Advanced Technologies

Speakers
Mark Govett
Greg Pratt, Isidora Jankov, Jebb Stewart

Subject Matter Experts (SMEs)
Leon Benjamin, Michael Leon
Chris Harrop, Duane Rosenberg
Jonathan Joyce, Christina Kumler
Technology
• Data Systems
• GPU Computing
• Exascale Computing
• Machine Learning
• Cloud Computing
• Visualization

Development
• MADIS
• AQPI
## Investment and Impact

<table>
<thead>
<tr>
<th>Explore and track potential technologies</th>
<th>Investigate promising technologies to understand potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop prototypes to understand, measure value, capability</td>
<td>Sustain investment to improve capabilities</td>
</tr>
<tr>
<td>Sustain investment to improve capabilities</td>
<td>Transition capability to an operational entity</td>
</tr>
<tr>
<td>○ performance, ease-of-use, data handling, flexibility, understanding</td>
<td></td>
</tr>
</tbody>
</table>

**GSL Funds**

**GSL, JTTI WPO, NWS Funds**
NOAA surface stations with MADIS

- Revolutionized data systems development
  - Thousands of providers
  - Millions of observations
  - Standardized data access
  - High-quality QC procedures
  - Operational capability
  - Transitioned to NWS

- Established a high quality standard for handling observations
AQPI – observations, models, forecasters

• Prediction
  o Flooding, waste water, coastal impacts, streams flow

• Users
  o Cal Dept of Water Resources
  o 9 San Francisco counties
  o USGS
  o CIRA
  o NOAA GSL, PSL
GPU Computing

● 2010: GSL built directive-based GPU compiler
  ○ Worked with the industry to develop, improve standard for GPU programming

● 2015: GSL demonstrated performance and portability with a single Fortran code on CPU, GPU and MIC processors with Nonhydrostatic Icosahedral Model (NIM)
  ○ Approach adopted by MPAS model

● 2017-18: Parallelization of FV3 dycore (UFS)
  ○ Poor performance and portability showed that a major rewrite would be required
  ○ GFDL modeling team support
Explore how to develop kilometer-scale, global earth system models for Exascale Computing Era (2025 -)
- Performance: target operational capability
- Portability: CPU, GPU, hybrid
- Productivity: for scientists, developers, engineers, users
- Software: manage complexity, explore alternative languages
- Visualization: handle high volume data effectively

Evaluate algorithms for scientific accuracy and computational performance
- Spectral element and finite volume approaches
- Cartesian, icosahedral, cube-sphere grids

Push the boundaries in science
- Enable sub-kilometer processes

Evolution of Computing

<table>
<thead>
<tr>
<th>Era</th>
<th>Processors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000's</td>
<td>hundreds</td>
</tr>
<tr>
<td>2010's</td>
<td>thousands</td>
</tr>
<tr>
<td>2020's</td>
<td>millions</td>
</tr>
</tbody>
</table>

GeoFLuid Object Workbench (GeoFLOW)
Visualizations Reaching Forecasters

Widely used visualization capabilities

Interactive smoke visualization
(Peak ~ 1 million request per hour)

Weather Archive and Visualization Environment (WAVE)
Visualizations Reaching the Public

Engaging Visualization, Driving Readers to Stories

Arctic sea ice minimum

African dust across the Atlantic
Visualizations Reaching the World

Science on a Sphere
NOAA’s Premier Education Tool

177 exhibit installations

Found in...
23 countries & 33 states

+67 million visitors
(Pre-COVID #)

38 SOSx® installations

+250 network members

+330,000 Facebook® followers

+25,000 SOSx downloads

2021 Global Systems Laboratory Science Review
Cloud Development for NOAA

Modeling and Computing

- Development of UFS and Global Workflow
  - Ability to run end-to-end workflow using cloud services
- Rapid Refresh Forecast System (RRFS) in the cloud (Partnership with EMC)

Exascale Visualization and Analysis

- Multi-threaded data processing
- Data storage, access, tools

Leadership

- GSL co-lead of OAR Cloud Tiger Team

Computing and Data Handling Pipeline

2021 Global Systems Laboratory Science Review
Feature detection, tracking and prediction

Tracking
● Generate probabilistic forecasts of areas of likely convection initiation

Feature Detection
● Detect and target areas for data extraction

Physics Parameterizations
● Radiative Transfer Model
● Physics guided neural network with physical constraints for higher accuracy
Summary

• Relevance
  • Computational challenges running cloud resolving models on exascale computers
  • Develop cloud, ML, visualization to handle enormous amounts of data

• Quality
  • Cloud and Machine Learning demonstrate new capabilities in data, computing
  • Demonstrate world-class research in GPU, exascale
  • Impactful visualizations support forecasters, communicate science to world

• Performance
  • GPU research has been impactful
  • NIM demonstrated performance and portability on CPU, GPU is achievable
  • MADIS transition to NWS operations
  • SOS installations around the world viewed by millions of people