CERRA - Copernicus European Regional ReAnalysis

Impact of Satellite radiances in an European Reanalysis System

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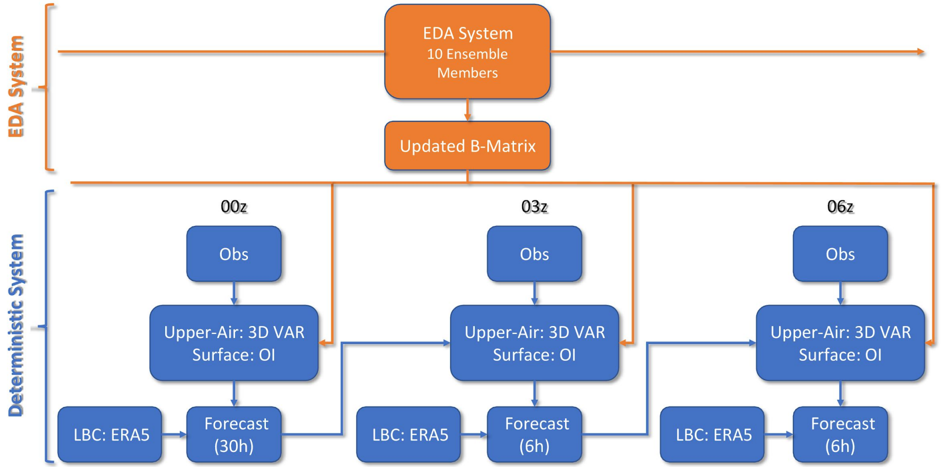
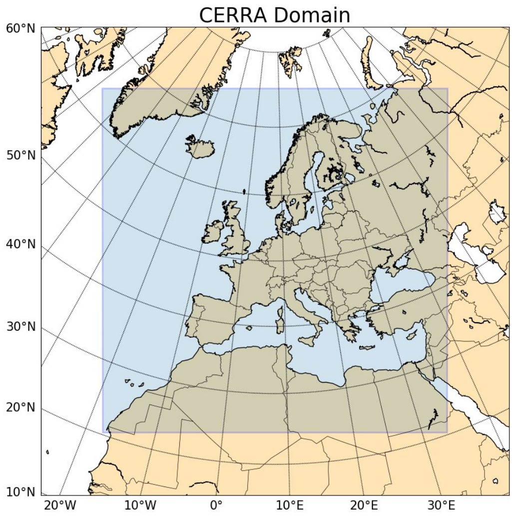
Outline

- ➢ CERRA system & satellite observations in CERRA system
- ➢ Impact of radiance observations
- ➢ Tuning of the radiance assimilation
- ➢ Concluding remarks

CERRA reanalysis system





NWP system:

-- 10 member EDA at 11 km resolution
-- High-resolution det syst. at 5.5 km res.
-- Using Aladin physics
-- LBC: ERA5
-- 106 vertical levels
-- OI for surface assimilation
-- 3D-Var upper-air assimilation

Observations:

-- Conventional (including local)
-- Satellite

Period:

-- From early 1980s to near real time.

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Satellite observations in CERRA

Satellite (based) Observations		
Instrument	**Satellites**	**Location / Origine**
Advanced Microwave Sounding Unit –A (AMSU-A)	NOAA – 15, 16, 18, 19 MetOp-A, B, C	MARS Archive, ECFS
Advanced Microwave Sounding Unit –B (AMSU-B) and Microwave Humidity Sensor (MHS)	NOAA – 16, 17, 18, 19 MetOp – A, B, C	MARS Archive, ECFS
Microwave Sounding Unit (MSU)	NOAA-6, 7, 8, 9, 10,11,12,14	MARS Archive
Infrared Atmospheric Sounding Interferometer (IASI)	MetOp – A, B,C	EUMETCast, Reprocessed, ECFS
Atmospheric Motion Vectors (AMV)	NOAA, MetOp – A, B,C, METEOSAT	MARS Archive
Scatterometer	NSCAT– ERS2, Seawinds – QuickSCAT, OceanSat2 - OceanSCAT, Metop - A, B, C – ASCAT	EUMETSAT Data Center
GPS Radio Occultation (GPS-RO)	Metop, COSMIC, CHAMP, GRACE	Reprocessed Climate Data Records
Ground - Based GNSS - ZTD (GPS-ZTD)	GPS and GLONASS	Reprocessed data

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The default thinning distance

Instrument	RMIND_RAD1C (km)	RFIND_RAD1C (km)
AMSU-A	60	80
AMSU-B	40	80
MHS	40	80
IASI	60	80

The active channels

Instruments	Satellite Platform	Channels
MSU	NOAA - 6, 7, 9, 10, 11, 12, 14	2,3,4
AMSUA	NOAA - 15, 16, 18, 19, Metop - A, B, C	5,6,7,8,9
AMSUB	NOAA - 16, 17, 18,	3,4,5
MHS	NOAA - 19 METOP - A, B, C	3,4,5
IASI	METOP - A, B, C	38, 51, 63, 85, 104, 109, 167, 173, 180, 185, 193, 199, 205, 207, 212, 224, 230, 236, 239, 242, 243, 249, 296,, 337, 345, 386, 389, 432, 2701, 2819, 2910, 2919, 2991, 2993, 3002, 3008,3014, 3098, 3207, 3228, 3281, 3309, 3322, 3438, 3442, 3484,3491, 3499, 3506, 3575, 3582, 3658, 4032

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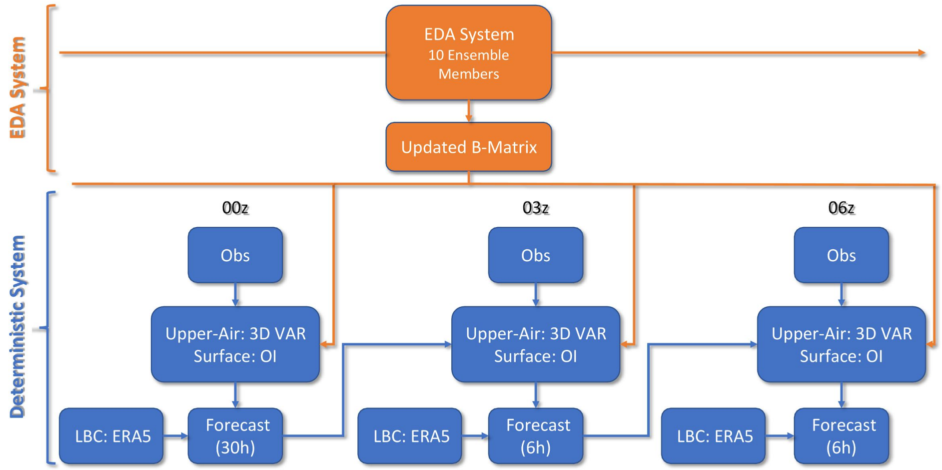
The performed long experiment runs



-- Full system was used in this study:
  -- EDA + high-res system

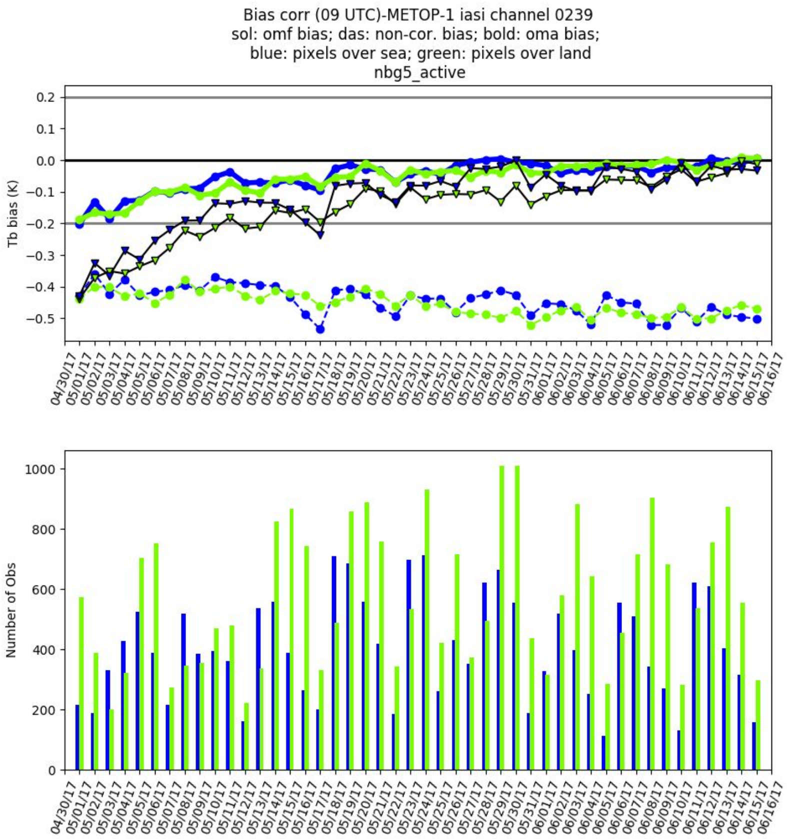
-- NoSatRad: All obs except radiances
-- AllSatRad: All obs including radiances

Verification periods:
  -- Dec 21, 2017 - Jan 15, 2018
  -- May 29 - June 18, 2018

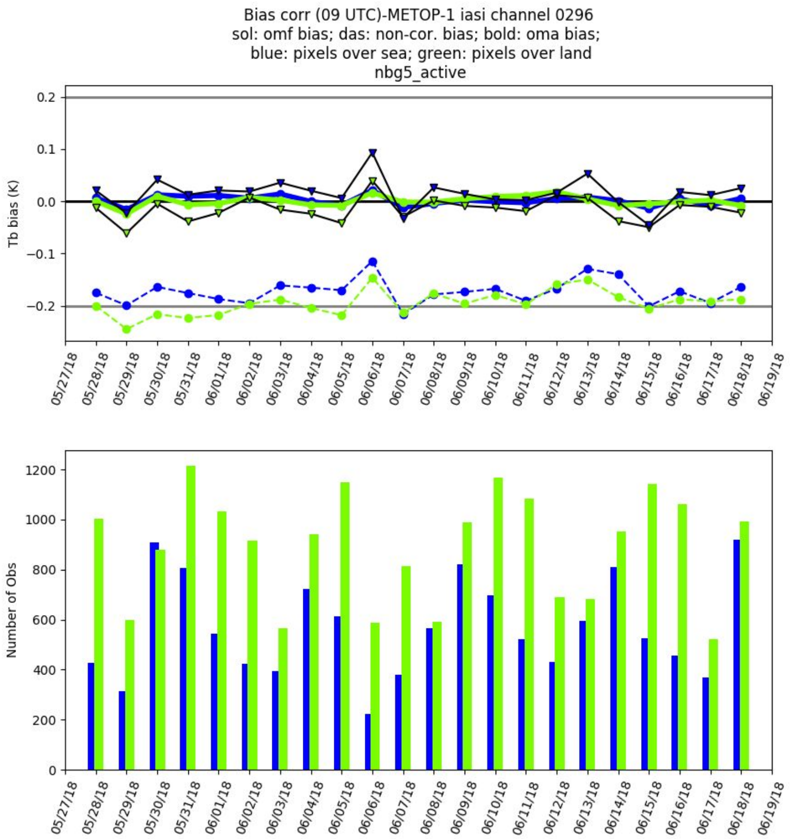
  -- Long forecasts (24 h): 00 and 12 UTC

Spinup of VarBC coefficients

Spinup period



Active assimilation



Spinup of VarBC coefficients

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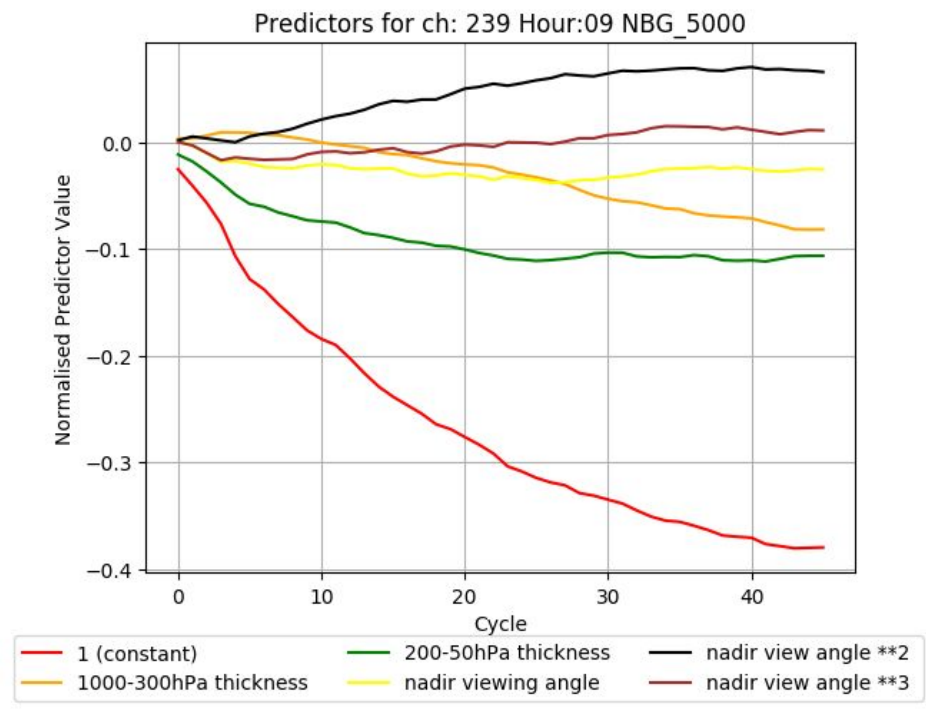
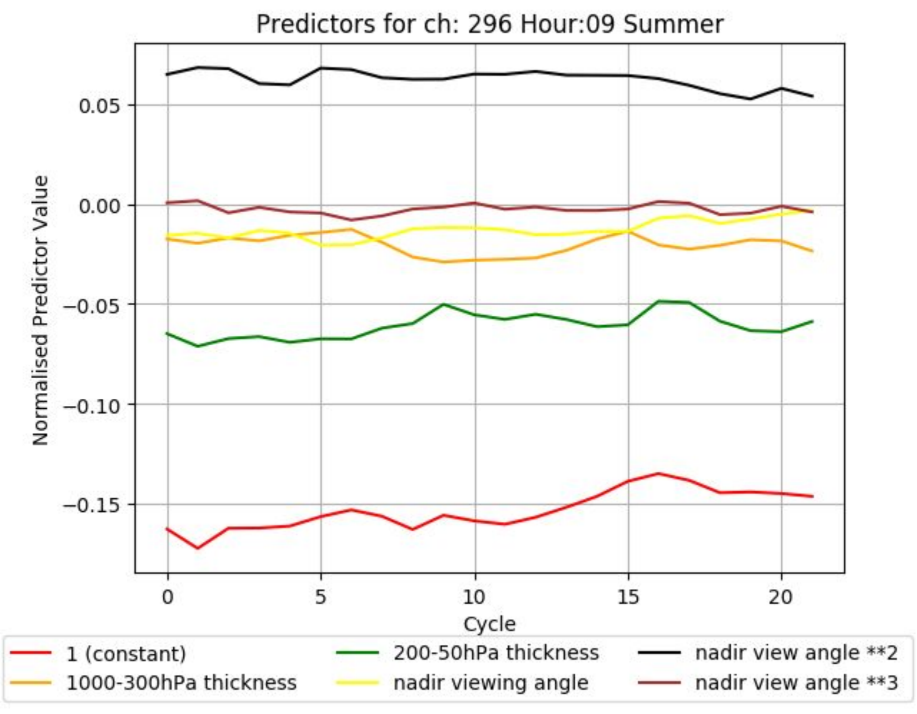
Spinup period



Active assimilation



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Sensitivity of CERRA analysis to the observations -- a full day mean DFS

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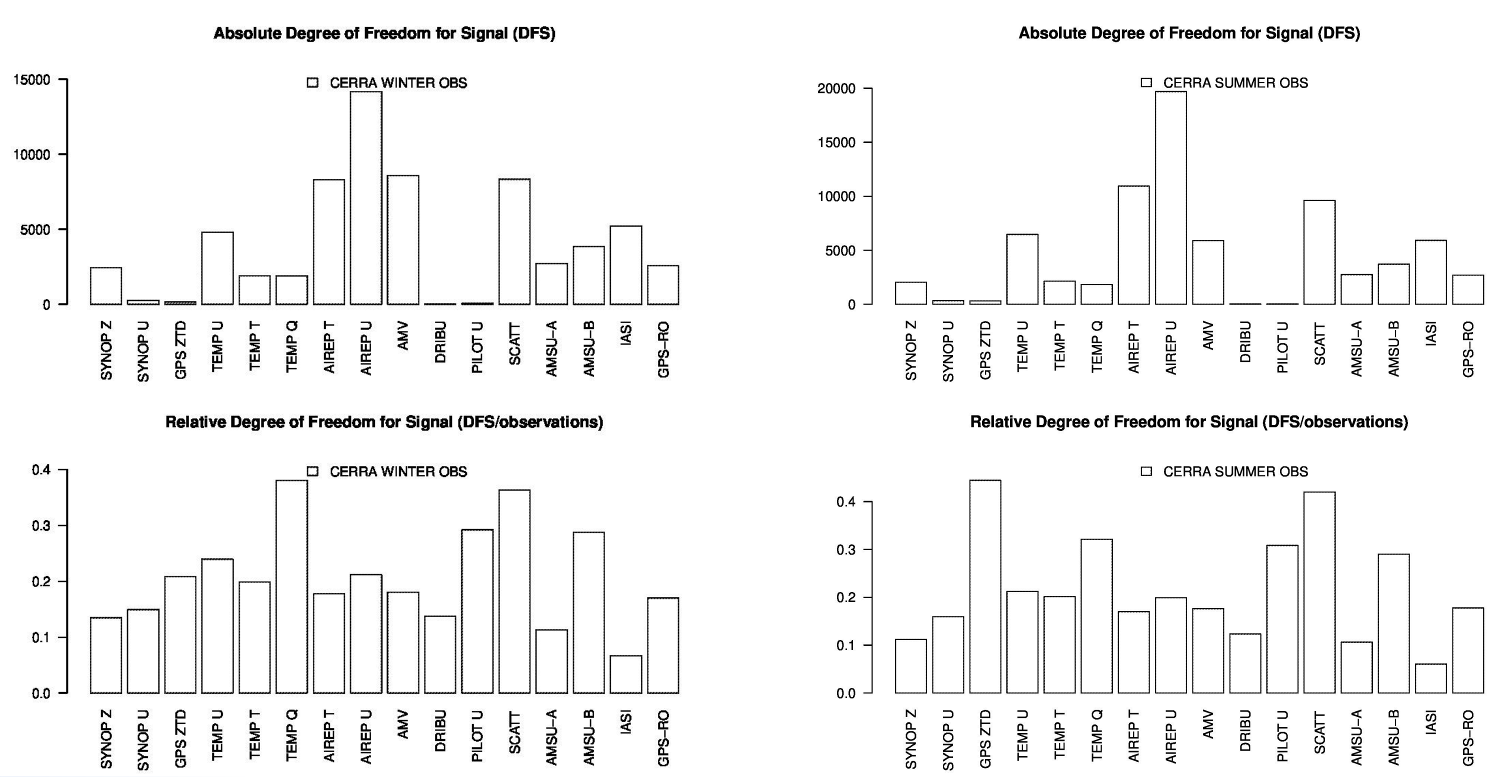
Degrees of Freedom for Signal (DFS) - one day, computed from all assimilation times



Winter Dec 26, 2017

Summer June 11,2018

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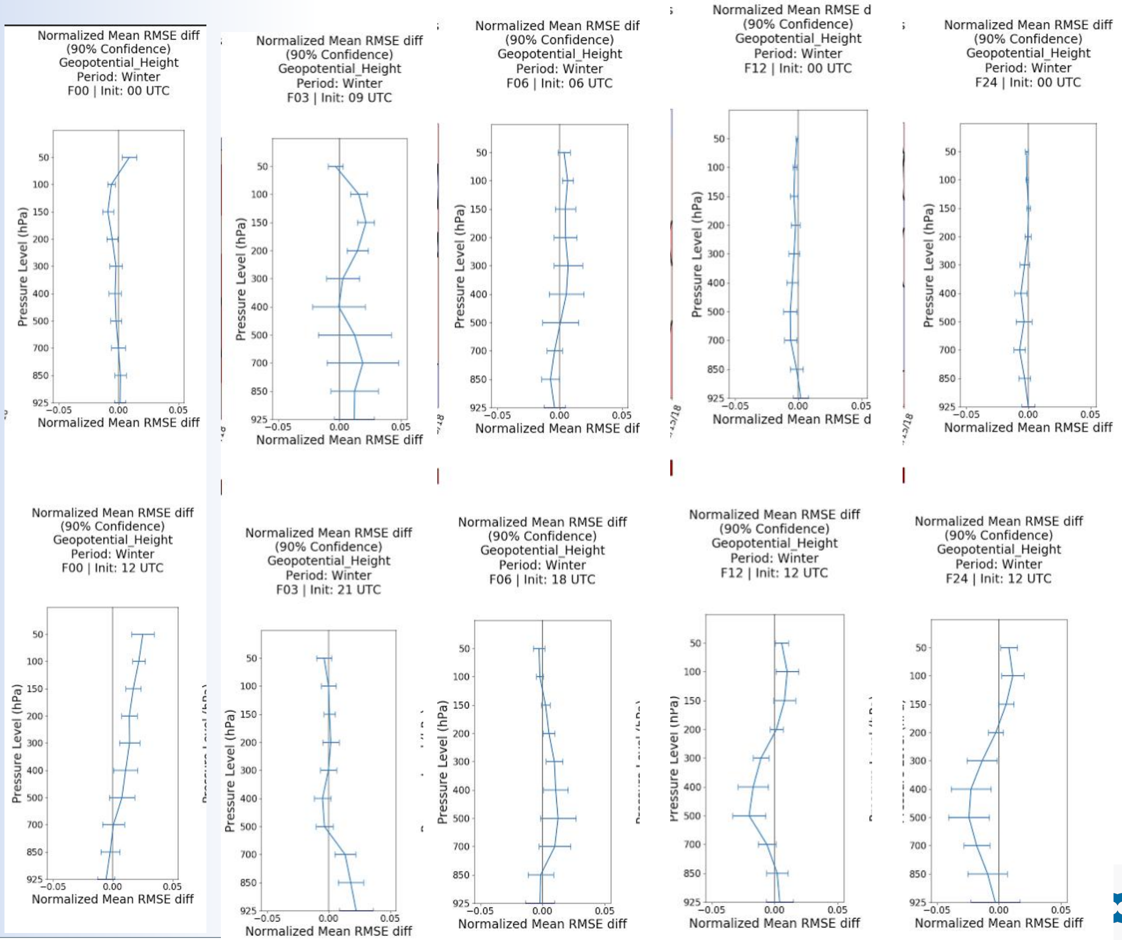
Impact of AllSatRad, verif. at available radiosonde times (00, 12 UTC)



Winter period:
Dec 21, 2017 - Jan 15, 2018

Positive /negative
⇒ negative / positive impact

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Impact of AllSatRad, verif. at available radiosonde times (00, 12 UTC)

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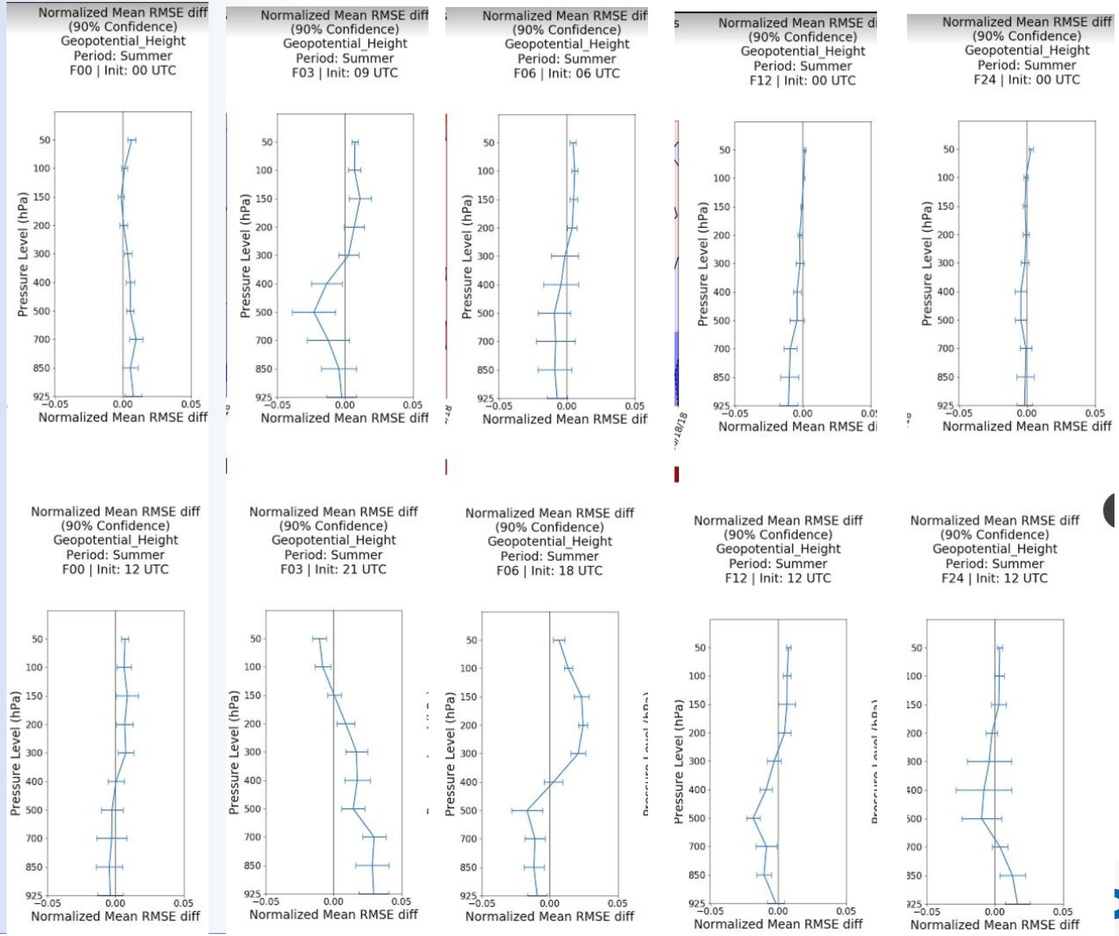

Summer period:
May 29, 2018 - Jun 18, 2018

Positive /negative
⇒ negative / positive impact

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Impact of AllSatRad on CERRA forecast

Sensitivity of the forecasts to the used observations using Moist Total Energy Norm (MTEN) (Storto and Randriamampianina, 2010)

wants to be evaluated. The impact of the observations is evaluated by means of a cost function, given as

$$J = \left\langle M_t(\mathbf{x}^{a}_{ctr}) - M_t(\mathbf{x}^{a}_{i}),\quad M_t(\mathbf{x}^{a}_{ctr}) - M_t(\mathbf{x}^{a}_{i}) \right\rangle, \qquad (2)$$

where $\mathbf{x}^{a}_{ctr}$ and $\mathbf{x}^{a}_{i}$ are the analysis from the "all-observation" experiment and that with the withholding of the *i*-th observing group, respectively, M_t is the (fully non-linear) forecast model operator and $\langle \ldots, \ldots \rangle$ stands for the moist total energy norm, defined as in Ehrendorfer *et al.* (1999):

$$\left\langle \mathbf{x}^{i}_{t} - \mathbf{x}^{ctr}_{t}, \mathbf{x}^{i}_{t} - \mathbf{x}^{ctr}_{t} \right\rangle = \int_{\eta_0}^{\eta_1}\int_{D} \left(u^2 + v^2 + \frac{c_p}{T_r}T^2 + \frac{RT_r}{p_r^2}p^2 + \frac{L^2}{c_p T_r}q^2 \right) \frac{\partial p_r}{\partial \eta} d\eta\, dD \qquad (3)$$

where u, v, T, p, q being respectively the difference of *u*- and *v*-component of wind, temperature, surface pressure and specific humidity between the control forecast and the one without the *i*-th set of observations; c_p, R, L are specific heat at constant pressure, gas constant of dry air, and latent heat condensation; T_r and p_r are reference temperature and reference pressure; η is the vertical coordinate. The previous norm is integrated over all the vertical levels between η_0 and η_1 and over the domain D, which may coincide with the whole model domain depending on the definition of the localisation operator **P**. In our case, for example, the AROME-Arctic domain was divided into four equal sub-domains (*see Fig*

Impact of AllSatRad on CERRA forecast

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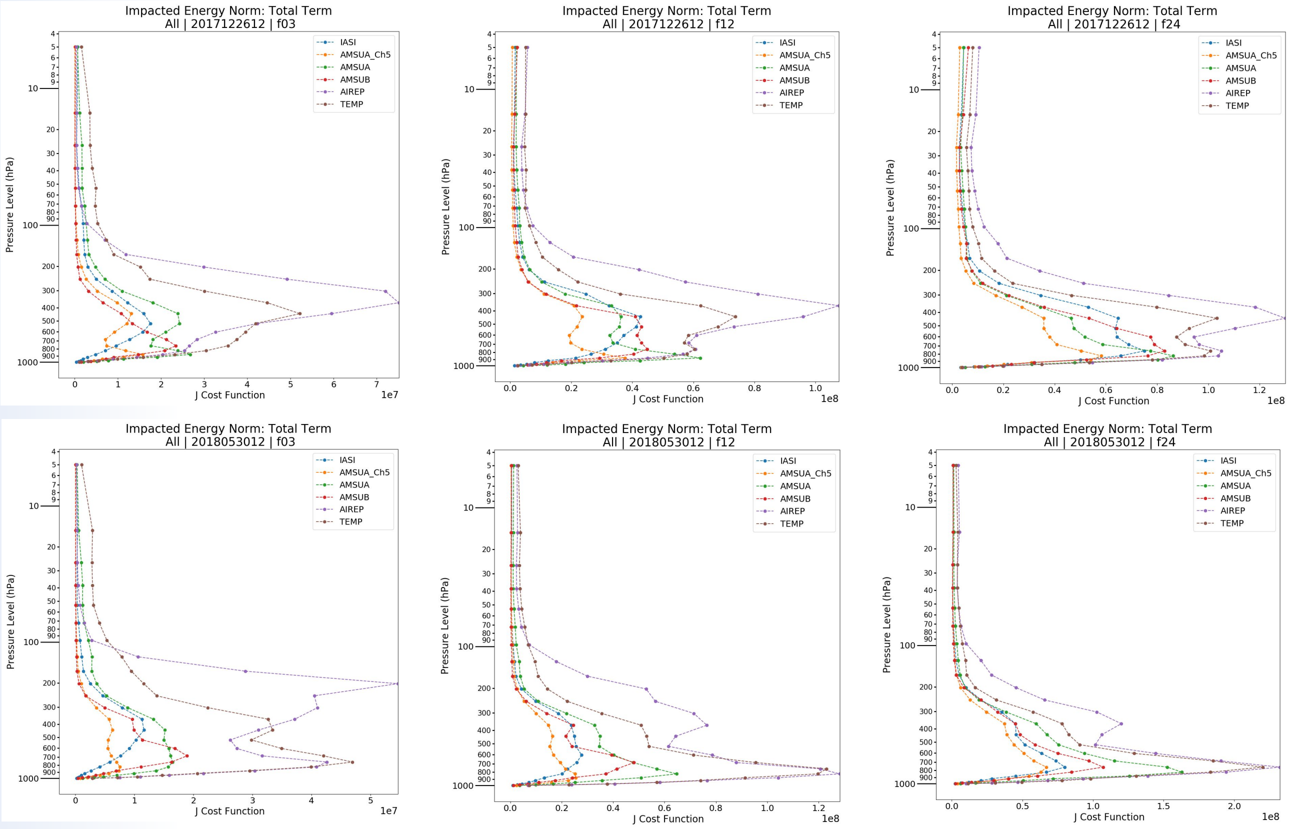

Winter case

Summer case

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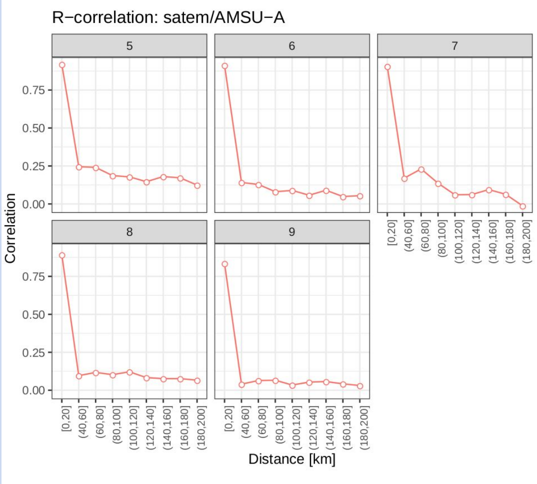
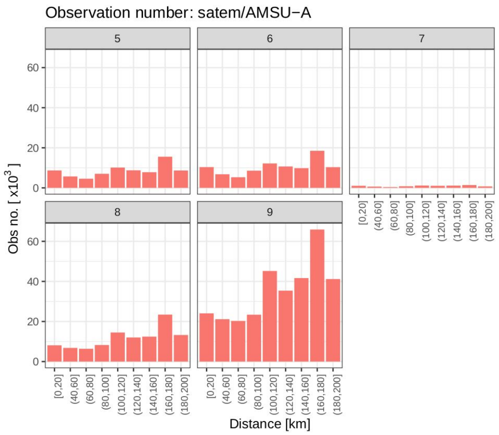
Impact of AllSatRad, verif. at available radiosonde times (00, 12 UTC)





Statistics over a month.

Obstool:

Liu and Rabier (2003) found in a simulation study that the smallest analysis error was obtained when a thinning scale corresponds to the distance at which error correlation of temperature (or radiances) reaches 0.2. This is for the case when error correlations in R are neglected and the diagonal observation errors are not inflated.

Correlated observations:

(Bormann and Bauer, 2010; Bédard and Buehner, 2020)

-- Relax the thinning distance
-- Increase the observation errors

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Impact of AllSatRad, verif. at available radiosonde times (00, 12 UTC)

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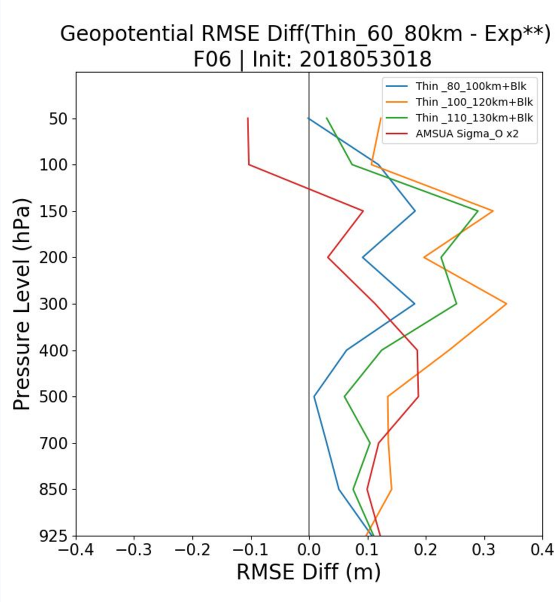

Single analysis time testing

Chosen time: May 30, 2018 18 UTC

Tested: different thinning distances

- -- 80 / 80 km
- -- 80 / 100 km
- -- 100 / 120 km
- -- 110 / 130 km
- -- blacklisting of 6 IASI ch
- -- Increase of obs error 2x
- -- IASI assim over sea only

⇒ **best setting:**

-- 100 / 120 km; blackl. of 6 IASI ch; and IASI data over sea only

Six IASI ch:

-- 104, 180, 2991, 3098, 3309, 3506

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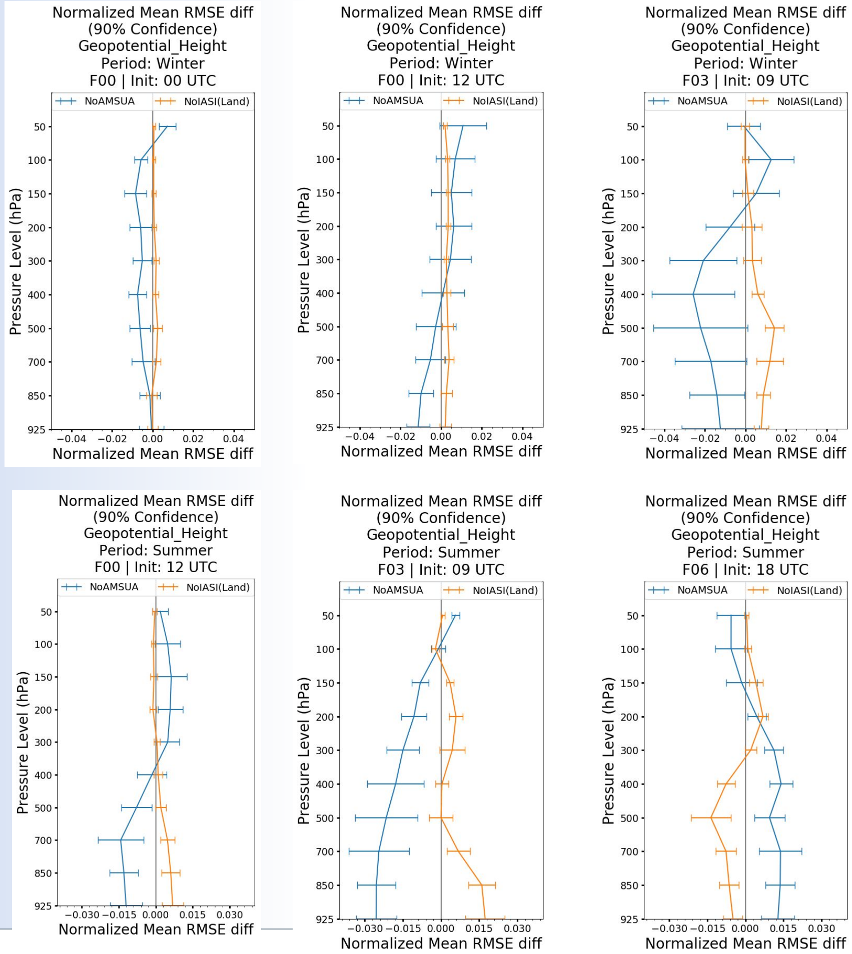
Impact of AMSU-A and IASI over land



Blue lines: impact of AMSU-A

Orange line: impact of IASI over land

Positive / negative ⇒ negative / positive impact

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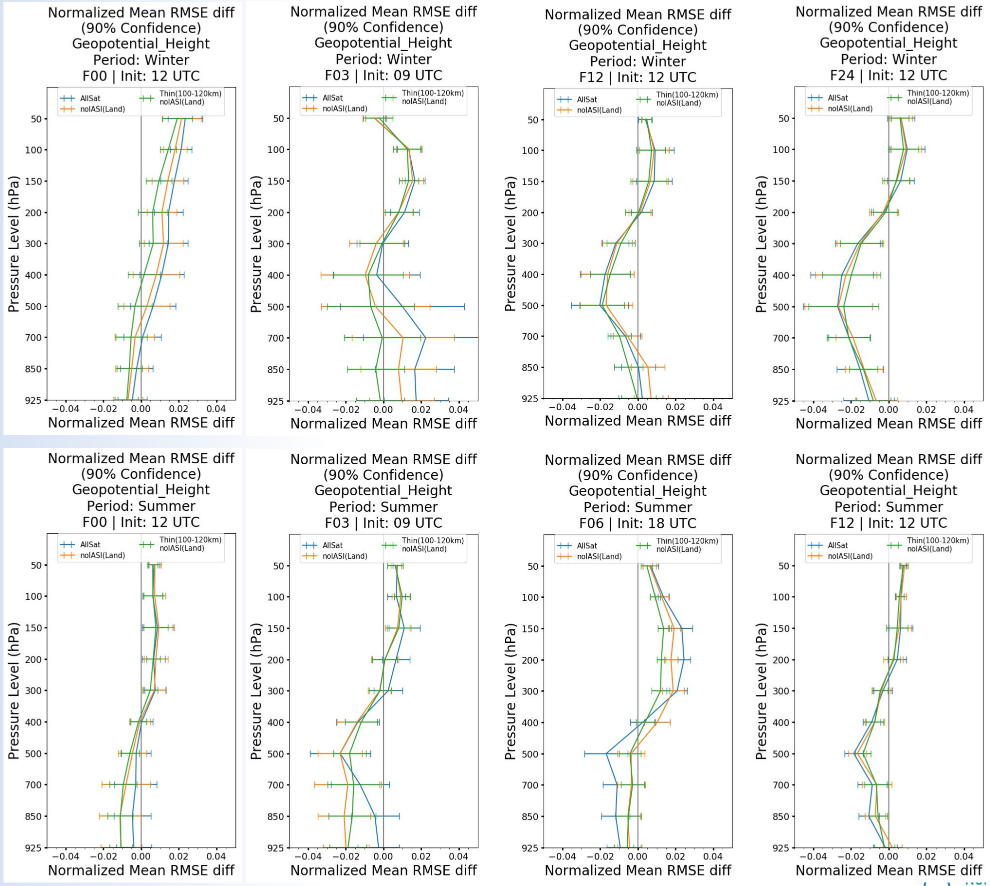
Impact of AMSU-A and IASI over land



Blue lines: All sat radiance impact

Orange line: All sat, new IASI over sea only

Green: All sat, new IASI over sea only, new thin

Positive / negative ⇒ negative / positive impact

Green option: improves the analyses and 3 hours forecasts and keep the good impact on (long) short-range forecasts (12 & 24 h).

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CONCLUDING REMARKS

– DFS and MTEN diagnostics showed that conventional observations have the most impact on CERRA analyses and forecasts, respectively.

– Tuned system provides better impact of radiances on analyses and very short-range forecasts (ex. 3h) while keeping the good impacts on short-range forecasts (12 & 24 h).

Optimal setup:

⇒ thinning of radiances data by 100 / 120 km, blacklisting of 6 IASI channels and assimilating them over sea only.

Have we learned something?

⇒ increasing obs error and relaxing thin distance provided comparable results in lower troposphere.

⇒ to be continued ...

– Tuning of the data assimilation system is needed when using settings that differ from the operational system.

– Paper on this study/report is out in *Remote Sensing*: **https://doi.org/10.3390/rs13030426**

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Thank you for your attention !

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Two Step Non-Cycling Data Assimilation Approach for VARBC Spinup