



Environment
Canada

Environnement
Canada

Canada

HPC at the Canadian Meteorological Centre

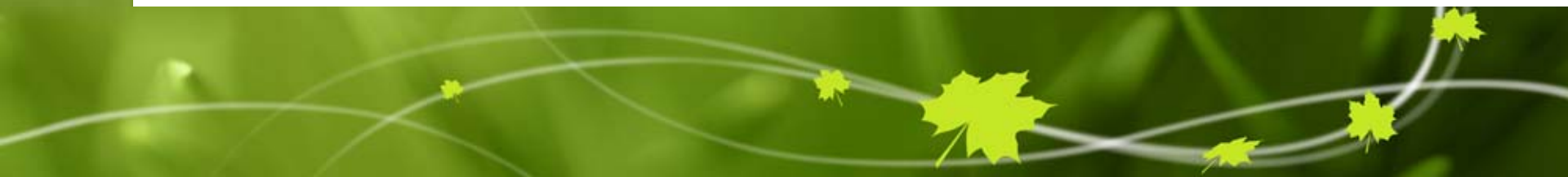
Luc Corbeil

Chief, Supercomputer, Systems and Storage

Bertrand Denis

Chief, Numerical Weather Prediction Section

Fourteenth Workshop on Use of High Performance Computing in Meteorology
1 – 5 November 2010, ECMWF, Reading, UK



Outline

- Part one (Luc)
 - CMC introduction
 - Facility fun
 - IT resources
 - Front-ends
 - Supercomputer
 - Storage
- Part two (Bertrand)
 - Historical HPC evolution and forecast quality
 - Current modeling systems
 - HPC utilization
 - Future modeling systems



Canadian Meteorological Centre

Meteorological Research
Division: Data
Assimilation, Modeling,
Cloud Physics

CMC Development
Division: Data
Assimilation,
Numerical Weather
Prediction, Weather
Elements, Scientific
Applications

IT Infrastructure (CIOB): Supercomputer,
National Telecommunications, Network,
User support

CMC Operations: Analysis & Prognosis,
Env. Emergency Response, Air Quality,
Implementation and Operational Services



Environment
Canada

Environnement
Canada

Canada

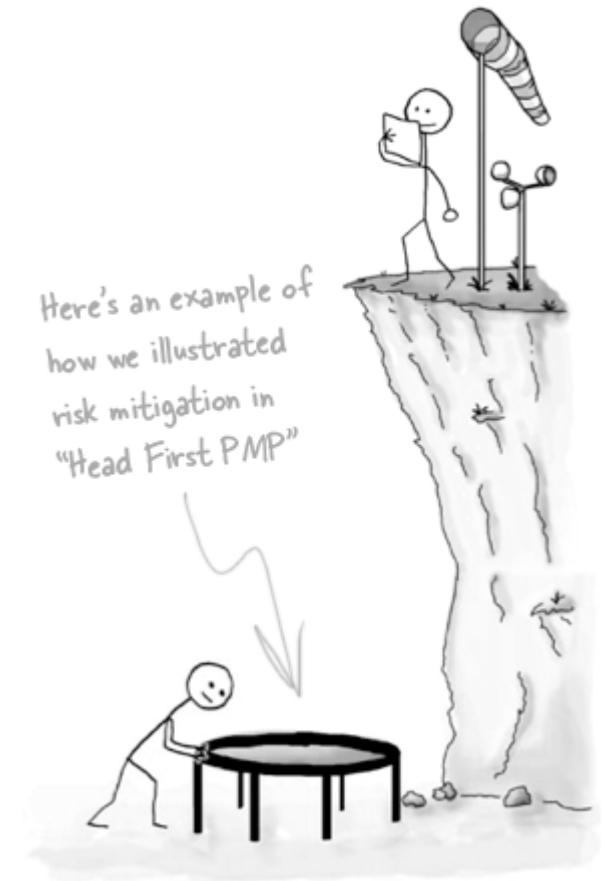
Simulating Earthquake

- The work involves:
 - Removing existing asphalt, gravel and insulation
 - Drill thousands of small holes in the top concrete slab
 - Build new rod structure using the holes
 - Add concrete slab on top of the existing
 - Insulation, gravel and asphalt
- Lots of limitations for the contractor
 - Type and weight of equipment
 - Threshold for vibration
 - Testing prior to key phases



Simulating Earthquake (2)

- Mitigation
 - Lots and lots of discussions
 - With Vendors
 - With other sites
 - With Facilities/Contractor.
 - Close monitoring, installation of seismic detectors
 - Pray for RAID arrays, tape drives and everything else!!!



Simulating Earthquake (3)

- Outcome
 - Vibration not an issue at all
 - Many HD failures in a single cabinet, but after drilling was over.
 - Drilling in cracked concrete can lead to water leaks



Front-end renewal

- O3000 SGI servers retired
- Replaced by commodity clusters and storage
- Found good/green usage for legacy hardware



Environment
Canada

Environnement
Canada

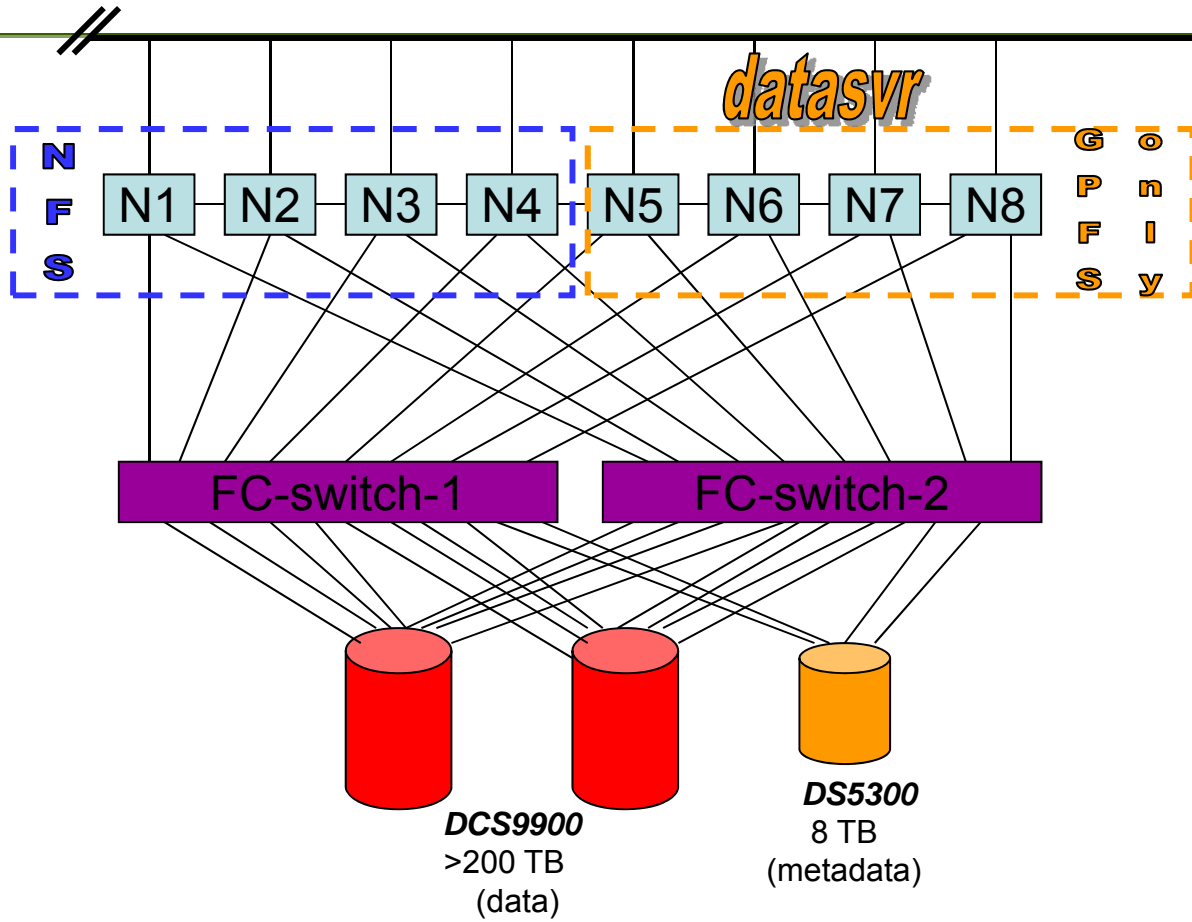
CNFS: Sitewide Storage

- CNFS (Clustered NFS)
 - scale-out HA NFS built on top of Linux GPFS servers
 - SLES support from Novell, then transferred to IBM
 - IP failover
 - Can have both GPFS and NFS clients
 - Performance: up to 500MB/s for reads and writes
 - 10GigE network, DCS9900 SATA storage, 8Gb FC
 - Acts like a scalable NAS



CNFS: Sitewide Storage

10 GigE TCP/IP

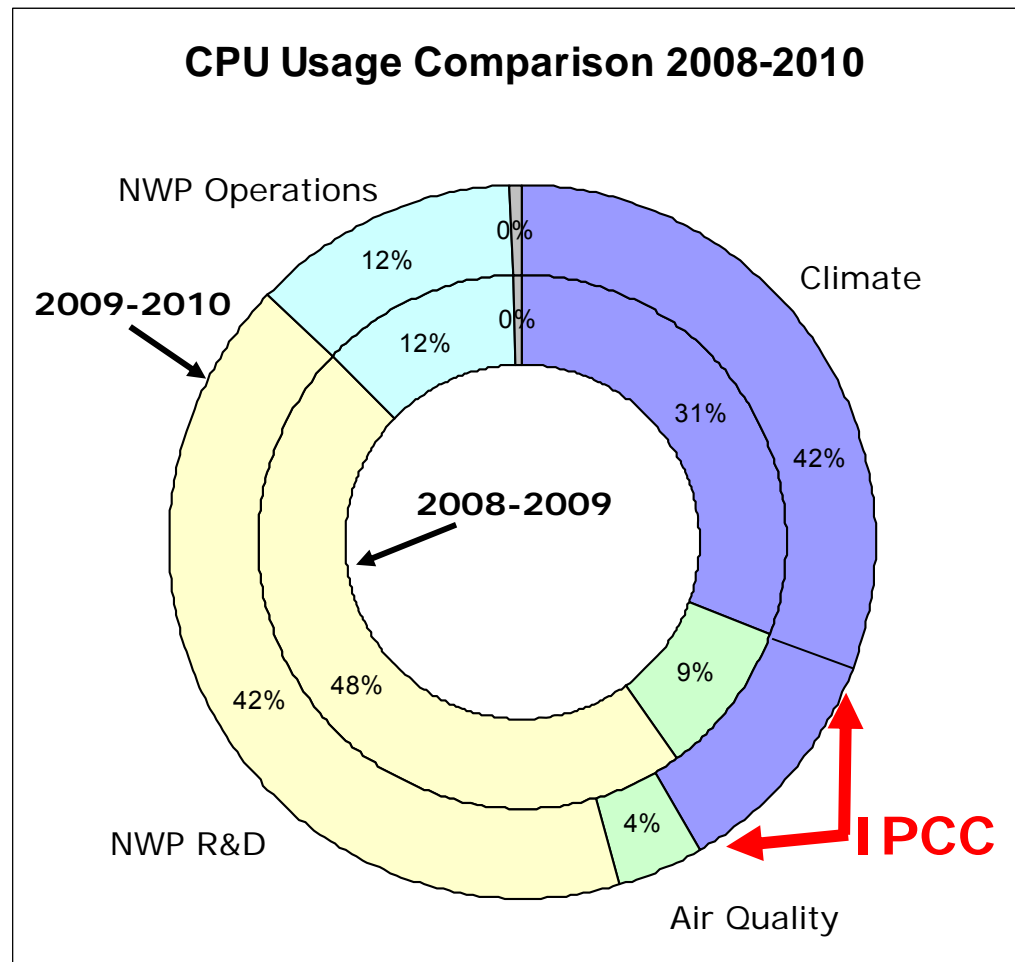


Supercomputer: IBM eServer pSeries p5 575 1.9GHz Saiph/Zeta

- IBM p575+
 - Two clusters of 131 and 133 compute nodes
 - 8 dual-core Power5+ 1.9 GHz/node
 - 16 physical processors + SMT enable
 - 64 GB RAM
 - Total 4224 PEs, 17 TB/RAM
 - 2 head nodes, 6 I/O nodes/cluster (NSD)
 - 64 TB shared disk (raw), 55 TB accessible
 - Federation Switch
 - Electricity: ~600 kW
 - One of the last mission critical p5+ operational cluster
 - Until February 29 2012.

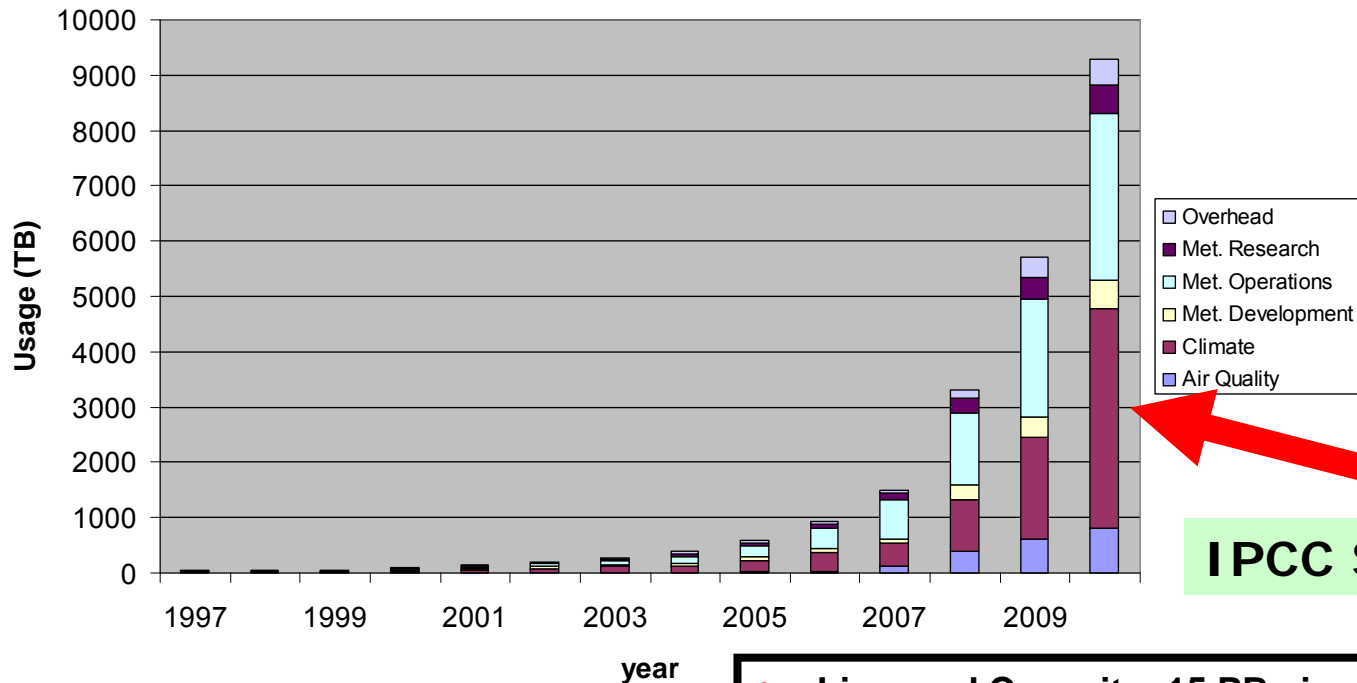


Supercomputer Usage



CFS: Archiving

Space usage on cfs



IPCC Storage challenge

- Licensed Capacity: 15 PB single copy.
- 13k slots
- Daily: Write: 25 TB / Read: 10 TB



Environment
Canada

Environnement
Canada

Canada

Outline (recall)

- Part one (Luc)

- CMC introduction
- Facility fun
- IT resources
 - Front-end
 - Supercomputer
 - Storage

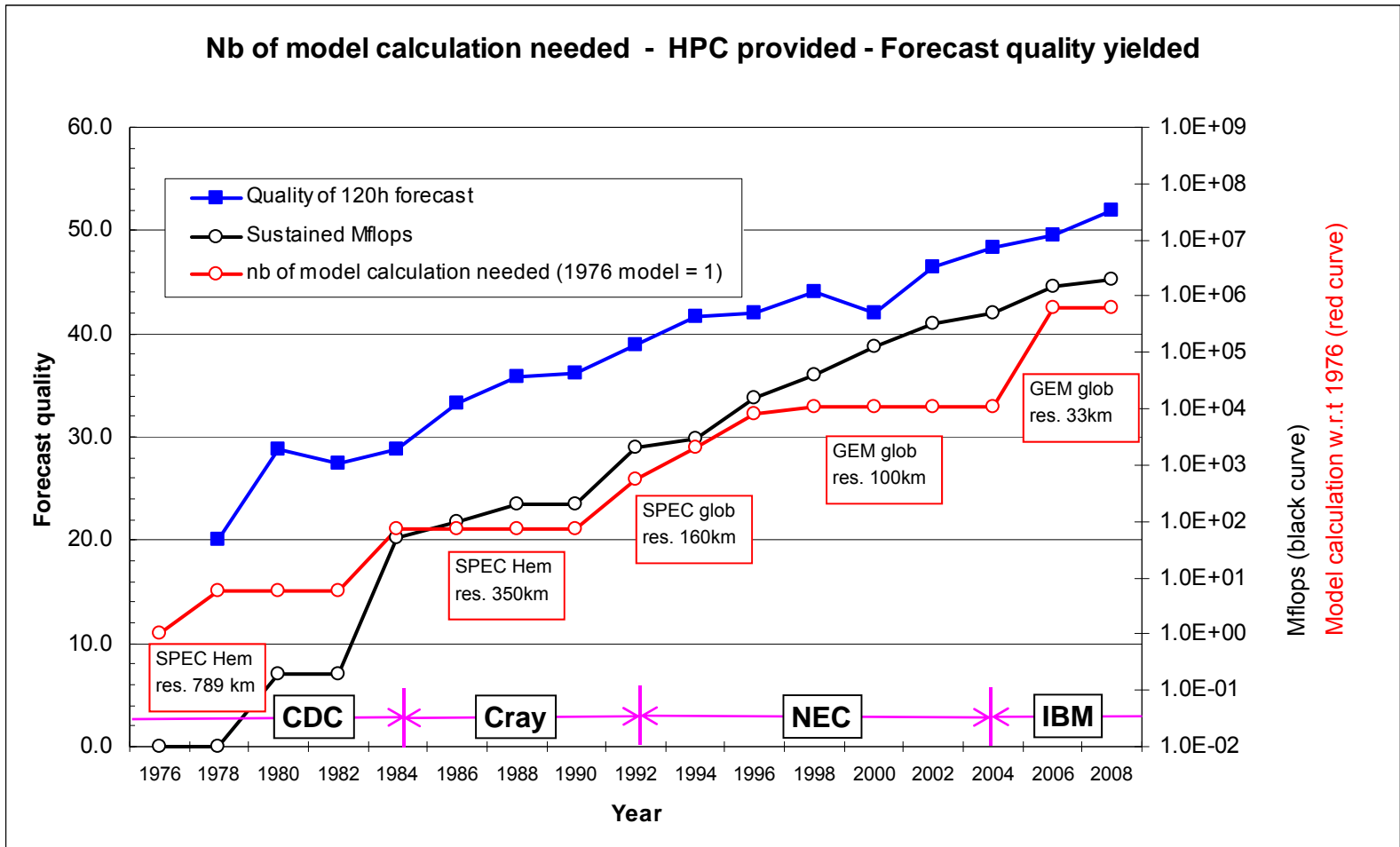
**Now, let's see how
we take advantage
of (dry) IT resources**

- Part two (Bertrand)

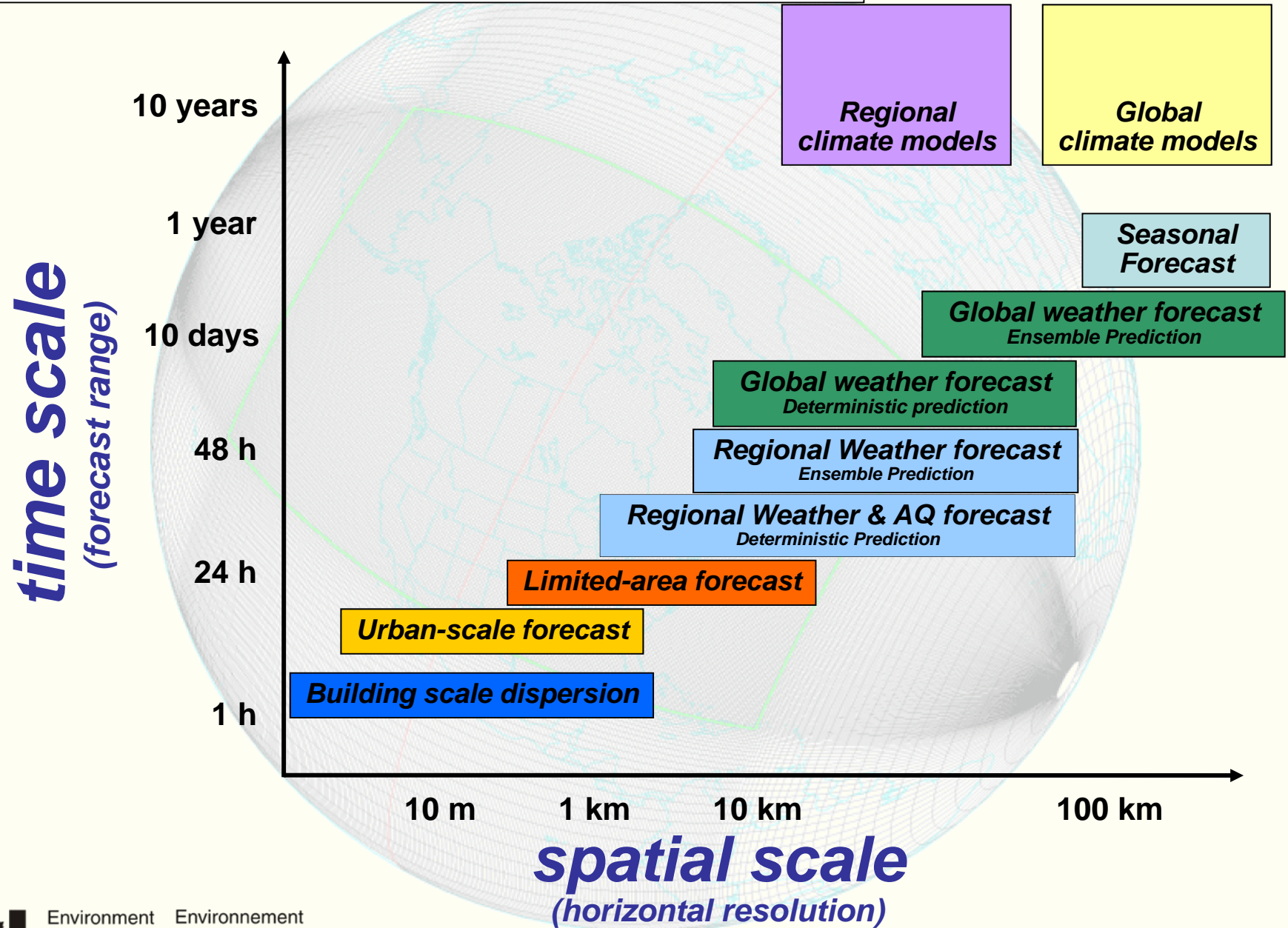
- Historical HPC evolution and forecast quality
- Current modeling systems
- HPC utilization
- Future modeling systems



Historical HPC evolution and forecast quality at CMC

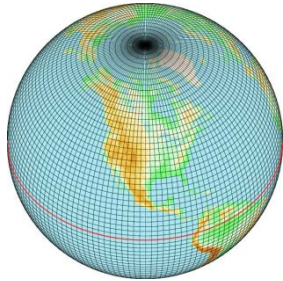


Spatial and time scales covered by the NWP models run on the CMC HPC system

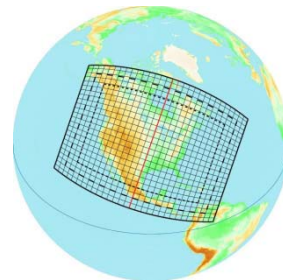
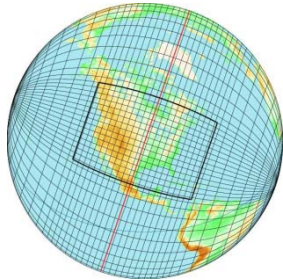


CMC-MRD unified multi-scale model : GEM

GEM= Global Environmental Model

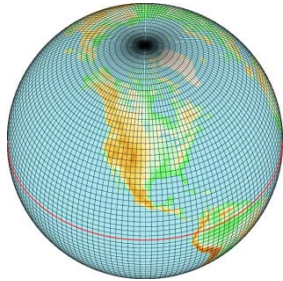


- Global constant resolution (regular lat-lon grid) (GEM-Global)
 - Medium-range deterministic forecasts (33 km)
 - Seasonal forecasts / Climate simulations (100 -200 km)
 - Medium-range EPS (100 km)

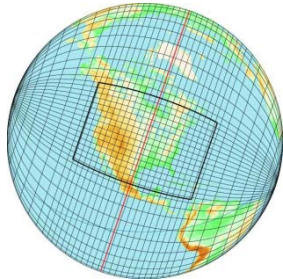


CMC-MRD unified multi-scale model : GEM

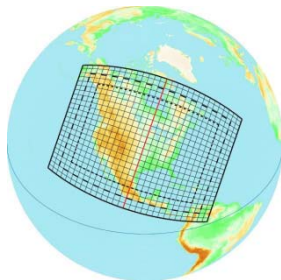
GEM= Global Environmental Model



- Global constant resolution (regular lat-lon grid) (GEM-Global)
 - Medium-range deterministic forecasts (33 km)
 - Seasonal forecasts / Climate simulations (100 -200 km)
 - Medium-range EPS (100 km)

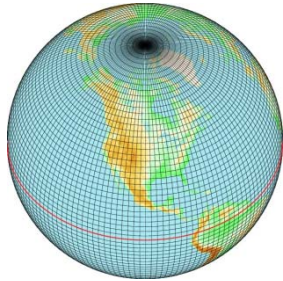


- Global variable resolution (stretched grid)
 - Regional climate simulations (55 km)
 - Short-range deterministic forecasts (GEM-Regional 15 km)
NB: Replaced by a LAM 15 km 10 days ago

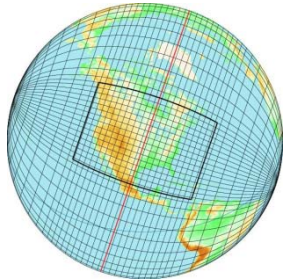


CMC-MRD unified multi-scale model : GEM

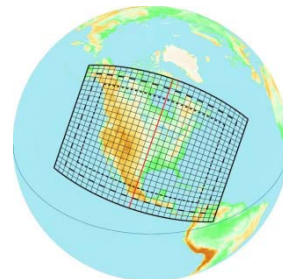
GEM= Global Environmental Model



- Global constant resolution (regular lat-lon grid) (GEM-Global)
 - Medium-range deterministic forecasts (33 km)
 - Seasonal forecasts / Climate simulations (100 -200 km)
 - Medium-range EPS (100 km)



- Global variable resolution (stretched grid)
 - Regional climate simulations (55 km)
 - Short-range deterministic forecasts (GEM-Regional 15 km)
NB: Replaced by a LAM 15 km two weeks ago

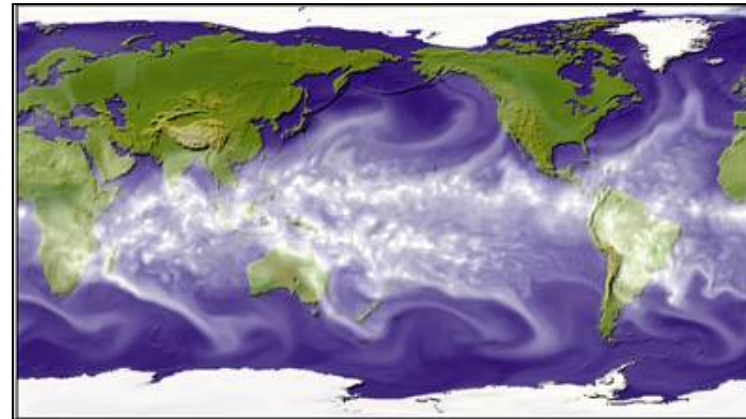


- Limited-area (LAM) constant resolution lat-lon grid
 - Regional Weather & AQ forecasts (15 km)
 - Short-range high-res. deterministic forecasts (GEM-LAM 2.5/1.0 km)
 - Urban emergency response (250 m)
 - Regional climate simulations (15-55 km)
 - Short-range regional EPS (33 km)



Analysis & Prediction at CMC

- Weather & Seasonal **Forecasting**:
 - Medium range (5-day) forecast
Global 33 km resolution grid
 - 48/54-hour forecast
Regional 15 km resolution grid
 - 24-hour forecast
*4 Limited-Area 2.5 km resolution grids
+ 1 km resolution grid over the 2010 winter Olympics*
 - Extended-range (16-day) ensemble forecast
20 members 100 km resolution
 - Seasonal (4-month) ensemble forecast
40 members 200-500 km resolution



Global forecast



Analysis & Prediction at CMC

- **Weather & Seasonal Forecasting:**
 - Medium range (5-day) forecast
Global 33 km resolution grid
 - 48/54-hour forecast
Regional LAM-15 km resolution grid
 - 24-hour forecast
*4 Limited-Area 2.5 km resolution grids
+ 1 km resolution grid over the 2010 winter Olympics*
 - Extended-range (16-day) ensemble forecast
20 members 100 km resolution
 - Seasonal (4-month) ensemble forecast
40 members 200-500 km resolution

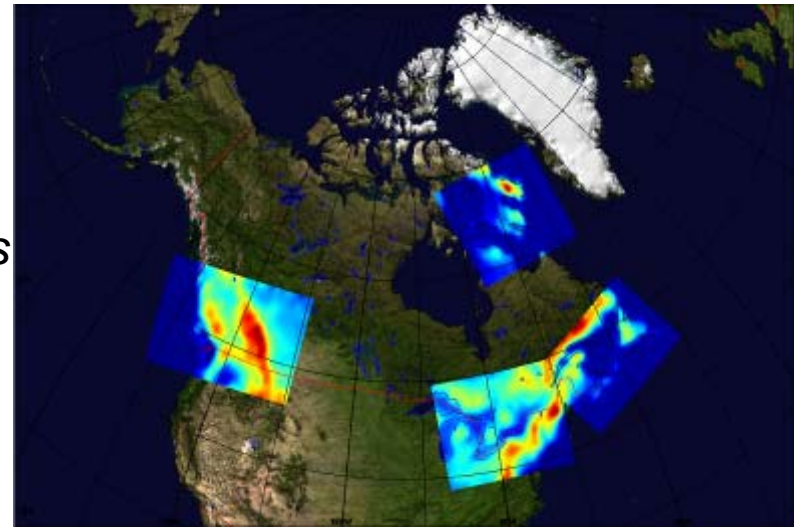


15 km resolution forecast
of cloud fraction



Analysis & Prediction at CMC

- **Weather & Seasonal Forecasting:**
 - Medium range (5-day) forecast
Global 33 km resolution grid
 - 48/54-hour forecast
Regional LAM-15 km resolution grid
 - 24-hour forecast
4 Limited-Area 2.5 km resolution grids
+ 1 km resolution grid over the 2010 winter Olympics
 - Extended-range (16-day) ensemble forecast
20 members 100 km resolution
 - Seasonal (4-month) ensemble forecast
40 members 200-500 km resolution



Four grids with 2.5 km resolution



Current High-res LAM windows

LAM 2.5km West BC and AB

LAM 2.5km Arctic Baffin Island

LAM 2.5km Atlantic

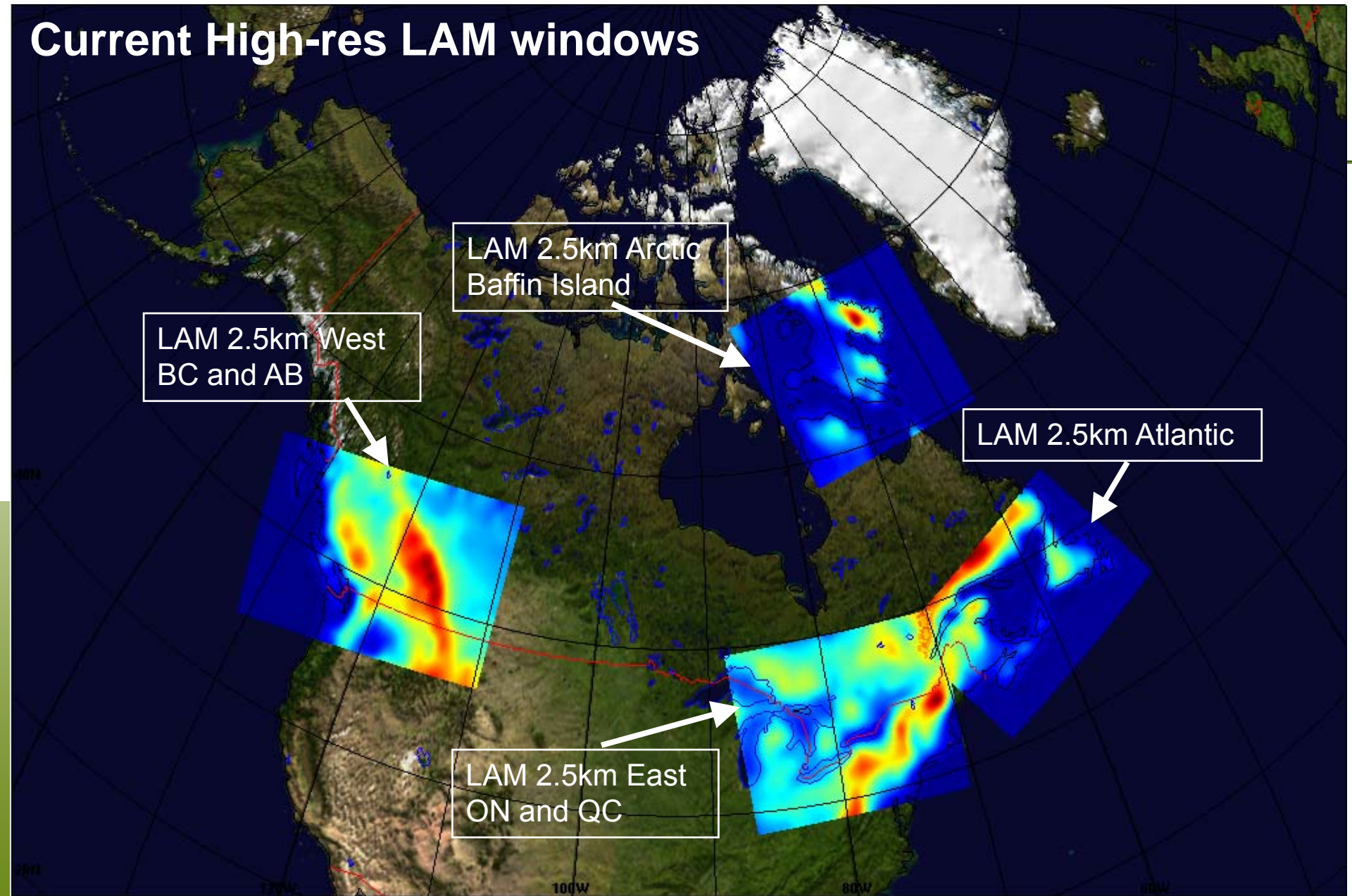
LAM 2.5km East ON and QC



Environment Canada

Environnement Canada

Canada



Current High-res LAM windows

LAM 2.5km West BC and AB

LAM 2.5km Arctic Baffin Island

LAM 2.5km Atlantic

LAM 2.5km East ON and QC



Environment Canada

Environnement Canada

Canada

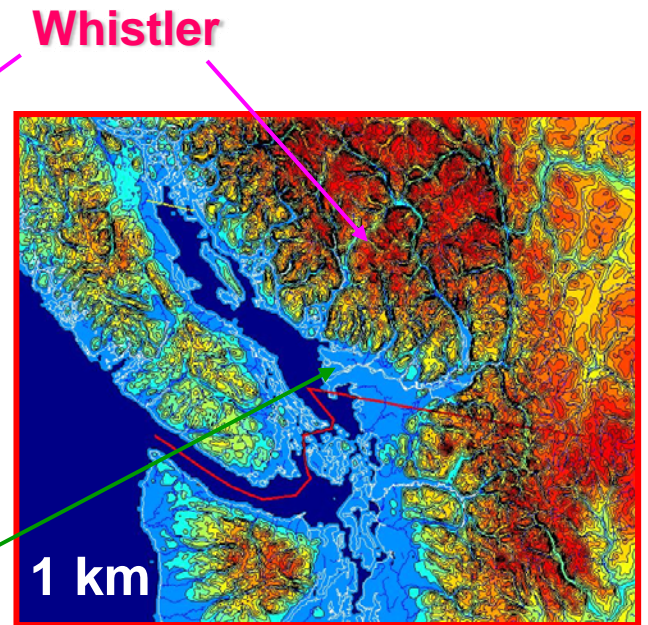
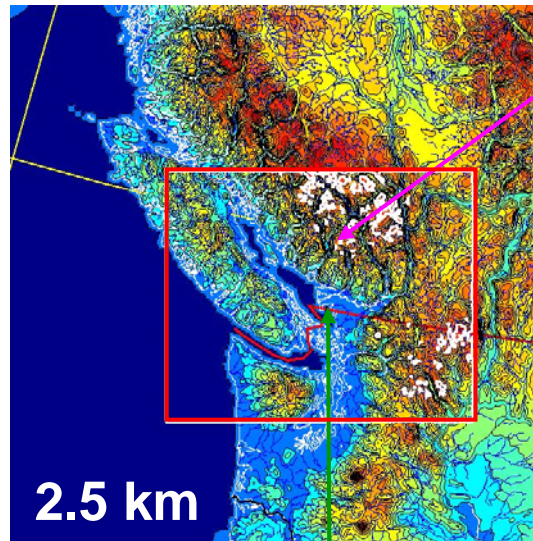
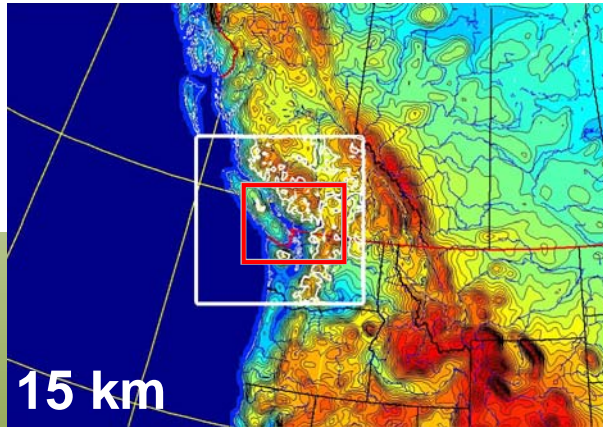
Analysis & Prediction at CMC

- **Weather & Seasonal Forecasting:**
 - Medium range (5-day) forecast
Global 33 km resolution grid
 - 48/54-hour forecast
Regional LAM-15 km resolution grid
 - **24-hour forecast**
4 Limited-Area 2.5 km resolution grids
+ 1 km resolution grid over the 2010 winter Olympics
 - Extended-range (16-day) ensemble forecast
20 members 100 km resolution
 - Seasonal (4-month) ensemble forecast
40 members 200-500 km resolution



Special demand: 2010 Vancouver Winter Olympics

A 1-km resolution LAM prediction system was run twice daily to support Olympics Forecaster Team



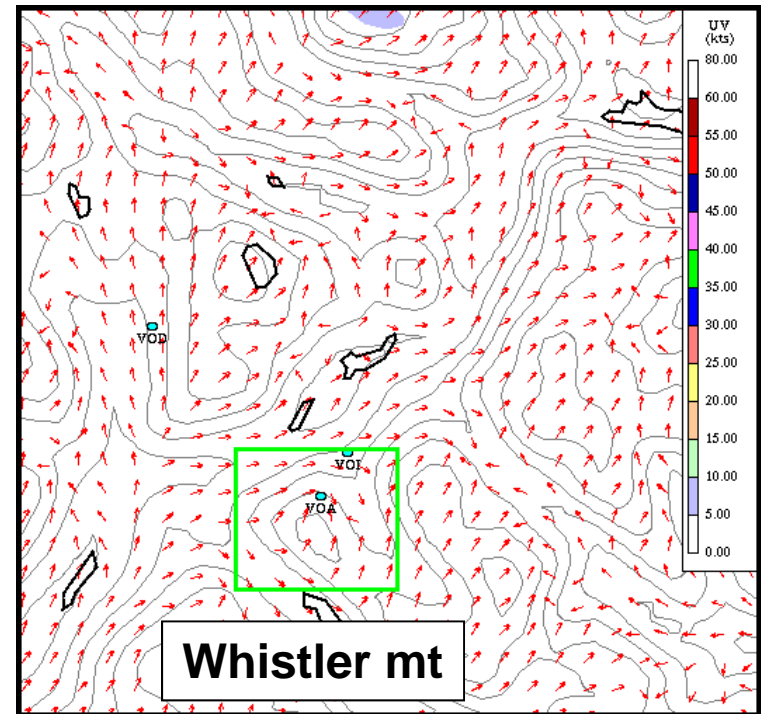
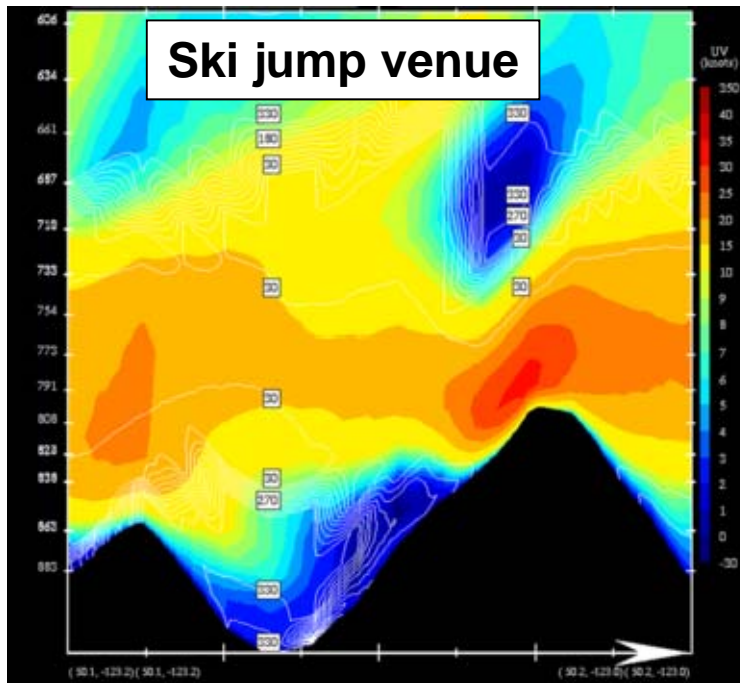
Special demand: 2010 Vancouver Winter Olympics

Our 1-km LAM was really appreciated by the Olympic Forecasters

- > thanks to our strong numerical model and to the available HPC power

“... help build our conceptual model for strong outflow and gave us a heads up to look for gravity wave turbulence”

“GEM-LAM-1km is able to resolve flow around the Whistler Mt”



Analysis & Prediction at CMC

- **Weather & Seasonal Forecasting:**

- Medium range (7-day) forecast

Global 33 km resolution grid

- 48/54-hour forecast

Regional LAM-15 km resolution grid

- 24-hour forecast

4 Limited-Area 2.5 km resolution grids

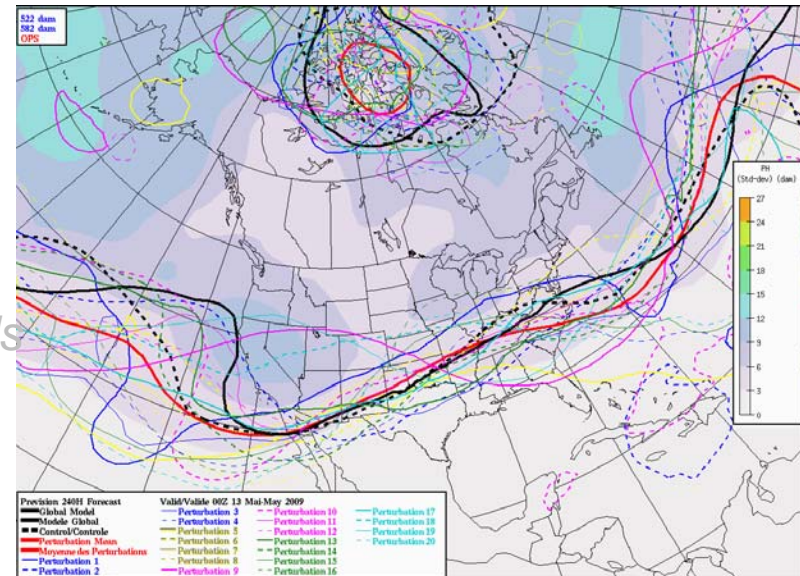
+ 1 km resolution grid over the 2010 winter Olympics

- Extended-range (16-day) ensemble forecast (twice daily)

20 members 100 km resolution

- Seasonal (4-month) ensemble forecast

40 members 200-500 km resolution



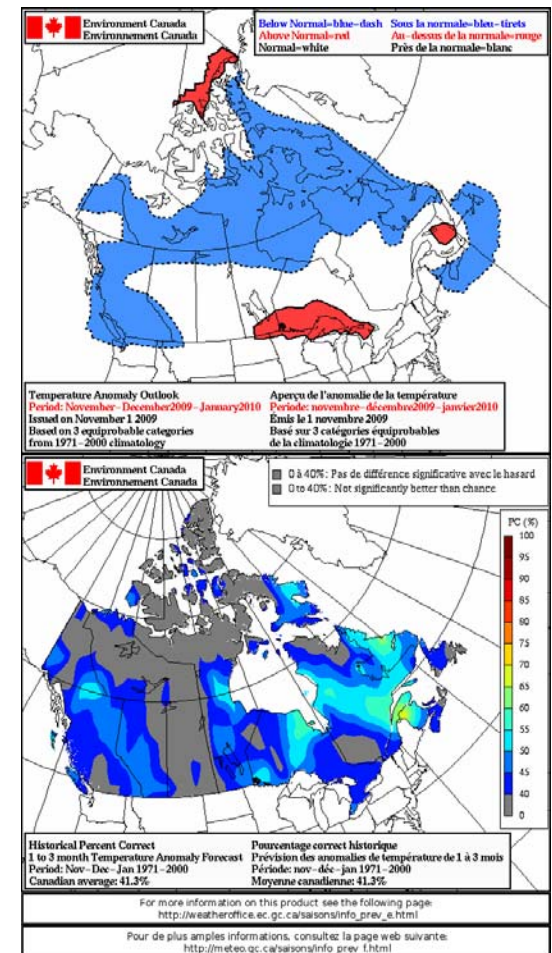
Ensemble forecast



Analysis & Prediction at CMC

- **Weather & Seasonal Forecasting:**
 - Medium range (7-day) forecast
Global 33 km resolution grid
 - 48/54-hour forecast
Regional LAM-15 km resolution grid
 - 24-hour forecast
4 Limited-Area 2.5 km resolution grids
+ 1 km resolution grid over the 2010 winter Olympics
 - Extended-range (16-day) ensemble forecast
20 members 100 km resolution
 - Seasonal (4-month) ensemble forecast
40 members 200-500 km resolution

Seasonal Forecast



Environment
Canada

Environnement
Canada

Canada

Analysis & Prediction at CMC

- Wave Forecasting:

- Spectral Wave Model (WAM)

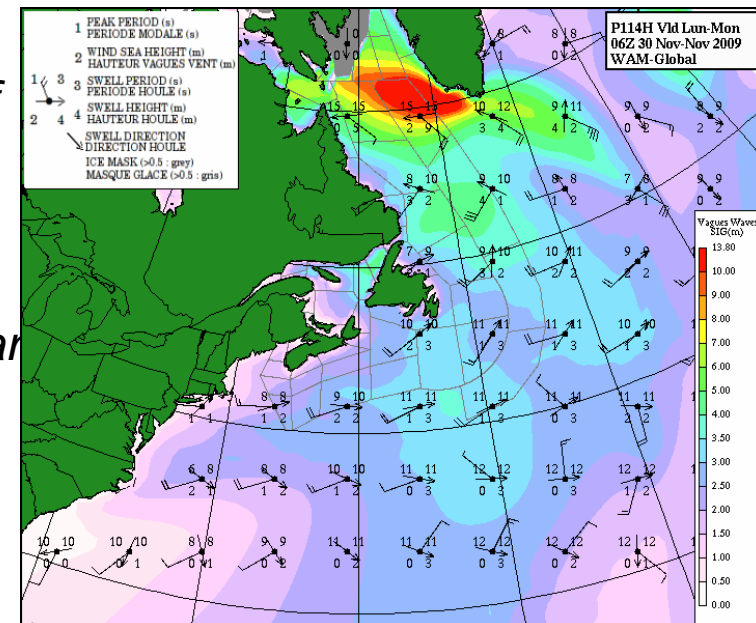
48-h regional / 120-global forecasts of wave height and period, swell height and period, and wave and swell directions;

Regions: Pacific, Atlantic and Canadian Great Lakes

- Air Quality Forecasting

- GEM-MACH : in-line chemical and weather model

48-hour forecasts of tropospheric ozone, NO₂, PM2.5 and PM10 for North America



Global WAM – Atlantic domain



Analysis & Prediction at CMC

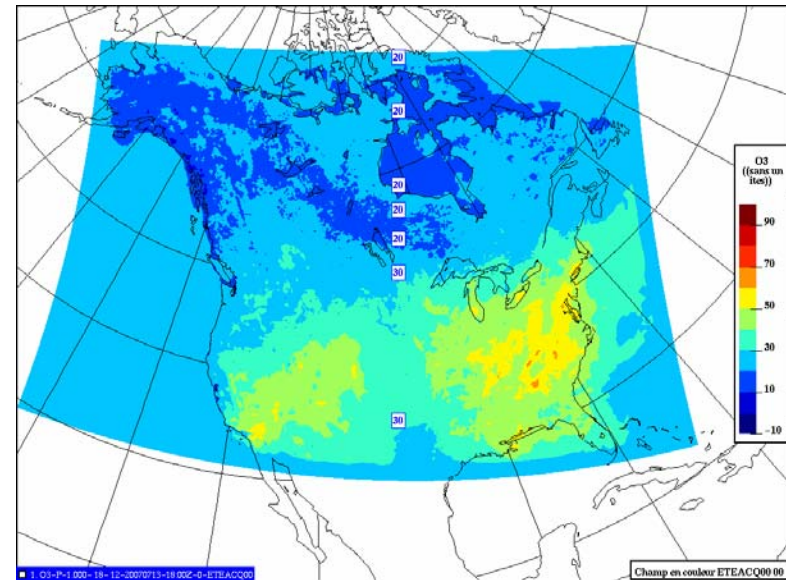
- Wave Forecasting:

- Spectral Wave Model (WAM)
48-hour forecasts of wave height and period, swell height and period, and wave and swell directions;
3 Regions: Pacific, Atlantic and Canadian Great Lakes

- Air Quality Forecasting

- GEM-MACH : in-line chemical and weather model

48-hour forecasts of tropospheric ozone, NO₂, PM2.5 and PM10 for North America

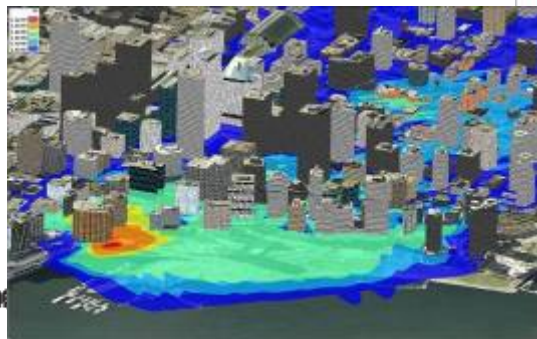
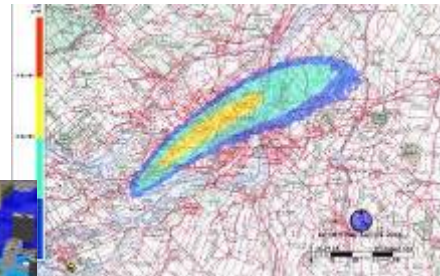
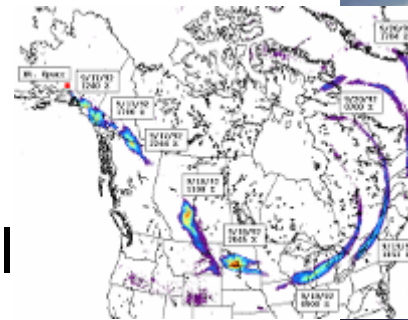
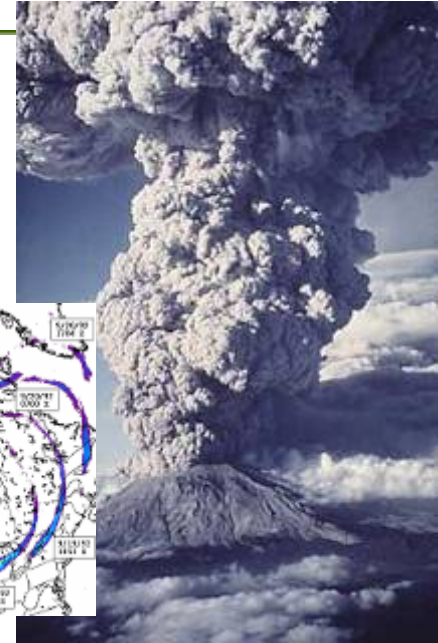


GEM-MACH



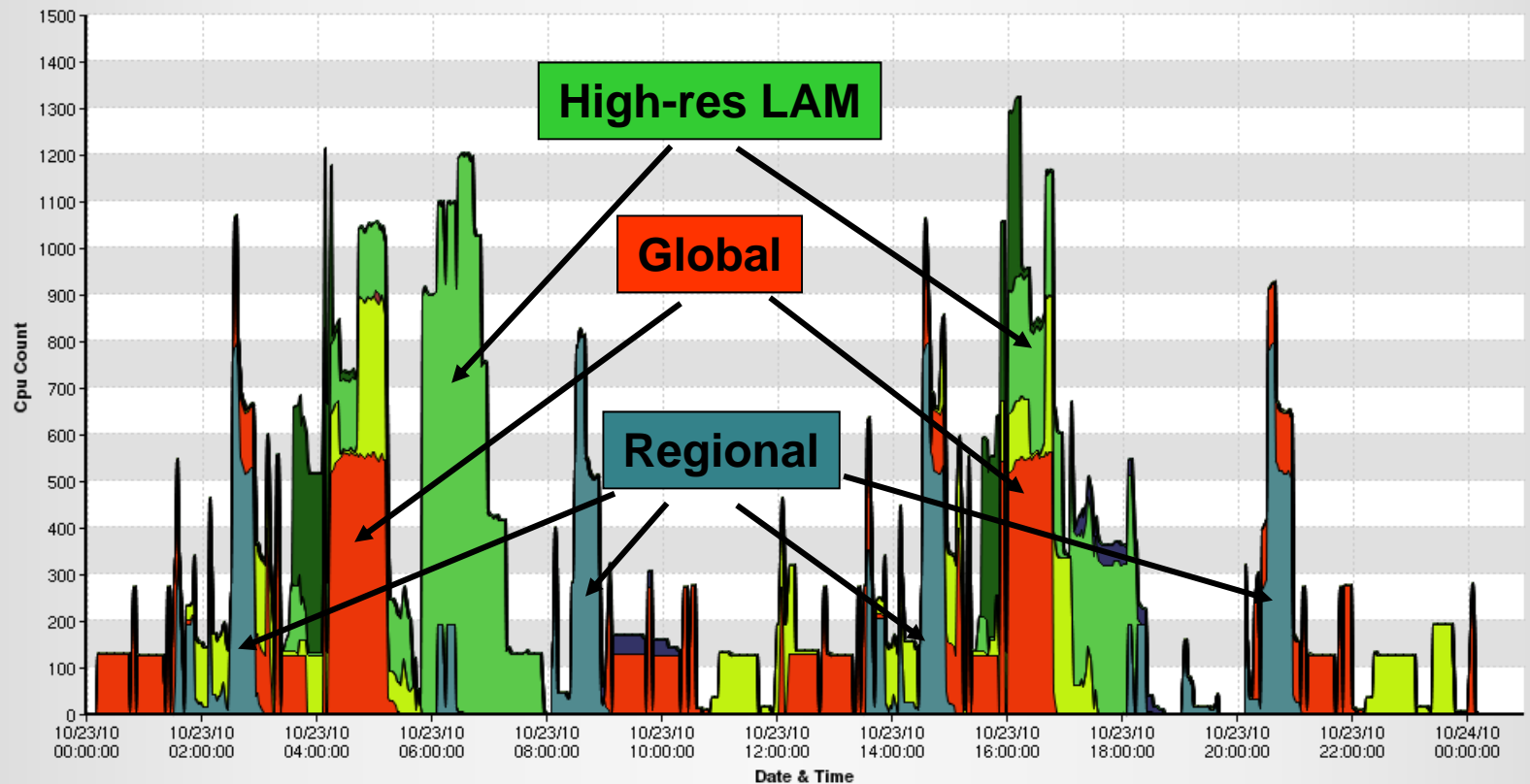
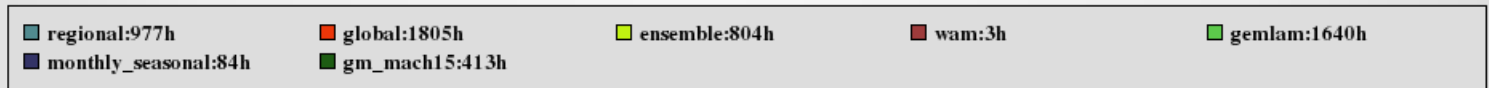
Analysis & Prediction at CMC

- Environmental Emergency applications – dispersion modeling
 - Nuclear and volcanic ash
 - Release of hazardous chemical
 - National security issues

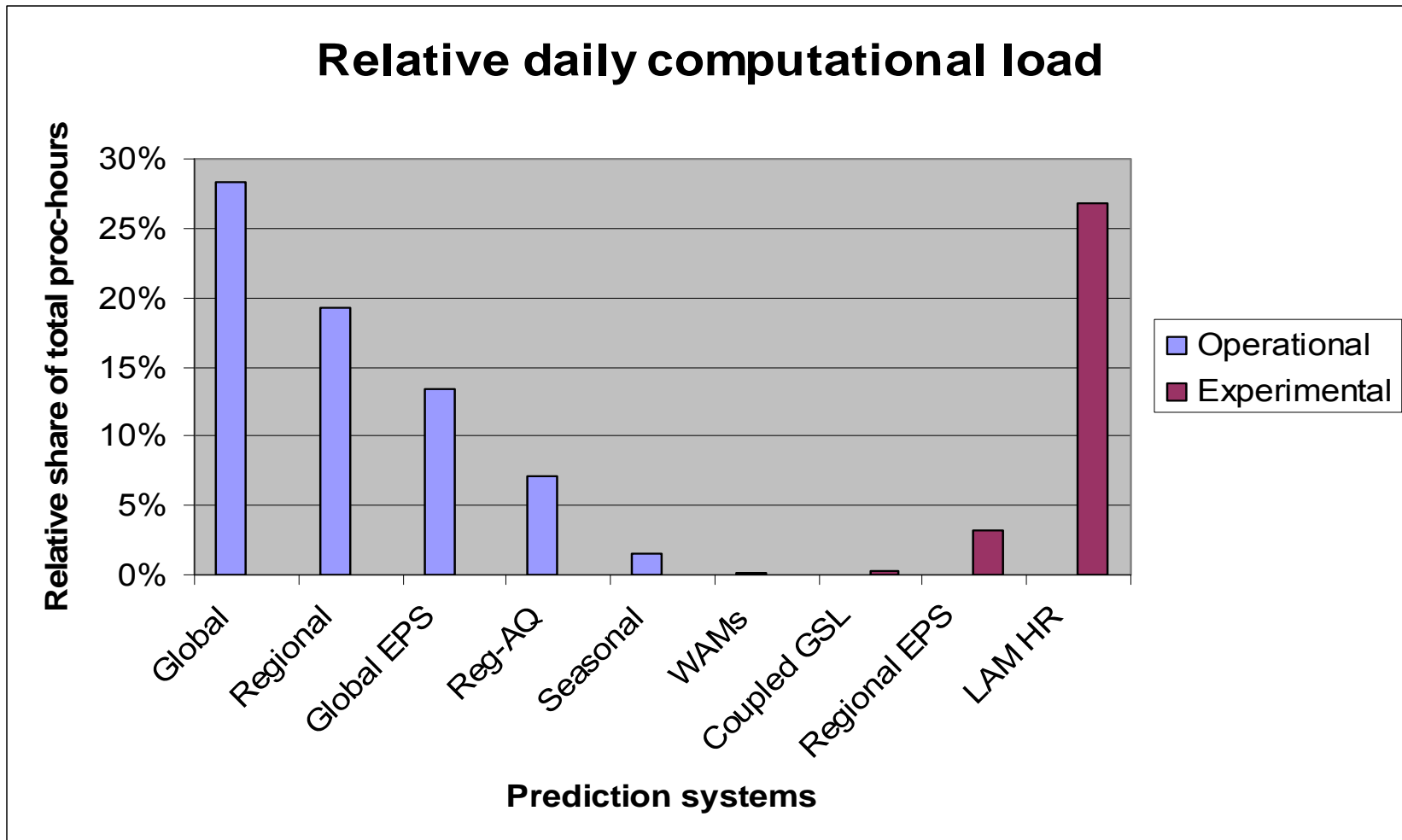


CMC NWP systems – computational load -

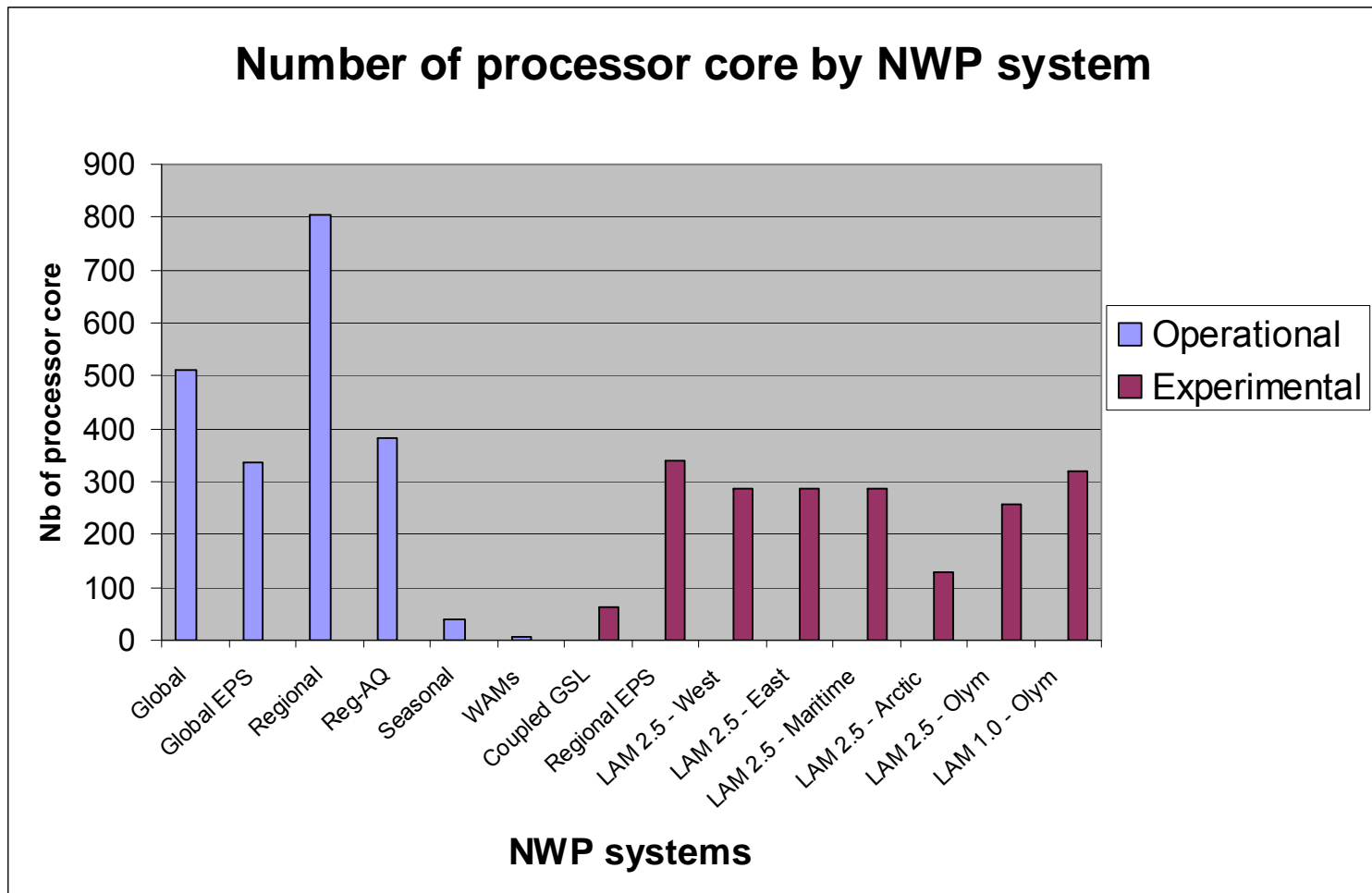
IBM Production class usage 2010-10-23 : Operational Total Cpu Hours 5725.60



CMC NWP systems – computational load -



CMC NWP systems – computational load -



A few words about Climate Modeling..

- Coupled Global Climate Model
 - Spectral T63L35 , dynamics 192x96, physics 128x64, top 1mb
 - soon T127L35, dynamics 384x192, physics 256x128
- Canadian Centre for Climate modeling and analysis (CCCma)
 - R&D group based in Victoria (BC), 5 000 km away from CMC
- Currently running IPCC runs:
 - 30 concurrent runs
 - ~ **50% of the available HPC at CMC (last 6 months)**
 - 3 Petabytes on tapes (last 12 months)



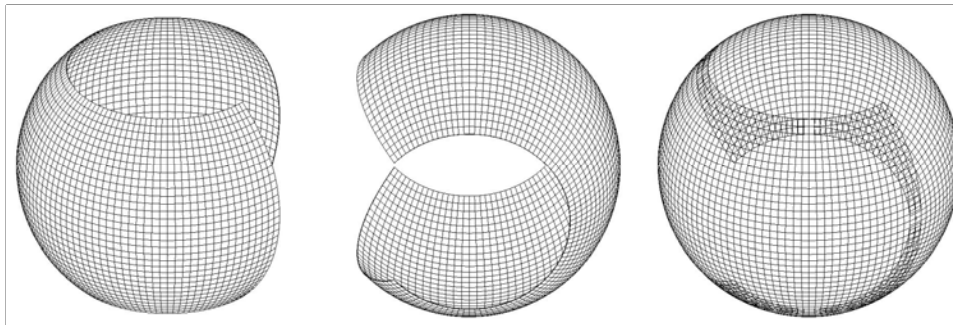
Near future

- Experimental systems becoming operational
 - Gulf of St-Lawrence coupled forecast system (late 2010)
 - Regional EPS (21 mem; 33 km) (2011)
 - At least one high-res LAM 2.5 km window
- Regional (continental) 15 km -> 10 km (2011) => 1440 proc cores
- Global EPS 100 km -> 66 km (2011) ; possibly extended to 30 days
- Global 33 km
 - 2 x more assimilated data (2011)
 - 33 km -> 25 km (2012)
- Atmos-Ocean coupled seasonal forecast system (2011)

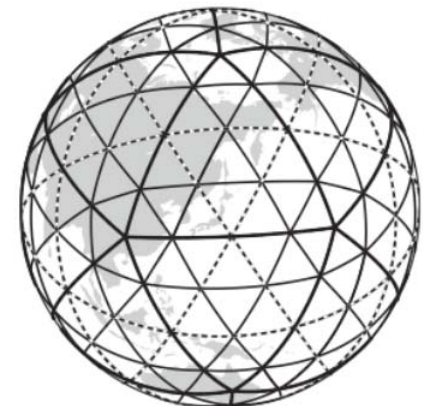


Future

- Yin-Yang grid
 - Good scaling expected (many 10,000 proc cores)
 - See Vivian Lee's talk later today



- Icosahedral grid
 - Scaling even better than Yin-Yang grid



Thank you !

For more info:

Bertrand.Denis@ec.gc.ca

Luc.Corbeil@ec.gc.ca



Environment
Canada

Environnement
Canada

Canada