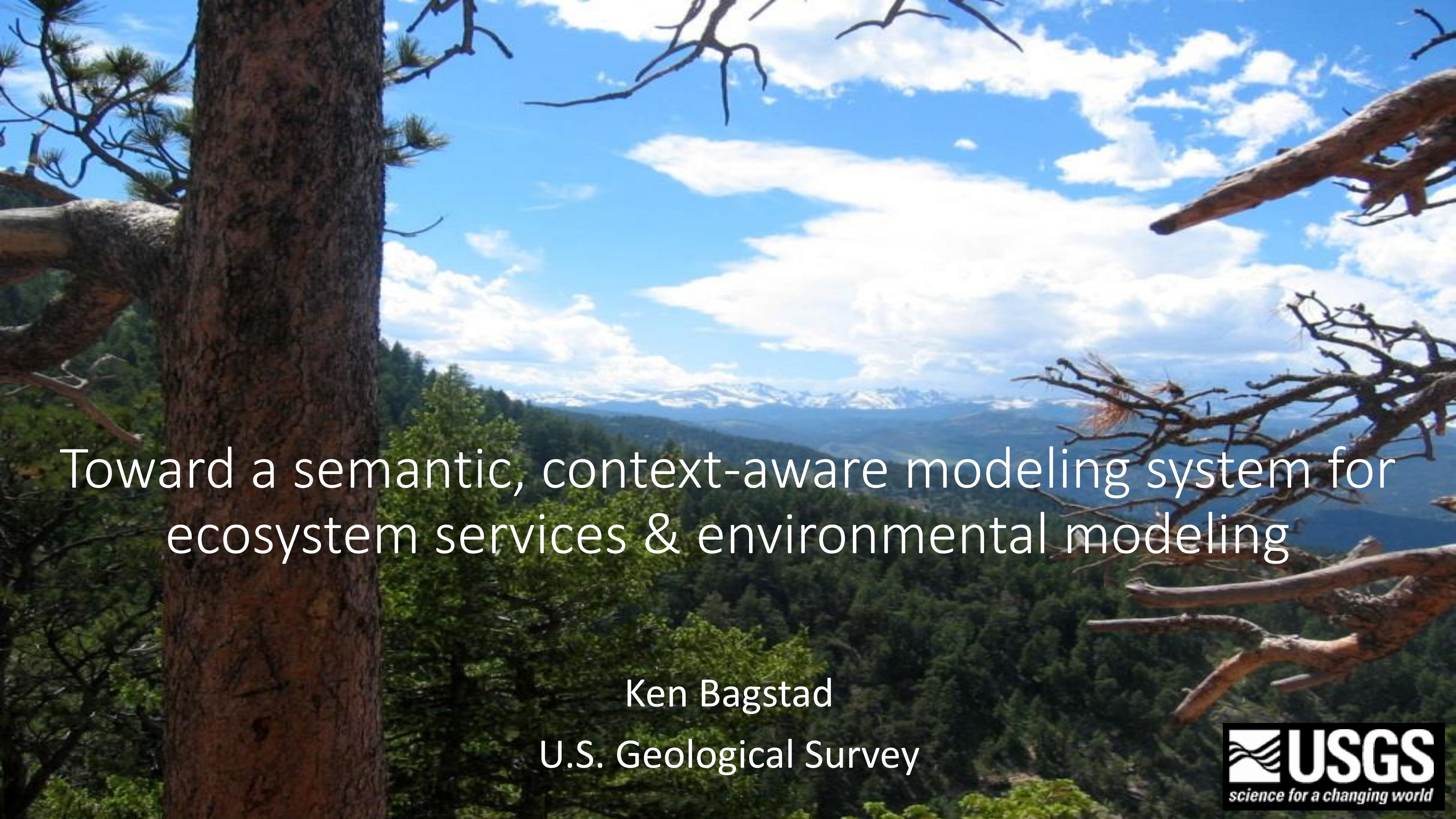


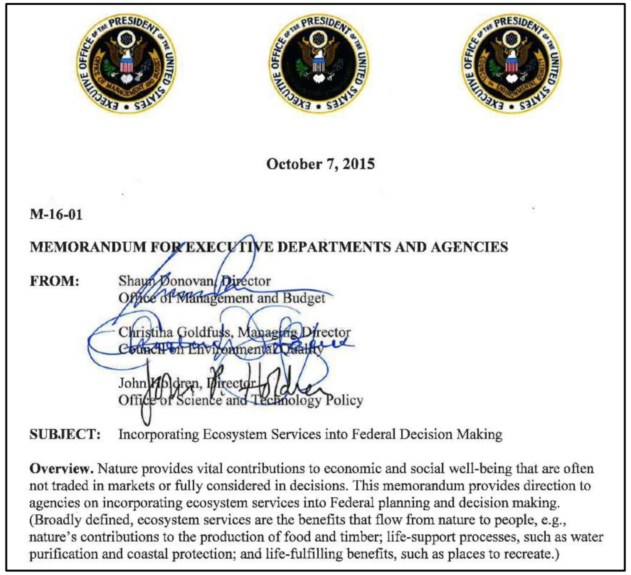
Toward a semantic, context-aware modeling system for ecosystem services & environmental modeling

Ken Bagstad
U.S. Geological Survey

science for a changing world

Mainstreaming ecosystem services

Interest in: cross-jurisdictional management; evaluating tradeoffs; increasing responsivity to the public



October 7, 2015

M-16-01

MEMORANDUM FOR EXECUTIVE DEPARTMENTS AND AGENCIES

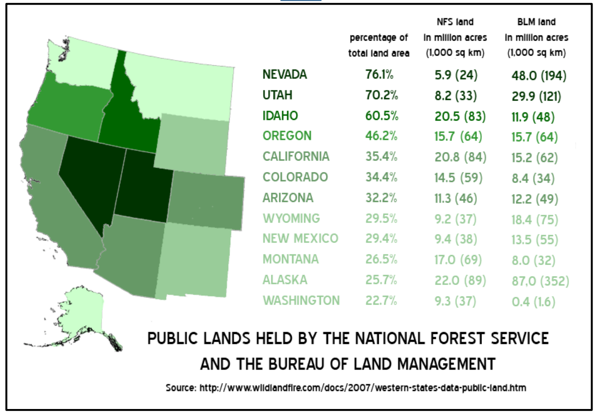
FROM: Shaun Donovan, Director
Office of Management and Budget

Christina Goldfuss, Managing Director
Council on Environmental Quality

John Holdren, Director
Office of Science and Technology Policy

SUBJECT: Incorporating Ecosystem Services into Federal Decision Making

Overview. Nature provides vital contributions to economic and social well-being that are often not traded in markets or fully considered in decisions. This memorandum provides direction to agencies on incorporating ecosystem services into Federal planning and decision making. (Broadly defined, ecosystem services are the benefits that flow from nature to people, e.g., nature's contributions to the production of food and timber; life-support processes, such as water purification and coastal protection; and life-fulfilling benefits, such as places to recreate.)

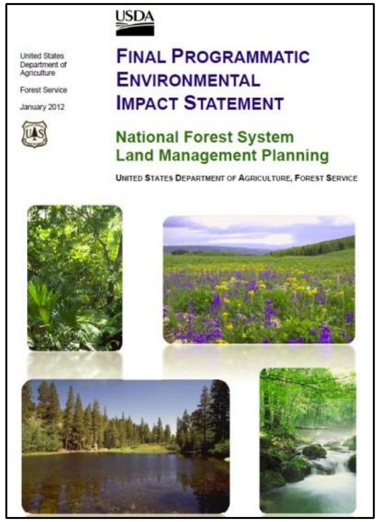


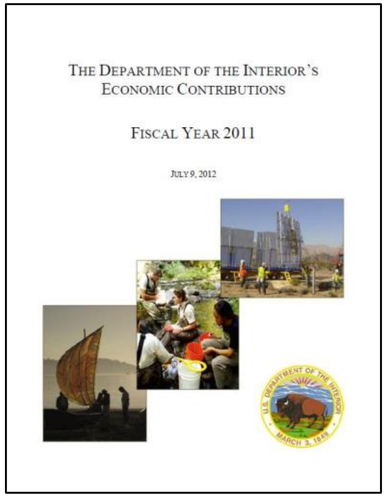
	percentage of total land area	NFS land in million acres (1,000 sq km)	BLM land in million acres (1,000 sq km)
NEVADA	76.1%	5.9 (24)	48.0 (194)
UTAH	70.2%	8.2 (33)	29.9 (121)
IDAHO	60.5%	20.5 (83)	11.9 (48)
OREGON	46.2%	15.7 (64)	15.7 (64)
CALIFORNIA	35.4%	20.8 (84)	15.2 (62)
COLORADO	34.4%	14.5 (59)	8.4 (34)
ARIZONA	32.2%	11.3 (46)	12.2 (49)
WYOMING	29.5%	9.2 (37)	18.4 (75)
NEW MEXICO	29.4%	9.4 (38)	13.5 (55)
MONTANA	26.5%	17.0 (69)	8.0 (32)
ALASKA	25.7%	22.0 (89)	87.0 (352)
WASHINGTON	22.7%	9.3 (37)	0.4 (1.6)

PUBLIC LANDS HELD BY THE NATIONAL FOREST SERVICE AND THE BUREAU OF LAND MANAGEMENT

Source: http://www.wildlandfire.com/docs/2007/western-states-data-public-land.htm

Same, *but* short on resources & in-depth technical expertise

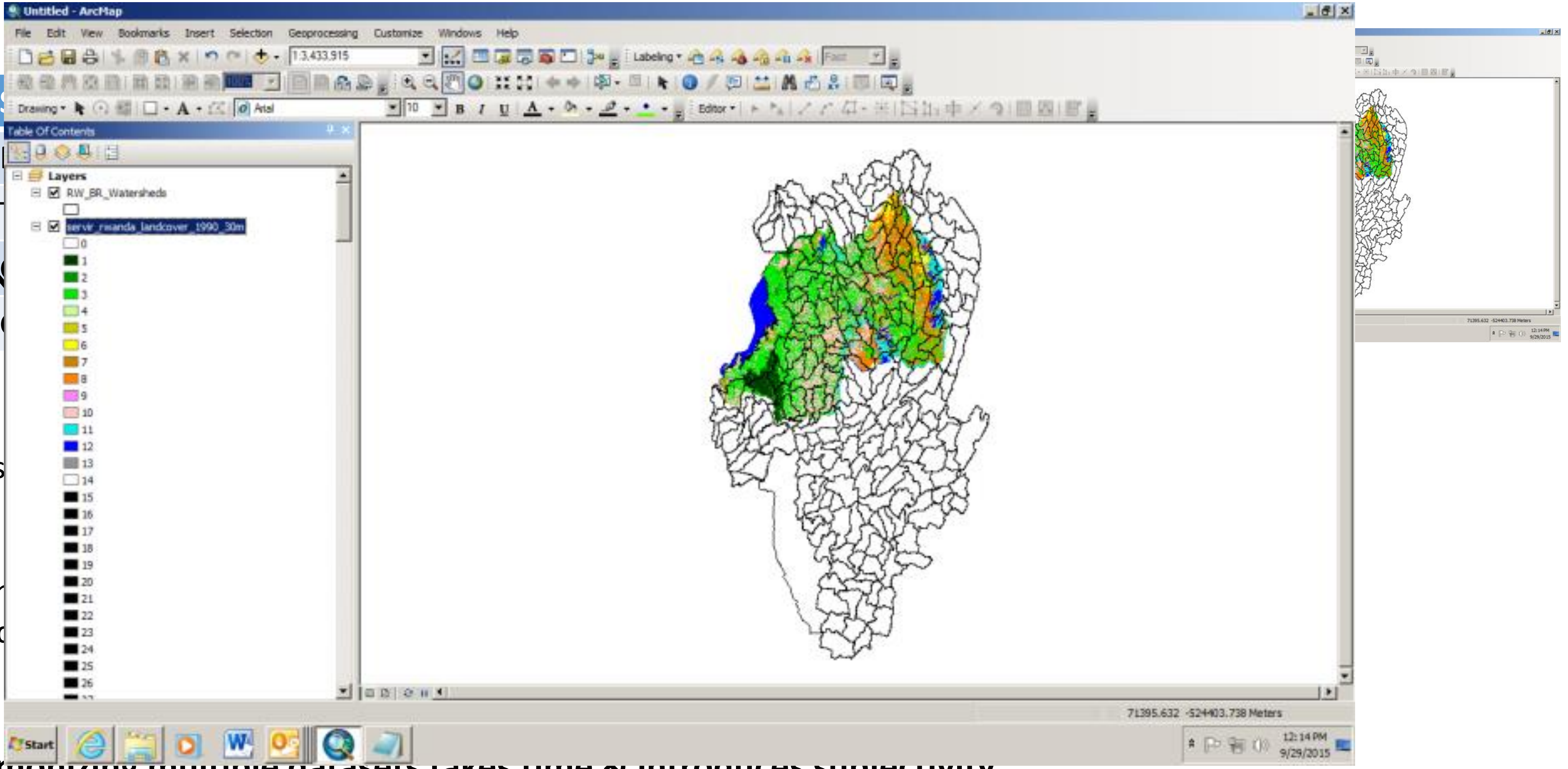




Classifying land cover: A semantic jungle

Data source
SERVIR
SERVIR
ESA-CCI
GlobeLand

Dense forest
Moderate fores
Sparse forest
Woodland
Closed shrublar
Open shrubland



Manually harmonizing multiple datasets takes time & introduces subjectivity

A semantic approach to ecosystem services (Villa et al. 2014)

OPEN ACCESS Freely available online

PLOS | ONE

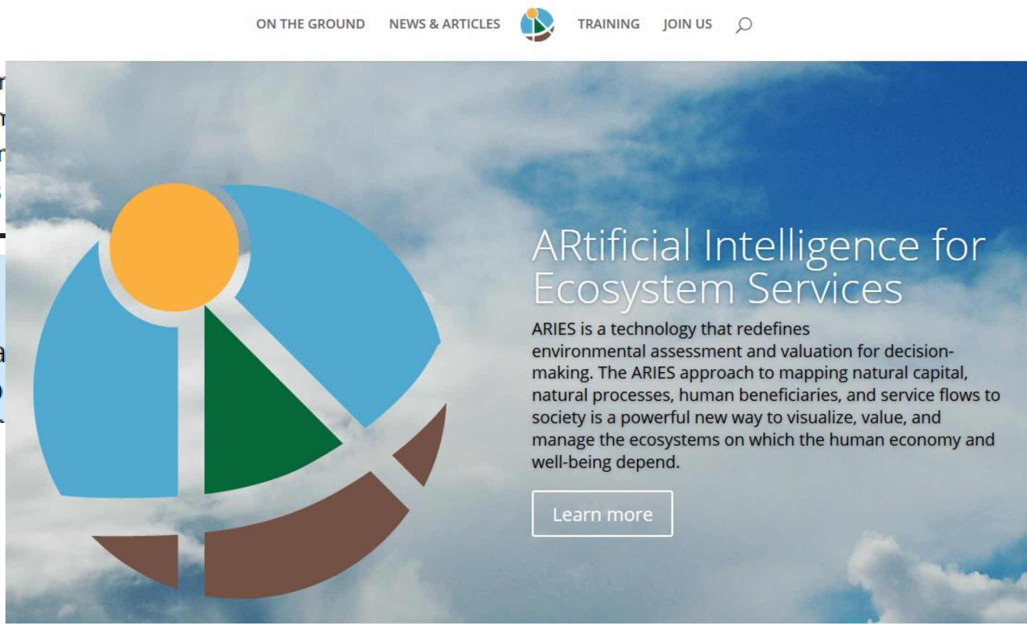
A Methodology for Adaptable and Robust Ecosystem Services Assessment

Ferdinando Villa[1*], Kenneth J. Bagstad[2], Brian Voigt[3], Gary W. Johnson[4], Rosimeiry Portela[5], Miroslav Honzák[5], David Batker[6]

1 Basque Centre for Climate Change (BC3), IKERBASQUE, Basque Foundation for Science, Bilbao, Bizkaia, Spain, 2 Geosciences & Environmen
U.S. Geological Survey, Denver, Colorado, United States of America, 3 Gund Institute for Ecological Economics, Rubenstein School of Environm
University of Vermont, Burlington, Vermont, United States of America, 4 Department of Computer Science, University of Vermont, Burlingtor
America, 5 Conservation International, Arlington, Virginia, United States of America, 6 Earth Economics, Tacoma, Washington, United States

Abstract

Ecosystem Services (ES) are an established conceptual framework for attributing value to the benefits tha
to humans. As the promise of robust ES-driven management is put to the test, shortcomings in our ab



http://aries.integratedmodelling.org

Key design principles for semantic modeling

1. Keep semantics as modular as possible

2. Reuse existing expert knowledge wherever possible

3. Formalize semantics in *ontologies**

*Concepts & their interrelationships precisely defined

Anything we can observe (with data) has a *subject*

- Countable, physical, recognizable object
- Examples:
  1. A mountain
  2. A population of humans
  3. A population of trees (i.e., a forest)
  4. A river




Typical data describe a subject's specific *quality*

- Described by an *observer type* (e.g., measurement, count, percentage, proportion…)
- Examples:
  1. The elevation of a mountain (measurement)
  2. Per capita income of a group of humans (value)
  3. Percent tree canopy cover (percent)
  4. A river's stream order (ranking)




Over time, subjects may experience *processes*

- Examples:
    1. Erosion of a mountainside
    2. Migration of a human population
    3. Tree growth in a forest
    4. Streamflow in a river




A single, time-limited process is an *event*

- Examples:
    1. A snowfall event on a mountain
    2. The birth of a new human in the population
    3. The death of a tree in the forest
    4. A flood event on a river




Relationships connect two subjects

- Examples:
  - Structural connection – <u>Parenthood</u> connects <u>parents</u> to <u>children</u>
  - Functional connection – <u>Ecosystems</u> providing a particular benefit to <u>human beneficiaries</u>
- Very important for agent-based models




Observables can also have one or more *traits*

- "Adjectives" that add descriptive power to further modify a concept
- Add flexibility without adding more complexity to the ontologies
- Four types:

1. Attributes (Temporal, frequency, min/max/mean, etc.)
2. Identities (Authoritative species or chemical names)
3. Strata (Soil, atmosphere, ocean, forest)
4. Orderings (High-Moderate-Low)

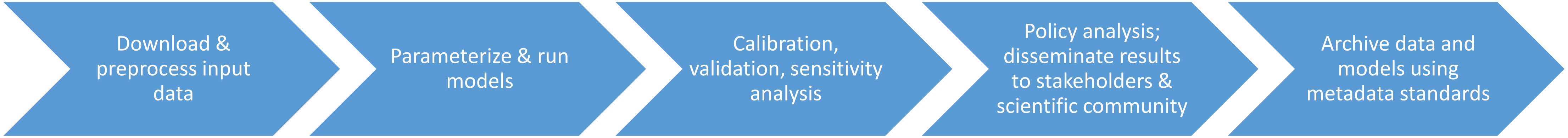
A language to define data for environmental modeling

- Subjects
- Qualities
- Processes
- Events
- Relationships
- Traits

In all cases, use accepted authorities when available (IUPAC, GBIF, AGROVOC, etc.)

Standard data & modeling flow

- First time running an environmental modelers:



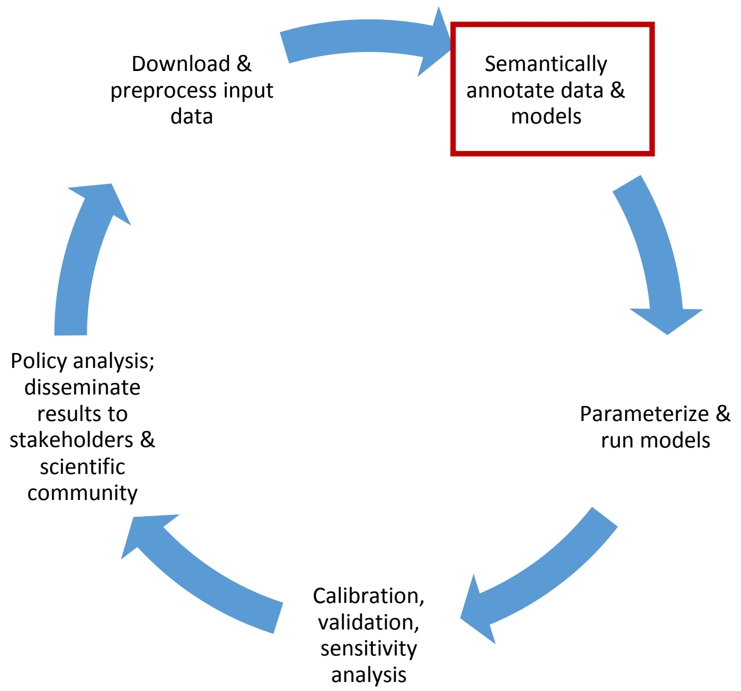
- Second, third, fourth time:

Same thing!

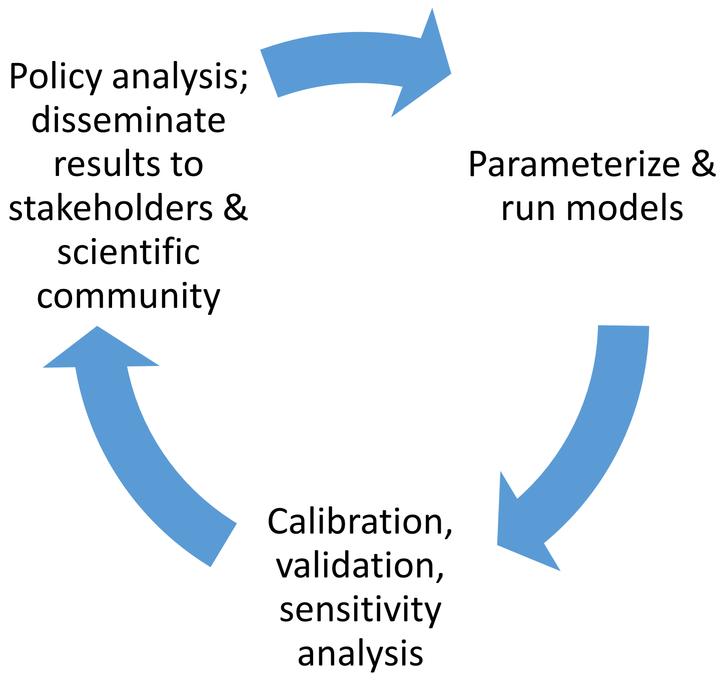
At the end of the project, budgets are tight, and people want to get the paper/report out without worrying about proper archiving

Semantic data & modeling flow

- First time modelers:



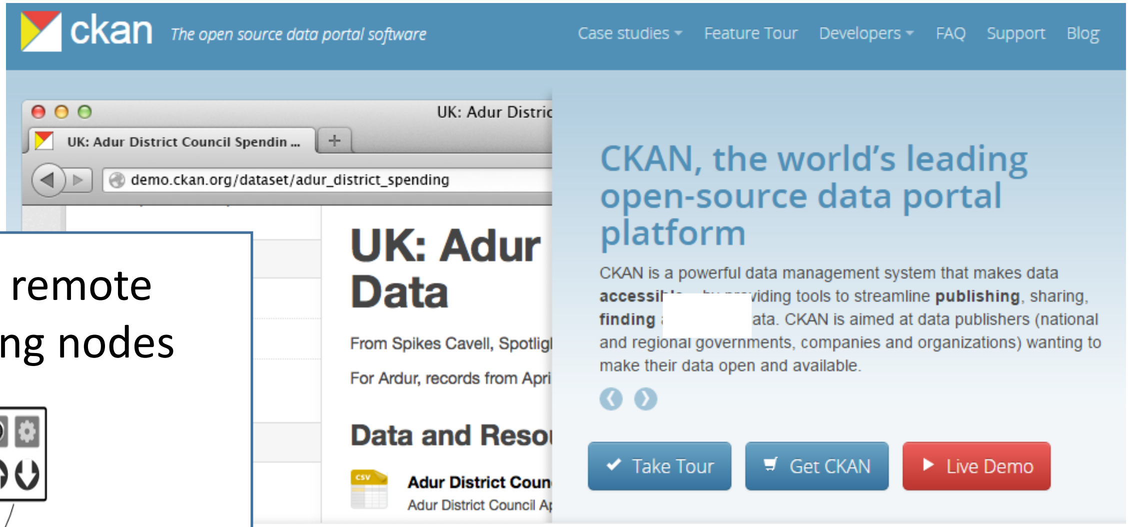
Second, third, fourth time modelers:

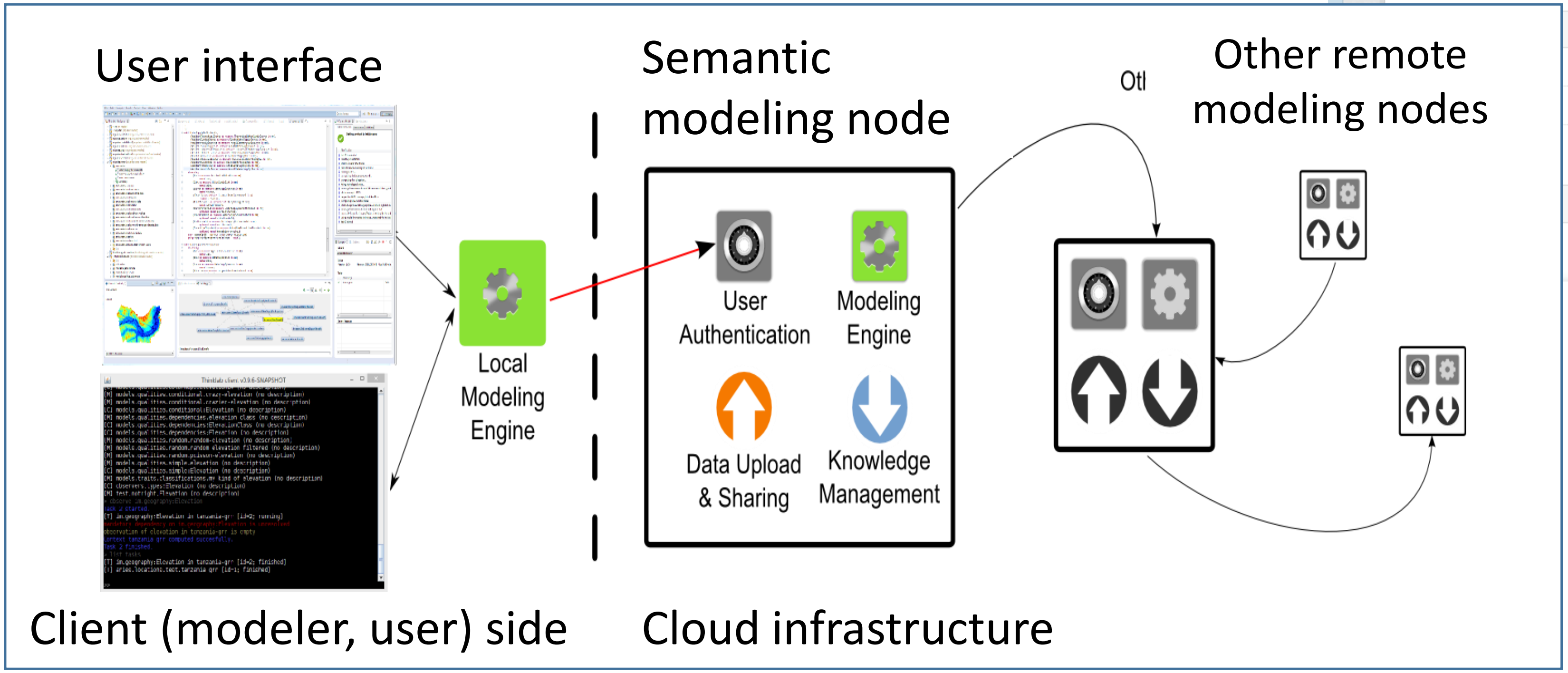


- Archival work is <u>*up front*</u>, after that it's usable by anyone

Cloud-based data and models: Toward context-aware modeling

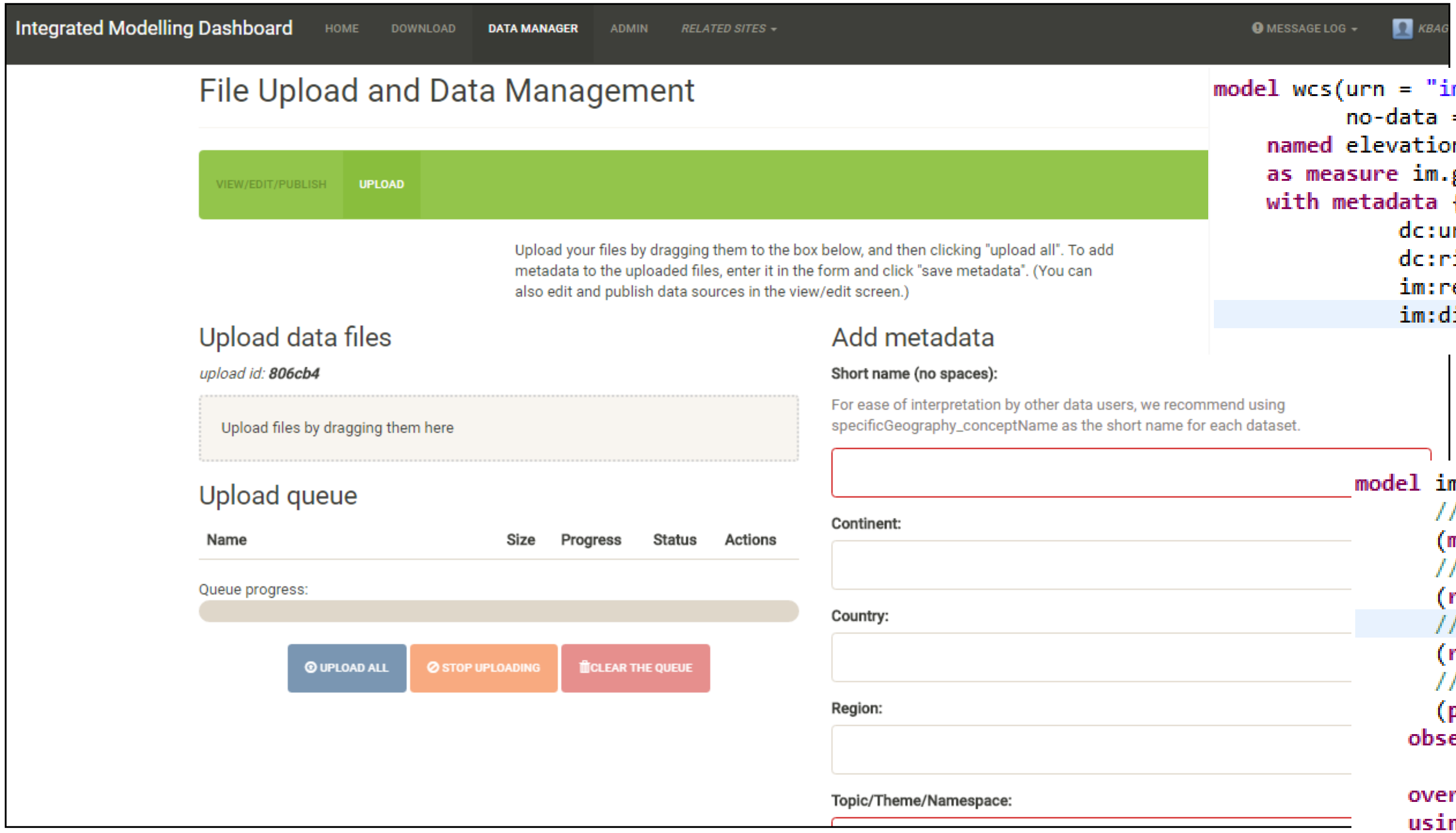
- Many global & national datasets served by Web Coverage Service (WCS)/Web Feature Service (WFS)
- Data export via CKAN





GeoServer

Data and model annotation




```
model wcs(urn = "im:global.geography:dem90m",
          no-data = -32768.0)
    named elevation-global
    as measure im.geography:Elevation in m
    with metadata {dc:originator "SRTM DEM 90m resolution, hydrologically corrected"
              dc:url "http://www2.jpl.nasa.gov/srtm/"
              dc:rights "cc-attr-nomod"
              im:reliability 80
              im:distribution "public"};
```

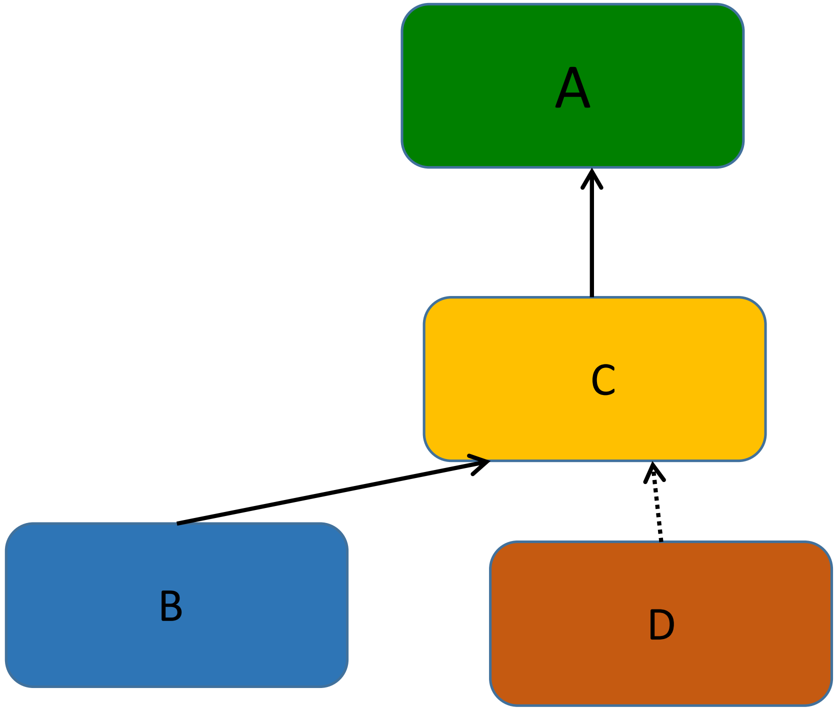
```
model im.hydrology:Watershed,
      //  pit-filled land elevation.
      (measure im.hydrology:Elevation in m),
      // TODO make this a classification so we know what the numbers mean
      (rank im.hydrology:FlowDirection),
      // TODO make this a measurement of actual area
      (rank im.hydrology:ContributingArea),
      // channel network
      (presence of im.hydrology:Stream)
    observing
       (Elevation as measure im.geography:Elevation in m)
    over space
    using hydrology.watershed();
```

Incorporates different models based on context & purpose

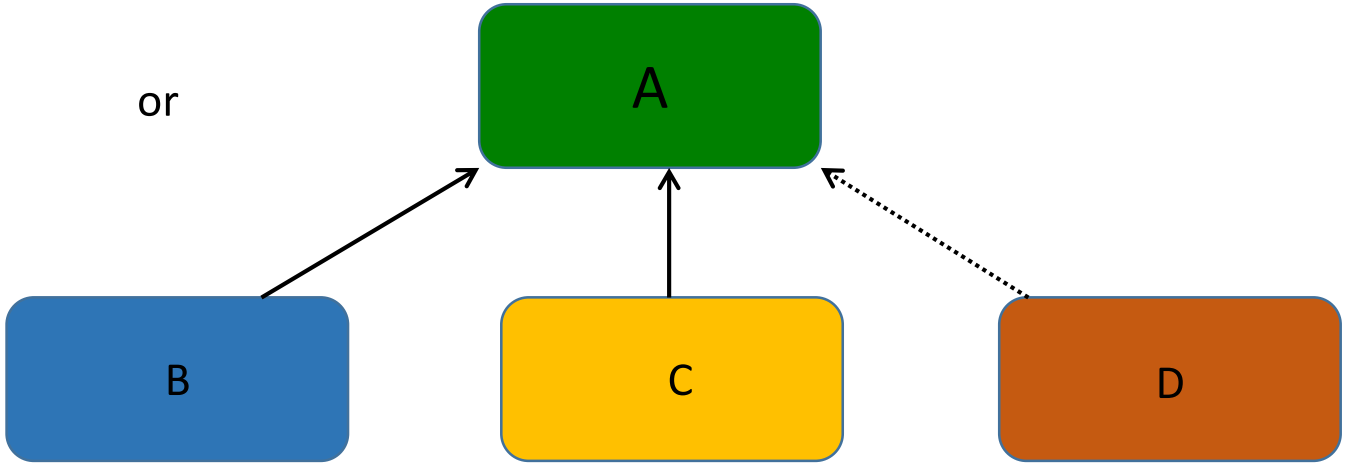
- Bayesian belief networks
- Simple deterministic/mathematical models
- Lookup tables
- Process models
- Agent-based models
- Multicriteria analysis

Structural learning: data-driven modeling using Bouckeart 2008

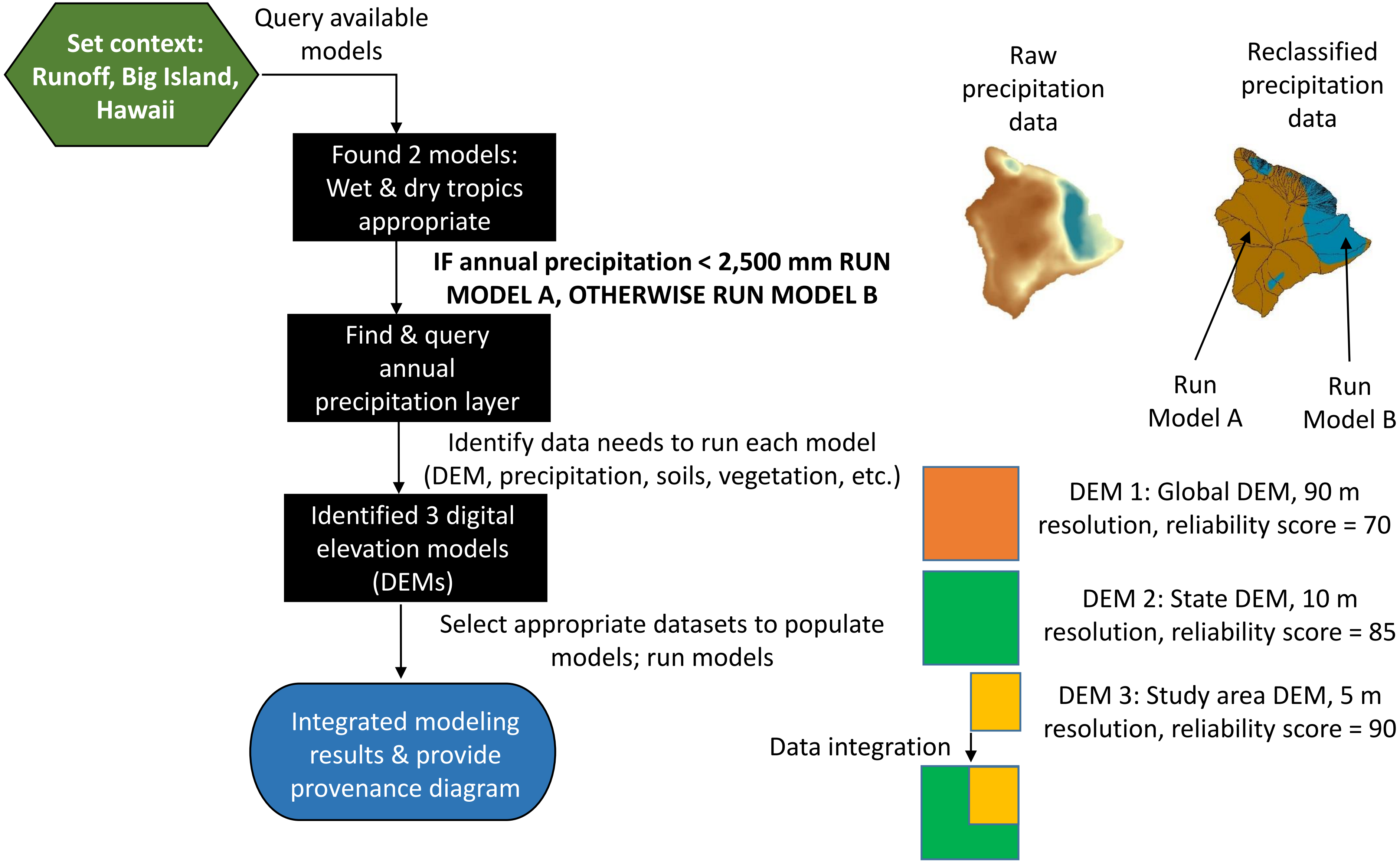
Structural learning using hill climbing, simulated annealing, tabu search algorithms



or



Automating data & model assembly: Opens door for machine reasoning, pattern recognition



Current activities and teams in ARIES

Developers: descriptional conventions and software stack:

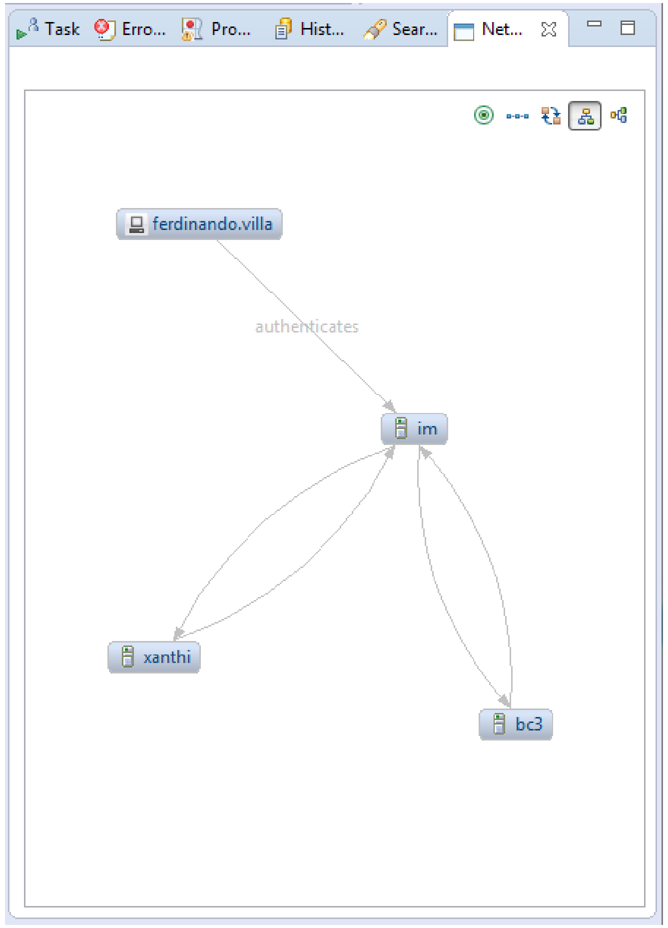
1. Modeling language and "glue" semantics for existing content
2. Client infrastructure for modelers
3. Client infrastructure for end users
4. Server infrastructure serving data and models

Philosophers: ontologies for socio-environmental systems

1. Foundational ontologies (subjects, processes, events, qualities, relationships, traits);
2. Domain ontologies (ecology, agriculture, policy, geography…)

Modelers: in charge of data and model content

1. Global data/models for rapid assessment
2. Detailed, specific content for case studies
3. System switches automatically based on context.

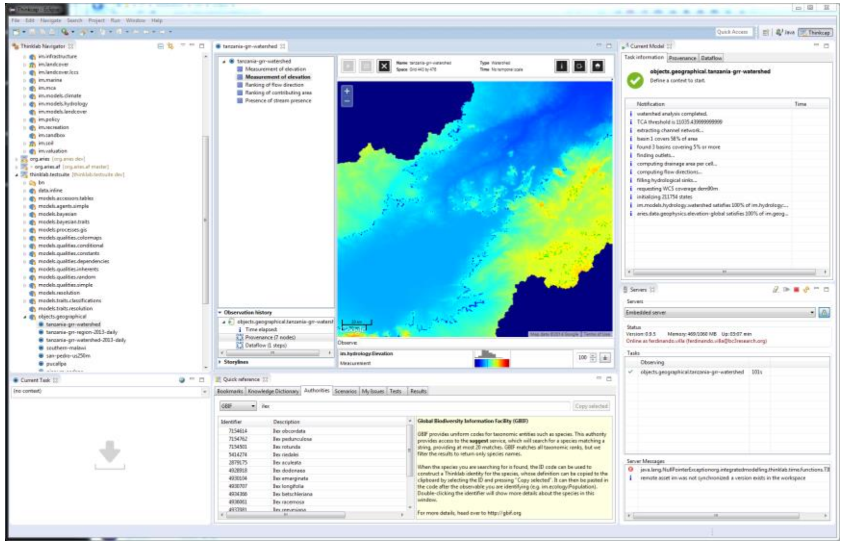


The SMM cloud, as seen from Bilbao in Dec 2014

Current Infrastructure

Semantic modeling language [well developed]
Documentation and web presence [ahem]
Domain ontologies [in progress]
Client infrastructure

- Command-line client [for experts]
- Integrated Development Environment [good]
- User client [to be developed]



Server infrastructure

- Modeling engine [local and remote]
- Authentication and data retrieval services [online]
- Collaboration infrastructure [certification, user management, data upload and publishing]

Training: International Spring University [yearly in Bilbao, since 2013]: 2-week intensive course, rebooting in 2018 with support for web explorer interface. *Looking for more collaborations and opportunities to share and disseminate.*

Thanks!

kbagstad@usgs.gov