Performance and Cost Evaluation of Public Cloud Cold Storage Services for Astronomy Data Archive and Analysis

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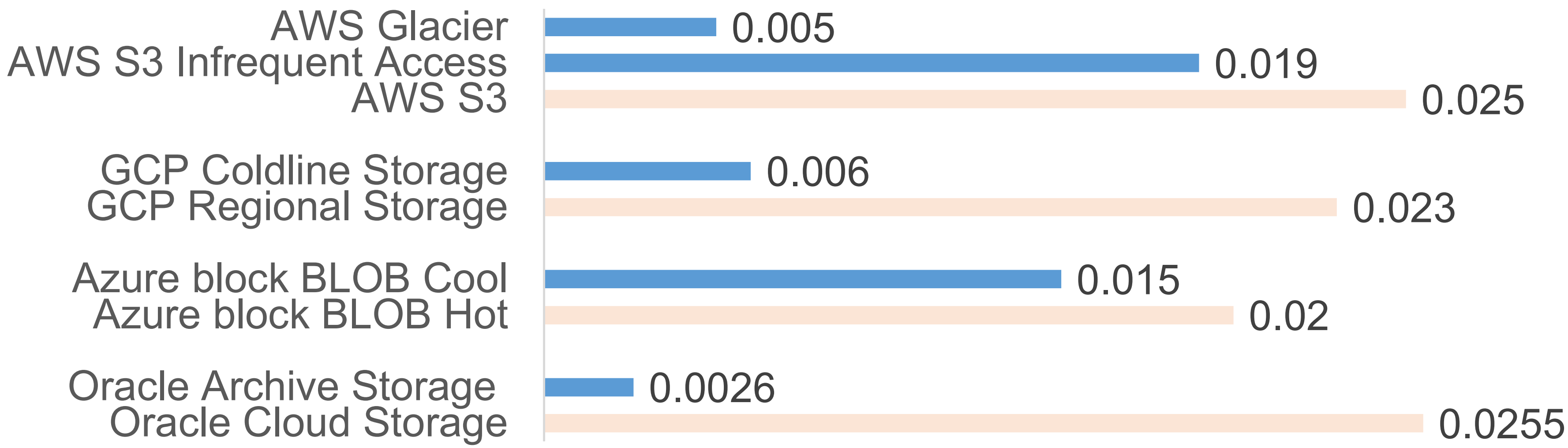
Hiroshi Yoshida, Kento Aida

Center for Cloud Research and Development,
National Institute of Informatics

Cloud Cold Storage Services

- Major public IaaS providers provide cold storage services.



Price unit: USD/(GB*month) [as of September 2020, **Japan region**

- Data store charge is relatively inexpensive compared to standard object storage services (2/3 - 1/10).
- Drawbacks
  - Time consuming restoration process (hours)
  - Extra charge for data retrieval
  - Minimal retention period (30 – 90 days)
  - Limited performance, or extra charge for additional performance
  - Reduced availability

Experiment in Cloud Cold Storage Services

- **Is it possible to adopt cloud cold storage to store a large amount of scientific research data for a long time?**
  - Expectation
    - Data store in clouds: Reduction of TCO and storage management labor
    - Data analyses in clouds: Flexibility to adapt to resource requirement

- Performance and cost of public clouds in scientific applications have not been well studied.
  →Difficult to determine whether cold storage services meet the performance requirements of research applications
  →Difficult to assess the feasibility of storing and accessing research data in cold storage services in terms of cost

- Evaluation using astronomical research data and applications
  - Store the observation and analysis data of the ALMA telescope project
  - Port the data archive system “NGAS” to AWS
  - Run common analysis applications “CASA” on a variety of instances to analyze the retrieved observation data inside cloud

Data and Application Used in the Experiment

■ Archive data

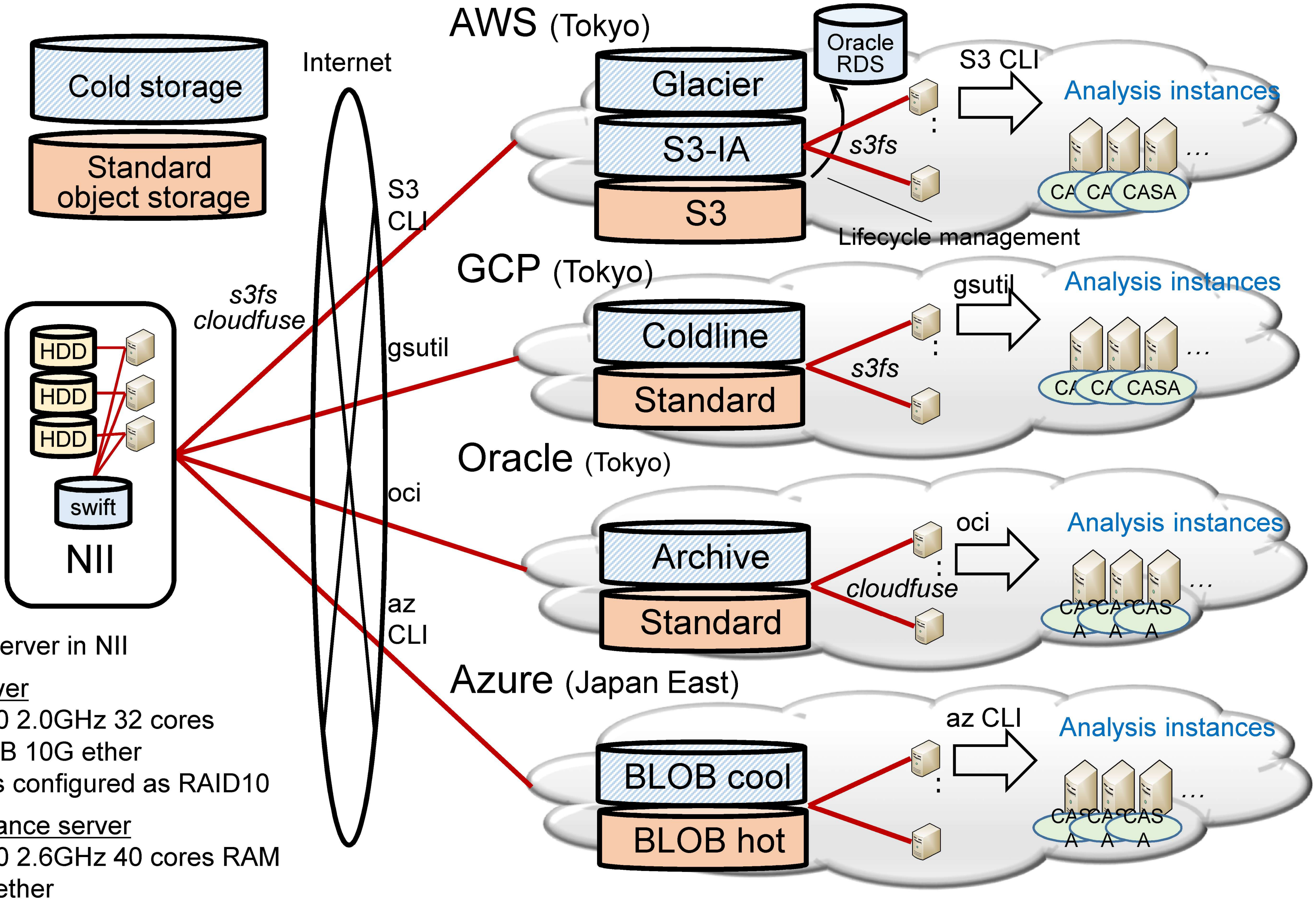
Data contents	ALMA radio telescope Observation/analysis data provided by National Astronomical Observatory of Japan (NAOJ)
Quantity	**58.5TiB, 1,380,000 files**
Size	Average 44MiB (falls between smaller than 1MiB and larger than 100GiB)
Application	Archive management: NGAS (Next Generation Archive System)

■ Analyzed data

Category	Number of datasets	Estimated analysis time	Size (GiB)	Number of included files
Small	3	≃ 1 hour	0.4～ 0.6	99～ 267
Medium	3	≃5 hours	2.2～ 3.9	240～4,000
Large	3	≃1 day	9.0～26.1	2,421～3,879
XLarge	1	≫ 1 day	87.3	456

■ Application: CASA (Common Astronomy Software Applications)

Experiment Environment



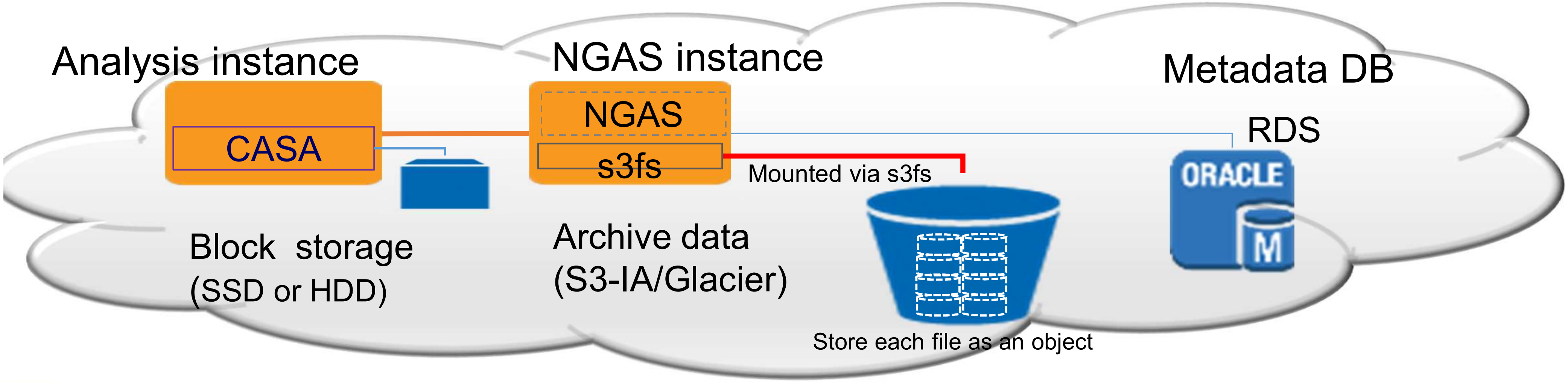
On-premise server in NII

Standard server
Xeon E5-2650 2.0GHz 32 cores
Memory 64GiB 10G ether
External disks configured as RAID10

High performance server
Xeon E5-2660 2.6GHz 40 cores RAM 128GiB 10G ether
External RAID connected via iSCSI

Target of experiments and System Configuration

- First step (FY2017 – FY2018)
  - Evaluate performance, cost, and manageability by porting archive management system NGAS to AWS and storing archive data in S3-IA and Glacier
- Second step (FY2019-)
  - Analyze observation data on public cloud instances to evaluate performance and cost
  - Investigate optimal selection and usage of instances



First Step Experiment

- First step (FY2017 – FY2018)
  - Evaluate performance, cost, and manageability
    by porting archive management system NGAS to AWS
    and storing archive data in S3-IA and Glacier
- Second step (FY2019-)
  - Analyze observation data on cloud instances on the instances of public cloud services to evaluate performance and cost
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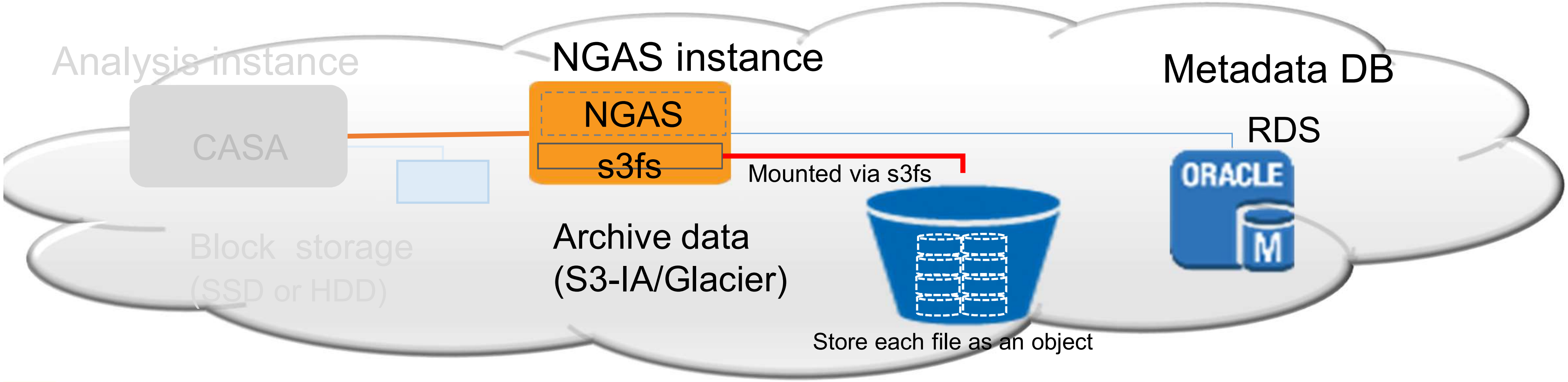
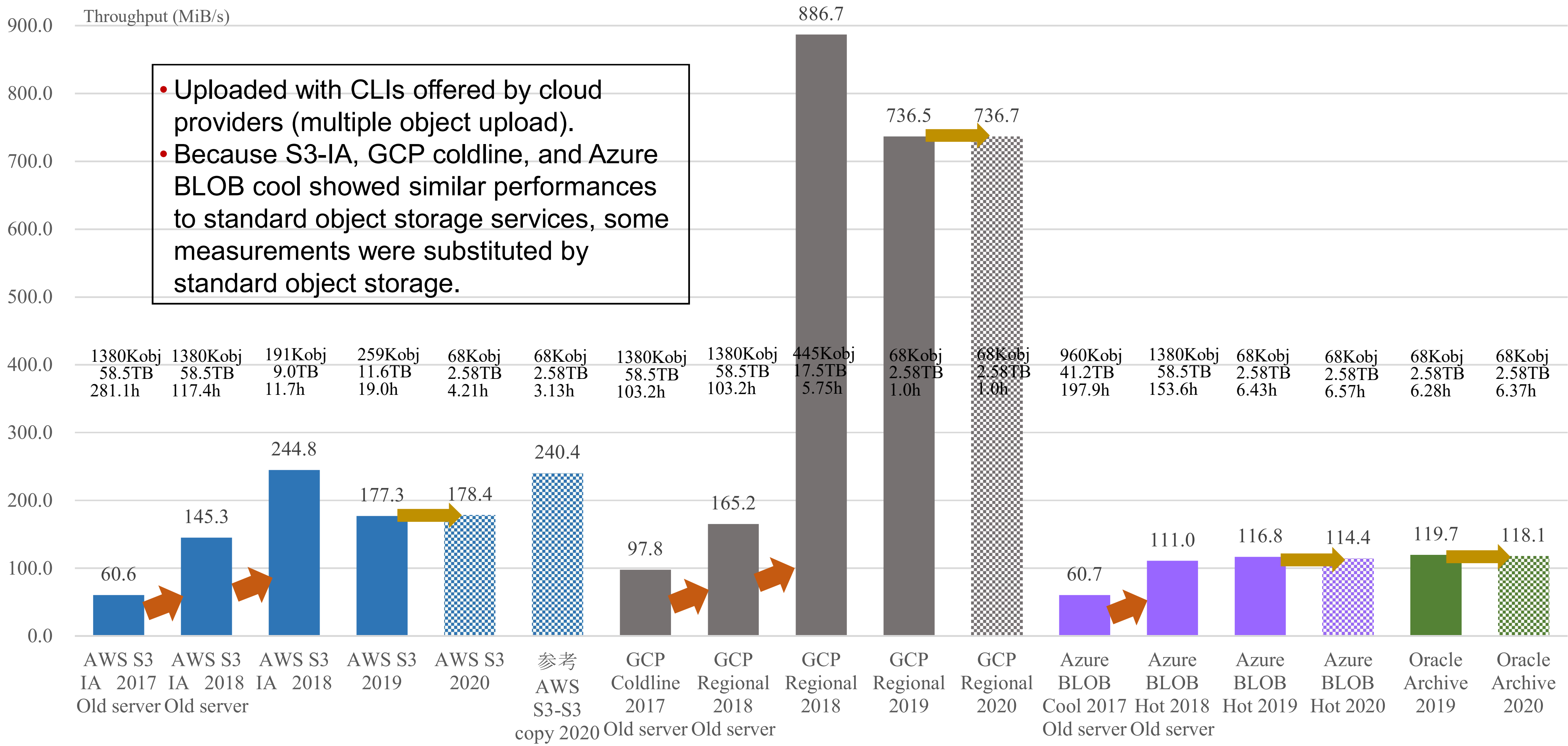


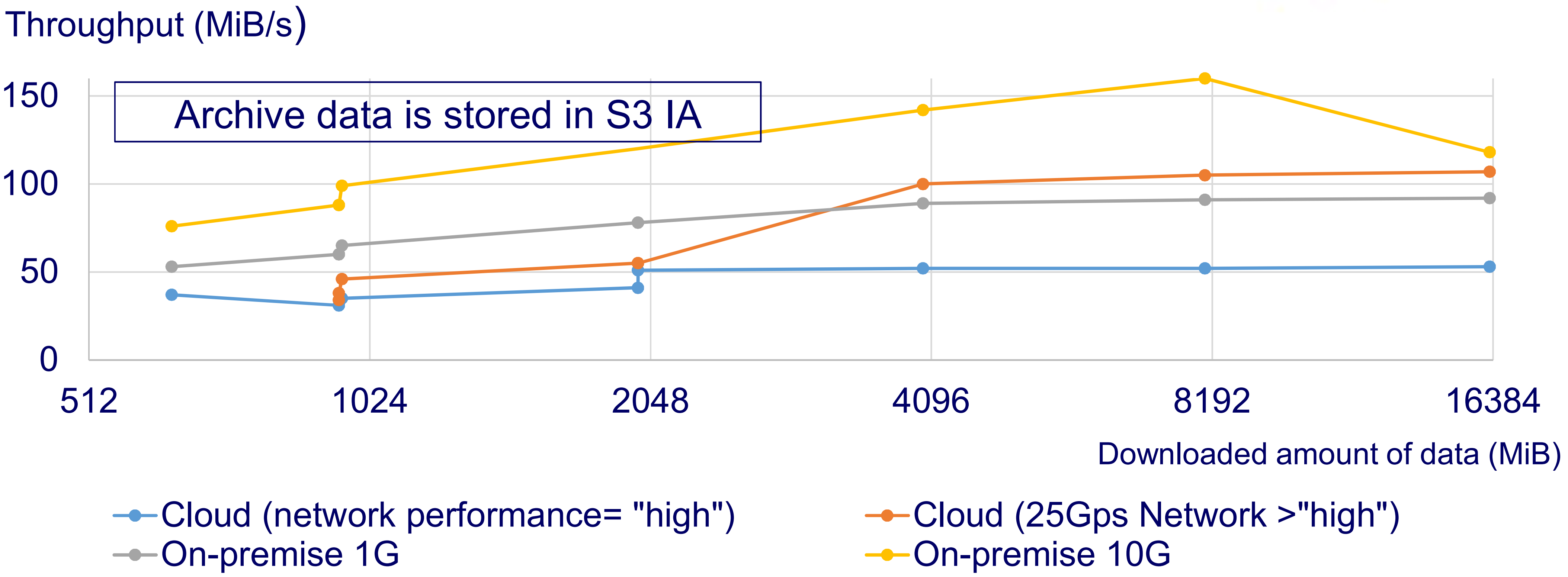
Performance of Uploading Archive Data via Internet



- Uploaded with CLIs offered by cloud providers (multiple object upload).
- Because S3-IA, GCP coldline, and Azure BLOB cool showed similar performances to standard object storage services, some measurements were substituted by standard object storage.

- The performance requirements can be generally fulfilled.
- Significant Performance improvement between 2017 and 2018
  - No performance increase after 2018

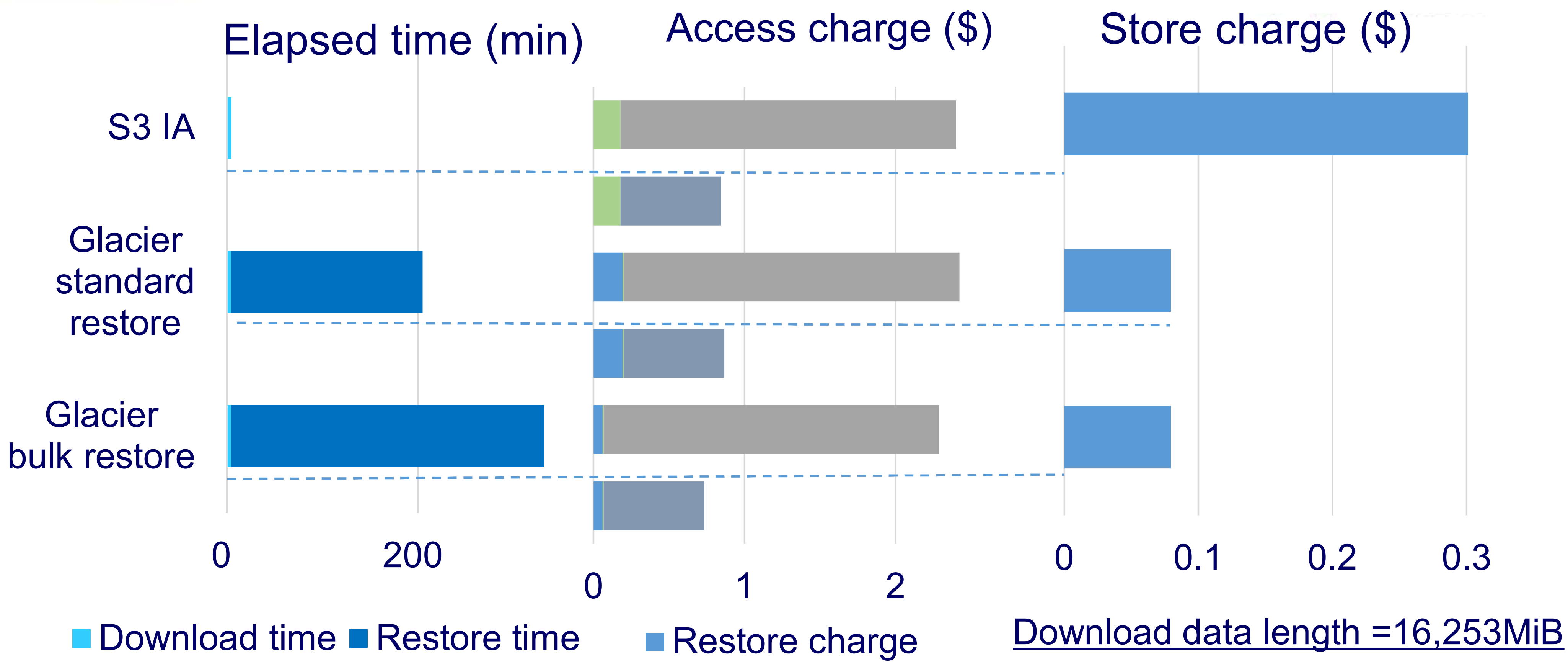
Data Download Performance of NGAS



- Performance of cloud NGAS is lower than that of on-premise NGAS
  - Possible causes
    - Performance difference between S3 and on-premise storage
    - Overhead of s3fs
    - Too small RDS instance
- Throughputs can be increased by increasing network performance

  → Practical performance can be achieved with appropriate sizing.

Download Performance and Cost of NGAS on AWS

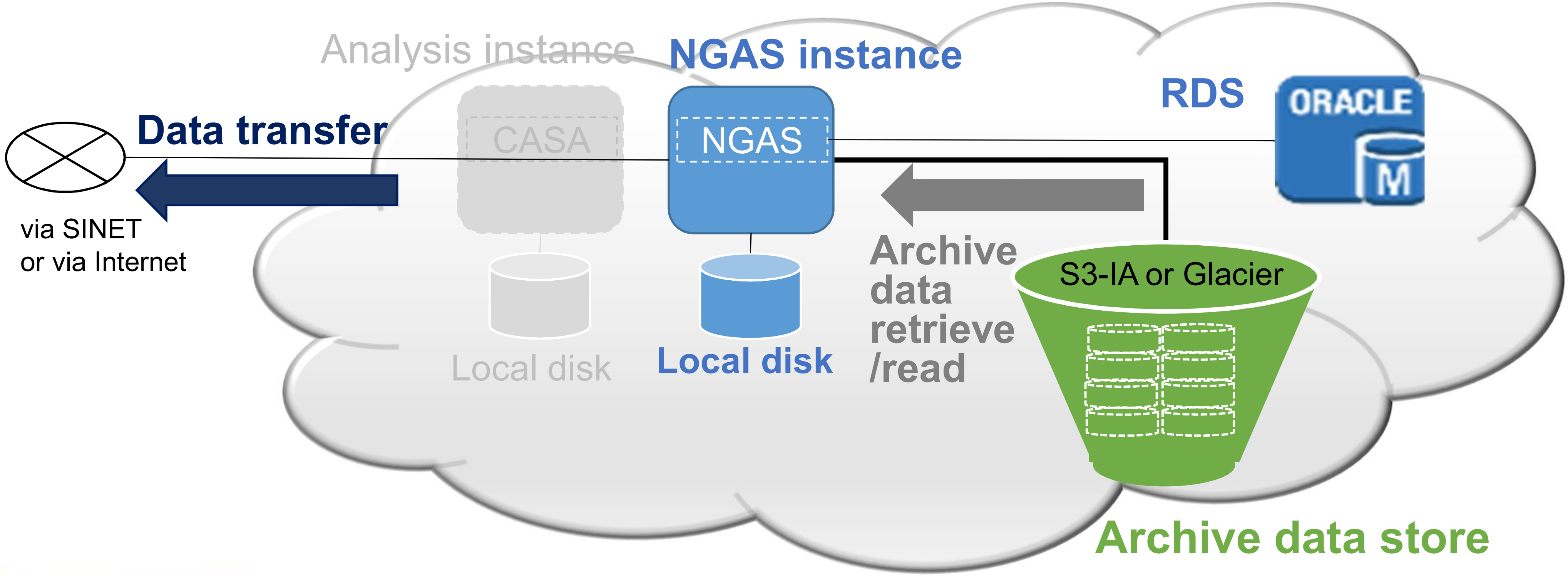


- ✓ S3 IA: actual measurement
- ✓ Glacier performances are estimated from manual restore operations

- A retrieval from cold storage requires read cost and retrieve cost.
- Restore time and cost are required in Glacier, instead of low store cost.
- Large egress transfer costs are required.

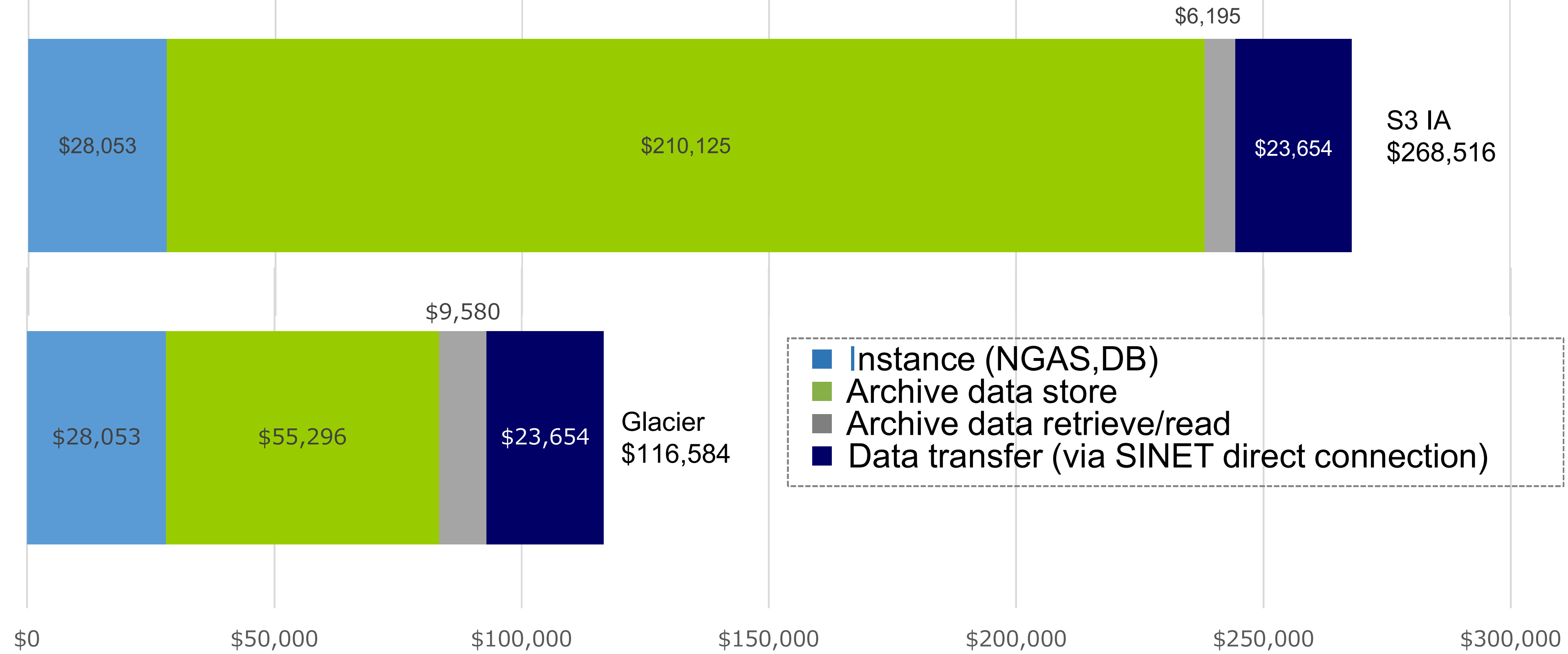
Cost Estimation Model of NGAS on AWS

- Parameters
  - Charge for NGAS and RDS instances
    based on instance types and local disk capacity
  - Capacity of archive data store
  - Amount of archive data retrieval/read
    - Read request charge can be converted
      to the proportional charge to the retrieval amount approximately .
  - Amount of egress data transfer



Yearly Cost Estimation of NGAS on AWS

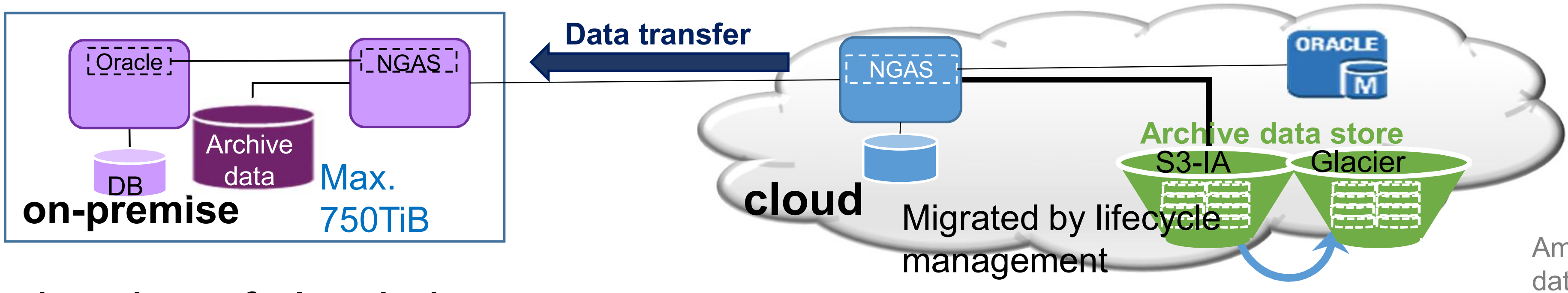
- Store 900TiB archive data in S3- IA / Glacier and retrieve 550TiB/year



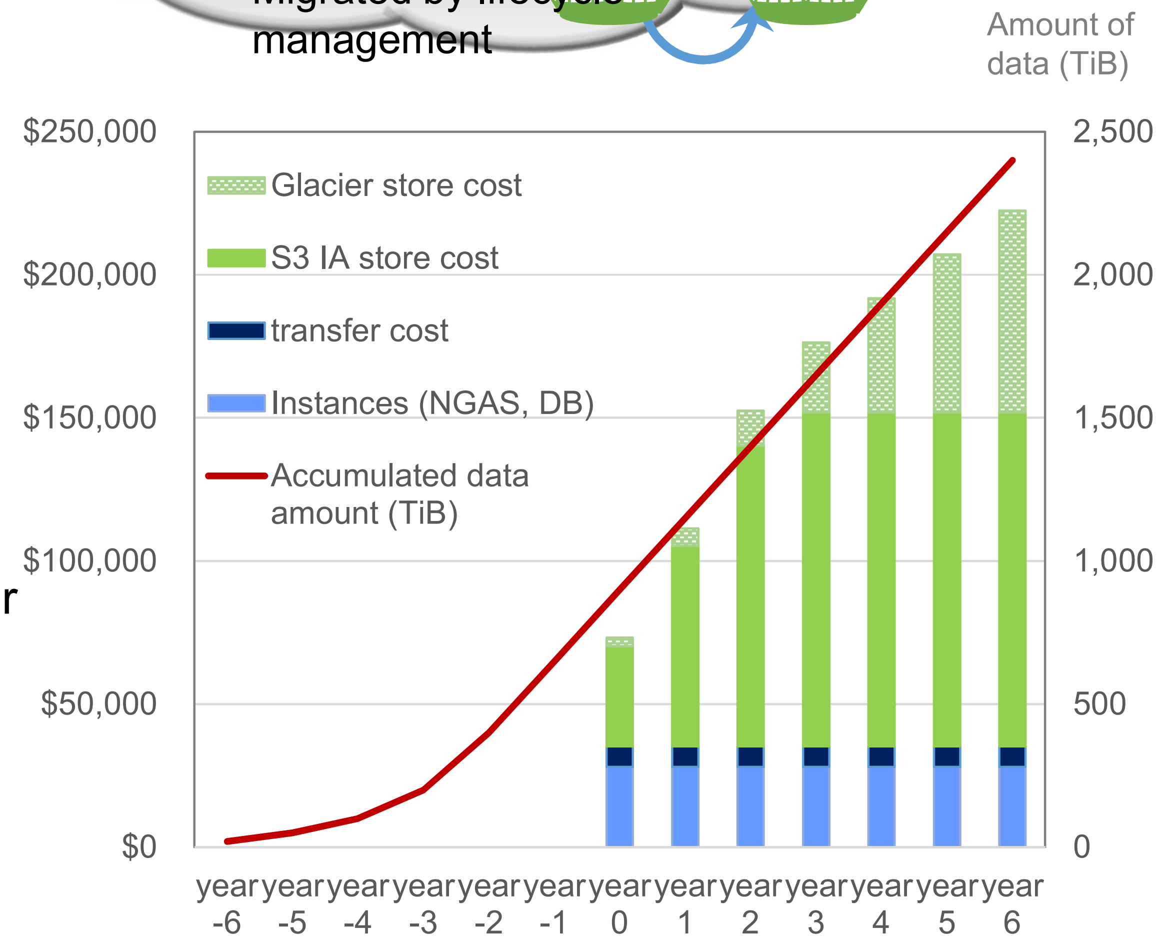
- Store cost of Glacier is less than one third of that of S3 IA
  - Tiered storage including Glacier, S3 IA, and on-premise archive can be a solution to balance cost saving with the disadvantages of retrieval time.
- Relatively high egress transfer cost
  → Motivation for the second step experiment (analyses in cloud)

Hybrid Configuration of Archive System

- Tiered storage including Glacier, S3 IA, and on-premise storage

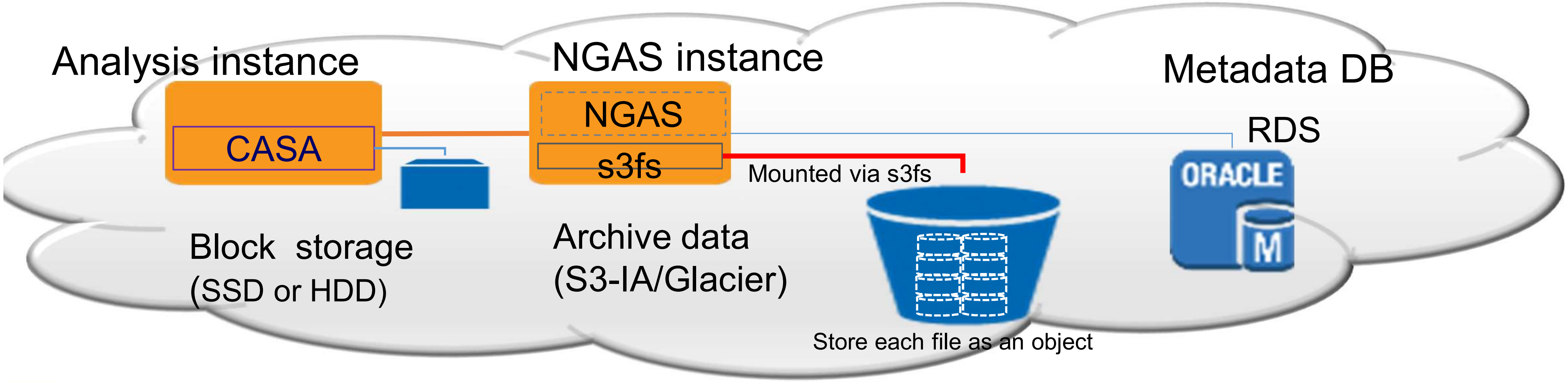


- Estimation of cloud charge in a hybrid configuration
  - Amount of archive data is 900TiB in year 0; increases 250TiB/year
  - Datasets are stored in on-premise storage for 3 years, S3 IA for 2 years, and then migrated to Glacier.
  - Amount of downloads is 550TiB/year; 20% from S3 IA and 10% from Glacier (**i.e. only 10% of downloads require additional 200 minute restore time**).



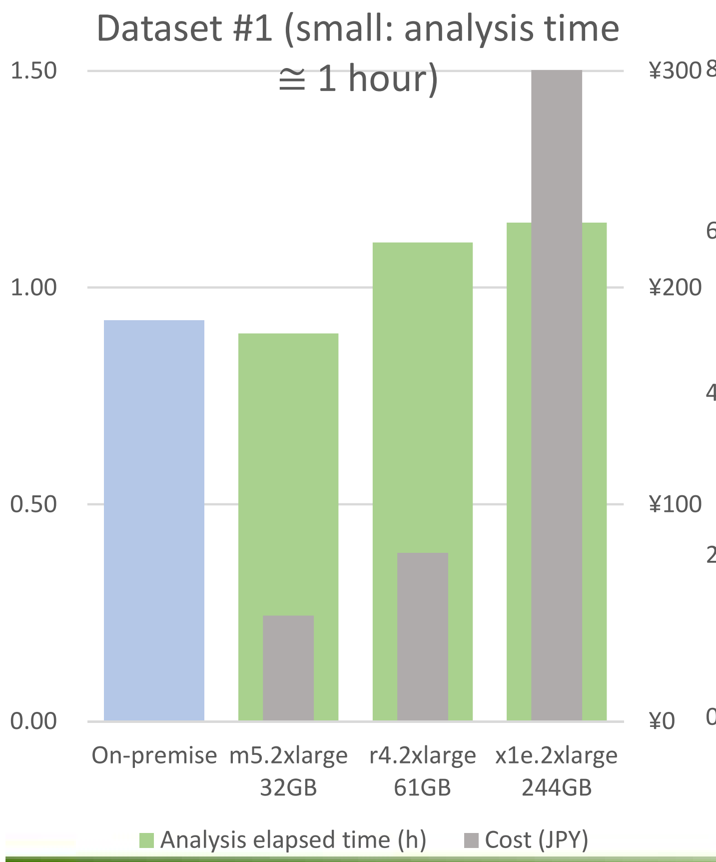
Second Step Experiment

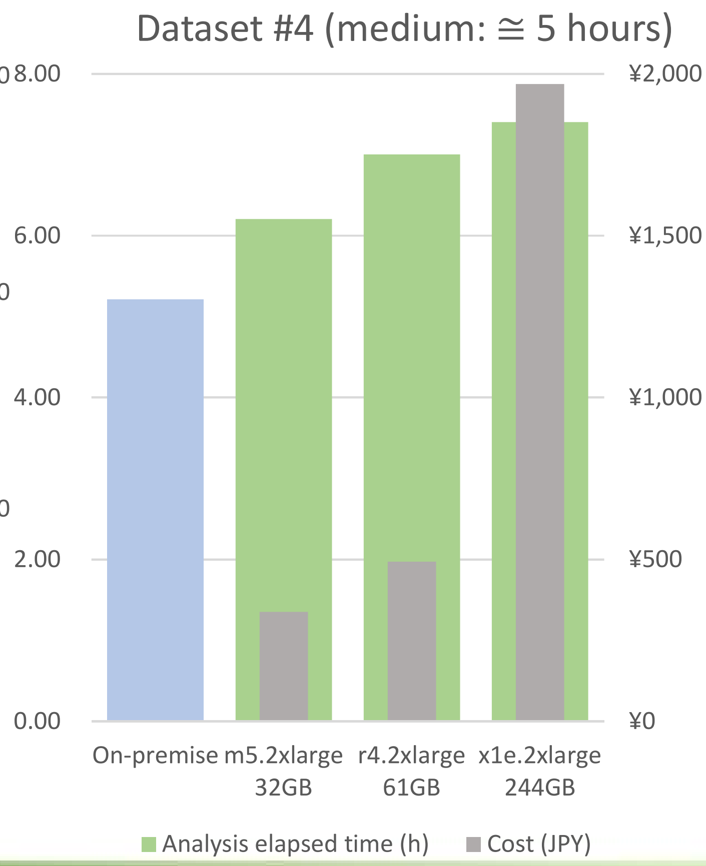
- First step (FY2017 – FY2018)
  - Evaluate performance, cost, and manageability by porting archive management system ”NGAS” to AWS and storing archive data in S3-IA and Glacier
- Second step (FY2019-)
  - Analyze observation data on public cloud instances to evaluate performance and cost
  - Investigate optimal selection and usage of instances

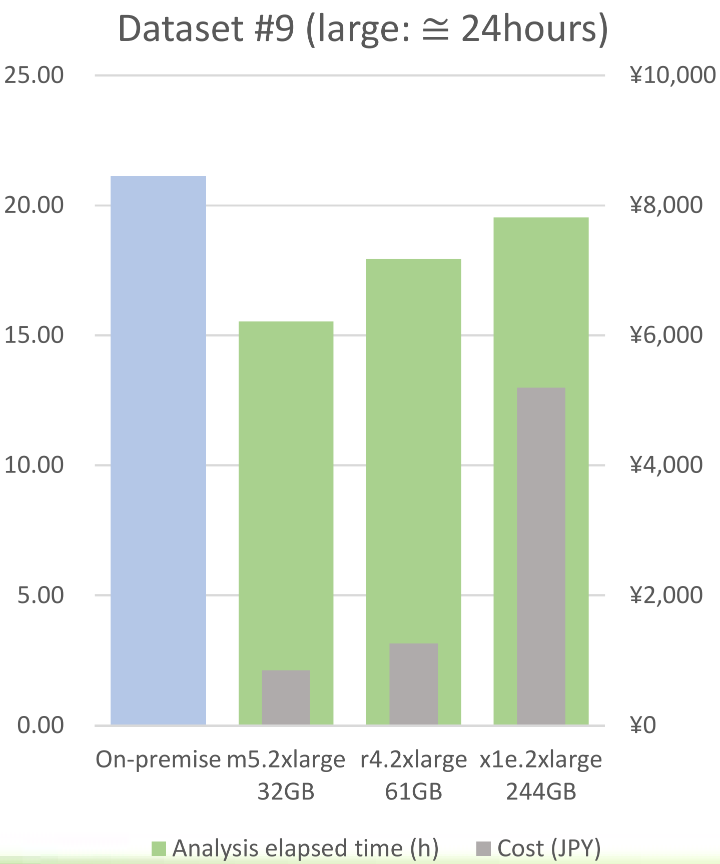


Elapsed Time and Cost of Data Analyses in AWS

- Enough performance for practical use
- Performance differences are not caused by the differences of memory capacity but by the differences of instance generation.
  - The analyses of chosen datasets don't require large memory capacity.
  - 61GB and 244GB memory instances belong to the older generations.



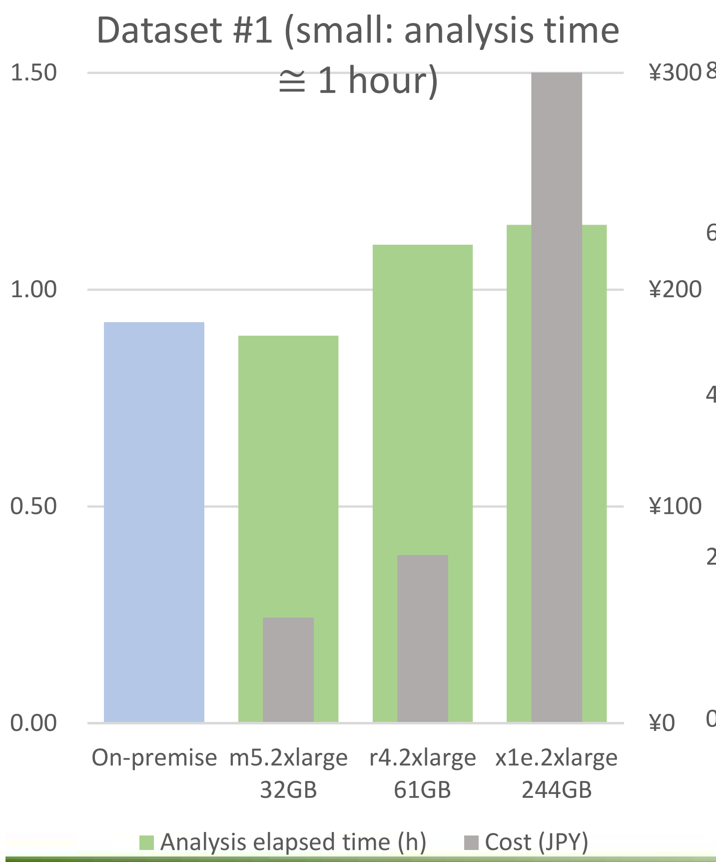


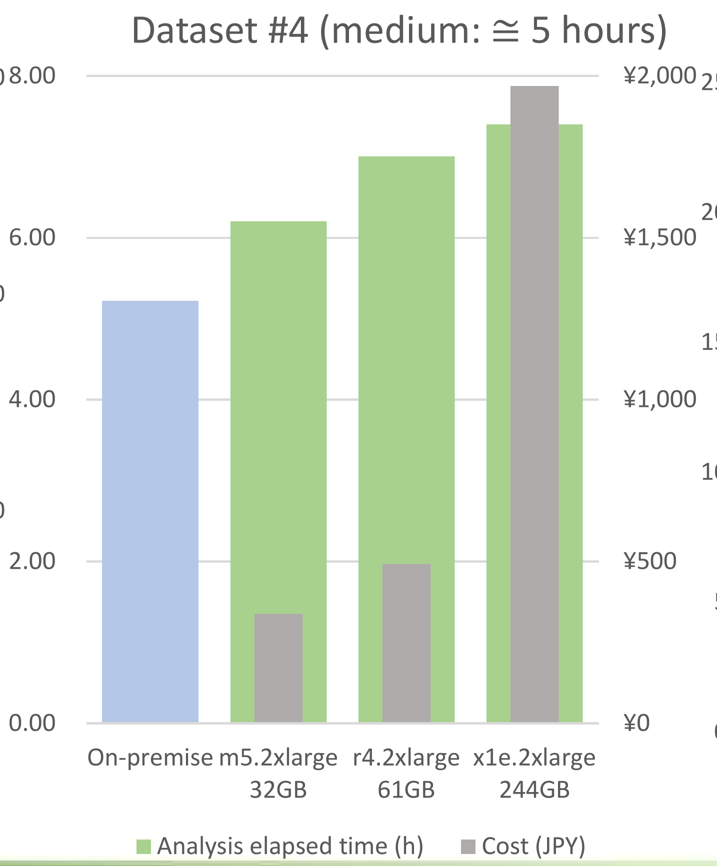


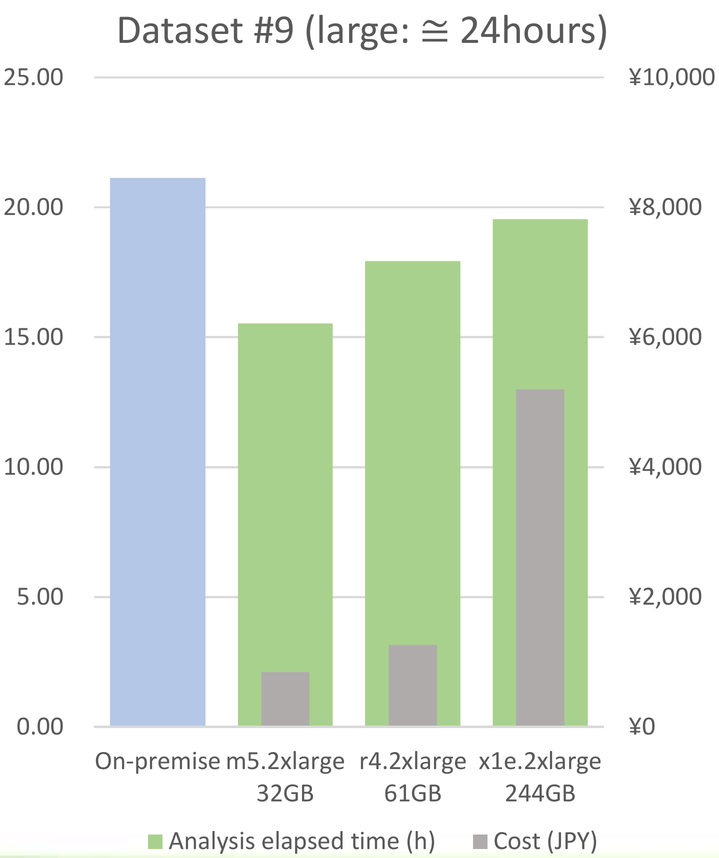
Elapsed Time and Cost of Data Analyses in AWS

- Instances with large capacity memories are expensive.
- A new generation instance is usually less expensive than old generation one with the same specification.

→Adopt new generation instances whenever possible
Select instances with appropriate memory capacity



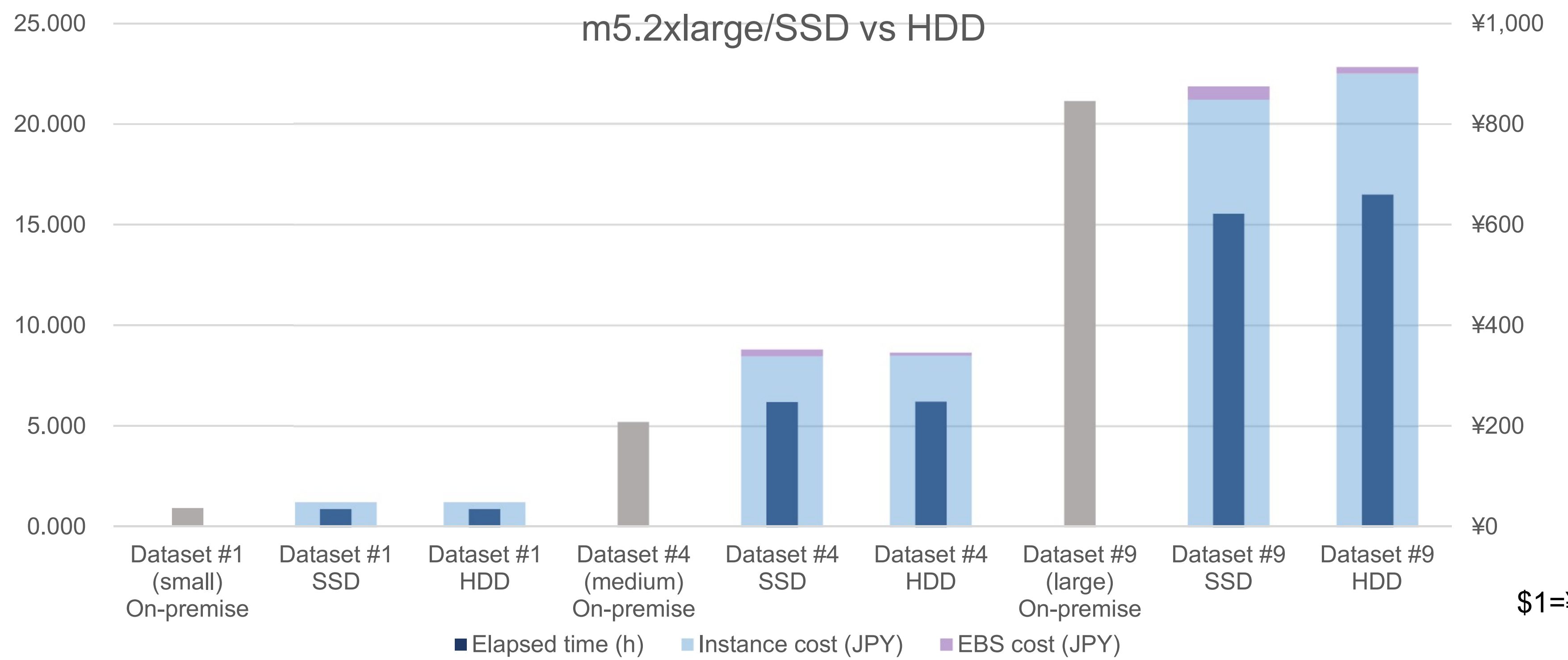




Cost Optimization Points (1): SSD vs HDD

- SSD and HDD can be chosen as block storage media.
  - Analysis data, working data, final results are stored in block storage.
- Up to 20% reduction of elapsed time by using SSD
- The increase of instance charge caused by the increase of elapsed time is higher than the cost difference between SSD and HDD.

  →In CASA cases, SSD is always better.



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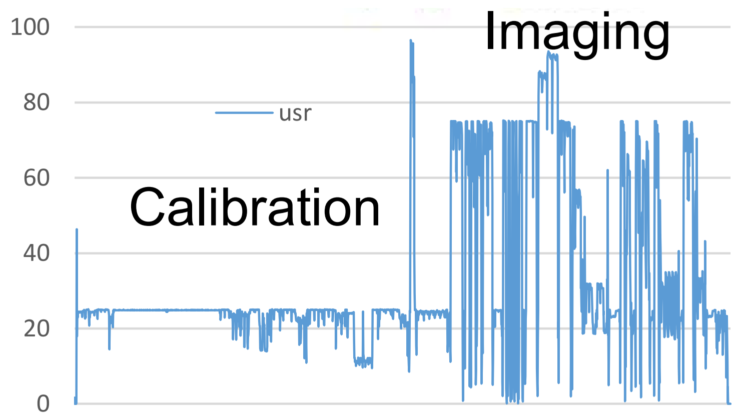
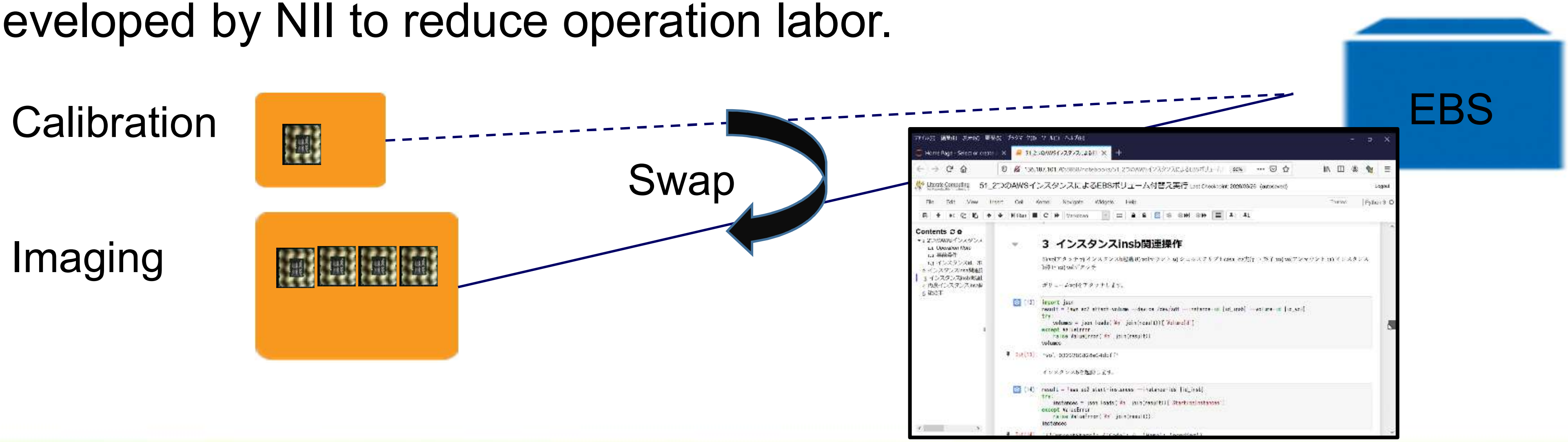
Cost Optimization Points (2): Instance Swap

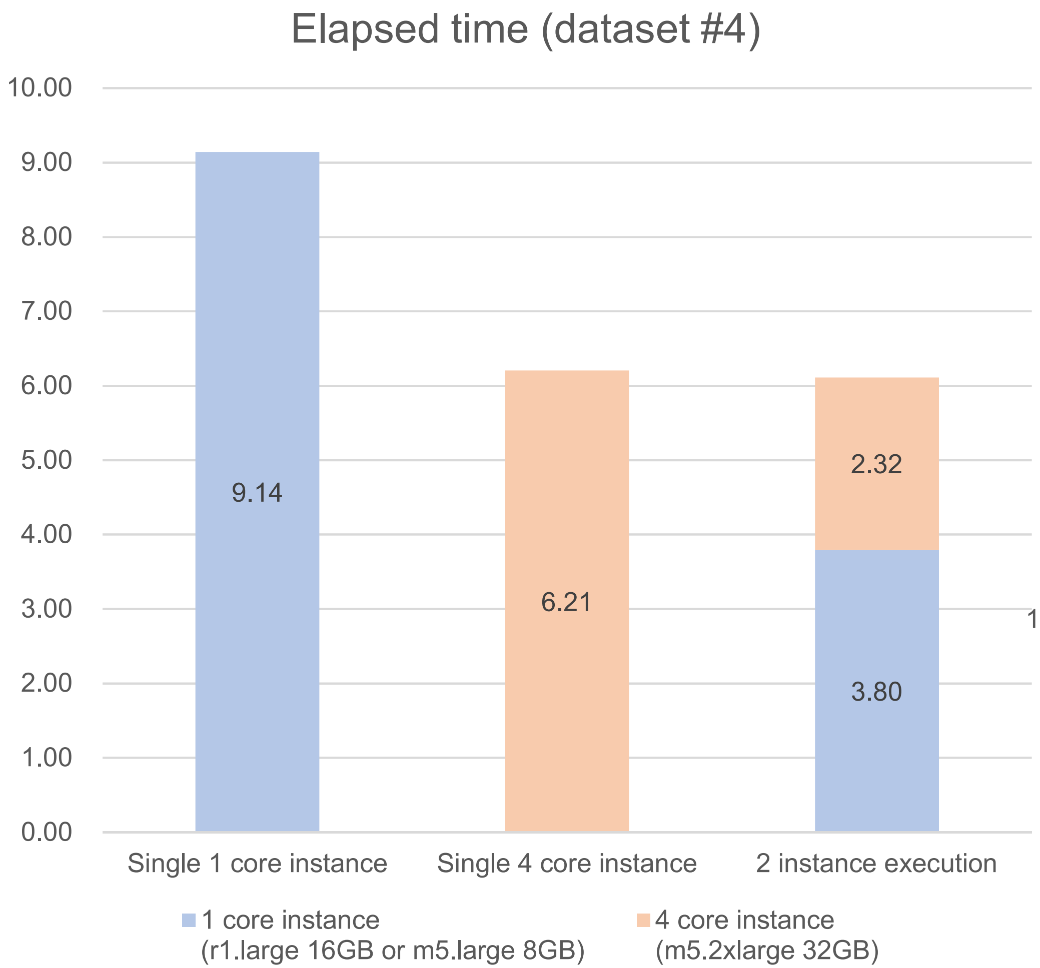


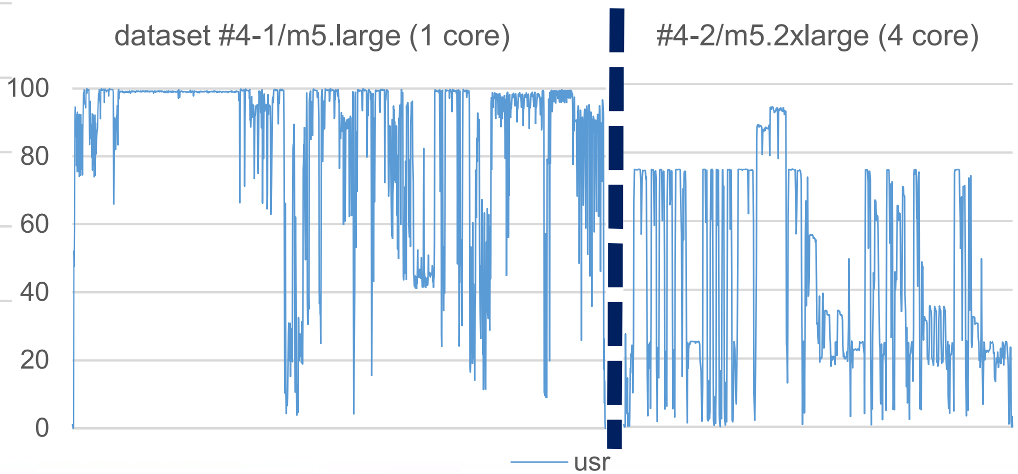
- Observation
  - Calibration is performed mostly on 1 core.
  - Imaging is performed on more cores.
  - Cloud block storage volumes can be dynamically attached to/detached from an instance using CLI and/or API
- Instance swap
  1) Perform calibration on a 1-core instance
  2) Attach the volume including working data to a multi-core instance and perform imaging
- The workflow is automated by using literate computing technology developed by NII to reduce operation labor.



Advantage of Instance Swap

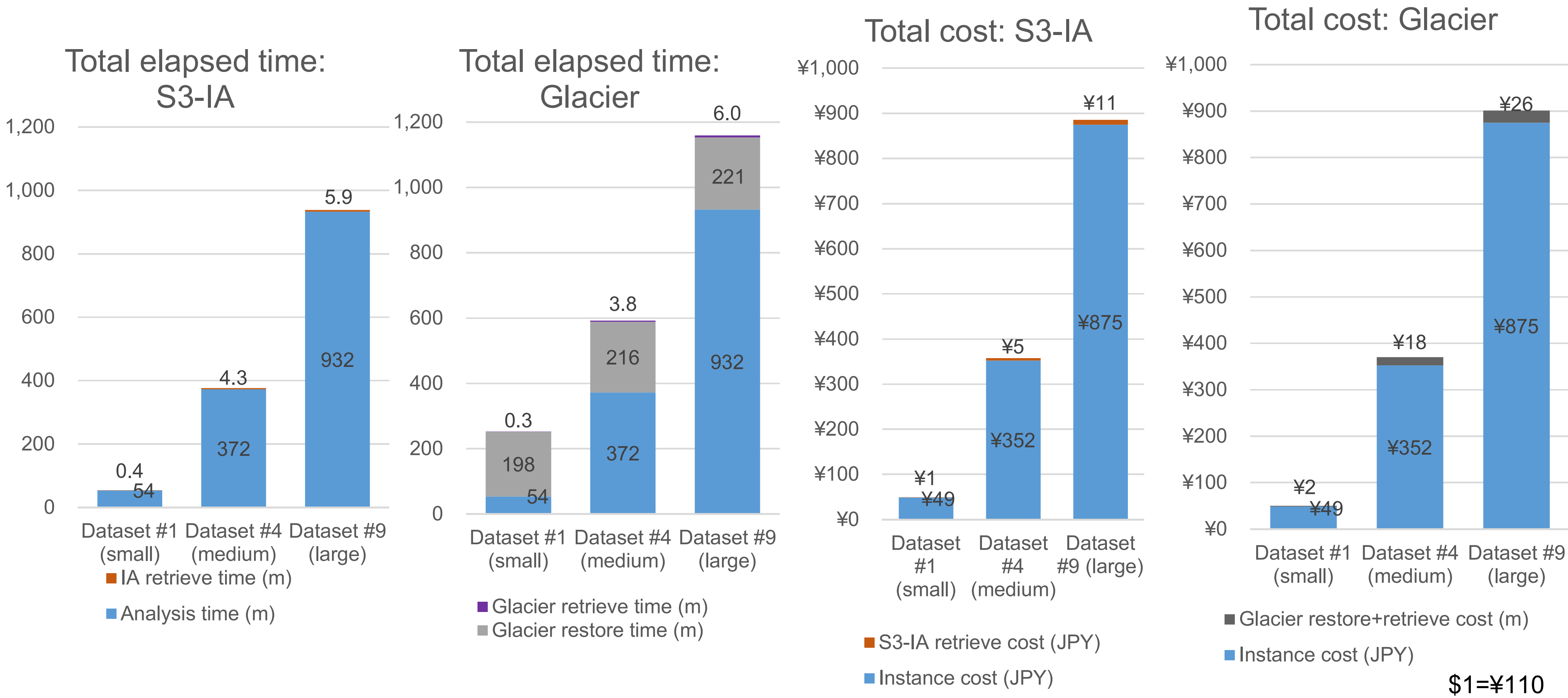
- Example: dataset#4
  46% cost reduction as the elapsed time is retained
  or 49% higher performance with additional 12% cost





Performance and Cost from Archive to Analysis

- Retrieving and analyzing datasets archived in S3 IA and Glacier
  - Total elapsed time
  - Total cost



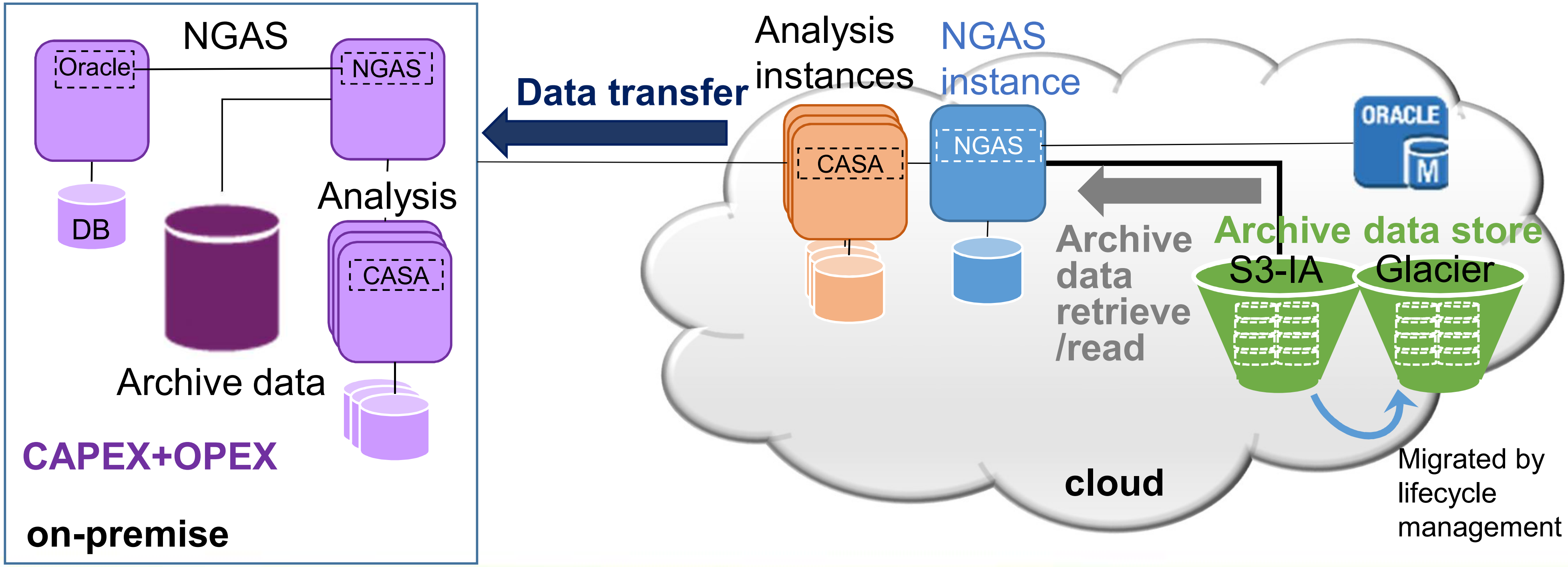
- Glacier is advantageous to store cost in spite of long elapsed time and extra charge
  - 200 minute restore time before analysis
  - Restore operation charge

Hybrid Configuration Including Analysis System

- Optimization points of archive location and analysis location
  - Access frequency of datasets based on the age of data
  - Performance (1) data retrieval (2) data transfer (3) analysis
  - Cost ▪ Cloud charge (1) data store (2) data retrieve/read (3)egress data transfer (4) analysis instances
    ▪ CAPEX+OPEX of the on-premise system

✓ Resource deployment flexibility in cloud

✓ Usability and automatability of workflow



Summary

- Practical results on storing and analyzing scientific research data in cloud are acquired.

- Practically acceptable performance of data access can be achieved with appropriate sizing of resources and tuning of the system.
  - Inexpensive cold storage services (such as Glacier) are significant options in terms of store cost, although they require hourly restore time before accessing data.
    - Can be mitigated with an appropriate tiered storage architecture

- The cost estimation model enables to estimate total cost in cloud.
    - Data store and egress transfer costs are major parts of the total cost of the archive system.
    - Data retrieval costs of cold storage services have little effect.
  - The model is also capable to estimate cost on a hybrid system organized by clouds and on-premise systems.

Next Steps

- Establish methodology to estimate required resources such as number of cores, CPU usage patterns, memory capacity, and block storage capacity based on the dataset characteristics to choose optimal instance

- Optimization of the hybrid system configuration and archive/analysis locations

- Investigate optimizations of applications and usages of cloud services
  - Improve mapping between files and objects to accelerate restore operation
    e.g., 1 file to 1 object → multiple files to 1 object
  - Adopt cloud-native object storage API to improve performance
  - Instance swap

- Share the practical information and the best practices of cloud usage with researchers of other scientific field

NII

Inter-University Research Institute Corporation / Research Organization of Information and Systems

National Institute of Informatics