Integration of Grid and Sensor Web for Flood Monitoring and Risk Assessment from Heterogeneous Data

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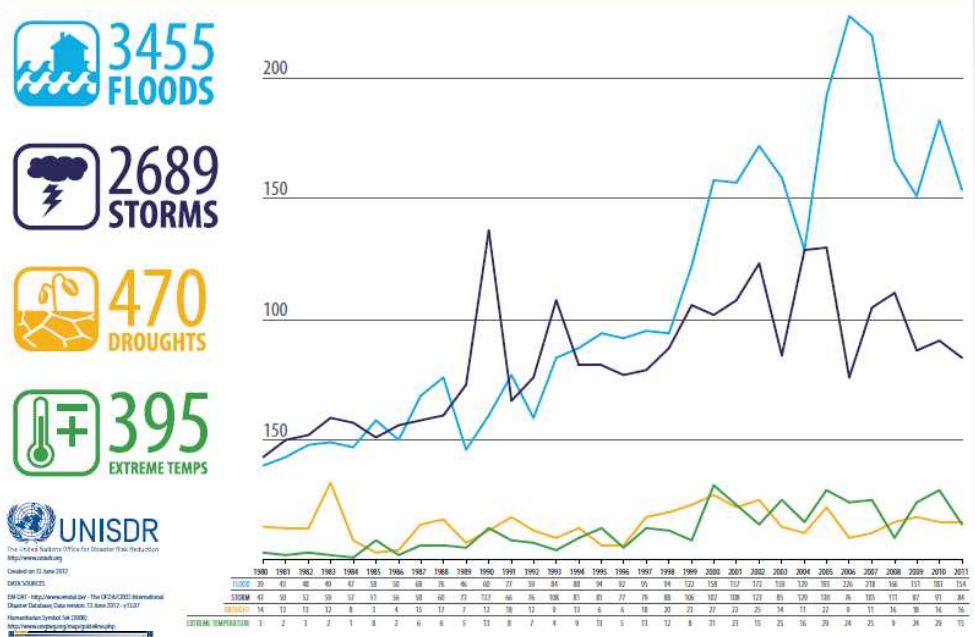
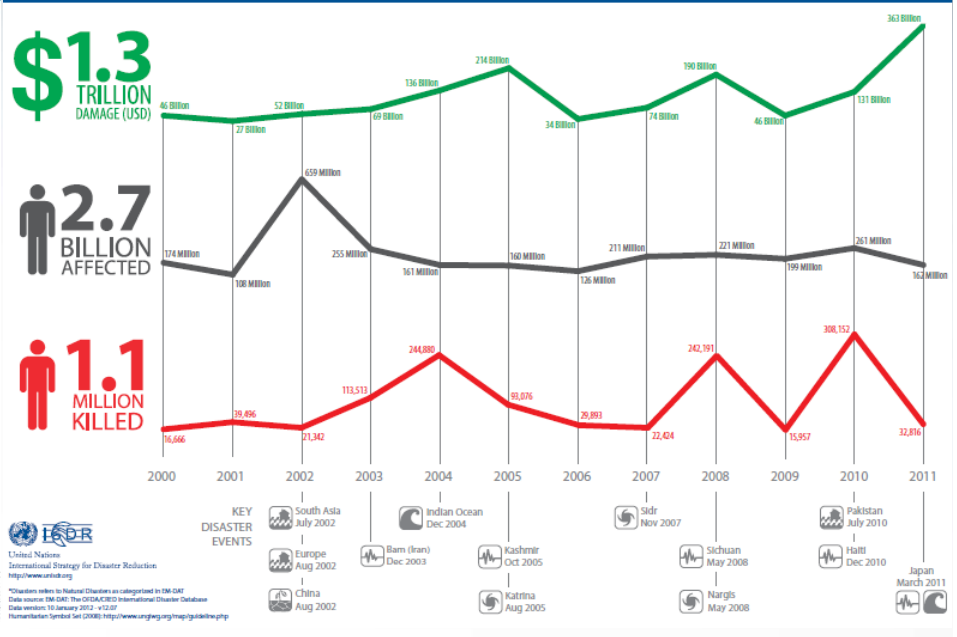
Natural Disasters





http://www.unisdr.org/we/inform/disaster-statistics

- Risk-oriented approach
  - *protection against disasters to managing the risks of disasters*
  - Ex.: European Flood Risk Directive (FRD)

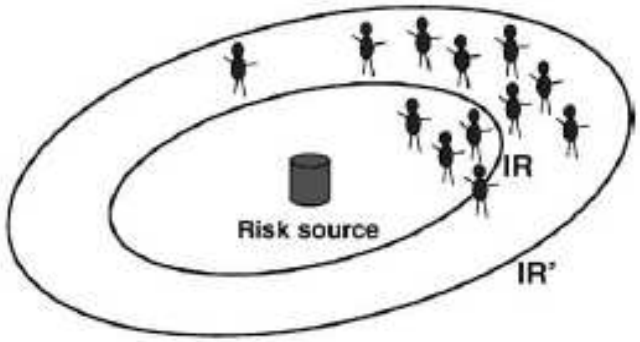
Disaster Risk Assessment

- *Risk*
  - *combination of the probability of a disaster and of the potential adverse consequences for human health, the environment, economic activity, …*

Risk = F (hazard, vulnerability)

- *Integrated risk in area A*

$$R_A(x,y) = \int\int_A r(x,y)dxdy$$

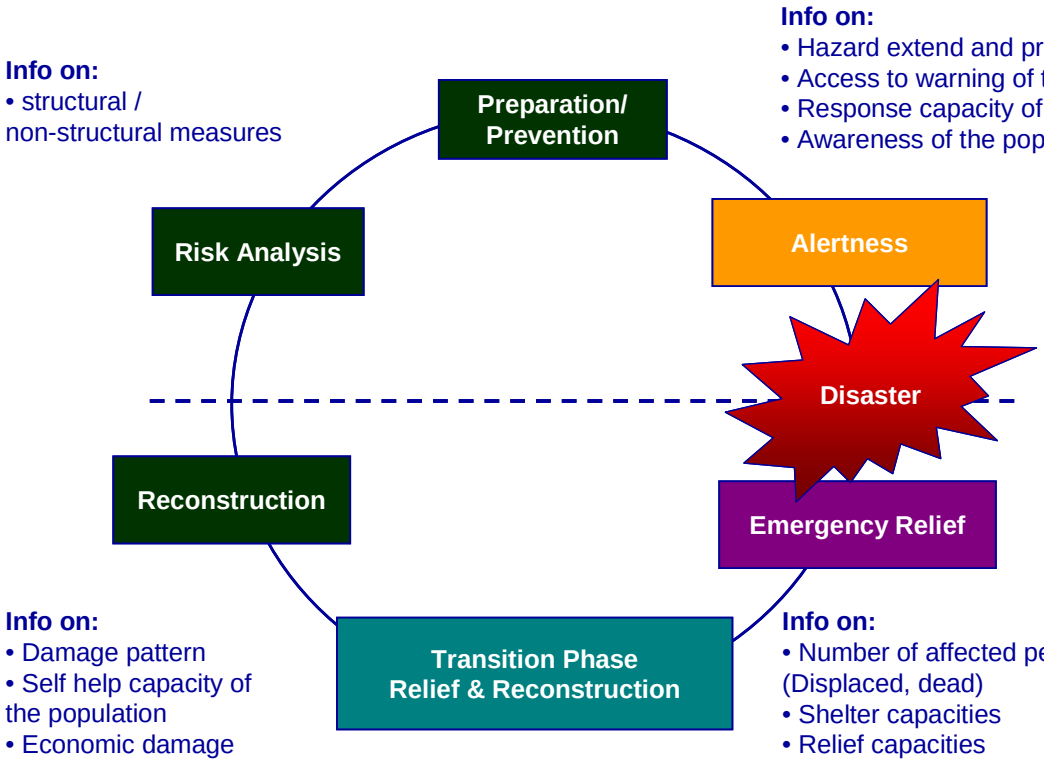


where r(x,y) is individual risk at point (x,y)

$$r(x,y) = \int_0^\infty h_{xy}(z)\, p_{xy}(z)\, dz$$

Earth Observation (EO) for Disaster Risk Assessment

- To support the full **Disaster Management Cycle**

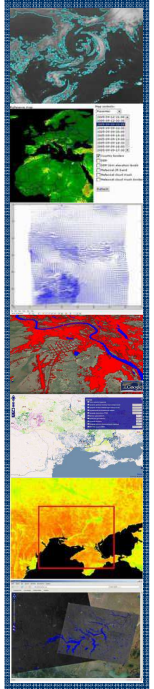


Sandy, USA, 29.10.2012

Floods, Ukraine, 27.07.2008

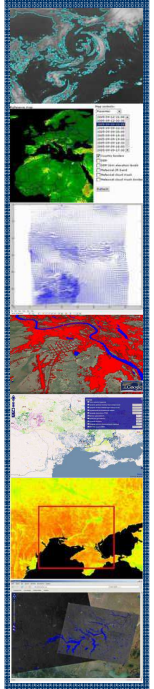
- Advantages for mapping:
  - Hazard/probability
  - Vulnerability

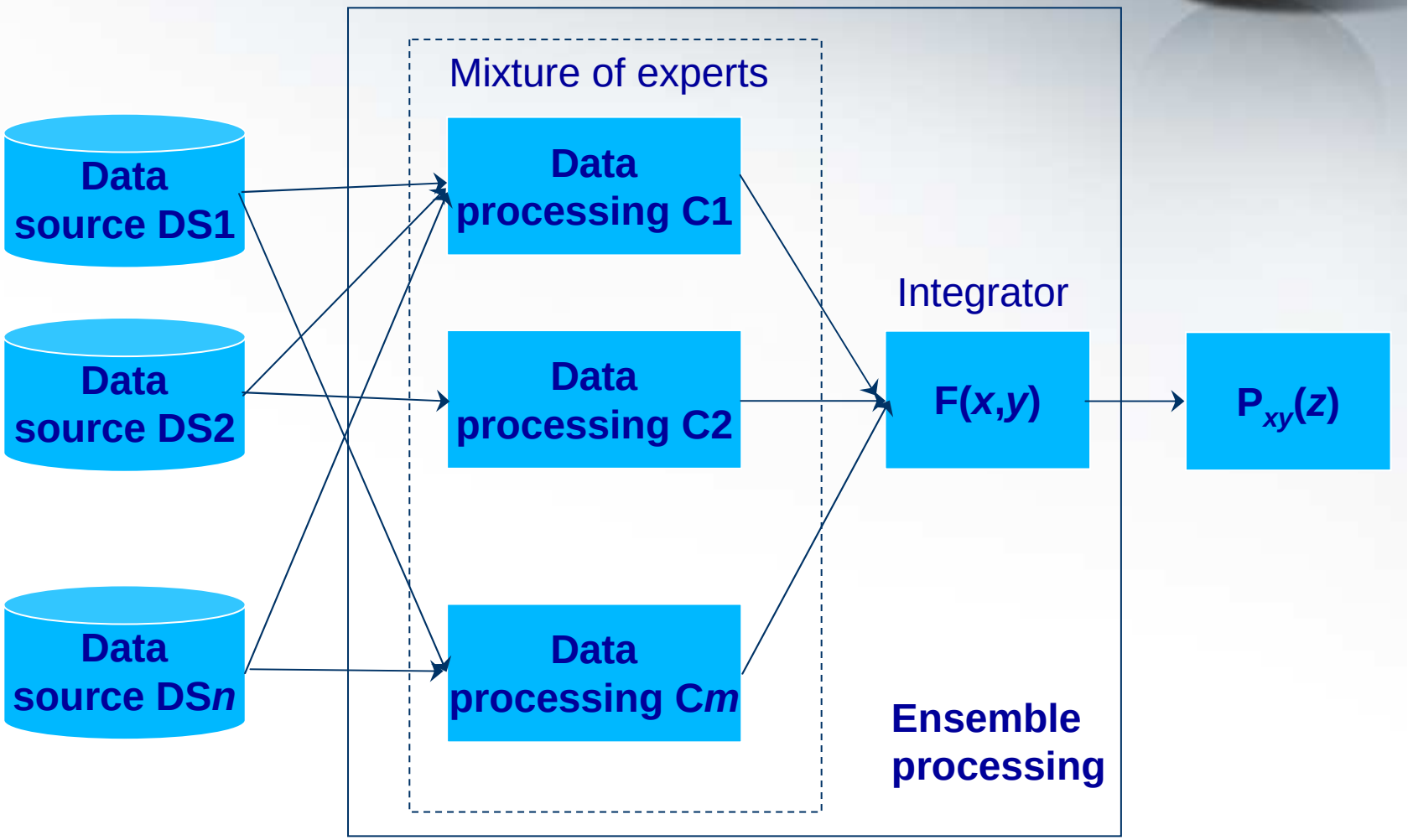
EO for Disaster Risk Assessment



- **Natural disasters**
  - Floods
  - Droughts
  - Fires
  - Storms
  - Earthquakes, volcanoes
  - Landslides
- **Hazard mapping**
  - Disaster mapping
  - EO data time-series processing
    - E.g. using extreme-value-theory (EVT), frequency analysis
  - Data assimilation
- **Vulnerability**
  - Land cover (crop) mapping, assets mapping, …
- **Operational disaster risk assessment**
  - Integration of heterogeneous data, sensors, models, …
  - Service-oriented approach

Deriving Disaster Probability Density Function

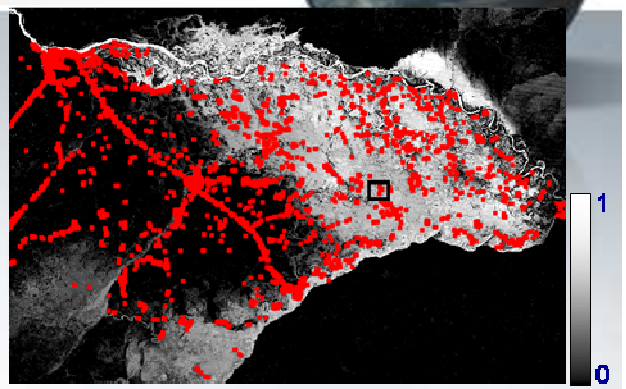




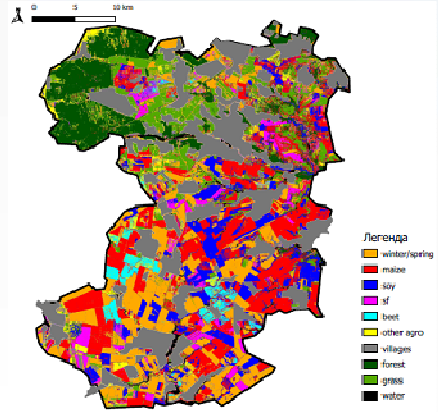
$P_{xy}(z)$ is probability density function

Case studies

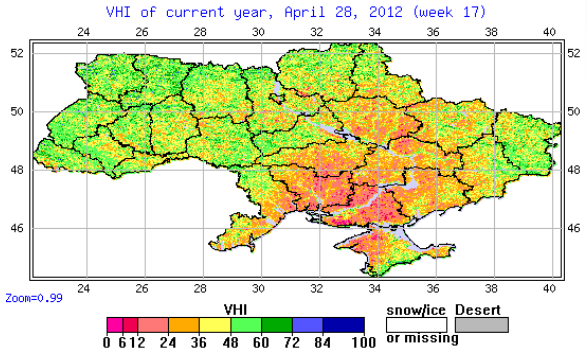
- Case study 1:
  - Flood hazard mapping from EO data time-series
    - Frequency analysis based on flood extent maps derived from 102 Lndsat-5/7 scenes
- Case study 2:
  - Agriculture monitoring
    - Integration of optical and SAR images for crop mapping
- Case study 3:
  - Drought hazard mapping from EO data time-series
    - Application of the extreme value theory (EVT) to EO data



Probability of inundation overlaid on dwelling density

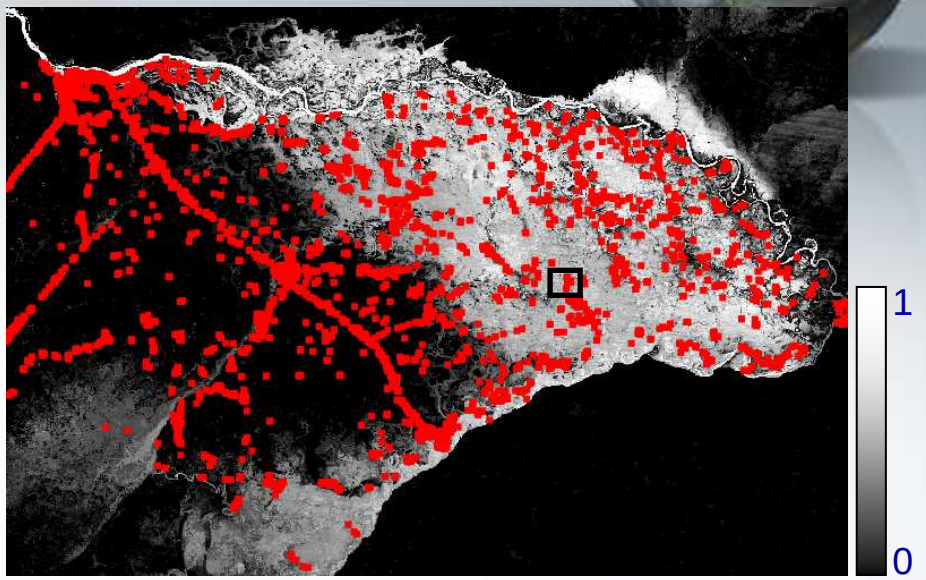


Crop classification using a combination of EO-1

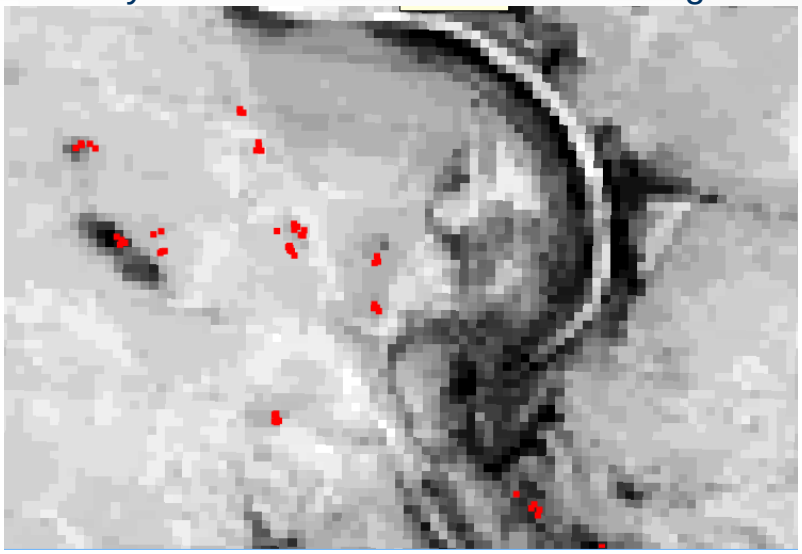


Case study 1: Flood hazard mapping from EO data time-series

- Within Namibian SensorWeb Pilot
- Region: Katima Mulilo, Namibia
- Data
  - Satellite
    - Landsat-5/TM and Landsat-7/ETM+
      - 102 scenes
      - Time period
        - » 1989-2012
    - TRMM
      - Time period
        - » 1999-2010
  - Ground
    - Water level and water flow
    - Time period
      - 1943-1954
        1965-2010

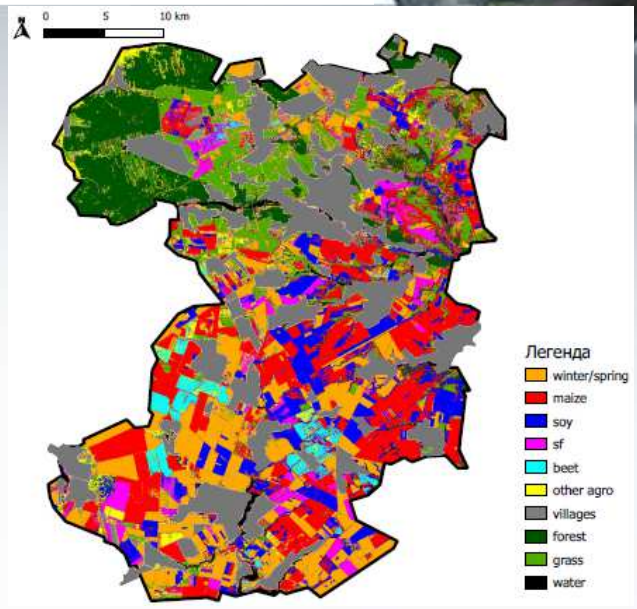


Probability of inundation overlaid on dwelling density

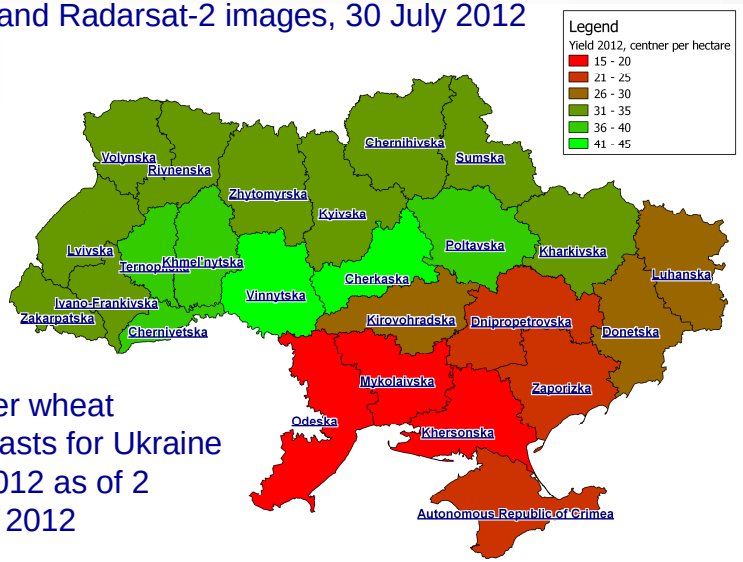


Case study 2: Agriculture monitoring

- Within GEO GLAM and JECAM
  - Established JECAM test sites in Ukraine
  - SOAR-JECAM
    - “SAR parameters optimization for crop classification”
  - Tasks
    - Crop mapping and area estimation
      - SAR and optical satellite images assisted by ground surveys
    - Crop yield forecasting
      - Based on MODIS data and statistics



Crop classification using a combination of EO-1 and Radarsat-2 images, 30 July 2012

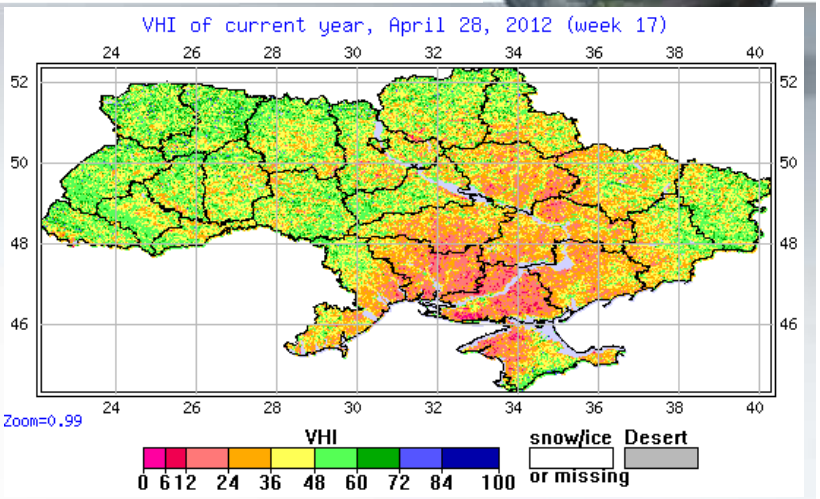


Winter wheat forecasts for Ukraine for 2012 as of 2 June 2012

Case study 3: Drought hazard mapping from EO data time-series

- Application of the extreme value theory (EVT) to EO data
  - Vegetation Health Index (NOAA)
  - Period: 1981-2012
  - Spatial resolution 16 km or 256 km^2
    - Density of weather stations in Ukraine: ~3353 km^2

Drought level	VHI
Abnormally dry condition	35-40
Moderate	26-35
Severe	16-25
Extreme	6-15
Exceptional	0-5



Poisson process and Generalized Pareto distribution (Poisson-GP)

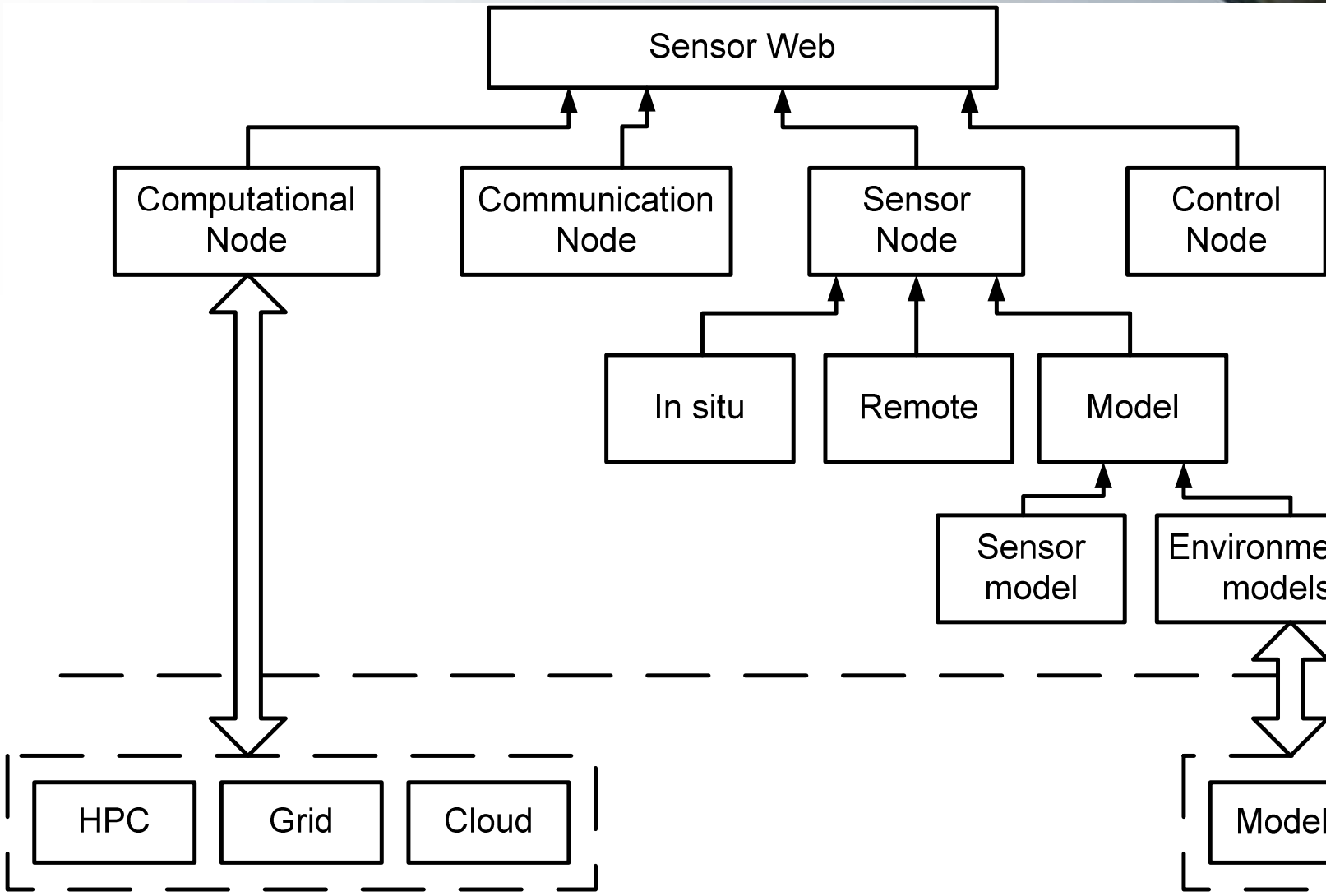
$$P(Y < y \mid \alpha, k) = 1 - \left(1 - k\frac{y}{\alpha}\right)^{1/k}, y = x - x_0$$

Parameters estimation – probability weighted moments (PWM)

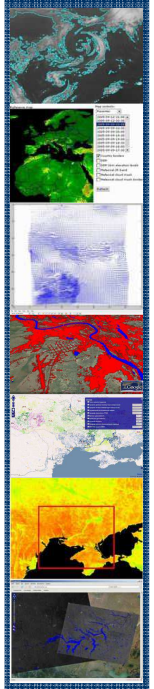
$$\hat{k} = \left(\frac{b_0}{2b_1 - b_0}\right) - 2, \hat{\alpha} = (1+k)b_0$$

$$b_r = \frac{1}{n}\sum_{i=1}^{n}\frac{(i-1)(i-2)\ldots(i-r)}{(n-1)(n-2)\ldots(n-r)}y_{(i)}$$

Sensor Web Architecture

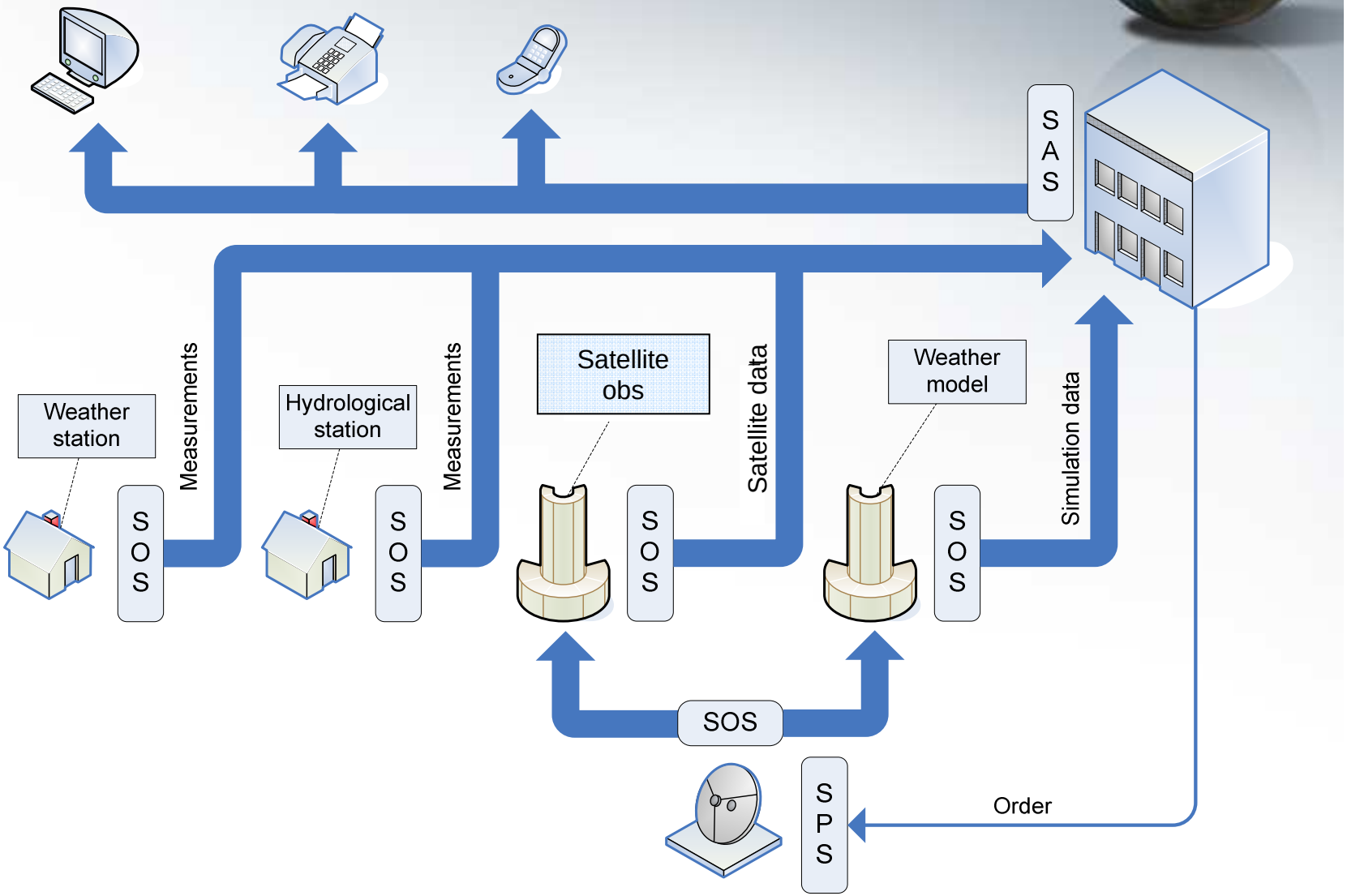


Grid & Sensor Web Integration

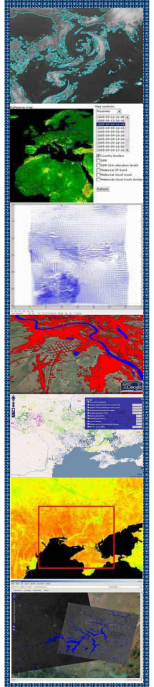


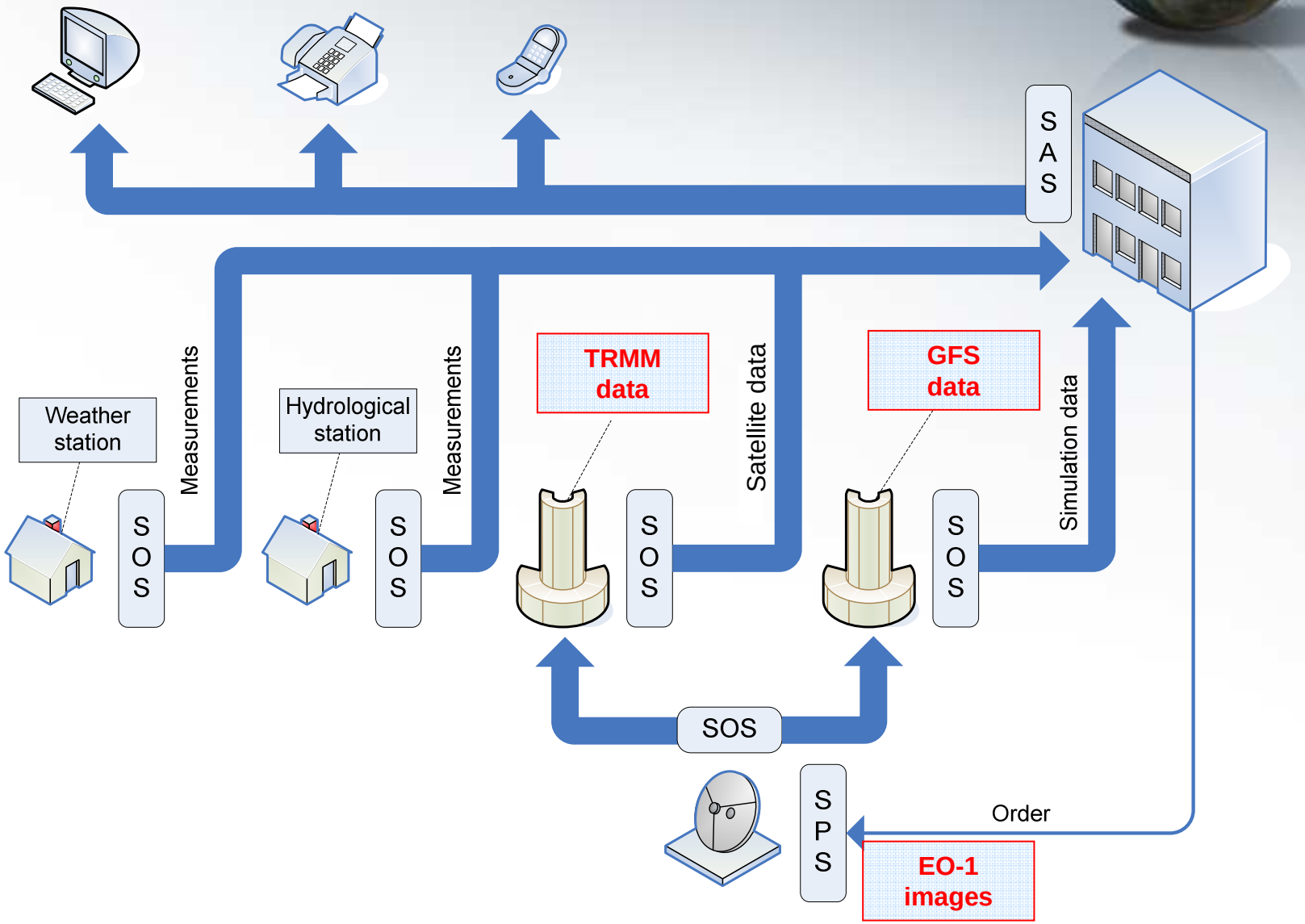
- Benefits from integration with the Grid platform like Globus Toolkit:
  - **Sensors discovery** could be performed through the combination of **Index Service** and **Trigger Service**;
  - High-level access to XML description of the sensors and services could be made through queries to the **Index Service**;
  - Grid platform provides a convenient way for the implementation of **notifications** and **event triggering** using corresponding platform components;
  - **Reliable File Transfer** (RFT) service provides reliable data transfer for large volumes of data;
  - **Globus Security Infrastructure** provides enforcement of data and services access policies in a very flexible way allowing implementation of desired security policy

Sensor Web Architecture for Flood Application

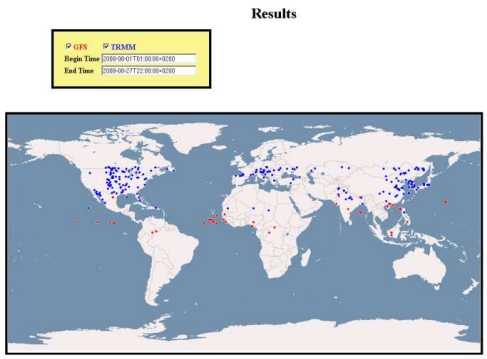


SW Architecture for Flood Application



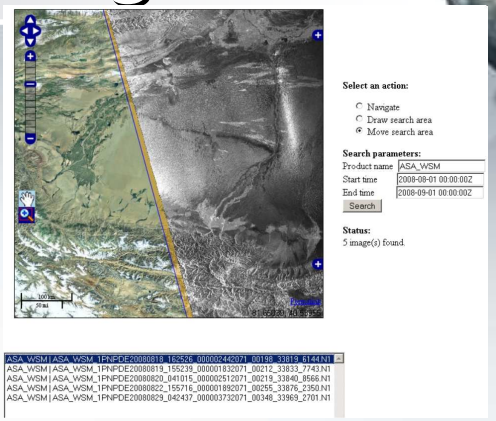


Workflow for Data Planning, Acquisition and Processing



SOS Interface to GFS & TRMM data

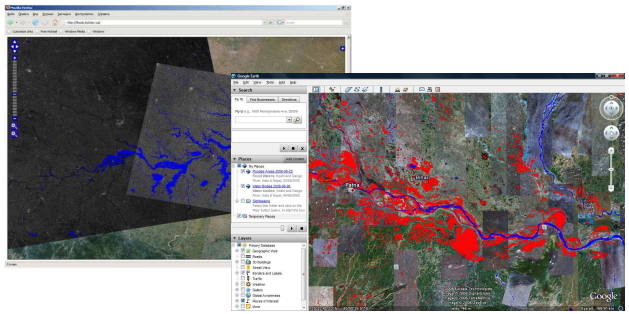
SPS



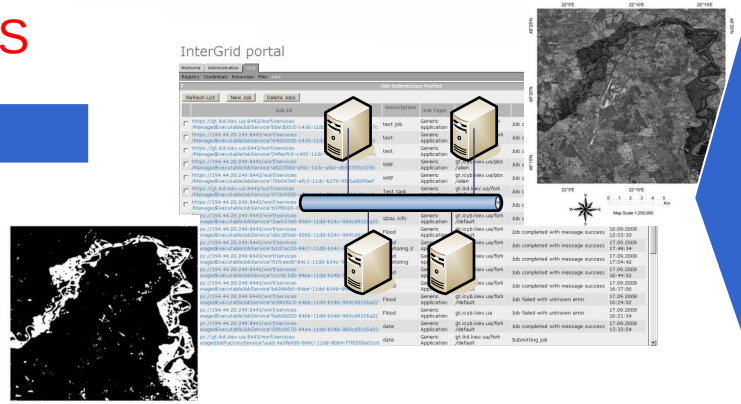
Satellite Observations

Processing services

WMS



Visualization of Data

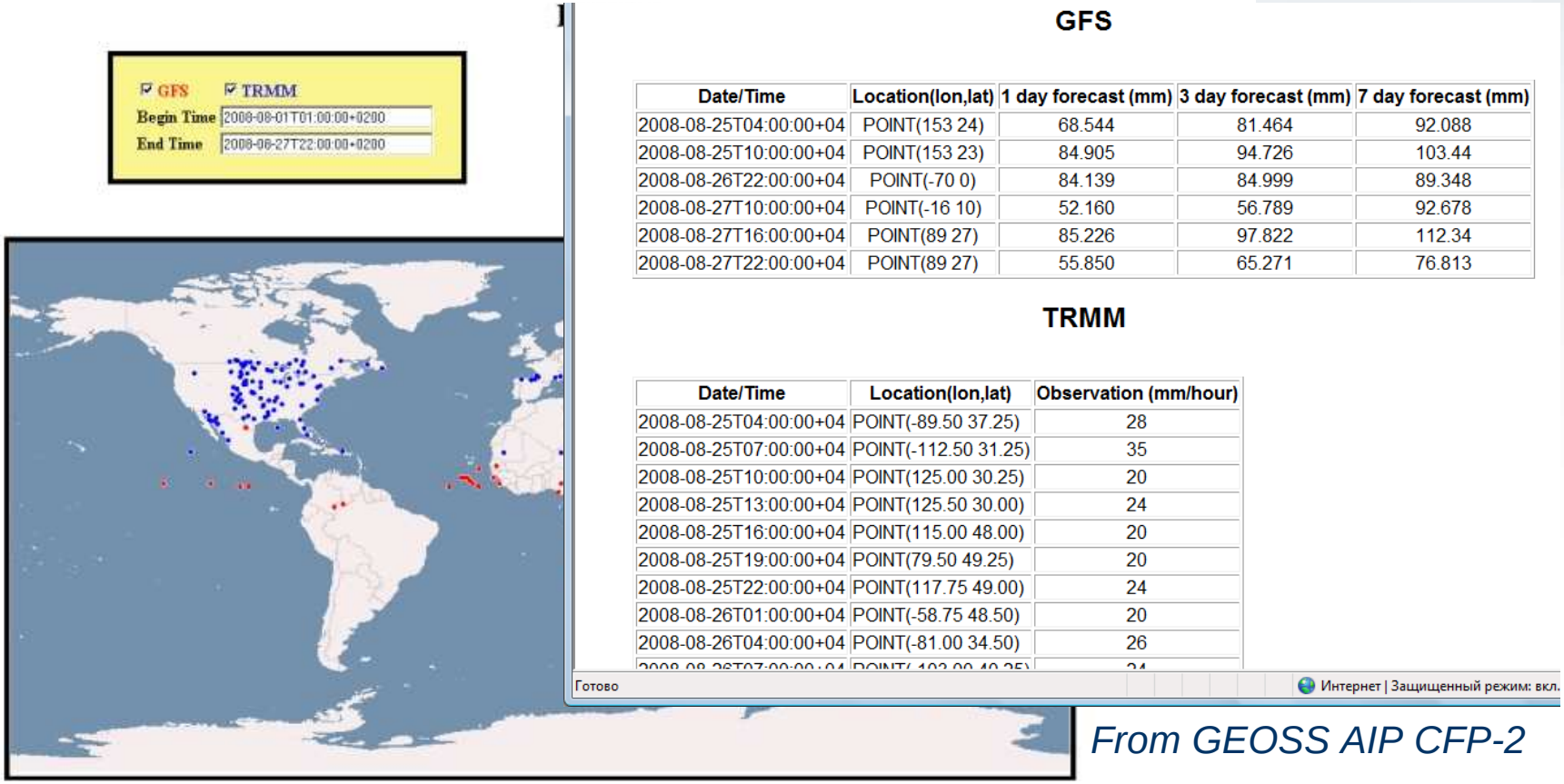


Data Processing in Grid

SRI 2013

Models and observations

- Meteorological forecasts are operationally obtained from the **Global Forecasting System** (GFS, 1 deg.) using the Sensor Observation Service (SOS). **Tropical Rainfall Measuring Mission** (TRMM) data (0.25 deg.) using SOS are also provided.



GFS

Date/Time	Location(lon,lat)	1 day forecast (mm)	3 day forecast (mm)	7 day forecast (mm)
2008-08-25T04:00:00+04	POINT(153 24)	68.544	81.464	92.088
2008-08-25T10:00:00+04	POINT(153 23)	84.905	94.726	103.44
2008-08-26T22:00:00+04	POINT(-70 0)	84.139	84.999	89.348
2008-08-27T10:00:00+04	POINT(-16 10)	52.160	56.789	92.678
2008-08-27T16:00:00+04	POINT(89 27)	85.226	97.822	112.34
2008-08-27T22:00:00+04	POINT(89 27)	55.850	65.271	76.813

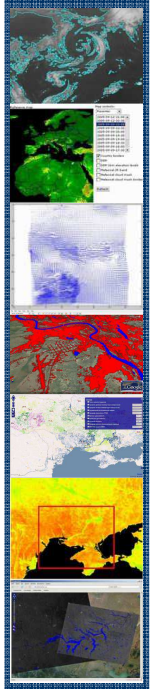
TRMM

Date/Time	Location(lon,lat)	Observation (mm/hour)
2008-08-25T04:00:00+04	POINT(-89.50 37.25)	28
2008-08-25T07:00:00+04	POINT(-112.50 31.25)	35
2008-08-25T10:00:00+04	POINT(125.00 30.25)	20
2008-08-25T13:00:00+04	POINT(125.50 30.00)	24
2008-08-25T16:00:00+04	POINT(115.00 48.00)	20
2008-08-25T19:00:00+04	POINT(79.50 49.25)	20
2008-08-25T22:00:00+04	POINT(117.75 49.00)	24
2008-08-26T01:00:00+04	POINT(-58.75 48.50)	20
2008-08-26T04:00:00+04	POINT(-81.00 34.50)	26

Готово | Интернет | Защищенный режим: вкл.

From GEOSS AIP CFP-2

SOS response for TRMM



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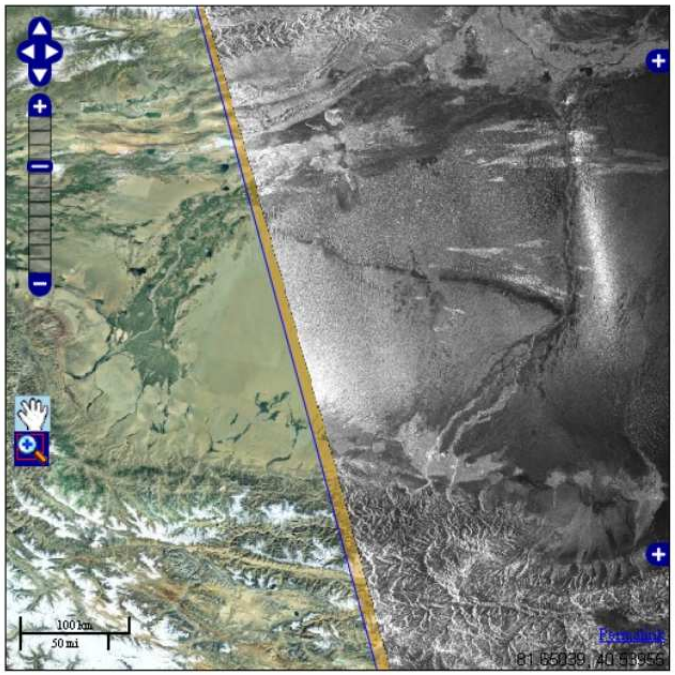
SPS for EO data acquisition

- 2) We use the Sensor Planning Services (SPSs) to request satellites to acquire images of the specific territory for flood assessment.



Select an action:

- Navigate
- Draw search area
- Move search area

Search parameters:

Product name	ASA_WSM
Start time	2008-08-01 00:00:00Z
End time	2008-09-01 00:00:00Z

Search

Status:
5 image(s) found.

ASA_WSM|ASA_WSM_1PNPDE20080818_162526_000002442071_00198_33819_6144.N1
ASA_WSM|ASA_WSM_1PNPDE20080819_155239_000001832071_00212_33833_7743.N1
ASA_WSM|ASA_WSM_1PNPDE20080820_041015_000002512071_00219_33840_8566.N1
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ASA_WSM|ASA_WSM_1PNPDE20080829_042437_000003732071_00348_33969_2701.N1

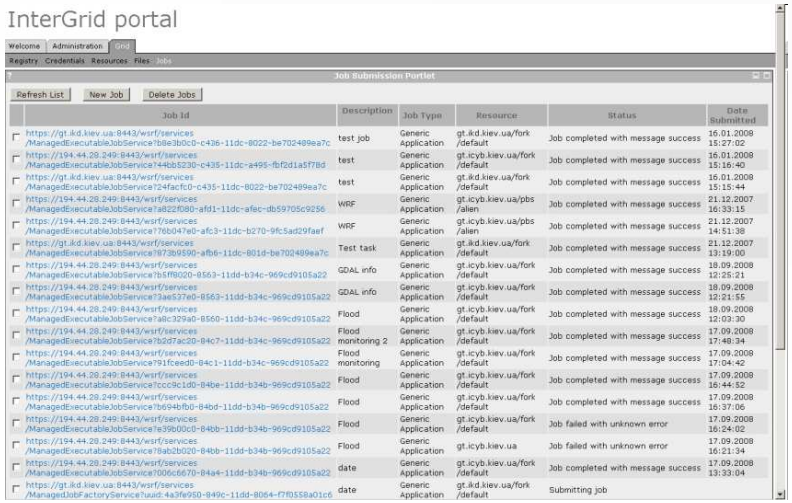
Currently, **EO-1** can be accessed & processed **operationally**!

High-resolution SAR imagery (**not operational**):

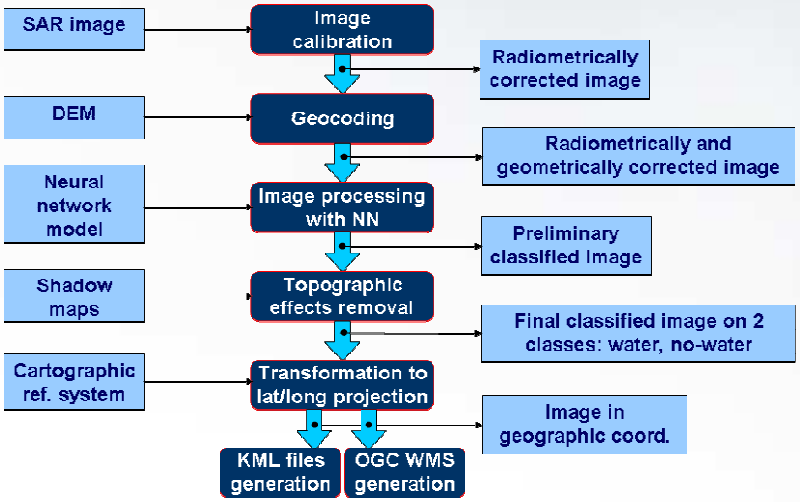
- **RADARSAT-2** via **GEOSS Disaster** and **Flood Sensor Web**
- **TerraSAR-X** via Science Service System

Data processing

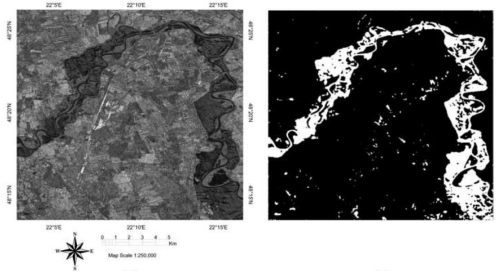
- 3) The acquired data are then processed in the Grid in order to produce the necessary flood products.



InterGrid portal

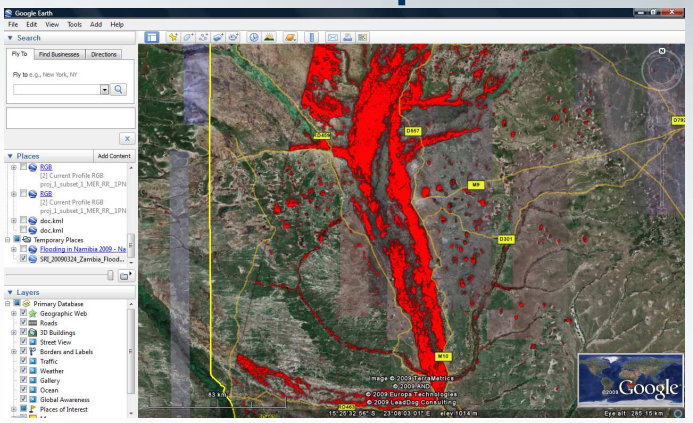


Processing workflow (being put onto Grid)

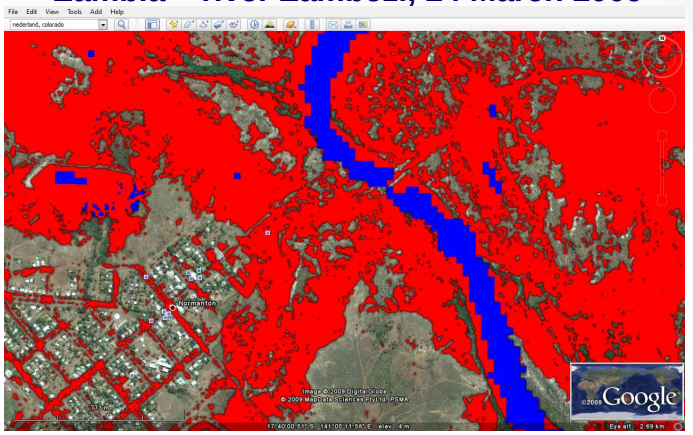


Visualization of data

- 4) The processed data are then used to generate WMS, Google's KML files, maps, etc.
  - Open-source software
    - UNM Mapserver v5
    - OpenLayers framework
    - GDAL
  - Standards
    - Open Geospatial Consortium (OGC)
      - Web Mapping Service (WMS)
      - Web Feature Service (WFS)
      - Keyhole Mark-up Language (KML)

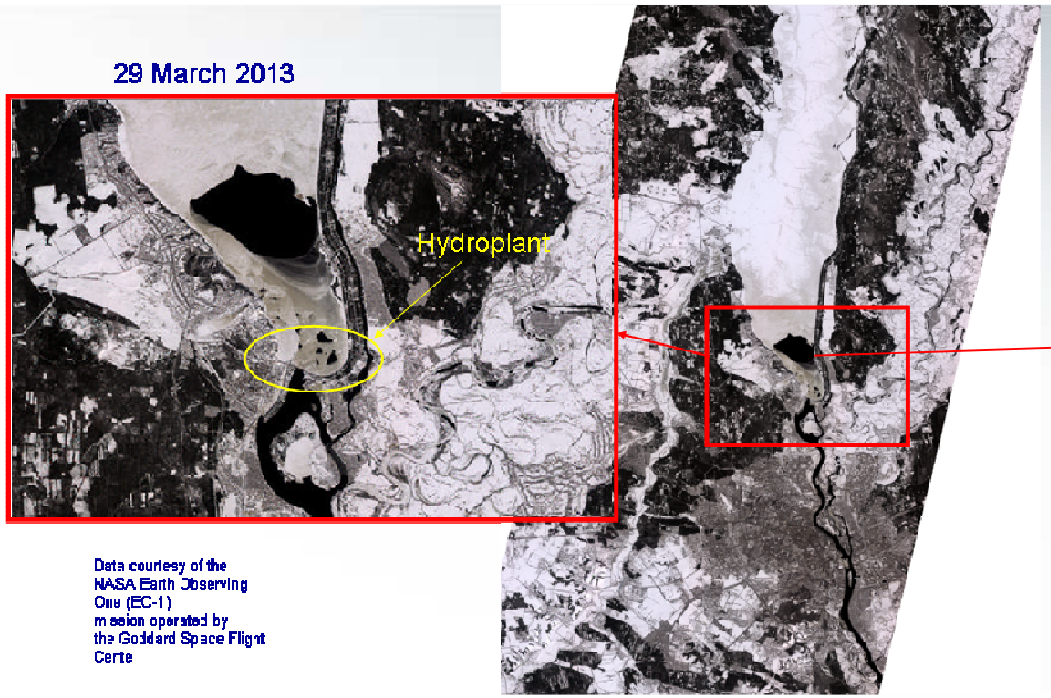


Zambia – river Zambezi, 24 March 2009



Australia – river Normanton, 14 Feb 2009

Performance evaluation



08 April 2013

EO-1 Image acquired

Image available @ ftp

Processed images available on Web

Fri Mar 29, 2013 @09:59 AM

Fri Mar 29, 2013 @01:25 PM

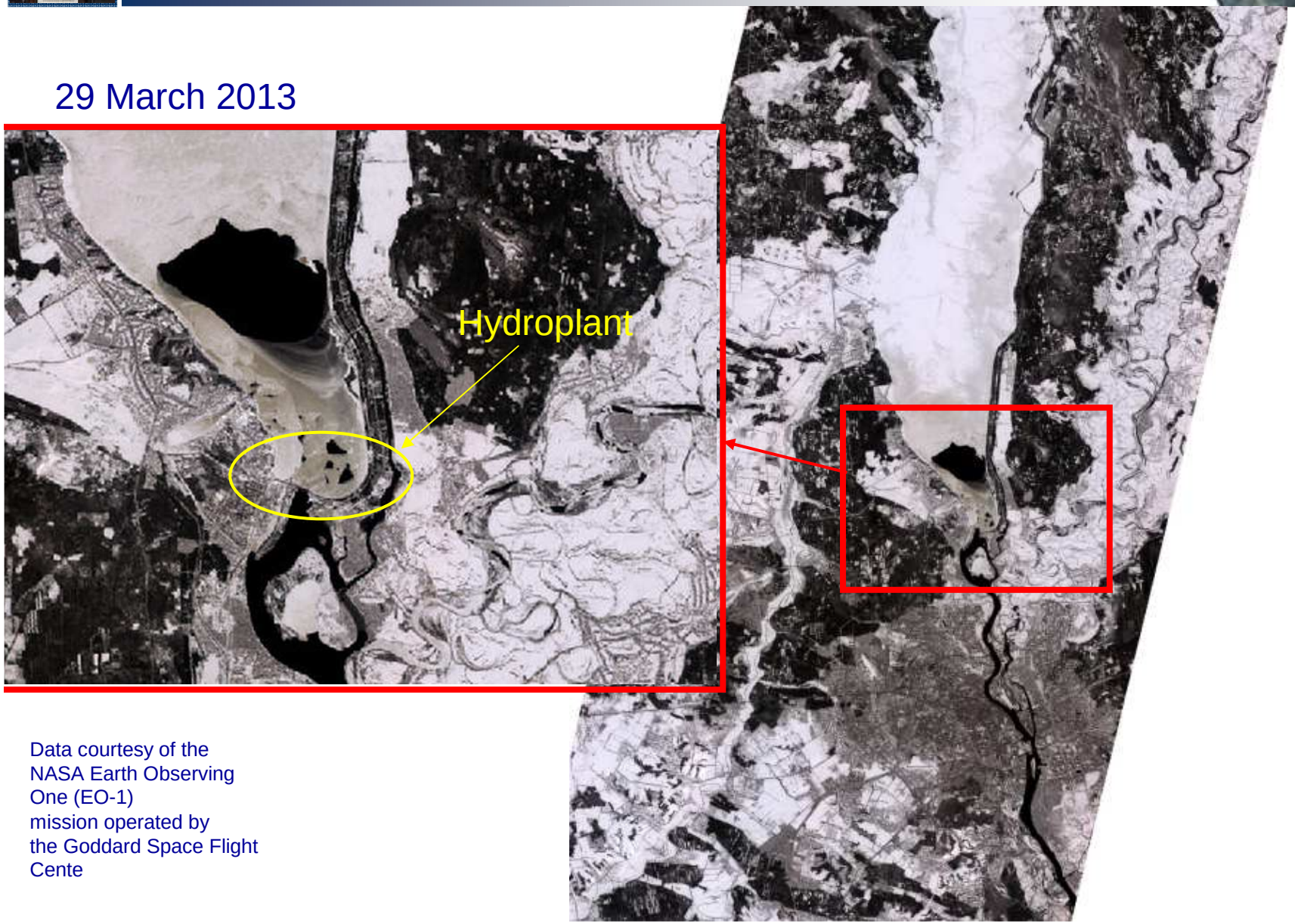
Fri Mar 29, 2013 @04:25 PM

~ 6.5 hours

All time local Ukrainian

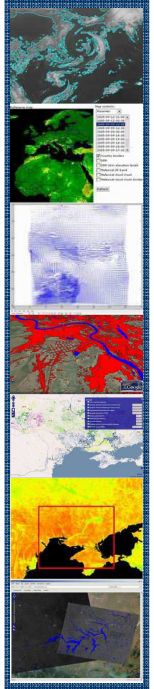
EO-1 / Advanced Land Imaging

29 March 2013

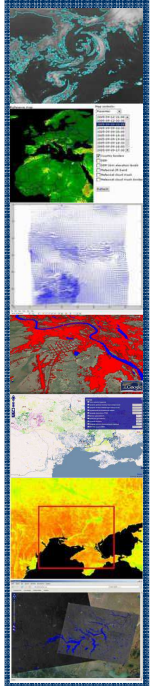


Data courtesy of the NASA Earth Observing One (EO-1) mission operated by the Goddard Space Flight Cente

Summary



- EO provide advantages and benefits for disaster risk assessment in terms of both:
  - *Hazard mapping* (probability density function estimation)
  - *Vulnerability mapping*
- Disaster risk assessment requires integration of multi-source data => *take advantage of Sensor Web*
- Need for models => *integration with Model Web*
  - E.g. global meteorological models (GFS); frequency analysis, modeling of extremes from satellite data and products
- Integration of Sensor Web and Grid => *to provide processing services*



Thank You!

SRI
2013