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NWP Centre reports:
Recent upgrades and developments in the use of satellite radiances at ECCC

Alain Beaulne, Josep Aparicio, Seung-Jong Baek, Maziar Bani Shahabadi, Patrice Beaudoin, Joël Bédard, Mark Buehner, Jean-François Caron, Chantal Côté, Ping Du, Normand Gagnon, Sylvain Heilliette, Pieter Houtekamer, Ervig Lapalme, Thomas Milewski, Judy St-James and Yulia Zaitseva

Environment and Climate Change Canada
Canadian Meteorological Center, Dorval, Québec, Canada

Contact: alain.beaulne@ec.gc.ca

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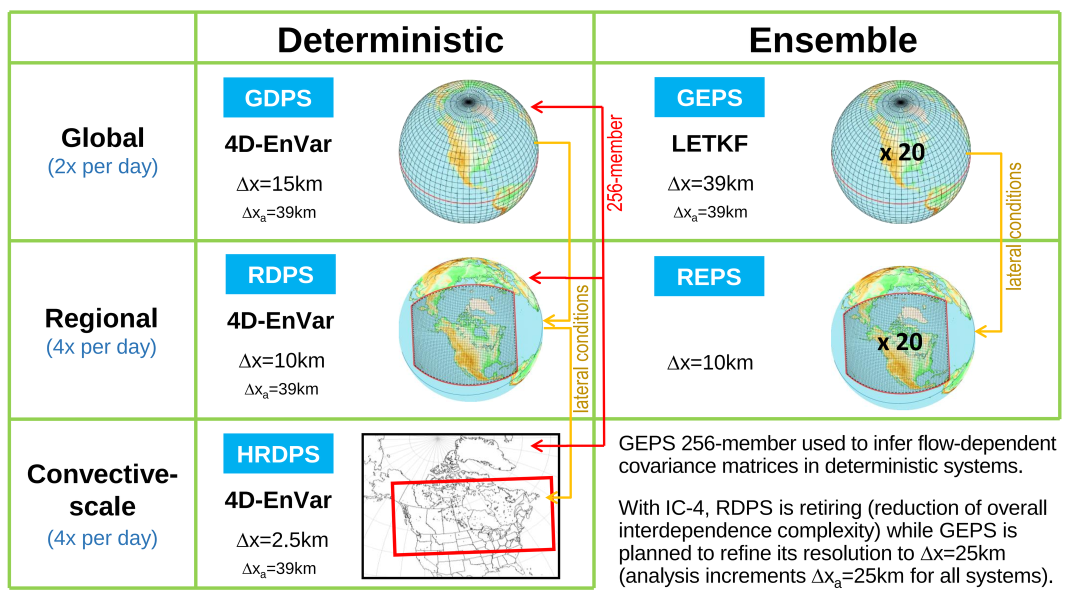
In the context of Environment and Climate Change Canada (ECCC) forecast systems Innovation Cycles (IC), major upgrades are being made, at regular intervals, to the complete operational suite of atmospheric and environmental systems. On December 1st, 2021, **IC-3** implementation consisted in over 170 innovations in 31 systems at all scales.

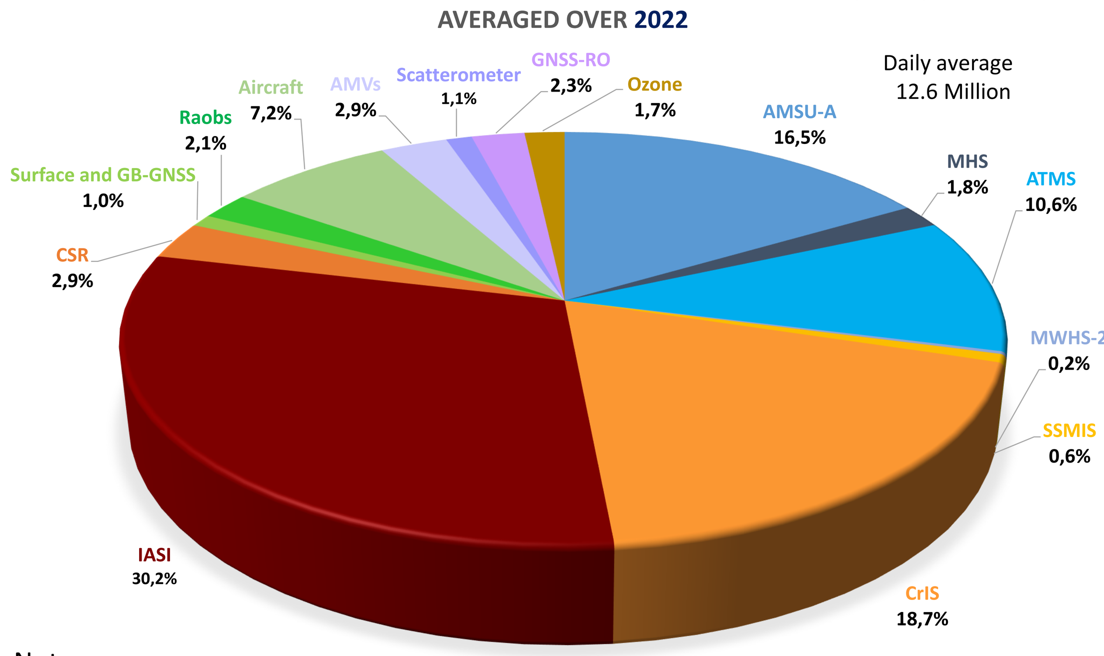
As part of this ambitious entreprise, both the Science and Technology Branch (research) and the Meteorological Service of Canada (development) data assimilation sections have collaborated during IC-3 to develop and test scientific and technical innovations that were implemented in four core atmospheric numerical weather prediction (NWP) systems and are currently working actively in the finalization of new innovations for **IC-4**, which is planned for operational implementation in Summer 2024.

This poster presents the main innovations, impacting satellite radiance data assimilation, that were implemented during IC-3 and envisioned for IC-4.

NWP Systems



Assimilated data



Notes:
- Ozone data only in GDPS
- No data assimilation in REPS
- GEPS: no MWHS-2, SSMIS, CSR and much less number of channels for CrIS and IASI.

IC-3 data assimilation innovations

RTTOV radiance computation on model levels
- Improved computations from the use of prognostic variables on model levels instead of interpolated to the predefined RTTOV levels.

Slant-path computation
- New approach uses slanted viewing geometry by interpolating prognostic variables to a different horizontal position at each model level.

All-sky for AMSU-A channels 4 and 5
- Assimilation in the GDPS of these temperature sensitive radiances over oceans in cloud-affected, non-precipitating areas.

Use of the VIIRS cloud mask for CrIS-FSR quality control
- Allow better detection and rejection of cloud contaminated radiances.

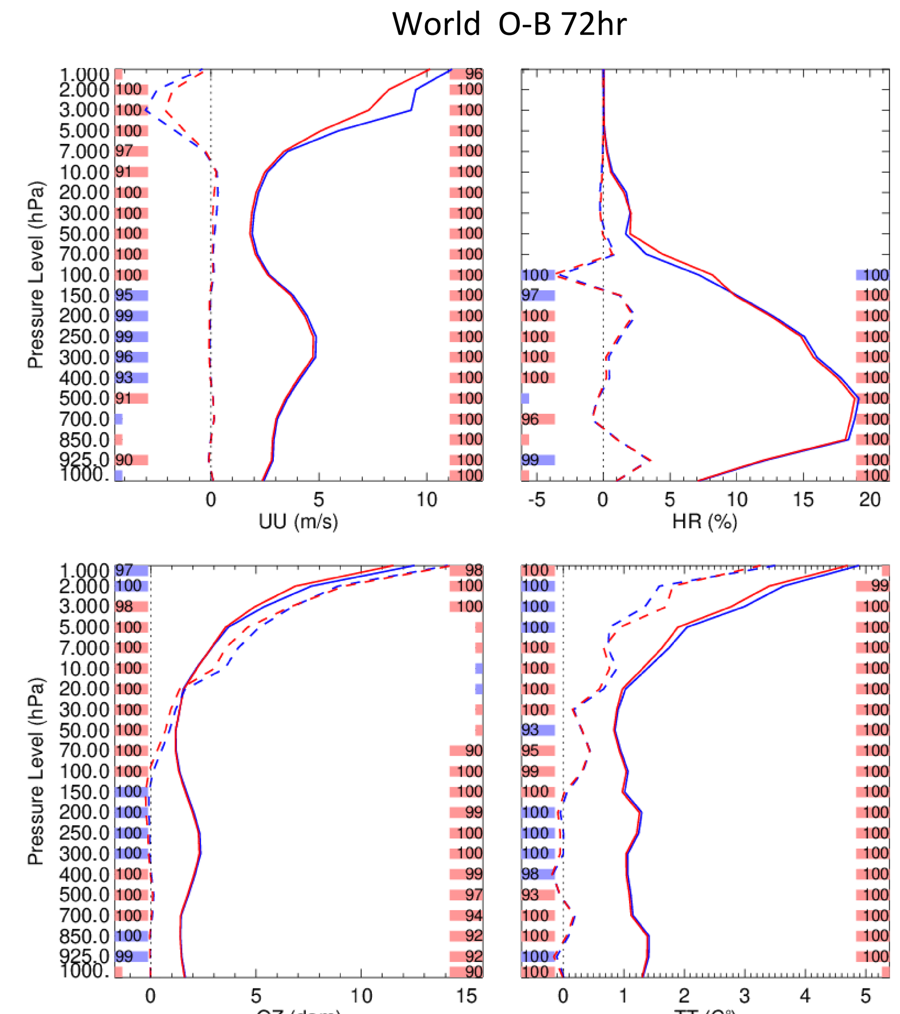
Horizontal scale-dependent localization
- Raw background-error covariances impact areas need to be spatially contained.
- Transition from a unique localization radius (best suited for large scales) to three values more appropriate for large, medium and small scales.

New B matrices weights
- 4D-EnVar uses hybrid background-error covariances as a combination from homogeneous isotropic (Bnmc) and flow dependent (Bens).
- Transition from a « 2/3 Bens – 1/3 Bnmc » approach to a new approach giving full weight to Bens except from mid stratosphere up.

GEPS data assimilation scheme
- Change from perturbed-obs ENKF to LETKF.

Continuous development of MIDAS
- The Modular and Integrated Data Assimilation System is a unified framework for research and operational use aiming to facilitate the transition towards coupled data assimilation of different components of the Earth system (similar to IFS/OOPS (EMCWF) and JEDI (JCSDA).
- Dynamic bias correction stand-alone programs for all radiances has been integrated, in addition to the quality control and thinning of most instruments.
- Integration of LETKF in addition to all pre- and post-processing programs related to the GEPS assimilation cycle.

Plot: Vertical profile verifications (bias = dashed lines, standard deviations = full lines) of 72 hours forecasts against ECMWF analysis for the GDPS Summer 2019 Experiment and Control for main variables over the World. Above 10hPa, improvements in UU are due to the horizontal scale-dependent localization and new B matrices weights innovations, standard deviations of GZ and TT to the RTTOV radiance computation on model levels innovation, whereas heating is expected and due to ozone innovations (not mentioned in this poster). Tropospheric improvements comes mainly from the combined impact of the various data assimilation innovations.



UU = wind speed, HR = relative humidity, GZ = geopotential, TT = temperature
Statistical significance shown for bias (left) and standard deviations (right) of plots.

Assimilated radiance data

These tables indicate the current usage of the various instruments assimilated into the global, regional and high-resolution deterministic systems. Instruments written in green background are planned for on-the-fly implementation within the next year.

Use of Microwave Sounder radiances

Instruments	Satellites	DBNet	Channels			
			sea	sea/low topo	sea/land	All-sky
AMSU-A	NOAA-15/18/19 Metop-B/C	Yes	4, 5	6	7 - 14	4, 5
MHS	NOAA-19 Metop-B/C	Yes	2, 5		3, 4	No
ATMS	NPP, NOAA-20 NOAA-21	No	5, 6, 17 - 19	7, 8, 20 - 22	9 - 15	No
MWHS-2	FY-3C	No	10, 14 - 15	11 - 13		No

Use of Microwave Imager radiances

Instruments	Satellites	DBNet	Channels			
			sea	sea/low topo	sea/land	All-sky
SSMIS	DMSP-17/18	No	12 - 18			No

Use of Geostationary infrared radiances

Instruments	Satellites	Channels				
		sea	sea/low topo	sea/land	CSR	ASR
SEVIRI	MeteoSat-9/11		6.2, 7.3 um		N/A	Yes
ABI	GOES-16 GOES-18		6.2, 6.9, 7.3 um		Yes	No
AHI	Himawari-9		6.2, 6.9, 7.3 um		Yes	No

Use of Hyperspectral Infrared Sounder radiances

Instruments	Satellites	DBNet	Number of channels							
			LW (CO2)		LW (Window)		MW (H2O)		SW (CO2)	
			land	ocean	land	ocean	land	ocean	land	ocean
CrIS	NPP, NOAA-20 NOAA-21	No	44		0	17	29 N/A on NPP		0	13
IASI	Metop-B/C	No	75		0	23	35		0	9

R&D innovations towards IC-4

Upgrade to RTTOV v13 and RTTOV-SCATT
- Use of the latest version of the radiative transfer model in addition to using RTTOV-SCATT for all-sky assimilation of humidity channels.

Purely ensemble-based B matrices in 4D-EnVar
- No more use of an homogeneous isotropic counterpart.

All-sky for ATMS and MHS
- Extension of all-sky assimilation to ATMS temperature channels 5-6 (non-precipitating over ocean) and MHS humidity channels 3-5 (over ocean, using RTTOV-SCATT).

Continuous development of MIDAS
- Finalisation of integration of the quality control processing and thinning procedure for all radiance instruments data.
- Better modularity and consolidation will improve and ease future work in data assimilation development.

Grid-space localization in LETKF
- Currently obs-space localization which increases obs error covariance with increasing distance from the analyzed level and grid point.
- Planned grid-space localization as done in 4D-EnVar, which is appropriate for satellite radiances and improve their assimilation.

Removal of static bias correction of high-peaking channels
- Currently static for AMSU-A ch. 13-14 and ATMS ch. 14-15 (coefficients based on air-mass predictors) to prevent bias drifts. All other radiances dynamic.
- Planned usage of weighted averages of dynamic and static bias correction (ultimate goal would be purely dynamic bias correction for all radiances).

GEPS own radiance processing
- Currently uses already bias corrected and background checked data from the GDPS.

Monitoring and evaluation

Observation impact monitoring tool
- FSOI tool implemented in experimental mode: covers the global and Canadian domains, dry energy norm, tropospheric layer (sfc-100hpa), instrument impact only.
- For IC-4: switch to a moist energy norm, addition of stratospheric layer (100-1hpa) for the global domain, channel-specific impact for radiances with low interchannel correlation (using a simplified R matrix).
- Can be used to monitor R&D work.

Monitoring system and website
- Modernization of the current 20-years old system maintained in R&D.
- New system (coming soon) is built as a unified task sequencer that will be run and maintained in operations, using up to date coding.
- Is configurable and can be used to monitor R&D work.

Enhancing forecast verifications
- Typical evaluation metrics against radiosondes and analyses.
- Current development of a tool to evaluate against various assimilated observations using the observation operators in MIDAS.

Further outlook

Improved convective-scale NWP
- Development of the HREPS with LETKF for providing high-resolution ensemble covariances to the HRDPS system.

Reduced thinning with observation error variance inflation
- Continuation of the work presented during ITSC-XXII

GEPS
- Use of all-sky assimilation