INDUSTRY TRENDS & CAPABILITIES IN NWP

MARIA PIRONE
Sr. Business Development Manager, Environmental Solutions
Space & Intelligence Systems
Acknowledgements

This presentation is a compilation of material from leaders in the modeling, HPC & remote sensing communities as noted below-


Rothfusz, L, P. Schlatter, et al, 2016: A Future Watch/Warning Concept: Forecasting a Continuum of Environmental Threats (FACETs)

IDC Reports, 2015

Special thanks to the folks at Earthcast Technologies and Penguin Computing for providing sample model data and information about the HPC Cloud market.
“May you live in interesting times.” Confucius

Well, we live in interesting times....

There is a modestly paced paradigm shift underway in our Modeling Community, influenced by unrelated external factors coming together at the same time.

This isn’t a bad situation, it isn’t a setback for the Weather Enterprise, or the industries that depend on NWP and weather forecasts.

We haven’t experienced anything of this magnitude in the past 25 years and will probably not experience it again, quite so dramatically, in another 25 years.

As critical users of forecast products, this presentation is meant to give you insight and guidance in determining how to navigate through this change and, perhaps, how to optimize your access to the weather information you need.
Changing NWP Landscape

Industry offerings now include products and output from their own model runs--

**Government**

- Department of Energy
- NASA
- National Weather Service

**Academia**

- UCAR
- NCAR
- UCAR Universities

**Industry**

- AccuWeather
- Earthcast Technologies
- Panasonic
- Spire
- TempoQuest

The Weather Company
An IBM Business
What are the drivers influencing NWP?

NWP or Model Performance is influenced by advances in Atmospheric Science, HPC Technology and Earth Observations in concert with one another.
Science: What’s holding us back?

When done within a Multi-scale Model Framework (MMF) it is computationally expensive.
Today’s MMF parameterizes clouds differently in low vs high resolution and we don’t completely understand the processes inside individual clouds.

Scientists’ goal is to produce a consistent representation of cloud processes at coarse and fine scales-

For a unified *global-to-local-scale modeling Framework.*
CRM (including Unified Parameterization) science development requires key resources-

- More frequent, evenly dispersed, hyperlocal observations of moisture & temperature for the Planetary Boundary Layer
- Additional computational resources to run the improved cloud physics
- And even more computational resources to generate ensembles with post-processed statistically derived probabilities.

With those needs met—storm scale “WOF” may eventually become a reality-
Technology: HPC Industry Trends

The Broader HPC Market

| The Broader HPC Market Growth to 2019 |  |  |  |  |  |  |
| Server | 10,222 | 10,718 | 11,467 | 12,958 | 14,073 | 15,165 | 8.2% |
| Storage | 4,229 | 4,504 | 4,865 | 5,546 | 6,123 | 6,796 | 9.9% |
| Middleware | 1,163 | 1,217 | 1,294 | 1,426 | 1,534 | 1,645 | 7.2% |
| Applications | 3,598 | 3,769 | 4,028 | 4,479 | 4,824 | 5,167 | 7.5% |
| Service | 1,819 | 1,895 | 2,006 | 2,223 | 2,356 | 2,497 | 6.5% |
| Total | 21,032 | 22,103 | 23,660 | 26,632 | 28,910 | 31,270 | 8.3% |

Source: IDC 2015

But what about the computational resources needed to pull this off?

Affordability? Scalability? Accessibility?

While large private HPC data centers continue to thrive—what about HPC Cloud or POD- Cloud on Demand?

Has it peaked? Is it capable to support the modeling community?

HPC Forecasts

- Forecasting a 8.2% yearly growth from 2014 to 2019
- 2019 should reach $15.2 billion

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Supercomputer</td>
<td>3,995</td>
<td>3,150</td>
<td>5,034</td>
<td>9.8%</td>
</tr>
<tr>
<td>Divisional</td>
<td>1,355</td>
<td>1,524</td>
<td>2,156</td>
<td>7.2%</td>
</tr>
<tr>
<td>Departmental</td>
<td>3,363</td>
<td>3,831</td>
<td>5,406</td>
<td>7.1%</td>
</tr>
<tr>
<td>Workgroup</td>
<td>1,586</td>
<td>1,718</td>
<td>2,569</td>
<td>8.4%</td>
</tr>
<tr>
<td>Total</td>
<td>10,299</td>
<td>10,222</td>
<td>15,165</td>
<td>8.2%</td>
</tr>
</tbody>
</table>

Source: IDC 2015
HPC Server Market: By Industry/Applications ($000)

<table>
<thead>
<tr>
<th>Industry/Applications</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-Sciences</td>
<td>1,090,722</td>
</tr>
<tr>
<td>CAE</td>
<td>1,299,380</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>187,851</td>
</tr>
<tr>
<td>DCC &amp; Distribution</td>
<td>704,950</td>
</tr>
<tr>
<td>Economics/Financial</td>
<td>614,503</td>
</tr>
<tr>
<td>EDA / IT / ISV</td>
<td>807,199</td>
</tr>
<tr>
<td>Geosciences</td>
<td>838,157</td>
</tr>
<tr>
<td>Mechanical Design</td>
<td>61,079</td>
</tr>
<tr>
<td>Defense</td>
<td>1,140,544</td>
</tr>
<tr>
<td>Government Lab</td>
<td>1,986,865</td>
</tr>
<tr>
<td>University/Academic</td>
<td>2,043,357</td>
</tr>
<tr>
<td>Weather</td>
<td>493,773</td>
</tr>
<tr>
<td>Other</td>
<td>94,903</td>
</tr>
<tr>
<td>Total Revenue</td>
<td>11,363,283</td>
</tr>
</tbody>
</table>
Cloud HPC market size is estimated to grow from $4.37 billion in 2015 to $10.83 billion by 2020, at an estimated compound annual growth rate of 19.9%. The main factors driving the growth of cloud HPC are:

- Complex applications management
- Emergence of big data market
- Adoption of the pay-as-you-go model
Data Intensive Uses of HPC & HPC Cloud

HPDA = Data-Intensive Computing Using HPC

Drivers:
- Competition
- Complexity
- Time

Modeling & Simulation
- Existing HPC users
  - Larger problem sizes
  - Higher resolution
  - Iterative methods
  - EP jobs to the cloud (Novartis)
- New commercial users
  - E.g., SMEs

Advanced Analytics
- Existing HPC users
  - Intelligence community, FSI
  - Data-driven science/engineering (e.g., biology)
  - Knowledge discovery
  - ML/DL, cognitive, AI
- New commercial users
  - Fraud/anomaly detection
  - Business intelligence
  - Affinity marketing
  - Personalized medicine

HPDA Includes Cumulative Results of Iterative Methods
- Parametric modeling (product design)
- Stochastic modeling (financial)
- Ensemble modeling (weather/climate)
HPC Cloud without the Capital Investment

“.....no monthly fee, no long term commitment..pay as you go.”

It’s the mantra of HPC Cloud on Demand services.

1000’s of CPU Cores at your fingertips.
No managing of applications.
No data center costs – power, communications, A/C or storage.
Pay for what you use not what is in the room.
Use as little or as much as you need—flexible
Compute power for your variable needs.

Who wouldn’t want this exciting accessibility to resources that were previously out of reach?
Observations: Next Generation

- Mesonets of surface observations multiplying daily—implemented by Academia, Private Sector, State & Local Government.
- Lidar, Aircraft data (MDCRS, TAMDAR, WVSS II), Total Lightning data, Webcams, mPing -- reporting PBL conditions for model input and/or V&V of NWP output.
- Technology has once again had a positive impact on advances in this area.
NASA Earth Science Missions and Instruments

Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF

Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)
## Next Generation Satellite Missions & Instruments

<table>
<thead>
<tr>
<th>Satellite / Sensor</th>
<th>Legacy</th>
<th>MSA</th>
<th>Improved Capability</th>
<th>Initial Operations Date</th>
</tr>
</thead>
</table>
| GOES-R / ABI                | GOES-NOP     | 1-8  | 16 vs 5 imagery channels
2X spatial resolution
> 4X temporal resolution
~21 vs 5 derived products | Spring 2017  |
| GOES-R / GLM                | none         | 1-7  | Total lightning, hemispheric, every 20 s                                           | Fall 2017               |
| SNPP-JPSS / VIIRS          | POES & MeTOP /AVHRR | 1-8  | 21 vs 5 channels
2X spatial resolution
~41 vs 5 derived products | 2015 > Summer 2017 |
| GCOM-W / AMSR2              | none         | 2,4,5,6,7,8 | 4 (Microwave) imagery channels
10 derived products | 2016 > Summer 2017 |
| JASON 2 & 3 / Altimeter     | none         | 4,5  | 4 derived products                                                                | Fall 2016               |
| Himawari / AHI              | MTSAT Imager | 1-8  | Nearly identical to GOES-R
> 4 vs 0 derived products     | Dec 2015 – Jul 2016 |
| GPM / GMI                   | none         | 4,5,7,8 | 4 (Microwave) imagery channels
> 3 derived products        | 2016 > Summer 2017 |
| Sentinel & RadarSAT / SAR   | none         | 4,5  | 1 derived product                                                                | Summer 2016             |

**MSA = Mission Service Areas for Weather**

1. Severe
2. Routine
3. Aviation
4. Tropical
5. Marine
6. Fire
7. Precip / Hydrology
8. Winter Weather

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**FPFW Meeting, NBAA- BACE, Nov 1-3 2016 – Orlando**

**NWP Panel Session | 16**
World-Wide Coverage with ABI-class Imagers
Geostationary Lightning Mapper (GLM)

- GLM provides hemispheric displays of lightning events
- Provides earlier indication of extreme weather development

Lightning surge of over 200% occurred 14 minutes prior to a confirmed tornado touchdown
Current GOES Imager Channels (Wavelength) Used for Observation

1: 2: 0.64 µm (Red; 2 km) 
3: 
4: 
5: 
6: 
7: 3.9 µm (Shortwave Window) 
8: 6.2 µm (Upper Level Water Vapor) 
9: 
10: 
11: 
12: 
13: 
14: 11.2 µm (IR Longwave) 
15: 
16: 13.3 µm (CO2) 

Image courtesy of Tim Schmit
GOES-R Advanced Baseline Instrument (ABI)

Earth Image Depends Upon ABI Channel (Wavelength) Used for Observation

1: 0.47 µm (Blue; 1 km)
2: 0.64 µm (Red; 0.5 km)
3: 0.86 µm (Veggie; 1 km)
4: 1.37 µm (Cirrus; 1 km)
5: 1.61 µm (Snow/Ice)
6: 2.3 µm (Cloud Particle Size)
7: 3.9 µm (Shortwave Window)
8: 6.2 µm (Upper Level Water Vapor)
9: 6.9 µm (Mid-Level Water Vapor)
10: 7.3 µm (Low-Level Water Vapor)
11: 8.4 µm (Cloud Top Phase)
12: 9.6 µm (Ozone)
13: 10.3 µm (Clean IR Longwave)
14: 11.2 µm (IR Longwave)
15: 12.3 µm (Dirty IR Longwave)
16: 13.3 µm (CO2)

3x Spectral Bands
4x Spatial Resolution
6x Temporal Resolution

Image courtesy of Tim Schmit
Observations: Summary

- The planet will be observed from space with three distinct high resolution moisture channels, at the very least, to assimilate into global models.
- Mesonet observations will continue to flourish and provide substantive information where previously there was none.
- The next few years will provide new observations that will be tailored for cloud processes in the boundary layer.
- And perhaps additional ground networks to better observe the lower 5km of the atmosphere “from the ground up” will be deployed.
Forecast Example: EarthCast®

- Why? Because the models, the computational resources and the observations are accessible to scientists with modeling credentials…

- Hosted on a POD Cloud, providing 10km global and 3 km nested grids in a NASA spectral model that uses satellite data, mesonets, global obs, and other observations hourly out to 36 hours.

- 3km nest has Cloud Resolving Model to depict local convection.

- Accessible on mobile or web interface—

Science - Technology – Observations are here and will provide the back drop for a new WOF process and, model guidance that when coupled with new observations depicts the certainty in the hyperlocal future conditions.
EarthCast® Solution

EarthCast is an advanced global to local prediction system that delivers:

- Truly local to global capability with accurate and detailed information about hazardous environmental conditions before they occur.
- Highly detailed HyperResolution forecasts over cities and airports, along transportation routes; and over remote territories.

Revolutionizing How Environmental Predictions are Made: Local to Global

High Performance Computing

High Performance Computing
EarthCast Web Application

Local to Global Display of Hazardous Conditions and Forecasts
Forecast Solutions at High Temporal & Spatial Resolutions for Unique Requirements

3 Hr Predicted Visibility & Surface Wind Vector Colored by Speed  2016-09-14 15:00:00Z
Providing Value Where Surface Observations are Sparse
Thank you.

For more information contact:

Maria Pirone
+1 (202) 257-8877 (cell)
+1 (571) 203-7361 (office)

mpirone@harris.com

Harris Corporation, Space and Intelligence Systems
www.harris.com