Community Satellite Processing Packages

– Facilitating Improvements in Real-time Satellite Data Applications

Allen Huang, Liam Gumley, Kathy Strabala, Scott Mindock, Graeme Martin, Ray Garcia, Geoff Cureton, Jim Davies, Nick Bearson, Elisabeth Weisz, Nadia Smith, Bill Smith Sr. & many others

2015 CSPP/IMAPP Users' Group Meeting

Eumetsat, Darmstadt, Germany

15 April, 2015

Community Satellite Processing Packages

– Facilitating Improvements in Real-time Satellite Data Applications

Outline:

1. CIMSS Processing Packages: ITPP, IAPP, IMAPP, CSPP, CSPP-Geo
2. IMAPP (2014/2015) Overview
3. CSPP Overview
4. Innovations with new sponsors:
   - 4.1 ISEE (**I**nnovative **S**atellite **E**nhanced **E**xploration)
   - 4.2 Technology insertion for DB-CRAS & IDEA-I
5. Summary

From ITPP, IAPP, IMAPP to CSPP 1992 to 2015 (1/2)

- 1992: TOVS (TIROS-N) export package started
- 1993: 1st release of ITPP for NOAA-8
- 1999: 1st release of IAPP for NOAA-15
- 2000: 1st release of IMAPP for Terra MODIS
- 2002: 1st IMAPP science products released for Terra MODIS & 1st release for both Terra & Aqua MODIS
- 2004: 1st IMAPP training workshop at Nanjing, China
- 2005: 2nd & 3rd IMAPP training workshops & IAPP V2.1 released. 1st release of IMAPP AIRS/AMSU/HSB sounding rtv.

IMAPP: 61 releases since May 2000

CSPP: 29 releases since March 2012

From ITPP, IAPP, IMAPP to CSPP 1992 to 2015 (2/2)

- 2006: 1st IMAPP AMSR-E soil moisture & workshops in Norway & S. Africa
- 2007: IMAPP AMSR-E Snow Water Equivalent & workshop in Brazil
- 2008: 1st release of IMAPP DB-CRAS NWP model
- 2009: 1st release of Google Earth
- 2010: IMAPP Virtual Appliance
- 2012: CSPP 1st release for Suomi NPP & IDEA-I 1st release
- 2015: CSPP-IAPP for NOAA 15/16/18/19 & Metop A/B release
- 2015: CSPP-GEO for GOES GRB & GVAR

IMAPP: 61 releases since May 2000

CSPP: 29 releases since March 2012

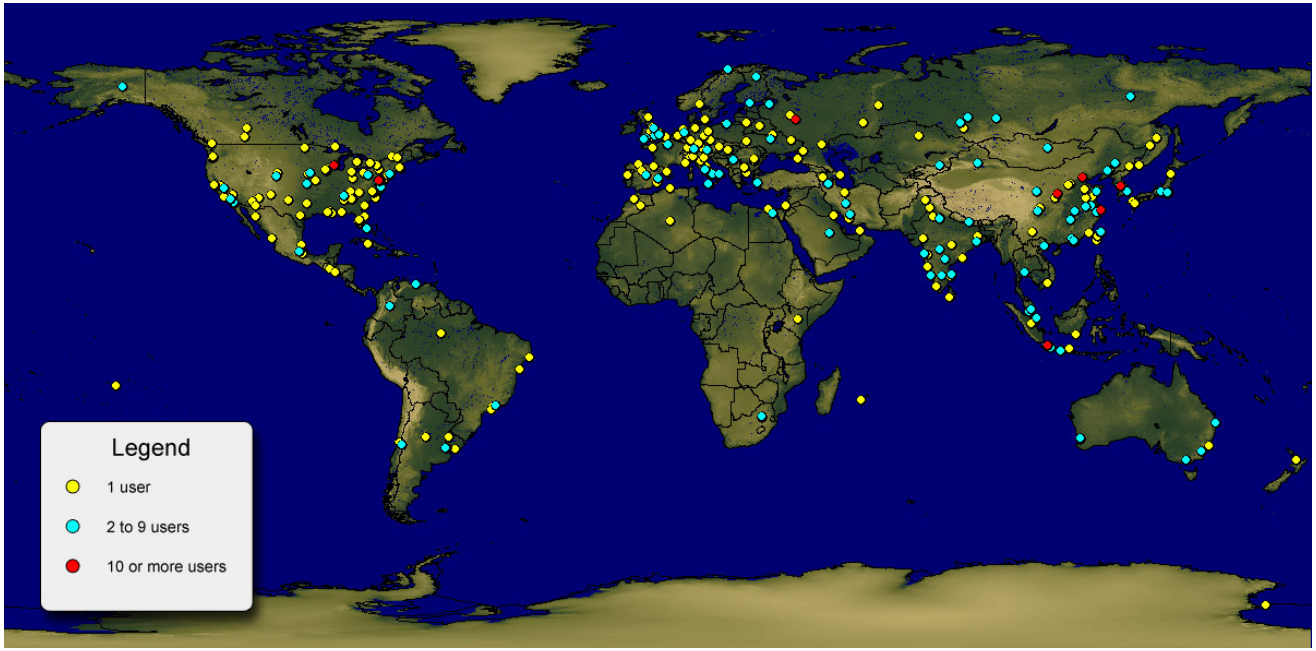
Since 1999 NASA funded

International MODIS/AIRS Processing Package (IMAPP)

Purpose: To allow DB users capability of producing local Aqua and Terra products from direct broadcast data

- Software packages derived from the operational EOS processing
- Modified to be compatible with direct broadcast data.

http://cimss.ssec.wisc.edu/imapp



More than 2,000 in 76 countries Global IMAPP users

International MODIS/AIRS Processing Package (IMAPP) for Direct Broadcast

Kathleen Strabala, Liam Gumley, Allen Huang, James Davies, Elisabeth Weisz & others

- Entering 15th year of funding
- More than >2,000 users from 76 countries
- >10 direct broadcast workshops held on 5 continents
- >60 software packages released

IMAPP: 8 S/W Releases 2014-2015 (1/3)

1. **March 16, 2015** (MODIS Level 2 Product Software Update Version 3.1) Update to the IMAPP MODIS Level 2 software package that includes support for the MODIS atmosphere products. This update includes the addition of the MOD06OD optical properties Collect 6 NASA baselined software that generates the Cloud Effectieve Radius and Cloud Optical Thickness products
2. **10-13 February 2015** (Miami Direct Broadcast Applications Workshop) Training workshop in support of X/L Band antenna installed at the Atlantic Oceanographic and Meteorological Laboratory (AOML) of NOAA, Miami, Florida. The workshop was held to support the National Weather Service in Miami, the National Hurricane Center, the Hurricane Research Division and the US Florida Agencies.
3. **August 28, 2014** (MODIS L1B GeoTIFF Reprojection Software Version 1.2) Update to the software (Polar2Grid) that enables users to create reprojected MODIS L1B, GeoTIFF files as well as 24 bit True Color GeoTIFF files, in a selection of projections or grids to use for the remapping, for entire swaths of data or covering a user defined region. This software also creates reprojections in a format required for display in the US National Weather Service AWIPS visualization system.

IMAPP: 8 S/W Releases 2014-2015 (2/3)

4. August 8, 2014 (MODIS Level 2 Product Software Update Version 3.0)
Update to the IMAPP MODIS Level 2 product generation package that includes the MODIS atmosphere products. This update includes major changes including the inclusion of NASA baselined Collect 6 atmosphere software, which will create products identical in format (including metadata) as the official archived HDF4 product files.
5. May 20, 2014 (AIRS, CrIS and IASI Stratospheric Ozone Intrusion Air Quality Forecast Software Version 1.0)
First release of a Hyperspectral Sounder Stratospheric Ozone Intrusion IDEA-I air quality forecast tool that uses a trajectory model to forecast the movement of high concentration ozone regions in three dimensions over a 48 hour period. The package includes PHP software that can display the output set of trajectory forecast images as a Web Browser animation.
6. April 29, 2014 (AIRS, CrIS and IASI Dual Regression Retrieval Software Version 1.3)
Update to the software package that uses input Aqua AIRS, Suomi NPP CrIS or MetOP IASI radiances and retrieves vertical profiles of temperature, moisture, ozone as well as cloud and surface properties at single Field-of-View (FOV) resolution. This software package update includes improvements in distinguishing clear sky from low cloud.

IMAPP: 8 S/W Releases 2014-2015 (3/3)

7. April 22, 2014 (MODIS GeoTIFF Web Mapping Service (MWS) Display Package Version 1.0)
First release of a software package that provides users with the capability to display and share satellite GeoTIFF products through a web browser in a Google Maps interface. It is designed specifically for display of MODIS and VIIRS default GeoTIFF files created by the Polar2Grid reprojection software package.
8. March 19, 2014 (Aqua and Terra HYDRA2 Multispectral Data Analysis Toolkit Version 1.0)
First release of a visualization and analysis toolkit for interrogating NASA EOS Aqua and Terra and JPSS S-NPP instrument data. This toolkit was developed to assist research and development of remote sensing applications as well as education and training of remote sensing scientists.

CSPP Release History (1/3):

1. April 9, 2015 (CSPP Advanced Clear-Sky Processor for Oceans (ACSPO) Software Version 1.0)
2. April 3, 2015 (CSPP International ATOVS Processing Package (IAPP) Software Version 1.0)
3. February 24, 2015 (CSPP NUCAPS CrIS/ATMS EDR Retrieval Software Version 1.0)
4. February 2, 2015 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 2.1)
5. October 20, 2014 (CSPP Suomi NPP Patch for SDR Version 2.0)
6. September 3, 2014 (CSPP VIIRS SDR GeoTIFF and AWIPS Reprojection Software Version 1.2)
7. August 4, 2014 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 2.0)
8. August 4, 2014 (CSPP Suomi NPP VIIRS EDR Software Version 2.0)
9. August 4, 2014 (CSPP Suomi NPP Imagery EDR Software Version 2.0)
10. May 16, 2014 (CSPP CLAVRx VIIRS, MODIS and AVHRR Cloud Retrieval Software Version 1.0)

CSPP Release History (2/3):

11. April 29, 2014 (CSPP CrIS, AIRS and IASI Dual Regression Retrieval Software Version 1.3)
12. March 21, 2014 (CSPP Suomi NPP Imagery EDR Software Version 1.1)
13. March 20, 2014 (CSPP Microwave Integrated Retrieval System (MIRS) Software Version 1.0)
14. March 19, 2014 (CSPP Suomi NPP HYDRA2 Multispectral Data Analysis Toolkit Version 1.0)
15. February 14, 2014 (CSPP Suomi NPP VIIRS EDR Software Version 1.2.1)
16. December 18, 2013 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 1.5)
17. December 18, 2013 (CSPP Suomi NPP VIIRS EDR Software Version 1.2)
18. October 18, 2013 (CSPP VIIRS SDR GeoTIFF and AWIPS Reprojection Software Version 1.1)
19. September 24, 2013 (CSPP CrIS, AIRS and IASI Dual Regression Retrieval Software Version 1.2)
20. July 8, 2013 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 1.4)

CSPP Release History (3/3):

21. July 8, 2013 (CSPP Suomi NPP VIIRS EDR Software Version 1.1)
22. April 29, 2013 (CSPP CrIS, AIRS and IASI Dual Regression Retrieval Software Version 1.1)
23. February 22, 2013 (CSPP VIIRS SDR GeoTIFF and AWIPS Reprojection Software Version 1.0)
24. February 8, 2013 (CSPP Suomi NPP VIIRS Cloud Mask and Active Fires EDR Software Version 1.0)
25. February 8, 2013 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 1.3)
26. November 26, 2012 (CSPP CrIS, AIRS and IASI Dual Regression Retrieval Software Version 1.0)
27. October 4, 2012 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 1.2)
28. May 4, 2012 (CSPP CrIS UW Retrieval Software Version 1.0)
29. March 14, 2012 (CSPP Suomi NPP VIIRS and ATMS SDR Software Version 1.0)

Current CSPP LEO Software

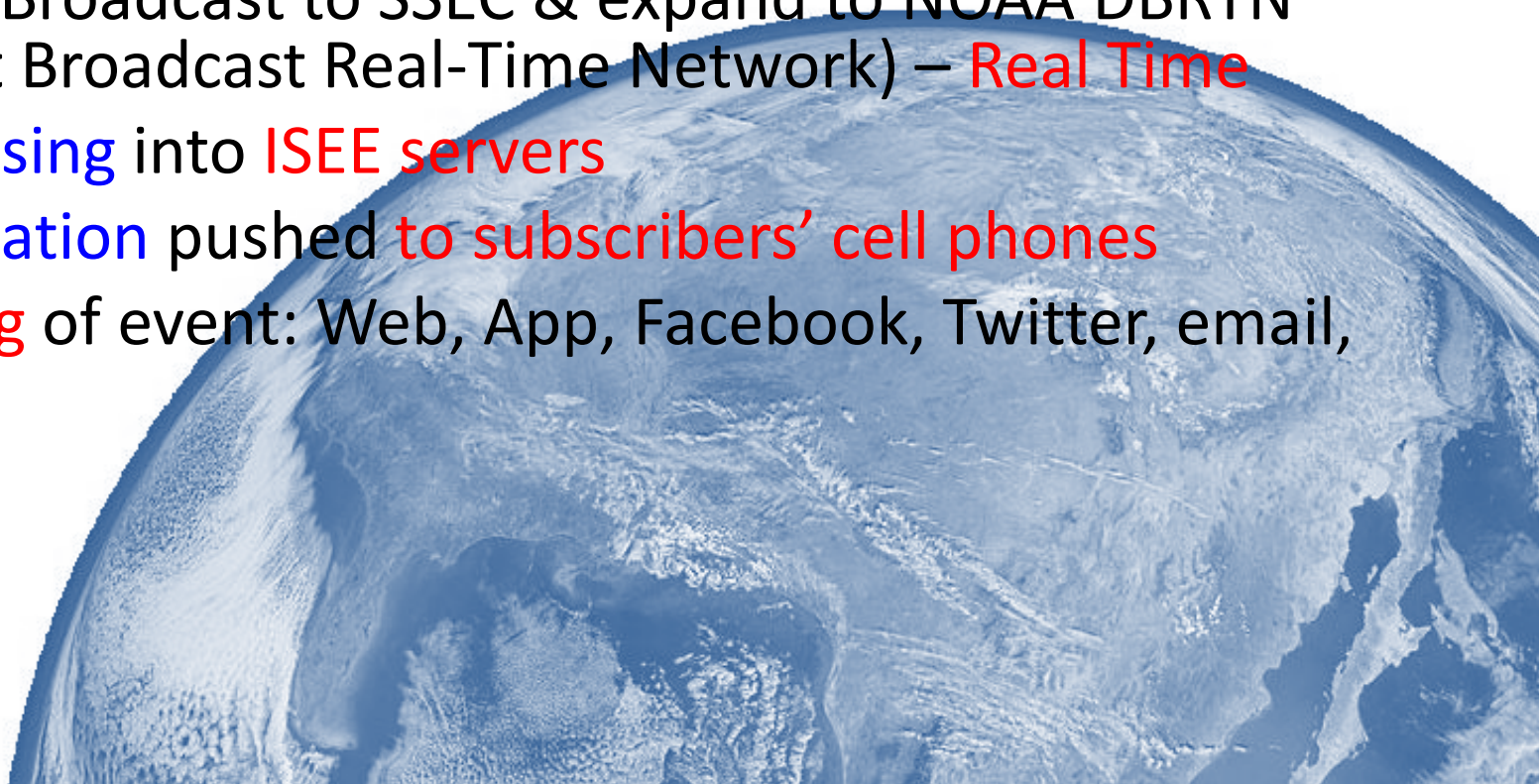
1. Suomi NPP CrIS, VIIRS and ATMS SDR (geolocation and calibration)
2. Suomi NPP VIIRS EDR (cloud mask, active fires, surface reflectance, NDVI, SST, aerosol optical thickness)
3. CrIS, IASI, and AIRS Dual Regression Retrieval
4. VIIRS SDR GeoTIFF and AWIPS Reprojected Imagery
5. Microwave Integrated Retrieval System (MIRS)
6. Clouds from AVHRR Extended (CLAVR-x)
7. HYDRA2 Multispectral Data Analysis Toolkit
8. Suomi NPP Imagery EDR (projected imagery for AWIPS)
9. NUCAPS – NOAA Unique CrIS ATMS Processing System
10. ACSPO - Advanced Clear-Sky Processor for Oceans

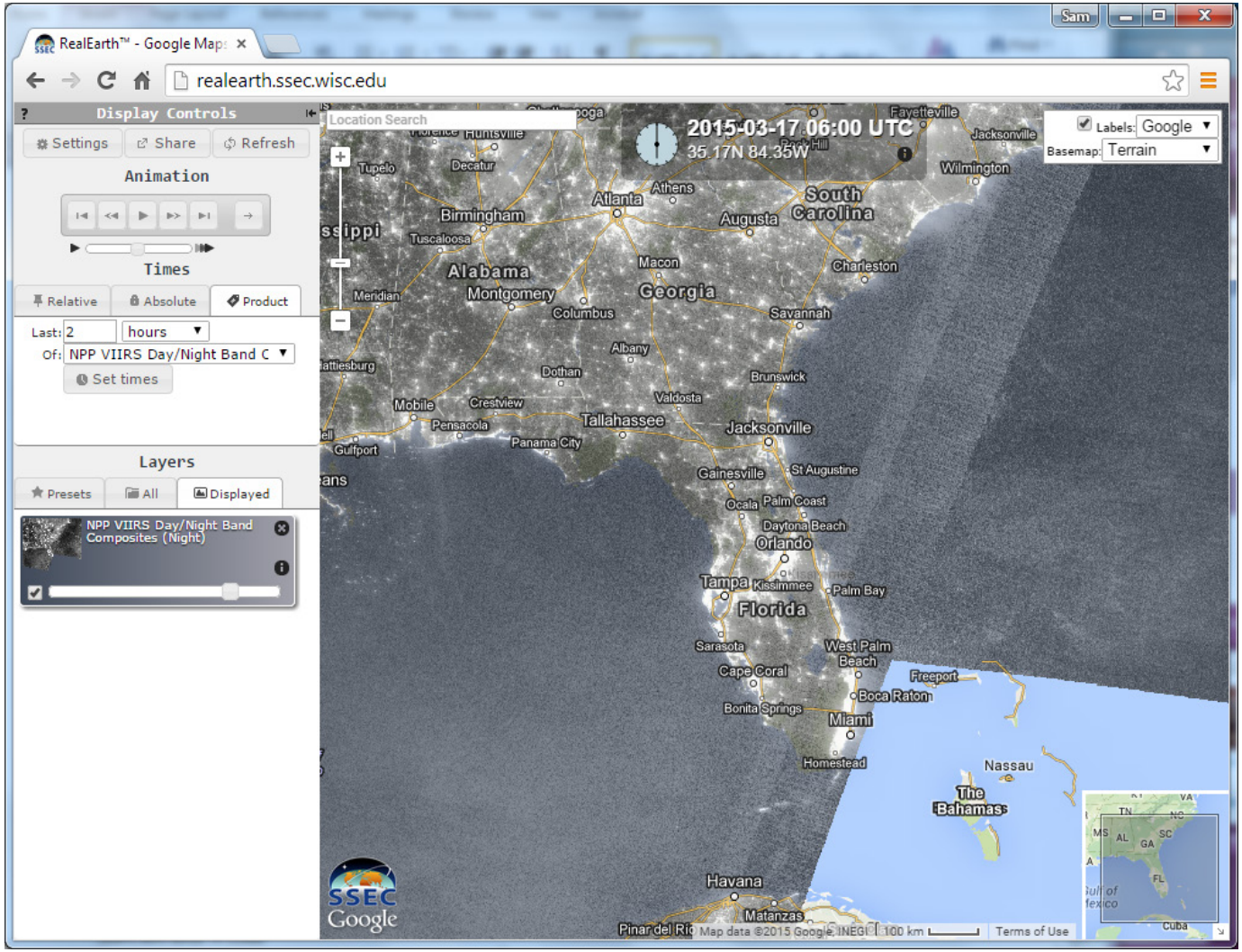
CSPP GEO

- NOAA GOES-R Project is funding the development of a CSPP GEO software package.
- Supported satellites/sensors will include GOES-R ABI (GRB), GOES-N Imager (GVAR), and Himawari-8 AHI (HSF).
- CSPP GEO will create Level 1B products for all sensors on GOES-R (from GRB downlink).
- CSPP GEO will create atmosphere, cloud, and surface products from ABI Level 1B data via the GEOCAT framework.

ISEE Scenario

1. Event is seen, investigated & understood with ISEE
2. Event on Earth: fire, flood, volcano, algal bloom, pollution, fog, severe wx, & unusual phenomenon
3. **S-NPP/JSPP** Satellite Observation – Primary
4. Integrated with other Data/Information
5. Direct Broadcast to SSEC & expand to NOAA DBRTN (Direct Broadcast Real-Time Network) – Real Time
6. Processing into ISEE servers
7. Notification pushed to subscribers' cell phones
8. Sharing of event: Web, App, Facebook, Twitter, email, blog





RealEarth™

https://re.ssec.wisc.edu showing S-NPP day/night imagery

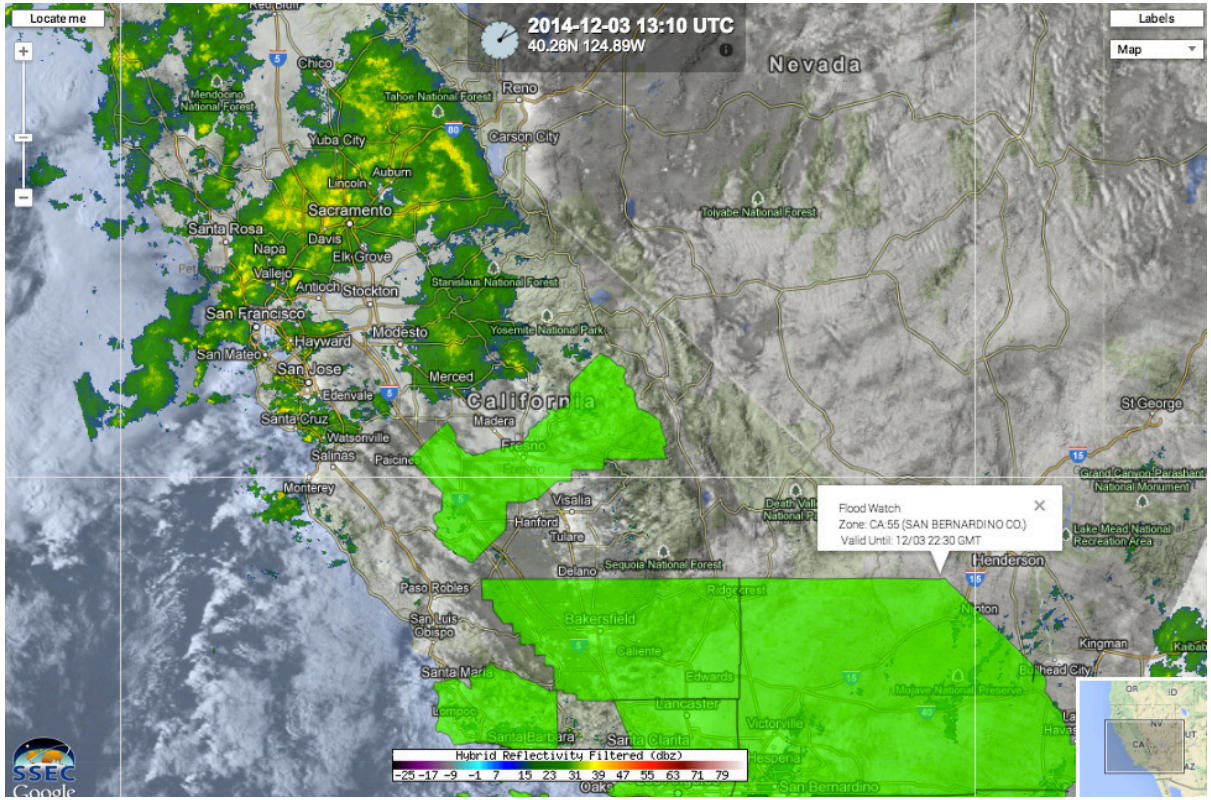
Innovative Satellite Enhanced Exploration

ISEE ISEE ISEE ISEE

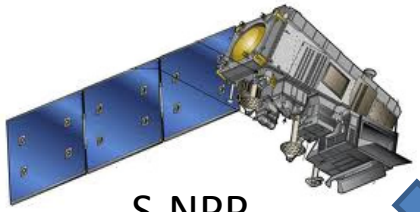
ISEE Example-1:

- SuomiNPP DayNightBand ConUS Composite with
- Unidata NEXRAD Radar Reflectivity Composite and
- NWS Flood Watches/Warnings

Dec 3, 2014 13:10Z

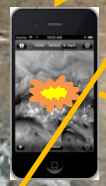


ISEE Synopsis
1st Gen



S-NPP

"I See!"



Accelerator-based (GPU/MIC) WRF model development at SSEC/CIMSS UW-Madison

- **Will greatly benefit high resolution regional forecasting real-time capability**

- Intel awarded SSEC a two-year grant to develop Intel MIC Xeon Phi Coprocessor based WRF using open ACC common architecture
  - SSEC becomes one of the Intel Parallel Computing Center (IPCC)
  - Open Source with minimum changes to WRF existing code structure
  - Less time consumption to adopt/adapt
  - Projected speedup is about <10
- NVIDIA, world largest GPU chip maker, is funding SSEC to develop a GPU-CPU Hybrid WRF prototype using CUDA architecture
  - CUDA based unique architecture
  - Need time consuming code porting & optimization
  - Projected speedup is about ~100
- IBM Power architect, WRF experiment with POWER CPU+ NVIDIA GPU
- TQI, GPU/CUDA based WRF for Low Latency Wx Forecast applications

HPC is one of the pillar of Why are the Weather Forecast Models still not accurate enough?

Three critical factors:

1. Imperfect MODEL
2. Lack of/Erroneous INITIAL DATA/CONDITIONS
3. Lack of COMPUTING POWER
   - Increasing needs of ensemble runs
   - Increasing demands for higher resolution
   - Increasing high frequency of assimilations
   - Increasing model complexity

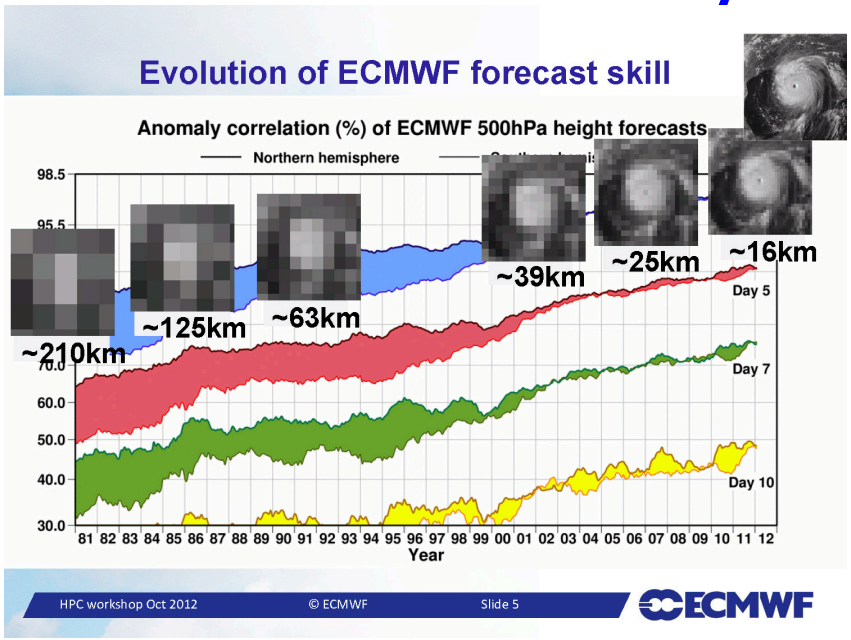
   Resulting to high demand in computing resources

100,000 to 200,000 CPU cores required for:

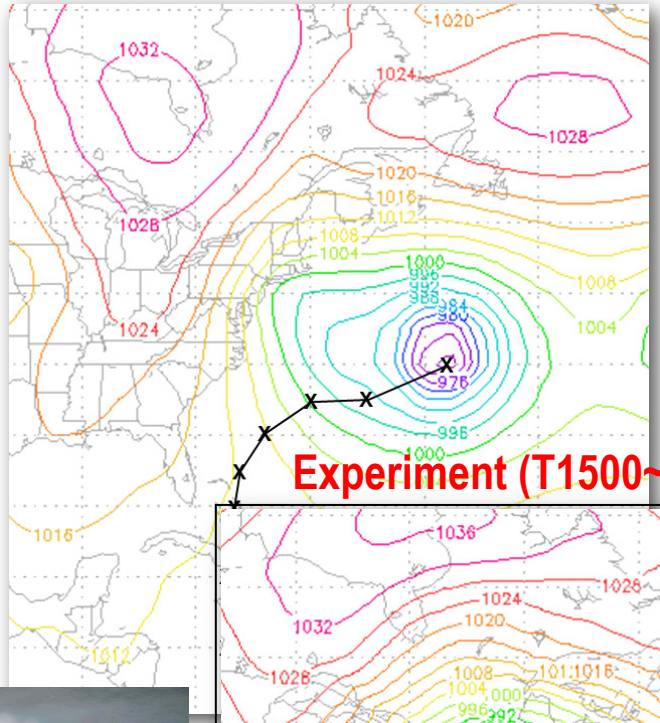
- **Global cloud resolving**
  NIM **@2KM** resolution, **2x/day**
- **Regional Models**
  North American (NA) Domain HRRR **@<1KM**, **hourly**
- **Ensembles**
  HRRR **@3KM** NA, 100 members, **hourly**

Reference : 250,000 CPU cost ~$100M; use 7,000KW & ~$8M/year energy bill

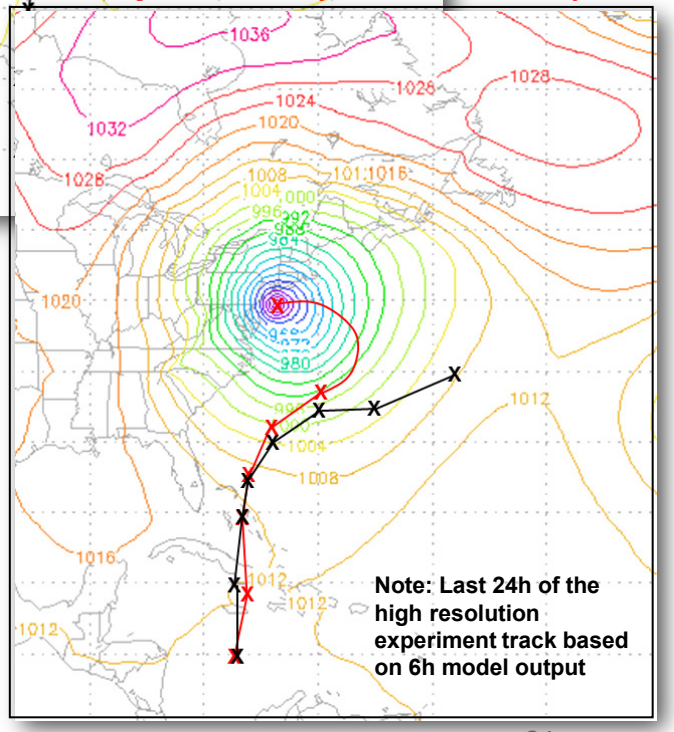
Coarse Model Resolution Greatly Limit Weather Forecast Accuracy



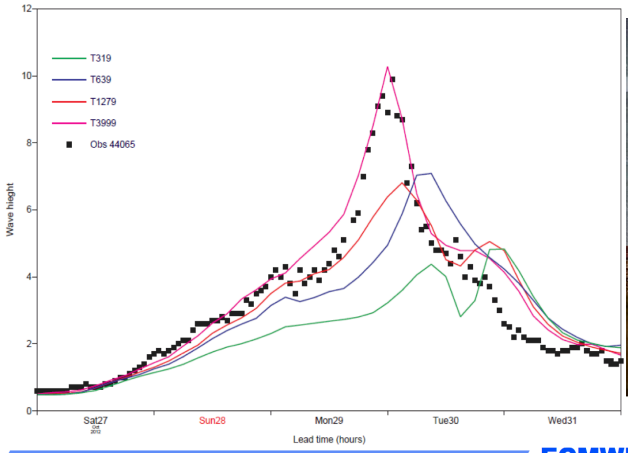
Operational (T574~ 27km)



Experiment (T1500~ 13km)



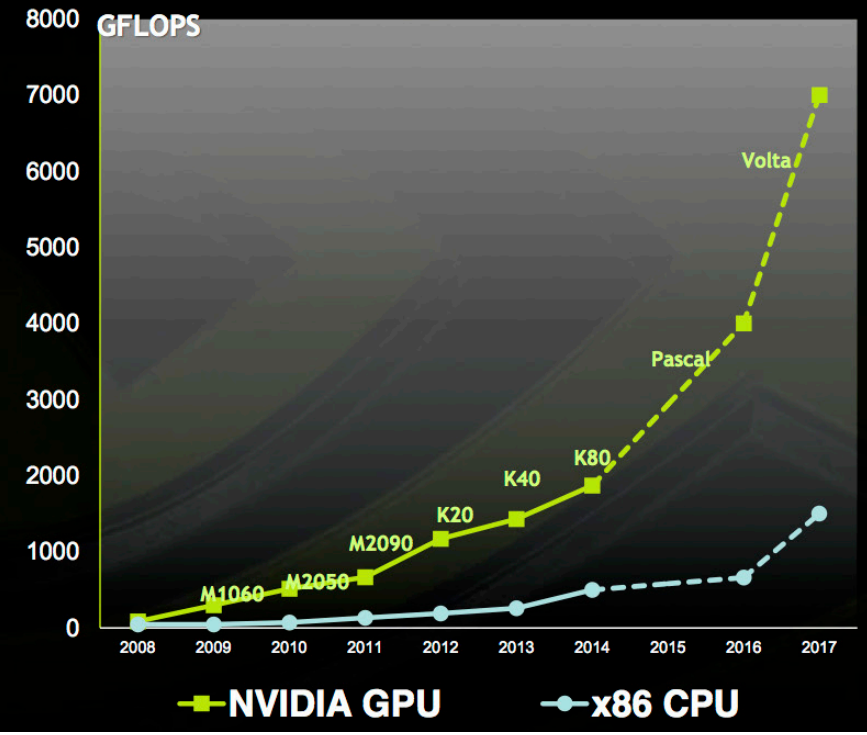
Wave height 72h forecast, T3999 (~5km)

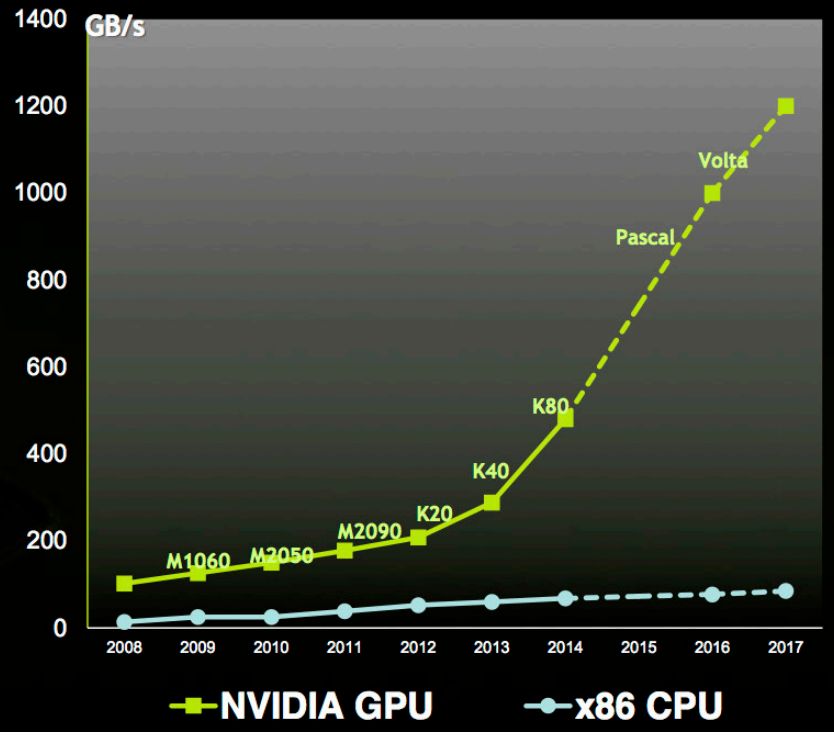


2X resolution ≈ 10X of computing cost

GPU Performance – FLOPS & Memory Bandwidth

GPU Motivation (I): Performance Trends





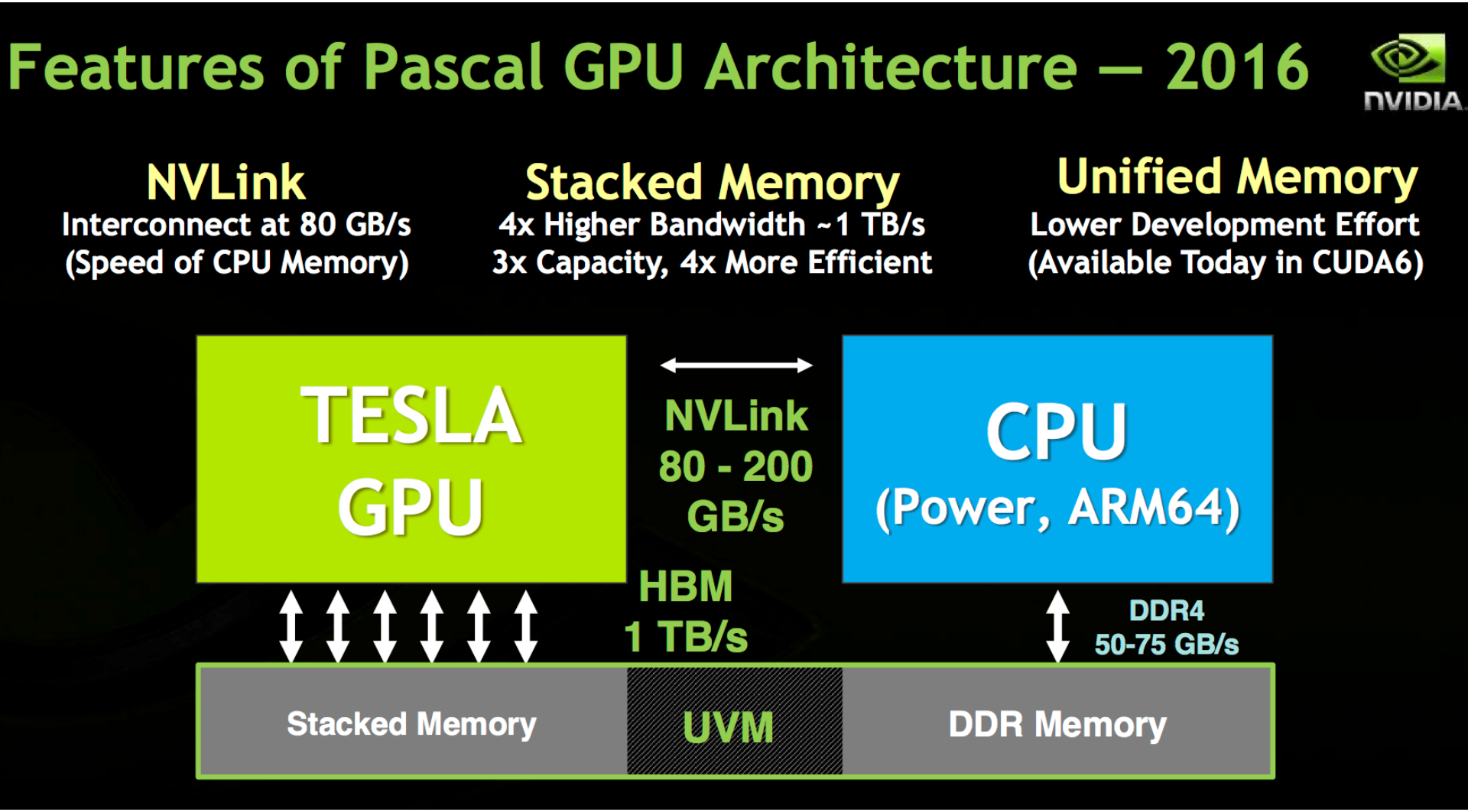
GPU Performance

Significant Progress in All Fronts – Especially Performance/Energy

	2012 **M2075**	**K20X**	**K40**	2014 **K-80** (2014/2012)
Peak SP Peak SGEMM	1.03 TF	3.93 TF 2.95 TF	4.29 TF 3.22 TF	8.74 TF 5.6 TF (~8x)
Peak DP Peak DGEMM	.515 TF	1.31 TF 1.22 TF	1.43 TF 1.33 TF	2.91 TF 1.87 TF (~5x)
Memory size	6 GB	6 GB	**12 GB**	24 GB (4x)
Mem BW (ECC off)	150 GB/s	250 GB/s	288 GB/s	480 GB/s (~3x)
Memory Clock		2.6 GHz	3.0 GHz	
# of Cores	448	2688	2880	4992 (~5x)
Total Board Power	**235W**	**235W**	**235W**	Same

GPU Performance –

Architecture Enhancement: 1) faster interconnect, 2) higher bandwidth & 3) lower development effort



WRF (Weather Research & Forecasting) Overview

- WRF is mesoscale and global Weather Research and Forecasting model
- Designed for both operational forecasters and atmospheric researchers
- WRF is currently in operational use at numerous weather centers around the world
- WRF is suitable for a broad spectrum of applications across domain scales ranging from meters to hundreds of kilometers.

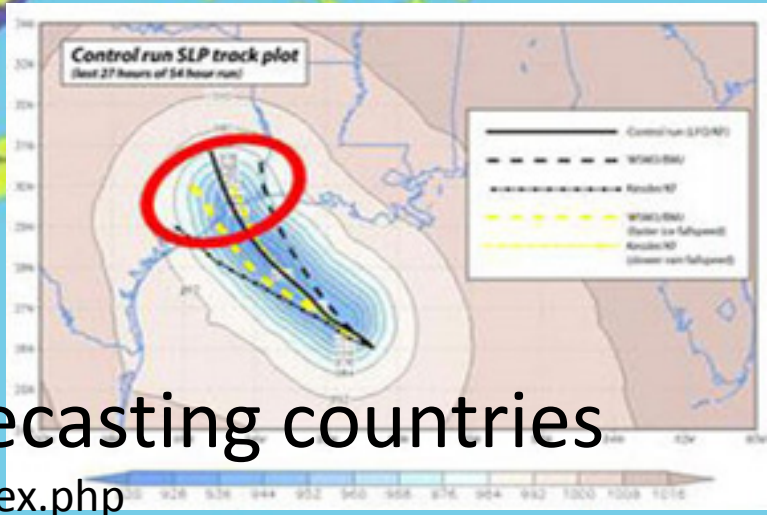
- Increases in computational power enables
  - Increased vertical as well as horizontal resolution
  - More timely delivery of forecasts
  - Probabilistic forecasts based on ensemble methods

- Why accelerators?
  - Cost performance
  - Need for strong scaling

>25,000 registrants

>14 operational/real-time forecasting countries

http://www.wrf-model.org/index.php



WRF simulation of Hurricane Rita (2005) tracks
Wikimedia Commons

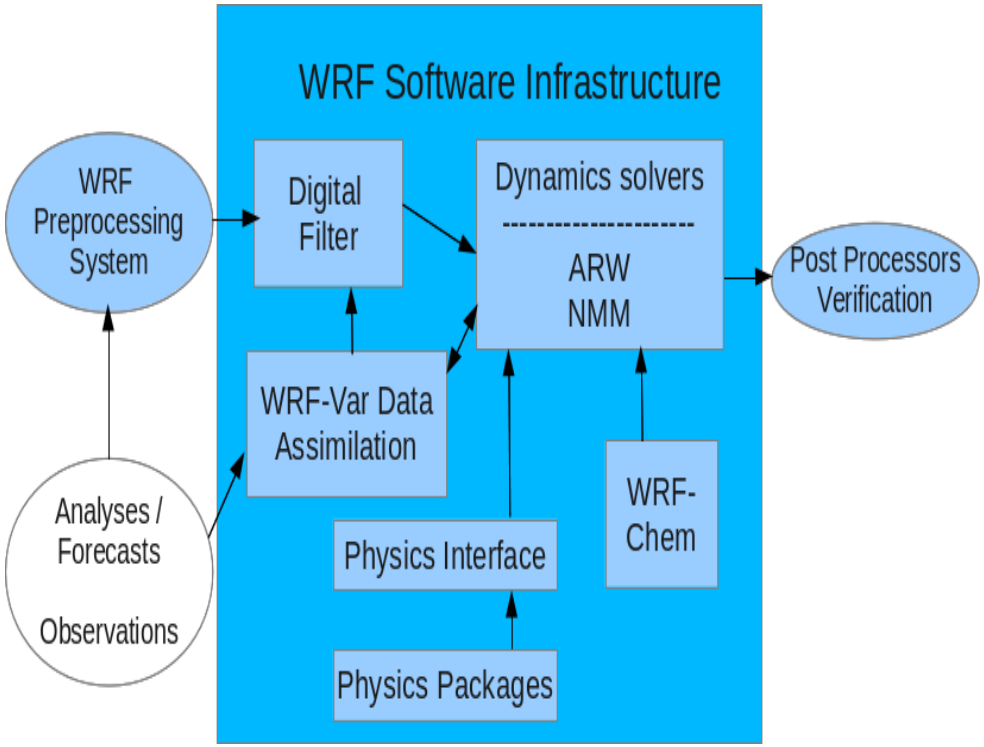
User Countries

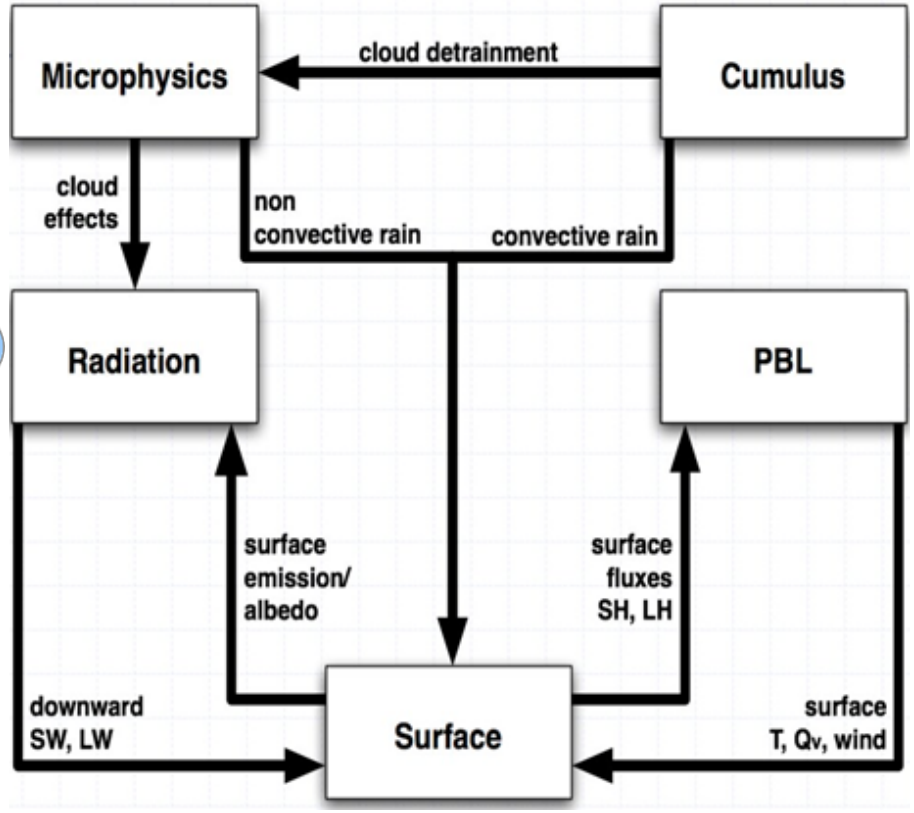
Operational/Realtime Forecasting Countries

153 Countries

Image: Welcome Remarks, 14th Annual WRF Users' Workshop.

WRF system components

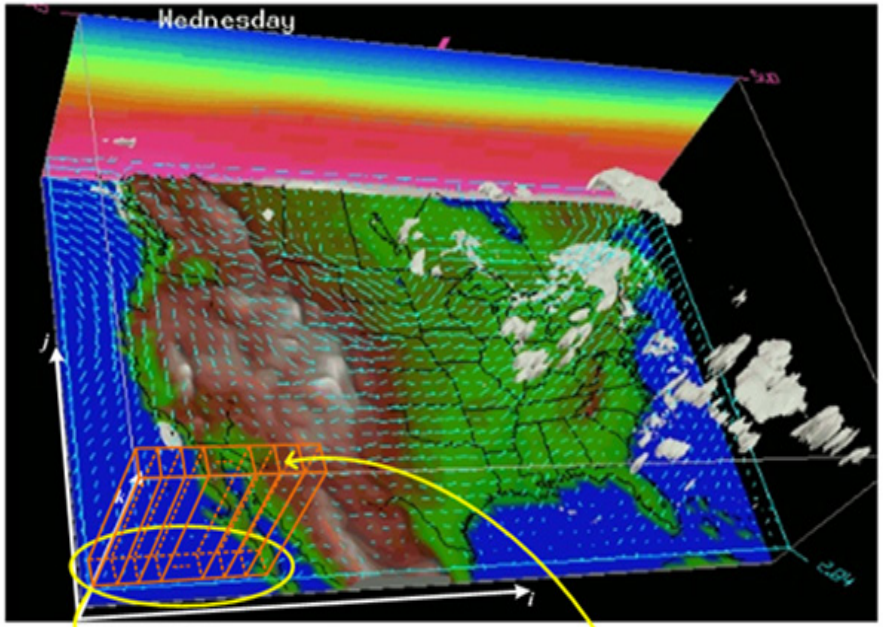




Jimy Dudhia: WRF physics options

- WRF has ~60,000 line of codes
- The WRF physics categories are **microphysics**, cumulus parametrization, planetary boundary layer (PBL), land-surface model and radiation.

CUDA-based GPU accelerated WRF modules



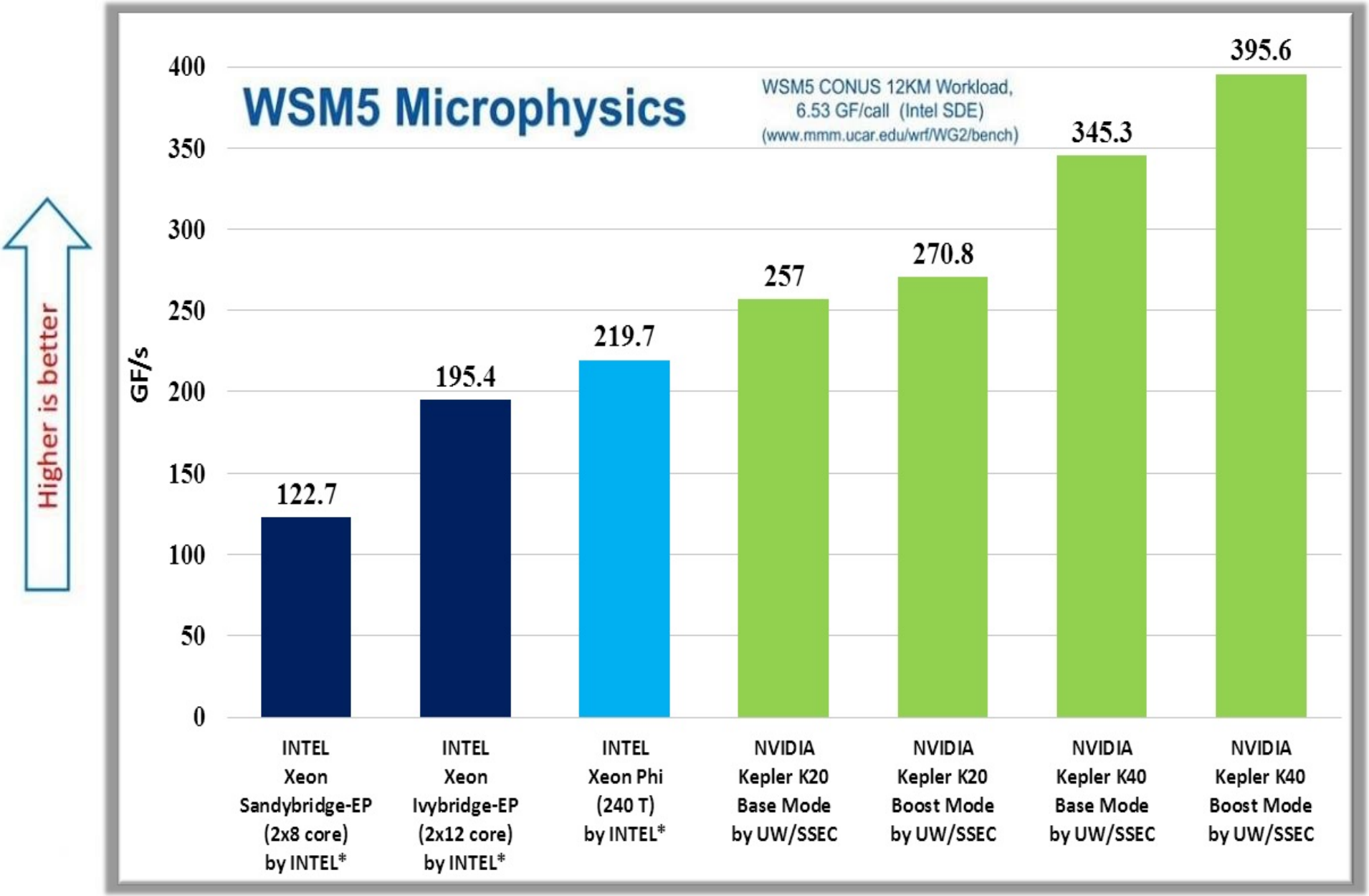
WRF Module name	Speedup vs. one thread on 1.8Ghz Sandy Bridge (gfortran v.4.6.2)
Single moment 6-class microphysics	500x
Eta microphysics	272x
Purdue Lin microphysics	692x
Stony-Brook University 5-class microphysics	896x
Betts-Miller-Janjic convection	105x
Kessler microphysics	816x
New Goddard shortwave radiance	134x
Single moment 3-class microphysics	331x
New Thompson microphysics	153x
Double moment 6-class microphysics	206x
Dudhia shortwave radiance	409x
Goddard microphysics	1311x
Double moment 5-class microphysics	206x
Total Energy Mass Flux surface layer	214x
Mellor-Yamada Nakanishi Niino surface layer	113x
Single moment 5-class microphysics	350x
Pleim-Xiu surface layer	665x

Radiation	RRTMG LW	123x / 127x	JSTARS, 7, 3660-3667, 2014
	RRTMG SW	202x / 207x	Submitted to J. Atmos. Ocean. Tech.
	Goddard SW	92x / 134x	JSTARS, 5, 555-562, 2012
	Dudhia SW	19x / 409x	
Surface	MYNN SL	6x / 113x	
	TEMF SL	5x / 214x	
	Thermal Diffusion LS	10x / 311x [2.1 x]	(GPU) Submitted to JSATRS
PBL	YSU PBL	34x / 193x [2.4x]	(GPU) Submitted to GMD
	TEMF PBL	[14.8x]	(MIC) SPIE:doi:10.1117/12.2055040
CU P	Betts-Miller-Janjic (BMJ) convetion	55x / 105x	

GPU speedup: speedup with IO / speedup without IO

MIC improvement factor in [ ]: w.r.t. 1st version multi-threading code before any improvement

Cloud Microphysics			
	Kessler MP	**70x / 816x**	**J. Comp. & GeoSci., 52, 292-299, 2012**
	Purdue-Lin MP	**156x / 692x [4.2x]**	**(GPU) SPIE: doi:10.1117/12.901825**
	WSM 3-class MP	**150x / 331x**	
	WSM 5-class MP	**202x / 350x**	**JSTARS, 5, 1256-1265, 2012**
	Eta MP	**37x / 272x**	**SPIE: doi:10.1117/12.976908**
	WSM 6-class MP	**165x / 216x**	**Submitted to J. Comp. & GeoSci.**
	Goddard GCE MP	**348x / 361x [4.7x]**	**(GPU) Accepted for publication in JSTARS**
	Thompson MP	**76x / 153x [2.3x]**	**(MIC) SPIE: doi:10.1117/12.2055038**
	SBU 5-class MP	**213x / 896x**	**JSTARS, 5, 625-633, 2012**
	WDM 5-class MP	**147x / 206x**	
	WDM 6-class MP	**150x / 206x**	**J. Atmo. Ocean. Tech., 30, 2896, 2013**

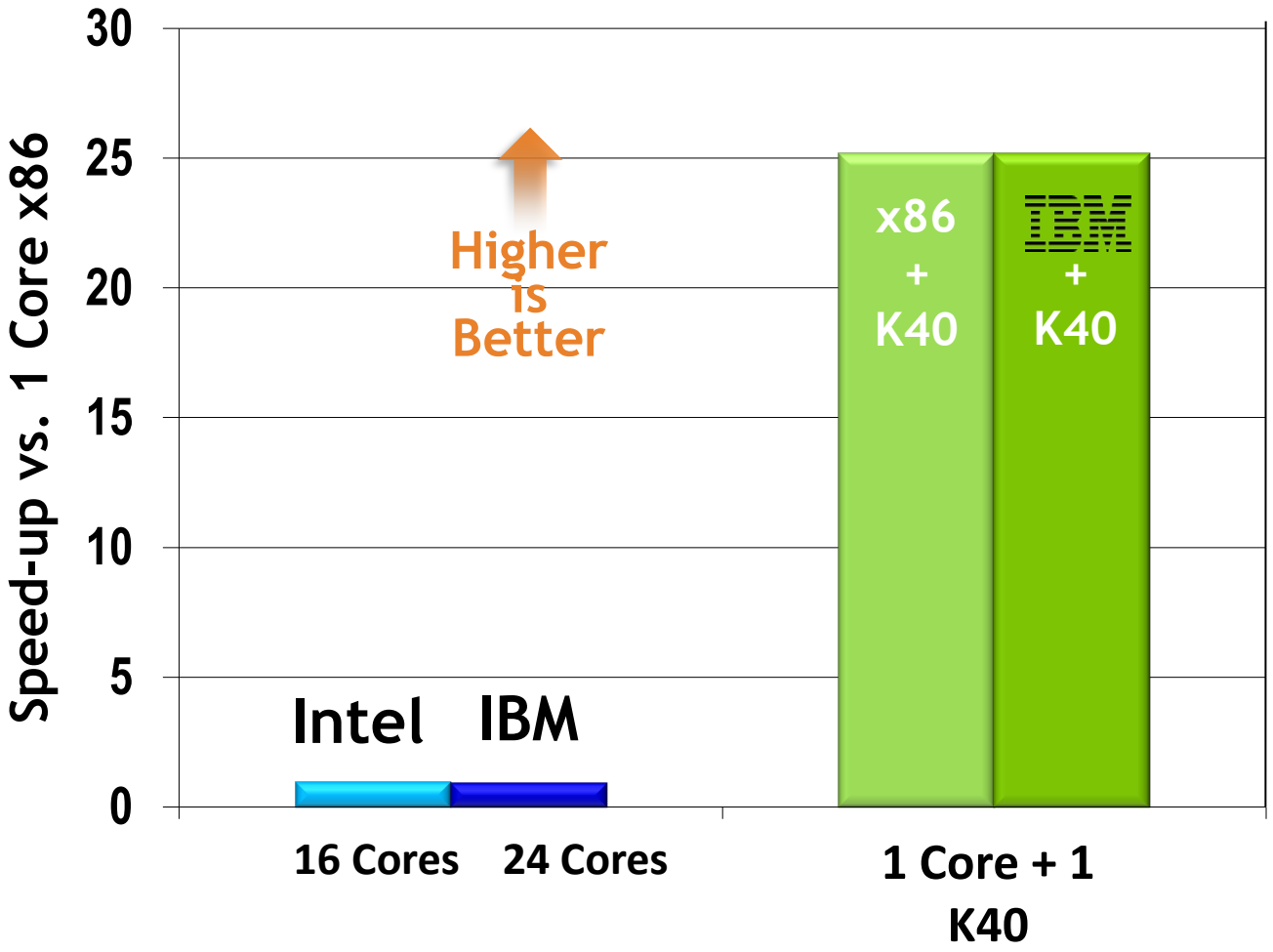


* *Code Restructuring to Improve Performance in WRF Model Physics on Intel Xeon Phi*. J. Michalakes. Workshop on Programming Weather, Climate and Earth System Models on Heterogeneous Multi-core Platforms, Boulder, Colorado, Sept. 19-20, 2013. (http://data1.gfdl.noaa.gov/multi-core/presentations/michalakes_5.pdf)

WRF WSM6 Results for Power8 + K40

http://www.wrf-model.org/

Numerical Results Validation Confirmed by SSEC



Results from NVIDIA PSG Cluster (HQ, USA)

NVIDIA PSG Cluster

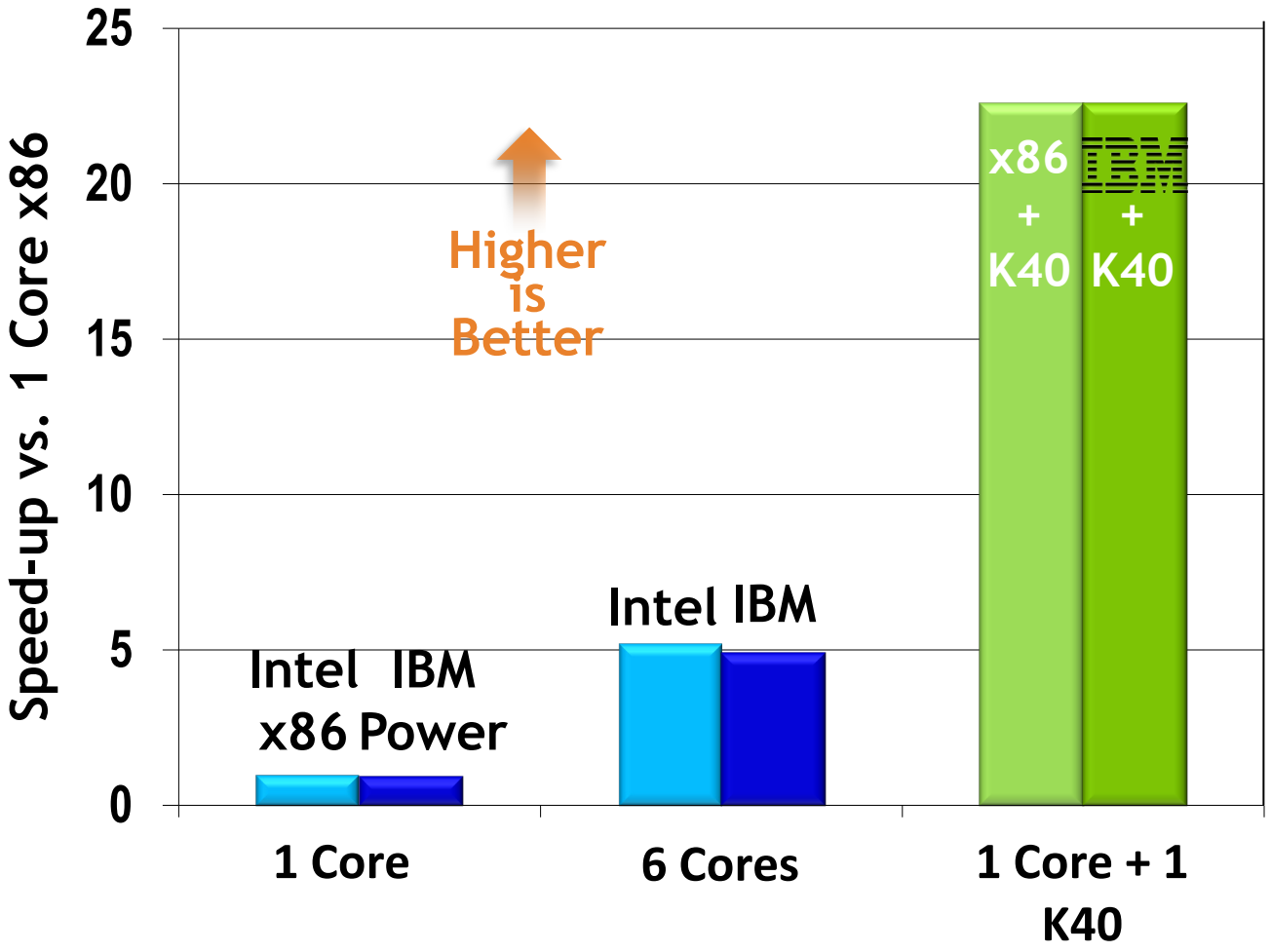
http://psgcluster.nvidia.com/trac

- WRF revision 3.6.1
- CONUS 12 km
- All results single socket
- IBM Power 8:
  - 12 Cores @3.9 GHz
- Power 8 Compiler: gftn 4.9.1
- x86 Xeon E5-2698 v3:
  - 16 Cores @ 2.3 GHz
- X86 Compiler: gftn 4.4.7
- NVIDIA Tesla K40 GPU
- CUDA 7.0.27

COSMO Dynamics Results for Power8 + K40

http://www.cosmo-model.org/

Numerical Results Validation Confirmed by MeteoSwiss



Results from NVIDIA PSG Cluster

NVIDIA PSG Cluster

http://psgcluster.nvidia.com/trac

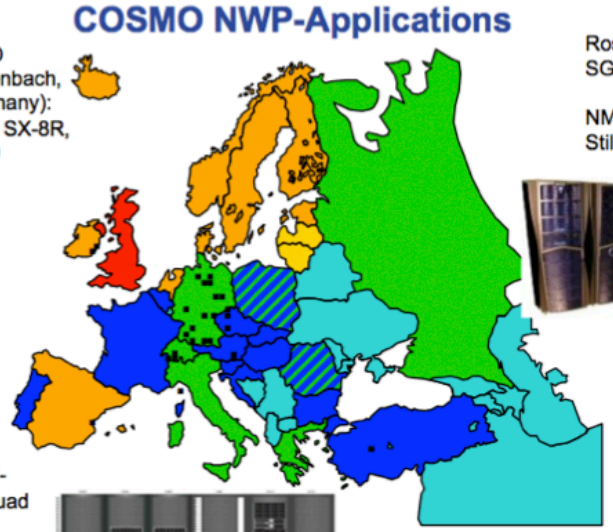
- COSMO SVN revision 6307
- PerformanceUnittest.Dycore case, 122 x 122 (x60)
- All results single socket
- IBM Power 8:
  - 12 Cores @3.9 GHz
- Power 8 Compiler: gcc 4.9.1
- x86 Xeon E5-2690 v2:
  - 8 Cores @ 3.0 GHz
- X86 Compiler: gcc 4.8.2
- NVIDIA Tesla K40 GPU
- CUDA 5.5

What is COSMO?

DWD (Offenbach, Germany): NEC SX-8R, SX-9

MeteoSwiss: Cray XT4: COSMO-7 and COSMO-2 use 980+4 MPI-Tasks on 246 out of 260 quad core AMD nodes

ARPA-SIM (Bologna, Italy): Linux-Intel x86-64 Cluster for testing (uses 56 of 120 cores)



USAM (Rome, Italy): HP Linux Cluster XEON biproc quadcore System in preparation

Roshydromet (Moscow, Russia), SGI

NMA (Bucharest, Romania): Still in planning / procurement phase

IMGW (Warsawa, Poland): SGI Origin 3800: uses 88 of 100 nodes

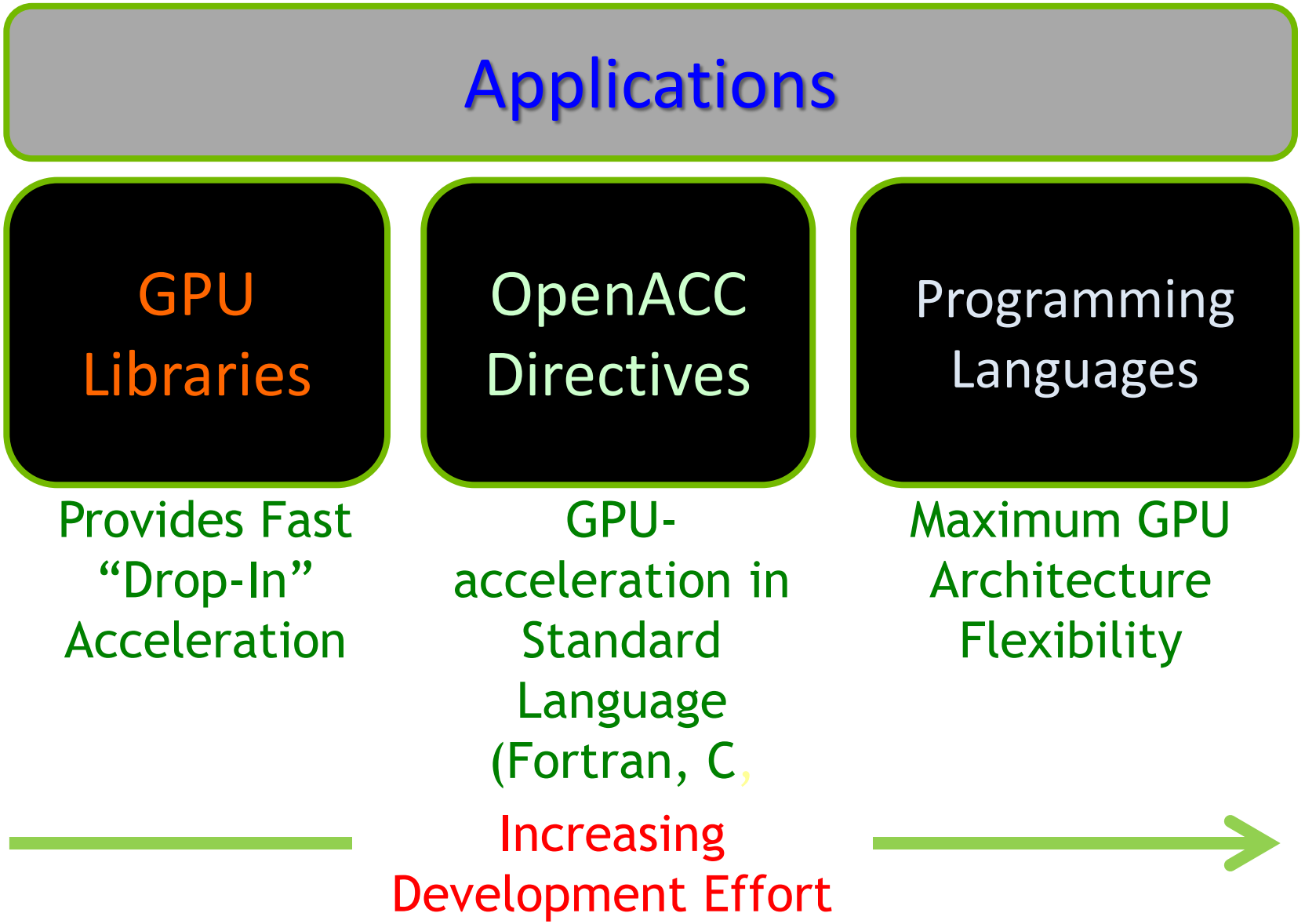
ARPA-SIM (Bologna, Italy): IBM pwr5: up to 160 of 512 nodes at CINECA

COSMO-LEPS (at ECMWF): running on ECMWF pwr6 as member-state time-critical application

HNMS (Athens, Greece): IBM pwr4: 120 of 256 nodes

- Consortium for Small-Scale Modeling
- http://www.cosmo-model.org/
- Limited-area climate model
- Used by 7 weather services and O(50) universities and research institutes

Programming Strategies for GPU Acceleration



Trends in Earth System Model

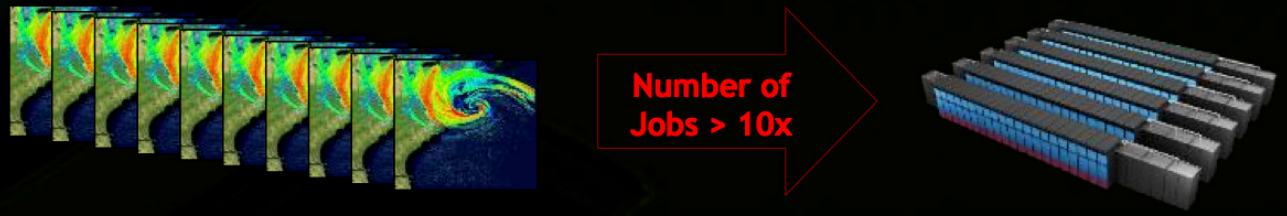
Increased Demands for Computing (>100 to >1,000)

GPU Motivation (III): Model Trends in ESM

- **Higher grid resolution with manageable compute and energy costs**
  - Global atmosphere models from 10-km today to cloud-resolving scales of 3-km

Source: Project Athena – http://www.wxmaps.org/athena/home/

- **Increase ensemble use and ensemble members to manage uncertainty**



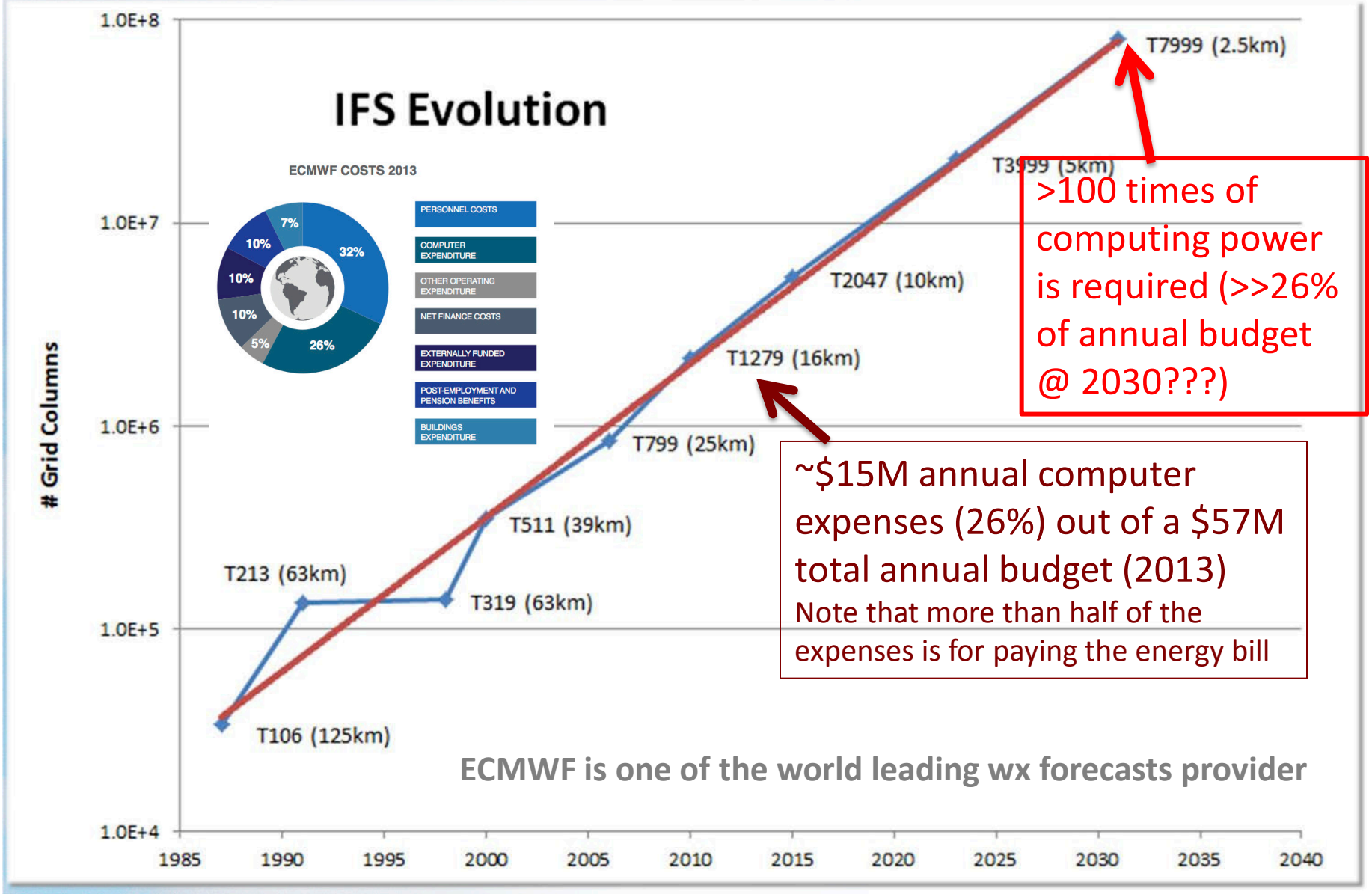
- **Fewer model approximations, more features (physics, chemistry, etc.)**

Accelerator technology identified as a cost-effective and practical approach to future computational challenges

HPC Trends at Large NWP/Climate Centers

Motivation for x86 Migration Includes Preparation for Future Accelerator Deployment

	Organization	Location	Models	Previous HPC	Current HPC	Size / Cost (M) / Date
Operational NWP	ECMWF	Reading, UK	IFS	**IBM Power**	Cray XC30 – x86	3.5 PF / $65 / Jun 2013
	Met Office	Exeter, UK	UM	**IBM Power**	Cray XC30 – x86	16 PF / $120 / Oct 2014
	DWD	Offenbach, DE	COSMO, ICON, GME	NEC SX-9	Cray XC30 - x86	2 PF / $23 / Jan 2013
	MF	Toulouse, FR	ALADIN, AROME	NEC SX-9	Bull - x86	5 PF / $? / Nov 2012
	NOAA/ NCEP	*Various*, US	GFS, WRF, FIM, NIM	**IBM Power**	IBM iDataPlex - x86 Cray XC40 - x86	5 PF / $50/yr / Oct 2015
Research	DKRZ/MPI-M	Hamburg, DE	ICON, MPI-ESM	**IBM Power**	Bull - x86	3 PF / $35 / May 2014
	NCAR	Boulder, US	CESM, WRF, MPAS-A	**IBM Power**	IBM iDataPlex - x86	1.6 PF / ~$30 / Nov 2011


IFS Evolution
Grid Columns
1.0E+8
1.0E+7
1.0E+6
1.0E+5
1.0E+4
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
T7999 (2.5km)
T3999 (5km)
T2047 (10km)
T1279 (16km)
T799 (25km)
T511 (39km)
T319 (63km)
T213 (63km)
T106 (125km)
ECMWF COSTS 2013
32%
26%
10%
10%
10%
7%
5%
PERSONNEL COSTS
COMPUTER EXPENDITURE
OTHER OPERATING EXPENDITURE
NET FINANCE COSTS
EXTERNALLY FUNDED EXPENDITURE
POST-EMPLOYMENT AND PENSION BENEFITS
BUILDINGS EXPENDITURE
>100 times of computing power is required (>>26% of annual budget @ 2030???)
~$15M annual computer expenses (26%) out of a $57M total annual budget (2013)
Note that more than half of the expenses is for paying the energy bill
ECMWF is one of the world leading wx forecasts provider

GPU Performance –

Overall System savings: 1) Initial Acquisition, 2) power & cooling & 3) facilities

ESRL Global Model Plans

A presentation to:
ECMWF 15th Workshop
On HPC in Meteorology
October 2, 2012

Alexander E. MacDonald
Director
Earth System Research Lab
Boulder, Colorado

Deputy Assistant Administrator
NOAA Research

Slide #36

Peta Flop Computing in 2012

DOE

Jaguar System
- 2.3 PetaFlops
- 250,000 CPUs
- 284 cabinets
- 7000 KW power
- **Cost: ~ $100 million**
- **Building: $75 million**
- **Reliability in hours**

Equivalent GPU System
- 2.3 PetaFlop
- 600 Kepler GPUs
- 10 cabinets
- 200 KW power
- **Cost: ~ $5 million**
- **Reliability in weeks**

- **Large CPU systems (>100 thousand CPUs) are unrealistic for operational weather forecasting**

	CPU cost	GPU cost
– Power & Cooling:	$8.4 M / year	$0.2M / year
– System Cost:	$100M	$5 M
– Facilities	$75M	$0.8M

- GPU-based systems will dominate super-computing within 3 years
  - 75 percent of HPC customers are expected to use GPUs in 2014 (HPC study, 2012)

36

Accelerator-based (GPU/MIC) WRF model development at SSEC/CIMSS UW-Madison

- **Will greatly benefit high resolution regional forecasting real-time capability**

- Intel awarded SSEC a two-year grant to develop Intel MIC Xeon Phi Coprocessor based WRF using open ACC common architecture
  - SSEC becomes one of the Intel Parallel Computing Center (IPCC)
  - Open Source with minimum changes to WRF existing code structure
  - Less time consumption to adopt/adapt
  - Projected speedup is about <10
- NVIDIA, world largest GPU chip maker, is considering funding SSEC to develop a GPU-CPU Hybrid WRF prototype using CUDA architecture
  - CUDA based unique architecture
  - Need time consuming code porting & optimization
  - Projected speedup is about ~100
- IBM Power architect, WRF experiment with POWER CPU+ NVIDIA GPU
- TQI, GPU/CUDA based WRF for Low Latency Wx Forecast applications

Community Satellite Processing Packages

– Facilitating Improvements in Real-time Satellite Data Applications

Summary

With strong support from NASA & NOAA support, SSEC/UW is committed to fully support NASA & NOAA Direct Readout/Broadcast activities to:

- Maintain existing DB Processing Packages (i.e. IMAPP) for MODIS and AIRS and to develop new capabilities/applications and package for NPP/JPSS (CSPP, LEO/GEO), & METOP (L1-L2 PP) systems.
- Upgrade DB real-time processing system efficiency, functions, and effort in enhancing Numerical Weather Prediction (DBCRAS->GPU-WRF) and air quality model (IDEA-I) and other applications to directly assimilate real time products (i.e. clouds, water vapor, and aerosol) to optimize broad use of DB products.
- Support NOAA NNWS offices & Real-Time DB users in the efficient and broad use of the current and future polar orbiting satellite data/information.
- Offer DB users training workshops in processing algorithms, S/W package operations and real-time applications
- Organize CSPP/IMAPP Users' Group meeting as often as needed
- Innovate to support JPSS program goal and program Scientist's vision

ITSC-20 to be held at Grand Geneva Resort and Spa, Lake Geneva, Wisconsin

28 October to 3 November2015

Consider to host 3rd CSPP/IMAPP Users' Group Meeting in the near future!

Thank you for your Patience,

any question is welcomed!