SPACEBORNE REMOTE SENSING TECHNIQUES FOR DISASTER MONITORING APPLICATIONS WITH EMPHASIS ON MICROWAVE SENSORS

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Themes of this workshop

In this Workshop, the suggested themes are:

1. Forest Fires
2. Earthquakes
3. **Floods**, Landslides
4. **Tsunami, Dangerous sea conditions**
5. Pollution, and Dust Storms

This paper addresses the capability of only Microwave Sensors and restricts to 3 and 4
REMOTE SENSING MISSION REQUIREMENTS

Requirements of the RS missions are constrained by several factors and a few are highlighted below.

THEY NEED TO BE TRIED IN SMALLSATS

• Availability of suitable Sensors – New sensors are expected to be tried for proof-of-concept on small satellite platform. No known pressure sensor for atmospheric pressure (GPS-ROS has shown some potentiality)
• No known sensor for sub-water sensing! Inferred only through surface features (Bathymetry)
• Need to go for Missions with required Optimal Sensor Combinations Examples: Sharing common hardware for Radiometer and Radar. Judicious choice of frequency is to be made due to FREQUENCY REGULATIONS (Example: SKYLAB’s RADSCAT, ESA’s AMI)
• Temporal and Spatial Repetititivity: Ocean-atmospheric-related disasters are expected to be in 30-40 degree latitudes – Therefore Inclined orbits are desired

TRMM was at 35 degrees, Megha-Tropiques at 20 degrees which gave up to 6 repetitive observations over the tropics.
Highlights of earlier Missions/Sensors

In context with Disaster Monitoring Applications, the following have significantly established capabilities

1. **Microwave Radiometers**
   From SEASAT in 1975 to TRMM and Megha-Tropiques in 2011
   *Cyclone tracking, wind speed and rainfall estimates*

2. **Scatterometers**
   From SEASAT to Quick-scat and Oceansat 2
   *Ocean surface wind velocity (Cyclones)*

3. **Altimeters:** Topex-Poseidon, Jasaon-1, -2, -3, SARAL)
   *Ocean surface level with an accuracy of a few cm - Tsunamis*

4. **Synthetic-Aperture Radars:**
   *A large number of land and ocean applications (inclu. Earthquakes)*
## Constellation launched / proposed

**Mission:** Disaster Monitoring Constellation (DMC) by SSTL (launched 34 satellites)

<table>
<thead>
<tr>
<th></th>
<th>Mass</th>
<th>Altitude</th>
<th>Major P/L; Specs</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alsat-1</td>
<td>686 km</td>
<td>Multi-spectral imager</td>
<td></td>
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<td>2</td>
<td>UKDMC</td>
<td></td>
<td>12 kg, 650 km swath;</td>
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<tr>
<td>3</td>
<td>Nigeriasat-1</td>
<td></td>
<td>1 GByte data 600 x 500 km</td>
<td></td>
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<tr>
<td>4</td>
<td>Beijing-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Nigeriasat-2</td>
<td></td>
<td>Multi-spectral, PAN</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>SSTL 100 v 3.0</td>
<td>100 kg</td>
<td>SWIR 1550-1750 nm Blue 450-515 nm Green 525-605 nm Red 630-690 nm NIR 774-900 nm</td>
<td>10 - 15 m VSNIR 20 - 30 m SWIR</td>
</tr>
<tr>
<td>8</td>
<td>NovaSAR-S (Planned 2014)</td>
<td>400 kg</td>
<td>Synthetic Aperture Radar 15 to 750 km; 6-30 m Resln.</td>
<td>Floods / disasters</td>
</tr>
</tbody>
</table>
1. Cyclonic events detected by microwave radiometers
Microwave Radiometers on Indian satellites

1979, 81: Satellite Microwave Radiometer (SAMIR) showed the possibility of cyclone detection in spite of operational limitations.

The Region of Bay of Bengal was covered in a few days but the gross cyclonic wind effects on ocean surface roughness could be observed.
19 GHz Microwave Brightness Temperature distribution over the Bay of Bengal 25-29 July 1979
Megha-Tropiques
Payloads, Spacecraft, Launcher, Ground segment &
Science

Azimuth and Elevation Plot (29 Occultation events in 2 hours)

- Navigation
- Navigation Search
- Rising Space Weather
- Rising Occultation
- Setting Space Weather
- Setting Occultation

MTS, INREAP, MT, UOC-UCB, Observations, Temperature in 2014-12-25
Tracking the Thane Cyclone using MADRAS 18.7 GHz Channel
Challenges in Realising the Megha-Tropiques Mission

Presented at NSSS-2012, SV University, Tirupati

14-17 February 2012

CANEUS SSTDM 2014
Tracking another Indian Ocean Cyclone using MADRAS 18.7 GHz Channel

MADRAS 27 Dec 2011

MADRAS 30 Dec 2011

Kalpana Composite 30 Dec 2011

Kalpana WV 30 Dec 2011
SAPHIR Derived Humidity over Thane Cyclone (Dec 28, 2011 all passes)
Humidity maps show cyclonic structure with high humidity in the central portion of the storm for all the six layers (PK Pal Indo-French Workshop Dec 2012)
TRMM Microwave Imager (TMI) 85 GHz brightness temperature pattern just before the landfall of the Orissa super-cyclone. The eye of the cyclone can be more accurately located in this channel and can therefore improve the accuracy of forecast of the track of tropical cyclones. (MADRAS has the 89 GHz channel)
2. Ice-snow extent detected by microwave radiometers
OCEANSAT-1 (1999) RADIOMETERS OBSERVE THE SEASONAL CHANGES OF ANTARCTIC ICE COVER

FIG. 1. Weekly Average 18GHz (V) Brightness Temperature Images over Antarctic Region from MSMR for Four Different Seasons
3. Tsunami conditions – manifested by Sea-surface height detectable by ALTIMETERS
**Principle of an altimeter**: Time taken for a two-way transit of electromagnetic waves (pulse) is measured to get height $H$. 
Detection of Tsunamis by altimeters

- Tsunamis are waves triggered by the vertical deformation of the ocean bottom, caused by submarine earthquakes or landslides.
- They lead to waves crossing the oceans at high speed (around 800 km/h), and a potentially enormous quantity of water flooding the coasts when these waves come to shore.
- Theoretically, sea level anomalies observed by altimetry should reflect these waves.
- However, observation is difficult, since the additional height is one of the signals of ocean variability.
- Studying the differences between the few altimetric observations and the tsunami propagation models should enable the scientific community to enhance their understanding of such phenomenon and to fine-tune the models.
- Only a multidisciplinary, multi-technique study can grasp all the forces at work here (geophysical, hydrodynamic, energetic etc.).
Jason Altimeter data
Sea-level rise due to long-term effects using altimeter
Inverse barometer not applied

Rate = 3.4 ± 0.4 mm/yr
4. Ice-snow depth measured by unfocused airborne synthetic-aperture radar at 150 MHz
RADAR FOR ICE THICKNESS MEASUREMENTS

- RADAR MEASURES RANGE (DISTANCE)
- A SHORT ELECTROMAGNETIC WAVE – PULSE SENT FROM A RADAR (TRANSMITTER) HITS THE TARGET AND RETURNS TO THE RADAR (RECEIVER) AFTER TRAVERSING TWO TIMES THE DISTANCE (D)
- THE TIME DELAY (T) GIVES THE TWO-WAY DISTANCE (2D)
- HENCE THE ACTUAL DISTANCE IS
  \[ D = \frac{cT}{2} \]
- WHERE c IS THE VELOCITY OF LIGHT (EM WAVES)
HISTORICAL BACKGROUND

An airborne radar used as an “altimeter” in Greenland (Waite, 1959) showed a larger altitude than the actual clear altitude and hence crashed by touching the ice surface (over-estimated altitude).
THUS AN APPLICATION WAS FOUND - RADAR FOR ICE THICKNESS MEASUREMENTS

- ELECTROMAGNETIC WAVES CAN PASS THROUGH ICE, SNOW, SMOKE, CLOUDS, DUST, ETC. HENCE A RADAR WORKS IN VARIOUS ATMOSPHERIC CONDITIONS

- IT ALSO WORKS IN DAY AS WELL AS NIGHT

- IN AN ICE MEDIUM THERE WILL BE TWO RADAR RETURN (ECHO) PULSES
  - ONE REFLECTED FROM THE TOP SURFACE (ICE)
  - THE SECOND ONE FROM THE BOTTOM SURFACE (ROCKY, SOIL)

- THE DIFFERENCE IN TIME DELAY WILL GIVE THE THICKNESS, D

- WAVE PROPAGATES SLOWER BY 1/SQRT OF THE DIELECTRIC CONSTANT (ABOUT 3.1 FOR SNOW/ICE)

- THE ACTUAL THICKNESS IS D/(SQRT(3.1))
RADAR ON HUT PULLED BY A "TUCKER" ON A FAST-MOVING GLACIER – "DOWNSTREAM-B" IN ANTARCTICA
Depth in Ice, > 1.2 km

Vertical profile in ice
Gangotri Glacier retreated 26.5 meters per year from 1968-2006.
Shows Glacier Region
Earthquakes

Envisat WSM/IM InSAR image of Bam, Iran. Interferogram shows ground motion associated with the 26 December 2003 earthquake

http://www.esa.int/spaceinimages/Images/2004/07/Envisat_WSM_IM_InSAR_image_of_Bam
Possible satellite configuration/s

1. Spacecraft with a single sensor
2. Composite sensors sharing common hardware
3. Satellites in constellation
## PROPOSED SPACEBORNE INSTRUMENTS

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<tr>
<th>Instrument</th>
<th>Specifications, nominal</th>
<th>Applications</th>
</tr>
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<tbody>
<tr>
<td>Radiometer</td>
<td>8, 36 GHz 0.5 -1 K Sensitivity 1000 km swath</td>
<td>Cyclone-tracking, wind-speed</td>
</tr>
<tr>
<td>Radiometer</td>
<td>90 GHz 0.5 -1 K Sensitivity 1000 km swath</td>
<td>Ice-melt monitoring, floods</td>
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<tr>
<td>Altimeter</td>
<td>13 GHz A few km Foot Print, 5 cm Accuracy</td>
<td>Sea level, Tsunami</td>
</tr>
<tr>
<td>Unfocused SAR</td>
<td>UHF /L-Band Better than 2 m</td>
<td>Ice/glacier depth, floods</td>
</tr>
<tr>
<td>GPS Sounder</td>
<td>L1, L2; L5? 2 K accuracy</td>
<td>Atmos. temp and humidity</td>
</tr>
</tbody>
</table>

**Notes:**
1. The above are in order of technical ease and cost.
2. Airborne versions are strongly suggested before spaceborne version.
3. Combination of the sensors will be based on a specific mission and sharing of common hardware.
Preliminary Functional Block Diagram

Fig:1 - 90 GHz Radiometer Preliminary Block Diagram
Un-focused Synthetic-aperture Radar
Radiometer – Altimeter combination

Notes:
1. Frequency of Alt is as per allocation (Ku or Ka)
2. Radiometer may be designed at the same frequency / or multiplied
3. Common antenna, common Local Oscillator save power and space
4. Selective or simultaneous (inter-pulse) operation (less interference)
PROPOSED CONSTELLATION

• MICROWAVE RADIOMETERS 18 & 36, AND 90 GHZ
• SYNTHETIC-APERTURE RADAR AND ALTIMETER
• CONSTELLATION OF THREE - FOUR SATELLITES
• INCLINED ORBIT OF 30 – 40 DEGREES FOR HIGH TEMPORAL MEASUREMENTS
• COVERAGE OF THE DYNAMIC OCEAN AND ATMOSPHERIC ACTIVITIES OF THE GLOBE
• MULTIPLE AND / OR STAND-ALONE SENSORS BASED ON SEASONAL ACTIVITIES (POWER CONSTRAINTS).
• RADAR AT LOWER ALTITUDE (400 KM) OTHERS AT 600 KM
THANKS