National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

NASA Sea Level Change Portal

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive, Pasadena, CA 91109-8099, U.S.A.

Sea Level Change Portal Team

Carmen Boening (PI/JPL)

JPL Team
Hugh (Pat) Brennan, Daniel Delany, Kevin Gill, Frank Greguska, Ben Hamlington, Thomas Huang, Nga Quach, Holly Shaftel, and Victor Zlotnicki

MooreBoeck Team
Andera Boeck, Bergen Moore, and Justin Moore

© 2018 California Institute of Technology. Government sponsorship acknowledged.
Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsements by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

NASA Sea Level Change Portal – https://sealevel.nasa.gov

Goals for the NASA Sea Level Change Portal

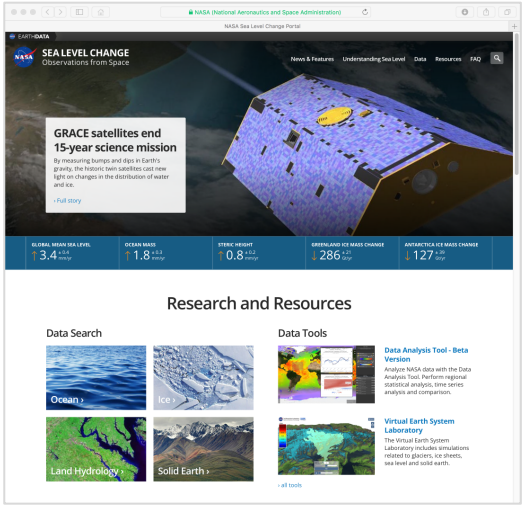
- Provide scientists and the public with a “one-stop” source
- Provide current sea level change information and data
- Provide interactive tools for analyzing and viewing regional data
- Provide virtual dashboard for sea level indicators
- Provide latest news, quarterly report, and publications
- Provide ongoing updates through a suite of editorial products

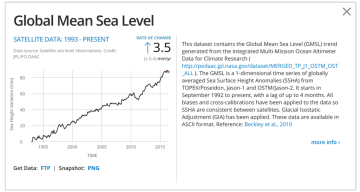
Requires

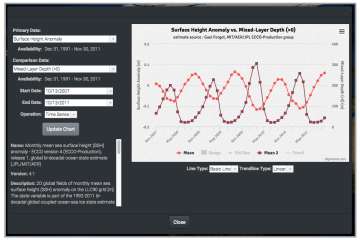
- Interdisciplinary collaboration
- Connect disciplines and evaluate dependencies

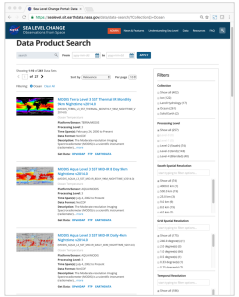
Sea Level Change Portal facilitates

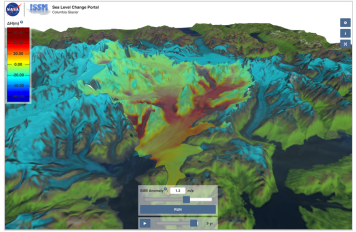
- Easy interdisciplinary data comparison
- Access to latest news and information
- Collaboration (data and information exchange)











National Aeronautics and Space Administration

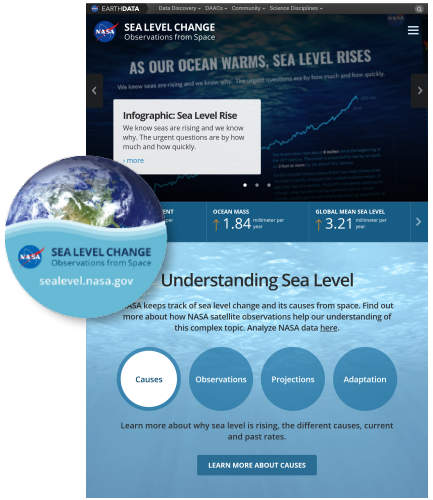
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Social Media

372,000
monthly page views

170,000
sessions

143,000
users

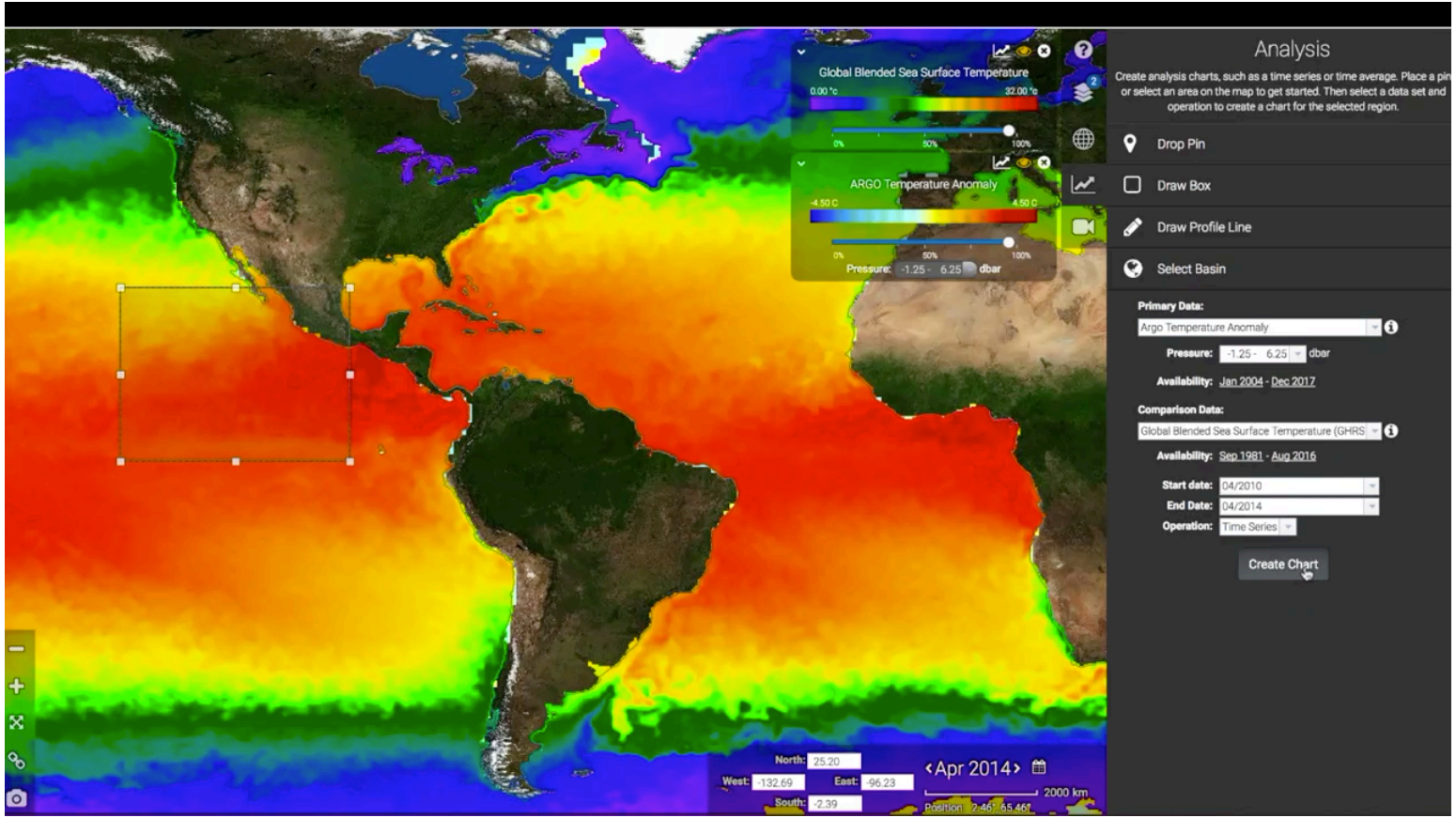


Over 38,000
Followers

Over 29,000
Followers

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Visualize and Analyze Argo with Satellite Observations

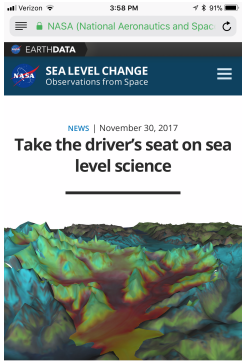


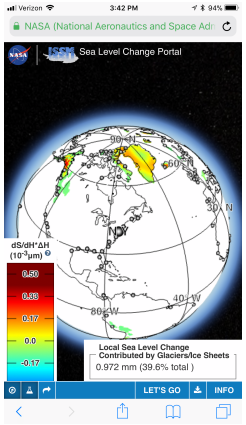
National Aeronautics and Space Administration

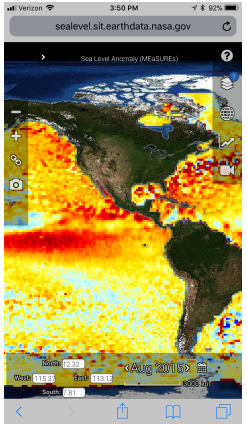
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

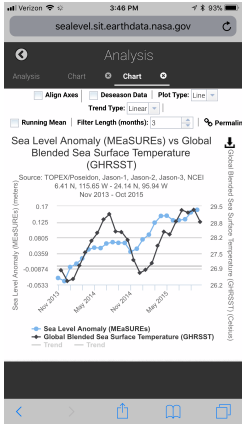
Mobile Friendly

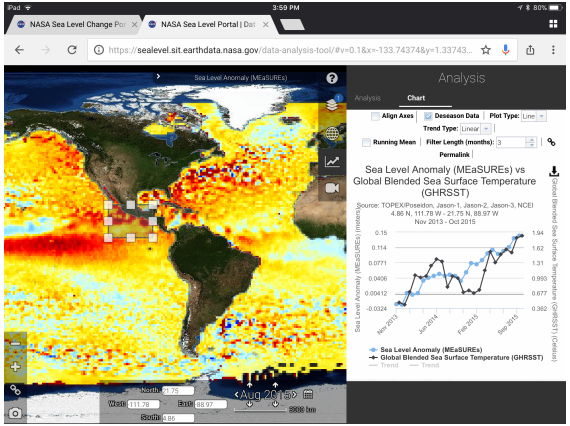
Research and Resources

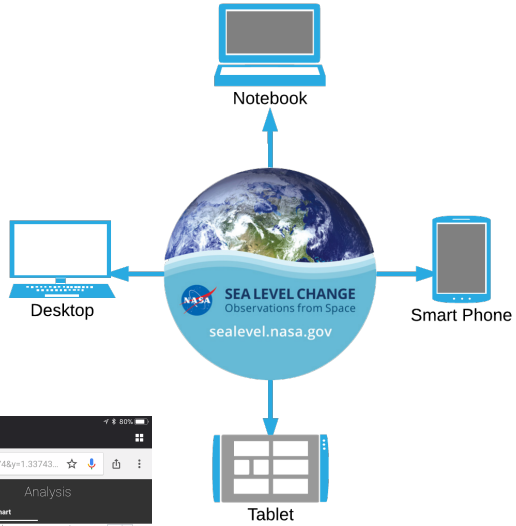










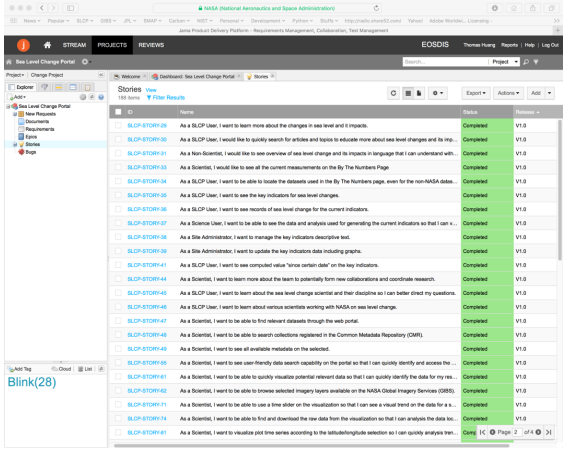


Mobile - https://sealevel.nasa.gov/data-analysis-tool/

Requirement Management

2016
N-SLCT Meeting
Norfolk, VA

- User Stories
  - UI/UX assessment
  - NASA Sea Level Science Team
  - User feedbacks
- Internal team review before each new development cycle
- Categorize
- Prioritize
- Project Management Approval
- Schedule
- Weekly development team review



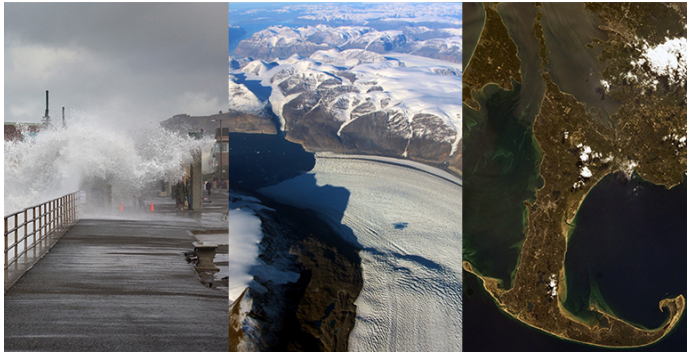
Requirement Management

2017 - 2020 NASA-Sea Level Change Team

- Team Lead: **Ben Hamlington**, Old Dominion University Research Foundation, Norfolk, Virginia
- Selected investigations:
  - **Identifying, quantifying, and projecting decadal sea level change**, Benjamin Hamlington, Old Dominion University Research Foundation
  - **Understanding current and projected sea level change with multi-satellite observations, modeling and climate system assimilation**, Sophie Nowicki, NASA Goddard Space Flight Center, Greenbelt, Maryland
  - **Understanding and predicting coastal sea level variability around the United States**, Manoochehr Shirzaei, Arizona State University, Tempe
  - **Using satellite measurements to improve regional estimates of the impacts of sea level change**, Robert Nerem, University Of Colorado, Boulder
  - **Global interconnections of cryosphere and solid Earth, sea-level change and ice mass balance**, Erik Ivins, NASA Jet Propulsion Laboratory (JPL), Pasadena, California
  - **A NASA web portal for sea level change**, Carmen Boening, JPL
  - **21st century regional sea level projections due to land ice mass losses and geodynamic adjustments using 3-D Earth models**, Regine Hock, University Of Alaska, Fairbanks
  - **Quantifying and reducing uncertainty in future global and local sea-level estimates: linking physics, observations, and risk analysis to inform climate adaptation**, Isabella Velicogna, University Of California, Irvine

New NASA-Sea Level Change Team and team leader announced

https://sealevel.nasa.gov/news-features/sea-level-news



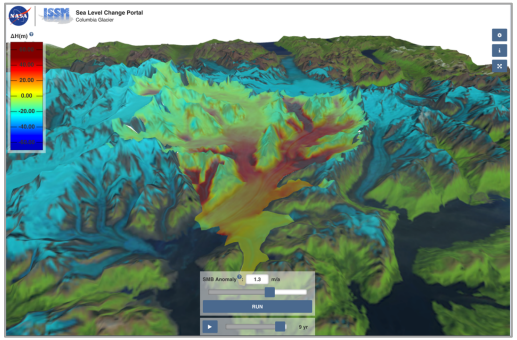
Left: Higher Pacific sea levels increase coastal flooding risks. Credit: Flickr user Alan Grinberg, "Coming Ashore!", CC BY-NC-ND 2.0.
Middle: One of many Greenland glaciers losing mass and contributing to sea level rise. Credit: NASA/OIB.
Right: Part of Massachusetts, a victim of nuisance flooding brought about by sea level rise. Astronaut photo ID: ISS028-E-9967.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

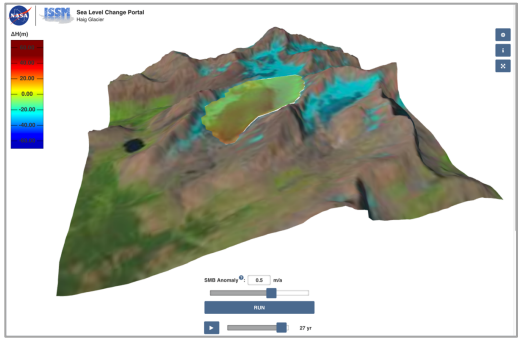
Virtual Earth System Laboratory (VESL) – PI: Eric Larour

Suite of Interactive Simulation Tools for Glaciers, Ice Sheets, Sea Level, and Solid Earth

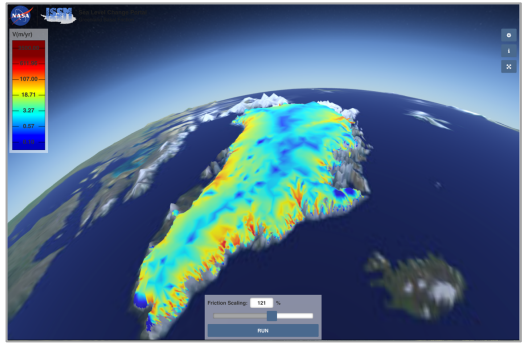
Simulation Service on Amazon Cloud



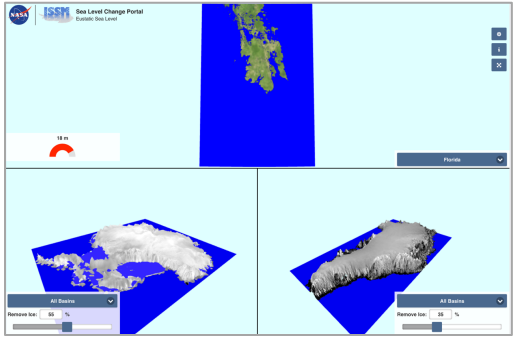
Columbia Glacier



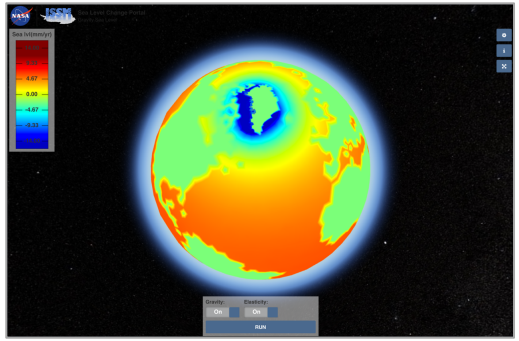
Haig Glacier



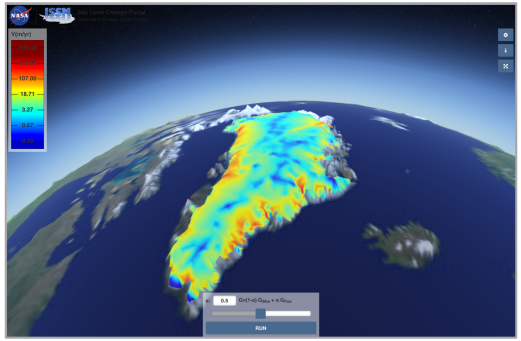
Greenland Basal Friction



Eustatic Sea Level



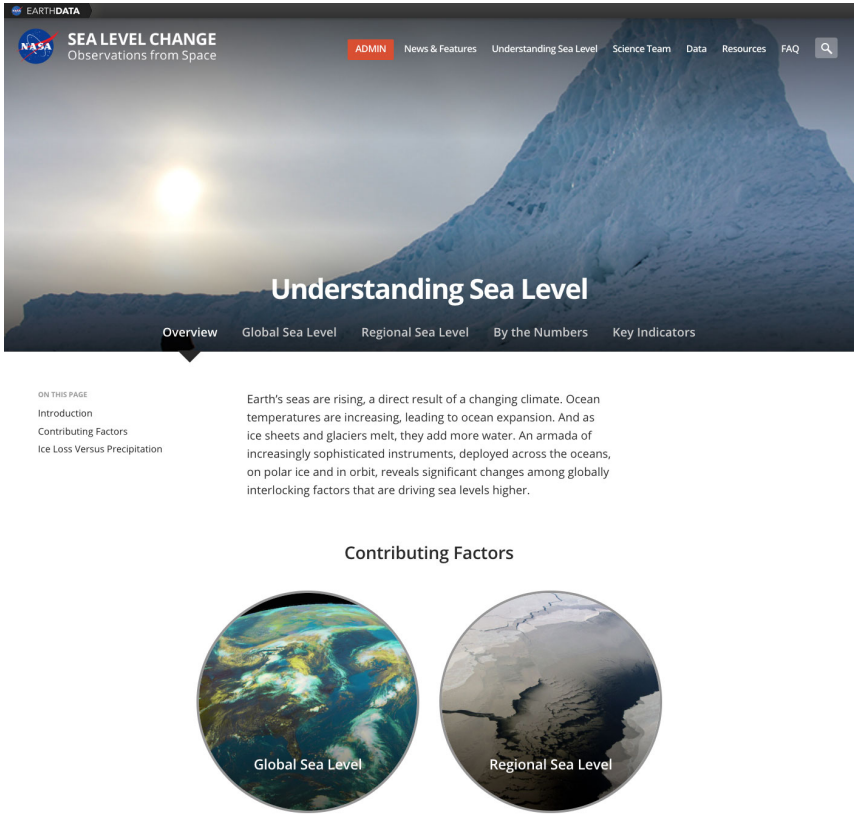
Local Sea Level

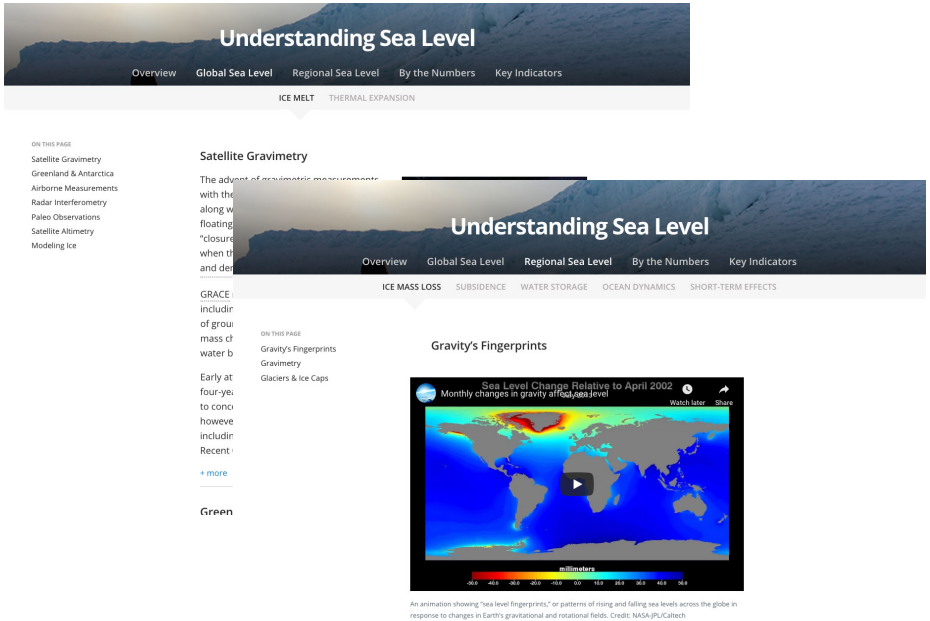


Greenland Steady-State-Friction

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Understanding Sea Level – A redesign to facilitate teaching and public education on NASA Sea Level Science





NASA Sea Level Change Portal

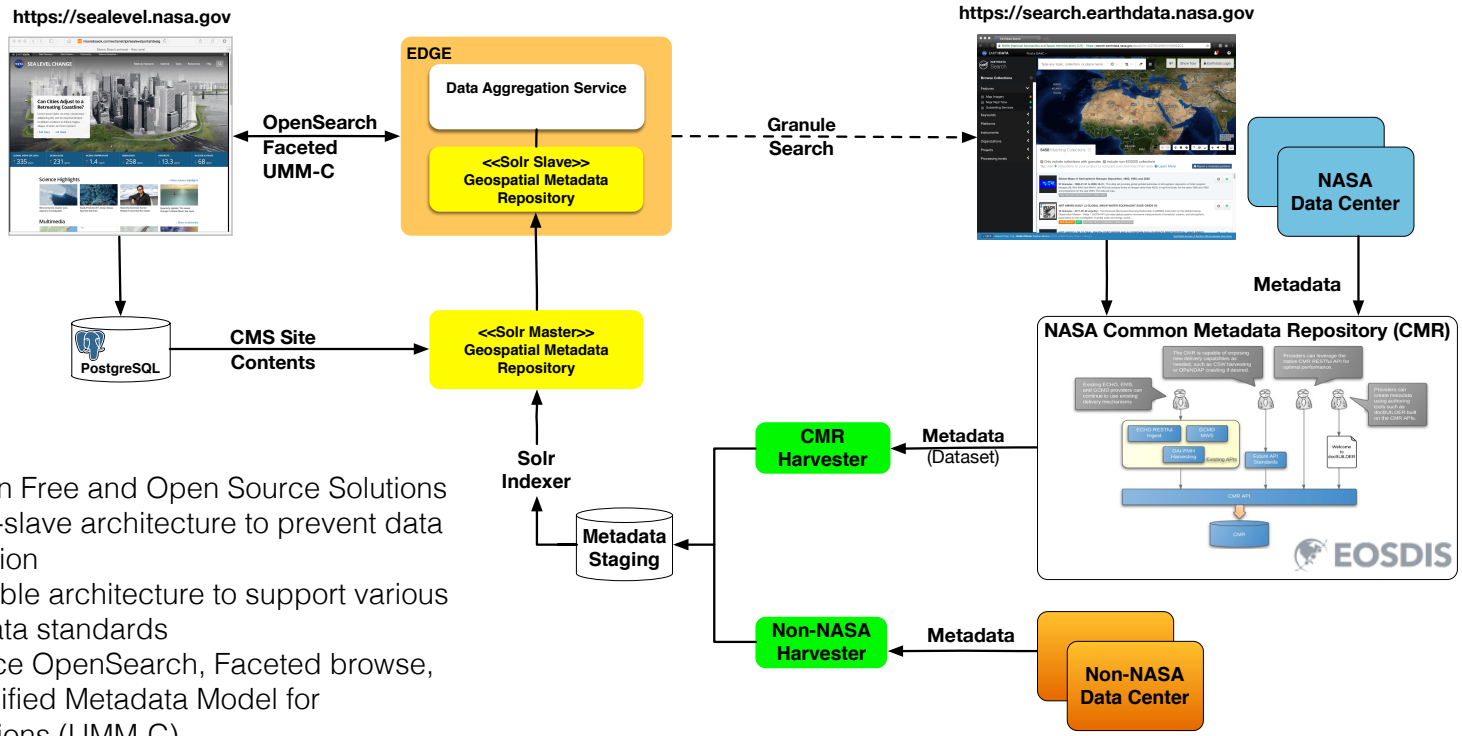
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Sea Level Data Analysis Tool 2.0 - Alpha

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

One-Stop Search



- Build on Free and Open Source Solutions
- Master-slave architecture to prevent data corruption
- Extensible architecture to support various metadata standards
- Embrace OpenSearch, Faceted browse, and Unified Metadata Model for Collections (UMM-C)

Cloud-based Sea Level Analytics Platform

- The JPL engineering team collaborated with Apache Software Foundation and established the open source Science Data Analytics Platform (SDAP) https://sdap.apache.org
- New analytic architecture is based on the SDAP architecture
- Deployed under Amazon Web Service (AWS) commercial cloud platform
- Same programming language neutral web service interfaces, Applications can interact with the Sea Level's cloud-based analytics platform using any programming languages (e.g. JavaScript, Python, Java, C/C++, IDL, MATLAB, etc.)
- Fast in-memory parallel analytics (currently 5x performance speedup)

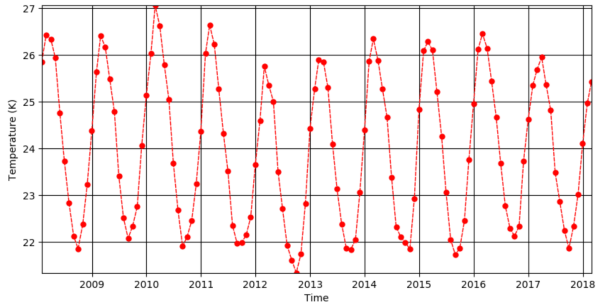
jupyter SLCP AVHRR Time Series Example Last Checkpoint: an hour ago (unsaved changes)

In [32]:
```
import requests
import json
import matplotlib.pyplot as plt
import datetime

#New AWS backend
url = 'http://ec2-54-184-139-61.us-west-2.compute.amazonaws.com:32139/nexus/timeSeriesSpark?'
url += 'ds=AVHRR_OI-NCEI-L4-GLOB-v2.0'
url += '&minLat=-20.483909114307 73&minLon=-19.287254629966725&maxLat=-6.968752585279951&maxLon=0.5631315220428235'
url += '&startTime=1199221237&endTime=1519862400&mask=3&lowPassFilter=False&seasonalFilter=false'

ts = json.loads(str(requests.get(url).text))
dates = []
means = []
for data in ts['data']:
    means.append (data[0]['mean'])
    dates.append (datetime.datetime.fromtimestamp((data[0]['time'])))

# plot the extracted means
plt.figure(figsize=(10,5), dpi=100)
lines = plt.plot(dates, means)
plt.setp(lines, color='r', linewidth=1.0, linestyle='--',
         dash_capstyle='round', marker='.', markersize=10.0, mfc='r')
plt.grid(b=True, which='major', color='k', linestyle='-')
plt.xlim(dates[0], dates[-1])
plt.xlabel('Time')
plt.ylim(min(means), max(means))
plt.ylabel ('Temperature (K)')
plt.show()
```

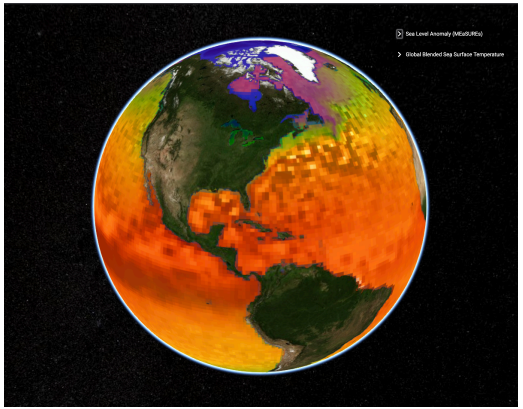


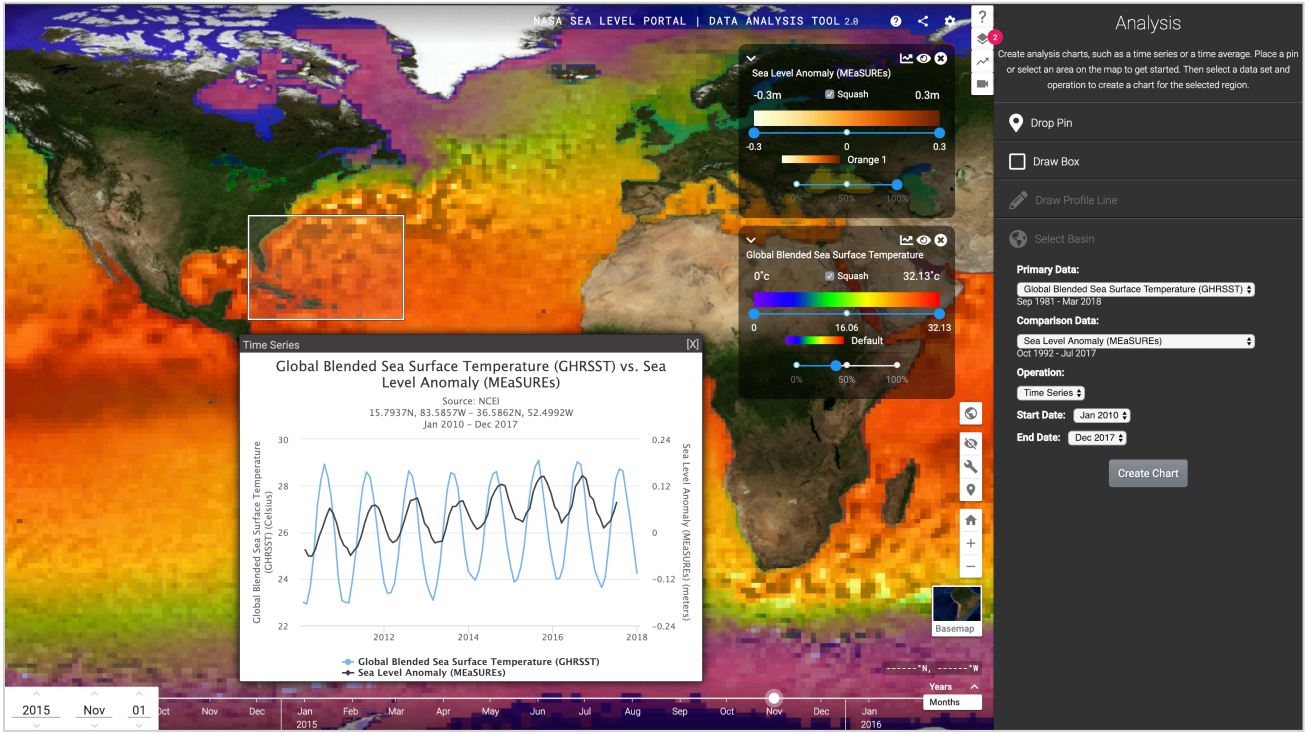
Compute time series with SLCP Cloud Analytics Platform using Python

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Data Analysis Tool 2.0 (Alpha)

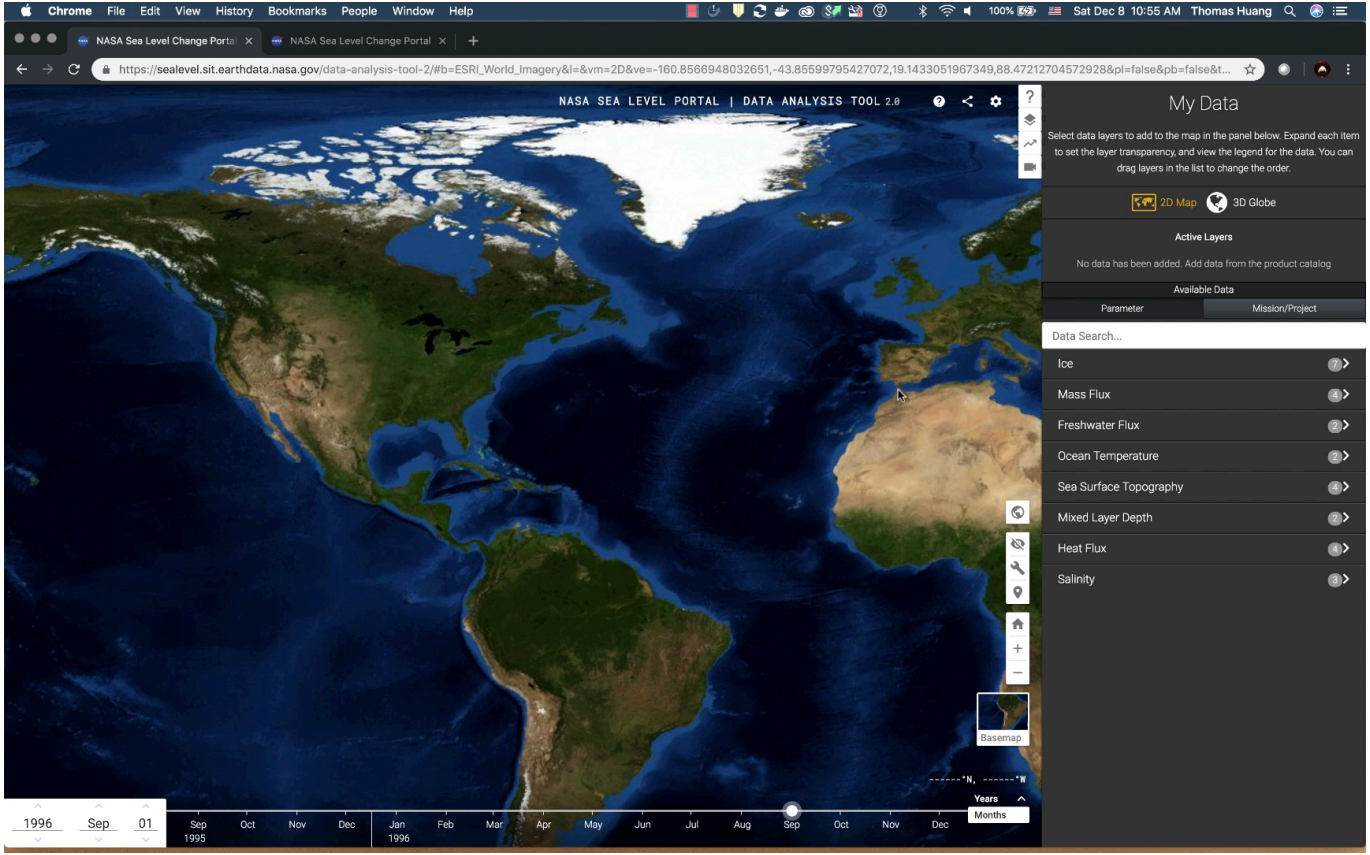
- New open source web-based visualization solution
- Significant loading and visualization speedup
- New 3D visualization
- Provides more flexible UI customization





National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

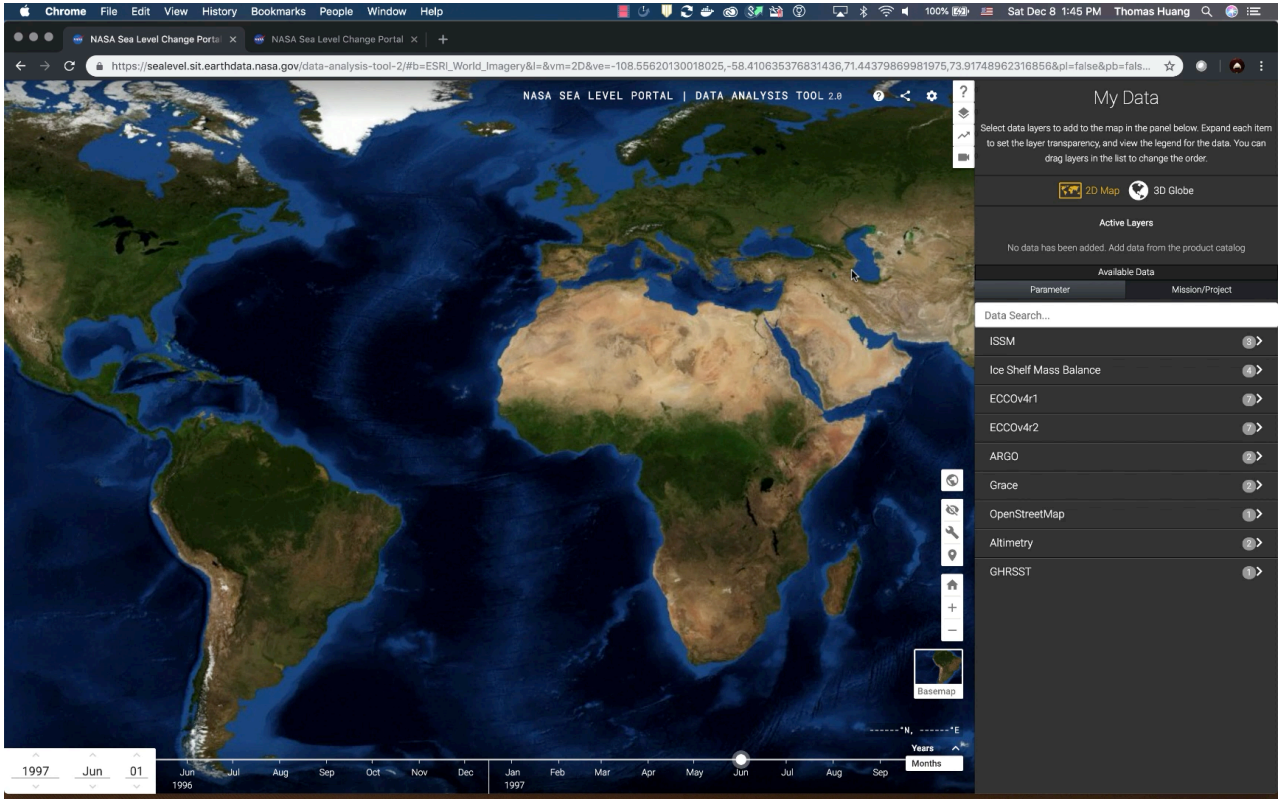
Data Analysis Tool 2.0 (Alpha)



National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

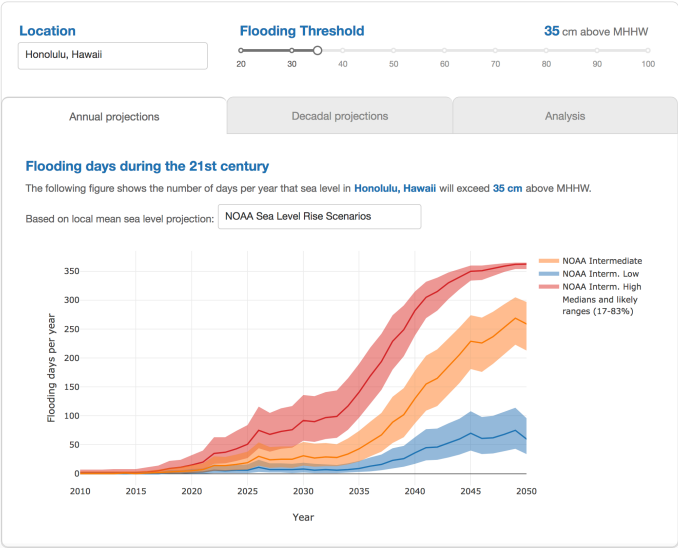
Data Analysis Tool 2.0 (Alpha) – Dynamic Color

- Dynamic Color is a new DAT 1.0 capability – in production
- DAT 2.0 – user can change layer color in 2D and 3D mode and to saturate/eliminate color range



What's new in 2019?

- Projection tools
  - Sea Level predictions from models (e.g. Nerem, Kopp et al)
  - Nuissance flooding at tide gauge locations (e.g. Thompson et al)
  - Coastal sea level attribution
- In-situ data comparison in DAT (e.g. tide gauge data)
- New Data Analysis Tool 2.0
- New Cloud-based Sea Level Data Analytics Platform
- VESL updates
- Continued dataset support (e.g. GIA, vertical land motion, ice shelf melt rates)
- Continued NASA Sea Level Change Team publication highlights
- Integrating data from new/recent missions (e.g. OMG, GRACE-FO, Jason-3, ICESat-2) and supporting visualization, analysis and easy access



National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Sea Level Change Portal Team

Carmen Boening (PI/JPL)

JPL Team
Hugh (Pat) Brennan, Daniel Delany, Kevin Gill, Frank Greguska, Ben Hamlington, Thomas Huang, Nga Quach, Holly Shaftel, and Victor Zlotnicki

MooreBoeck Team
Andera Boeck, Bergen Moore, and Justin Moore

Backups

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

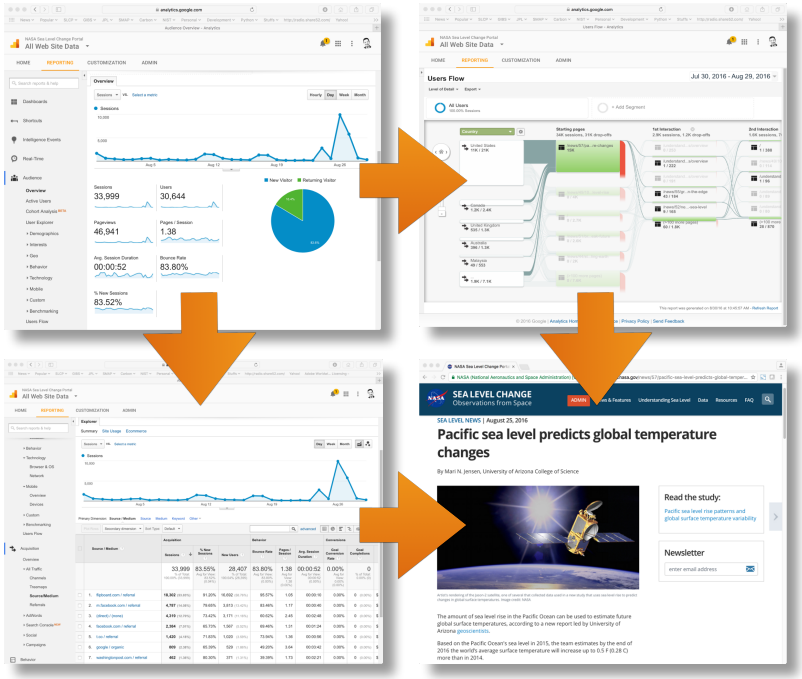
Analyze User Interactions

Guide website layout

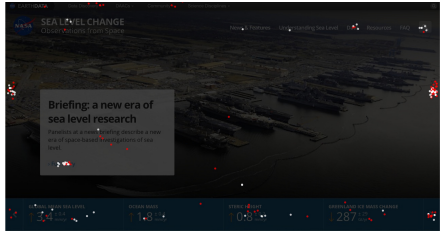
Determine effectiveness of articles and contents

Identify popular media outlines

New and returning users



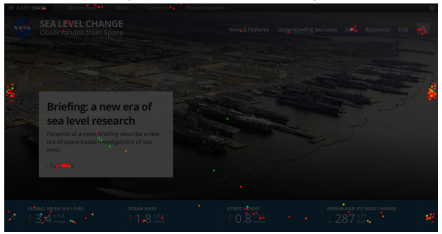
New vs. Returning



New vs Returning

Name	Amount
New	259
Returning	226
Total	485

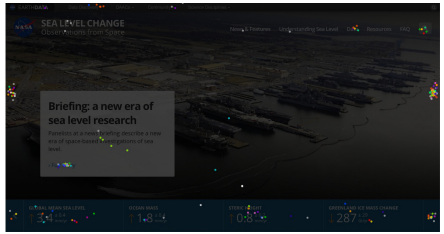
Referrer (Media Outlets)



Referrer

Name	Amount
sealevel.nasa.gov	284
climate.nasa.gov	83
washingtonpost.com	36
google.com	21
facebook.com	14
Direct	10
grace.jpl.nasa.gov	8
politics.ie	8
nasa.gov	3
outlook.office.com	3
students.keele.ac.uk	3
earthdata.nasa.gov	2
prnewswire.com	2
terradaily.com	2
Other	6
Total	485

Time to Click



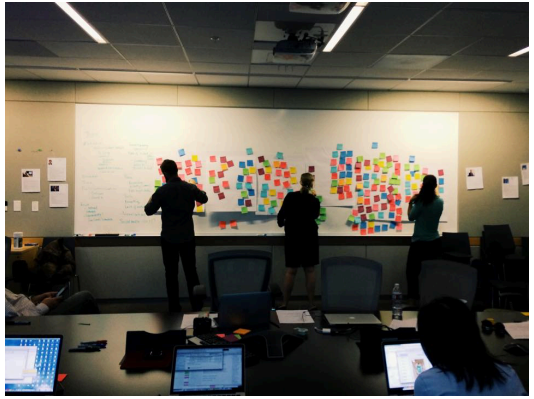
Time of Day

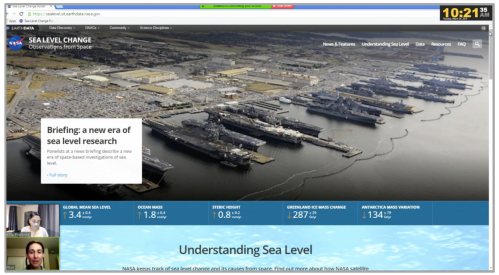
Name	Amount
05:00 PM-05:30 PM	40
10:00 PM-10:30 PM	35
06:30 PM-07:00 PM	30
03:00 PM-03:30 PM	27
06:00 PM-06:30 PM	27
07:00 PM-07:30 PM	23
11:30 PM-00:00 AM	20
04:00 AM-04:30 AM	19
05:30 PM-06:00 PM	19
07:30 PM-08:00 PM	19
04:30 PM-05:00 PM	18
03:30 PM-04:00 PM	17
04:00 PM-04:30 PM	16
09:00 PM-09:30 PM	16
Other	159
Total	485

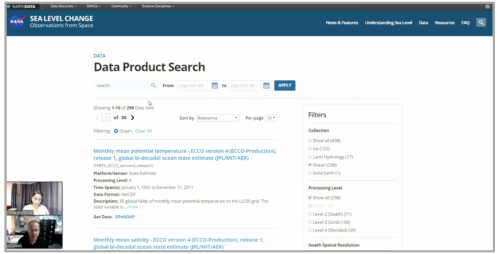
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

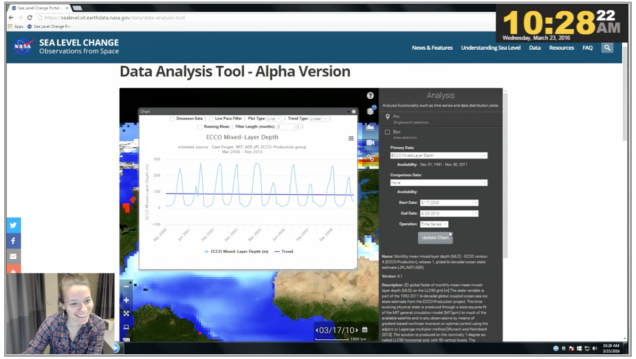
UX Assessment

- **Understand** how and for what purposes users obtain sea level change data and information
- **Describe** users' pain points and unmet needs for extracting, visualizing, comparing and analyzing sea level change data
- **Investigate** users' current practices, interests and preferences for engaging in interaction with other sciences and the public about sea level change
- **Identify** opportunities for enhancing cross-disciplinary collaborative activities on the web portal.









National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Traditional Method for Analyze Satellite Measurements

Search → Download → Compute

Depending on the data volume (size and number of files)

It could take many hours of download – (e.g. 10yr of observational data could yield thousands of files)

It could take many hours of computation

It could require expensive local computing resources

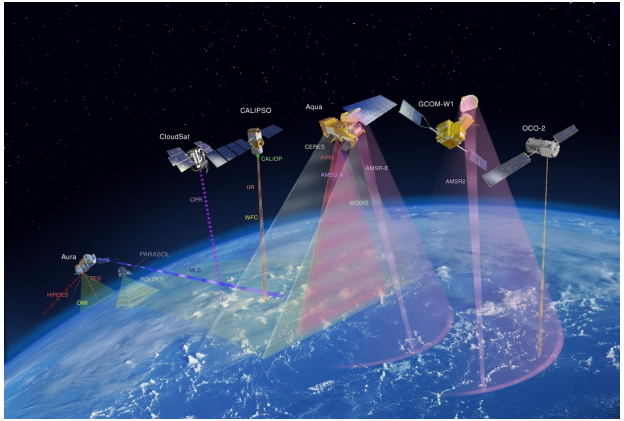
Often after result is produced, purge downloaded files

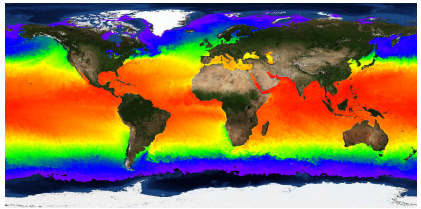
Observations

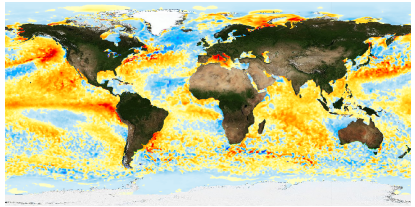
Traditional methods for data analysis (time-series, distribution, climatology generation) can't scale to handle large volume, high-resolution data. They perform poorly

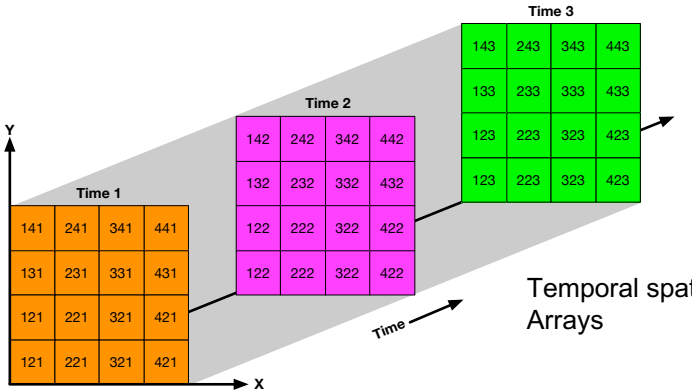
Performance suffers when involve large files and/or large collection of files

A high-performance data analysis solution must be free from file I/O bottleneck







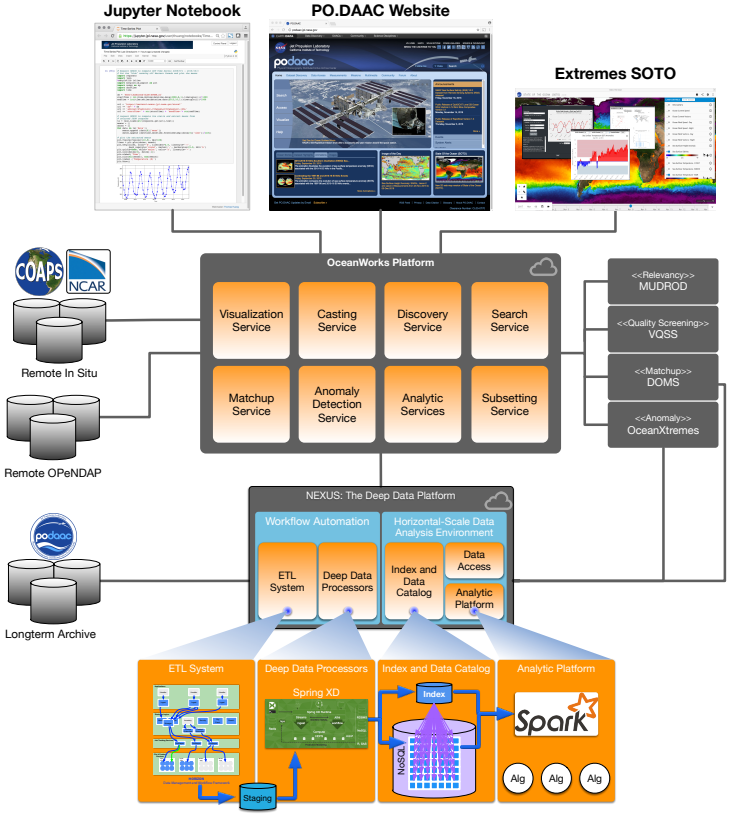


Temporal spatial Arrays

AIST OceanWorks

OceanWorks is to establish an **Integrated Data Analytic Center** at JPL by bringing together several big data technologies developed under the NASA ESTO/AIST program

- **OceanXtremes –** Anomaly detection and ocean science
- **NEXUS –** Big data analytic platform
- **Data Container Studies**
- **DOMS –** Distributed in-situ to satellite matchup
- **MUDROD –** Search relevancy and discovery – linking datasets, services, and anomalies through recommendations
- **VQSS –** Virtualized Quality Screening Service



THUANG/JPL © 2017. All rights reserved.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

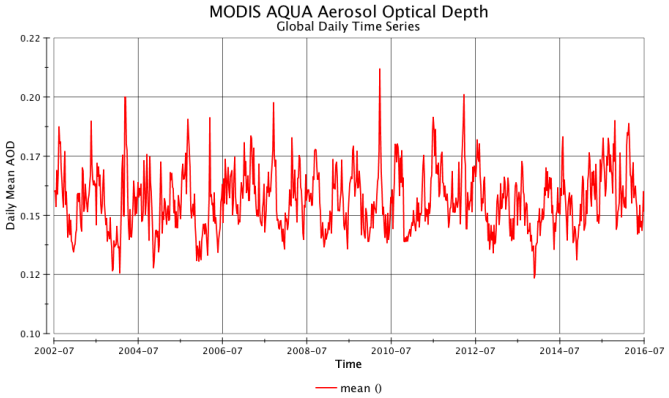
NEXUS Performance: Custom Spark vs. AWS EMR

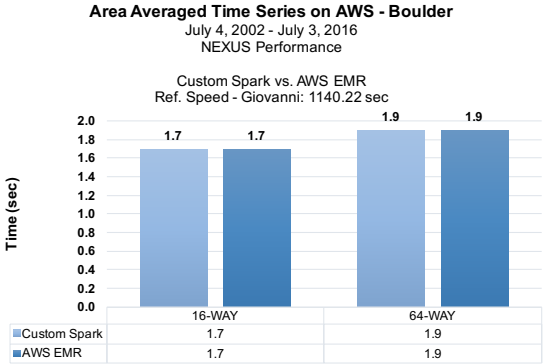
Dataset: MODIS AQUA Daily
Name: Aerosol Optical Depth 550 nm (Dark Target) (MYD08_D3v6)
File Count: 5106
Volume: 2.6GB
Time Coverage: July 4, 2002 – July 3, 2016

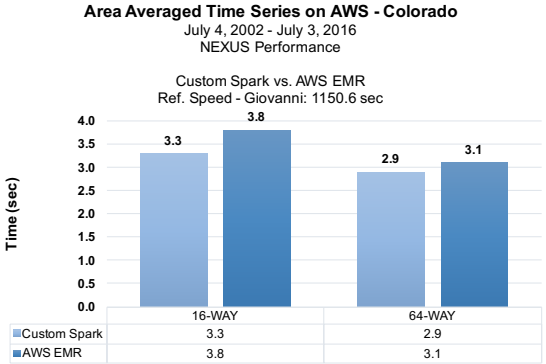
Giovanni: A web-based application for visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data.

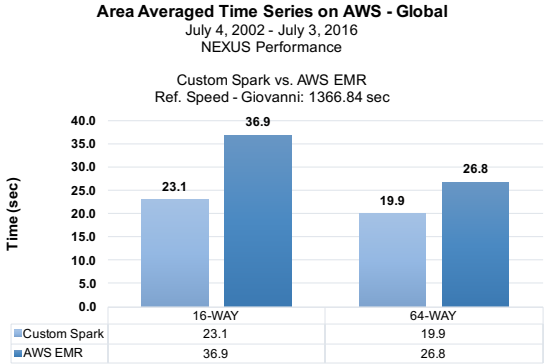
- Represents current state of data analysis technology, by processing one file at a time
- Backed by the popular NCO library. Highly optimized C/C++ library

AWS EMR: Amazon's provisioned MapReduce cluster





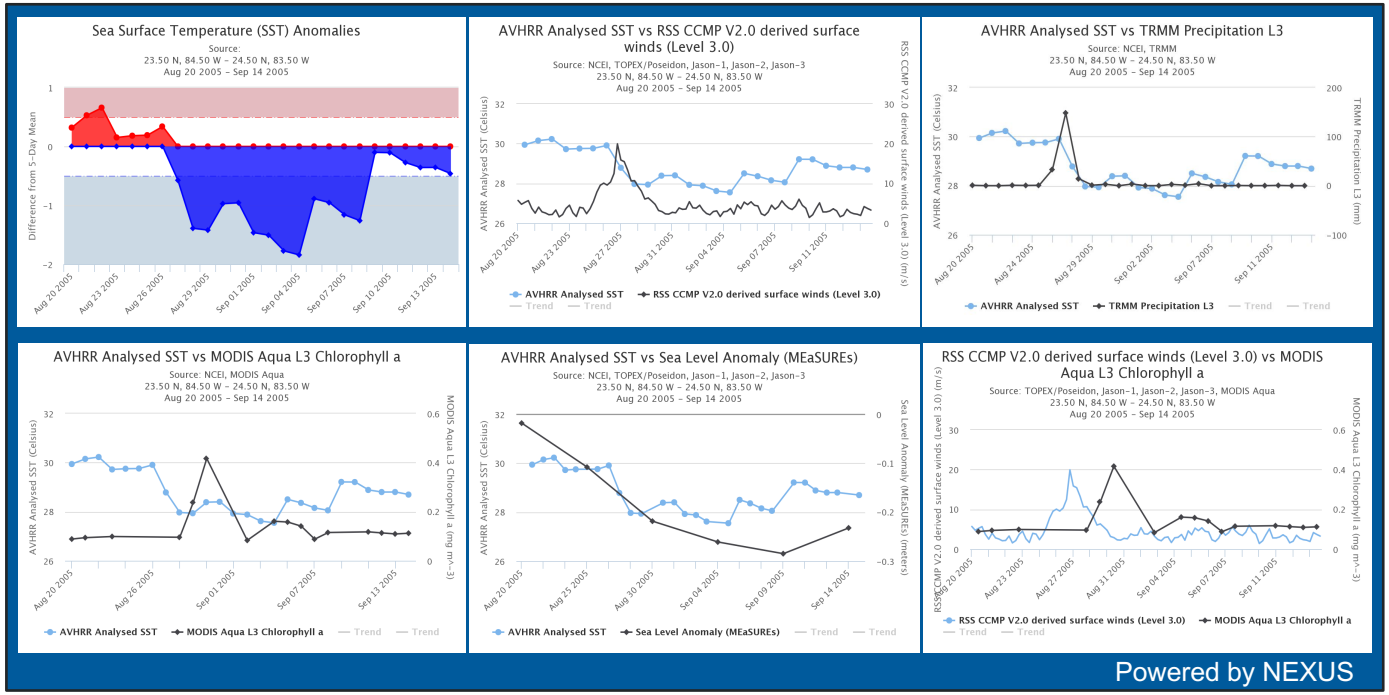




THUANG/JPL © 2017. All rights reserved.

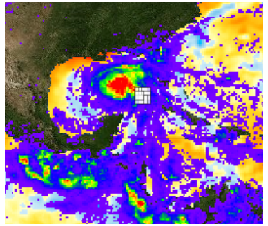
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Hurricane Katrina Study



Hurricane Katrina passed to the southwest of Florida on Aug 27, 2005. The ocean response in a 1 x 1 deg region is captured by a number of satellites. The initial ocean response was an immediate cooling of the surface waters by 2 ℃ that lingers for several days. Following this was a short intense ocean chlorophyll bloom a few days later. The ocean may have been “preconditioned’ by a cool core eddy and low sea surface height.

The SST drop is correlated to both wind and precipitation data. The Chl-A data is lagged by about 3 days to the other observations like SST, wind and precipitation.



Hurricane Katrina TRMM overlay SST Anomaly

A study of a Hurricane Katrina–induced phytoplankton bloom using satellite observations and model simulations
Xiaoming Liu, Menghua Wang, and Wei Shi
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 114, C03023, doi:10.1029/2008JC004934, 2009

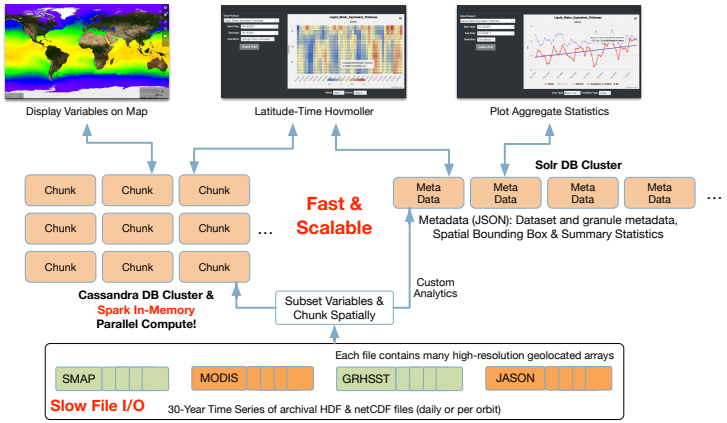
THUANG/JPL © 2017. All rights reserved.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

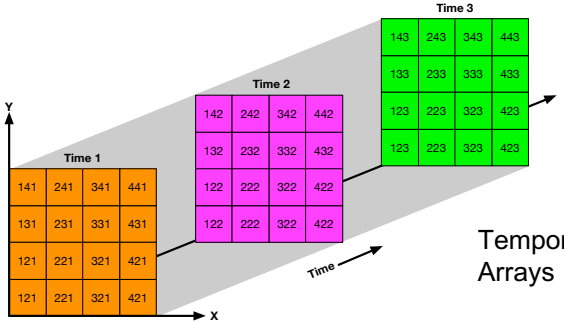
NEXUS: Scalable Data Analytic Solution

- NEXUS is a data-intensive analysis solution using a new approach for handling science data to enable large-scale data analysis
- Streaming architecture for horizontal scale data ingestion
- Scales horizontally to handle massive amount of data in parallel
- Provides high-performance geospatial and indexed search solution
- Provides tiled data storage architecture to eliminate file I/O overhead
- A growing collection of science analysis webservices using Apache Spark: parallel compute, in-memory map-reduce framework
- Pre-Chunk and Summarize Key Variables
  - Easy statistics instantly (milliseconds)
  - Harder statistics on-demand using Spark (in seconds)
  - Visualize original data (layers) on a map quickly (Cassandra store)
- **Algorithms** – Time Series | Latitude/Time Hovmöller| Longitude/Time Hovmöller| Latitude/Longitude Time Average | Area Averaged Time Series | Time Averaged Map | Climatological Map | Correlation Map | Daily Difference Average

Open Source: Apache License 2
https://github.com/dataplumber/nexus



Two-Database Architecture

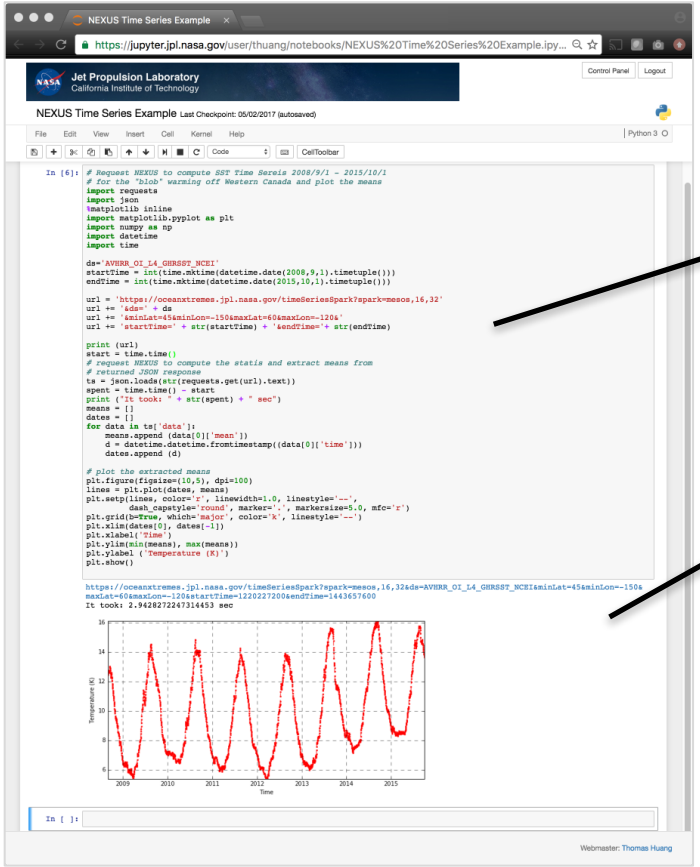


Temporal spatial Arrays

THUANG/JPL © 2017. All rights reserved.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Enable Science without File Download




```
# Request NEXUS to compute SST Time Series 2008/9/1 - 2015/10/1
# for the "blob" warming off Western Canada and plot the means
…
ds='AVHRR_OI_L4_GHRSST_NCEI'

url = … # construct the webservice URL request


# make request to NEXUS using URL request
# save JSON response in local variable
ts = json.loads(str(requests.get(url).text))

# extract dates and means from the response
means = []
dates = []
for data in ts['data']:
    means.append (data[0]['mean'])
    d = datetime.datetime.fromtimestamp((data[0]['time']))
    dates.append (d)

# plot the result
…
```

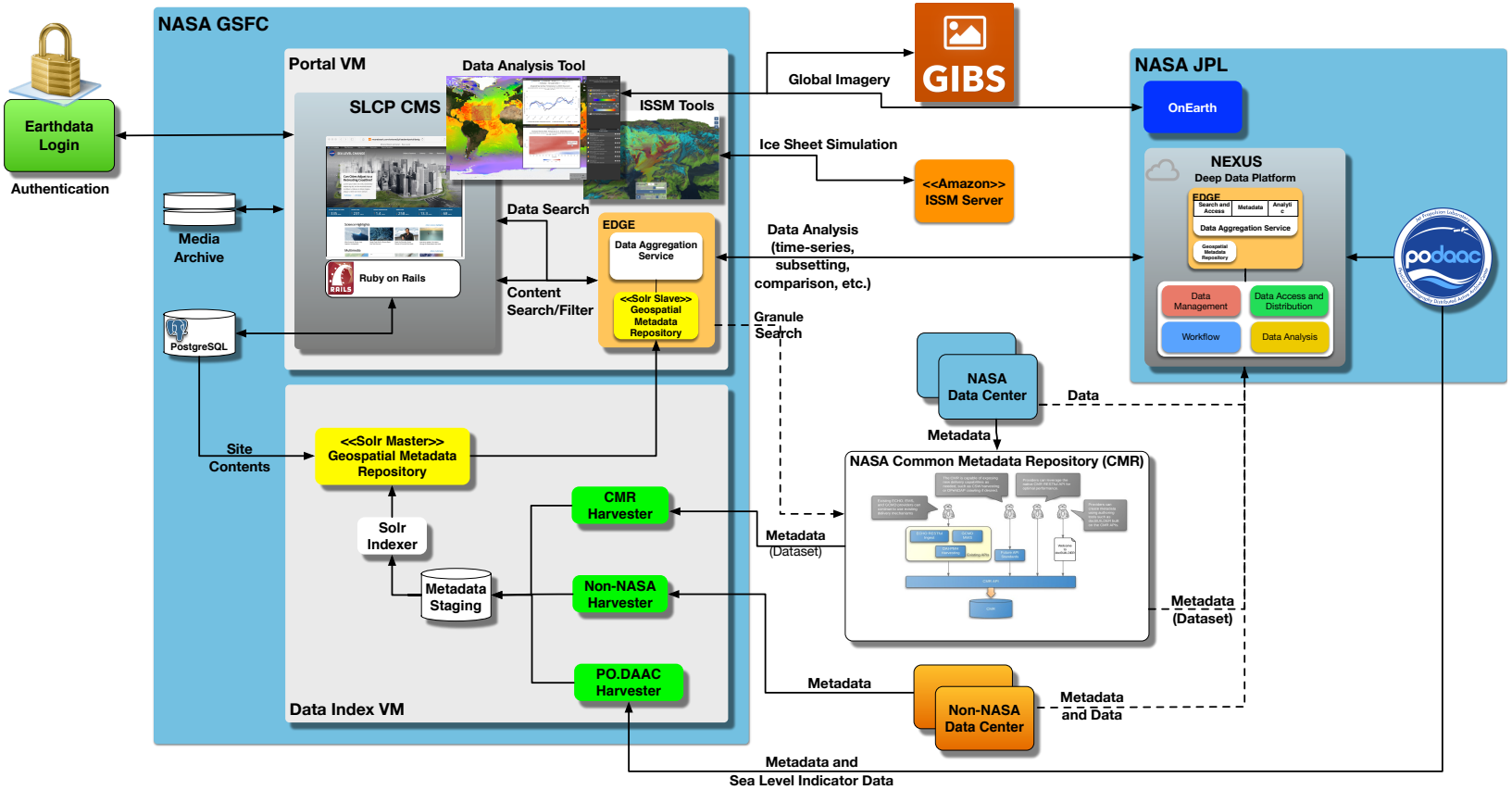
```
https://oceanxtremes.jpl.nasa.gov/timeSeriesSpark?spark=mesos,16,32&ds=AVHRR_OI_L4_GHRSST_NCEI&minLat=45&minLon=-150&maxLat=60&maxLon=-120&startTime=1220227200&endTime=1443657600

It took: 2.9428272247314453 sec
```

THUANG/JPL © 2017. All rights reserved.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

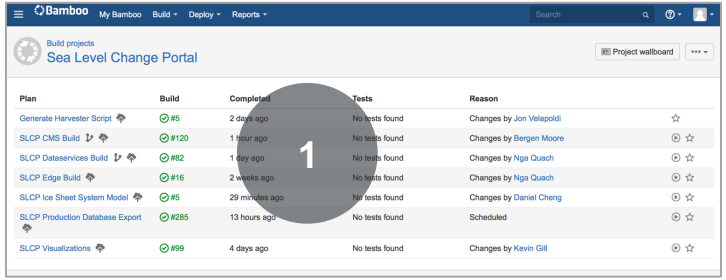
Under The Hood



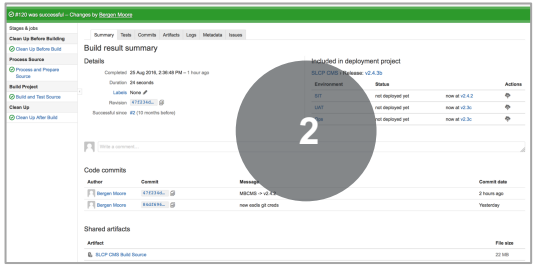
THUANG/JPL © 2017. All rights reserved.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

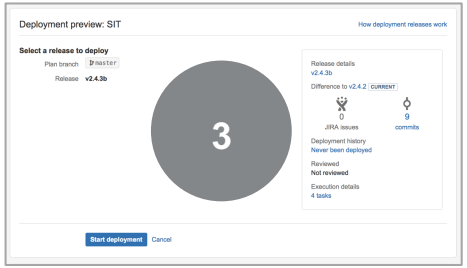
Rapid Deployment



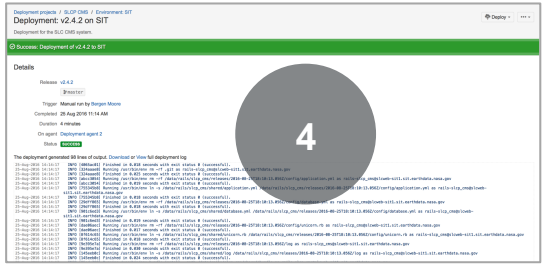
- Minimal downtime between deployments
- Orchestrate what changes to include for each environment
- Contents replication from Production to development and test environments
- No remote login required



Create New Release



Deploy



Deployment Log

THUANG/JPL © 2017. All rights reserved.

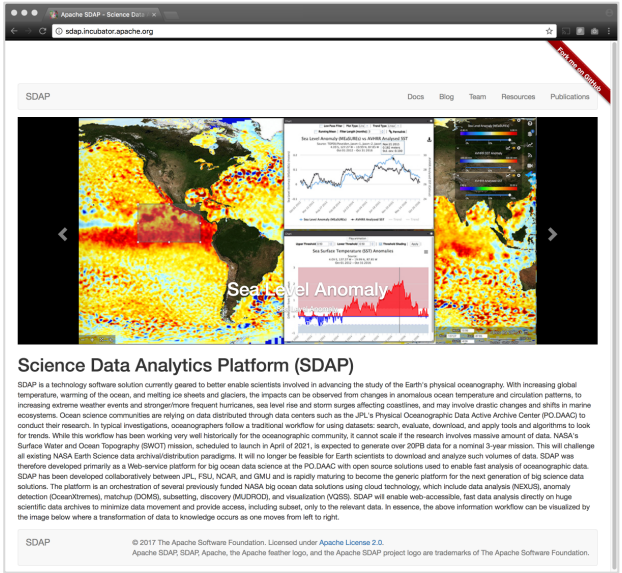
Open Source

Technology sharing through Free and Open Source Software (FOSS)

Further technology evolution that is restricted by projects / missions

Science Data Analytic Platform (SDAP), the implementation of **NASA AIST OceanWorks**, in **Apache Incubator**

- Cloud platform
- Analyzing satellite and model data
- In situ data analysis and coordination with satellite measurements
- Fast data subsetting
- Mining of user interactions and data to enable discovery and recommendations
- Streamline deployment through container technology

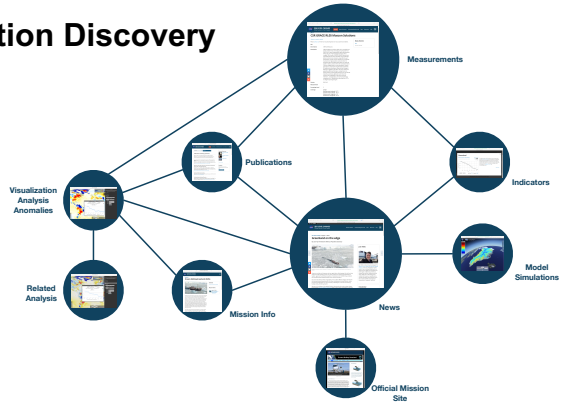


http://sdap.incubator.apache.org

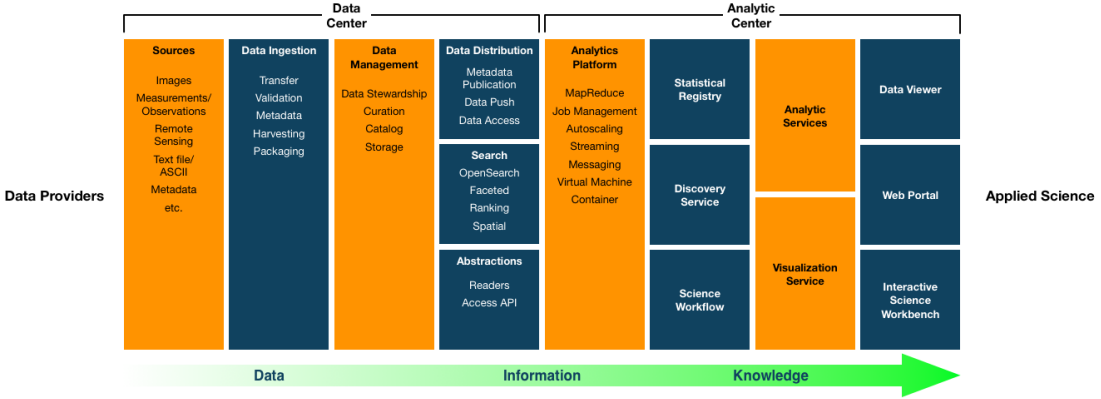
What to expect in 2018?

- A platform to transform data into knowledge
- Enable information discovery through dynamic ranking, recommendations, and linking
- Models and projections
- More visualizations
- Enhance support for in situ data and analysis
- Enhance support for hydrological basin analysis
- Enhance mobile experience
- More data for user to visualize and analyze
- Cloud deployment automation

Improve Information Discovery



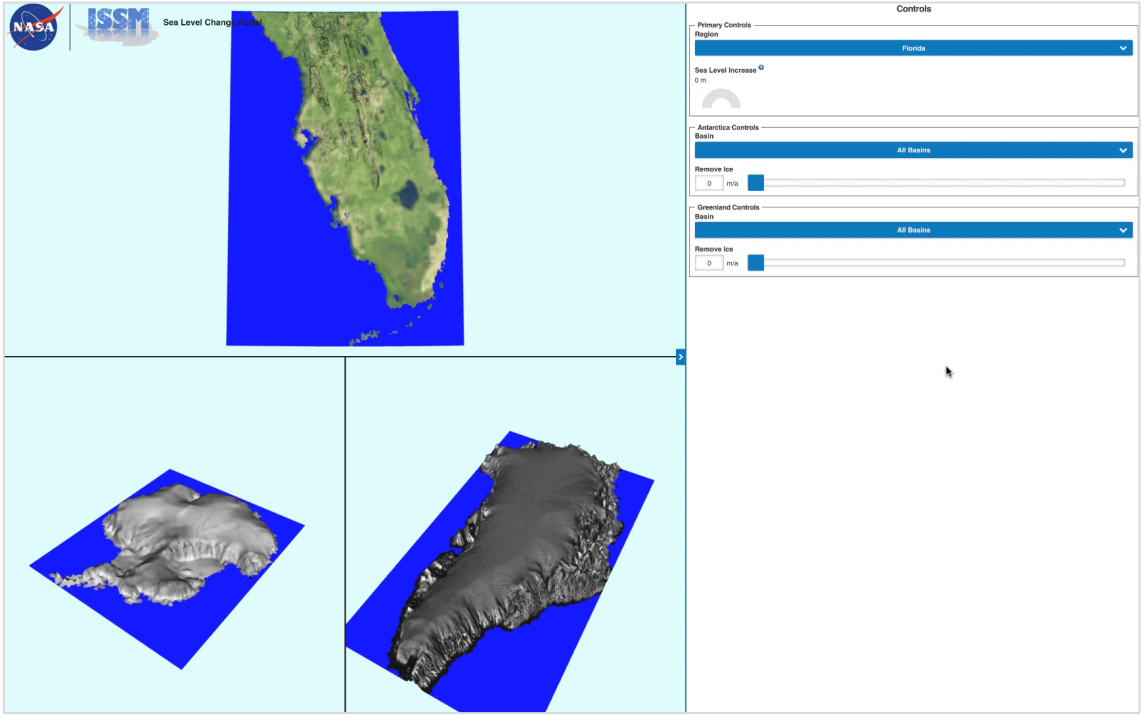
Transforming Data to Knowledge

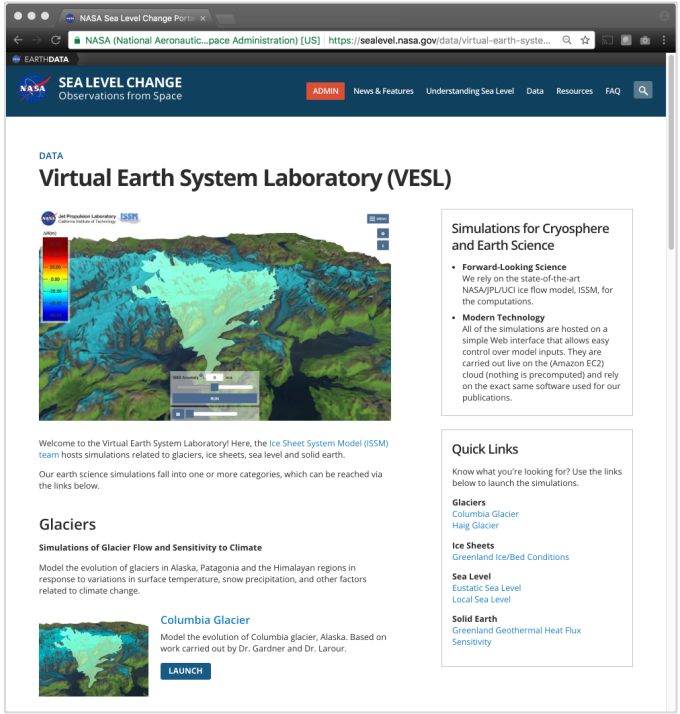


THUANG/JPL © 2017. All rights reserved.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Virtual Earth System Laboratory (VESL)





- Web-based 3D Simulations
- Computation on Amazon Cloud

THUANG/JPL © 2017. All rights reserved.