



Collaborative, Complex and Critical  
Decision-Support in Evolving Crisis

Multi-disciplinary approaches to intelligently sharing large-  
volumes of real-time sensor data during natural disasters

Stuart E. Middleton<sup>1</sup>, Zoheir A. Sabeur<sup>1</sup>, Peter Lowe<sup>2</sup>, Fernando Chaves<sup>3</sup>, Siamak Tavakoli<sup>4</sup>

<sup>1</sup>IT Innovation Centre, University of Southampton, UK

<sup>2</sup>Deutsches Geo-Forschungs-Zentrum - GFZ, Germany

<sup>3</sup>Fraunhofer IOSB, Germany

<sup>4</sup>Queen Mary University of London, UK

[www.it-innovation.soton.ac.uk](http://www.it-innovation.soton.ac.uk)

[sem@it-innovation.soton.ac.uk](mailto:sem@it-innovation.soton.ac.uk)

4<sup>th</sup> September 2011



Co-funded by the European Commission under FP7 (Seventh Framework Programme)  
ICT-2009.4.3 Intelligent Information Management - Project Reference: 258723



# Overview

- Problem statement – Tsunami early warning
- Geo-distributed heterogeneous data sources
- Knowledge-based service architecture
- Research challenges
- Summary

# Problem statement

- Background – Tsunami warning systems
  - Tsunami event in Indian Ocean 2004 prompted the German-Indonesian Tsunami Early Warning System (**GITEWS**) which was deployed in 2008
  - The Distant Early Warning System (**DEWS**) follow-on project (2007 – 2010) employed an Enterprise Service Bus and supported OGC standards
  - The Collaborative, Complex and Critical Decision Support in Evolving Crises (**TRIDEC**) project (2010 – 2012) is continuing this work looking at intelligent support of evolving crises with real-time geo-distributed heterogeneous data sources

# Problem statement



Damages by tsunami: City of Concepcion, Chile imaged on January 10th 2010 (left) and on February 27th 2010 (right) by the RapidEye satellite constellation. The right image was taken eight hours after an earthquake of magnitude 8.8 had occurred and the resulting tsunami had affected the shoreline

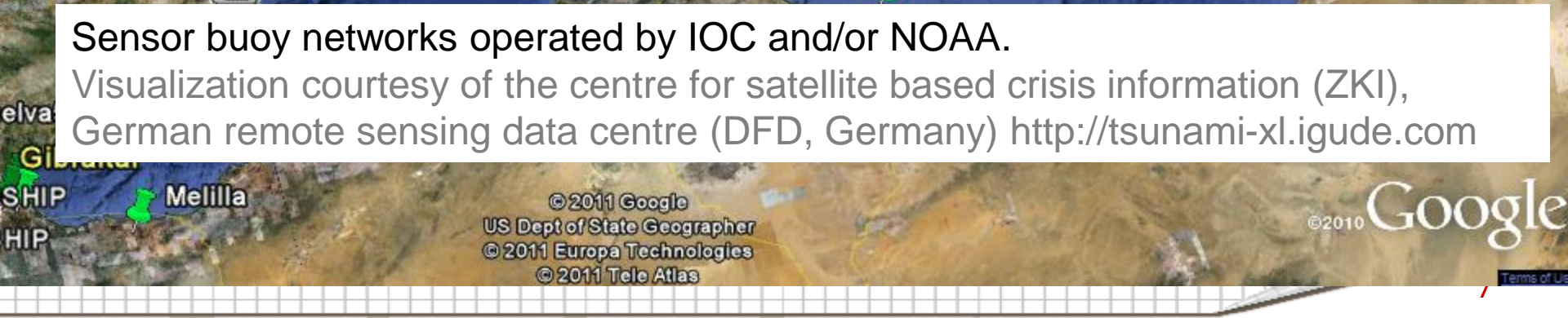
# Problem statement

- Geo-distributed data in Eastern Mediterranean region
  - Regional early warning centres, national early warning centres, user generated content on Web
- Heterogeneous real-time data
  - Sensor systems, satellite images, camera feeds, expert reports, Web 2.0 content (Twitter, You Tube etc.), simulations & models
- Crises evolve over time – so must processing systems!
  - Assess Tsunamigenic properties of earthquake, likelihood of Tsunami, monitor Tsunami progress, Tsunami warning dissemination
  - New data sources & existing sources re-configuration



# Geo-distributed heterogeneous data sources

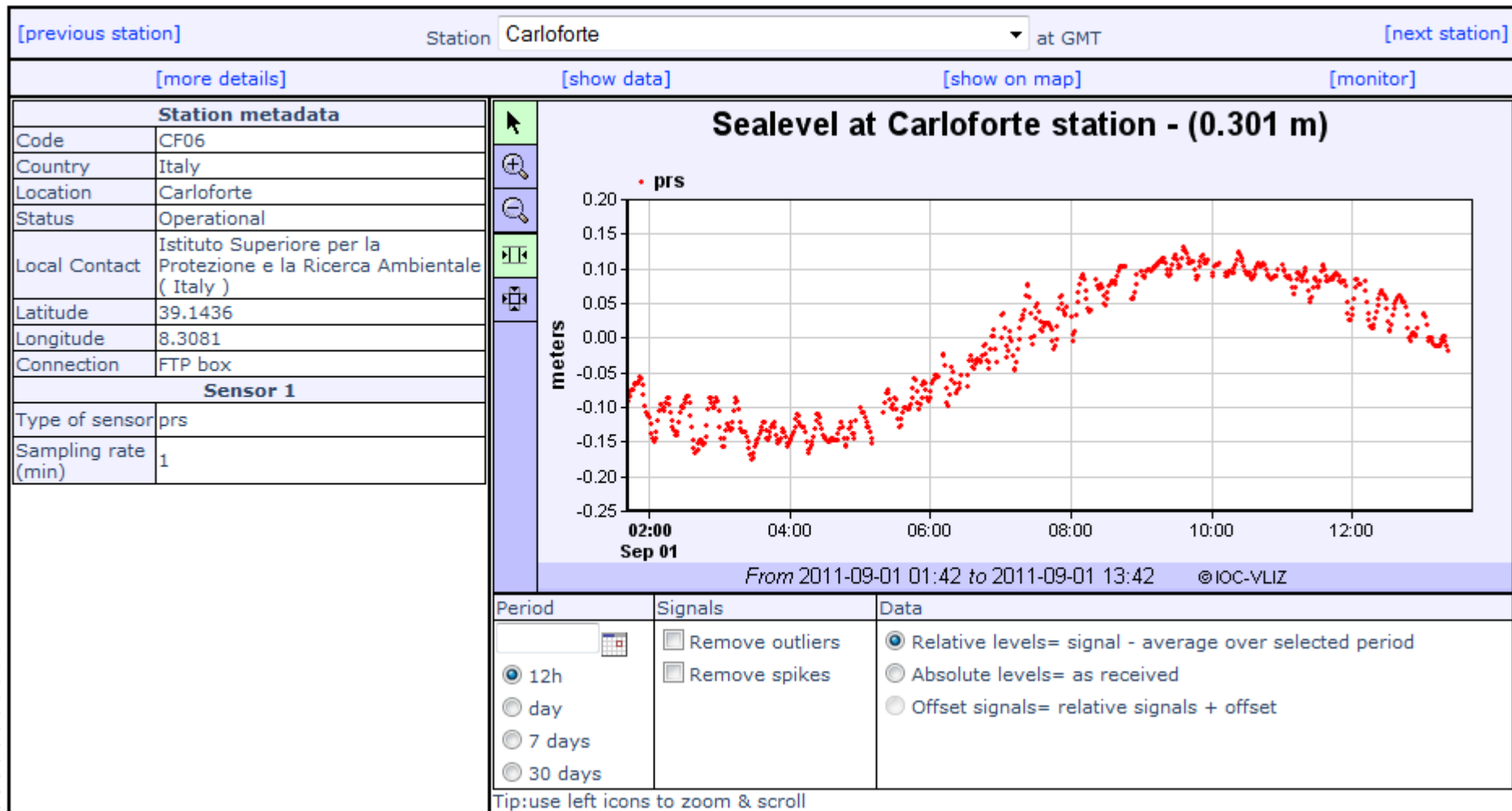
- In-situ sensors [time series]
  - Seismic sensors, Tide gauges, Deep water buoys
  - High quality measurements, configurable, few in number
- Satellite & image data [raster images, video]
  - Satellite imaging, Radar images, Camera footage at coastal sites
- Expert reports, simulations & alerts [text, xml, binary]
  - SeisComp3 earthquake alert messages, Tsunami wave propagation simulations, bathymetry reports etc.
- Web 2.0 content [text, xml, video]
  - Twitter messages, You Tube videos, RSS new stories
  - Variable quality measurements, user generated, many in number



Visualization courtesy of the centre for satellite based crisis information (ZKI),  
German remote sensing data centre (DFD, Germany) <http://tsunami-xl.igude.com>



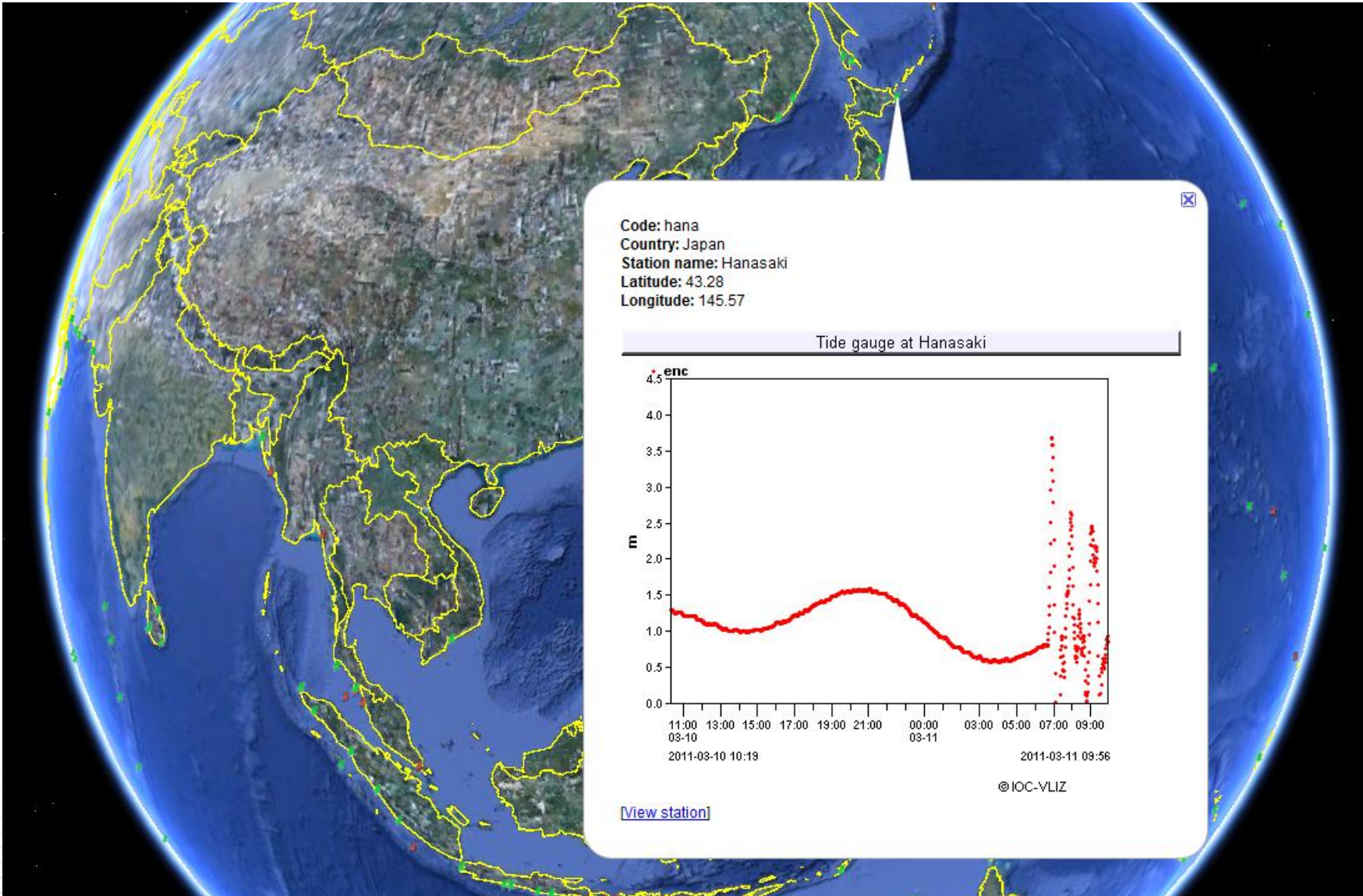
# Geo-distributed heterogeneous data sources



Sea level measurements from a buoy sensor unit.

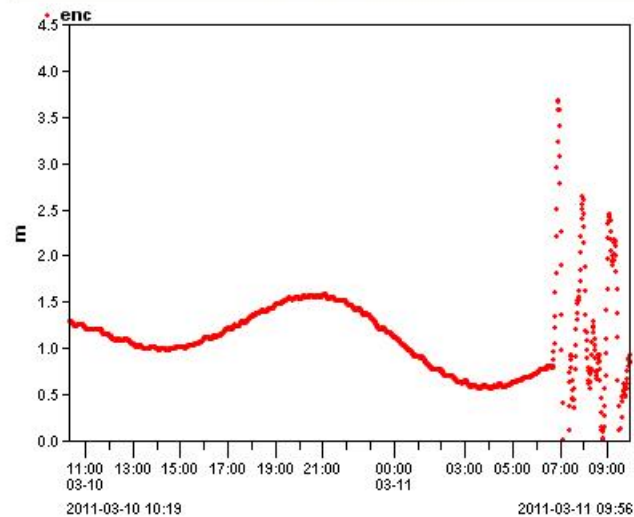
Measurement data courtesy of the on-line sea level station monitoring facility (UNESCO/IOC) <http://www.ioc-sealevelmonitoring.org>





Code: hana  
Country: Japan  
Station name: Hanasaki  
Latitude: 43.28  
Longitude: 145.57

Tide gauge at Hanasaki



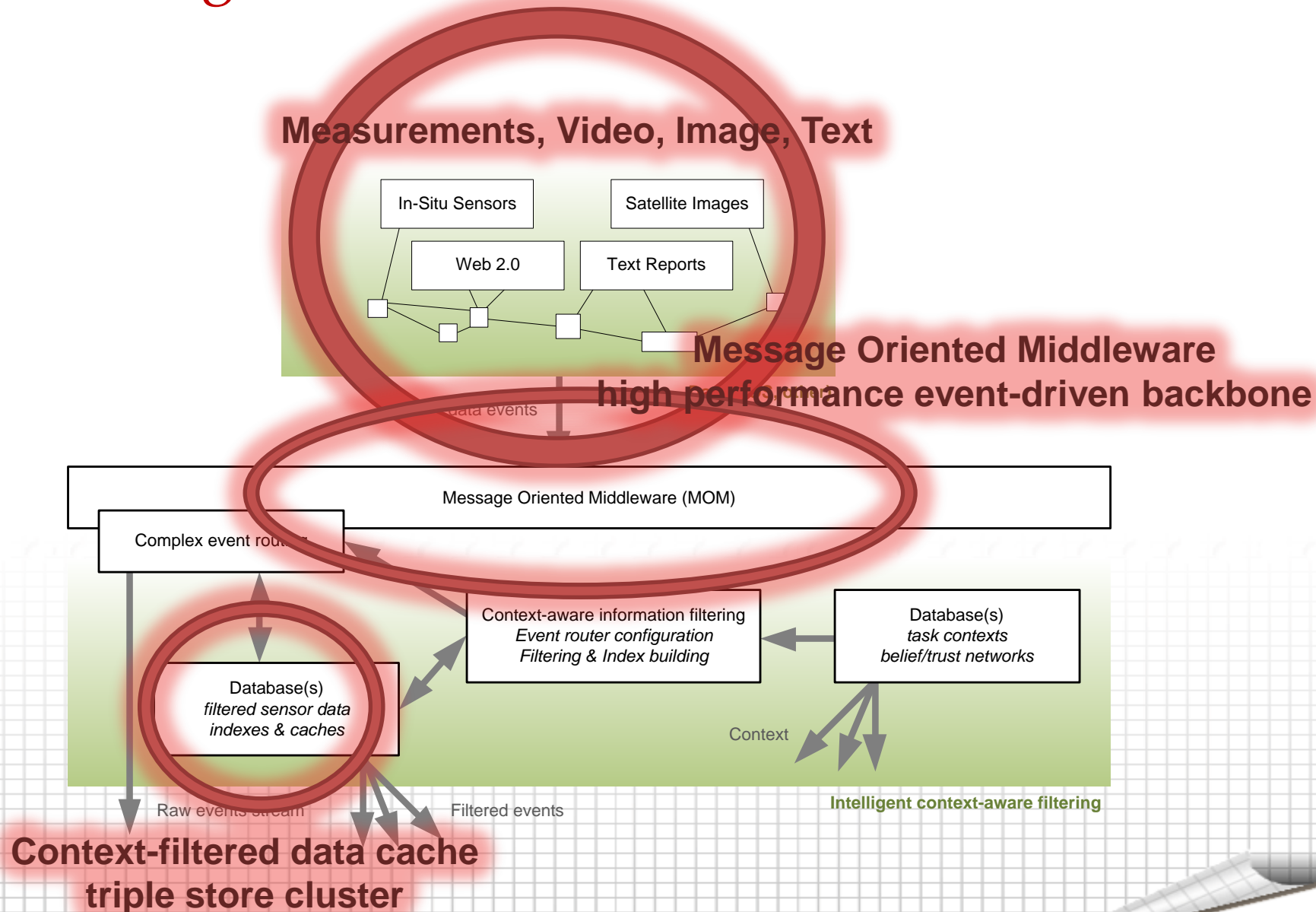
© IOC-VLIZ

[View station](#)

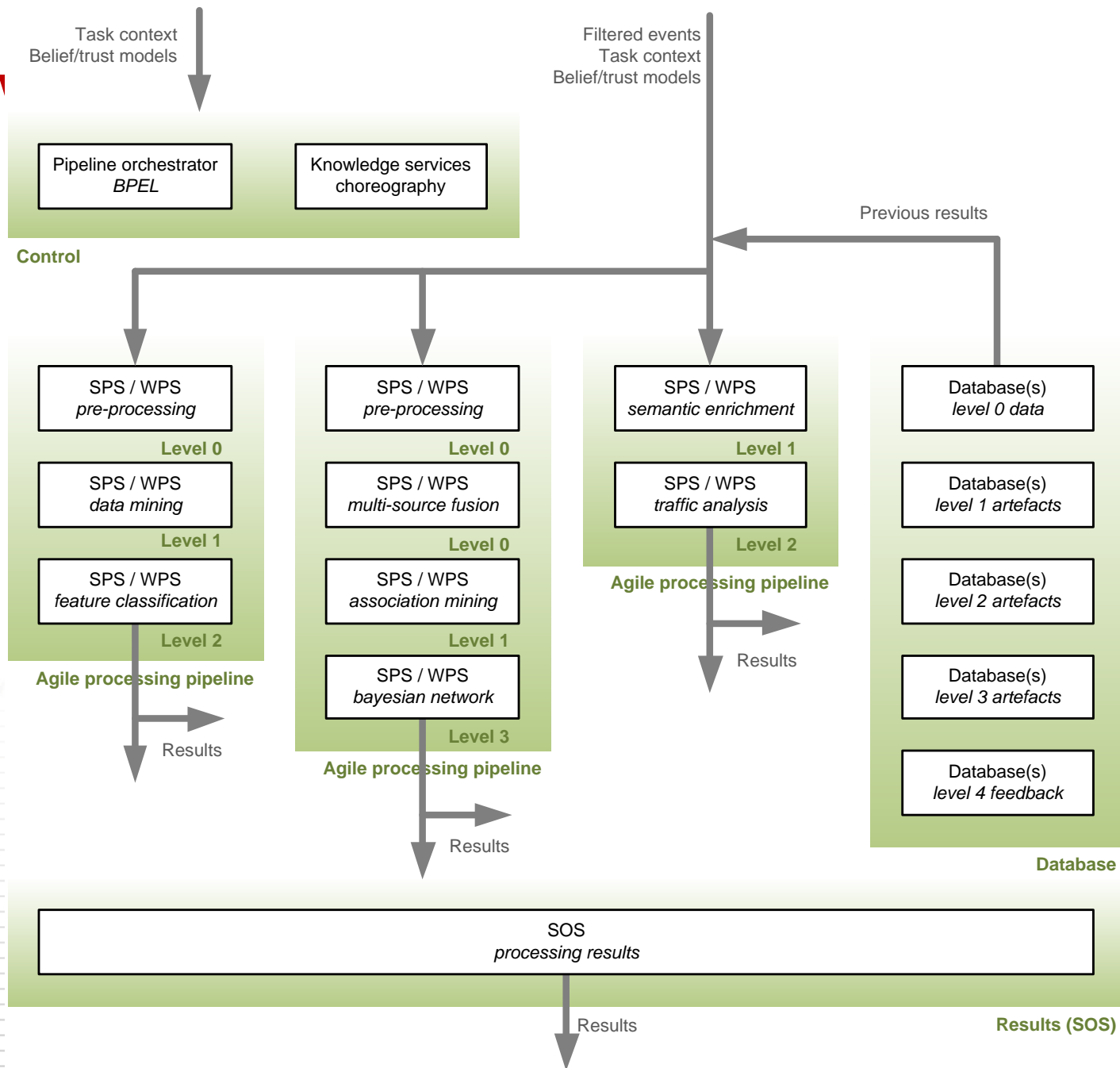
Tsunami event (2011-03-11) tide gauge measurement in passage of the Tohoku  
Measurement data courtesy of the on-line sea level station monitoring facility  
(UNESCO/IOC) <http://www.ioc-sealevelmonitoring.org>

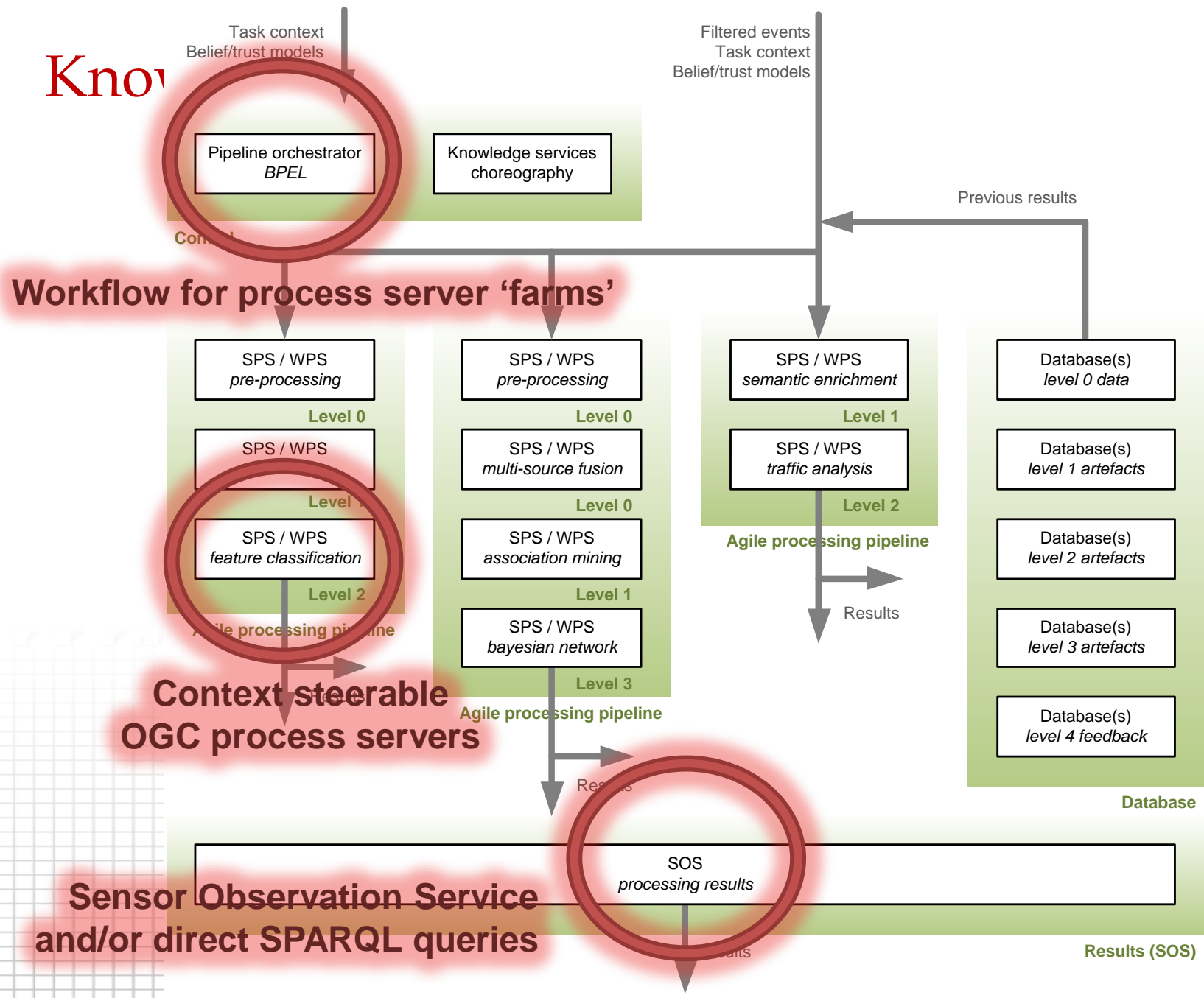


# Knowledge-based service architecture









# Research challenges

- Scalable management of large data volumes
- Semantic interoperability of heterogeneous data
- Agile processing during real-time crises
- Uncertainty management
- Data fusion and mining



# Research challenges

- Scalable management of large data volumes
  - Event-driven backbone (40,000+ messages/sec)
  - Geo-distributed message brokers, fault tolerance
- Semantic interoperability of heterogeneous data
  - W3C & OGC standards, domain ontologies
  - Metadata driven 'plug-in' sensor & data pre-processing
  - Semantic registry & vocabulary mapping
- Agile processing for real-time crises
  - Real-time steerable OGC services to host processes
  - Real-time adjustable BPEL processing workflows

# Research challenges

- **Uncertainty management**
  - Data source accuracy and reliability
  - Trust and belief modelling of data sources
  - Provenance records (data source & subsequent processing steps)
- **Data fusion and mining**
  - Offline and online algorithms creating reports for decision support
  - Explicit semantic level for result data [raw data, features, relationships & situations, impact assessments]
  - Use of feedback and task context to improve accuracy & relevance
  - Uncertainty propagation

# Summary

- Tsunami warning in the Eastern Mediterranean region
- Geo-distributed heterogeneous data sources
  - In-situ sensors, satellite images, video data, expert reports & alerts, web 2.0 content
- Knowledge-based service architecture
  - Scalable event driven messaging backbone
  - Semantic interoperability using W3C & OGC standards
  - Agile processing of data for real-time crises
  - Uncertainty management, data fusion and data mining
- Acknowledgements
  - TRIDE<sup>3</sup>DEC IP FP7-258723 <http://www.tridec-online.eu>



# TRIDEC Partners



- Helmholtz Centre Potsdam GFZ - German Research Centre for Geosciences (*Germany*)  
Centre for GeoInformation Technology
- University of Southampton, IT Innovation Centre (*United Kingdom*)
- Queen Mary and Westfield College, University of London - Department of Electronic Engineering (*United Kingdom*)
- JOANNEUM RESEARCH  
Forschungsgesellschaft mbH - DIGITAL - Institute of Information and Communication Technologies (*Austria*)
- IOSB - Fraunhofer-Institute of Optronics, System Technologies and Image Exploitation (*Germany*)
- TDE Thonhauser Data Engineering GmbH (*Austria*)
- Q-Sphere Limited (*United Kingdom*)
- Instituto de Meteorologia, I.P. - Departamento de Sismologia e Geofísica (*Portugal*)
- Alma Mater Studiorum- Università di Bologna - Department of Physics (*Italy*)
- Bogazici Universitesi - Kandilli Observatory and Earthquake Research Institute (*Turkey*)

