QCon

Please evaluate my talk via the mobile app!

INTERNATIONAL
SOFTWARE DEVELOPMENT
CONFERENCE

A Research Agenda and Vision for Big Data at NASA

Chris Mattmann

Chief Architect, Instrument and Science Data Systems,
Jet Propulsion Laboratory, California Institute of Technology

Adjunct Associate Professor, USC
Director, Apache Software Foundation

Agenda

- Big Data – JPL's Initiative
- Some Big Data Technologies from the Apache Software Foundation
- JPL's Big Data: ASO, RCMES, SKA, V-FASTR
    - Rapid Algorithm Integration, Smart Data Movement, Transient Archives, Automated text/metadata extraction and MIME identification
- Big Data Vision and Wrapup

And you are?

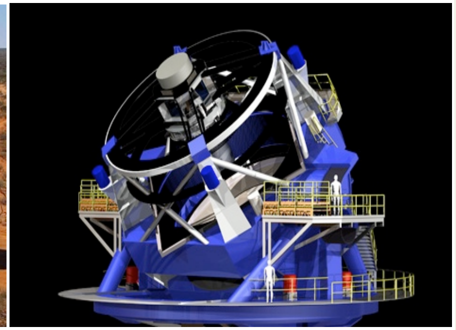
- Chief Architect at NASA JPL in Pasadena, CA USA
- Software Architecture/ Engineering Prof at Univ. of Southern California
- One of original PMC members for Apache Nutch
  – predecessor to Hadoop
- Apache Board of Directors involved in
  – OODT (VP, PMC), Tika (PMC), Nutch (PMC), Incubator (PMC), SIS (PMC), Gora (PMC), Airavata (PMC)

Some "Big Data" Grand Challenges I'm interested in

- *How do we handle 700 TB/sec of data coming off the wire when we actually have to keep it around?*
  - Required by the Square Kilometre Array
- *Joe scientist says I've got an IDL or Matlab algorithm that I <u>will not change</u> and I need to run it on 10 years of data from the Colorado River Basin and store and disseminate the output products*
  - Required by the Western Snow Hydrology project
- *How do we compare petabytes of climate model output data in a variety of formats (HDF, NetCDF, Grib, etc.) with petabytes of remote sensing data to improve climate models for the next IPCC assessment?*
  - Required by the 5th IPCC assessment and the Earth System Grid and NASA
- *How do we catalog all of NASA's current planetary science data?*
  - Required by the NASA Planetary Data System

Image Credit: http://www.jpl.nasa.gov/news/news.cfm?release=2011-295

Big Data Strategic Initiative



Future Opportunities: Mission and instrument competitions, data-intensive industries, LSST, future radio observatories.

JPL Concept: Big data technology for data triage, archiving, etc.

Key Challenges this work enables: Broaden JPL business base (relevant to 1X, 3X, 4X, 7X, 8X, 9X Directorates)

Initiative Long Term Objectives

- Apply lower-efficient digital architectures to future JPL flight instrument developments and proposals.
- Expand and promote JPL expertise with machine learning algorithm development for real-time triage.
- Utilize intelligent anomaly classification algorithms in other fields, including data-intensive industry.
- Build on JPL investments in large data archive systems to capture role in future science facilities.
- Enhance the efficiency and impact of JPL's data visualization and knowledge extraction programs.

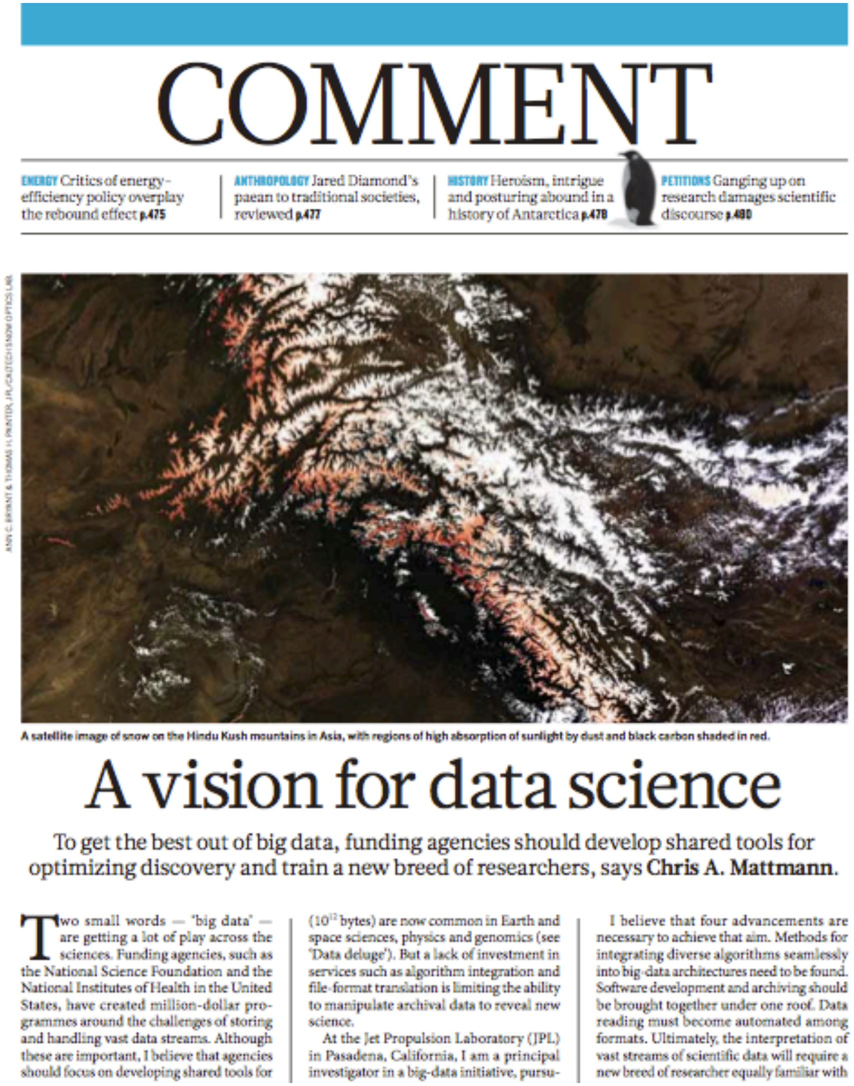
Initiative Leader: Dayton Jones
Steering Committee Leader: Robert Preston

Task Title	PI	Section
1 Power Minimization in Signal Processing for Data-Intensive Science	Larry D'Addario	335
2 Machine Learning for Smart Triage of Big Data	Kiri Wagstaff	388
3 Archiving, Processing and Dissemination for the Big Date Era	Chris Mattmann	388
4 Knowledge driven Automated Movie Production Environment distribution and Display (AMPED) Pipeline	Eric De Jong	3223

Initial Major Milestones for FY13	Date
Report on end-to-end power optimization of instruments	Jun 2013
Hierarchical classification method for VAST and ChemCam	Jan 2013
Demonstrate smart compression for Hyperion and CRISM	Mar 2013
Cloud computing research and scalability experiments	Feb 2013
Data formats and text, metadata extraction in big data sys.	Aug 2013
Develop AMPED pipeline and install in VIP Center	Dec 2012

Credit: Dayton Jones

Recent pub highlights



COMMENT

ENERGY Critics of energy-efficiency policy overplay the rebound effect p.475

ANTHROPOLOGY Jared Diamond's paean to traditional societies, reviewed p.477

HISTORY Heroism, intrigue and posturing abound in a history of Antarctica p.478

PETITIONS Ganging up on research damages scientific discourse p.480

A satellite image of snow on the Hindu Kush mountains in Asia, with regions of high absorption of sunlight by dust and black carbon shaded in red.

A vision for data science

To get the best out of big data, funding agencies should develop shared tools for optimizing discovery and train a new breed of researchers, says **Chris A. Mattmann**.

Two small words — 'big data' — are getting a lot of play across the sciences. Funding agencies, such as the National Science Foundation and the National Institutes of Health in the United States, have created million-dollar programmes around the challenges of storing and handling vast data streams. Although these are important, I believe that agencies should focus on developing shared tools for

(10^{12} bytes) are now common in Earth and space sciences, physics and genomics (see 'Data deluge'). But a lack of investment in services such as algorithm integration and file-format translation is limiting the ability to manipulate archival data to reveal new science.

At the Jet Propulsion Laboratory (JPL) in Pasadena, California, I am a principal investigator in a big-data initiative, pursu-

I believe that four advancements are necessary to achieve that aim. Methods for integrating diverse algorithms seamlessly into big-data architectures need to be found. Software development and archiving should be brought together under one roof. Data reading must become automated among formats. Ultimately, the interpretation of vast streams of scientific data will require a new breed of researcher equally familiar with

- Nature magazine piece on "A Vision for Data Science" in Jan. 24th issue
  - Big Data Initiative highlighted
- *Outline algorithm integration (regridding, metrics); automatic understanding of data metadata formats and open source as "key issues"*

Data Science/Big Data progress

- Named to Editorial Board of Springer Journal of Big Data
- Helping to define USC's M.S. in Data Science program
- Won/Submitted several Big Data proposals for direct funding
  - DARPA Open Source Program Office XDATA
  - NSF Major Research Instrumentation (RAPID)
  - NSF Polar Cyberinfrastructure, NSF EarthCube (both via USC)
  - President's/Director's Fund for Cosmic Dawn/OVRO
  - National Science Foundation: High Performance Computing System Acquisition (submitted)

SpringerOpen

Journal of Big Data

Editors-in-Chief
Borko Furht and Taghi M. Khoshgoftaar
Florida Atlantic University, Boca Raton, Florida, USA

Where do Big Data technologies fit into this?

U.S. National Climate Assessment
(pic credit: Dr. Tom Painter)

SKA South Africa: Square Kilometre Array
(pic credit: Dr. Jasper Horrell, Simon Ratcliffe

The Apache Software Foundation

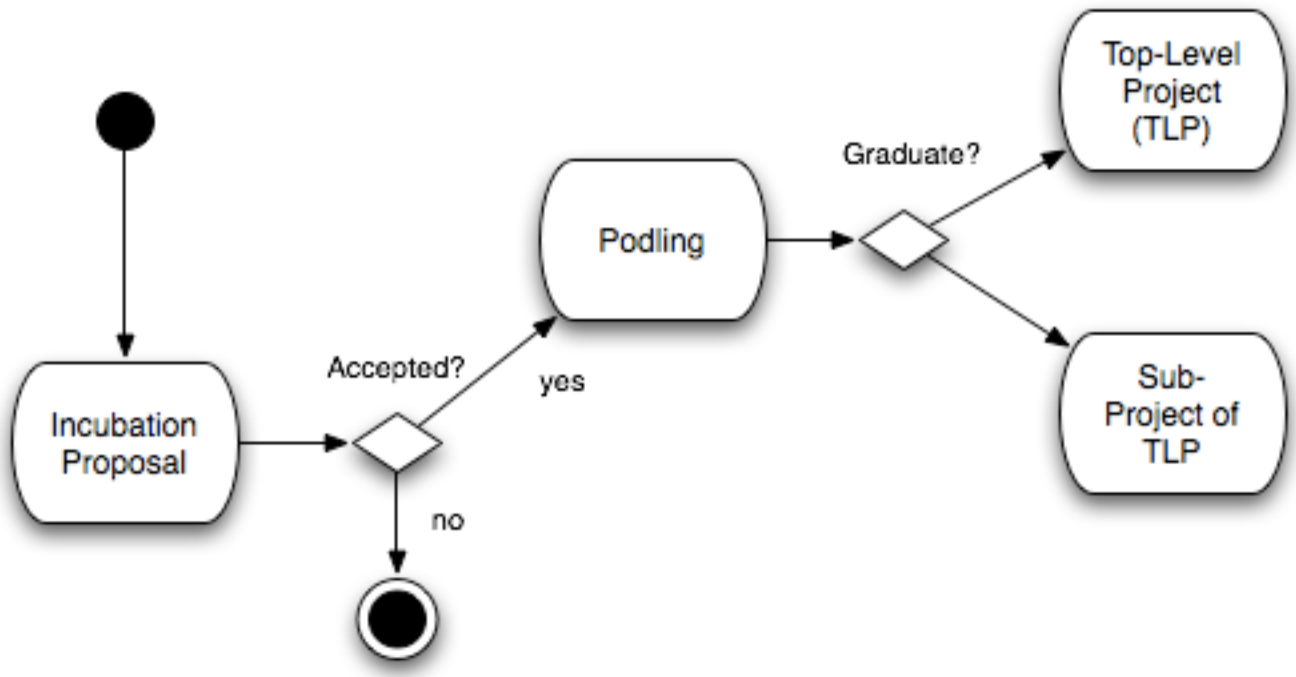
- Largest open source software development entity in the world
  - Over 2600+ committers
  - Over 4200+ contributors
  - Over 400+ members
- 100+ Top Level Projects
  - 57 Incubating
  - 32 Lab Projects
- 12 retired projects in the “Attic”
- Over 1.2 *million* revisions
- 501(c)3 non-profit organization incorporated in Delaware

-Over 10M successful requests served a day across the world

-HTTPD web server used on 100+ million web sites (52+% of the market)

Apache Maturity Model

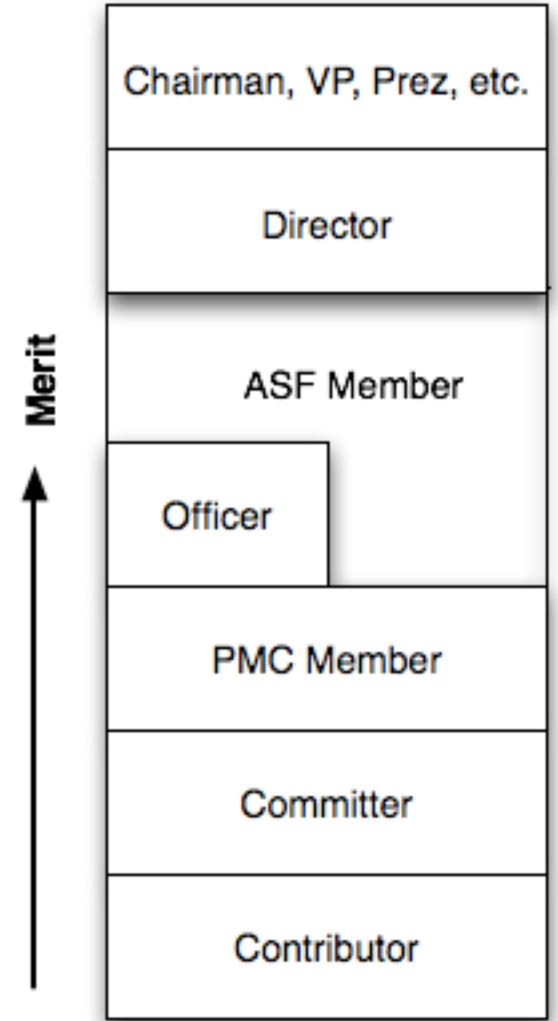
- Start out with Incubation
- Grow community
- Make releases
- Gain interest
- Diversify



- When the project is ready, graduate into
  - Top-Level Project (TLP)
  - Sub-project of TLP
- Increasingly, Sub-projects are <u>discouraged</u> compared to TLPs

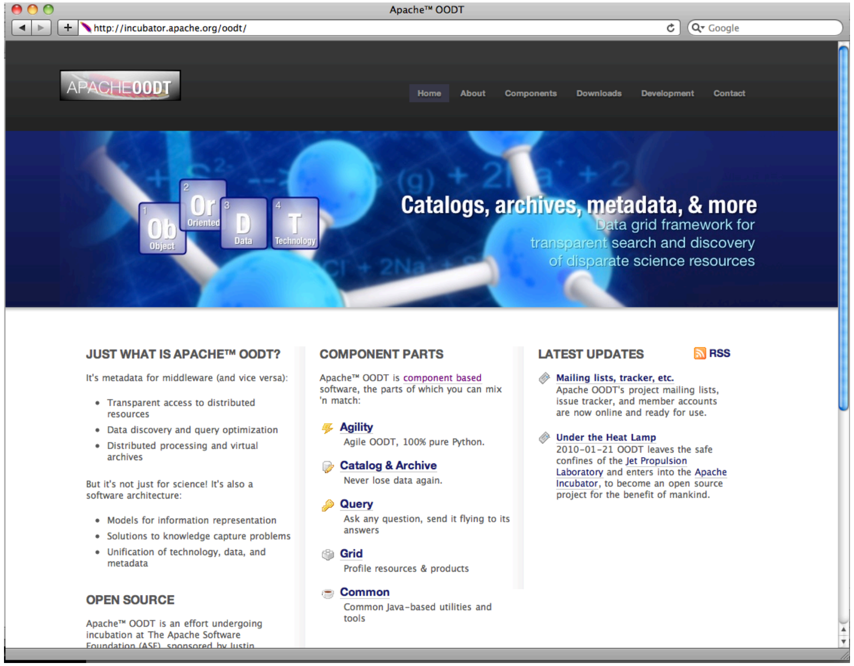
Apache Organization

- Apache is a meritocracy
  - You earn your keep and your credentials
- Start out as *Contributor*
  - Patches, mailing list comments, etc.
  - No commit access
- Move onto *Committer*
  - Commit access, evolve the code
- *PMC Members*
  - Have binding VOTEs on releases/personnel
- *Officer (VP, Project)*
  - PMC Chair
- *ASF Member*
  - Have binding VOTE in the state of the foundation
  - Elect Board of Directors
- *Director*
  - Oversight of projects, foundation activities



Apache OODT

- Entered "incubation" at the Apache Software Foundation in 2010
- Selected as a top level Apache Software Foundation project in January 2011
- Developed by a community of participants from many companies, universities, and organizations
- Used for a diverse set of science data system activities in planetary science, earth science, radio astronomy, biomedicine, astrophysics, and more



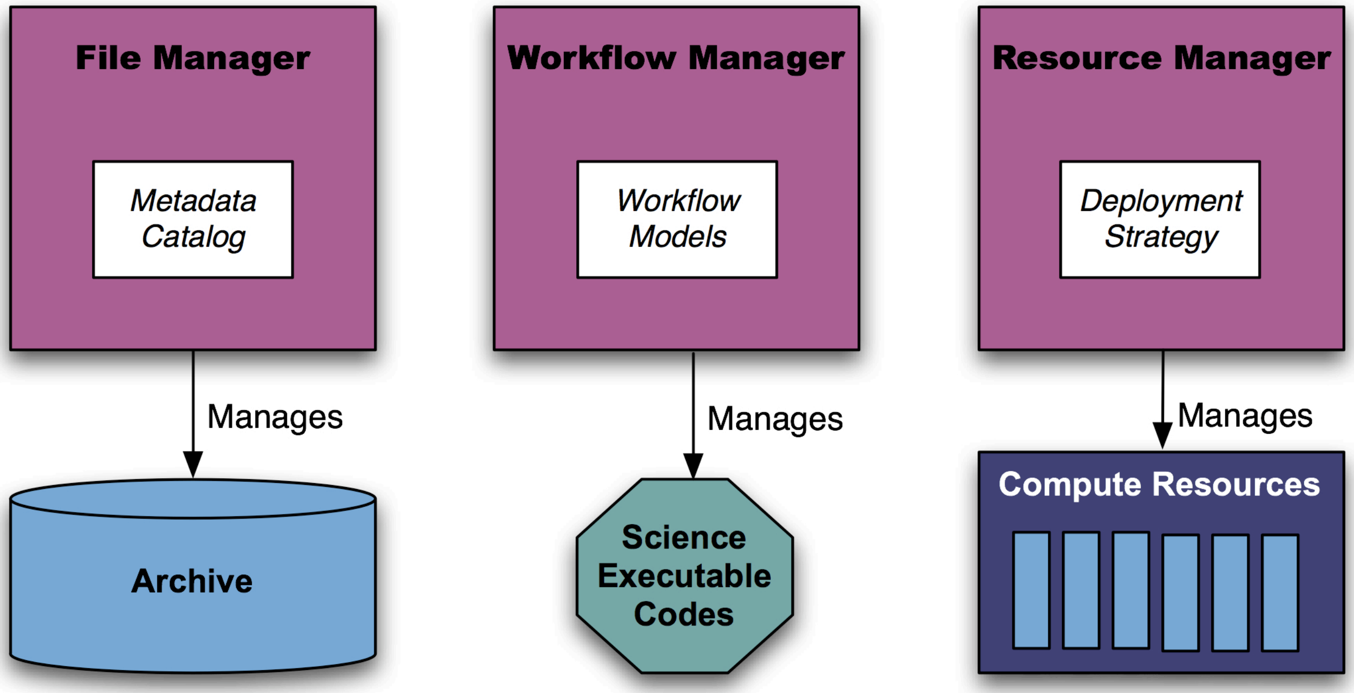
OODT Development & user community includes:

Apache OODT: OSS "big data" platform originally pioneered at NASA

- OODT is meant to be a set of tools to help build data systems
  - It's not meant to be "turn key"
  - It attempts to exploit the boundary between bringing in capability vs. being overly rigid in science
  - Each discipline/project extends

- Projects that are deploying it operationally at
  - Decadal-survey recommended NASA Earth science missions, NIH, and NCI, CHLA, USC, South African SKA project
- Why Apache?
  - Less than 100 projects have been promoted to top level (Apache Web Server, Tomcat, Solr, Hadoop)
  - Differs from other open source communities; it provides a governance and management structure

OODT Core Components

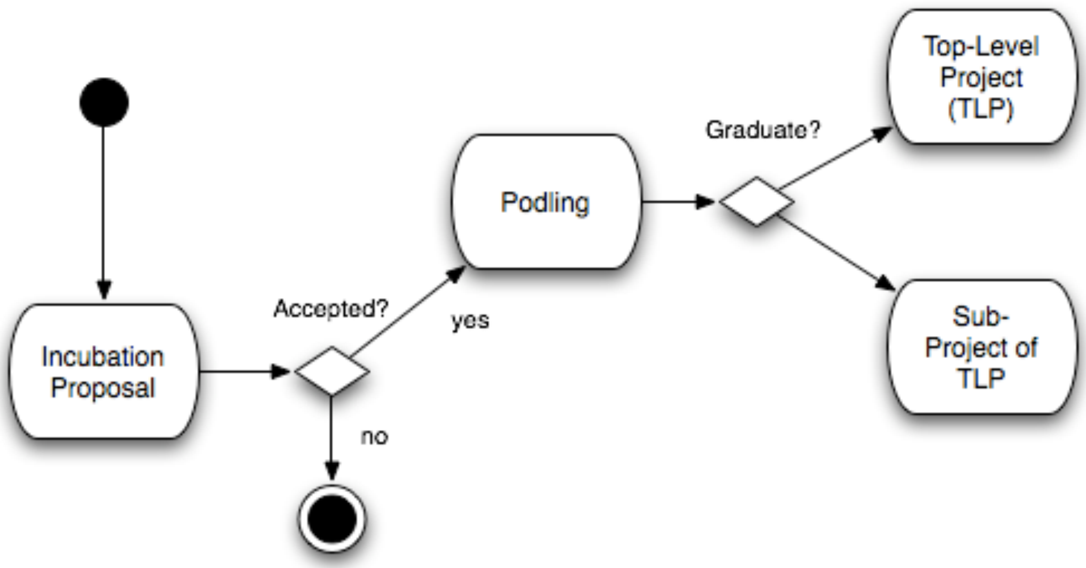


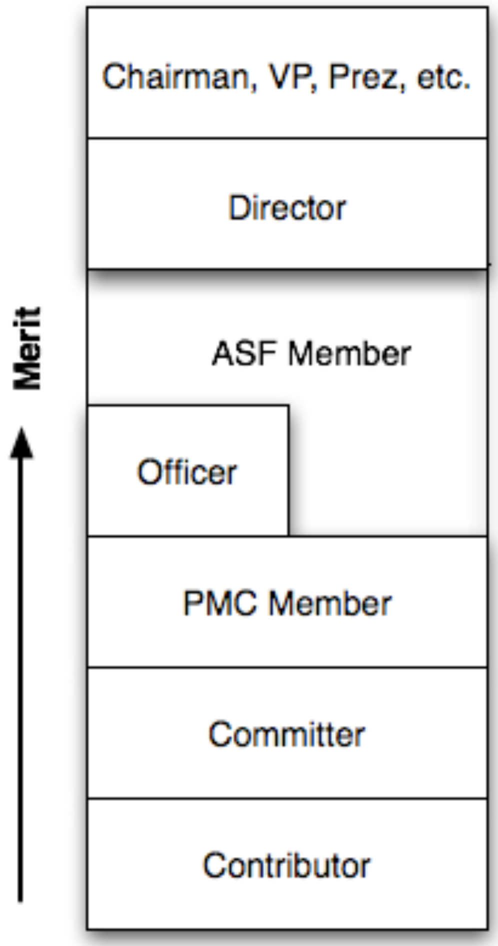
- **All Core components implemented as web services**
  - XML-RPC used to communicate between components
  - Servers implemented in Java
  - Clients implemented in Java, scripts, Python, PHP and web-apps
  - Service configuration implemented in ASCII and XML files

Why Apache and OODT?

- OODT is meant to be a set of tools to help build data systems
  - It’s not meant to be “turn key”
  - It attempts to exploit the boundary between bringing in capability vs. being overly rigid in science
  - Each discipline/project extends
- Apache is the elite open source community for software developers
  - Less than 100 projects have been promoted to top level (Apache Web Server, Tomcat, Solr, Hadoop)
  - Differs from other open source communities; it provides a governance and management structure

Governance Model+NASA=♥





- NASA and other government agencies have tons of process
  - <u>They like that</u>

Apache Open Climate Workbench..OCW

Foundation Projects People Get Involved Support Apache Planet Apache

The Apache Software Foundation

Blogging in Action.

The Apache Software Foundation Blog

« The Apache Software... | Main

MONDAY MAR 03, 2014

The Apache Software Foundation Announces Apache™ Open Climate Workbench™ as a Top-Level Project

Open Source analysis and evaluation toolkit initiated by UCLA and NASA/JPL's Regional Climate Model Evaluation System (RCMES) scientific collaboration; used in regional weather research and global climate dynamics modeling

Forest Hill, MD –03 March 2014– The Apache Software Foundation (ASF), the all-volunteer developers, stewards, and incubators of more than 170 Open Source projects and initiatives, announced today that the Apache Open Climate Workbench Project (a.k.a. "Apache Climate" or "Apache OCW") has graduated from the Apache Incubator to become a Top-Level Project (TLP), signifying that the project's community and products have been well-governed under the ASF's meritocratic process and principles.

Apache Climate is a climate evaluation toolkit used to leverage model outputs from organizations such as the Earth System Grid Federation (ESGF), the Coordinated Regional Downscaling Experiment (CORDEX), the U.S. National Climate Assessment (NCA), and the North American Regional Climate Change Assessment Program (NARCCAP), coupled with remote sensing data from the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and other agencies.

"Collaboration and science go hand in hand so it's great to see NASA, CORDEX, NARCCAP, universities from around the world, and the greater climate science community embracing Open Source and the ASF," said Michael Joyce, Vice President of Apache Climate. "The Open Climate Workbench has had an amazing journey with a great team of contributors and I'm excited to see where it's going."

Originally seeded from the Regional Climate Model Evaluation System (RCMES) code from the Joint Institute for Regional Earth System Science and Engineering (JIFRESSE) scientific collaboration between University of California at Los Angeles (UCLA) and the NASA Jet Propulsion Laboratory (JPL), the Apache Climate toolkit includes capabilities for data rebinning, metrics computation, and visualization. RCMES now relies extensively on Apache Climate; those members of the global climate community who have been using RCMES prior to its submission to the Apache Incubator in February 2013 have

Calendar

« March 2014

Sun	Mon	Tue	Wed	Thu
2	3	4	5	6
9	10	11	12	13
16	17	18	19	20
23	24	25	26	27
30	31			

Today

Search

Search

Hot Blogs (today's hits

- foundation | 368
- OOo | 1237
- flex | 416
- hbase | 336
- couchdb | 271
- tomcat | 232
- cloudstack | 22
- sqoop | 172
- infra | 134

Apache Open Climate Gets To

by Sudarshana Banerjee • March 3, 2014

Like Share 1

TM

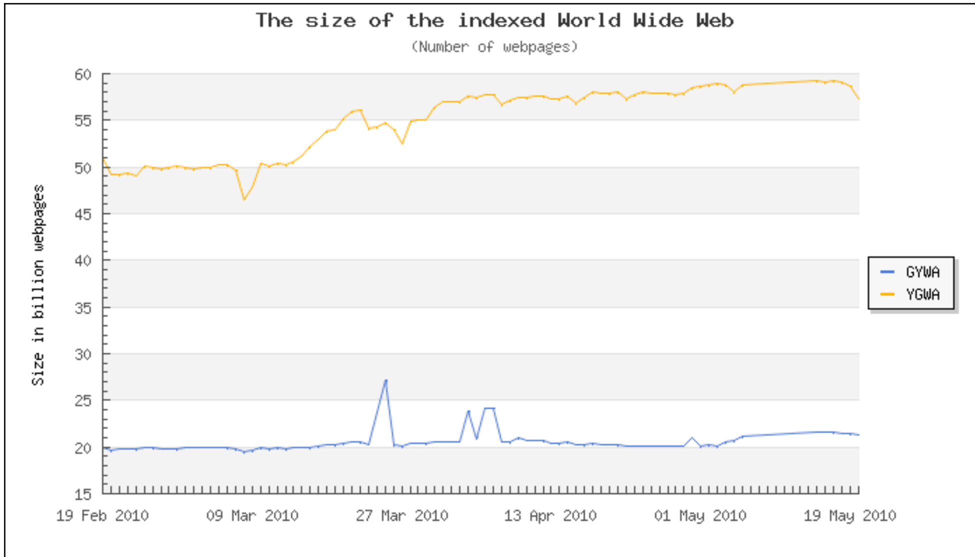
The Apache Open Climate Workbench Project has gradua

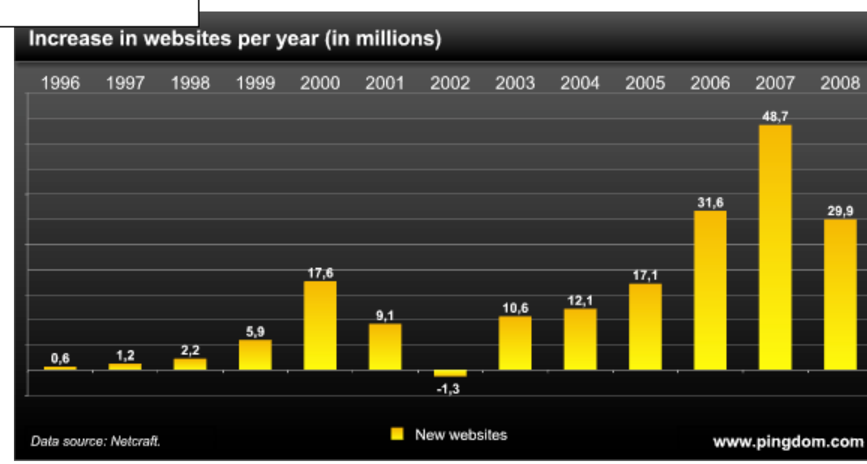
The Apache Open Climate Workbench software is release

Apache Climate is a climate evaluation toolkit used to leverage model outputs from organizations such as the Earth System Grid Federation (ESGF), the Coordinated Regiona Downscaling Experiment (CORDEX), the U.S. National Climate Assessment (NCA), and the North American Regional Climate Change Assessment Program (NARCCAP), coupled with remote sensing data from the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and other agencies.

[Image courtesy: Apache Software Foundation]

The Information Landscape





Proliferation of content types available

- By some accounts, 16K to 51K content types*
- What to do with content types?
  - Parse them
    - How?
    - Extract their text and structure
  - Index their metadata
    - In an indexing technology like Lucene, Solr, or in Google Appliance
  - Identify what language they belong to
    - Ngrams

*http://filext.com/

Apache™ Tika is…

- A content analysis and detection toolkit
- A set of Java APIs providing MIME type detection, language identification, integration of various parsing libraries
- A rich Metadata API for representing different Metadata models
- A command line interface to the underlying Java code
- A GUI interface to the Java code

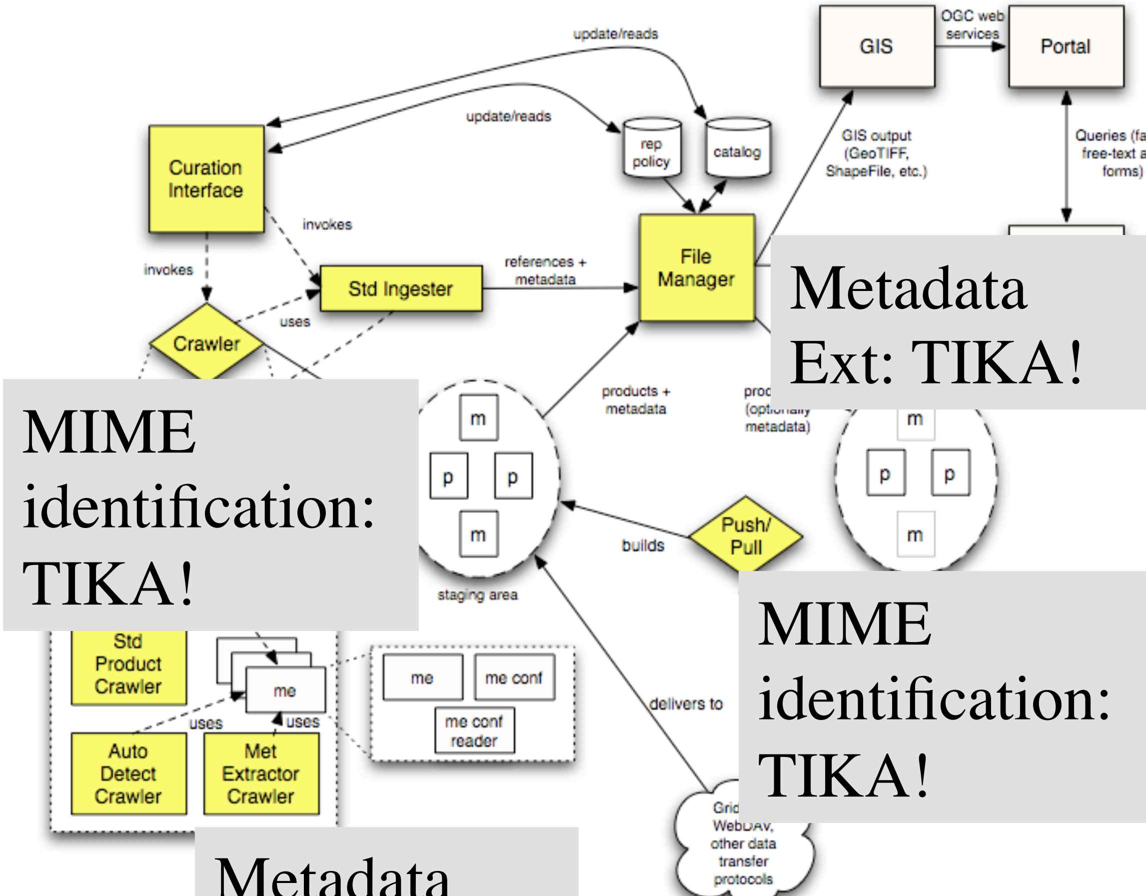
Science Data File Formats

- Hierarchical Data Format (HDF)
  - http://www.hdfgroup.org
  - Versions 4 and 5
  - Lots of NASA data is in 4, newer NASA data in 5
  - Encapsulates
    - Observation (Scalars, Vectors, Matrices, NxMxZ…)
    - Metadata (Summary info, date/time ranges, spatial ranges)
  - Custom readers/writers/APIs in many languages
    - C/C++, Python, Java

Science Data File Formats

- network Common Data Form (netCDF)
  - www.unidata.ucar.edu/software/**netcdf**/
  - Versions 3 and 4
  - Heavily used in DOE, NOAA, etc.
  - Encapsulates
    - Observation (Scalars, Vectors, Matrices, NxMxZ…)
    - Metadata (Summary info, date/time ranges, spatial ranges)
  - Custom readers/writers/APIs in many languages
    - C/C++, Python, Java
  - Not Hierarchical representation: all flat

OODT + Tika integrations



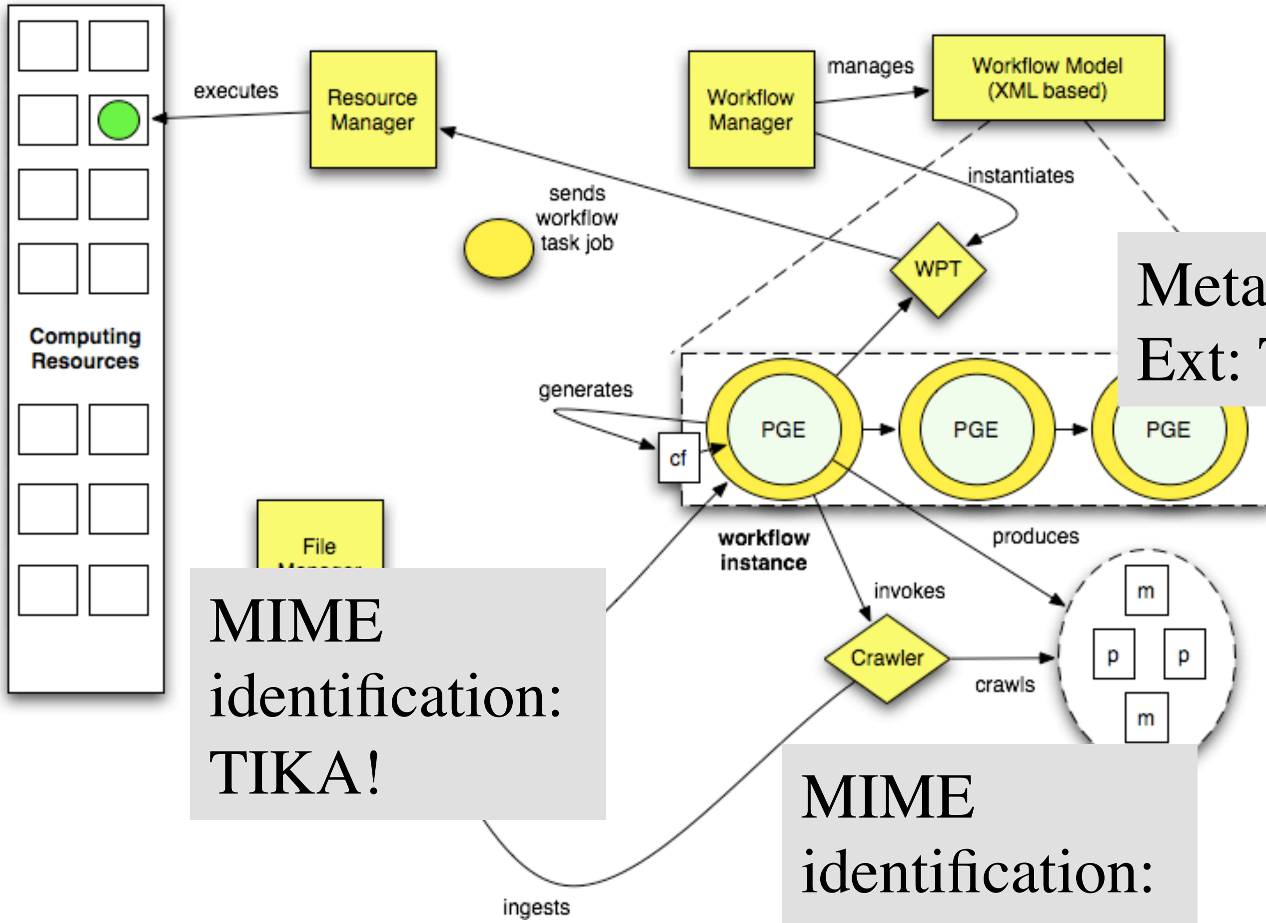
Metadata Ext: TIKA!

MIME identification: TIKA!

MIME identification: TIKA!

Metadata Ext: TIKA!

OODT + Tika integrations



Metadata Ext: TIKA!

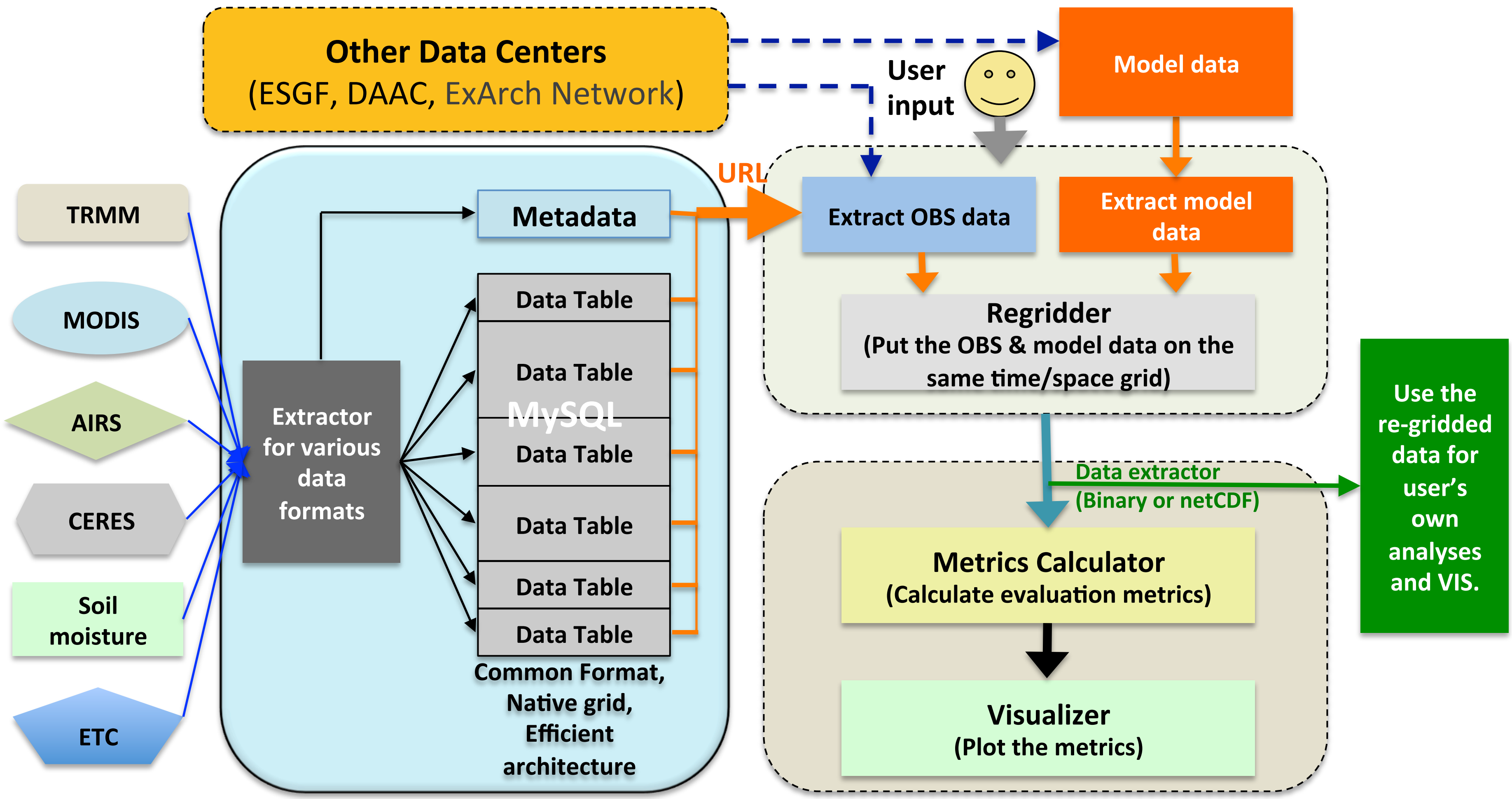
MIME identification: TIKA!

MIME identification: TIKA!

Now some specific NASA/JPL project examples

RCMES2.0

(http://rcmes.jpl.nasa.gov)

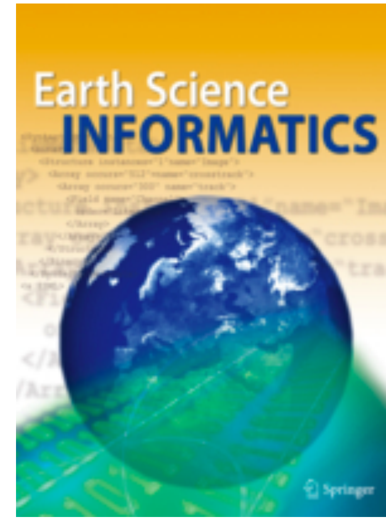


Raw Data:
Various sources, formats, Resolutions, Coverage

RCMED
(Regional Climate Model Evaluation Database)
A large scalable database to store data from variety of sources in a common format

RCMET
(Regional Climate Model Evaluation Tool)
A library of codes for extracting data from RCMED and model and for calculating evaluation metrics

Evaluation of Cloud Computing for Storage & Application of NASA Observations



Challenge

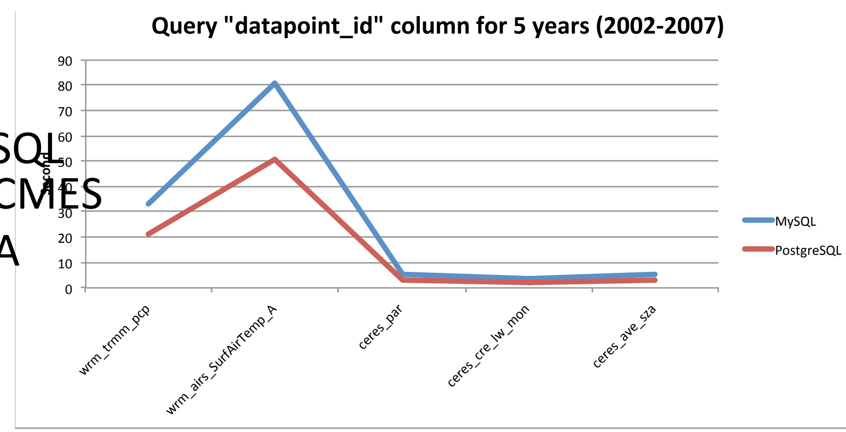
- Regional climate model evaluation with daily temporal resolution to assess representation of extreme events.
- More voluminous, requires scalability in web services, system throughput, and also elasticity based on study demands

Objective

- Understand and evaluate popular cloud computing technologies, and provide a framework for selecting the best one for supporting Regional Climate Model Evaluation System (RCMES) & applications such as the National Climate Assessment and IPCC's CORDEX regional model evaluations.

Results

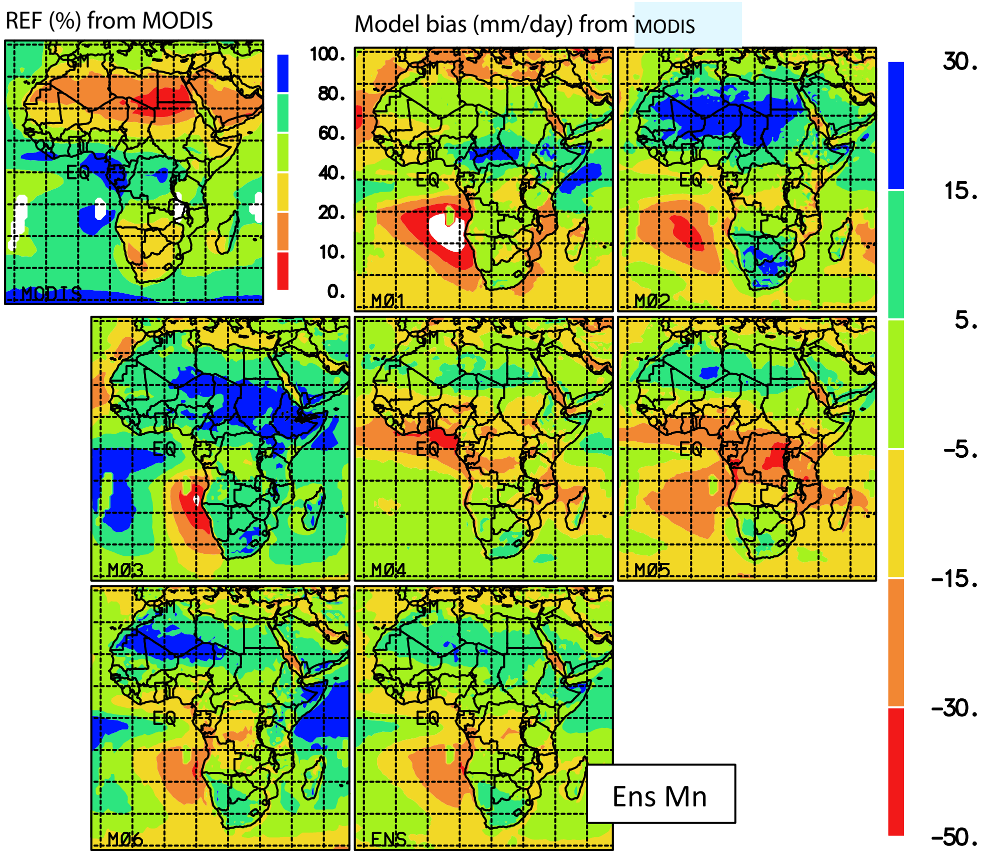
- Conducted evaluation demonstrating 44 % avg query time speedup of PostGIS over MySQL for 5 years of 5 parameters of obs data in RCMES
- Will incorporate into RCMES to facilitate NCA and CORDEX regioal model evaluations.



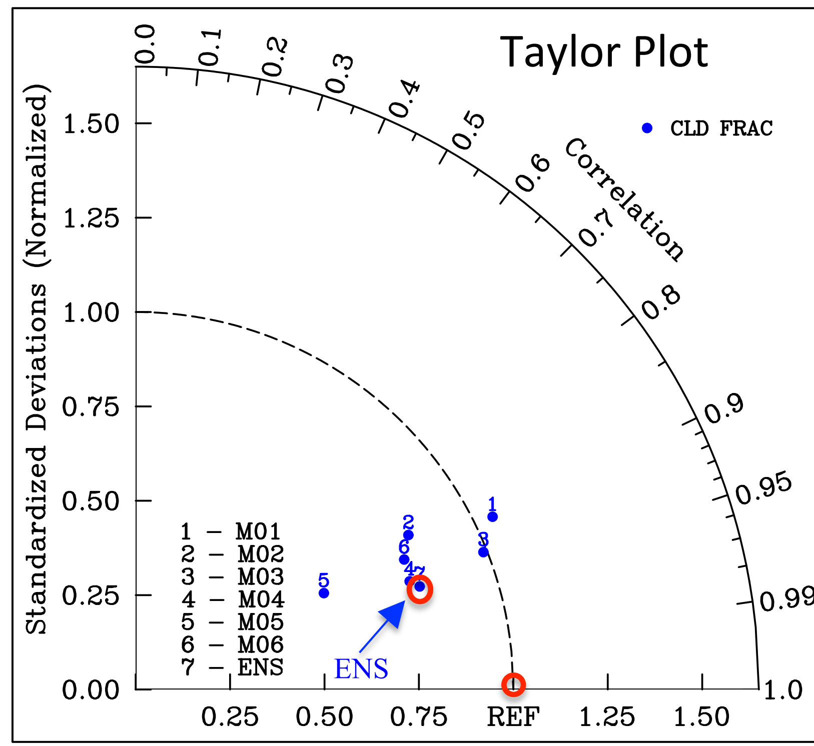
C. Mattmann, D. Waliser, J. Kim, C. Goodale, A. Hart, P. Ramirez, D. Crichton, P. Zimdars, M. Boustani, H. Lee, P. Loikith, K. Whitehall, C. Jack, B. Hewitson. Cloud Computing and Virtualization Within the Regional Climate Model and Evaluation System. *Earth Science Informatics*, 2013.

Example application for CORDEX-Africa

Annual Cloudiness Climatology Against MODIS; 2001-2008



Kim et al. 2013, In press



NOTE: The blank areas in the REF (MODIS) data are due to missing values.

NARCCAP Multi-decadal Hindcast Evaluation Result

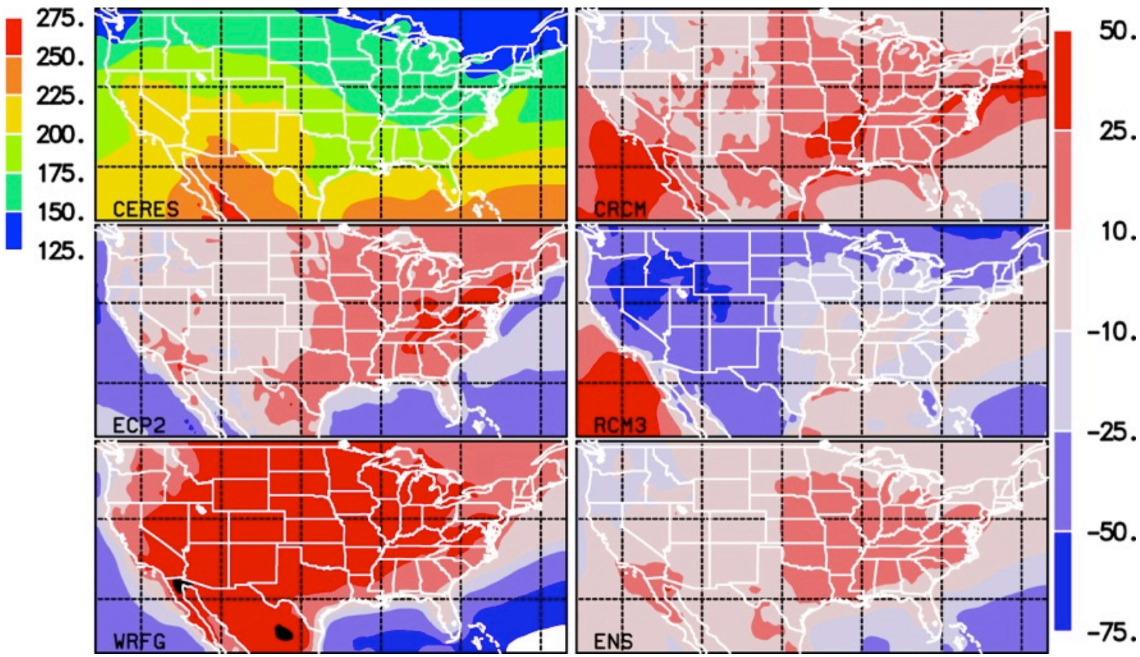


Figure. RCM biases in surface insolation against CERES

Considerable biases exist in surface insolation fields, a not so typical variable scrutinized in RCMs.

Kim, J., D.E. Waliser, C.A. Mattmann, L.O. Mearns, C.E. Goodale, A.F. Hart, D.J. Crichton, and S. McGinnis, 2013: Evaluations of the surface air temperature, precipitation, and insolation over the conterminous U.S. in the NARCCAP multi-RCM hindcast experiments using RCMES. J. Climate, In press.

Table 2. The relationship between precip & insolation biases.

Model	Land-mean bias – Precipitation (mm/d)	Land-mean bias - Insolation (Wm^{-2})	Bias pattern Correlation
CRCM	0.33	10.2	-0.47
ECP2	0.41	9.0	-0.28
RCM3	0.54	-29.9	-0.50
WRFG	-0.08	30.4	-0.18
ENS	0.25	4.9	-0.62

Table 1. The RCMs evaluated in this study.

Model ID	Model Name
M01	CRCM (Canadian Regional Climate Model)
M02	ECP2 (NCEP Regional Spectral Model)
M03	MM5I (MM5 – run by Iowa State Univ.)
M04	RCM3
M05	WRFG (WRF – run by PNNL)
ENS	Model Ensemble (Uniform weighting)

Snowmelt Runoff Forecasting

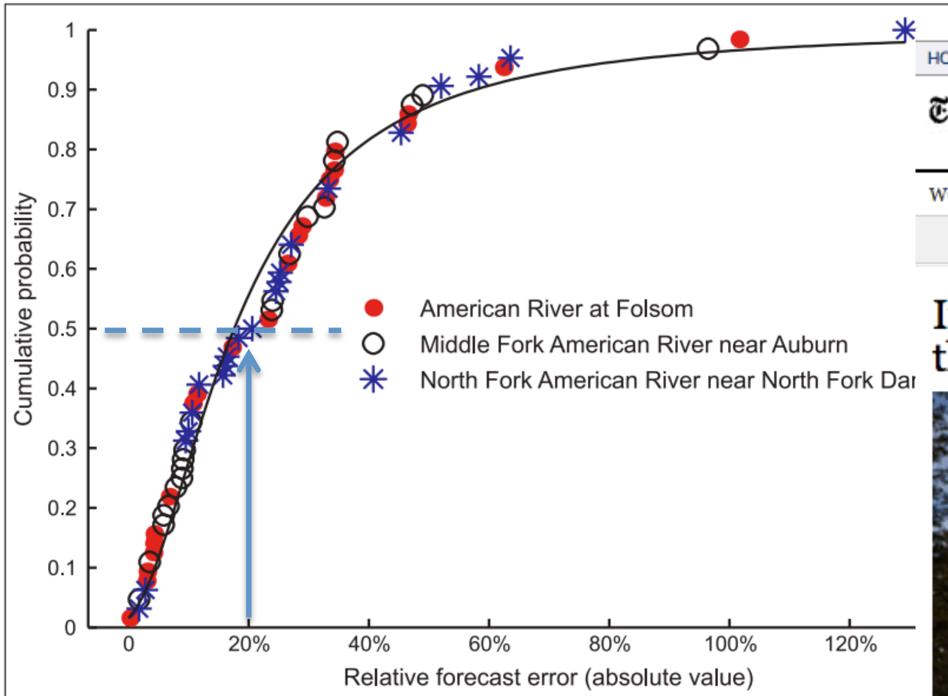


Fig. 1. Errors in the 1 April forecast for April–July runoff in the American River, 1990–2011, base on gauges at Auburn and Folsom, in California. Note that the median error is 18% and the 80 percentile (1 year in 5) error is 39%. The plot was generated from information from the Califo Data Exchange Center.

Dozier 2012

In 1 of 5 years, forecast errors are greater than 40%. Half the time, they are greater than 20%. These come from poor data and poorly constrained science.

HOME PAGE | TODAY'S PAPER | VIDEO | MOST POPULAR | U.S. Edition

The New York Times

U.S.

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINI

POLITICS | EDUCATION | TEXAS

In California, Reading the Snow to Tell the Future for the Water Supply

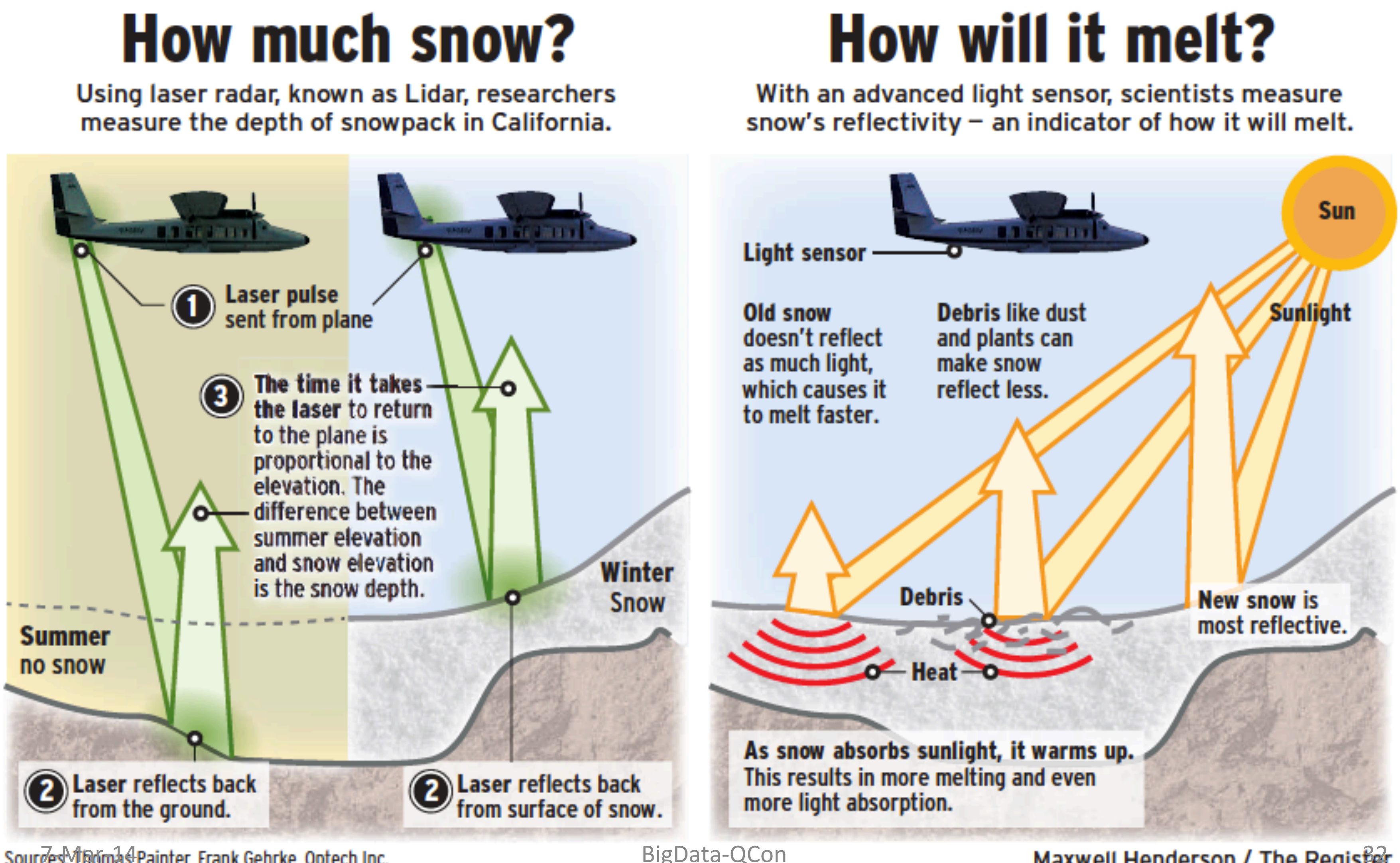
Max Whittaker for The New York T

Frank Gehrke, center, has led snowpack surveys in California for a quarter-century. The state's multibillion-dollar agricultural industry pays close attention.

By NORIMITSU ONISHI

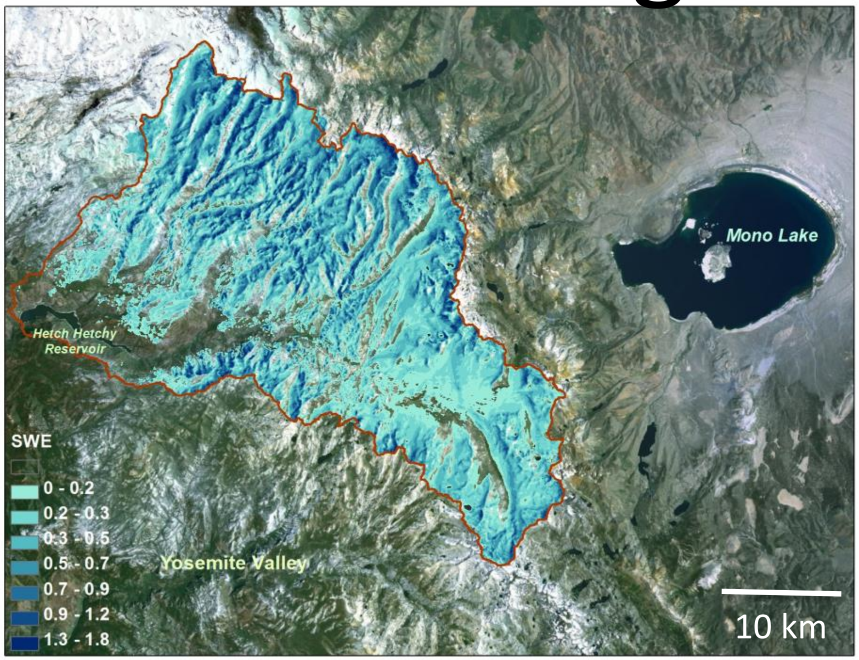
Published: February 7, 2013

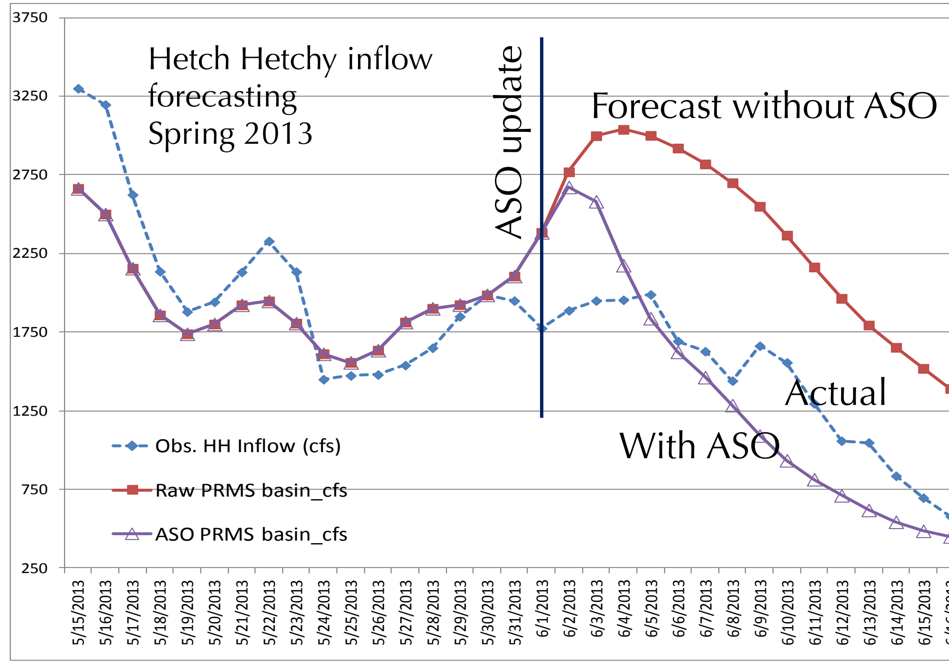
Credit: Tom Painter, JPL



Credit: Tom Painter, JPL

Improved Estimates for Water Management in California





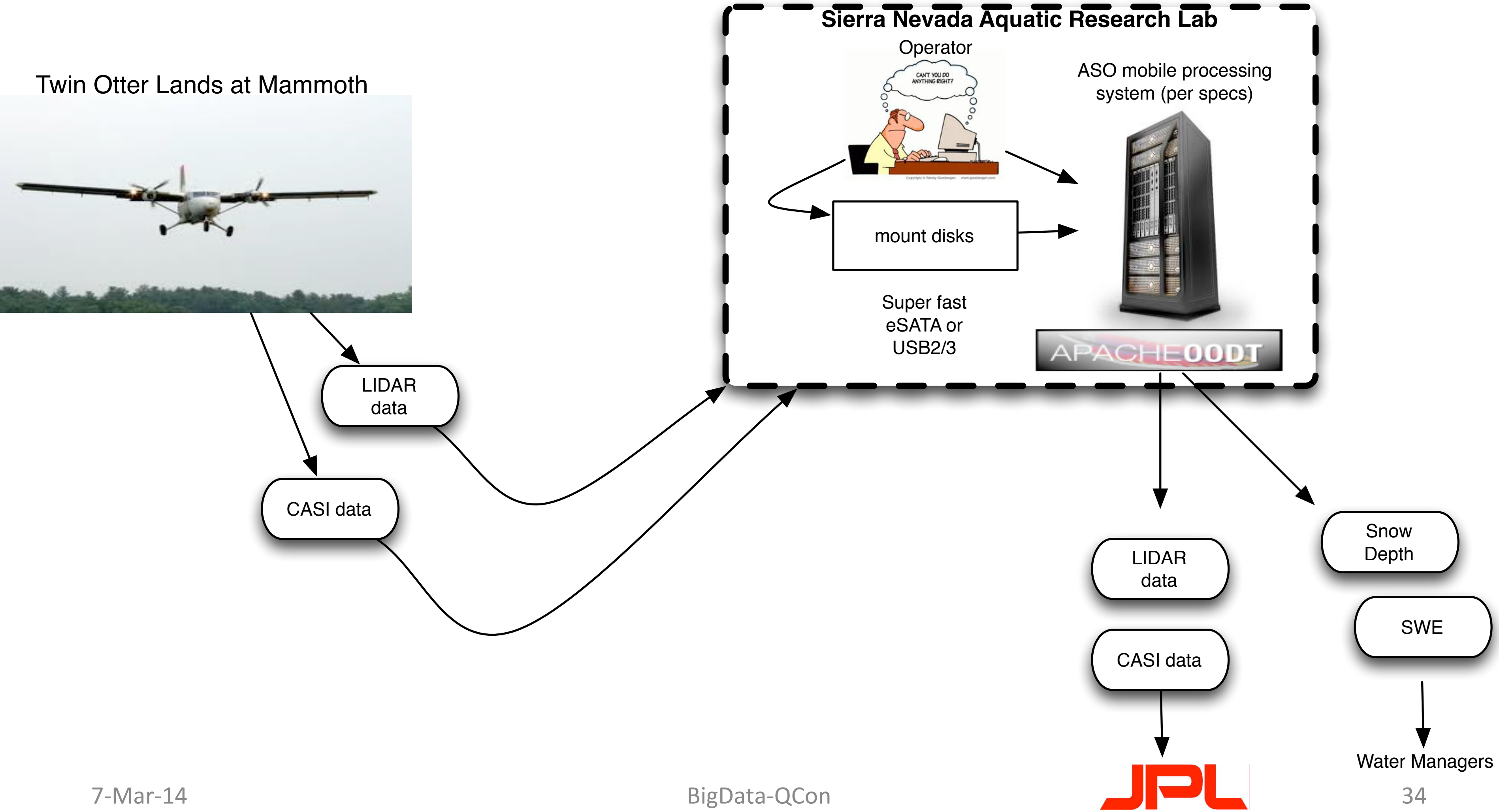
AIRBORNE SNOW OBSERVATORY

The JPL ASO team and California Dept. of Water Resources (DWR) prediction of water inflow into the Hetch Hetchy Reservoir in thousand acre feet (shown in red) was modified on June 1, 2013 based on snow water equivalent (SWE) data from the NASA/JPL Airborne Snow Observatory. The new forecast (shown in purple) provided a factor of 2 better estimate of the actual inflow (shown in blue) and enabled water managers to optimize reservoir operations in its first year.

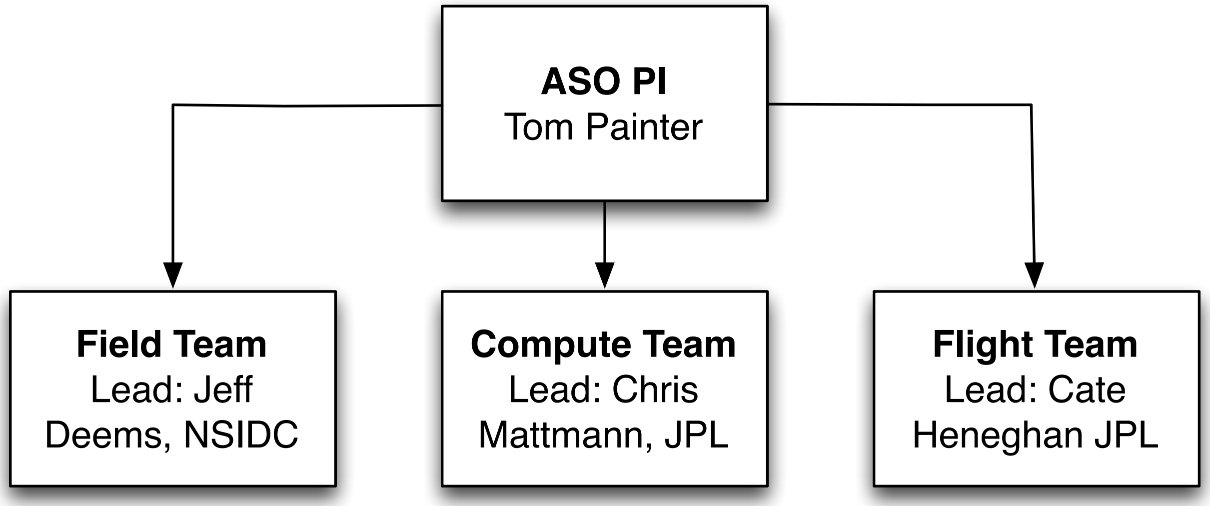
Tom Painter, JPL

How did ASO go from acquired data to...improving water estimates?

The ASO Compute Team



Who is the ASO Compute Team?

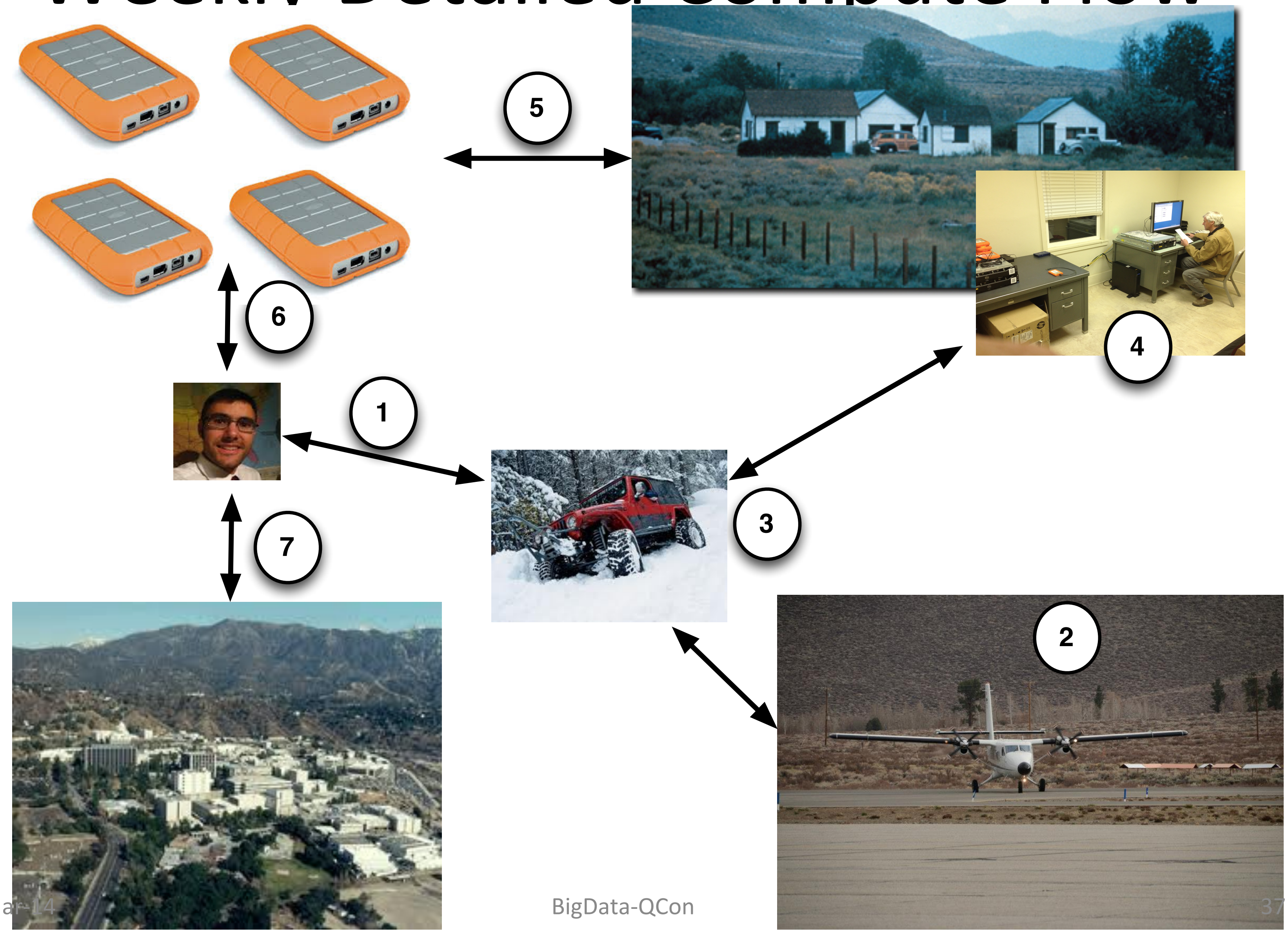


Paul Ramirez, Andrew Hart, Cameron Goodale, Felix Seidel, Paul Zimdars, Susan Neely, Jason Horn, Rishi Verma, Maziyar Boustani, Shakeh Khudikyan, Joseph Boardman, Amy Trangsrud, Cate Heneghan

What do we do?

- Job #1
  - Don’t lose the bits
- Job #2
  - Rapidly, and automatically process algorithms delivered by ASO scientists
    - Spectrometer (raw radiance data through basin maps of albedo)
    - LIDAR (raw data through snow depth/SWE)
- Job #3
  - Ensure that executed algorithms can easily be rerun, and that we catalog and archive the inputs, and outputs
- Job #4
  - Deliver the outputs of the algorithms (“move data around”)
- Job #5
  - Reformat the data, and convert it, and deliver maps, movies, higher level EPO
- Job #6
  - Entertain the rest of the team

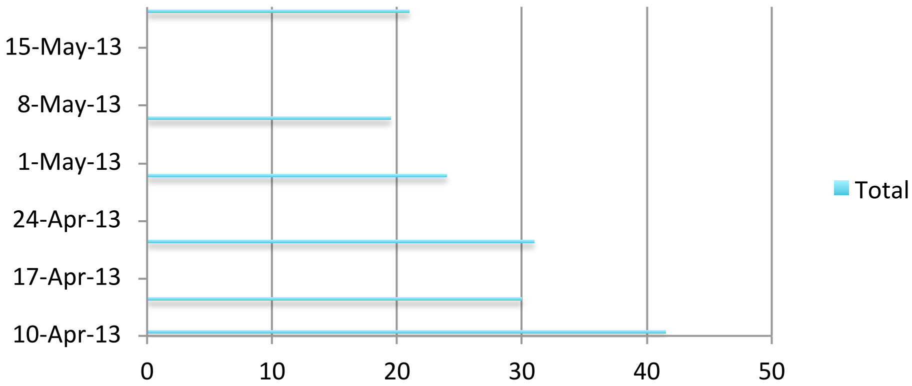
Weekly Detailed Compute Flow

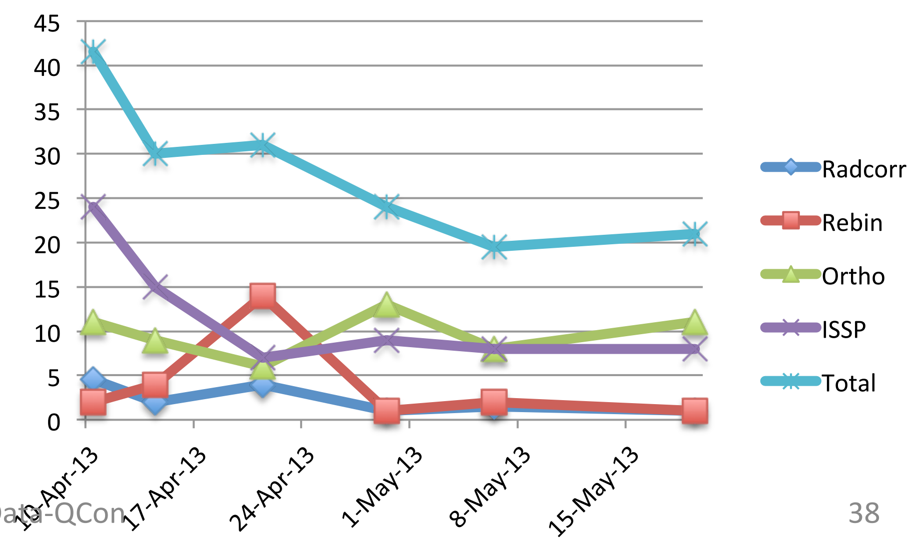


Rodeo improvements over time (CASI/spectrometer)

- Earlier, ISSP was dominant processing time in rodeo
  - Eventually Ortho became a problem too due to issues like flying off DEM; and/or discovery of resource contention at alg. Level
- Radcorr and Rebin processing time were equated to nil through paralllelism and automation
- Within a month of near automation, we were making 24 hrs on CASI side
- Updates to algs to make deadline

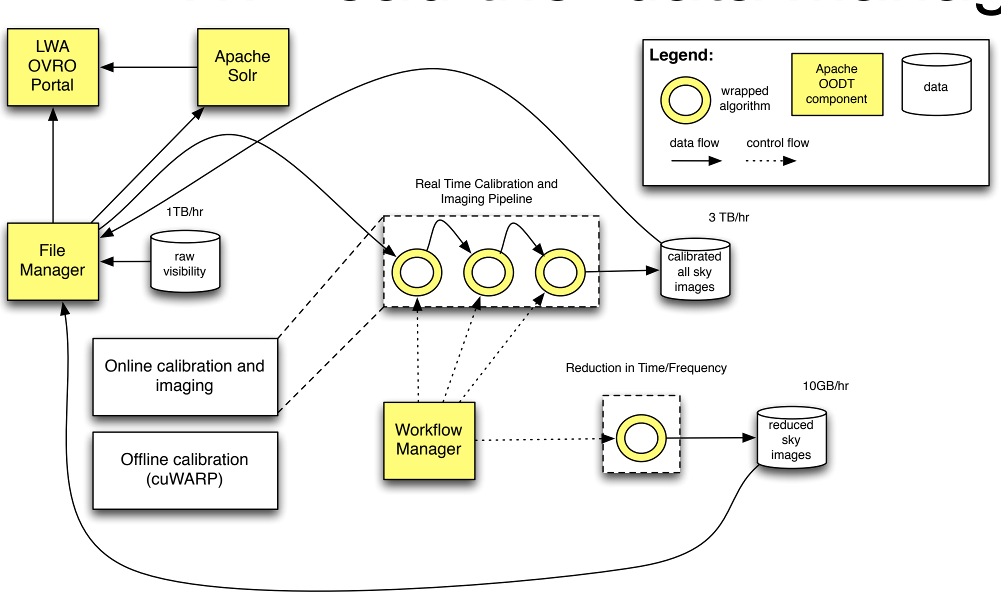
Total CASI 24 rodeo processing time in hours: 4/10/2013 - 05/15/2013





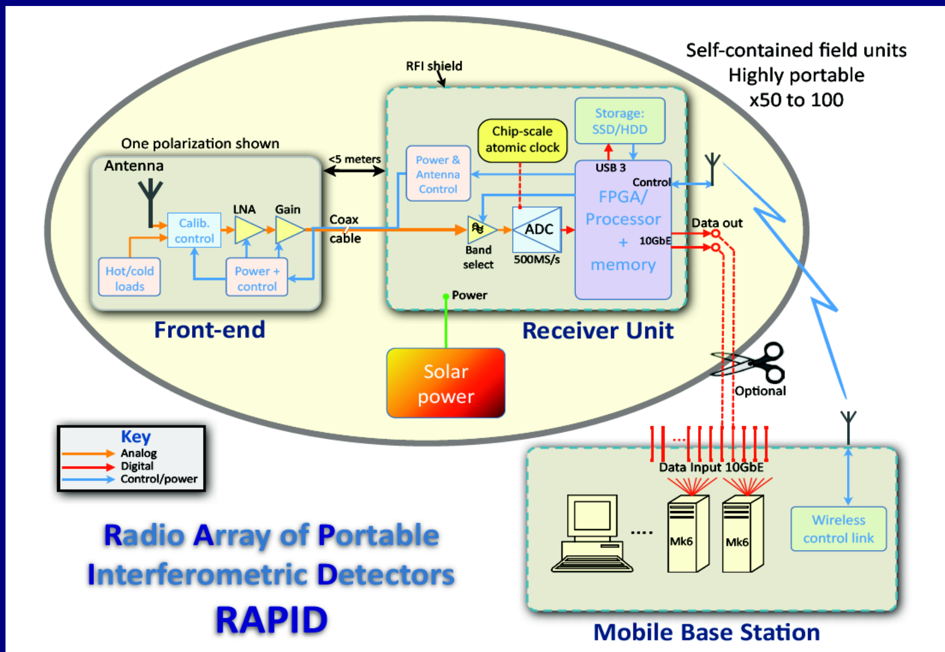
Owen's Valley Radio Observatory

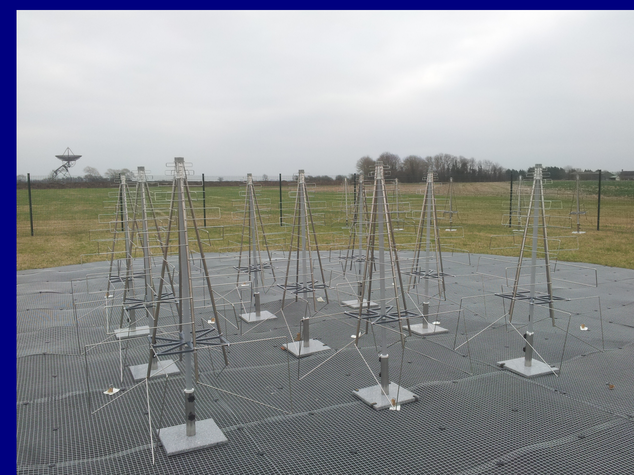
- LWA Owens Valley Radio Observatory – Probing for Cosmic Dawn
  - Joe Lazio, JPL co-PI, Gregg Hallinan, Caltech co-PI
  - Larry D'Addario, Chris Mattmann JPL co-Is
- Will lead the data management for OVRO



RAPID

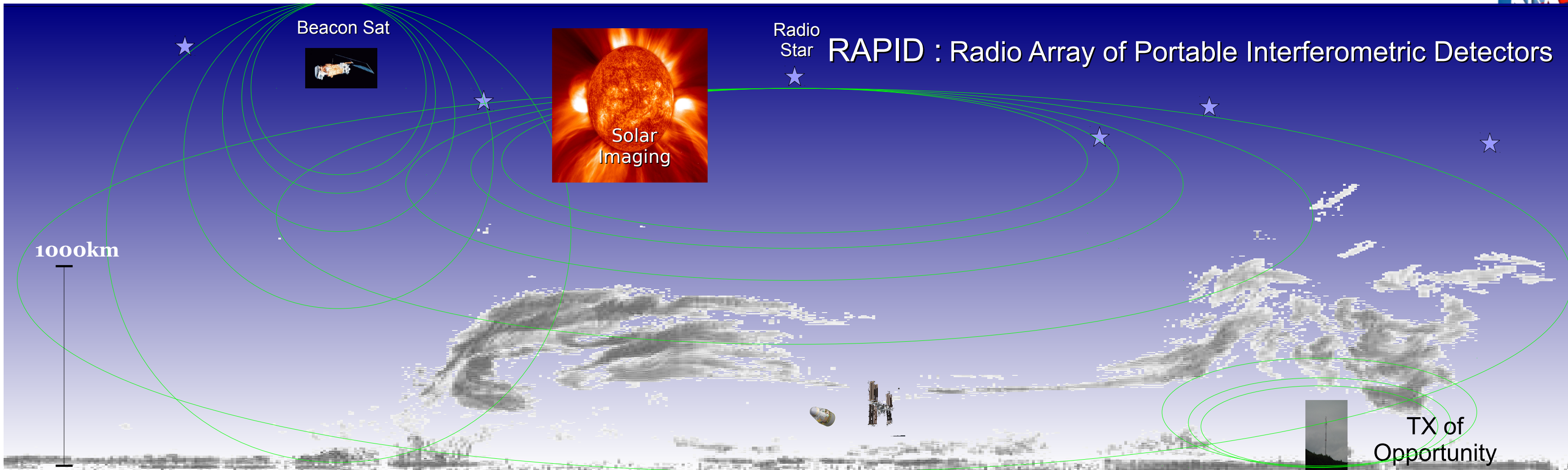
Radio Array of Portable Interferometric Detectors



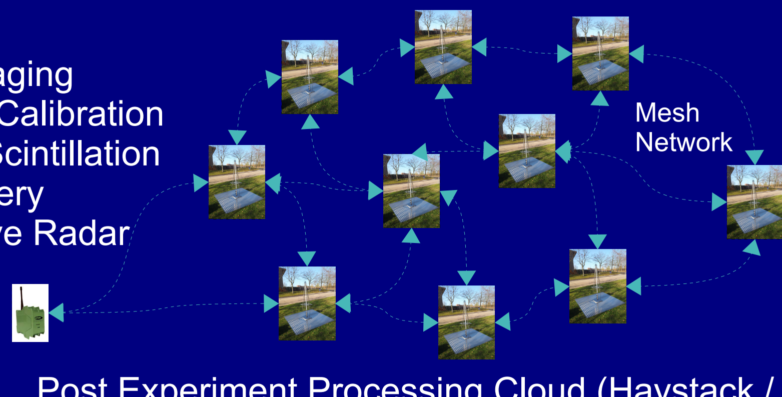


Go Where the Science is Best!
Deploy Where there is No Infrastructure
Reconfigure as Needed to Optimize Performance
Simplify by Using Raw Voltage Capture

RAPID : Radio Array of Portable Interferometric Detectors



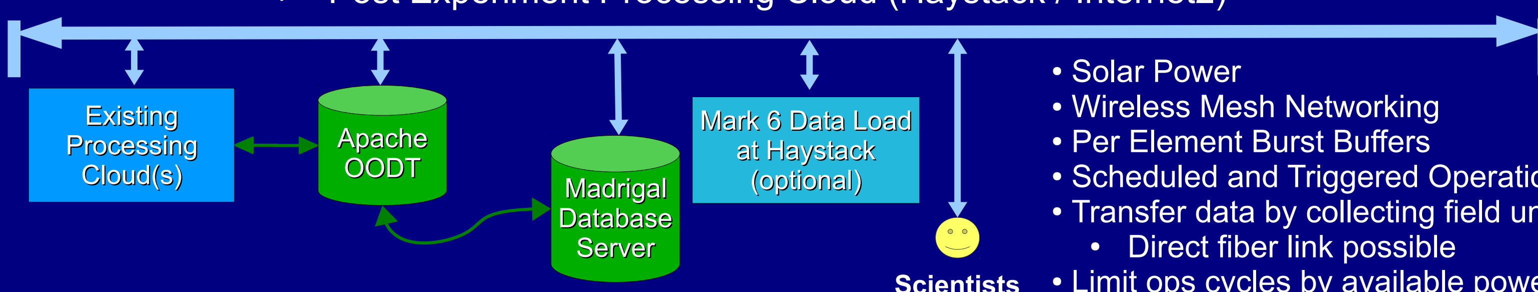
Techniques
Aperture Synthesis Imaging
Absolute Temperature Calibration
Ionospheric TEC and Scintillation
Digital Imaging Riometery
Bi-static Active / Passive Radar
Spectral Monitoring



Science Targets
Solar Imaging
Galactic Synchrotron Emission
Cosmic Ray Air Showers
Ionospheric Irregularities
Ionospheric Scintillation

Go Where the Science is Best!

Post Experiment Processing Cloud (Haystack / Internet2)

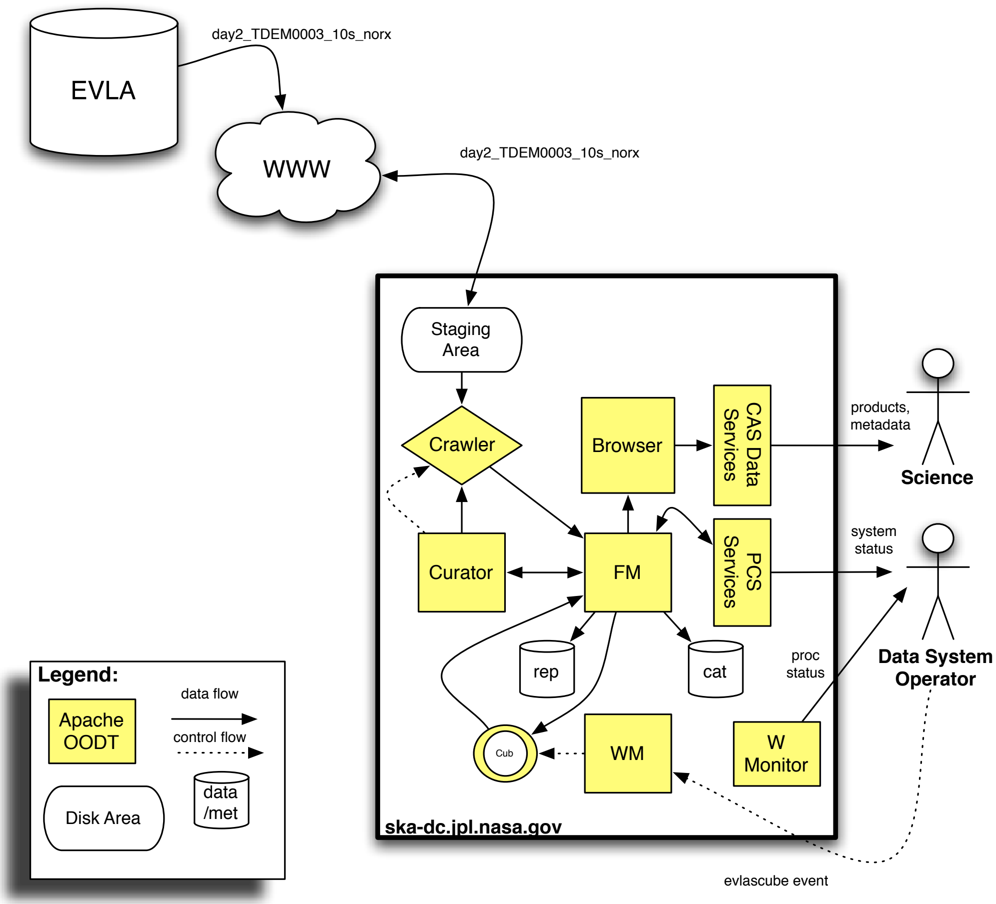


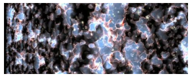
- Solar Power
- Wireless Mesh Networking
- Per Element Burst Buffers
- Scheduled and Triggered Operations
- Transfer data by collecting field units
  - Direct fiber link possible
- Limit ops cycles by available power
- Offline processing (post deployment)

U.S. National Radio Astronomy Observatory (NRAO)

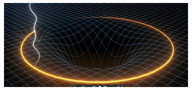
- Explore JPL data system expertise
  - Leverage Apache OODT
  - Leverage architecture experience
  - Build on NRAO Socorro F2F given in April 2011 and Innovations in Data-Intensive Astronomy meeting in May 2011
- Define achievable prototype
  - Focus on EVLA summer school pipeline
    - Heavy focus on CASApy, simple pipelining, metadata extraction, archiving of directory-based products
    - Ideal for OODT system

SKA/NRAO Architecture



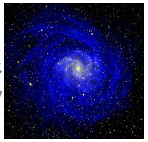


Emerging from the Dark Ages & the Epoch of Reionization

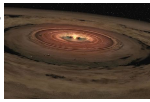


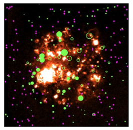
Strong-field Tests of Gravity with Pulsars and Black Holes

Galaxy Evolution, Cosmology, & Dark Energy



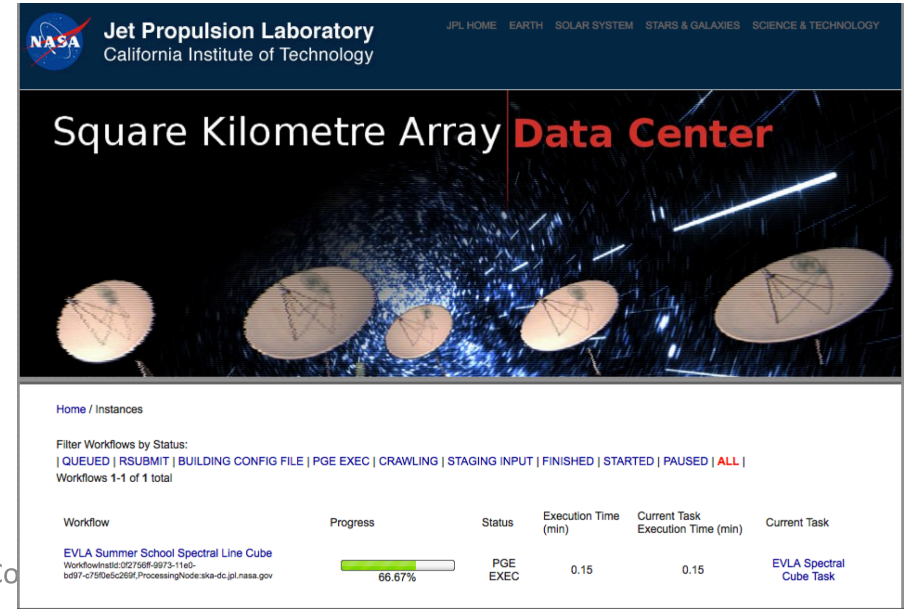
The Cradle of Life & Astrobiology





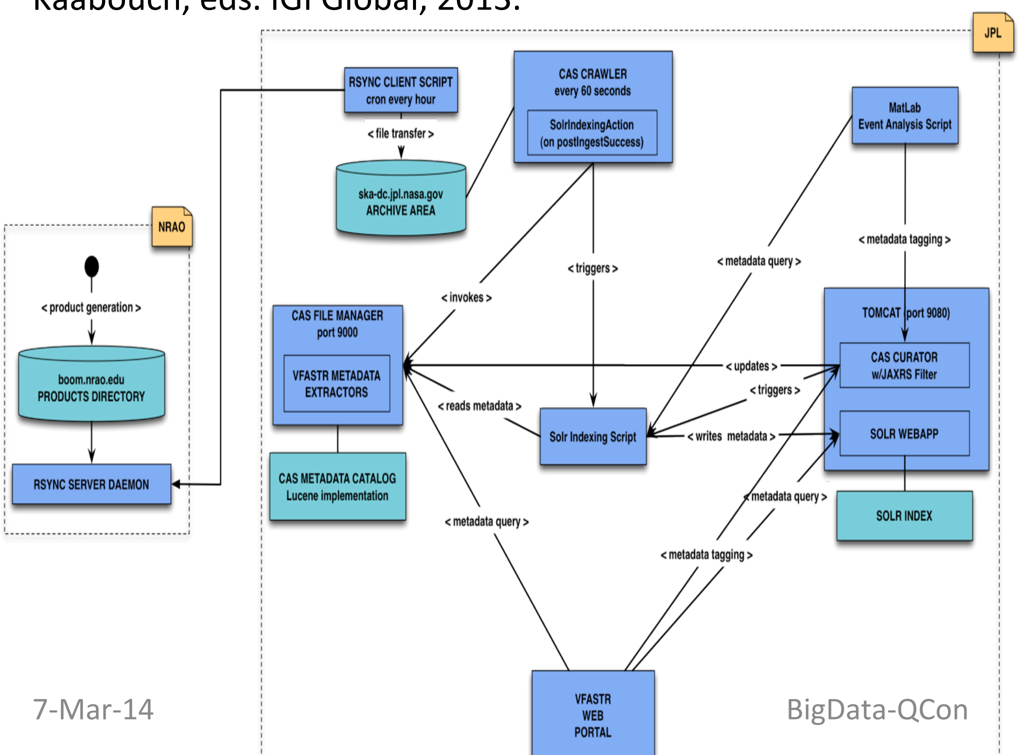
Origin & Evolution of Cosmic Magnetism

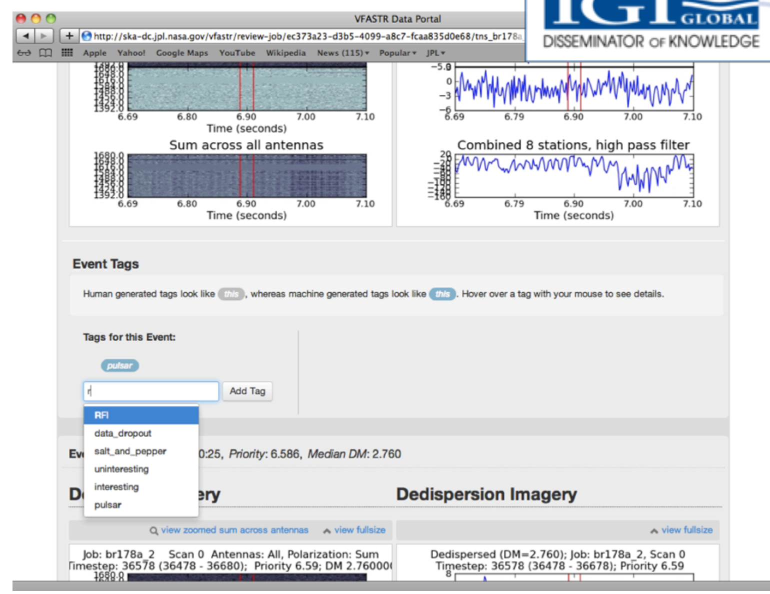
Exploring the Universe with the world's largest radio telescope



Fast Radio Transients

- VFASTR Transient Event Collaborative Review Portal – collaboration with Wagstaff/ Thompson
  - Web-based platform for easy and timely review of candidate events
  - Automatic identification of interesting events by a self-trained machine agent
  - **Demonstrates rapid science algorithm integration**
    - C. Mattmann, A. Hart, L. Cinquini, J. Lazio, S. Khudikyan, D. Jones, R. Preston, T. Bennett, B. Butler, D. Harland, K. Cummings, B. Glendenning, J. Kern, J. Robnett. Scalable Data Mining, Archiving and Big Data Management for the Next Generation Astronomical Telescopes. *Big Data Management, Technologies, and Applications*. W. Hu, N. Kaabouch, eds. IGI Global, 2013.



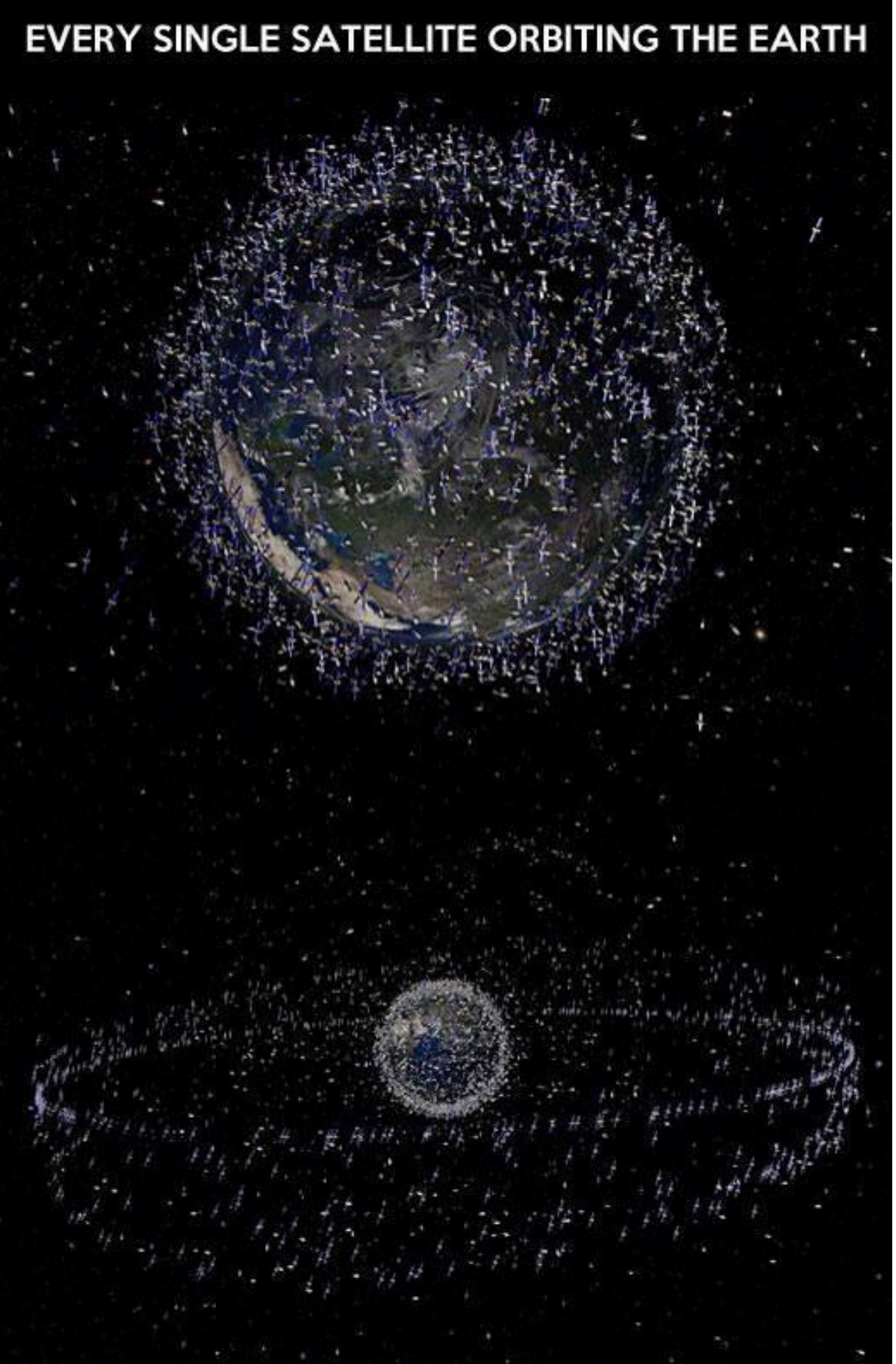


Data Scientist Training

- Supervised 4 current postdocs (co-supervise with Waliser and Painter) and 1 current PhD in Atmospheric Sciences (Whitehall)
  - *What am I doing on her dissertation committee?*
- USC and UCLA in-flow and outflow
  - Hired ~10 USC PhD and MS students at JPL
  - Attracting more all the time
  - Fielding them in courses at USC in Search Engines/Big Data, and in Software Architecture
  - $$$ at USC and UCLA from NSF to flow in and out

NASA: where from here?

- Agency framework for open source: we can't do it all on our own
- Strategic investments/opportunities
  - Rapid Science algorithm integration
    - Needed by next gen missions (Space/airborne), e.g., ASO, needed by next gen astronomical archives e.g., SKA, and existing NRAO work, and collaborations (MIT)
  - Smart data movement
    - Needed by next gen missions, climate science work (RCMES, ESGF), and next gen astronomy data transfer (S. Africa to US)
  - Transient/Persistent archives (Science Computing Facilities)
    - How do we get it done for cheaper, tear it down, stand it up quickly
  - Automatic text/metadata extraction from file formats
    - There will never be a "god" format, so we need Babel Fish – needed by ASO, RCMES, SKA, XDATA
- More data scientist training



Credit: Vala Afshar, Extreme Networks

Thank you!

chris.a.mattmann@nasa.gov
@chrismattmann/Twitter

http://sunset.usc.edu/~mattmann/

QCon

Please evaluate my talk via the mobile app!

INTERNATIONAL SOFTWARE DEVELOPMENT CONFERENCE