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Canada

Ensemble Forecast Systems and Future Applications at MSC

Stéphane Gagnon and Xingxiu Deng

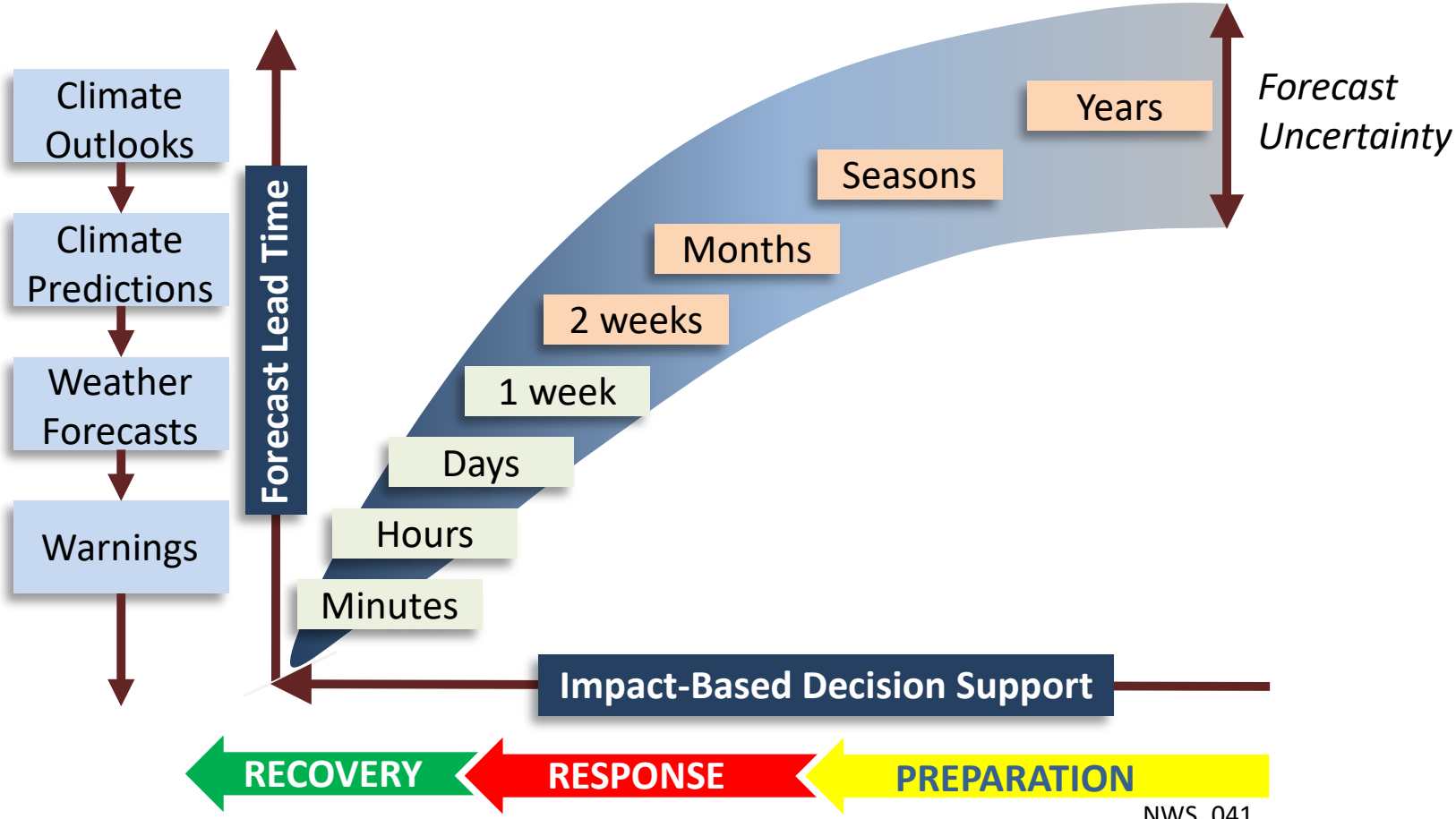
27 August 2019
8th NCEP Ensemble User Workshop
College Park, Maryland, USA

Outline

- Introduction on our capacities
- Recent upgrades to Canadian EPS
- Redefining MSC Weather Services
  - With increasing use of EPS

Our capacities:
from global to regional to local

Prediction timescales and decision support:



NWS_041

Our capacities:
from global to regional to local

Resolution

Months to Year

CanSIPS: 2 coupled climate models, 20 members, 30 yrs hindcast, 1 / 3 months forecast up to 9 months leadtime; probabilistic and anomaly forecasts

1 to 4 weeks

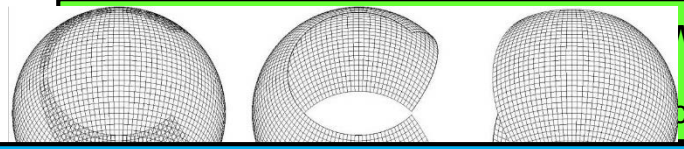
Global Ensemble Prediction System (GEPS); NAEFS:

Hor. Res. 39 km, 4 analysis cycle per day, 256 members in EnKF assimilation, 20 fcst members, 2 x16 days fcst / day

weeks

(GDPS):

cle / day, 2 x 10 day fcts / day



Minutes to Hrs Nowcast

1 to 3 Days

Regional Ensemble Prediction System (REPS):

Horizontal resolution 10km, 20 members, 4 x 72h fcsts / day

Regional Deterministic Prediction System (RDPS):

Hor. Res. 10 km, 4 anal. cycle (tied to GDPS) / d, 4 x 48-54h fcsts / day

High resolution DPS: Hor. Res. 2.5 km, no assimil. 4 x 48h fcsts / day

Minutes to Hours

Urban-scale modeling system

Forecast period covered

GEM5 physics : How to Find out More

manuscript submitted to *Journal of Advances in Modeling Earth Systems (JAMES)*

Modernization of Atmospheric Physics Parameterization in Canadian NWP

R. McTaggart-Cowan[1], P. A. Vaillancourt[1], A. Zadra[1], S. Chamberland[1], M. Charron[1], S. Corvec[2], J. A. Milbrandt[1], D. Paquin-Ricard[1], A. Patoine[2], M. Roch[1], L. Separovic[1], J. Yang[1]

[1]Atmospheric Numerical Weather Prediction Research Section, Environment and climate Change Canada, Dorval, Québec, Canada
[2]Numerical Weather Prediction Development, Meteorological Service of Canada, Environment and Climate Change Canada, Dorval, Québec, Canada

Key Points:

- An updated suite of parameterizations for atmospheric physics is developed for Canadian NWP
- Representation of the global energy budget is improved in the model climatology
- Significant improvements in guidance quality are seen in upper-air, surface and precipitation scores

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Recent upgrade to the Canadian Global Ensemble Prediction System

Xingxiu Deng, Pieter Houtekamer, Juan Sebastian Fontecilla, Hai Lin, Normand Gagnon

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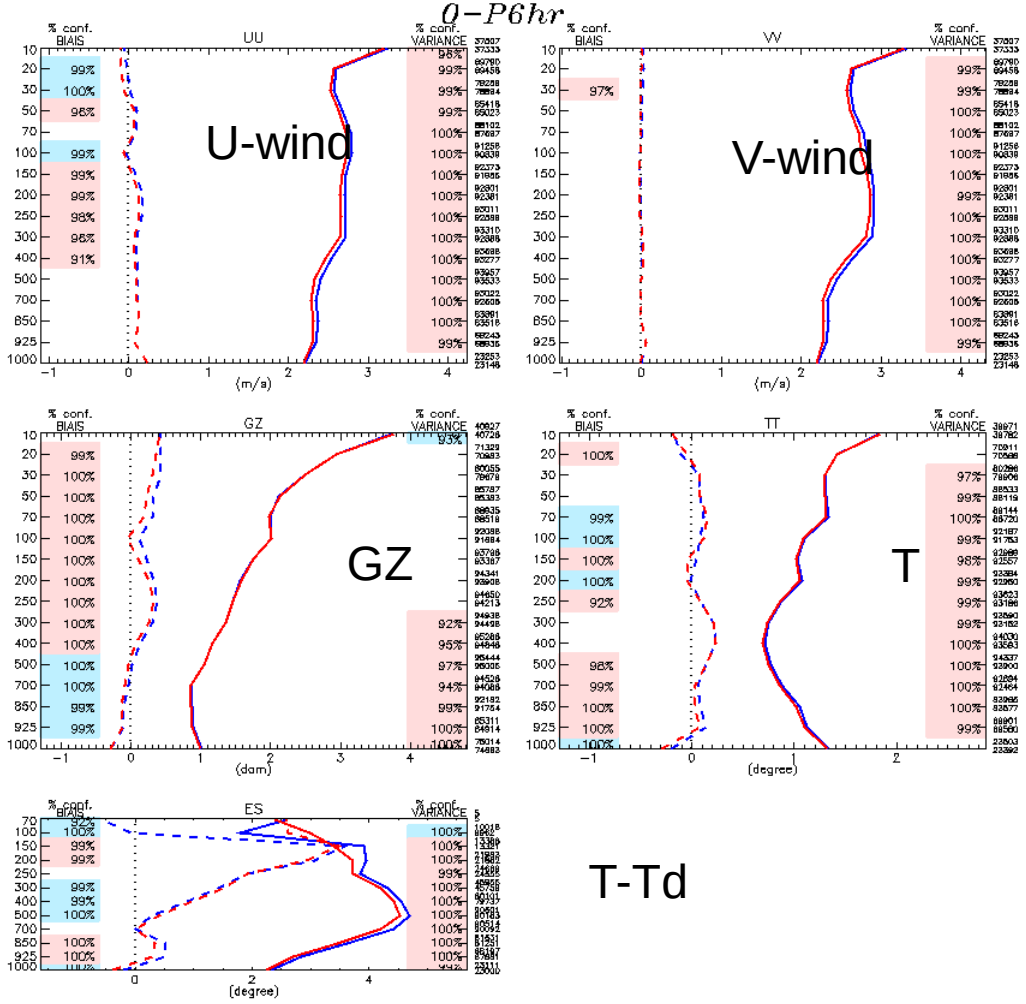
Major changes in version 6.0.0

- For the data-assimilation component, the hybrid gain algorithm is used, following up on work at NCEP (S. Penny) and at ECMWF (Bonavita et al). Here the EnKF 256 analyses are recentered around the mean of the EnKF and the EnVAR analyses.

- For the medium-range forecasts, the atmospheric model is coupled with the NEMO ocean model and the sea ice model.

EnKF verifications against Radiosondes



blue: version 5.0.0
red: version 6.0.0

Significant improvement in the standard deviation for the wind components, for the temperature and for dewpoint depression.

Summary of verification results

- The quality of the new EnKF trial fields is significantly improved.
- The GEPS 6.0.0 forecast performance is significantly improved for most regions and fields.
- The reforecasts are significantly improved for surface temperature and geopotential heights, especially for weeks 3 and 4.
- The forecast skill of MJO is improved by about 4 days.

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CMC - REPS

Major upgrade on the 3rd of July 2019

CMC - REPS

REPS changes with upgrade of July 2019

- REPS adopts the configuration of the RDPS
  - LAM grid at 10 km
  - 84 levels with lid at 0.1 hPa
- Initialized with RDPS UA analysis with GEPS perturbations recentered around the RDPS analysis
- Use of RDPS surface fields in good equilibrium with model physics
- Piloted by GEPS (lateral boundaries only)
- GEM version 5 (much improved)
- Physics Tendencies Perturbations (PTP) during integration
- 4 runs per day

CMC - REPS

REPS impact of upgrade of July 2019

- Major upgrade
  - Use of the RDPS analysis at 10 km
  - Recentering of GEPS perturbations
  - Use of much improved GEM version 5
- Scores are much improved
- Next steps
  - Perturbations type (e.g. stochastic physics)
  - Amplitude of perturbations

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Redefining MSC Weather Services

Weather & Environmental Services

Impact Forecasting & Communication

Being more and more client centric

Context

Recognizing that we are living in a changing World …

- Evolving needs of our Clients:
  - More than ever **dependent** on weather, climate and environmental prediction information for their **decision-making process to reduce impacts** or take advantage of opportunities;
  - Our Clients and partners **more sophisticated** than before;
  - Asking for **more details** in space and time with **uncertainty/scenarios**, in a **seamless way** as much as possible;
  - Geolocalization technologies (ex: GPS) give us the capability of providing our Clients with **hyperlocal information**, and they are expecting that;
  - Would like to receive early notifications based on their own **user-defined criteria**, in addition to the MSC standard warning criteria;

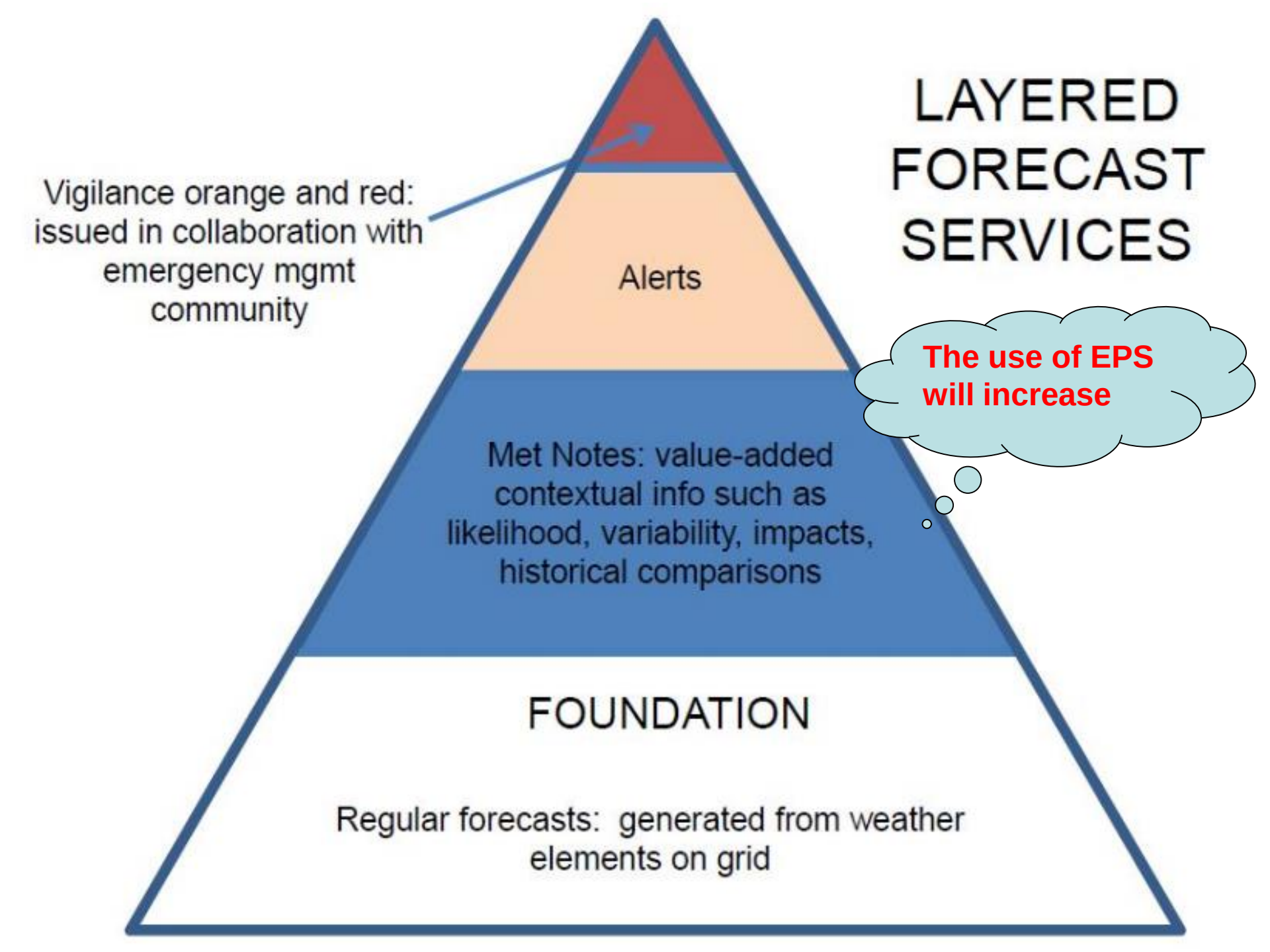
MSC SMC

Context (continued)

MSC NextGen project is aiming at developing event-based forecasting and integrated multi-hazard early warning systems,

Part of the NextGen Weather Prediction System vision is that by 2023 :

- **Forecast data/info on grid at all scale (spatial and lead time)**
  - The prediction system will evolve from scheduled region/area-based products to a more on demand at any location, anytime system presented in a seamless manner
  - NWP systems provide High Impact MetObjects in a suitable form for meteorologist intervention when and where necessary
  - Increasing availability of products via new technologies
  - Exploiting the continuing improvements of numerical prediction systems to meet client-focused service standards

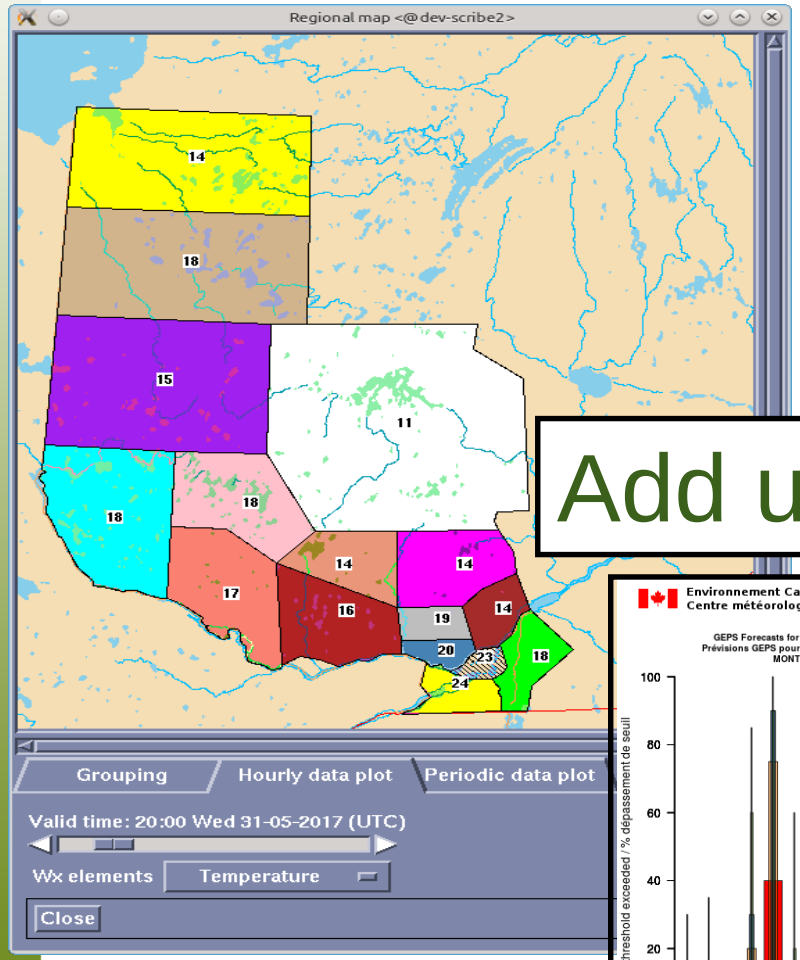

LAYERED FORECAST SERVICES
Vigilance orange and red: issued in collaboration with emergency mgmt community
Alerts
The use of EPS will increase
Met Notes: value-added contextual info such as likelihood, variability, impacts, historical comparisons
FOUNDATION
Regular forecasts: generated from weather elements on grid

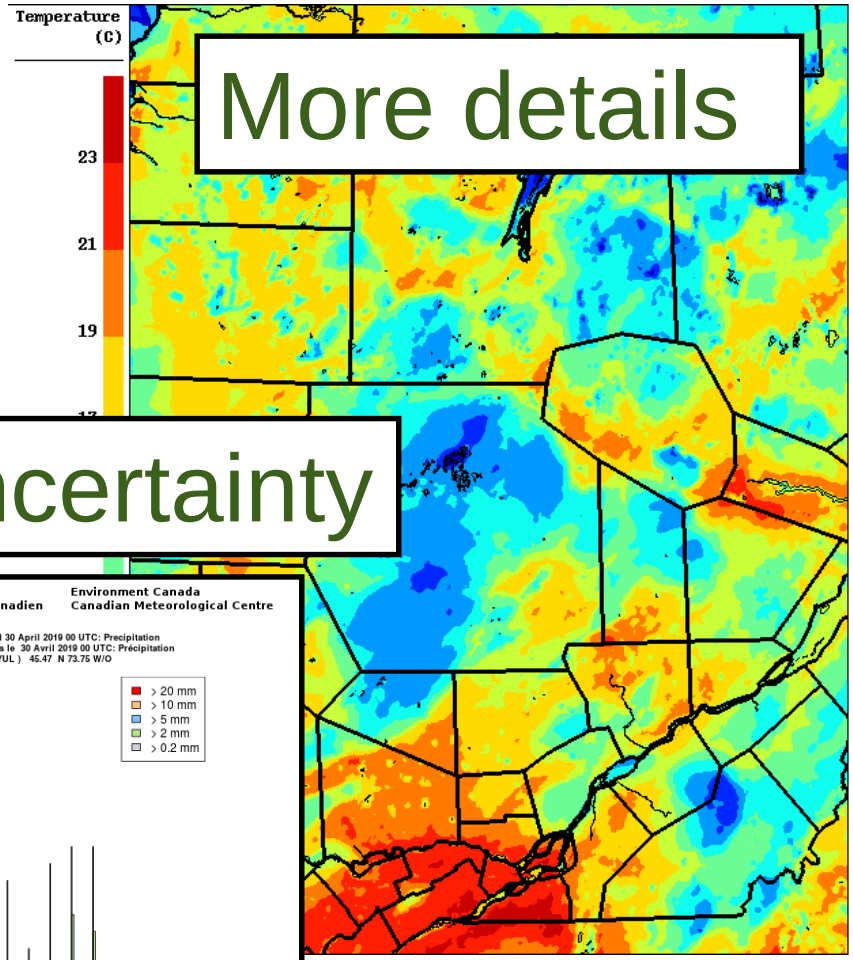
Weather Elements Production System

From a point forecast representing a region to a forecast anywhere at anytime (grid point forecast)

Curent situation:

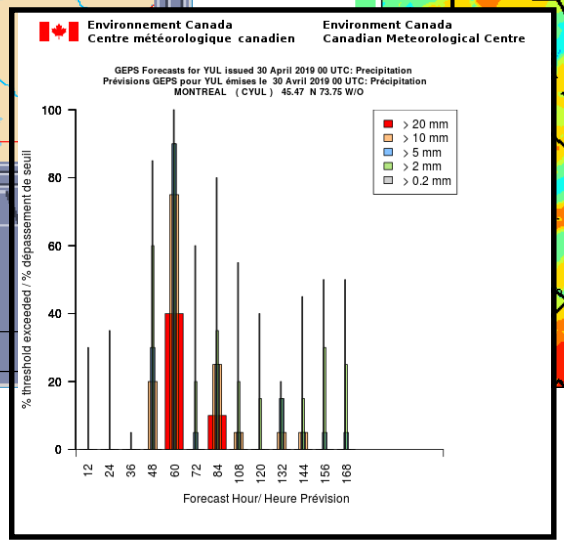
Our operational NWP data production is not fully exploited





More details

Add uncertainty



Weather Elements on Grid

- Precipitation
  - Amount
    - Liquid
    - Solid snow
    - Solid ice pellets
    - Freezing
  - Intensity
  - Character
  - Types
    - Rain
    - Freezing rain
    - Drizzle
    - Freezing drizzle
    - Snow
    - Ice pellets
- Probabilistic fields
  - Precipitation occurrence
  - Freezing rain
  - Freezing drizzle
  - Snow squall
  - Hail
  - Thunderstorm occurrence

- Sky conditions
- Snow level
- Temperatures
  - Air temperature at screen level
  - Dew point temperature at screen level
- Wind
  - Dominant speed
  - Dominant direction
  - Gust speed
- Fog
  - Liquid
  - Icing
- Blowing snow

Challenges

- Innovating new products and services
  - From point forecast representing a region to gridded forecast
  - Adding uncertainty → Increasing use of EPS
    - Intervals / Percentiles / Probabilities
    - Scenarios in support to communicate risks and impacts
- Future role of operational meteorologists
  - No grid editing tools
  - Change of paradigm – let routine forecasts go and focus on communication / High impact weather
    - More and more client centric
  - Closer collaboration with developers to improve the quality of automated forecast

Warning Production System

With the MetObject approach being use, the diagnostic of High Impact Weather at all scale and all lead time becomes an unavoidable and a high priority.

Next phase of warning re-engineering will change the paradigm of what a warning is…

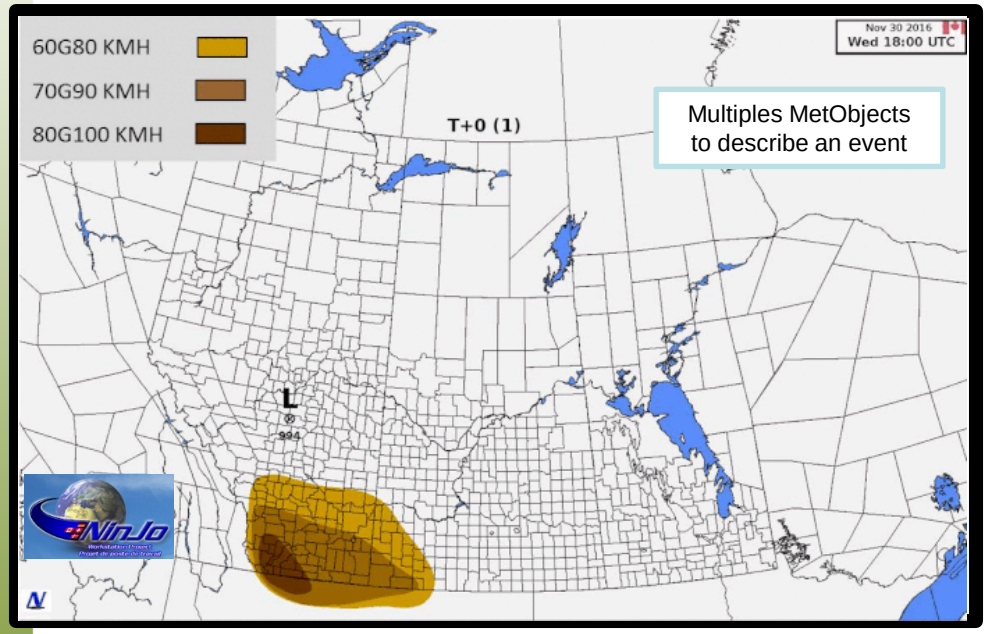
- Alerts will be a way to draw attention to weather situations that may have high impact
  - Disrupt society or cause risk to life
  - Not simply a forecast that a meteorological threshold will be reached or surpassed
- Primary role for meteorologists in the SPCs will be to identify and describe the potential high impact situations (on any timescale)
  - Requires routine collaboration with public officials to assess risks
  - Requires awareness of major public events

Alerting concept will be different…

- Focus will be on the potential impacts caused by one or more weather parameters
  - E.g. a combination of snow accumulations and wind causing traffic disruptions and potential flight delays
- Alerts will complement forecast information not duplicate it
- Alerts will be tiered in a different way
  - Situation will be expressed in terms of risk and certainty
  - Likely to involve the use of colour
- Early notification will be incorporated in routine alerting service

Using the MetObject approach

An event is represented by multiple MetObjects moving through time and space.

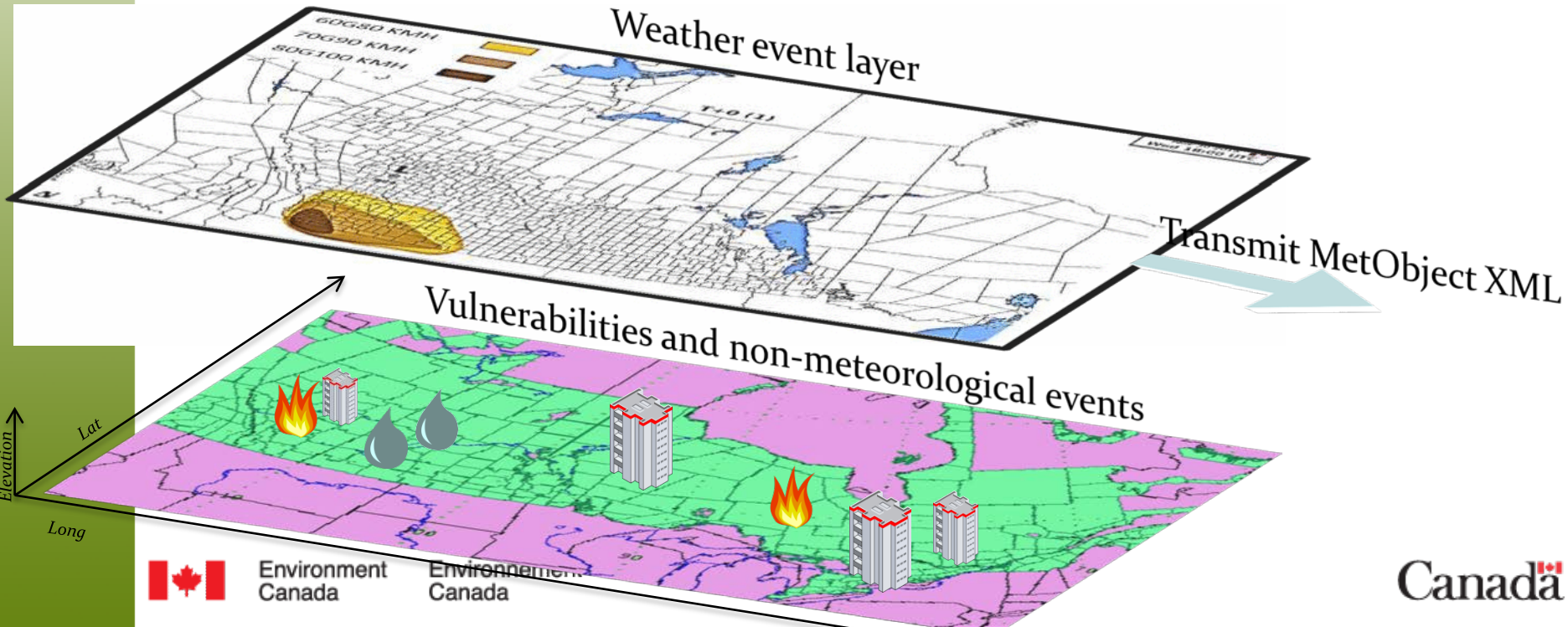


- MetObject is a simplified representation of meteorological and related information.
- Aligns better with human conceptual perceptions of weather.

Using the MetObject approach cont.

Will be able to

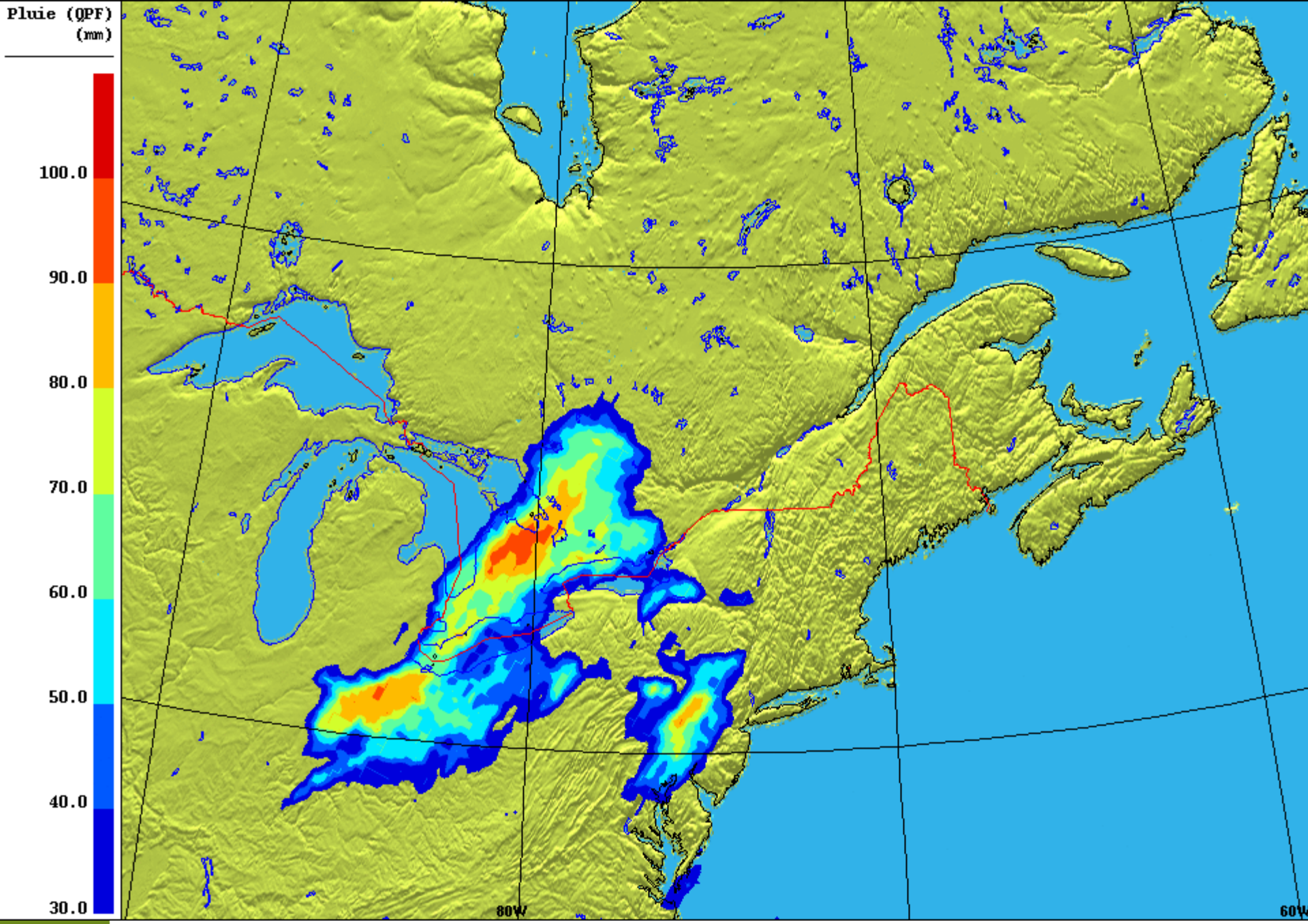
- Cross-reference a MetObject with other relevant contextual information
- Use a MetObject representation as a data transmission and exchange format
- Reduce over-warnings by alerting only impacted areas instead of the entire forecasting zone.



Warning Program : Types of HIW events

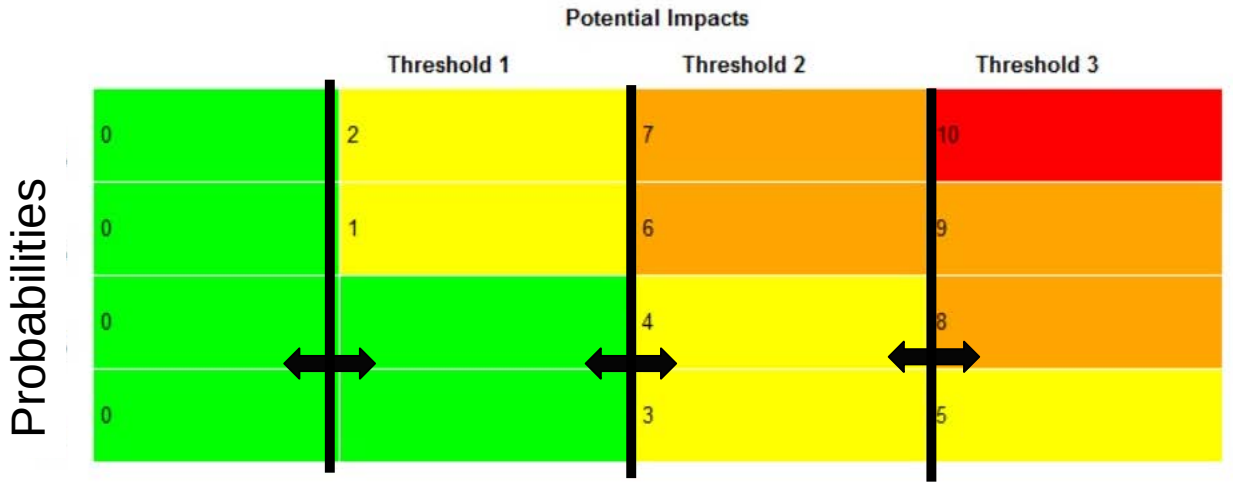
Warnings	NW/EP Systems

• Extreme Cold / Heat wave
  – Flash freeze
• Hi winds
• Heavy snow/rain
• Freezing rain
• Blizzard / Blowing snow
• Air quality / UV
• Severe Thunderstorms
  – Lightning, hail, tornado
• Storm surge
• Fog
	• SIPI - NowCasting
	• HRDPS
	• (G/R)DPS
	• **(G/R)EPS**
	• Extended GEPS (monthly)
	• AQRDPS
	• Other systems …
	  – Ice, wave, oceans, surface, hydro, …


Pluie (QPF)
(mm)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
80W
60W

Vigilance products

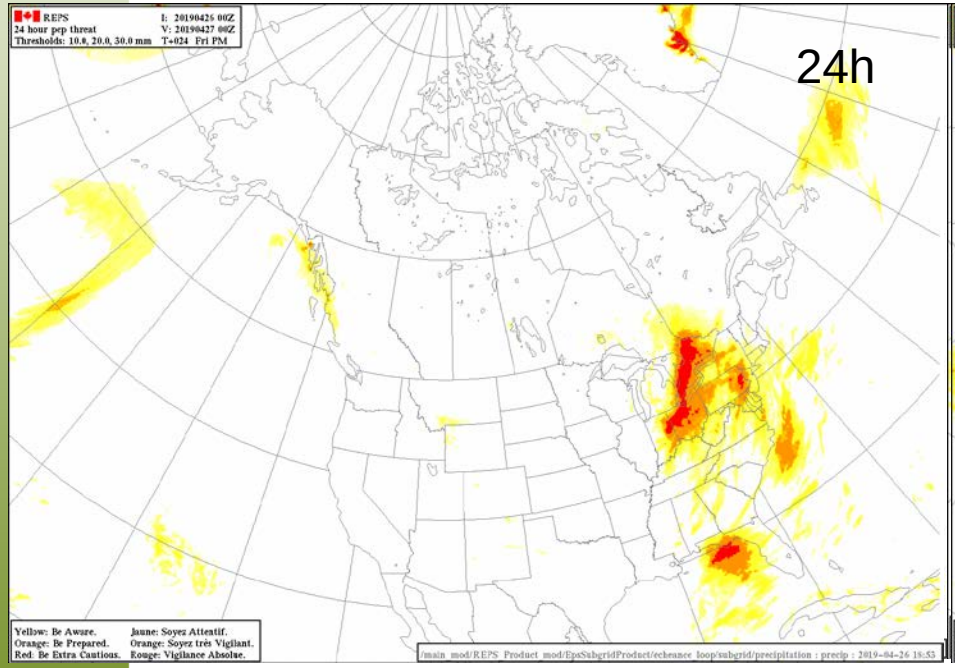
Vigilance : dynamical thresholds

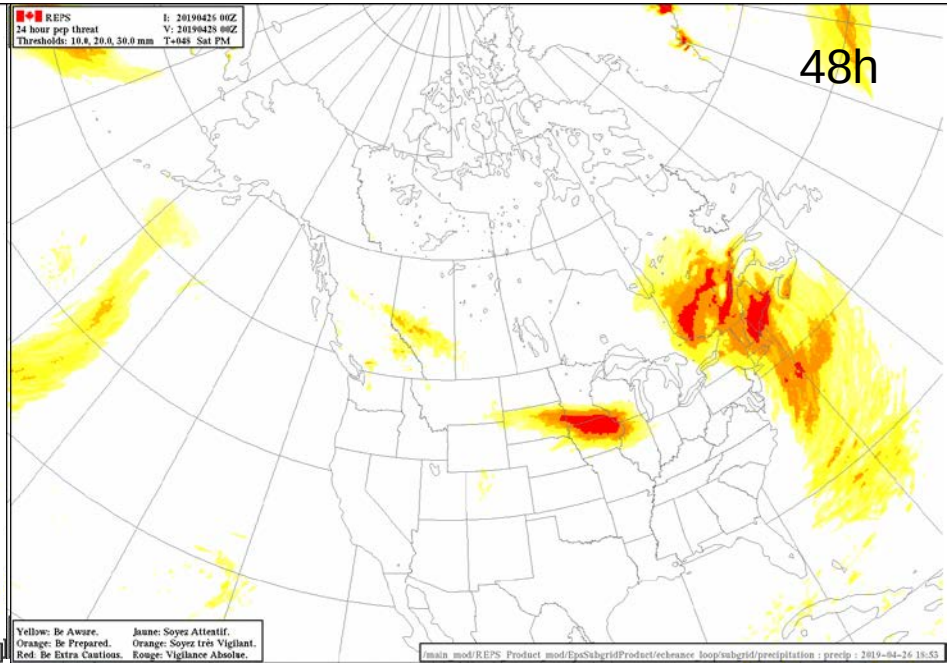


Vigilance products : Probability and **dynamical** vulnerability thresholds

Vigilance : dynamical thresholds

REPS 24h precipitation threat: Thresholds: 10,20,30 mm





Vigilance Products from (R/G)EPS

- List of variables available:
  - **Temperature max**
  - **Temperature min**
  - **High wind and gust**
  - **Humidex max**
  - **Wind-chill**
  - **Total Precipitation**
  - **Rain, snow, FZRA, ice pellet**
  - **Surface runoff -new-**
  - Many more to come …

Conclusion

New Science and Technology capabilities will soon offer opportunities for improving our products and services, namely

- From large forecast regions to high resolution gridded
- From mainly deterministic forecasts to fully probabilistic forecasts
- From predefined forecast updates deadlines (currently 3/day) to continuous high-frequency updated forecasts
- Having operational meteorologists focusing on communication helping partners in their decision-making process

Extras

Plan de 10 ans: Atmos/Ocean-Glace/Surface

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Introduction

- The Canadian GEPS produces 16 day forecasts twice per day and 32 day forecast once a week on Thursday.
- An upgrade to the Canadian GEPS was done on 3 July 2019 after a final series of tests and a 3-month parallel testing.
- Changes in the new version (6.0.0) will be summarized.
- Verification results will be shown for the Canadian CMC as well as for the NAEFS combined ensemble.
- Verification results for the GEPS reforecast will also be shown.
- Future work will be briefed in the end.

Major changes in version 6.0.0

- For the data-assimilation component, the hybrid gain algorithm is used, following up on work at NCEP (S. Penny) and at ECMWF (Bonavita et al). Here the EnKF 256 analyses are recentered around the mean of the EnKF and the EnVAR analyses.

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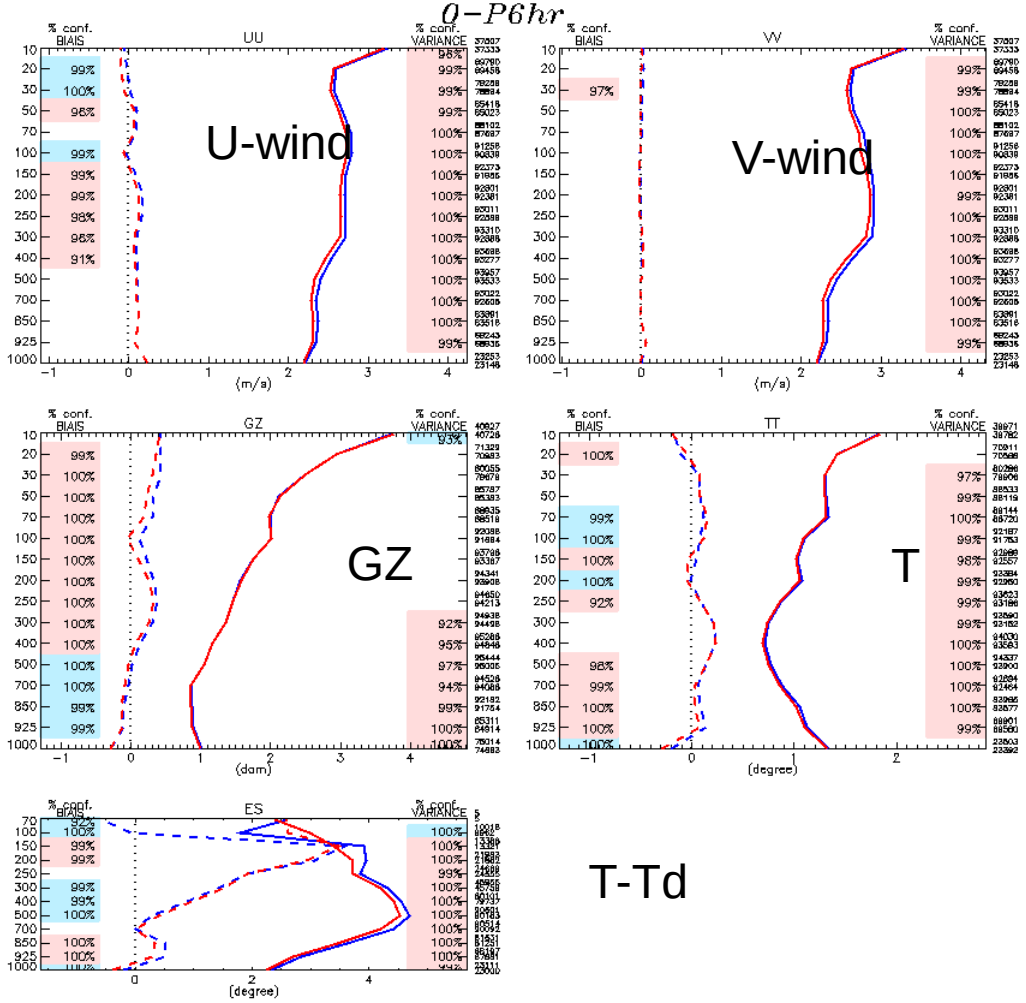

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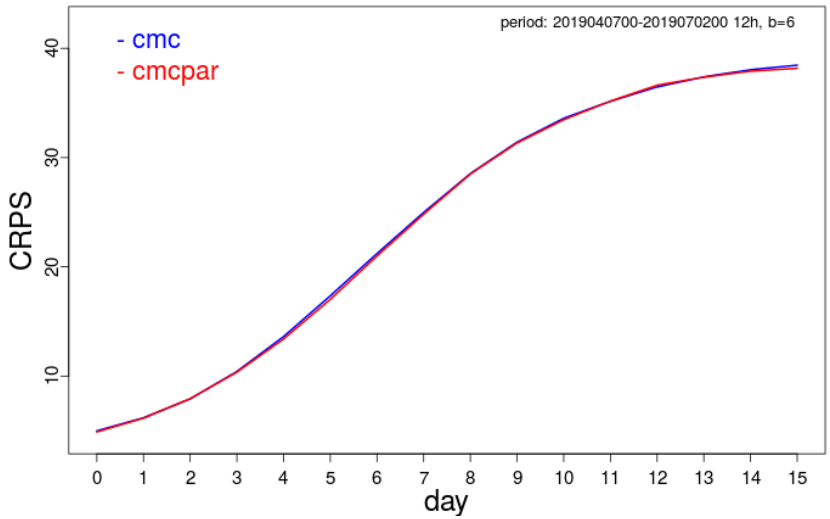
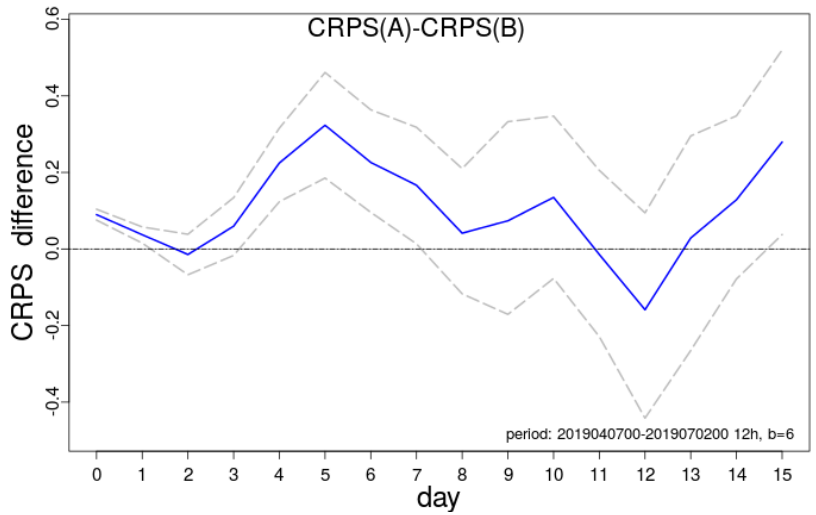
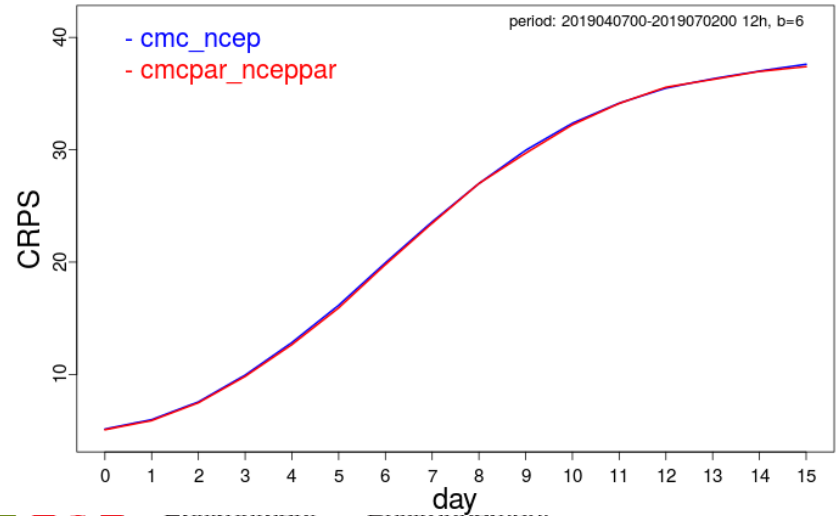
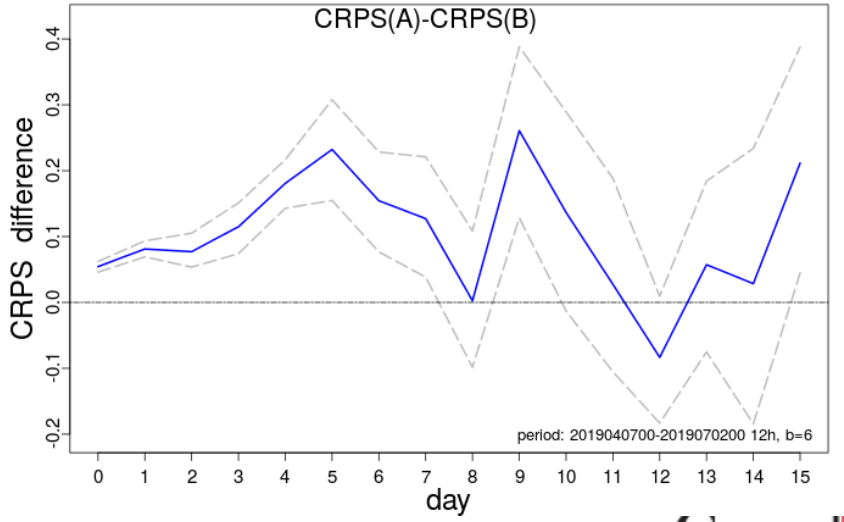
Verification of the GEPS against Radiosondes, GZ 500 hPa, Global

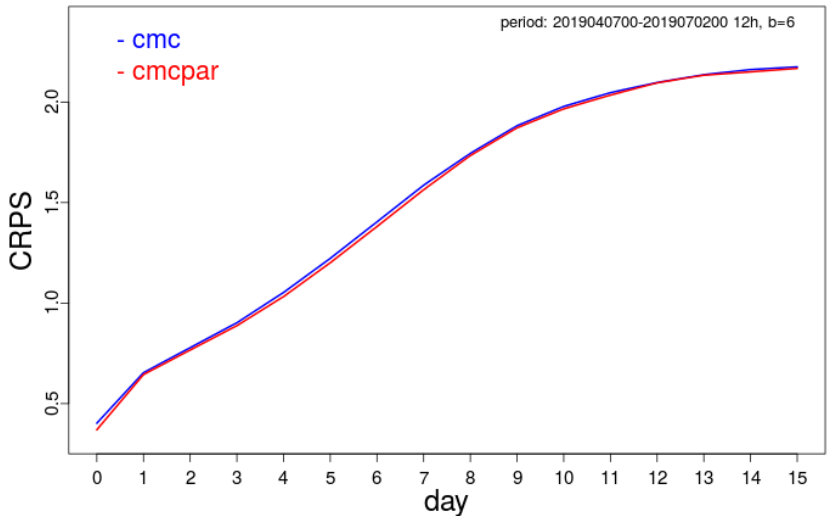


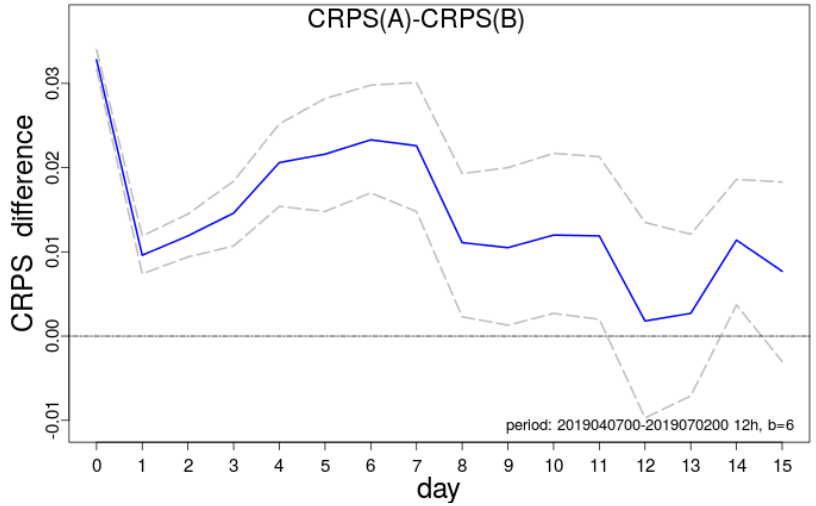


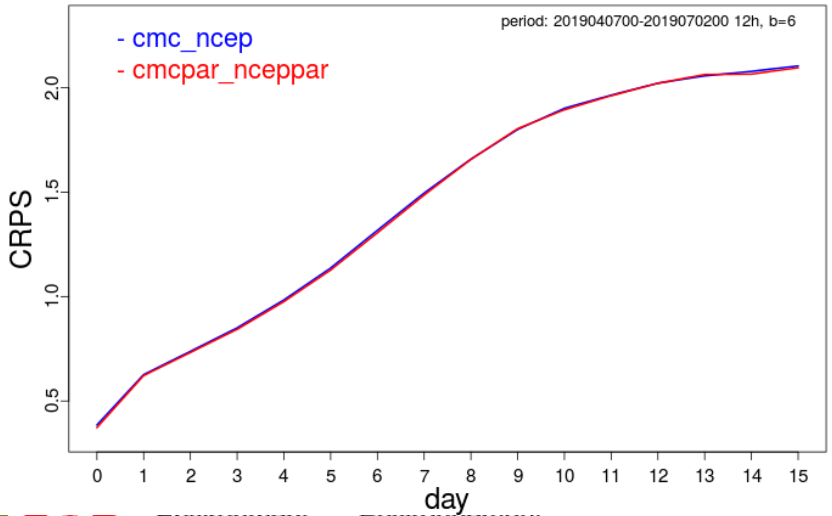


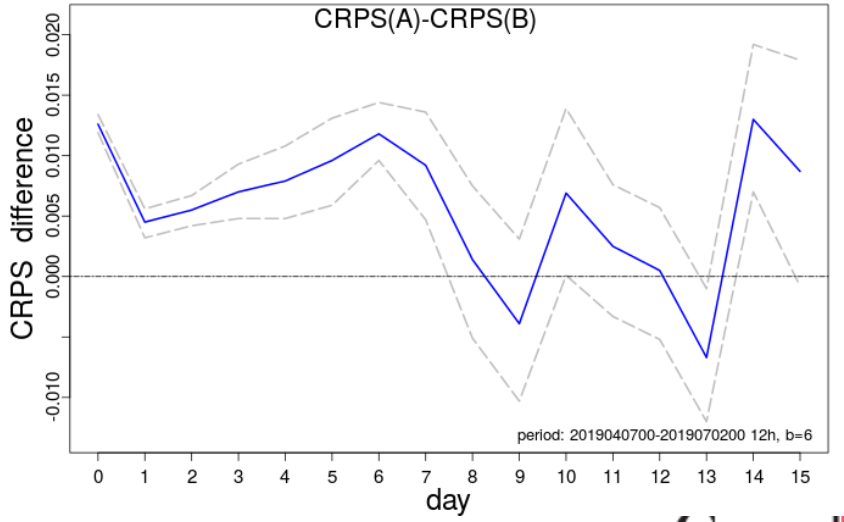


Verification of the GEPS against Radiosondes, T 850 hPa, Global

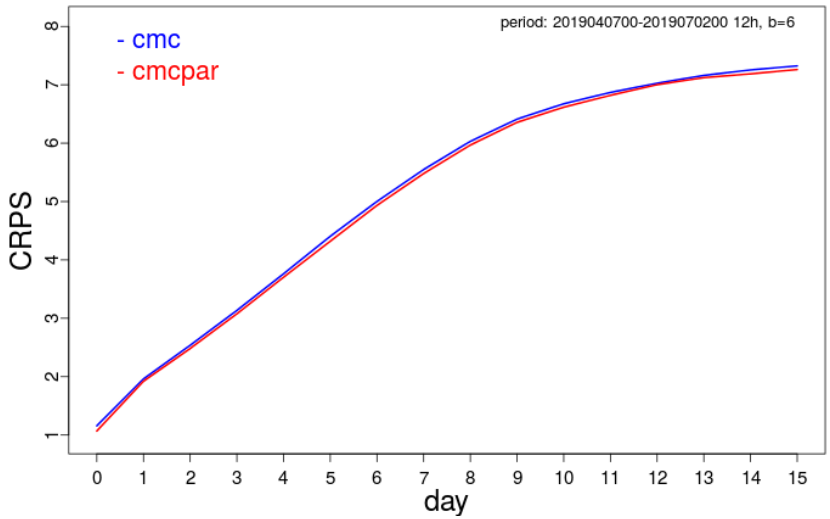


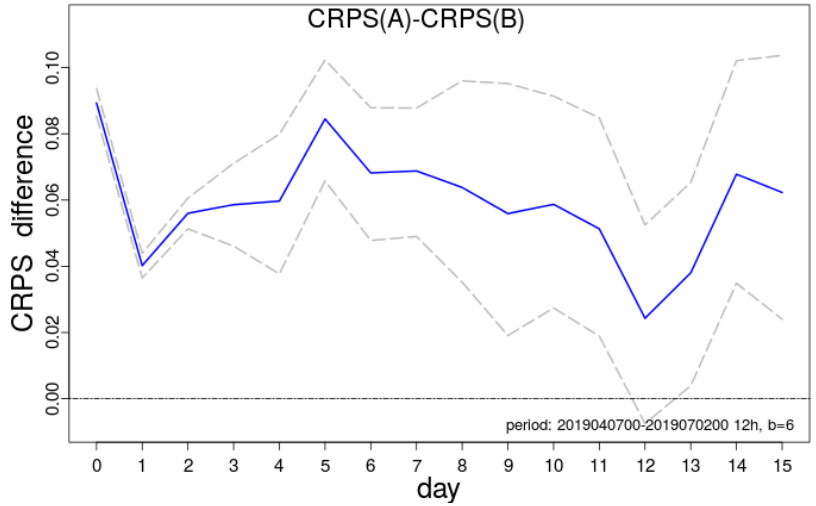


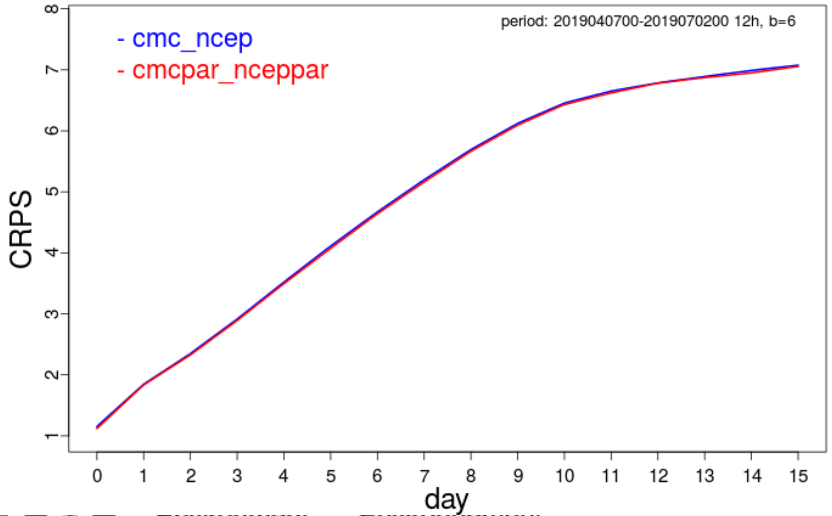


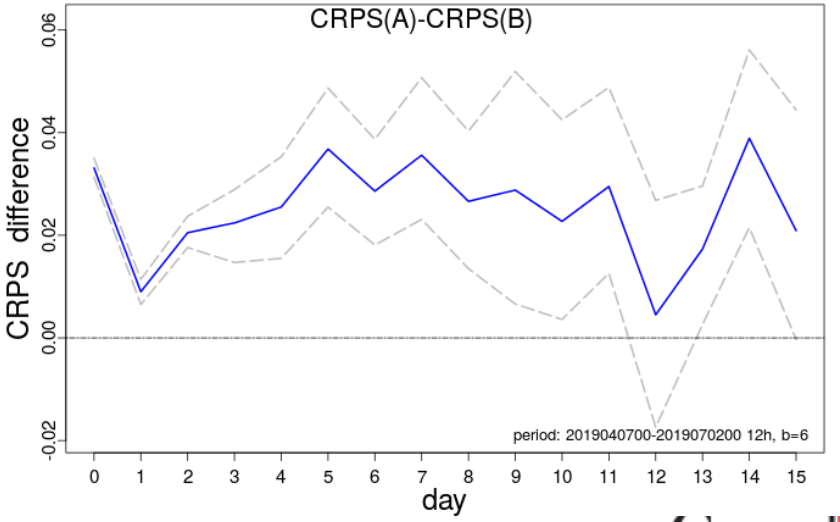


Verification of the GEPS against Radiosondes, zonal wind 250 hPa, Global

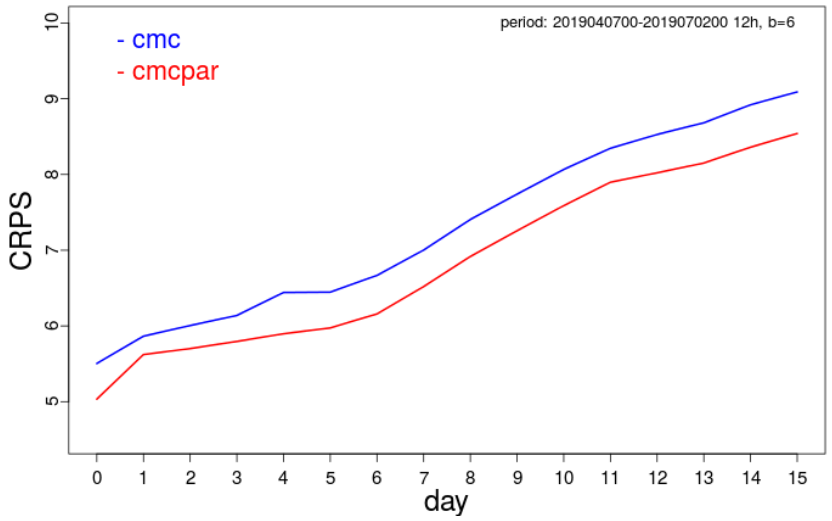


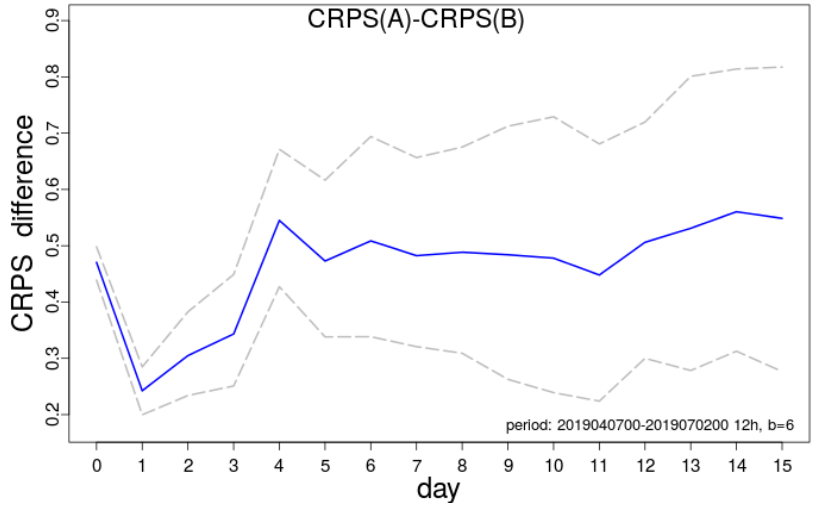


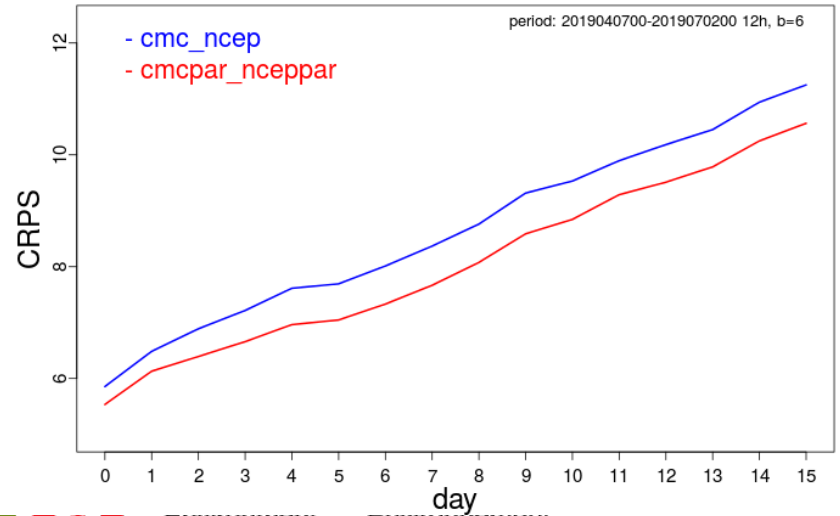


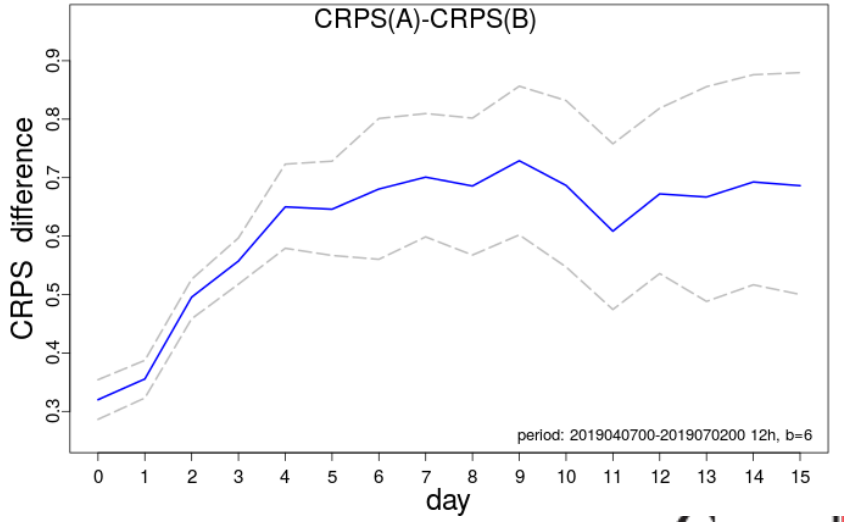


Verification of the GEPS against Radiosondes, GZ 500 hPa, Tropics

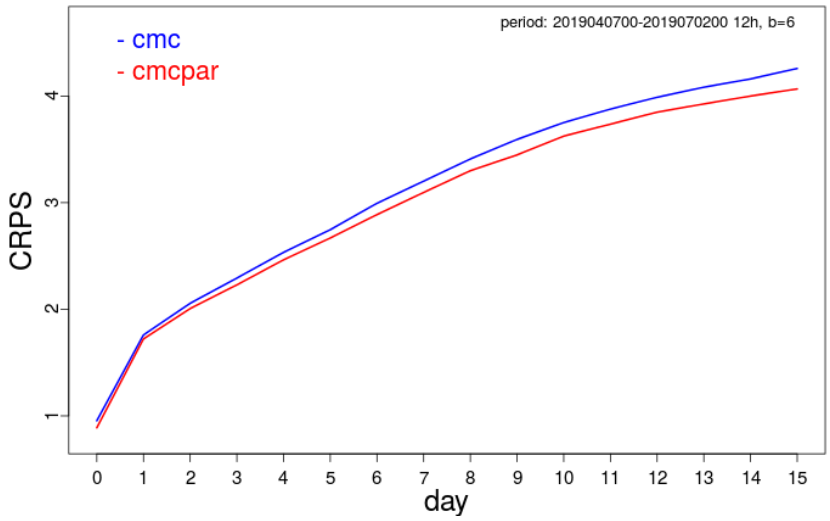


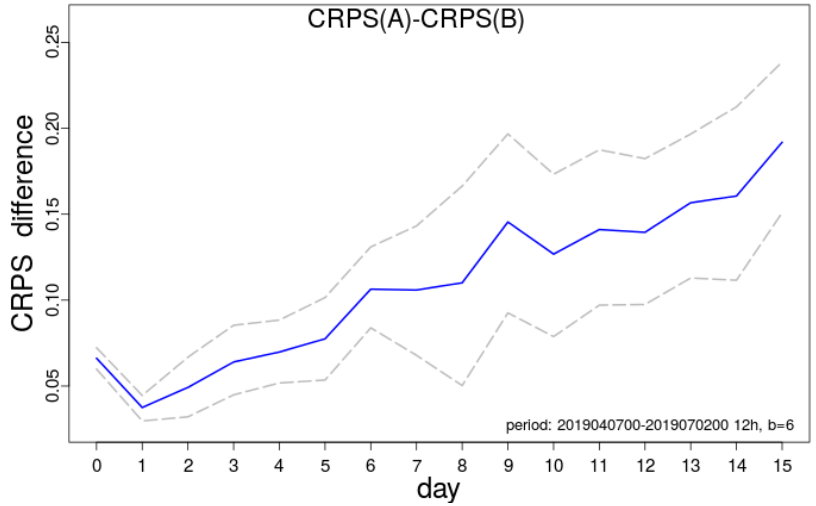


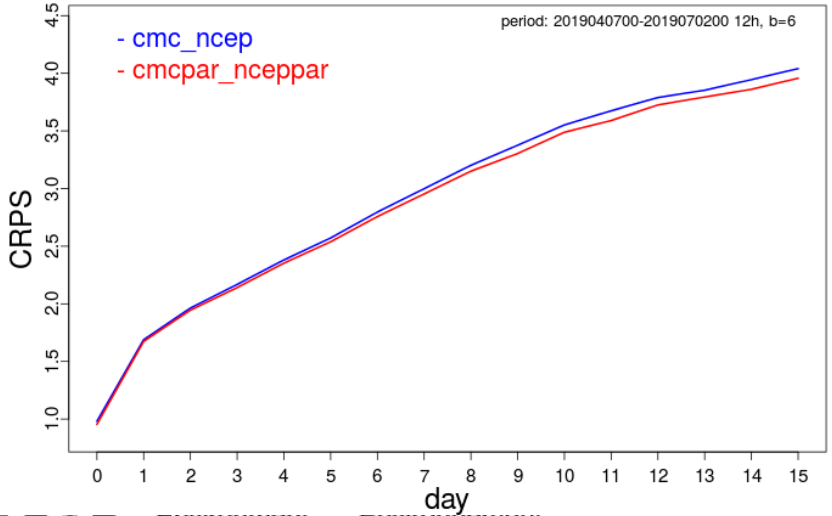


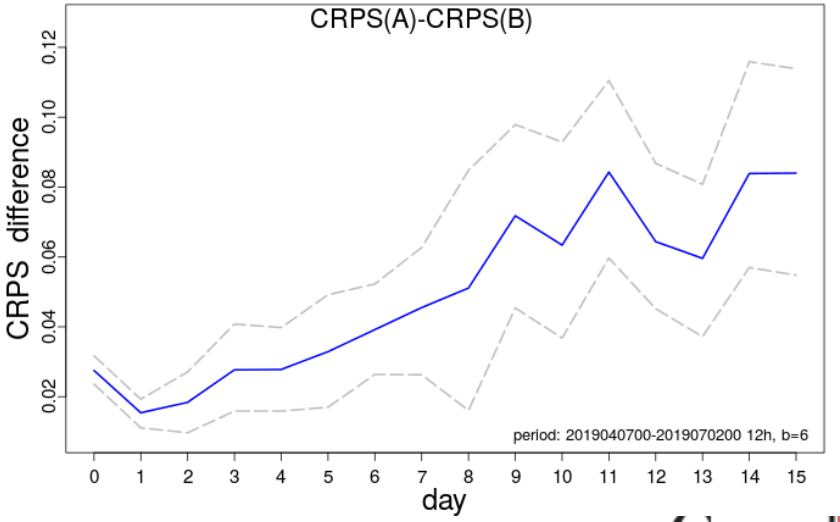


Verification of the GEPS against Radiosondes, zonal wind 250 hPa, Tropics

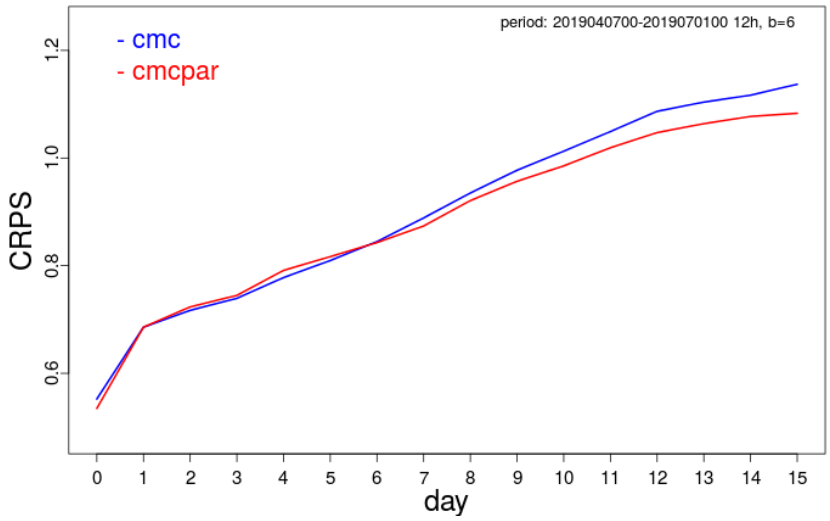


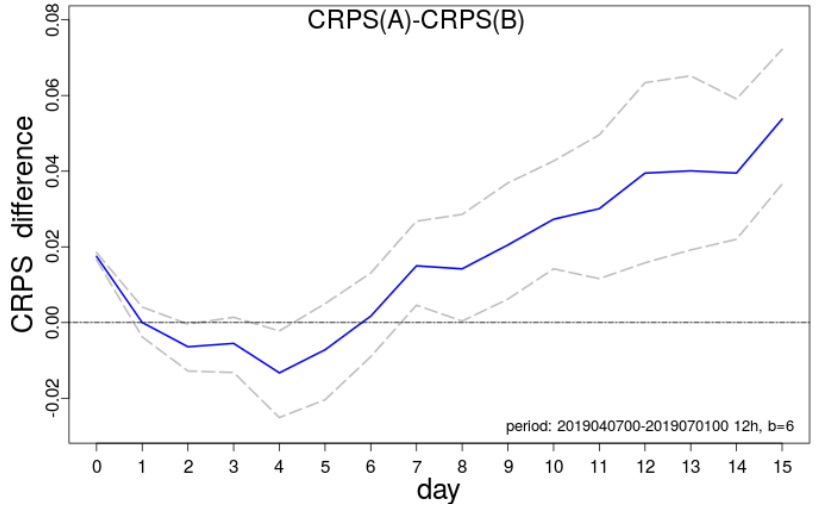


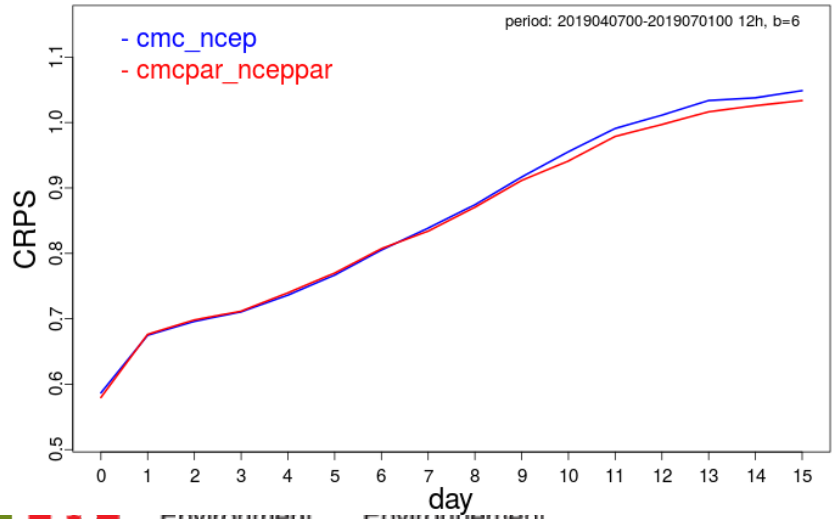


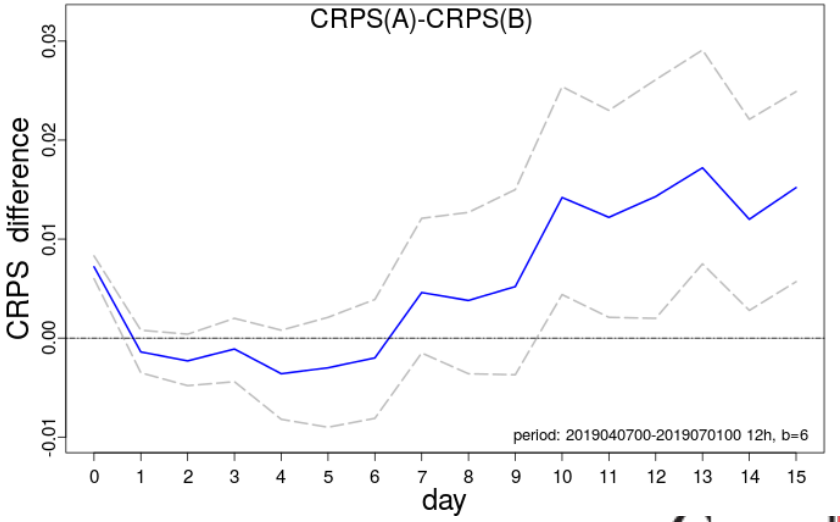


Verification of the GEPS against surface pressure observations, Tropics









GEPS 6.0.0 : reforecast

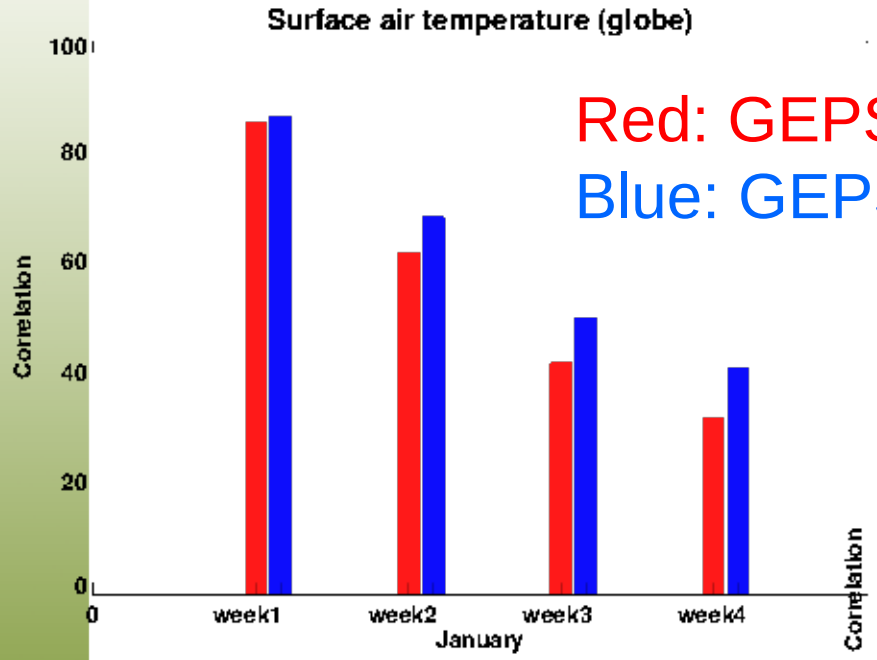
- Reforecast or hindcast: an important component of the monthly forecast system. Historical forecasts over the last 20 years (1998-2017) are performed with the same forecast system as the operational medium-range one.

- In this new version, the GEM-NEMO coupled model is used.

Reforecast: operational configuration

- A 32-day forecast started every Thursday uses climatology created by reforecasts of 4 members over 20 years (1998-2017) for the same date, and for 4 other dates (every Thursday two weeks before and after). For exampe, a forecast of July 4 needs a reforecast for June 20, June 27, July 4, July 11 and 18 (in total 400 historical forecasts: 4 members*5 dates*20 years).
- The 4 members are chosen in function of the year to make sure that each of the twenty model configurations is picked as often as the others.

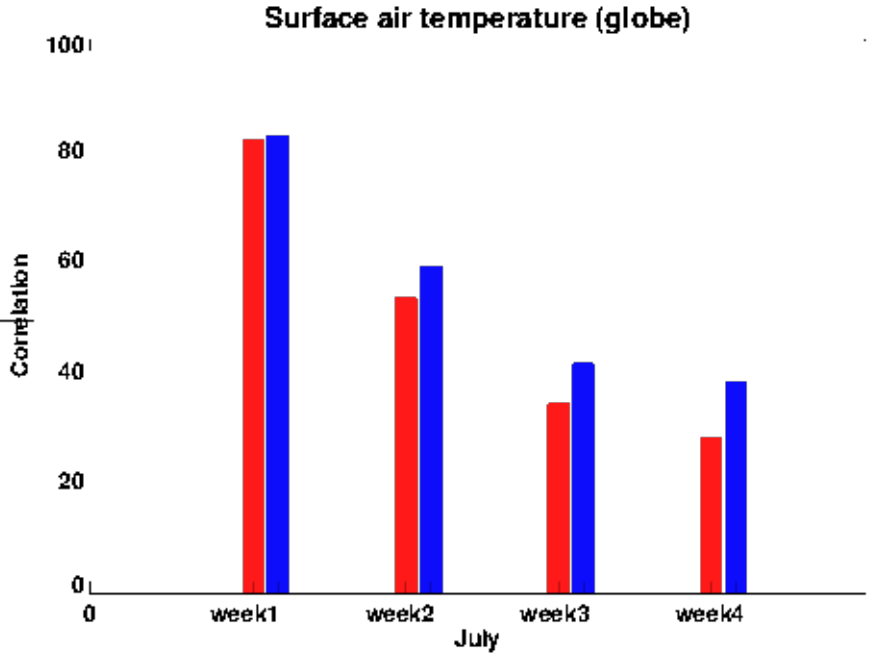
Reforecast verification against ERA-interim re-analysis: 20-member 32-day forecasts over 20 years for 1 January and 1 July, Global



Red: GEPS 5.0.0 reforecast

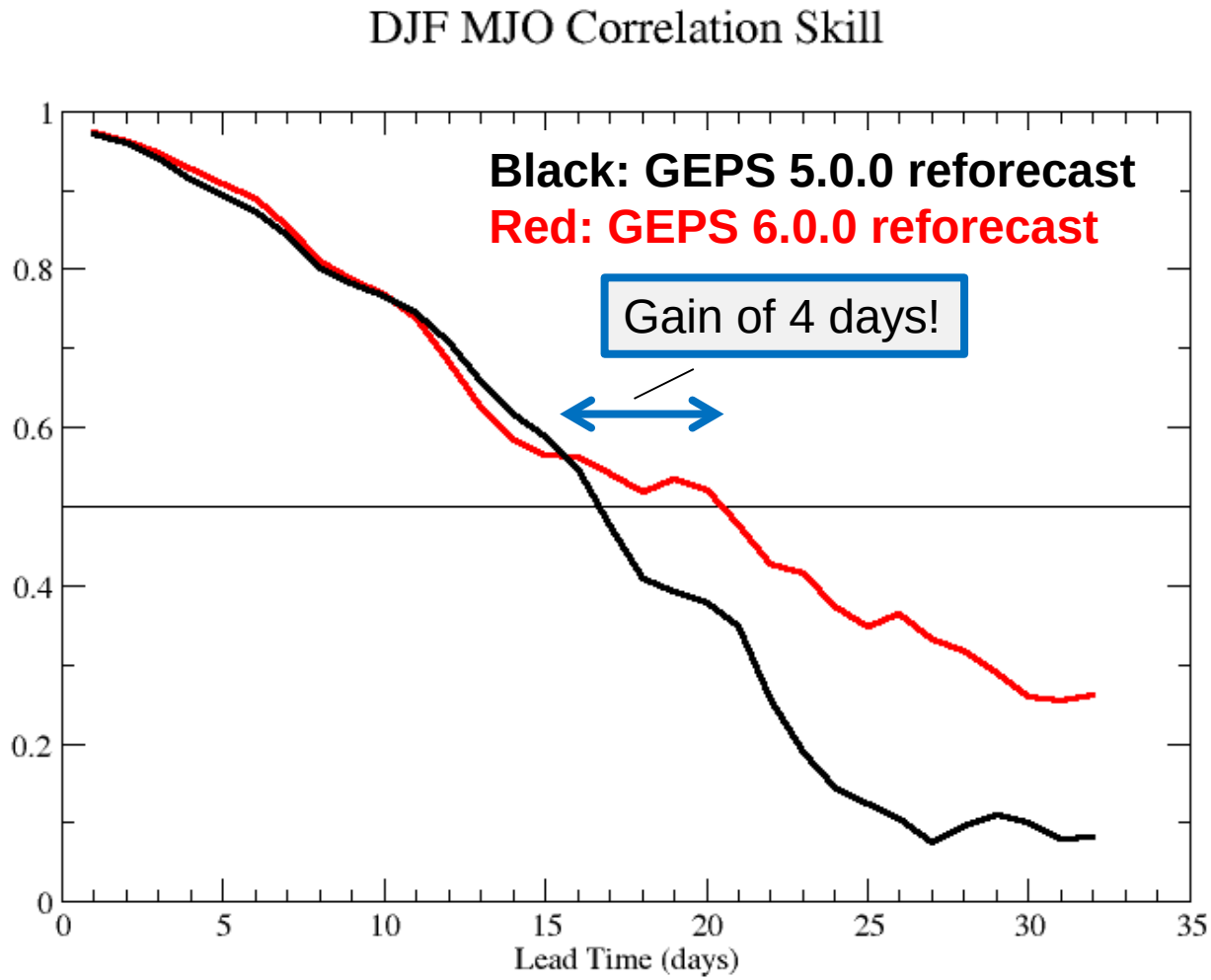
Blue: GEPS 6.0.0 reforecast

1 January



1 July

Reforecast verification against re-analysis: 4-member 32-day forecasts over 20 years for Dec. 1, Jan. 7 and Feb. 4



Summary of verification results

- The quality of the new EnKF trial fields is significantly improved.
- The GEPS 6.0.0 forecast performance is significantly improved for most regions and fields.
- The reforecasts are significantly improved for surface temperature and geopotential heights, especially for weeks 3 and 4.
- The forecast skill of MJO is improved by about 4 days.

Future work

- Use of tuned CMC-hybrid gain for data assimilation (recentering analyses for the half of the ensemble around the 4DEnVar analysis while the other half of the ensemble remains unchanged, reduced Isotropic perturbations).
- Upgrade model physics by using GEM5 with re-tuned perturbations.
- Coherent use of GEM model in the trial and the forecasts (PTP, SKEB, IAU, physics recycling, vertical levels, etc)
- New surface scheme SVS with CaLDAS initialization.