ESTO-Sensor Web NRA

Sensor-web Operations Explorer (SOX) for Integrated Air Quality Campaign

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Research Team

Co Investigators

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Kumarech Singh, (VT)

Infusion

Atmospheric composition mission study

CLARREO mission concept design

OCO mission science

SOX

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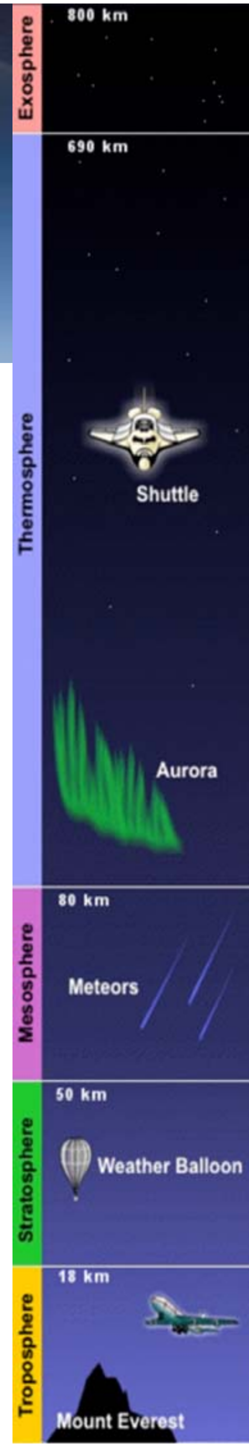

Sensor Web

A sensor web is a **coordinated observation infrastructure** employing multiple sensors that are distributed on one or more platforms.

The number and type of sensors and the platform distribution in time and space can be optimized to answer specific science questions.

Air Quality

Air pollution is **a chemical, physical** (e.g., particulate matter size), **or biological agent** that modifies the natural characteristics of the atmosphere in an unwanted way.

Gases such as carbon dioxide, methane, and fluorocarbons (which contribute to global warming) and emissions from fossil fuel burning have been identified as pollutants.

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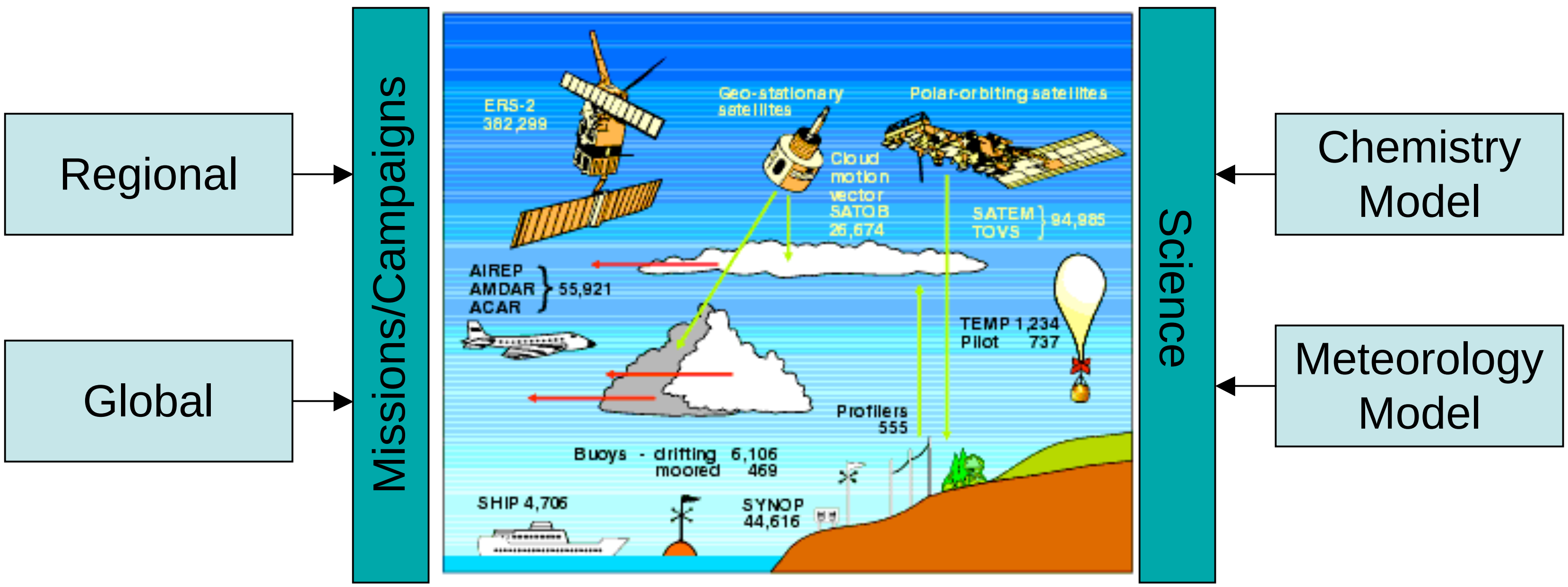
Air Quality Campaign

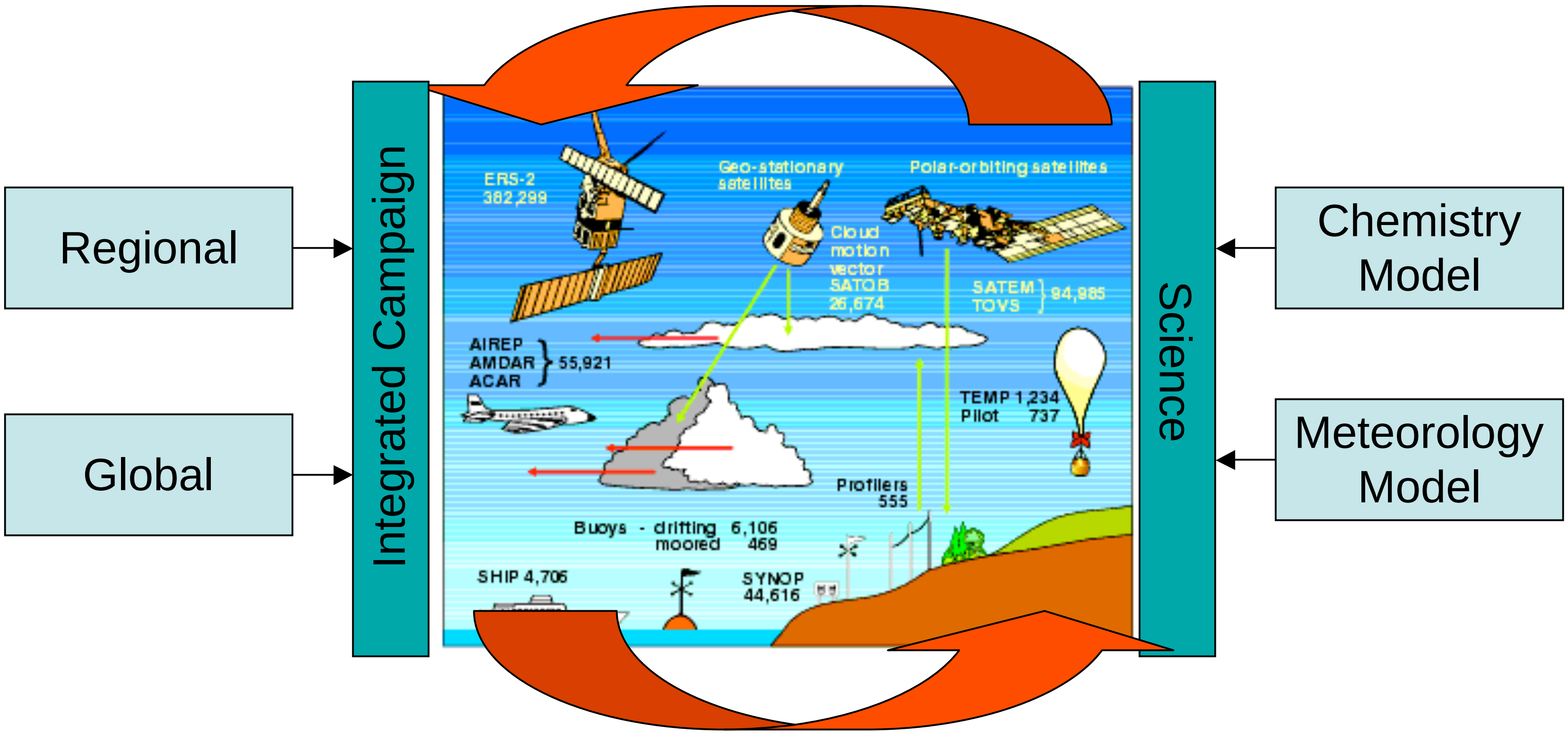
The quantification of the process governing the distribution and evolution of trace gases and aerosols requires an integrated approach that combines observations from **satellites, aircraft, sondes, and surface measurements** with chemistry and transport models acting on both regional and global scales.



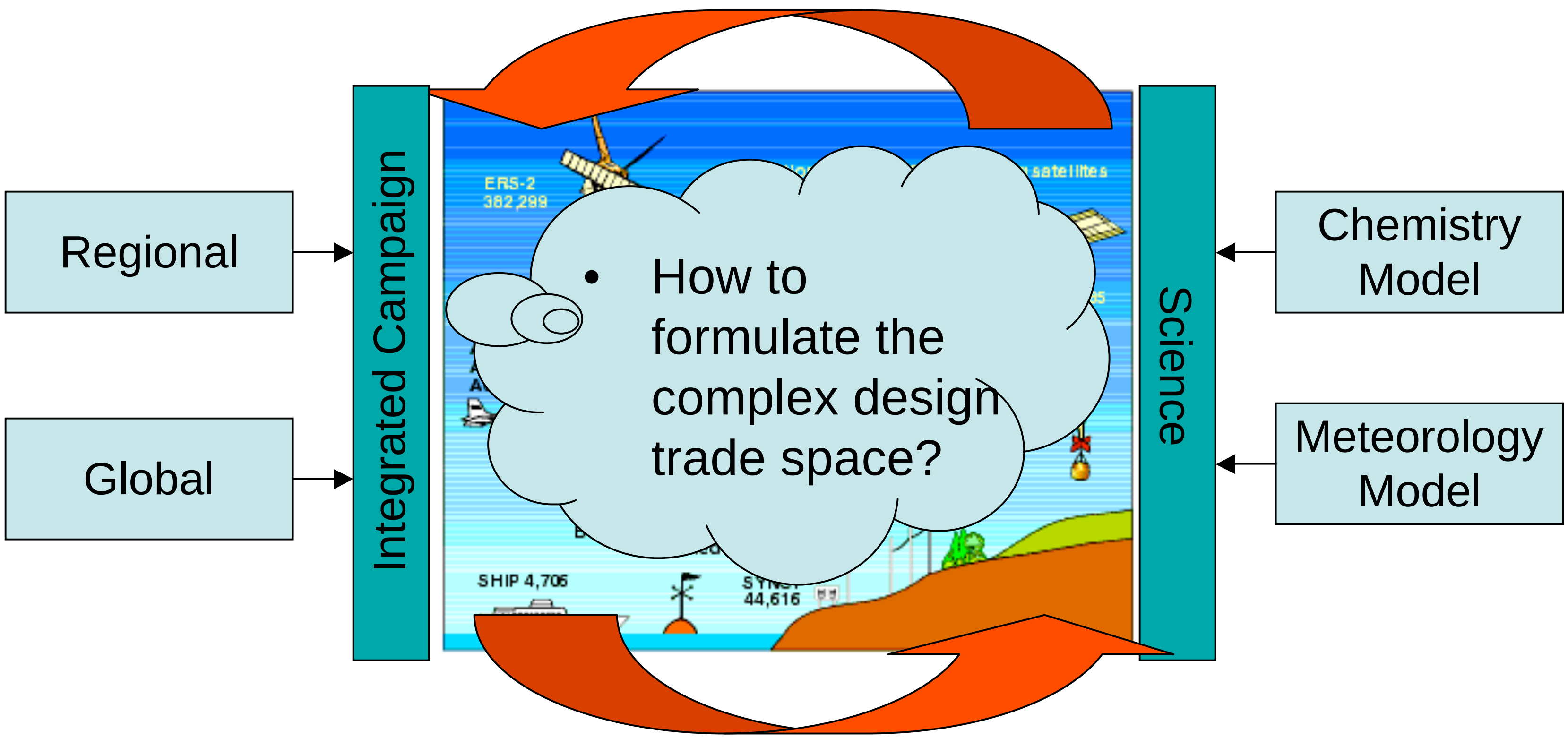
SOX

Goal

Develop **integrated air quality mission concepts** utilizing space-borne air-bone, and in-situ observation resources (current and future) for improved air quality prediction.



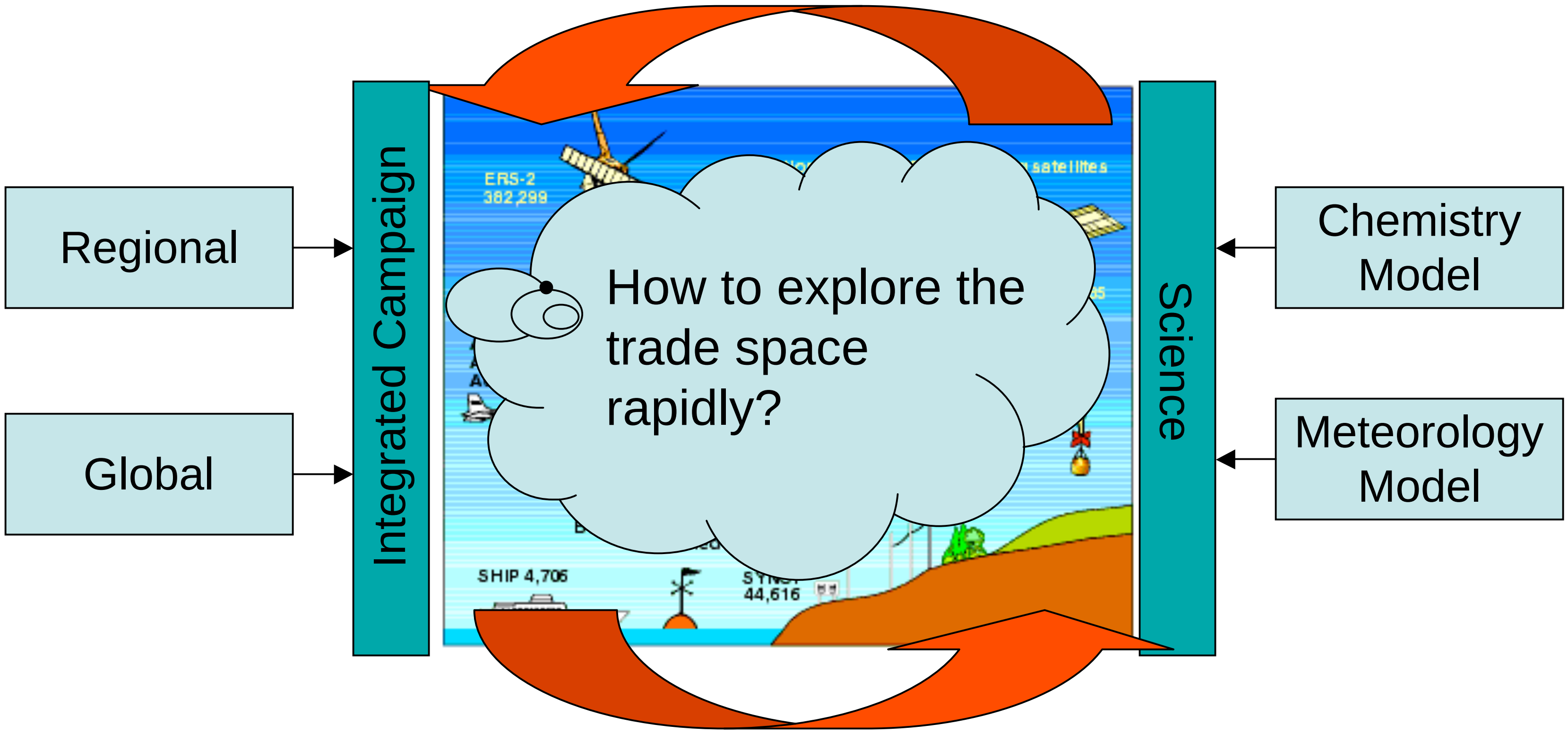
Challenges


Regional
Global
Integrated Campaign
Science
Chemistry Model
Meteorology Model
• How to formulate the complex design trade space?
ERS-2
382,299
SHIP 4,706
44,616

SOX

Challenges

- ✓ How to formulate the complex design trade space?



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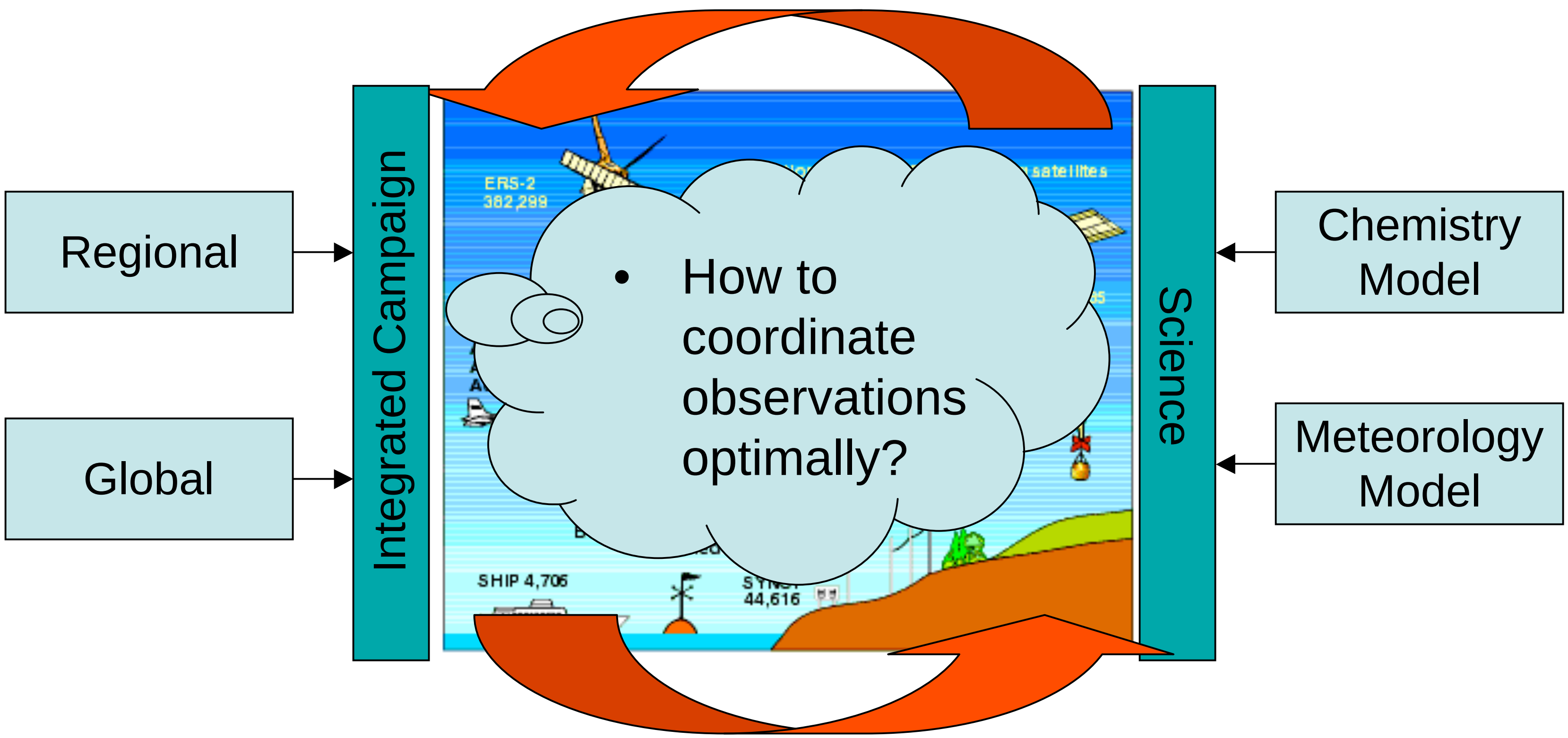
Challenges

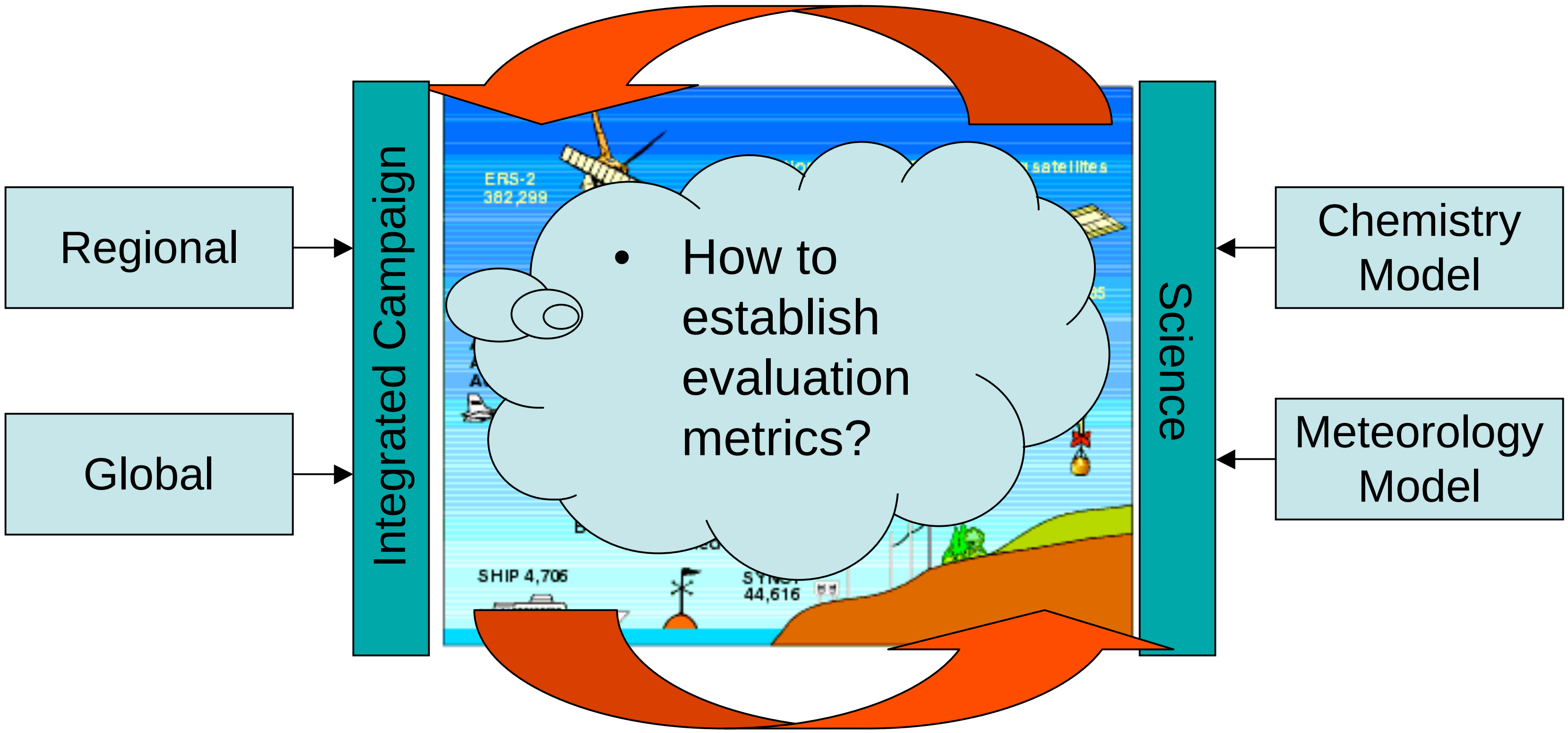
- ✓ How to formulate the complex design trade space?
- ✓ How to explore the trade space rapidly?



SOX

Challenges

- ✓ How to formulate the complex design trade space?
- ✓ How to explore the trade space rapidly?
- ✓ How to coordinate observations optimally?



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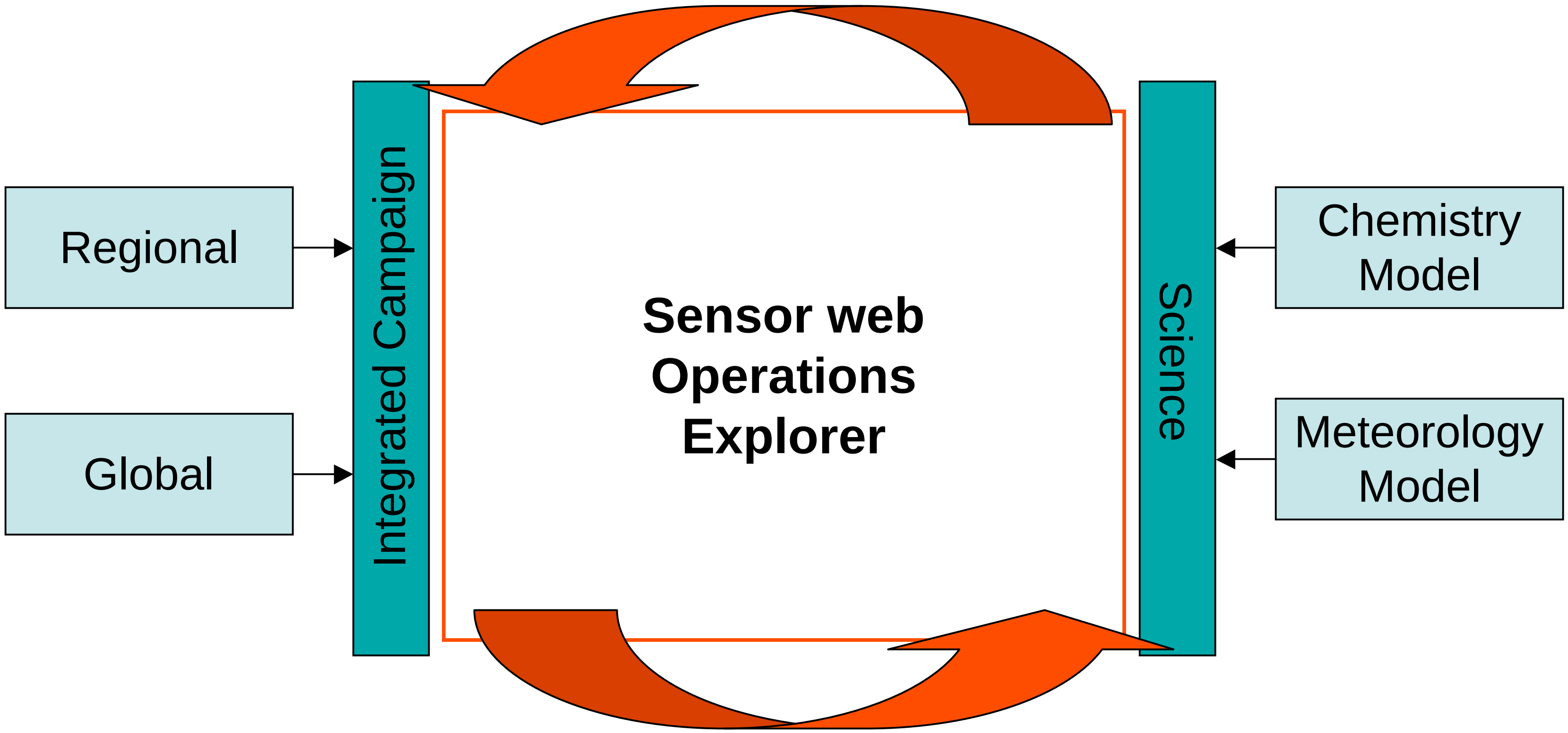
Challenges

- ✓ How to formulate the complex design trade space?
- ✓ How to explore the trade space rapidly?
- ✓ How to coordinate observations optimally?
- ✓ How to establish evaluation metrics?



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Objectives

❖Enable adaptive **measurement strategy exploration** on a sensor web for rapid air quality assessment.

❖Provide **collaborative campaign planning process** among distributed users.

Concept Design Process

Sensor-web Operations Explorer (SOX)

Virtual Experiment

❖Provide a comprehensive **sensor-web system simulation** with multiple sensors and multiple platforms.

❖Provide quantitative **science return metric** that can identify where and when specific measurements have the greatest impact.

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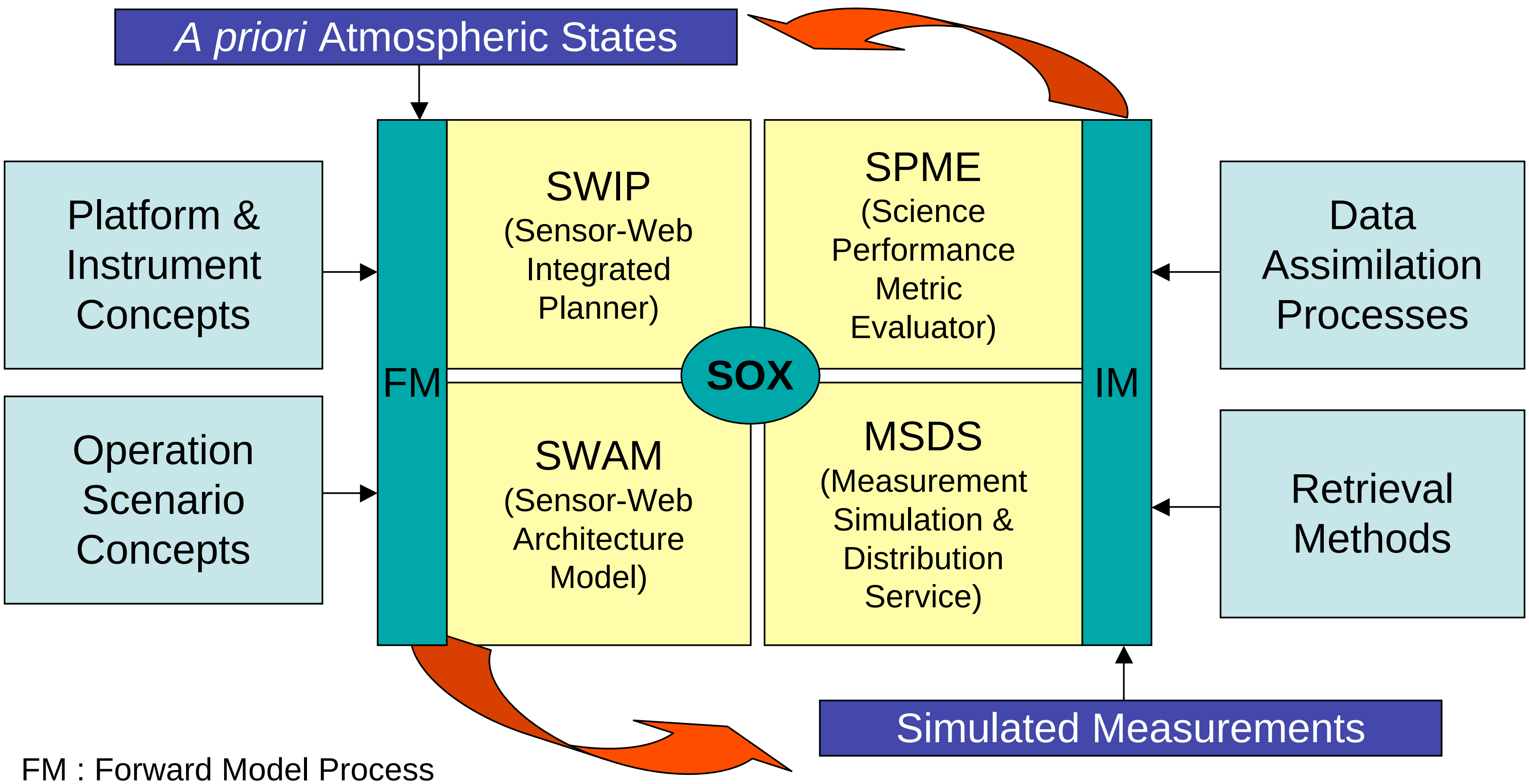
Approach



FM : Forward Model Process
IM : Inverse Model Process

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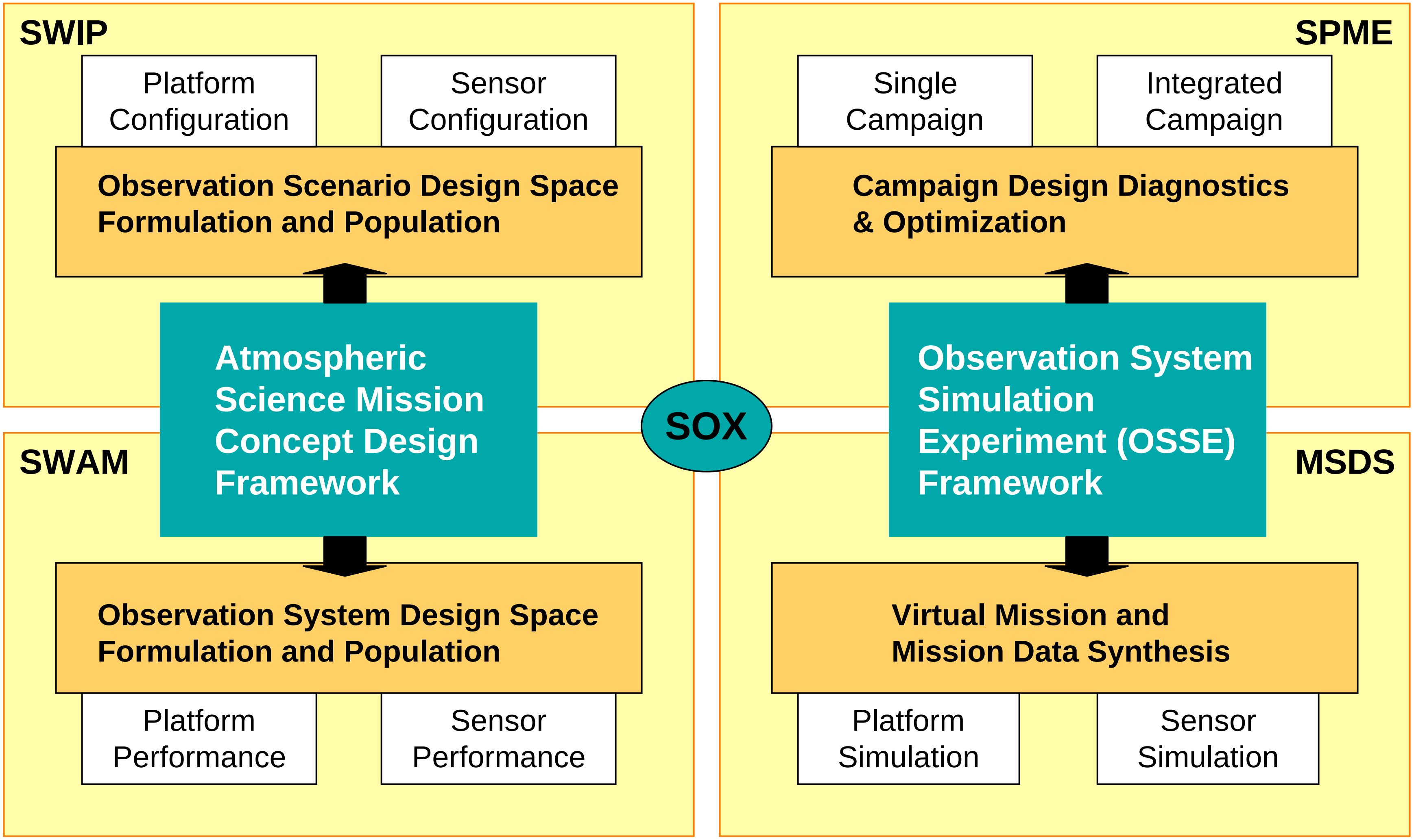
Frameworks



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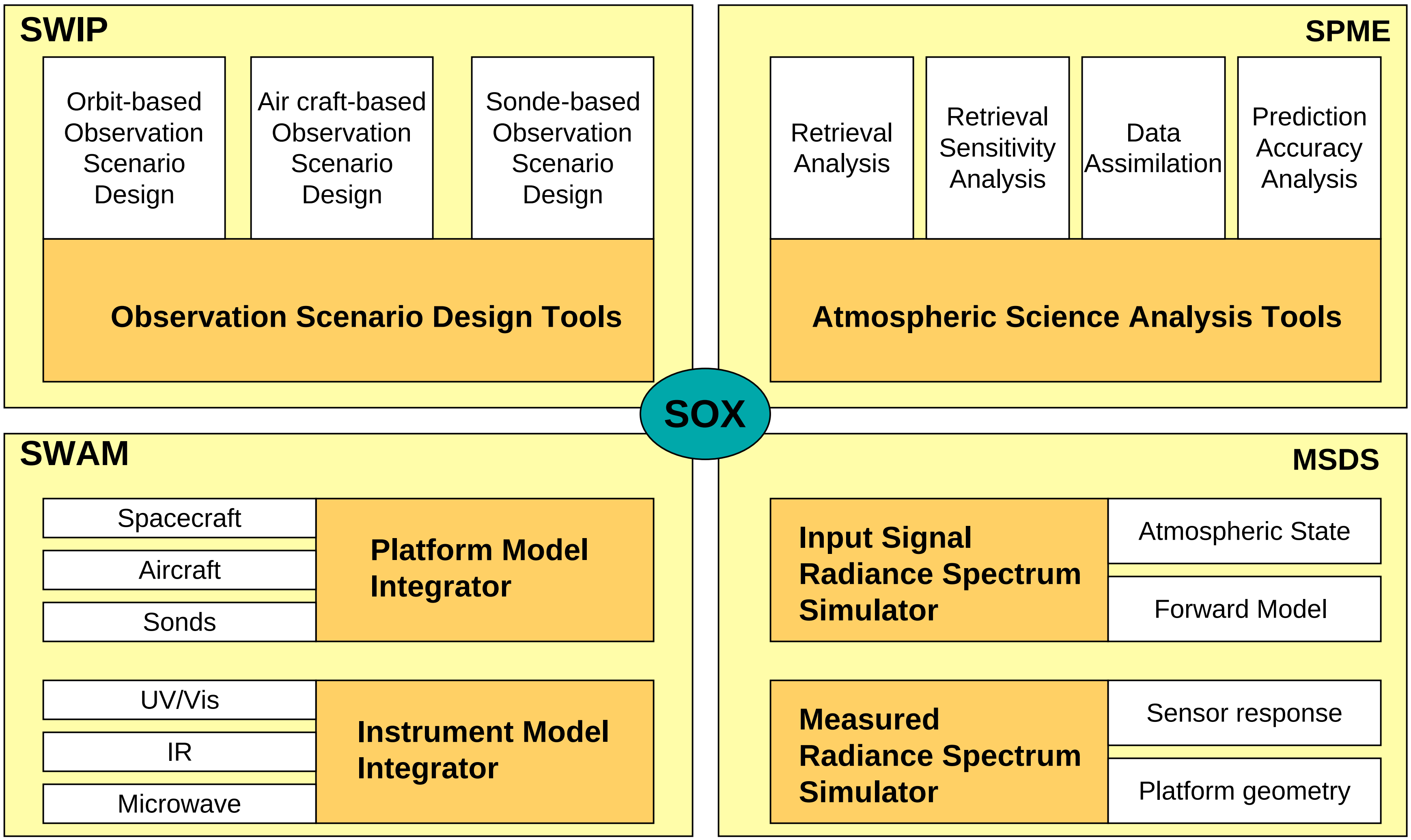
Software System



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Web Services

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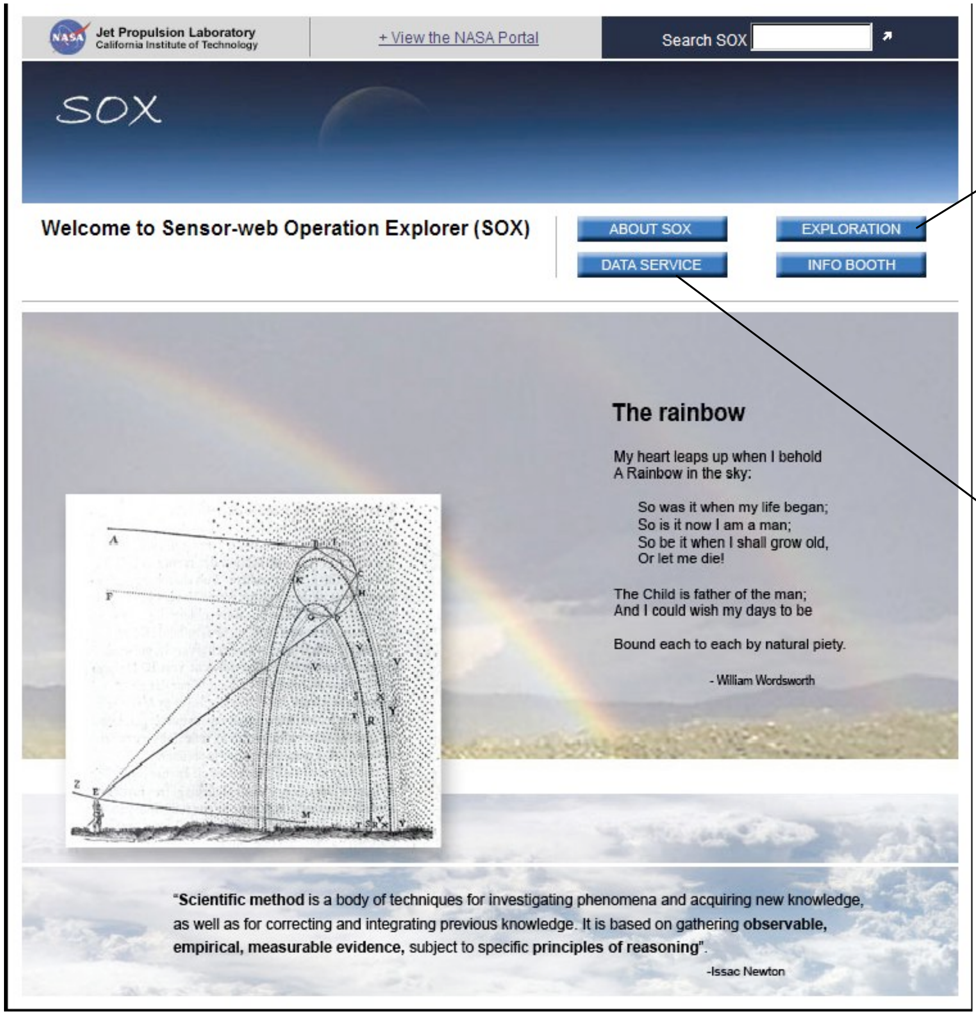

Exploration

- Observation scenario
- Measurement quality
- Retrieval analysis
- Data Assimilation

Data Service

- Observation scenario
- Measurement quality
- Retrieval analysis
- Assimilation

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Web Services

Request Manager

Logs exploration requests and
composes command lines.

Resource Manager

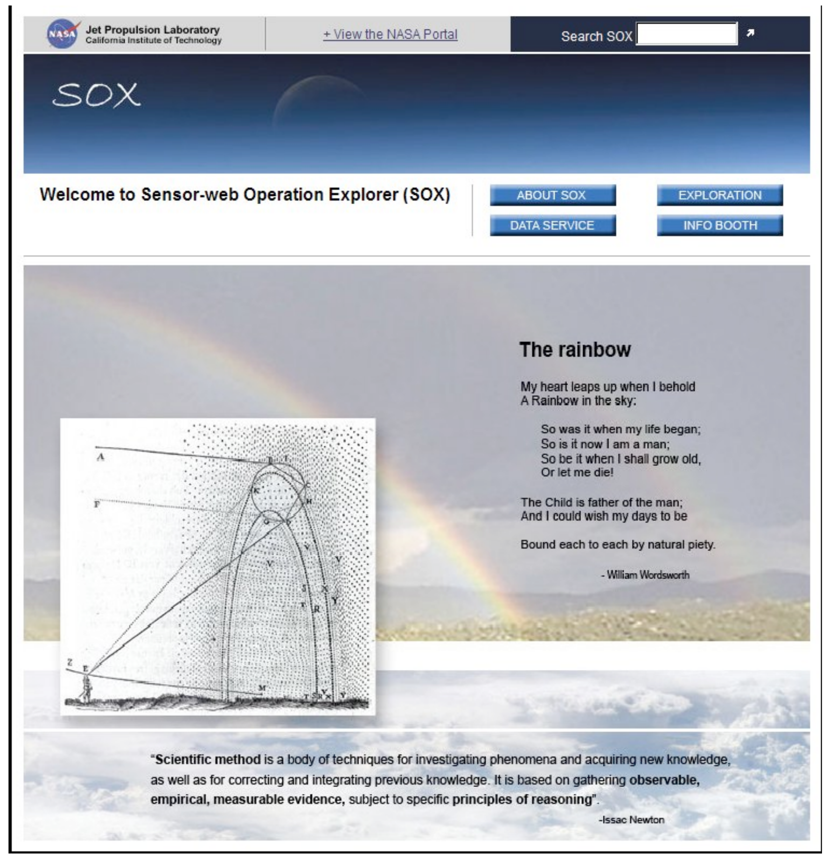
Monitors availability of the
computational resources.

Execution Manager

Dispatches command lines to
available resources.

Exploration Requests

Exploration Results



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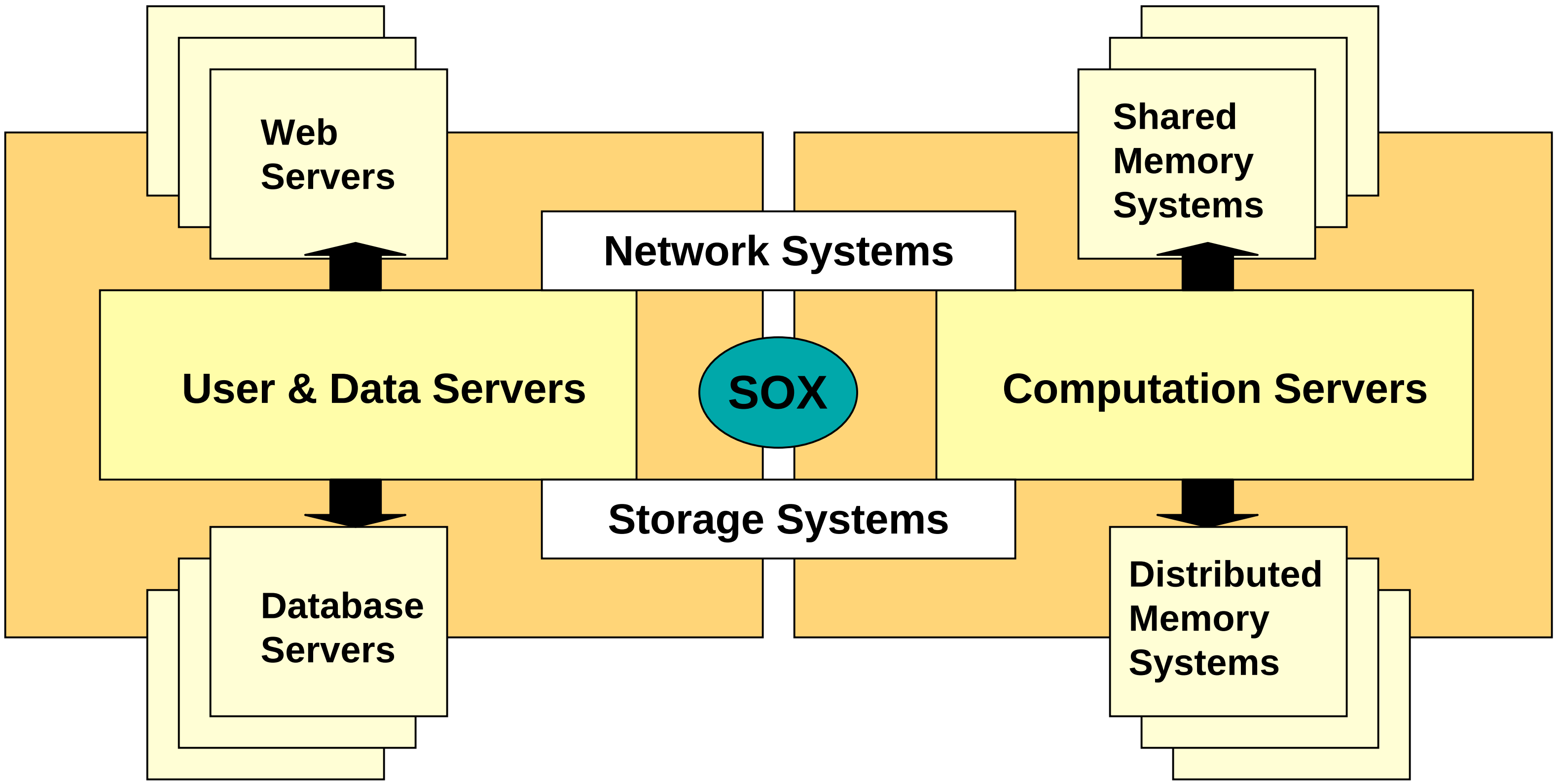
Hardware System



Use Case

Earth Atmospheric Science Mission Concept Study

Using **OSSE**s to more fully evaluate possible approaches (getting to the right design for the **Instrument** and the **Mission**):

National Aeronautics and Space Administration

Quantifying the science impact of instrument and missions designs: The ozone case

Presented by Annmarie Eldering

Jet Propulsion Laboratory
California Institute of Technology

AGU Joint Assembly
May 28, 2008, Ft. Lauderdale, FL

Contributors: Kevin Bowman, Meemong Lee, Zheng Qu, Mathew Yeates

JPL Clearance: N/A

Last Modified: 5/27/2008

www.nasa.gov

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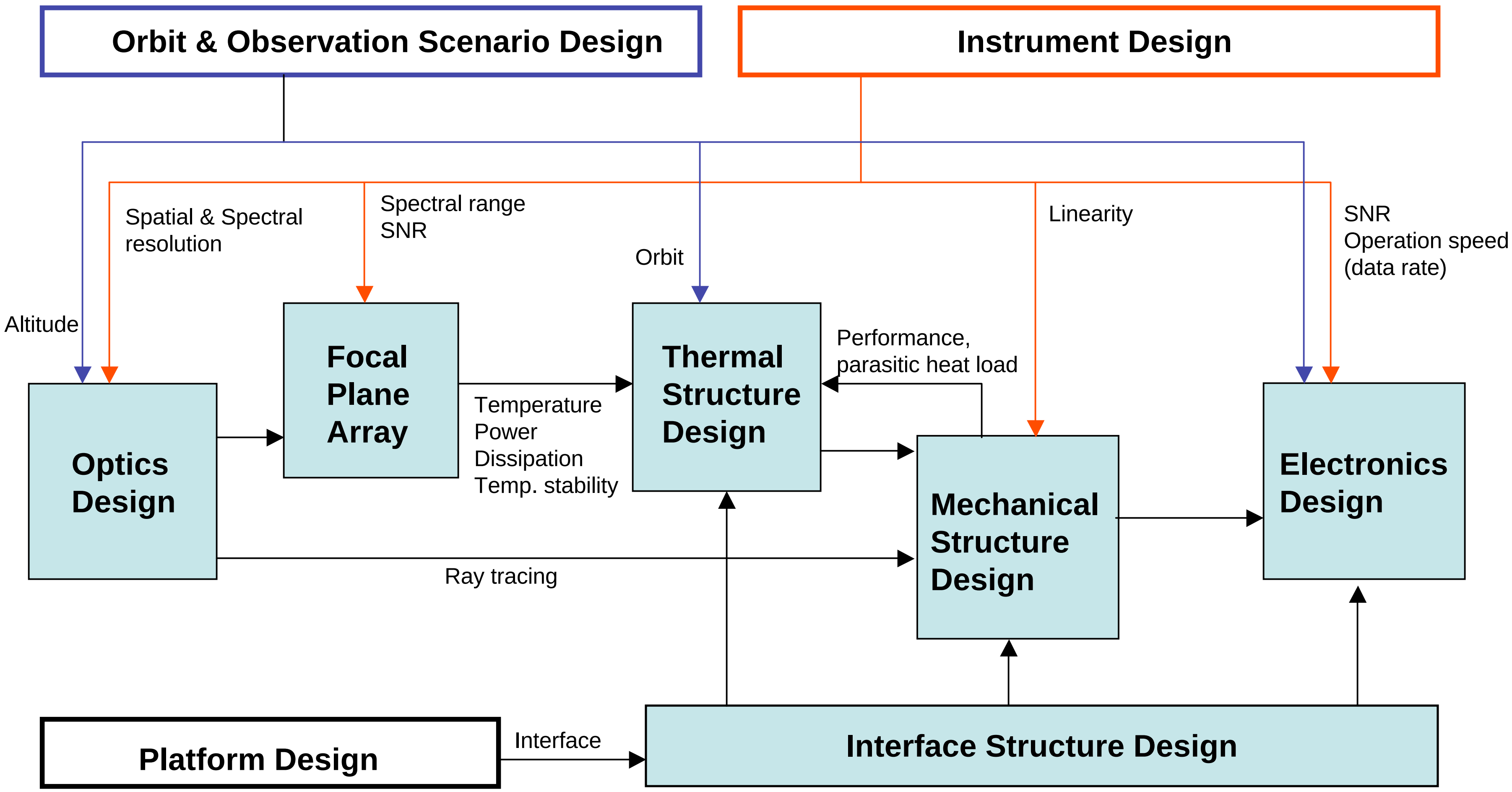
Trade Space



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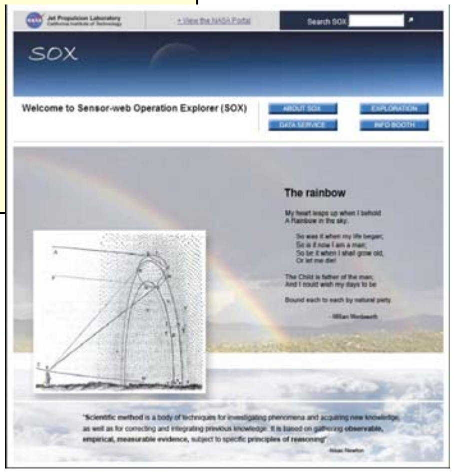
Use Case

Step 1

Scientists use ‘Orbiter’, a space-borne observation scenario design tool, provided in the SWIP module to configure platform and sensor operations including
- **orbit properties**
- **observation timeline**
- **sampling frequency**
- **spatial coverage**
- **temporal condition**
- **spatial condition**

A sample list that satisfies the above definitions is composed.



SOX

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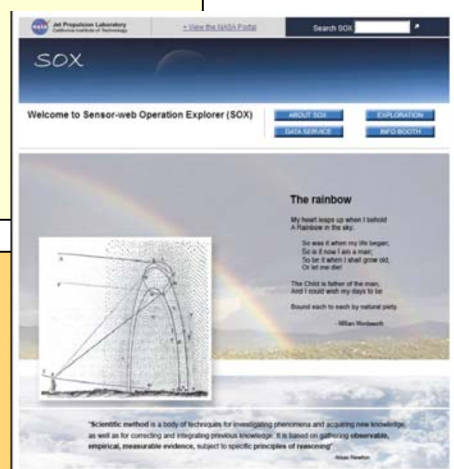

Step 2

Scientists use a parametric sensor model worksheet (Excel) provided in the SWAM module to specify the performance range of the configured sensors:
- **spectral range**
- **spectral resolution**
- **SNR**
- **spectral drift**
- **line shape**
- **quantization levels**

An instrument list that satisfies the above performance range is composed.

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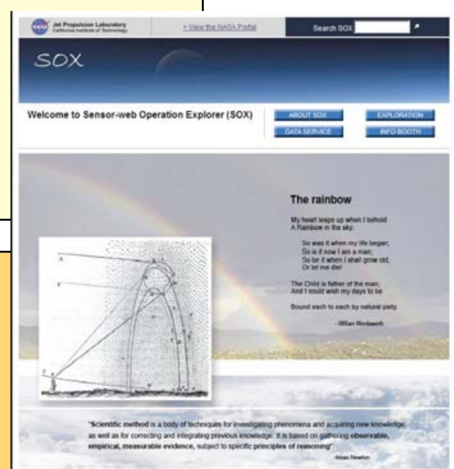

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An instrument list that satisfies the above performance range is composed.

Step 3

Scientists submit the sample list and the instrument list to SOX web service to perform virtual mission and to generate mission data products.

The sample list is used for simulating
- **atmospheric state from the phenomena database**
- **radiance spectrum using a forward model**
- **platform-centric observation geometry**

The instrument list is used for simulating
- **field of view tracing**
- **radiometric sensor response**

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Use Case

Iterative Concept Maturation

Step 1

Scientists use 'Orbiter', a space-borne observation scenario design tool, provided in the SWIP module to configure platform and sensor operations including
- orbit properties
- observation timeline
- sampling frequency
- spatial coverage
- temporal condition
- spatial condition

A sample list that satisfies the above definitions is composed.

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- spectral resolution
- SNR
- spectral drift
- line shape
- quantization levels

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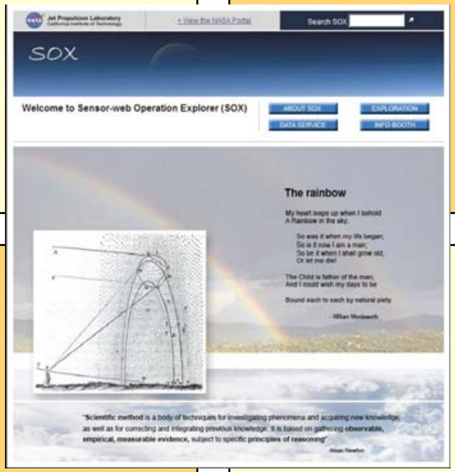

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The sample list is used for simulating
- atmospheric state from the phenomena database
- radiance spectrum using a forward model
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The instrument list is used for simulating
- field of view tracing
- radiometric sensor response

Step 4

Scientists submit retrieval analysis requests to SOX web service on the simulated measurements resulting from the virtual mission. The retrieval analysis generates altitudinal retrieval error and bias for each measurement.

The retrieval results are used for
- data assimilation
- instrument performance dependency
- observation scenario dependency

SPME module provides multi-dimensional interactive visualization tools.

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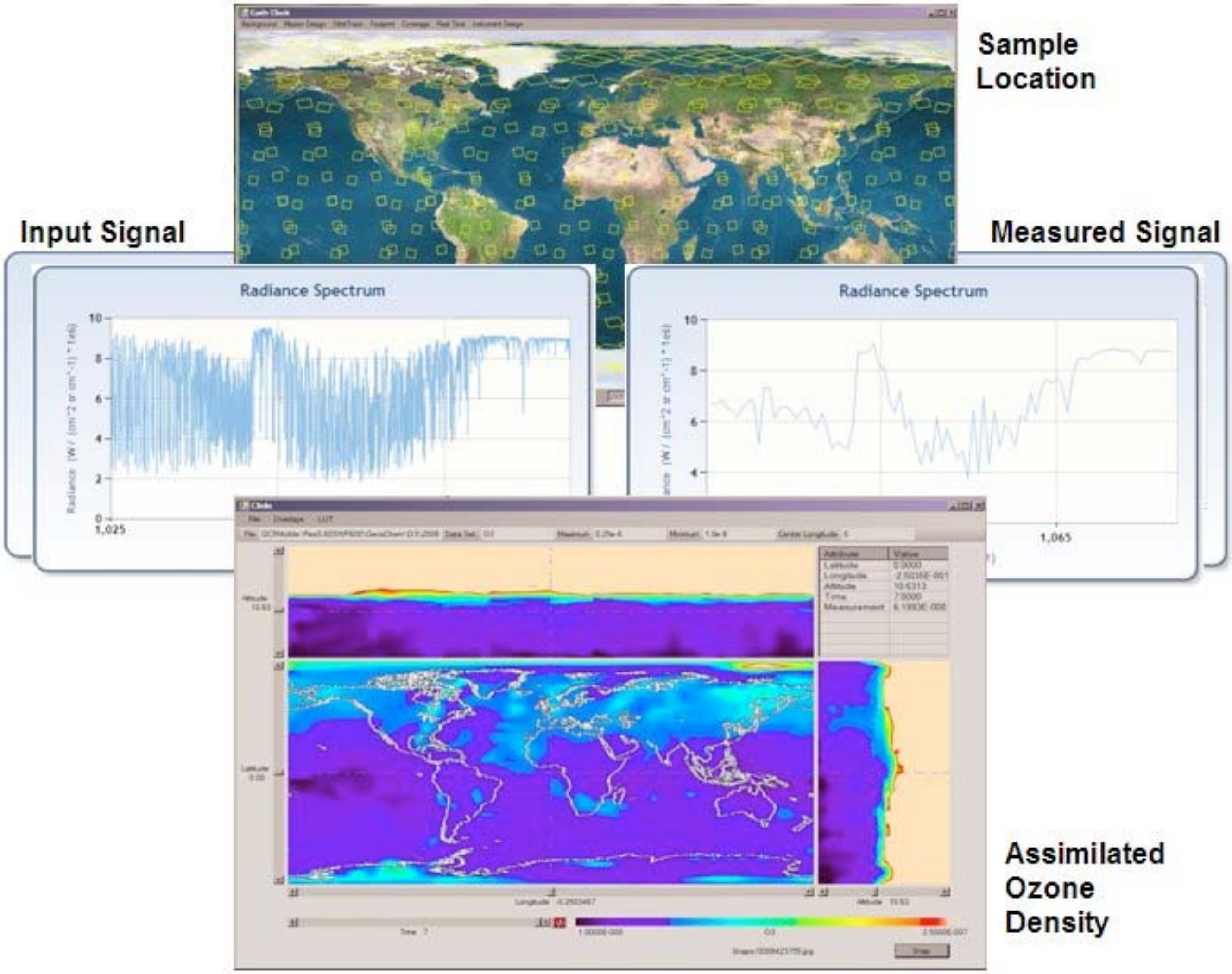
Use Case


Sample Location
Input Signal
Measured Signal
Radiance Spectrum
Radiance Spectrum
Assimilated Ozone Density

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Details, Details, Details…

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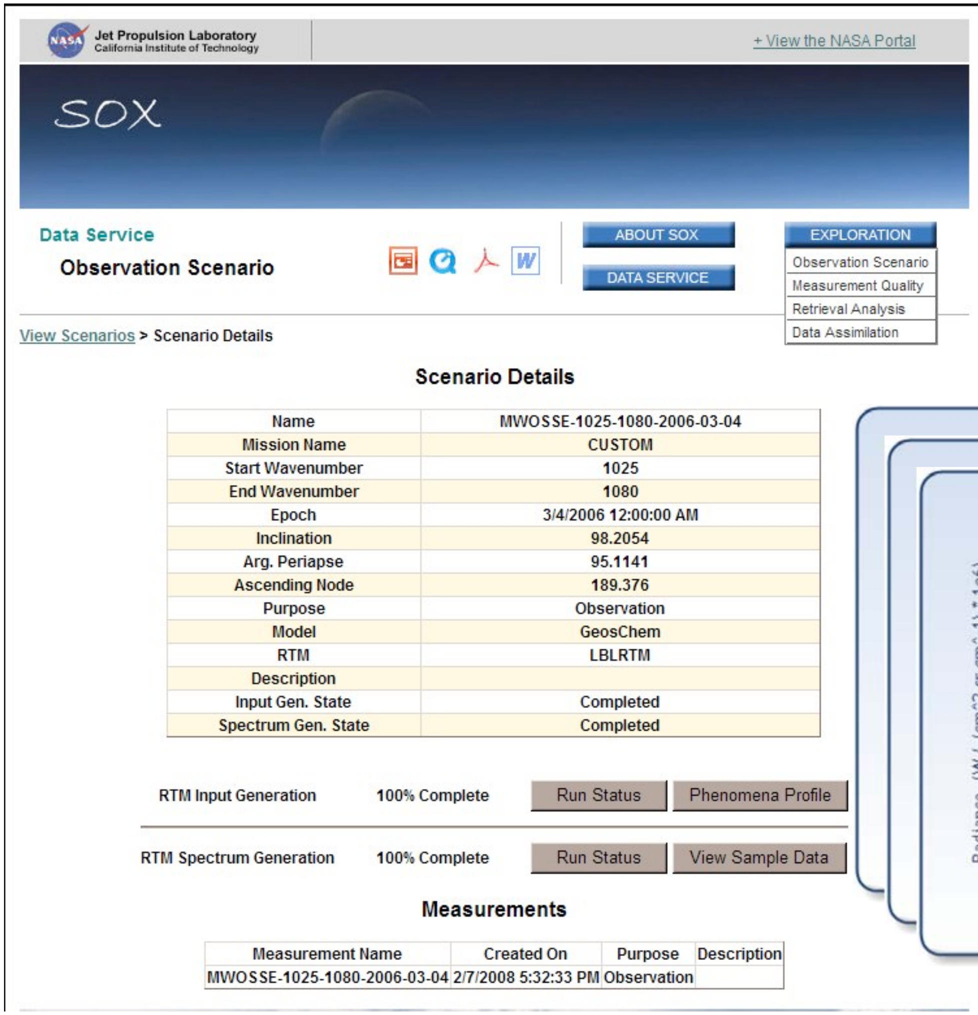
Signal Simulation

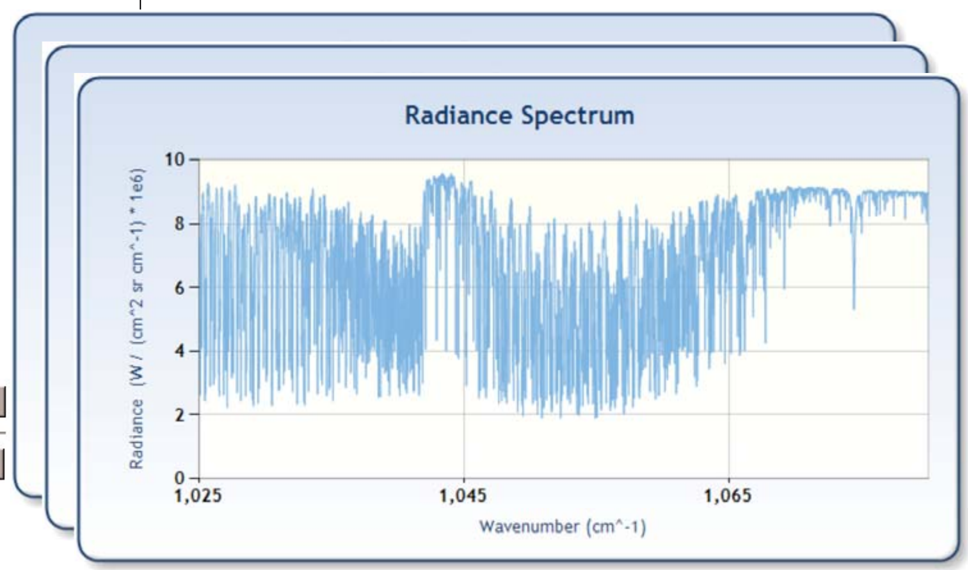


Name	MWOSSE-1025-1080-2006-03-04
Mission Name	CUSTOM
Start Wavenumber	1025
End Wavenumber	1080
Epoch	3/4/2006 12:00:00 AM
Inclination	98.2054
Arg. Periapse	95.1141
Ascending Node	189.376
Purpose	Observation
Model	GeosChem
RTM	LBLRTM
Description	
Input Gen. State	Completed
Spectrum Gen. State	Completed

Measurement Name	Created On	Purpose	Description
MWOSSE-1025-1080-2006-03-04	2/7/2008 5:32:33 PM	Observation	

For each sample in the observation scenario, an atmospheric state vector is composed and a signal radiance spectrum is simulated.

Signal Radiance Spectra



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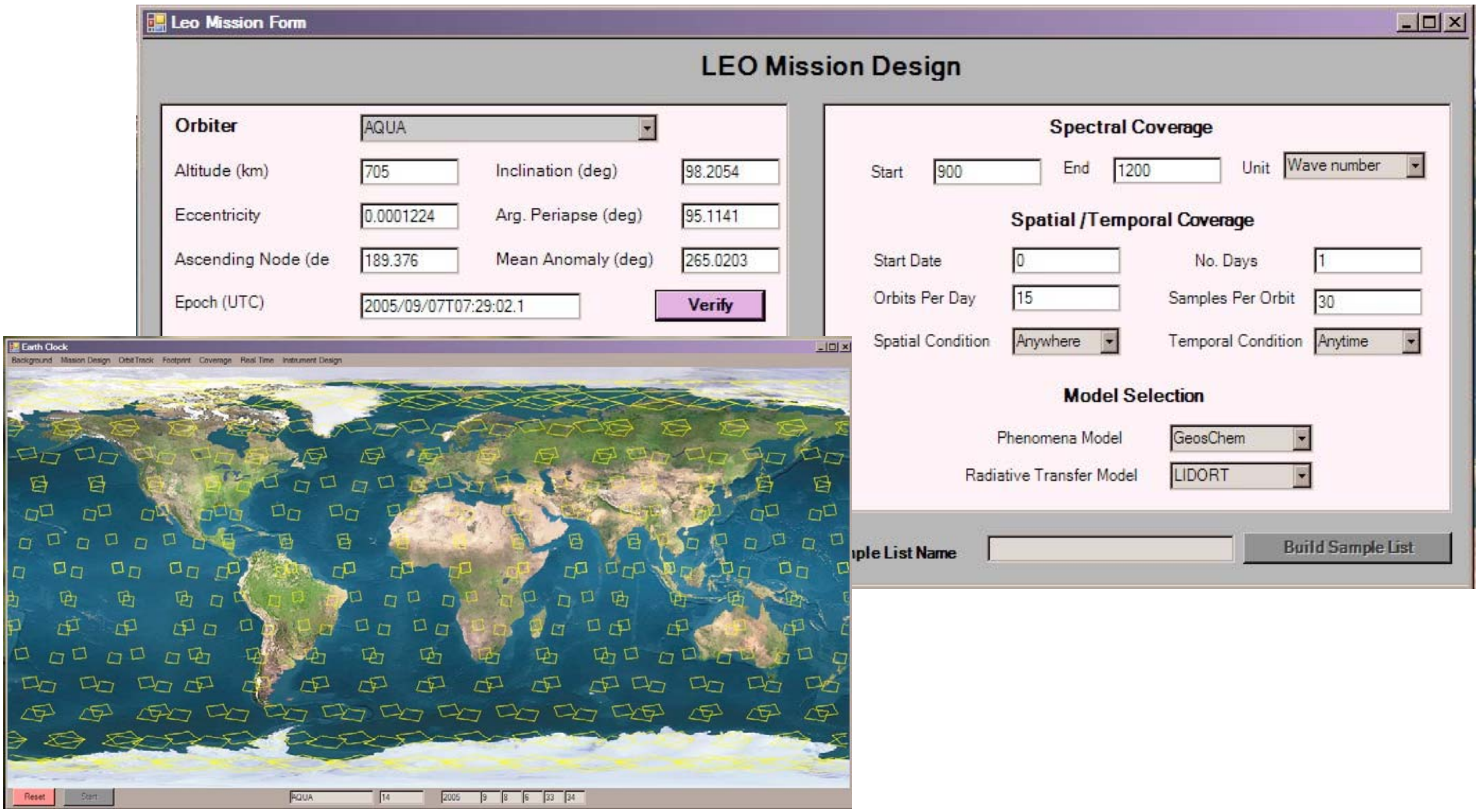
Mission Design



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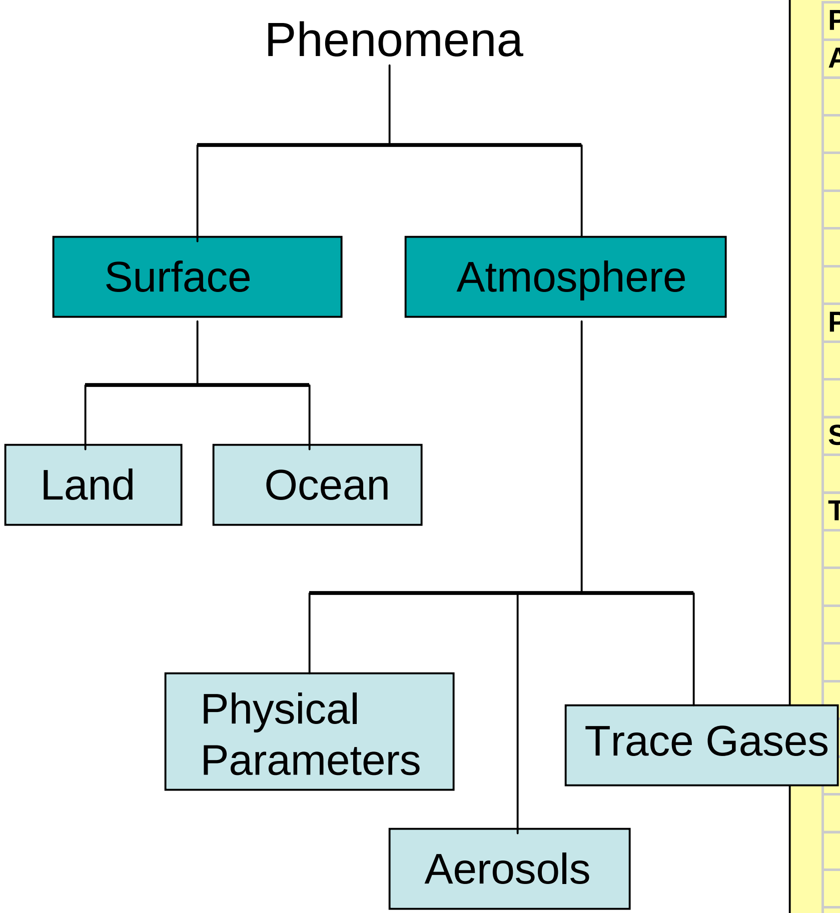
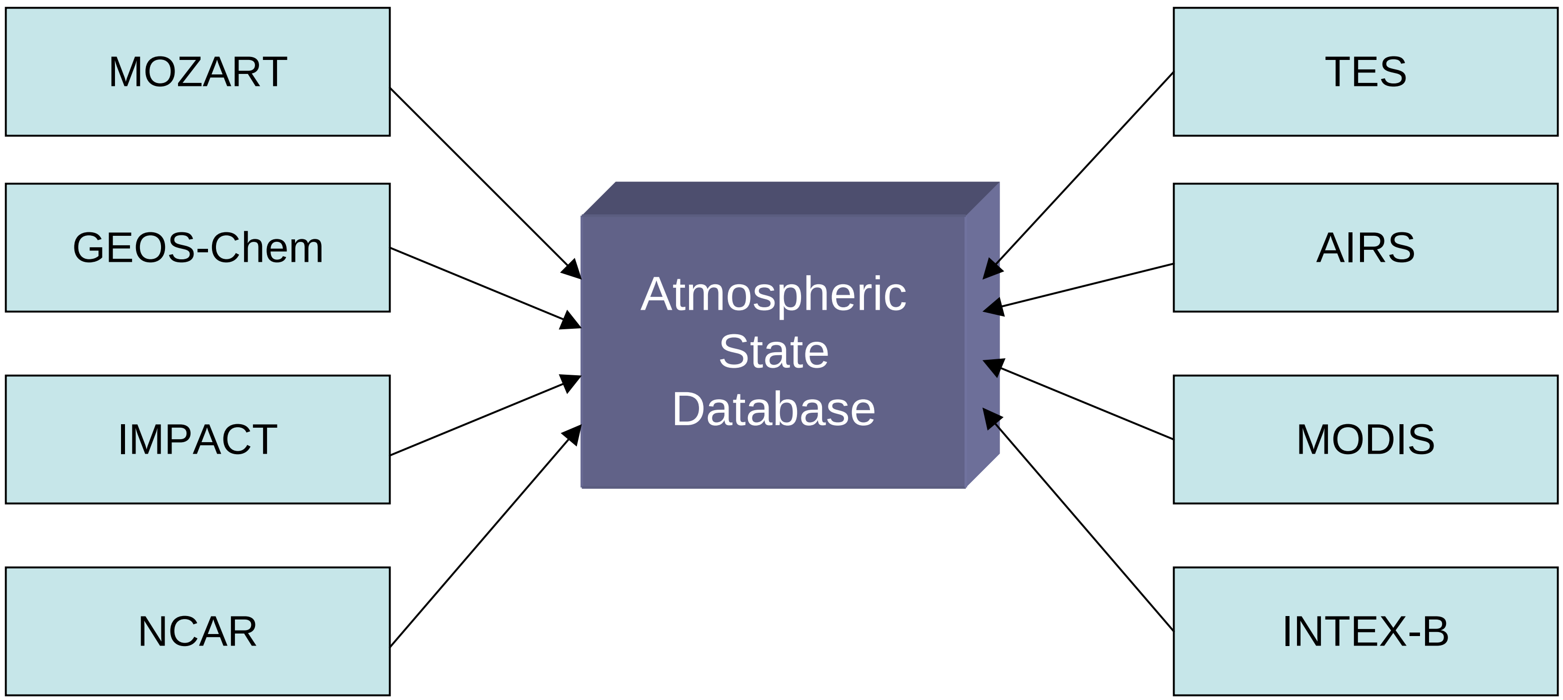
Parametric Atmospheric State



Property	Name	Symbol	Altitude	Wavelenth
Aerosol	Black Carbon		n	y
	Dust		n	y
	Haze		n	y
	Organic Material		n	y
	Sea Salt		n	y
	Optical Depth		y	y
	Single Scatter		y	y
Physical	Humidity	Q	y	n
	Pressure	P	y	n
	Temperature	T	y	n
Surface	Direct Reflectance		n	y
	Diffused Reflectance		n	y
Trace Gas	Carbon Monoxide	CO	y	n
	Carbon Dioxide	CO2	y	n
	Carbon Tetachloride	CCl4	y	n
	Chlorifluoro Carbons	CFC12	y	n
	Freon	CF2Cl2	y	n
	Hydrochloric Acid	HCl	y	n
	Nitrogen Monoxide	NO	y	n
	Nitrogen Dioxide	NO2	y	n
	Nitous Oxide	N2O	y	n
	Nitrogen Pentoxide	N2O5	y	n
	Ozone	O3	y	n
	Methane	CH4	y	n

Atmospheric State Database

A comprehensive atmospheric state database needs to be composed for the exploration time period and resolution. The database composition requires integration of the chemistry models, aerosol models, reflectance datasets, and mission data products.



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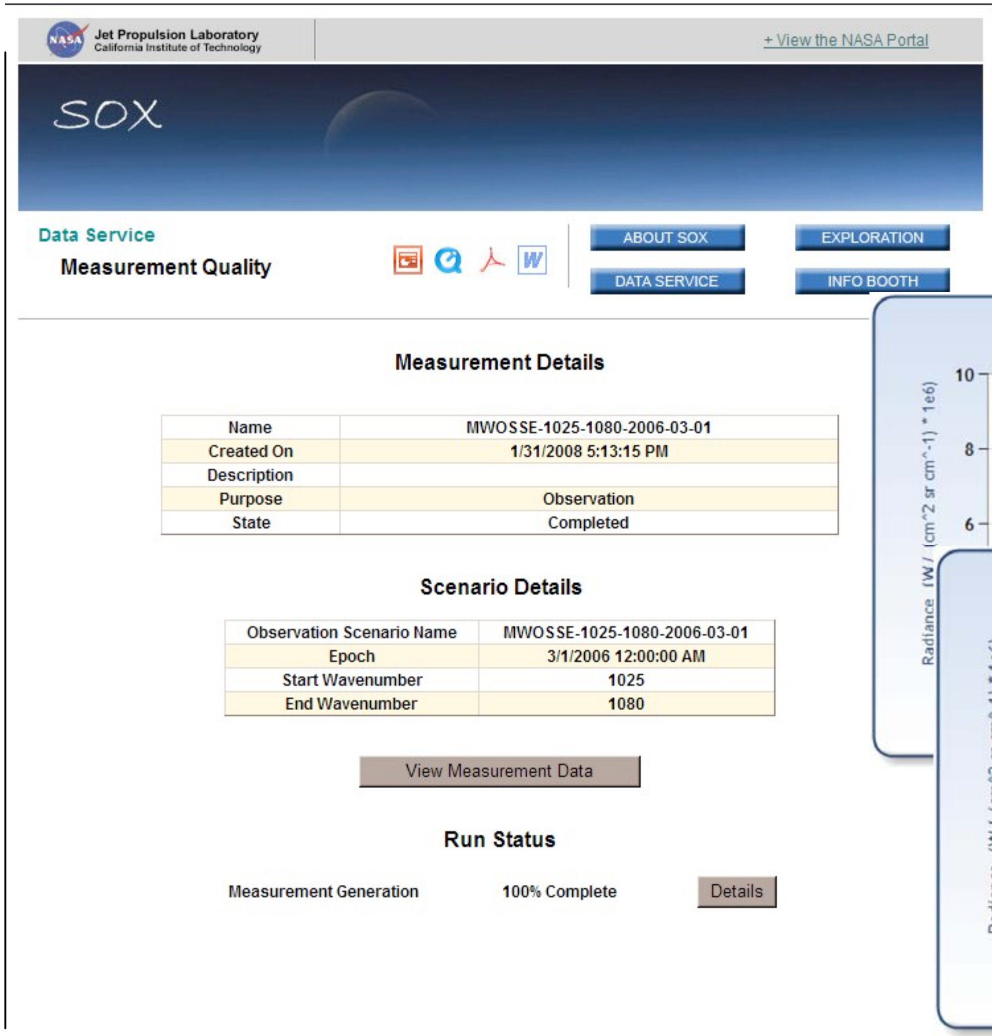
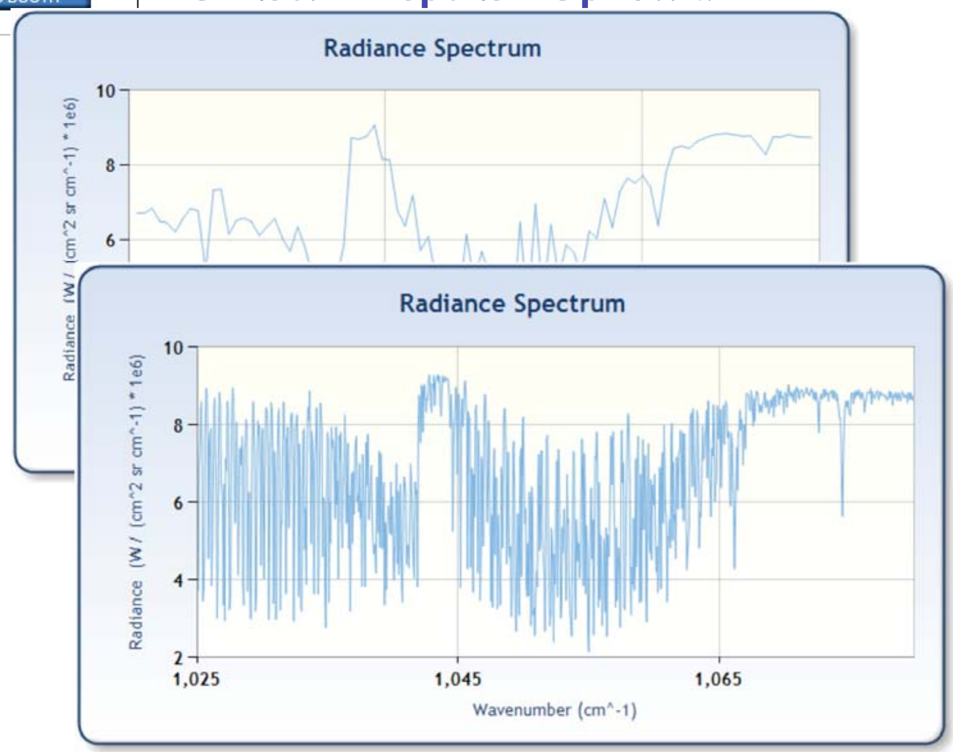
Measurement Simulation



For each signal radiance spectrum, a set of sensor response is simulated based on the performance range specification of the sensors.

Sensor Response Spectra



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Virtual Sensor Web

Transforms the parametric atmospheric state into a measurement data simulating the measurement physics of each instrument. An instrument system is described employing three generic instrument device properties, imager, spectrometer, and radiometer.

S
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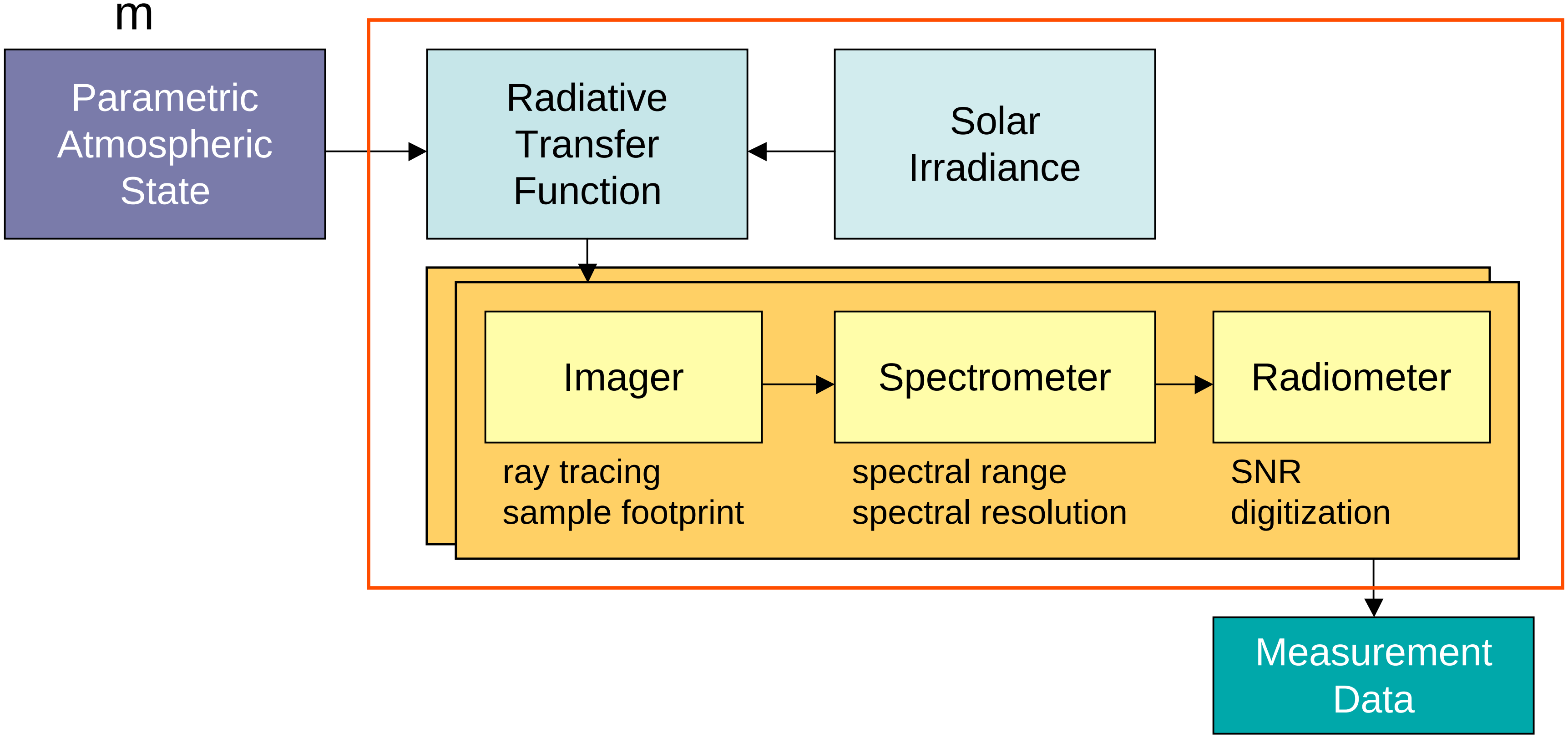
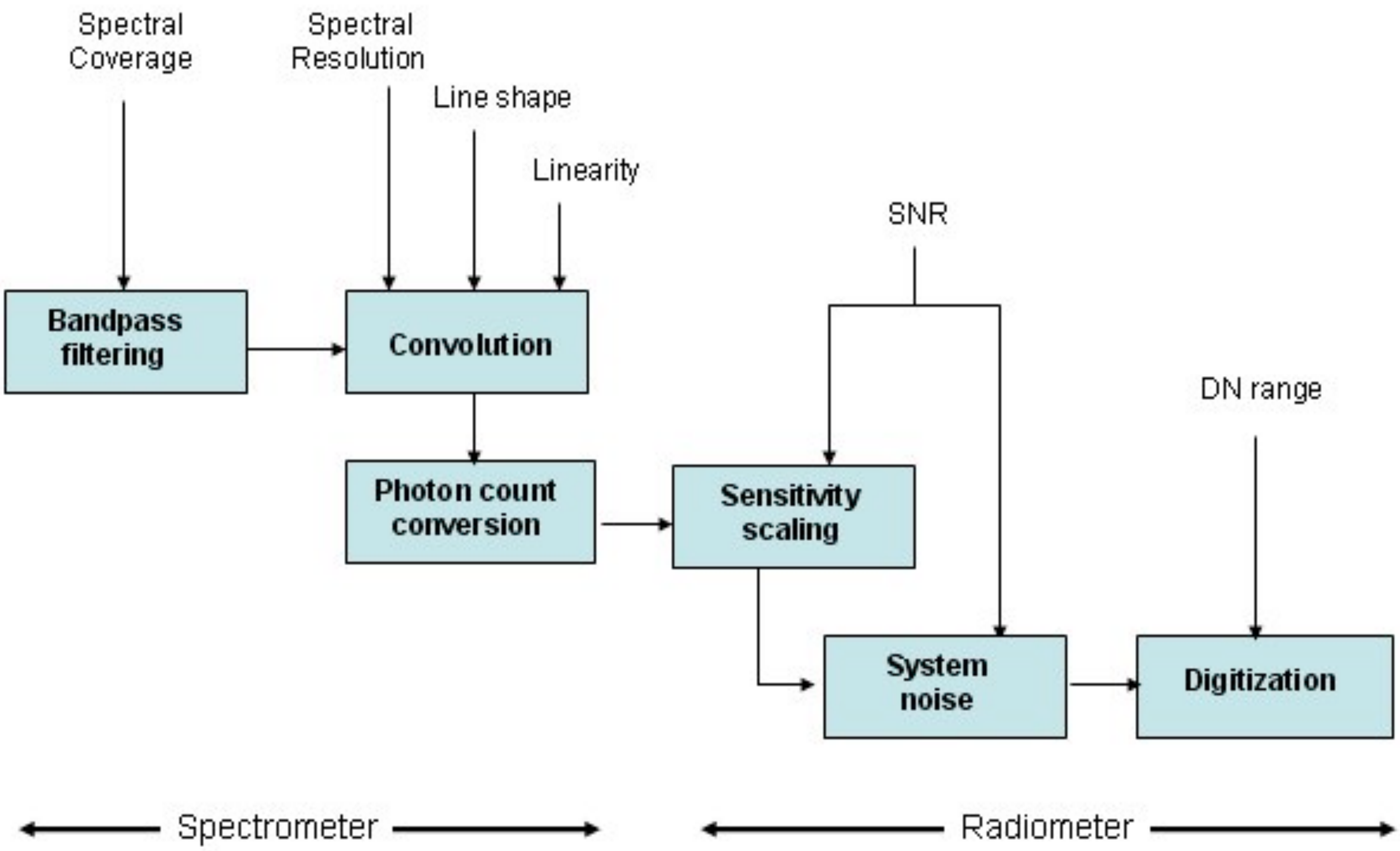


Virtual Instrument



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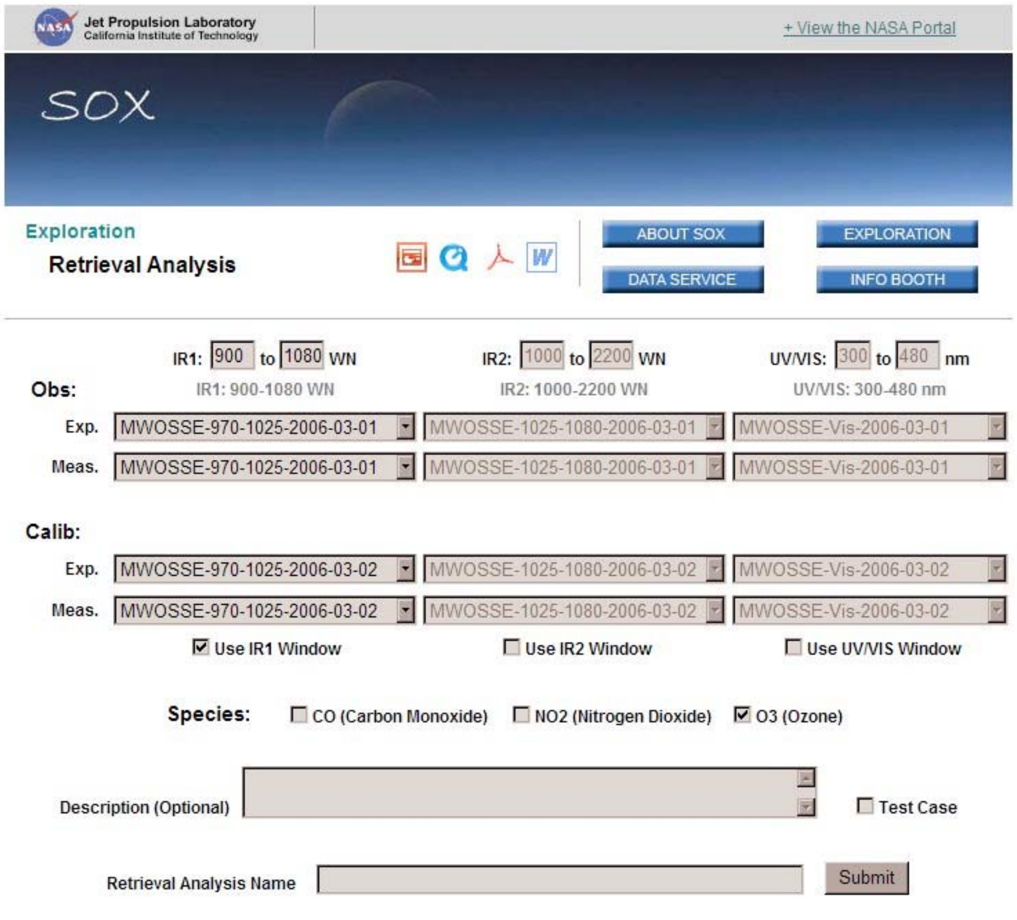
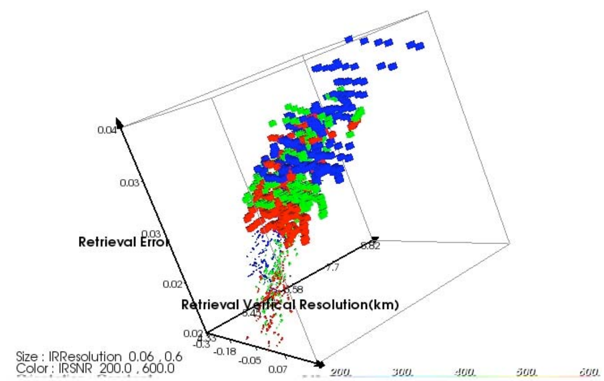
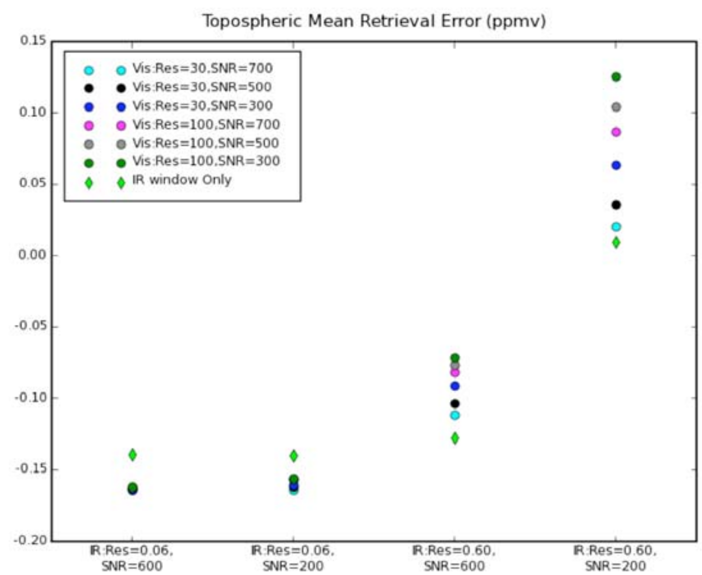
Retrieval Sensitivity Analysis







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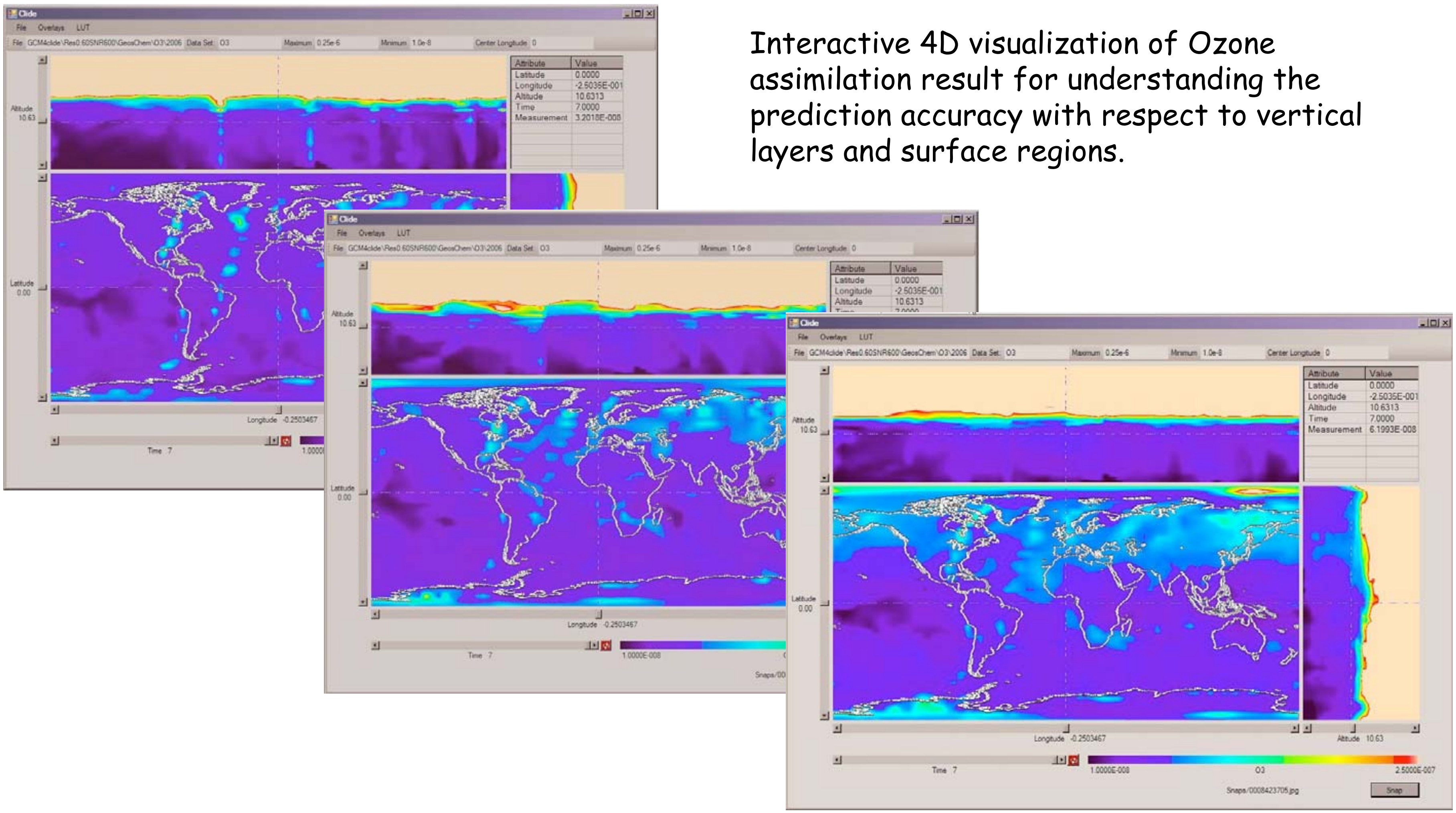
Data Assimilation



Interactive 4D visualization of Ozone assimilation result for understanding the prediction accuracy with respect to vertical layers and surface regions.

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TRL Status

Category	Capabilities	TRL-'06	TRL-'07	Current
Observation Platform Modeling	Space-borne	3	5	5
	Air-borne	-	-	**3**
	In Situ	-	-	-
Instrument Type Modeling	UV/Vis	-	5	5
	IR	3	5	5
	MicroWave	-	-	**3**
Simulation Product Distribution Service	Atmospheric State	-	-	**3**
	Single instrument	3	5	5
	Multiple instruments	-	-	**4**
	Retrieval Results	3	4	5
Science Impact Analysis	Ozone	2	3	**4**
	CO	2	3	4
	NO_x	-	-	2
	SO_x	-	-	-

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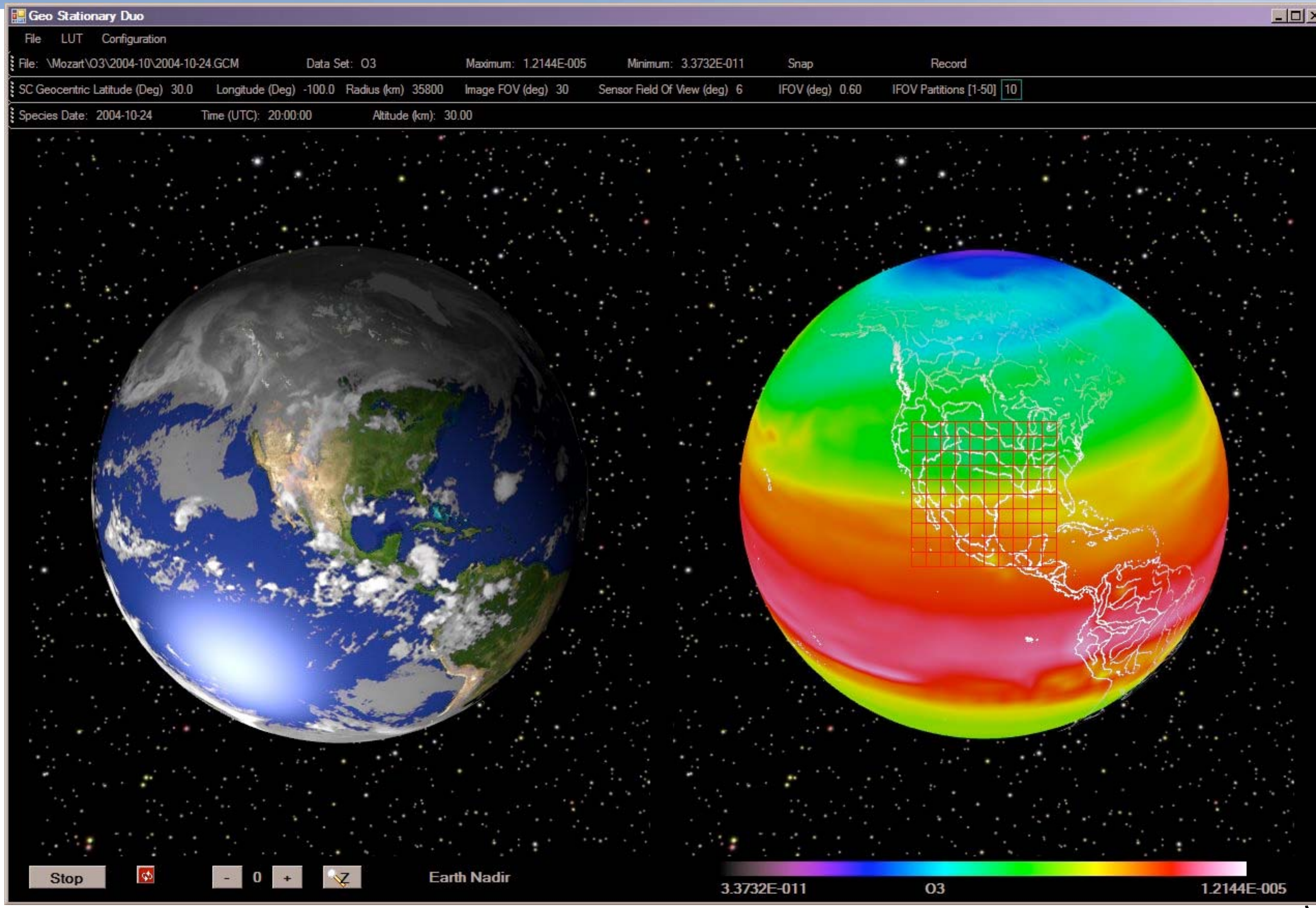
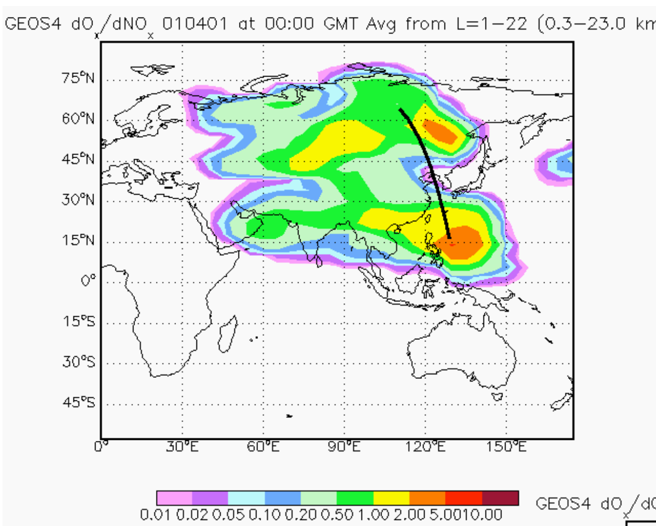
Current Work

- Use regional model fields and **geo-stationary** viewing
- Assimilate into regional model and **make AQ forecasts**



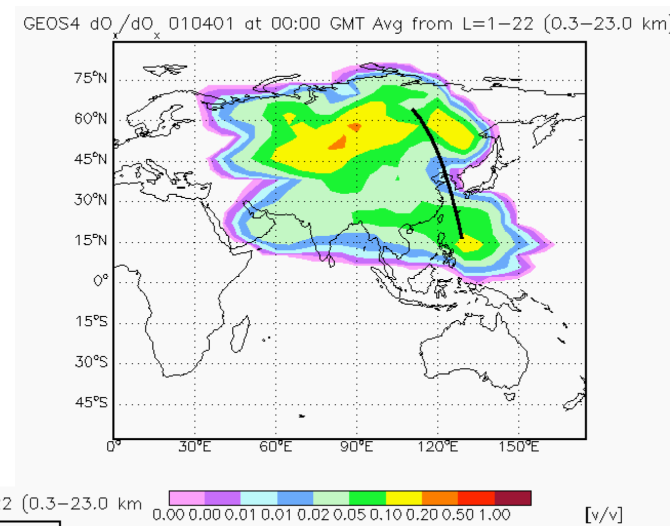
Future Work

dO3/dNOx

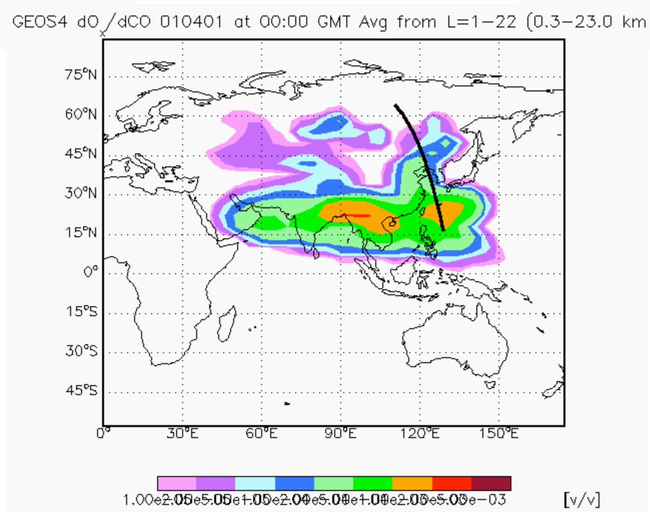


4D-Variational Assimilation Framework for Targeted Observation

dO3/dOx



dO3/dCO



GEOS-4 chemistry, transport and convection adjoint influence functions (48 hours simulation from 2001/04/01)

O_3 : Ozone
CO : Carbon monoxide
NOx : Nitrogen oxides (NO, NO_2)

$dO_3/dNOx$ implies the changes in ozone at a given space and time to the changes in Nitrogen oxides at any other space and time.