



PUBLIC SECTOR SUMMIT ONLINE

Forecasting the weather with AWS Cloud

Stefan Cecelski, PhD
Senior Data Scientist and
Engineer
Maxar

Defining Numerical Weather Prediction (NWP)

- NWP is the process of creating representations of future atmospheric states (forecasts) using mathematical models.
 - Fundamental equations of motion, thermo, physics, calculus, chemistry, etc. for every x, y, z, and t around the world + even a random number generator every now and then!
- Several governments and institutions run global (and regional) NWP models to produce forecasts.
 - NOAA → GFS or American
 - ECMWF → Euro or European
 - And others...





Maxar Goals for Running NWP on Cloud HPC

- **Goal #1:** To run and produce forecasts of the Finite Volume Cubed Sphere Global Forecast System (FV3GFS) **faster** than NOAA does for delivery to a number of Maxar clients.
 - Provide clients with the ability to make informed decisions faster based on weather forecasts of 1-15 day lead times.
 - Create custom output (maps and data) that is aligned with customers' business, mission, and operations.



Maxar Goals for Running NWP on Cloud HPC

- **Goal #2:** Produce highly correlated forecast output (such as weather patterns and deviations from climatology) to what NOAA produces.
- **Goal #3:** Leverage cloud high performance computing (HPC) built within AWS to emulate and exceed the performance of NOAA bare-metal HPC cluster to produce and deliver the FV3GFS forecast output.



How Maxar Leverages AWS Cloud HPC for NWP

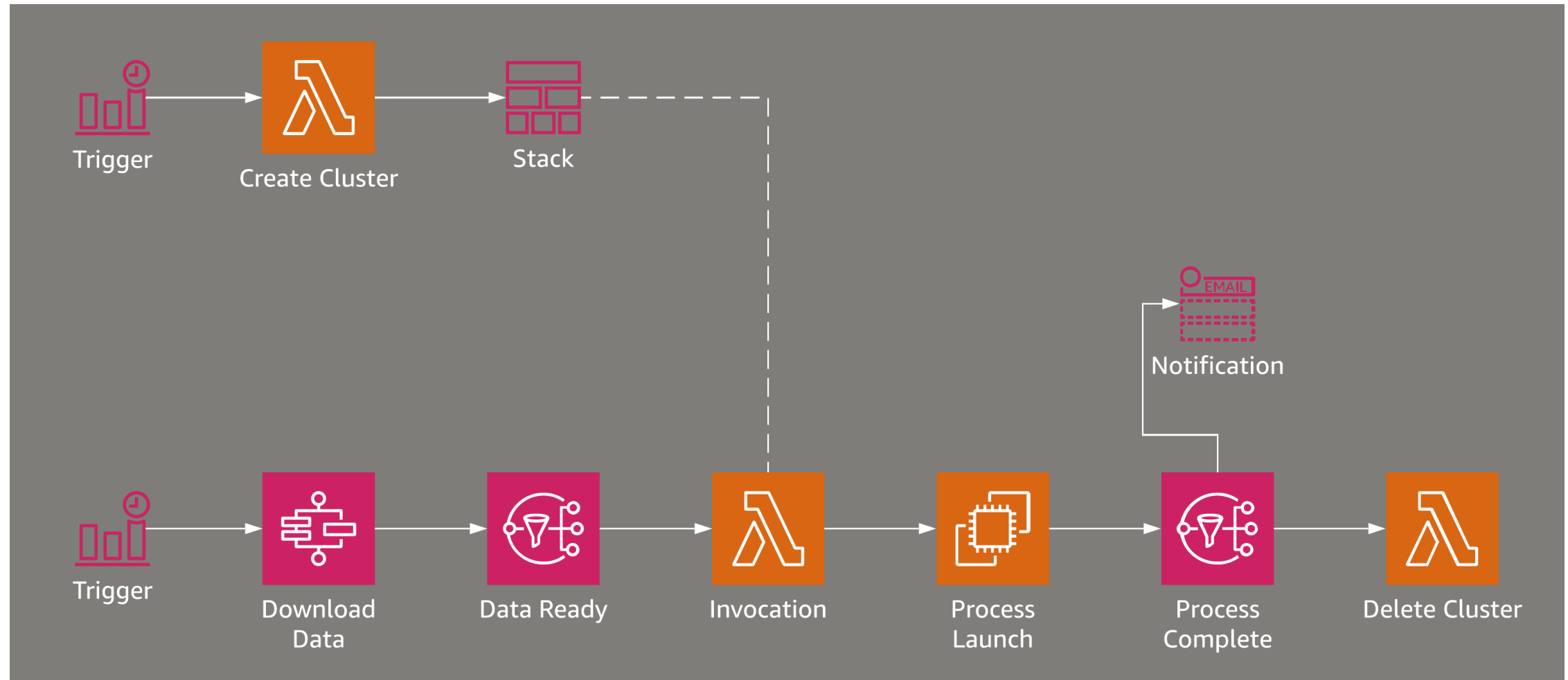


A Fully Automated Workflow

- HPC cluster resources (Amazon EC2 instances, Amazon EBS volumes, FSx Lustre) are re-allocated each day.
- Workflow execution is automated using a series of Step Functions and Lambda functions with AWS SNS notifications.
- Use a Lambda layer for AWS ParallelCluster to simplify deployment.
- AWS CloudFormation stacks to build the AWS resources for the workflow.
- Infrastructure updates are automatically deployed to AWS Regions using CodePipeline.



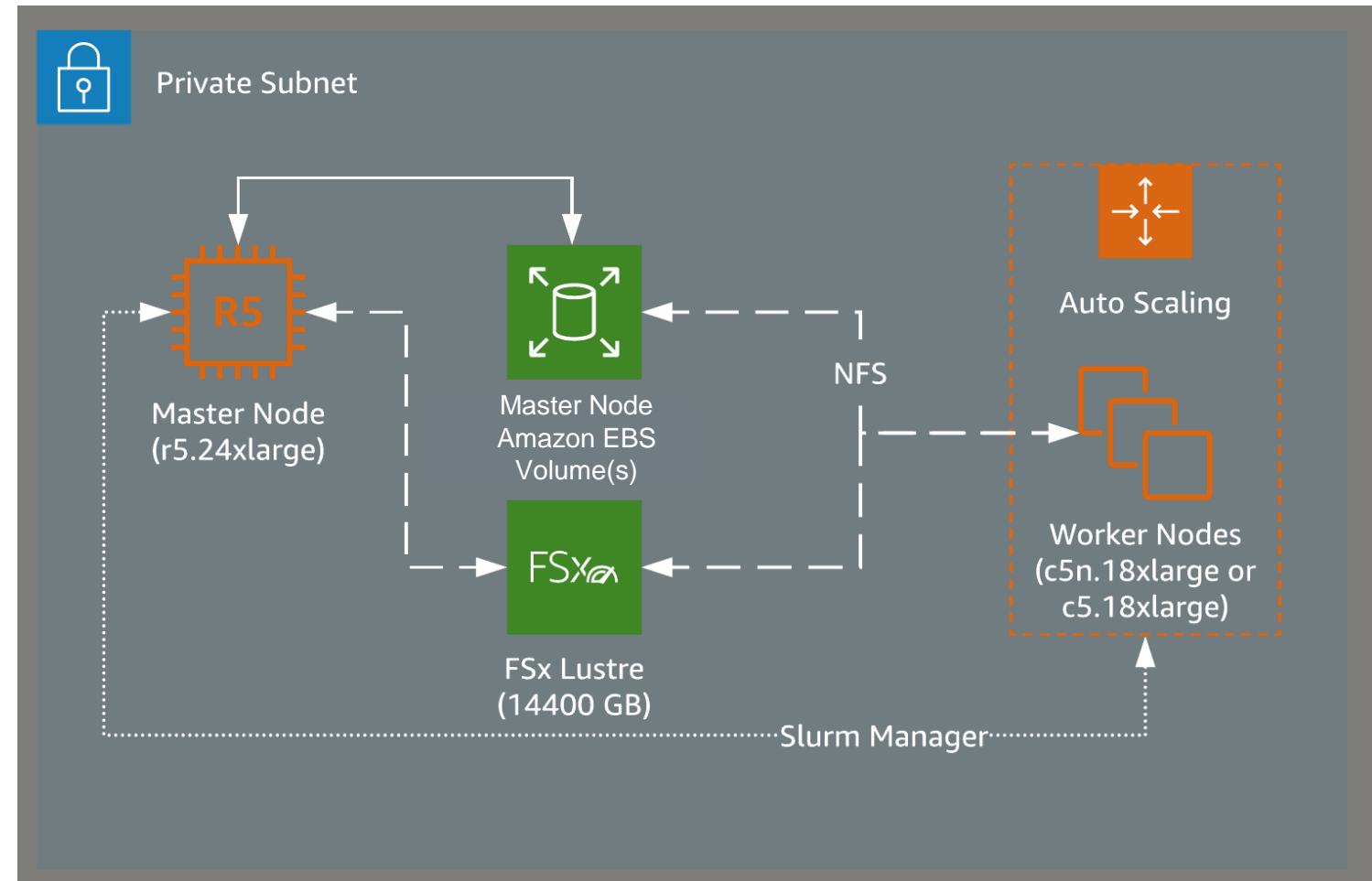
A Fully Automated Workflow





A Cloud HPC Environment for the FV3GFS Application

- AWS ParallelCluster software orchestrates the spin-up/spin-down of cluster resources.
- FV3GFS is compiled using Intel's Parallel Studio XE compiler environment, 2020 update 1.
- Executed on AmazonLinux 2 operating system.
- Network interconnect is either Elastic Fabric Adapter (EFA) or TCP depending on instance type.





Benchmarking Cluster Performance for NWP



Finding the Ideal Cluster Configuration

- **37** different cloud HPC cluster configurations were built to test the FV3GFS application on as little as **252** cores to over **11,000** cores.
- Maxar currently runs the application in production on both c5.18xlarge and c5n.18xlarge Amazon EC2 instances.
 - **24** of the test cluster configurations utilize c5n.18xlarge with the EFA networking adapter (max 100Gbps).
 - The remaining **13** test configurations use c5.18xlarge instances with TCP networking (max 25Gbps).
- All configurations leverage a **14TB** FSx Lustre file system with a progressive file layout (PFL) across the 12 object storage targets (OSTs).



Assessing FV3GFS Performance

- While numerous metrics can be analyzed to assess the performance of the FV3GFS application on AWS Cloud HPC, we decided to focus on **total wall clock time** initially given its importance for the previously set goals.
 - Other metrics such as integration time, I/O timing, scaling curves, and so forth are also analyzed but not as critically.
- Maxar defines **total wall clock time** as the time it takes the FV3GFS application to complete a 16-day simulation.



Cirrus performance baselines – 16-day weather forecast

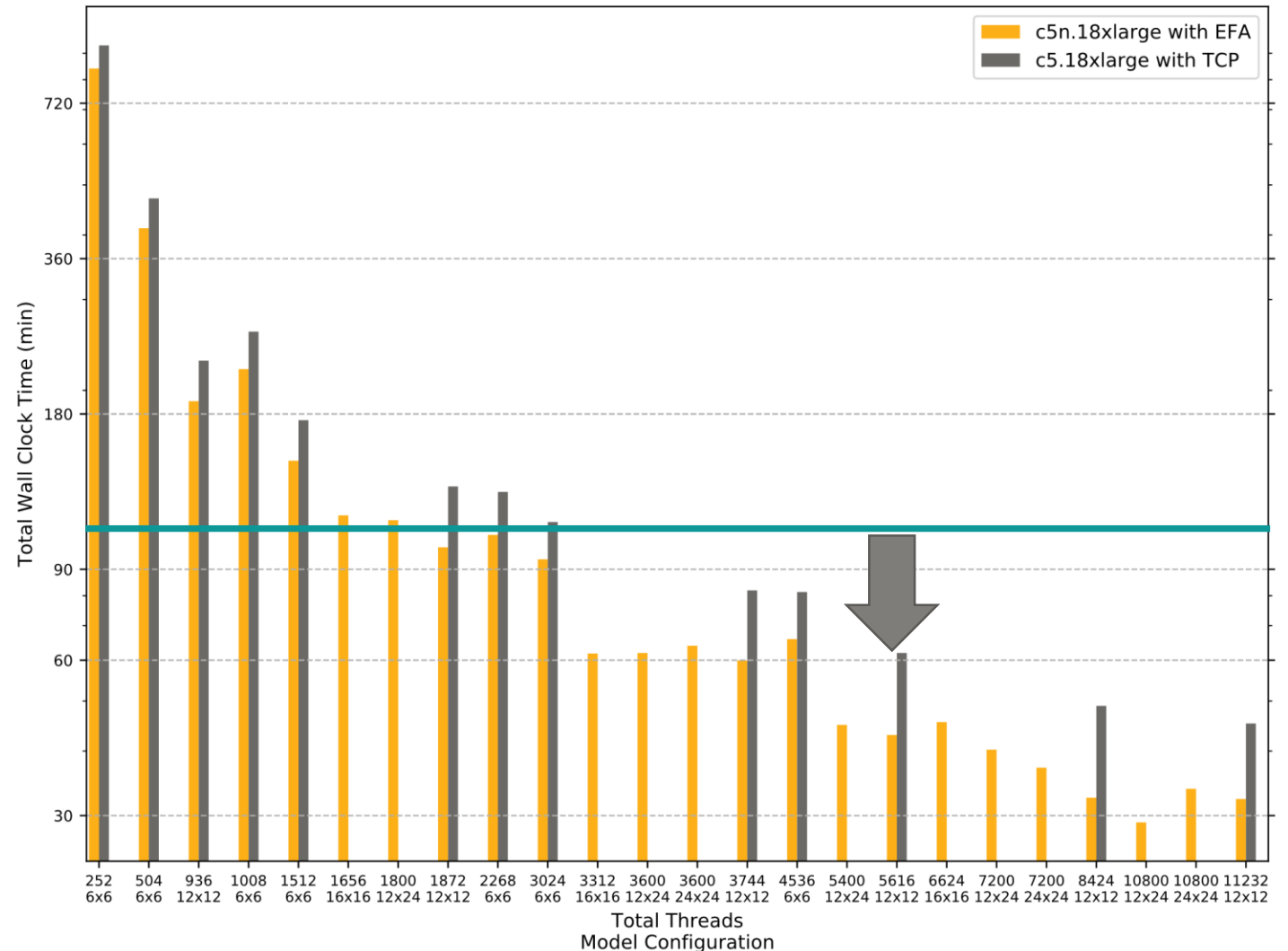
Cluster	Wall Clock Time for 16-day FV3GFS Forecast	Total Node Count	Total Core Count	Number of MPI Threads	Number of OpenMP Threads	Worker Node Amazon EC2 Instance Type	Physical Cores per Instance	RAM per Instance (GB)	Network Max Bandwidth (Gbps)
Cirrus Prod	~40-43 min	156	5616	936	6	c5n.18xlarge	36	192	100
Cirrus Backup	~48-53 min	234	8424	936	9	c5.18xlarge	36	144	25
NOAA*	~100 min	148	3552	1776	2	-	24	-	100

*Estimated configuration based on documentation



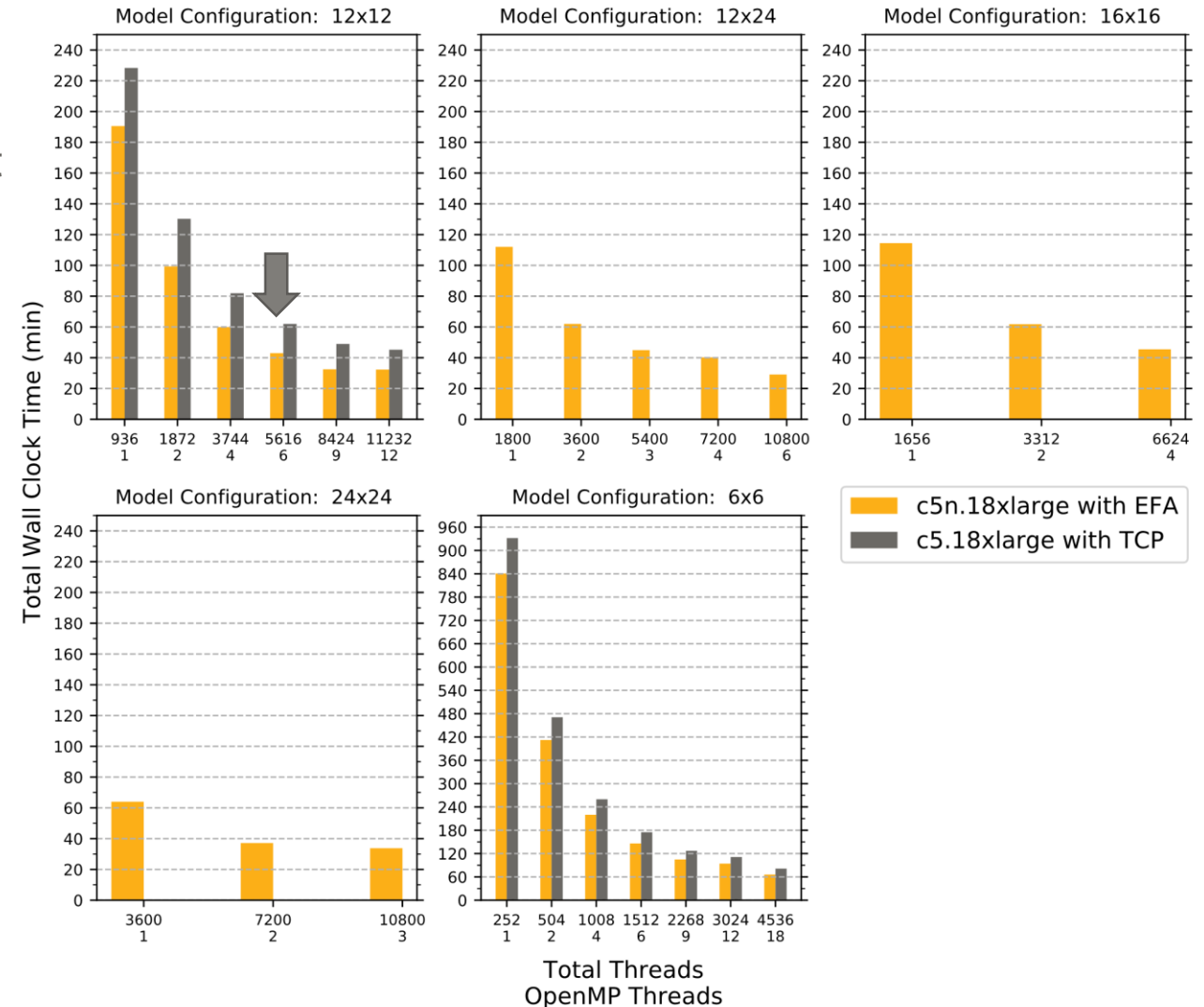
Results – FV3GFS total wall clock time

- Numerous configurations outperform NOAA's bare metal time of ~100min (horizontal green line).
- Current production (arrow) configuration is exceptionally performant at its given core count.
 - Other configurations with higher core counts perform worse.
- One configuration achieved a sub-30 minute total wall clock time.
- In general, the 11,000 core count mark coincided with near 30-minute total wall clock times for a 16-day forecast.



Results – FV3GFS total wall clock time

- Smaller model configurations (6x6) rely too heavily on OpenMP threading to boost total application thread count.
- Performance lacks compared to other configurations.
- 16x16, albeit configurable to c5/c5n instances, has the worst performance of the larger configurations for varying core counts.
- The 12x24 configuration exhibits strong scalability at higher MPI thread counts with varying OpenMP shows potential for larger MPI threading compared to the production configuration (12x12).





Final Thoughts



Conclusions

- The FV3GFS NWP application is scalable from 100s to 11,000+ cores, and potentially even more, on AWS Cloud HPC configured with c5n.18xlarge instances and EFA networking.
 - The scalability of the application is highly dependent on model configuration and the balance between MPI and OpenMP threading.
- Maxar, with its production system, cut the total run time of the FV3GFS by over **50%** compared to NOAA.
- Cost to develop and operate the production solution is significantly below the \$500+ million, 10-year program for NOAA's bare metal supercomputer.



Awareness of Maxar's Cloud-Based HPC Solution for NWP

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HPC Wire
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Maxar Builds HPC on AWS to Deliver Forecasts 58% Faster Than Weather Supercomputer

By Amazon Web Services

June 30, 2020

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When weather threatens drilling rigs, refineries, and gas companies want to move fast to protect their assets. And for firms that trade commodity shares in oil, livestock, the weather can significantly impact the damage, these companies need the earliest possible storm strikes. That's the challenge [Maxar Technologies](#) faces.

Historically, many industries have relied on reports generated by the on-premises supercomputer operated by the National Oceanic and Atmospheric Administration. However, the weather predictions take an average of 100 minutes to process global data. Similar to how NASA has expanded its partnerships with private firms to acquire commercial space hardware and services, the processing and delivery of critical weather data products could also be effectively commercialized.

To resolve this issue, Maxar sought to significantly reduce the time needed to generate numerical weather predictions. So Maxar turned to [Amazon Web Services](#).

Cloud HPC Achieves the «Impossible»

To complement the enhanced computing and networking, the application uses Amazon FSx for Lustre to accelerate the read/write throughput of the application. Maxar also takes advantage of AWS ParallelCluster, an open source cluster management tool that makes it easy to deploy HPC clusters with a simple text file that automatically models and provisions resources. Initially, Maxar designed a cloud HPC cluster with 234 Amazon EC2 instances capable of producing a numerical weather prediction forecast in roughly 53 minutes, just about half the 100 minutes that the NOAA supercomputer takes to complete the same forecast. This accomplished Maxar's initial performance goal, so the team set its eyes on enhancing the design to reduce cost.

Maxar wins AWS award for Best HPC Solution for Public Sector

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Maxar Uses AWS to Deliver Forecasts 58% Faster Than Weather Supercomputer

personnel and equipment. And for firms that trade to limit damage, these companies need the earliest possible

oceanic and Atmospheric Administration (NOAA). However, they would require much faster weather warnings to protect and services, the processing and delivery of critical weather

with the fast networking speed provided by AWS, we accomplished what many IT experts considered impossible."

Stefan Cecelski
Data Scientist, Maxar Technologies

Maxar Blog
on Cloud
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Using the Cloud to Forecast Clouds: Leveraging AWS to Run Global Numerical Weather Prediction at Scale

By: Travis Hartman, Director of Analytics @ Weather, Maxar Technologies

Read Time: 7 minutes

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