Acquiring Comprehensive Observations using an integrated Sensor Web for Early Warning

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• Science and Natural Disasters
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What Drives Our Planet?

EARTH'S ENERGY BUDGET

Radiated to space from clouds and atmosphere: 64%
Radiated directly to space from earth: 6%
Absorbed by atmosphere 15%
Absorbed by clouds 3%
Conduction and rising air 7%
Carried to clouds and atmosphere by latent heat in water vapor 23%
Absorbed by land and oceans 51%

Incoming solar energy 100%

Reflective by atmosphere 6%
Reflective by clouds 20%
Reflective from earth's surface 4%

Greenhouse Gases
Other Anthropogenic Forcings
Natural Forcings

1.4 ± 0.2
0.7 ± 0.2
0.6 ± 0.2

CO₂
CH₄
(indirect via O₃ and H₂O)
CFCs
 indirect via stratospheric ozone

0.35 ± 0.05
0.15 ± 0.05

N₂O

Sulfate + Nitrate
0.8 ± 0.4

Black Carbon

0.7 ± 0.2

Organic Carbon
Biomass Burning
Soil Dust
Forced Cloud Changes
Land Cover Alteration

0.2 ± 0.1
0.2 ± 0.2
-0.1 ± 0.2
-0.2 ± 0.2

-0.2 ± 0.2

-1.1 ± 0.5

Volcanic Aerosols
(range of Decadal mean)

0.4 ± 0.2

Sun
(0.2 - 0.5)

indirect via O₃

(indirect via O₃ and H₂O)

Sun

(indirect via O₃)

(indirect via stratospheric ozone)

(nitrate)

(tropical)

semi-direct,
dirty cloud
& snow effects)

Tropospheric Aerosols

Re: J. Hansen/NASA GISS

S. Habib/EWC III-rev1.ppt (3/27/06)
Sun and Earth Science

Biosphere changes
- Land cover Land use
- Coastal zone erosions
- Carbon cycle

Atmospheric chemistry
- Pollutants
- Transport phenomena
- Aerosols

Climate system
- Transient climate
  - El Nino
  - Soil Moisture
  - Sea surface winds
- Long term – Radiation balance

Weather Phenomena
- Precipitation
- Cloud cover
- Sea surface winds
- Tropospheric winds
- Hurricanes

Contribute to Natural or Anthropogenic Disaster Phenomena

Heliosphere
- Magnetic Field
- Atmosphere
- Plasma
- Radiation
- Solar Winds
- Energetic Particle

Oceans
- Productivity and ocean color
- Carbon sequestering
- Salinity
- Sea Surface Temperature
- Global water cycle

Solid Earth
- Magnetic field
- Gravity
- Surface topography
- Surface transformation

S. Habib/EWC III-rev1.ppt (3/27/06)
Natural Disasters

Direct

• Earthquakes
• Volcanoes
• Tsunamis
• Hurricanes or Typhoons
• Landslides
• Floods
• Tornadoes
• Severe Weather
• Drought
• Fires
• Dust Storms
• High Winds

Indirect

• Public Health
• Air Quality
• Invasive Species

Consequential
Natural Disasters can Feed Other Disasters

Earthquake/Tsunami -> Occurrence of Floods

Volcanic Eruption

Severe Weather

Fires

Contaminated Fresh Water Supply

Aerosol and Dust deposition and suspension

Spread of Multiple Infectious Diseases

Aerosol and Dust deposition and suspension -> Breathing problems

Electric Grid Outages

Shutdown City

Air Quality

Public Health

Anthropogenic or Technological
Preparedness to Prediction to Prevention

Governmental Operational Agencies, NGOs & Social Scientists

Observations, Data Ingestion and Integration

Models, Learning Tools and Intelligent Processing

Assist Decision Making Process

Impact Mitigated

Yes

Generated Timely Alert

Situation understood and control measures in place

No

Disasterous Situation

Deploy Observing Systems

Models, Learning Tools and Intelligent Processing

Assist Decision Making Process

Science

Pro-active Approach

Governmental Operational Agencies & NGOs

Science

Reactive Approach
Remote Sensing Technologies
Passive (UV, Visible, IR, Microwave)
Active (Radar, SAR, Lidar)

High temporal resolution
High spatial resolution
High spectral resolution

In situ
Airborne
Space based

Sensor Webs
Constellations
Formations
Clusters
Virtual Platforms
Virtual Apertures

DSS

S. Habib/EWC III-rev1.ppt (3/27/06)
Why Multiple Sensors and Vantage Points

**Satellites**  
100 - 10,000 km

**Airplanes**  
1 - 100 km  
Study Areas

**Towers**  
~ 1 km  
Flux Tower Sites

**In situ platforms**  
1 - 100 m  
Process Study Plots  
Validation Sites
Mekong Malaria in Tak, Thailand

2-Year Prediction of Malaria Cases Based on Environmental Parameters (temperature, precipitation, humidity, vegetation index)

Temperature--satellite
Rainfall--satellite
Pf Parasite—field observations

Satellite Vegetation Data used for Insecticide Planning

- Surface Hydrology
- Climate Prediction
- Vector Habitat
- Transmission
- Risk Prediction

Field data

Satellite Data

Models

Tak

Pf cases
Temperature (deg C) x 100
Rainfall (mm) x 5 + 1000

Aqua
Landsat
Terra

TRMM

Mekong Malaria in Tak, Thailand
Near-Earth Space Weather Effects

- Solar Wind
- Magnetosphere
- Ionosphere
- Electromagnetic Radiation
- Energetic Charged Particles

SOHO, ACE and EPRI Ground Sensors
Thermal Anomaly prior to Earthquake Occurrence

- normally appear 4-20 days before an earthquake;
- affects area of several thousands or tens of thousand square km;
- displays a positive or negative deviation of > 2-4°C;
- disappears a few days after the event;
- variable shape – temporal and spatial dynamics

2-5 year average

sigma level

anomaly

observed data

Time or distance

NASA GSFC, Dec 21, 2005, D.Ouzounov
Multi-Sensor Detection

GOES, MODIS, METEOSAT, GMS, NOAA

9 - 12 μm IR

DEMETER

TEC Changes

Ionosphere

Atmospheric Electrical Field

EQ Lights

High E-field Gradients

Increased Air Conductivity

VLF, HF, UHF

SLHF

Radon

Heating

High E-field Gradients

ULF, ELF Magnetometers

Seismic Focus

GPS

F0F2

GPS Rcvr

Ionosonde

Re. D. Ouzounov / NASA GSFC
Asian Dust & microbes? Long Range Transport

“2001 Perfect Dust Storm”

Sea of Japan
4/9/2001

Dust layer

Lidar Profiling

Dust Particles

Dust Front

Dun-Huang, China
4/6/2001

Dust layer

NASA/GSFC
4/14/2001

Dust layer

TOMS Aerosol Index - time series

Source Regions

Dust Front

50 µm

4/4
4/6
4/7
4/10
4/13
4/16
Floods – a serious threat

SNOTEL Ground Data (NOAA)

Field Measurements (BOR)

Hydrologic Model

Water Resources Applications

Regulating Reservoirs

Land Models

SMOS

Hydros

Aqua Terra

SWE Estimates

Floods

SWE (inches)

0 - 3
0 - 6
6 - 9
9 - 12
12 - 14
14 - 18
18 - 21
21 - 24
24 - 27
27 - 30

NASA
Drought in Mozambique

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<td>NDVI, Fire prod, H₂O Vapor</td>
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<td>Predicted Precipitation, Winds, pressure, relative humidity</td>
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<td>SST anomalies and ENSO forecast</td>
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Re: June 9-15, 2005, Famine Early Warning System Network (FEWSNET)
Dedicated Zonal Observers

Data production facility

Local wireless networks

Transportation Industry

Individual users

Ultra Long Duration Balloons (ULDBs)
40,000m for > 6 months

Other Pilots
Notional Integrated Observing System

Vantage Points
- Far-Space
- Near-Space
- Airborne
- Terrestrial

Capabilities
- LEO/MEO: Active & passive sensors for trends & process studies
- Suborbital: In situ measurement in research campaigns & validation of new remote sensors
- Surface-Based Networks: Ocean buoys, air samplers, strain detectors, ground validation sites
- Information Systems: Data management, data assimilation, modeling & synthesis

Sensor Nodes
Computing Nodes
Communication Fabric
Information Storage Nodes
Data Assimilation & Forecast Models
Data Warehouses & Data Mining
Summary

• Observing systems should be science driven --- closely coupled with natural disasters
• No single entity can take on this responsibility --- pooling of resources is critical
• Must capitalize on using existing sensors to solve critical societal problems
• Both observing platforms/sensors and models are integral to forming a sensor web
• Complex phenomena e.g., earthquakes, floods, drought and more can benefit from additional observations and assimilation techniques to further our understanding