FLOOD PROPAGATION AND DAMAGE EVALUATION INTEGRATING HYDRAULIC MODELING AND SATELLITE OBSERVATION

Elena Angiati[3], *Giorgio Boni*[2], *Laura Candela*[1], *Silvana Dellepiane*[3], ***Fabio Delogu***[2], *Luca Ferraris*[2], *Roberto Rudari*[2], *Franco Siccardi*[2], *Giuseppe Squicciarino*[5], *Nazareno Pierdicca*[4], *Luca Pulvirenti*[4], *Cosimo Versace*[6].

[1]Italian Space Agency, Unità Osservazione Della Terra, CGS, Contrada Terlecchia, 75100 Matera (Italy)
[2]CIMA Research Foundation, Savona University Campus,Via Armando Magliotto 2, I-17100 Savona (Italy)
[3]University of Genoa, Dept. of Biophysical and Electronic Eng. (DIBE),Via Opera Pia 11a, I-16145, Genoa (Italy)
[4]Sapienza University of Rome, Dept. of Electronic Eng. (DIE), via Eudossiana, 18 - 00184 Rome (Italy)
[5]ACROTEC S.r.L., Via Armando Magliotto, 2 17100 Savona (Italy)
[6]CONSORZIO COS (OT), Via Casalnuovo, 86, 75100 Matera (Italy)

OPERA Project: Civil Protection from Floods

2007-2010
Demonstrative pilot project of ASI (Italian Space Agency) and DPC (Department for Civil Protection) for EO-based applications

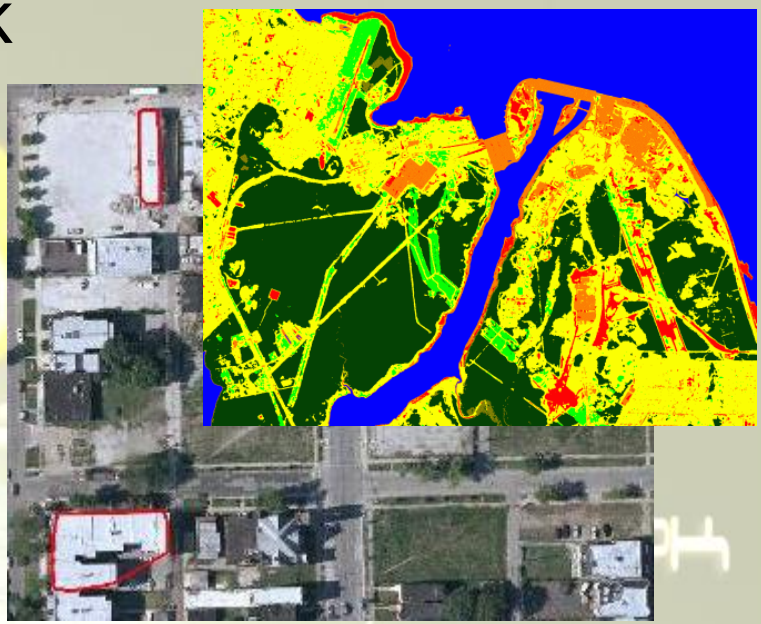
Multi-mission, focus on COSMO-Skymed

Shortly (end 2010) entering the operative phase within the National System for Civil Protection

The main functionalities of the project for the three main phases of the flood risk management

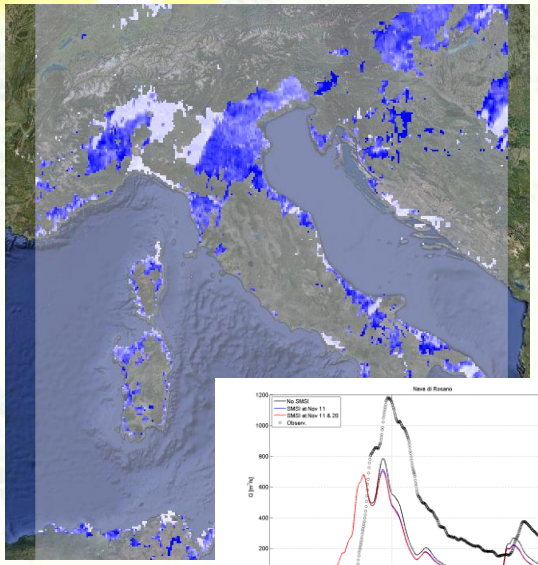
Planning and Preparedness

Rapid land-use update, critical infrastructure, vulnerability, …



Early Warning

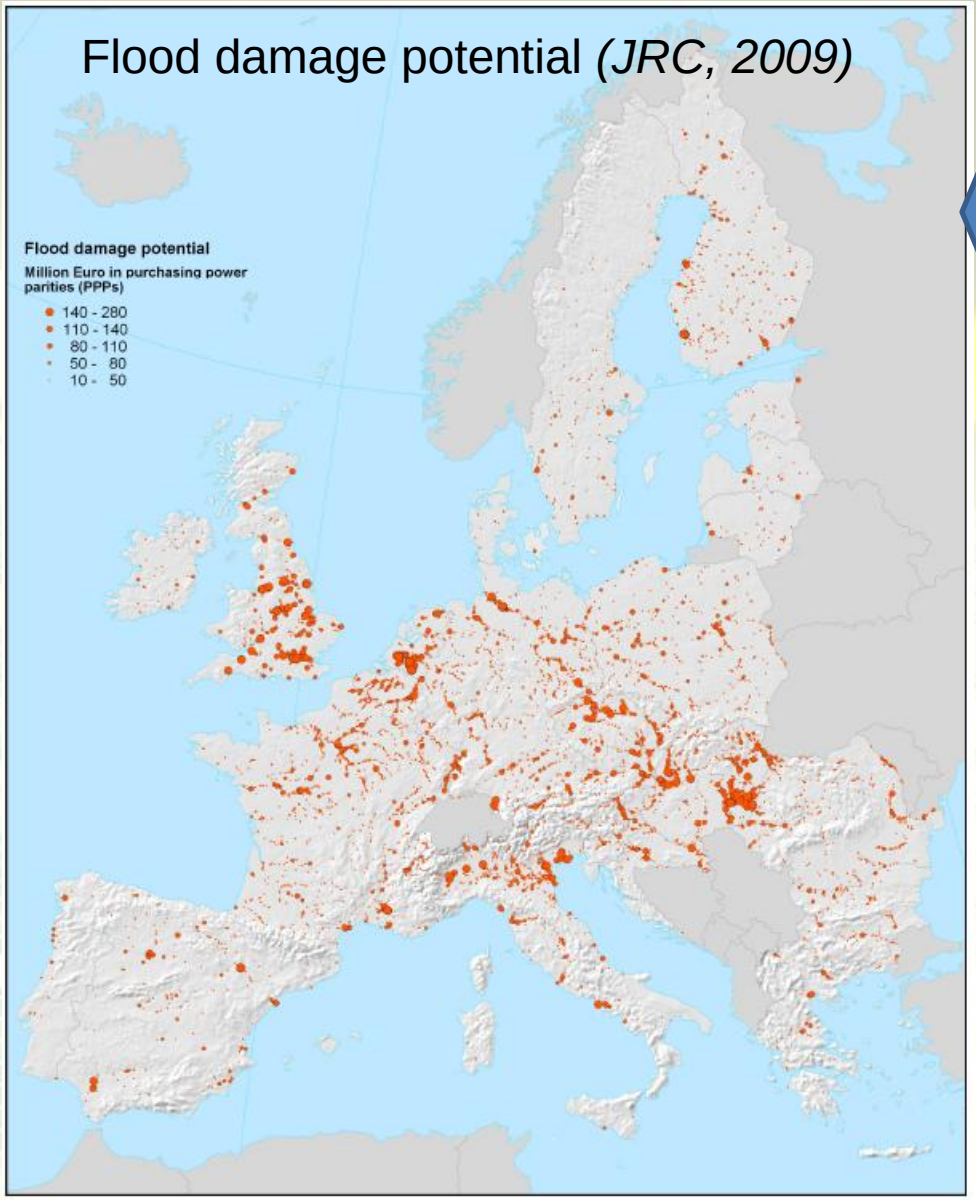
Soil moisture monitoring, assimilation in hydrologic forecasting models



Rescue and damage evaluation

This presentation

Flood damage potential *(JRC, 2009)*



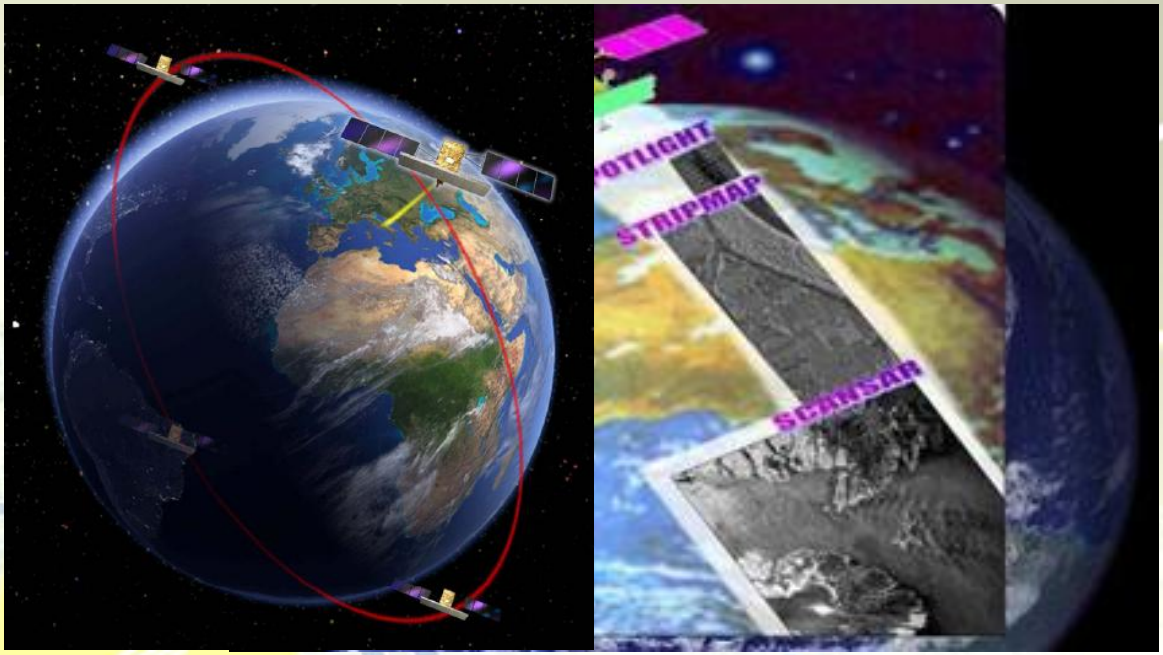
MOTIVATION

High flood risk (hazard×damage) is concentrated in urban areas.

Rescue and recovery management at all levels (regional, national, international) is rapidly moving toward a fast-track damage assessment.

Ground survey accurate but sparse, inaccurate and slow in remote areas.

Central role of the COSMO-SkyMed capabilities in the emergency management



SPOTLIGHT
1 m Resol.
(10 km X 10 km)

HIMAGE
3x3 – 5x5 m Resol.
(40 km X 40 km)

Revisit time at mid lat.
~ 4.5 *h* average
~ 12 *h* max

Response time (*request* → *delivery*)
VERY URGENT – 12 *h*
CRISIS – 29 *h*
ROUTINE – 44 *h*

Damage evaluation as a combination of deferred-time and real-time EO products

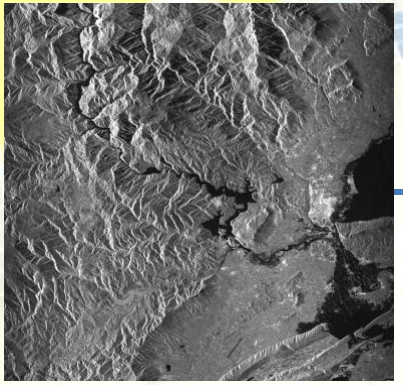
Deferred-time

Multispectral Optical Imagery

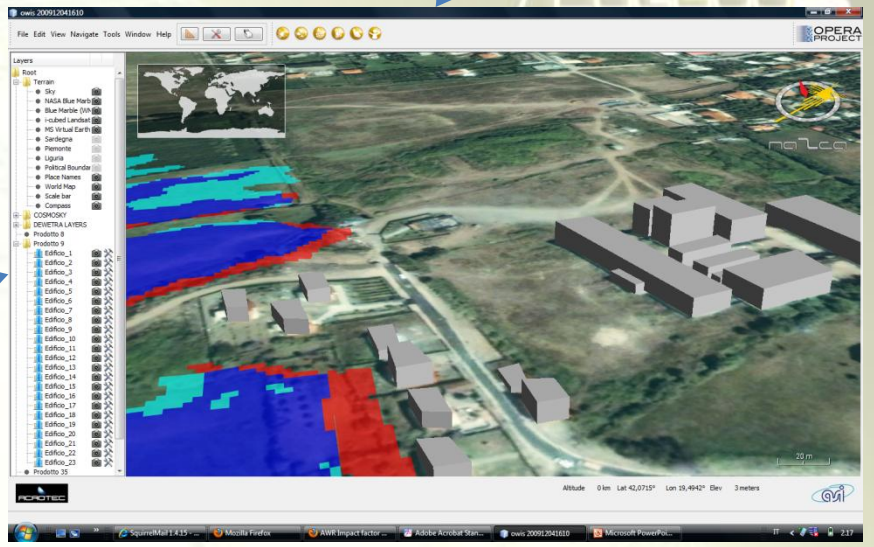
Vulnerability

Real-time

SAR



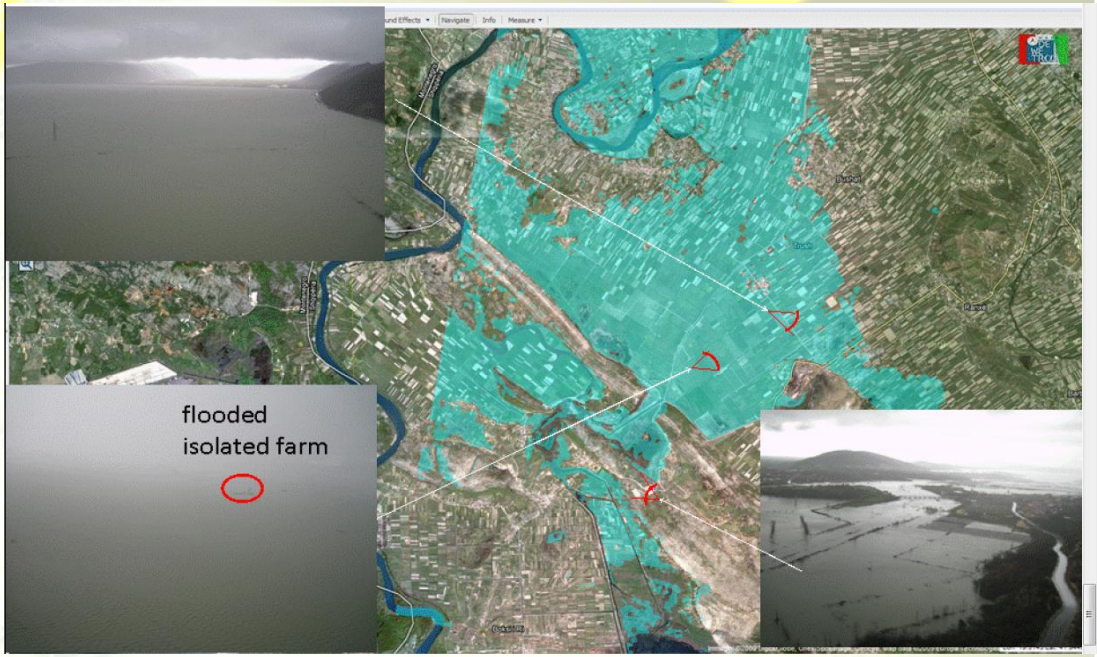
Flood extent and intensity



A real case-study I: The flooding of the plain of Skodar (Albania) from the Buna River, Jan 2010

Delivered products:

-Fast-ready flood maps
-Detailed flood maps
-Elements at risk
-Vulnerability map
-Damage maps



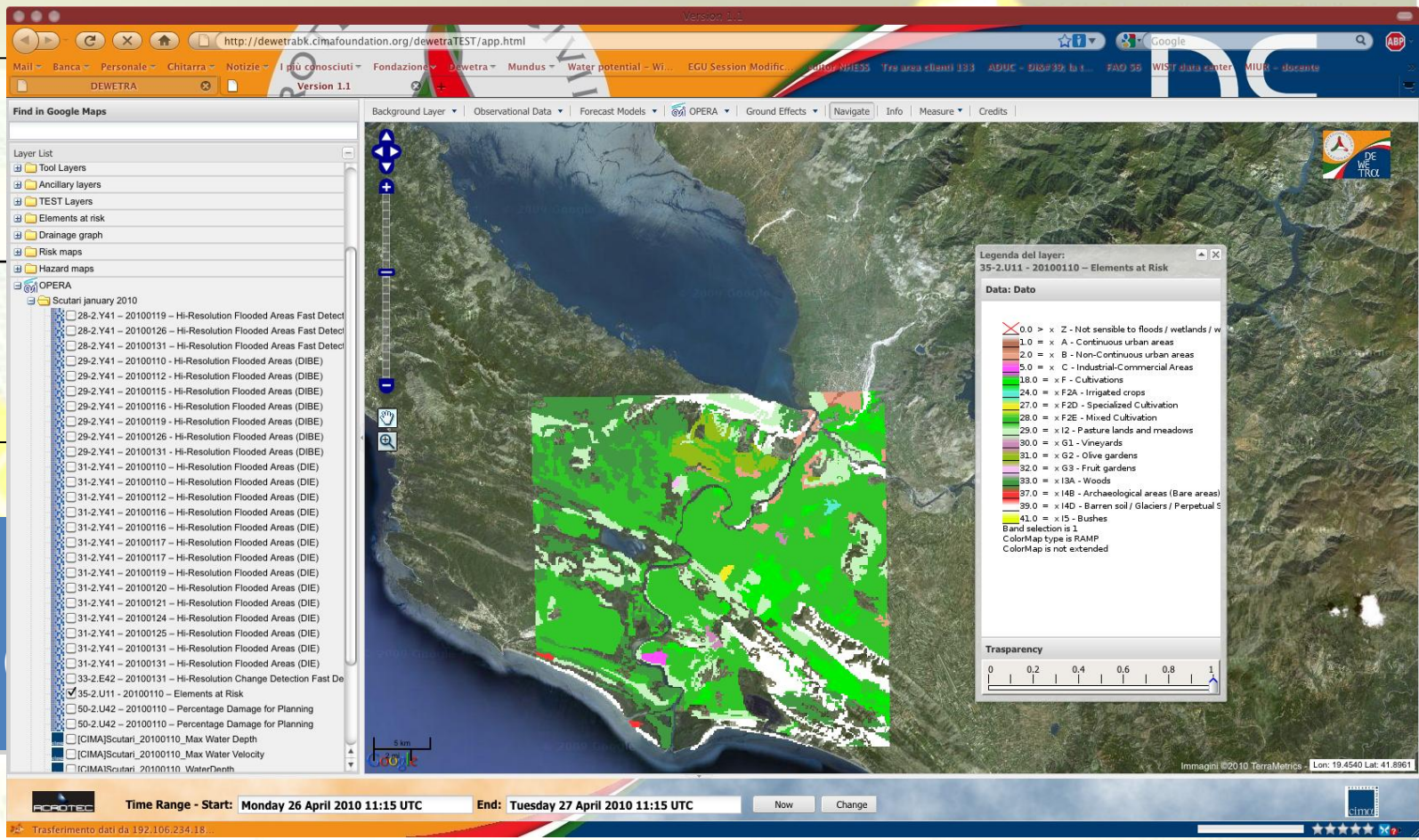
T_0 Time: Jan 9, 2010, 11:00am LT, assistance requested by government of Albania to Italian DPC

T0: Trigger, DPC request to OPERA team

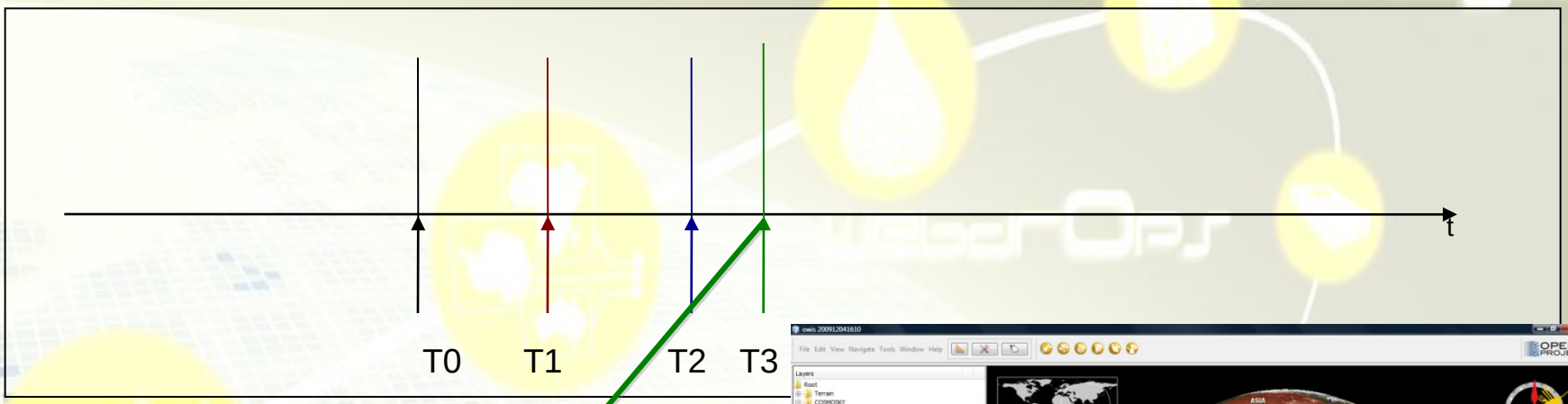
T_1 Time (T_0+6h): Jan 9, 2010, 05:00pm LT, planning and request of COSMo-SkyMed acquisitions

Planning and request of acquisition (Very Urgent mode through DPC)

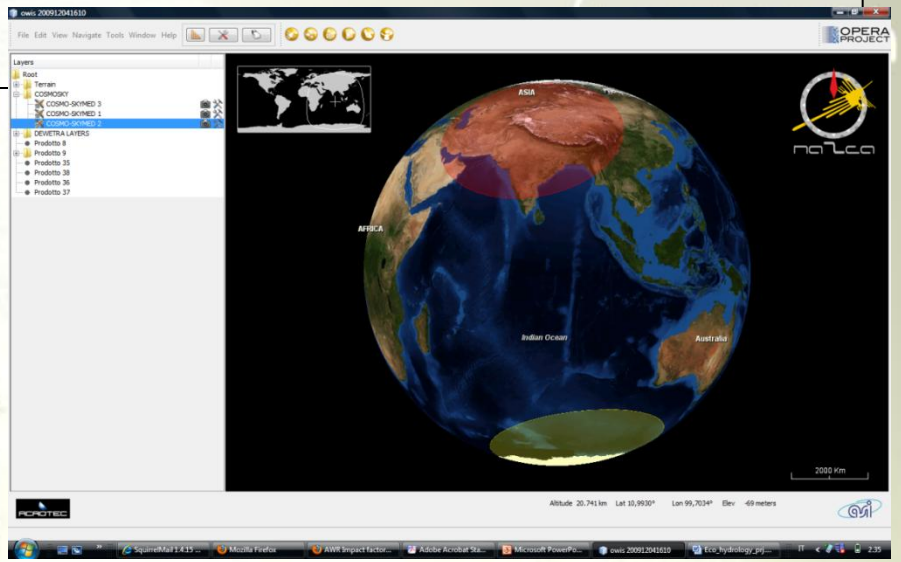
T_2 Time (T_0+23h): Jan 10, 2010, 12:00am LT, cartography available



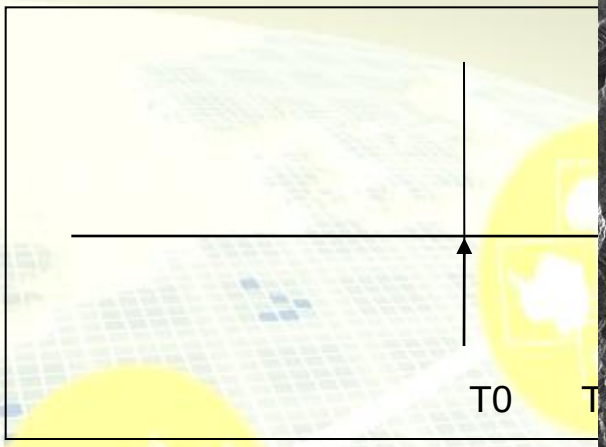
T_3 Time (T_0+29:50h): Jan 10, 2010, 04:50pm LT, first acquisition



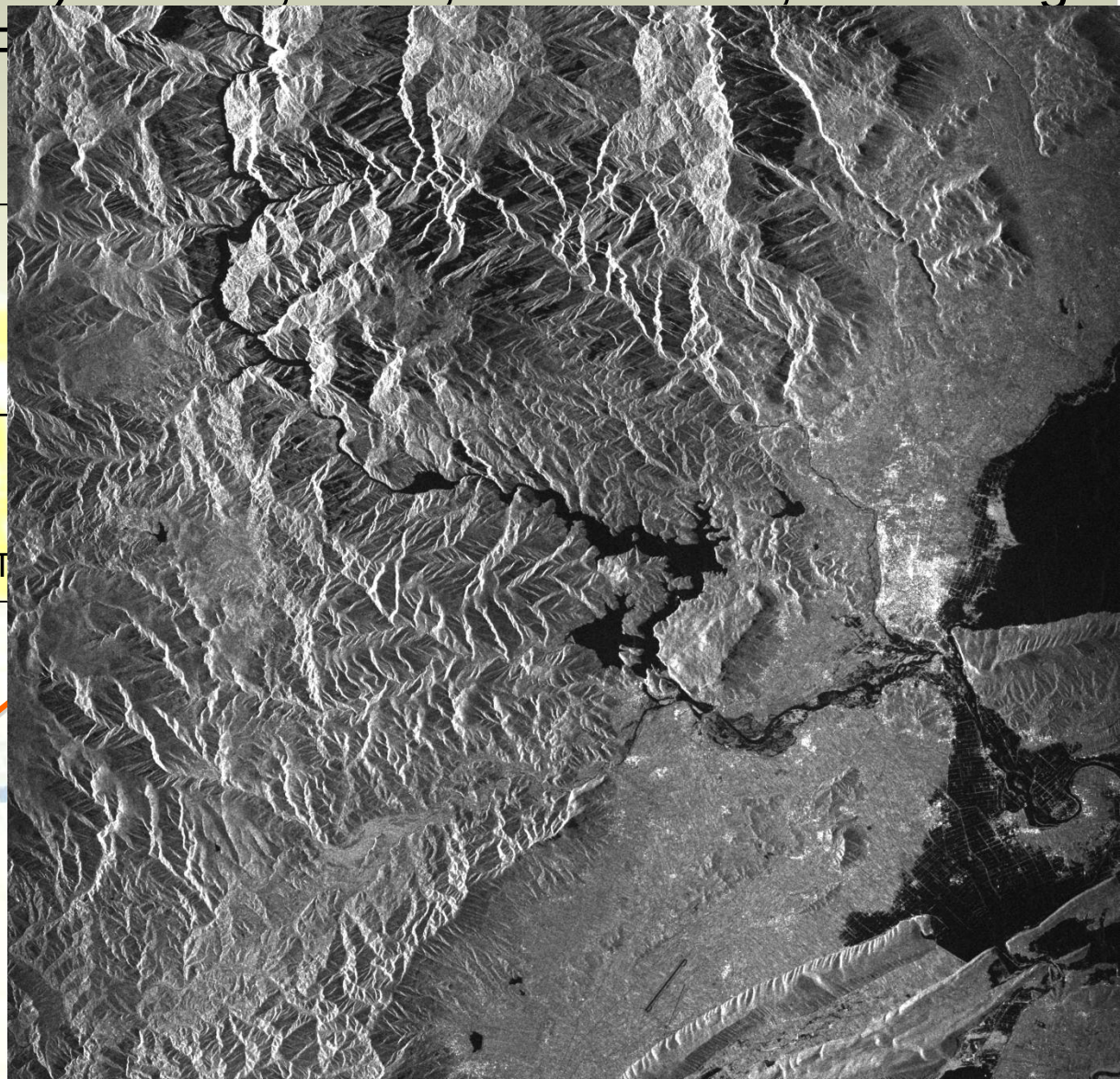
First acquisition (first revisit after request)



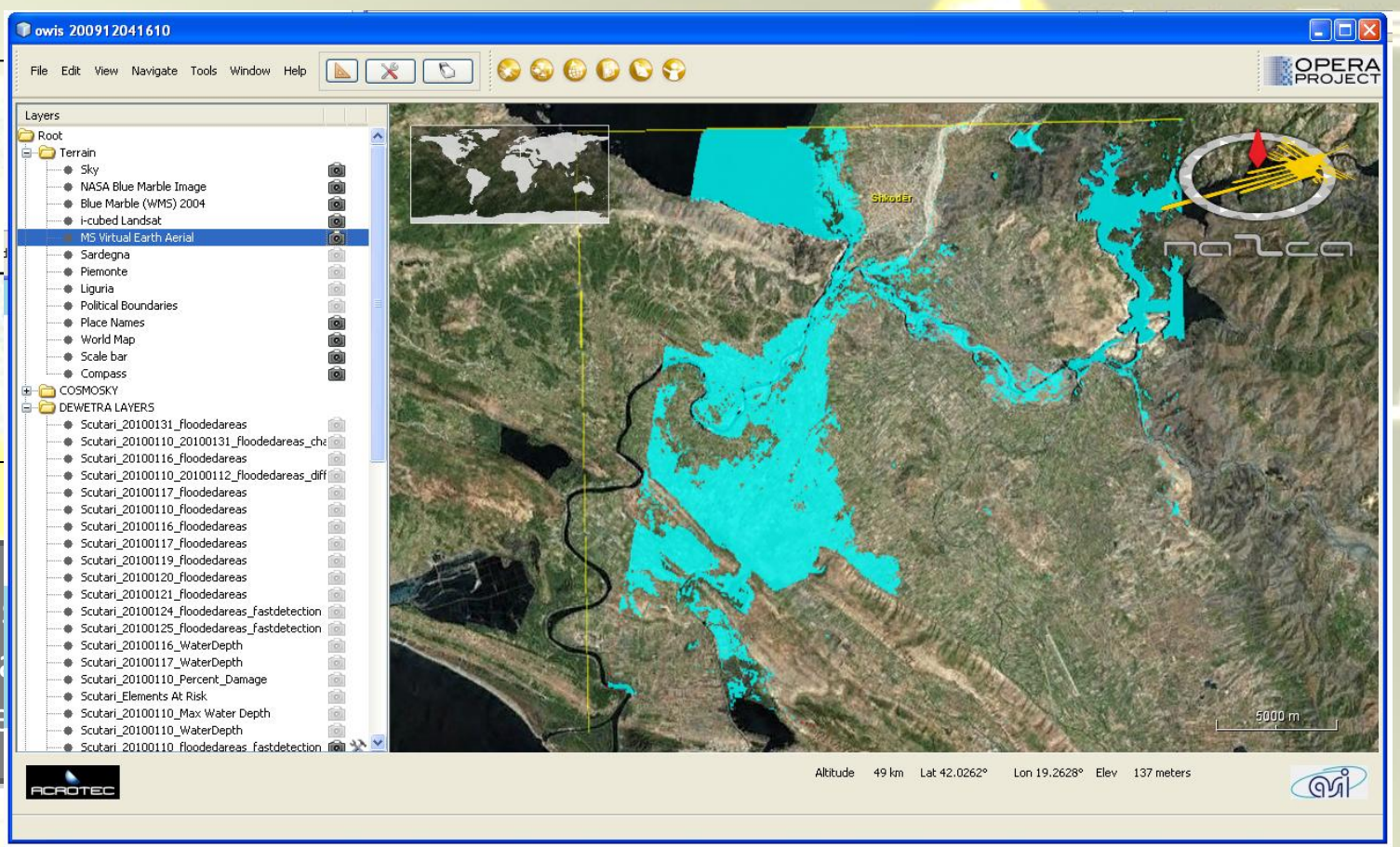
T_4 Time (T_0+47h): Jan 11, 2010, 10:00am LT, First image delivered to OP



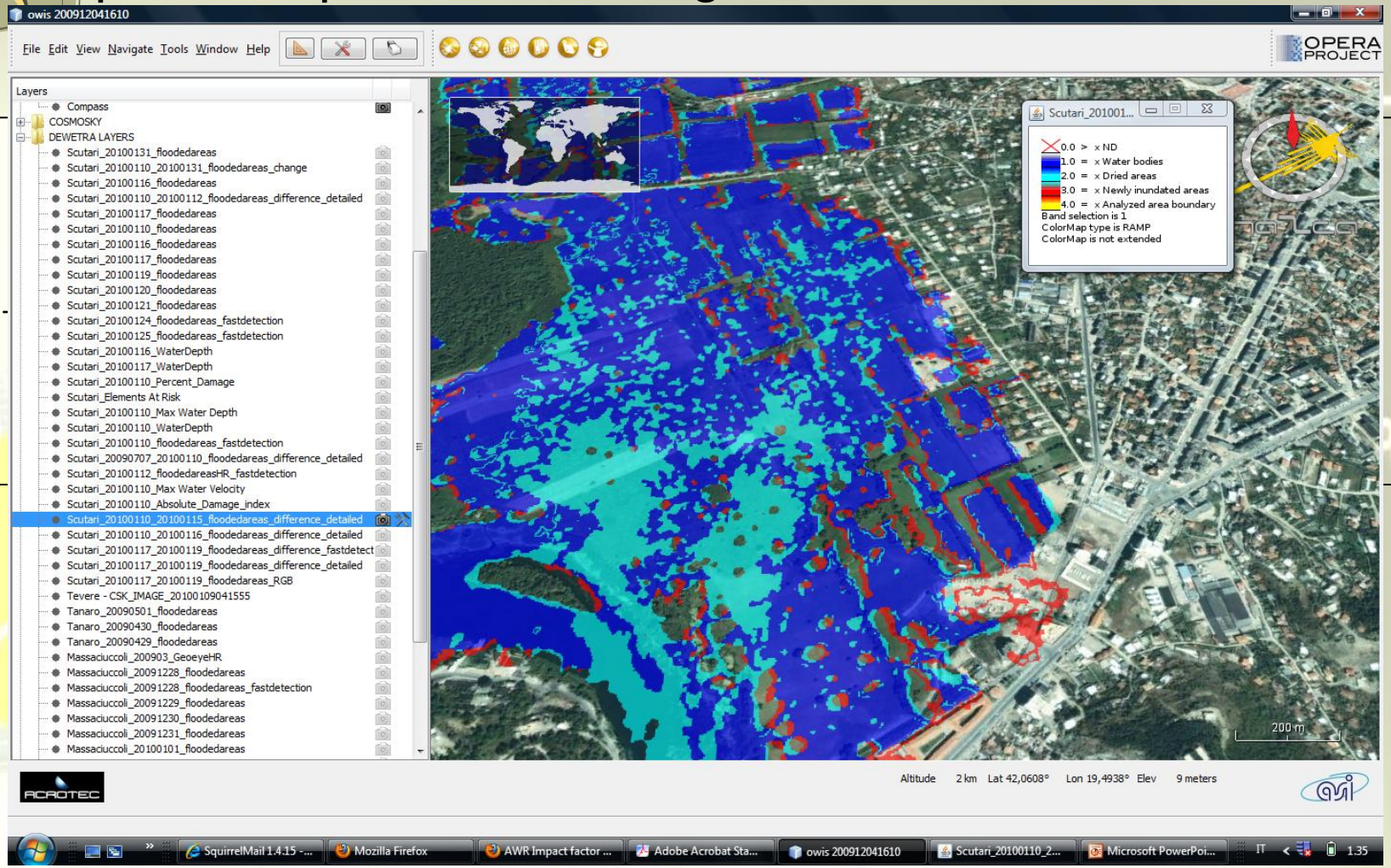
Imagery available to OPERA DataBase



T_5 Time (T_0+53h): Jan 11, 2010, 5:00pm LT, first products published through the OPERA interface

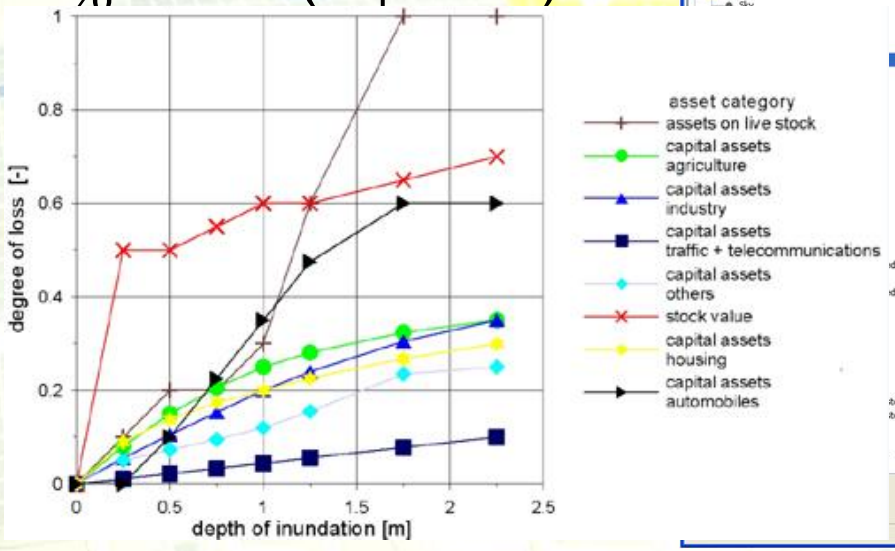


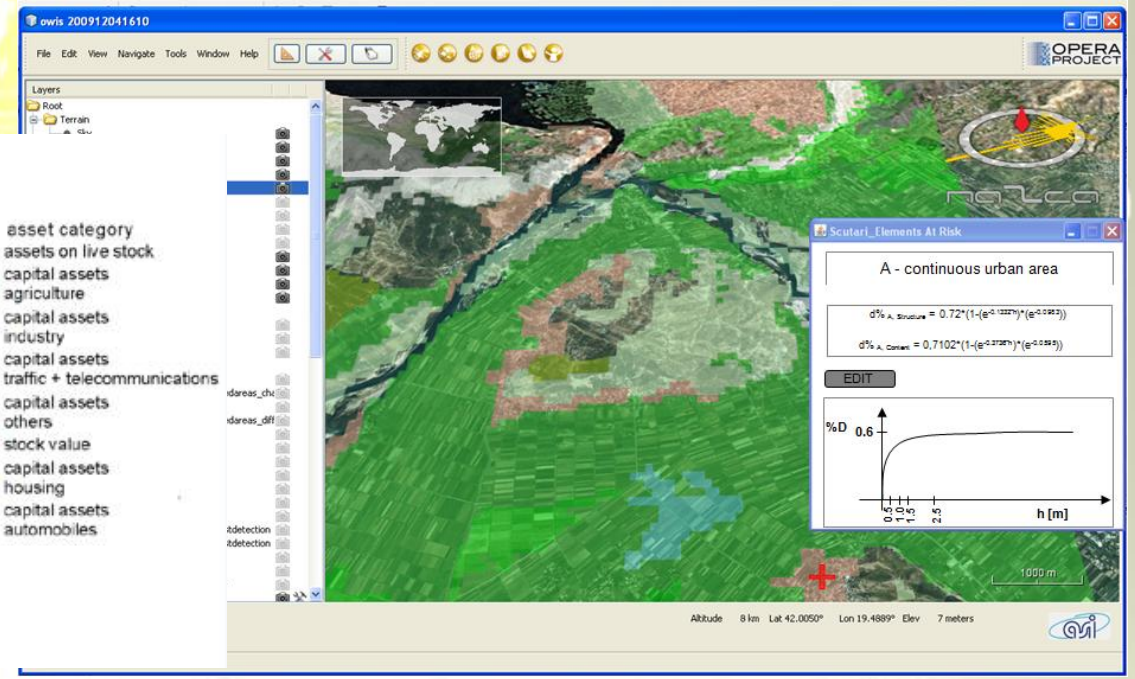
T_6 Time (T_0+71h): Jan 12, 2010, 12:00am LT, All products published through the OPERA interface



Vulnerability product: combines a map of elements at risk (e.g. from Urban Land Use, supervised or unsepervised) with a flood vulnerability function

$$D_{\%} = F\left(Y|LU\right)$$

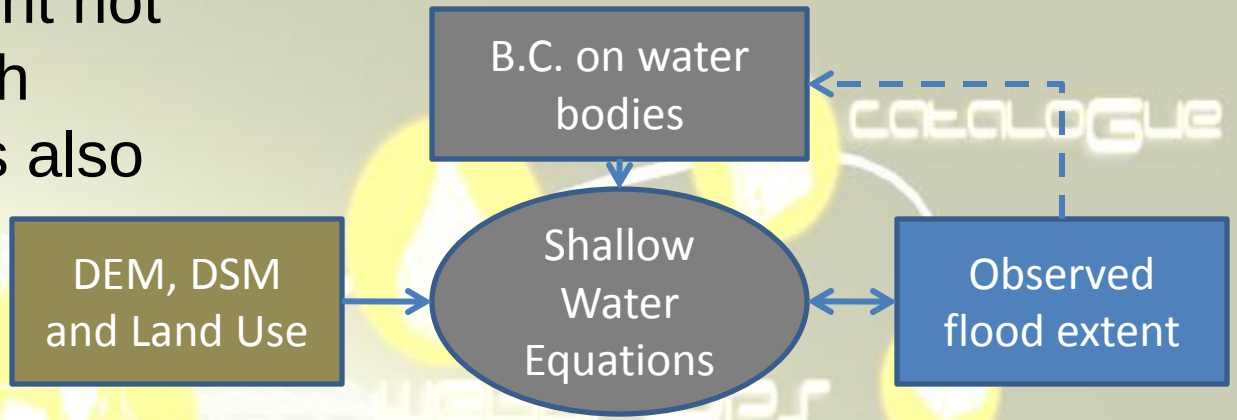


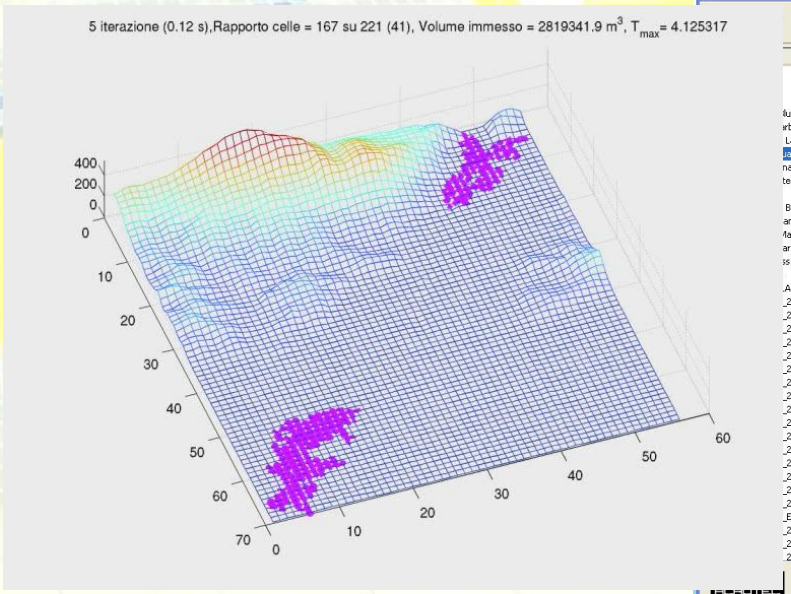


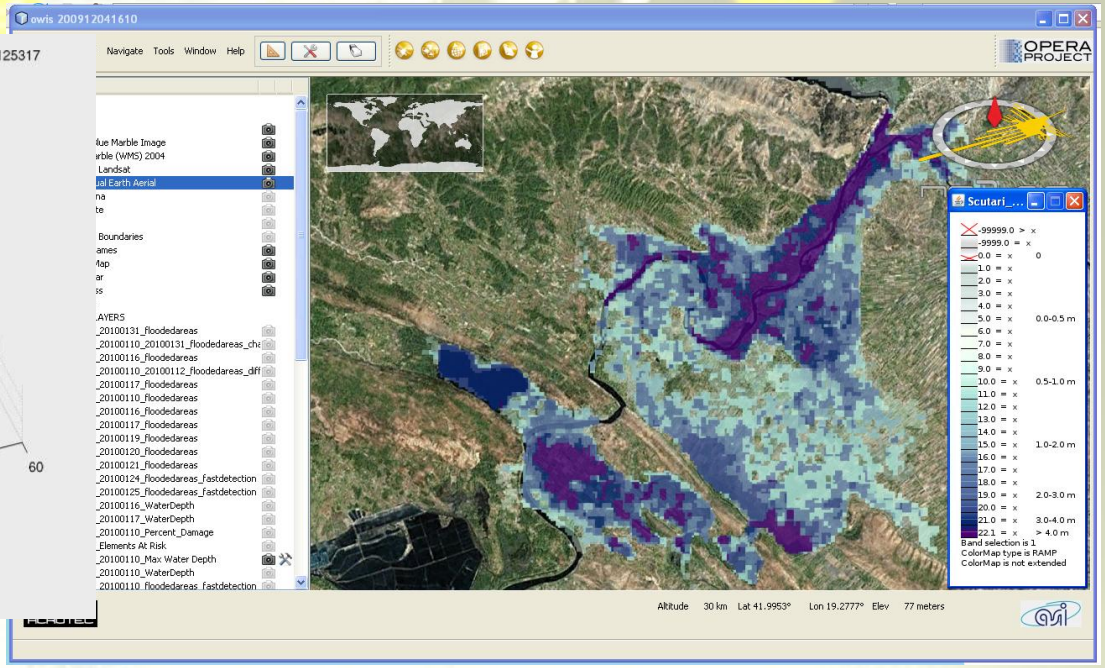
Klaus & Schmidtke, 1990

From vulnerability to damage: flood extent not enough, water depth (velocity optional) is also required.

Hydraulic data assimilation system







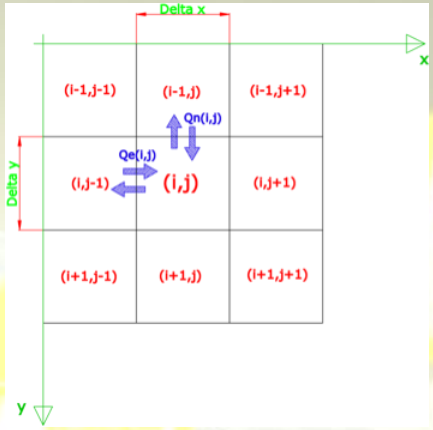
Equations:

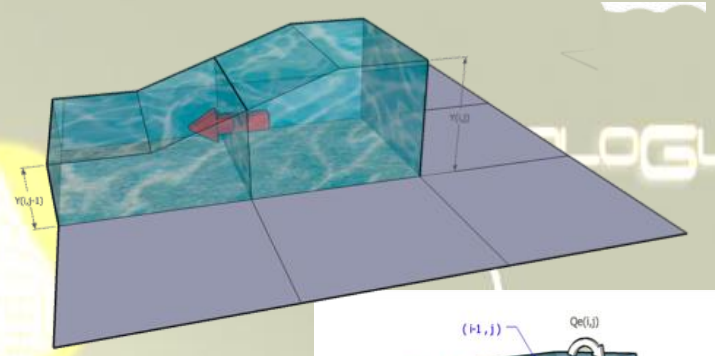
$$\frac{\partial (Y+z)}{\partial x} = -\frac{u\sqrt{u^2+v^2}}{C^2\, Y}$$

$$\frac{\partial (Y+z)}{\partial y} = -\frac{v\sqrt{u^2+v^2}}{C^2\, Y}$$

$$\frac{\partial Y}{\partial t} + \frac{\partial (Yu)}{\partial x} + \frac{\partial (Yv)}{\partial y} = 0$$

Spatial discretization: storage cells





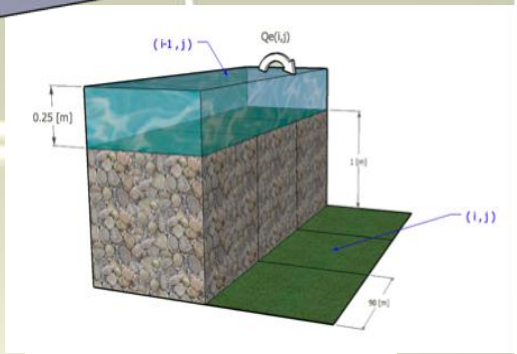
Head gradients:

$$\mathbb{J}_{\parallel E} = \frac{H_{i,j-1} - H_{i,j}}{\Delta x}$$

$$\mathbb{J}_{\perp E} = \frac{\frac{1}{4}\left(H_{i-1,j-1} + H_{i-1,j} - H_{i+1,j-1} - H_{i+1,j}\right)}{\Delta x}$$

Flux limiter: Weir Equation

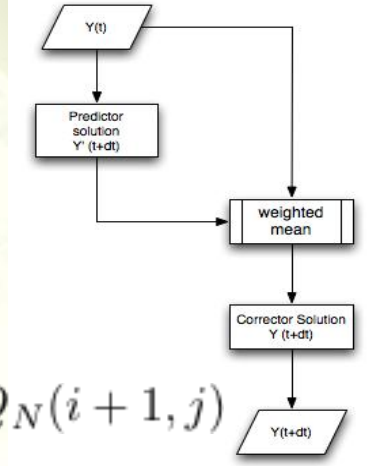
$$Q_{SE}(i,j) = C_Q\ \Delta y\ Y(i,j)\ \sqrt{2\ g\ Y(i,j)}$$



Flow :

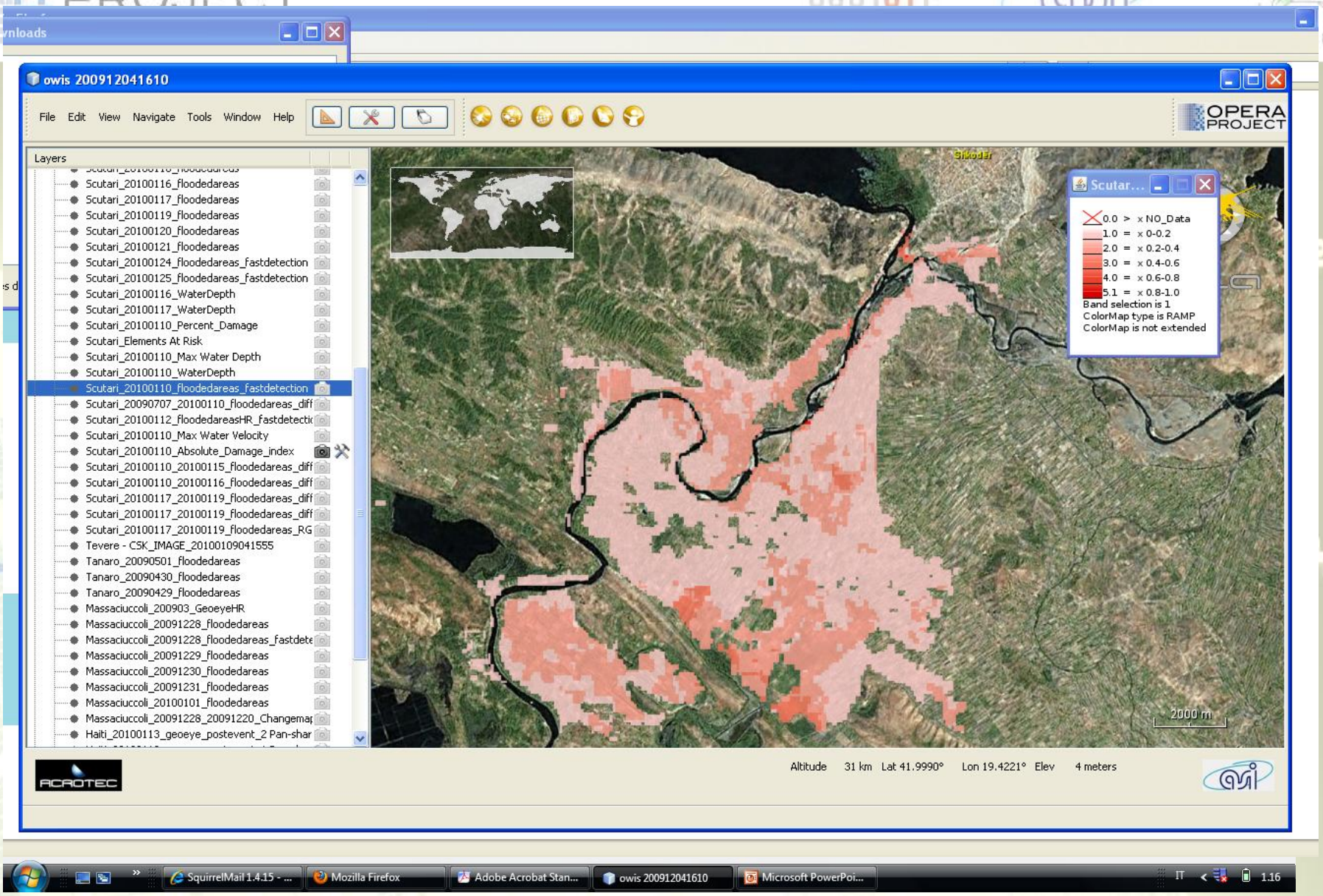
$$Q_E(i,j) = \frac{c_m \left(\frac{Y_{i,j-1}-Y_{i,j}}{2}\right)^{2/3} \mathbb{J}_{\parallel}}{\left(\mathbb{J}_{\parallel}^2 + \mathbb{J}_{\perp}^2\right)^{1/4}} \Delta x \left(\frac{Y_{i,j-1}-Y_{i,j}}{2}\right)$$

Time discretization: explicit predictor-corrector with weighted mean



Water Depth @ t+dt: $Y_{t+\Delta t} = Y_t + \frac{\Delta t}{\Delta x\ \Delta y}\ Q$

Where: $Q(i,j) = Q_E(i,j) - Q_E(i,j+1) + Q_N(i,j) - Q_N(i+1,j)$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OPERA PROJECT
Layers
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Scutari_20100119_floodedareas
Scutari_20100120_floodedareas
Scutari_20100121_floodedareas
Scutari_20100124_floodedareas_fastdetection
Scutari_20100125_floodedareas_fastdetection
Scutari_20100116_WaterDepth
Scutari_20100117_WaterDepth
Scutari_20100110_Percent_Damage
Scutari_Elements At Risk
Scutari_20100110_Max Water Depth
Scutari_20100110_WaterDepth
Scutari_20100110_floodedareas_fastdetection
Scutari_20090707_20100110_floodedareas_diff
Scutari_20100112_floodedareasHR_fastdetecti
Scutari_20100110_Max Water Velocity
Scutari_20100110_Absolute_Damage_index
Scutari_20100110_20100115_floodedareas_diff
Scutari_20100110_20100116_floodedareas_diff
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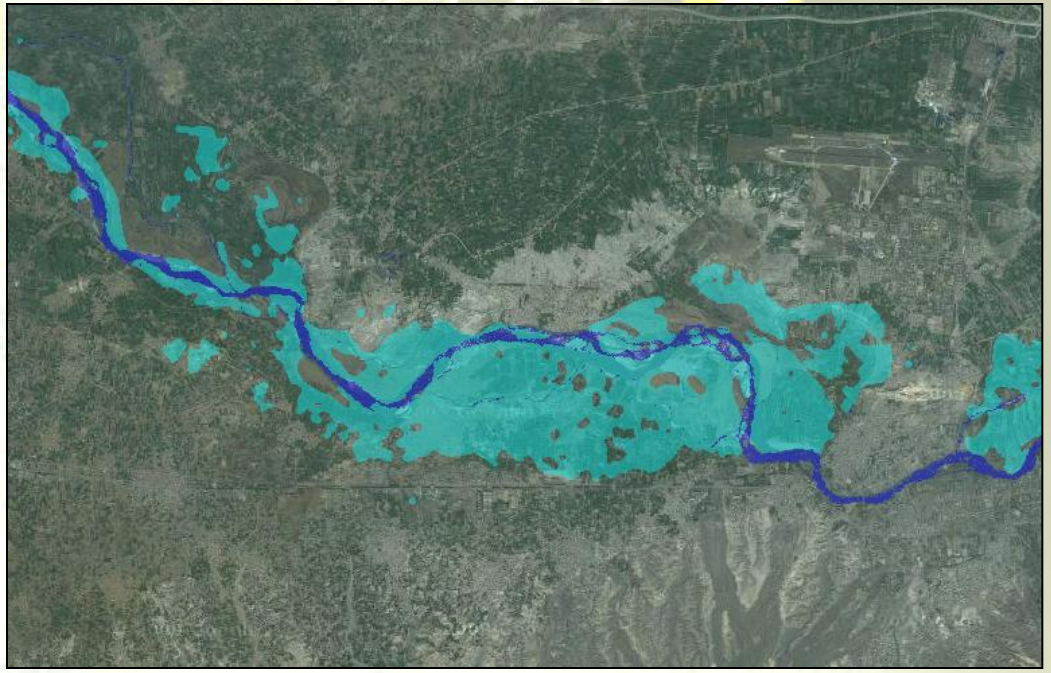
Massaciuccoli_20100101_floodedareas
Massaciuccoli_20091228_20091220_Changemap
Haiti_20100113_geoeye_postevent_2 Pan-shar
Scutar...
0.0 > x NO_Data
1.0 = x 0-0.2
2.0 = x 0.2-0.4
3.0 = x 0.4-0.6
4.0 = x 0.6-0.8
5.1 = x 0.8-1.0
Band selection is 1
ColorMap type is RAMP
ColorMap is not extended
2000 m
ACROTEC
Altitude 31 km Lat 41.9990° Lon 19.4221° Elev 4 meters
SquirrelMail 1.4.15 - ...
Mozilla Firefox
Adobe Acrobat Stan...
owis 200912041610
Microsoft PowerPoi...
IT
1.16

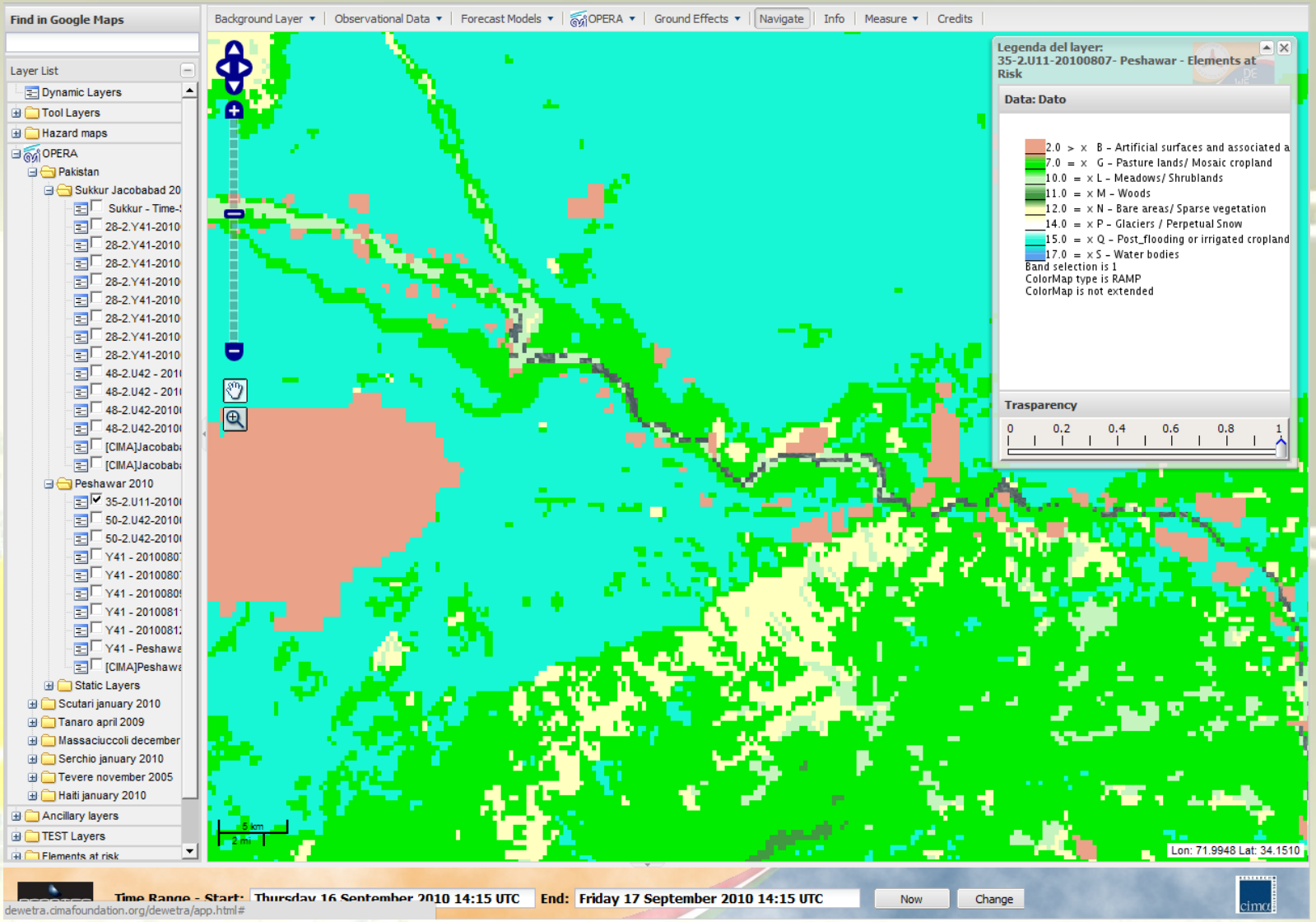
% Damage

A real case-study II: The flooding near Peshawar (Pakistan) from the Kabul River, Aug 2010

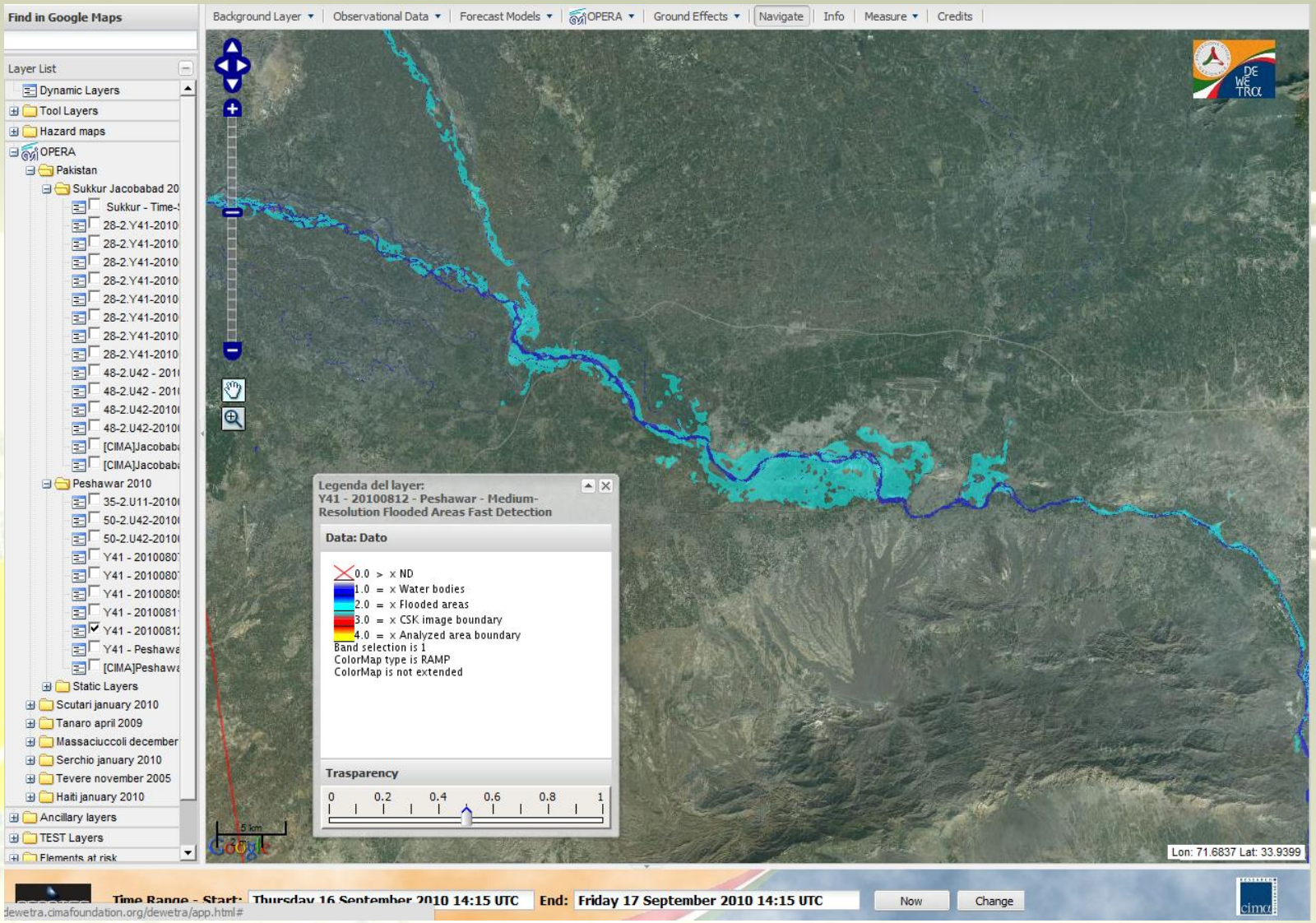
Delivered products:

-Fast-ready flood maps
-Detailed flood maps
-Elements at risk
-Vulnerability map
-Damage maps

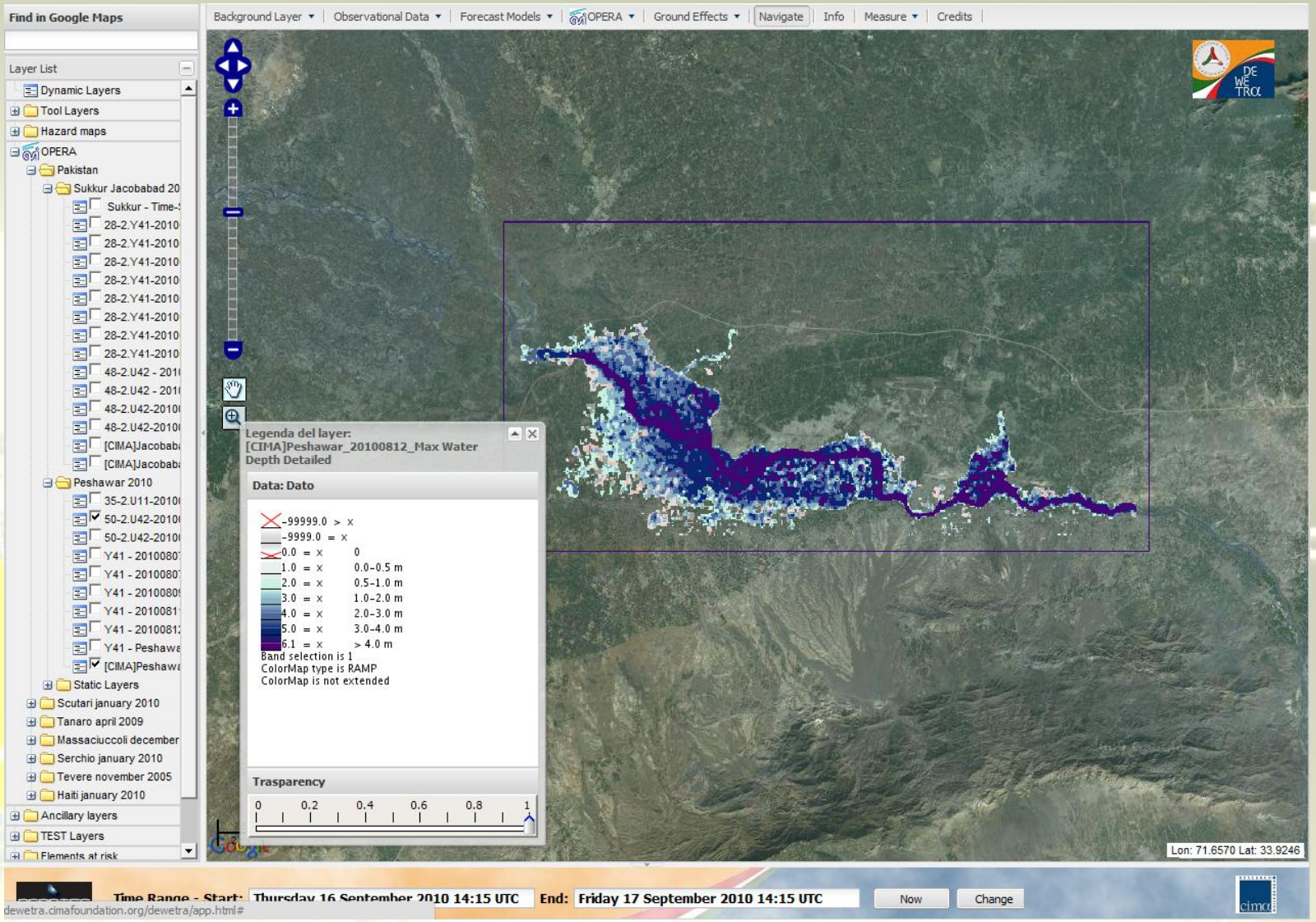




Vulnerability

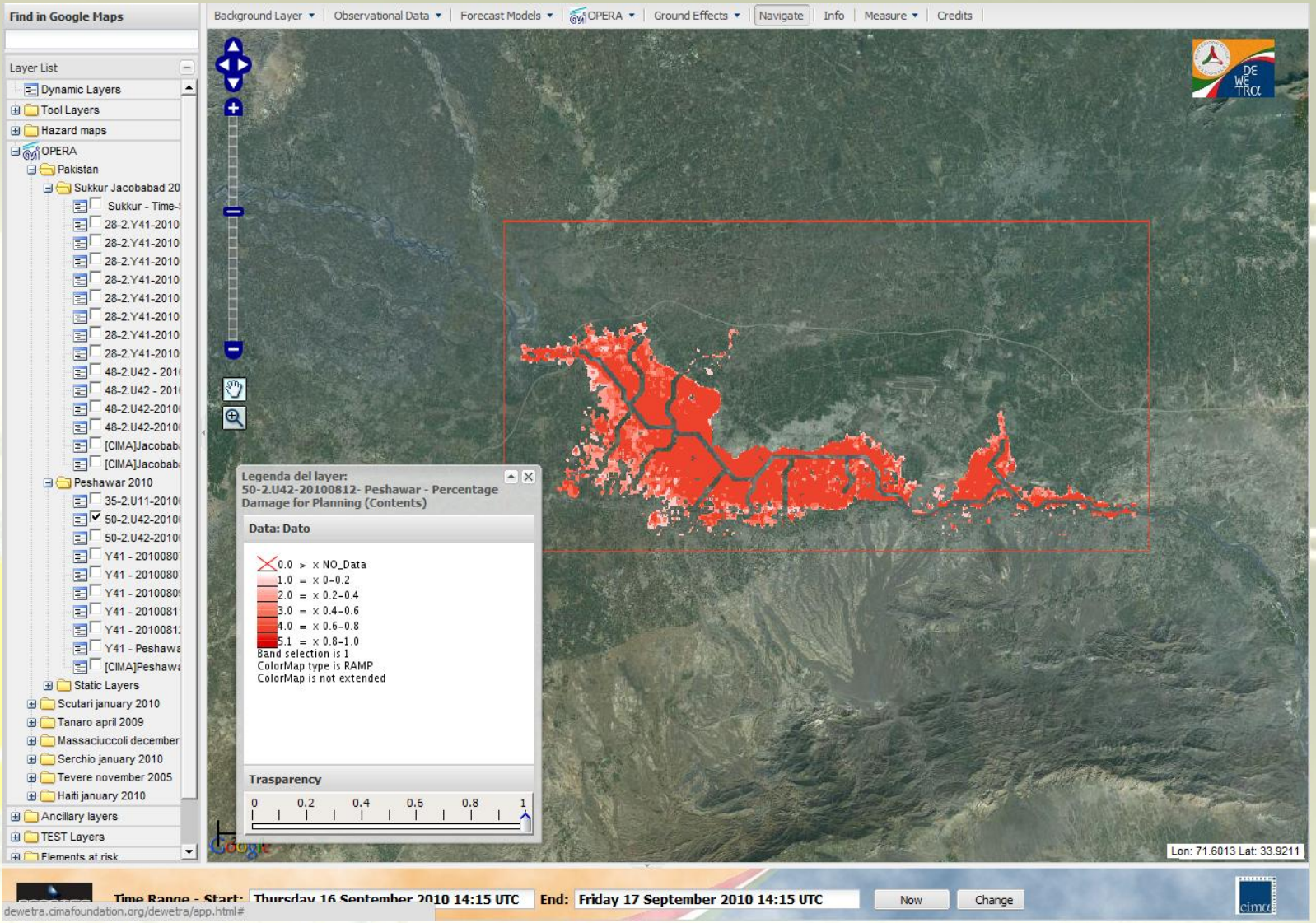


Flood Extent


Find in Google Maps
Background Layer
Observational Data
Forecast Models
OPERA
Ground Effects
Navigate
Info
Measure
Credits
Layer List
Dynamic Layers
Tool Layers
Hazard maps
OPERA
Pakistan
Sukkur Jacobabad 20
Peshawar 2010
Static Layers
Scutari january 2010
Tanaro april 2009
Massaciuccoli december
Serchio january 2010
Tevere november 2005
Haiti january 2010
Ancillary layers
TEST Layers
Elements at risk
Legenda del layer:
[CIMA]Peshawar_20100812_Max Water Depth Detailed
Data: Dato
-99999.0 > x
-9999.0 = x
0.0 = x 0
1.0 = x 0.0-0.5 m
2.0 = x 0.5-1.0 m
3.0 = x 1.0-2.0 m
4.0 = x 2.0-3.0 m
5.0 = x 3.0-4.0 m
6.1 = x > 4.0 m
Band selection is 1
ColorMap type is RAMP
ColorMap is not extended
Trasparency
0 0.2 0.4 0.6 0.8 1
Lon: 71.6570 Lat: 33.9246
Time Range - Start: Thursday 16 September 2010 14:15 UTC
End: Friday 17 September 2010 14:15 UTC
Now
Change
dewetra.cimafoundation.org/dewetra/app.html#

Water Depth

OPERA PROJECT
Protezione civile dalle alluvioni.



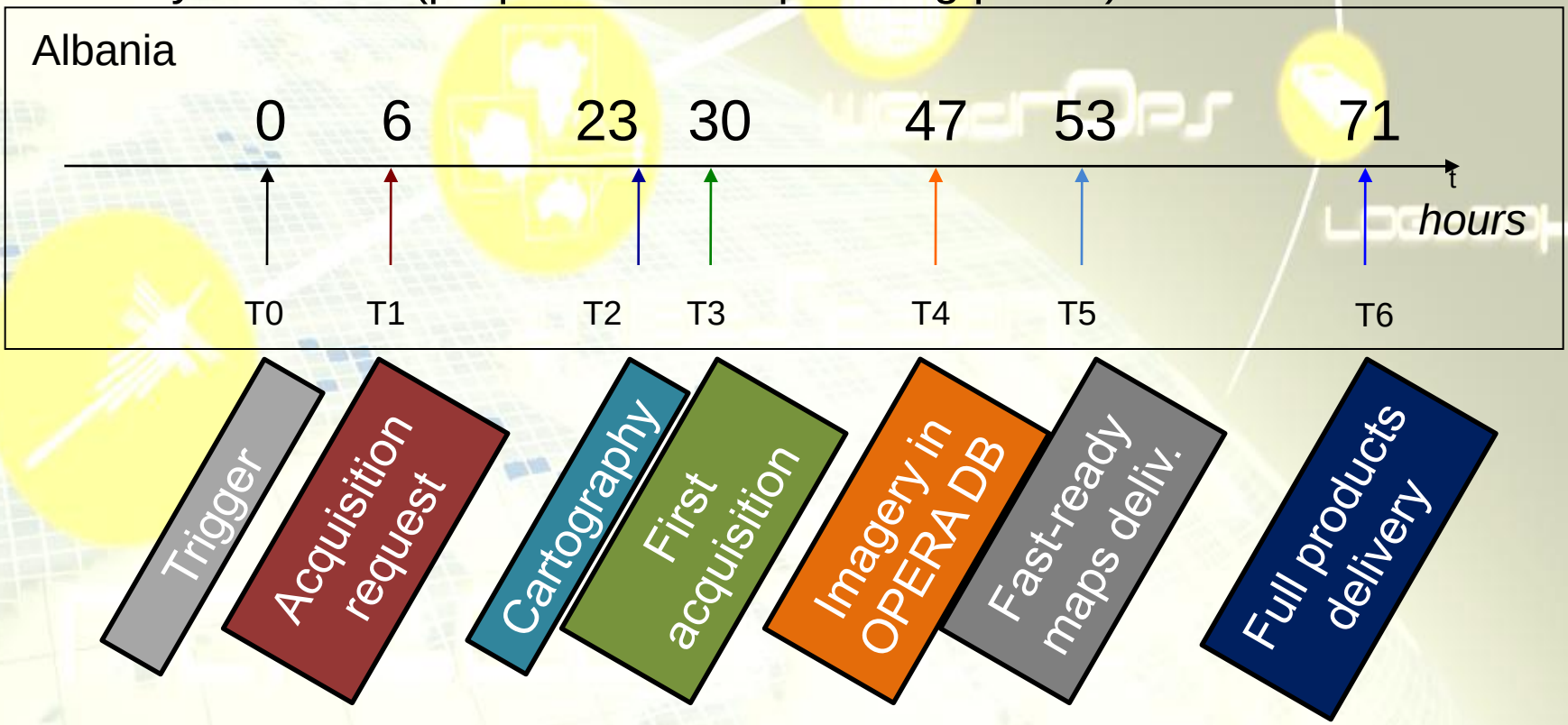
% Damage

Conclusions

- Accuracy of flooded area mapping from good to very good (local surveys from DPC).
- Joint use of imagery and hydraulic modeling strongly increases the informative content of delivered products.
- What needs to be surely improved is timing, but margins for improvements are high given that:

……..

- Upgrade from demonstrative to operational (24/7) would strongly reduce latency in planning of acquisition and automated product delivery (no need for DPC-OPERA team feedback).
- In places with standard monitoring (the Albania and Pakistan evaluation had to start from scratch) local cartography and vulnerability products would be already available (preparation and planning phase).



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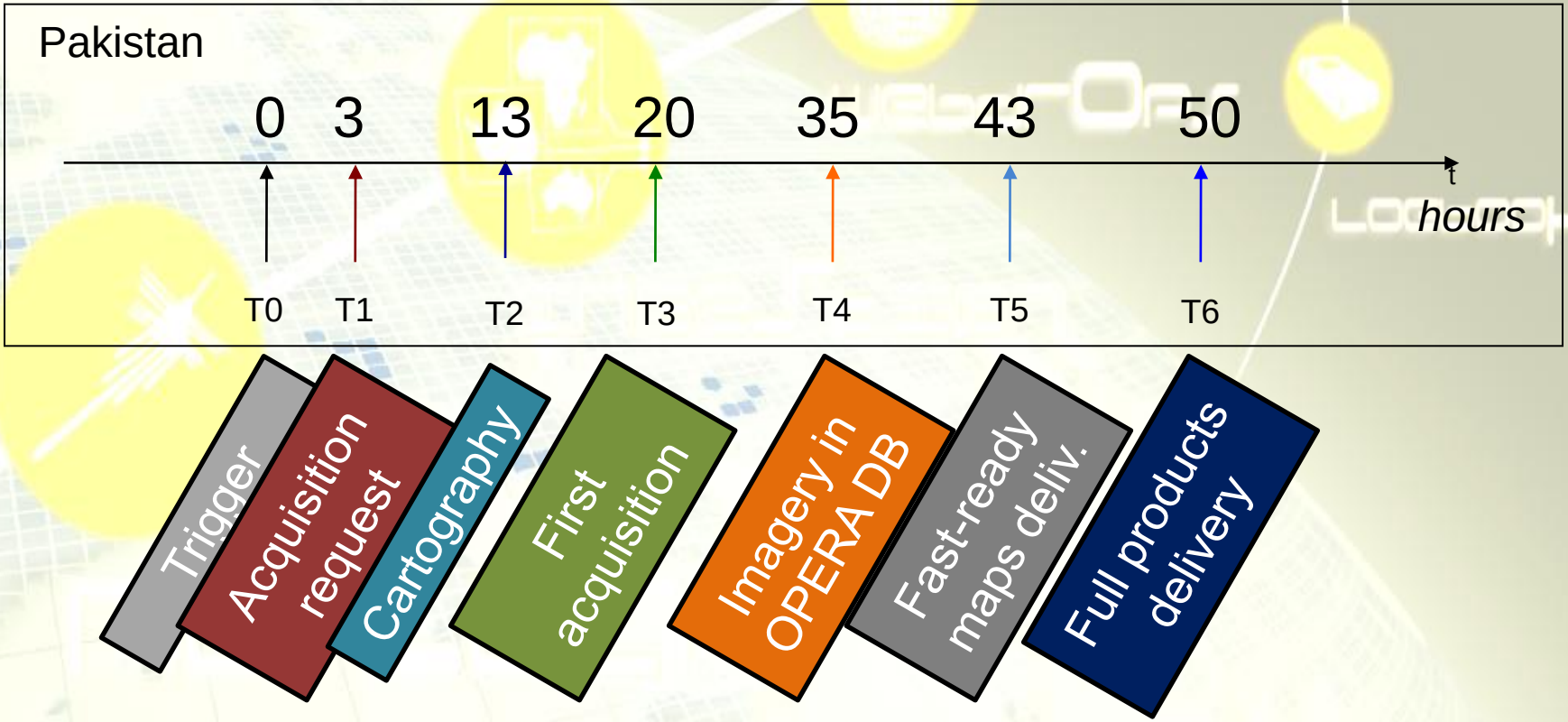

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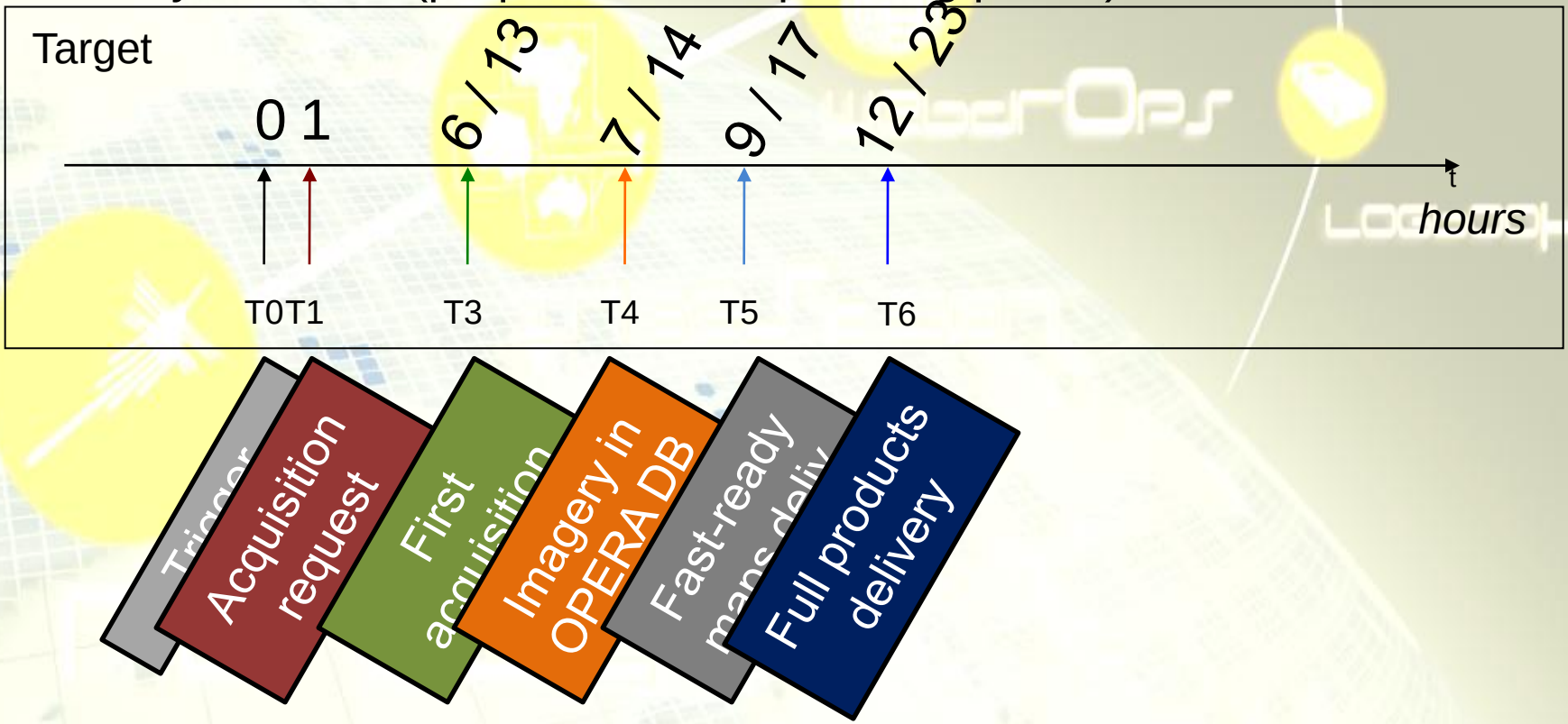

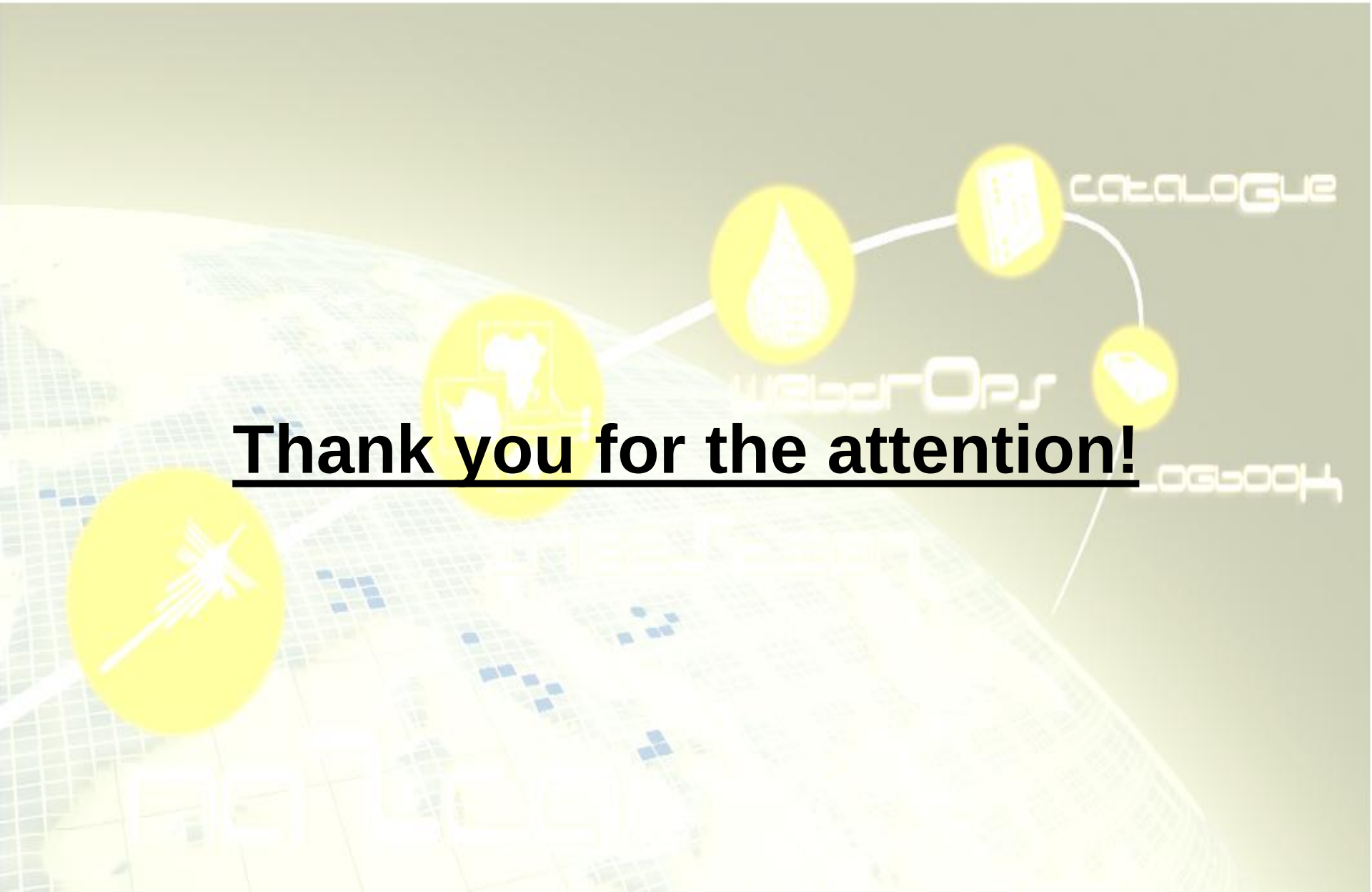
Thank you for the attention!