MSC Ensemble Applications & Transformation

9th NOAA Ensemble Users Workshop, 2023
Stéphane Gagnon (presenter)
Meteorological Service of Canada
Environment and Climate Change Canada

The MSC's Capabilities and Information Services Support many specialized clients

Client	GOVERNMENT OPERATIONS CENTRE	CANADIAN COAST GUARD	DEPARTMENT OF NATIONAL DEFENCE	EMERGENCY MANAGEMENT ORGANIZATIONS	FLOOD & WILDFIRE FORECASTING AGENCIES	PUBLIC HEALTH AUTHORITIES
						
Their Role	The GOC performs assessments of all-hazard risks of national interest requiring coordinated response. They also convene all authorities and organizations in response.	The CCG performs search and rescue, ice breaking operations, and disseminates mariner safety information in remote, weather-hazardous areas.	DND defends Canadian sovereignty, assists in time of natural disasters and contributes to international peace support and peacekeeping operations.	Provincial, Regional and Municipal EMOs plan for and respond to events that may impact citizens in their jurisdictions, including extreme weather events.	Provincial, Regional and Municipal agencies responsible for wildfire and flood forecasting/alerting and in some instances managing water levels	Federal, Provincial and Municipal health authorities provide guidance and tools to help protect the health of Canadians including air quality and heat related events.
MSC Provides	• Tailored weather weekly and seasonal outlooks • Customized daily overviews with hazard identification • Weekly national overview • Wildfire and flood situational reports • Customized products and services to support active response situation, including embedded meteorologists on request	• Ice analysis and hazard information in support of icebreaking activities • Embedded MSC specialists on icebreakers providing ice information • Tailored sea ice and iceberg information for ice avoidance • Marine Weather forecasts which are relayed by CCG via radio to mariners	• Direct meteorological support through ~40 meteorologists stationed on Cdn Forces Bases • Specialized and tailored products providing meteorological intelligence in support of domestic and global operations • Support for search and rescue operations	• Tailored early notification products ahead of potentially significant weather events • Consultation and advice by Warning Preparedness Meteorologists • Direct media or public communication support as required	• Specialized forecasts in advance of and during high impact events • Real-time water level and flow data are provided directly to support their preparedness, forecasting and warning activities • Weekly and seasonal Flood potential tools, products • Wildfire and flood situational reports	• Tailored early notification advice prior to poor air quality and heat events by Warning Preparedness Meteorologists • Collaboration on public messaging during extreme heat events and poor air quality incidents • Daily Air Quality Health Indexes forecasts

The MSC also promotes situational awareness through…

- Provision of multi-scale, multi-hazard 24/7 dispersion modelling to other ECCC specialists, NRCan, DND, NAV CANADA and PT EMOs in response to environmental emergencies, or volcanic ash events
- Modelling for biological, chemical, and nuclear incidents provided to Health Canada as well as international bodies such as the International Atomic Energy Agency and the World Meteorological Organization
- Weather forecasts and warnings to the aviation industry under contracted service with NAV CANADA – the private sector operator of the national air navigation system.

Increasingly unprecedented weather has become the new normal

Strengthening weather and environmental prediction services is essential to **provide early warning of impending impacts and support robust emergency preparedness and response** in response to Canada's new weather reality.

2022

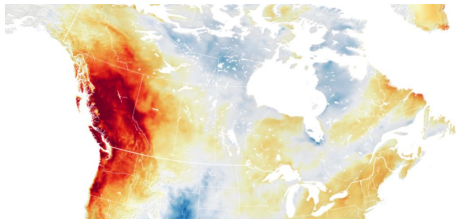
Hurricane Fiona, Atlantic provinces

2020

Calgary Region Hailstorm and Prairie Winds

- Significant hail.
- 50-60mm of rain.
- 4th highest insured damage event in Canadian history ($1.2B).

2021



West Coast Heat Wave

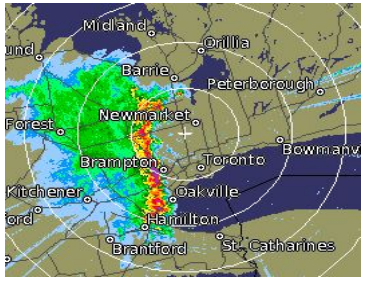
- 789 new daily high temperatures records set in Canada between June 26 and July 4.
- Major health risk to vulnerable populations.
- Significant ecological impact on water quality and animal life.

2021

British Columbia Flooding

- Extreme rainfall, power outages, dyke breaches, mudslides and extensive flooding.
- 4 fatalities.
- Impacts also included evacuation orders, road and rail closures, and gasoline purchase limits.

2022



Ontario & Quebec Derecho

- A fast-moving line of storms swept along Canada's most densely populated corridor.
- 12 fatalities.
- 6th most expensive natural disaster in Canadian history.

Advancing weather services through planned model improvements

Atmosphere | Land | Water | Ocean | Ice

Atmospheric NWP

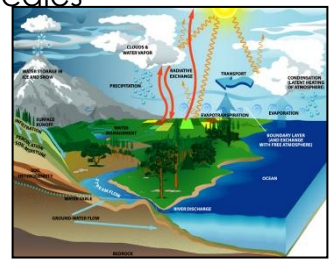
- Improvement to model's dynamical core
- Preparing the Global Ensemble at 25 km resolution
- Increase of high-resolution model grid in the north
- Continue testing very high resolution systems

Environmental NWP

- Improving storm surge, ocean and ice prediction
- Improving hydrodynamic prediction and applications
- Development of sea surface temperature analysis
- Improving surface and river prediction system

Evolving Earth System Predictions

Generates a digital replica of the Earth, including human-induced changes at certain scales



Ensemble vs Deterministic systems

Current situation:

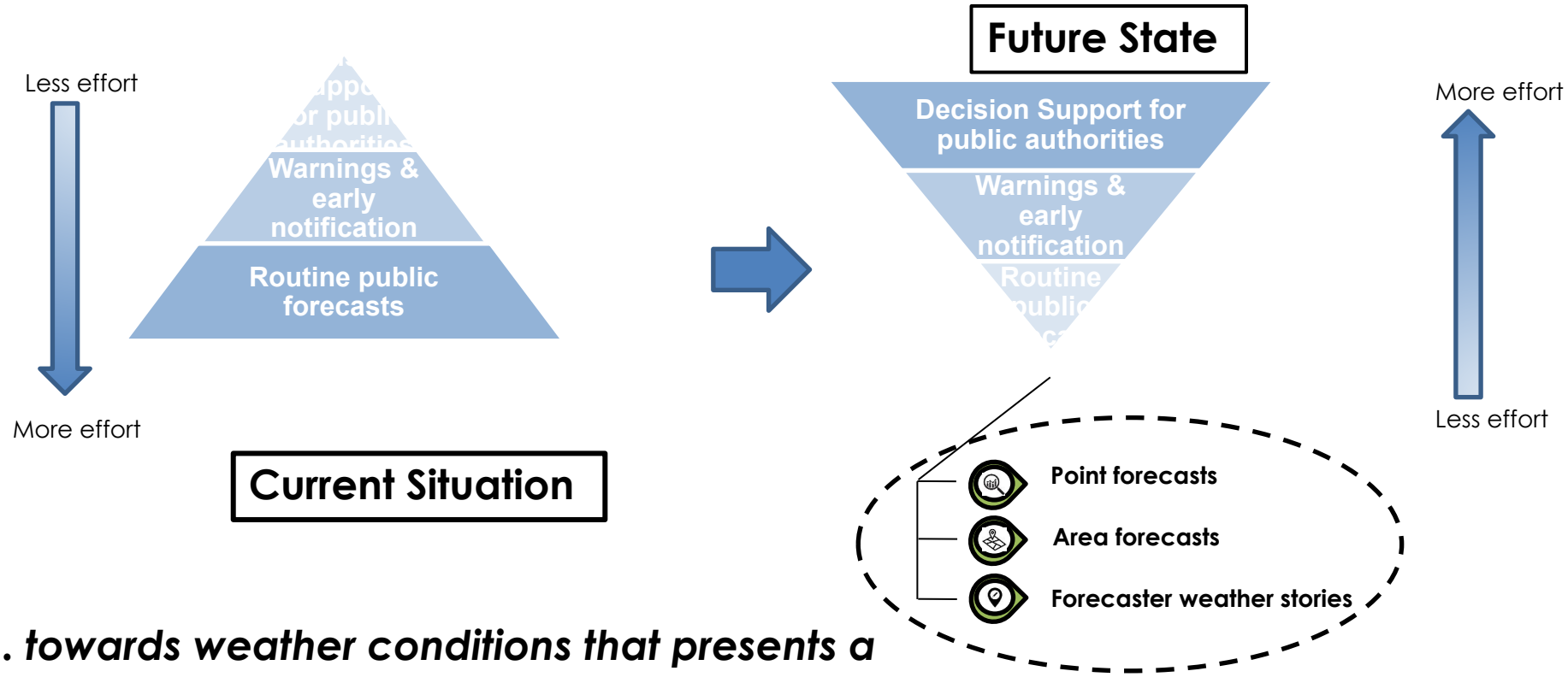
- Ensemble systems are increasingly used by operations.
- The trade-off between lower-resolution ensembles and higher-resolution determinis tic forecasts is such that services are provided through both approaches.

- **Vision:** When ensembles will reach 10 km globally and ~1 km at the regional scale, deterministic approaches may become obsolete.

For more information:
16A.1 - Environment and Climate Change Canada NWEP Systems and R2O Collaboration: Overview, Vision and Future Plans [Oral, Jan 12th @ 15:45]

Actionable services: impact-based decision support

Shifting priorities towards decision support services, impact-based warnings, and early notification …

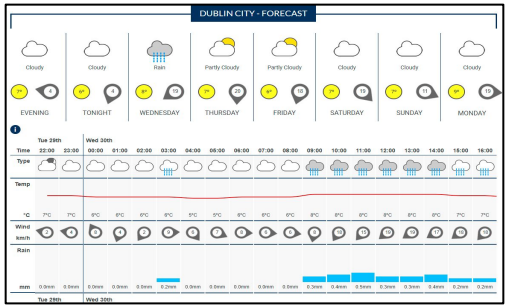


… towards weather conditions that presents a risk to the lives and livelihoods of Canadians

Actionable services: impact-based decision support

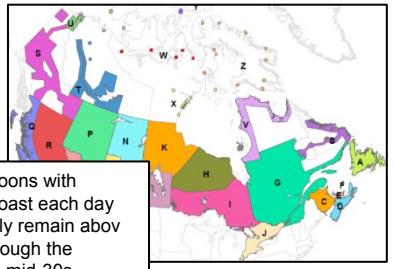
Point forecasts with high temporal and spatial resolution

- Meteograms for more than 10,000 locations
- Model-driven product
- No intervention by forecasters



Area summary forecasts

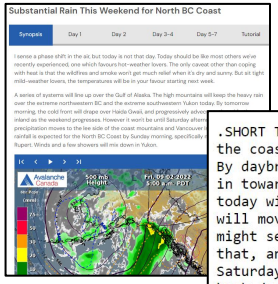
- Targeting media and Text-to-voice services
- Towards increasing automation



Dry and warm weather during the afternoons with areas of morning low clouds along the coast each day through Saturday. Temperatures will likely remain abov e normal across much of Coastal BC through the holiday weekend with highs in the low to mid-30s.

Forecaster Weather Stories

- Fee-form text discussion with accompanying
- Forecaster-driven product
- Primarily targeting the public



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WEonG : Weather Elements on Grid
A new set of data supporting the different forecasting programs in the context of MSC transformation

(1) Public
(2) Marine
(3) Air quality and Health
(4) Aviation / DND
(5) Hydro-meteorology

Production
&
Dissemination

Canada

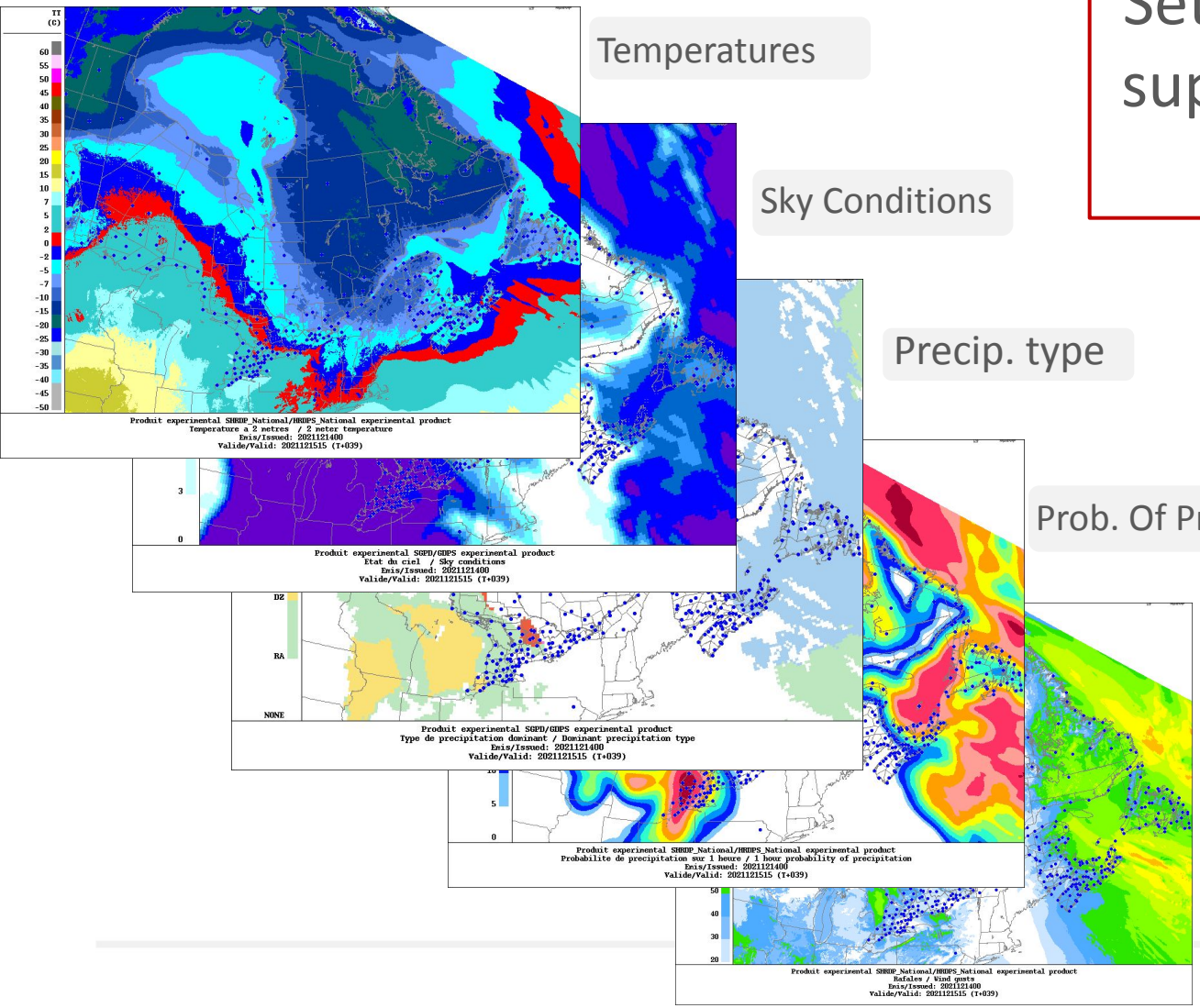
MSC GeoMet

Datamart

NinJo
Meteorological Workstation
Station de travail météorologique

Ex. : WEonG – Public Program

Set of coherent fields supporting the public program



Road Map : WEonG Development Plan

Towards increasing use of EPS

Main challenge : Supporting current production system while supporting MSC transformation … with limited resources.

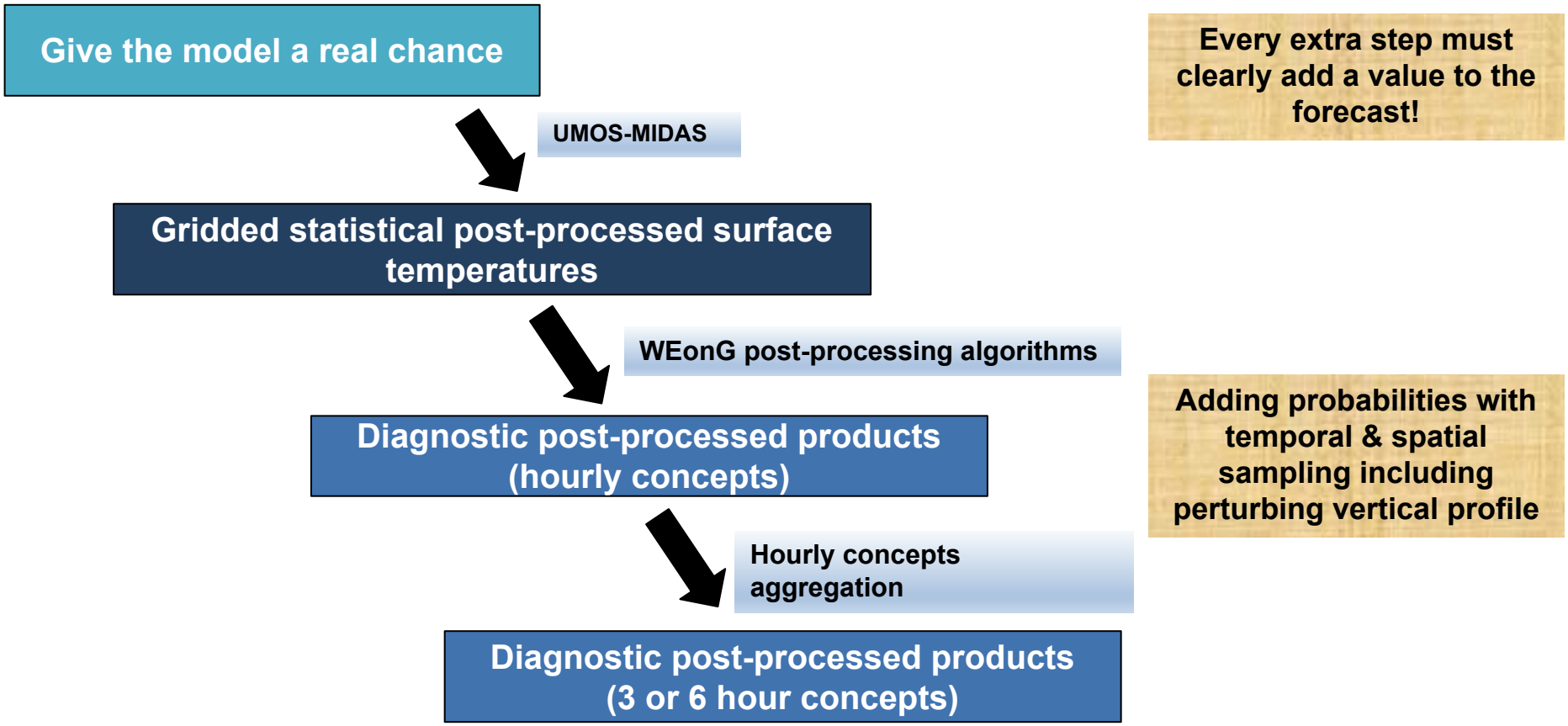
✔ Developing the WEonG foundation with deterministic models and integrating gradually probabilities

Exp: 2023
Ops: 2024

- In progress : WEonG-EPS
  - Challenges : data management, efficient computer processing, calibration, useful data/info, …

Exp: early 2024
Ops: late 2024

WEonG Development Strategy



Precip info could take different forms

- Intensity / Amount
- Character
  - Showers, Snow Squall, Thunderstorms, …
- Type
- (calibrated) Probabilities

Impact on …

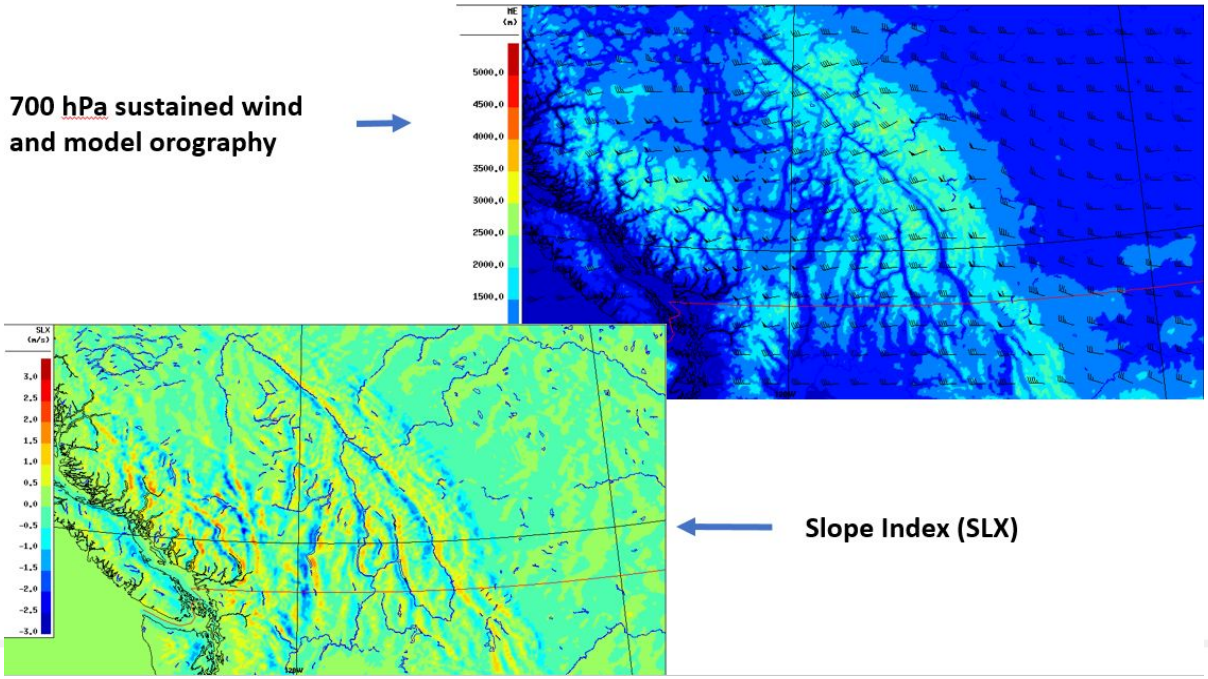
- Visibilities
- Runoff – water flow - flooding
- Surface conditions
- Dryness, …

Diagnostic post-processing in the WEonG

Probability of precipitation in different steps

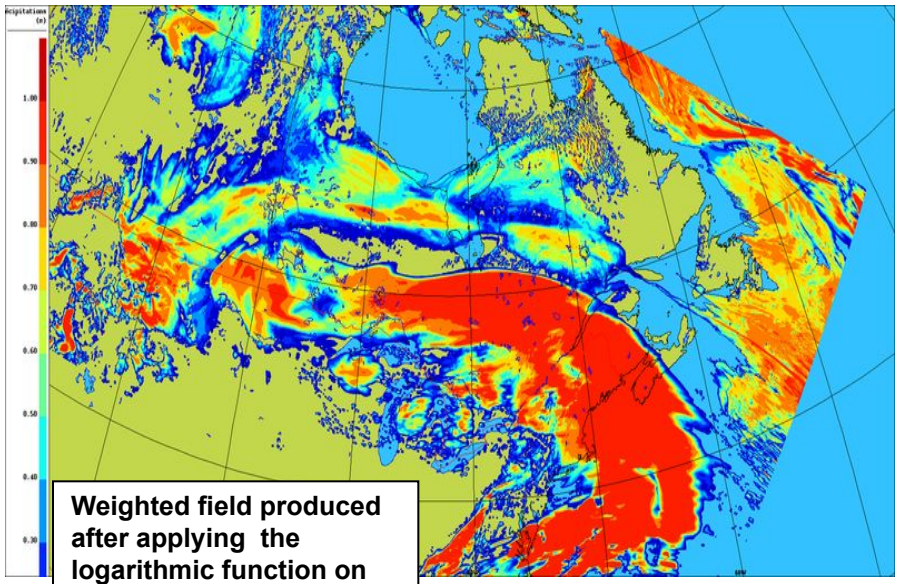
Step 2 - Slope index:

- Scalar product between 700 hPa winds and the model orographic gradient.
- Helps detect and remove grid points within the sampling radius that are downslope (no precipitation).

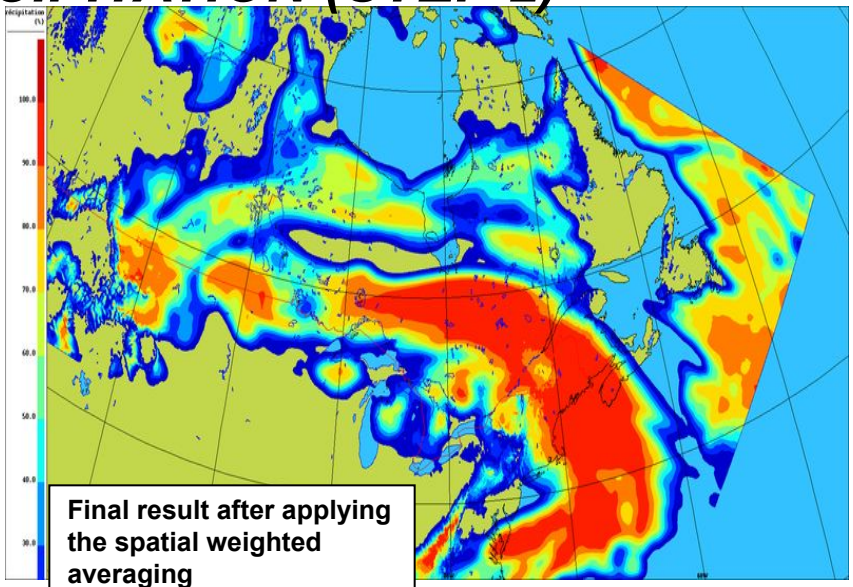


DIAGNOSTIC POST-PROCESSING IN THE WEONG

PROBABILITY OF PRECIPITATION (STEP 2)



Weighted field produced after applying the logarithmic function on hourly accumulation field



Final result after applying the spatial weighted averaging

- The probability of precipitation is simply *the spatial weighted averaging method* applied on the weighted field (upper left).

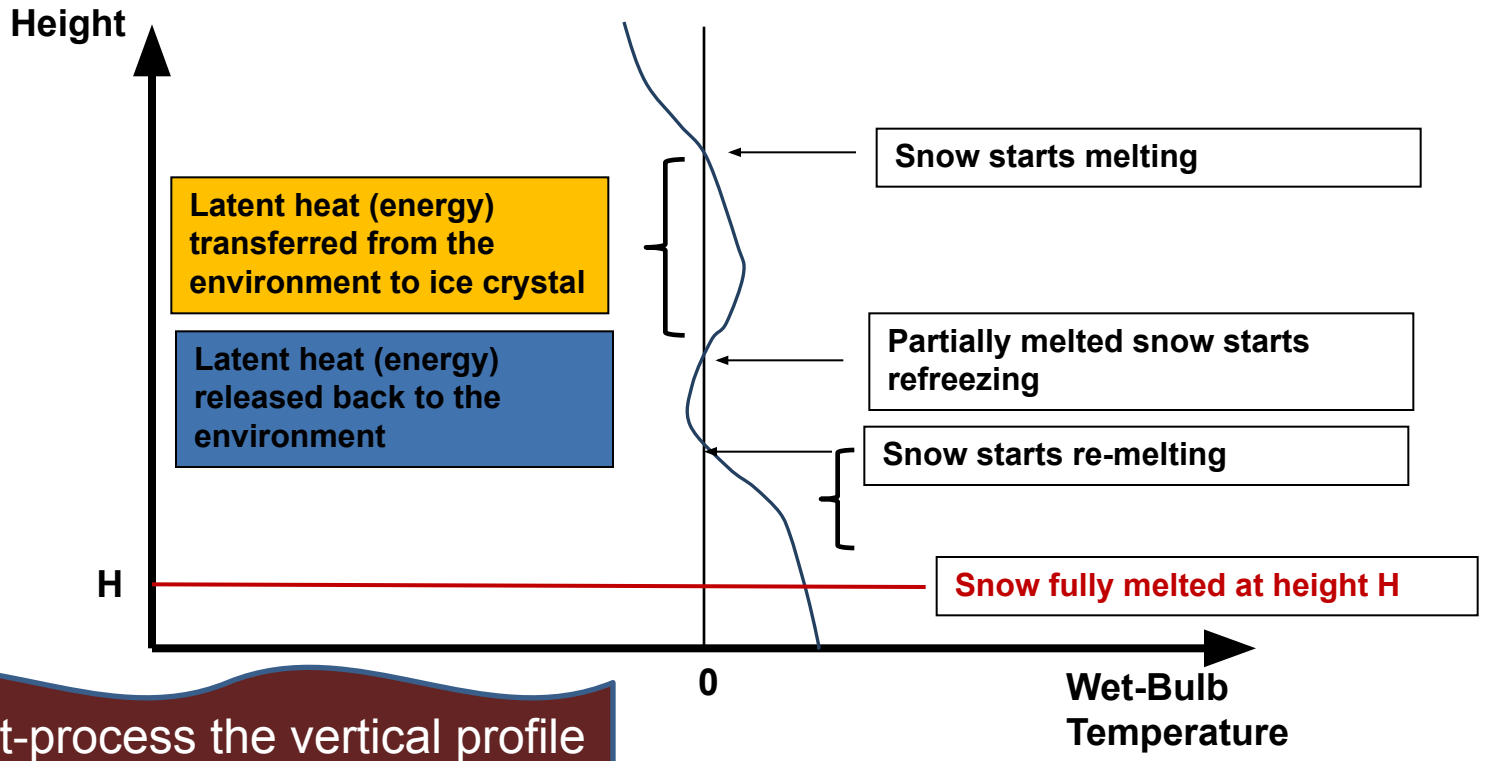
- By using the spatial weighted averaging, the final output is less sharp and much smoother (better reliability).

Diagnostic post-processing in the WEonG

The latent heat method (conceptual diagram)

Q = amount of energy needed to melt snow = precipitation rate (mm/hr) * 334

where 334 = latent heat (joules for 1 gram of ice)

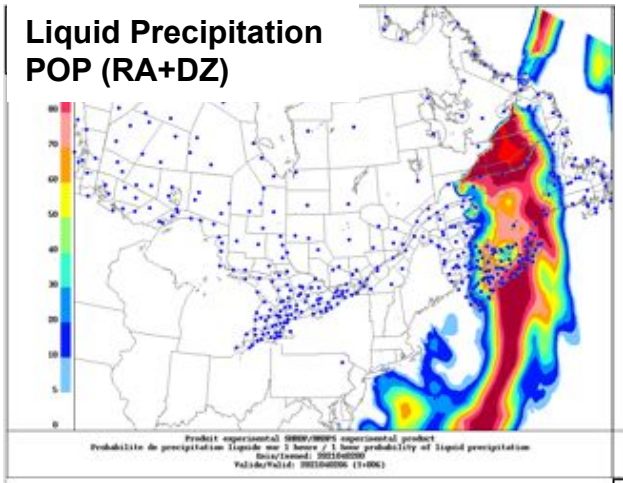


In post-process the vertical profile is perturbed to extract different possibility of pcpn type

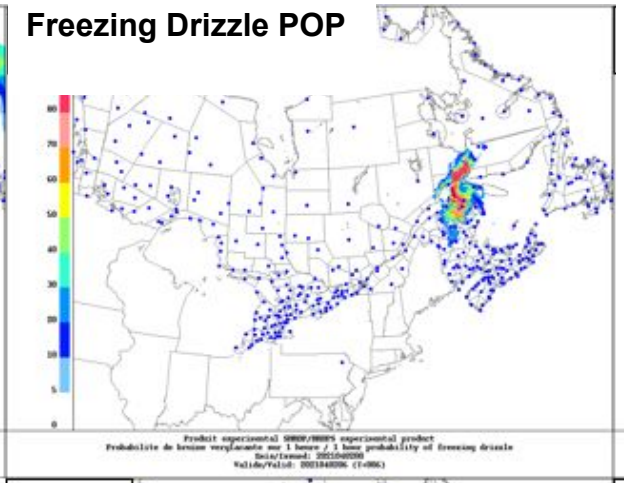
Diagnostic post-processing in the WEonG

Precipitation type probabilities

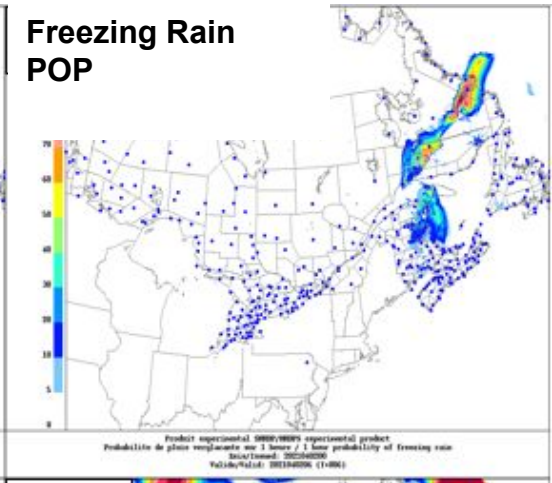
Liquid Precipitation POP (RA+DZ)



Freezing Drizzle POP



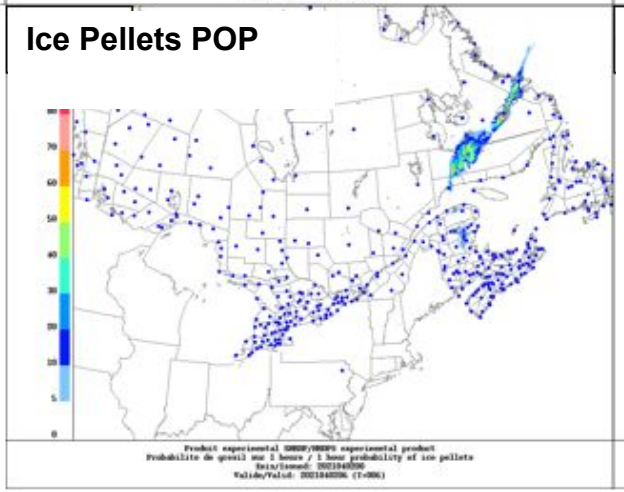
Freezing Rain POP



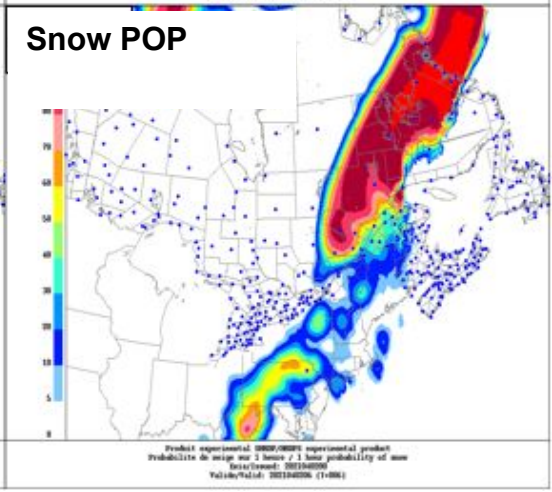
Precipitation type probabilities over Eastern Canada:

Run: 2021-04-02 00Z
Valid time: 2021-04-02 06Z

Ice Pellets POP



Snow POP



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Towards increasing use of EPS

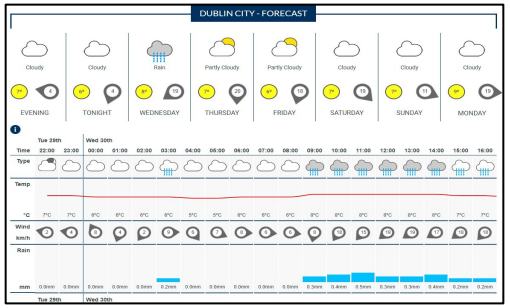
Next steps … WEonG-EPS

- Service specifications
- HIW – extreme – unprecedented weather
- OMPS: Optimal Meteorological Prediction System
  - Our “National Blend of Models”
  - Accessing international forecasting model data

Actionable services: impact-based decision support

Point forecasts with high temporal and spatial resolution

- Meteograms for more than 10,000 locations
- Model-driven product
- No intervention by forecasters



- Based on WEonG-EPS: Fully automated
- Weather element with info derived from EPS
  - How to express uncertainty for each variable
    - i.e. Probabilities for specific thresholds, ranges, percentile, …
- Confidence indices

Actionable services: impact-based decision support

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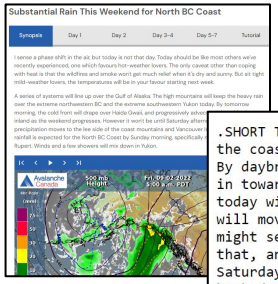

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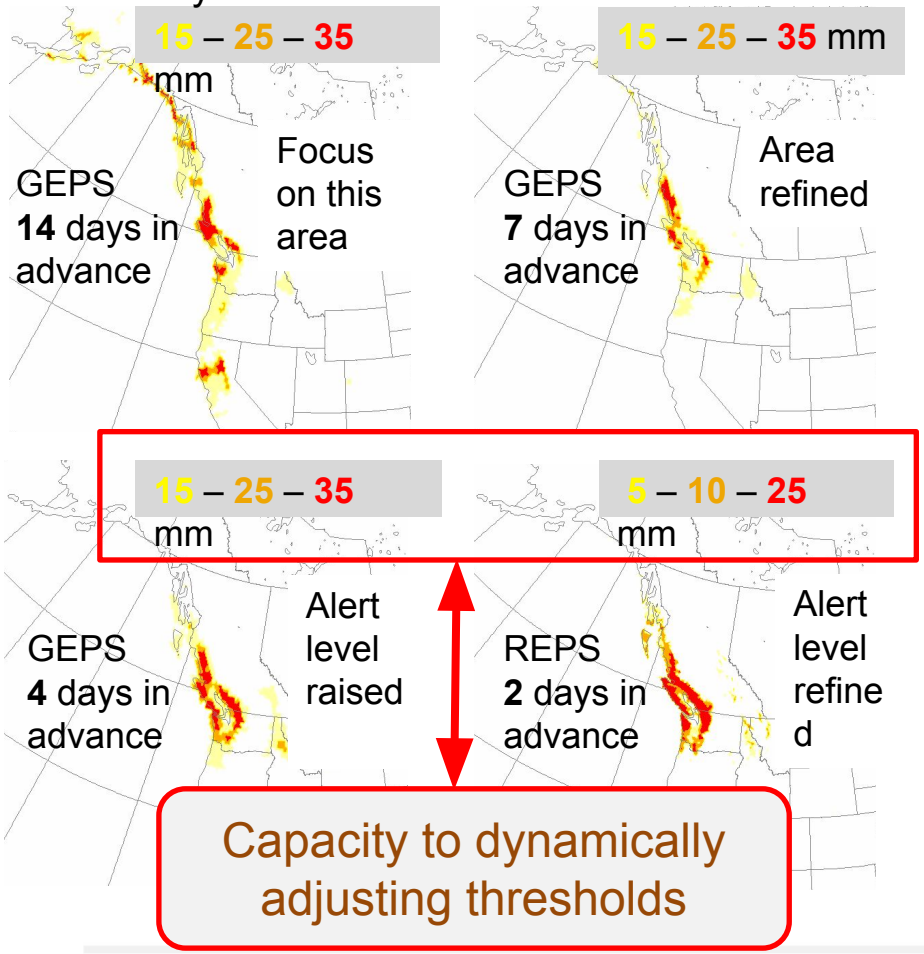
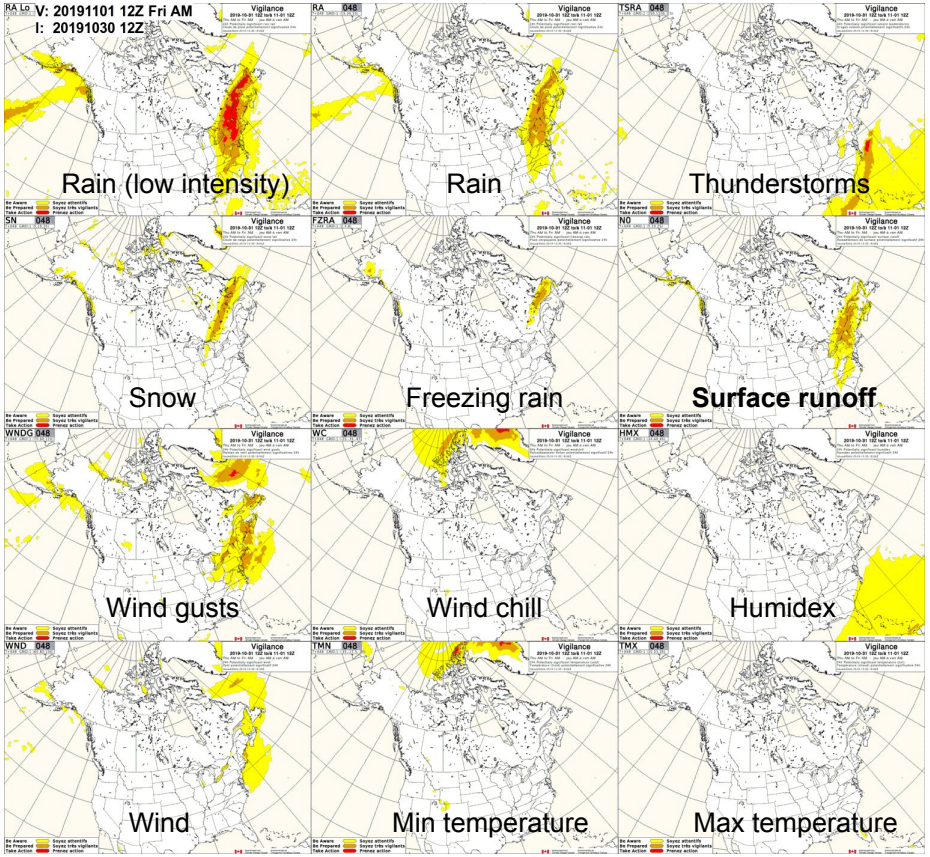
- Uncertainty communication
- Risk communication supported by expressing: scenarios, extreme weather possibilities, …
- Vigilance map

VIGILANCE APPROACH FOR EXTREME WEATHER

Surface runoff from atmospheric ensemble prediction systems: valid 00 UTC 15 November 2021



Forecast issued 2 UTC 30 Oct 2019 valid 12 UTC 1 Nov 2019



SYSTÈME DE VIGILANCE / VIGILANCE SYSTEM (ec.gc.ca)

Khanh-Hung Lam

Summary

MSC transforms itself by introducing more & more info from EPS

- Based mainly on WEonG new offer

There is a need for exploration in

- Blending methods of models
- Extracting Confidence and Scenarios
- New Statistical Post-processed methods – AI/ML algo
  - From point to gridded Stat PP algo

Importance of International data exchange agreements

- Contingency purposes
- Increase ensemble set of data – extraction of scenarios

Questions?

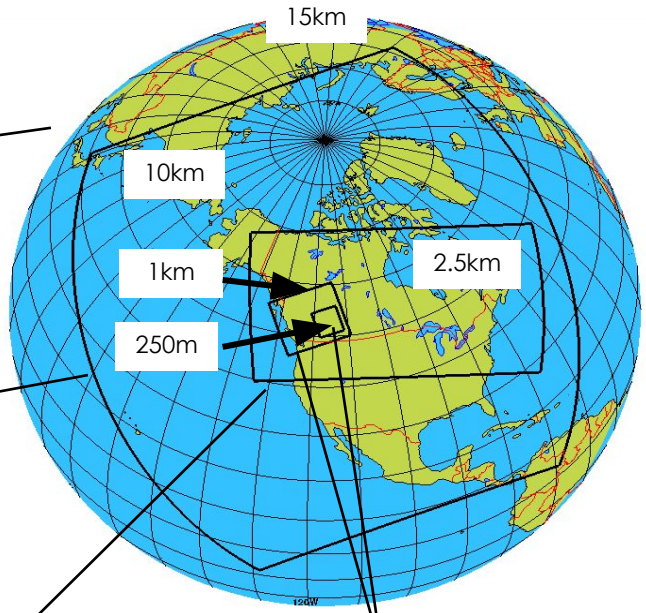
Overview of operational NWP systems

Earth Prediction Systems

Global
Coupled Atmosphere-Ocean-Ice
- **15 km deterministic**; forecast to T+240h twice/day (00,12 UTC)
- **39 km ensemble**; 20+1 ensemble members; forecast T+384h twice/day (00,12 UTC) and T+32 days once/week

Regional
- **10 km deterministic**; forecast to T+84h 4 times/day (00, 06, 12, 18 UTC)
- **10 km ensemble**; 20+1 ensemble members; forecast to T+72h 4 times/day (00, 06, 12, 18 UTC)

High-resolution
- **2.5 km deterministic**; forecast to T+48h 4 times/day (00, 06, 12, 18 UTC)



Experimental very high-res
- Up to 250-m resolution
- Forecast T+12h once/day (12 UTC)
- Relocatable

Applications include forest fires, summer severe convection, and urban meteorology

Other systems
- Canadian monthly/seasonal forecast
- Regional air-quality deterministic forecast with/without wildfire emissions (10 km)
- Regional air quality analysis (10km)
- Nowcast (hourly) forecast system (12h forecasts)
- Regional/high-res precipitation analysis (10 km/2.5 km)

Ice-Ocean Regional
- Stand alone
- 1/12°
- Assimilation runs once/day (00 UTC)
- Forecast to T+48h 4 times/day (00, 06, 12, 18 UTC)

Ice-Ocean Coastal
- Stand alone
- West and east coast domains
- 1/36°
- Analysis runs once/day (00 UTC)
- Forecast to T+48h 4 times/day (00, 06, 12, 18 UTC)

Other systems
- Water Cycle Prediction System
- Global/regional deterministic wave
- Global/regional ensemble wave
- Global deterministic storm-surge
- Regional ensemble storm-surge

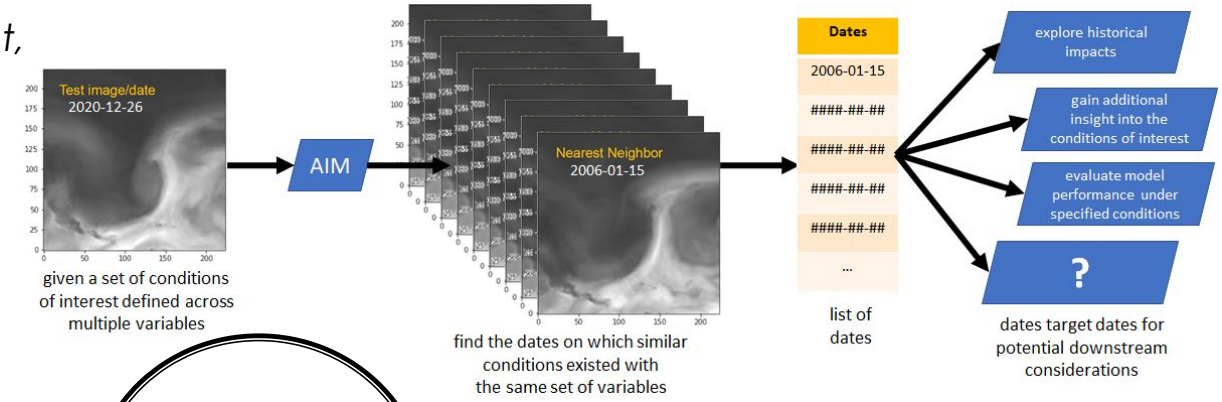
Current weather forecast guidance for 7-day forecast:
Day 1 & 2 = Regional deterministic
Day 3 to 5 = Global deterministic
Day 6 & 7 = Global ensemble

Artificial Intelligence and big data

IBM PAIRS: ECCC Proof of Concept Exploration Experimentation

To learn, gain knowledge & insight, on how MSC could improve its transformation activities by leveraging AI / ML capabilities

- Example of Analogues of Weather Patterns, in collaboration with IBM
- Initiated March 2022



Internal activities

Digital Earth Canada – Labs Canada Pilot Project

Ground-to-cloud provisioning of Big Weather Data for AI processing through MSC application programming interfaces (APIs)

- Cloud provisioning of MSC GeoMet API platform
- Perform AI/ML techniques to assess model/prediction performance against observations

WMO Information System (WIS) 2.0

Canada is a key participant in defining the future state architecture and transition to WIS 2.0.

MSC to host the WIS 2.0 Global Discovery Catalogue, which provides the ability to search for WMO members' datasets.

MSC to contribute to the development of WIS2-in-a-box, a system to share data using the WIS2 framework.