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Canada

Progress and Future Directions of the Canadian Weather and Environmental Prediction Systems

Weather and Climate | Air Quality | Ice | Water

Michel Jean

Director General

Weather and Environmental Operations

Meteorological Service of Canada

13th Workshop on Meteorological Operational Systems

ECMWF November 2011

Outline

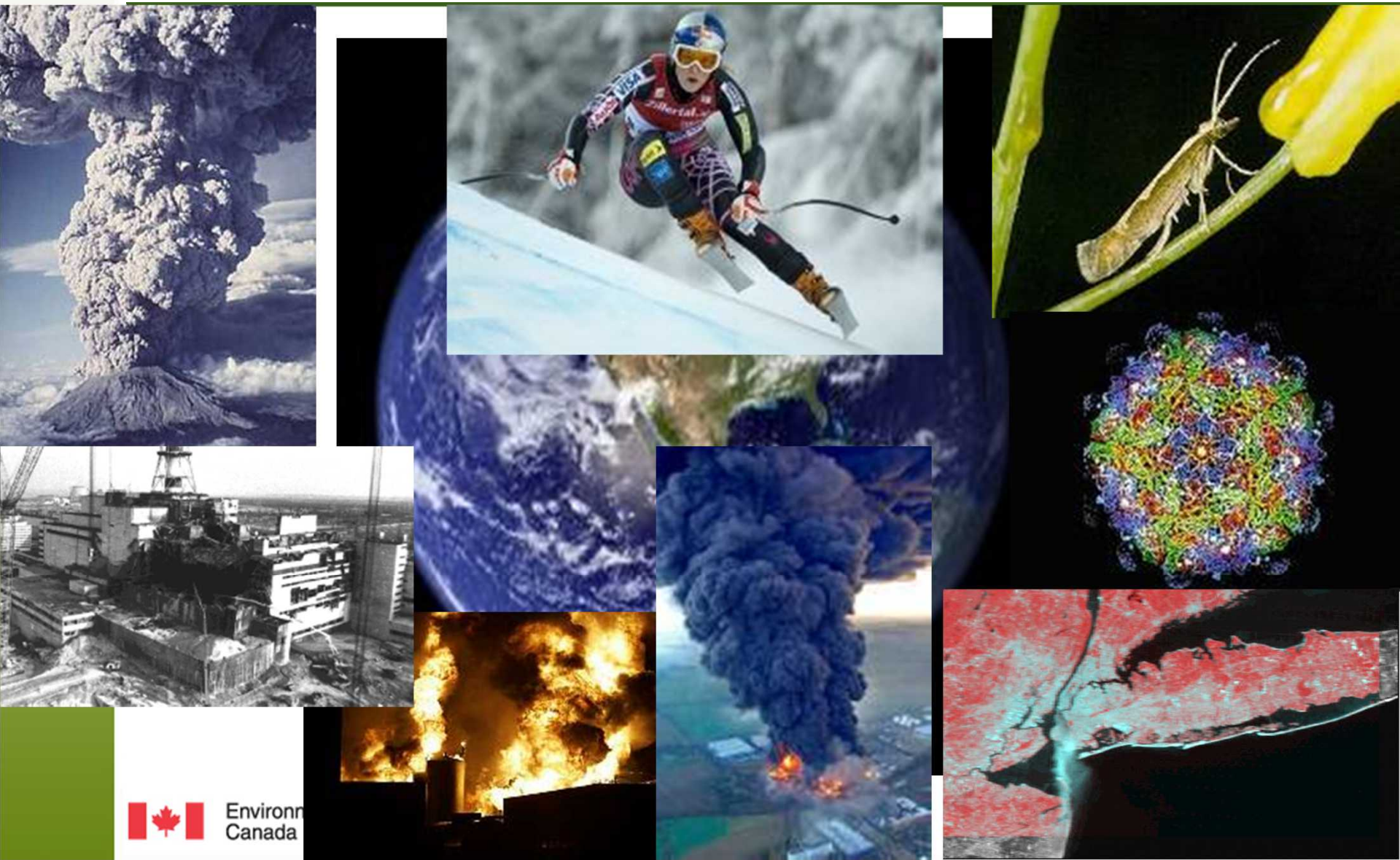
- A bit of context….
- Where we are
- Where we are heading
- Environmental predictions
- Human and technological dimensions

Acknowledgements

- Dr Gilbert Brunet, Director Meteorological Research division
- Mr André Méthot, Director National Prediction Development
- Mr Richard Hogue, Director National Prediction Operations
- Dr Bertrand Denis, on assignment, NWP and HPC systems
- Mr Pierre Pellerin, Chief, NWP-Environment research, MRD
- Dr Martin Charron, Chief, NWP-Atmosphere research, MRD
- Mr Kirk Johnstone, Manager, Prediction and Training Section, MSC
- Ms Jennifer Milton, Executive Director WEO
- Mr John Parker, Manager Operations, Atlantic Region
- Mr Dave Jackson, Director Canadian Ice Service
- Mr Steve Blackwell, Ninjo Forecaster Worskstation project manager
- And many others….

A bit of context….

Our business… more than « *what's the weather going to be tomorrow?* »



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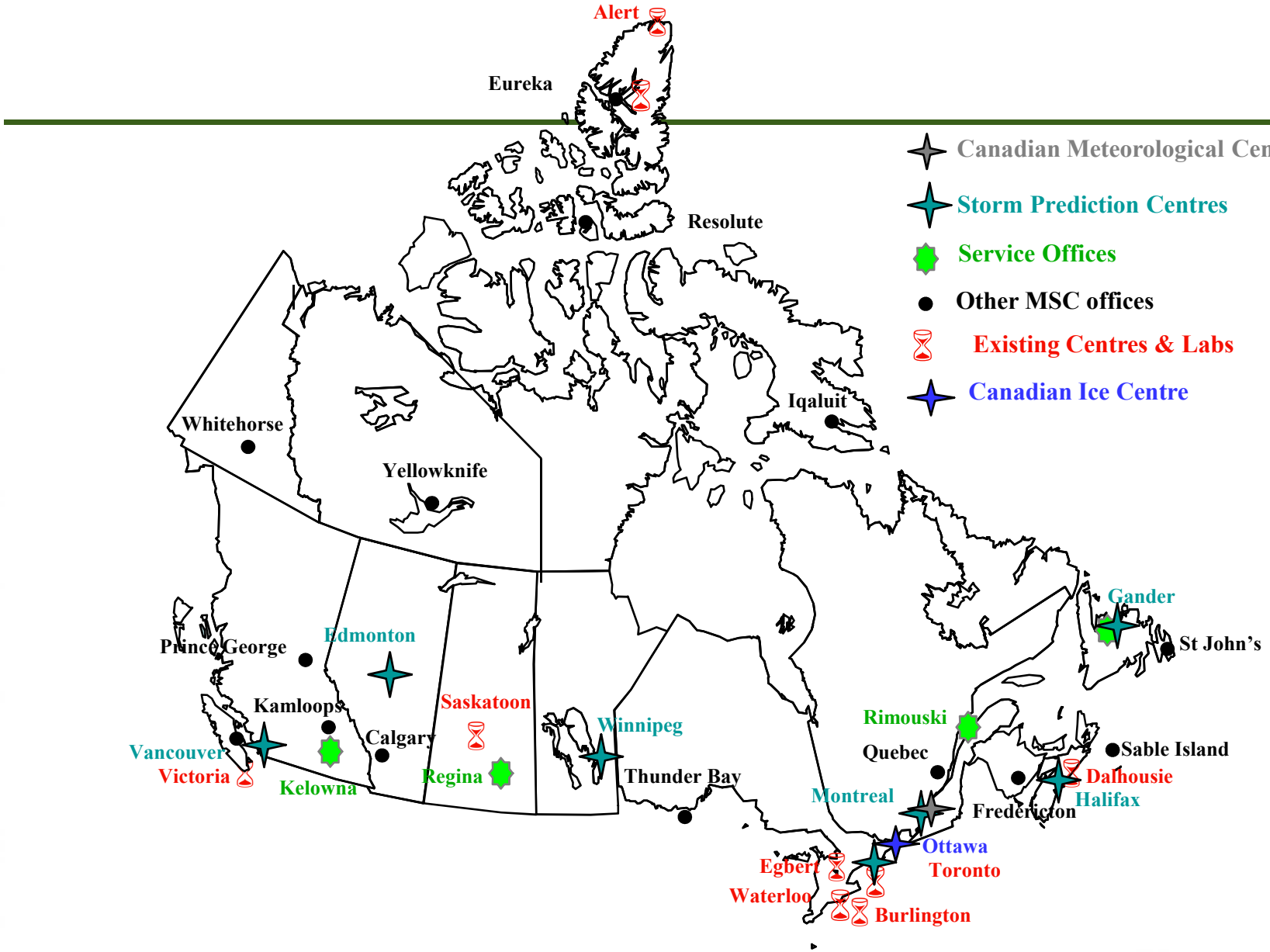
Dealing with increasing vulnerabilities

What we do: Our Service Footprint



A Unique Federal Mandate…

- Equip Canadians with information on changing weather, water, air quality, and climate conditions that impacts their health, safety and economic prosperity
- 1600 professional & technical experts with operating budget of $270M, of which 25% is cost recovered
- Celebrating its140th anniversary this year

Today's Meteorological Service is a complex scientific & technical enterprise

International Cooperation and Stakeholder Engagement

Real-Time Monitoring

Analysis & Prediction

Prediction Models

Storm Prediction Centers

Forecast and Warning Delivery

Research & Technology

Who we Serve:
Our Core Public Good Mission

- Our 24/7 services are highly valued by Canadians:
  - Canadians experience high impact weather all year long from coast to coast to coast, generating significant media interest
  - Annually EC produces 1.5 million weather forecasts, 15,000 severe weather warnings, 500,000 aviation forecasts and 200,000 marine, ice and sea-state forecasts
  - The Weatheroffice website registers over 50% of all government web visitors – on the order of 50 million visitors per month
  - Over 90% of Canadians access EC weather information on a daily basis with 50% using it to conduct their daily business

The Future for the Meteorological Service of Canada

Strategic Outcome for Canada:

Canadians are equipped to make informed decisions on changing weather, water and climate conditions

Our Vision:

Enable Canadians and policy-makers to take appropriate actions to enhance their benefits and reduce their risks to significant changes in weather, climate, water and air quality.

The Future for the Meteorological Service of Canada

Implement a strategic vision for our weather and environmental services that responds to emerging environmental, societal and political landscapes and realities by:

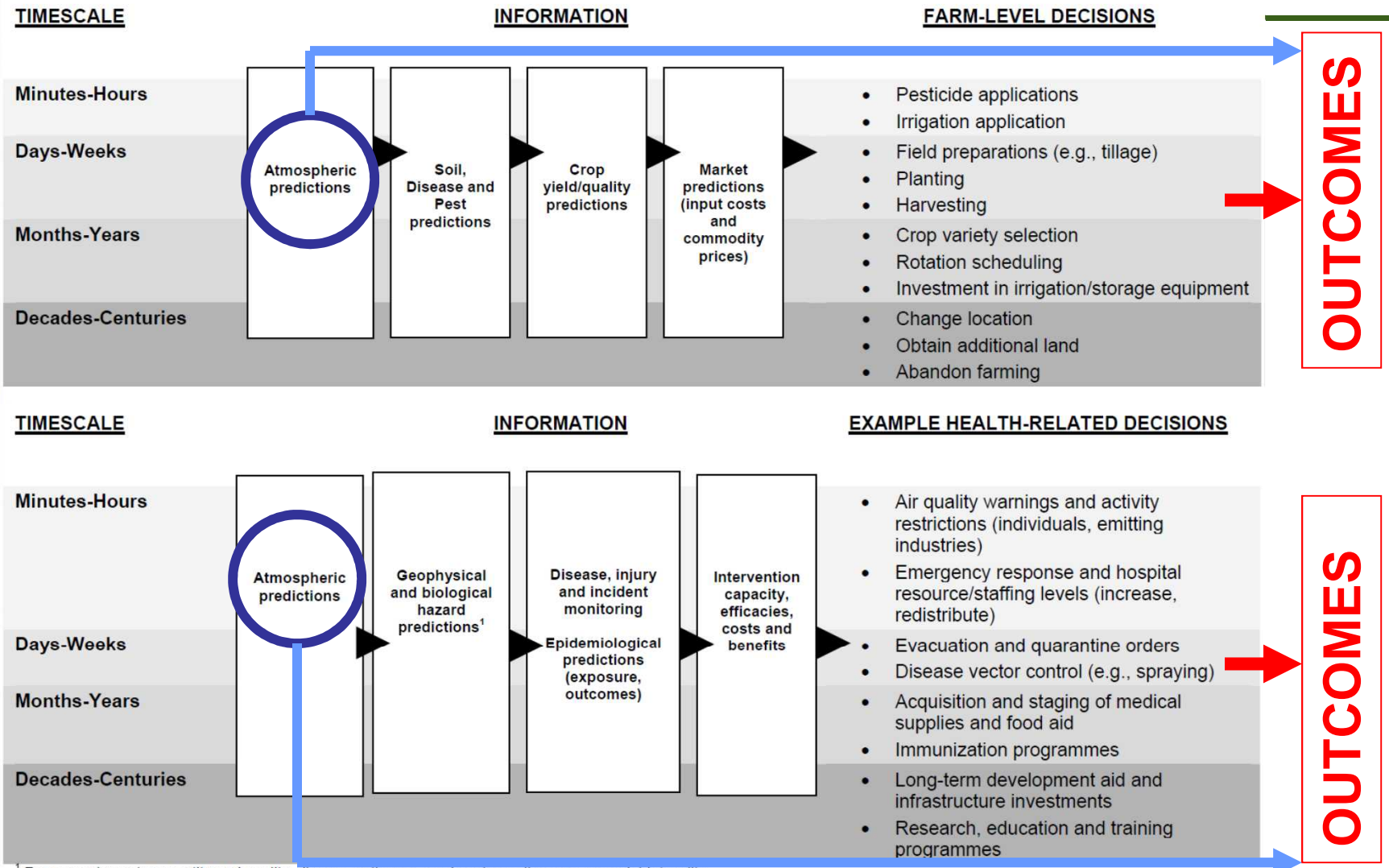
- Strengthening our operational, predictive and alerting capacity;
- Providing Canadians with end-to-end seamless weather and climate services at all time scales to support decision-making in adapting to variable weather and climate conditions;
- Enhancing our services to meet the emerging demands for weather and environmental information in Canada's vast Northern Territory, in support of safety and security

How do we do reach that goal?

By enabling a multi-hazard multi-scale weather and environmental alerting platforms from nowcasting to climatological timescales that takes into consideration the complete cycle relating weather to impacts and the underlying infrastructures (social, physical and environmental)

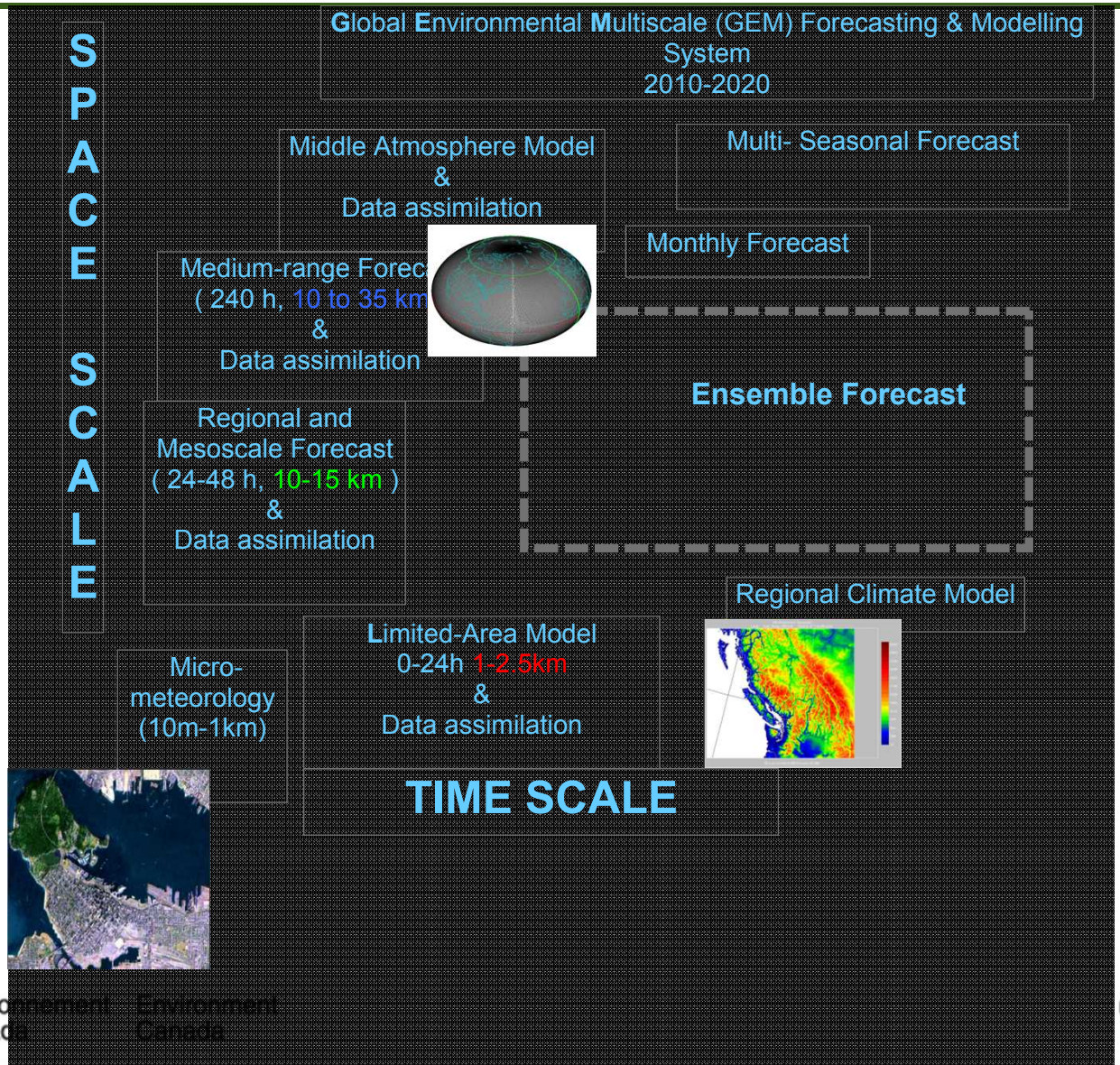
Monitor, Analyze, Predict and Inform on Varying Timescales

Weather and Climate Services Examples (Mills, 2009)



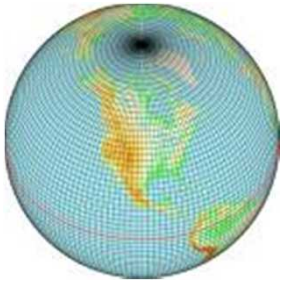
[1] For example: water quantity and quality, disease pathogens and vectors, allergens, crop yields/quality

An unified numerical forecasting system for seamless (e.g. multi-scale and multi-disciplinary) applications

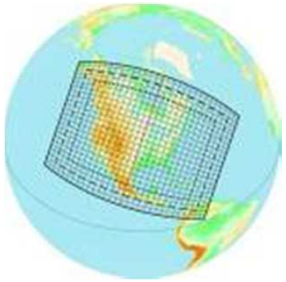


CMC-MRD unified model : GEM

GEM= Global Environmental Multi-scale model



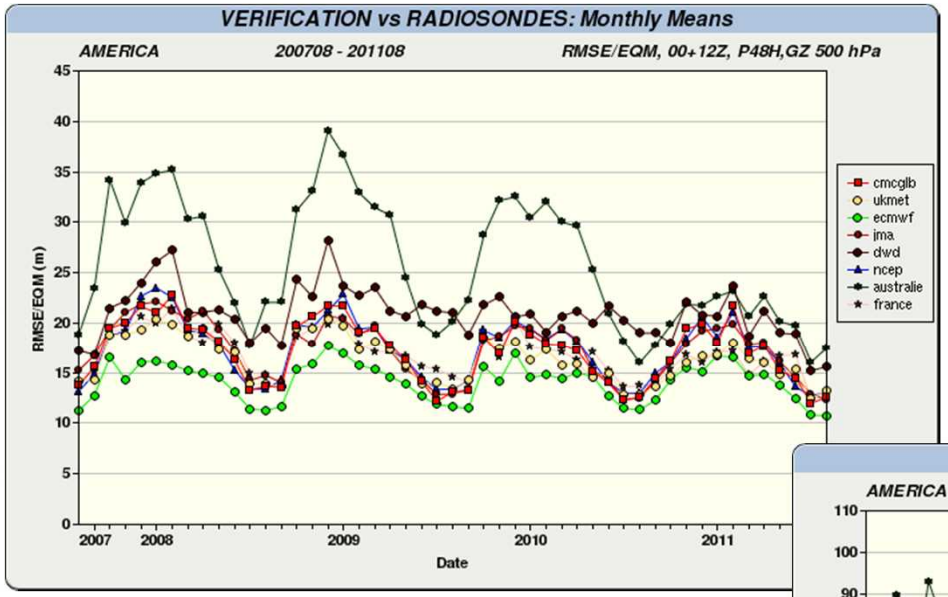
- Global constant resolution (regular lat-lon grid) (GEM-Global)
  - Medium-range deterministic forecasts (33 km)
  - Seasonal forecasts / Climate simulations (100 - 200 km)
  - Medium-range EPS (66 km)



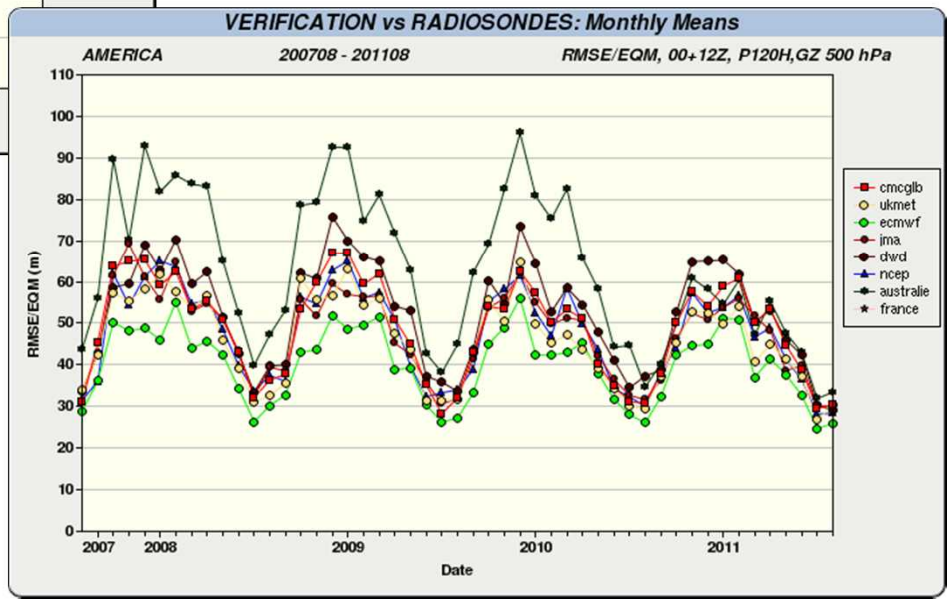
- Limited-area (LAM) constant resolution lat-lon grid
  - Short-range high-res. deterministic forecasts (GEM-LAM 15/2.5/1.0 km)
  - Short-range EPS (33 km)
  - Urban emergency response (250 m)
  - Regional climate simulations (15-55 km)

- Global variable resolution (stretched grid)
  - Short-range deterministic forecasts (GEMREG-15km: operational till 2010)
  - Regional climate simulations
  - Regional seasonal forecasts

RMS Errors for day 2 and day 5 forecasts of GEM (33km) over North America



48h 500mb forecast



120h 500mb forecast

Verification period:
mid-2007 -> mid-2011

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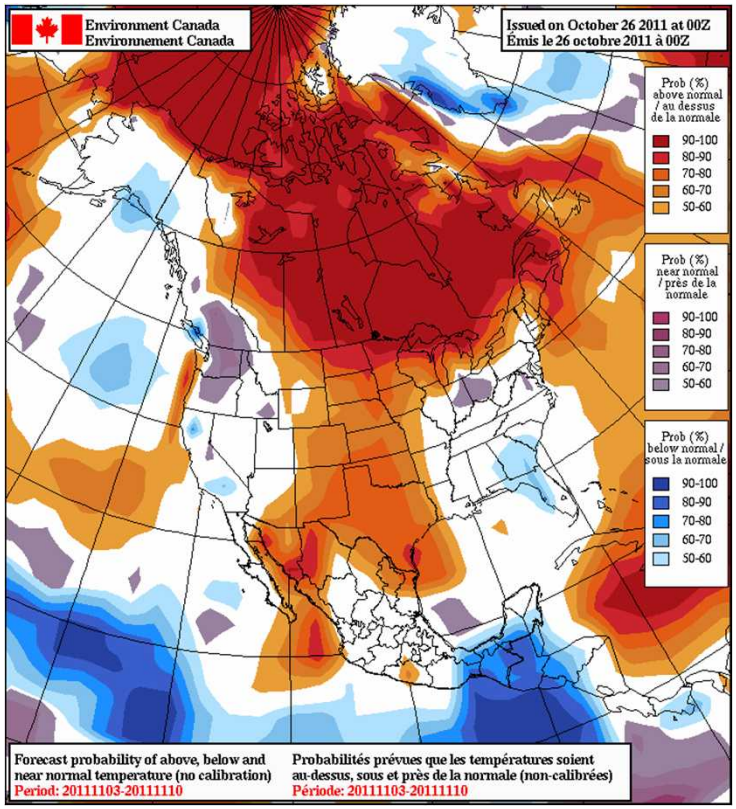
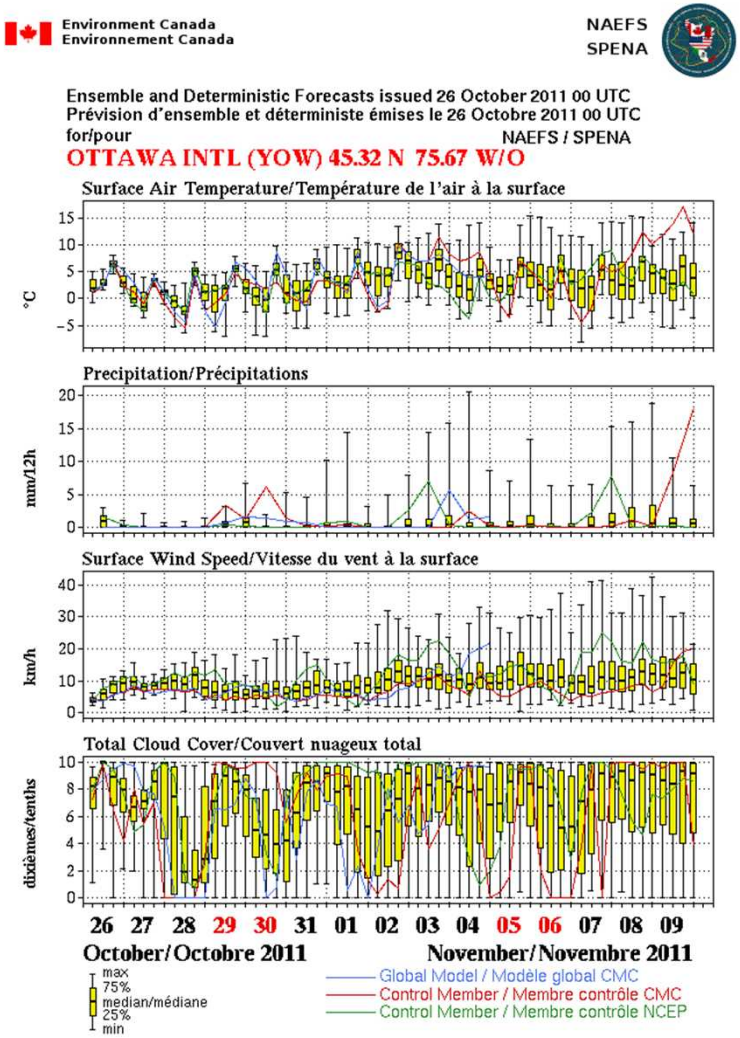
North American Ensemble Forecast System (NAEFS):

Joint project involving MSC, NWS and the NMSM

Week-2 temperature outlook



EPSgrams



Recent changes (2011)

- Totally new operational systems -

- **New CaPA Precipitation Analysis for North America**
- **New coupled Atmos-Ocean-Ice forecast system for the Gulf of ST-Lawrence**
- **New Regional Ensemble Prediction System**
  - North American domain
  - 33 km resolution
  - 20 members; 72 h forecasts
- **New Scribe Nowcasting system**

Recent changes (2011)

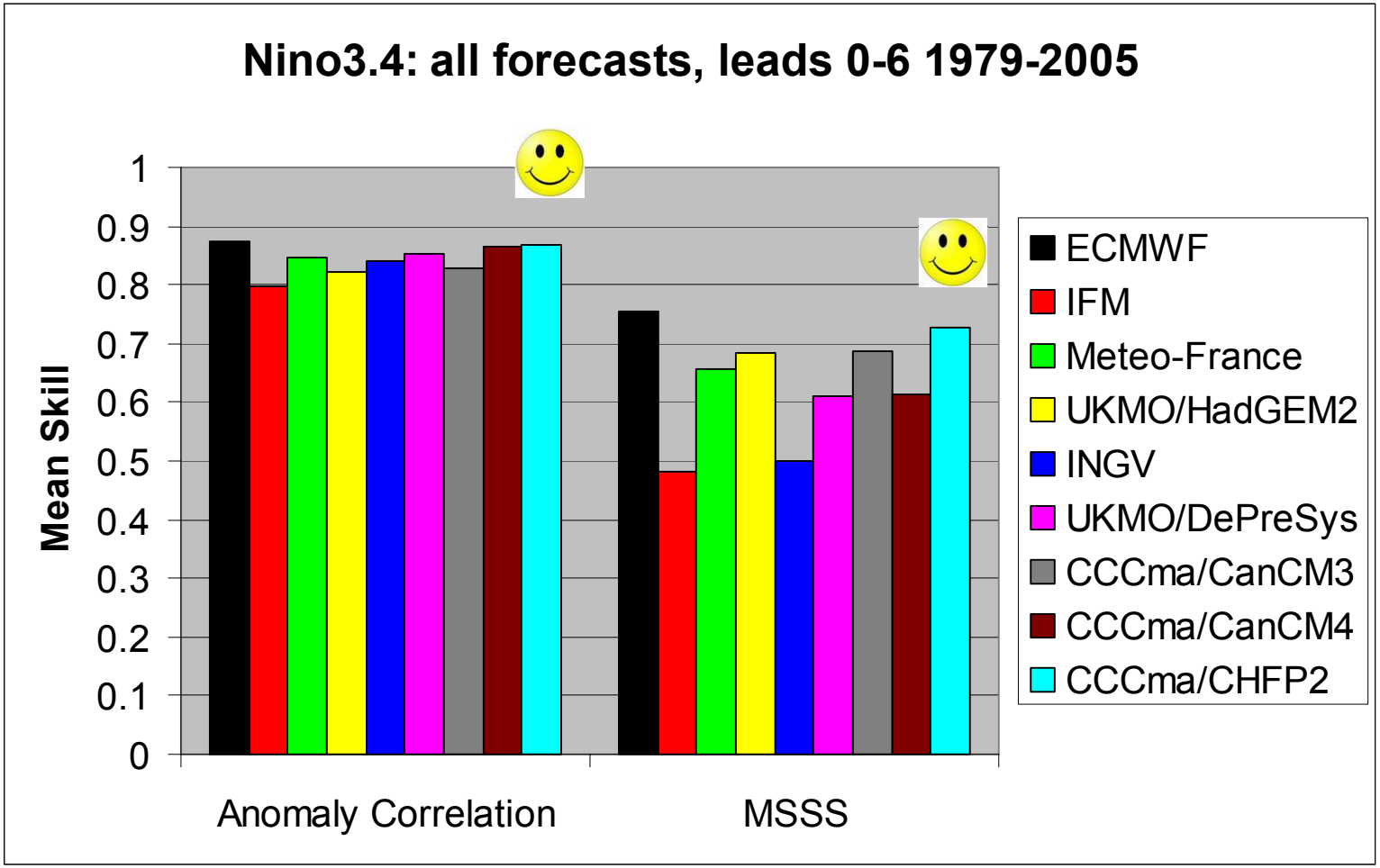
- Upgrades to existing systems -

- **Improved Global Deterministic Prediction System**
  - Reduction of tropical cyclone false alarms
- **Improved Global Ensemble Prediction System**
  - From 100 km to 66 km horizontal resolution
  - From 10 hPa to 2 hPa
  - From 96 to 192 EnKF assimilation members
  - Improved physics package
- **Improved High Resolution Deterministic Prediction System** (experimental LAM 2.5 km windows)
  - Based on the successful Olympic version
- **Improved Air Quality Forecast System**
  - Updated emission inventories
  - Improved numerics near the model top

Soon to be implemented

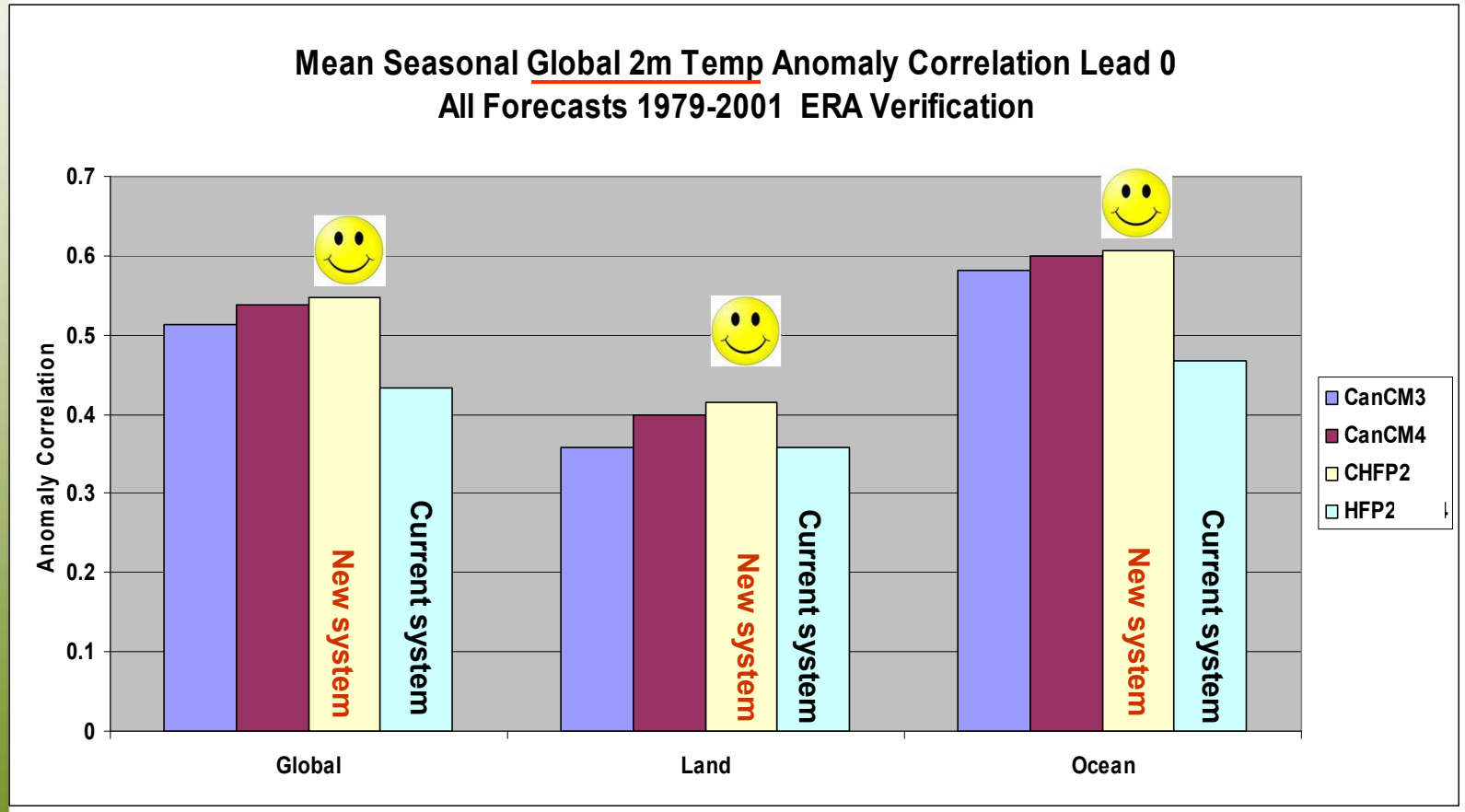
- 200% increase in the data volume assimilated in the deterministic systems (Global & Regional) (Nov. 2011)
  - more IASI, AIRS and SSMIS channels, reduced horizontal thinning for satellite radiances, humidity from aircraft
- New Global SST analysis (Nov. 2011)
- A new one-tier (fully coupled) multi-seasonal forecast system (up to 12 months) (Dec. 2011)

New 1-tier multi-seasonal forecast system- Inter-comparison: ENSEMBLES Project



Comparison of **individual model forecasts** (ENSEMBLES forecasts use ensemble size 9, CCCma ensemble size 10), with CHFP2 skills shown for comparison

First season (Lead 0 months)



To come in 2012

- **Regional Deterministic Prediction System**
  - from 15 km to 10 km resolution
  - From a 3D to 4D-Var assimilation system
- **Global Deterministic Prediction System**
  - From 33 to 22 km resolution
- **Global Ensemble Prediction System**
  - extended to 35 days once a week
- **Gulf of ST-Lawrence Coupled system**
  - from 15 km to 10 km resolution

- **More satellite data assimilated**
  - NPP, Metop-B, ADM-Aeolus

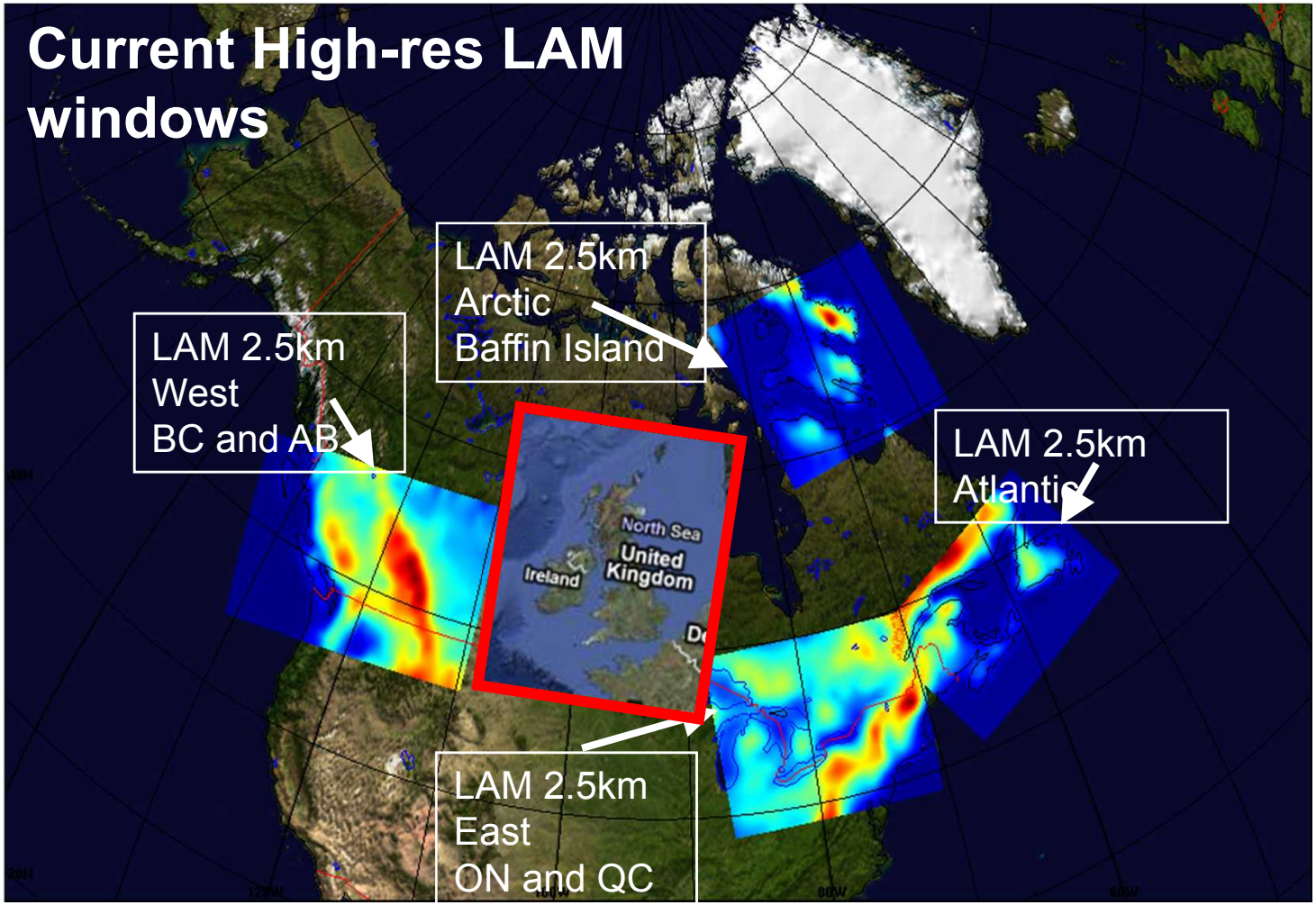
To come in 2012 (cont'd)

- **New 3D-var sea-ice analyses:**
  - Global
  - North America
  - Gulf of St-Lawrence
- **New Global and Regional Ocean prediction systems**
- **New Canadian Land Data Assimilation System**
- **New high-resolution land surface prediction system**
- **Forest fire effects in air quality prediction system**
- **New wave ensemble prediction system**

Longer term..

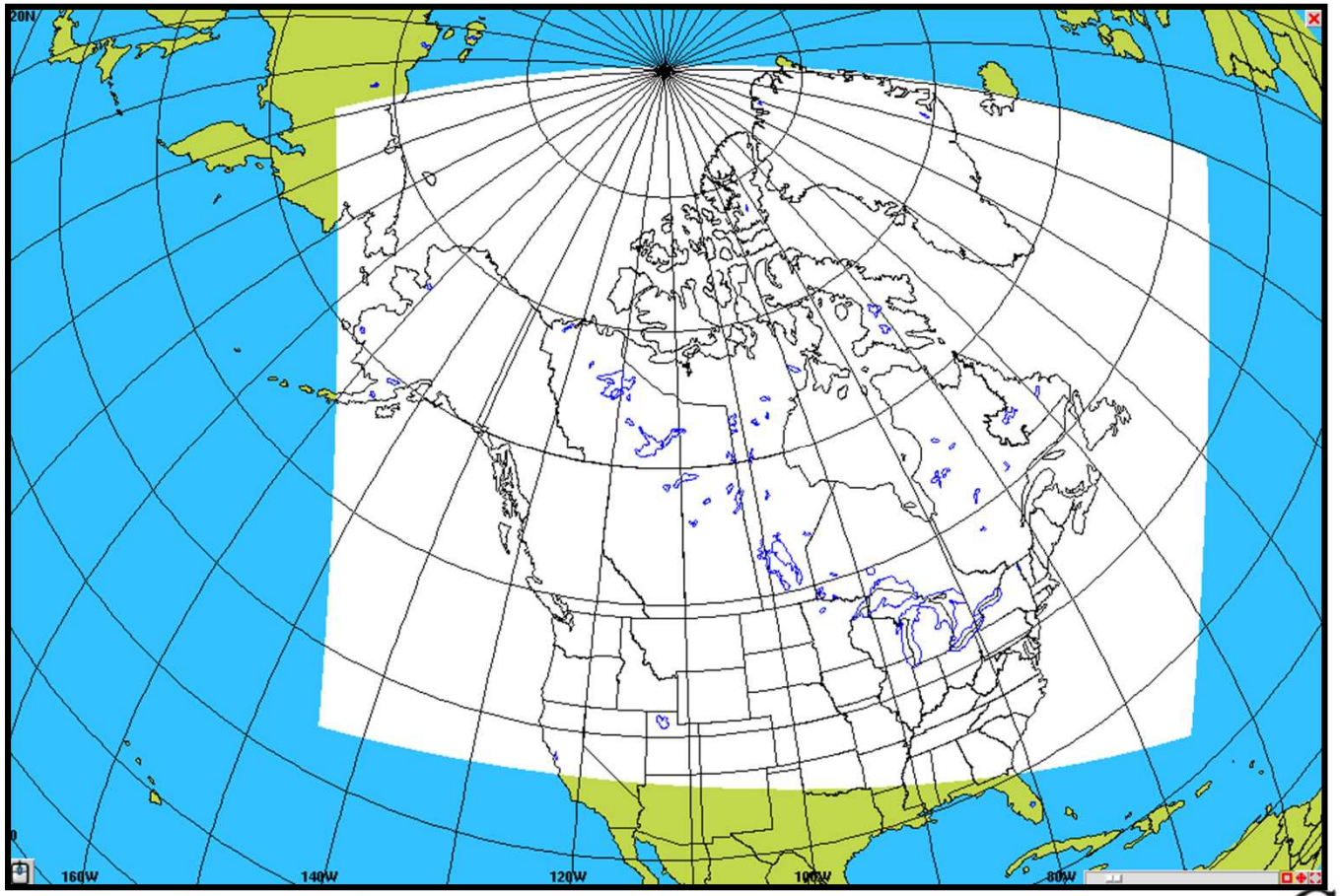
- Data assimilation…. 4-D Var, EnKF, EnVar, Hybrid?
- Further significant increases of satellite data;
- Broadening of applications (agriculture, forestry, health, energy, ecosystem, emergency response)
- Further increase in main model resolutions with emphasis in ensemble forecasting approaches (probabilistic forecasts)
- Urban meteorology… towards capabilities to provide guidance at the urban scale (air quality applications, release of hazardous material, etc.)
- Integrated multidisciplinary approach to environmental prediction (coupled atmosphere-ocean-ecosystem, air quality (chemistry);
- Etc.

One of our challenge: a very large country

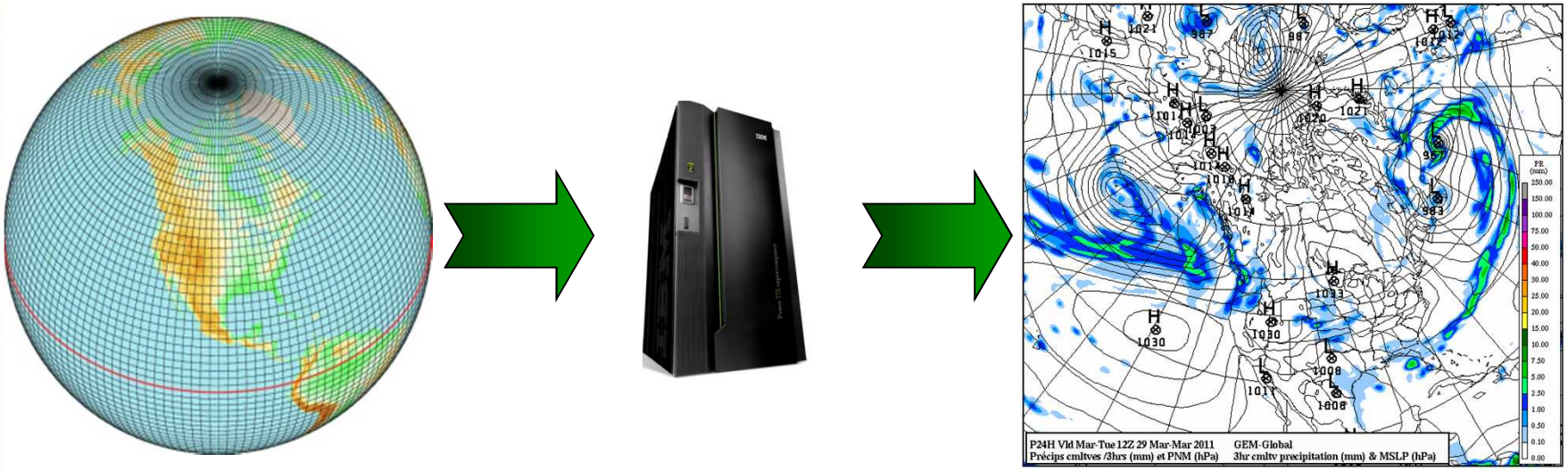


One of our goal (2015)
2.5 km res. from coast to coast to coast

2015: GEM-LAM 2.5 km window (3000x2400)

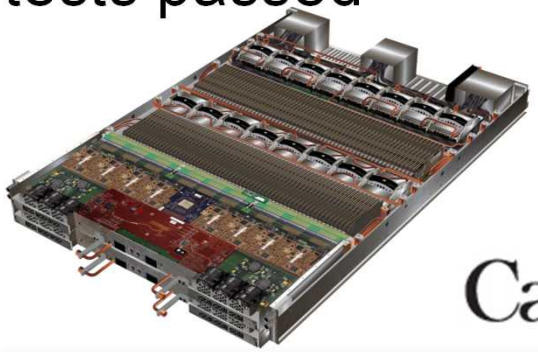


With the help of increase HPC power..



Environment Canada
New IBM P7 Supercomputer

- 2 clusters; 8192 cores each;
- ~ 1/2 PFlops peak total
- System is being installed off-site
- Migration of operational jobs start this month (Nov.)
- Hoping that acceptance tests passed before end of 2011
- Operational early 2012

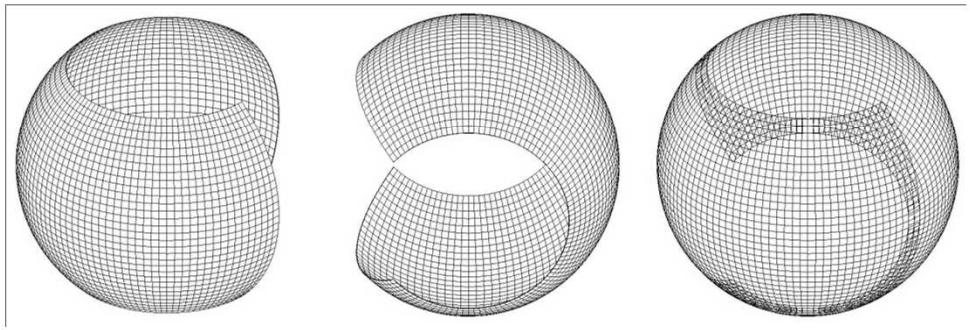


Evolution of some core systems

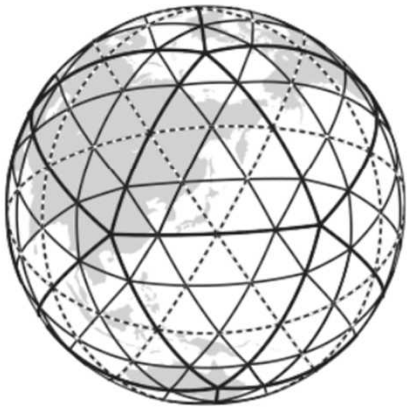
	2012	2015	2020
Global	**Det. 25 km** **EPS 50 km**	**Det. 20 km** **EPS 35 km**	**Det. 10 km** **EPS 20 km**
Regional	**Det. *10* km** **EPS 20 km**	**Det. 25 km** **EPS 10 km**	**Det. 1.0 km** **EPS 2.5 km**
Local	**Det. *2.5 km***	***Special needs*** ***Special needs***	***Special needs*** ***Special needs***
Urban	***Det. 250-> 5m***	***Det. 3m ?*** ***EPS 5m ?***	***Det. 1m ?*** ***EPS 5m ?***

New modeling approaches needed

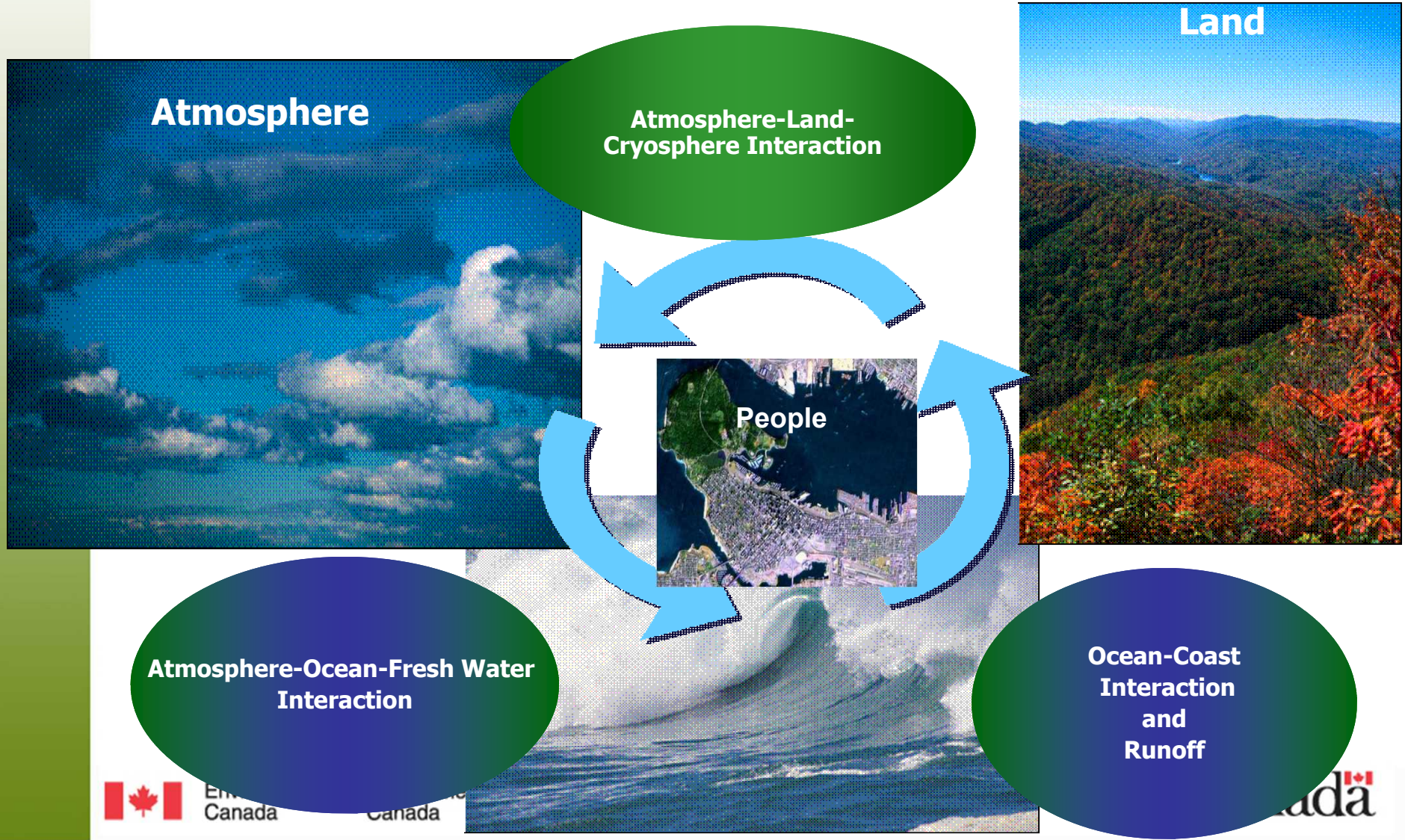
- Yin-Yang grid
  - Good scaling expected (many 10,000 proc cores)



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

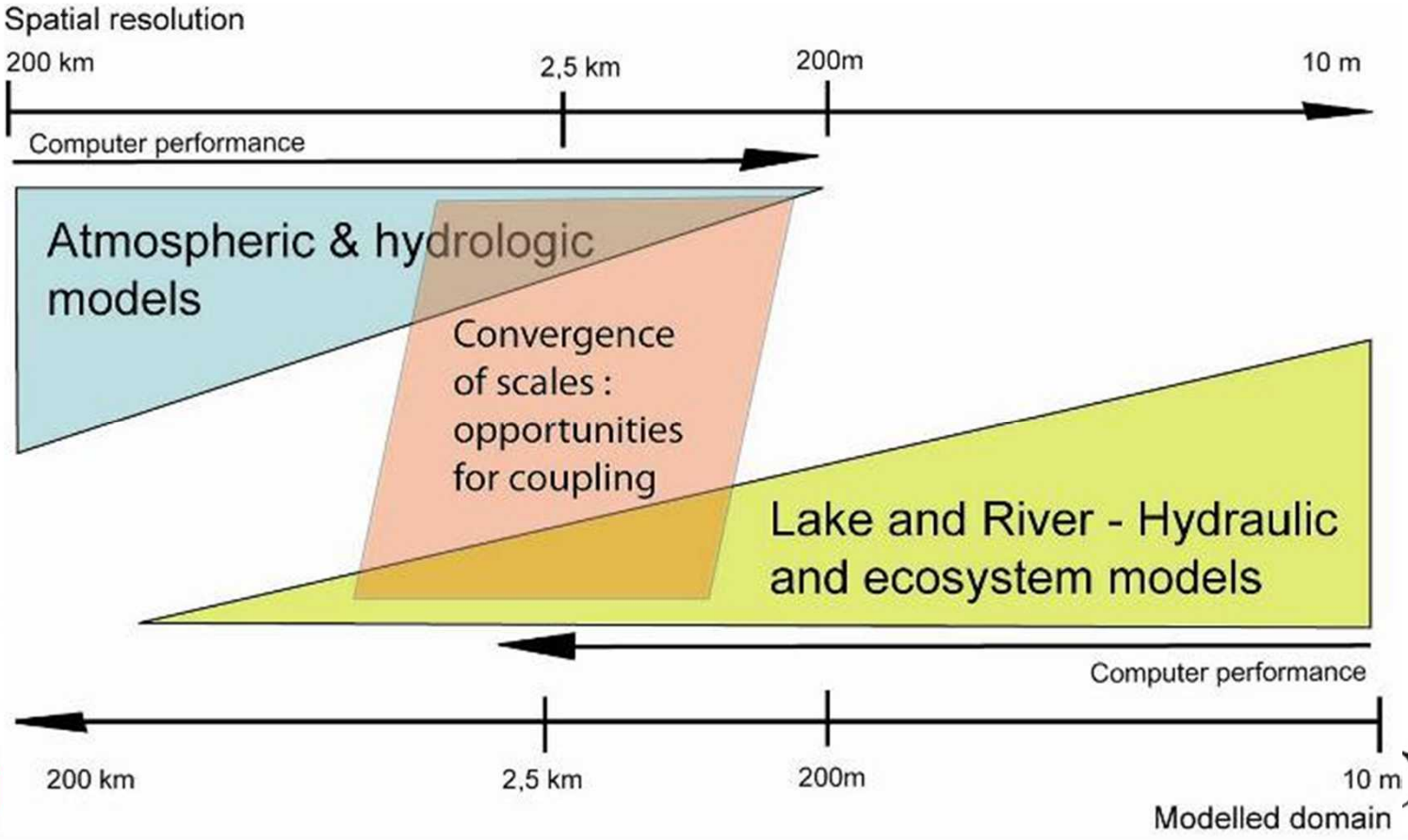


Toward Environmental Prediction…..



Why it is possible ?
Why Couple Models?

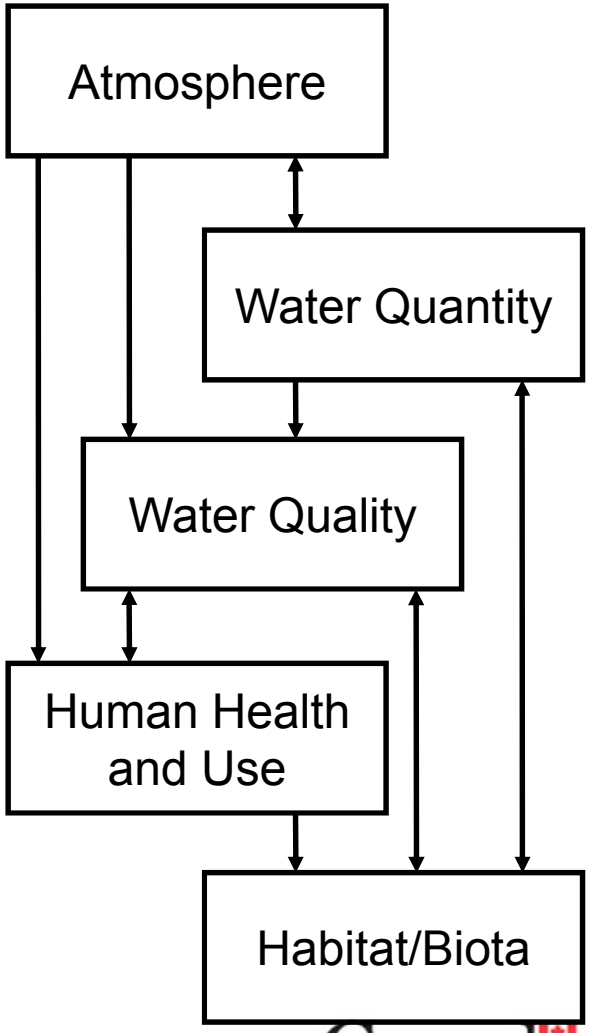
- No single group has all the required expertise
- Established models exist for most components
- Modeling scales are converging



Environmental Prediction System for the Great Lakes – St. Lawrence basin:

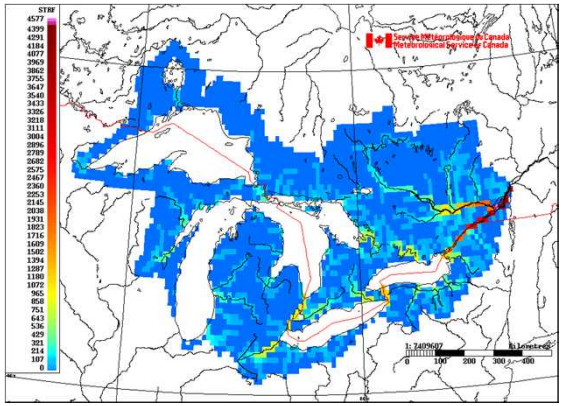
Towards an integrated Earth Science System for the Basin

- Operational system which predicts physical parameters of the earth system and ecosystem state variables
  - Nowcast and hindcast mode: interpolation of observations in space
  - Forecast mode: extrapolation in time
- Numerical models which deal with the dynamics and thermodynamics of the system
  - mass, energy and momentum balance
- System designed for decision making purposes
  - Improved weather forecasts
  - Management of international waters and ecosystem protection
  - Water quantity and water quality prediction
  - Currents, Water Temperature, Ice prediction
  - Emergency response
  - Adaptations and Studies
  - atmosphere, land-surface, hydrology, lakes, rivers, ice, waves, habitat
- A Collaborative Project:
  - EC (ASTD, NWRI, MSC), DFO, IJC, Universities

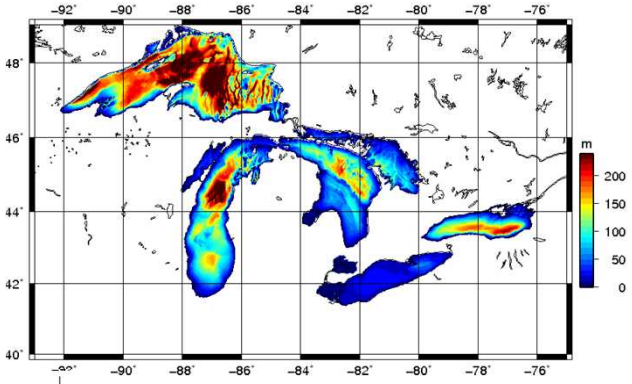


Integrated operational environmental prediction system for Great-Lakes and St. Lawrence

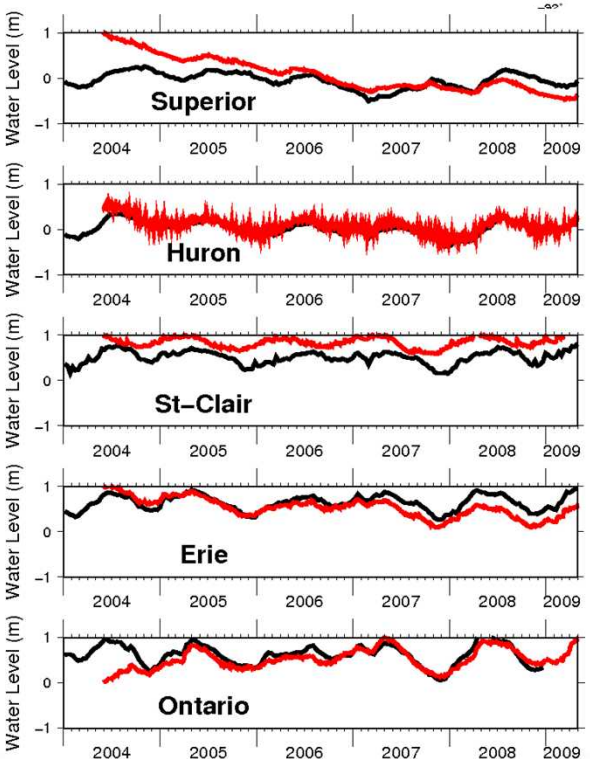
Hydrological-Lake-Ice forecasts:



Hydrological Model



3D Lake-Ice Model



Water Levels simulated

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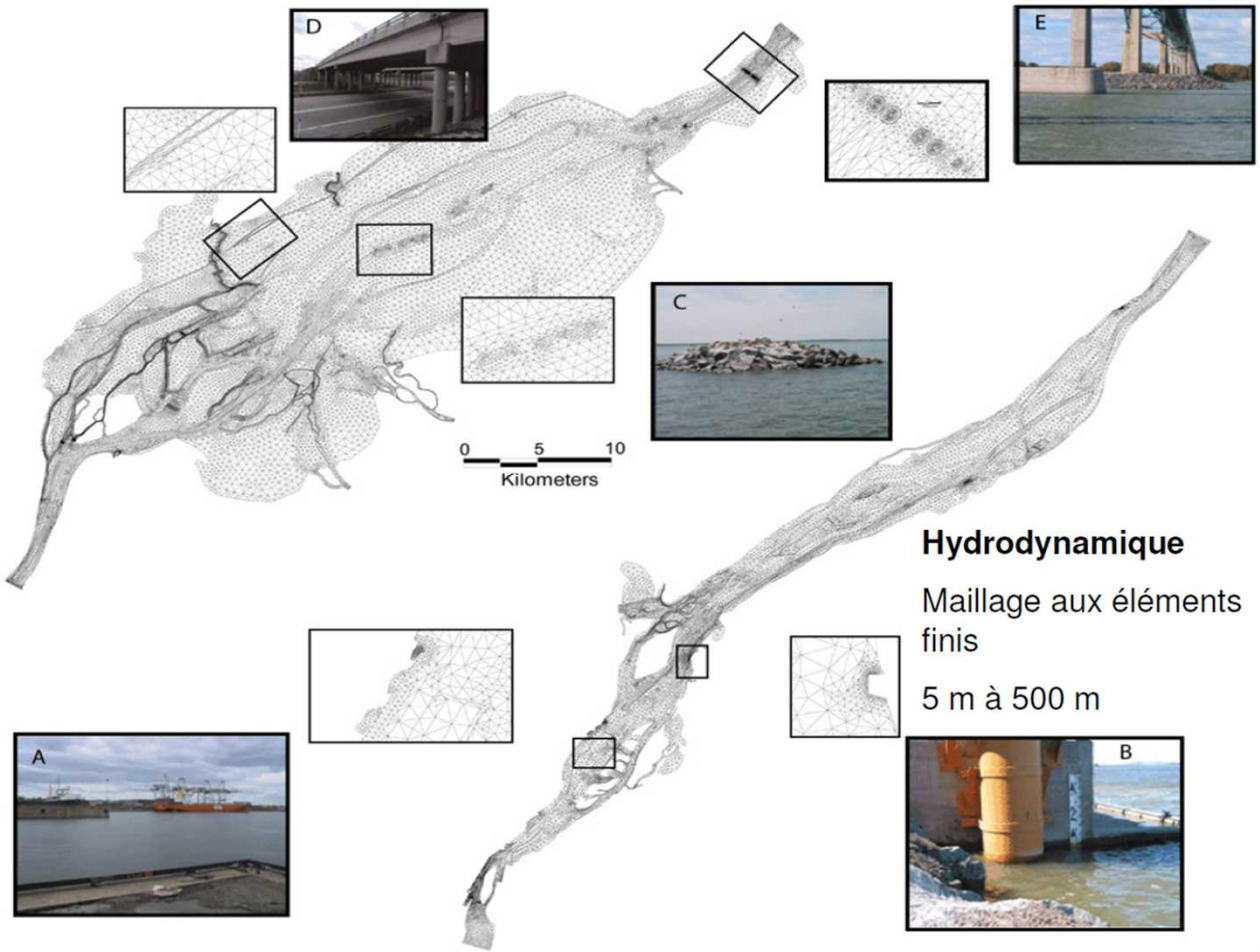
Environmental Prediction System
The St-Lawrence river:

Hydrodynamic modeling



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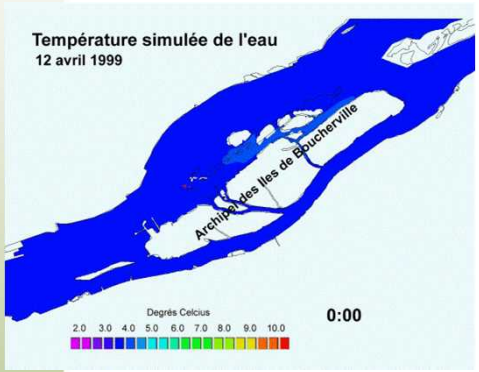
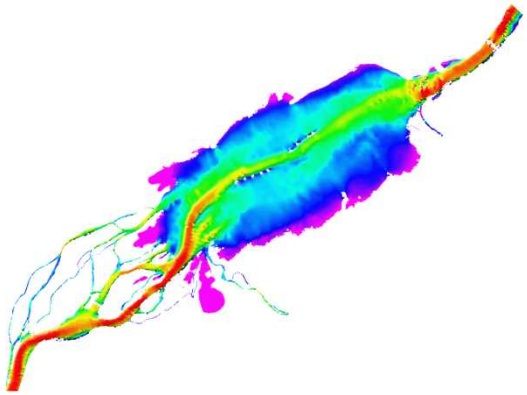
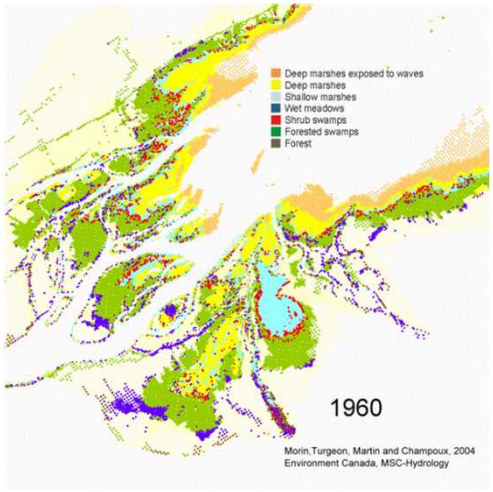
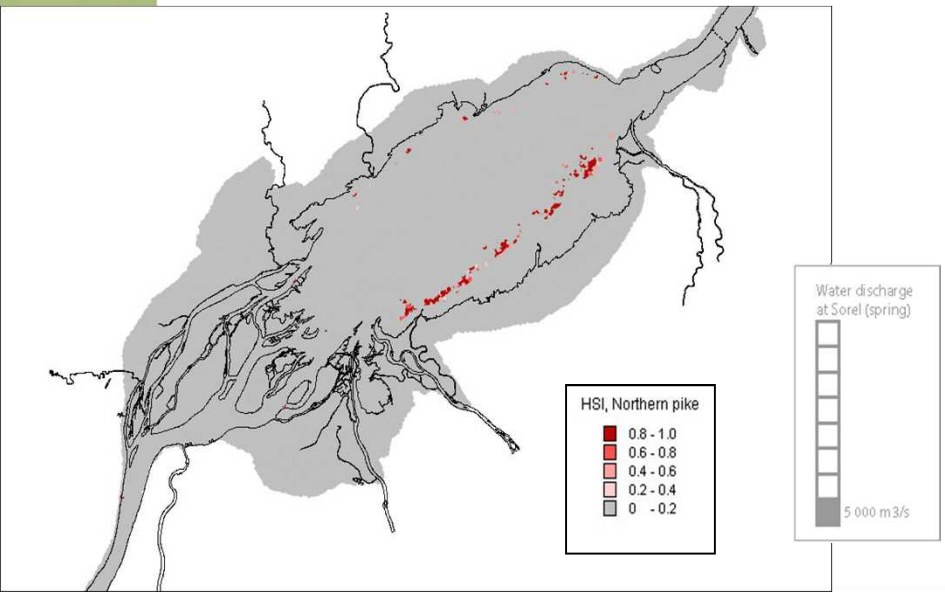
Environmental Prediction System
The St-Lawrence river:



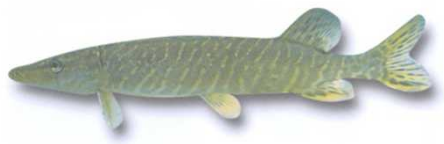




Physical drives: Water Temperature, water velocity, vegetation



SPAWNING HABITAT
Lac Saint-Pierre



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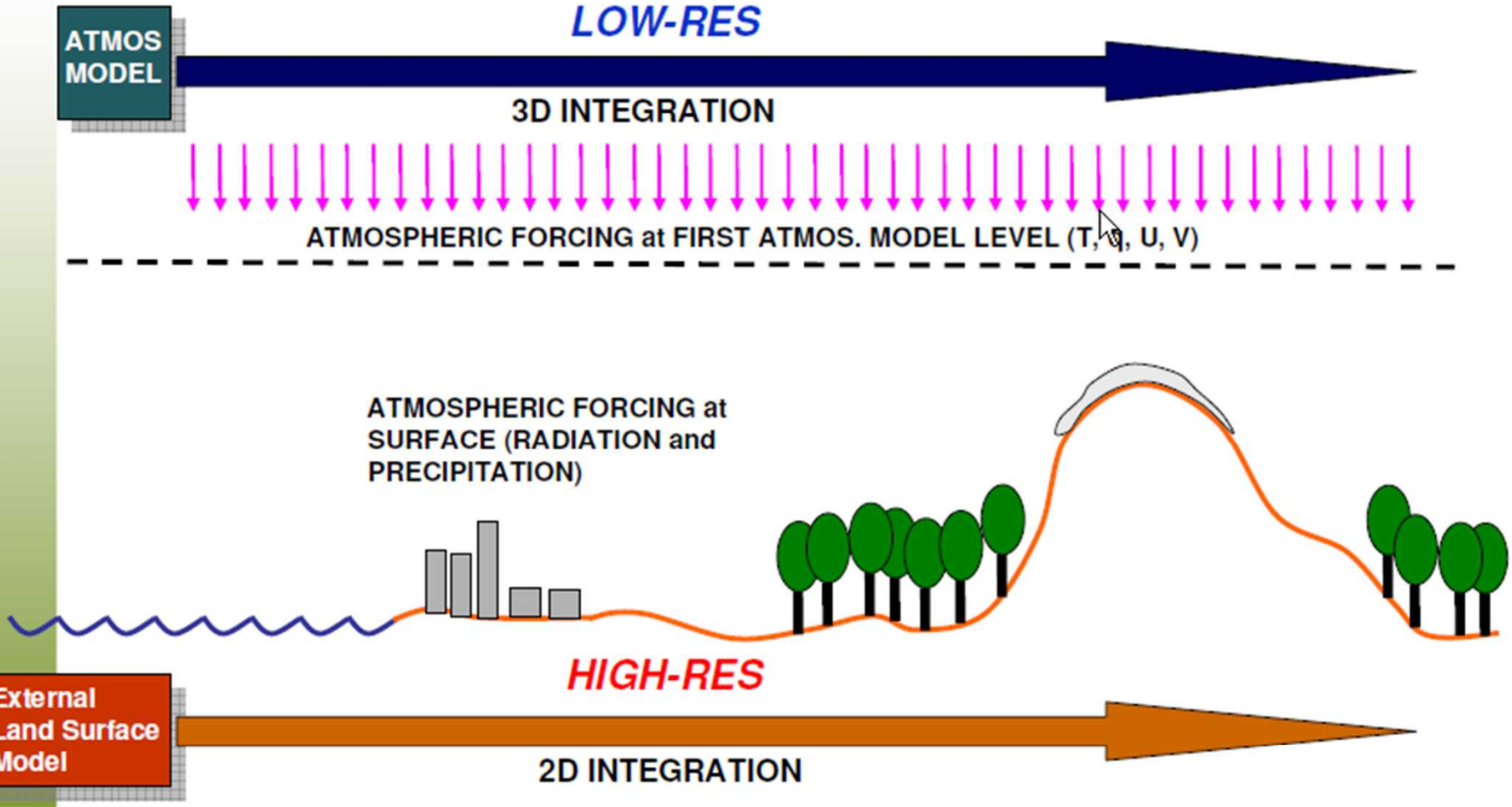
Québec
Natural Resources & Wildlife, Québec

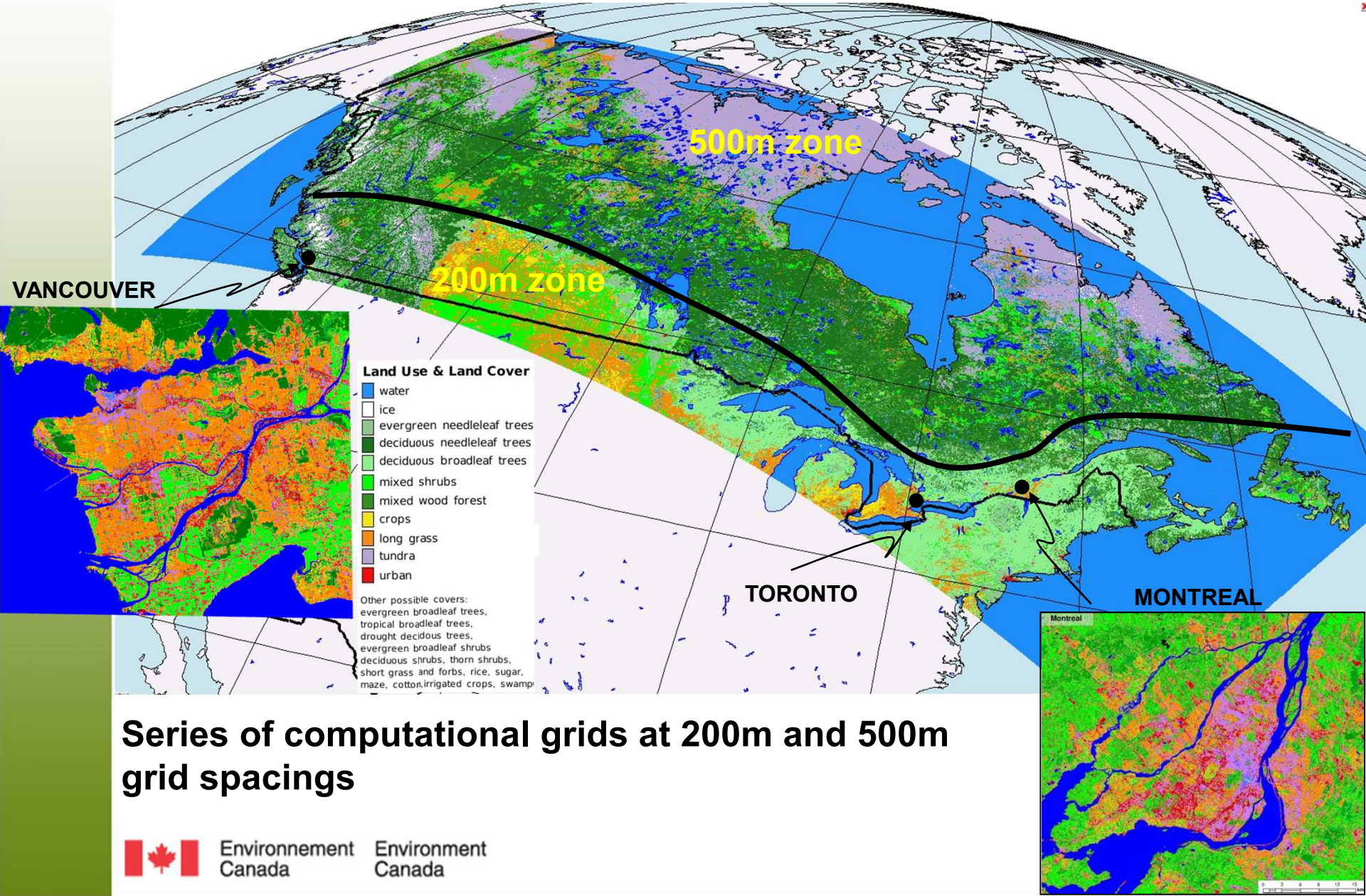
EXTERNAL LAND SURFACE MODELING SYSTEM (GEM-Surf)



With horizontal resolution as high as that of surface databases (e.g., 100 m)

Computational cost of off-line surface modeling system is *much less* than an integration of the atmospheric model

Near future: Very detailed Weather and Environmental Forecasts (OPERATIONAL IMPLEMENTATION in 2012)



Series of computational grids at 200m and 500m grid spacings

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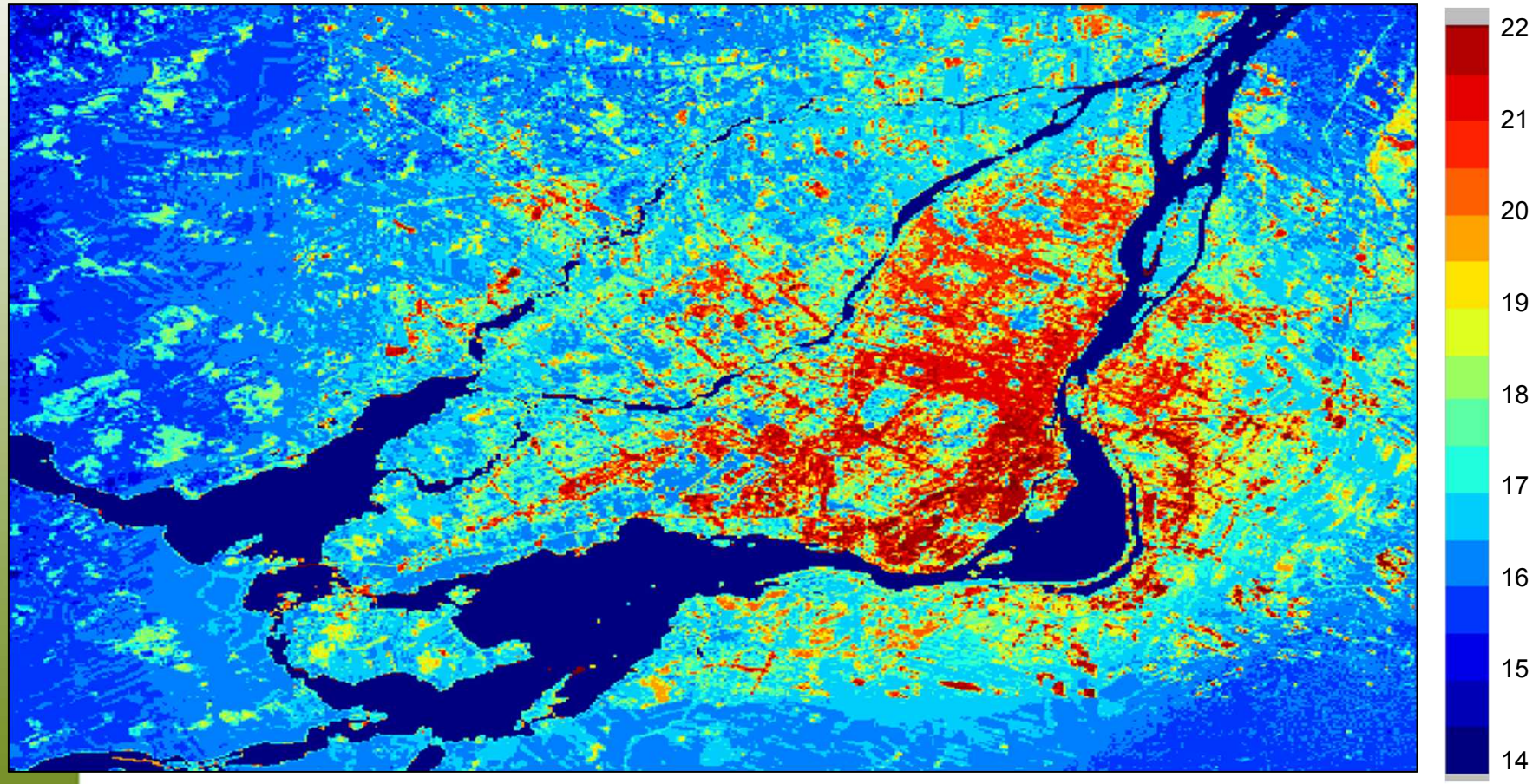
HIGH-RESOLUTION MODELING of the URBAN ENVIRONMENT (120m)

- 6 July, 01:00 LST

Nocturnal 2m air temperature (simulation, 120m)

Montreal Island



► UHI : 5-6 °C

(Leroyer et al. 2010)

Emerging Integrated Environmental prediction system

Air quality and chemical weather

- Multi-scale approach: global down to human scale
  - Interfacing with effects models for human and ecosystem health
- Refinement of chemical processes to link with health triggers
- Full use of satellite, remote sensing and surface observations to inform integrated modelling system from emission to transport to effect

Feb 3rd, 2006 in Montreal

Canadian Coupled Atmosphere- Ice Ocean Forecast System

Canada requires ocean forecasts and information services for:

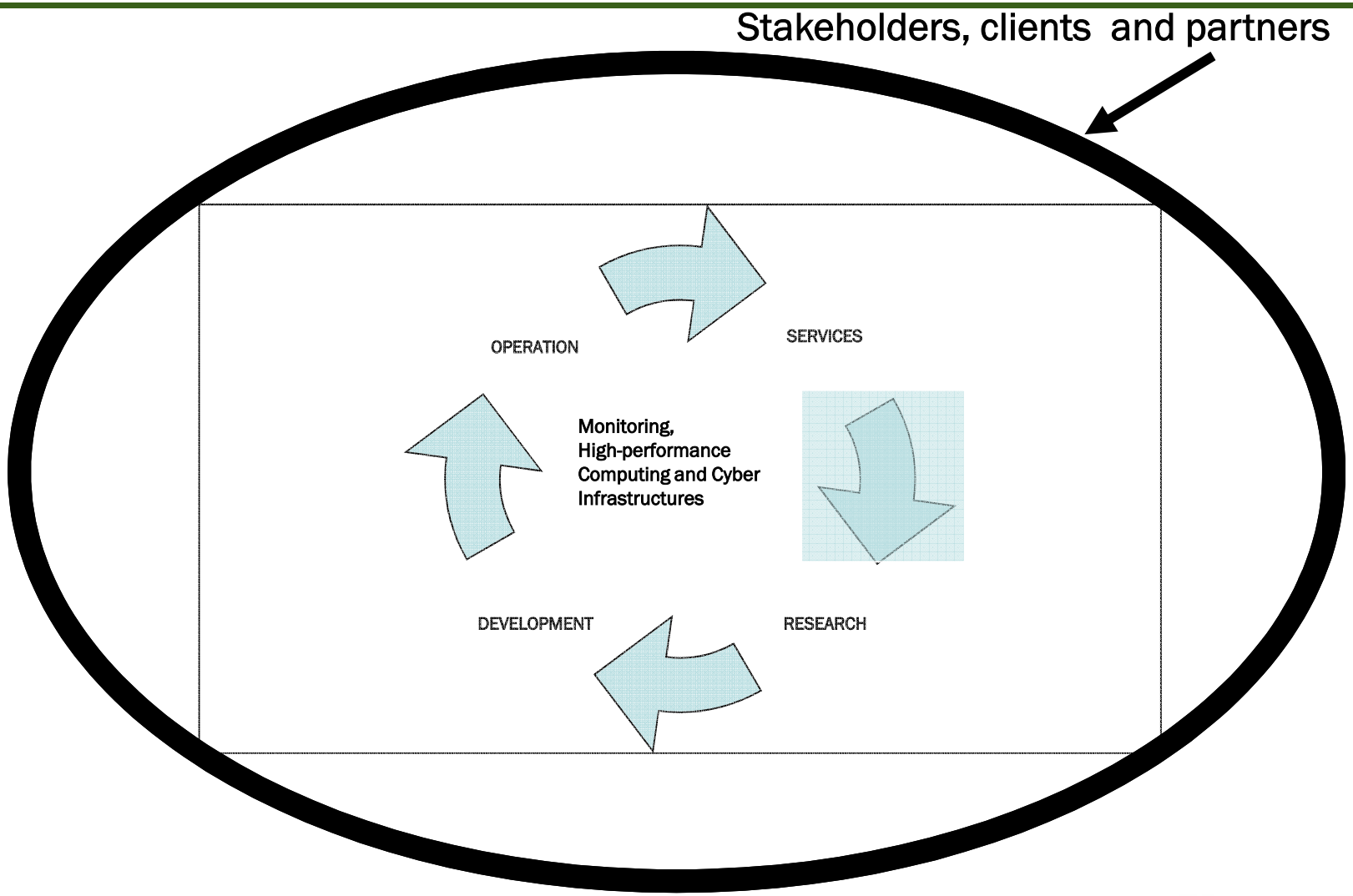
- Weather prediction
- Sea ice prediction (e.g. CCG: seal hunt, navigation)
- Fisheries and aquaculture management
- Increased understanding of biological field observations
- Attribution and mitigation of regional climate change impacts
- Risk assessment for extreme events (sea level, waves, currents)
- Search and Rescue, dispersion of pollutants

Key elements for the future roadmap…

Efficient Technology Transfer process :

Optimizing Research to Operations…

The Innovation Chain: a Technology/Service driven process



Numerical Prediction Innovation Committee
Chair: DG Meteorology, Co-chair: DG S&T

- Members are all DGs and directors (including Services) responsible for the chain of innovation
- R&D section chiefs are invited to present their activities on a continuous basis
- ToR:
  - Implementation management of R&D innovations
  - Long term planning of future implementations, including resources allocations and re-allocations
  - Dissemination of short and long term plans

→ Implementing the NWP innovations into the operational context:

Comité des Passes Opérationnelles et Parallèles (CPOP)
(Operational and Parallel runs Comittee)

National Lab Research Themes/Roles

- **Atlantic Lab for Marine and Coastal Meteorology**
  - Role: Improved scientific understanding and prediction of high-impact meteorology in marine and coastal environments.
- **Québec Lab for Severe Weather Meteorology**
  - Role: Improved prediction of severe weather processes with numerical weather prediction models.
- **Ontario Lab for Nowcasting and Remote Sensing Meteorology**
  - Role: Improve detection and prediction of severe weather processes in all seasons at time scales from 0 to approximately 12 hours.
- **Prairie and Northern Lab for Hydrometeorology and Arctic Meteorology**
  - Role 1: Improved detection and prediction of Arctic high-impact meteorology.
  - Role 2: Improved prediction of hydrometeorological processes.
- **Pacific and Yukon Lab for Coastal and Mountain Meteorology**
  - Role: Improved detection and prediction of high-impact meteorology in complex terrain and urban environments.
- **National Lab for Aviation Meteorology (Virtual laboratory)**
  - Role. To undertake R&D in aviation meteorology with the goal of providing more accurate, more relevant and timelier forecasts in order increase the safety and efficiency of aviation operations.

Focus on Performance & Service Improvement

- Our Quality Management System (QMS) is registered to the ISO9001:2008 standard, an accomplish of which we are very proud…
  - Facilitates the connection between needs of Canadians with our products and services, measures their satisfaction and leads to improvements
- Leveraging international cooperation and improvements along with our research and development focus lead to service improvements for all Canadians

Key elements for the future roadmap…

Implementing key

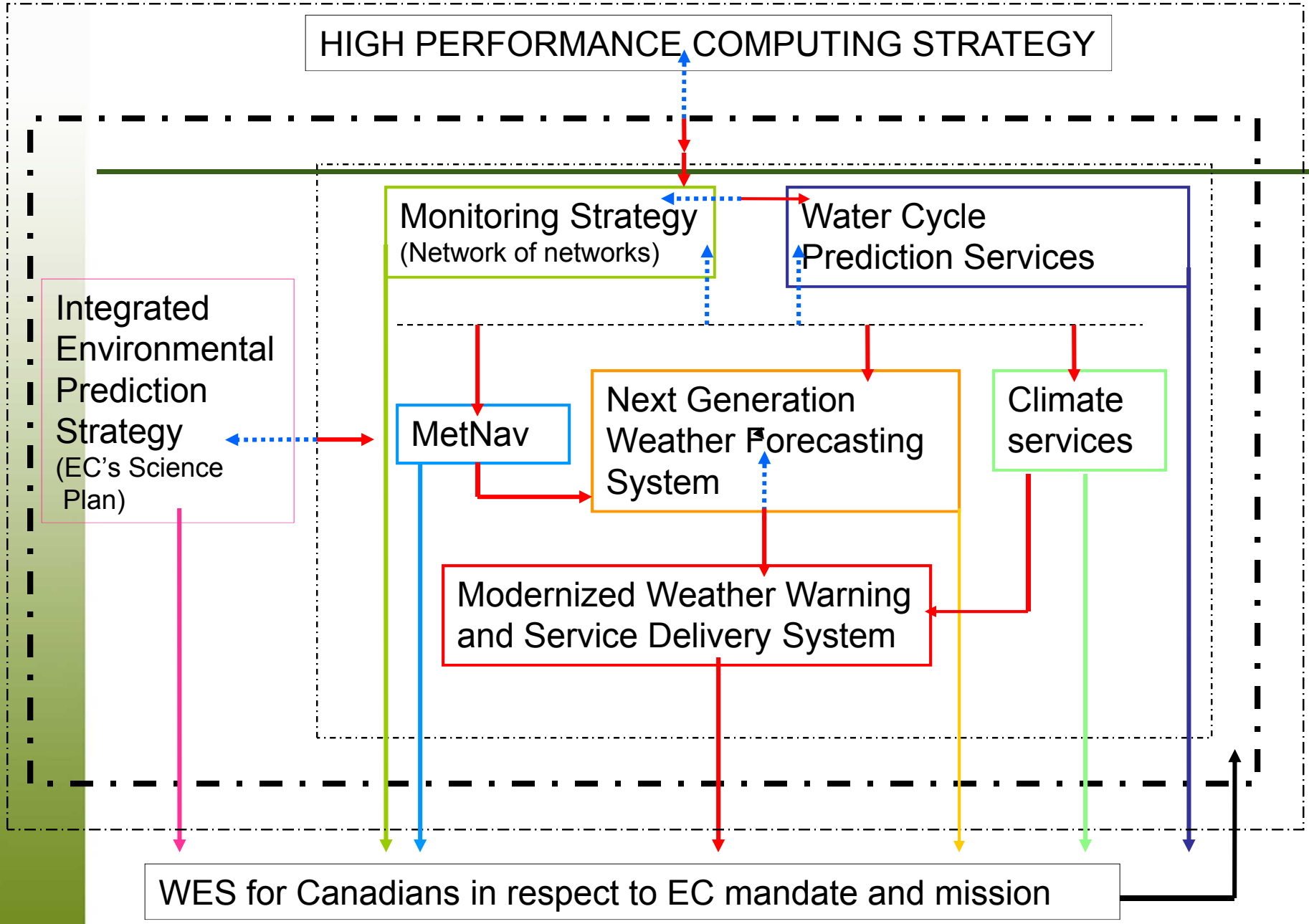
« Signature projects »

Charting a course for the future of weather forecasting within the MSC

Identifying Key strategies that integrates the vision and mandate of MSC (signature projects):

- Weather Warning and Service Delivery System Re-engineering
- Modern Day Monitoring Strategy
- Next Generation Prediction System
- High Performance Computing
- Air Quality and Health Services
- METAREAs Initiative
- Integrated Environmental Prediction Science
- Climates and Water Services Strategy

Integrating specific programs and tools dealing with the detection, evaluation and information of weather related risks and impacts


HIGH PERFORMANCE COMPUTING STRATEGY
Monitoring Strategy
(Network of networks)
Water Cycle
Prediction Services
Integrated
Environmental
Prediction
Strategy
(EC's Science
Plan)
MetNav
Next Generation
Weather Forecasting
System
Climate
services
Modernized Weather Warning
and Service Delivery System
WES for Canadians in respect to EC mandate and mission

Key elements for the future roadmap…

The human and changing roles, e.g. Role of the operational forecaster

Vision to Role of the Operational Meteorologist…

- Forecast system needs to change to achieve the Vision:
  - Monitoring
  - Prediction
  - Science
  - Services
- Defining, refining and realizing the operational meteorologists role in the system is essential to achieve the Vision. The role must:
  - Facilitate the best application of human's skills;
  - Make the best use of technological progress;
  - Enable adaptability and responsiveness to client requirements;
  - Support effective decision making by enabling the forecast of impacts.

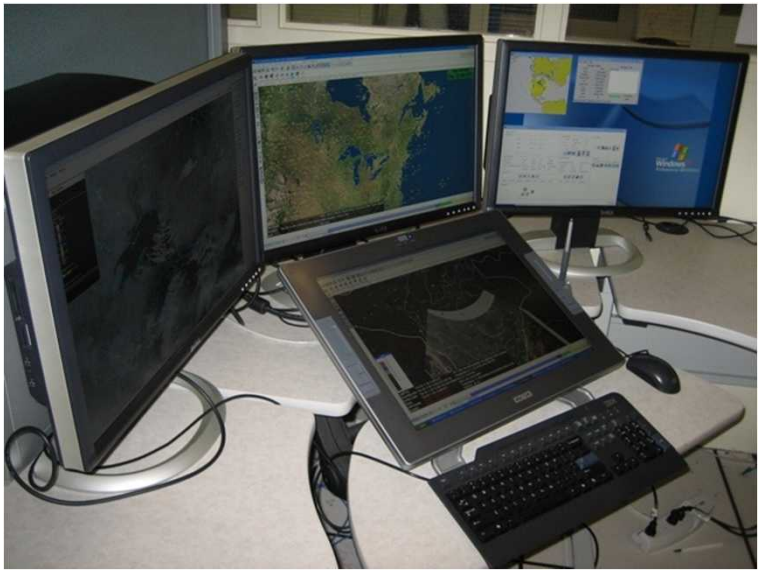
Thrusts for the Role of Operational Meteorologists

- Provision of early-warning consultation and advice about severe weather, including evaluation and advice on scenarios in the context of potential impacts or risks.
  - Making sense of probabilistic information
- Forecasting severe weather based on analysis of observations and diagnosis of weather phenomena and model performance.
- Supervision of forecast systems
- Scientific development and improvement of warning and forecast systems
- Monitoring and quality assurance of products
- Learning – maintaining and developing necessary skills and competencies.

Supported by technological tools and training…

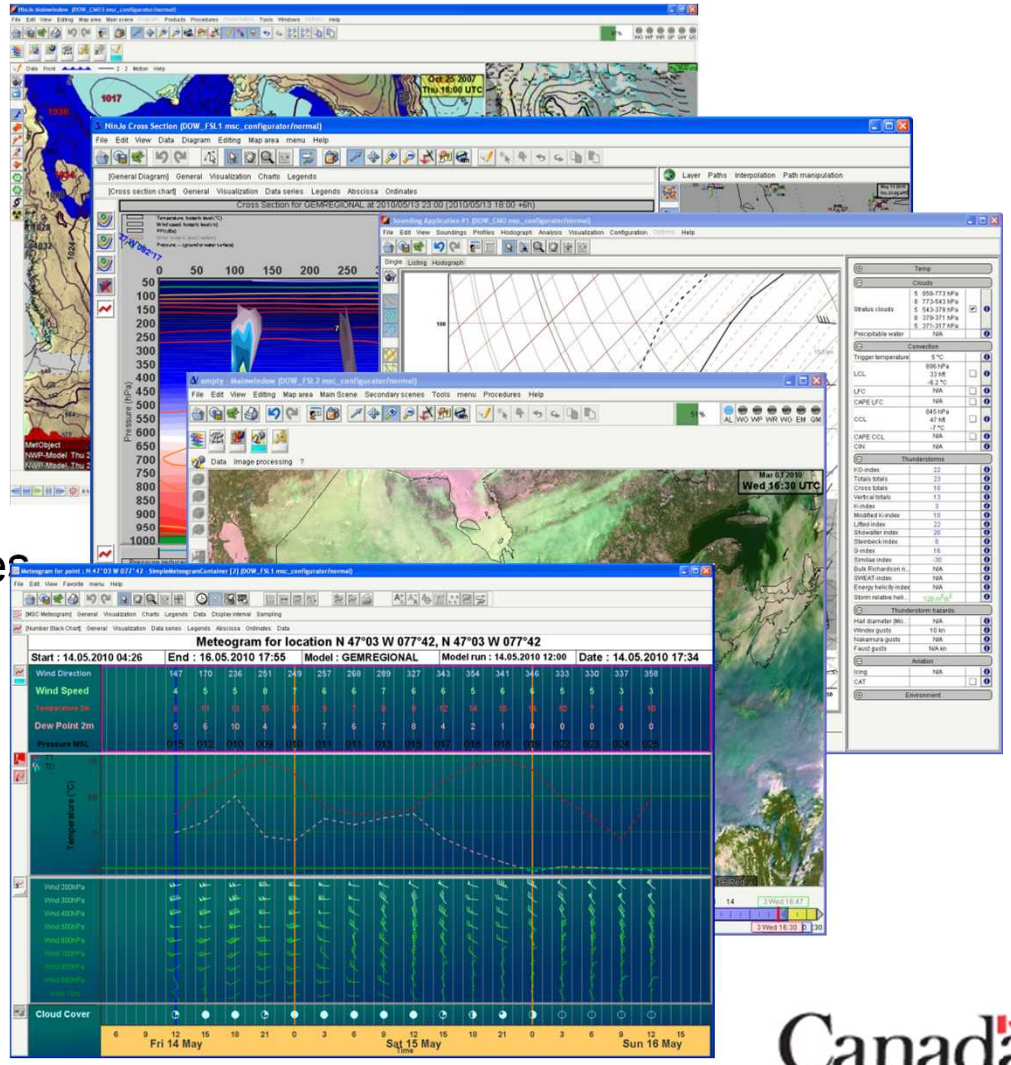
NinJo at MSC

- MSC is a member of the NinJo Consortium (with Germany, Switzerland, Denmark), since 2003
- The NinJo workstation is deployed in forecast centres across Canada and will become a mission critical component of our forecast production system in 2012.

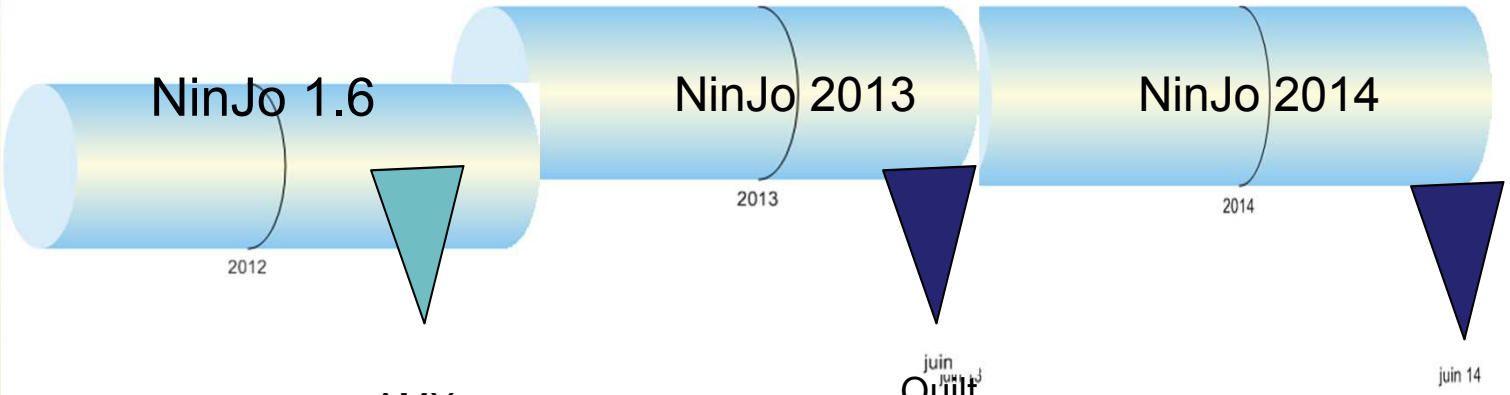


NinJo to be the core of MSC's Next Generation Forecast System

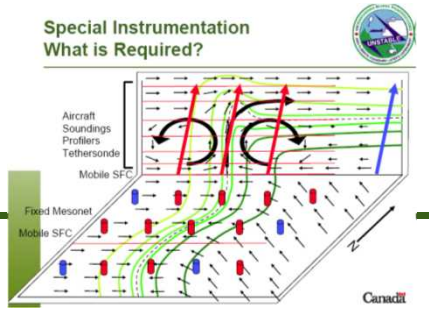
- NinJo-centric
- Event-driven warnings
- Nowcasting
- Data-cube interaction
- Tool for effective forecaster intervention
  - Decision support
  - Maximize the role of the human in the process
- Collaboration between offices



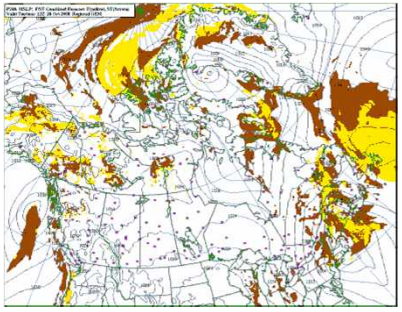
Timeline

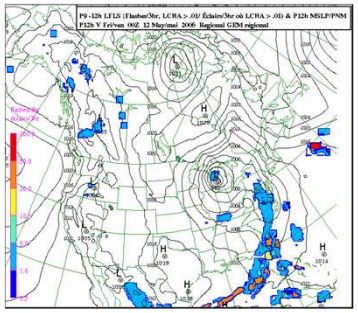

NinJo 1.6
2012
NinJo 2013
2013
NinJo 2014
2014
sept. 11
mai 12
juin
juin 14
AMX
Hurricane GUI
URP IV
THUMP/WADS
Quilt
Veille / Wx Watch
Edigraf/GFA
Scribe
MultiAlert
BullPrep

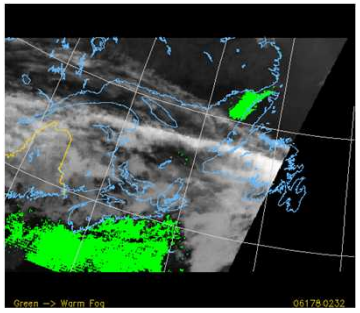
Severe Weather and Warning Applications

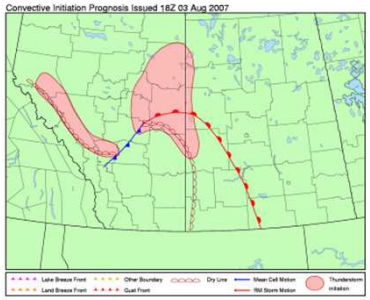


- ELBOW/Tornadoes in Ontario Project
- Border Air Quality Meteorology Project
- UNSTABLE Project
- Research Support Desk Applications
- Lightning Forecasting Project
- Arctic Blizzard Forecasting Project
- Fog Research and Modeling Project
- Arctic Ice Fog Forecasting Project
- iCAST Project
- Urban Meteorology









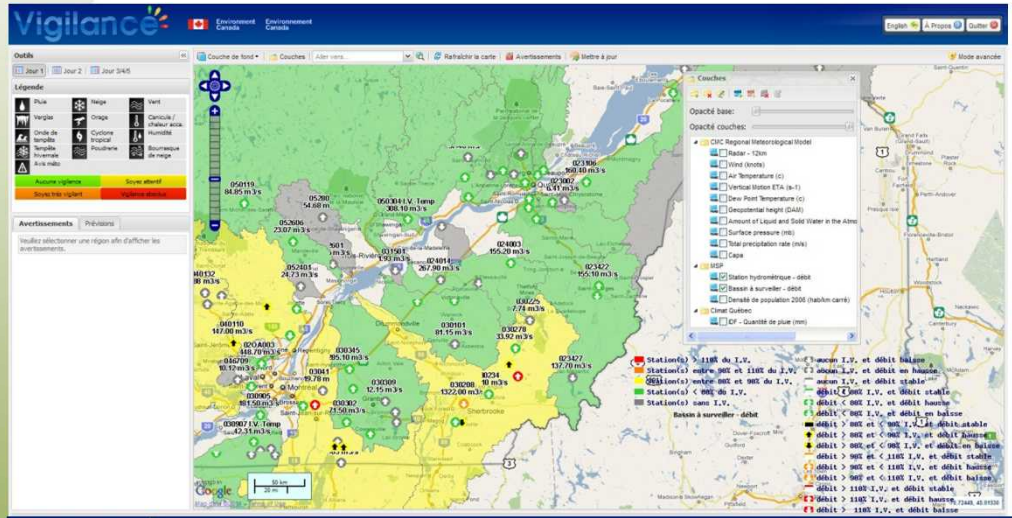
The RSD Initiative

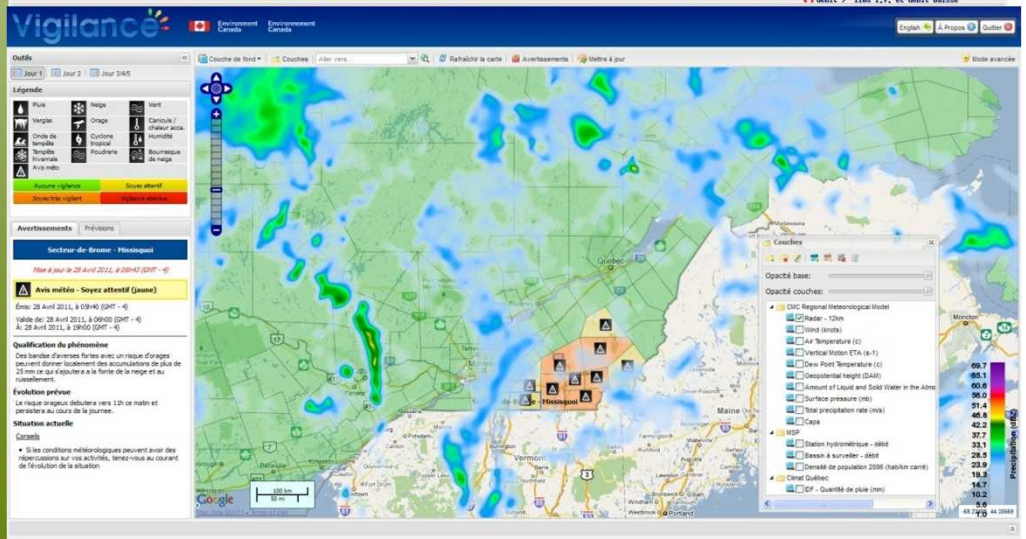
The **Research Support Desk (RSD)** initiative facilitates the interaction of research and operations *in a real-time setting* - a unique approach

- Facilitates knowledge / tech transfer between research and operations
- Provides interactive mentoring thereby providing assistance to forecasters during HIW events
- Has allowed critical real-time testing and evaluation of new tools / techniques (e.g. iCAST) - forecasters have influenced development
- Researchers also gain first-hand knowledge of the 'science gaps' facing forecasters and the prediction program.

Weather Vigilance Prototype (tools)

Risk = f (Hazard, Vulnerability) → Risk Communication





- **Vulnerability (Societal / Environmental)**
  - o Integrating antecedent conditions

→ Impact based regional dynamic thresholds

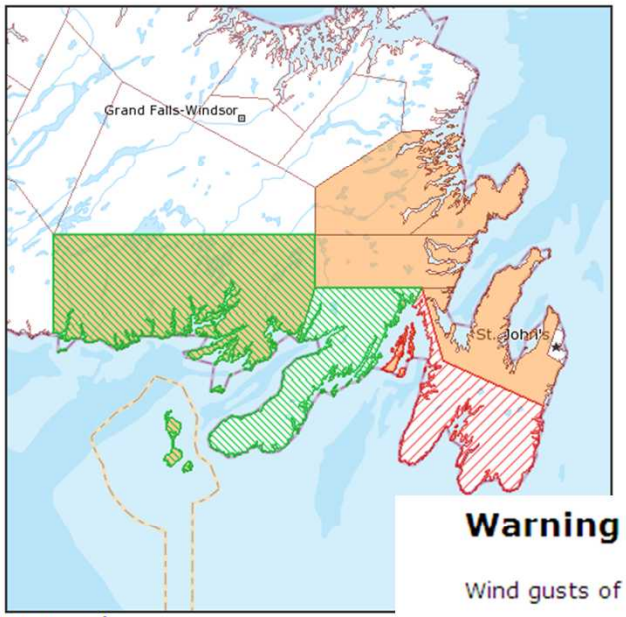
- **Risk based communication**
  - o Early warning
  - o "Complete" communication
  - o Linking weather-impact
  - o Cross-jurisdiction coherence
  - o Recurrent experience feedback (improving iteratively)

Email Linked to Webpage

NewfoundlandBoth

Issued at Thu Oct 27, 2011 13:17 UTC by Environment Canada:

- **Wind warning CONTINUED** for **Avalon Peninsula South, NL** (021200)
- **Wind warning ENDED** for **Burin Peninsula, NL** (022100)
- **Wind warning ENDED** for **Ramea - Connaigre, NL** (022300)



Map Legend

- User Subscribed Polygon
- Alerted Polygon
- Alert Ended Polygon
- User Drawn Polygon
- EC Warning Sub-Region Border

Warning Statement

Wind gusts of up to 110 km/h are expected early this afternoon.

This is a warning that potentially damaging winds are occurring in this region. Monitor weather conditions..Listen for updated statements.

An intense low pressure system just northeast of the Grand Banks will continue to move east away from the island today. Rain and strong northwesterly winds will diminish throughout the day as the low departs. Due to cool autumn temperatures, precipitation is expected to fall as wet snow over inland and higher terrain areas of western, northern, and Central Newfoundland. 5 centimeters of wet snow is possible today. Motorists are advised to be prepared for winter driving conditions.

Additionally, another low pressure system will develop near Cape Cod today. This system will intensify as it tracks northeastward passing southeast of the Avalon Peninsula late in the day on Friday. Rain will spread over Eastern Newfoundland ahead of this system before changing to snow, with the Avalon Peninsula expecting to see the highest accumulations.

Please refer to the latest public forecasts for further details.

Latest information is always available here: http://weatheroffice.gc.ca
Mobile Version: NewfoundlandBoth

Environnement Canada

Charting a course toward the future

- An efficient technology transfer process
- Implementing key « signature » projects
- A vision for the role of the forecaster in this road towards the future

Summary… a Canadian perspective

- Canadians demanding more and better integrated environmental information to support decision-making:
  - Mitigate increasing vulnerability of society, economy and infrastructure in face of increasing severity & occurrence of high impact events such as severe weather and pollution episodes
  - Know the risks and adapt to a changing climate (extreme weather, development of the North, etc…)
  - Maximize efficiency of economy and operations
  - Reduce emissions and avoid health risks of pollution exposure
  - Support sustainable use and development of natural resource
- Integrated multidisciplinary approach to environmental prediction
  - coupled atmosphere-ocean-ecosystem (whole-earth simulation), air quality (chemistry)
- Broadening of applications
  - emergency response, ecosystem, agriculture, forestry, health, energy

Summary… supporting a broad and global perspective

- Global community of NMHS hold a key role in providing the vision, expertise, products and services related to multi-hazards environmental alerting platforms
- The international framework must include key partnerships and provide a reliable and sustainable infrastructure on which the vision of disaster risk reduction activities will ensure that its purpose is met.
- Improvements in understanding weather, water and environmental processes, such as in the oceans and polar areas will improve global environmental modeling
- Development and sharing of expertise, knowledge and practices will enable scientific and technical education and training, provide a sound basis for current and future generations in dealing with environemental hazards.

Issues to be dealt with….

- Data standards and metadata
  - Global Data Management Framework ?
  - Global Data Mining capability … WIS ?
- ‘GEO’ as a ‘convergence’ mechanism ?
- Deterministic versus Ensemble… How do we manage the interface ?
- Characterizing uncertainty… in an understandable way
- Disseminating information… how can we cope with the speed of technological development ?
- The evolving role of the forecaster ?
  - Technological interface required, training, etc
- The evolution of the Service Interface….
  - Capacity building with user community

Thank you !