Recent changes in the ECMWF NWP system

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Changes since ITSC-24

New model cycles

Since ITSC-24, ECMWF implemented two substantial upgrades of its Integrated Forecasting System (IFS). The upgrades (**48R1** and **49R1**) had a significant positive impact on forecast skill in the medium range and monthly forecasts. Changes involving passive radiances are summarised below.

Configuration of ECMWF global NWP system:

- Spatial resolution (Ensembles and Control): TCO1279 (≈9km)
- Incremental analysis resolution: TL511 (≈40km)
- Vertical resolution: 137 levels, up to 0.01 hPa
- Assimilation system: 12h 4d-Var with 8h early delivery window; background errors of the day from 50-member Ensemble of Data Assimilations (EDA)

48R1 (27 June 2023)

- Upgrade to RTTOV to V13
- Assimilation of microwave imagers over land surfaces and polar ocean
- Improved treatment of mixed land-water and water-sea-ice scenes for MW instruments
- Extended use of lowest humidity-sounding channels over snow-free land at high latitudes
- Activate ATMS humidity channels over snow
- ATMS Lambertian surface reflection over snow and sea-ice
- Slant-path interpolation for MW humidity sounders assimilated in the all-sky system
- Unified VarBC setup for IR sounders
- Allow usage of all pixels from IASI
- Aerosol type classification in IR data
- Update on the IR trace gas detection
- Details of other aspects of the cycle: **https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+48r1**

49R1 (12 Nov 2024)

- Upgrade to RTTOV to V13.2, including a new neural network-based surface emissivity model (SURFEM)
- Scene dependent observation errors for CrIS (NPP and NOAA-20)
- Increased density of SEVIRI data
- Superobbing and increased density for cross-track MW humidity sounders
- Increased resolution of MW imager superobs (from 80 km to 40 km)
- Activation of AMSU-A window channels (1 and 2)
- Activation of imager channels from F-18 SSMIS
- Hybrid machine-learning/physical sea-ice emissivity scheme, allowing retrieval of sea-ice concentration and assimilation of MW imagers in sea-ice areas
- Revised convective precipitation fraction assumption for all-sky MW assimilation
- Details of other aspects of the cycle: **https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+49r1**

Microwave sounders/imagers usage

	AMSUA (all-sky)	MHS (all sky)	ATMS	SSMIS (all sky)	MWHS2 (all-sky)	GMI (all-sky)	AMSR2 (all-sky)
Metop-B	1-2,5,8-14	3-5					
Metop-C	1-2,5-7,9-14	3-5					
NOAA-15	1-2,5,7-10,12-13						
NOAA-18	1-2,5-7,10-14						
NOAA-19	1-2,5-6,9-14	4-5					
S-NPP			6-15,18-22				
NOAA-20			6-15,18-22				
NOAA-21			6-15,18-22				
F-17				8-14,16-17			
F-18				9-14,17			
FY-3D					2-7,11-15		
FY-3E					2-7,11-15		
GCOM-W1							5-11,13
GPM						1-6,8,10-13	

Table 1: Assimilated microwave sounding/imaging channels (for up-to-date status check https://obsstatus.ecmwf.int/)

Main MW changes:

Thinning + superobbing for MW Humidity sounders

- *Made possible by the increase of inner-loop resolutions*
- *140% more usage of 183GHz radiances*
- Improves stdev(o-b) for various observations sensitive to lower-tropospheric humidity or wind; neutral for medium range
- *Improved short-range forecast metrics of humidity and winds (particularly in the Southern Hemisphere)*

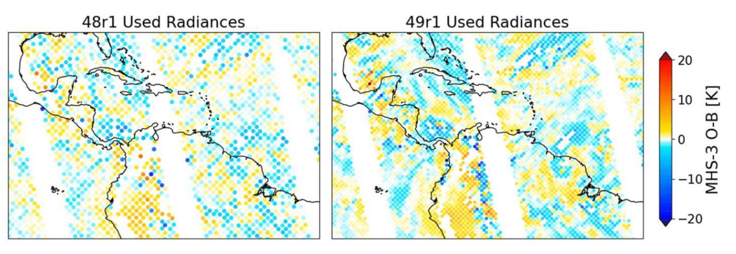

Fig 1: Background departures (O-B) for assimilated radiances from Metop-B MHS channels 3 over central America. The left shows data usage at Cy48r1 (111km spacing). Right shows Cy49r1 (70km spacing with 50km superobbing).

Machine learning Sea ice fraction from microwave imagers

- *Combination of machine learning and data assimilation to simultaneously estimate the sea ice fraction from microwave imager. Allowed new empirical surface emissivity model*
- *New sea ice estimation activated for two microwave sensors (AMSR2 and GMI) in cycle 49r1*
- *For more details see poster 7p01 by N. Bormann)*

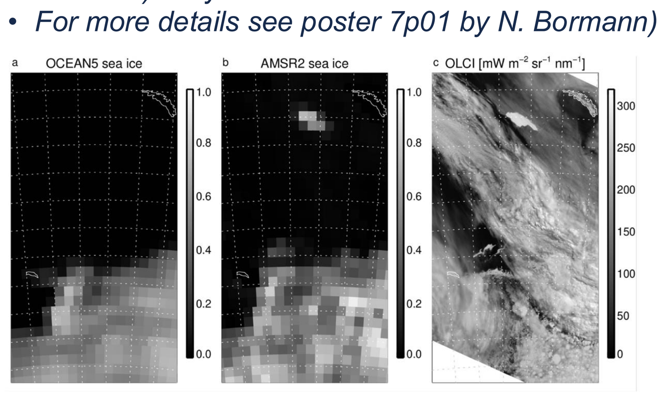

Fig 2: Sea-ice in Antarctica showing iceberg A-68A in 4th Dec 2020. Sea-ice fraction from OCEAN5 analysis (left), Derived Sea ice from AMSR2 (middle) and OLCI visible radiances from Channel 10 (right).

AMSU-A Window Channel Assimilation

- *Extend the usage of AMSUA to 23.8 and 31.4 GHz channels (already used from other MW imagers)*
- *Improves temporal sampling of All-sky radiances in the tropics to constrain the low-level moisture, winds and clouds*
- Improved stdev(o-b) for various observations sensitive to lower-level humidity or wind
- Comparable impact to MW imagers (when these are not used). Smaller impact in a full observing system

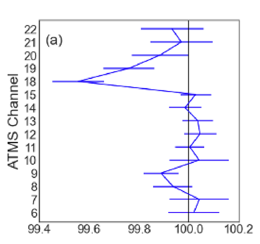

Fig 3: impact of assimilating AMSUA Ch 1 and 2 measured by the normalised change in std. dev. of FG departures against ATMS. Below 100% indicate improvements.

ATMS Lambertian surface reflection over snow and sea-ice

- *Lambertian reflection leads to better simulations over snow and sea-ice for 183 GHz channels*
- *Helped activate ATMS humidity channels over snow*

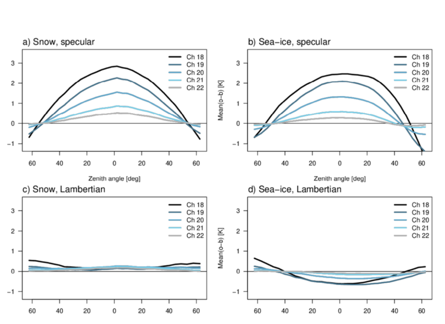

Fig 4: impact of Lambertian reflection on the simulation of ATMS humidity channels over snow (left panels) and sea-ice (right panels).

Slant-path interpolation for MW humidity sounders assimilated in all-sky

- *Stand satellite geometry fully taken into account in the simulation and assimilation of all sky radiances from selected sounders*
- *Significant improvements in the simulation of brightness temperatures from model fields. This is most noticeable for large zenith angles for upper tropospheric and stratospheric channels*
- *Overall positive impact*

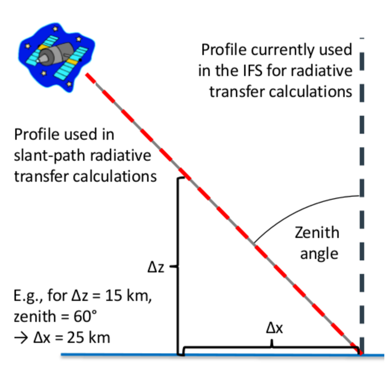

Fig 5: Slant-path application geometry

Geostationary radiances usage

	SEVIRI	ABI	AHI
METEOSAT-10	6.2 and 7.3 micron (WV)		
METEOSAT-9	6.2 and 7.3 micron (WV)		
GOES-18		6.3, 6.9 and 7.3 micron (WV)	
GOES-19		6.3, 6.9 and 7.3 micron (WV)	
HIMAWARI-9			6.2, 6.9 and 7.3 micron (WV)

Table 3: Assimilated geostationary radiances

Main GEOS changes:

Increased density of SEVIRI data

- *Density of SEVIRI radiances increased from 125 km to 75 km leading to ~ 3 times increase of used data*
- Improved stdev(o-b) for various observations sensitive to humidity

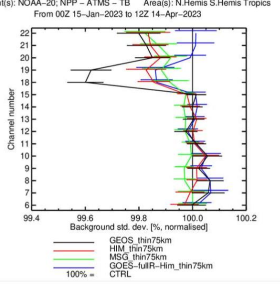

Fig 6: impact of reduced thinning of radiances from Geostationary satellite measured by the normalised change in std. dev. of FG departures against ATMS. Below 100% indicate improvements.

Timeline of main operational changes applied to radiances

DJF 2023
- Activation of GOES-18 CSR
- Re-activation MWHS2/FY-3D (ch 2 to 7)
- Activation of MWHS2/FY-3E
- GOES-17 CSR retired
- Metop-B/AMSUA Ch 7 excluded

MAM 2023
- Activation of MET-10 ASR
- MET-11 ASR excluded
- SNPP/CrIS excluded (unwanted bias change)

JJA 2023
- Implementation 48R1
- Activation NOAA-21/ATMS
- AMSUA Obs Errors update: NOAA-18 (Channel 5) and Metop-C (Channels 5, 7 and 8)
- SNPP/CrIS failed

SON 2023

DJF 2024
- Activation NOAA-21 CrIS

MOM 2024

JJA 2024
- Metop-C AMSUA Ch8 blocklisted
- Metop-C/AMSUA Ch5-7 excluded over sea-ice and snow

SON 2024
- Implementation 49R1
- Improve usage DBNet (MHS, AMSUA and ATMS)
- Long outage SNPP/ATMS (10 weeks)
- FY-3C/MWHS2 retired

DJF 2025
- **Activation CrIS Short Wave channels**
- SNPP/ATMS re-activated
- Metop-B/AMSUA Ch 5 excluded over land and sea-ice

MAM 2025
- Monitoring MET-12 ASR
- Monitoring GOES-19 CSR
- NOAA-21 CrIS excluded (for 3 weeks)
- GOES-16 CSR retired

https://confluence.ecmwf.int/display/FCST/Observations+data+events

Radiative transfer

- **Upgrade to RTTOV 13.0 (48R1): Improved RTTOV-SCATT and revised gas optical depth coefficients for the MW sensors**
- **Upgrade to RTTOV 13.2 (49R1):**
  - New SURFEM emissivity model trained on PARMIO reference model (supports sub-mm frequencies, 6 – 10 GHz and future stokes instruments such as WSFM/CIMR)
  - Measured GMI spectral response functions: replace idealised top-hat functions with pre-launch measured values
  - New neural network-based surface emissivity model (SURFEM)
- **Impact:**
  - Improved background fit to microwave observations at lower frequencies. Some slight worsening at higher frequencies
  - Reduced RMSE (against own analysis) scores in the southern high latitudes, likely correspond with the improved high windspeed behaviour

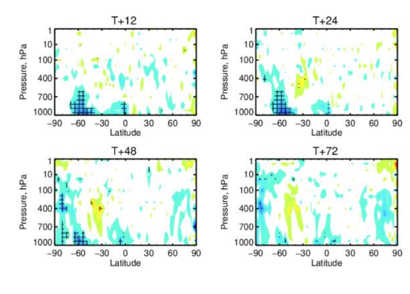

Fig 7: Normalised difference in RMSE of temperature forecasts resulting from the upgrade to RTTOV 13.2 compared to 13.0

Hyper-spectral infrared sounders usage

	Long-wave	Window + Ozone	Water Vapour	Short-wave
Metop-A IASI	153	28	32	7
Metop-B IASI	153	28	32	7
AIRS	80	27	7	19
NOAA-20 CrIS	88	23	36	60
NOAA-21 CrIS	88	23	36	60

Table 2: Number of channels used channels (for up-to-date status check **https://obsstatus.ecmwf.int/)**

Main IR changes:

Scene-dependent observation errors for hyperspectral IR

- *Modelling of observation errors in the short-wave band to make them dependant on the magnitude of the signal (larger for colder scenes)*
- *Errors are prescribed in radiance space and dynamically mapped to Brightness temperatures (assimilated)*
- *Improved fit to observations*
- *Positive impact in the short range*

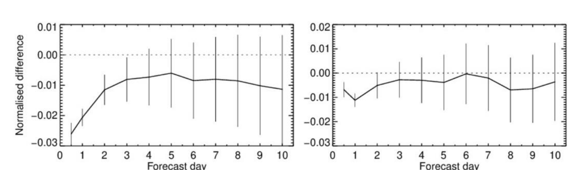

Fig 8: Impact of assimilating short-wave CrIS channels in addition to long- wave channels with scene dependent errors on 500hPa geopotential height verified against operational analyses, for the Southern Hemisphere (left) and Northern Hemisphere (right). Negative values indicate a reduction in geopotential height RMSE

Main upcoming radiance changes (cycle 50R1)

The upcoming ECMWF model cycle 50R1 (expected to be implemented in Q4 2025) will include significant various data assimilation changes:

- Improved radiative transfer model RTTOV-14
- Further reduced thinning for Geostationary radiances
- Skin temperature estimates from AMSR2, GMI and geostationary imager radiances used in the coupled ocean-atmosphere assimilation system
- Improved use of All-sky MW over sea-ice
- Assimilation of 183 GHz channels over high orography
- Further reduced thinning for Geostationary radiances and assimilation of the window channel
- Scene dependent observation errors for IASI

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