CMC Centre Update

WGNE 38

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Outline

Overview of current operational transfer: “Innovation Cycle 4”:

Global ensemble upgrade

Retirement of Regional Deterministic Prediction System

Current research in operational systems

An over-forecast convective precipitation case study

Reducing the model’s weak-intensity bias for tropical cyclones

Developing and AI Roadmap

Innovation Cycle #4

An upgrade to the full suite of systems is in the pipeline for operationalization in mid-2024

- Installation for parallel runs have begun

All systems (>40) are being updated within the Innovation Cycle

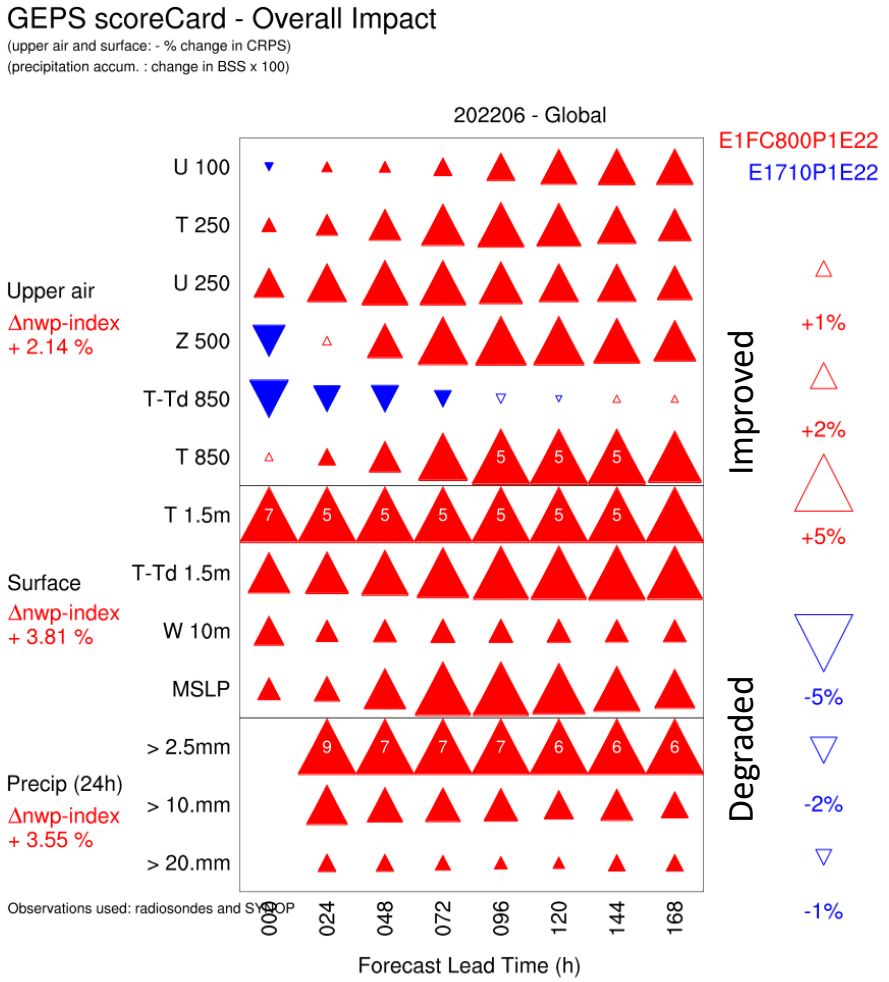
- Interdependency between systems has led to two separate invalidations of the “final cycles” because of technical errors in high-level systems

The first delivery that will be based on longer testing periods (4-month summer 2022 and 8-month fall/winter/spring 2021-22) rather than two 2.5-month periods:

- Improved sampling will help us to compute more robust statistics
- Changes to components of the land surface scheme and ocean model can have very long time-scales

Major Upgrade to Global Ensembles

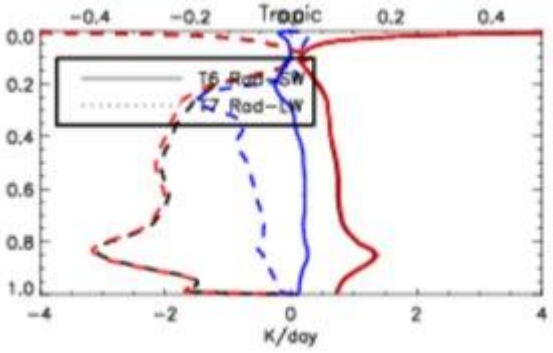
- Unchanged components:
  - Members in LETKF assimilation (256) and forecast (20+1)
  - System uncertainty via EDA and additive inflation
  - Model uncertainty represented by SKEB and SPP
- Updated components (high-impact changes in blue):
  - Global Yin-Yang grid moves from a 39 km grid to a 25 km
  - Physics configuration updated to adapt to change in resolution and reduce biases*
  - Ranges of SPP perturbations adjusted to recenter on updated configuration
  - Advection SPP element reduced to match improved RMSE
  - Stochastic pattern generator reconfigured to give uniform coverage of “Gaussian” stochastic perturbation fields



Percentage change in the global continuous ranked probability score (CRPS) for the summer 2022 final cycle period, with significant (95%) changes filled.

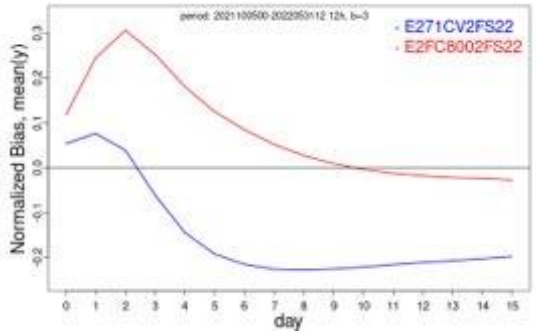
Tropical Tropopause Bias

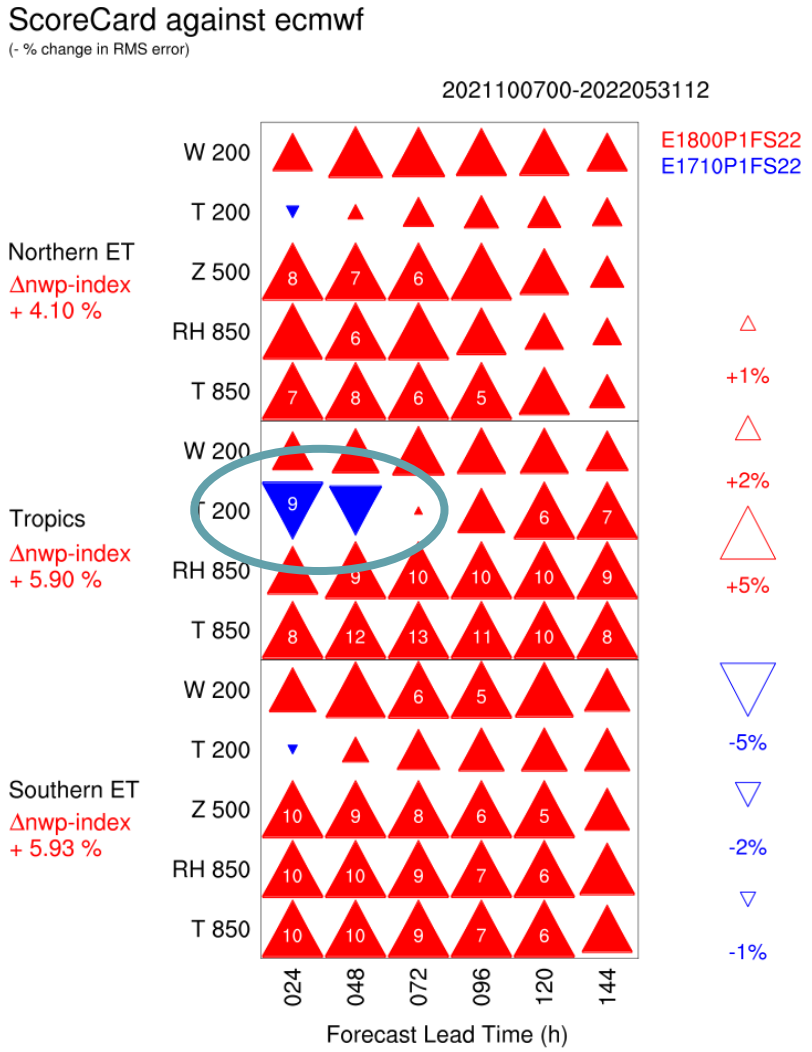
The current GEPS suffers from a warm bias near the tropical tropopause:



Increase in the effective ice radius (from 15 μm to 23 μm) reduces optical depth and leads to cooling of cirrus cloud layers.

More surface insolation prevents ocean cooling; however, upper-air cooling is amplified by ~25% in the new evaluation periods.

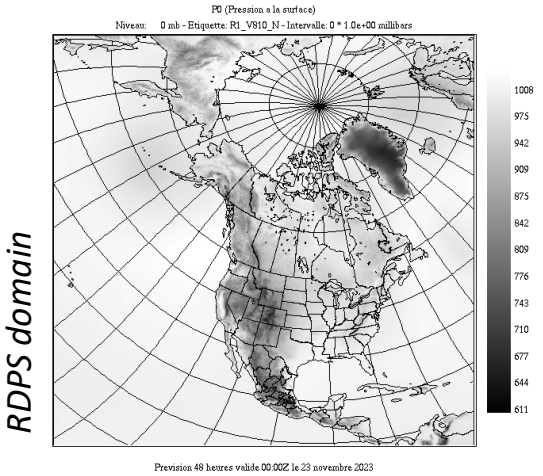




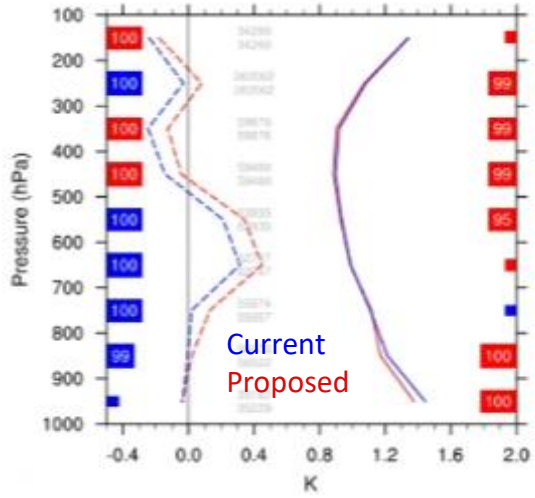
Percentage change in the global control member RMSE for the fall/winter 2021-2022 final cycle period, with significant (95%) changes filled.

Retirement of the RDPS

- CMC has run the Regional Deterministic Prediction System on a 10-km limited-area grid since 2012
- With the global model at 15 km and a national high-resolution model (2.5 km), the RDPS added little value:
  - The RDPS becomes the control member of the regional ensemble system, run on the current RDPS domain (20+1 members)
- A global 10-km Yin-Yang model is used in a discontinuous cycle using the 15 km Global background
  - Forecast skill is generally improved because of global observations and model upgrades (removal of duplicate convective condensate detrainment)
  - “Regional” forecasts are still distributed on the RDPS domain



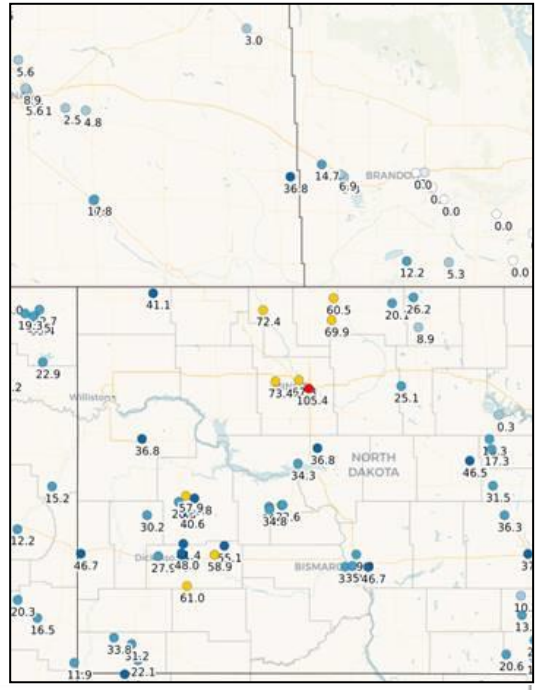
Temperature



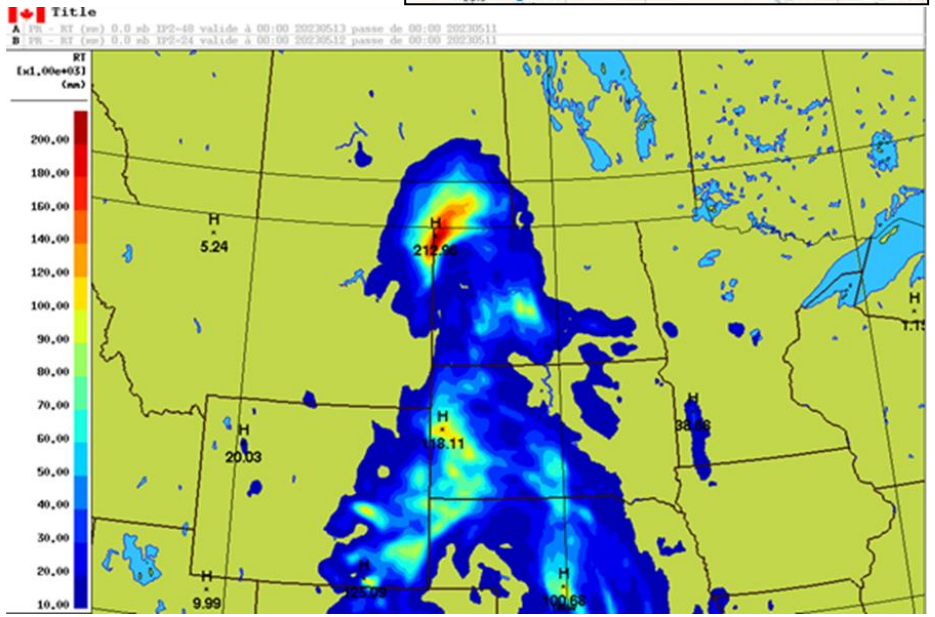
Temperature bias (dashed) and error standard deviation for 2022 summer over North America from aircraft observations.

Heavy Precipitation Case Study

- Forecasters noted a case of significant Global (15 km) and Regional (10 km) model over-prediction of convective rainfall over the Prairies:
  - Predicted accumulations (>200 mm) doubled observed accumulations over 24 h
- A series of sensitivity tests showed that the accumulations were very sensitive to the conservation corrections applied to the Sundvist-type microphysics scheme



CoCoRaHS observations (right) and RDPS predictions (bottom) for 24-h accumulation to 00Z 13 May 2023.



Heavy Precipitation Case Study

- Schemes to conserve total water and moist static energy:
  - Multiplicative tendency correction is applied to enforce conservation when needed (except for the Kain-Fritch deep convection: precipitation correction)
- Reformulation of the microphysics temperature tendency virtually eliminates non-conservation

$$\left(\frac{\partial T}{\partial t}\right)_{cond} \quad \frac{L_{eff}}{c_p}(C-E) - \frac{L_f}{c_p}M_s$$

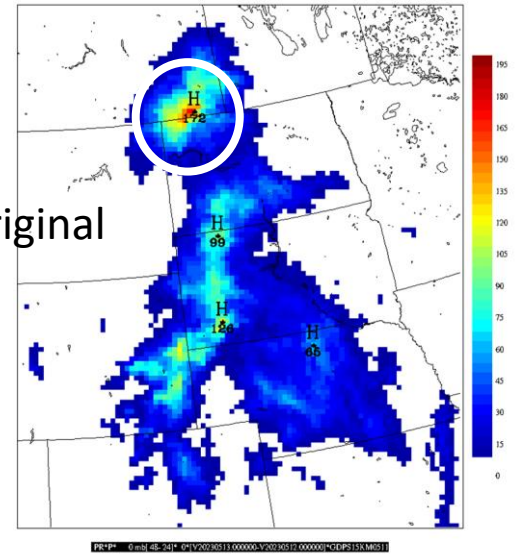
becomes

$$[c_p - L_f(T)q_c\frac{df_{ice}}{dT}]\frac{\partial T}{\partial t} = [-(c_{pv}-c_{pd})T]\frac{\partial q_v}{\partial t} + \hat{L}_{eff}(T)\frac{\partial q_c}{\partial t} + g\frac{\partial}{\partial p}[\hat{L}_l(T)P_l + \hat{L}_i(T)P_i]$$

  - Correcting conservation problems internally is important, so that any “fixer” corrects only numerical errors
- Demonstrates the importance of the conservation project proposed by Peter and Romaine

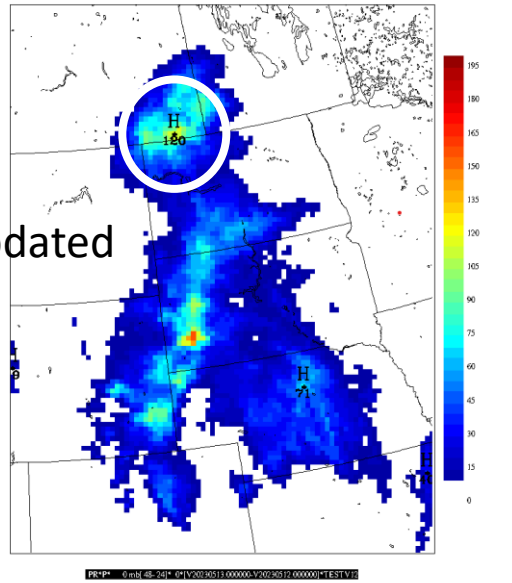
GDPS-**15km** 5.20-rc2
max PR 24-48h = **172 mm**

Original



max PR 24-48h = **120 mm**

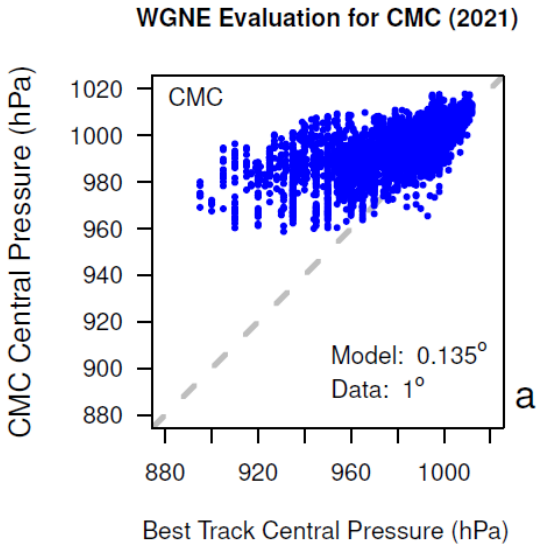
Updated

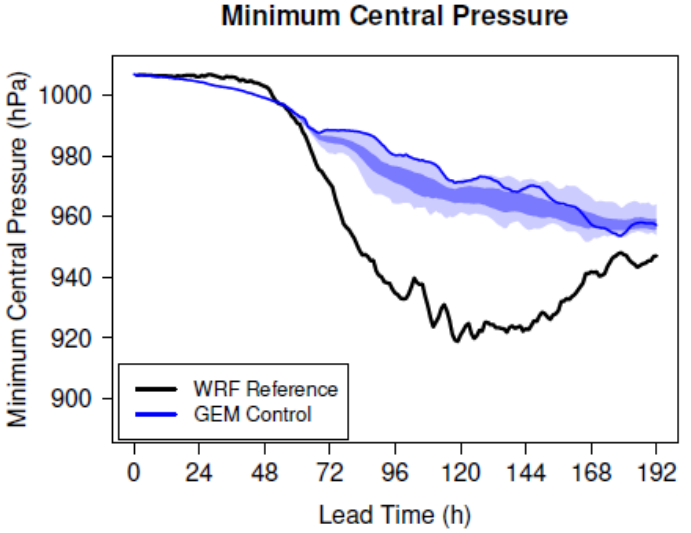


Rainfall accumulations for period on previous slide.

Global Model Tropical Cyclone Intensity

- Success of 2019 physics upgrade in reducing false alarms confirmed by utility noted by NHC forecasters (2023)
- However, both JMA WGNE verif and DIMOSIC results confirm weaker intensities than can be explained by 15 km grid spacing
- A “hierarchy of models” approach is used to eliminate possible sources:
  - A semi-idealized tropical channel simulation reproduces the operational forecast bias
  - A WRF simulation is used as a “reference” solution





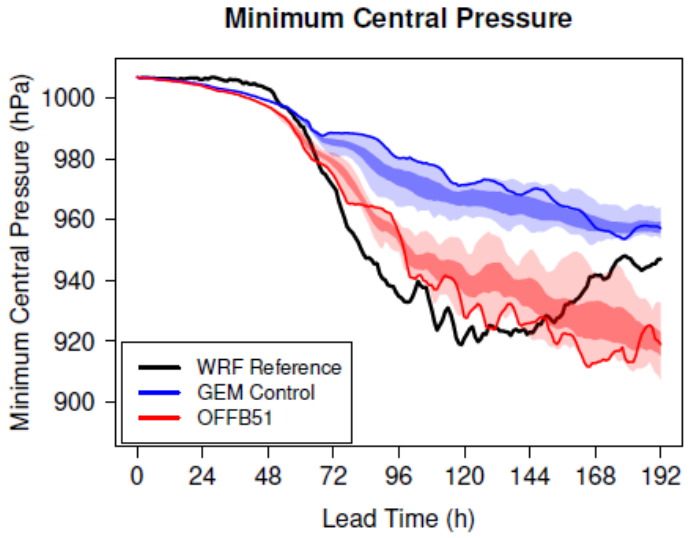
WGNE verification (top) from Masashi Uije, and central pressure evolution in a tropical aqua-channel simulation (bottom).

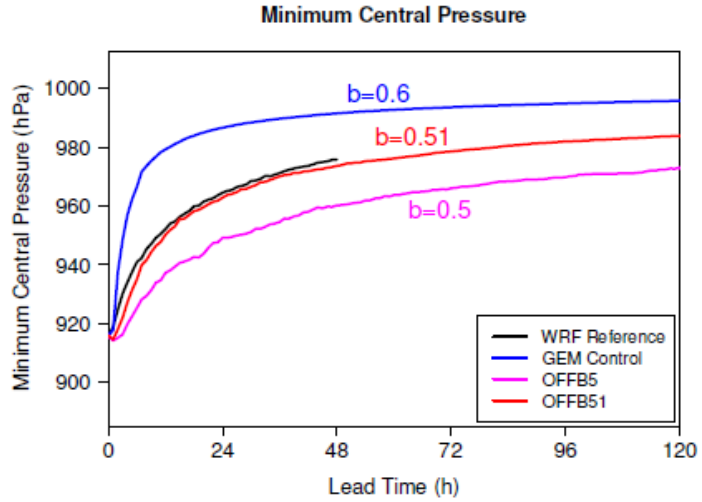
Global Model Tropical Cyclone Intensity

- Introduction of WRF physics into GEM had negligible impact on intensity (!)
- Off-centering (b>0.5) in the implicit semi-Lagrangian dynamical core is the root cause

$$\frac{F_i^A - F_i^D}{\delta t} + bG_i^A + (1-b)\,G_i^D = 0$$

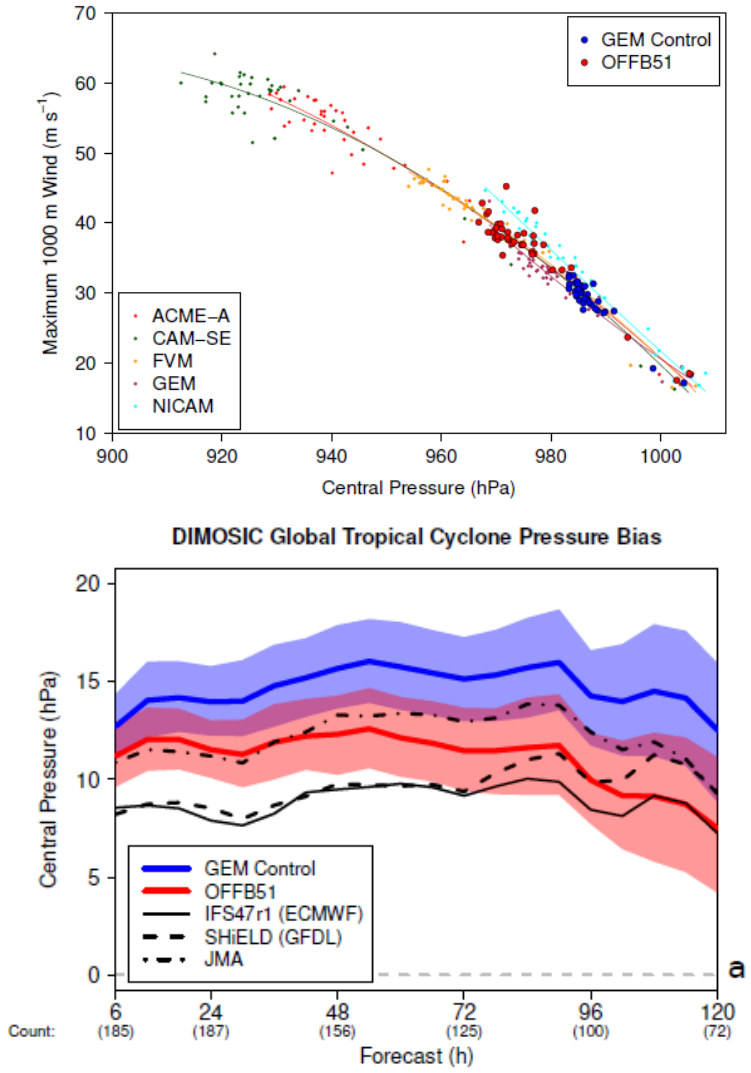
- A vortex spin-down test is used to constrain this "free" parameter that controls resonance and the growth instabilities:
  - Damping effect is timestep-dependent*
  - Leads to imbalance that decelerates and drives inflow





Global Model Tropical Cyclone Intensity

- Structural sensitivity to physical parameterizations is conditional on b<<0.6 (the value used in operational configurations):
  - Conditional sensitivities pose a particular development challenge
- DCMIP-2016 results show that b=0.51 shifts intensity along the expected wind-pressure curve
- A rerun of DIMOSIC shows that GEM's central pressure bias becomes similar to that of other participating models



Wind-pressure relationship in DCMIP-2016 simulations (top) and mean central pressure errors from selected DIMOSIC models (bottom).

Development of AI Roadmap

- Most ML investigations have focused on NWP post-processing
- We have an ongoing project to develop an AI-based emulator for the radiation scheme:
  - Created the ClimART benchmark dataset from climate simulations
  - Some success for clear-sky radiative transfer, but clouds are challenging
- A “tiger team” is working on development of an AI Roadmap for the CMC:
  - Series of seminars from external researchers, vendors and internal experts
  - Follow-up meeting with IBM regarding the possible utility of foundation models for generation of guidance
  - A first iteration of the Roadmap should be ready by the end of 2023

~~The~~ A Future

- Planning for Innovation Cycle 5 is beginning, with an expected delivery near the end of 2025
  - Pace of deliveries is slowed by the complexity of the operational suite, interdependencies and dependent systems
  - Operational transfers must fit between frequent computing upgrades (30 mo)
- Focus for model IC-5 atmospheric model development:
  - Replace pressure-based coordinate with height-based coordinate (stability)
  - Modernize physics configuration in the 2.5 km high resolution system
    - Increase the number of levels and lower the bottom (thermodynamic) level to 10 m
    - Simplify the treatment of clouds by reducing redundancy in parameterized sources, limiting inconsistencies and passing information between schemes
    - Connect PBL and shallow convection in the spirit of an EDMF PBL scheme
    - …