DEM based Flood Area Mapping Technique for Real Time Flood Early Warning Systems

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United Nations-ISRO India Workshop

on Use of Earth Observation Data in Disaster Management and Risk Reduction: Sharing the Asian Experience

Outline:-

1. Introduction
2. Objectives
3. Motivation and Components of a Flood Early Warning System
4. Study Area and Data set used
5. Proposed Method of Approach:
   - DEM based Flood Area Mapping
   - Demonstration through Oct-2013, Nov-2013 flood events of AP, India
   - Validation
6. Conclusion

Introduction

DISASTERS

NATURAL

- Floods
- Landslides
- Drought
- Earth Quake

MAN MADE

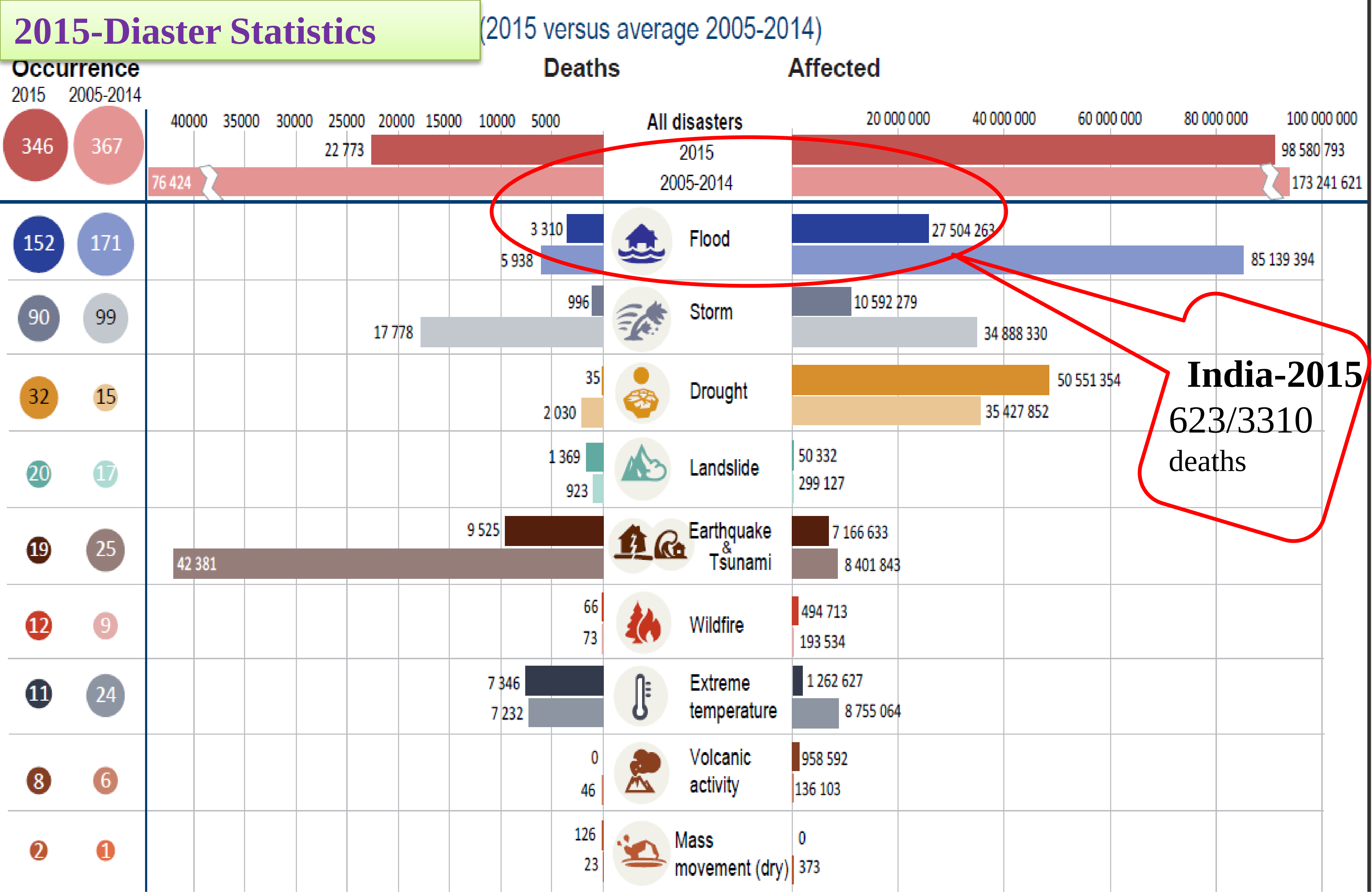
- Accidents
- Industrial mishaps

- **Natural Disasters result in loss of human life and property**

- **Global Economy suffers a colossal loss due to inability to prevent natural and man-made disasters.**

- **Among natural disasters world over 'Flood' is No-1 is divesting the hotspot both in turn of human loss and economic loss than any other natural disasters**

2015-Disaster Statistics



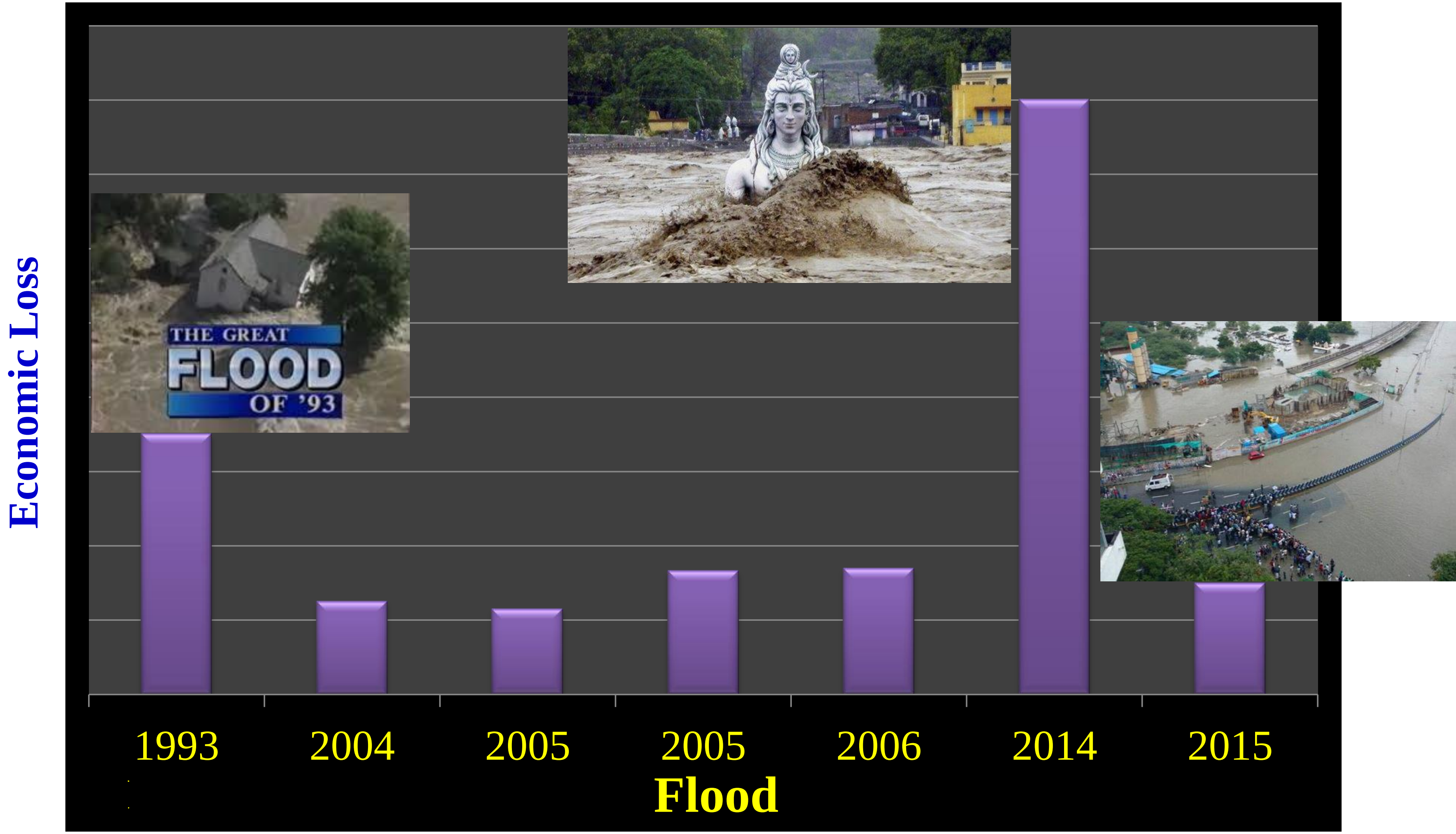
Source: EM-DAT (25th January 2016) : The OFDA/CRED - International Disaster Database www.emdat.be Université catholique de Louvain Brussels - Belgium

UNISDR
The United Nations Office for Disaster Risk Reduction
www.unisdr.org

USAID
FROM THE AMERICAN PEOPLE

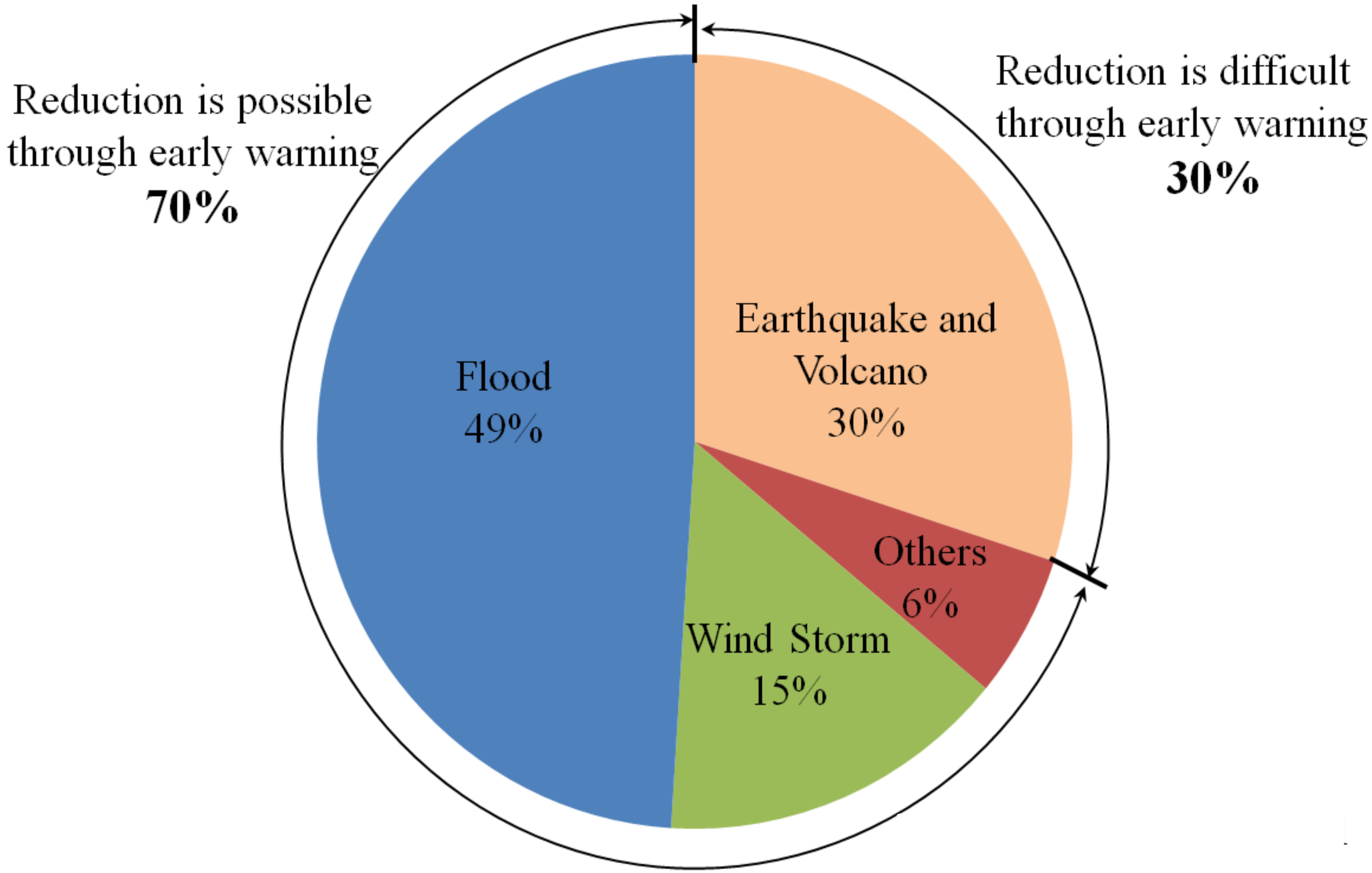
Centre for Research on the Epidemiology of Disasters (CRED), IRSS
Université catholique de Louvain, Belgium
Tel. +32 27643327
contact@emdat.be
www.cred.be

Estimated economic damages reported by Flood related disasters of India from 1993 to 2015 (in US$ X 1000 billion ranging from 20-180)



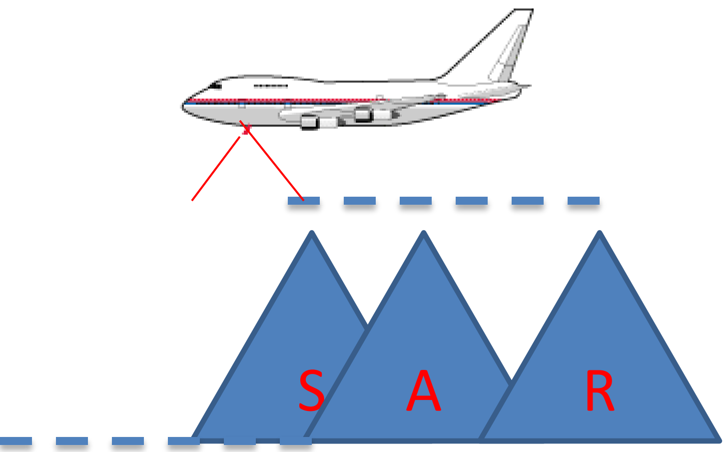
Approx., hence with noise/error

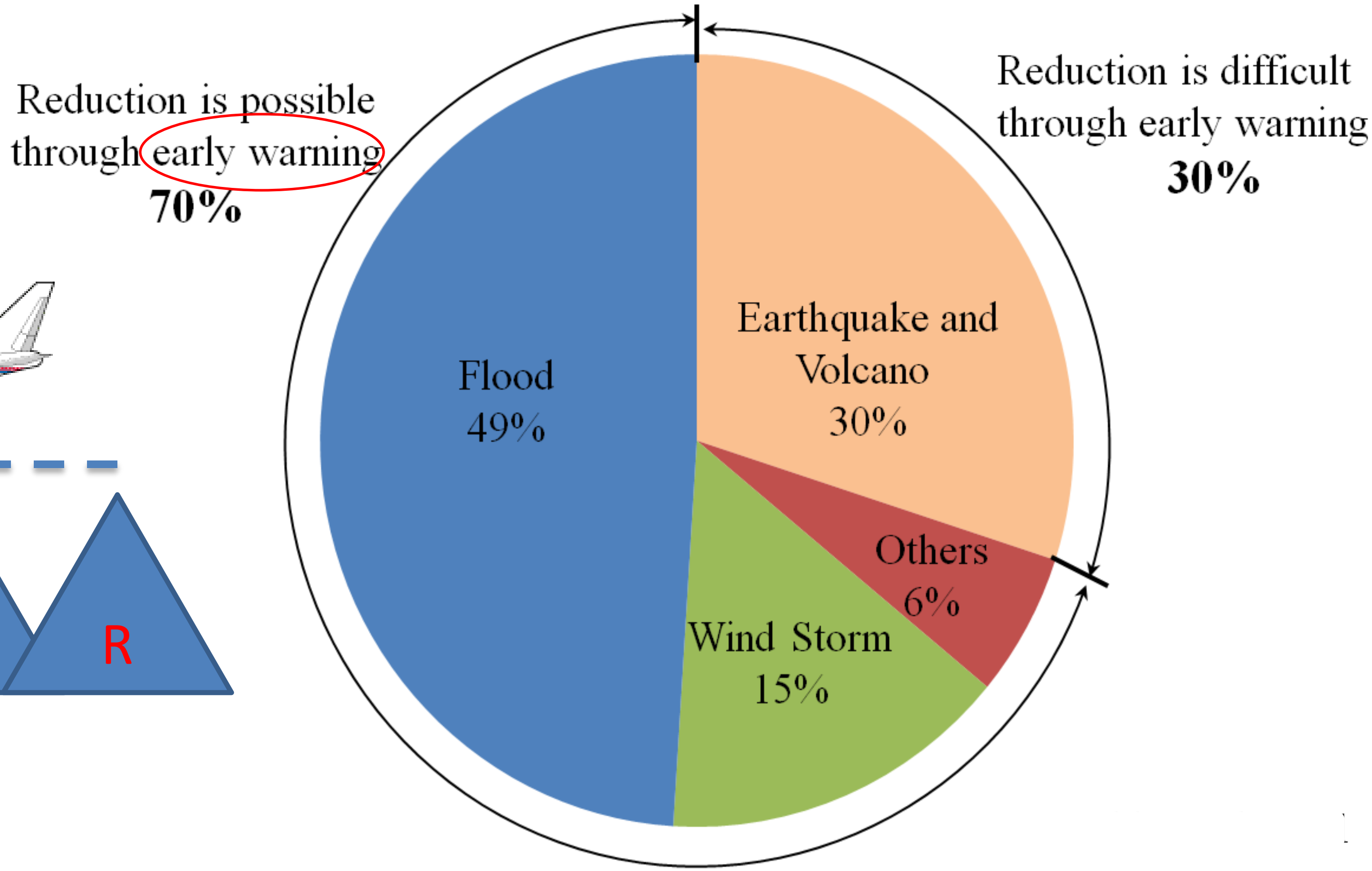
Role of effective Early Warning Systems
(W.r.t Human loss)



Source: World Watch 2001.

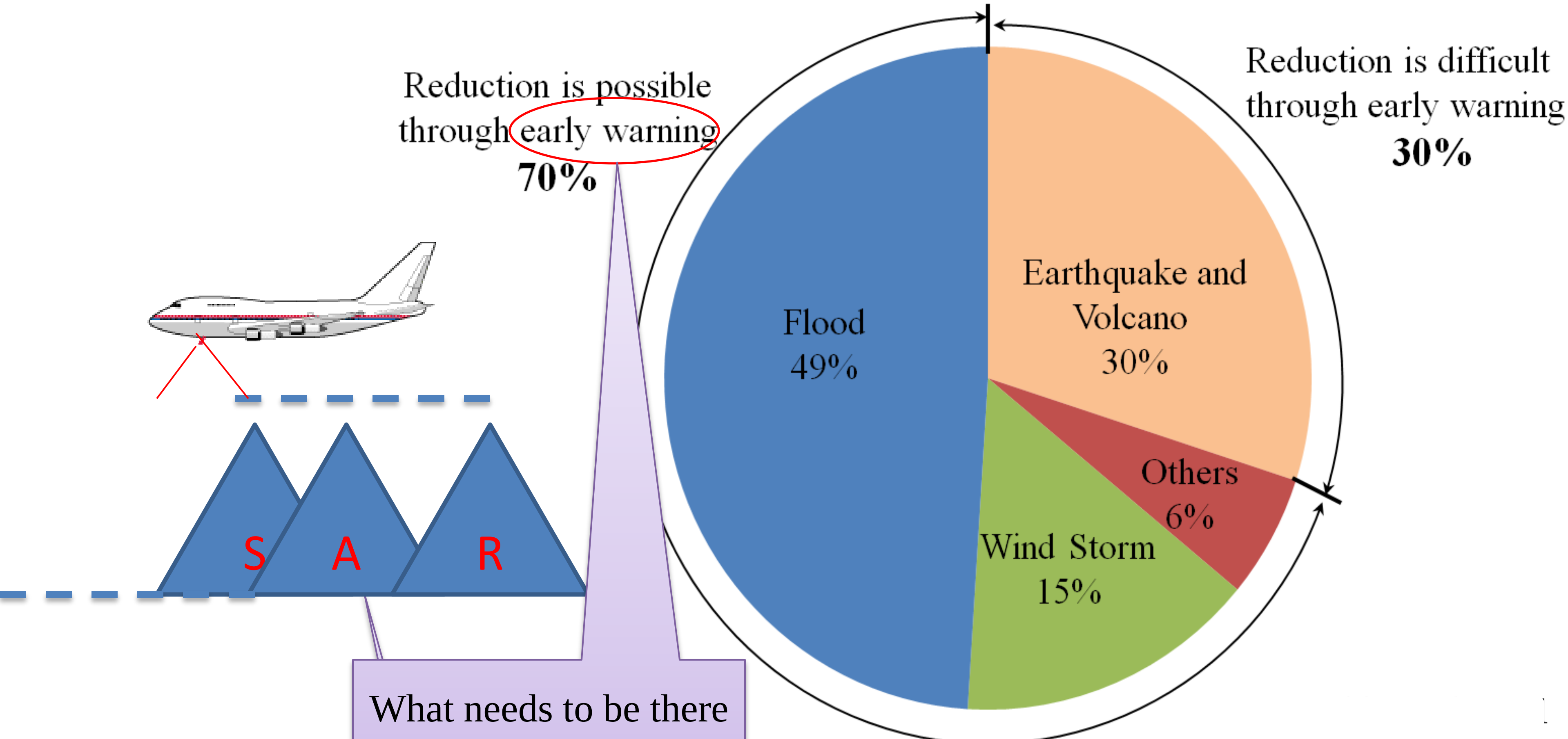
Role of effective Early Warning Systems
(W.r.t Human loss)





Source: World Watch 2001.

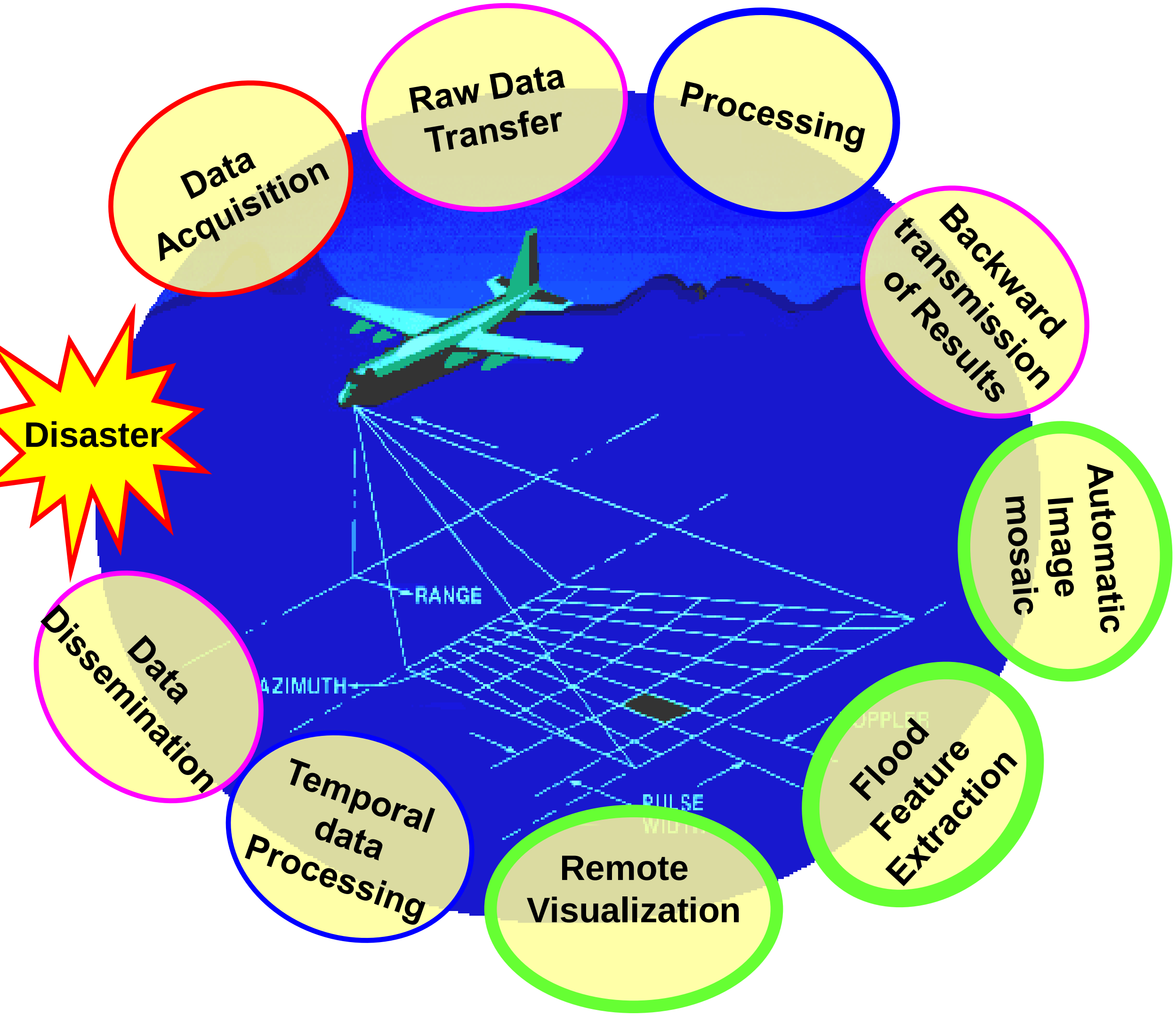
Role of effective Early Warning Systems
(W.r.t Human loss)

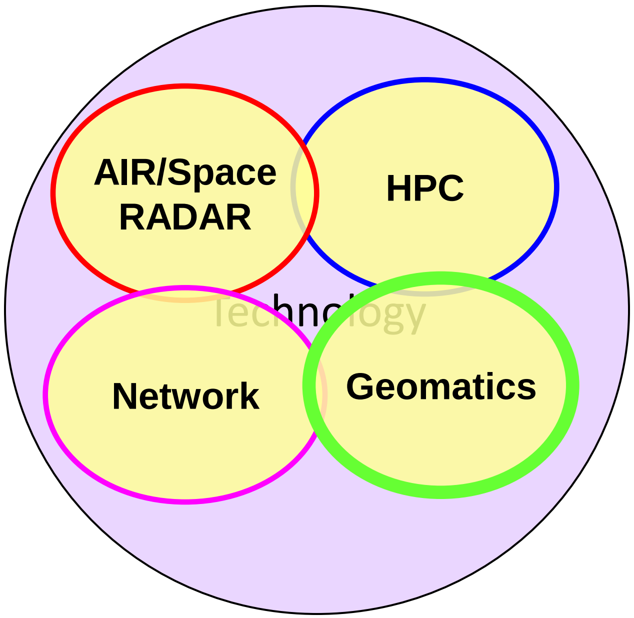


What needs to be there for an effective early warning system (components) ?

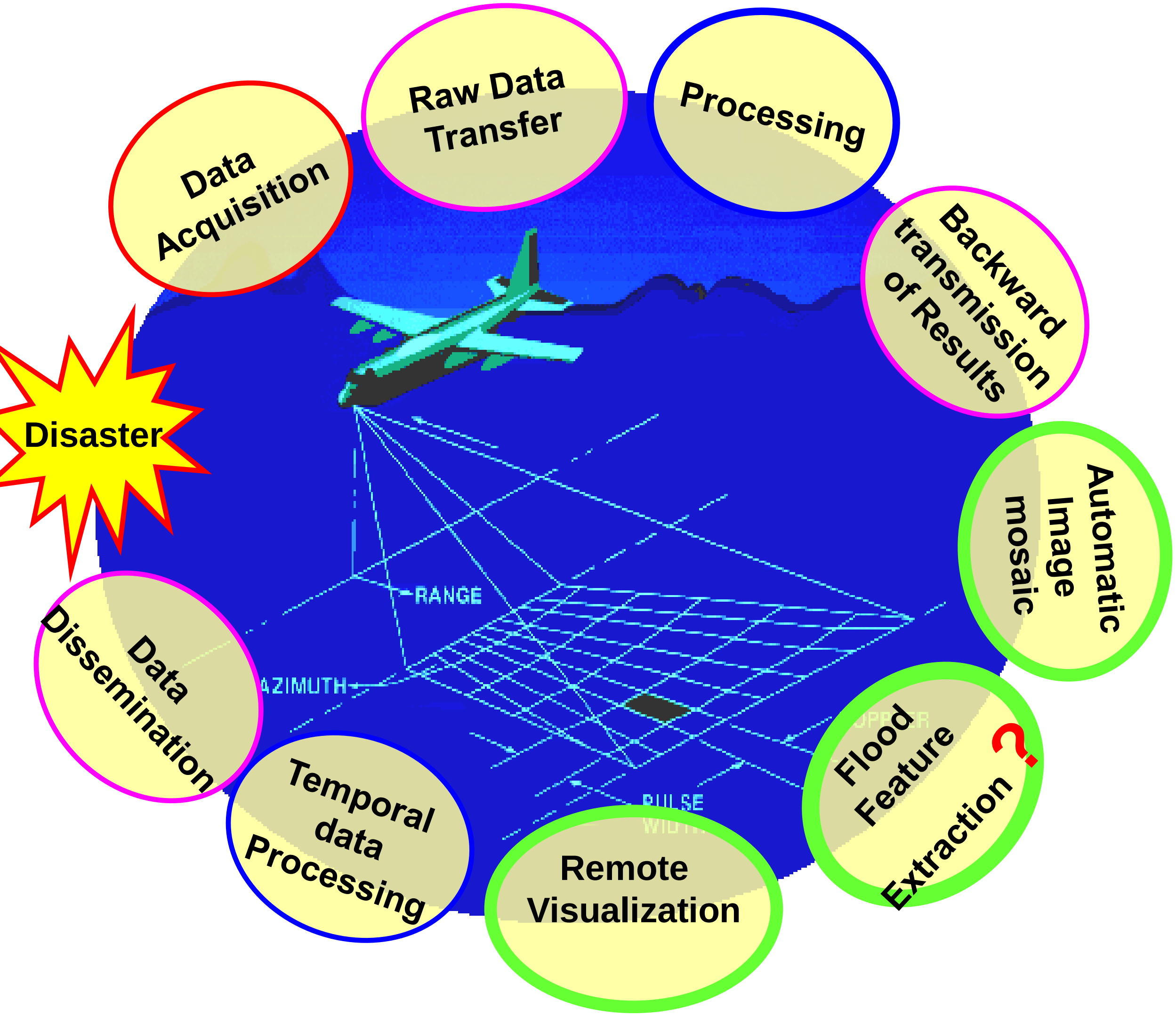
Source: World Watch 2001.

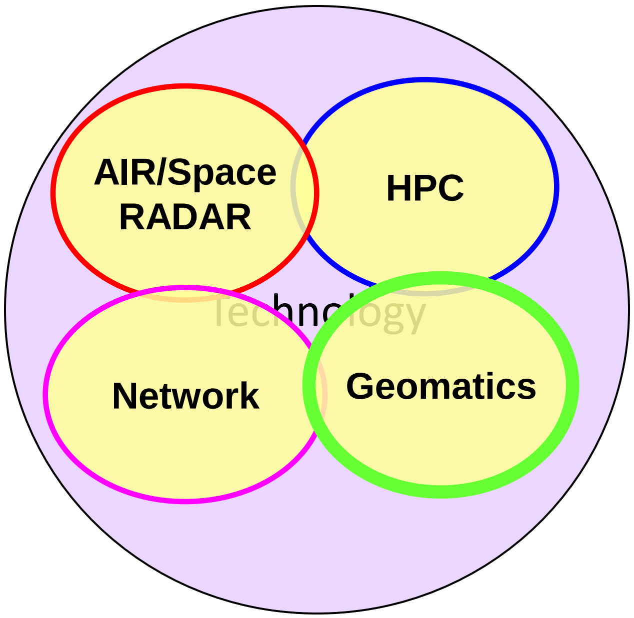
Components of SAR based Flood Early Warning System and Motivation



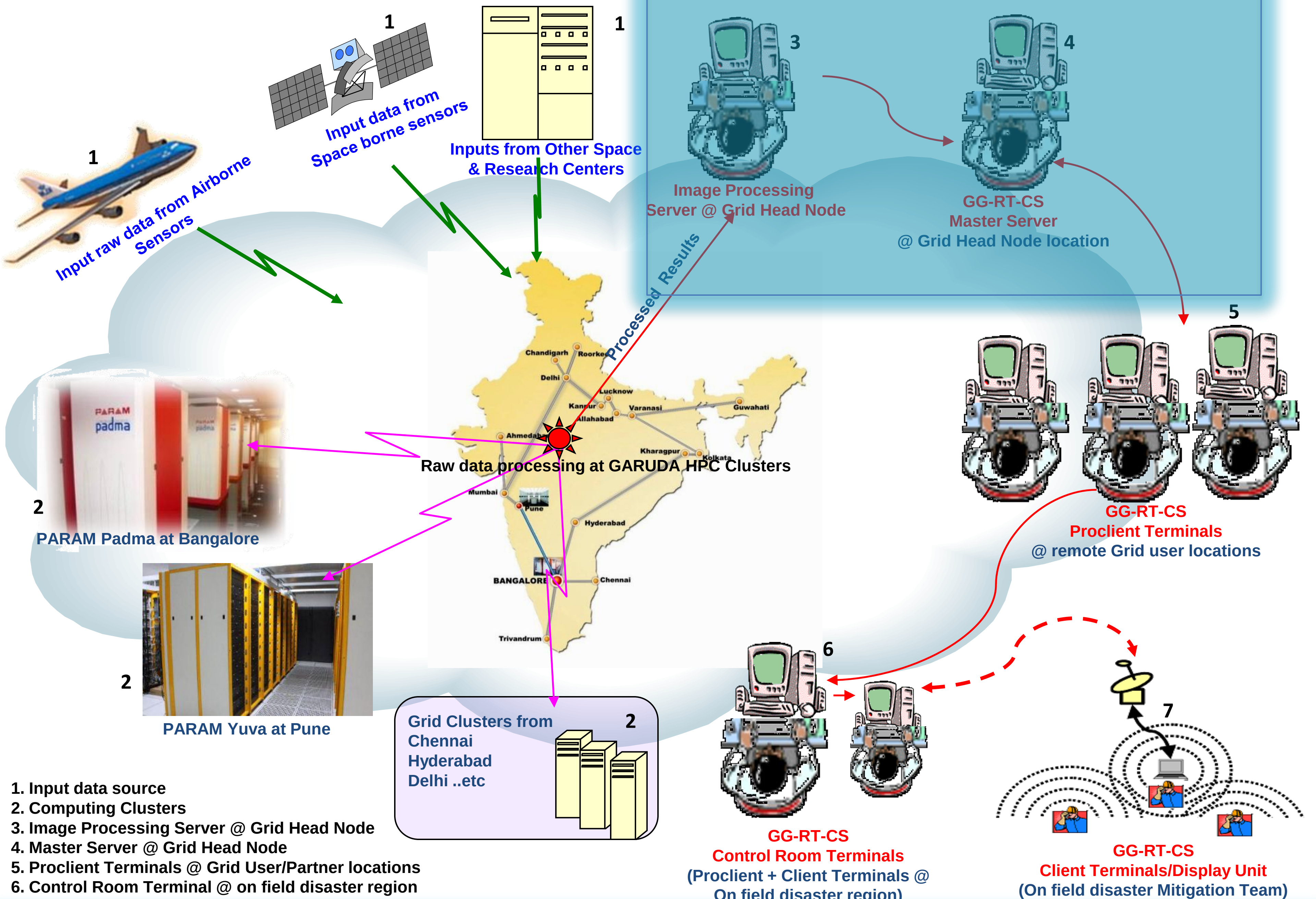


Components of SAR based Flood Early Warning System and Motivation





Overview of Grid enabled FAS



1. Input data source
2. Computing Clusters
3. Image Processing Server @ Grid Head Node
4. Master Server @ Grid Head Node
5. Proclient Terminals @ Grid User/Partner locations
6. Control Room Terminal @ on field disaster region
7. Client Terminals/Display Units of disaster mitigation team

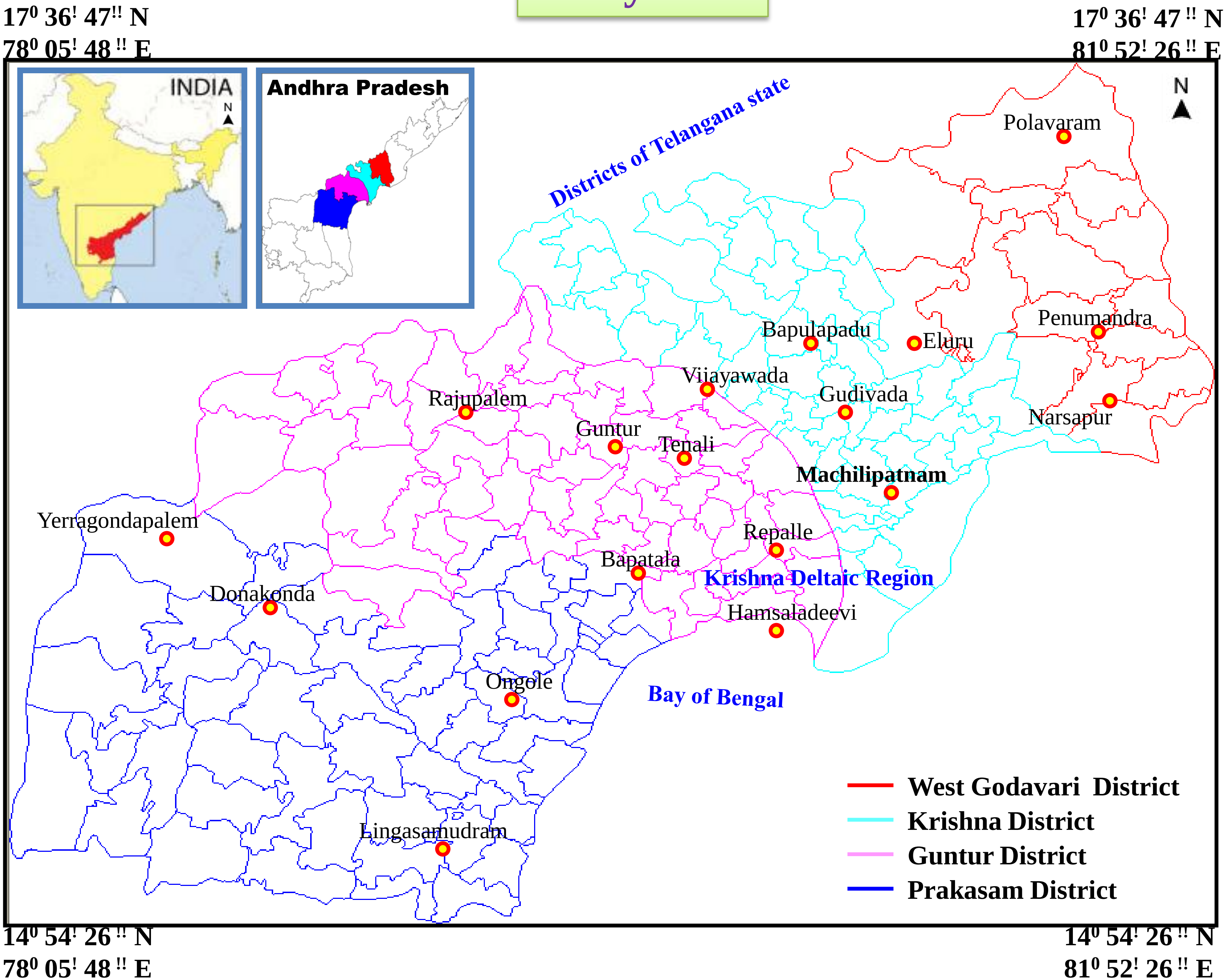
….is there any method to map the inundated pixels with least manual intervention ?

Objectives: -

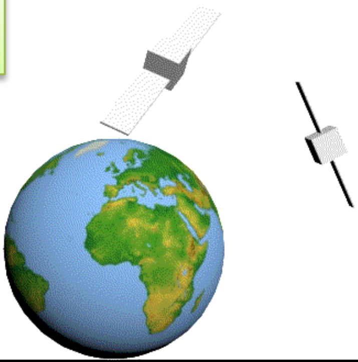
1. To develop a RADAR (SAR) image analysis technique that can map the inundated information with least manual intervention and with maximum possible automation.

2. Evaluation of proposed model with different SAR data sets of different flood events, field database.
   - Deriving the precise backscattering range of fully inundated partially inundated and non-flooded regions and its analysis.

Study Area


17^{0} 36$^{!}$ 47$^{!!}$ N
78^{0} 05$^{!}$ 48$^{!!}$ E
17^{0} 36$^{!}$ 47$^{!!}$ N
81^{0} 52$^{!}$ 26$^{!!}$ E
INDIA
N
Andhra Pradesh
Districts of Telangana state
N
Polavaram
Penumandra
Bapulapadu
Eluru
Vijayawada
Gudivada
Narsapur
Rajupalem
Guntur
Tenali
Machilipatnam
Yerragondapalem
Repalle
Bapatala
Krishna Deltaic Region
Donakonda
Hamsaladeevi
Ongole
Bay of Bengal
Lingasamudram
West Godavari District
Krishna District
Guntur District
Prakasam District
14^{0} 54$^{!}$ 26$^{!!}$ N
78^{0} 05$^{!}$ 48$^{!!}$ E
14^{0} 54$^{!}$ 26$^{!!}$ N
81^{0} 52$^{!}$ 26$^{!!}$ E

About disaster event and dataset used

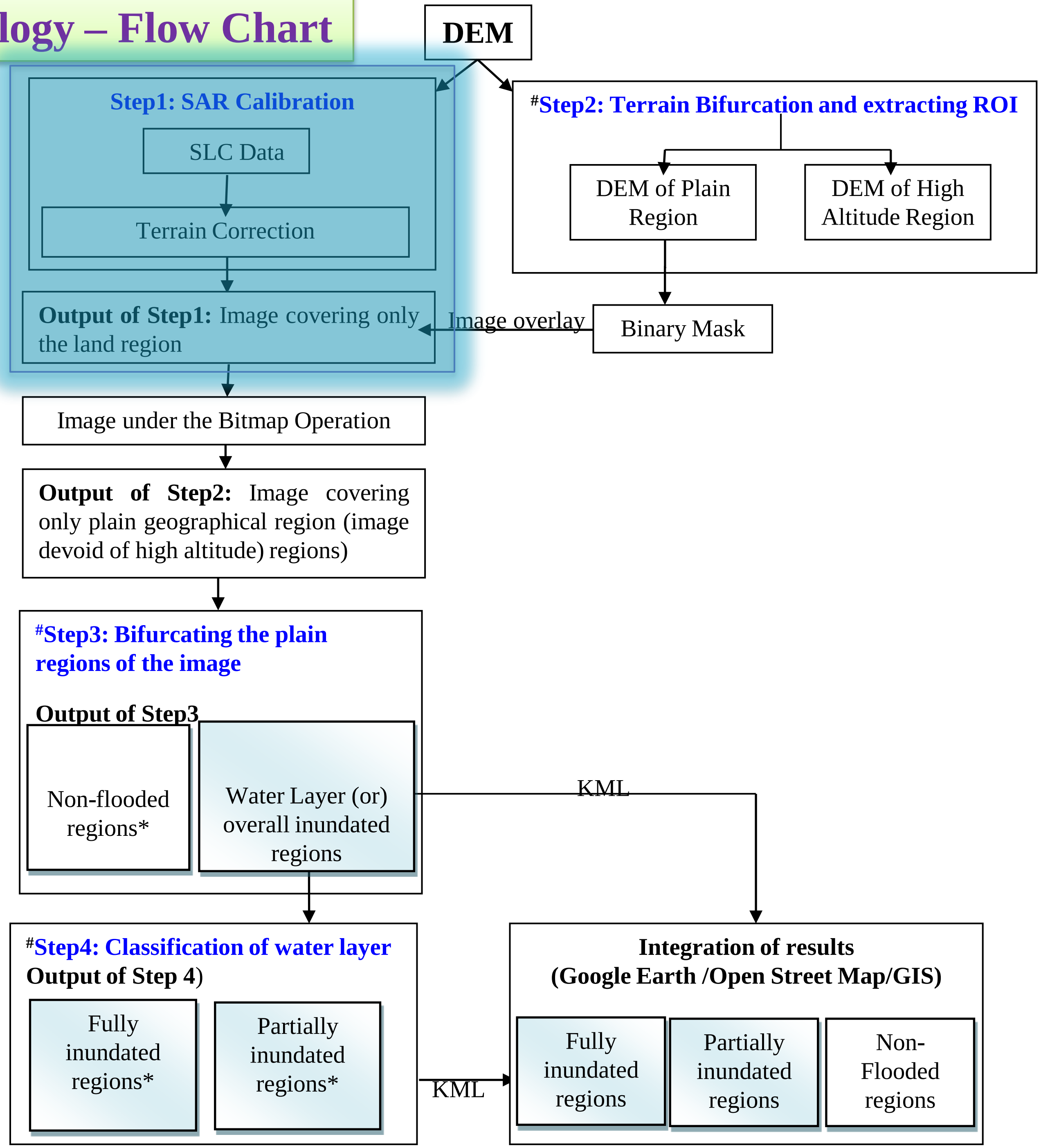


	Flood due to rain during October 2013	**Flood due to Helen cyclone November 2013**
SLC data	RADARSAT-2	RADARSAT-2
Duration of downpour	$22\text{-}27^{th}$ Oct. 2013	19 – 23 Nov. 2013
Acquisition date	28 October, 2013	24 November, 2013
Beam Mode	ScanSAR Wide	
Swath Width (km)	500	
Pass	Ascending	Descending
Image Incidence angle	20^{o} to 49^{o}	33^{o} to 49^{o}
Polarization	HH	
Multilook	2:4	
Pixel spacing (m)	50	

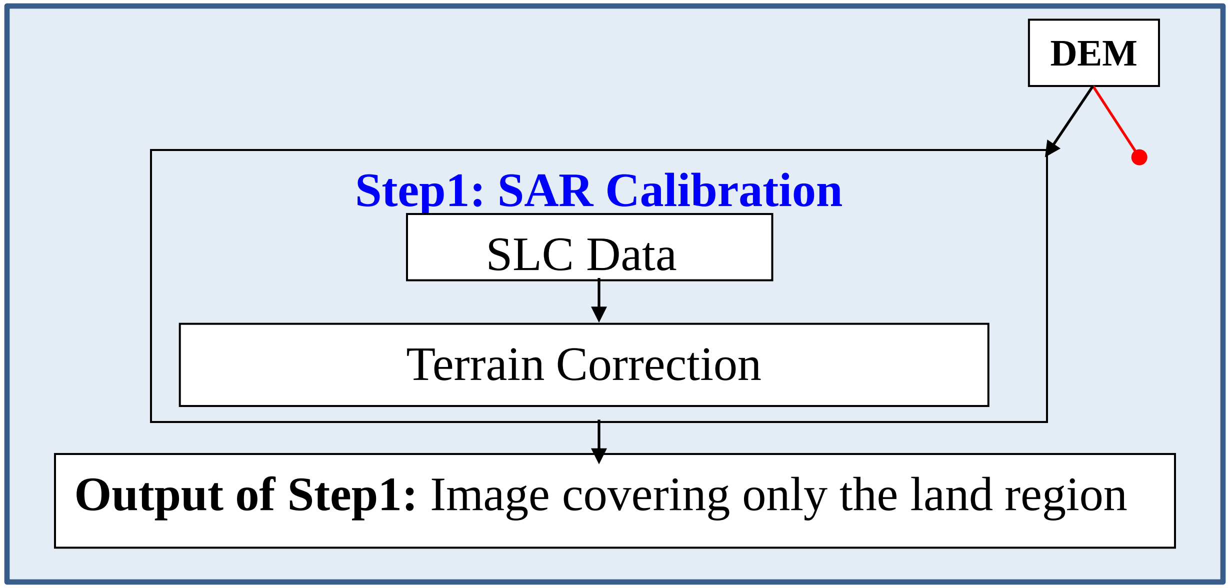
Methodology - DEM based Flood Area Mapping Technique

- **Step1: SLC data Calibration and extracting land region of the image.**
- **Step2: Terrain Bifurcation and extraction of region of interest**
- **Step3: Bifurcating the Plain regions of image to extract the water layer**
- **Step 4: Classification of Water Pixels**
- **Dissemination of Critical information**

Methodology – Flow Chart



Step-1 SLC data Calibration and extracting the land region of the image

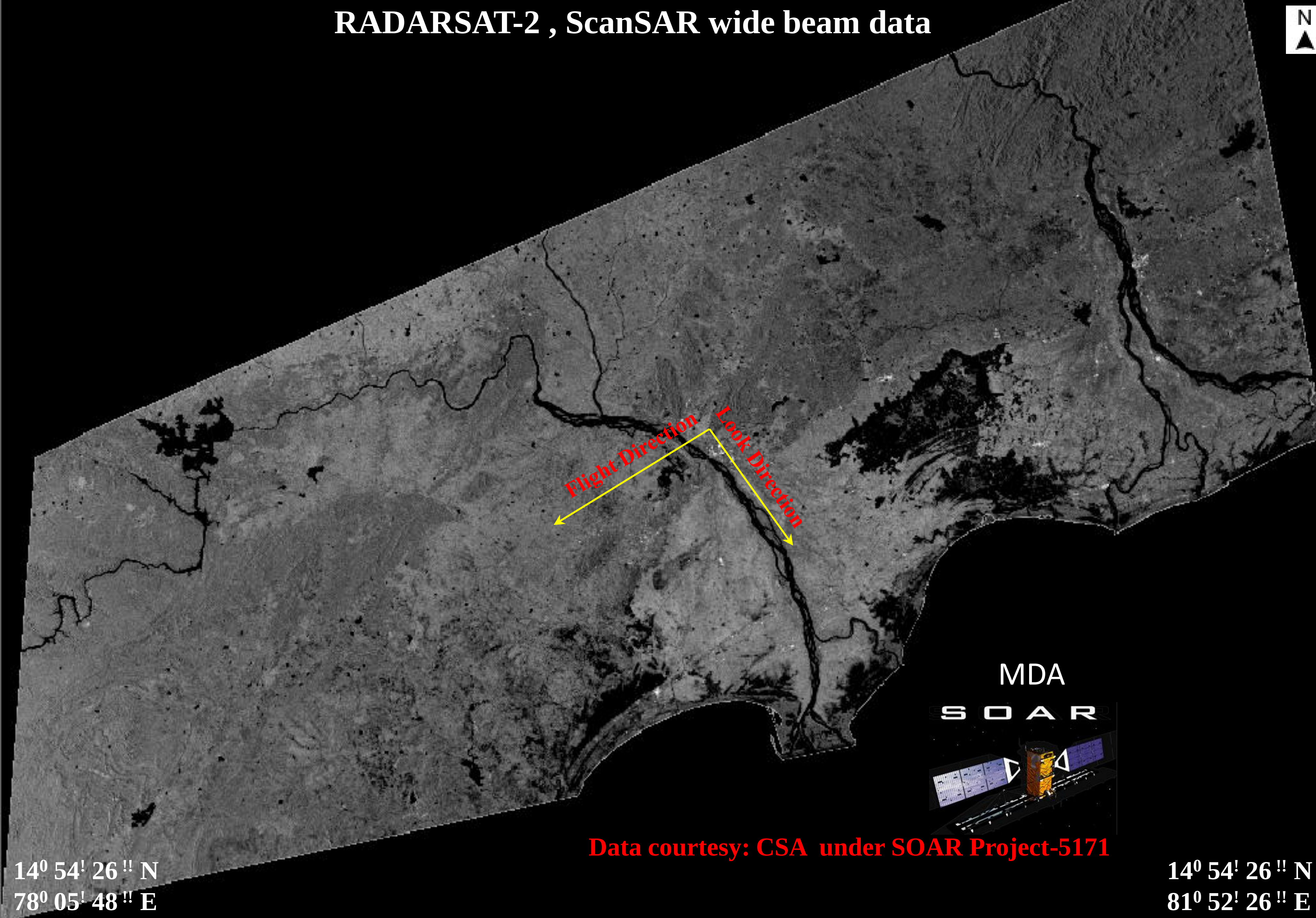


RDTC Algorithm

- Calibration (using metadata of given SLC)
- Image formation
- Terrain Correction (using DEM)
- Mask of sea surface &
- dB image formation

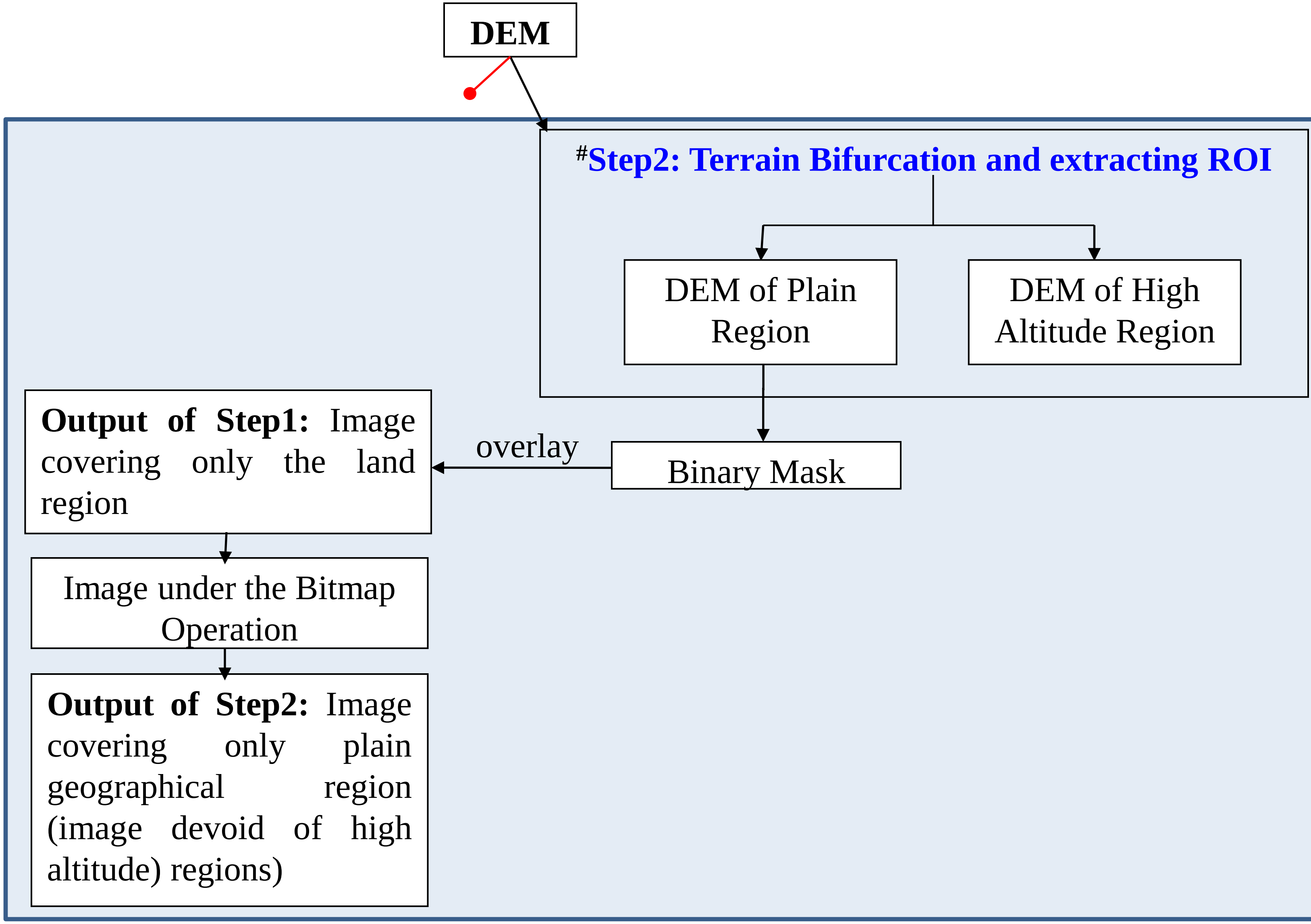
Output of Step-1: October-2013, Flood event of AP, India

RADARSAT-2 , ScanSAR wide beam data



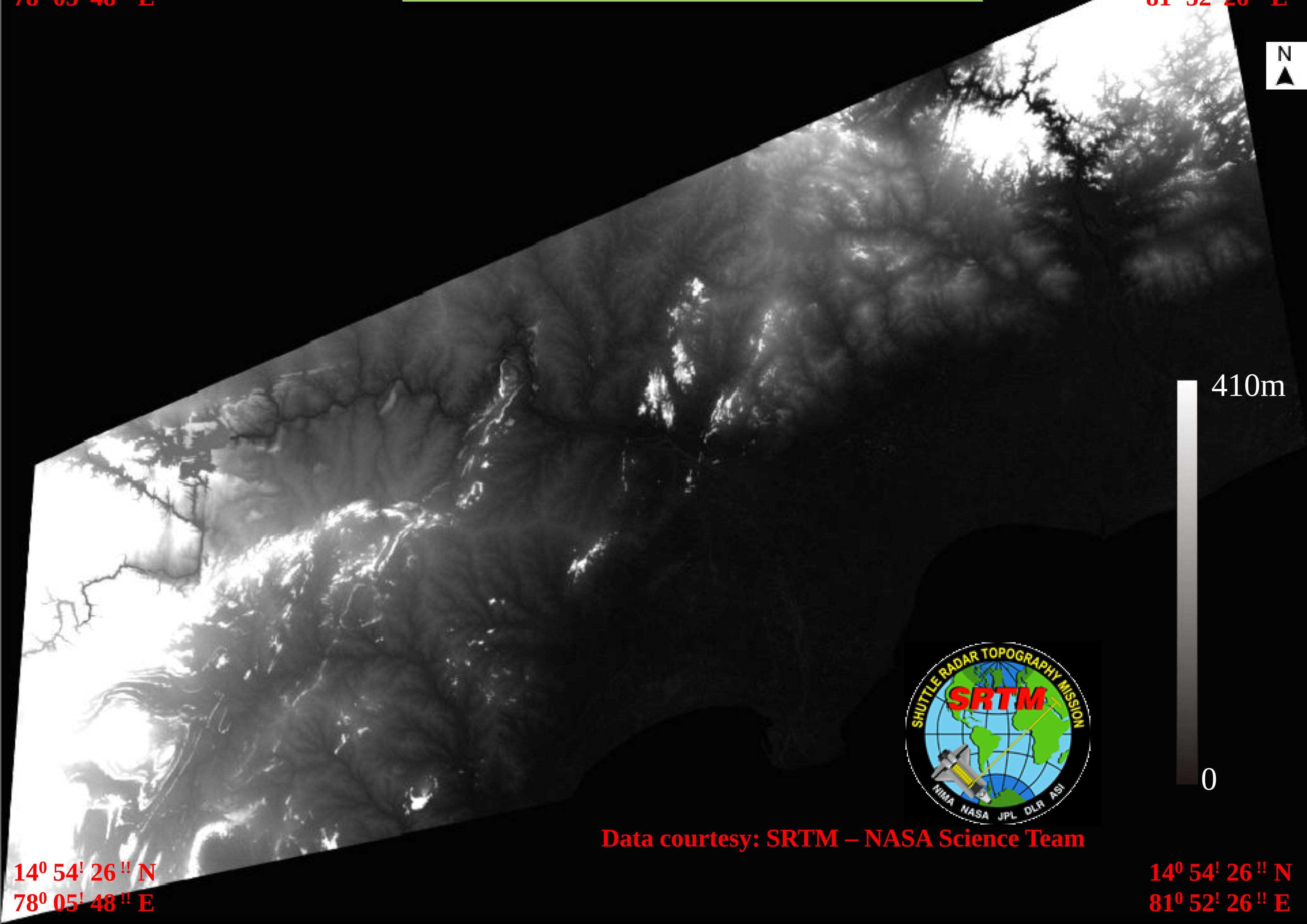
Data courtesy: CSA under SOAR Project-5171

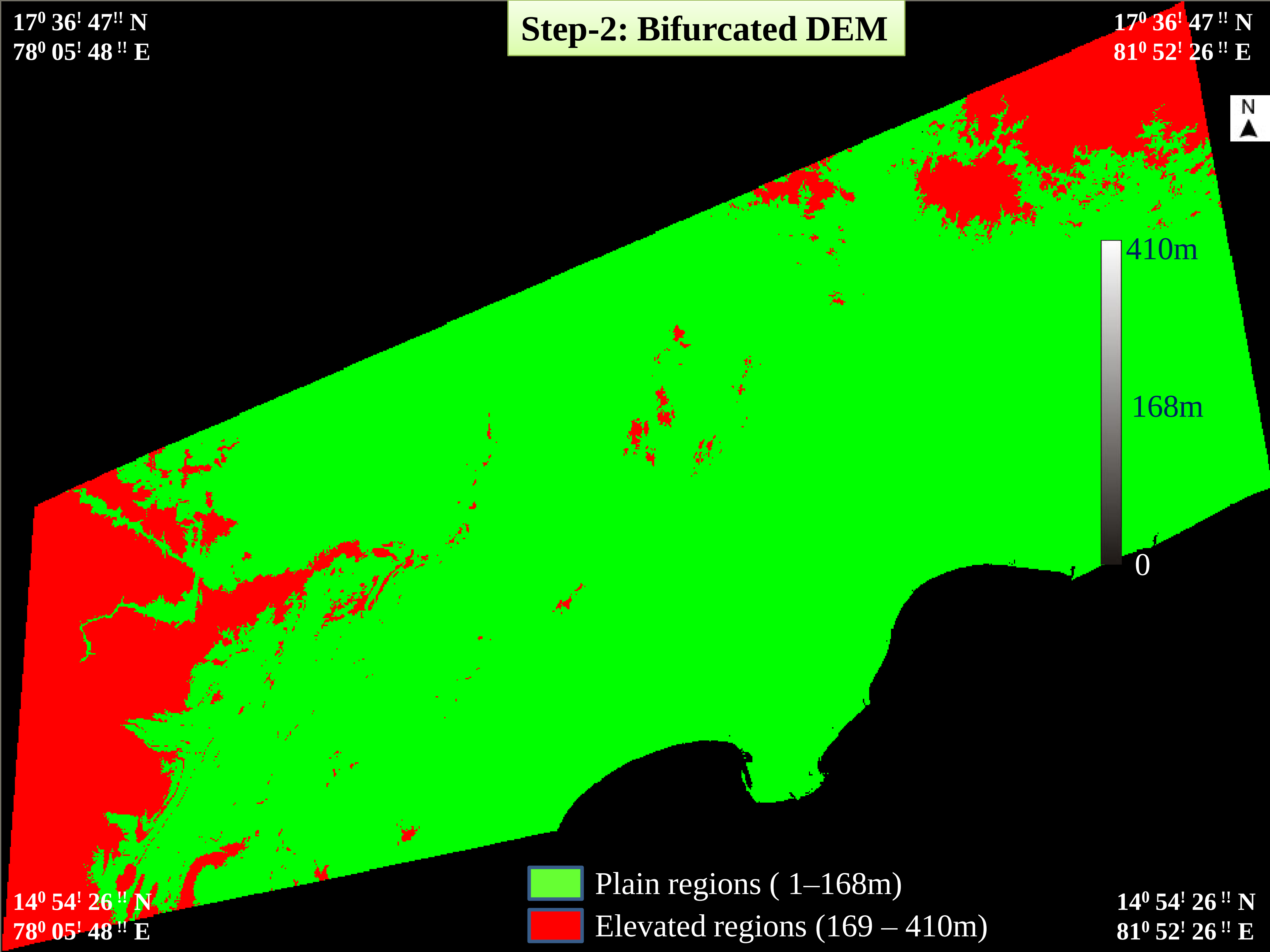
Step-2 Terrain Bifurcation and extraction of region of interest



ISODATA clustering

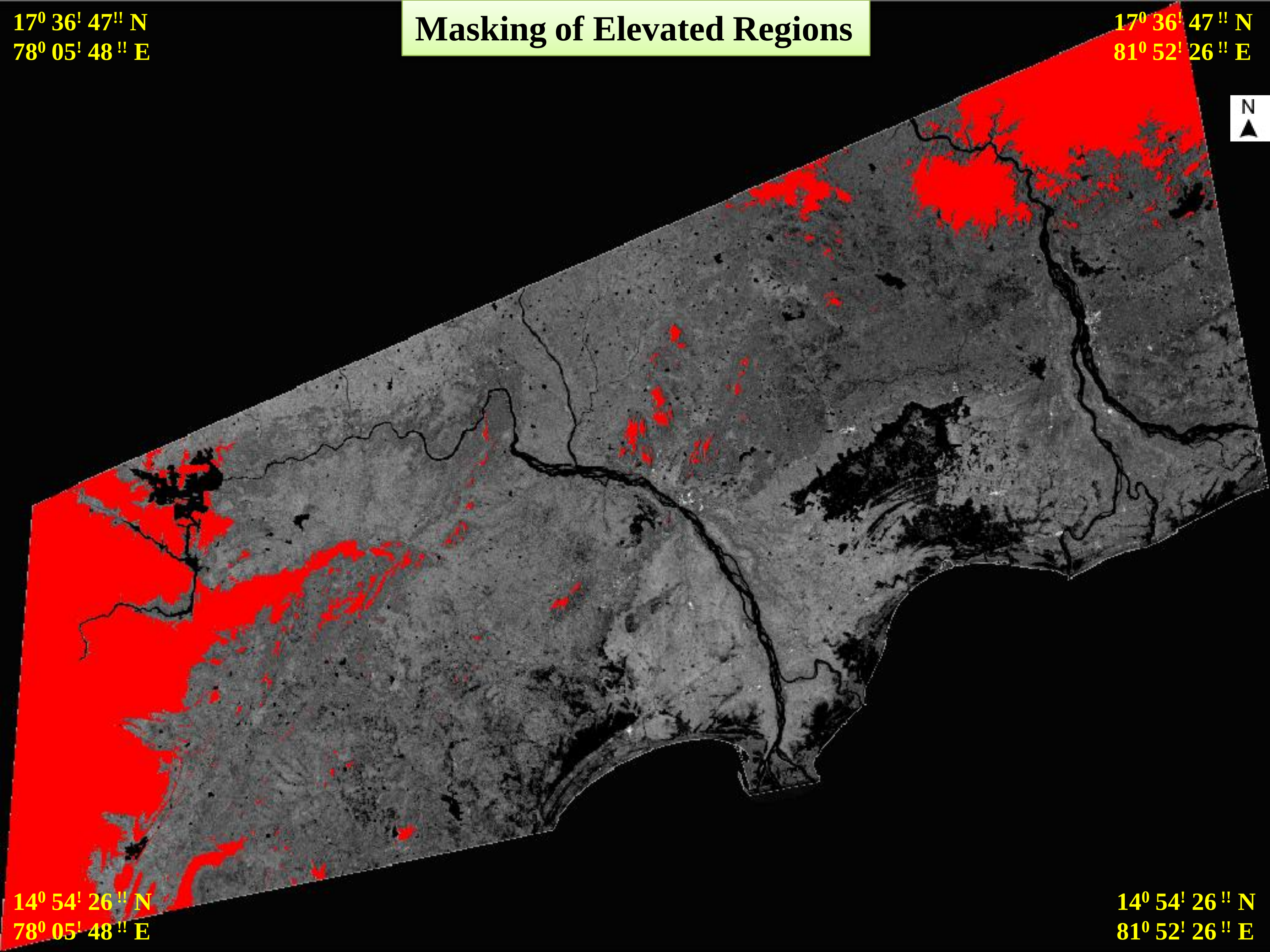
SRTM DEM of the disaster region



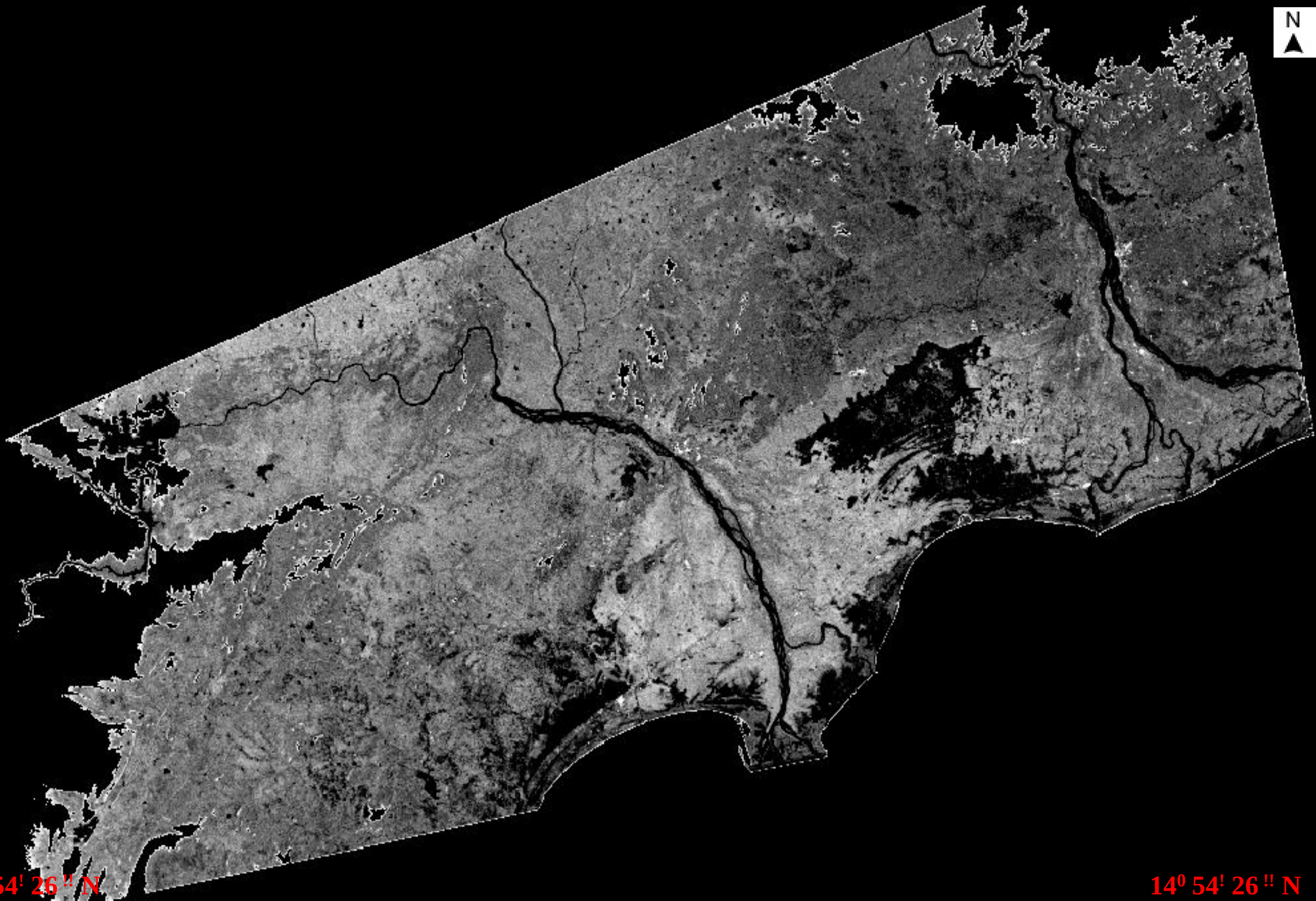


Step-2: Bifurcated DEM
17⁰ 36ꜝ 47ꜝꜝ N
78⁰ 05ꜝ 48ꜝꜝ E
17⁰ 36ꜝ 47ꜝꜝ N
81⁰ 52ꜝ 26ꜝꜝ E
14⁰ 54ꜝ 26ꜝꜝ N
78⁰ 05ꜝ 48ꜝꜝ E
14⁰ 54ꜝ 26ꜝꜝ N
81⁰ 52ꜝ 26ꜝꜝ E
N
410m
168m
0
Plain regions (1–168m)
Elevated regions (169 – 410m)

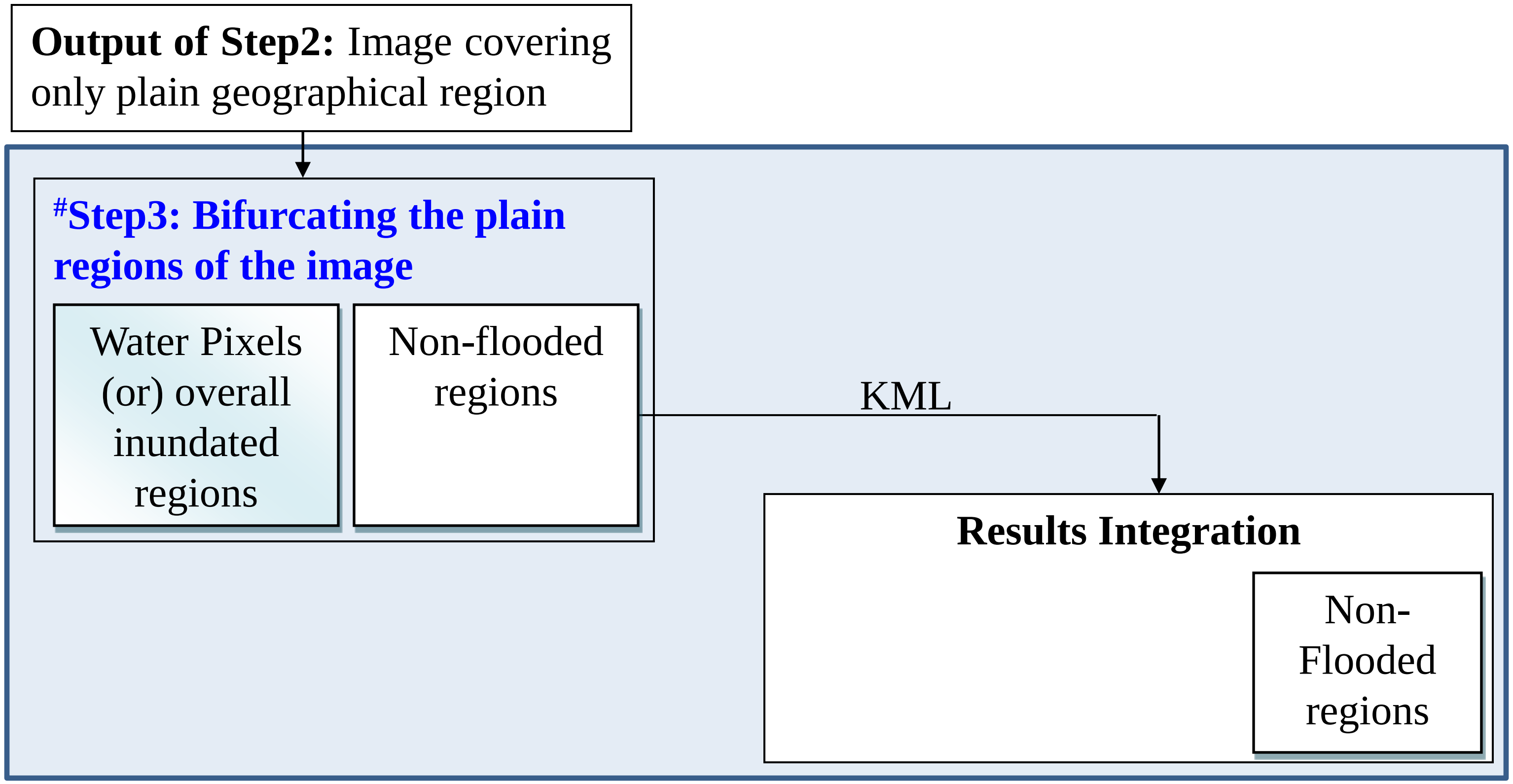
Masking of Elevated Regions



Output of Step-2: Plain Regions of the SAR image



Step3 Bifurcating the Plain regions of image to extract the ‘water pixels/water layer’

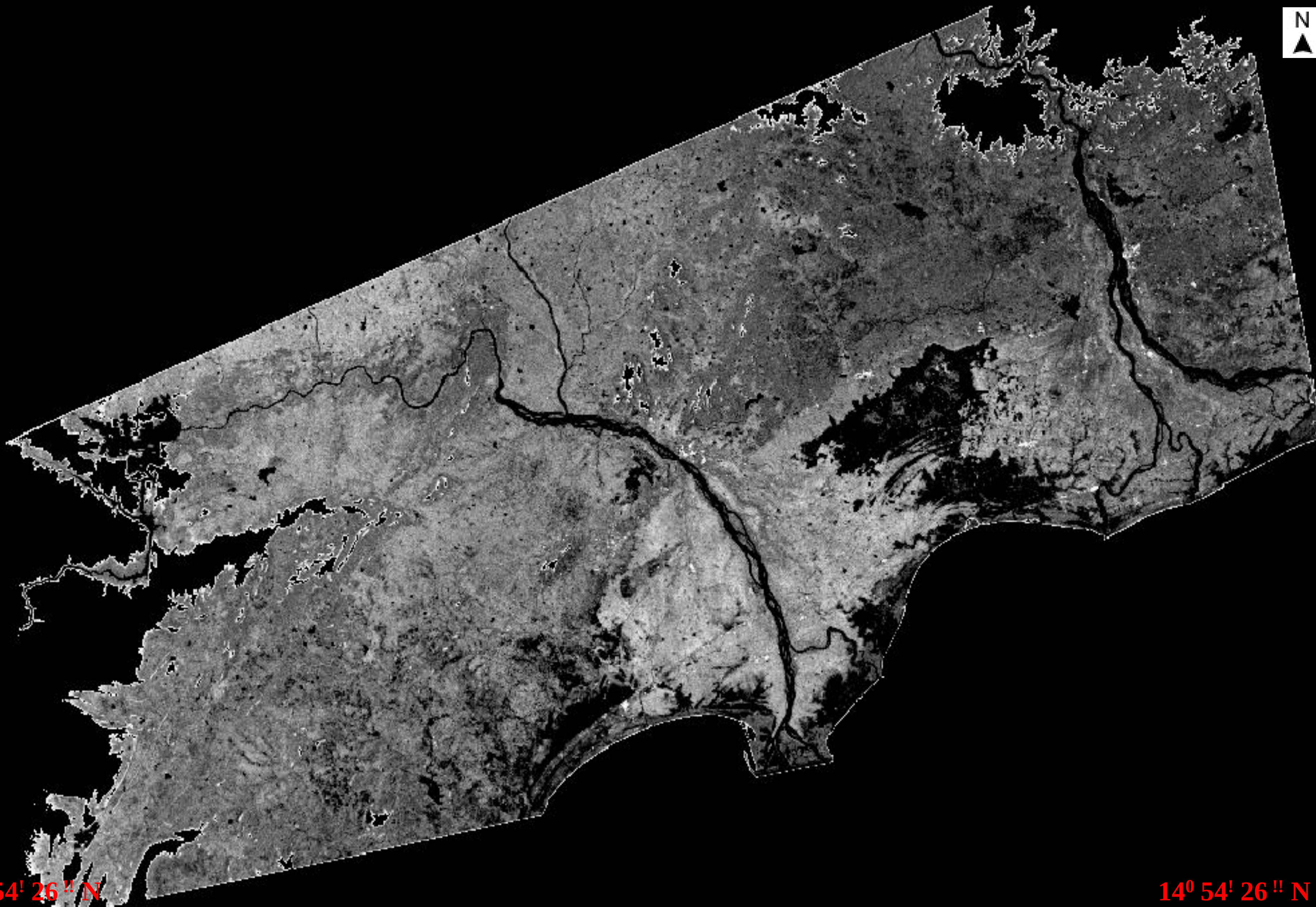


ISODATA clustering

Plain Regions of the SAR image

17° 36' 47'' N
78° 05' 48'' E

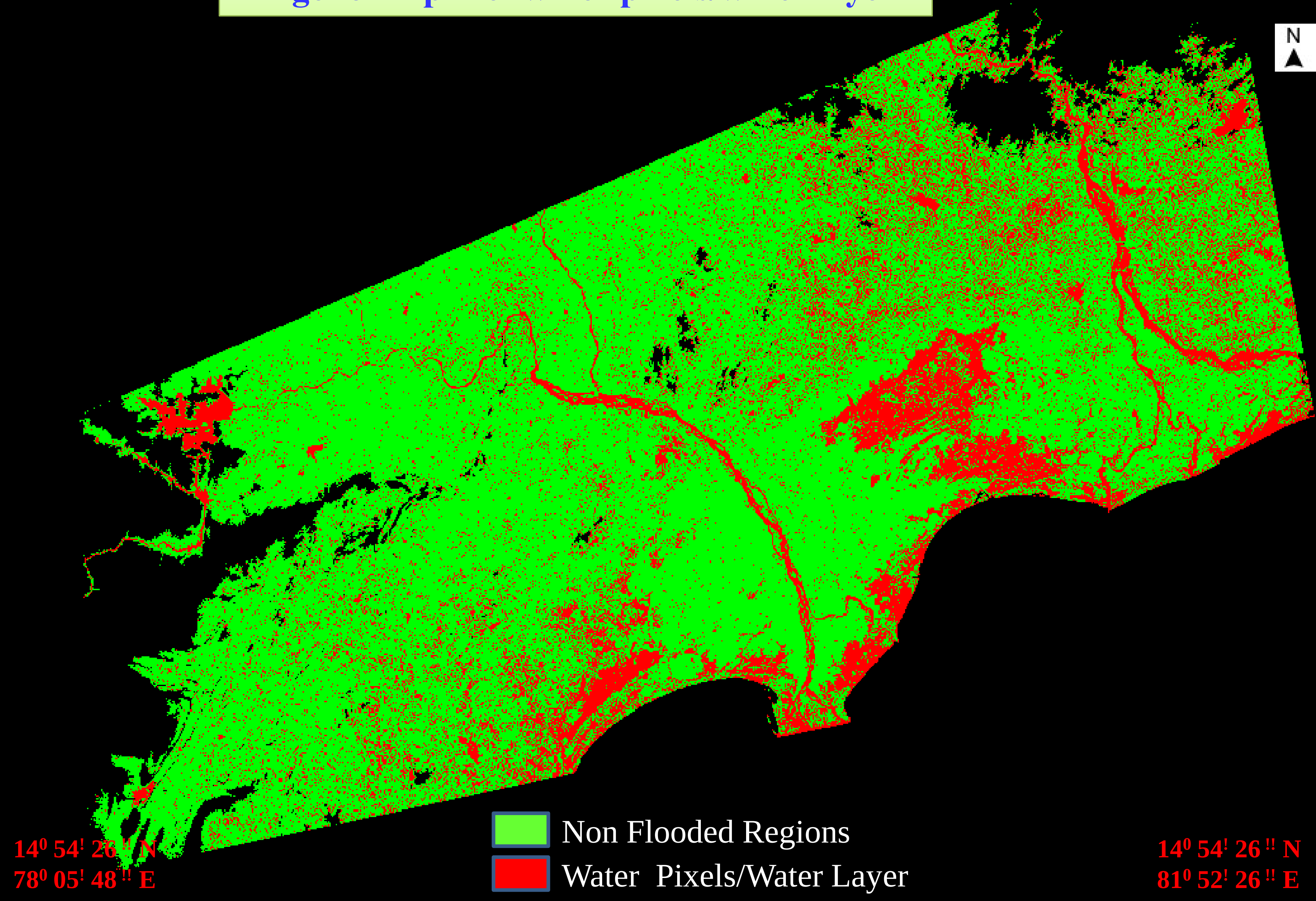
17° 36' 47'' N
81° 52' 26'' E



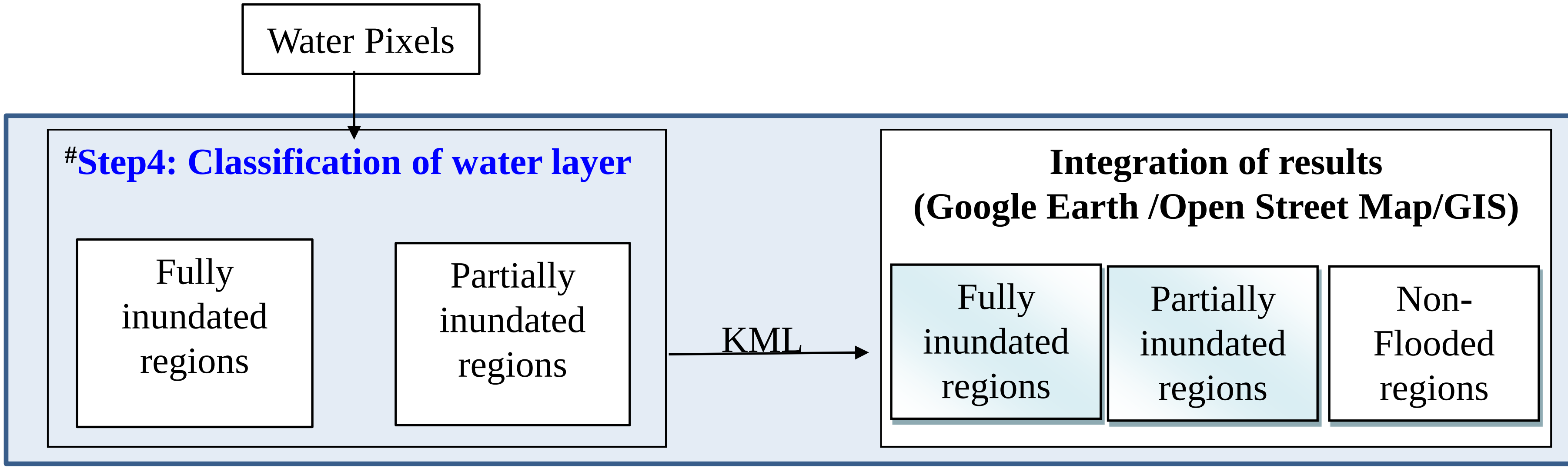
14° 54' 26'' N
78° 05' 48'' E

14° 54' 26'' N
81° 52' 26'' E

Step-3: Bifurcating the Plain regions of image to map the ‘water pixels/water layer’

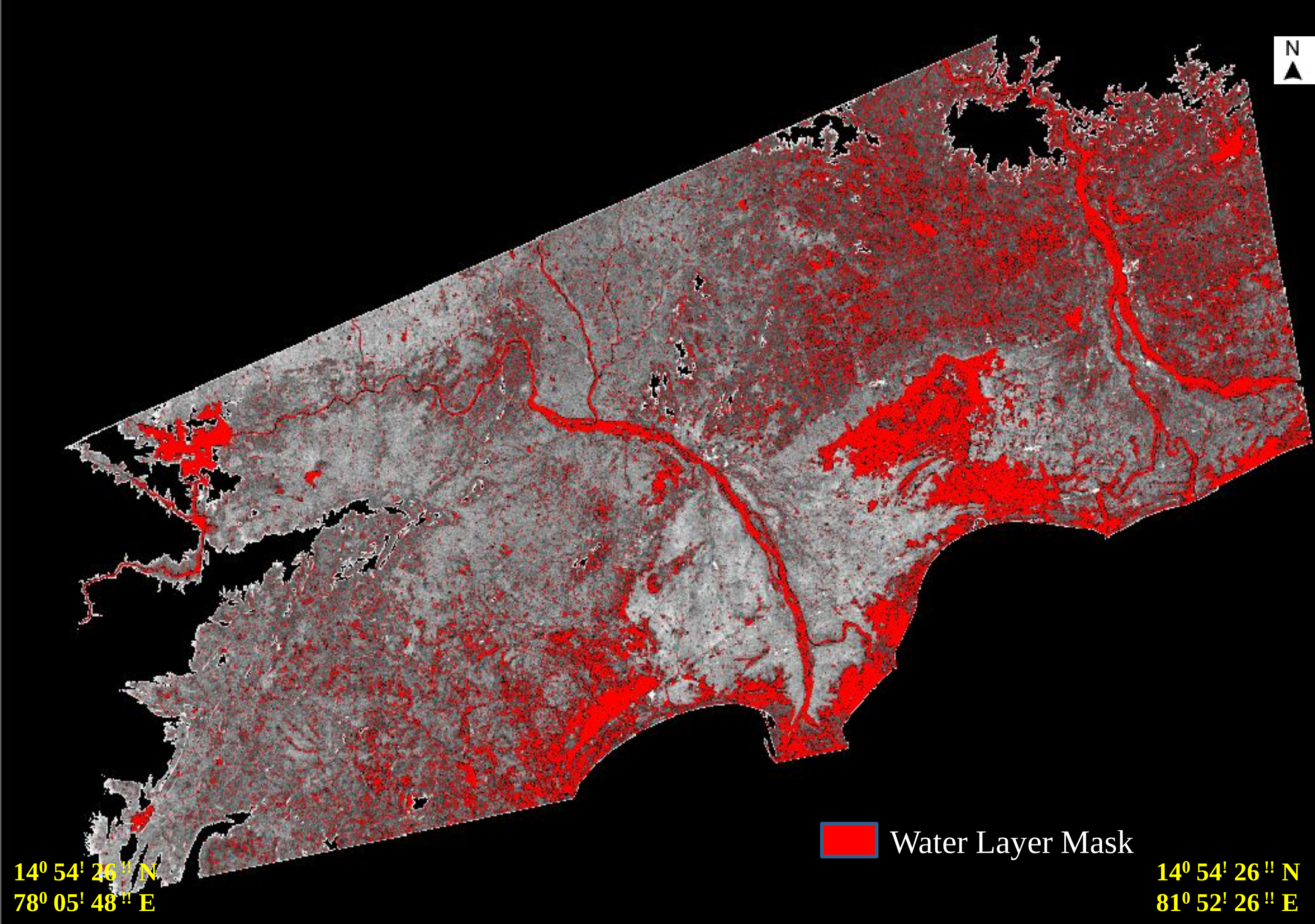


Step 4 Classification of Water Pixels

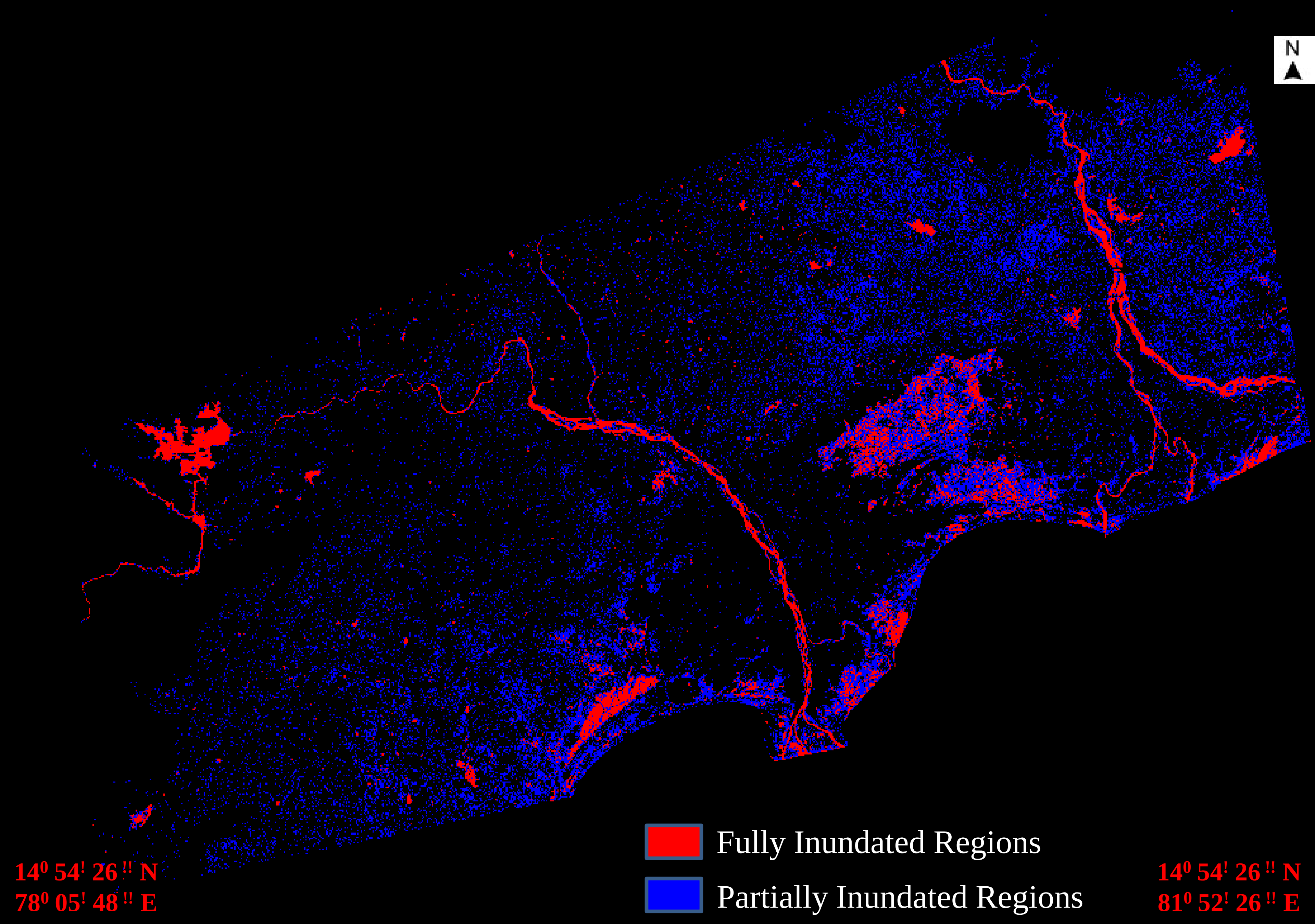


ISODATA clustering

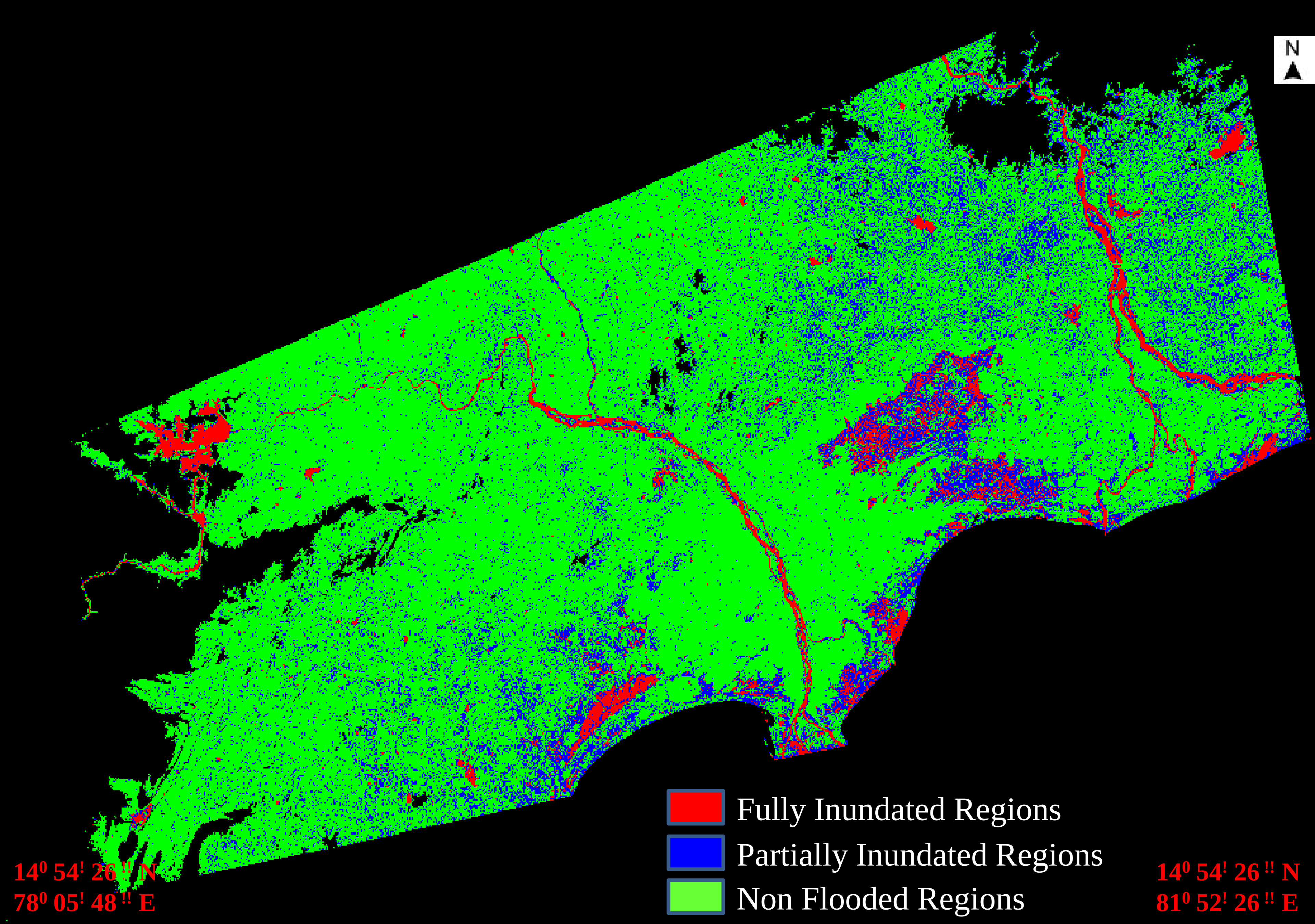
Mask of Water Pixels over the Oct.2013 RADARSAT-2 image



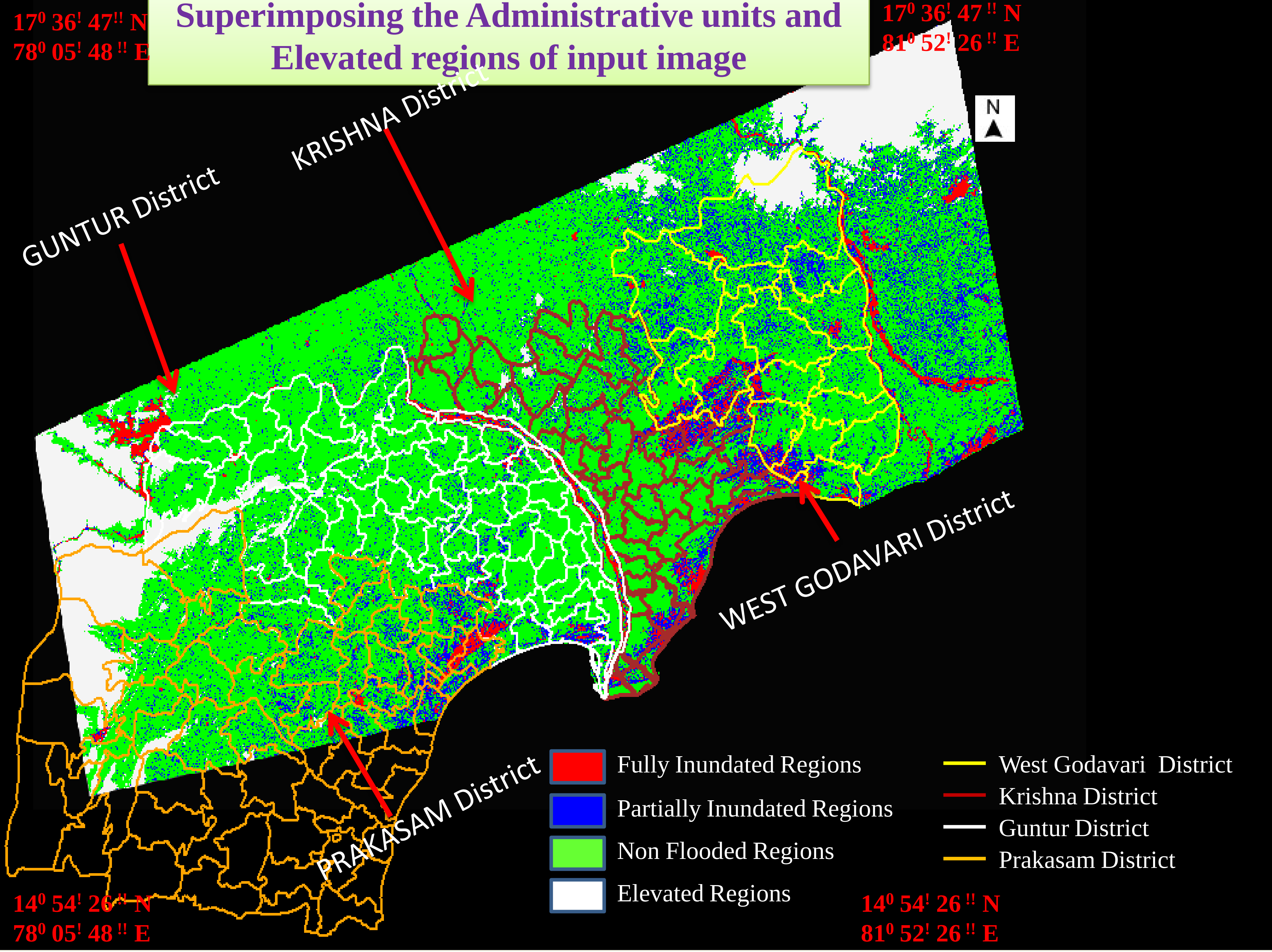
Output of Step-4: Classification of Water Pixels



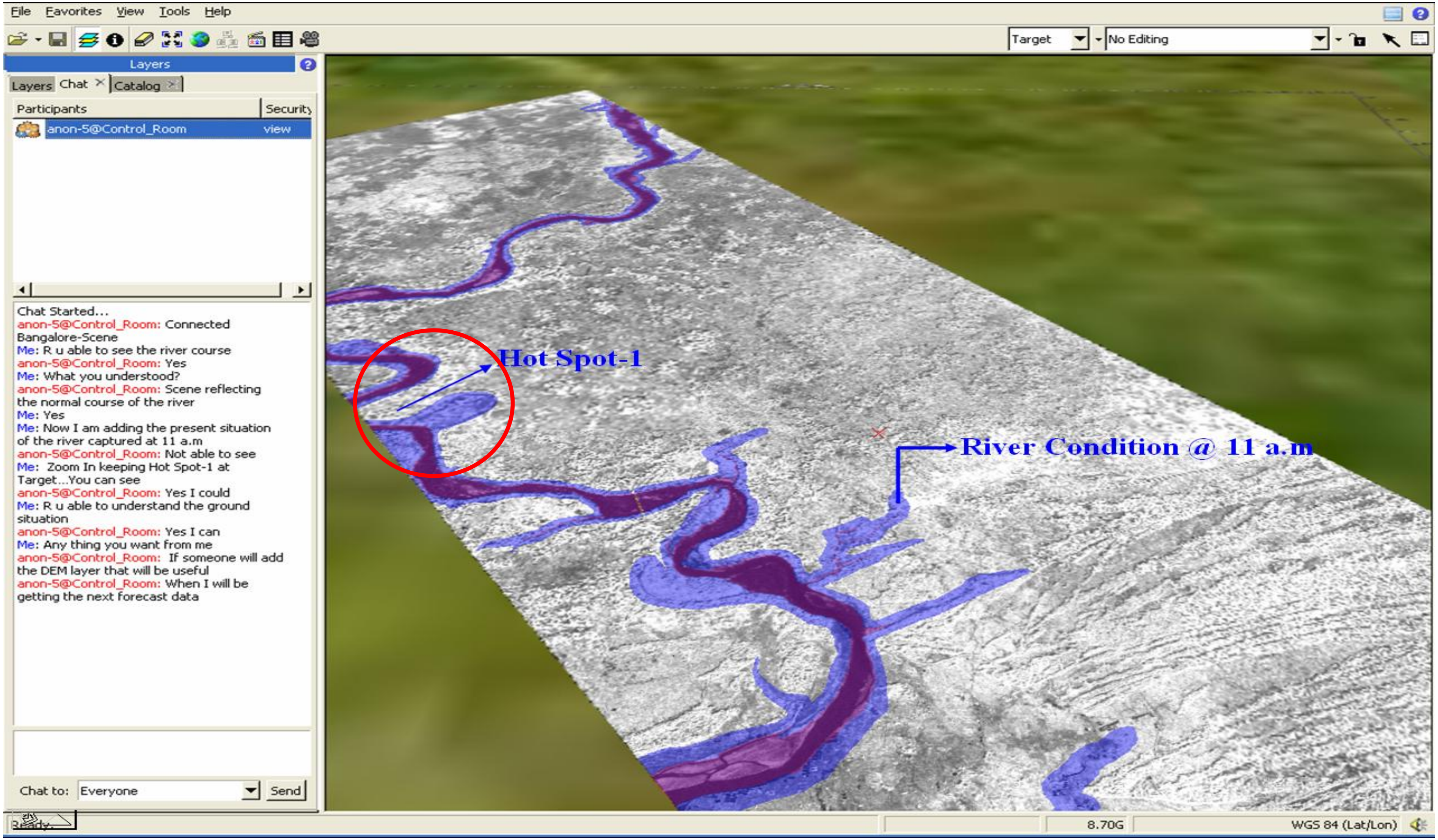
Integration of Step-3 & Step-4 Results



Superimposing the Administrative units and Elevated regions of input image



Information dissemination during a real time scenario - WMS Setup



Few more details About method of approach

- To support the maximum possible automation process the clustering parameters is hardcoded throughout the model execution.

- Due to sequential implementation of image clustering and focusing the next level operation at each stage the frequency of pixels has been gradually reduced as well as the backscattering range of object of interest has been narrowed down.

- All these increases the accuracy of the classification.

Validation..?

- **Field database information collected from ISRO-Bhuvan is used**

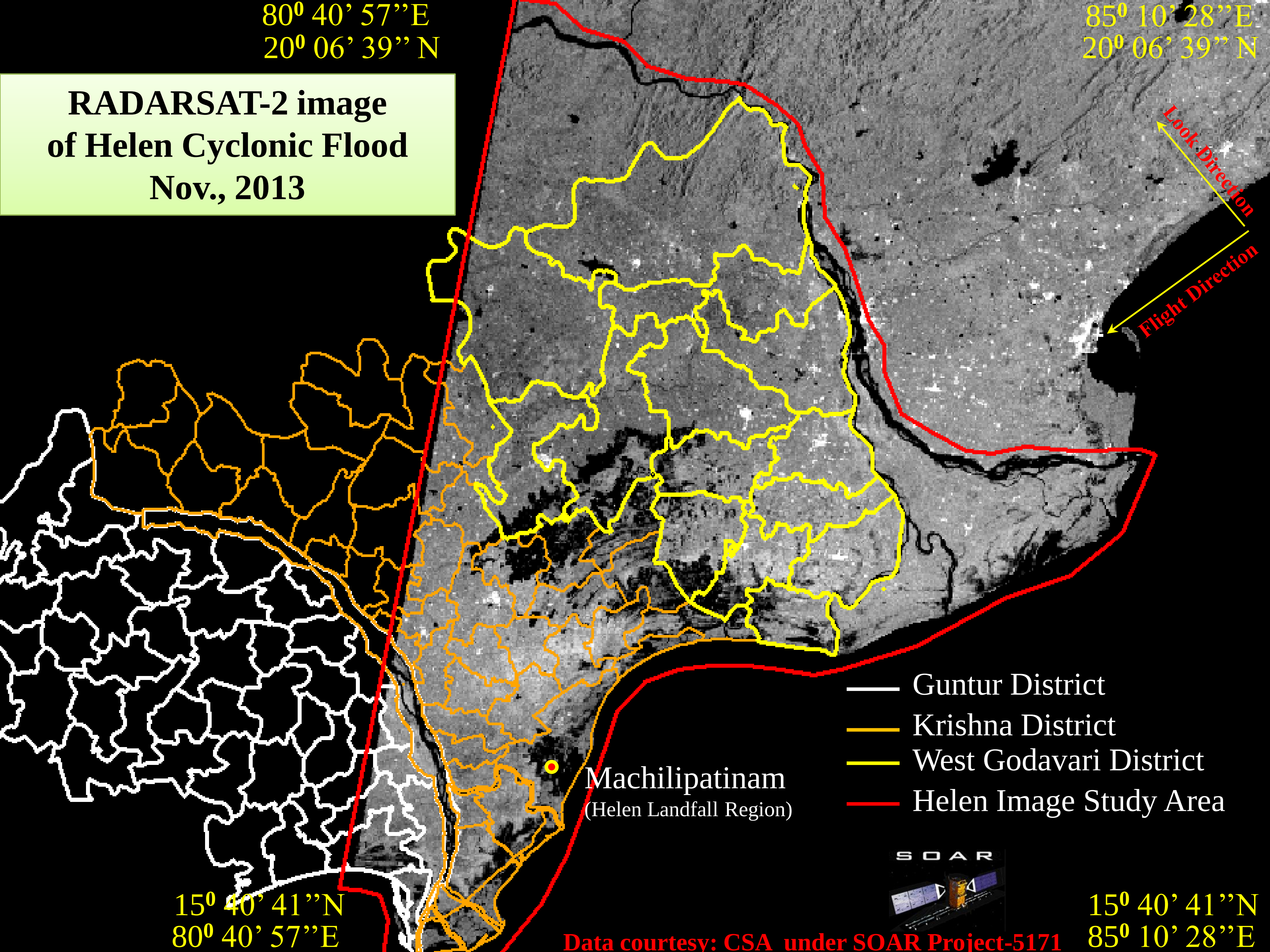
Courtesy: DMS Cell of NRSC, Hyderabad, and Bhuvan Portal, ISRO

bhuvan
Gateway to Indian Earth Observation

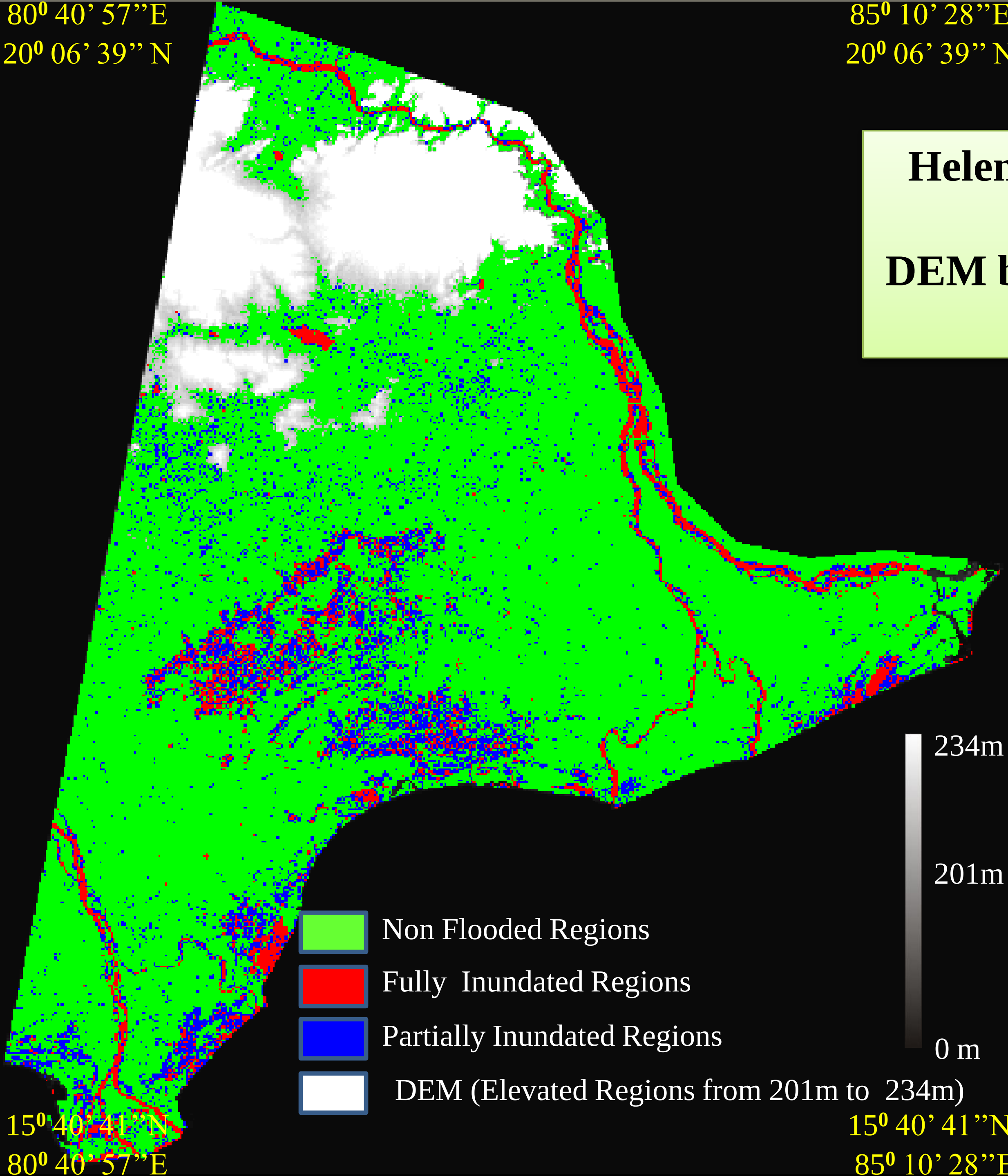
National Remote Sensing Centre

LAT	LONG	NRSC Field Record	DEM-SAR-FA-Classification	DATE	DISTRICT	MANDAL	CROP	CROPSTAGE	STATUS
15.953800	80.504100	Partially Inundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Crop Partially submerged and damaged
16.000220	80.437200	Fully Inundated	Uninundated	31/10/2013	Guntur	Kakumanu	Rice	Maturity Level	Fully damaged
15.817100	80.387300	Partially Inundated	do	31/10/2013	Prakasam	Vetapalem	Rice	Transplanting 15-20 days	Crop Partially submerged and damaged
15.774800	80.174900	Uninundated	do	31/10/2013	Prakasam	Inkollu	Cotton	Ball formation	Good Crop Cover but flowering damaged due to cyclor
15.982900	80.454200	Fully Inundated	Partially Inundated	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Fully damaged
15.985400	80.508000	Uninundated	do	31/10/2013	Guntur	Bapatla	Rice	LateTransplantion	Good Crop Cover still Water in the field
15.958500	80.438900	Uninundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Good Crop Cover still Water in the field
15.994000	80.487200	Partially Inundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Panicle Damage
15.776800	80.175100	Uninundated	do	31/10/2013	Prakasam	Inkollu	Cotton	Ball formation	Crop damaged severly
15.874900	80.330700	Fully Inundated	do	31/10/2013	Prakasam	Karamchedu	Rice	Transplanting 15-20 days	Crop Fully submerged and damaged
15.934500	80.492800	Partially Inundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Crop Partially submerged and damaged
15.931600	80.449800	Fully Inundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Crop Fully submerged and damaged
15.926900	80.471000	Fully Inundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Crop Fully submerged and damaged
15.873700	80.297200	Fully Inundated	Partially Inundated	31/10/2013	Prakasam	Karamchedu	Rice	Maturity Level	Fully damaged
15.850000	80.348200	Fully Inundated	do	31/10/2013	Prakasam	Chirala	Rice	Maturity Level	Crop Fully submerged and damaged
15.938800	80.444300	Fully Inundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Crop Fully and Partiallysubmerged and damaged
15.922200	80.473000	Fully Inundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Crop Fully submerged and damaged
15.940300	80.443900	Fully Inundated	do	31/10/2013	Guntur	Bapatla	Rice	Maturity Level	Crop Fully and Partiallysubmerged and damaged
15.844300	80.353300	Fully Inundated	do	31/10/2013	Prakasam	Chirala	Rice	Maturity Level	Crop Fully submerged and damaged
15.867500	80.336000	Partially Inundated	Fully Inundated	31/10/2013	Prakasam	Karamchedu	Rice	Transplanting 15-20 days	Crop Fully and Partiallysubmerged and damaged

Study of
Helen Cyclonic Flood of November-2013


80⁰ 40' 57"E
20⁰ 06' 39" N
85⁰ 10' 28"E
20⁰ 06' 39" N
RADARSAT-2 image
of Helen Cyclonic Flood
Nov., 2013
Look Direction
Flight Direction
Guntur District
Krishna District
West Godavari District
Helen Image Study Area
Machilipatinam
(Helen Landfall Region)
SOAR
15⁰ 40' 41"N
80⁰ 40' 57"E
15⁰ 40' 41"N
85⁰ 10' 28"E
Data courtesy: CSA under SOAR Project-5171

Helen Flood Area Mapping using the proposed DEM based SAR Image Flood Area Mapping Techniques



Field Photographs

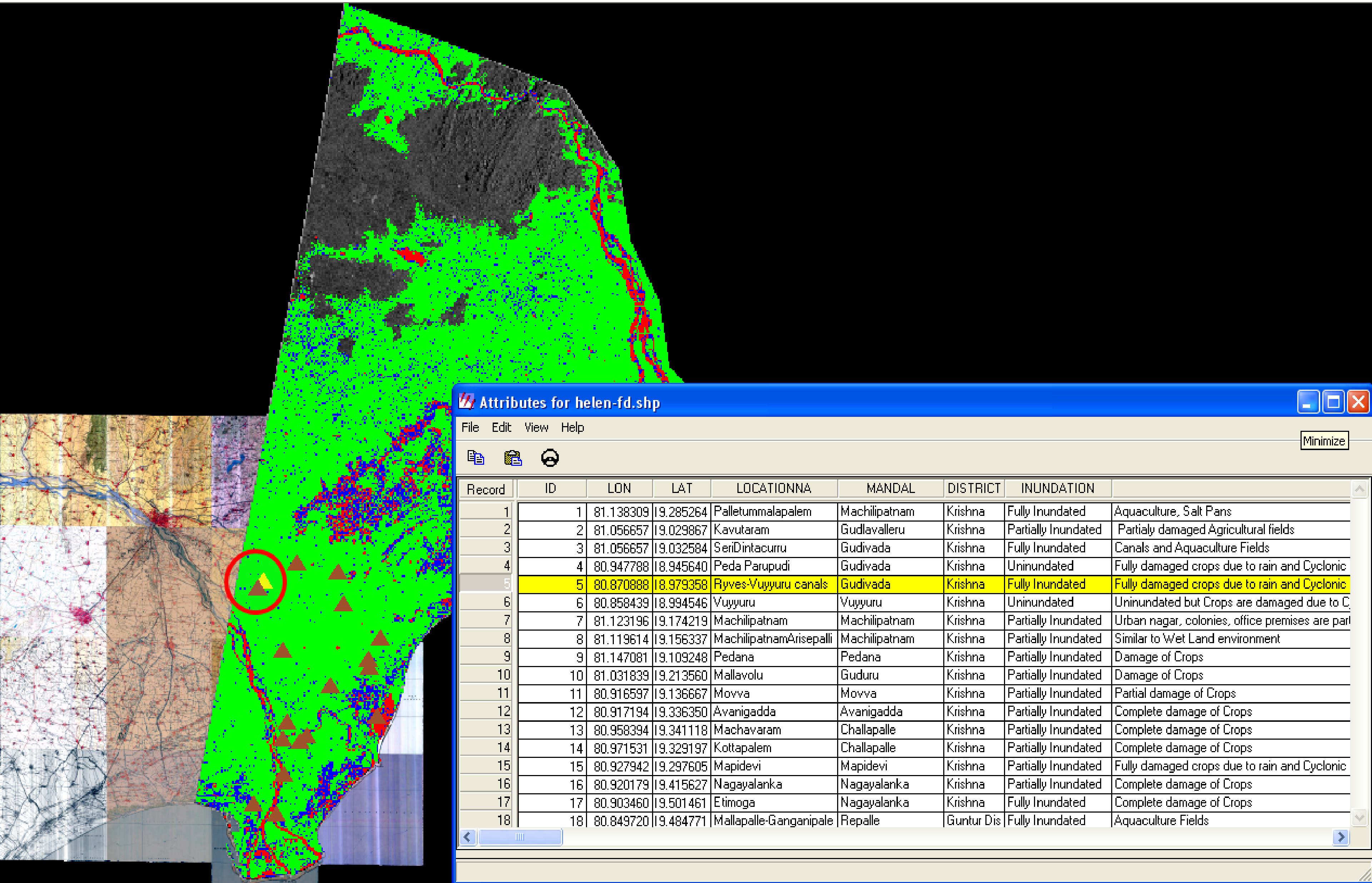


Cyclone : Helen
Landfall : 22 NOV 2013, 6pm Machilipatnam, AP, India
Moderate Rainfall : From 17 to 21, NOV. 2013
Intense Rainfall and Flood : From 22 to 23 NOV. 2013
Field Trip to Machilipatnam : From 24- 27 NOV, 2013
Date of SAR Acquisition : 24 NOV 2013, RADARSAT-2 , HH Pol.. Data
Order Placed on : 22 NOV, 2013 (RADARSAT – SOAR)



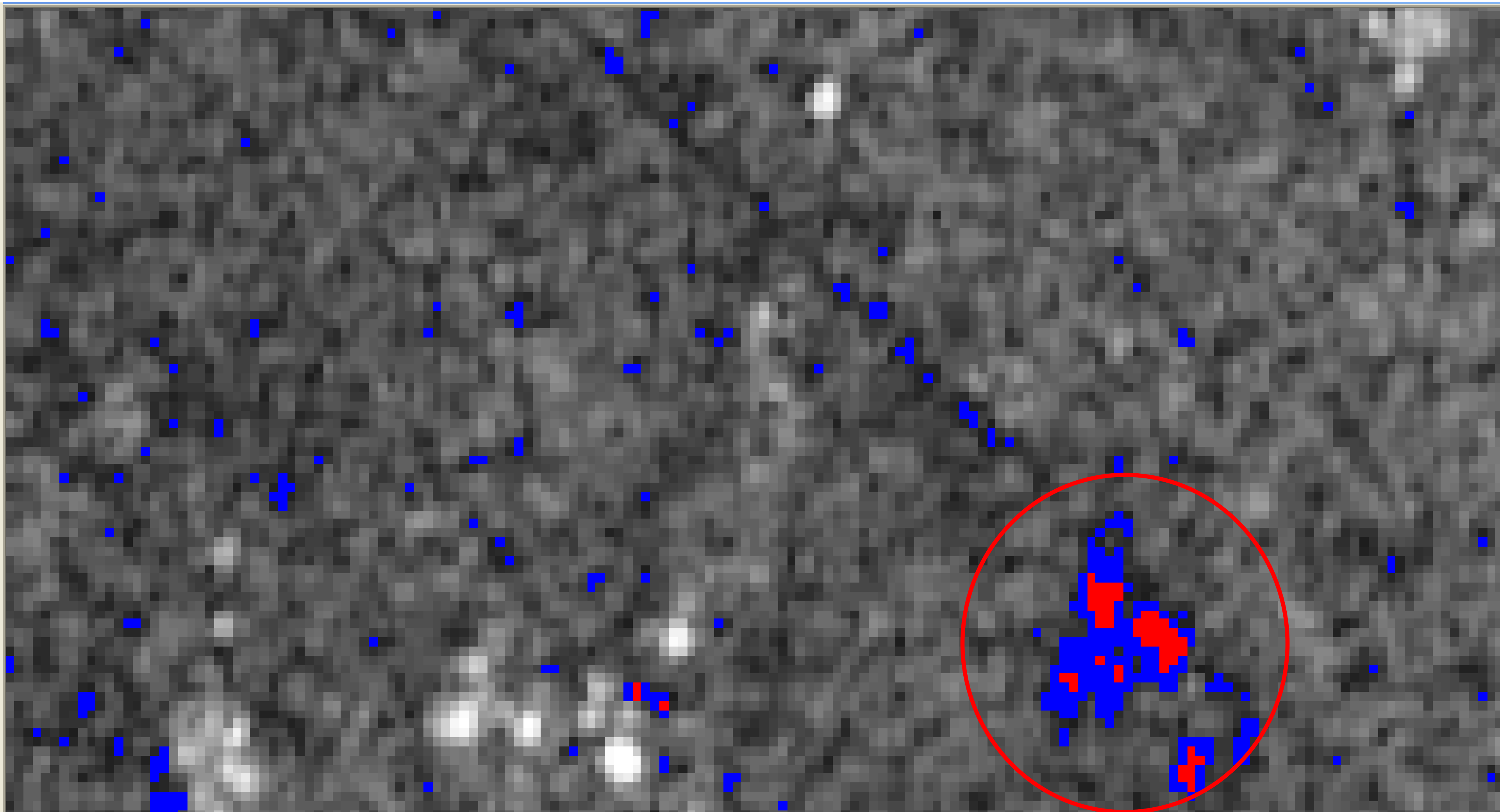


Analyzing the integrated results
(Integration of processed result and Field database)

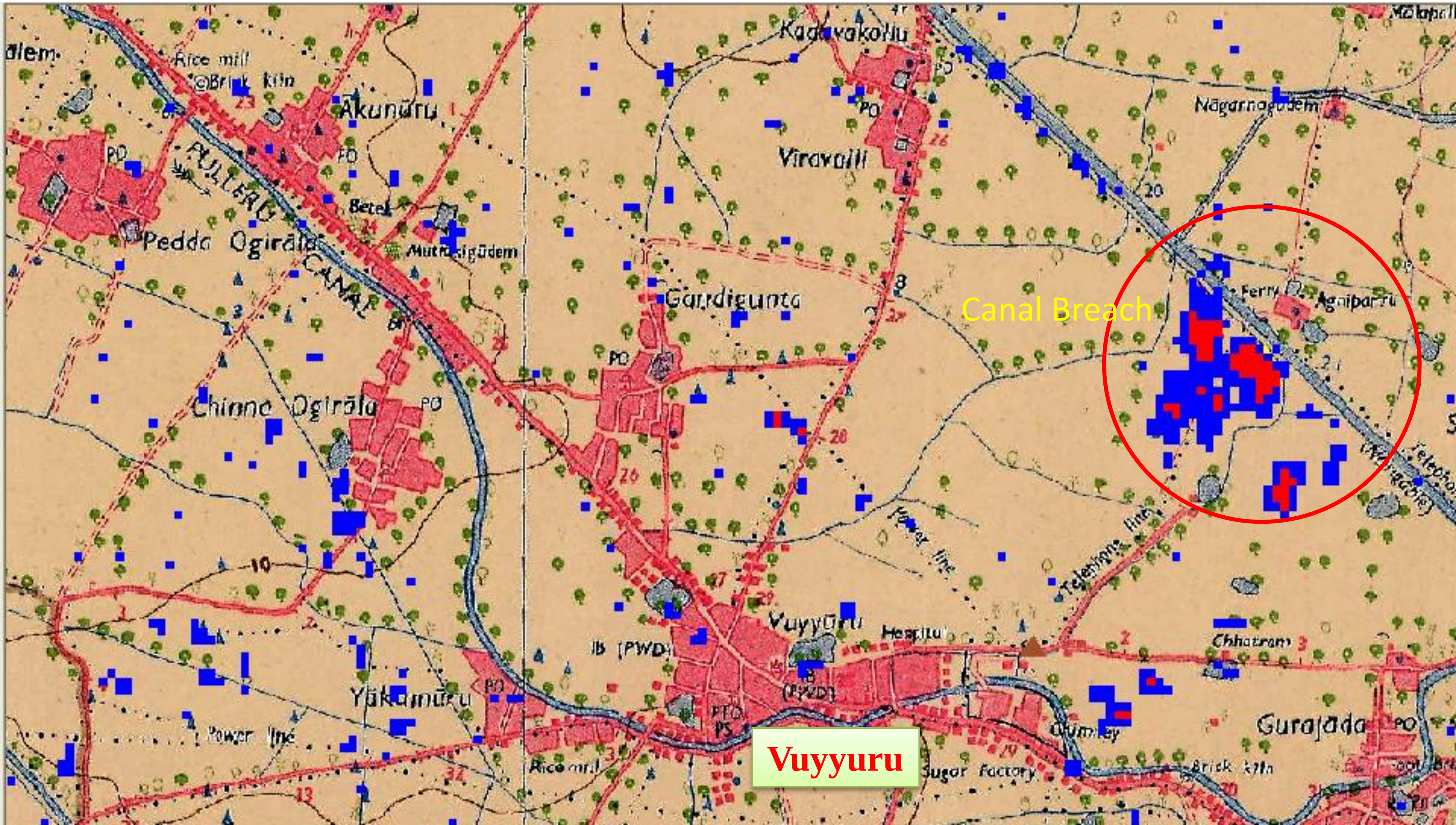


Record	ID	LON	LAT	LOCATIONNA	MANDAL	DISTRICT	INUNDATION	
1	1	81.138309	19.285264	Palletummalapalem	Machilipatnam	Krishna	Fully Inundated	Aquaculture, Salt Pans
2	2	81.056657	19.029867	Kavutaram	Gudlavalleru	Krishna	Partially Inundated	Partialy damaged Agricultural fields
3	3	81.056657	19.032584	SeriDintacurru	Gudivada	Krishna	Fully Inundated	Canals and Aquaculture Fields
4	4	80.947788	18.945640	Peda Parupudi	Gudivada	Krishna	Uninundated	Fully damaged crops due to rain and Cyclonic
5	5	80.870888	18.979358	Ryves-Vuyyuru canals	Gudivada	Krishna	Fully Inundated	Fully damaged crops due to rain and Cyclonic
6	6	80.858439	18.994546	Vuyyuru	Vuyyuru	Krishna	Uninundated	Uninundated but Crops are damaged due to C
7	7	81.123196	19.174219	Machilipatnam	Machilipatnam	Krishna	Partially Inundated	Urban nagar, colonies, office premises are parl
8	8	81.119614	19.156337	MachilipatnamArisepalli	Machilipatnam	Krishna	Partially Inundated	Similar to Wet Land environment
9	9	81.147081	19.109248	Pedana	Pedana	Krishna	Partially Inundated	Damage of Crops
10	10	81.031839	19.213560	Mallavolu	Guduru	Krishna	Partially Inundated	Damage of Crops
11	11	80.916597	19.136667	Movva	Movva	Krishna	Partially Inundated	Partial damage of Crops
12	12	80.917194	19.336350	Avanigadda	Avanigadda	Krishna	Partially Inundated	Complete damage of Crops
13	13	80.958394	19.341118	Machavaram	Challapalle	Krishna	Partially Inundated	Complete damage of Crops
14	14	80.971531	19.329197	Kottapalem	Challapalle	Krishna	Partially Inundated	Complete damage of Crops
15	15	80.927942	19.297605	Mapidevi	Mapidevi	Krishna	Partially Inundated	Fully damaged crops due to rain and Cyclonic
16	16	80.920179	19.415627	Nagayalanka	Nagayalanka	Krishna	Partially Inundated	Complete damage of Crops
17	17	80.903460	19.501461	Etimoga	Nagayalanka	Krishna	Fully Inundated	Complete damage of Crops
18	18	80.849720	19.484771	Mallapalle-Ganganipale	Repalle	Guntur Dis	Fully Inundated	Aquaculture Fields

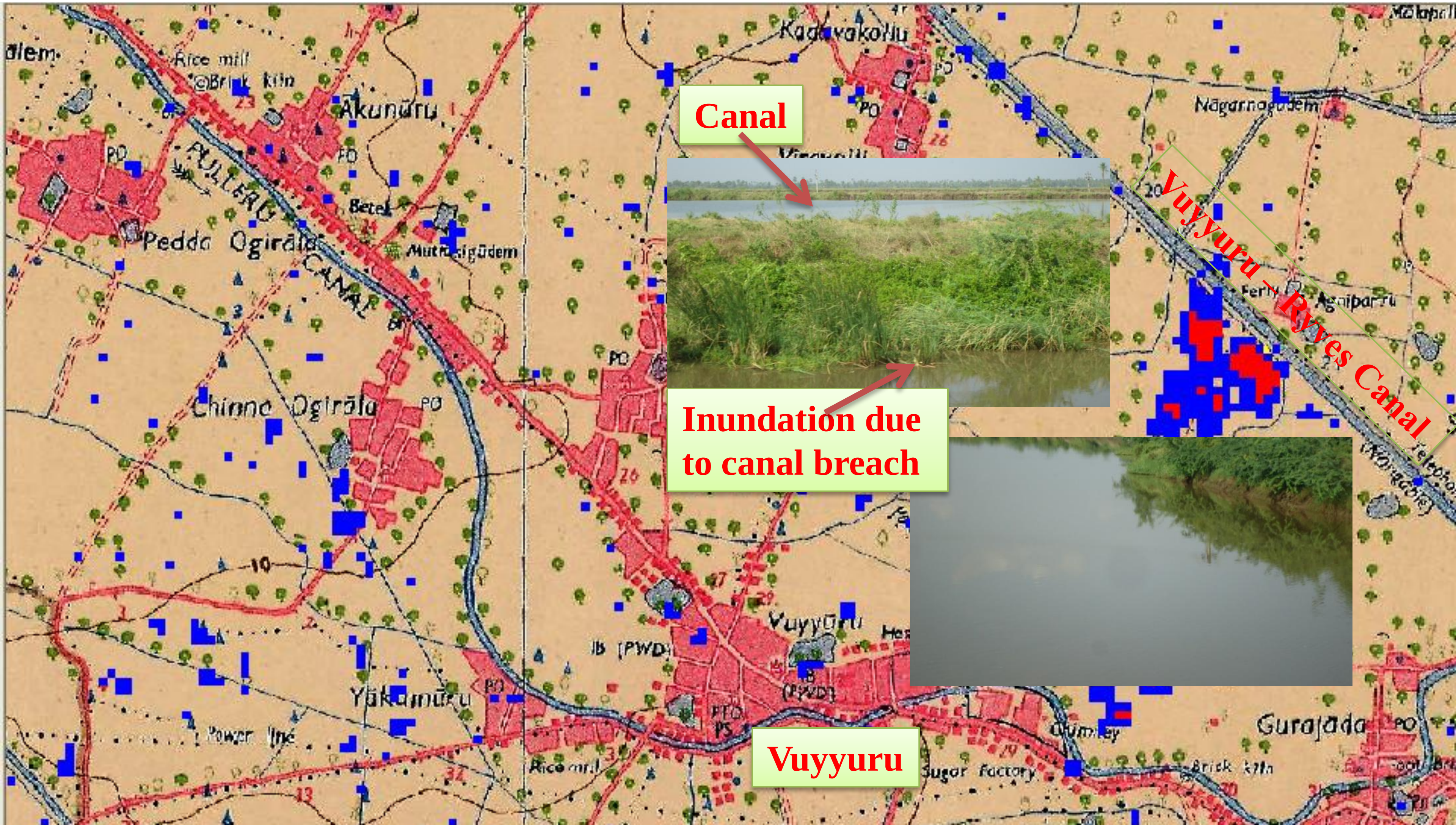
Helen: Processed result and Field database study at …location



Results ….on Topo map..it near to Vuyyuru



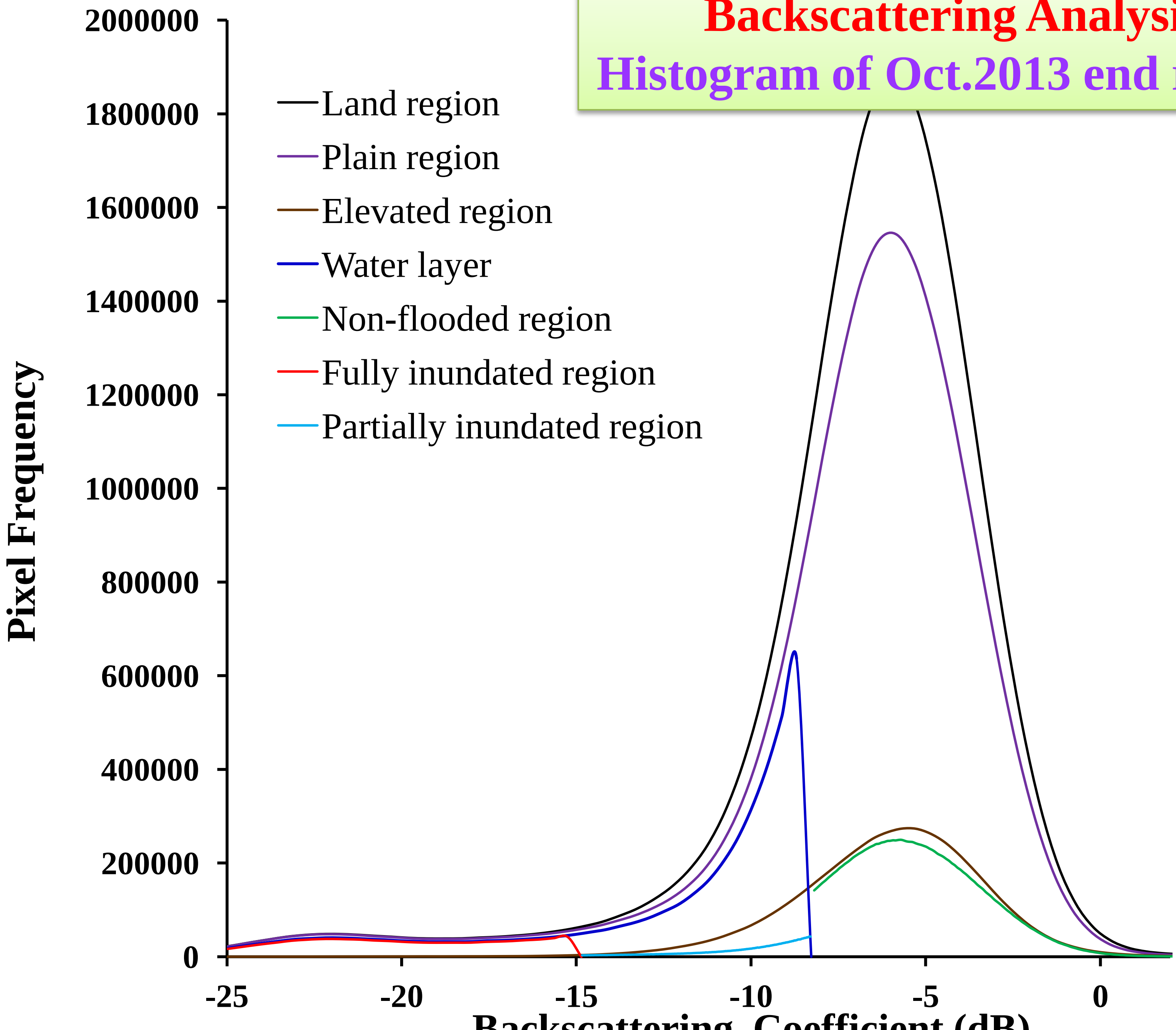
Cross Validating with Field Photographs



Backscattering Analysis

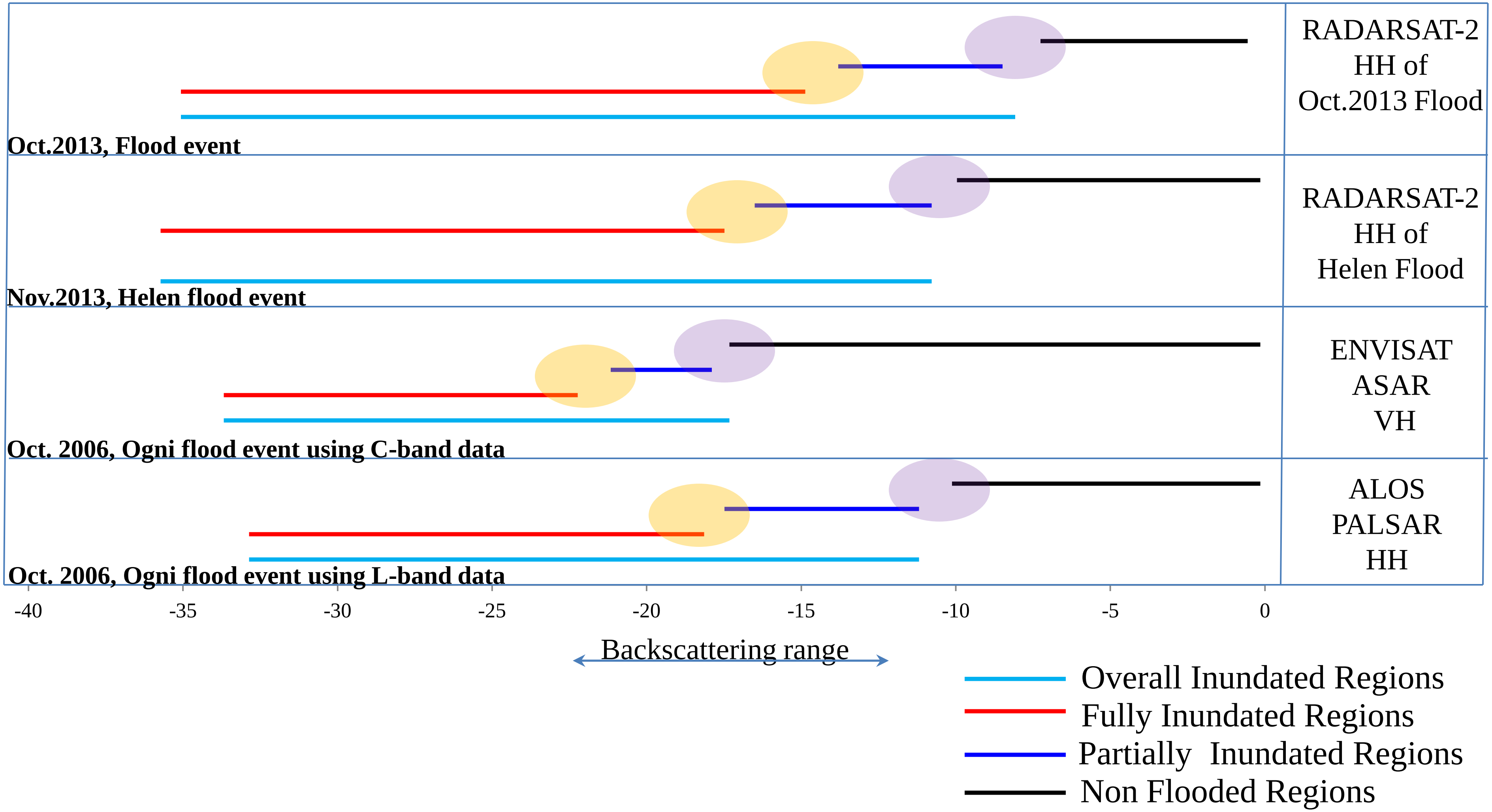
Flood due to →	Oct.2013 Flood due to rain	Nov, 2013 Helen Cyclonic Food
Input SAR data	C- band, RADARSAT-2, HH	
Overall Water Inundated Regions	-8 to -35	-11 to -35
Fully Inundated Regions	-15 to -35	-17 to -35
Partially Inundated Regions	-8 to -14	-11 to -16
Non Flooded Regions	-7 to -1	-10 to -1

Backscattering Analysis
Histogram of Oct.2013 end results



C- band, HH, RADARSAT-2 image of 28 OCT, 2013

Backscattering Range of Case Studies



Conclusions

- The 'SAR image based Flood Area Mapping technique' has been demonstrated with the help of RADARSAT-2 data of Oct.2013 and Nov.2013 flood event of Andhra Pradesh state, India.

- The proposed technique can differentiate and map the fully inundated, partially inundated and non-flooded pixels of SAR image without the use of any multi-layer GIS techniques.

- The derived results has been validated with the help of Field database (NRSC-Bhuvan for Oct.2013 and Real time field DB for Nov.2013)

- Able to define the backscattering range of end results without overlapping with other classes than any other existing methods.

- The suggested techniques will make available the end results within shortest possible time without much manual intervention.

Fully Inundated Regions

Partially Inundated Regions

Conclusions

- The ‘SAR image based Flood Area Mapping technique’ has been demonstrated with the help of RADARSAT-2 data of Oct.2013 and Nov.2013 flood event of Andhra Pradesh state, India.

- The proposed technique can differentiate and map the fully inundated, partially inundated and non-flooded pixels of SAR image without the use of any multi-layer GIS techniques.

- The derived results has been validated with the help of Field database (NRSC-Bhuvan for Oct.2013 and Real time field DB for Nov.2013)

- Able to define the backscattering range of end results without overlapping with other classes than any other existing methods.

- The suggested techniques will make available the end results within shortest possible time without much manual intervention.

Significance

- Partially inundated and fully inundated regions of known and unknown disaster region can be identified with least manual intervention.

- Logically eliminating elevated hilly regions and shadow pixels

- Enhances the accuracy …due to adopting sequence of image extraction and subsequent processing approach

- With all the above, supporting the disaster mitigation operations through shortest possible mapping process.

Acknowledgement

Thank You

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