A physically based observation error covariance matrix for IASI

Hyoung-Wook Chun[1], Reima Eresmaa[2], Anthony P. McNally[2], Niels Bormann[2], and Marco Marticardi[2]

[1]Korea Institute of Atmospheric Prediction Systems (KIAPS), Seoul Korea (hwchun@kiaps.org)

[2]European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, UK

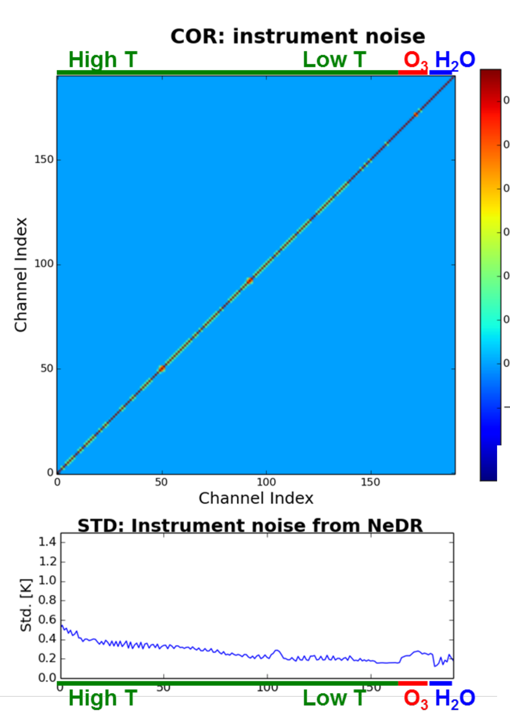
KIAPS
KOREA INSTITUTE OF ATMOSPHERIC PREDICTION SYSTEMS

Introduction

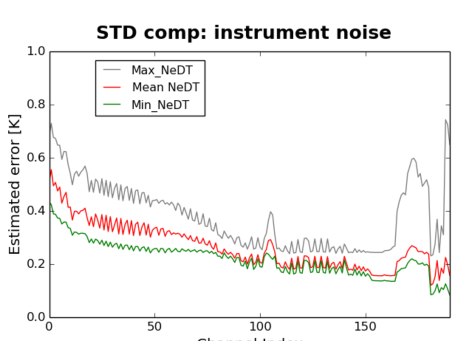
Since IASI data was first assimilated operational centres have adopted a pragmatic approach and used greatly simplified representations of the error covariance matrix (e.g., Collard and McNally 2009). Inter-channel correlations have been ignored and error values inflated in parts of the spectrum where this approximation is thought to be least valid (e.g. window and water vapour channels). Even with this degree of simplification the assimilation of IASI observations has had a well documented positive impact on NWP forecasting systems (Collard and McNally 2009, Hilton et al. 2009, Guidard et al. 2011). However, more recent work using techniques to estimate the full error covariance from a diagnosis of innovation statistics have suggested that further improvements can be obtained and in particular highlighted the importance of explicitly accounting for inter-channel (Weston et al. 2014, Bormann et al. 2015).

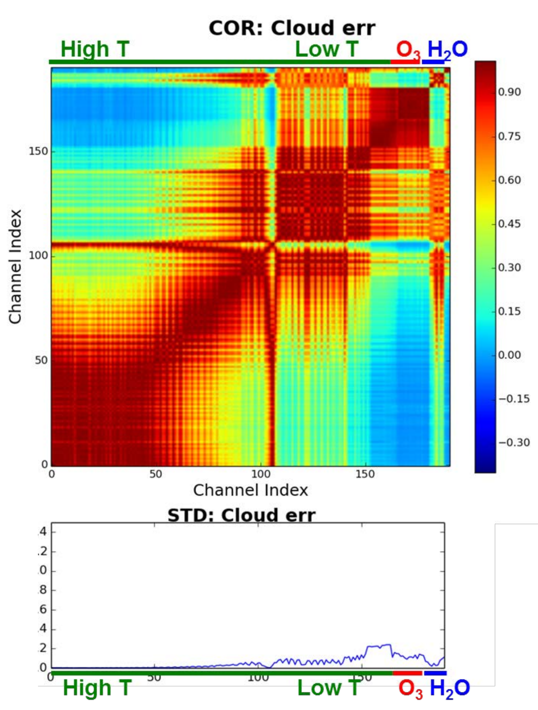
Inspired by (and indeed guided by) these encouraging results, the work described in this study explores an alternative approach to construct a full error covariance for IASI by modelling the individual sources of uncertainty and then combining these in a total error estimate. The motivation to pursue this *physical* approach (as opposed to the statistical innovation diagnosis) is threefold. Firstly, it may allow us to attribute some of the important features present in the diagnosed covariance estimates to real physical sources of error (e.g. residual cloud contamination) and may additionally provide some insight as to why the diagnosed estimates invariably need to be empirically inflated before use. Secondly, the use of a physically based (independent) derivation of the observation error covariance would reduce the potential for dependencies between background errors and observation errors in the assimilation system. Finally, if the individual sources of error (and their variability location to location) are better understood, the problem of allowing for scene dependence of observation error covariance in the assimilation scheme is significantly more tractable.

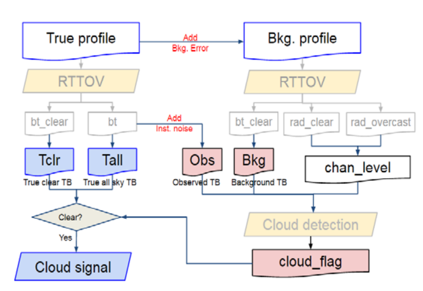
Physically based observation error (R)



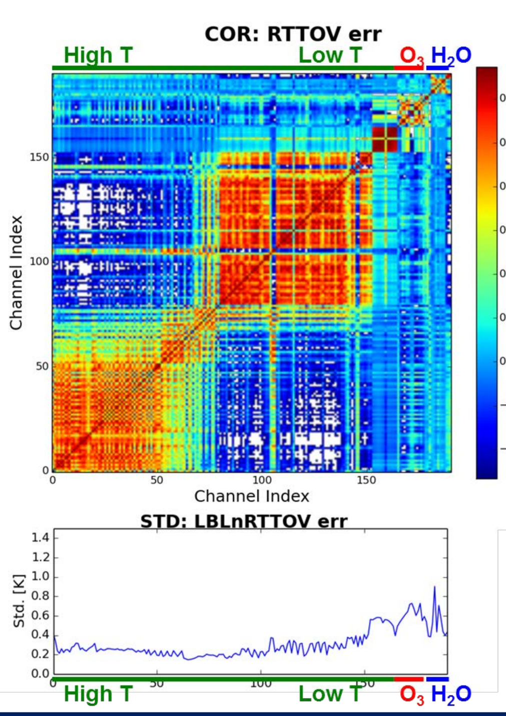
- NeDR
  - Noise equivalent differential radiance
  - provided by CNES
  - Constant
- NeDT
  - Noise equivalent differential temperature
  - scene dependent



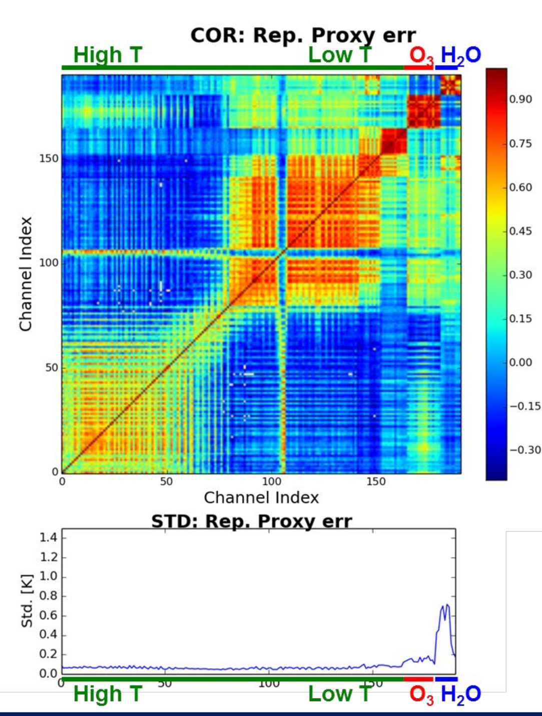




- True profile: NWP SAF data set (Eresmaa and McNally, 2014)
- Cloud detection algorithm: (McNally and Watts 2003)
- Cloud error when cloud_flag for window channel is clear
- Cloud errors can be retrieved with respect to clear channel reference.
- Caution: Cloud error is dependent on background error

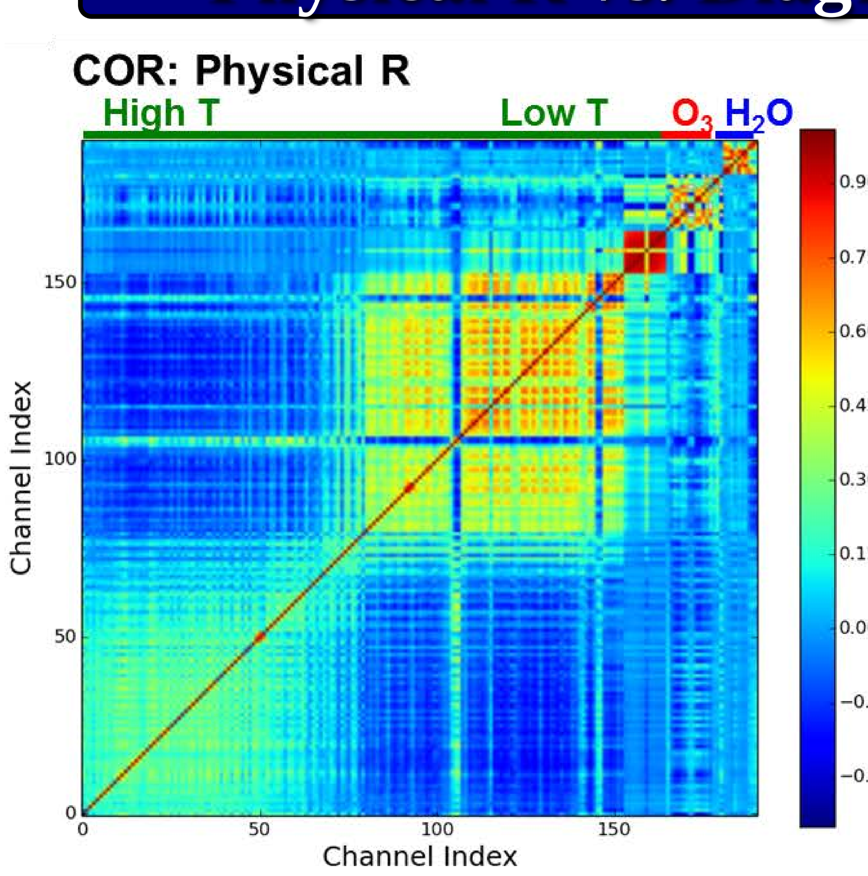


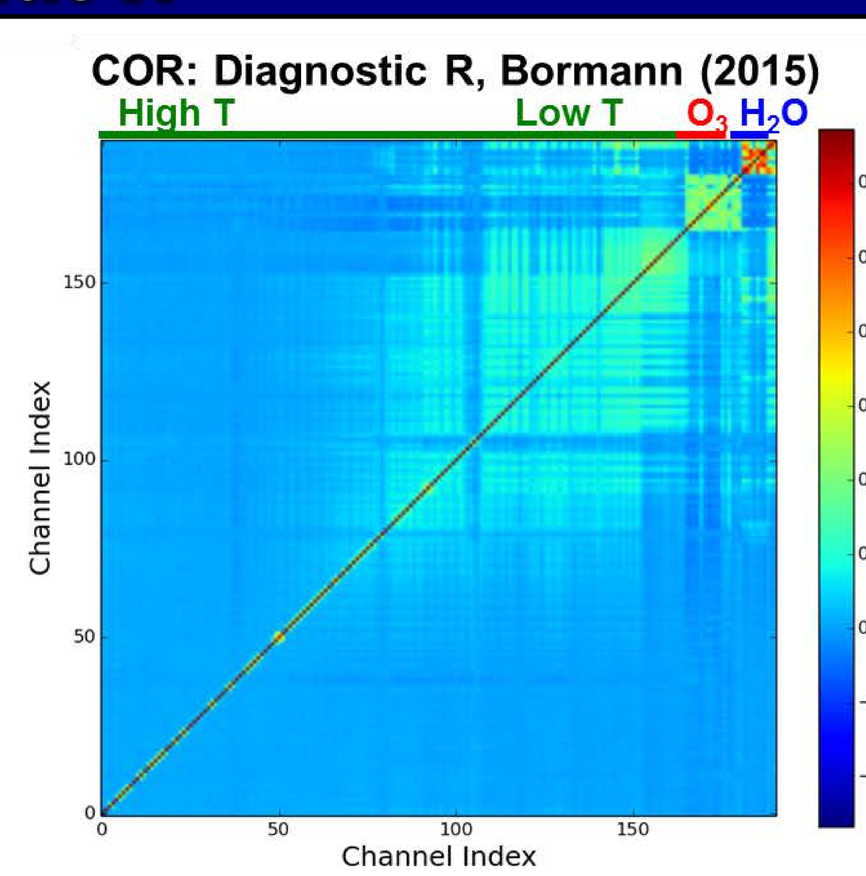
- RTTOV error
  - Regression error during calculation of RT coefficients over a set of 5160 profiles
- LBLnRTTOV
  - standard deviation of the difference between observed IASI and simulated IASI with GRUAN profile (Manus Island, during 2011-2013, 27 samples)
  - While IASI instrument noise has been removed from the standard deviation, small sample and radiosonde error have not been considered.

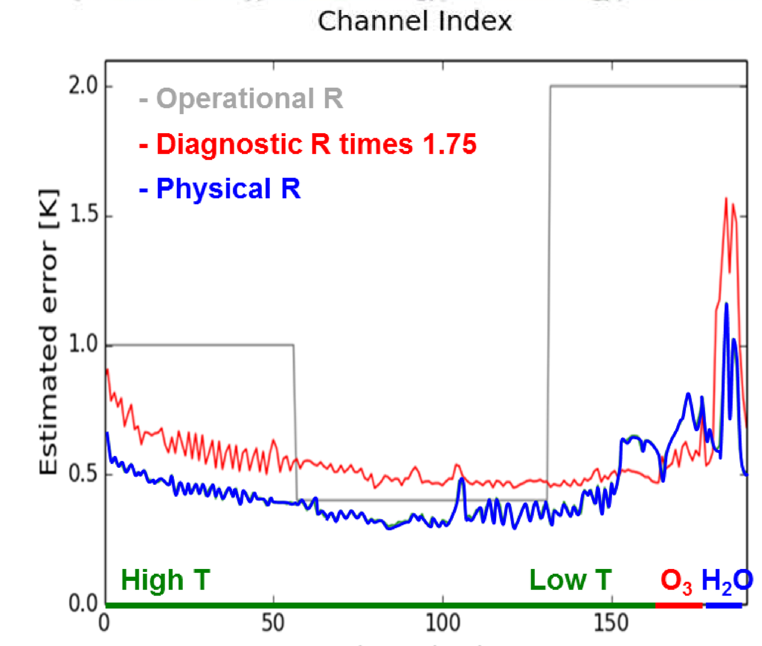


- Rep_Proxy comes from the background departure difference between T1270 and T159 with re-setting for positive definite matrix.
- The Rep_Proxy only gives an idea which channels are affected by representativeness errors.

Physical R vs. Diagnostic R





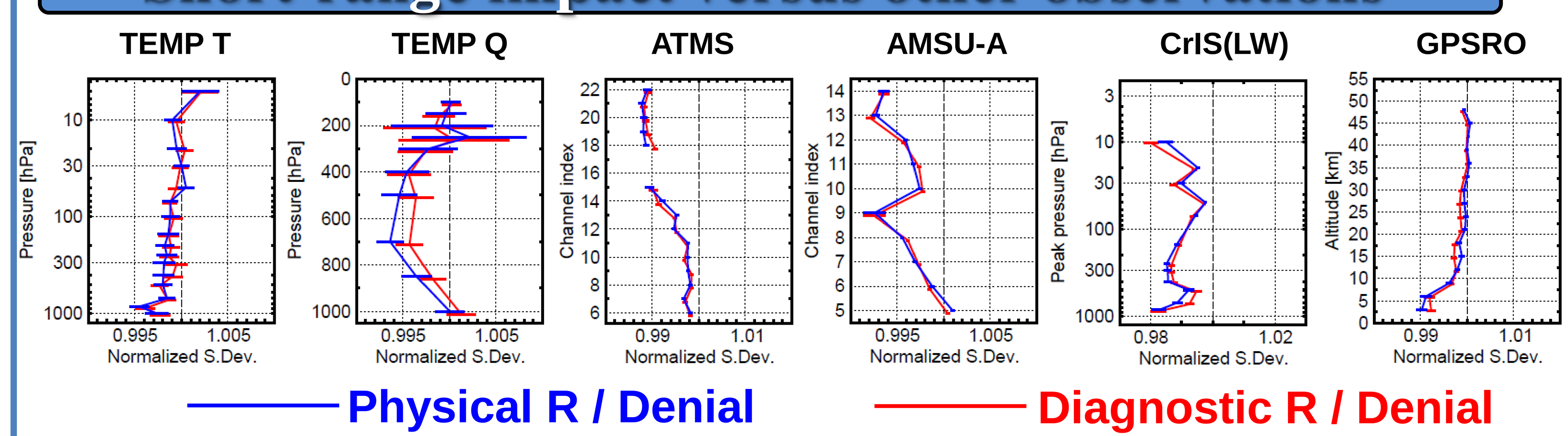


- **Physical R**
  Summation of the four individual sources of error (i.e. instrument noise, cloud screening error, forward model error, and representativeness error)
- **Diagnostic R, Bormann (2015)**
  Total observation error obtained based on departure statistics from assimilation systems.
- **Physical R has larger errors (diagonal elements) than those diagnostic R and stronger inter-channel correlations**

Experiments

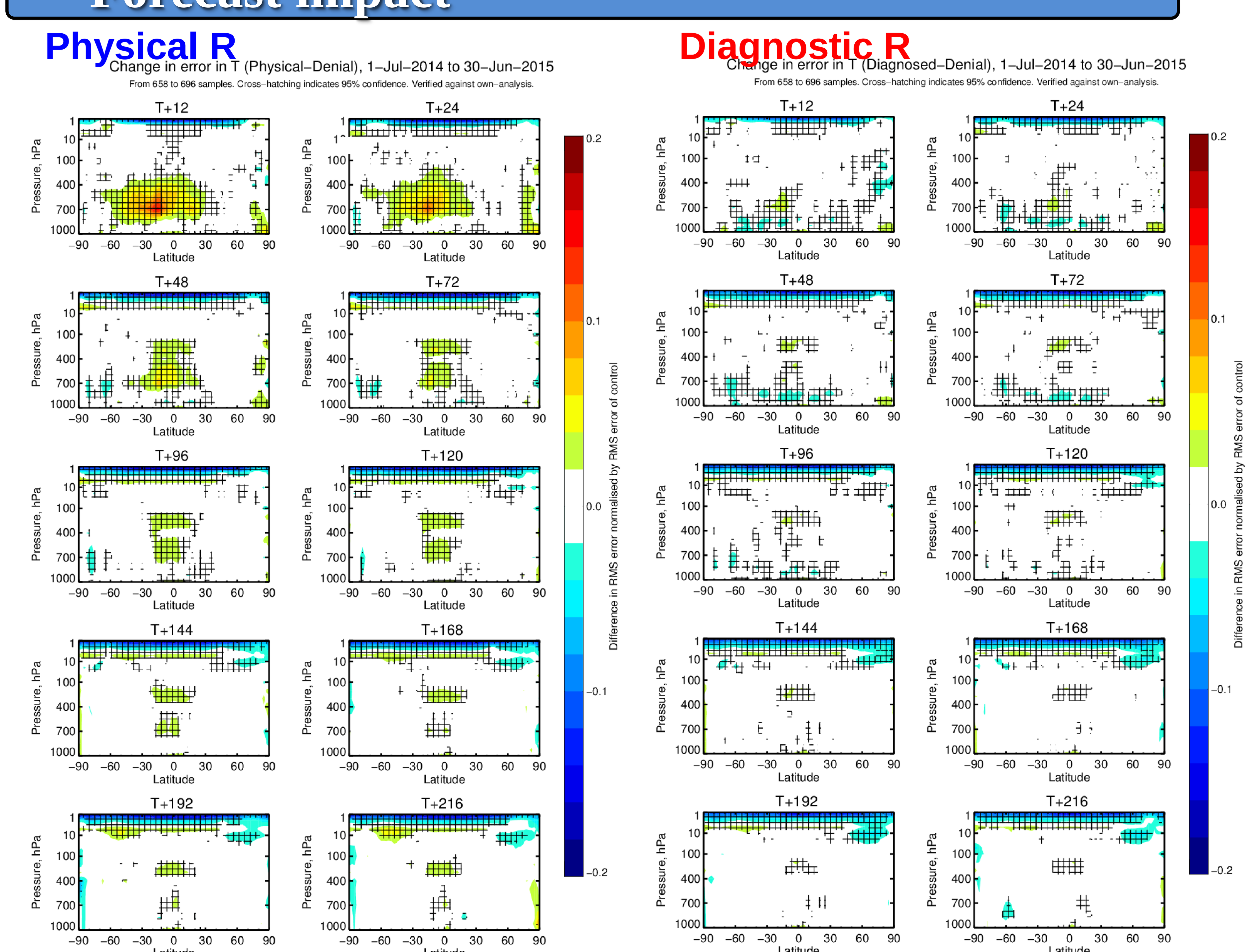
- 191 IASI radiances are assimilated for ECMWF IFS system : CY41, T639, 137 vertical levels during 12 months (1 Jul 2014 -30 Jun 2015)
  with different kinds of IASI observation error covariance (R)
  - Control: Operational R (without inter-channel correlation) in IFS
  - Diagnostic R in Bormann et al. 2015
  - Physical R in this study
  - Denial IASI radiances

Short-range impact versus other observations



- Normalized standard deviation of observation minus background departure on various independent observations. The normalization is with respect to the denial run. Bars indicate the 95% confidence intervals. The values less than 1.0 indicate better scores.
- The physically based error estimate performs well in short-range impact test against other observations, comparable to that of an empirically tuned covariance based on innovation diagnosis.

Forecast impact



- Zonal means of the normalized differences of the root mean squared forecast error of temperature between Physical R (Diagnostic R) and denial. Cross-hatching indicates statistical significance at the 95% level. Blue (negative) areas indicates the experiments has lower RMS error (better scores) than the control.
- In contrast to the short-range impact, physical R has worse score in the medium range than diagnostic R. Even though 6hour forecast impacts against other observation are similar between physical R and diagnostic R but 12 hour forecast impacts are dramatically different.

Summary

- Building up a physically-based observation error covariance matrix for IASI radiance assimilation from a knowledge of individual sources of error.

source	dominant channels
instrument noise	All, especially T sounding ch.
cloud error	Window ch.
radiative transfer error	All, especially O_3 and WV ch.
representativeness error	WV ch.

- The combination of these produces a covariance with stronger inter-channel correlations than those diagnosed from innovations.
- The physically based error estimate performs well in short range impact against other observation, comparable to that of an empirically tuned covariance based on innovation diagnosis.
- In contrast to the short range, diagnostic R has better score than denial but physical R has worse score than denial in medium range forecasting.