FOSS4G NA 2018:
How NASA is Building a Petabyte Scale Geospatial Archive in the Cloud

Dan Pilone – NASA EED2 / Element 84, Inc.
Patrick Quinn - NASA EED2 / Element 84, Inc.
Alireza Jazayeri – Development Seed
Katie Baynes - NASA / GSFC
Kevin Murphy – NASA / HQ

The material is based upon work supported by the National Aeronautics and Space Administration under Contract Number NNG15HZ39C
NASA’s Earth Science Data Systems Program

- Actively manages NASA’s Earth science data as a national asset (satellite, airborne, and field)
- Develops capabilities optimized to support rigorous science investigations
- Processes (and reprocesses) instrument data to create high quality long-term earth science data records.

Single largest repository of Earth Science Data, integrating multivariate/heterogeneous data from diverse observational platforms.

http://go.nasa.gov/2mMd5g1
Earth science open data policy

• NASA’s Earth Observation data is collected continuously. For over half a century these invaluable records of Earth processes have provided a critical resource for scientists and researchers.

• Since 1994 NASA Earth science data have been free and open to all users for any purpose as quickly as practical after instrument checkout and calibration.
Earth Observing System Data and Information System (EOSDIS)

EOSDIS

Capture and clean

Distribute

Transform*

Archive

Process

Commercial

Research

Applications

Education

*Subset, reformat, reproject
Distributed Active Archive Centers (DAACs), collocated with centers of science discipline expertise, archive and distribute standard data products produced by Science Investigator-led Processing Systems (SIPS)
EOSDIS core services

Open data APIs and Free data download

Open service APIs

Open source clients
Data-centric users
https://search.earthdata.nasa.gov

Imagery-centric users
https://worldview.earthdata.nasa.gov
Preparing for the future
New instruments and missions.

2017 NRC Decadal Survey - Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond

User expectations continue to evolve.
EOSDIS is many interconnected systems…

- EOSDIS Earthdata Search web applications
- Global Imagery Browse Services (GIBS)
- Common Metadata Repository (CMR)
- Data ingest, archive, and distribution
- Metrics, authentication, monitoring, distribution services, etc.
80 TBs/day
generation

400 TBs/day
reprocessing

300 GB
Granules

150 PBs @ 50 Gbps
processing speed for months
EOSDIS is the premier Earth science archive, but we are always looking for ways to improve.

The current architecture will not be cost effective as the annual ingest rate increases from 4 to 50PB/year.

It will become increasingly difficult and expensive to maintain and improve our current system as data volumes and research demands continue to increase exponentially.

EOSDIS is developing open source cloud native software for reuse across the agency and throughout the government.

Cloud offers benefits like the ability to analyze data at scale, analyze multiple data sets together easily and avoid lengthy expensive moves of large data sets allowing scientists to work on data “in place”.
We **have** to change the paradigm
EOSDIS works well, but can we do better?

• Can we evolve NASA archives to better support interdisciplinary Earth science researchers?
• What system architecture(s) will allow our holdings to become interactive and easier to use for research and commercial users?
• Can we afford additional functionality?
• How will data from multiple agencies, international partners, and the private sector be combined to study the earth as a system?
  – GOES-R, CubeSats, Copernicus…
Conceptual ‘data close to compute’

The operational model of consolidating data—allowing users to compute on the data in place with a platform of common tools—is natural to cloud; it is a cost-effective way to leverage cloud and could be applicable to many businesses and missions.

Bring customers to the data

**Large volume data storage:** Centralized mission observation and model datasets stored in auto graduated AWS object storage (Amazon S3, Amazon S3 IA, Amazon Glacier)

**Scalable compute:** Provision, access, and terminate dynamically based on need. Cost by use

**Cloud Native Compute:** Cloud vendor service software stacks and microservices easing deployment of user based applications

**EOSDIS applications and services:** Application and service layer using AWS compute, storage (Amazon S3, Amazon S3 IA, Amazon Glacier), and cloud native technologies

**Non-EOSDIS/public applications and services:** Science community brings algorithms to the data. Support for NASA and non-NASA
Past 24 Months: Focused on evaluation and planning for a cloud migration in 4 areas

- Compliance, Security, Cost Tracking
- Core Archive Functionality and Processing
- End-User Application Migration
- Pursuing Cloud Partnerships
Starting AWS migration

Since September 2016, EOSDIS has migrated two of its core systems, Common Metadata Repository (CMR) and Earthdata Search, into the Amazon cloud to immense success.

- One year migration effort
- Over 500K queries per day
- Open source
- Open access API
Global Imagery Browse Service (GIBS) in the cloud service swap

AWS CloudFormation
Amazon S3
AWS CloudFormation
Amazon SNS/SQS
Amazon DynamoDB / SQS
IAM
Scheduler/ dispatcher
Amazon CloudWatch

Product configuration
Handlers
Generation
MRFGen

Ops console

Custom service
Cloud services
External NASA/GIBS Library
Data
GIBS-in-the-cloud ingest & processing

- **AWS**
- **Scheduler (66 LoC)**
- **Dispatcher (106 LoC)**
- **Product config**
- **Handlers**
- **Generation**
- **MRFGGen**
Cloud performance affected architecture

On-premises implementation showed consistent performance during load testing vs. more sporadic latencies in AWS
Ingest: Earth science Imagery Processing
### OCTOBER 17-20, 2017 AWS announcements!

<table>
<thead>
<tr>
<th>Date</th>
<th>Announcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 20</td>
<td>AWS Config Adds Support for AWS CodeBuild</td>
</tr>
<tr>
<td>Oct 20</td>
<td>Amazon QuickSight Adds Support for Combo Charts and Row-Level Security</td>
</tr>
<tr>
<td>Oct 19</td>
<td>AWS Direct Connect now live in Vancouver, Manchester and Perth</td>
</tr>
<tr>
<td>Oct 19</td>
<td>Manage Amazon Simple Queue Service costs using Cost Allocation Tags</td>
</tr>
<tr>
<td>Oct 19</td>
<td>Amazon Athena is now available in the EU (Frankfurt) region.</td>
</tr>
<tr>
<td>Oct 19</td>
<td>Amazon Redshift Spectrum is now available in Europe (Ireland) and Asia Pacific (Tokyo)</td>
</tr>
<tr>
<td>Oct 18</td>
<td>Amazon EC2 Spot Can Now Encrypt your EBS volumes at launch time</td>
</tr>
<tr>
<td>Oct 17</td>
<td>Amazon Redshift announces Dense Compute (DC2) nodes with twice the performance as DC1 at the same price</td>
</tr>
</tbody>
</table>
Ingest: Earth science imagery processing...

Discover
- Provider
- Discover HTTP Tiles

Sync
- Sync HTTP URLS

Process
- Generate thumbnails and tiles
- Source image storage
- Imagery locks
- Imagery storage

Execution flow:
- Data store
- Data fetch

So Q2 2016
Ingest & Archive with AWS Step Functions

Scheduler → AWS Step Functions → Workflow Execution
- Discover granules
- Sync
- Processing step 1
- Processing step 2
- Submit to CMR

Workflow data/service interaction:
- Provider
- CMR
- Temporary storage
- Granule storage

Collections table → Dashboard → Workflow Execution

Distribution
Cumulus Major System Components

A lightweight framework consisting of:

**Tasks** a discrete action in a workflow, invoked as a Lambda function or EC2 service, common protocol supports chaining

**Orchestration engine** (AWS Step Functions) that controls invocation of tasks in a workflow

**Database** store status, logs, and other system state information

**Workflows(s)** file(s) that define the ingest, processing, publication, and archive operations (json)

**Dashboard** create and execute workflows, monitor system
AWS Step Functions Workflow Execution

Scheduler

Discover Granules

Sync

Processing Step 1

Processing Step 2

Submit to CMR

EOSDIS Archive

Dashboard

SIPS Filesystem

SIPS Staging

Legacy SIPS

Cloud Aware SIPS
Cloud scale science data

- **Data can be generated at scale** in AWS and placed in accessible buckets, avoiding massive data moves.

- Ingest, archival, validation, processing, etc. can **scale dynamically** based on incoming data streams, reprocessing needs, etc.

- **Entire petabyte scale archive** is directly accessible, with no transfer time or costs, to science users in the same region for longtime series or multiproduct use.

- **Data processing, transformation, and analysis services** can be spun up, NASA funded or completely independently, leveraging the data with scalable compute and cost and access-managed output targets.
HOW DO USERS USE THIS DATA?
Data Access Use Cases

- Traditional file based Data Access
- Distribution from Access Services
- Computing and Analysis Near the Data
Basic Data Access
**User**

**NASA CMR**
- Initial search via NASA CMR APIs, returning metadata and access URLs

**Data Distribution Service**
- The access URL is to an EOSDIS distribution service, verifying user permissions and distribution rates; returning a time limited, signed URL pointing to actual data location.

**EOSDIS S3 Archive**
- Data is distributed from S3 to end users as entire files or partial sequences as requested.*

---

*Egress controls may drive a more sophisticated solution.*
Basic Amazon S3 egress

Amazon S3 → Internet → People
Amazon S3 with CloudFront
Amazon S3 through AWS Direct Connect to on-premises distribution pipe
Request limiting using Lambda and API Gateway
Egress costs range more than 13x across those models
Egress costs are a **big** deal…

…but they weren’t our only issue…
Hard cost controls are essential

• The Anti-Deficiency Act (ADA) disallows unbounded costs

• We needed a means of absolutely limiting egress costs
Circuit Breaker Conceptual design

• Lambda 1: Calculate Amazon S3 egress
  – Watch each bucket’s "Bytes Downloaded" via CloudWatch
  – Post totals

• Lambda 2: Break the circuit (if needed)
  – If total from first billing period to now exceeds our threshold…
  – …lock down Amazon S3 bucket policy
Data Access Use Cases

Traditional file based Data Access

Distribution from Access Services

Computing and Analysis Near the Data
Distribution from Access Services
Example access services

- OPeNDAP access
- OGC WxS Implementations
- Format transformations (repackaging)
- Reprojection, mosaicing, etc
S3 is a Distribution Mechanism
- Mark Korver @ AWS
User

Data Service
(OPENDAP,
AppEEARS, EGI)

s3GET

process....

return s3 redirect to results

s3PUT Results

get results...

EOS Archive
Bucket

S3 Dist
Bucket
Favor Re-architecture over “just getting into the cloud”

- Natural Inflection Point
- Managed Services
- Opportunity for Innovation
- Better leverage cloud cost models
Psycho-Social

GO HANDS-ON QUICKLY
EED2 HACKFEST 2016
CAPABLE OF SPENDING ENTIRE ANNUAL BUDGET

EED2 HACKFEST 2016
MOST LIKELY TO GO INTO OPERATIONS

EED2 HACKFEST 2016
MOST INNOVATIVE

EED2 HACKFEST 2016
MOST POINTS

EOSDIS
LOOKING FORWARD
What we’re working on now…

- Efficient data services access and distribution
- Cost effective large archive storage
- Data disaster recovery and preservation approaches
- Third party cloud native data use at scale
- Expanding the paradigm of an established community
Here’s where we want help
Ways to Compute Near the Data?

- EC2 Instances mounting data via \texttt{yas3fs}
- Jupyter Notebooks with \texttt{s3contents} or \texttt{boto3}
- Serverless implementations with \texttt{SNS/SQS} and containerized code (ECS)
- Managed solutions like \texttt{Athena} or \texttt{RedShift Spectrum}
Call for help

• What can we do to make it easier for you use to use the data in the cloud?
• What are barriers to you using the cloud for processing at scale?
• What kind of sample code, documentation, reference implementations, etc. would help you?
• Would you use / want to use the data as is on S3 or via some other access API?
• Right now discovery and getting a URL to the data goes through the CMR. Are there other ways you’d like to be able to find and access the data? Flat file catalogs?
Thank you!

Majority of code discussed today is Open Source:
https://github.com/nasa

Dan Pilone // dan@element84.com
This material is based upon work supported by the National Aeronautics and Space Administration under Contract Number NNG15HZ39C.
Acronym List

- AWS – Amazon Web Services
- CNES - Centre national d'études spatiales
- DAAC – Distributed Active Archive Center
- EC2 – Elastic Compute Cloud
- EED2 – EOSDIS Evolution and Development 2
- FOSS4G – Free and Open Source for Geospatial
- GOES-R - Geostationary Operational Environmental Satellite
- IAM – Identity and Access Management
- JSON – JavaScript Object Notation
- OGC – Open Geospatial Consortium
- OPeNDAP - Open-source Project for a Network Data Access Protocol
- MRF – Metadata Raster Format
- NRC – National Resource Council
- S3 – Simple Storage Service
- S3 IA – Simple Storage Service Infrequent Access
- SNS – Simple Notification Service
- SQS – Simple Queuing Service
- URS – User Registration Service