



Government
of Canada

Gouvernement
du Canada



Weather and Climate



Air Quality



Ice



Water Availability



Extremes

Moving toward Impact-based Forecasting in Meteorological Service of Canada

Paul Yang

**Chief, Analysis and Prognosis Section
Canadian Centre for Meteorological and
Environmental Prediction
Meteorological Service of Canada**

2nd RWIBF-RAII, Seoul, South Korea

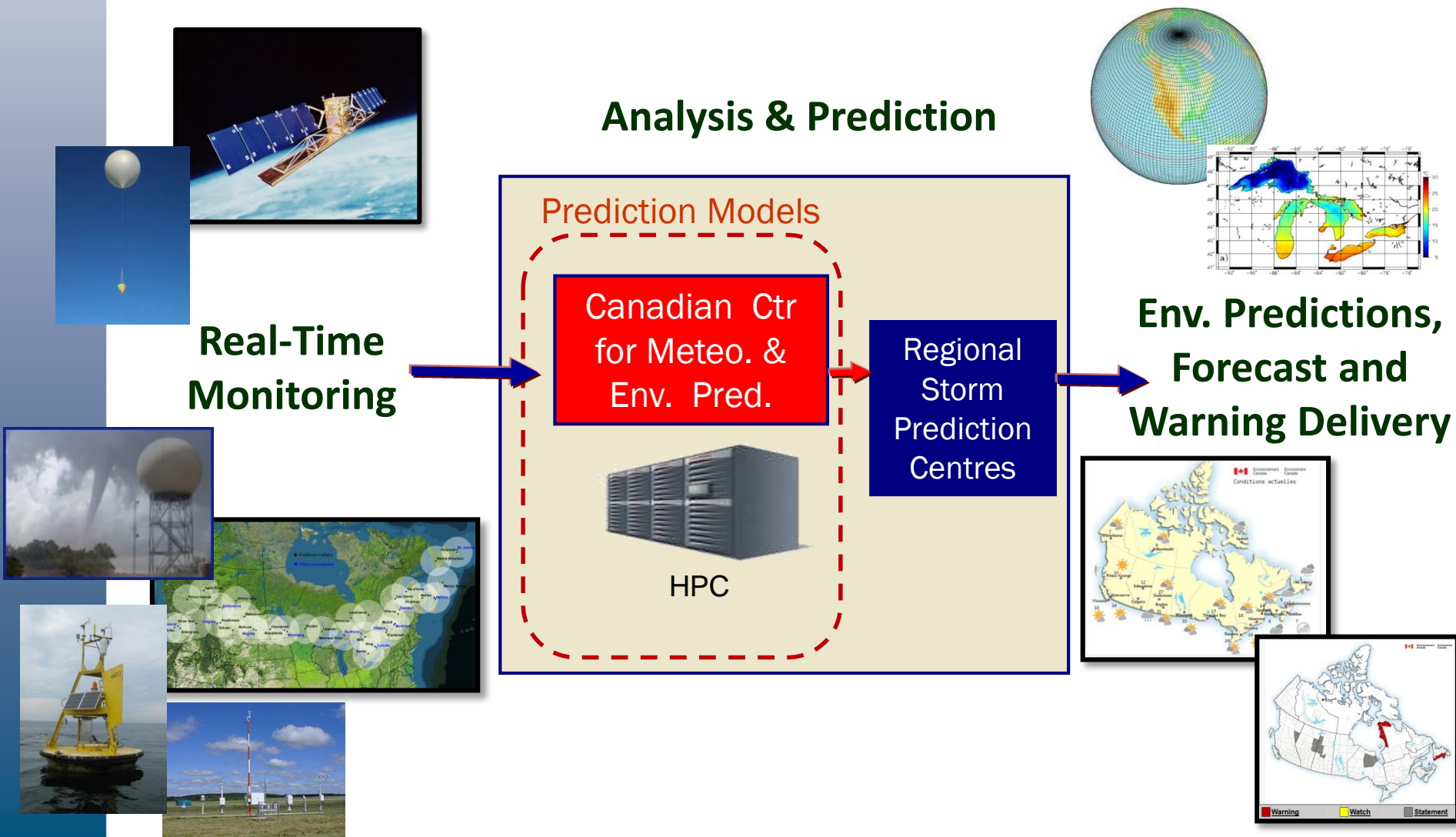
November 19-21, 2018

Canada 

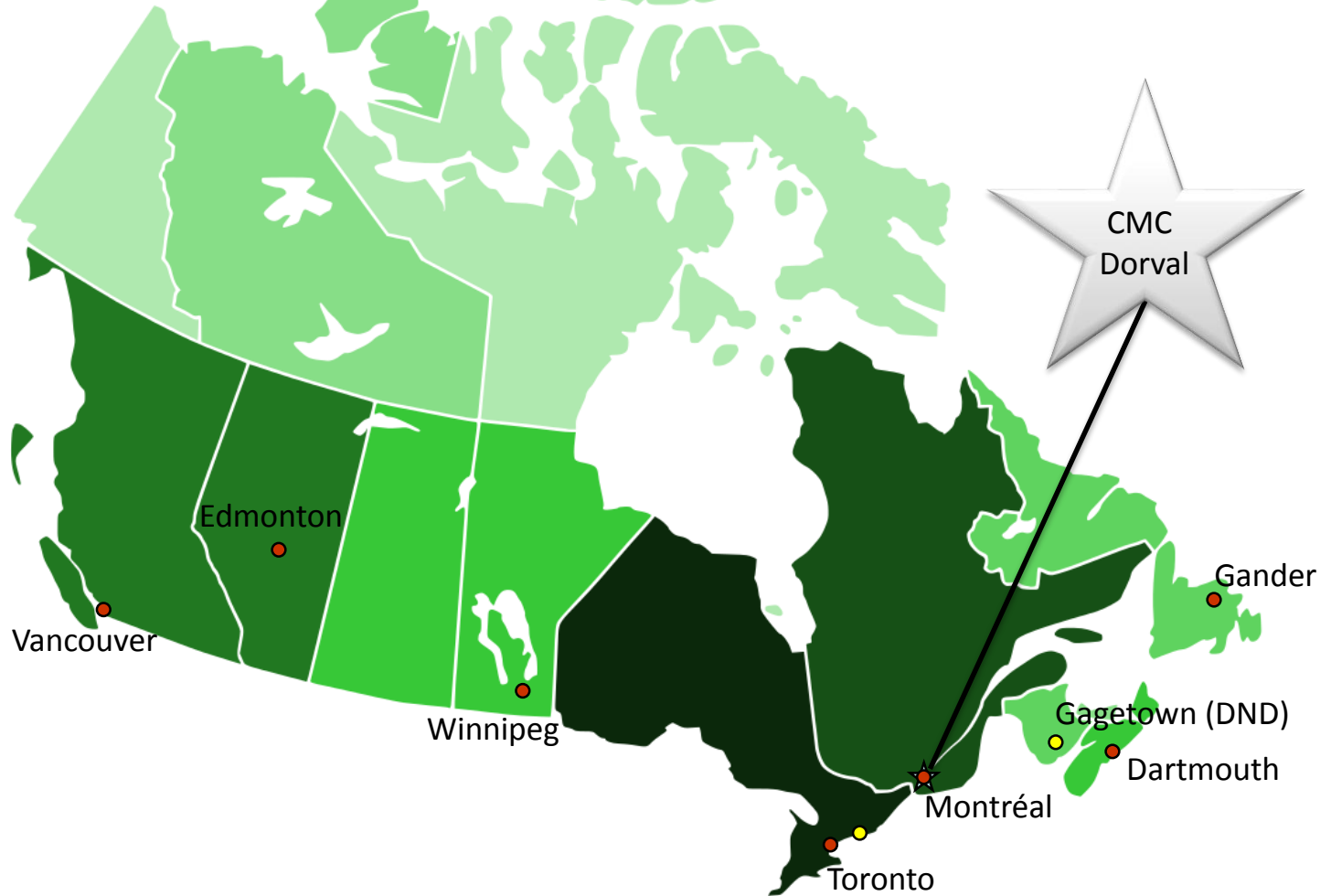
Outline

- Overview of organization/warning services of Meteorological Service of Canada (MSC)
- Impact-based forecasting in MSC regional centres
- IBF approach in MSC at national level
 - Centre for Meteorological and Environmental Prediction (CCMEP) (or Canadian Meteorological Centre, CMC)
 - ADS (Aviation and Defence Services)
- Summary

MSC's Analysis and Forecast Production Chain



Prediction and services centres of MSC



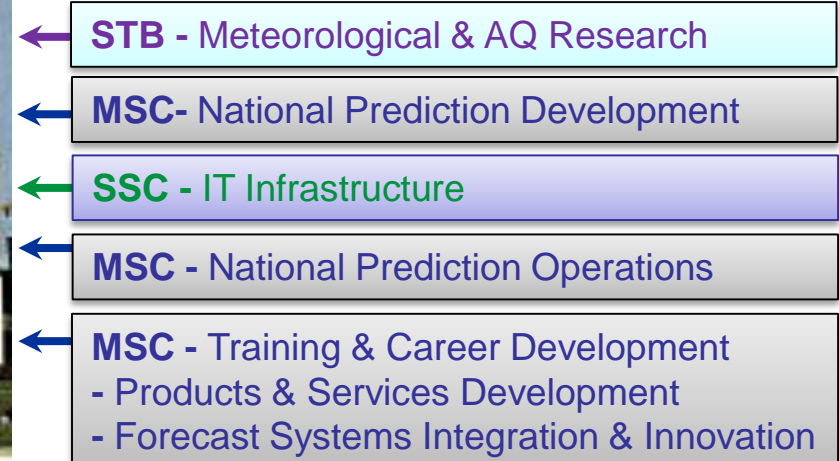
Canadian Meteorological Centre (CMC)

Research, Development, Operations and Informatics all under one roof

A unique centre in Canada, truly 'operational' (24/7) support, supercomputing centre; home to environmental programs in weather and environmental prediction, and expertise during environmental emergencies

- Very few similar centres across the world
- Identified as a critical facility by the Gov. of Canada
- International mandates:
 - Emergency response: nuclear & VAAC
 - and WMC
- National centre to receive and distribute meteorological data
- National centre for provision of meteorological forecasts to a wide variety of users
- National telecommunication centre

Colocation of key components optimizes effective science and technology transfer, and fosters greater innovations



Impact-based forecasting

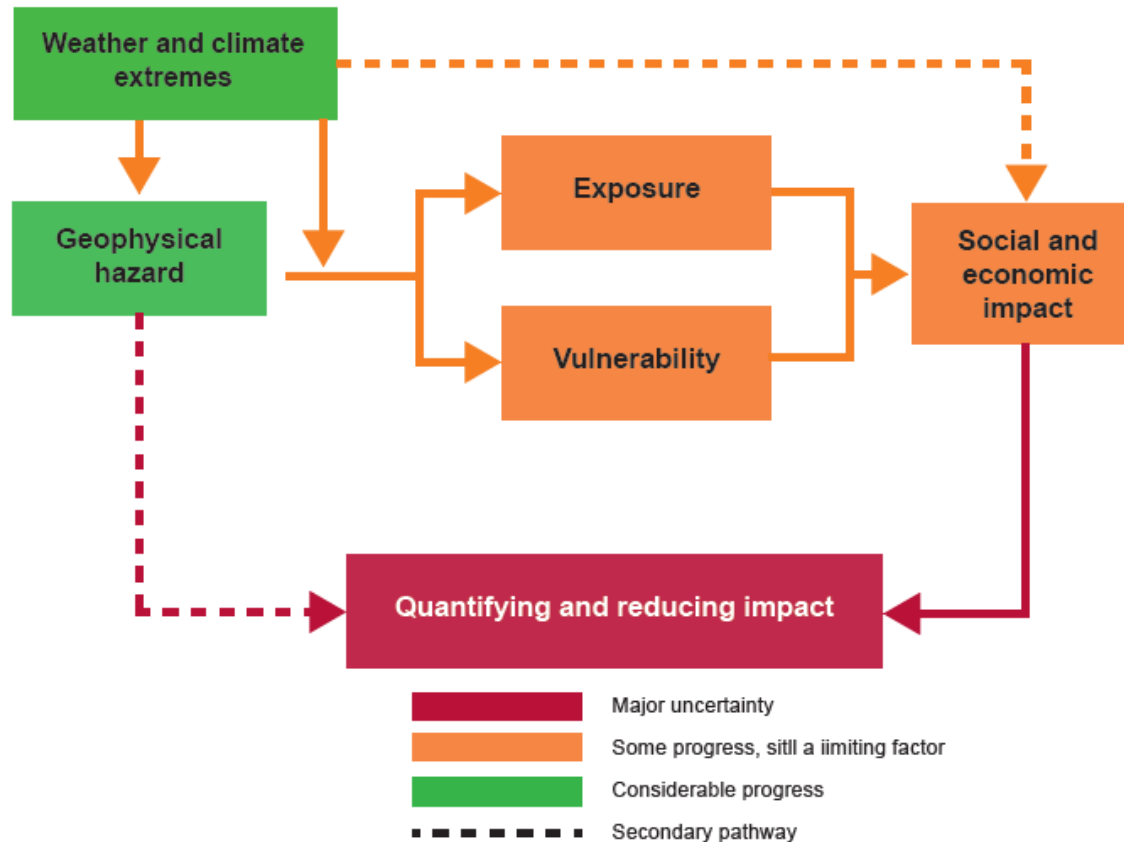


Figure 1. Relationship among the key elements of an impact forecast system

Impact-based forecasting

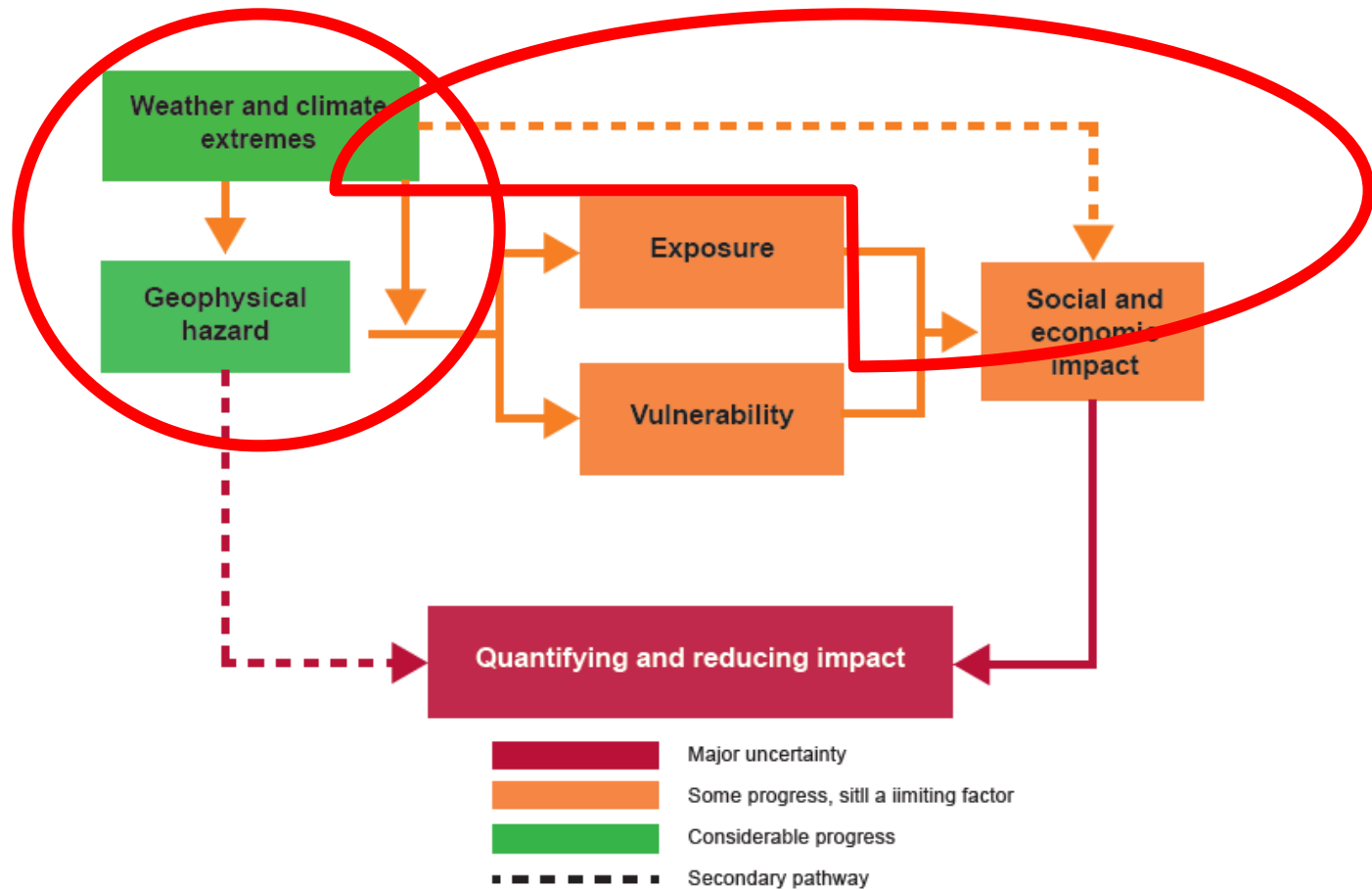


Figure 1. Relationship among the key elements of an impact forecast system

Impact-based Forecasting

... Having the most powerful dissemination tool (or hazard based warnings) does not imply the warning system will convey the most understandable, complete and useful information needed to support users in their decision making process... (MSC- vigilance project)

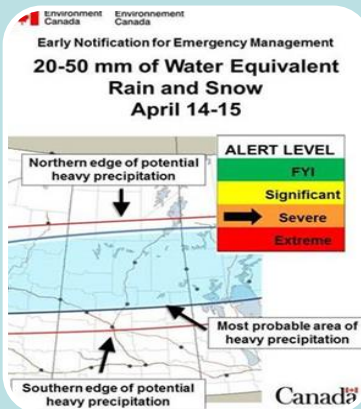
... From “What the weather will be” to “what the weather will do” – (Weather Ready Nations)

Weather Warning Program: Outreach and decision support services



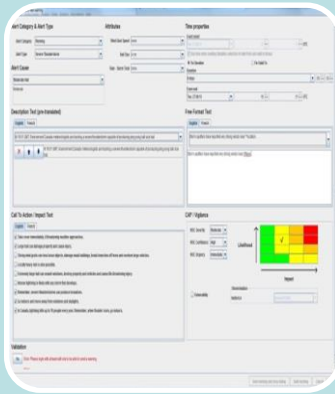
1. Dedicated “Weather Preparedness Meteorologists (WPM) ”
 2. Decision Support Desks (supporting operations and WPM)
- Work with decision makers (emergency management community and public health officials at all levels of government), the media, public event planners for impact-based services

Moving toward Impact-based Forecasting in Regional Centres



Early Weather Notifications

- Target: EMOs, GOC, QRT, Sector specific
- Weather situation, potential impacts, severity and risks, confidence
- EC Alert me
- Email, consultations, Twitter
- WPMs with Storm Prediction Centres (SPCs)



Weather Warning Program

- Target: General Public
- Weather Statements, Warnings
- Criteria specific.
- *Potential impacts and Call for action*
- Dissimination: web-WxOffice, Media, CAP, Broadcast Intrusive, Twitter
- SPCs

Early weather notification (text and/or graphics) in collaboration with Emergency Management



Highlights:

Significant snowfall accumulations are expected ...

Weather Event Impacts:

- Challenging travel conditions, particularly over high terrain and in mountain passes
- Visibility will be reduced in falling snow, especially on the TransCanada highway west of Calgary and Highway 93 through the Jasper and Banff National Parks
- Visibility will be reduced on the TransCanada highway and Highway 3 on Tuesday night
- Hazardous conditions related to heavy snow falling on leafy trees

Weather Event Details:

...
Some considerations for early season snow and total accumulation forecasts:

Small changes in ground surface temperatures will determine whether the snow will accumulate or melt initially

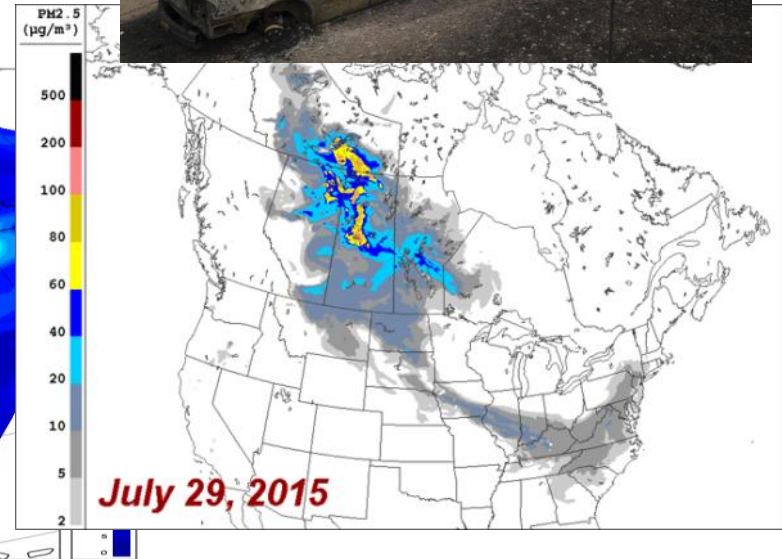
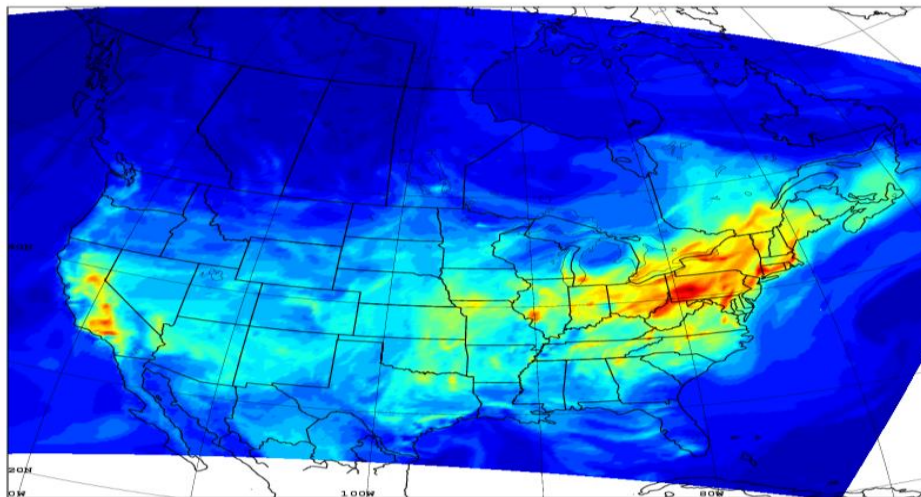
...
Total depth of snow at the end of the event may vary as wet snow will settle over the period of the forecast

Certainty:

MODERATE - Weather models, both Canadian and International, have come into good agreement regarding the heavy snowfall with this system. ...

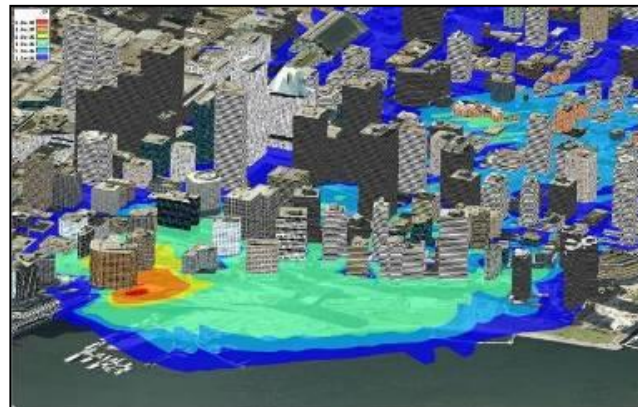
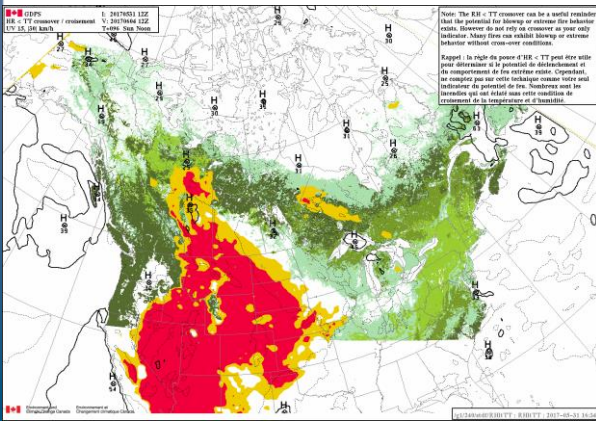
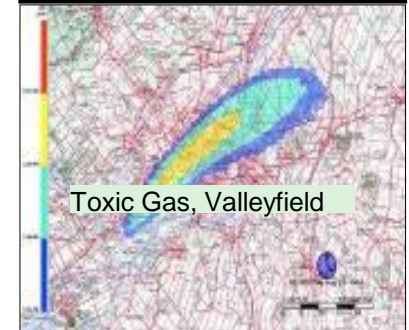
Weather & Environmental Programs : Partnering with health authorities

- Air Quality forecasts, smog alerts and to inform regulatory regime (model scenarios)
- Air Quality Health Index (AQHI) with Health Canada and provinces
- Heat alert programs in collaboration.
- Warning products may be issued by 3rd party
- NWP developments of which
 - Wild Fire Smoke Prediction System 'Firework'



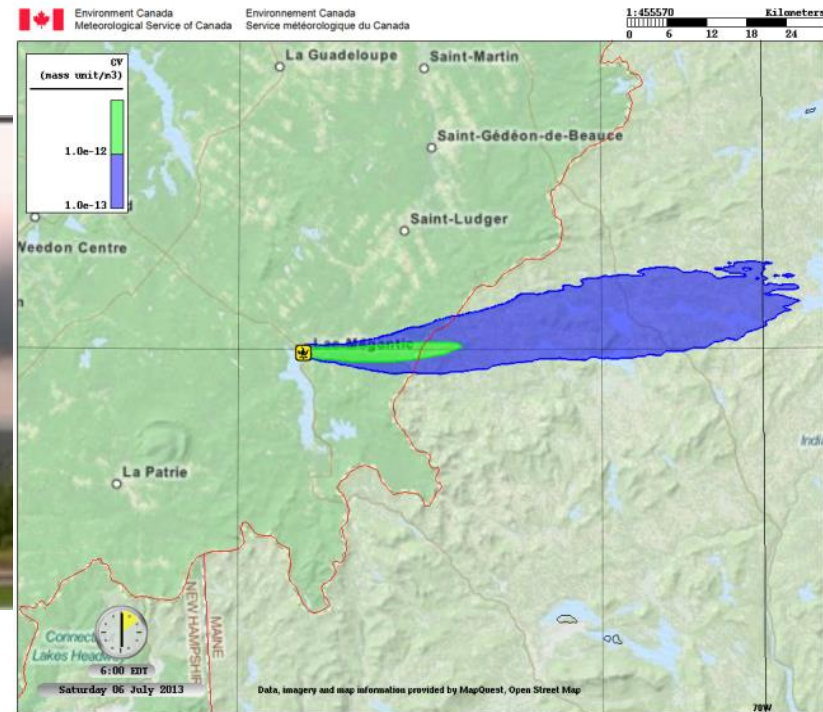
Supports to Emergency Response Services: Focus on Impacts

- NWP innovation incl environmental models.
Emerging needs - New products (ex: vigilance charts using EPS, threat maps, Fire Wx risks)
- Criteria developed in collaboration with sectors
- National Vigilance Project: mid- to long-term focus
- RSMC, National & Regional Operations



Environmental / nuclear emergency → Dispersion modeling

e.g. Lac-Mégantic train derailment disaster, July 6, 2013



Concentrations relatives près de la surface [unité de masse/m³]

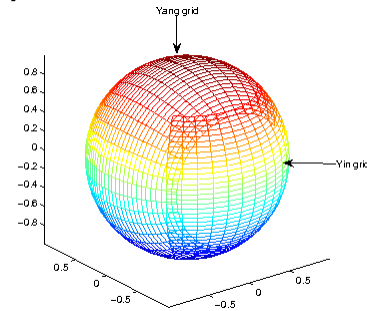
Toward IBF at the National Operations

- Shifting focus from day 1-5 to day 3-7... and beyond.
 - Why?
 - Model discrepancy increases beyond day 1&2
 - Regional forecasters are the experts on day 1&2
 - Demand from clients: Federal GOC, WPMs
- The primary model: Canadian Global Ensemble Prediction System (GEPS)
 - To get the likelihood of impacts and High Impact Weather
 - UK Met Likelihood-Impact Matrix approach is used

Background

GEPS (Global Ensemble Prediction System)

- 39 km Yin-Yang grid (since September 2018)
- 20 members plus one control member
- Generate forecasts to T+384 (15 days)
- Once a week forecasts to T+768 (32 days)



GEPS Vigilance

- Looks at when a number of members forecast a particular threshold to predict high-impact weather
- But what is high-impact weather?

Current thresholds for GEPS vigilance

Criteria for GEPS Vigilance

Element	Low	Med	HI	Season	Champs	Calculated		
24h rain QPF	>= 15 mm	>= 30 mm	>= 50 mm	All year	RN	diff between fcst and 24 hours ago		
24h rain 10 QPF	>= 10 mm	>= 20 mm	>= 30 mm	All year	RN	diff between fcst and 24 hours ago	ajout 11 decembre 2017	
24h fza QPF	>= 2 mm	>= 4 mm	>= 8 mm	Oct 1 - April 30	FR	diff between fcst and 24 hours ago	modif 11 decembre 2017	anciens seuils 2 5 10
24h snow QPF	>= 5 cm	>= 10 cm	>= 20 cm	Sept 1 - April 30	SN	diff between fcst and 24 hours ago	modif 11 decembre 2017	anciens seuils 5 15 30
Wind	>= 60 km/h >= 32.4 kts	>= 80 km/h >= 43.2 kts	>= 100 km/h >= 54.0 kts	All year	UVMX	max of fcst and 12 hour ago	deprecated?	
Wind Gust	>= 60 km/h >= 16.67 m/s	>= 80 km/h >= 22.22 m/s	>= 100 km/h >= 27.78 m/s	All year	WGE	max of fcst, 6, 12 and 18 hour ago	Threshold increased to 70, 90, 110 km/h	
TT - extreme cold	<= -20 C	<= -27.5 C	<= -35 C	Oct 1 - April 30	T8	Only available at T+24, 48, etc.		
TT - extreme hot	>= 30 C	>= 33 C	>= 36 C	May 1 - Sept 30	T7	Only available at T+24, 48, etc.		
Humidex	>= 34	>= 40	>= 46	May 1 - Sept 30	HMX			
Wind chill	<= -25	<= -35	<= -45	Oct 1 - April 30	REMNI			
Thunderstorms	CAPE >= 250 J/kg	CAPE >= 1200 J/kg	EHI >= 1	May 1 - Sept 30	TODO			

Future thresholds could be variable based on clients' needs

Likelihood-impact matrix

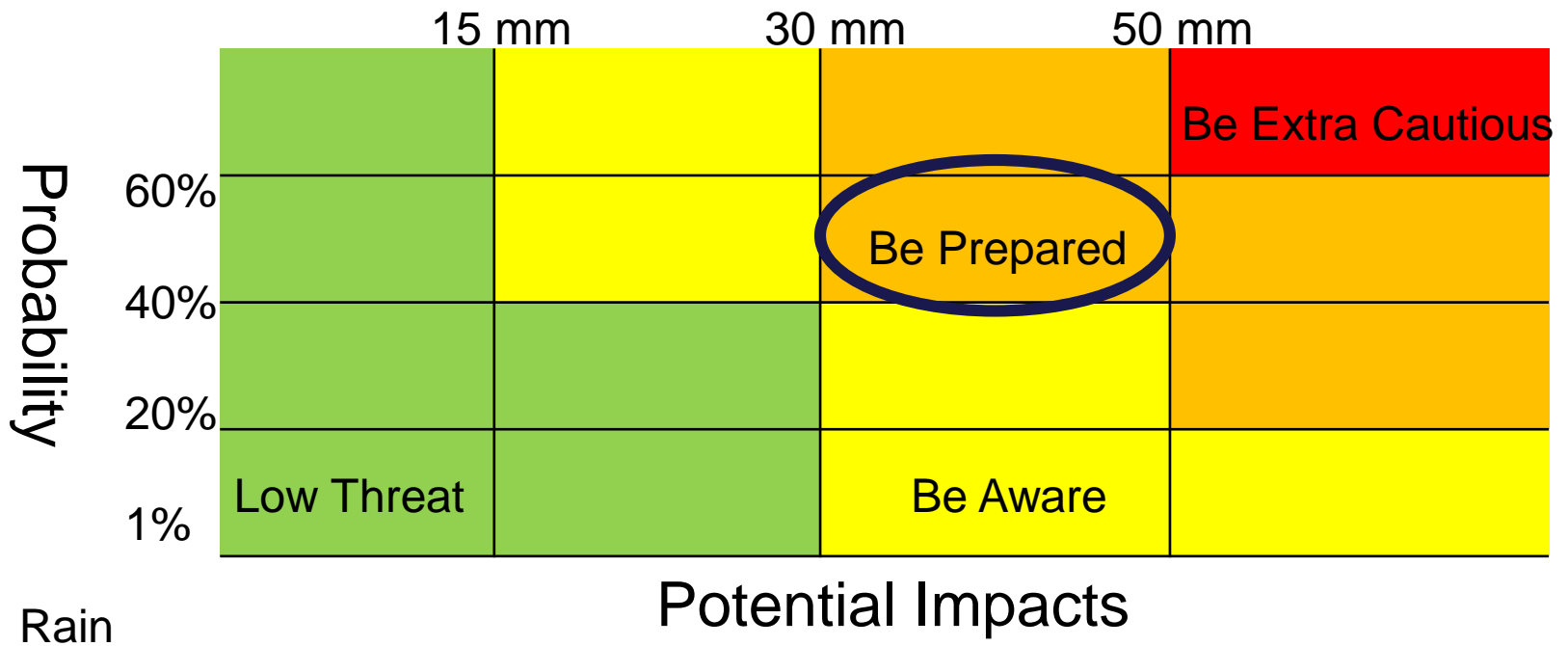
- Note: Potential Impact thresholds depend on the wx element(s)

		Low Threshold	Medium Threshold	High Threshold
Probability				Be Extra Cautious
			Be Prepared	
	Low Threat		Be Aware	
		Potential Impacts		

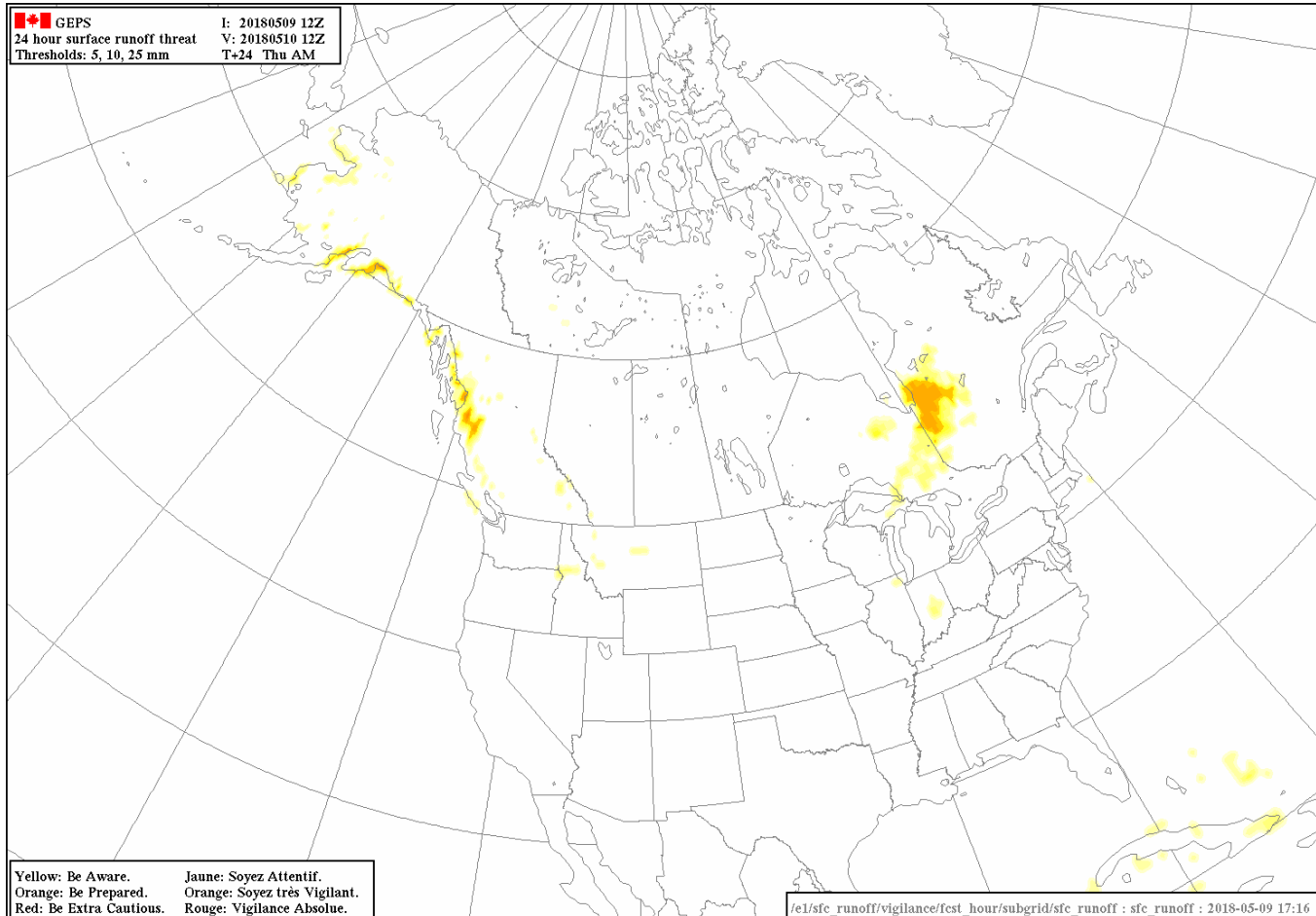
Likelihood-impact matrix

Example: A rain event

-10 members forecast between 30 and 50 mm for a location



Example: GEPS Vigilance product



The Super-grid

- The idea behind super-grid calculations is to be able to better identify significant events in the long term.
 - Member dispersion increases with increased forecast lead time, giving less agreement on events at each grid point
 - So we calculate the probabilities not for one point but for a given region (containing multiple grid points).

The Super-grid

X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	☑	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	☑	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X

The Super-grid

1x1

checks single
grid points
where to see if
threshold is
met

X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	☑	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X

The Super-grid

3x3

searches an
area containing
9 grid points

X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	☑	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X

The Super-grid

5x5

searches an
area containing
25 grid points

X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	☑	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	☑	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X

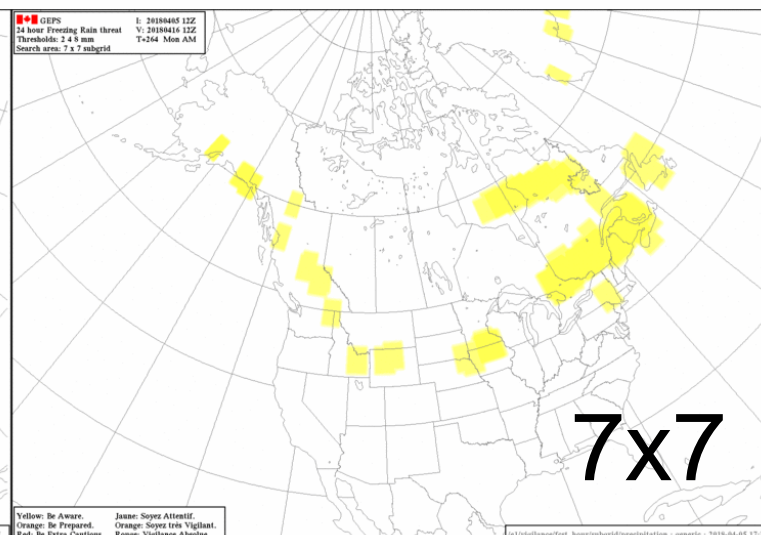
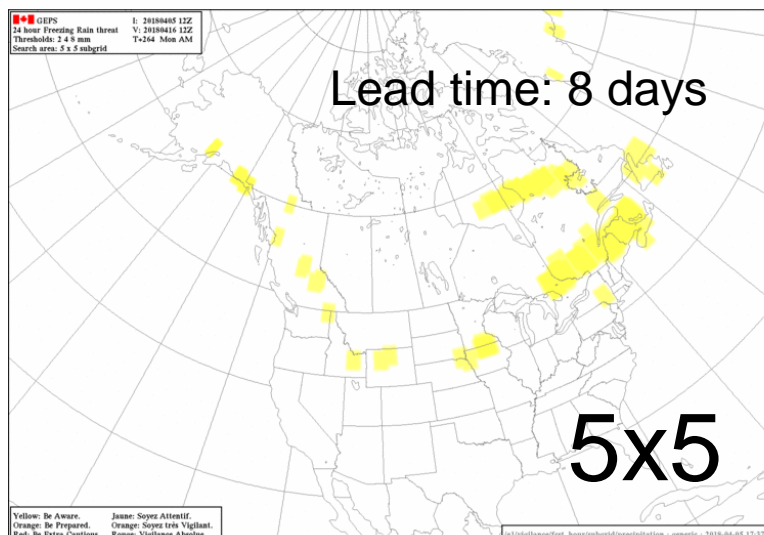
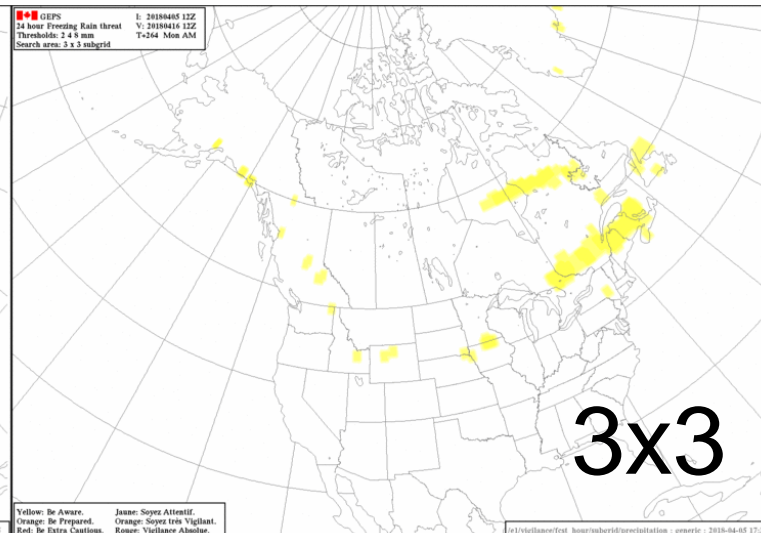
The Super-grid

7x7

searches an
area 49 grid
points

X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	☑	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	☑	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X

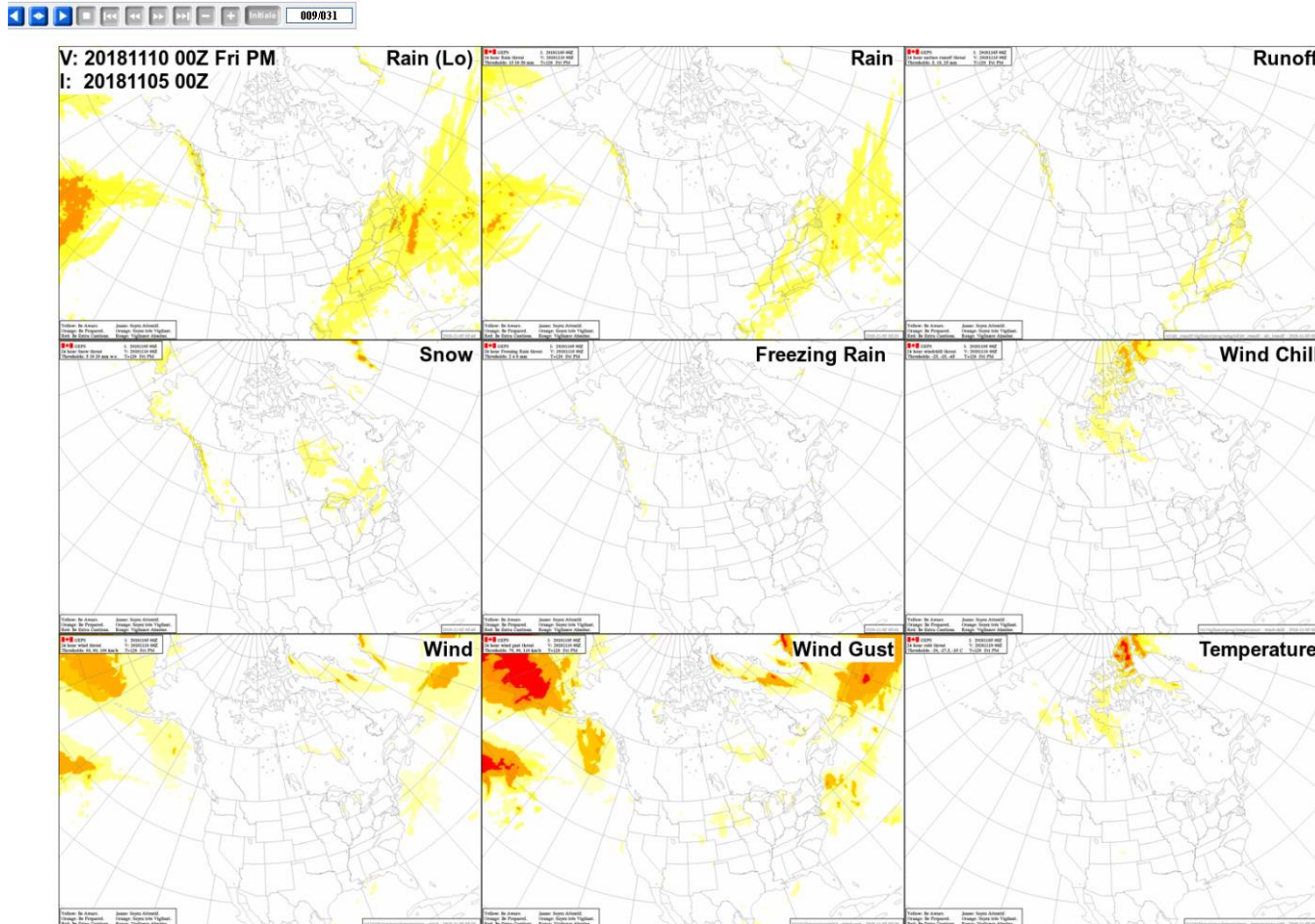
Super-grid display (April 2018 Ice Storm in ON/QC)



Current GEPS vigilant charts at A&P

GEPS VIGILANCE CHARTS					
Date : 20181105 Run : 00					
FIELDS	VALUES	SUBGRIDS	7 DAYS THREAT	WEEK 1 TREND	WEEK 2 TREND
Total			Total		
Vigilance Quilt					
RA	RA	RA	RA	RA	RA
Ra-Winter	Ra-Winter	Ra-Winter			
SN	SN	SN	SN	SN	SN
FZRA	FZRA	FZRA	FZRA	FZRA	FZRA
TSRA	TSRA	TSRA	TSRA	TSRA	TSRA
Precip montage				Precip montage	Precip montage
RUNOFF		RUNOFF	RUNOFF	RUNOFF	RUNOFF
RUNOFF 2-10 σ			RUNOFF 2-10 σ	RUNOFF 2-10 σ	RUNOFF 2-10 σ
RUNOFF All σ			RUNOFF All σ	RUNOFF All σ	RUNOFF All σ
WINDS	WINDS		WINDS	WINDS	WINDS
WIND GUSTS	WIND GUSTS		WIND GUSTS	WIND GUSTS	WIND GUSTS
WINDCHILL	WINDCHILL		WINDCHILL	WINDCHILL	WINDCHILL
Temperature	Temperature		Temperature	Temperature	Temperature
Humidex	Humidex		Humidex	Humidex	Humidex
FOREST FIRES					
THREAT	West	East	Canada		
RELIEF	West	East	Canada		
HYDROLOGY					

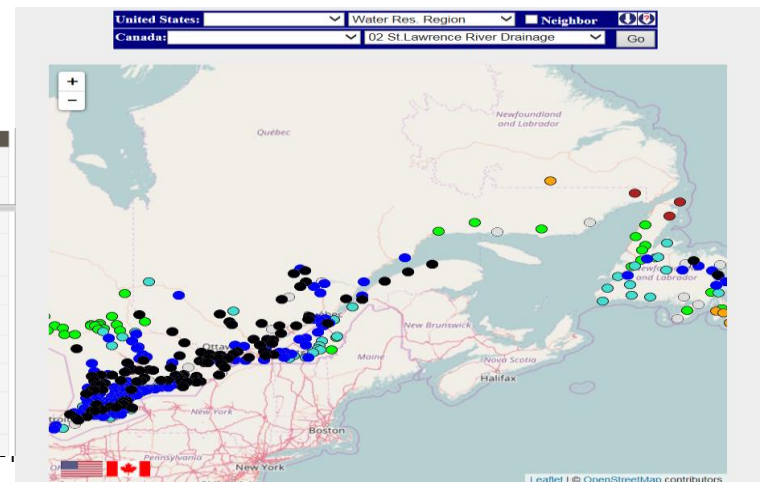
Current GEPS vigilant products at A&P



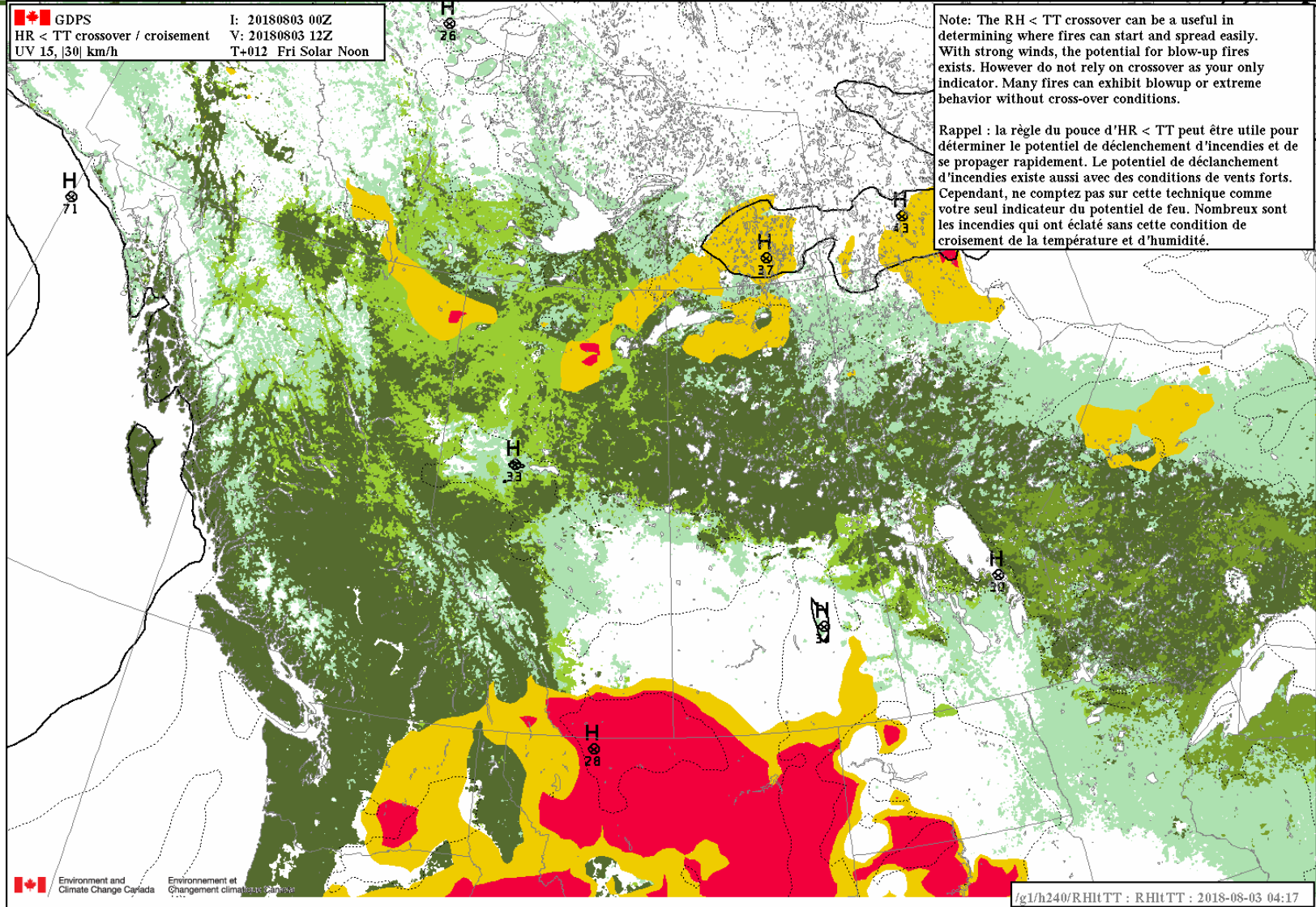
Supporting Emergency response: Spring floods in Canada (2017)

- ECCC (hydrology + atmospheric), Federal and provincial GOCs and DMAs, IJC, Ottawa River Regulation Board, EMOs, Municipalities, Health, National Defence, Hydro-Electric agencies
- Tailored information (incl. consolidated reports)
- Coordination with U.S. (North American Water Watch)
- Experimental NWP coupled products
- Onsite and embedded WPMs

Nom d'eau	Lieu d'information	État	Inondation	Variable hydro- météorologique	Unité	Quantité observée	Quantité prévue	Nombre de stations
Lac des Deux Montagnes	À Sainte-Anne-de-Bellevue	Inondation majeure	↑	Niveau (m)	23,30	24,64	0204013	
Lac des Deux Montagnes	À Pointe-Cabaret	Inondation majeure	↓	Niveau (m)	23,36	24,76	043108	
Rivière des Mille-Îles	À Bois-des-Filons	Inondation majeure	↑	Débit (m ³ /s)	780,00	1 062,65	0204003	
Rivière des Prairies	À la tête des rapides du Cheval Blanc (chenal sud)	Inondation majeure	↑	Débit (m ³ /s)	2 700,00	3 414,00	043301	
Rivière Matapédia	Au point couvert en amont d'Amqui	Inondation majeure	↑	Débit (m ³ /s)	81,00	90,93	011508	
Rivière Matapédia	À 4 km en amont de l'Assemblée-Quégan	Inondation majeure	↓	Débit (m ³ /s)	570,00	701,40	011509 ¹⁴	
Fleuve Saint-Laurent	À Trois-Rivières	Inondation moyenne	↑	Niveau (m)	3,25	3,60	03360 ¹⁴	
Fleuve Saint-Laurent	Au lac Saint-Pierre	Inondation moyenne	↑	Niveau (m)	2,70	3,55	15975 ¹⁴	
Rivière des Mille-Îles	Sur la rivière des Mille Îles à Deux-Montagnes	Inondation moyenne	↑	Niveau (m)	23,88	24,64	043205	
Rivière Matapédia	Au point couvert en amont d'Amqui	Inondation moyenne	↑	Niveau (m)	158,57	158,89	011508	



Supporting Emergency response: Forest Fires in Canada (2017 & 2018) - Crossover



Other services at A&P: National briefings

- Weekly briefing to ferderal GOC
- National Briefings on Monday and Friday to WPMs and MTs
- Special briefings to partners

Early notification messages (text or graphics) in collaboration with Emergency Management



Highlights:

Significant snowfall accumulations are expected ...

Weather Event Impacts:

- Challenging travel conditions, particularly over high terrain and in mountain passes
- Visibility will be reduced in falling snow, especially on the TransCanada highway west of Calgary and Highway 93 through the Jasper and Banff National Parks
- Visibility will be reduced on the TransCanada highway and Highway 3 on Tuesday night
- Hazardous conditions related to heavy snow falling on leafy trees

Weather Event Details:

...
Some considerations for early season snow and total accumulation forecasts:

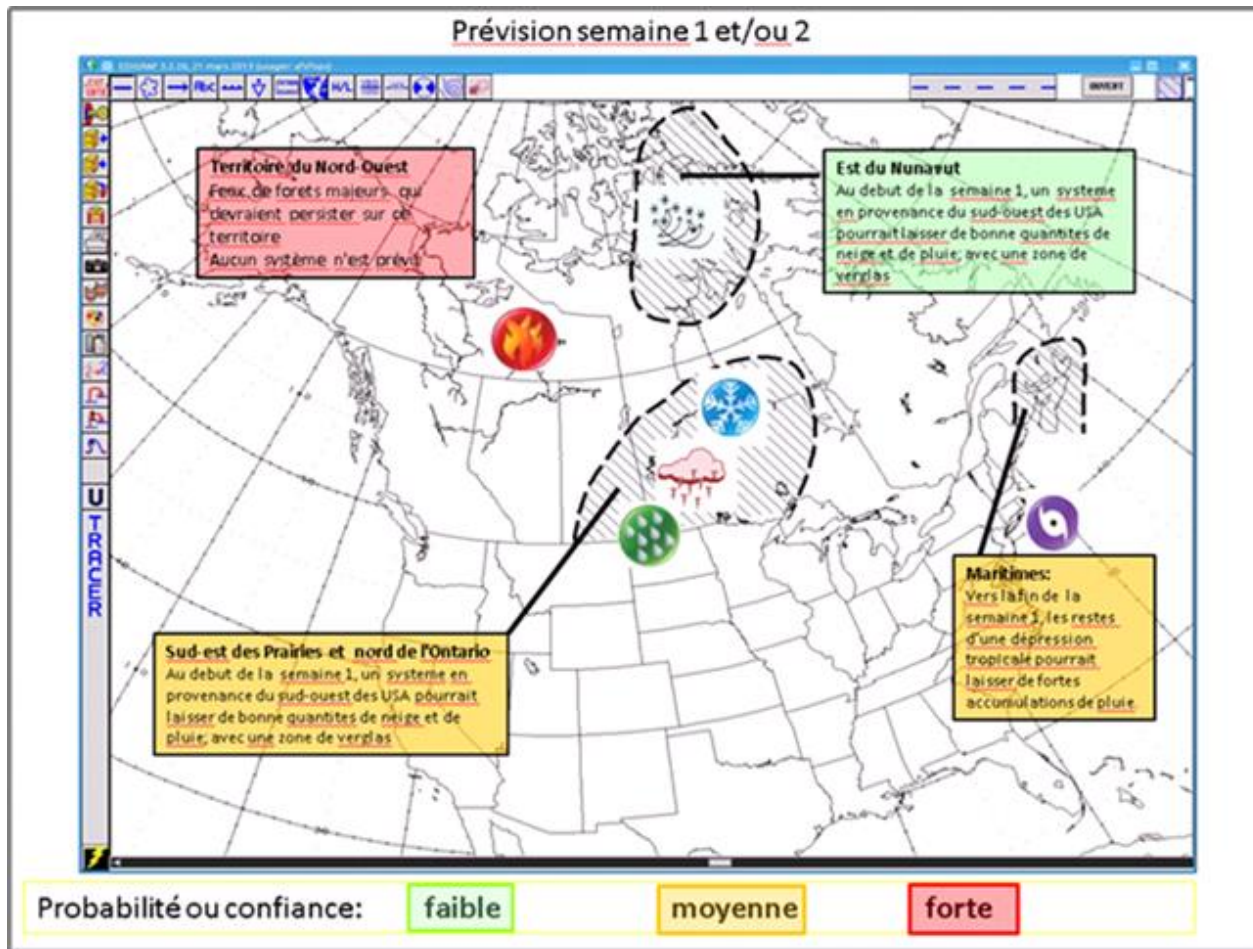
Small changes in ground surface temperatures will determine whether the snow will accumulate or melt initially

...
Total depth of snow at the end of the event may vary as wet snow will settle over the period of the forecast

Certainty:

MODERATE - Weather models, both Canadian and International, have come into good agreement regarding the heavy snowfall with this system. ...

Other services at A&P: National Vigilance Weather Charts (Days 2-7, weekly)





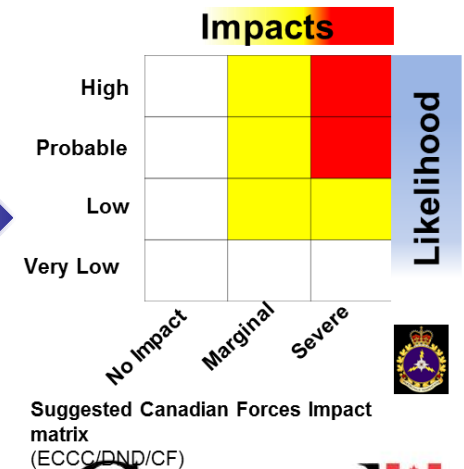
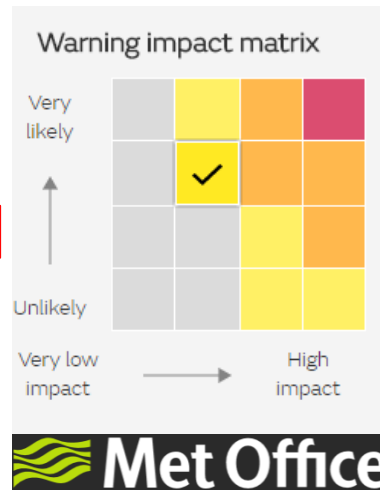
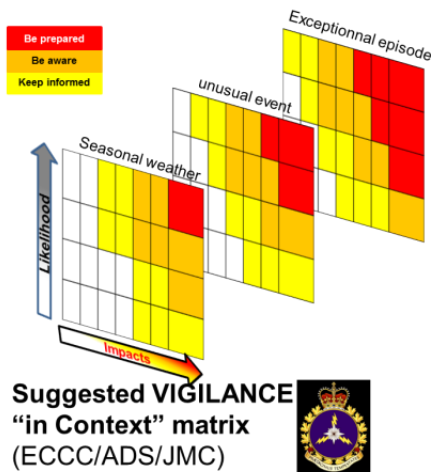
Government of Canada

Gouvernement du Canada



New concepts of valuing outputs from EPS to better serve CAF

By David Dégardin et Marie-France Turcotte



Impacts on Environment / Population

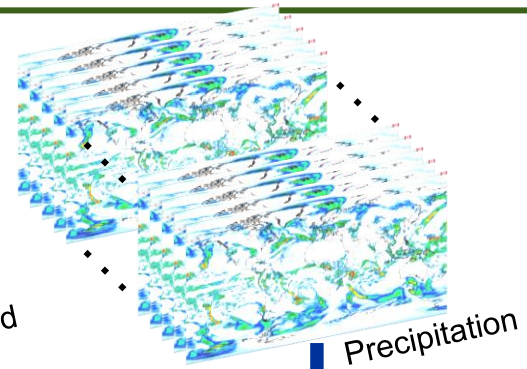
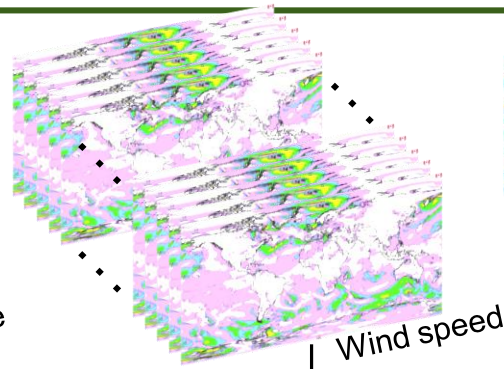
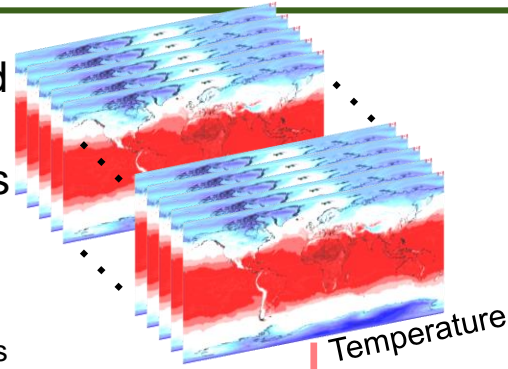
Canada
Impacts on Operations / Troops

How does the concept work?

Forecasted weather parameters (GEPS)

- 20 members
- Δx : 50km
- Up to 15 days

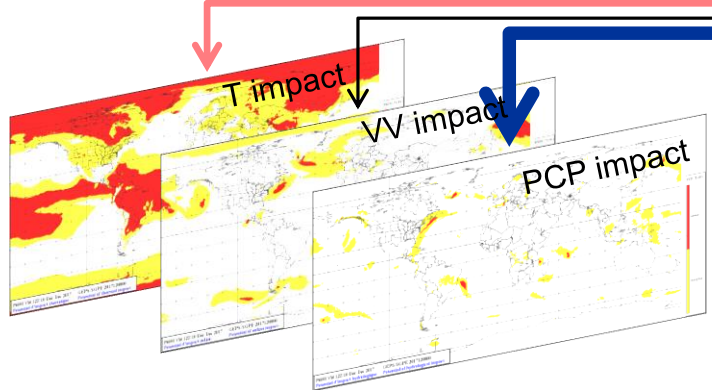
*GEPS: Global Ensemble Prediction System



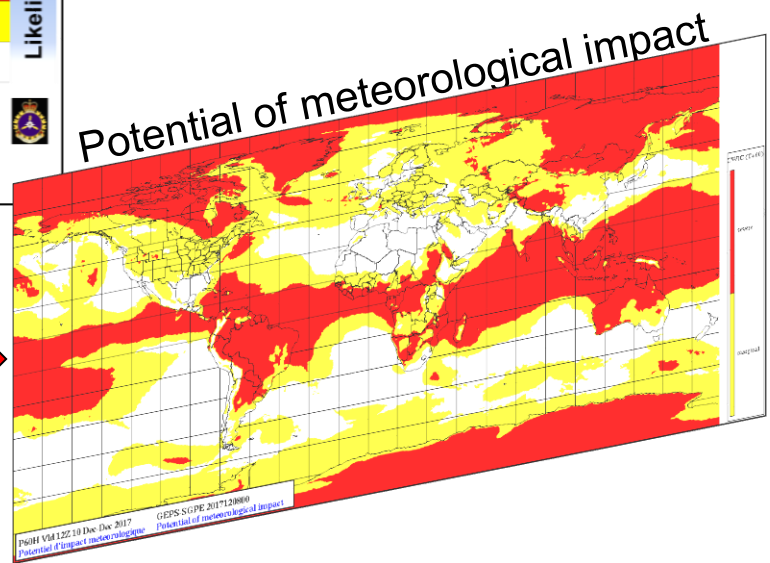
Potential Impacts due to forecasted weather parameters

		Impacts			Likelihood
		No Impact	Marginal	Severe	
High					
Probable					
Low					
Very Low					

Suggested Canadian Forces impact matrix (ECCC/DND/CF)



Consolidation



How to get this Matrix ?

Current standards outputs from the GEPS are:

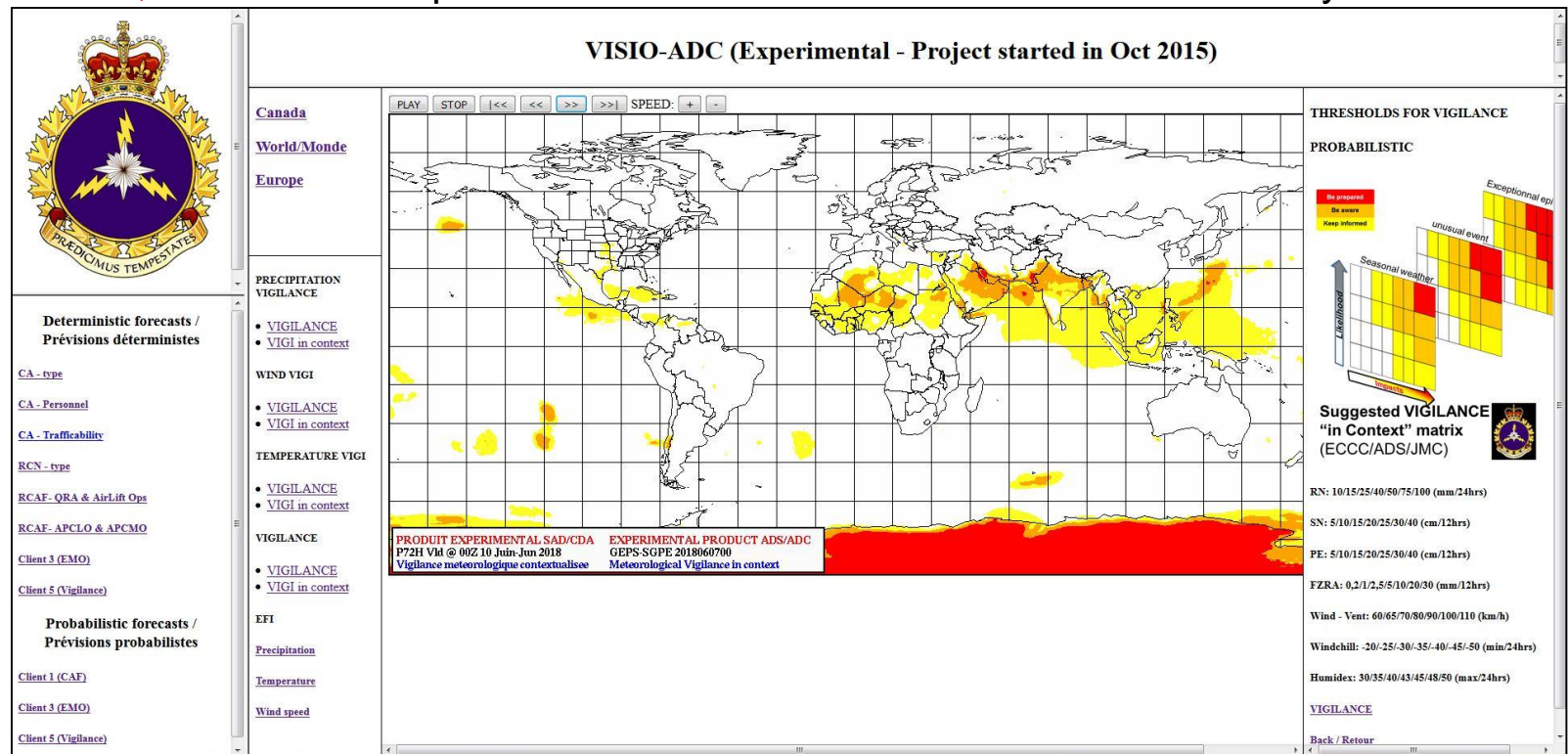
- Standard statistics (mean, spread, ...)
 - The mean provides a good guide to the forecast element with confidence, but it rarely captures the risk of extreme events.
 - The spread provides a measure of the level of uncertainty.
- Basic Probabilities
 - Probability is often estimated as a simple proportion of the ensemble members that predict an event to occur at a particular location or grid point. This MAY not be the real Prob.
- **Quantiles (Percentiles)**
 - A set of quantiles of the ensemble distribution provides a summary of the uncertainty.
 - Commonly used quantiles: max/min, and 25th, 50th (median) and 75th percentiles.
 - Others often used include the 5th, 10th, 90th and 95th percentiles.
 - **Allows a useful flexibility to modify thresholds of impacts depending on considered vulnerabilities, and clients' sensitivity.**
- **Extreme Forecast Index (EFI)**
 - Designed to measure how extreme a given ensemble forecast is.
 - **Allows a useful capability to define the potential impact in a “*climatological*” context.**



What does the proof of concept look like?

For a “Contextualized Vigilance” Approach

- Thresholds based on Canadian standards (or client defined) and **combined with climatological context characterized by EFI values.**
- **25%, 50% and 75%** probabilities of occurrence define the « sensitivity ».



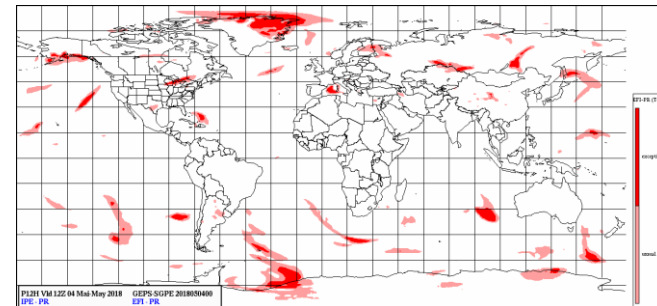
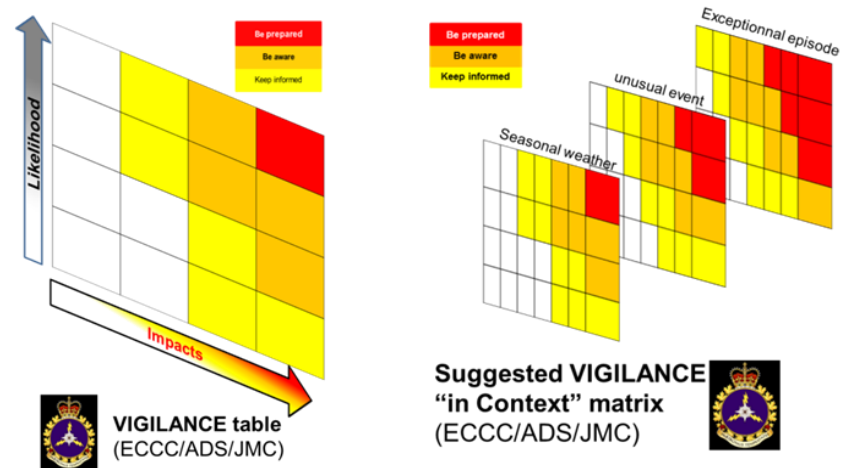
How to achieve this latter ?

1. From the likelihood-impact matrix adapted with the Canadian standards.

- Assume that warning thresholds are defined to be in accordance with the season where they mainly occur.
- Impact categories are segmented in order to give some granularity within the matrix

2. The EFI identifies regions where unusual or exceptional events could occur

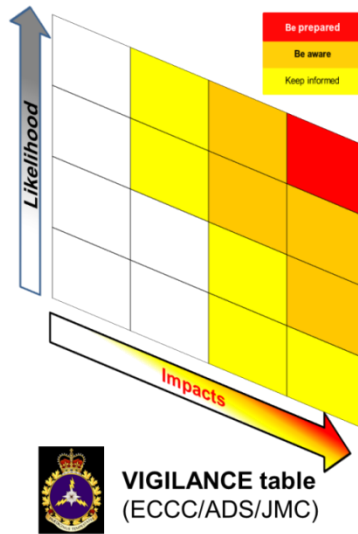
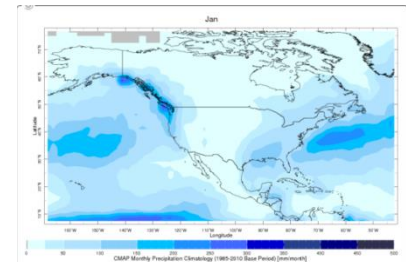
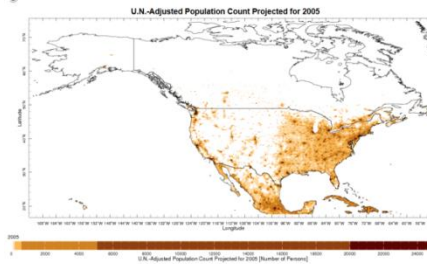
- The 2D matrix is extended into a 3D matrix in accordance with the forecast exceptionality of the event.
- Impacts increase with non-seasonal events



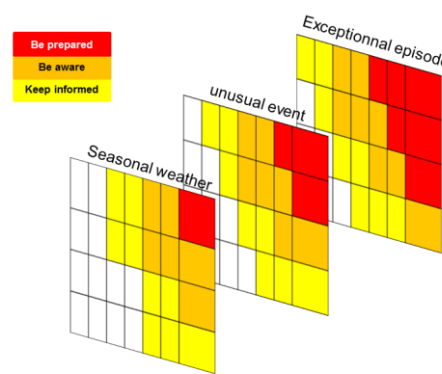
How to improve this latter ?

Other fields should/could be incorporated so that vulnerabilities to weather hazards can be considered. This will help forecasters pay more attention to HIW during their forecasting process.

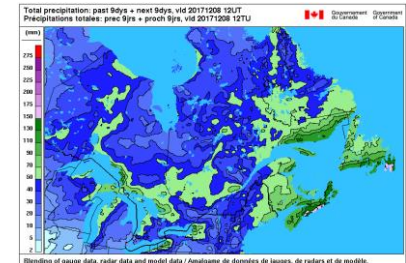
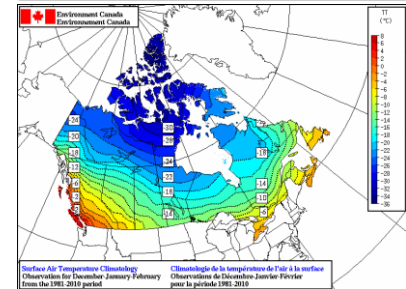
- Population density (NCR tornadoes 21/09/18)
- Urbanisation rate
- Land use cover
- Climatology
- Latest hazard assessment
- ...



VIGILANCE table
(ECCC/ADS/JMC)

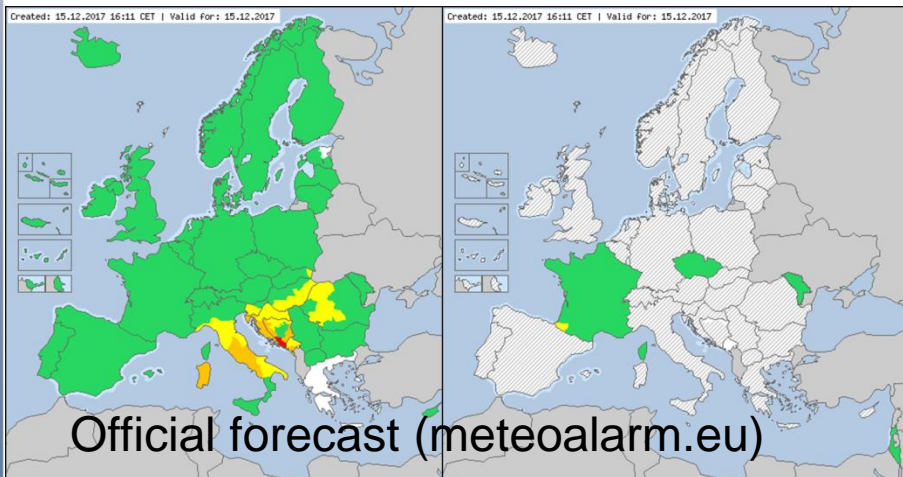


Suggested VIGILANCE
"in Context" matrix
(ECCC/ADS/JMC)

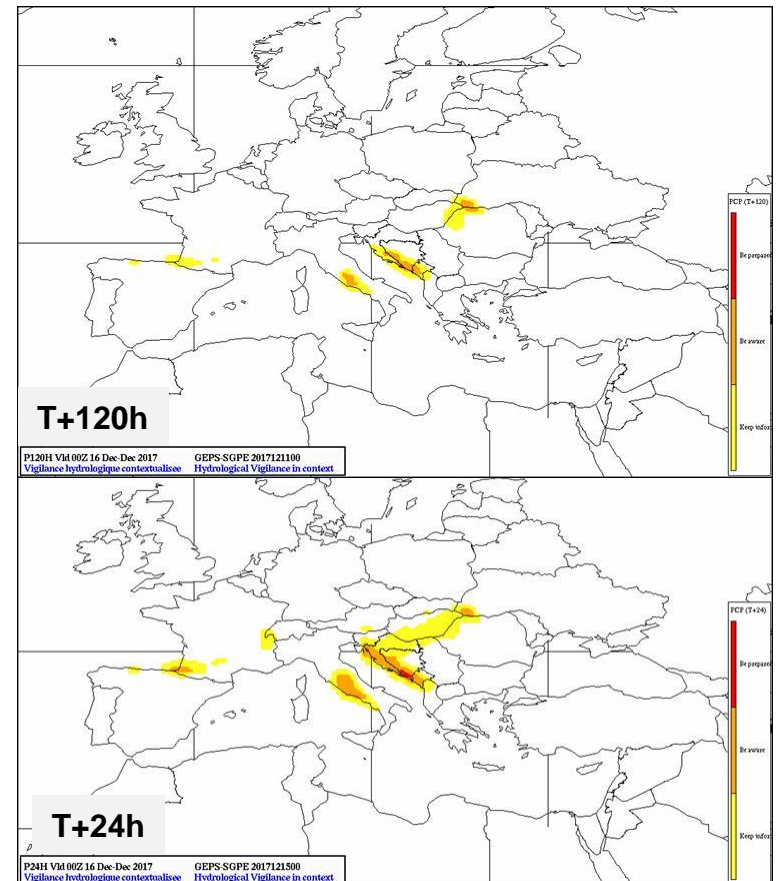


What about performances ?

Flood event December 15th, 2017



The hydrological contextualized vigilance gives very interesting signals, up to 5 days ahead, when rain is concerned.



Summary

- Collaborative approach to deliver forecasting services in MSC
- Moving toward IBF at all levels
 - Regions are providing early notifications to EMOs etc.
 - A&P and ADS are using GEPS to serve specific clients: UK MET matrix and UK Met matrix + EFI
- GEPS shows ability to predict HIW with a significant lead time

Acknowledgements

- MSC offices for providing inputs on IBF
- Jennifer Milton, Carmen Hartt, Allan Rahill, Charles Creese, Sébastien Chouinard and Michael Schäffer *et al.* for their contributions to this presentation
- David Dégardin, Marie-France Turcotte and Jim Prime for sharing their work
- WMO for funding the trip
- KMA for the support
- Thank you for your presence

Thank You

