Air Quality & Health Scenario Engineering Report
GEOSS Architecture Implementation Pilot

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</tbody>
</table>

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Air Quality & Health Scenario

1. Introduction

1.1 Scope of this document

This Engineering Report describes how the Air Quality Workgroup used and tested the GEOSS Common Infrastructure (GCI) in order to register, discover, and access datasets relevant to air quality management during AIP Phase 3. The air quality data used in working with the GCI during AIP-2 were OGC WMS, WCS and SOS services.

1.2 GEOSS AIP

The GEOSS Architecture Implementation Pilot (AIP) task develops process and infrastructure components for the GCI and the broader GEOSS architecture as a means of coordinating cross-disciplinary interoperability deployment. The AIP Task provides phased delivery of components to GEOSS operations, with each phase consisting of: architecture refinement based on user interactions; component deployment and interoperability testing; and SBA-focused demonstrations.

This Engineering Report (ER) is a key result of the second phase of AIP. AIP-3 was conducted from January 2010 to December 2010. A separate ER describes the overall process and results of AIP-3 and thereby provides a context for this Community SBA ER.¹

1.3 Summary of SBA development

During AIP-3, the Air Quality & Health SBA refined the air quality community infrastructure and developed implementation scenarios focused on using sensor observation services and web processing services. The observation and processing services involved multiple OGC SOS services and clients for accessing, spatially interpolating, and visualizing air quality related measurements from ground-based monitoring networks.

1.4 Future work

The Air Quality & Health Workgroup during AIP-2 centered on OGC WMS and WCS services. In AIP-3, the focus was on OGC SOS and WPS services. The result is experience with a range of data access and processing services that would benefit from an integrated examination as applied to air quality and health use cases and scenarios. Future work along these lines could include:

- Improving registration of metadata for WCS, SOS and WFS services through community catalogs
- Improving the ability to use services was they are discovered through the GCI
- WPS and SOS implementations and registration with GCI
- More data services. Other services were provided during AIP-3 but were not included in demonstration scenario. A future AIP would be an opportunity to tie together multiple services and components being made available across the air quality and health communities.

2. Community SBA Objectives

The SBA objectives in AIP-3 were based on the generic air quality scenario² developed during the AIP-2 RFP.

This scenario describes how air quality and related earth observations could be used to inform a wide spectrum of decision making; it is structured around three types of decision-making end users:

1. A policy-maker, needing synthesized information on the importance of intercontinental pollutant transport
2. An air quality compliance manager, who needs to assess whether a regional pollution event was due to an "exceptional event"
3. The public, needing information about air quality now and in the near future to make activity decisions

¹ A listing of all AIP-3 Engineering Reports: http://www.ogcnetwork.net/AIP3ERs
² http://wiki.esipfed.org/index.php/GEOSS_AIP_AQ_Scenario
In general, the scenario envisions GEOSS facilitating two broad goals: building connections to facilitate movement of data between actors, and developing interoperable tools for intercomparison and fusion of a wide variety of atmospheric data. A number of the actors in the scenario have overlapping roles, and in reality the same individuals will serve several downstream decision makers. In fact, the common need for integrated atmospheric observations is a primary motivation for the structure of this scenario.

The overall objective of the AQ Workgroup during AIP-2 was to test and evaluate the GEOSS Common Infrastructure (GCI) from the perspective of the air quality community and, in the process, define an initial AQ Community Infrastructure that connects with the GCI to share, find, and use distributed data, visualization and analysis services. There are numerous Earth Observations that are available and, in principle, useful for air quality applications such as informing the public and enforcing AQ standards. However, connecting a user to the right observations or models is accompanied by an array of hurdles. The GEOSS Common Infrastructure allows the reuse of observations and models for multiple purposes.

The goal of the AIP-3 for the AQ&H Community is to make better use of data and information from a variety of sources in order to support science, management and other decision-making processes. In particular, the AIP-3 effort focused on spatially interpolating air pollution concentration point measurements to gridded coverages for use by air quality researchers and public health scientists.

3. Scenario A: European Air Quality Measurements Interpolation

3.1 Actors

In order to successfully support decision making of politicians working on air quality policies, scientists prepare air pollutant estimates calculated from measurements gathered by a sparse network of air quality monitoring stations. Depending on the number of monitoring stations available and the interpolation method chosen, the estimates suffer a bigger or smaller estimation error.

This scenario provides an example (i) how a scientist uses interpolation to estimate the concentration of air pollutants in an administrative area a certain politician is responsible for and (ii) how the resulting estimation error can be communicated to improve decision making. Therefore, the following two actors have been identified:

- Politician: Policy maker preparing an agreement with industry to enhance the air quality in his administrative area.
- Scientists: Is asked by the politician to provide estimates of the concentration of air pollutants in the area of interest.

3.2 Context and pre-conditions

Data providers create standards-based services to their data and register those services with the GEOSS AQ Community Catalog, thereby making those services accessible via GEOSS Clearinghouses. Data analysts and air quality managers find and access those services via GEOPortals or AQ Community Portal for subsequent use analyses. The available services are tested to ensure they are active and that they comply with the relevant standards so that they can be reliably used with visualization and analysis tools.

Information Needs:

- SOS compliant air quality observation data gathered from monitoring stations
Table 1 – Pre-condition Steps in the European Air Quality Measurements Interpolation Scenario

<table>
<thead>
<tr>
<th>Steps</th>
<th>Description</th>
<th>Trans. Tech Use Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Register AQ Community Catalog</td>
<td>#1 Register Resources</td>
</tr>
<tr>
<td>1</td>
<td>Register SOS providing the air quality observations in AQ Community Catalog</td>
<td>#1 Register Resources</td>
</tr>
<tr>
<td>2</td>
<td>Register WPS providing interpolation methods in AQ Community Catalog</td>
<td>#1 Register Resources</td>
</tr>
</tbody>
</table>

3.3 Scenario Events

A growing amount of air quality observations is available via standardized web service interfaces such as SOS and, in principle, useful for air quality applications such as informing the public and enforcing AQ standards. However, connecting a user to the right observations or models is accompanied by an array of hurdles. The GEOSS Common Infrastructure allows the reuse of observations and models for multiple purposes.

The cyberinfrastructure envisioned by this scenario will enable analysts to combine wide range of air quality observations with interpolation methods provided by processing web services which will ultimately be used to produce a broad range of decision support products for a number of different audiences. A special focus of the scenario is the communication of the interpolation error which is often not considered when using the estimates to support decision about policies.
Table 1 – Steps in the European Air Quality Measurements Interpolation Scenario

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Trans. Tech Use Case</th>
<th>Specialized Use Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Scientist uses IP3 client application to submit a query to the IP3 Mediation Service and discover the presence datasets in SOS for the pollutant of interest.</td>
<td>#04 Client Search Metadata</td>
<td>Depending on the available metadata and search capabilities, different search specializations are possible (e.g. search on keywords, spatial extent, temporal extent, spatio-temporal extent, etc.)</td>
</tr>
<tr>
<td>1</td>
<td>IP3 Mediation Service mediates the query request distributing it to the Air Quality Community Catalog.</td>
<td>#06 Interact with Services</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Scientist browses SOSs returned by the query and selects one SOS.</td>
<td>#05 Presentation of reachable Services &amp; Alerts</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Scientist searches for interpolation services by using keywords.</td>
<td>#04 Client Search Metadata</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>IP3 Mediation Service mediates the query request distributing it to the Air Quality Community Catalog.</td>
<td>#06 Interact with Services</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Scientist browses WPSs returned by the query and selects one WPS.</td>
<td>#05 Presentation of reachable Services &amp; Alerts</td>
<td>Depending on the available metadata and search capabilities, different search specializations are possible (e.g. search on keywords, spatial extent, temporal extent, spatio-temporal extent, etc.)</td>
</tr>
<tr>
<td>6</td>
<td>Scientist creates WPS request by using the URL of the selected SOS and specifying the interpolation method and its parameters in the client application.</td>
<td>#06 Interact with Services</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Scientist executes interpolation through the client application.</td>
<td>#06 Interact</td>
<td></td>
</tr>
</tbody>
</table>
and retrieves the results.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>As the resulting value surface is interpolated and thus contains estimates, each value has an associated interpolation error. To decide, whether the values are usable, scientist visualizes also the error probability.</td>
<td>#07 Exploit Data Visually and Analytically</td>
</tr>
<tr>
<td>9</td>
<td>Scientist uses results to inform politician about air quality in her area of interest.</td>
<td>#07 Exploit Data Visually and Analytically</td>
</tr>
</tbody>
</table>

### 4. Scenario B: North American Air Quality Measurements Interpolation

#### 4.1 Actors

Air quality researchers and scientists who need ambient measurement/observation data. These actors also need methods for being able to combine the measurement/observation data with other information sources in order to conduct integrated analyses and assessments.

#### 4.2 Context and pre-conditions

Air quality data providers create standards-based services to their data and register those services with the GEOSS AQ Community Catalog, thereby making those services accessible via GEOSS Clearinghouses. Data analysts and air quality managers find and access those services via GEOPortals or the AQ Community Portal for subsequent use and analyses. The available services are tested to ensure they are active and that they comply with the relevant standards so that they can be reliably used with visualization and analysis tools. In general, Air Quality actors will have the following information and collaboration needs that include the functionality described in this scenario.

**Information Needs:**

- meteorological data, such as observations from ground-based networks, satellites, radiosondes, and forecasts from numerical models at various scales
- geographical data (land use, demographics, emissions-related activity, etc.)
- atmospheric composition (air quality) observations such as surface monitoring networks, satellite observations, radiosondes, ground-based remote sensors, and aircraft measurements
- numerical air quality chemical transport models (at regional to global scales)
- WMS compliant data services providing data/visualization that can be cataloged through Community Catalogs and accessed through Community Portals.
- WCS compliant data services providing data that can be cataloged through Community Catalogs and accessed through Community Portals
- SOS compliant data services providing access to environmental sensor data
- WPS compliant data services providing access to a variety of processes, including spatial interpolation

**Collaboration Functionality Needs:**

1. Service (WMS, Catalog, WCS, SOS, WPS) clients that can visualize service responses (SensorML, O & M, GML, etc.) and interact with end users as well as being able to be embedded in AQ portals.
2. Functionality for standard-based access to spatio-temporal data and metadata, and workflow software for service orchestration
3. WAF/CSW-compliant Community Catalog(s) for registering data and services to be harvested by the GEOSS Clearinghouse
4. AQ JSR268 Compliant Community Portal(s) for finding, accessing the data and services needed for the execution of the scenario,
5. Community of Practice Workspace(s) where the actors in the scenario can communicate and coordinate their activities.

4.3 Scenario Events

An Air Quality scientist wishes to perform spatial interpolation of air quality measurements for a given time and region in North America. The scientist performs a series of steps to discover a data access web service that offers air quality measurements and a processing web service that offers the ability to spatially interpolate measurement data. When the scientist has discovered services that meet his or her needs, the scientist, using available software, issues a request to the data access web service to retrieve measurement data. The scientist views the measurement data in his or her client application and decides to interpolate it. The scientist provides the data to the processing service offering interpolation, and the processing service returns the results. The scientist views the interpolation results and looks for outlying measurements. The following table describes this series of steps in more detail.

**Table 3 – Steps in the North American Air Quality Measurements Interpolation Scenario**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Trans. Tech Use Case</th>
<th>Specialized Use Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB-PD-01.</td>
<td>Discovery of Sensor Observation Service (SOS) offering air quality measurement data and WPS offering kriging interpolation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Associated Steps</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td>01.1</td>
<td>Scientist uses client application to submit a query to the IP3 Mediation Service and discover the presence of SOS services offering air quality measurements.</td>
<td>6: Interact with Services</td>
<td></td>
</tr>
<tr>
<td>01.2</td>
<td>IP3 Mediation Service mediates the query request, distributing it to the Air Quality Community Catalog.</td>
<td>4: Search for Resources 6: Interact with Services [discovery]</td>
<td></td>
</tr>
<tr>
<td>01.3</td>
<td>Scientist browses the list of SOSs returned by the query and selects the SOS that meets his or her needs.</td>
<td>5: Presentation of Reachable Services &amp; Alerts</td>
<td></td>
</tr>
<tr>
<td>01.4</td>
<td>Scientist searches for interpolation services by using keywords.</td>
<td>6: Interact with Services</td>
<td></td>
</tr>
<tr>
<td>01.5</td>
<td>IP3 Mediation Service mediates the query request, distributing it to the Air Quality Community Catalog.</td>
<td>6: Interact with Services</td>
<td></td>
</tr>
<tr>
<td>01.6</td>
<td>Scientist browses WPSs returned by the query and selects one WPS.</td>
<td>5: Presentation of Reachable Services &amp; Alerts</td>
<td></td>
</tr>
<tr>
<td>01.7</td>
<td>Scientist uses the client application to issue a GetObservation request to the Air Quality SOS for air quality measurements within the time period/region of interest. The request specifies an appropriate coordinate reference system in the srsName parameter and an appropriate resultModel in order to ensure interoperability with the WPS (this will be discussed later).</td>
<td>6: Interact with Services</td>
<td></td>
</tr>
<tr>
<td>01.8</td>
<td>Air Quality SOS returns observations that meet the specified criteria.</td>
<td>6: Interact with Services</td>
<td></td>
</tr>
<tr>
<td>01.9</td>
<td>Scientist views the returned observations in his or her client application.</td>
<td>7: Exploit Data</td>
<td></td>
</tr>
</tbody>
</table>

**AQH-D-02. Interpolation of air quality observations**
02.1. Scientist creates WPS request by using the returned observations from step 01.8 and specifying the interpolation method and its parameters in the client application

02.2. Scientist executes interpolation through the client application and retrieves the results.

02.3. As the resulting value surface is interpolated and thus contains estimates, each value has an associated interpolation error. To decide whether the values are usable, scientist visualizes the error probability interpolation in addition to the mean interpolation values.

02.4. The interpolation results help to visualize outlying measurement data and patterns in the measurement data. The scientist analyzes the interpolation results, using the results to inform decision makers about air quality at their points of interest.

5. System Model of the Scenario

Note: The following is the system model developed during GEOSS AIP-2. However, the overall architecture and context diagram still hold for GEOSS AIP-3.

This section contains system models for the scenario. Additional information about the modeling process can be found in the AIP-3 Summary ER and the Unified Model ER.³

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³ A listing of all AIP-2 Engineering Reports: http://www.ogcnetwork.net/AIP2ERs
Figure 2 - Context Diagram showing actors and entities external to GEOSS
6. Use Cases

6.1 AIP Transverse Use Cases

The GEOSS Architecture provides an easy process to use GEOSS components in support of the several SBA communities. At the core of this reusable process are community Scenarios and transverse Use Cases. Scenarios are implemented by use cases. Use cases describe reusable functionality of the GEOSS service oriented architecture implemented through Interoperability Arrangements.

AIP has developed a set of Use Cases that are useful across the several communities. The SBA scenarios use the

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4 For details, see “AIP Development Process,”

Transverse Use Cases in some cases with specializations. The transverse technology use cases supporting the community scenarios are grouped in five categories, as shown in Figure and in Table. The use cases are described in detail in a separate AIP-3 Engineering Report.\(^5\)

![GEOSS Transverse Technology Use Cases](image)

**Figure 4 GEOSS Transverse Technology Use Cases**

**Table 4 – AIP-3 Use Case Summaries**

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Title</th>
<th>Actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Register Resources</td>
<td>Register resources in GEOSS Components and Services Registry (CSR) or (CSR-registered) Community Catalog</td>
<td># GEOSS Provider # GCI Operator # Community Catalog Provider</td>
</tr>
<tr>
<td>10. Register New Interoperability Arrangements</td>
<td>Register in the GEOSS Standards and Interoperability Registry (SIR) new and recommended interoperability arrangements as well as utilized standards.</td>
<td># GEOSS Provider # GCI Operator</td>
</tr>
<tr>
<td>3. Harvest &amp; Query via Clearinghouse</td>
<td>This use case describes the steps for harvesting and/or querying service or content metadata from community catalogs or services via a GEOSS Clearinghouse</td>
<td># GEOSS Provider # GCI Operator # Community Catalog Provider</td>
</tr>
<tr>
<td>15. Share Best Practices</td>
<td>Share Best Practices for participating in GEOSS and addressing SBA’s in the Best Practices Wiki (BPW)</td>
<td># GEOSS User # GEOSS Integrator # GEOSS Provider</td>
</tr>
</tbody>
</table>

\(^5\) [http://www.ogcnetwork.net/AIP3ERs#UseCases](http://www.ogcnetwork.net/AIP3ERs#UseCases)
### Clients and Portals Use Cases

| 4. Search for Resources | Steps for portals and application clients to support the GEOSS user in searching for resources of interest via the GEOSS Clearinghouse or Community Catalogs | # GEOSS User  
# GEOSS Integrator |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------|------------------|
| 5. Present Services and Alerts | Present GEOSS User with services and alerts as returned per the user’s search criteria | # GEOSS User  
# GEOSS Integrator  
# GEOSS Provider  
# GCI Operator |
| 7. Exploit Data Visually and Analytically | Steps for exploitation in Client Applications of datasets served through Web Services and online protocols as used within GEOSS. | # GEOSS User  
# GEOSS Integrator |

### Deployment and Access Use Cases

<table>
<thead>
<tr>
<th>2. Deploy Resources</th>
<th>Deploy Resources for use in GEOSS</th>
<th># GEOSS Provider</th>
</tr>
</thead>
</table>
| 6. Interact with Services | Interact with Services | # GEOSS User  
# GEOSS Integrator |

### Service Testing Use Cases

| 9. Test Services | Service Provider tests its service using a proper Test tool discovered in the GEOSS CSR. | # GEOSS Provider  
# GCI Operator  
# Standards Authority |

### Processing Use Cases

| 8. Construct Processing Service | Design, implement, compose (if composite), deploy, and publish a processing service | # GEOSS Integrator  
# GEOSS Provider |
| 11. Execute Processing Service | Discover, bind, and orchestrate a processing service, to produce new derivative data resources | # GEOSS Integrator  
# GEOSS User  
# GEOSS Provider |

### Semantic Use Cases

| 12. Perform semantic mediation | Register, mediate, and map between disparate vocabularies used to describe GEOS resources. | # GEOSS Integrator  
# GEOSS Provider  
# GCI Operator |
| 13. Conduct semantic search | Utilize mediated vocabularies to extend GEOSS search queries across disparate domains or communities. | # GEOSS User  
# GEOSS Integrator |

### Network Use Cases

| 14. Develop data sharing network | Discover GEOSS resources, establish federation “contract” between them to assemble and publish a larger-scale system resource. | # GEOSS Provider  
# GEOSS Integrator |

### 6.2 Specialized Use Cases

Specialized use cases were developed for SOS and WPS access and use. The specialized use cases related to two AIP Transverse Use Cases, ‘6. Interact with Services’ and ‘7. Exploit Data Visually and Analytically.’ The implementation of these specialized use cases along with examples from a scenario demonstration are described in Chapter 7.

#### 6.2.1 Get Sensor Observations

One specialized use case for the Transverse Use Case ‘6. Interact with Services’ addresses an air quality researcher’s need for accessing air pollutant concentration measurement data. A researcher or analyst uses a web client
application to provide search and spatial, temporal, and pollutant filtering criteria needed to issue a GetObservation request to an SOS for air quality measurements. The request specifies an appropriate coordinate reference system in the srsName parameter and an appropriate resultModel in order to ensure interoperability with a ‘downstream’ web processing service.

6.2.2 Visualize Observations

Viewing the data returned from the SOS GetObservation request is a specialized use case of Transverse Use Case ‘7. Exploit Data Visually and Analytically.’ The air pollutant concentration measurement data that met the analysts filtering criteria are visualized in spatial maps, time series and descriptive tables.

6.2.3 Spatially Interpolate Observations

Another specialized use case for the Transverse Use Case ‘6. Interact with Services’ is an analyst executing a web service for spatially interpolating point measurement data, such as what might be returned from the GetObservation request described in section 6.2.1. Through a web client, an analyst designates the information required for a spatial interpolation web processing service by specifying the dataset, area, date/time, and particular interpolation settings. With the interpolation settings specified, the analyst executes interpolation through the client application that initiates the WPS request.

6.2.4 Visually Analyze Interpolated Results

Transverse Use Case ‘7. Exploit Data Visually and Analytically’ is refined through a specialized use case for visually analyzing the output of a spatial interpolation web processing service. The resulting spatially interpolated gridded output contains estimates of air pollutant concentrations over an area and each interpolated value has an associated error. To decide whether the values are meaningful and usable, analysts visualizes the error probability interpolation in addition to the mean interpolation values. The interpolation results help to visualize outlying measurement data and patterns in the measurement data. The scientist analyzes the interpolation results, using the results to inform decision makers about air quality at their points of interest.

The visualizations can be used to inform public health officials about air quality in their area of interest.

7. Implementation

7.1 Deployed Components

[Description of the engineering component types that have been deployed. Provide a “Wiring Diagram” showing the connections between the components. Provide a description of the components including the status of their registration in the GCI.]

During AIP-3, the following components were developed and deployed to illustrate the functionality described in the scenarios above:

- Services:
  - European Pollutant SOS
  - North American Air Quality SOS
  - Interoperability and Automated Mapping (INTAMAP) WPS
  - Image Generation Service (for further processing INTAMAP WPS output)

- Clients:
  - Northrop Grumman PULSENet Web Client
  - Google Earth
  - 52° North OX-Framework with WPS Adapter
  - AGUILA visualization client
For AIP-3, an SOS interface to the DataFed web services was developed based on an earlier version developed during a NASA ESTO AIST project, which provide access to air quality and other atmospheric and environmental measurements from a variety of monitoring networks in North America and around the world. In particular, the DataFed web services provide access to US Environmental Protection Agency (EPA) AIRNow fine particle (PM$_{2.5}$), inhalable coarse particle (PM$_{10}$), and ozone measurement data. A large majority of the SOS development effort for AIP-3 involved tailoring the SOS so that the service and its output could be used in conjunction with the INTAMAP WPS that provides spatial interpolation of measurement data.

In the European scenario, the OX-Framework, a thick client allowing the integration of several OGC services like WMS, WFS and WCS has been extended by a WPS connector. This connector provides functionality to connect to a SOS at first and, afterwards, to execute the interpolation provided by the INTAMAP WPS [1]. The interpolation results can also be retrieved from a WCS interface and thus be visualized in AGUILA. AGUILA is an exploratory data analysis tool which is capable of visualizing various types of data in different ways. It maintains interactive links between the different visualizations. In the European AIP-3 scenario, AGUILA is used to retrieve the interpolation results from a WCS and to visualize the uncertainty of the data, e.g. visualizing the first quartile of the interpolation results [2]. This scenario is visually depicted in the wiring diagram shown in Figure 5.

Figure 5 – European scenario wiring diagram.

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The scenarios that were demonstrated for AIP-3 (based on the generic scenarios described above) assume that measurement data is available through an OGC SOS 1.0 interface that provides observation data in OGC O & M 1.0 format as an ObservationCollection with Measurement type member elements. The scenarios further assume that the SOS can provide observation location/feature information in a Cartesian coordinate reference system (CRS) (e.g. European Petroleum Survey Group (EPSG) 3395) rather than the more common WGS 84 spheroid based CRS used by most SOS instances (e.g. EPSG 4326). These preconditions exist due to constraints in the INTAMAP WPS that performs the interpolation of observation data. The INTAMAP WPS requires a Cartesian CRS for compatibility with R, the statistical software used by the WPS to perform the interpolation. These constraints and preconditions are specified in the INTAMAP documentation, but the INTAMAP WPS Capabilities document and process description for the interpolate process do not provide parameters or properties that specify these constraints. In order to maximize interoperability in the future, a WPS that performs interpolation of observations in O & M format either needs to explicitly state input constraints in the process description for the interpolation process, or the WPS needs to be more flexible in supporting additional O & M types (e.g. O & M observations with SWE Common DataRecord or DataArray result types) and CRSes. Perhaps a WPS profile for spatial interpolation or SOS and O & M profiles for data that can be interpolated spatially should be developed. These preconditions may also make it difficult for a user to discover an SOS that can be used in conjunction with the INTAMAP WPS. In theory, any SOS that provides numerical measurement data from multiple sensors distributed over a geographic area should be a suitable candidate for use with the INTAMAP WPS. Currently, a user wanting to perform spatial interpolation of measurement data provided by an SOS needs to know that the INTAMAP WPS only supports Cartesian CRSes and that O & M observations must be specified using Measurement type and that a particular SOS supports providing observation data with a Cartesian CRS using O & M Measurement type. Another potential interoperability pitfall involves the output of the INTAMAP WPS. The output from the INTAMAP WPS is a coverage consisting of a standard Geography Markup Language (GML) RectifiedGrid along with Uncertainty Markup Language (UncertML) mean and variance values that map to cells in the GML RectifiedGrid. In general, this information is suitable for plotting results on a map or producing a georeferenced image of the interpolation results (based on color-coding pixel values based on data values) that can be displayed on a map, but clients need to have specialized knowledge of how to utilize the results given that the combination of a GML RectifiedGrid along with UncertML values is currently not a standard practice. Therefore, the scenarios demonstrated for AIP-3 assume that the client application is capable of processing the INTAMAP WPS output.

**7.2 Interoperability Arrangements**

The following interoperability arrangements were assumed for the scenarios described previously due to constraints imposed by the INTAMAP WPS:

- SOS supports a Cartesian CRS such as World Mercator (EPSG 3395) either directly or through reprojection
- SOS supports and advertises the O & M Measurement type as a resultModel for each offering associated with measurement data that can be interpolated
- SOS supports outputting the data in KML and/or other widely used formats to maximize interoperability/ease of visualizing the data

In order to alleviate the need for these arrangements or to ensure that the need for these arrangements is clearly stated and defined in the future, WPS and/or SOS/O & M profiles for spatial interpolation should be developed.

**7.3 Use of the GCI**

The methods for service and component registration to, and access from the GCI that were developed during AIP-2 were not updated during AIP-3.

**7.4 Demonstrations**

The spatial interpolation scenarios were compiled for a demonstration video for the GEO-VII Plenary. The following screenshots illustrate spatial interpolation results of measurement data retrieved from the DataFed SOS.
As the interpolation error is provided by the Intamap interpolation service, the results can be visualized as quantiles or as cumulative/exceedance probabilities using the AGUILA client. Figure 3 shows the visualization of the interpolation results of Dutch NO$_2$ measurements as first quartile (A) and as the cumulative probability of 5$\mu$g/m$^3$.

Figure 6 – Viewing INTAMAP WPS Spatial Interpolation Output in the PULSENet Client and Google Earth

7.5 Future plans for deployment

The Air Quality SOS based on DataFed WCS is available online at:

It is currently a prototype service that could be made operational with further testing, refinement and deployment. However, immediate plans are for the service to be persistently available for the foreseeable future for use through GEOSS.

The European Air Quality SOS is available online at:
http://giv-sos.uni-muenster.de:8080/AirQualitySOS/sos?REQUEST=GetCapabilities&SERVICE=SOS
For the AIP-3 scenario only measurements from the Netherlands have been provided. It is planned to extend the data to cover whole Europe. The current SOS deployment is also prototypical and is based upon the 52° North SOS version 3.1.1. It thus implements the SOS version 1.0. It is planned to update the SOS to the newer version 2.0, once the standard is published at OGC. It is also planned to implement the monitoring station descriptions according to the SensorML profile for discovery [3].

As described in section 7.1, the INTAMAP WPS only supports a certain observation type (Measurement) of O&M version 1.0. Currently, this information is given in the documentation of the INTAMAP project. In order to provide this information in the WPS service/process descriptions, a WPS metadata profile has to be developed. It is planned to create a subtype of the ows:Metadata type containing the supported observation/result types as input and the supported output types as well as supported CRS and other metadata needed. The INTAMAP WPS has been updated to the current version of the 52° North WPS and is currently running at:

http://giv-uw.uni-muenster.de:8080/intamap/WebProcessingService?REQUEST=GetCapabilities&SERVICE=WPS

It is planned to integrate the metadata profile into this implementation, once it is available.

In order to execute the interpolation in the European scenario, the OX-Framework has been extended by a WPS connector. Currently, this connector is very specific for the INTAMAP WPS. In future, the WPS connector of the OX-Framework might be extended to provide common processing functionality and to ease the integration of Sensor Web data services and WPSs.

8. References

