LADCO | LAKE MICHIGAN AIR DIRECTORS CONSORTIUM

Meteorology and Air Quality Modeling Using the AWS Parallel Cluster Cloud Service

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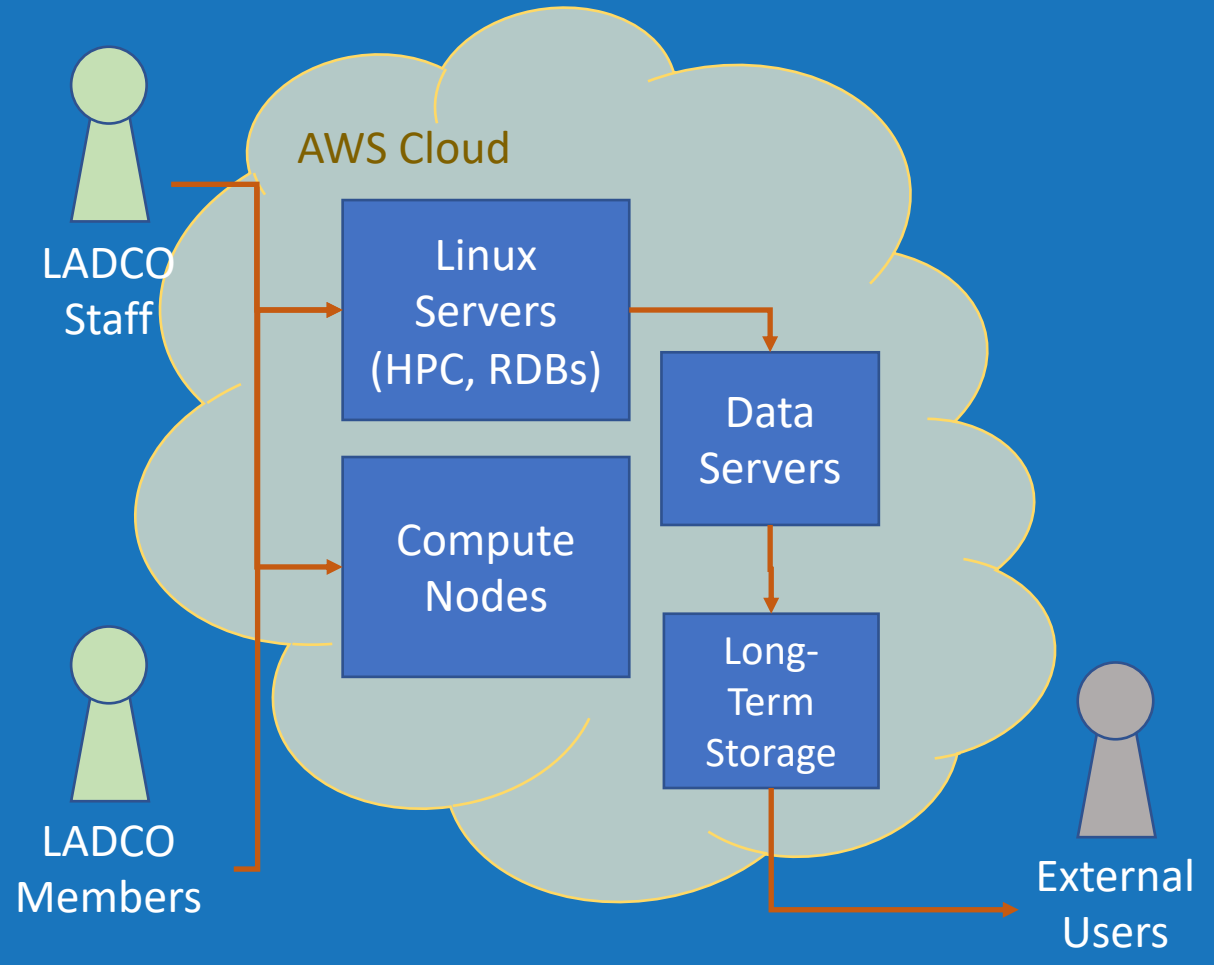
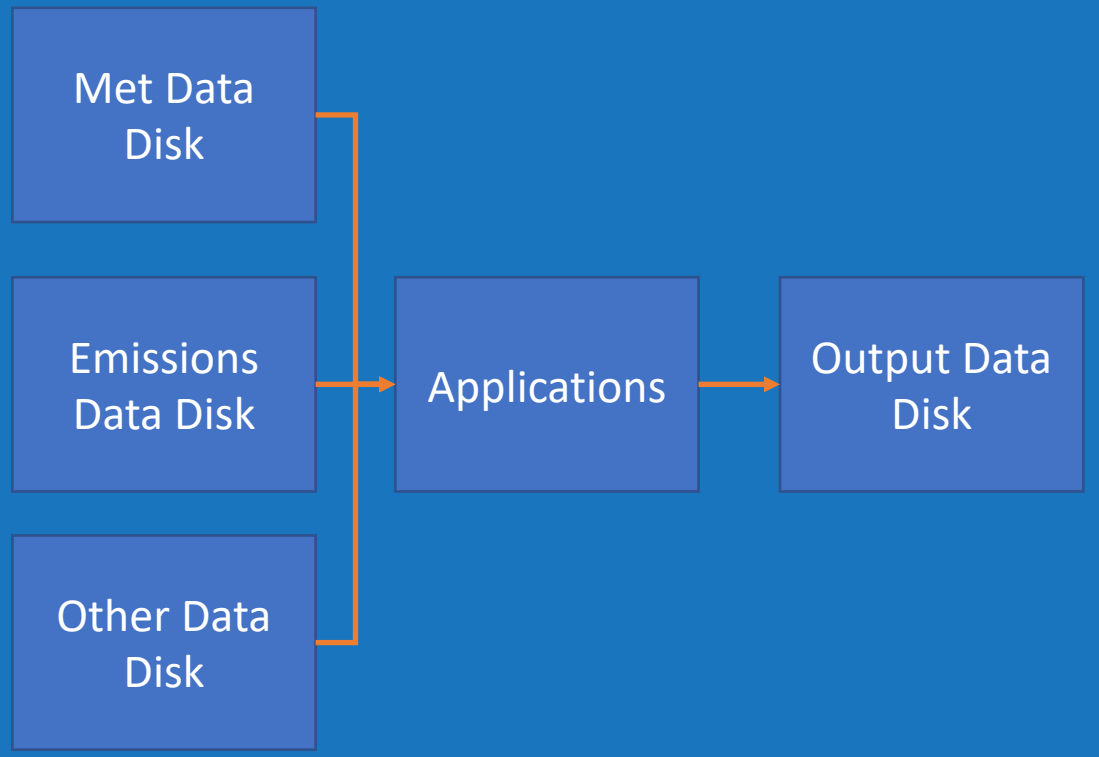
Why does LADCO need cloud computing?

- Supplement/replace the LADCO local compute cluster
- Access scalable high performance computing (HPC) resources
- Circumvent IT barriers at state air programs
- Enable collaboration in modeling and data analysis across the Consortium



Modeling Platform As a Service (PaaS)

- A PaaS is a pre-configured system with all data, software, and computing capacity needed for an application
- AWS Parallel Cluster provisions computing as needed and to meet demand
- LADCO modeling cluster includes all libraries and modeling software: WRF, SMOKE, CMAQ, CAMx, AMET, NCL, VERDI, R



Why Amazon Web Services Parallel Cluster?

- LADCO developer had familiarity with computing @ AWS
- At the time of development, AWS CfnCluster project was migrating to Pcluster
- How it works?

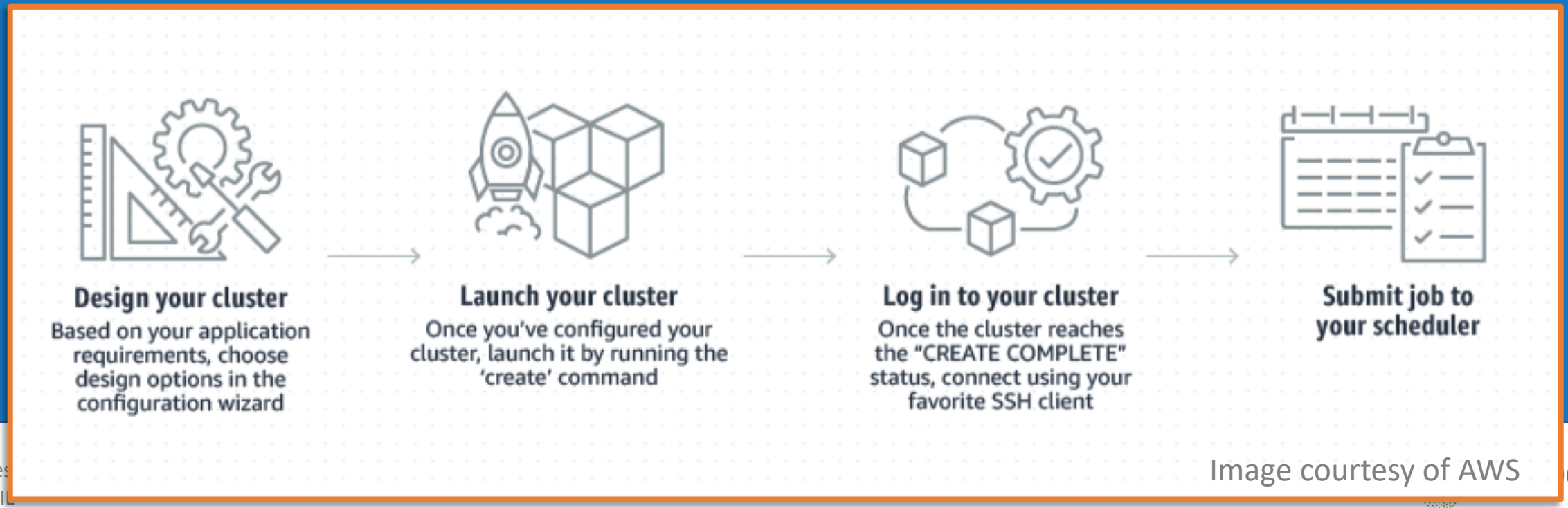
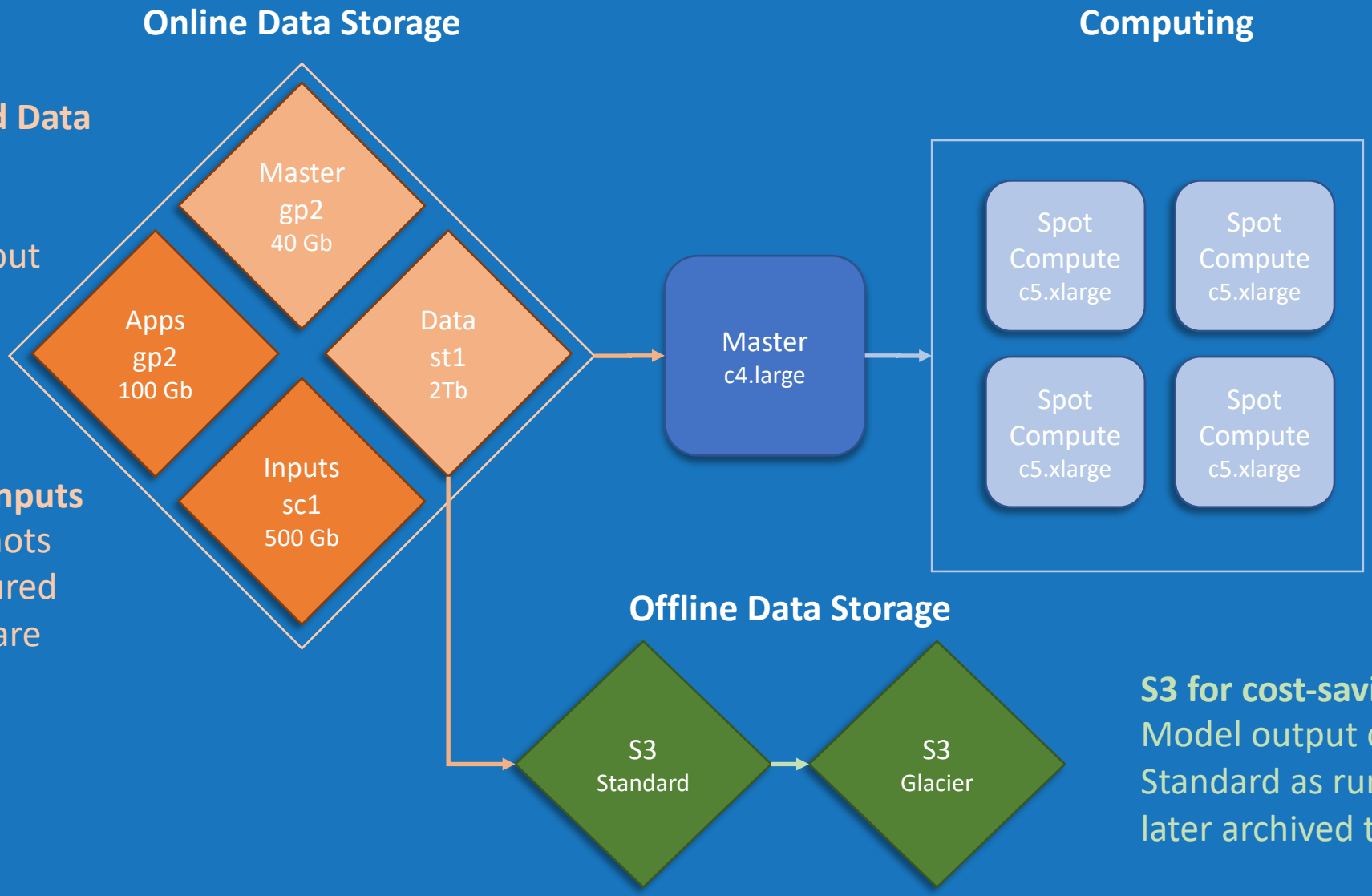


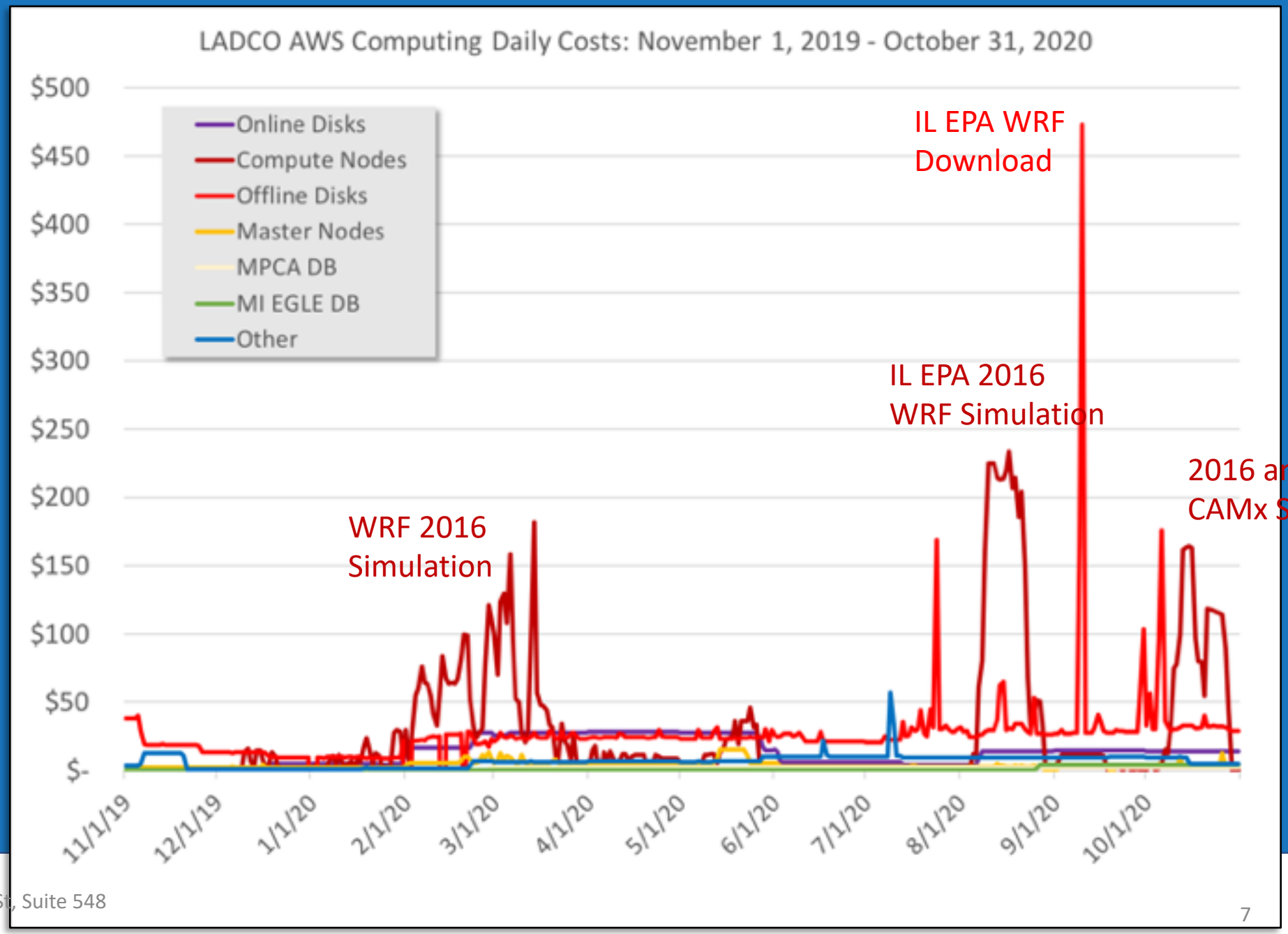
Image courtesy of AWS

LADCO AWS Modeling Schematic



LADCO Modeling Statistics @ AWS

Simulation	Simulation Period	EC2 Compute Instance	CPUs/ Run	Total CPUs	Hrs/ Run Day	CPU Costs ($)	$/Sim Day
WRF 12/4/1.33/1.33 Annual	15 days + 12 hour spin up	c4.2xlarge	48	1248	8	3,325	8.33
CAMx 12km 2016 and 2028	6 months + 10 day spin up	c4.2xlarge	64	256	1	2,220	2.81
CAMx 12km 2028 PSAT (28 srctags x N+S)	3 months + 10 day spin up	c4.2xlarge	96	384	4	3,830	9.22
CAMx 12km 2028 PSAT (31 src tags x N+S)	3 months + 10 day spin up	r5.2xlarge	96	384	4	3,210	7.74
CAMx 12km 2028 PSAT (24 region+src tags x N+S)	3 months + 10 day spin up	r5.2xlarge	96	288	6	3,860	9.53
CAMx 12km 2028 PSAT (25 region+src tags x N+S)	4 months + 10 day spin up	r5.2xlarge	96	384	5.5	2,420	5.83
CAMx 12km 2028 PSAT (25 region+src tags x Primary)	3 months + 10 day spin up	r4.16xlarge	96	384	6.5	4,825	11.63
CAMx 12km 2016 Annual	3 months + 10 day spin up	r4.16xlarge	64	256	1	1,160	2.80

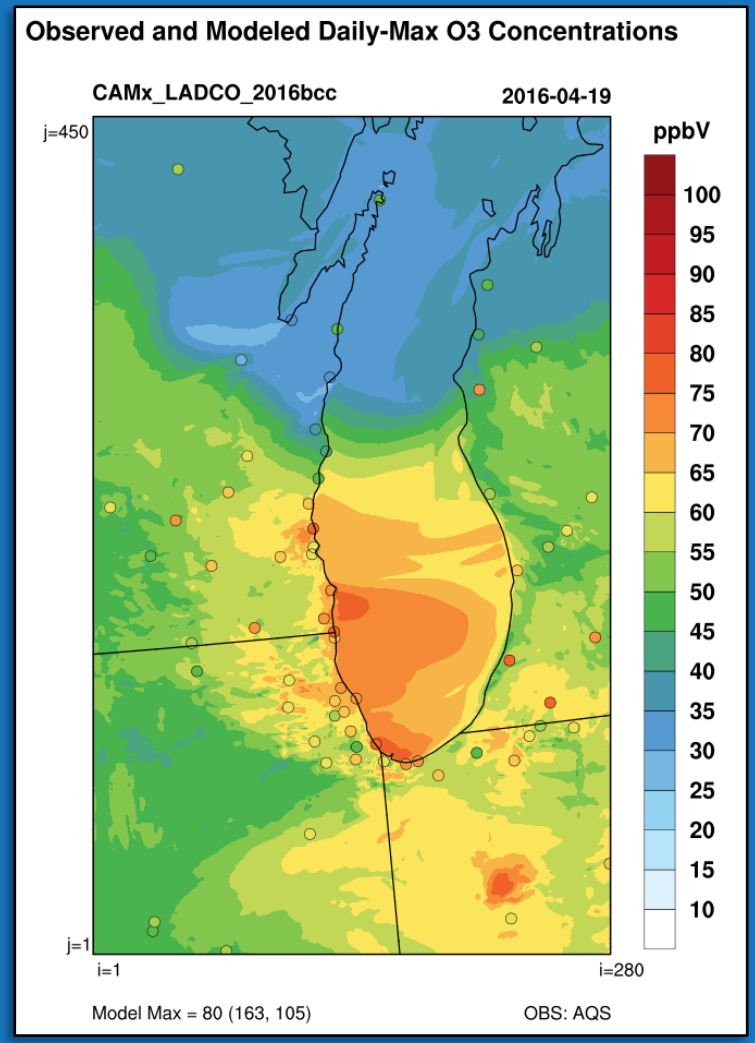

LADCO AWS Computing Daily Costs: November 1, 2019 - October 31, 2020
$500
$450
$400
$350
$300
$250
$200
$150
$100
$50
$-
Online Disks
Compute Nodes
Offline Disks
Master Nodes
MPCA DB
MI EGLE DB
Other
11/1/19
12/1/19
1/1/20
2/1/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
8/1/20
9/1/20
10/1/20
IL EPA WRF Download
IL EPA 2016 WRF Simulation
WRF 2016 Simulation
2016 and 2028 CAMx Simulations

Notes on Data Management

- Automate workflows
  - Online EBS volumes are the most expensive storage unit, need to automate moving data between less expensive offline and more expensive online disks
- The AWS Simple Storage Solution (S3) is a relatively cheap place to store data, and it's great for transferring large volumes of data
  - Egress fees ~$100/Tb to download
  - AWS Command Line Interface (CLI) uses multiple threads to transfer data, up and down from S3; terabyte scale electronic transfers are practical with S3
  - Example: > 4 Tb of WRF data downloaded by IL EPA in ~24 hours @ $500

Key Outcomes

- All LADCO modeling on AWS is done using Spot Instances
  - Learned to read the AWS Spot Market to find available, last-generation instances
- AWS is a practical solution for meteorology and air quality modeling
  - Annual 12km U.S. CAMx simulation costs ~$2.80/model day
  - Adding nested grids or instrumented models (i.e., PSAT) makes runs more expensive because they require more CPU-hours
- Don’t be afraid to scale up
  - Larger instances are more expensive per hour, but about the same cost per CPU-hour (the jobs run more quickly)
- LADCO invested ~$20k over a year to develop modeling capabilities on AWS



Next Steps

- Optimize AWS costs
  - Better manage offline and online storage costs
  - Shut down our compute servers more often
- Collect more data points on best practices
  - Transfer LADCO capabilities to other interested agencies
  - Learn from others using AWS (or other cloud services)
- Knowledge transfer to others in the community
  - MPI expertise to help determine the best configuration for AWS hardware
- National air quality modeling cloud computing workgroup

LADCO Cloud Computing Development Timeline