Community Development of the SWEET semantic system for Earth and Environmental Data –
A Call for Interest

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https://purl.org/space-ontology

Brandon Whitehead
ESIP Semantic Technology Committee chair

A session presentation for January 2022 ESIP Winter meeting

Introduction

Organizer: Robert Rovetto

- Member ESIP clusters & partner orgs.
  - Semantic Tech Committee, Etc.
- Conceptual modeling, Formal ontology, Terminology. Ethics, methodology.
- Focus on space ontology… https://purl.org/space-ontology
- Cert. commercial mariner. Water rescue training & focus.
- Aspiring PhD student, actively applying

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Meetings: https://tinyurl.com/y6anucqp
Services: https://tinyurl.com/yas7trzy

Co-organizer: Brandon Whitehead

- Member ESIP clusters & partner orgs.
  - Semantic Tech Committee Chair
- Environmental Data Scientist, Manaaki Whenua -- Landcare Research

Agenda GoogleDoc*:* https://tinyurl.com/4wfhcadz
Questions for attendees: https://tinyurl.com/SWEET-Questions

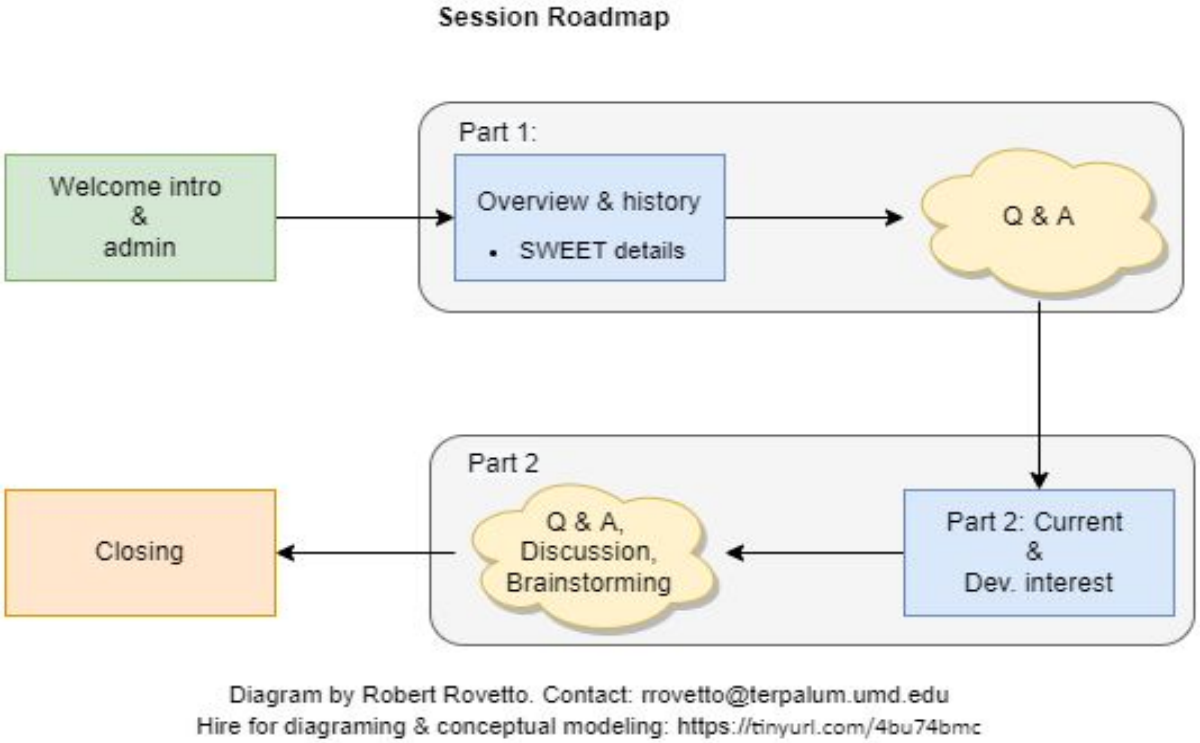
Acknowledgement of indigenous history & cultures.

Acknowledgements

- Input by B.Whitehead.
- Input by L.McGibbney (former SemTech chair)
- Made by R.Rovetto. Min. person hours: 70 hours work. No funding to declare.

Images with shadows, beginning slide 8, from PPTs (see references)

Session Roadmap



Questions for participants

- What are your research topics/expertise?
- What types of data do you work with?
- Do you have modeling challenges (and what are they)?
- What would you like to do with your data that you presently cannot?
  - How might SWEET help with that?

Can answer at: https://tinyurl.com/SWEET-Questions or agenda page

In a nutshell

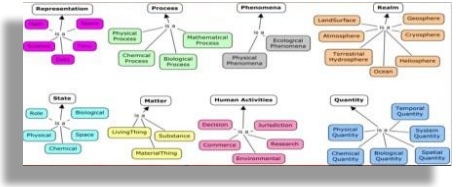
What is SWEET	□ a semantic technology. a knowledge organization system
Why should I care?	□ potential to help with your data needs, r&d, innovation,...
What problems is it solving?	□ content search, retrieval; syn, homyn support, …innovate
(Why important to develop)	□ for the same, for Earth sci, for innovation exploration

Computational Ontology(s)

- Various definitions. sometimes called semantic model, conceptual model, knowledge graph, …
  - Living catalog https://tinyurl.com/yrm78zpn
- Various dev. methodologies → automated, manual, …
- Can be developed to various degrees of complexity, size, and abstraction
  - sometimes used *as* other KOSs: as a taxonomy, a controlled vocab, as a database, …
- Pros & Cons as compared with other KOS
- one of many KOS composed of categories (metadata), capable of being formally defined (for computation & semantics) & structured (e.g., like a taxonomy)
  - A vocabulary + computable rules that constrain the meaning and use of the vocabulary → for formation of expressions that can be computed in machine inference, data queries, …
- Act as a semantic layer, providing an *interpretation of the meaning* of data elements
- As a terminological system, its terms can be mapped to others
- Can be *linked* to other ontologies

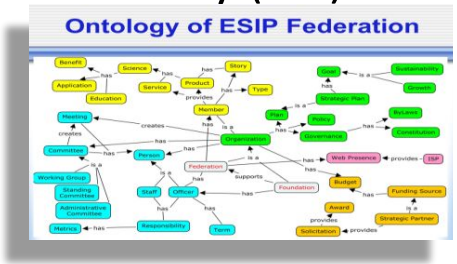
Ontology Consulting: https://tinyurl.com/34u9w6wx

Caution: Should ask… does a given ontology provide the desired/right meaning (or semantics) for your data? Owners & users should examine the (in)formal meaning expressed in any ontology (and what it assumes, imports) to determine suitability



SWEET Basics

- Semantic Web for Earth and Environmental Terminology (SWEET)
  - a suite of modular ontologies implemented in OWL
  - originally in the DARPA Markup Language (DAML) [7]
  - thousands of terms across relevant topics
- Developed at NASA JPL by Dr. Rob Raskin
  - used GCMD keywords. Decomposed into facets
- ESIP is current the steward of SWEET
  - approx. Mar 2017 SWEET files migrated to ESIP, by L. McGibbney (JPL)
  - https://github.com/ESIPFed/sweet
  - https://wiki.esipfed.org/Semantic_Technologies
  - living work. versions 3.x



NASA Support for SWEET

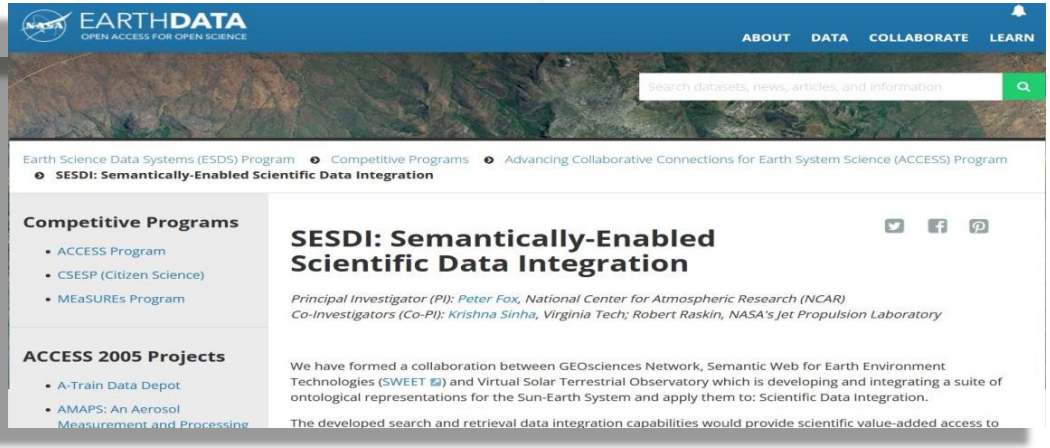
- AIST (2002-05)
  - SWEET development
- AIST/ACCESS (2006-09)
  - SESDI (Semantically-Enabled Science Data Integration) (Peter Fox, PI)

SWEET Users

- ESML- Earth Science Markup Language
- ESIP - Earth Science Information Partner Federation
- GEON- Geosciences Network
- GENESIS- Global Environmental & Earth Science Information System
- IRI- International Research Institute (Columbia)
- LEAD- Linked Environments for Atmospheric Discovery
- MMI- Marine Metadata Initiative
- NOESIS
- PEaCE- Pacific Ecoinformatics and Computational Ecology
- SESDI- Semantically Enabled Science Data Integration
- VSTO- Virtual Solar-Terrestrial Observatory

[10]

Example project



Some SWEET Benefits & Applications (1)

"Special emphasis on improving search for NASA Earth science data resources
- Atmospheric science, oceanography, geology, etc.

Provide a common semantic framework for describing Earth science information and knowledge

SWEET provides semantics tags to interpret data

SWEET supports model interoperability
- Earth Science terms
- Compatibility of model parameterizations, modules

SWEET supports grid interoperability
- Earth Science terms
- Grid concepts

Contributions of sweet - Improved data discovery without exact keyword matches" [1]

Some SWEET Benefits & Applications (2)

Circa 2011 and later

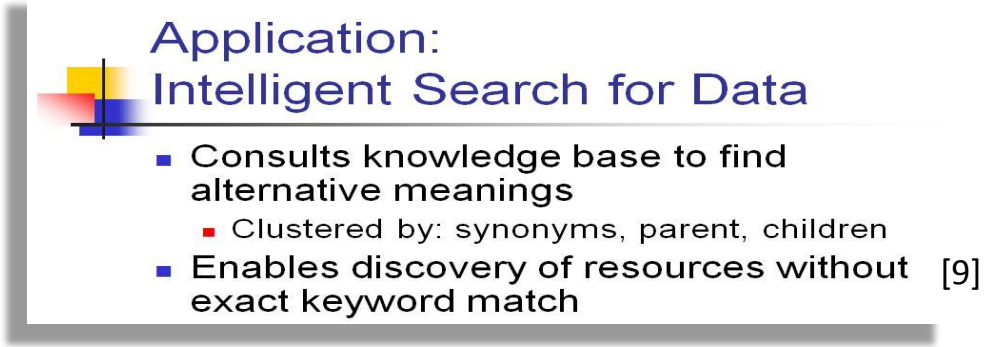
Used in NextGen Network Enabled Weather (NNEW) Ontology, within the US NextGen Air Transportation System project

2012

"we plan to replace part of the data-attributes ontology by importing the relevant Semantic Web for Earth and Environmental Terminology (SWEET) ontologies (Raskin and Pan 2005). SWEET provides **support for scientific and numerical concepts**, such as scientific units, scientific relations, provenance, and data representation. We believe that ontologies should carry as few ontological commitments as possible" [2, emph added]

Side note to be aware of: Relates to both technical & ethical aspects of ontology/semantics. Contact: rrovetto@terpalum.umd.edu to discuss.

Some SWEET Benefits & Applications (3)



[9]

2014:

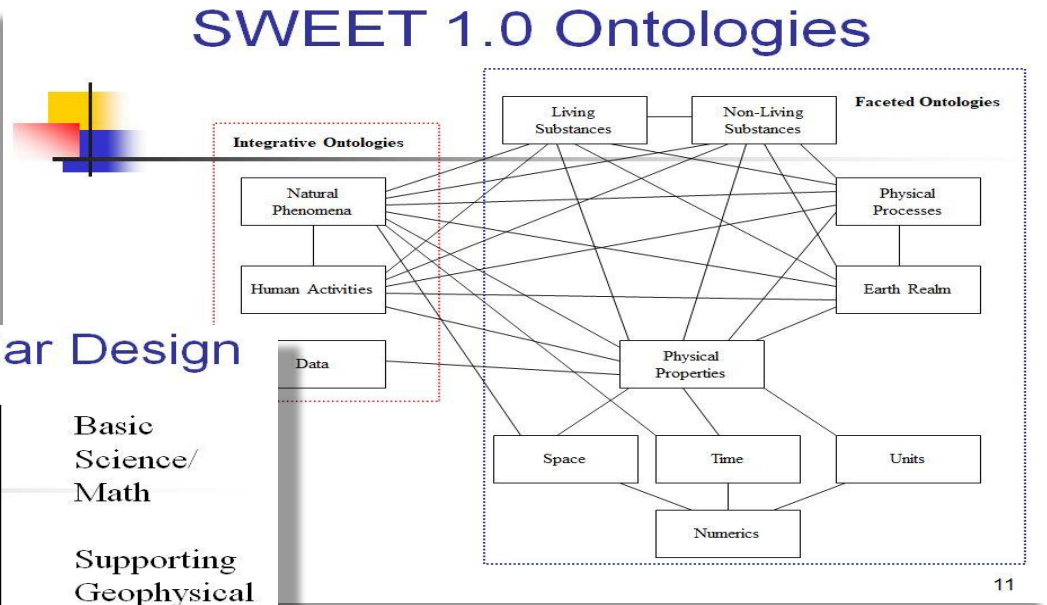
"This investigation suggested that the SWEET ontologies **do sufficiently represent the EES domain, and are broad in their topic coverage**." [5, emph added]

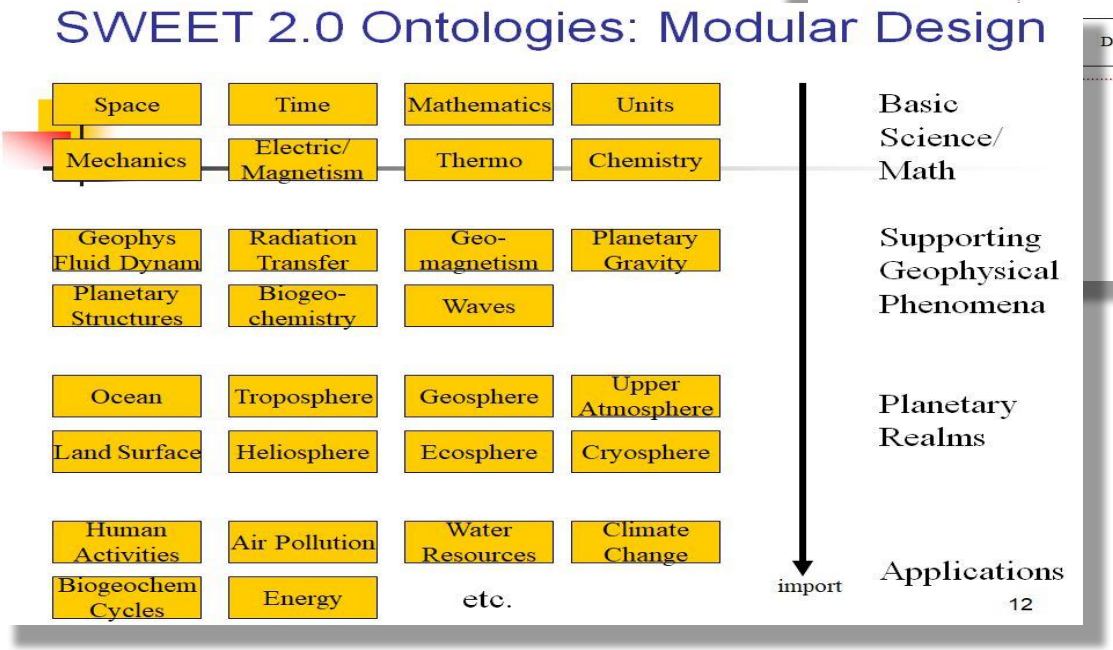
2021:

- "We **retrieve** phenomena and domain information using SWEET" [3, an ESIP presentation]
- "To create knowledge representations of science carried out in these publications, we use existing ontologies such as GCMD and SWEET." [4, an ESIP presentation]

SWEET Versions

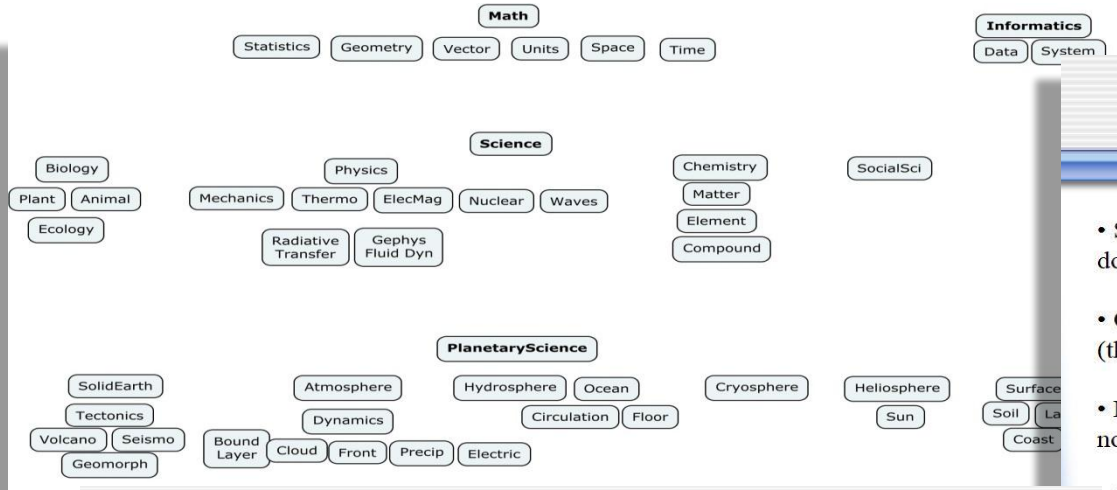
v. 1 to 3.5 (as of 2021)





Potential for SME to contribute to specific topics

SWEET 2.0 ontologies



SWEET 2.0 Modular Design

- Supports easy extension by domain specialists
- Organized by subject (theoretical to applied)
- Reorganization of classes, but no significant changes to content
- Importation is unidirectional

Math, Time, Space

Basic Science

Geoscience Processes

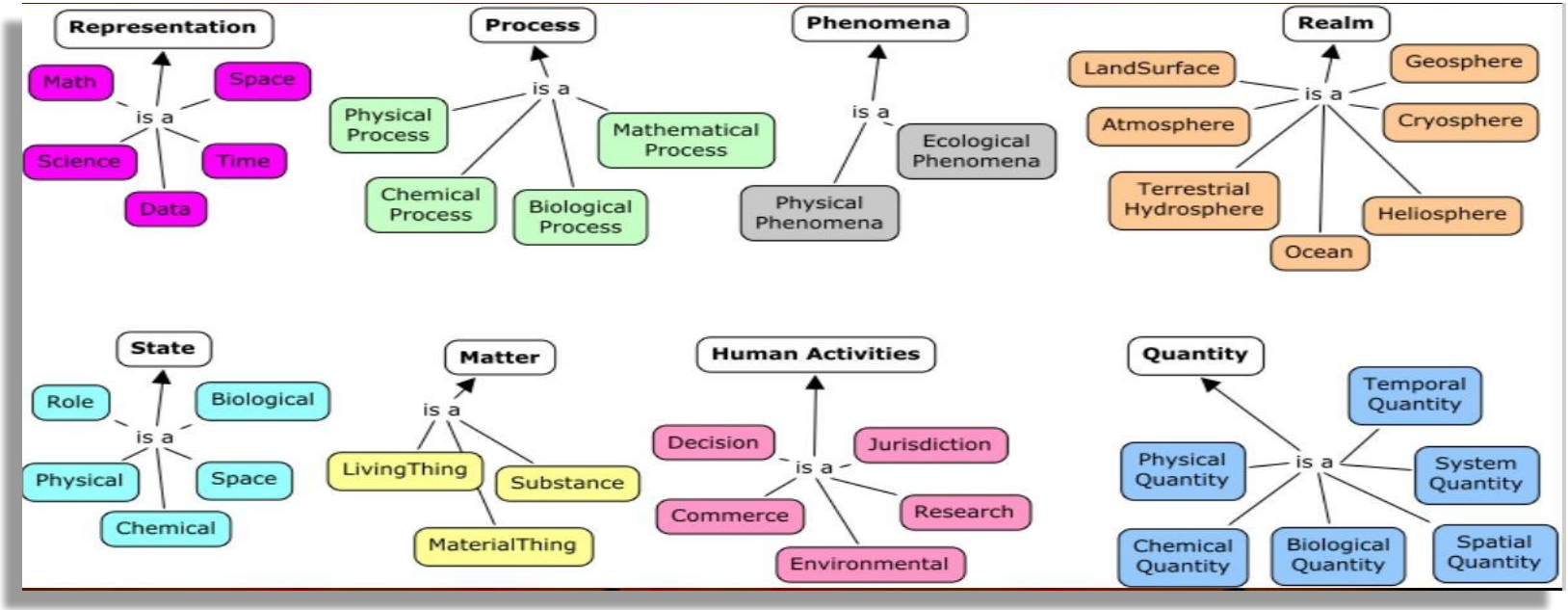
Geophysical Phenomena

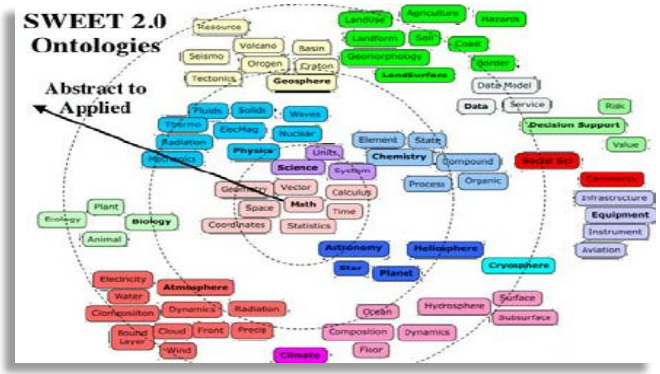
Applications

importation

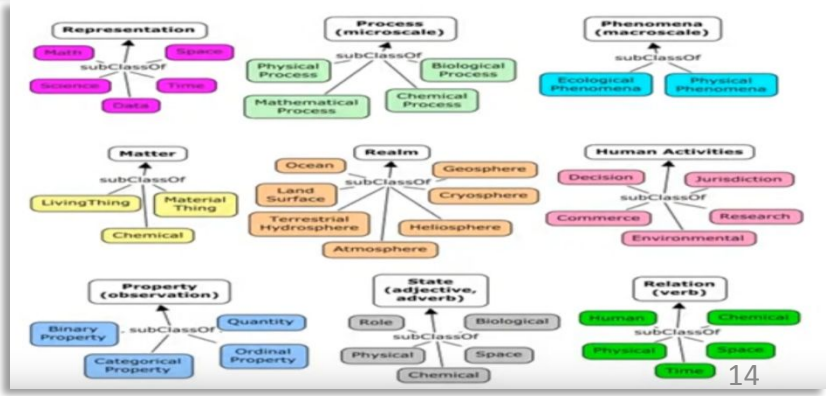
SWEET 2.0 New Features

- Organized by subject
  - Makes it easy for domain specialists to add new modules
- Smaller, modular ontologies
- 23 ontologies -> 80 ontologies

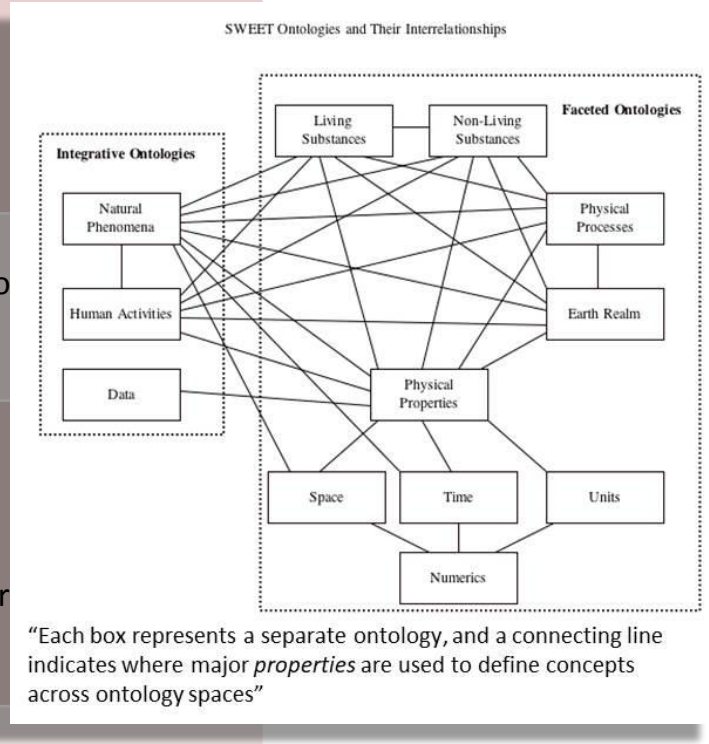




Broad categories

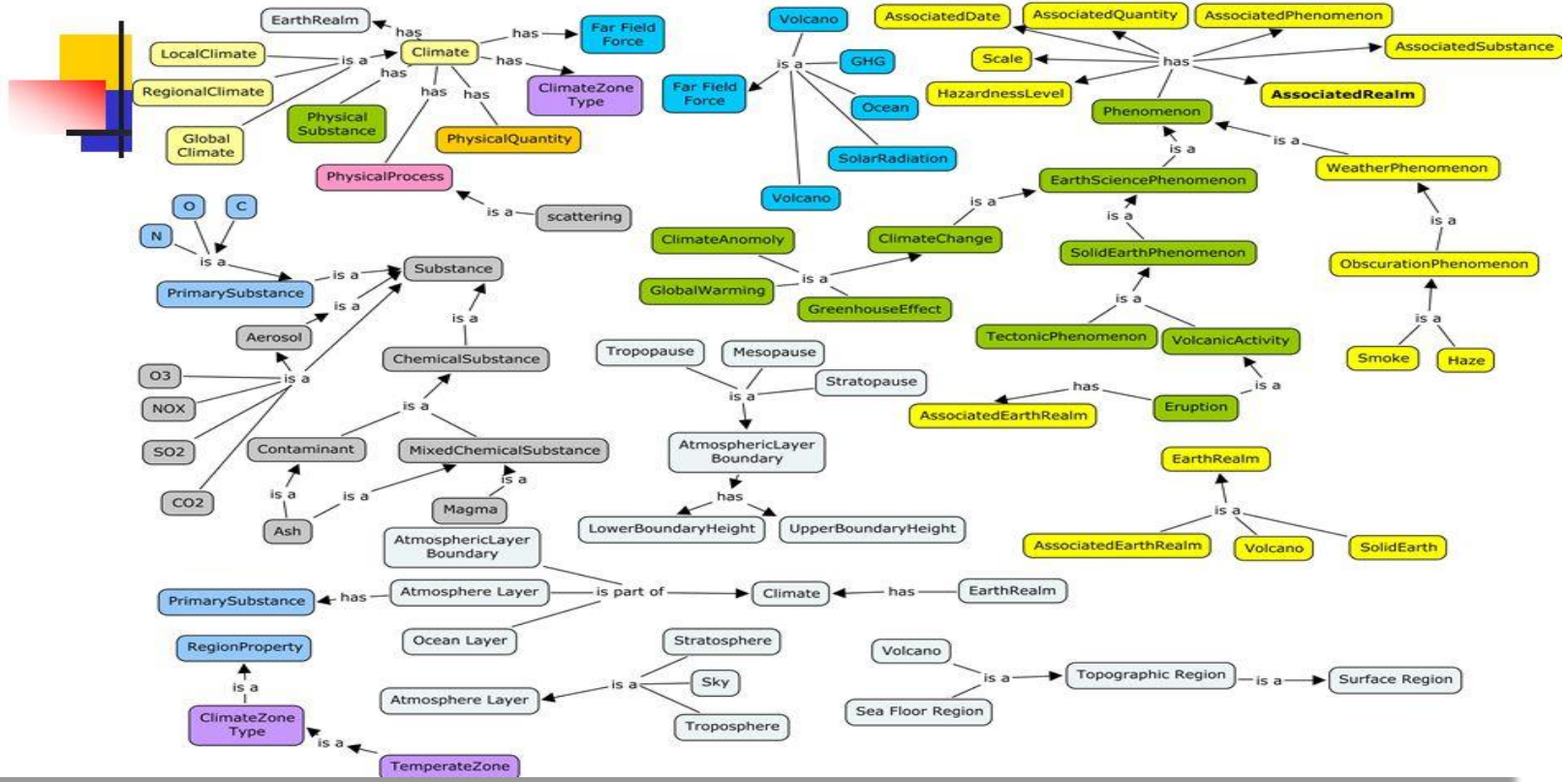


Selected Broad category/facet	Selected Category terms
Faceted Science Ontology	
Earth realms:	atmosphere, Ocean LandSurface
Physical properties:	temperature, composition, area, …
Substances:	CO2, water, lava, hydrogen, …
Living substances	Humans, fish, …
Processes	Diffusion, absorption, …
Integrative Science Ontologies	
Phenomena	Thunderstorm, Deforestation, Physical pro
	magnetism, convection, …)
Human Activities	Fisheries, IndustrialProcessing
Numerical Ontologies	
Intervals, numeric relations	
Functions	
Statistical concepts	
Spatial concepts/entities:	Relations (*above*, etc.); 0-, 1-, 2-, 3-D; coor
Temporal concepts/entities:	Instants, durations; Relations (*after,* etc.)
Spectral band	UV, …
Data Ontology	
Dataset characteristics:	Format, data model, ...
Provenance:	Source, ...
Parameters:	Scale factors, offset, …



"Each box represents a separate ontology, and a connecting line indicates where major *properties* are used to define concepts across ontology spaces"

Atmosphere Ontology



Some SWEET concepts

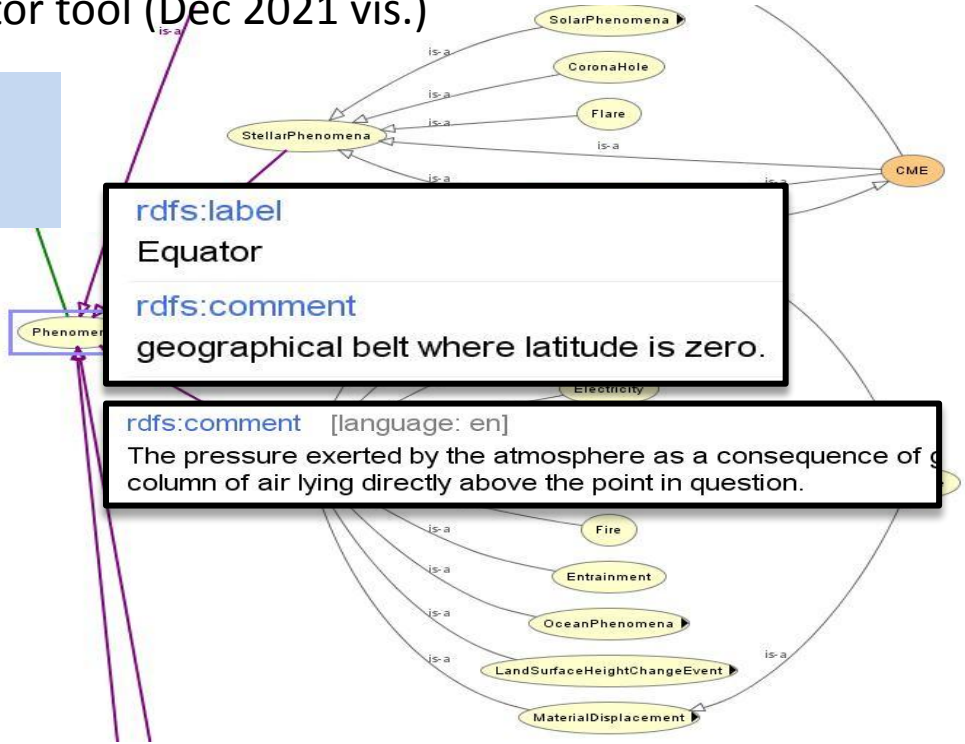
- v.2.0 visualized using an ontology editor tool (Dec 2021 vis.)

Non-relational Categories
(as type of OWL:Class)

- Phenomena
  - BiologicalPhenomena
  - EcologicalPhenomena
  - PhysicalPhenomena
  - PlanetaryPhenomena
    - Climate
    - ClimateChange
    - ClimatePhenomena
    - GeologicalPhenomena
    - GeospherePhenomena
    - HydrospherePhenomena
    - LaNina
    - MeteorologicalPhenomena
    - Weather
  - StellarPhenomena
- GeometricalObject_0D
- GeometricalObject_1D
- GeometricalObject_2D
- GeometricalObject_3D
- Hyperplane
- Ring
- Separation
- Interval

Relationships
(as type of
OWL:ObjectProperty)

- hasQuantity
- hasRadius
- hasRate
- hasReferenceDepth
- hasReferenceHeight
- hasResolution
- hasRock
- hasRole
- hasSecondOperand
- hasSpatialExtent
- hasSpatialProjection
- hasSpatialScale
- hasState
- hasStateOfMatter
- hasStatisticalDistribution



New in SWEET 2.1

- Version 2.1 provides a large module set for STATE
  - Mostly **adjectives** and **adverbs**
  - Examples: Role, color/band, shape, size, equilibrium type, activity level, connectedness, impact, substance form
  - Qualitative analog of "Quantity"
  - Enables greater separation of adjective from object to improve modularity
  - Mostly represented by OWL individuals
    - "types" of categorical, ordinal, and cardinal

Example Development & Modeling Activity

CF vs SWEET Representation

CF (*traditional single-attribute parameter name*):
tendency_of_mole_concentration_of_dissolved_inorganic_phosphorus_in_sea_water_due_to_biological_processes

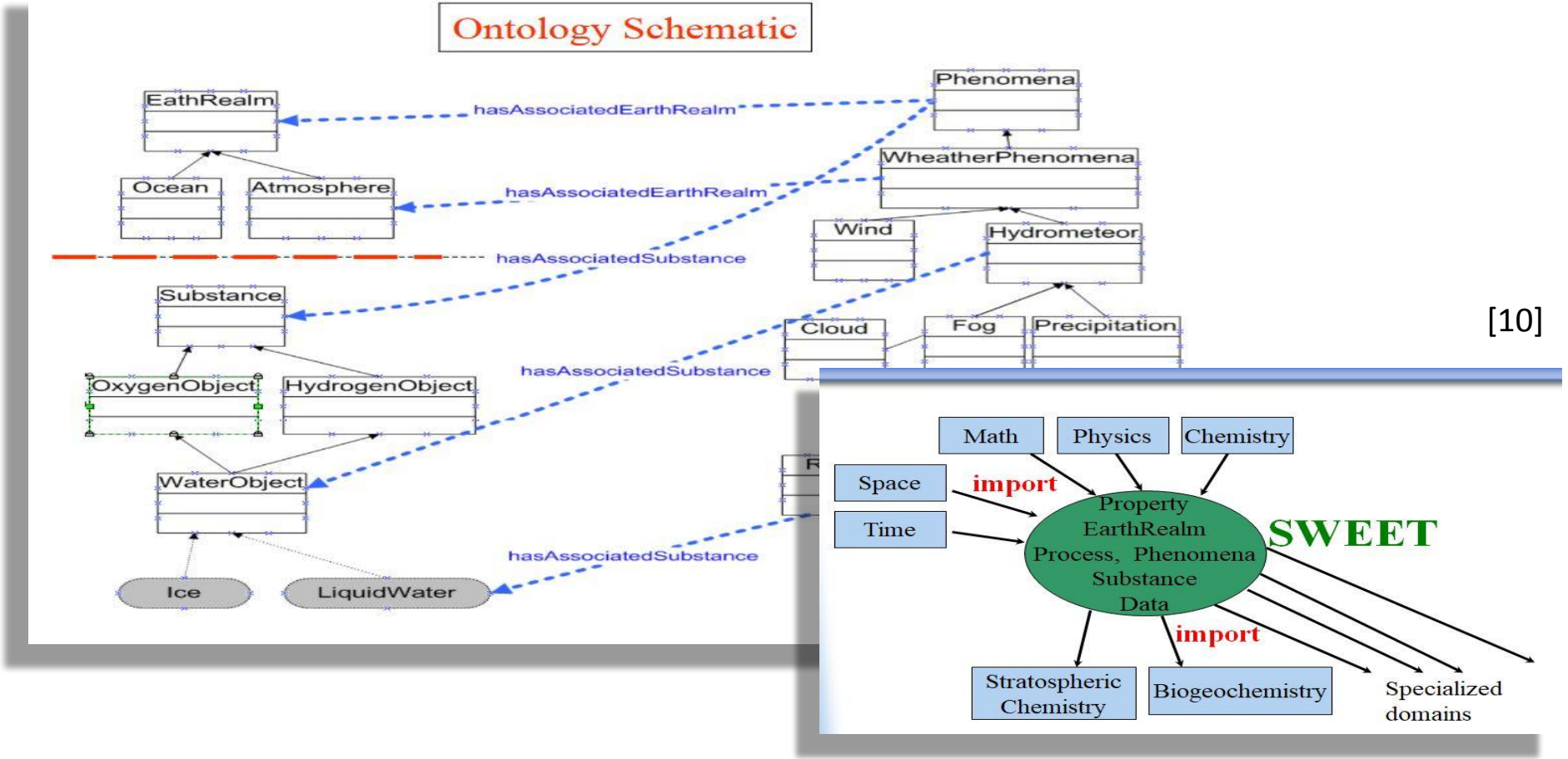
SWEET *(multi-attribute parameter name):*

- Quantity= mole_concentration
- Transformation= tendency
- State= dissolved, inorganic
- Substance= phosphorous
- Medium= sea_water
- Process= biological_processes

[10]

SWEET 2.1 Statistics

- Classes: 4400
- Individuals (mostly States): 2200
- Relations: 600


Ontology Schematic
EathRealm
Ocean
Atmosphere
hasAssociatedEarthRealm
hasAssociatedEarthRealm
hasAssociatedSubstance
Substance
OxygenObject
HydrogenObject
WaterObject
Ice
LiquidWater
hasAssociatedSubstance
hasAssociatedSubstance
Phenomena
WheatherPhenomena
Wind
Hydrometeor
Cloud
Fog
Precipitation
Math
Physics
Chemistry
Space
Time
import
Property
EarthRealm
Process, Phenomena
Substance
Data
SWEET
import
Stratospheric Chemistry
Biogeochemistry
Specialized domains

[10]

Some SWEET findings

Table 2 - SWEET Usability Measures

Metric	Evaluation output
User types using SWEET	Knowledge Engineer/ Project Manager Application User/ Ontology Developer
For what type of use was it conceived in first place?	Improving search for NASA Earth science data resources
How easy is it to extend SWEET?	Modular Design / Organized by Subject / Simple steps for extension
Cost of using the SWEET ontology	Free/ Open Source
SWEET Popularity	NASA/ The ESIP Federation/Taught Widely in Semantic Web Courses in Universities
Time to open SWEET	Less than a minute on a normal commodity machine

[8]

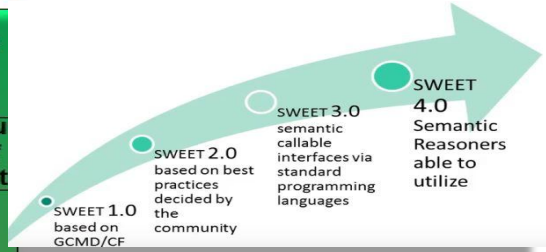
SWEET Future Community Plans

- Gain further support from Earth system science community
  - Workshop at Summer '08 Meeting of eSIP Federation
- Submit SWEET as community standard to NASA Earth Science Standards and Processes Working Group

18

Semantic Web Roadmap

		Current	Near Term	Mid Term	Long Term
Results	Outcome	◆ Improved Information Sharing	◆ Increased Collaboration & Interdisciplinary Science	◆ Acceleration of Knowledge Production	◆ Revolutionizing how science is done
	Output	◆ Geospatial semantic services established	◆ Geospatial semantic services proliferate	◆ Scientific semantic assisted services	◆ Autonomou inference of science result
Capability	Assisted Discovery & Mediation	◆ Common vocabulary based product search and access	◆ Semantic geospatial search & inference, access	◆ Semantic agent-based searches	◆ Semantic agent-based integration
	Interoperable Information Infrastructure	◆ Local processing + data exchange	◆ Basic data tailoring services (data as service), verification/ validation	◆ Interoperable geospatial services (analysis as service), explanation	◆ Metadata-driven data fusion (semantic service chaining), trust
Technology	Vocabulary	◆ SWEET core 1.0 based on GCMD/CF	◆ SWEET core 2.0 based on best practices decided from community	◆ SWEET 3.0 with semantic callable interfaces via standard programming languages	◆ Reasoners able to utilize SWEET 4.0
	Languages / Reasoning	◆ RDF, OWL, OWL-S	◆ Geospatial reasoning, OWL-Time	◆ Numerical reasoning	◆ Scientific reasoning



19

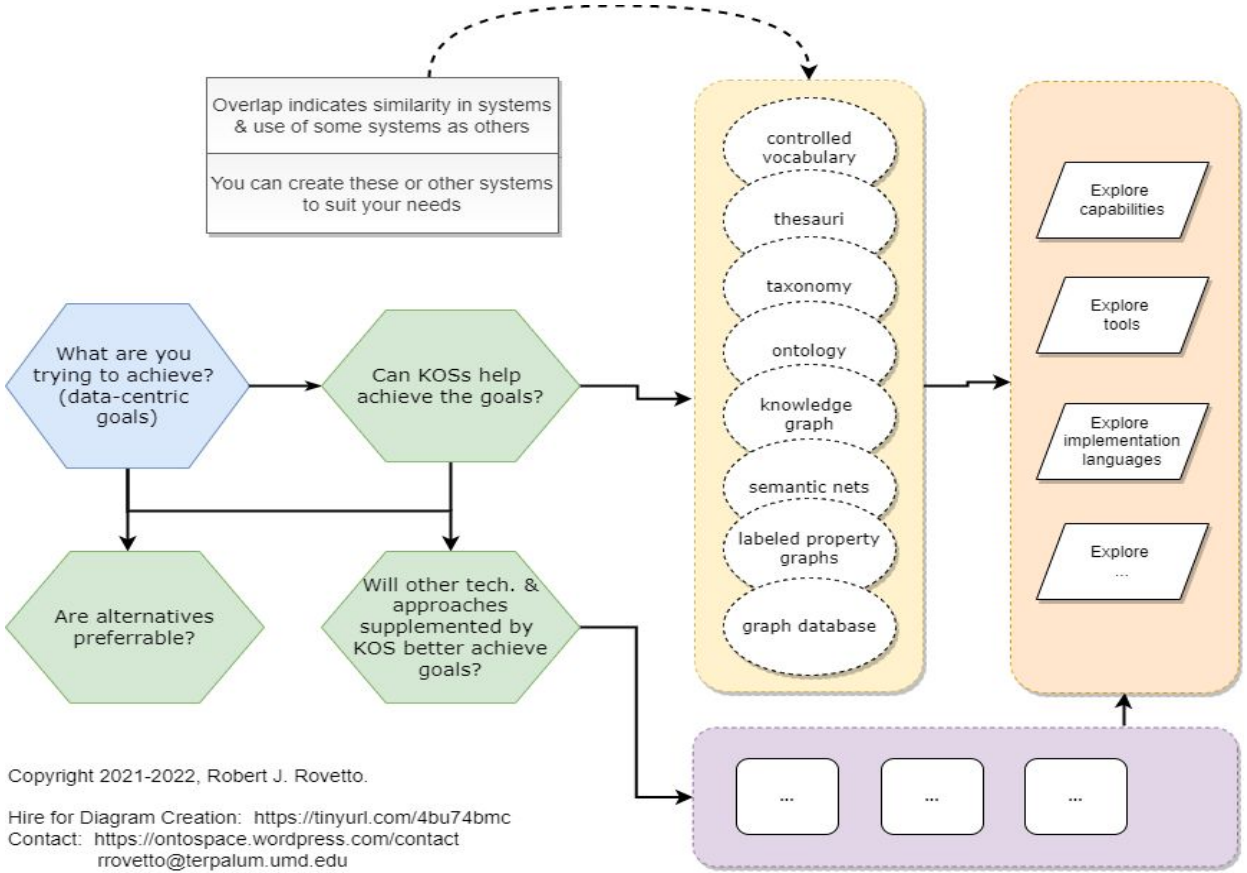
Background considerations: do you need a KOS, semantic system?

Knowledge organization systems, semantic resources, …

Related systems & approaches

- Formal concept analysis
- NLP, Machine learning
- Model-based systems engineering
- …

Can semantic approaches, in general, help?



Some considerations for your data goals/needs

- Various types of semantic systems, KOS, & tech. for your data
  - KOS: from thesauri to taxonomies to knowledge graphs. Varying functionalities, limitations, …
    - Some (or none!) may be most efficient for your needs.
  - Ontologies can be made to varying degrees of complexity.
  - Can "**automatically generate** the tags during the indexing process. Automatic tag creation involves **natural language processing** to ascertain the meaning of a term based on its context. In some cases, terms have **multiple meanings**, and tools such as Latent Semantic Analysis" [7, emphasis added]
- *Consider also **non**-semantic/semantic-web* systems and approaches
- Ability & precedent vision to develop SWEET to higher degrees of complexity
  - a matter of will, resources, etc. to do it

End of Part 1 (overview & history) – Questions - Discussion

- What do you find interesting thus far?

https://tinyurl.com/SWEET-Questions

- Consider the original questions
  - What are your research topics/expertise?
  - What types of data do you work with?
  - What would you like to do with your data that you presently cannot?
    - How might SWEET help with that?
  - Are you interested in contributing to SWEET?
    (e.g., SME, content, use-case development, applications, misc., etc.)

- Questions, ideas?

Part 2: SWEET Today & SWEET Development

- Updates
- Contributing page on GitHub
- Feedback from 2020 survey by B.Whitehead w/input by R.Rovetto
- Q&A Discussion
  - Neutral SMEs for each topic covered by SWEET
  - Propose, Create, Verify content, e.g. …
    - Create Local definitions SME focus on a topic, term or concept
    - Verify definitions SME quality control (e.g., verify accuracy)

Some SWEET updates at ESIP

- ESIP is current steward of SWEET
  - https://github.com/ESIPFed/sweet
  - https://github.com/ESIPFed/sweet/releases v. 2.3 □ 3.4
  - Semantic Technology Committee
    - https://wiki.esipfed.org/Semantic_Technologies
    - https://github.com/ESIPFed/sweet/wiki/Publications
  - Literature: https://tinyurl.com/Biblio-SWEET
  - SWEET is a living work

Example updates via SemTech:

- **2018:** "URI transition and governance, transition from OWL to Turtle serialization, linked data dispatch via the ESIP Community Ontology Repository [5], and ongoing alignment activities" [6]
- Can use GitHub for development ideas & suggestions

SWEET online - the ontologies

- Contributing description page:
  - https://github.com/ESIPFed/sweet/blob/master/CONTRIBUTING.md

Development

The development process for SWEET follows the Review-then-Commit software development process. For
Subsection below

How to work with us on Github, using git command line:

- Browse on ESIP repository: http://cor.esipfed.org/

http://sweetontology.net/phenOceanDynamics	SWEET Ontology Phenomena Ocean Dynamics
http://sweetontology.net/phenReaction	SWEET Ontology Phenomena Reaction
http://sweetontology.net/phenGeolTectonic	SWEET Ontology Phenomena Geologic Tectonic
http://sweetontology.net/phenMixing	SWEET Ontology Phenomena Mixing
http://sweetontology.net/phenOceanCoastal	SWEET Ontology Phenomena Ocean Coastal
http://sweetontology.net/phenOcean	SWEET Ontology Phenomena Ocean
http://sweetontology.net/phenGeolSeismicity	SWEET Ontology Phenomena Geologic Seismicity

Example files displayed in ESIP COR platform

http://sweetontology.net/phenEcology
http://sweetontology.net/phenElecMag
http://sweetontology.net/phenEnergy
http://sweetontology.net/phenEnvirImpact
http://sweetontology.net/phenFluidDynamics
http://sweetontology.net/phenFluidInstability
http://sweetontology.net/phenFluidTransport
http://sweetontology.net/phenGeol
http://sweetontology.net/phenGeolFault
http://sweetontology.net/phenGeolGeomorphology
http://sweetontology.net/phenGeolSeismicity
http://sweetontology.net/phenGeolTectonic
http://sweetontology.net/phenGeolVolcano
http://sweetontology.net/phenHelio
http://sweetontology.net/phenHydro
http://sweetontology.net/phenMixing
http://sweetontology.net/phenOcean
http://sweetontology.net/phenOceanCoastal
http://sweetontology.net/phenOceanDynamics
http://sweetontology.net/phenPlanetClimate

List of SWEET ontology files (subject-specific)

Some SWEET feedback (2020) (1)

"If I want to make additions or suggestions where do I go to do that [understand SWEET dev.]? Is it possible to merge my domain ontology with SWEET?"

- https://github.com/ESIPFed/sweet/

- (Idea) Exploratory dev. track: solicit persons to download versions, merge their domain ontology, in order to create innovating beneficial use-cases for Earth Sci data.
  - Example: 2005 with hydrogeology [11]
- Identify approaches, challenges, desiderata, etc.

Some feedback (2)

“Reach out to a wide swath of earth sciences and run them through an exercise of identifying their terminology and explaining how they relate to other terms in plain language. Getting input needs to be accessible and the approach structured.”

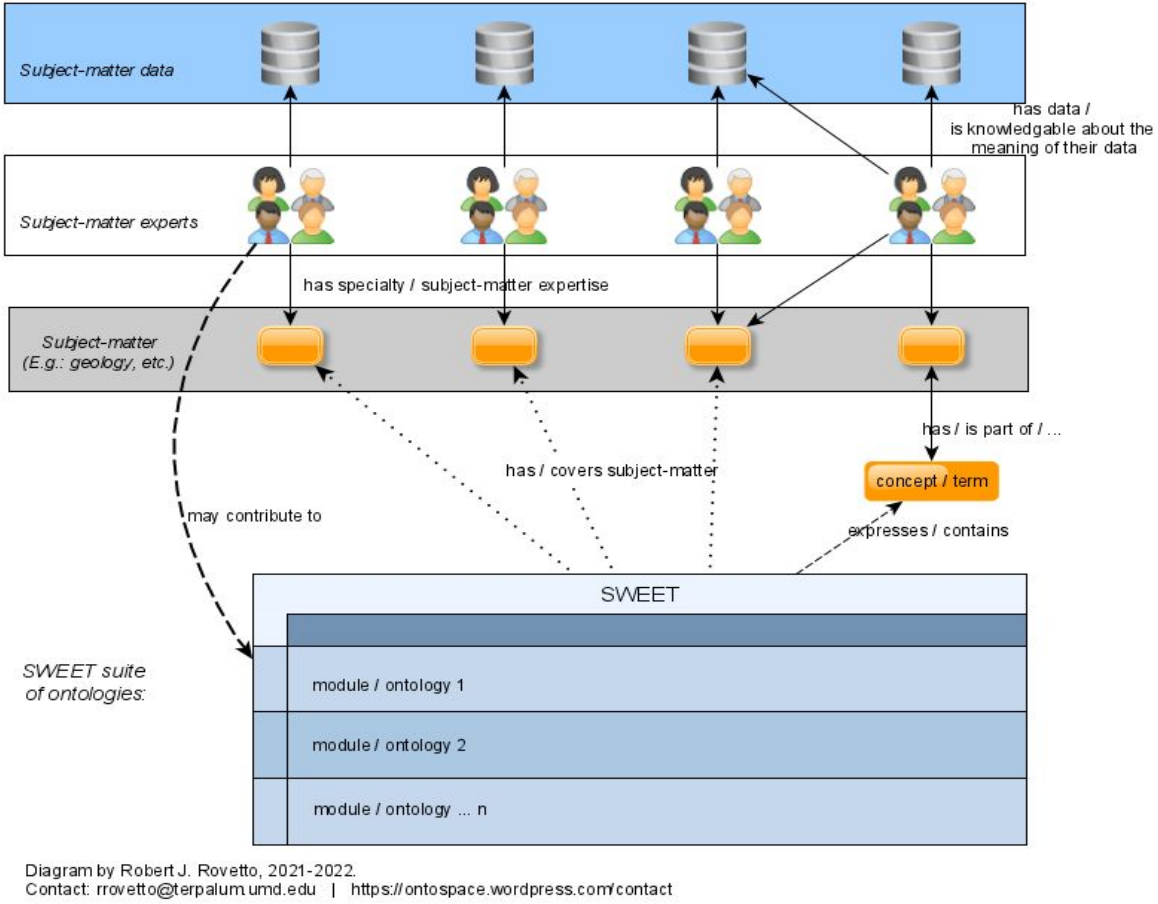
- In organizing this session, perhaps first-steps, brainstorming ideas, …

Some feedback (3)

"Need to increase visibility across federal agencies and extend the usage. Need specific maintenance team for **different subjects** in SWEET."

- (**Idea**) Neutral SME potentially help with their subject covered by SWEET
  - Note: *neutral* = focus on their subject/discipline/science. No preference/advocating for particular product, ontology, way of semantically modeling, characterization, etc.

Idea for community participation to develop & utilize beneficial applications of SWEET



Example Tasks:

Task: SME provides a set of subject-matter concepts or vocabulary.

Task: SME proposes definition.

If a computable def. is desired, the proposed def. can be translated into the selected computable formalism

Task: …

Some feedback (4)

"I'd like to make use of e.g. to align our vocabularies to, and I've always liked the facet based approach to the structure which I recommend to others when asked about constructing a controlled vocabulary."

- Identify vocabularies

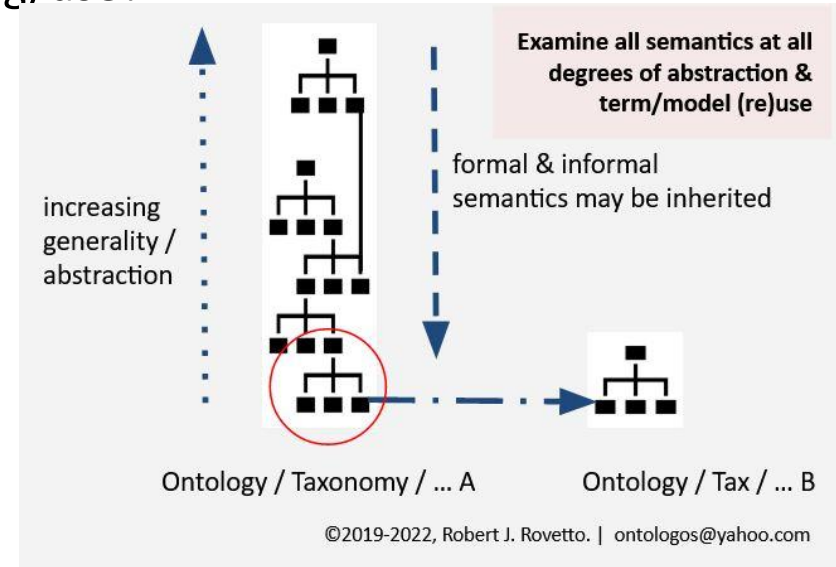
- Re: alignment/harmonization/mappings …
  - different approaches by distinct activities/groups. automated, manual,...
  - There are *types* & *degrees* of alignment/harmonization/mappings.
  - Not all groups will perform thorough harmonizations of terms or ontologies. So caution is in order (next slide).

- Explore facets…
  - See library science…faceted approaches are also used in other KOSs, e.g., taxonomies

A genote on mappings/harmonization/alignment

- Distinctions among each activity. Here taken as synonymous.
- Care is in order when doing mappings, harmonization, etc. …
- Same terms, but different intended meaning/use?
- Ambiguous or imprecise descriptions of the harmonized terms or ontologies
- Should explicitly state degree of analysis & mapping/harmonization/…

- Examples
  - ‘related to’ as very generic
    - more specific may be needed
- Examine all degrees of abstraction of the given mapped terms/ontologies



Ontology Consulting: https://tinyurl.com/34u9w6wx

Some feedback (5)

“list datasets that are mapped to SWEET [or use SWEET on specific datasets]”

- (Idea) Create a list or catalog of datasets. identify datasets, apply SWEET, discover desiderata, …

Candidate Development Tasks & Activities

What are some ways to do a hackathon to dev. SWEET?

Ideas for Candidate Ontology Development Tasks & Activities
General interest
Identify or propose use-cases
Identify or create applications of SWEET → apply SWEET (e.g., some in references, SWEET literature, ESIP presentations)
Explore organizational aspects: e.g., ideas for (sub)scoping of topic areas covered by SWEET, organizing SWEET individual ontologies (modules), …
Serve as SME
Quality control of descriptions/definitions of terms (e.g., for your subject expertise), both natural language, and computable
Propose additional domain terms/vocabulary/jargon, metadata. Propose additional SWEET ontologies/modules
Develop logical axioms/restrictions/constraints, computable definitions, etc.
Documentation products: SWEET manual, …
…?…

Questions / Discussion

- Q&A / discussion / breakout rooms
  - What do you find interesting? Areas for innovation? Unexplored applications to other data science techniques?
  - How might SWEET help with your data goals/needs?
  - Are you interested in contributing to SWEET?
    (e.g., SME, content, use-case development, applications, misc., etc.)

- Takeaway points

- Time-permitting: Demo:
  - Open SWEET online: Github → Pylode rendering
  - Opening SWEET in…COR? ontology-editor on desktop? online visualization?
  - Audience chose which SWEET module to open
  - …other ideas...

Thank you

- For you attention
- For your participation
- To ESIP staff, and fellow cluster members

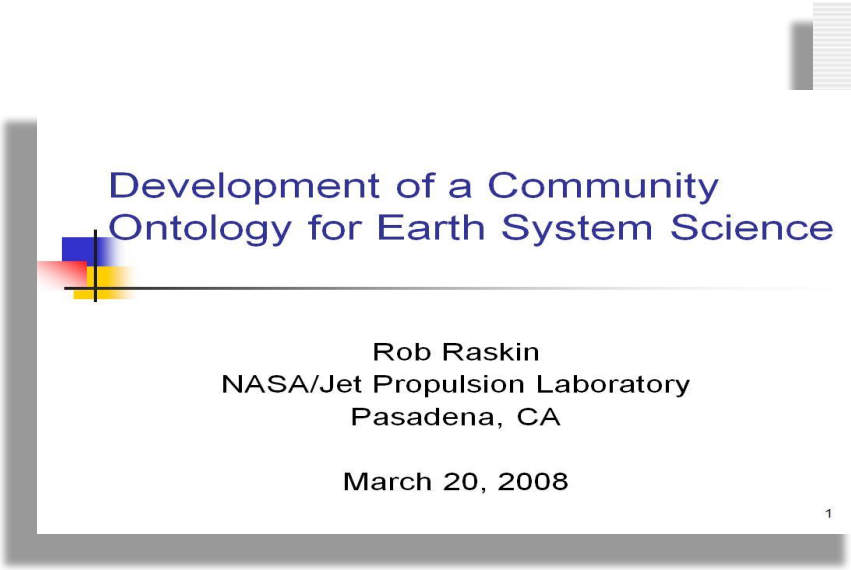
  www.esipfed.org 

- Pamela “Charley” Hayley, www.wayforagers.org

A session presentation for January 2022 ESIP Winter meeting

References (1)

Source material: Slides from past presentations by late Dr. Rob Raskin & others are raised images with shadows. Other material is quoted from cited references. Other content is by Rob Rovetto as indicated.



References (2)

Session Agenda Document: https://docs.google.com/document/d/1vRUlE3QqF68AF9JunAFj-zIY_uXoRrdroxLyZ3w9DAQ/
Session Meeting page:
- https://sched.co/qkoe
- https://2022esipjanuarymeeting.sched.com/event/qkoe/community-development-of-the-sweet-semantic-system-for-earth-and-environment-data-a-call-for-interest

SWEET Bibliography created by Robert Rovetto: https://tinyurl.com/Biblio-SWEET

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- [10] "SWEET 2.0 Ontologies", PPT, R.Raskin https://wiki.earthdata.nasa.gov/download/attachments/50792120/SWEET_SPG.ppt?version=1&modificationDate=1435254939370&api=v2
- [11] "Developing a Modular Hydrogeology Ontology Extending the Sweet Ontologies," Ajay Tripathi, https://scholarworks.gsu.edu/cgi/viewcontent.cgi?article=1002&context=geosciences_theses
- The SWEET 2.0 graph diagram with concentric circles is found in "Evolution in data and product management for serving operational oceanography, a GODAE feedback", and was cited as being from NASA SWEET (therefore, may be originally be from NASA JPL).
- Green arrow image from Video (see 'Other SWEET Links' slide)