ICOS Meeting
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Situation aware integrated carbon observation system

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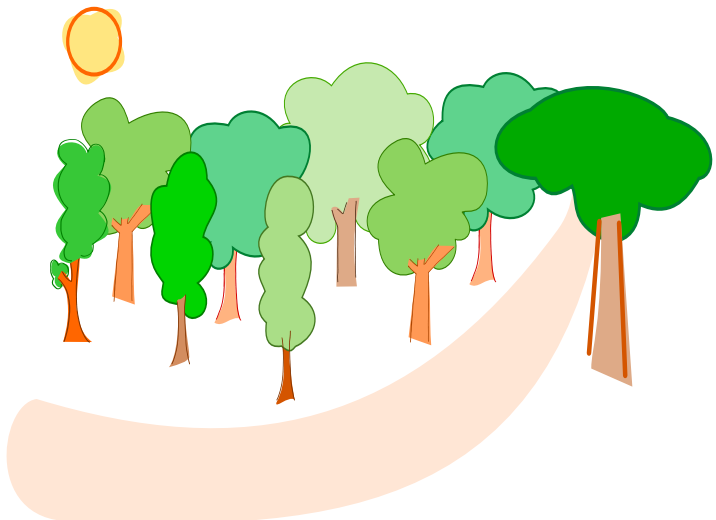

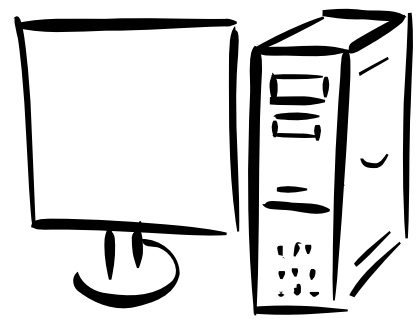

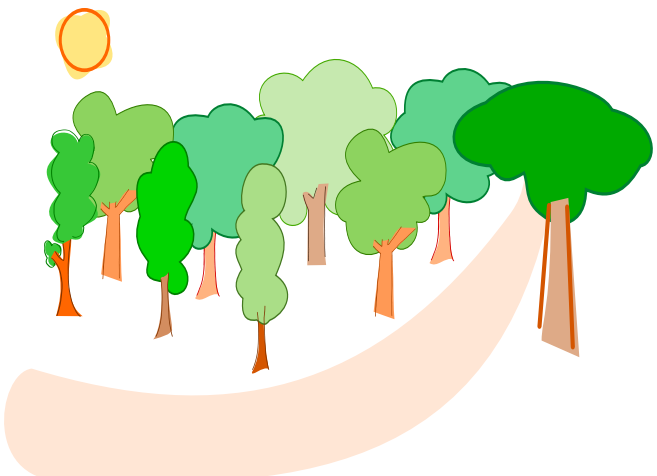

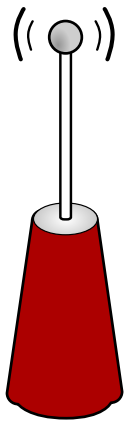

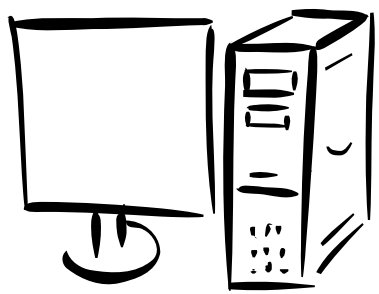

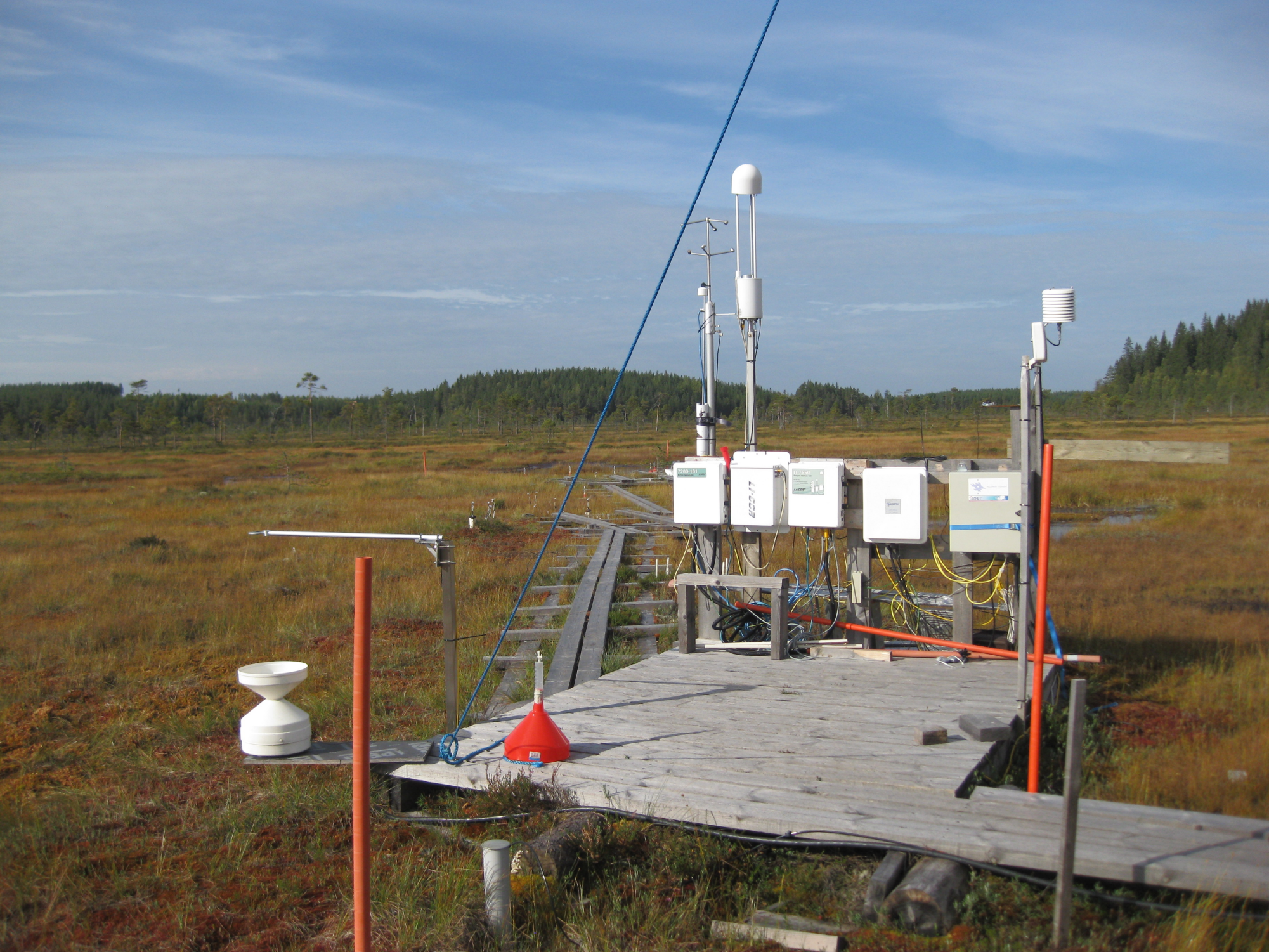

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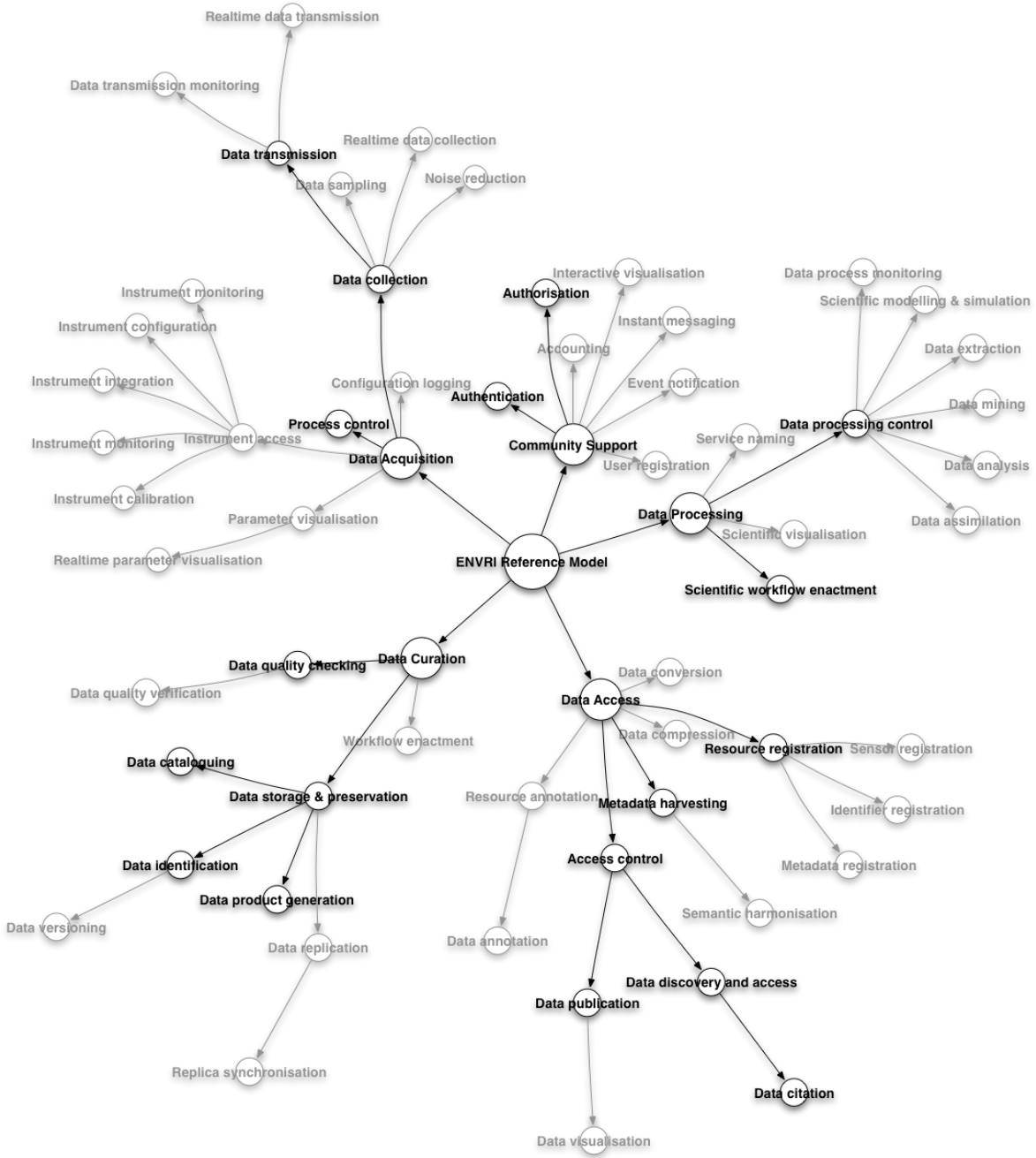
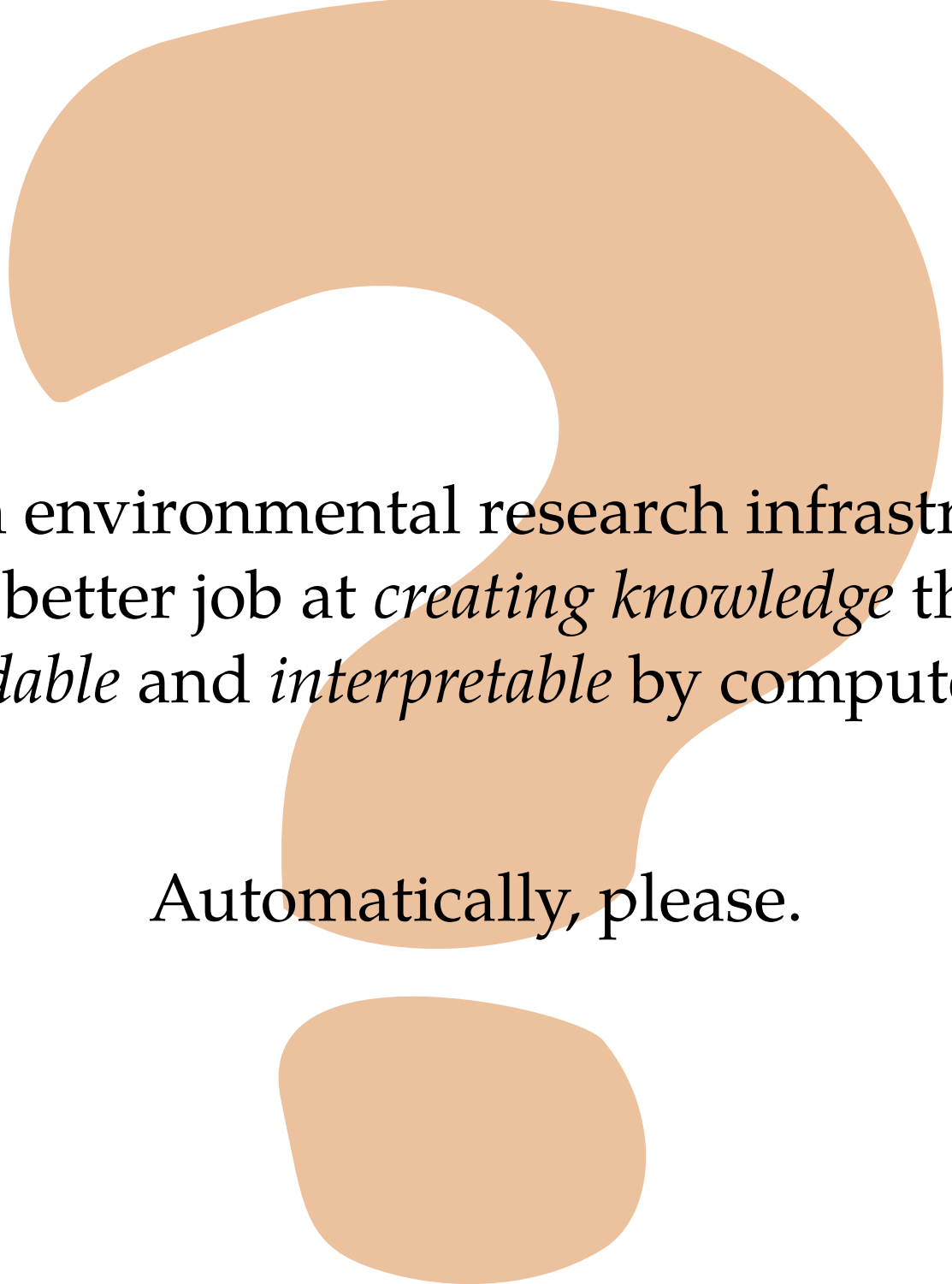
Environmental Research Infrastructure



(Source: ENVRI-RM, http://envri.eu/rm)



Can an environmental research infrastructure do a better job at *creating knowledge* that is *readable* and *interpretable* by computers.

Automatically, please.

Approach

The recipe

- Given is an environmental RI
  - Data acquisition, curation, access, processing
- Develop a *knowledge extension* for the RI
  - Acquire knowledge form data
    - Physically-/data-based models
    - Manually (if necessary)
  - Curate acquired knowledge
    - Represent and persist knowledge
    - So that it is readable and interpretable *by machines*
    - Yes, not *just* in a PDF or Word document, or a figure
  - Provide access to curated knowledge
    - Some Web service
  - Process knowledge
    - Visualization, analysis, reasoning

Situational knowledge

Information about situations,
i.e. structured parts of reality

Situation theory

- Barwise & Perry, Devlin (1980s)
- Mathematical ontology for situation semantics
- Situation s is said to support ($\models$) infons
- Infon σ is a tuple consisting of
  - Relation R
  - Objects $a_1, \ldots, a_m$
  - Polarity $1/0$
- Objects: individuals, temporal and spatial locations, attributes, values, situations

$$s \models \sigma$$

$$s \models\!\!\ll R, a_1, \ldots, a_m, 1 \gg$$

Situation theory

$$s \models\!\ll \text{carbon-sink}, \dot{e}, \dot{t}, 1 \gg$$

- $\dot{e}, \dot{t}$ are parameters, for ecosystem and temporal location
- Parameters *anchor* ($\rightsquigarrow$) objects
- $\dot{e} \rightsquigarrow$ Hyytiälä peatland
  - The ecosystem is an individual and spatial feature
  - May have attributes, e.g. geometry with coordinate data
- $\dot{t} \rightsquigarrow$ June - September, 2014

Situation theory

$$s \models\!\ll \text{sink-of}, \dot{e}, \dot{h}, \dot{t}, 1 \gg$$

(Alternative)

- $\dot{e} \rightsquigarrow$ Hyytiälä peatland
- $\dot{h} \rightsquigarrow$ Carbon
- $\dot{t} \rightsquigarrow$ June - September, 2014

Represent knowledge (and data)

RDF, RDFS, OWL

- RDF is a (meta-)data model
- RDF statement is triple (s, p, o)
- s, p are resources (URIs)
- o can be resource or literal
- RDFS and OWL are ontology languages
- RDFS for simple class and property hierarchies
- OWL for more expressive ontologies

Represent sensor data

- Semantic Sensor Network Ontology
- Observations, sensors, properties, features, ...
- Observation describes
  - Sensor that made it (device or human)
  - Property of feature observed
  - Observation value
  - Quality of observation
  - When and where the observation was made
- Example
  - Observation made by the thermometer on my balcony for the temperature of ambient air being -4.5 C today at 8:30 am.

Represent processed data

- RDF Data Cube Vocabulary
- Datasets and their observations
- Dataset describes its structure definition
- Structure definition describes
  - Component properties
  - Their metadata
- Observation describes
  - Dataset of which it is an element
  - Values for component properties
- Example
  - Observation of dataset *d1* with component property value for time 2014-12-09T00:00:10.000+03:00, temperature -6.5, humidity 72, wind speed 1.4, and rainfall 0.0

Represent situations

- Situation Theory Ontology
- Implements part of situation theory
- Situations and information about them
- Situation is a structured part of reality
- Example
  - Situation in which the Hyytiälä peatland is a carbon sink
  - Situation is a part of reality
  - The peatland and carbon are objects
  - They stand in relation to each other
  - Thus, structured part

Access and process situational knowledge

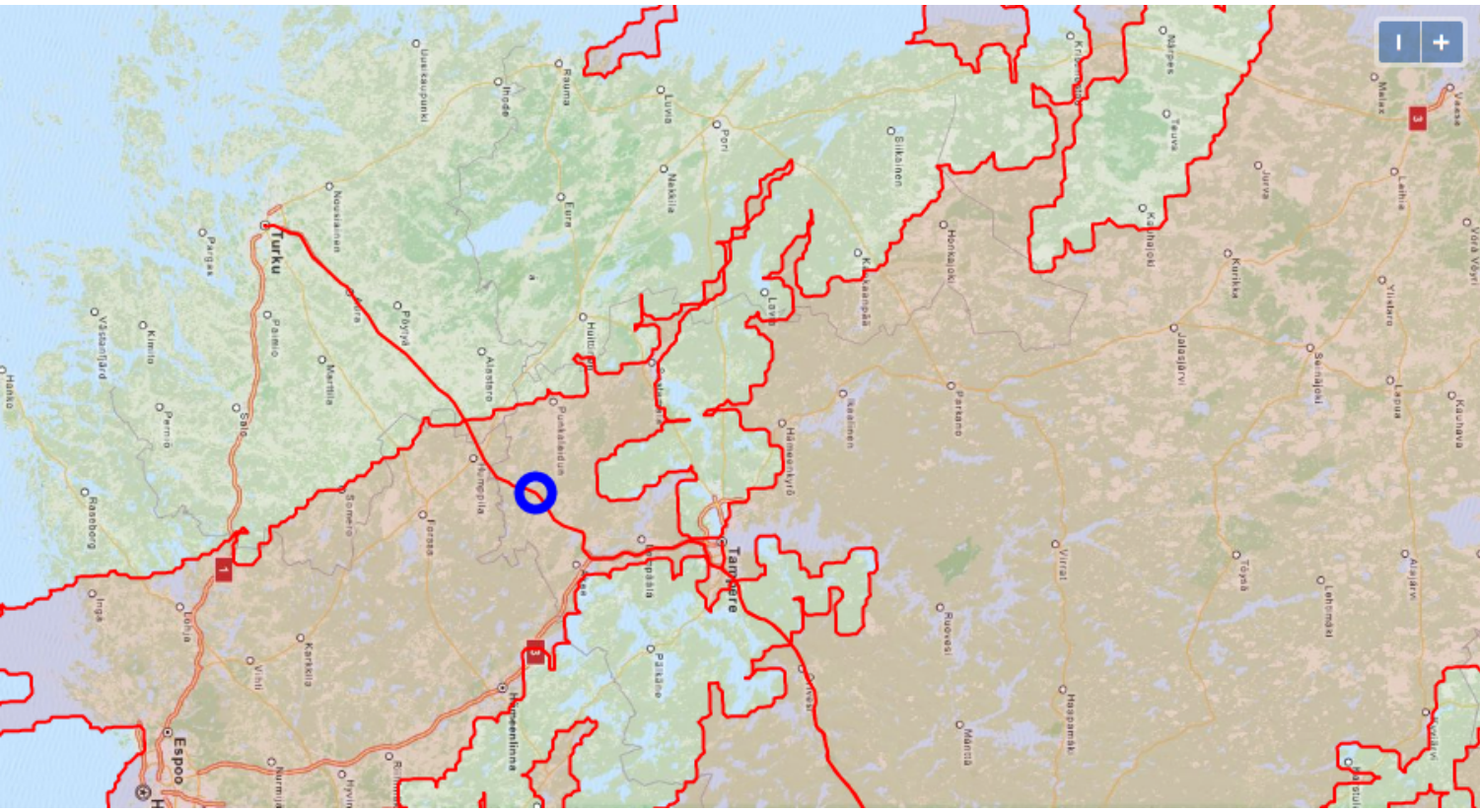
Query situations

```
select ?from ?to ?time ?temperature ?radiation ?humidity

a Situation [
  carbon-sink ;
  [ Hyytiala peatland ] ;
  [ hasBeginning [ ?from ] ; hasEnd [ ?to ] ]
] .
a Observation [
  dataSet [ theHyytialaDataset ] ;
  timePeriod ?time ;
  temperature ?temperature ;
  radiation ?radiation ;
  humidity ?humidity ;
]

filter (?time >= ?from && ?time < ?to)
```

Visualization



Situation reasoning

Situations in which a Finnish ecosystem with agricultural biomass is a carbon source

- Spatial reasoning for ecosystems *inside* Finland
- Conceptual reasoning for agricultural biomass types

Take aways

- Increasing role of sensors and computers in scientific processes
- A lot more data and complex data management and processing
- Thus, environmental research infrastructure
- Systems should automatically create knowledge (information)
- Knowledge should be readable and interpretable by computers
- Ontologies for data and knowledge representation
- Formal and explicit semantics of vocabulary
- Readable and interpretable by machines
- Shareable between human and computer agents
- Curation, access, and processing of knowledge
- Situational knowledge in particular