Intelligent Assimilation of Satellite Data into a Forecast Model Using Sensor Web Processes and Protocols

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SMART Project Objectives

- Develop and demonstrate the readiness of Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) technologies
  - Leverage OGC SWE experience of VAST partners to build knowledge and skills among the team
  - Feed back lessons learned and recommendations
- Use SWE protocols and standards to assimilate NASA satellite observations and retrievals into a regional weather forecast model over the southeastern U.S.
  - Prototype a scalable, extensible, reconfigurable and reusable architecture for atmospheric data assimilation
  - Facilitate data assimilation decisions while minimizing any required changes to forecast models
Data Integration Is Complicated

Inter-dependent Data and Processes

- Models & Forecasts
- Subset & Data Mining
- Satellite Data
- Airborne Data
- Surface Data

Manual Data Assimilation Strategy

Case Study Generation
Weather Forecast Model Runs
Sensor Tasking
Decision Support Systems
Sensor Web Enabled Integration

Sensor Web Enabled system eases data integration
- availability, timing, location and intensity

Inter-dependent Data and Processes

- Weather Forecast Model Runs
- Decision Support Systems
- Sensor Tasking
- Case Study

Semi-Autonomous Data Assimilation Strategy

Sensor ML

Aircraft Data

Surface Data

Derived Mined Data

Sat. Data
OGC Sensor Web Enablement (SWE) standards provide specifications for interfaces, protocols and encodings that are designed to enable implementation of interoperable, service-oriented networks of sensors and applications.

- Standard interfaces to sensor data can minimize the custom software required for management, visualization and analysis of different types of sensors and observations.

**SWE services implemented for this project include:**

- **Sensor Observation Services (SOS):** web service interface for requesting, filtering and retrieving sensor system information and observations
- **Observations and Measurements (O&M) Schema:** an XML schema for encoding sensor data objects
- **Sensor Alert Services (SAS):** web service interface for advertising, publishing and subscribing to alerts from sensors
- **Sensor Model Language (SensorML):** an XML schema for describing a functional model of a sensor system and related processes. Multiple processes can be combined with SensorML to form an executable process chain.
Problem/ Challenge
Assimilation of satellite observations such as AIRS can improve forecasts, but is computationally expensive.

- Swath coverage, storm position, data volume and availability all constrain assimilation decisions.
- SMART Assimilation: select only AIRS profiles that will have greatest impact – those that are co-located with significant weather.
SMART Assimilation of AIRS Data into a Weather Forecast Model

Event Identification

Data Access
- NAM forecast @ T1
- AIRS data

SensorML Process Chain
- SOS Client
- Phenomena Extraction Algorithm
- Event Filters
- SAS Client
- Satellite Footprint Intersection
- SensorML
- SOS adapter
- SOS

Send Alert w/:
- Region
- Time
- Phenomena

Notify modelers of WRF analysis

ARPS Data Analysis System

Data Assimilation for Models

SWE Interface components
- Processing components
- External components (data sources, models)

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Data Access Subsystem

- Data products acquired in near real time and made available by Sensor Observation Services

- SOS provides a standard access interface to data products
  - Can subset the data by parameter, as well as spatial and temporal range.
  - Converts data from native format to O&M format with either ASCII or Binary attachment.
Event Identification Subsystem (1)

Event Identification

SensorML Process Chain

SOS Client → Phenomena Extraction Algorithm → Event filters → Satellite Footprint Intersection → Satellite Footprint Prediction

SAS Client → SOS → Event filters

Send Alert with:
- Region
- Time
- Phenomena

Mine NAM forecasts for weather events and determine if coincident AIRS data is available

SensorML Process Chain

- Retrieves and mines NAM forecasts
- Leverages earlier data mining research for *Phenomena Extraction Algorithm*. Initially configured to detect low pressure systems:
  - relatively easy to detect in NAM forecasts
  - valuable in deciding whether to assimilate AIRS data
- *Event Filters* distinguish low pressure from high pressure systems
Sensor Observation Services

- **Satellite Footprint Prediction SOS** uses SensorML to determine satellites’ locations and instruments’ footprints at any given time.
- **Satellite Footprint Intersection SOS** determines whether a given instrument footprint intersects a specified spatio-temporal region of interest.
**Event Identification Subsystem (3)**

**Event Identification**

- **SOS Client**
- **Phenomena Extraction Algorithm**
- **Event filters**
- **Satellite Footprint Intersection**
- **SAS**
- **SOS adapter**
- **SOS**

**SensorML Process Chain**

1. NAM from Data Access Subsystem
2. Alert to Data Assimilation Subsystem

**Sensor Alert Service**

- Event filters publish weather “Phenomena” alerts
- SAS-SOS adapter queries the Satellite Footprint Intersection SOS for AIRS overpasses coincident with identified weather events
- SAS publishes “Phenomena / AIRS Intersection” alerts
Data Assimilation Subsystem

SensorML Process Chain

1. Triggered by a “Phenomena/AIRS Intersection” alert from the Event Identification SAS
2. SOS client retrieves the AIRS data
3. AIRS preprocessor translates AIRS data into the ASCII format required by the ADAS assimilation process
4. ADAS produces the analyses used to initialize the regional WRF model runs at SPoRT

A Web Notification Service (WNS) can broadcast the availability of each new ADAS analysis to the interested community
**Sensor Alert Services - Overview**

- An SAS is a registry for cross referencing different types of alerts and their subscribers
  - Not in itself an event notification system
  - Sensors advertise capabilities and publish alerts
  - Users subscribe to and listen for alerts

- SMART is leveraging the SAS package from 52°North
  - XMPP implementation – alerts are communicated via Multi-User Chat spaces (MUC)
  - Modified by SMART team to make it possible to send geographical information (i.e., bounding box) in an alert
SAS Interfaces

1. Advertise
2. PublicationID, MUC
3. Join MUC
4. Publish

SAS Interfaces

1. GetCapabilities
2. SubscriptionOfferings
3. Subscribe (sensorID)
4. MUC
5. Join MUC
6. Receive Alerts

Phenomena alert (event bbox, time window, phenomenon)

Satellite Footprint Intersection SOS

Phenomena/AIRS intersection alert (event bbox, time window, phenomenon, AIRS region, AIRS time window)

PEA Event filters

SAS client

XMPP

AIRS Pre-processor

SAS Listener

AIRS Intersection SOS Adapter

MUC

MUC

MUC

MUC
Year 2 Science Scenario Definition:
SMART Assimilation of AIRS Data into a Weather Forecast Model

Data Access
- NAM forecast @ T1
- AIRS data

SensorML Process Chain
- SOS Client
- Phenomena Extraction Algorithm
- Event Filters
- SAS client

SMART Server
- SOS Client
- SAS Pre-processor
- AIRS Pre-processor
- WNS
- ARPS Data Analysis System
- WRF Model Forecast @ T2

VAST Server
- Satellite Footprint Intersection
- SensorML
- SOS
- Listener
- Notify modelers of WRF analysis

SPoRT Server
- Satellite Footprint Prediction
- SensorML
- SOS

Event Identification
- Send Alert w/:
  - Region
  - Time
  - Phenomena

Data Assimilation for Models

Legend:
- SWE Interface components
- Processing components
- External components (data sources, models)
Lessons Learned (1)

Because SWE technologies are continuing to evolve, various SWE components must be upgraded and tested as new versions of standards are approved (e.g., SOS 1.0)

- It can be difficult to balance exploration of evolving technology developments against need to build stable demonstration applications
- If upgrades are not carefully coordinated, distributed applications will break
- Upgrades to new standards must be factored into the overall project schedule in order to meet milestones.
Lessons Learned (2)

Reference implementations of many OGC SWE technologies are available
- Oceans Interoperability Experiment is developing reference SOS implementations and cookbooks for in situ sensor platforms such as buoys.
- SMART has been successful in adapting SAS from 52°North
- New projects must take time to discover what is available and take advantage of existing work

Science/IT collaboration is critical to an advanced technology project such as SMART.
- A team comprising both scientists and software engineers will result in a more scientifically viable, real world result than a team of only scientists or only software engineers.