

Leveraging On-premise and Public Cloud Computing to Enable Advanced Rapid Imaging & Analysis for Monitoring Hazards

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Cloud Computing Governance
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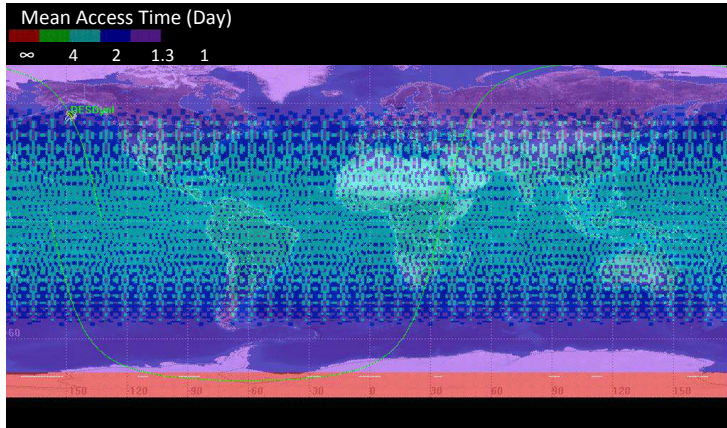
³ USGS Hawaiian Volcano Observatory

⁴ USGS Menlo Park Science Center

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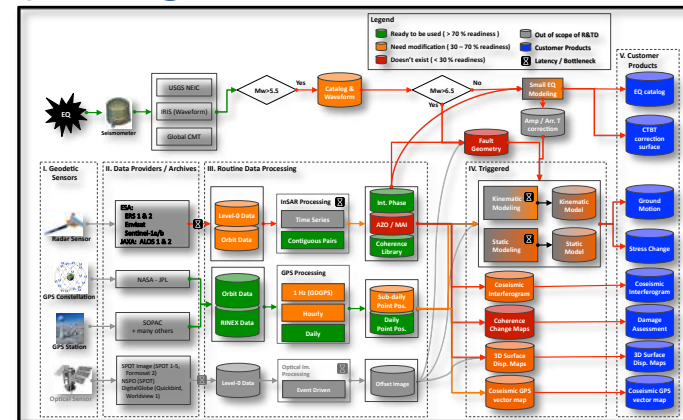


The Challenge of Leveraging Remote Sensing for Disaster Response

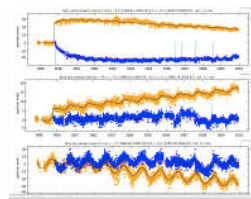


Automated data systems are required to analyze large quantities of data from proposed NASA NISAR (formerly DESDynI), other satellite missions, and rapidly expanding GPS networks.

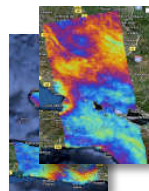
Going from Artisan to Automation: Use system engineering approach to translate specialized data analysis into operational capability.



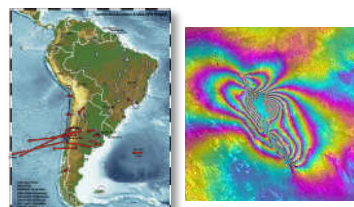
Demonstrate response to hazards with standardized set of data products for decision & policy makers.



Temporal Records of Ground Deformation



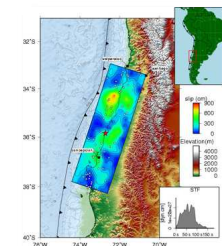
Spatial Maps of Ground Deformation



Coseismic Ground Deformation



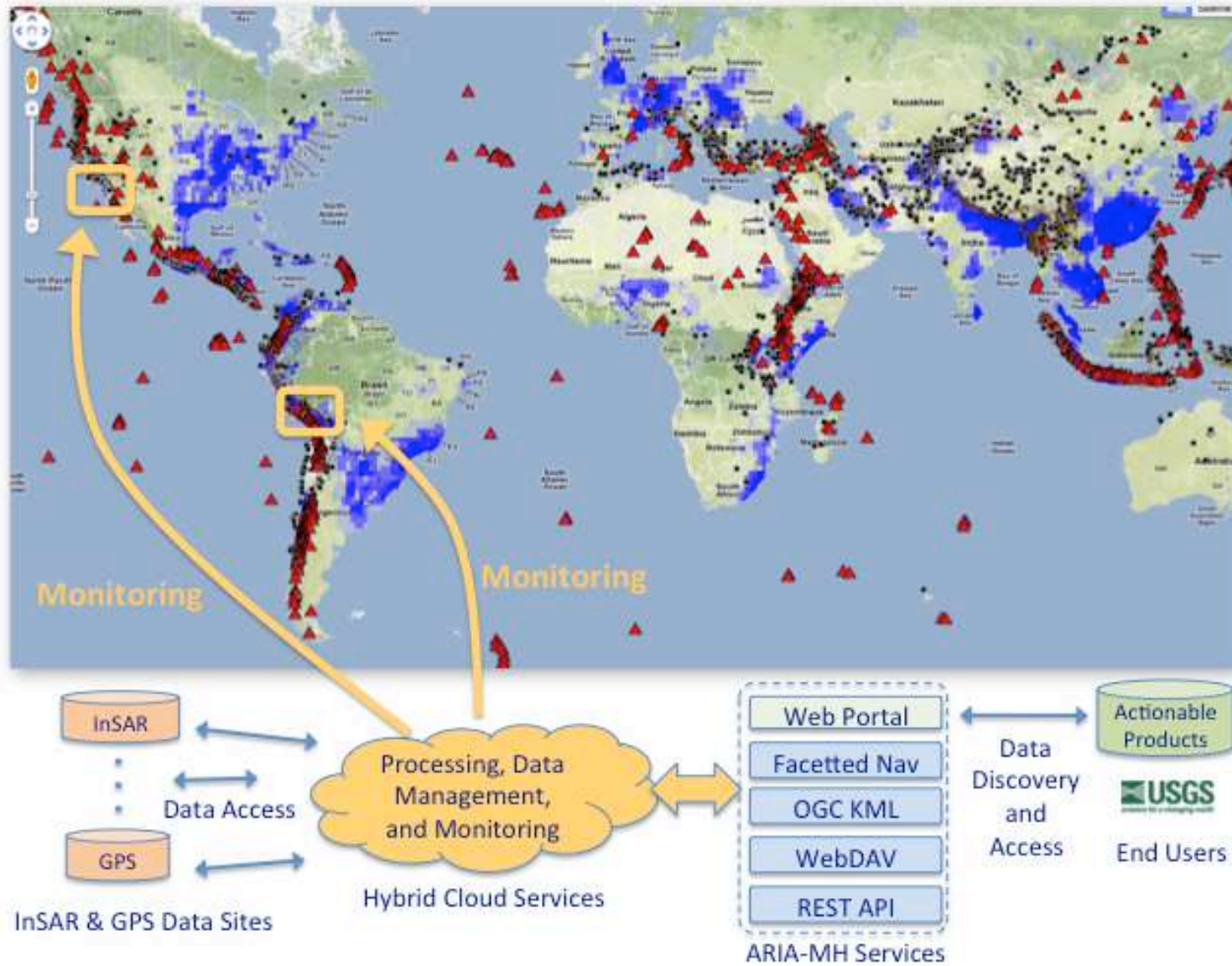
Coseismic Damage



Earthquake Models

- **High-volume, low-latency**, and automatic generation of NASA Solid Earth science data products (InSAR and GPS) to support hazards monitoring.
- Enabling both **science and decision-support** communities to monitor ground motion in areas of interest with InSAR and GPS data.
- Leverage and geographically optimize **hybrid Cloud**-based processing and data management of geodetic data products
- **Monitoring**
 - Event streams from USGS NEIC
 - Data product streams
- **Conditional** triggering of geodetic data processing

Elastic Processing, Data Management, and Monitoring



Near Real-Time Data Stream Established



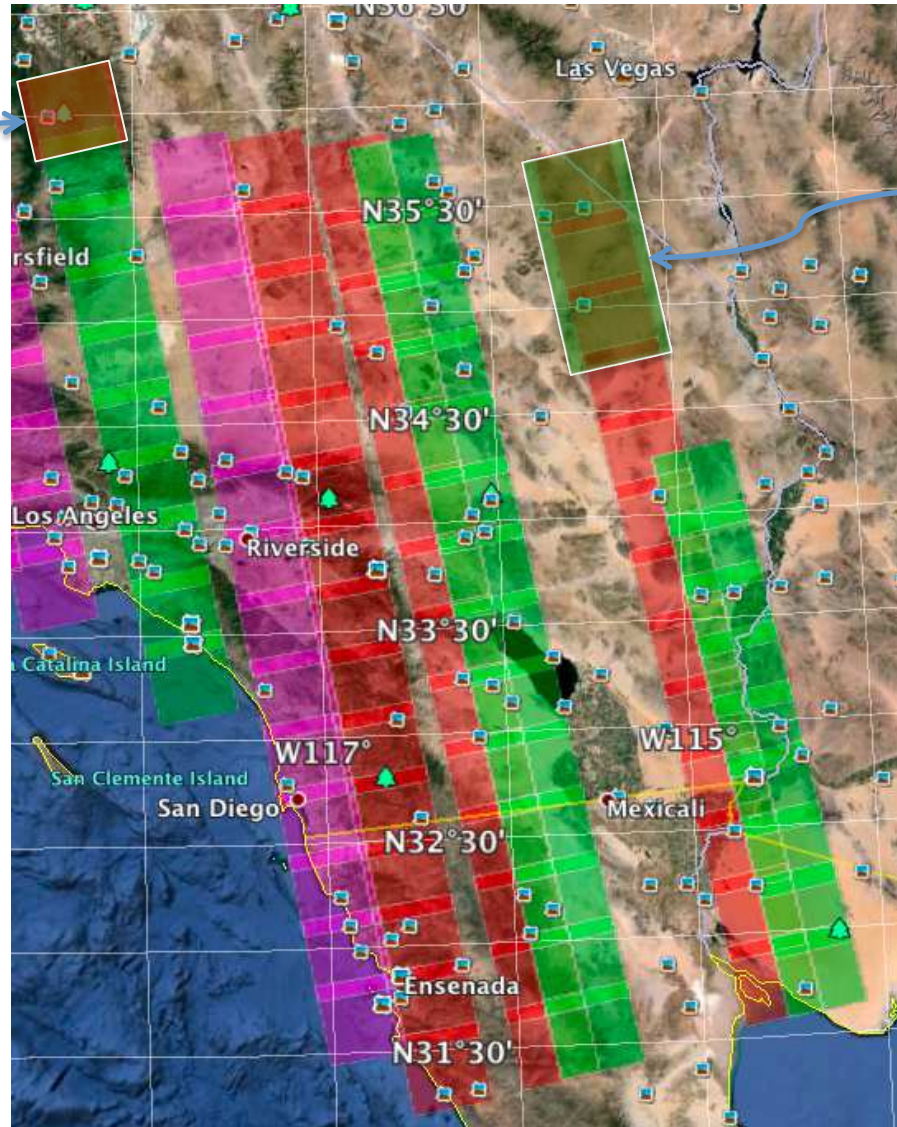
- JPL/Caltech/ASI collaboration effort opens flood of COSMO-SkyMed (CSK) data for select regions
 - Provides access to CSK X-band Level-0 SAR radar data from the Italian Space Agency (ASI)
 - *COSMO-SkyMed (CSK) data provided as part of a **technical collaboration** between JPL-Caltech and the Center for Earth Observations (CIDOT), Italian Space Agency (ASI) (CSK data © 2013 ASI).*
- Near real-time CSK data stream setup into ARIA-MH science data system
 - CSK constellation of 4 satellites has acquisition capacity of 450 frames/day for each satellite
 - Example: San Andreas Fault region of California
 - 580 GB of raw data every 16 days, about 500 frames.
 - ~2TB per month (for CSK on San Andreas Fault region)
 - raw + derived products doubles the data volume

Raw and Interferogram Scene Sizes



Single scene or frame

Stitched scene or frame



Big Data Needs



- Raw data
 - 1 frame = 40 x 40 Kms swath, 3 m. res., 1.2 Gb
 - Total = 580 Gb every 16 days of raw data
- Derived Data Volume
 - Minimum 2 frames for each interferogram
 - Up to 8X of baseline pairs from each frame
 - 3X data volume increase in derived data products from each frame
 - **California area only: PB-scale for 36-months of observations**
- Data movement and storage concerns for handling global-scale coverage

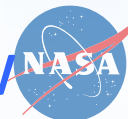
CSK Scene Footprints: Rolling 1-day view



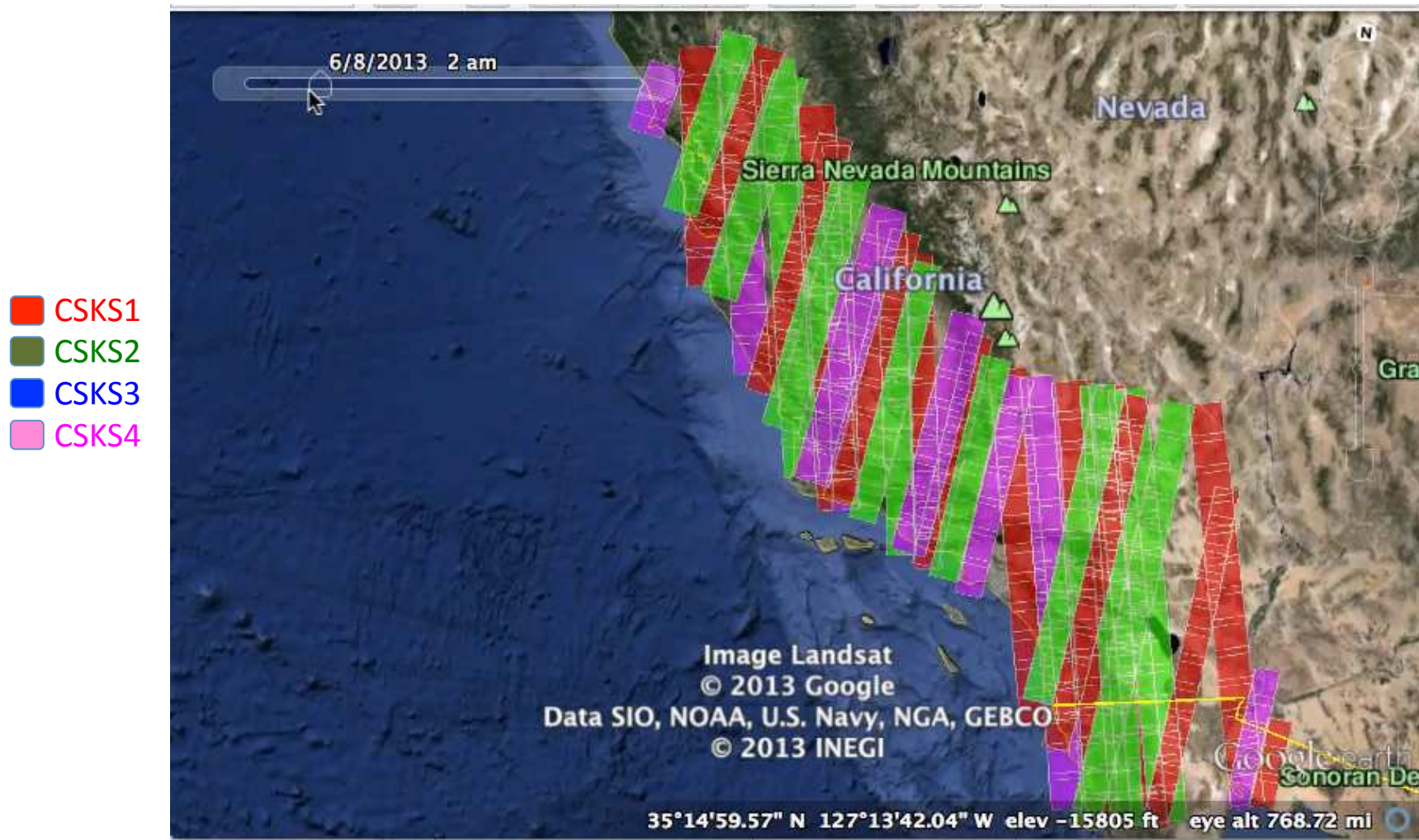
Satellite observation of granules from Italian X-band Level-0 SAR radar data



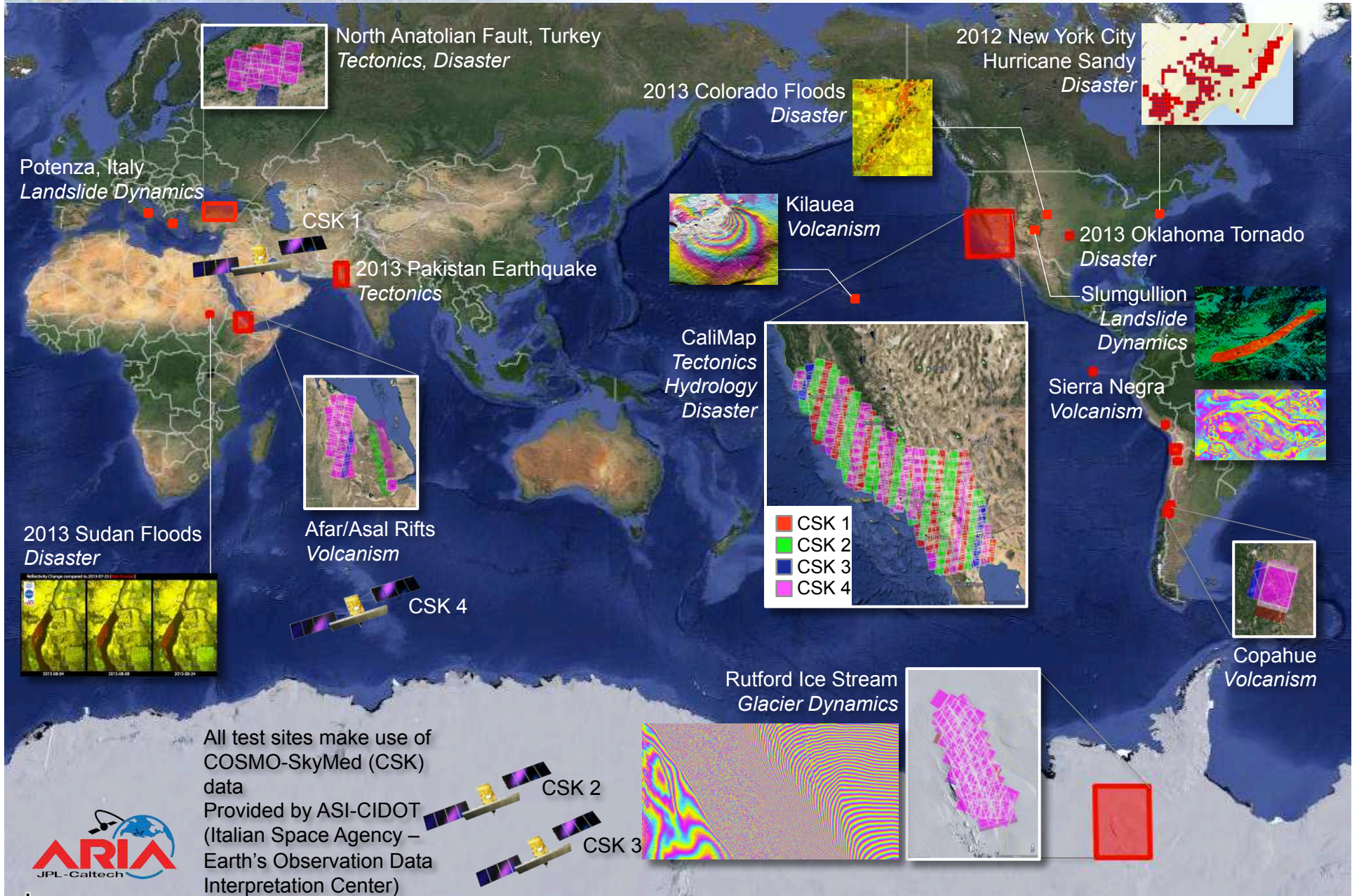
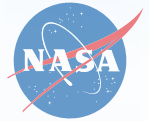
CSK Scene Footprints: Rolling 16-day cycle view



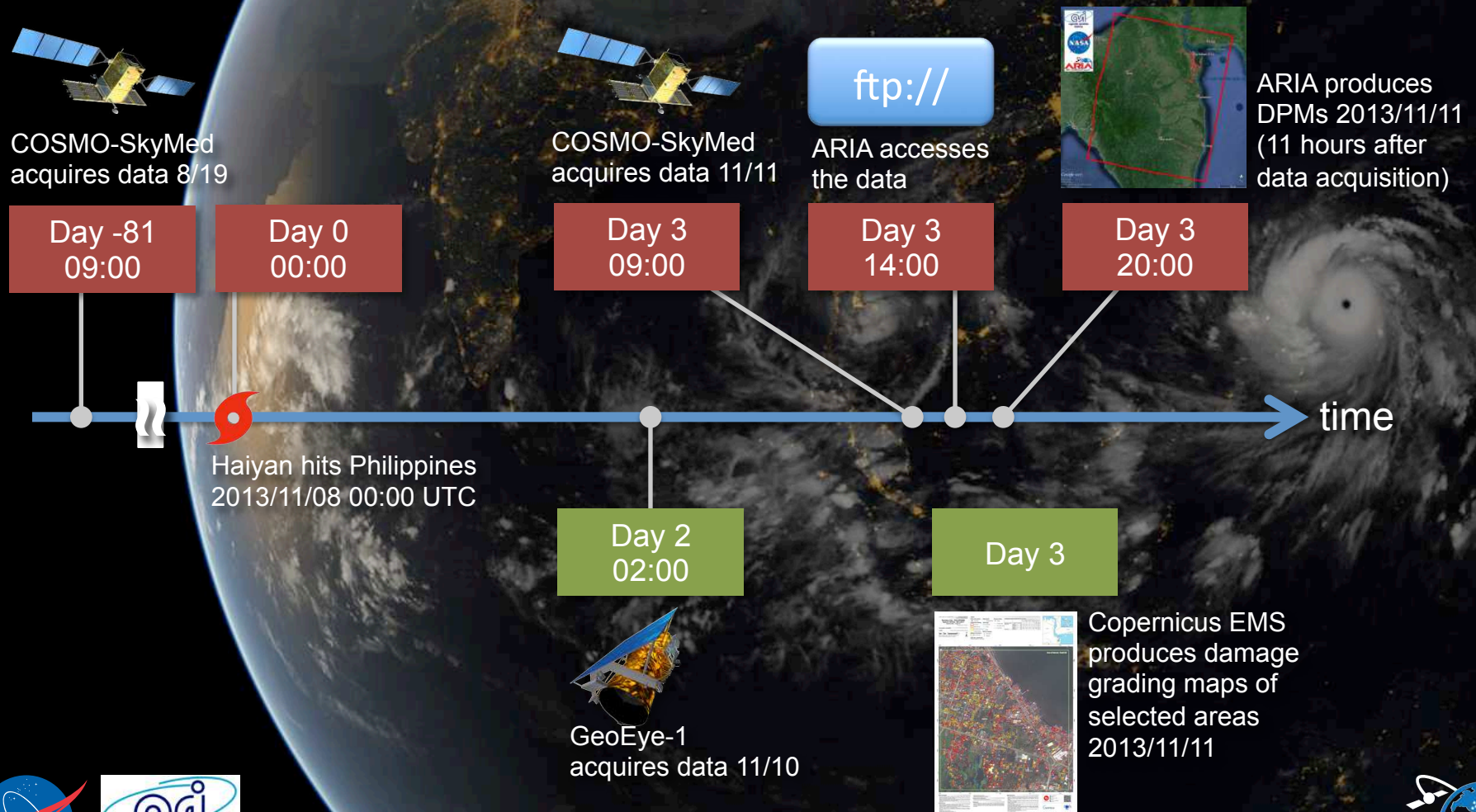
Satellite observation of granules from Italian X-band Level-0 SAR radar data



Projects Supported by ARIA-MH



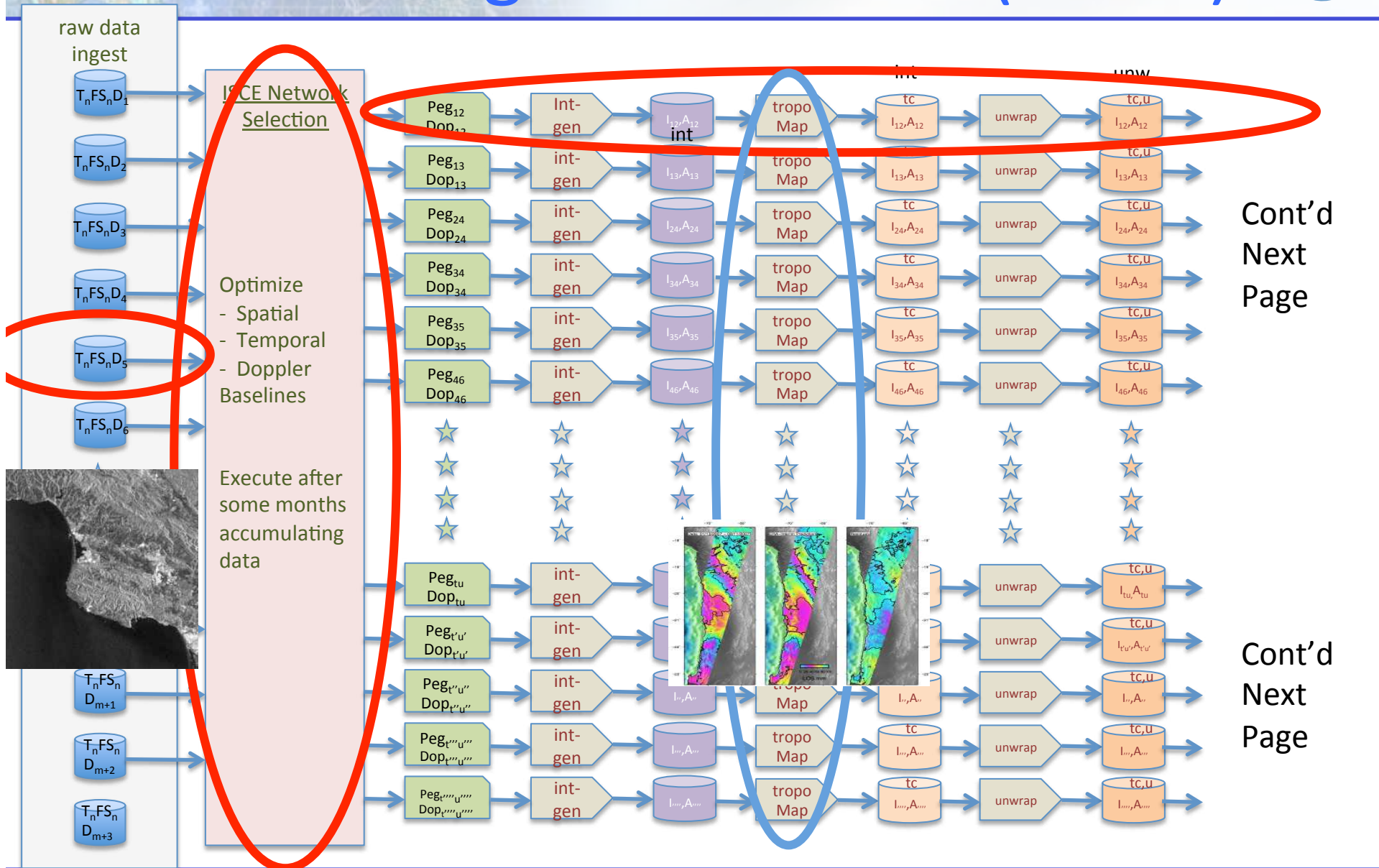
ARIA's Haiyan Response Timeline



Source: Sang-Ho Yun (JPL)



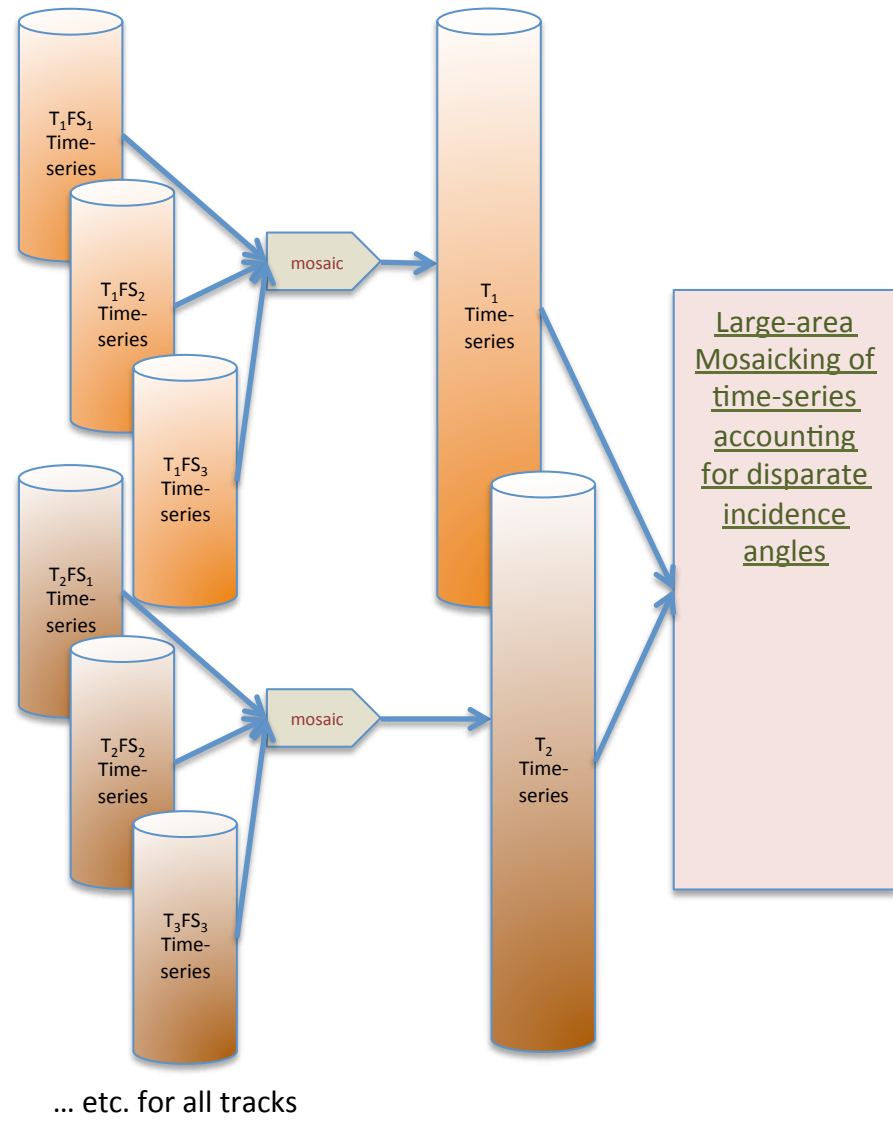
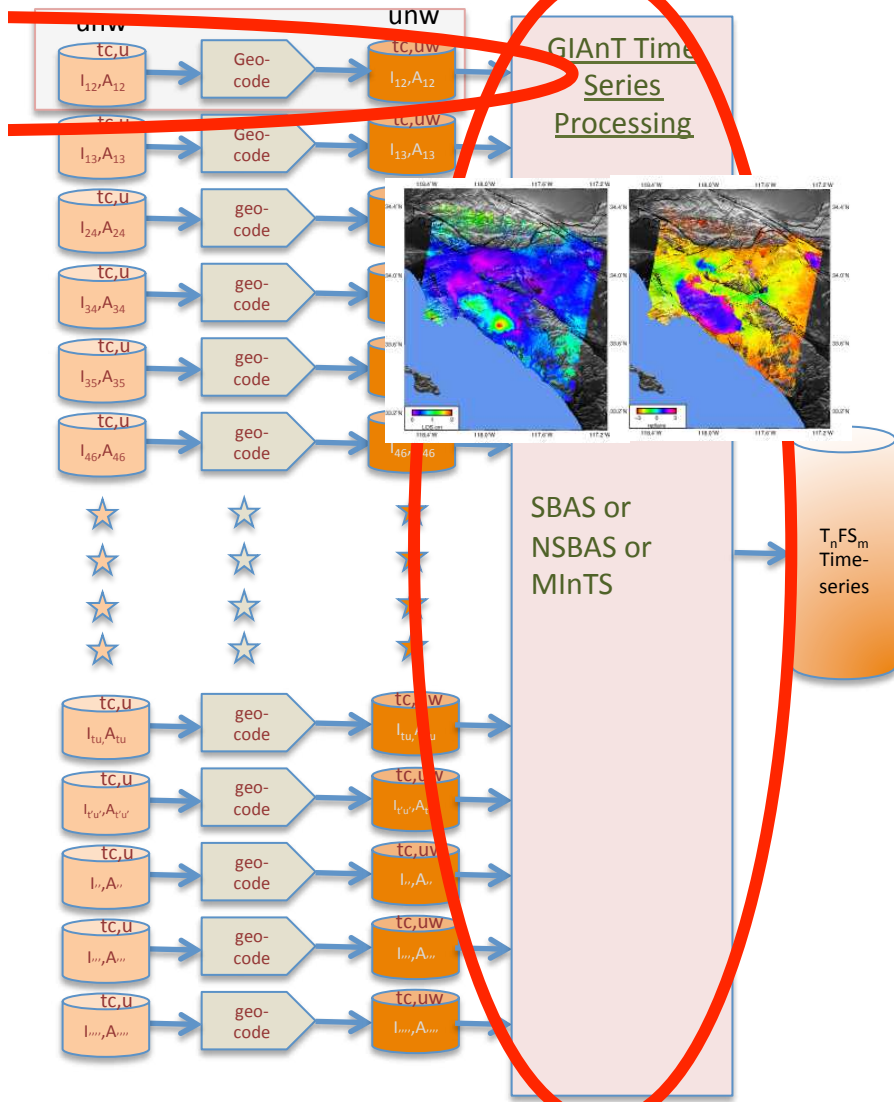
Processing Architecture (1 of 2)



Processing Architecture (2 of 2)






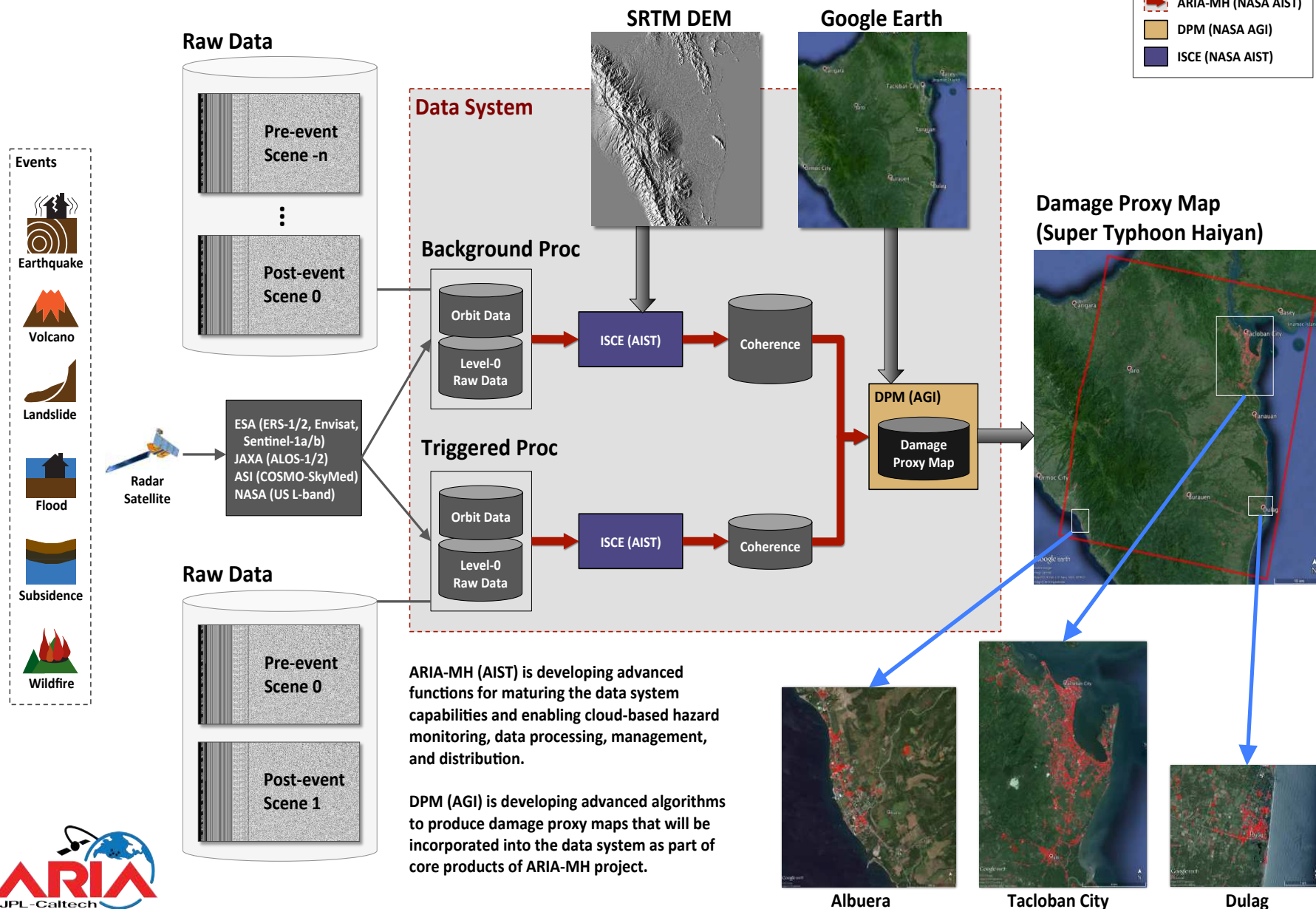
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DPM in ARIA-MH Project 2012.11.24

LEGEND

-  ARIA-MH (NASA AIST)
-  DPM (NASA AGI)
-  ISCE (NASA AIST)



Motivation for Cloud Computing



- Incoming flood of data volume
 - Nominally 1.2GB/scene
 - 100Ks of scenes
 - order of 10GBs-100GBs temp storage per data product processing
 - PBs total storage of products
 - Example InSAR satellites
 - COSMO-SkyMed (CSK) and CSK second generation data from ASI
 - Sentinel 1A/1B
 - ALOS-2
 - Decadal Survey: proposed NI-SAR mission (US L-band SAR)
- “Embarrassingly parallel” data product generation
- Monitoring
 - User definable bounding box regions of interest for nominal background monitoring/processing.
- Elasticity of computing when responding to events
- Process migration to geographically disperse data centers
 - ESDIS DAACs (e.g. ASF)
 - UNAVCO SAR Archive
 - ASI for CSK
 - DLR for TerraSAR-X
 - JAXA
 - Various GEO Supersites

Compute, Data, & Cost Estimates



- Notional analysis comparing local hardware purchase versus AWS GovCloud usage
 - Process 16-days of data in at most 8-days.
 - 26K compute hours on 8-core nodes (3 years wall-clock processing)
 - EC2 instances with
 - Persistent EBS for cached data
 - Ephemeral local VM disk for scratch disk
 - Use AWS Glacier for cheaper long term storage (with lower data access latency)
 - Break-even point before 1-year mark
 - AWS market prices frequently changes (*estimate already outdated*)
 - Costs based on today's dollars. Does not account for inflation. Does not account for future AWS price drops.
 - On-premise costs do not consider overhead costs of cooling and electrical

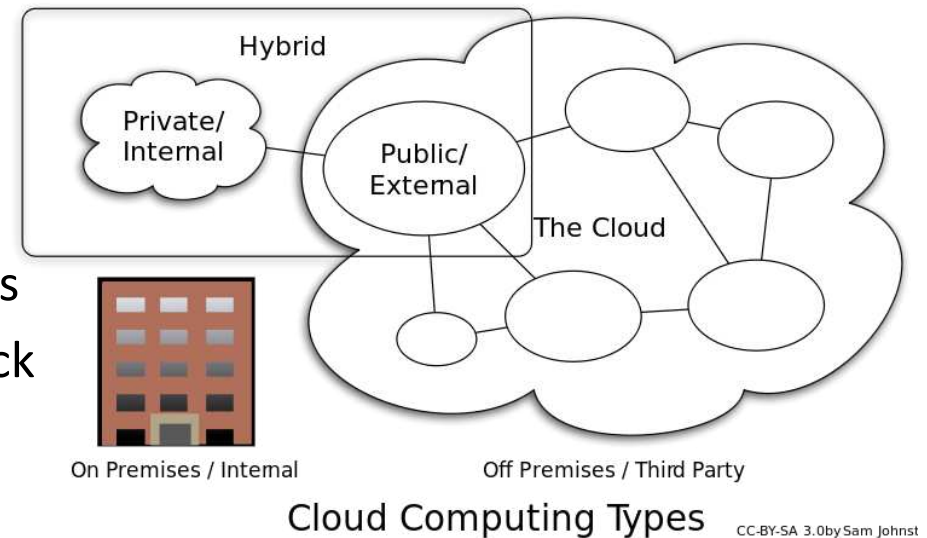
Cumulative months

		3	6	9	12	15	18	21	24	27	30	33	36
Local Cluster (Cumulative)													
Long-Term Storage	\$460.1	\$2.7	\$11.9	\$27.5	\$49.7	\$78.3	\$113.4	\$155.0	\$203.0	\$257.6	\$318.6	\$386.1	\$460.1
Transfer Fee for LTS data	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0
Transfer Fee for results	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0
CPU	\$135.0	\$11.3	\$22.5	\$33.8	\$45.0	\$56.3	\$67.5	\$78.8	\$90.0	\$101.3	\$112.5	\$123.8	\$135.0
Total		\$14.0	\$34.4	\$61.3	\$94.7	\$134.6	\$180.9	\$233.7	\$293.0	\$358.8	\$431.1	\$509.9	\$595.1
Amazon GovCloud (Cumulative)													
Long-Term Storage		\$0.21	\$1.1	\$3.2	\$7.0	\$13.0	\$21.6	\$33.4	\$48.9	\$68.5	\$92.8	\$122.2	\$157.3
Transfer Fee for LTS data		\$0.97	\$5.2	\$15.1	\$32.9	\$61.0	\$101.7	\$157.3	\$230.2	\$322.6	\$436.9	\$575.4	\$740.5
Transfer Fee for results		\$0.00	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0
CPU		\$6.22	\$18.7	\$37.3	\$62.2	\$93.3	\$130.6	\$174.2	\$223.9	\$279.9	\$342.1	\$410.6	\$485.2
Total		\$7.40	\$25.01	\$55.65	\$102.14	\$167.31	\$253.96	\$364.92	\$503.01	\$671.05	\$871.85	\$1,108.23	\$1,383.01

Hybrid Cloud Computing



- Utilizes both *on-premise* and *off-site* infrastructure
- “Sunken costs”: leverage *existing* infrastructure investment
- Hybrid data system architecture
 - Do “*keep up*” processing on-premise
 - “*Burst out*” to public cloud when demand exceeds on-premise resources
 - AWS-compatible Eucalyptus cloud stack
- Vendor lock in: decrease dependency on commercial vendors
- Recognize that not all resources need to be in the public cloud
 - ITAR / EAR99 software
 - AWS: GovCloud US
 - Currently high cloud storage costs



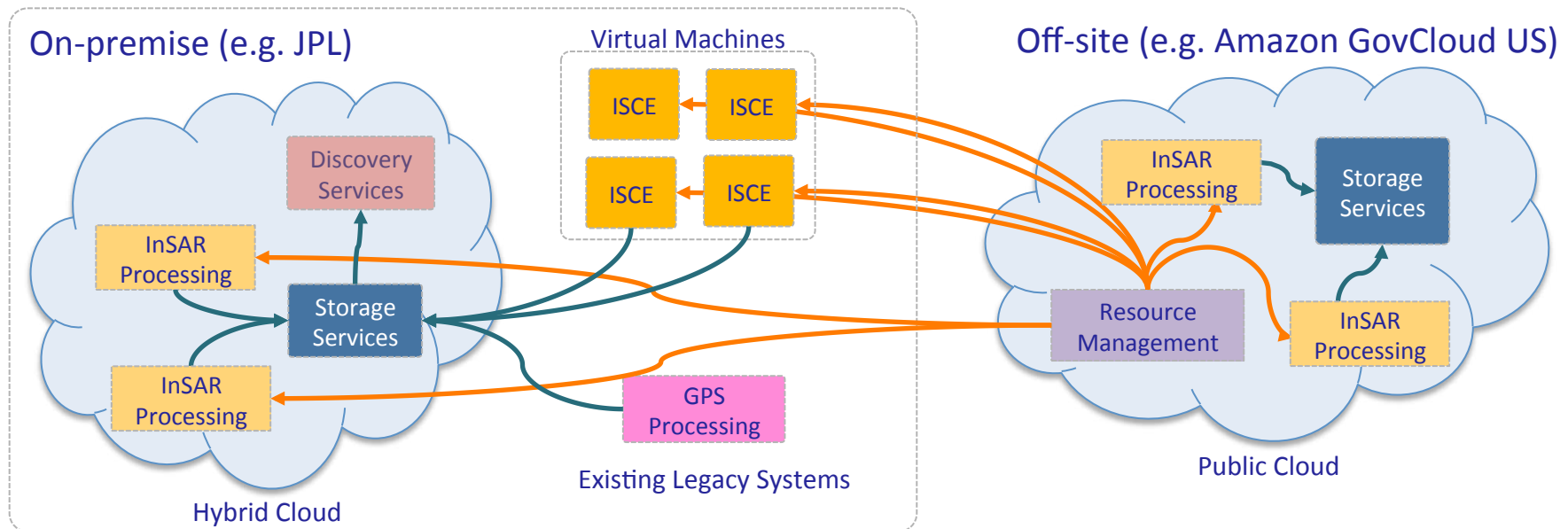
AWS and Eucalyptus Compatibility



Hybrid Cloud Computing Strategy



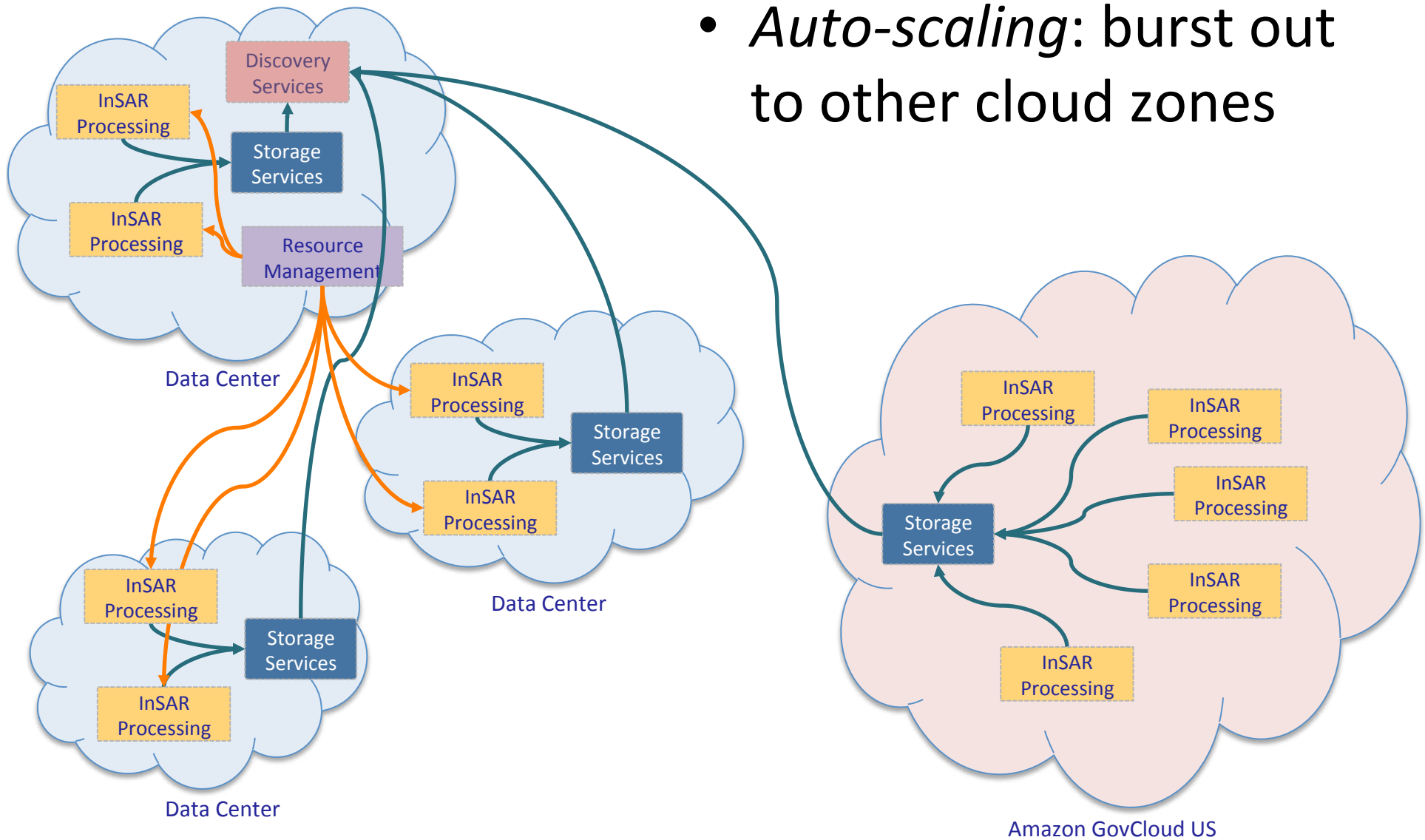
- Utilizes both **on-premise** and **off-site** infrastructure
 - Leverage existing infrastructure investment
 - PB-scale processing and storage in public cloud currently too expensive
- Hybrid Cloud data system architecture
 - **Burst out** to public cloud when demand exceeds on-premise resources
 - Deploy AWS-compatible Eucalyptus cloud stack **on-premise**
- **Heterogeneous** computing nodes
- Resource management and data discovery can run anywhere
- Deploy **localized data repositories** closer to processing VMs
- Leverage **Amazon GovCloud US** to address export control and firewall security issues



Hybrid Cloud Auto-Scaling

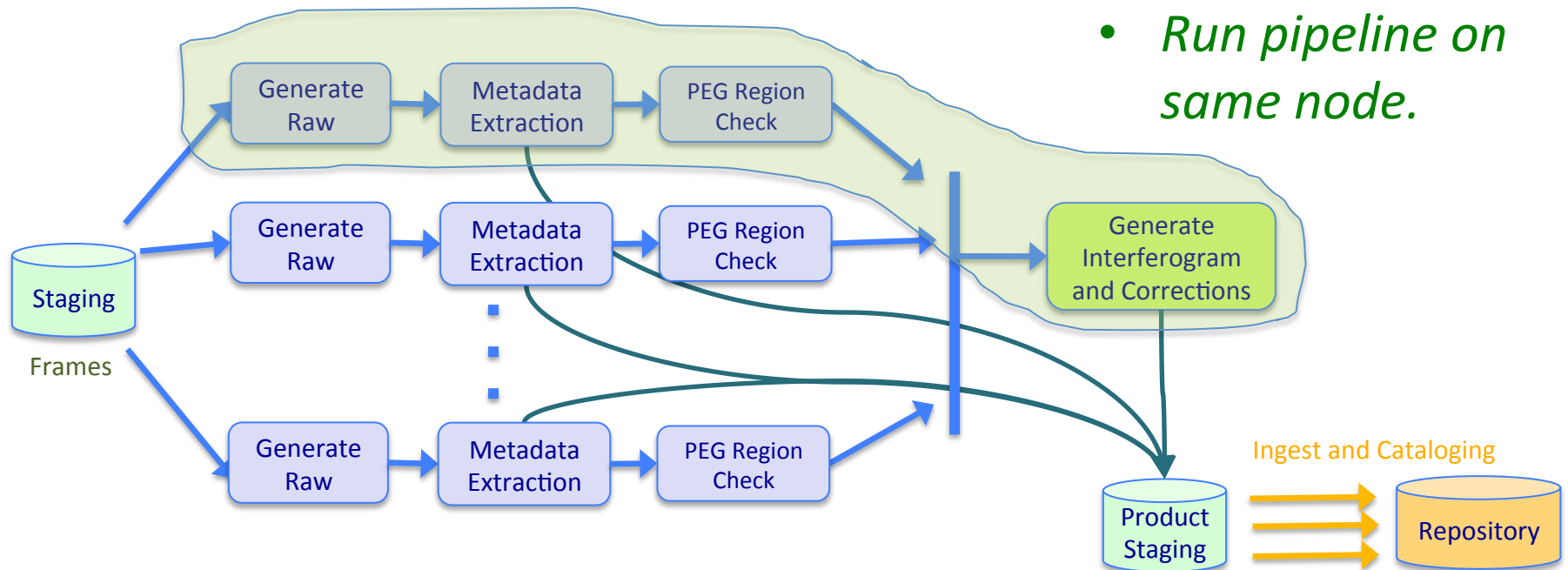


- *Auto-scaling*: burst out to other cloud zones



Leveraging Spatial Locality of Data

- **Want to minimize data movement time and costs**
 - Leverage data locality on each compute node
 - Run entire workflow pipeline on same compute node
 - Minimizes data movement for job staging in each processing step
 - Can map and *cache* data on compute nodes
 - Run storage repository close to compute nodes
- *Everything runs in parallel.*
 - *Run pipeline on same node.*



Faceted Resource Management

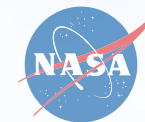


- Facetted view of distributed cloud compute jobs
- Distribution of job
 - Status
 - Types
 - Compute nodes
 - Hardware resource utilization
- Live DAV view

The screenshot displays the Mozart Job Management web interface. At the top, there are navigation tabs for 'Total', 'Queued', 'Running', 'Completed', and 'Failed'. A modal window is open, showing details for a job with ID 'create_interferogram-CSKS2_RAW_HI_05_HH_RD_20130525020436_20130525020443.interferogram.json_2-20131213T064'. The modal has tabs for 'Job info', 'Context', 'STDOUT', 'STDERR', and 'Work Dir', with 'Work Dir' selected. It shows the location of the job's working directory and a list of files and directories. The table below is a summary of the files shown in the screenshot:

Name	Last modified	Size
Parent Directory	-	-
checkInterferogramByInputHash.log	13-Dec-2013 08:28	153
context.json	13-Dec-2013 08:28	444
createInterferogram_0.log	13-Dec-2013 08:40	35K
CSKS2_RAW_B_HI_05_HH_RD_SF_20130525020432_20130525020439.h5	25-May-2013 04:36	1.0G
CSKS2_RAW_B_HI_05_HH_RD_SF_20130525020436_20130525020443.h5	25-May-2013 04:41	1.0G
CSKS2_RAW_B_HI_05_HH_RD_SF_20130525020441_20130525020448.h5	25-May-2013 04:49	1.0G
CSKS2_RAW_B_HI_05_HH_RD_SF_20130525020446_20130525020452.h5	25-May-2013 04:37	1.0G
CSKS2_RAW_B_HI_05_HH_RD_SF_20130813020359_20130813020406.h5	13-Aug-2013 06:28	1.0G
CSKS2_RAW_B_HI_05_HH_RD_SF_20130813020403_20130813020410.h5	13-Aug-2013 06:44	1.0G
CSKS2_RAW_B_HI_05_HH_RD_SF_20130813020408_20130813020415.h5	13-Aug-2013 06:28	1.0G
CSKS2_RAW_B_HI_05_HH_RD_SF_20130813020413_20130813020419.h5	13-Aug-2013 06:29	1.2G
CSKS2_RAW_HI_05_HH_RD_20130525020436_20130525020443.interferogram.json_2	13-Dec-2013 08:28	54K
file0D8FJ	13-Dec-2013 08:41	1.0G
filezOTW1u	13-Dec-2013 08:41	232M
getInputHash.log	13-Dec-2013 08:28	0
insarc.log	13-Dec-2013 08:28	0
insarcMH.xml	13-Dec-2013 08:37	1.5K
interferograms_found.txt	13-Dec-2013 08:28	7
isce.log	13-Dec-2013 08:40	622
job.json	13-Dec-2013 08:28	4.9K
netset_hash.txt	13-Dec-2013 08:28	32
output_0.raw_0	13-Dec-2013 08:38	1.0G
output_0.raw_0.aux	13-Dec-2013 08:38	350K
output_0.raw_1	13-Dec-2013 08:39	1.0G
output_0.raw_1.aux	13-Dec-2013 08:39	350K
output_0.raw_2	13-Dec-2013 08:40	1.0G
output_0.raw_2.aux	13-Dec-2013 08:40	349K
output_0.raw_3	13-Dec-2013 08:40	1.0G
output_0.raw_3.aux	13-Dec-2013 08:40	350K
stderr.txt	13-Dec-2013 08:28	490

Faceted Resource Management



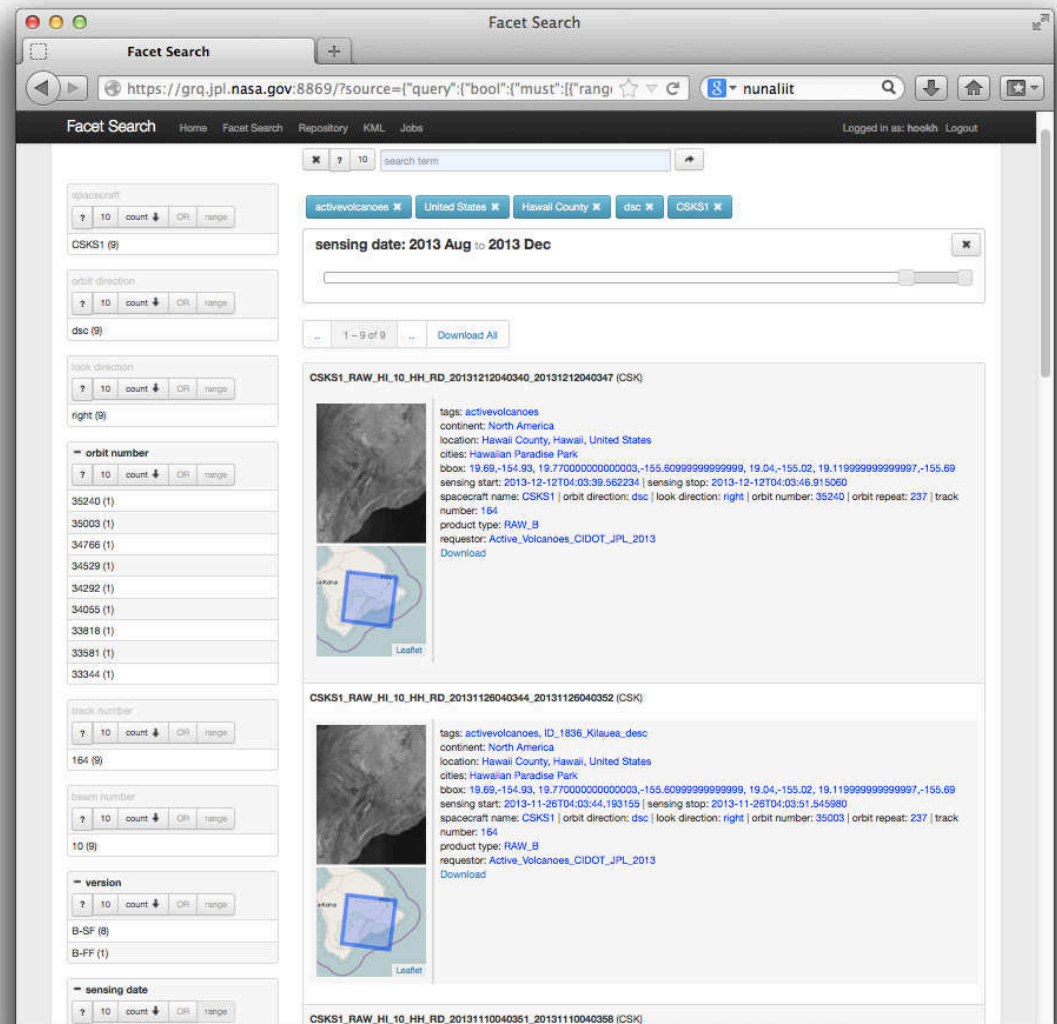
- Facetted view of distributed cloud compute jobs used in additional to AWS and Eucalyptus console

INSTANCE	STATUS	IMAGE ID	AVAILABILITY ZONE	PUBLIC ADDRESS	PRIVATE ADDRESS	KEY NAME	SECURITY GROUP	LAUNCH TIME
i-4E284475	Running	emi-697039CC	CLUSTER01	128.149.118.177	172.31.255.124	ariamh	wide-open	2013-12-11T15:54:07.564Z
i-EEA8460A	Running	emi-697039CC	CLUSTER01	128.149.118.176	172.31.255.110	ariamh	wide-open	2013-12-11T15:54:04.442Z
i-39103F31	Running	emi-697039CC	CLUSTER01	128.149.118.175	172.31.255.111	ariamh	wide-open	2013-12-11T15:54:01.035Z
i-1DCD46C0	Running	emi-697039CC	CLUSTER01	128.149.118.174	172.31.255.119	ariamh	wide-open	2013-12-11T15:53:57.085Z
i-ESCFA028	Running	emi-697039CC	CLUSTER01	128.149.118.173	172.31.255.112	ariamh	wide-open	2013-12-11T15:53:53.857Z
i-F3004509	Running	emi-697039CC	CLUSTER01	128.149.118.172	172.31.255.117	ariamh	wide-open	2013-12-11T15:51:57.051Z
i-49C44160	Running	emi-697039CC	CLUSTER01	128.149.118.170	172.31.255.121	ariamh	wide-open	2013-12-11T07:16:43.818Z
i-2930460C	Running	emi-697039CC	CLUSTER01	128.149.118.171	172.31.255.108	ariamh	wide-open	2013-12-11T07:13:31.150Z

Name	Instance ID	Instance Type	Availability Zone	Instance State	Status Checks	Alarm Status	Public DNS	Public IP	Key Name	Launch Time	Security
ARIAMH-worker-m1.xlarge-pool-1 0	i-a4a4f486	m1.xlarge	us-gov-west-1b	running	Initializing	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m1.xlarge-pool-1 1	i-aaa4f488	m1.xlarge	us-gov-west-1b	running	Initializing	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m1.xlarge-pool-1 2	i-a8a4f48a	m1.xlarge	us-gov-west-1b	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m1.xlarge-pool-1 3	i-aaa4f48c	m1.xlarge	us-gov-west-1b	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m1.xlarge-pool-1 4	i-aca4f48e	m1.xlarge	us-gov-west-1b	running	Initializing	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m1.xlarge-pool-1 5	i-b2a4f490	m1.xlarge	us-gov-west-1b	running	Initializing	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m1.xlarge-pool-1 6	i-b0a4f492	m1.xlarge	us-gov-west-1b	running	Initializing	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m1.xlarge-pool-1 7	i-b6a4f494	m1.xlarge	us-gov-west-1b	running	Initializing	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m3.2xlarge-pool-1 0	i-10a4f432	m3.2xlarge	us-gov-west-1a	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m3.2xlarge-pool-1 1	i-16a4f434	m3.2xlarge	us-gov-west-1a	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m3.2xlarge-pool-1 2	i-14a4f436	m3.2xlarge	us-gov-west-1a	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m3.2xlarge-pool-1 3	i-1aa4f438	m3.2xlarge	us-gov-west-1a	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m3.2xlarge-pool-1 4	i-18a4f43a	m3.2xlarge	us-gov-west-1a	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m3.2xlarge-pool-1 5	i-1ea4f43c	m3.2xlarge	us-gov-west-1a	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m3.2xlarge-pool-1 6	i-1ca4f43e	m3.2xlarge	us-gov-west-1a	running	2/2 check...	None			ariamh	2013-12-11T07...	allports
ARIAMH-worker-m3.2xlarge-pool-1 7	i-82a4f440	m3.2xlarge	us-gov-west-1a	running	2/2 check...	None			ariamh	2013-12-11T07...	allports

Facetted Data Product Repository

- Facetted view of data products
 - Enable users to “drill down” into multi-dimensional facets of data
 - Sequentially applies constraints
- Facets for *reverse geocoding* for all data products
- Interactive *leaflets*

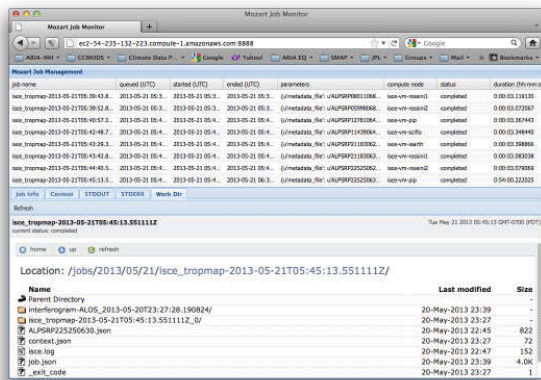


The screenshot displays the 'Facet Search' web application interface. The browser address bar shows the URL: [https://grq.jpl.nasa.gov:8869/7?source=\[\"query\":{\"bool\":{\"must\":{\[\"rangi\"}\]}\]}&page=1](https://grq.jpl.nasa.gov:8869/7?source=[\). The page features a search bar with the text 'nunalit' and a 'Facet Search' navigation menu. The main content area is divided into two columns. The left column contains several facet panels, each with a search icon, a count, and a 'range' button. The facets include: 'spaceraft' (CSKS1 (9)), 'orbit direction' (dsc (9)), 'look direction' (right (9)), 'orbit number' (a list of numbers from 35240 to 33344), 'track number' (164 (9)), 'swarm number' (10 (9)), 'version' (B-SF (8), B-FF (1)), and 'sensing date'. The right column displays search results for 'activevolcanoes' in 'United States', 'Hawaii County', 'dsc', and 'CSKS1' from '2013 Aug to 2013 Dec'. It shows a list of results with details for each, including tags, continent, location, bounding box, sensing start/stop, spacecraft name, orbit direction, look direction, orbit number, orbit repeat, track number, product type, and requester. Two sample results are shown, each with a satellite image and a map of Hawaii highlighting the location of Hawaiian Paradise Park.

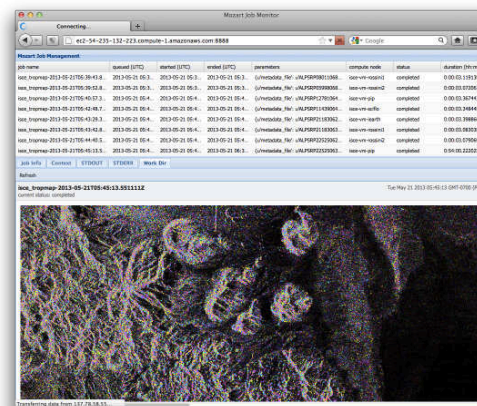
Data Access



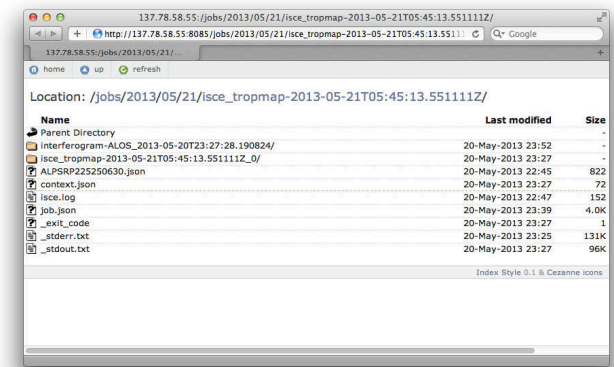
- Leverages interoperable WebDAV specification
- Extended from prior ACCESS-2011 work
- Enable access to data products via various interfaces



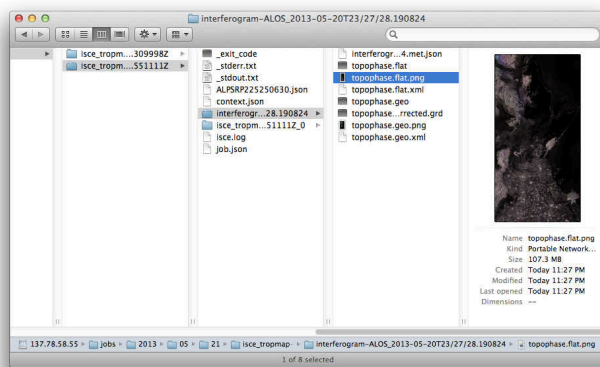
Job Management: browse remote jobs



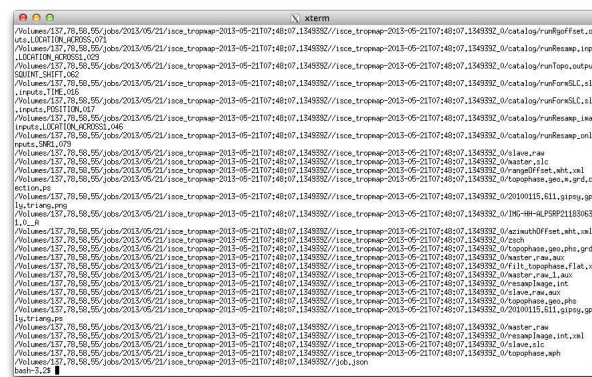
Job Management: browse "first looks"



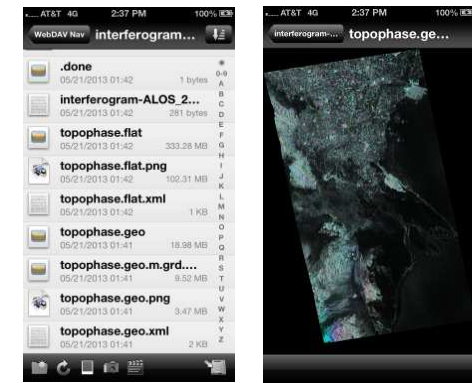
Web Interface to Repository of Data Products



MACOSX Finder: drag-and-drop to local file system mount

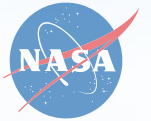


Command-line interface



Mobile phone interface

Conclusions



- The global coverage offered by satellite-based SAR missions, and rapidly expanding GPS networks can provide orders of magnitude more observations and improve hazard response
 - ...if we have a data system that can efficiently monitor and analyze the voluminous data, and provide users the tools to access data products.
- Hybrid cloud may be more effective for these needs
 - Do “keep up” processing **on-premise**
 - **Off-site** elasticity (bursting)
- Hybrid cloud computing may be a more effective approach to addressing lower latency and high data volume processing needs
- PB-scale data volumes in cloud computing and storage significant enough to **affect architectural design of data system**
- Lowest common denominator of services
 - Compute, Block storage, Bucket Storage, VM, and Identity
- Package management (e.g. Puppet/Chef) key to ease of deployment across cloud stacks
- Monitoring of events for automatic processing
- Monitoring of data products for custom actions