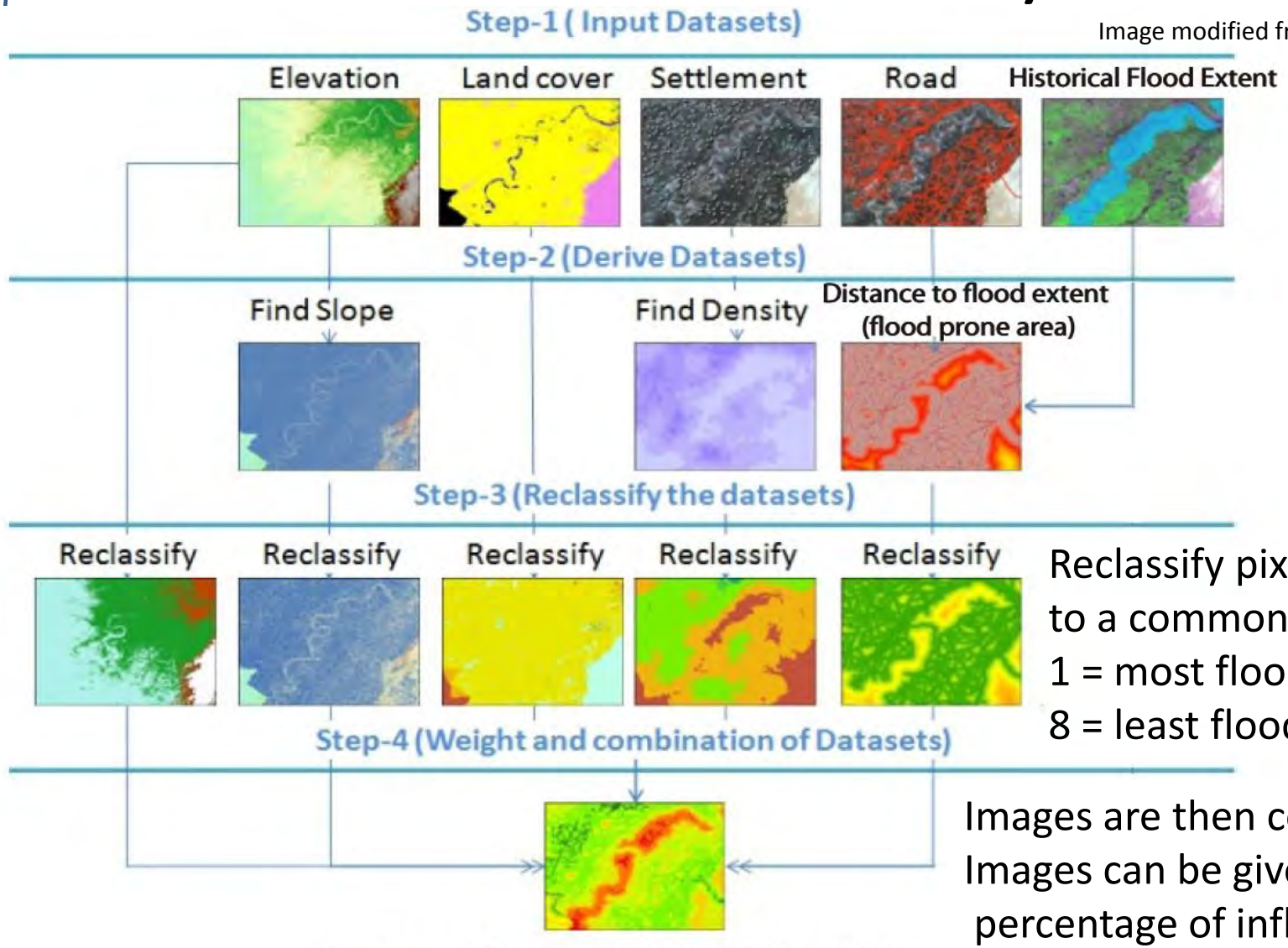


Figure 3. Flow diagram of flood shelter analysis

Reclassify pixels in images to a common scale (1 to 8)
1 = most flood potential
8 = least flood potential

Images are then combined.
Images can be given weights by percentage of influence

Example: Flood Shelter Analysis

Flood Shelter Suitability map For the North of the Sindh Province in Pakistan

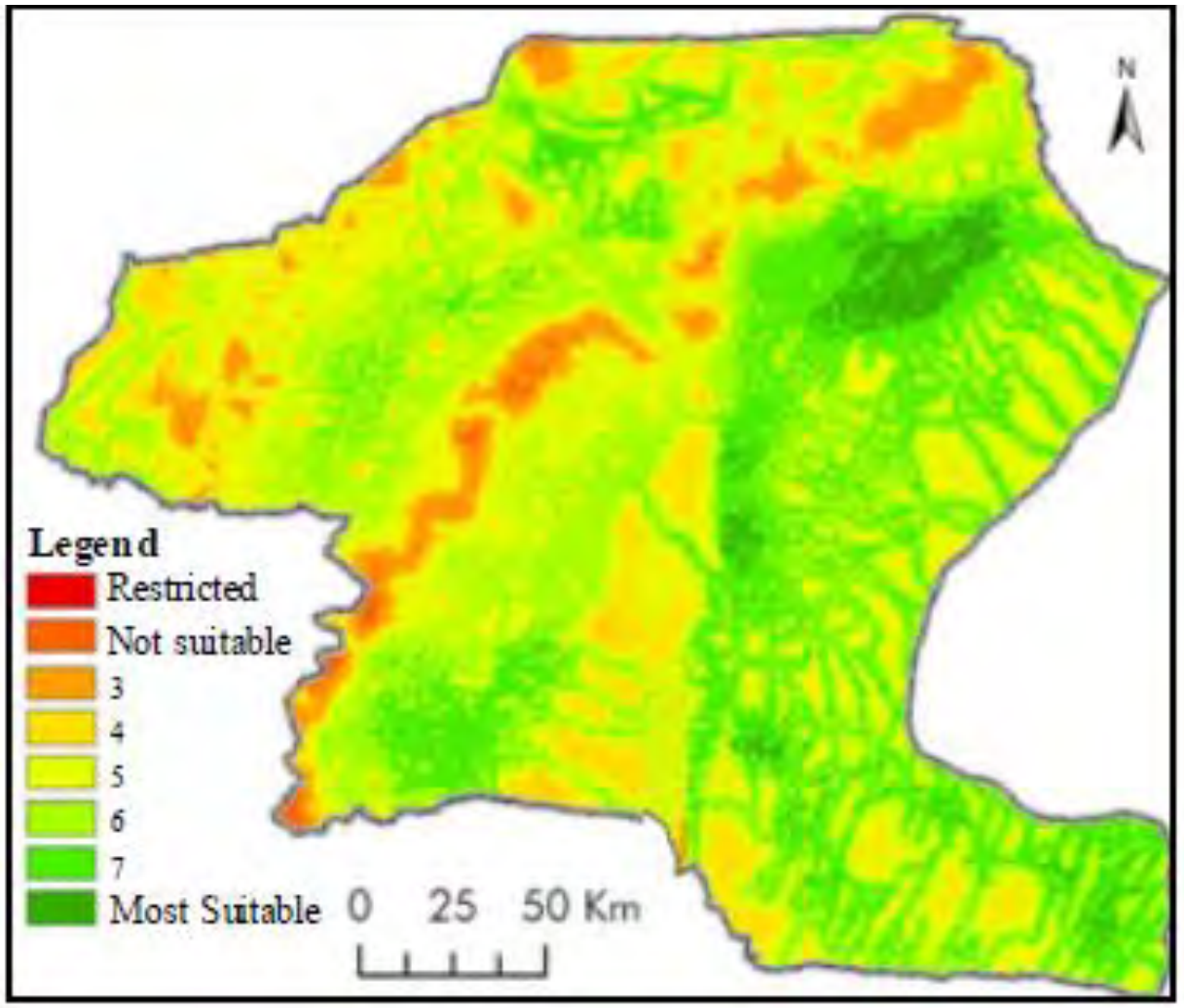


Image modified from: Uddin et al. 2013

Flood Forecasting

- Main way for forecasting flood is to use a hydrological model
  - Many different models
  - Usually based on rainfall, topography, land cover type, and soil properties
    - All parameters can be estimated by RS
    - rainfall is the main component to estimate runoff output necessary for flood forecasting
    - **Rainfall needs constant up to date data for flood forecasting (from rainfall gauges or TMPA)**

TMPA

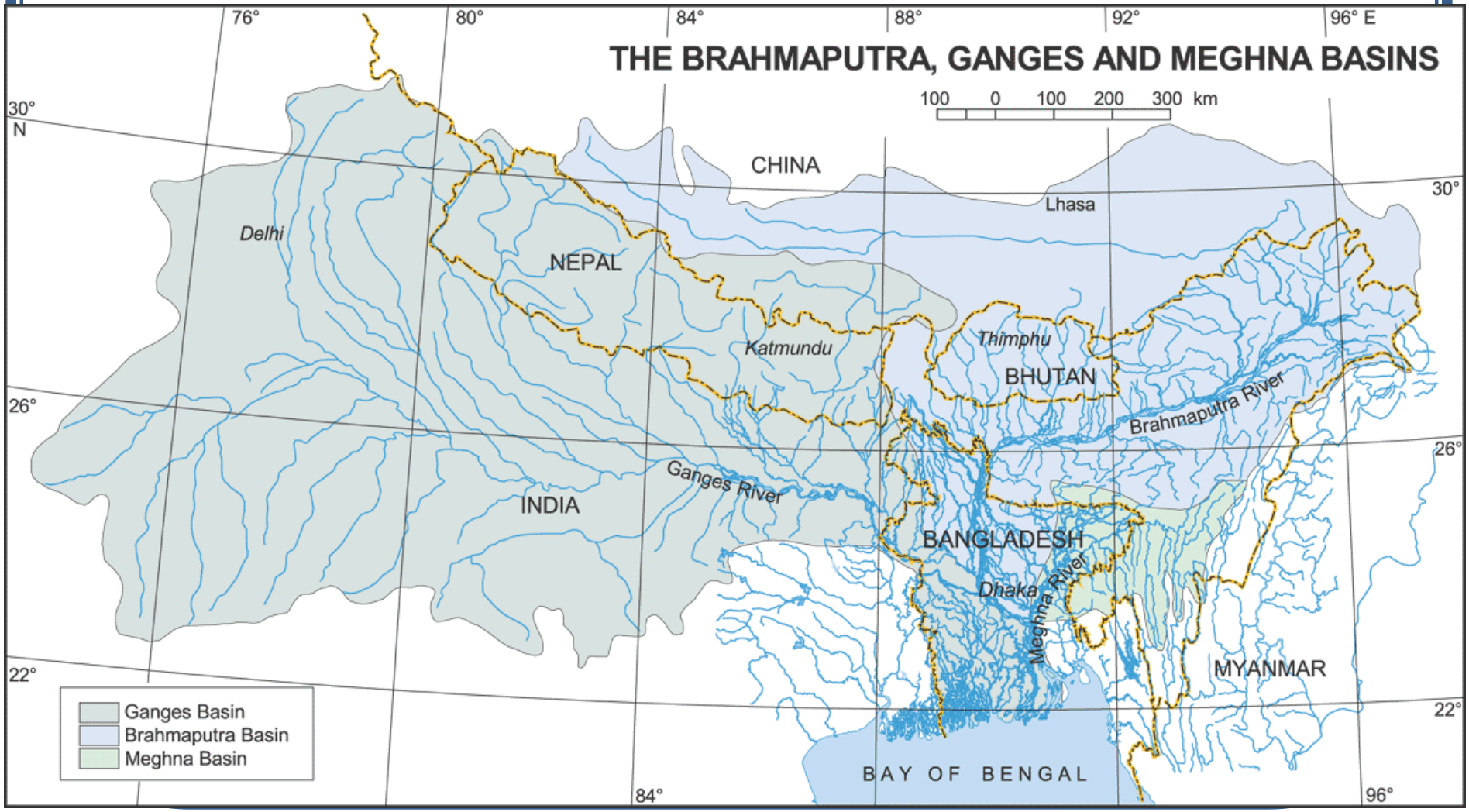
- Tropical Rainfall Measurement Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA)
  - constellation of satellites used to derive rainfall estimates
  - limited to Latitudes 50°N to 50°S (Calgary at 51°N)
  - Rainfall estimates at 3 hour increments with resolution of 0.25°×0.25° arc degrees

Benefits of RS for Rainfall Estimates

- There is no global treaty between countries to share stream flow and rainfall data
  - RS allows one to estimate rainfall across boundaries
  - Helps forecast flood event in nations/locations downstream (eg: Bangladesh).
- RS estimates rainfall data and predicts floods in places where rainfall gauges are not present
  - Accuracy is limited compared to rainfall gauges

RS in Flood Forecasting

Image source: http://www.bpedia.org/R_0208.php



Conclusion

- RS is a complementary technology. (Not intended to replace traditional flood mapping)
  - allows for continuous spatial data (not only point source)
  - RS needs a “ground truth”
- Efficient tool for mapping and monitoring, as it is fast and simple process
- Its derived products can be useful for emergency response and disaster preparedness
- Can be used towards flood forecast modelling

Thank you!

Questions ?