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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Operational use of inter-channel correlations for IASI in the DWD EnVar and investigation into the use of Reconstructed Radiances

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I) Introduction:

Hyperspectral infrared sounders like IASI or CrIS provide a very large number of channels which are spectrally very dense. This poster focuses on two challenges associated with this: First, observation errors display non-negligible error correlations between the channels that need to be taken into account in the assimilation system. The impact of using a full error covariance matrix R in the operational global ensemble variational data assimilation system (EnVAR) for the global ICON model system of DWD has been tested for IASI radiances. Secondly, in view of the future MTG-IRS for which data transmission is based on principal component compressed data, the use of reconstructed radiances for IASI assimilation is being tested.

II) Motivation:

Up to now, IASI radiances have been assimilated at DWD using a diagonal R matrix, diagnosed with Desroziers et al. (2005) method, but inflating diagonal elements to account for the neglected inter-channel correlations. A non-diagonal R matrix has been estimated using the Desroziers method and used in assimilation experiments ensuring it is invertible through setting a lower threshold on the size of eigenvalues.
Using the non-diagonal R matrix leads to positive impact on NWP forecasts, particularly for humidity fields which leads to much improved fit to other satellite observations sensitive to humidity.
In parallel, assimilation tests using reconstructed radiances, in an initial setup treating them similarly to raw radiances, have been run. As with raw radiances, a full R matrix has been diagnosed. As expected, much larger inter-channel correlations occur. Results of the assimilation of reconstructed radiances in comparison to raw radiances will be shown. An extension to the assimilation of CrIS FSR data using full R is ongoing.

I) Principal Component Analysis

Taking only leading PCs which represent directions of largest variability

- Compressed representation of IASI spectrum
- Noise reduction

$$p = E^T * N^{-1} * (x - \bar{x}) \in \mathbb{R}^s$$

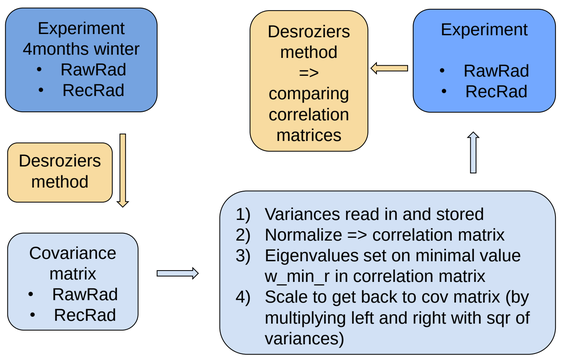
IASI L1C spectra: $x \in \mathbb{R}^{mxn}$
pc scores : $p \in \mathbb{R}^s$
mean of noise-normalised data set: $N^{-1} * \bar{x} \in \mathbb{R}^m$
covariance of noise-normalised data set: $C \in \mathbb{R}^{mxm}$
s most significant eigenvectors of C: $E \in \mathbb{R}^{mxs}$
number of channels: m
number of spectra in data set: n

Reconstructed Radiances (RecRad)

Transformation back into radiance space at a technical level RecRad treated like RawRad

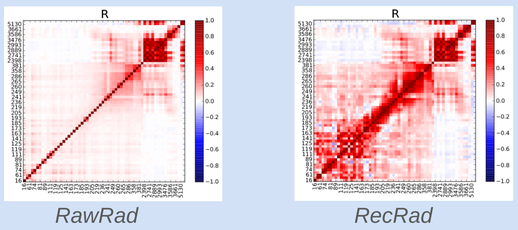
$$\tilde{x} = N * E * p + \bar{x} \in \mathbb{R}^m$$

II) Covariance matrix



III) Estimation for full R matrix

Based on run with non-diagonal R IASI



RawRad *RecRad*

VIII) References:

Andrey-Andrés, J. 2017: Impact of Principal Components compression on the assimilation of Hyperspectral infrared data. EUMETSAT Fellowship Report

Desroziers, G. et al. , 2005: Diagnosis of observation, background and analysis-error statistics in observation space. Q. J. R. Meteorol. Soc. 131, 3385–3396.

Matricardi, M. and McNally, A. P. 2014: The direct assimilation of principal components of IASI spectra in the ECMWF 4D-Var. Q.J.R. Meteorol. Soc., 140: 573–582. doi:10.1002/qj.2156.

Matricardi, M. 2015: The direct assimilation of principal components of IASI spectra in the ECMWF 4D-Var and the training of PC_RTTOV over land surfaces. EUMETSAT Contract No. EUM/CO/07/4600001011/PS.

McNally, A. P. and Watts, P., 2003: A cloud detection algorithm for high-spectral-resolution infrared sounders. Q. J. R. Meteorol. Soc., 129, 3411-3423.CV

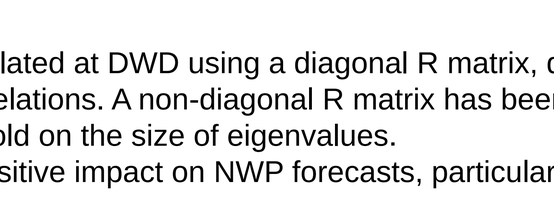
IV) Comparison RawRad vs RecRad

ICON EnVar @40km, online bias corr.
Exp a) RTTOV10 **46ch**
diagR 1 months in summer
Exp b) RTTOV12 **62ch** (16WV includ.)
diagR 3 months in winter
Convergence improved, IASI obs 4K
Exp c) RTTOV12 62ch **fullR1.0**
With ATMS humidity

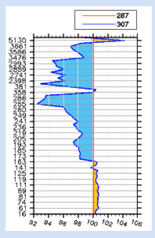
Covariance matrix IASI see III)

NWP trial departure statistics

Standard deviation (obs-fg)



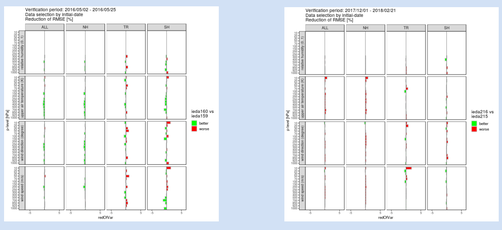
Left: Exp c) Radio-occultation relative differences
Stddev(o-fg) zmean increased for 20'km height in south polar region
Right: Exp c) Microwave rel. differences stddev(o-fg) decreased for channel 11-13



Left: Exp c) IASI rel. differences ni
Blue: less number of obs

Reduction of number of IASI obs due to cloud detection

Forecast verification



Evaluation against observations upper air rmse
Both with diagonal R IASI
Left: Exp a) 1 month in summer, RTTOV10
Right: Exp b) 3 months in winter, RTTOV12, 16 channels more

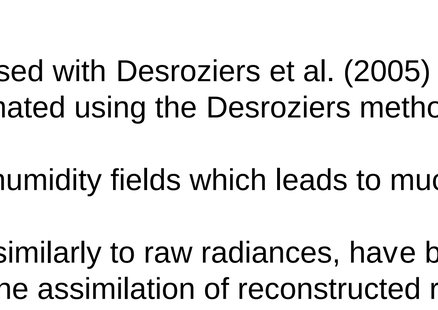
Ongoing: for RecRad new reference necessary for actual comparison with all new changes
e.g. IASI full R, modified MNW cloud detection scheme, Metop-C, ATMS hum.

V) IASI using full (non-diagonal) R including inter-channel correlations in global ensemble DA system operational since 27th february 2019

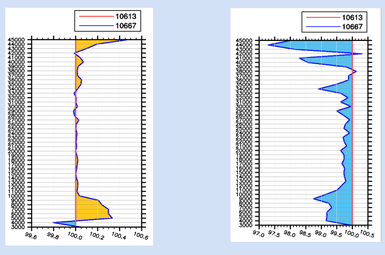
ICON EnVar + LETKF @26/52km
40 ensemble members
Online bias correction
62 assimilated IASI channels out of 354
scaling factor for R 1.0 of error std dev RTTOV12
3 months in summer 9.6. -3.9.2018

NWP trial departure statistics

Standard deviation (obs-fg)

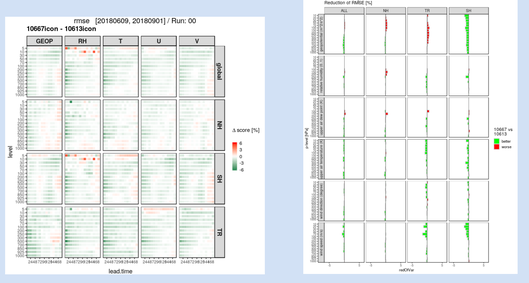


SATOB Wind relative differences
Stddev(o-f) reduced while more obs used



Radio-occultation relative differences
Stddev(o-f) reduced while more obs used

Forecast verification



Evaluation Rmse 3 months in summer
Left: against analysis *right: against observations*
Green: better with fullR IASI
Red: worse than reference with diagonal R

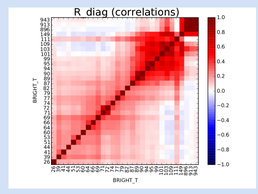
EVA: Slightly positive impact in all variables and regions
EVO: Neutral and very slighlty positive impact

VI) CrIS using full R

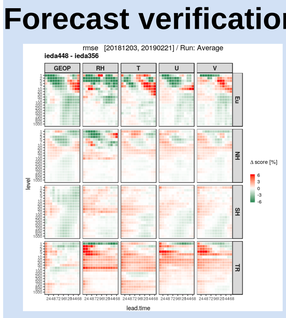
ICON EnVar + LETKF @26/52km
CrIS FSR on NOAA-20 full R 1.75
30 active out of 431 channel data set
RTTOV 12; 3 months in winter
IASI with full R 1.0

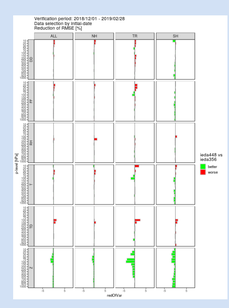
Covariance matrix CrIS

CrIS cov matrix
by Desroziers method
over 11 weeks in winter
Red: stronger correlation



Forecast verification





Evaluation CrIS full R 1.75 rmse 3 months in winter
Left: against analysis
Right: against observations upper air rmse
Green: better with additional CrIS channels
Red: worse than reference without any CrIS channels

EVO: Neutral and slighty positive in SH tropical stratosphere negative

VII) Conclusion:

IV) RecRad
- Technically tested in DA scheme
- Different impact whether IASI reference (RawRad) has diagonal or already full R
- No strong sensitivity of cov matrix to season or period
- Best cut-off limit for eigenvalues 0.2
- Ongoing: Further tuning of RecRad

V) IASI with inter-channel correlations
- Small but significant positive impact
- Operational since 27/02/2019

VI) CrIS FSR on NOAA-20 with inter-channel correlations
- Preliminary results

Ongoing: More active IASI channels
- Preliminary investigations

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