IDI/Research IT Showcase:
Research Application: Big Data and Earth Sciences

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\textsuperscript{3}California Institute for Telecommunications and Information Technology (Calit2), UCSD, La Jolla, CA
My Background

- BS Meteorology – University of Utah
- MA Climate and Society – Columbia University
- MS Civil Engineering – University of California, Irvine
- Ph.D. Civil Engineering – University of California, Irvine
- 2014/2015 California Council on Science and Technology Policy Fellow
  - Assemblymember Bill Quirk (D-Hayward)
- Postdoctoral Scholar – Scripps Institution of Oceanography
  - Forecast-Informed Reservoir Operations
    - Explore forecast accuracy and decision support logic for re-operations of a reservoir
  - Big Data
Outline

• Background on CW3E’s research and IT needs
  • West-WRF, High Resolution Numerical Model
  • CONNected objECT (CONNECT) Algorithm
Data is at the heart of what we do!

- High resolution numerical models
- Satellite images
- Ground based weather stations
- Weather radar
- Historical climate data

**Center for Western Weather and Water Extremes**

**Director:** F. Martin Ralph, Ph.D.  
**Website:** cw3e.ucsd.edu

**Strategies:** Observations, physical processes, modeling, decision support

**Scope:** A group of roughly 40 people with 10 major projects

**Partners:** California DWR, Sonoma County Water Agency, CNAP, USGS, San Diego Supercomputing Center

**Sponsors:** CA DWR, USACE/ERDC, NOAA, SCWA, NASA, USBR

**CW3E’s Core Efforts**

- Forecast-Informed Reservoir Operations
- Tools for California Water Extremes
- “West-WRF” Weather Model
- Climate Science
- Subseasonal-to-Seasonal Outlooks

**Key Phenomena Causing Extreme Precipitation in the Western U.S.** (Ralph et al. 2014)
*NASA Apollo 17 crew traveling toward the Moon
What is West-WRF?

CW3E has developed West-WRF to:
1. Serve as a testbed for understanding physical processes and their relationship to forecast error.
2. Improve the accuracy of extreme event forecasts. In the western US, these events pose unique challenges (see table).

**Unique Forecast Challenges Posed by Western US Extreme Events**

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Primary NWP Shortcoming</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>AR Landfall Characteristics</td>
<td>Location and strength of water vapor flux</td>
<td>Wick et al. (2013) Ralph et al. (2017)</td>
</tr>
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CW3E-SDSC Partnership

- Interdisciplinary team of SIO & SDSC Scientists, post-docs grad students and programmers.
- Working to an integrated research and operations plan
- SDSC Director and UCSD Physics Professor Mike Norman has been supportive of CW3E
- Computer time and disk storage on the Gordon and Comet supercomputers and 2 dedicated preprocessor and storage machines.

Extramural Support

- **NSF XSEDE**: (A. Martin, PI) Research and Production computing time
- **CA DWR Early Awards**: (F. M. Ralph, PI) Dedicated machines for preprocessing and storage
- **USACE FIRO**: (F. M. Ralph, PI) Research personnel at CW3E and subcontracted collaborators
- **CA DWR CA Info**: (F. M. Ralph, PI) Research and Production personnel at CW3E and SDSC
Real-Time CW3E West-WRF Forecasts

Automated Data Ingest, Archiving and Preprocessing System
Developed at SDSC with Funding from DWR

Cool Seasons (Dec – Mar) 2015, 2016, 2017:
- forecasts issued daily
- Finest spatial resolution: 3 km
- Simulated radar and GPS occultation observations at key locations
- Millions of supercomputing units used
- 3-D atmospheric data produced: 4.5 Tb

To left: real-time forecast of IVT (kg m\(^{-1}\) s\(^{-1}\)), IVT vectors, and sea-level pressure produced by West-WRF and published at cw3e.ucsd.edu

Event depicted: March 6, 2016

Data delivered in near-real-time
Forecast products published real-time to cw3e.ucsd.edu
Multi-Institutional Big Data Transformed Into Insight

- For Computational Earth Sciences (Sellars et al. 2013, 2015)
  - CONNected object (CONNECT) Algorithm, developed at UCI-CHRS
    - Team: Wei Chu, Scott Sellars, Phu Nguyen, Xiaogang Gao, Kuo-lin Hsu, and Soroosh Sorooshian

Data Hypercube:

CONNECT: Object Segmentation

Object Storage (PostgreSQL)

Set Object Criteria:
1. Each voxel must have 1mm/hr
2. Each object must exist for 24 hours
3. 6 voxel connections

Database Indexes:
1. Object ID Number
2. Latitude (of each voxel in objects)
3. Longitude (of each voxel in objects)
4. Time (hour)
Hyper-dimensional data from model reanalysis and satellite based sources for June 1, 2012 over the continental United States. Each image represents a specific atmospheric variable or feature.
NASA MERRA2 IVT (kg m$^{-1}$ s$^{-1}$)
Then I Talked to PRP and Research IT Engineers!

CENIC and Calit2’s PRP

<table>
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<tr>
<th>Tools</th>
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<tr>
<td>FIONA – Flash I/O Network Appliance: Linux PCs Optimized for Big Data on DMZs</td>
</tr>
</tbody>
</table>

*image courtesy of Larry Smarr

Working with:
John Graham and Joseph Keefe
CW3E Usage Pacific Research Platform

• Our data-centric approach was quickly adapted and enhanced to take advantage of the PRP’s end-to-end 10-100Gb/s connections using PRP’s FIONA technology

• Demonstrates the application of the multi-institutional rapid data access needs for applying an object characterization and segmentation approach CONNected objECT (CONNECT)
Team

- PRP/CONNECT Pilot Project
  - Dr. Scott L. Sellars (Scripps-CW3E)
  - Dr. Phu Ngyuen (UCI-CHRS)
  - Dr. Joulien Tatar (UCI-OIT)
  - Mr. John Graham (Qi)
  - Mr. Joseph Keefe (UCSD)
  - Dr. Ilkay Altintas (UCSD-SDSC)
  - Dr. Daniel Crawl (UCSD-SDSC)
  - Dr. Tom DeFanti (UCSD-Calit2)
  - Dr. Larry Smarry (UCSD-Calit2)
    • Director of Calit2
  - Dr. F. Martin Ralph (Scripps-CW3E)
    • Director of CW3E
  - Dr. Soroosh Sorooshian (UCI-CHRS)
    • Directory of CHRS

Science Engagement

PRP/SIO FIONA1

PRP/SIO FIONA2

Mr. Brian Kawseuk
CW3E

Not one, but two!
PAST: Big Data Analysis Pipeline: **One Variable**

2.4T
Time: 7d 10h 49min

2.4T to 100GB
Time: 10d 5h 05min

100GB to 50GB
Time: ~1d 14h 00m

50GB to 100MB
Time: ~1d 5h 00m

**Total time: ~20d 11h 0m**

- Not including data visualization
- Not including data mining/machine learning jobs
- Assumes we know what we are doing

Data Visualization And Search

Data mining and Discovery, Machine Learning

Download

Data organization
Variable format

CONNECT
Segmentation

CONNECT
Characteristic Calc.
First, the Results, in Megabytes, to Date

• Before PRP (7/16) NASA ----> local connection ----> SIO
  • 10MB/s download critical NASA data (2.4TB took over 7 days)

• Initial PRP test (8/16) NASA ----> PRP connection ----> SIO FIONA
  • 40MB/s (4x increase simply using the PRP and a FIONA DTN)

• PRP/CONNECT (4/17) SIO FIONA ----> via THREDDS ----> UCI FIONA
  • 559MB/s (56x increase)
  • Could be as much as 1896MB/s between FIONAs using Globus (almost 200x better) based on local testing
Developing a new workflow!

Pacific Research Platform (10-100 Gb/s)

UC, Irvine

GPUs

Calit2’s FIONA

SDSC’s COMET

GPUs

UC, San Diego

GPUs

Calit2’s FIONA
Conclusions

• None of this would be possible without engagement with UCSD IT staff and engineers

• Using PRP network via FIONA
  • Download speed from NASA increased 4x (40MB/s which is 4x faster than the 10MB/s standard connection previously being used by researchers at SIO).
  • Removing data transfer as a limiting constraint changes everything!
  • Researchers and scientists need to rethink how we are approaching data transfer and analysis

• PRP/CW3E/SIO “Big Data and the Earth Sciences: Grand Challenges Workshop”
  • May 31st to June 2nd, Four keynote lectures
  • 75+ registered participants
Thank you!
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