Integrating Inter-disciplinary Science Data with Semantic Mediation

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SESDI - Semantically-Enabled Science Data Integration

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Overview

- A little about semantics
- A little about integration
- Use case
- Semantic mis-understanding
- Impact of semantic mediation
- Methodology
- Some details of the integrating concepts
- Now, let's hook up some data
- Summary and outlook



A little about semantics

- Gives syntax *meaning*
- Basic element is the *triple*: {subject-predicate-object}

Interferometer is-a optical instrument

Optical instrument has focal length

An ontology is a representation of this knowledge

- W3C is the primary (but not sole) governing organization for languages, specifications, best practices, etc.
 - RDF Resource Description Framework
 - OWL 1.0 Ontology Web Language (OWL 2.0 on the way)
- Encode the knowledge in triples, in a triple-store, software is built to traverse the semantic network, it can be queried or reasoned upon
- Put semantics between/ in your interfaces, i.e. between layers and components in your architecture, i.e. between 'users' and 'information' to mediate the exchange

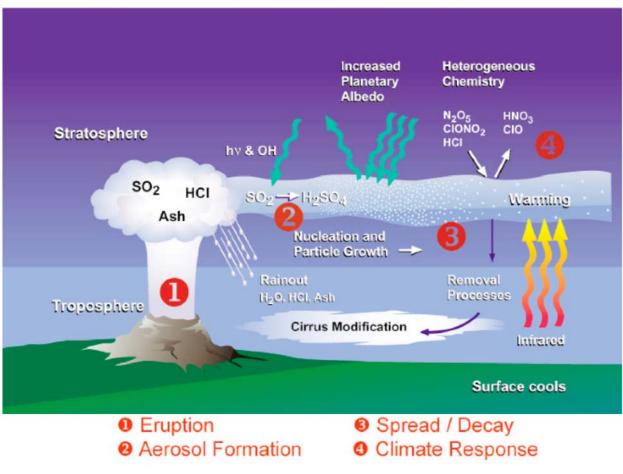


A little about integration

- When we integrate, we integrate concepts, terms
- In the past we would ask, guess, research a lot, or give up
- It's pretty much about meaning
- Semantics can really help find, access, integrate, use, explain, trust...
- What if you...
 - could not only use your data and tools but remote colleague's data and tools?
 - find and use data you could not before?
 - understood their assumptions, constraints, etc and could evaluate applicability?
 - knew whose research currently (or in the future) would benefit from your results?
 - knew whose results were consistent (or inconsistent) with yours?...



Integrative Use Case Determine the statistical signatures of both volcanic and solar forcings on the height of the tropopause





Challenges for Solar Radiation data integration

- Semantic misunderstanding
 - E.g. sunspot number and variations in solar radiation: over 90% of researchers outside the sub-field of solar radiation think: sunspot number *is a* measure of solar radiation
 - In reality: a sunspot number *is a* measure of the number of sunspots appearing on the visible solar surface, a sunspot *is an* indicator of the location of strong solar magnetic fields, strong magnetic fields are collectively known as solar activity, sunspots are observed to produce a localized *decrease* in the solar radiation output, at some wavelengths, *increase* at others, etc.
- Interfaces are built by computer scientists with syntax that often works within a discipline but rarely across them



SESDI Impact: A Better Way to Access Data

The Problem

Scientists only use data from a single instrument because it is difficult to access, process, and understand data from multiple instruments. A typical data query might be:

"Give me the temperature, pressure, and water vapor from the AIRS instrument from Jan 2005 to Jan 2008"

"Search for MLS/Aura Level 2, SO2 Slant Column Density from 2/1/2007"

A Solution

Using a simple process, SESDI allows data from various sources to be registered in an ontology so that it can be easily accessed and understood. Scientists can use only the ontology components that relate to their data. An SESDI query might look like:

"Show all areas in California where sulfur dioxide (SO2) levels were above normal between Jan 2000 and Jan 2007"

This query will pull data from all available sources registered in the ontology and allow seamless data fusion. Because the query is measurement related, scientists do not need to understand the details of the instruments and data types.



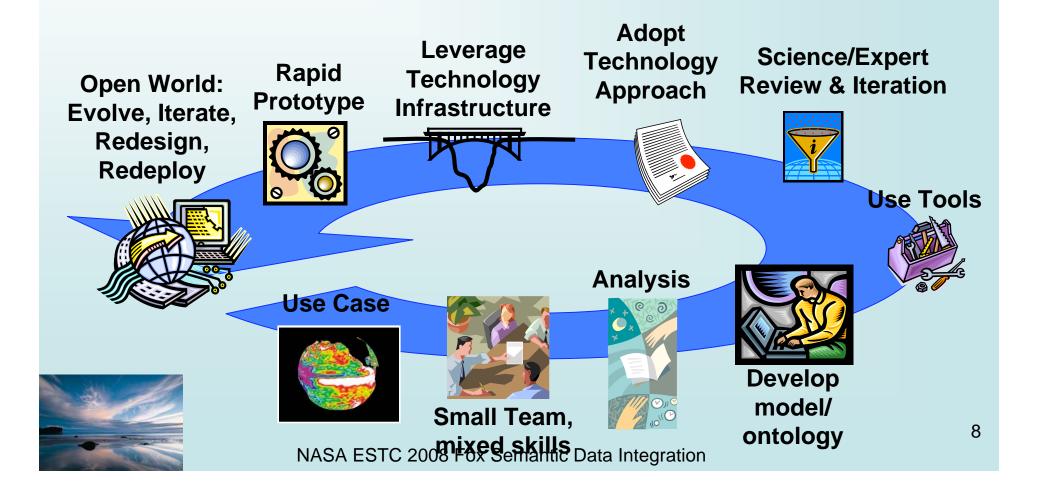
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Semantic Web Methodology and Technology Development Process

Establish and improve a well-defined methodology vision for Semantic Technology based application development

Leverage controlled vocabularies, etc.



Volcano-Atmosphere considerations

- Focus on tropopause -> temperature gradients
- Stratospheric and tropospheric aerosols, the tropospheric reservoir
- Quantities/processes: Gas, particles, ejecta, scattering
- Records: Pulses, e.g. in SO2 events
- Related aspects: SO2, H2SO4, O3 chemistry
- Data from: in-situ and remotely sensed observation, proxy, simulation, pseudo-proxy
- Processes: solar, volcanic, GHG, ocean, land-use
- Priors to consider: statistics of variability and extremes
- Main task: detection and attribution
- Solar-Atmosphere considerations are very similar

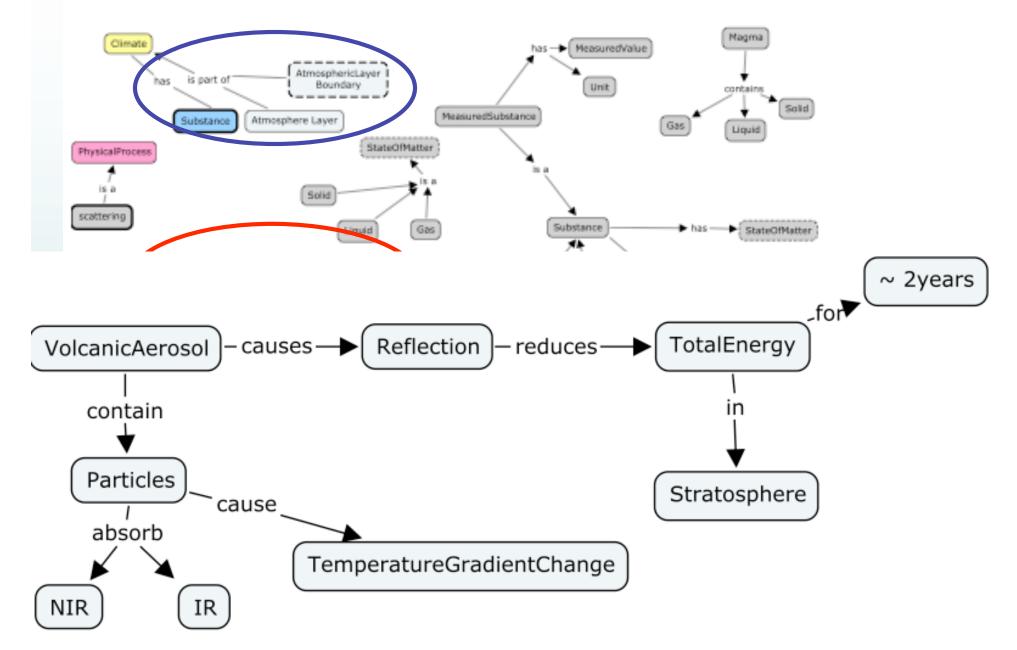


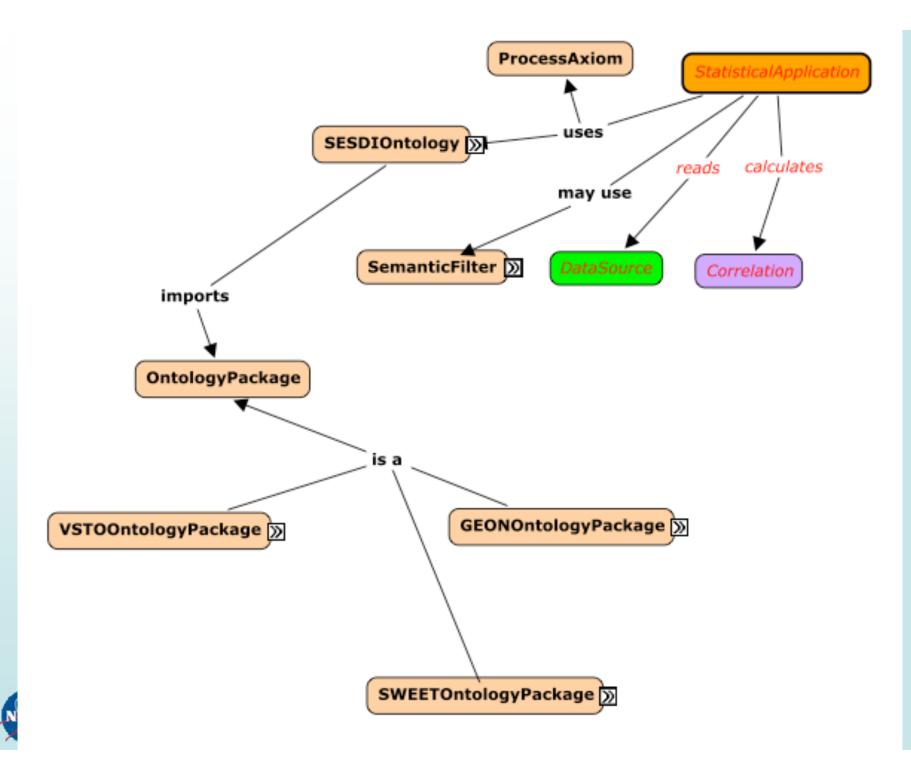
Components to implement

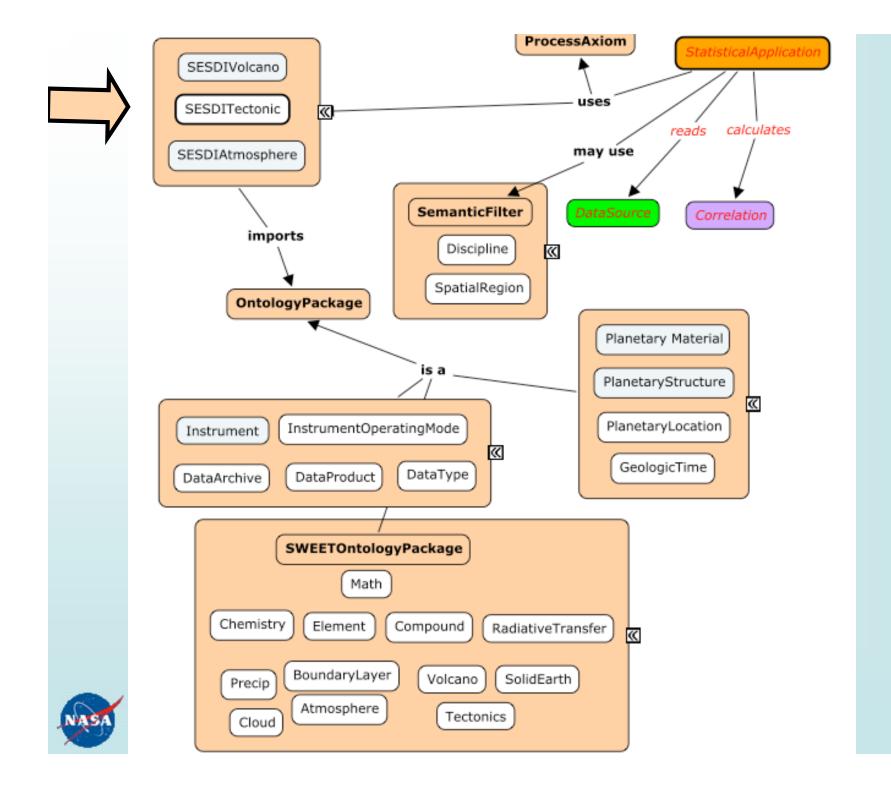
- An analysis application
- Cross-domain terms, concepts and relations (mediation here)
- Connections to underlying data (registration and mediation)
- Framework to put these together
- Integration connector

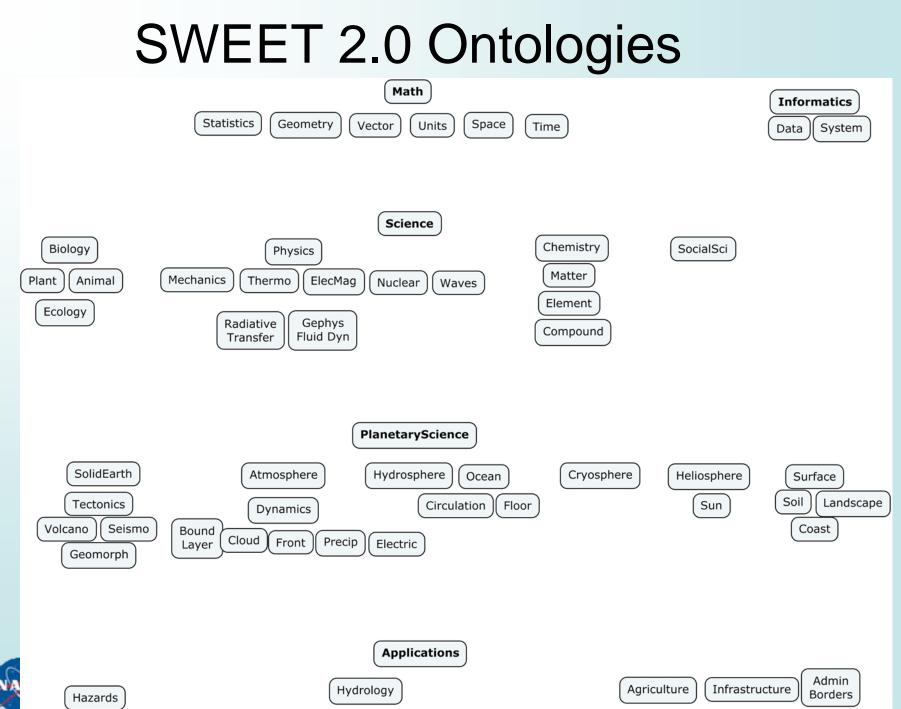


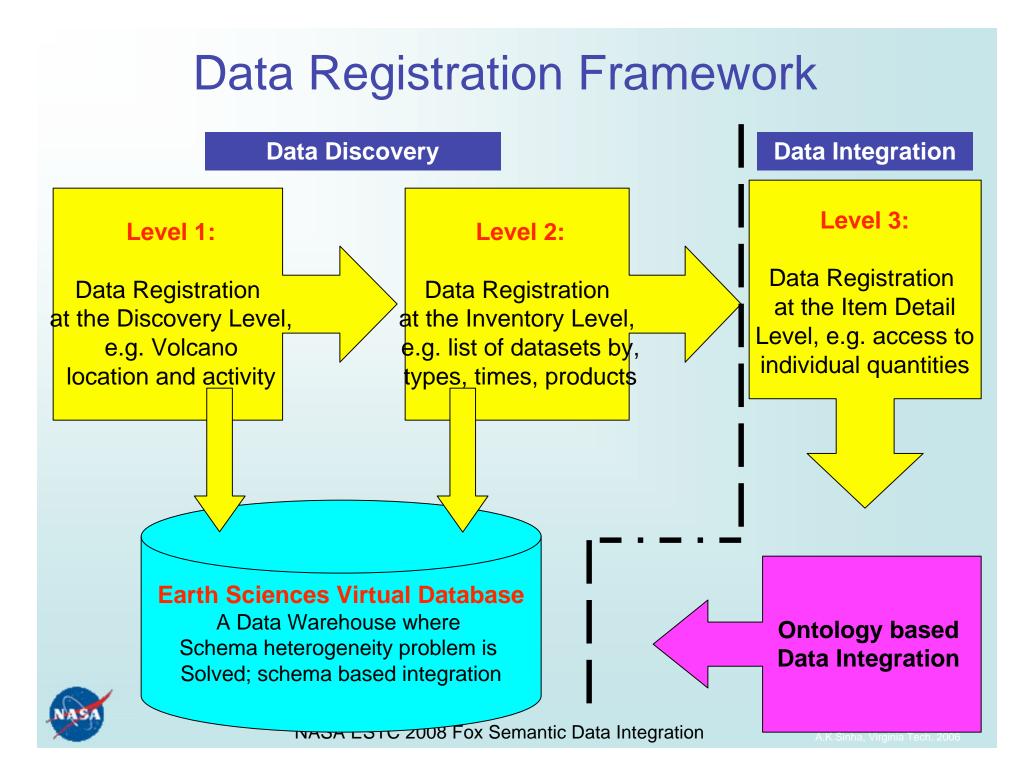
Detection and attribution relations...

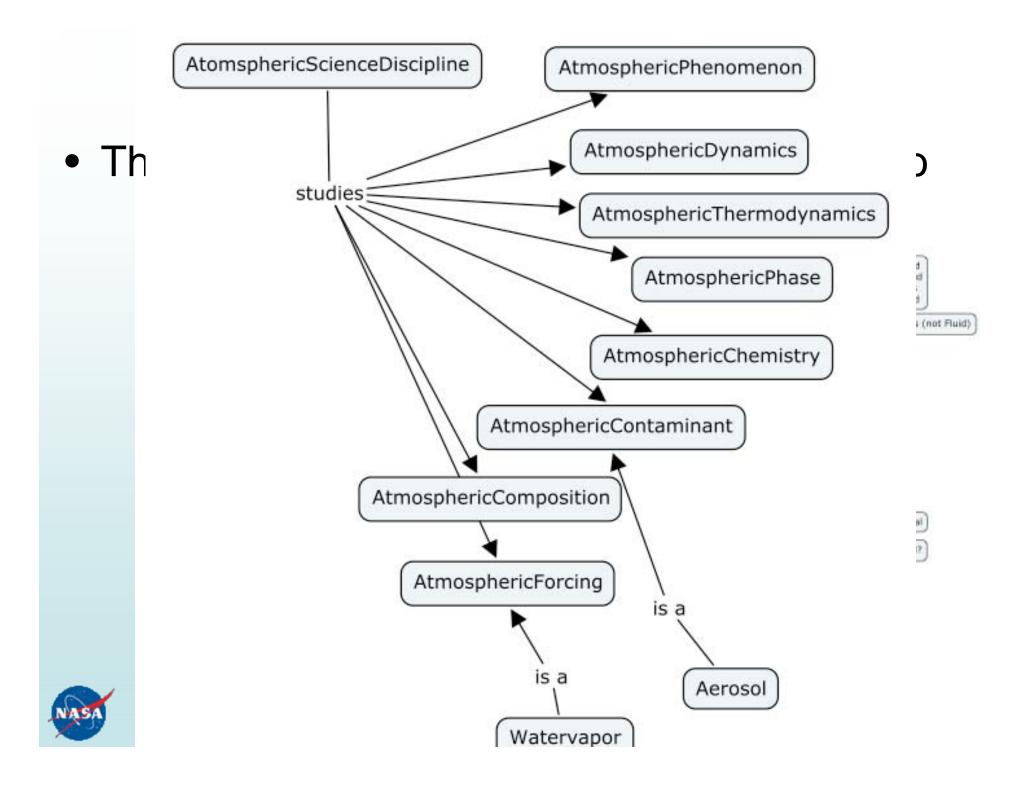












SEDRE: Semantically Enabled Data Registration Engine

• SEDRE: a system that enables scientists to semantically register data sets for optimal querying and semantic integration

 SEDRE enables mapping of heterogeneous data to concepts in domain ontologies



A. K. Sinha, A. Rezgui, Virginia Tech NASA ESTC 2008 Fox Semantic Data Integration

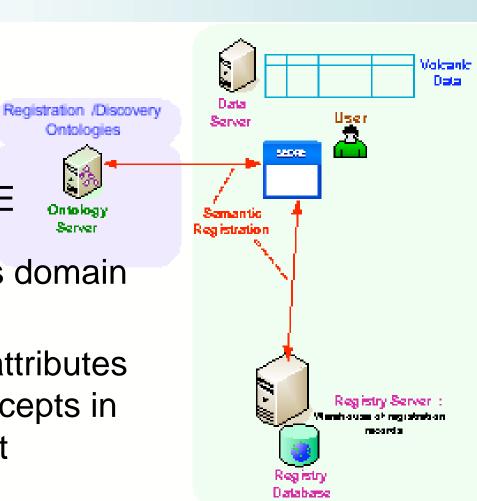
Semantic Registration in SEDRE: An Overview

Ontologies

Ontolo-ar

Server

- SEDRE is a desktop application
- Users download and install SEDRE
- SEDRE accesses domain ontologies
- Users map data attributes $(e.g., SO_2)$ to concepts in ontologies without 'knowing it'





Example 1: Registration of Volcanic Data

Location Codes:

• U - Above the 180° turn at Holei Pali (upper Chain of Craters Road)

• L - Below Holei Pali (lower Chain of Craters Road)

• UL - Individual traverses were made both above and below the 180° turn at Holei Pali

• H - Highway 11

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| 2 | 1/10/2002 | 660 | 380 | 9.2 | 9 | 6 | L | С | |
| 3 | 1/16/2002 | 610 | 180 | 8.9 | 14 | 7 | L | С | |
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| 5 | 2/4/2002 | 1050 | 270 | 5.5 | 54 | 3 | U | С | |
| 6 | 2/11/2002 | 1170 | 310 | 10.3 | 30 | 7 | L | В | |
| 7 | 2/21/2002 | 950 | 150 | 7.9 | 30 | 6 | L | С | |
| 8 | 2/25/2002 | 1280 | 240 | 11.3 | 30 | 6 | L | С | |
| 9 | 3/4/2002 | 720 | 120 | 5.2 | 40 | 6 | UL | С | |
| 10 | 3/18/2002 | 1010 | 250 | 14.7 | 30 | 7 | L | A | |
| 11 | 4/2/2002 | 1150 | 200 | 8.3 | 355 | 5 | L | В | |
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| м | ♦ ► ► \Shee | et1 / Sheet2 / | Sheet3 / | | < | | | | > |
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SO₂ Emission from Kilauea east rift zone vehicle-based (Source: HVO)

Abreviations: t/d=metric tonne (1000 kg)/day, SD=standard deviation, WS=wind speed, WD=wind direction east of true north, N=number of traverses 19 NASA ESTC 2008 Fox Semantic Data Integration

Loading Volcanic Data into SEDRE

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| Register Accou | ints Options Help | | Date | SO2 (t/d) | SD (I/d) | WS (m/s) | WD (deg |
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| My Documents | Gravity_Data.xls Rock_GeoChemistry_Data.xls Volcanic_of2007-1114_table3.xls Volcanic_of2007-1114_table6.xls | | | | | | |
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Registering Volcanic Data (1)

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| | | | | | | | | | | | | | | | | | | | 37392 | 1240 | 260 | 6.1 | 34 |
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Registering Volcanic Data (2)

| Location | | | | | | | | | | | | | | | | Γ | | Date | SO2 (t/d) | SD (t/d) | WS (m/s) | WD (degrees) |
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| | | | | | | | 2000 | | | _ | | | | | | | | 37291 | 1050 | 270 | 5.5 | 54 |
| Elevation / Depth | 1 | | | Sout | th | | | | | | ampling | Date | n I | | | | | 37298 | 1170 | 310 | 10.3 | 30 |
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Example 2: Registration of Atmospheric Data

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| 2 | -40.487 | -40.412 | 52.913 | 52.847 | 52.06 | 51.994 | 52.443 | 46.464 | 33.584 | 48.756 | 0.293 | 1.694 | |
| 3 | -40.371 | -40.303 | 52.06 | 51.994 | 51.244 | 51.178 | 51.61 | 46.838 | 29.258 | 48.365 | -0.443 | 1.39 | |
| 4 | -40.261 | -40.194 | 51.244 | 51.178 | 50.488 | 50.422 | 50.826 | 47.195 | 24.866 | 48.004 | 0.875 | 1.411 | |
| 5 | -40.153 | -40.089 | 50.488 | 50.422 | 49.778 | 49.711 | 50.095 | 47.533 | 20.499 | 47.661 | 1.021 | 1.429 | |
| 6 | -40.049 | -39.986 | 49.778 | 49.711 | 49,107 | 49.039 | 49.405 | 47.855 | 16,159 | 47.338 | -1.422 | 1.414 | |
| 7 | -39.946 | -39.885 | 49.107 | 49.039 | 48.46 | 48.391 | 48.746 | 48.165 | 11.842 | 47.012 | -1.247 | 1.593 | |
| 8 | -39.843 | -39.783 | 48.46 | 48.391 | 47.833 | 47.763 | 48.11 | 48.468 | 7.542 | 46.662 | 0.734 | 1.454 | |
| 9 | -39.738 | -39.681 | 47.833 | 47.763 | 47.215 | 47.143 | 47.488 | 48.767 | 3.249 | 46.117 | 1.735 | 1.424 | |
| 10 | -39.631 | -39.575 | 47.215 | 47.143 | 46.599 | 46.526 | 46.871 | 49.065 | 1.051 | 132.086 | 0.558 | 1.401 | |
| 11 | -39.521 | -39.467 | 46.599 | 46.526 | 45.983 | 45.907 | 46.255 | 49.366 | 5.345 | 133.58 | -0.208 | 1.088 | |
| 12 | -39.405 | -39.353 | 45.983 | 45.907 | 45.355 | 45.277 | 45.632 | 49.671 | 9.645 | 133.977 | 0.715 | 1.387 | ~ |
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Satellite data for SO₂ emissions

Abbreviation: SCD: Slant Column Density (in Dobson Unit (DU)) 23 NASA ESTC 2008 Fox Semantic Data Integration



Loading Atmospheric Data into SEDRE

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| | | | | | | 20080304 | 62332.647 | 0 | -39.822 | -40.049 |
| or Elements | | | | | | 20080304 | 62332.897 | 0 | -39.722 | -39.946 |
| SO2 HCI H2SO4 H2O | | | | | | 20080304 | 62333.147 | 0 | -39.622 | -39.843 |
| | | | | | | 20080304 | 62333.397 | 0 | -39.519 | -39.738 |
| HNO3 CIO N205 CION2 | | | | | | 20080304 | 62333.647 | 0 | -39.412 | -39.631 |
| | | | | | | 20080304 | 62333.897 | 0 | -39.3 | -39.521 |
| nents | | | | | | 20080304 | 62334.147 | 0 | -39.182 | -39.405 |
| H | | | | He | | | | | | |
| Li Be | | вс | N O | F Ne | ╡ | Concept | Data Attribute | Data Acquisition | Ur | nit |
| Na Mg | | AL Si | P S | | 1 * | | | | | |
| K Ca Sc Ti V Cr Mn Fe Cc |) Ni Cu Zn | Ga Ge | As Se | Br Kr | | | | | | |
| Rb Sr Y Zr Nb Mo To Ru Ri | | In Sn | Sb Te | | 3 | | | | | |
| | | | | At Rn | 3 | | | | | |
| <mark>Cs Ba Hf Ta W Re Os Ir</mark> | Pt Au Hg | TI Pb | Bi Po | AL DO | | | | | | |
| | | | | | 1 | | | | | |
| Fr Ra Rf Db Sg Bh Hs M | | | Uup Uuh | | - | | | | | |
| La Ce Pr Nd Pm Sn | n Eu Gd Tb | Dy Ho | Er Tm | Yb Lu | j _ | Add New Mapping | | Pagintar Data | 1 | |
| | n Eu Gd Tb | | | Yb Lu | j _ | Add New Mapping | | Register Data |] | |
| La Ce Pr Nd Pm Sn | n Eu Gd Tb | Dy Ho | Er Tm | Yb Lu | j _ | Add New Mapping | | Register Data |] | |
| La Ce Pr Nd Pm Sn | n Eu Gd Tb | Dy Ho | Er Tm | Yb Lu | j _ | Add New Mapping | | Register Data |] | |
| La Ce Pr Nd Pm Sn | n Eu Gd Tb | Dy Ho | Er Tm Fm Md | Yb Lu No Lr | j _ | Add New Mapping | | Register Data |) | |
| La Ce Pr Nd Pm Sn Ac Th Pa U Np Pu | n Eu Gd Tb J Am Cm Bk | Dy Ho | Er Tm Fm Md | Yb Lu No Lr | j _ | Add New Mapping | | Register Data |] | |
| La Ce Pr Nd Pm Sn Ac Th Pa U Np Pu mpounds Ixides Sulfides Sulfates Bromides Iodides | n Eu Gd Tb J Am Cm Bk Acetates | Dy Ho | Er Tm Fm Md | Yb Lu No Lr | j _ | Add New Mapping | | Register Data |] | |
| La Ce Pr Nd Pm Sn Ac Th Pa U Np Pu | n Eu Gd Tb J Am Cm Bk Acetates | Dy Ho | Er Tm Fm Md | Yb Lu No Lr e of pounds | j _ | Add New Mapping | | Register Data |] | |

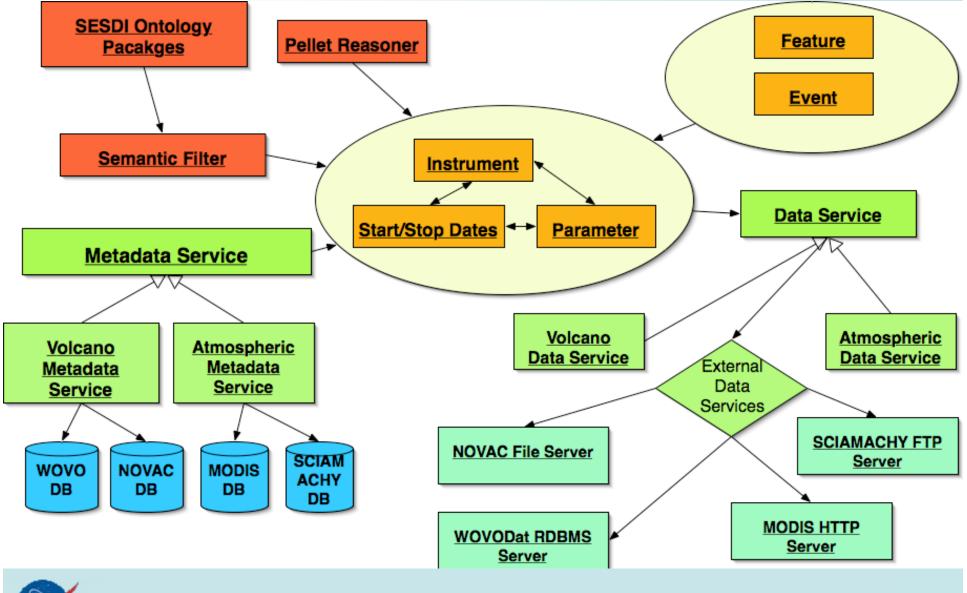


Registering Atmospheric Data (2)

| sphe | re | Atmo | sphe | ere | Biosp | here | Cryos | sphere | Hy | drosph | ere | | | | | | | | | | | | | | |
|----------|------------------|-------------|------|-----|----------|------|-------|--------|----|----------------|-----|-------|---------|---------|----------|----------|----------------|----------|---|---------------------|------------------------|-------------|-------|------------------|---|
| Loca | | | | | | | | | | | | | | | | | | | | A | RAA | SCD | error | chi2fit | |
| | La | titude | | | | | N | orth | | | | | | Sample | ID | ר | | | • | 584 | 48.756 | 0.293 | 1.694 | 9.771 | |
| | | | | | | | | | | | | | _ | | | | | | | 258 | 48.365 | -0.443 | 1.39 | 6.581 | |
| | Lon | igitude | | v | /est | | | | | East | | | | Station | ID | ור | | | | 866 | 48.004 | 0.875 | 1.411 | 6.779 | |
| | | | | n i | | | | | | | | | _ | | | | | | | 499 | 47.661 | 1.021 | 1.429 | 6.955 | |
| E | evatio | on / De | pth | | | | Sc | outh | | | | | S | ampling | Date | ור | | | | 159 | 47.338 | -1.422 | 1.414 | 6.811 | |
| | | | | | | | | | | | | | | | | | | | | 842 | 47.012 | -1.247 | 1.593 | 8.641 | |
| or Ele | ement | te | | | | | | | | | | | | | | | | | | 42 | 46.662 | 0.734 | 1.454 | 7.201 | |
| _ | S02 | | _ | нсі | | H2SO | | H2 | | | | | | | | | | | | 49 | 46.117 | 1.735 | 1.424 | 6.902 | |
| | 502 | | | ни | | H25U | 4 | H2 | 0 | | | | | | | | | | | 51 | 132.086 | 0.558 | 1.401 | 6.684 | |
| H | IN03 | | | CIO | | N205 | 5 | CIO | N2 | | | | | | | | | | | 45 | 133.58 | -0.208 | 1.088 | 4.033 | |
| | | | | | | | | | | | | | | | | | | | | 45 | 133.977 | 0.715 | 1.387 | 6.547 | |
| nents | | | | | | | | | | | | | | | | | | | < | 954 | 134.283 | -0.042 | 1.08 | 3.971 | |
| Li Na | Be M <u>c</u> | = | | | | | | | | | | | B Al | C Si | N P | 0 S | F Cl | Ne Ar | | Concept Latitude | Data Attribute lat. | Data Acqu | ~ | Unit | ~ |
| ĸ | Ca | $\exists -$ | | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr | | Longitude | lon. | | ~ | | ~ |
| Rb | Sr | | = | Zr | Nb | Mo | Тс | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | | Xe | 1 | S02 | SCD | Measured | ~ | Dobson Unit (DU) | ~ |
| Cs | Ba | | | Hf | Ta | W | Re | Os | lr | Pt | Au | Hg | TI | Pb | Bi | Po | At | Bn | | | | | | | |
| _ | Ra | = | 2 | | Db | | Bh | Hs | Mt | Ds | | Uub | Uut | Uua | Uup | Uuh | Uus | Uuo | * | | | | | | |
| Fr | Ва | _ | | Rf | \equiv | Sg | | | | | Rg | | | | <u> </u> | | | | | | | | | | |
| | | | | La | Ce | Pr | Nd | Pm | Sm | Eu | Gd | ТЬ | Dy | Ho | Er | Tm | ΥЬ | Lu | | Add New Mappin | | Register D | -+ | | |
| | | | | Ac | Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr | | Add New Mappin | _ | riegister D | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| npour | | | | | | | | | | | | | | | | Comp | of - oounds | , | | | | | | | |
| | | | | | | | | | | Acetat es O | | rides | | | | · · · |) Orga | nic | | | | | | | |
| ulfur | - | | | | | | | | | | | ide5 | | | | - |) Inorg | | | | | | | | |
| anur | IL AL | .10 | | | | | | | | | | | | | | <u> </u> | | | | | | | | | |



Semantic framework indicating how volcano and atmospheric parameters and databases can immediately be plugged in to the semantic data framework to enable data integration.



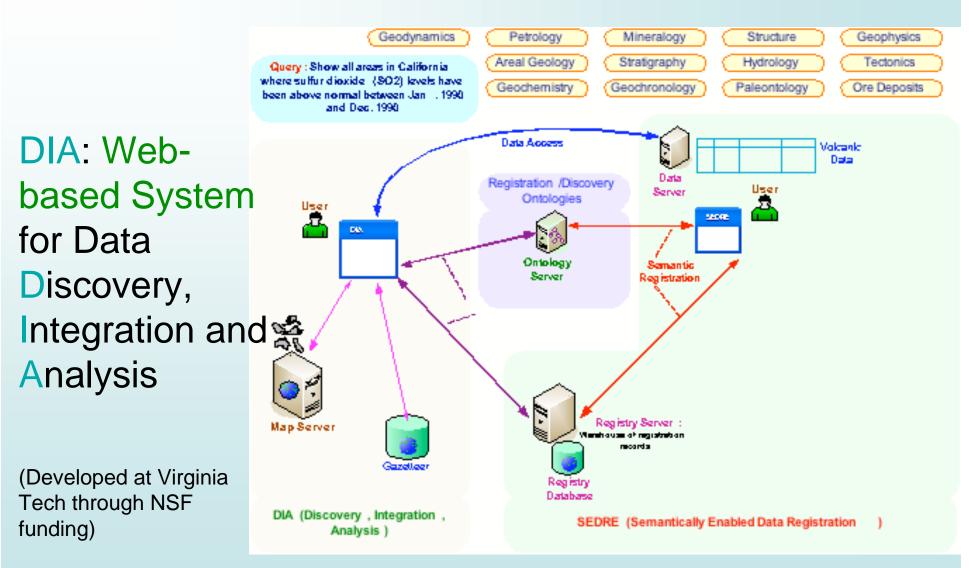
NASA ESTC 2008 Fox Semantic Data Integration

Summary and outlook

- Semantic data frameworks/ technologies are changing the landscape of providing data to scientists (in a good way)
- Tools for data registration are soon to be available
- Applications to perform data integration mediated by semantics are available
- Initial results applied to two volcanoes led to correlation of SO2 concentration from volcano and in the atmosphere and relation to H2SO4
- Solar radiation ontologies and data sources are in progress



SEDRE+DIA: Overview





General applicability

• To apply to another use case:

