Information Content and Optimal Channel Selection for AIRS

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Presentation layout

- Background of the study
- Experimental framework
- Validation of the NESDIS NRT channel selection
    - Versus an "optimal" channel selection (Rodgers)
    - Versus a (constant) "optimally derived" channel selection
- Robustness of the selection to different inputs
    - Air-mass dependence
    - Background error covariance
- Conclusion

Background of the study

- At day-1 after launch, AIRS data will be provided via NESDIS to the NWP community. For obvious technical reasons, only a reduced channel selection will be available in near real time.
- It is important to quantify the "loss" of information entailed by this reduced dataset and its impact on NWP
- Information content studies permit the evaluation (in a statistical sense) of the benefit of any new source of information on the quality of a given assimilation system
- Information content theory can help in the selection of channels judged as essential to maximise the impact of a new instrument

Background of the study (ctd)

- The goal of the study is to compare the “efficiency” of the NESDIS NRT channel selection with alternative methods based on information content theory

- Rabier et al. (2002) have developed an iterative method based on Rodgers (1996) and have applied it to IASI.

- This method might give us some guidance on how to progressively extend the number of channels one wants to ingest in the assimilation system

Experimental framework

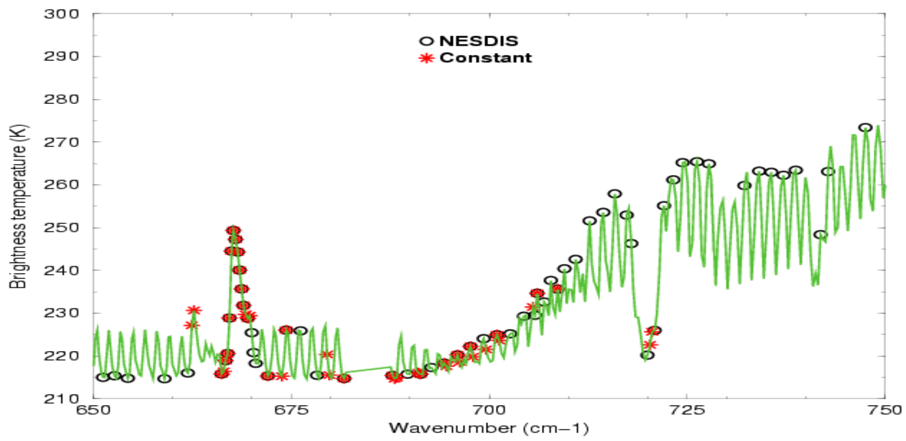
- Atmospheric situations:
  - 108 (T, Q, O3) profiles extracted from the new 60-level ECMWF sampled database
    - 19 polar, 75 mid latitudes, 14 tropical
- NESDIS NRT simulated reduced set:
    - 228 channels
- Surface temperature is not addressed in the study:
  - Window channels excluded
    - 2378 → 1576
    - 228 → 186
  - Ts excluded from the control variable
- Background error covariance matrix
  - Operational ECMWF B matrix
    - Based on ensemble of analyses
- Observational error:
  - latest noise from UMBC

Experimental framework (ct'd)

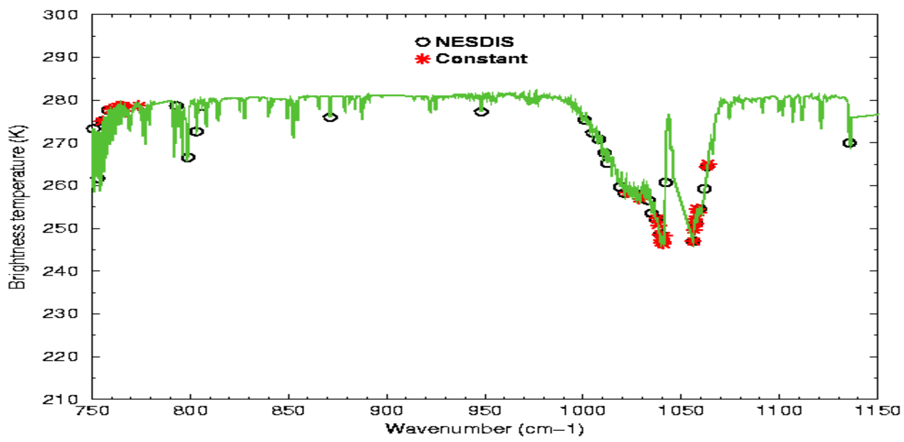
- Radiative transfer model:
  - RTAIRS (see Matricardi+Chevallier talk)
- Rodgers selection:
  - Maximise DFS (Degree of Freedom for Signal) or optimise ER (Entropy Reduction)
    - DFS = tr (I – A/B)
    - ER = -1/2log2[det(A/B)]
      - Iterative process to select sequentially the best channel according to this criterion
- Constant selection:
  - Average selection based on the 108 realisations
- Diagnostics
  - Information content: study of eigenvalues and eigenvectors of $B^{1/2}.H^t.R^{-1}.H.B^{1/2}$
  - DFS: gain in information brought by the data
  - Linear 1D-Var performance

Validation of NESDIS NRT channel selection

LW 15 µm CO2 band

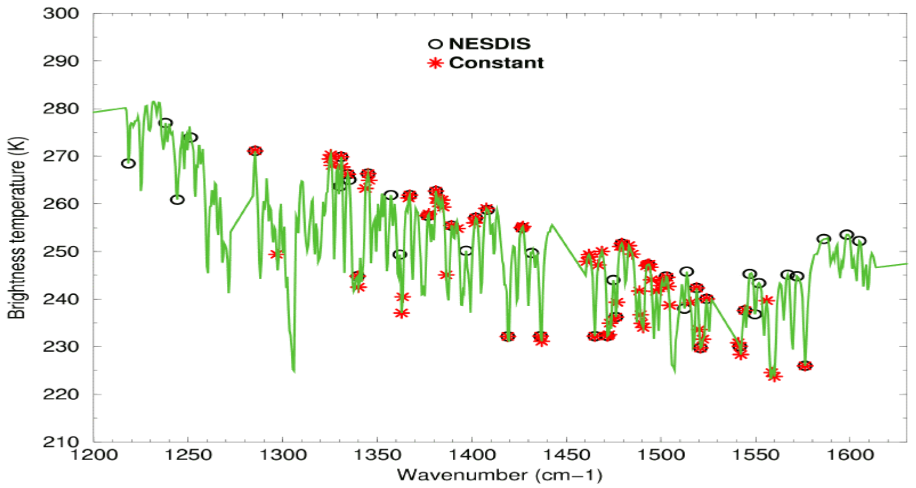


H2O window + 9 µm O3 band

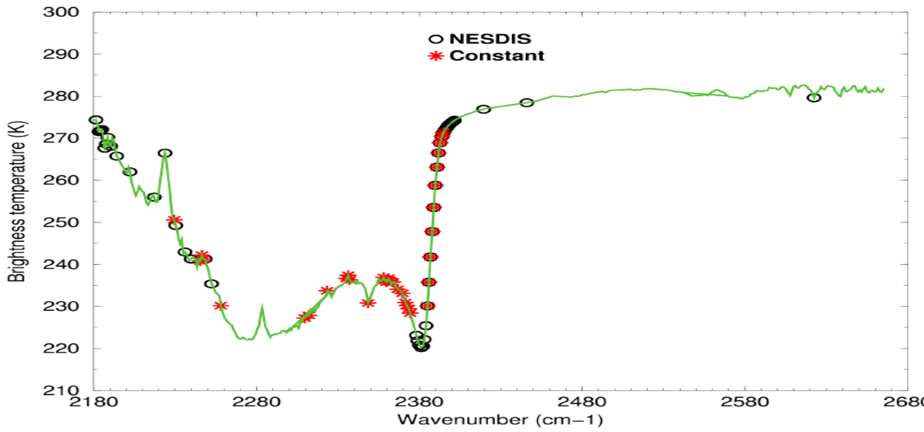


Validation of NESDIS NRT channel selection

6-7 µm H20 band



Shortwave 4.5-4.2 µm CO2 band



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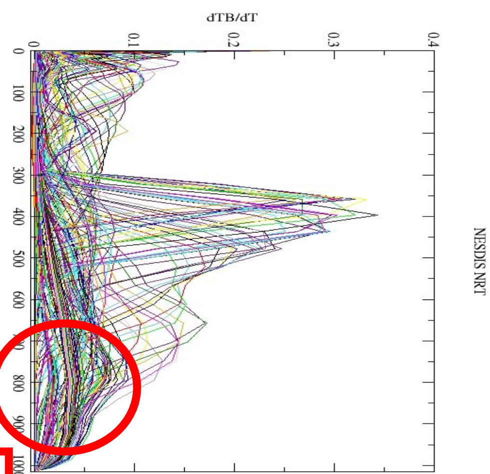
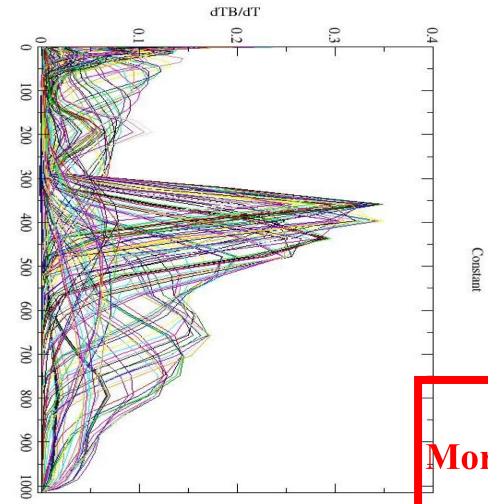
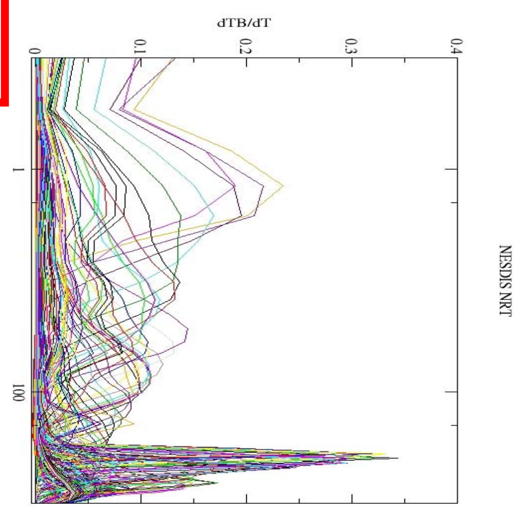
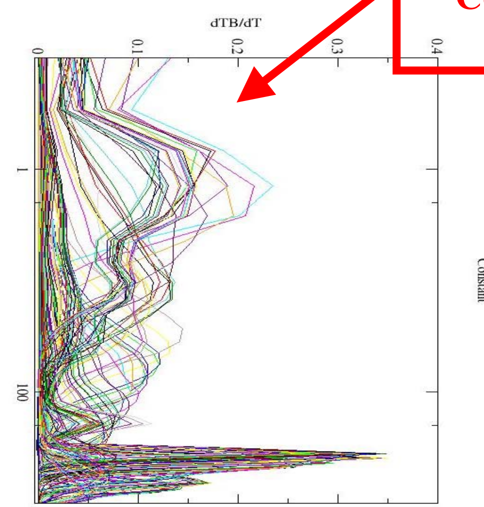




More low tropospheric channels in NESDIS NRT

More high stratospheric Channels in Constant selection



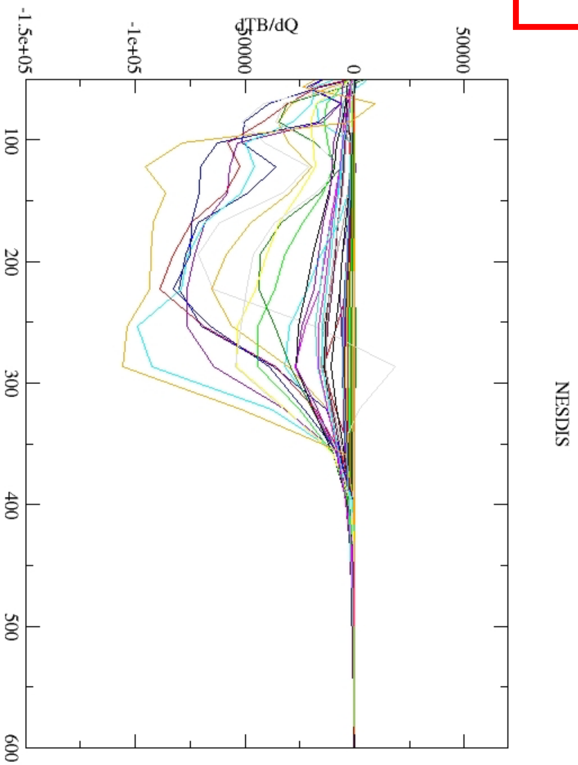


NESDIS selection

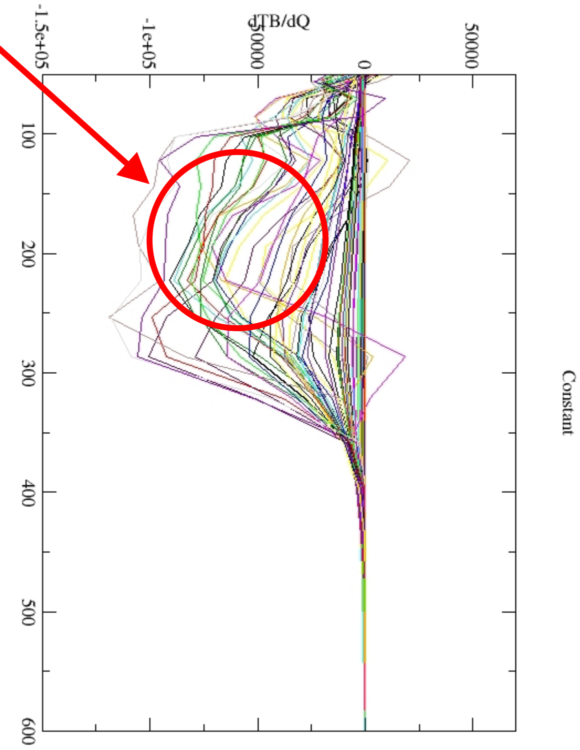
Constant selection

Validation of NESDIS NRT channel selection

More water vapour channels in Constant selection



NESDIS selection

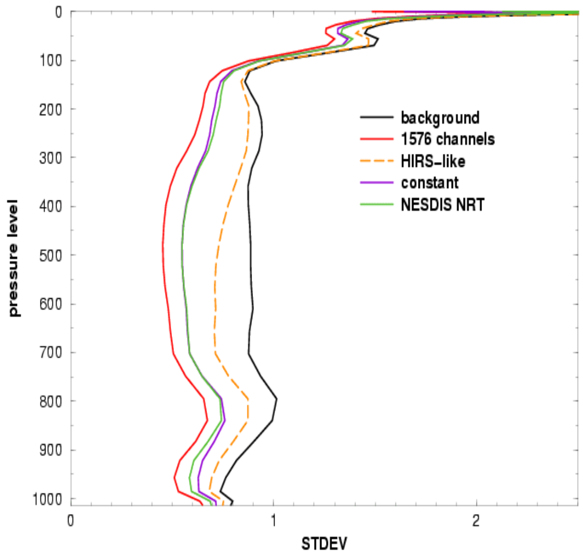


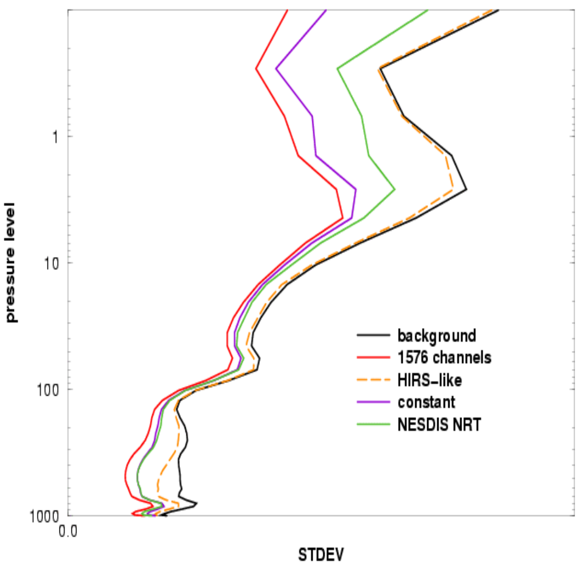
Constant selection

Validation of NESDIS NRT channel selection

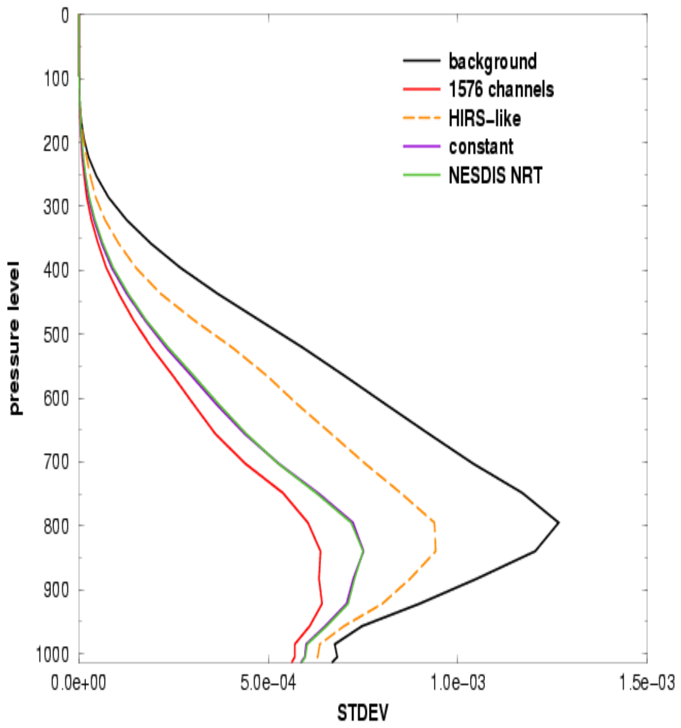
- **NESDIS: 23.7 vs CONSTANT: 25.8 indep. pieces of information**

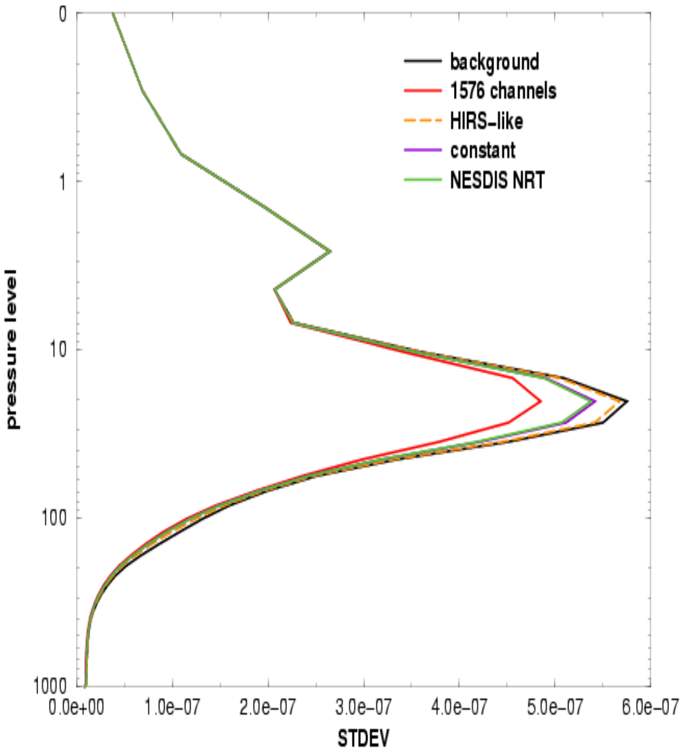
- **NESDIS : DFS=16.2 = 8.1 (T) + 6.5 (Q) + 1.6 (O3)**
- **Constant: DFS=18.2 = 9.2 (T) + 7.3 (Q) + 1.7 (O3)**





Validation of NESDIS NRT channel selection

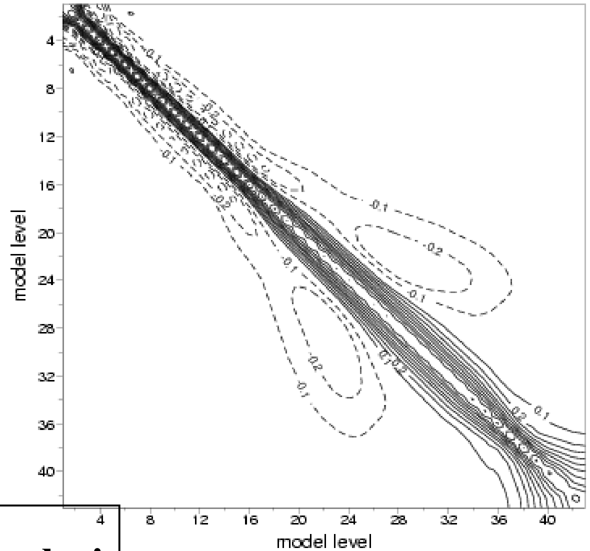




Validation of NESDIS NRT channel selection

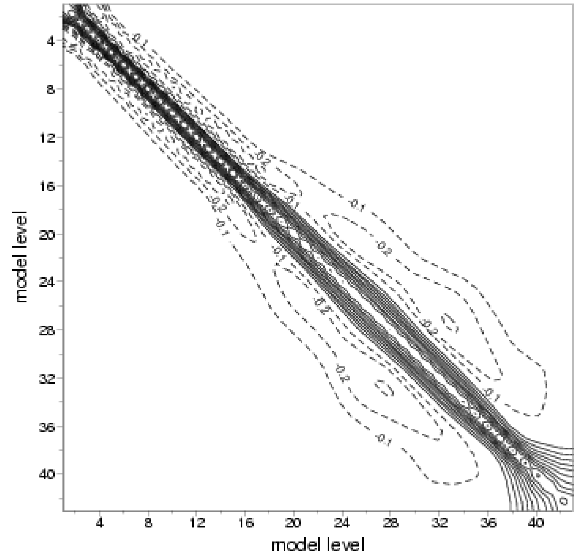
background

average temperature cors



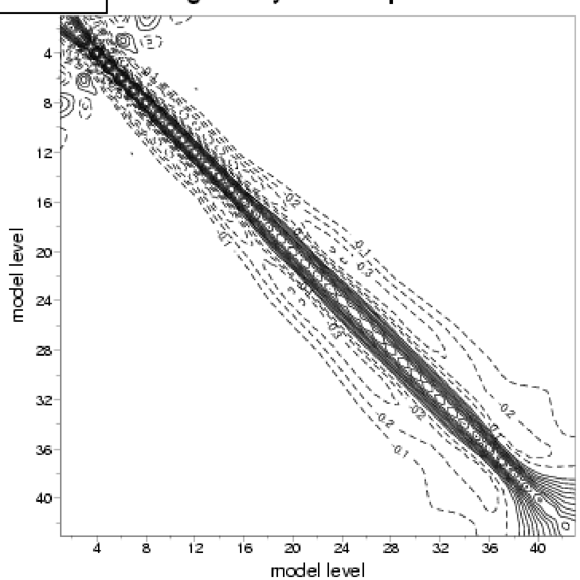
HIRS analysis

Hirs-like analysis temperature cors



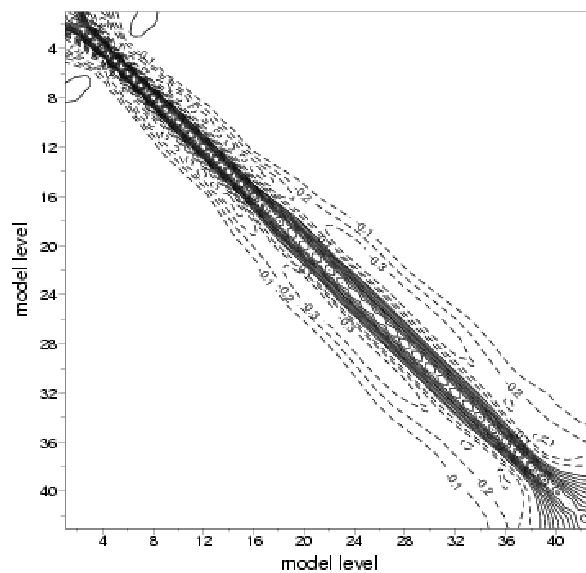
Const. analysis

consRodg analysis temperature cors

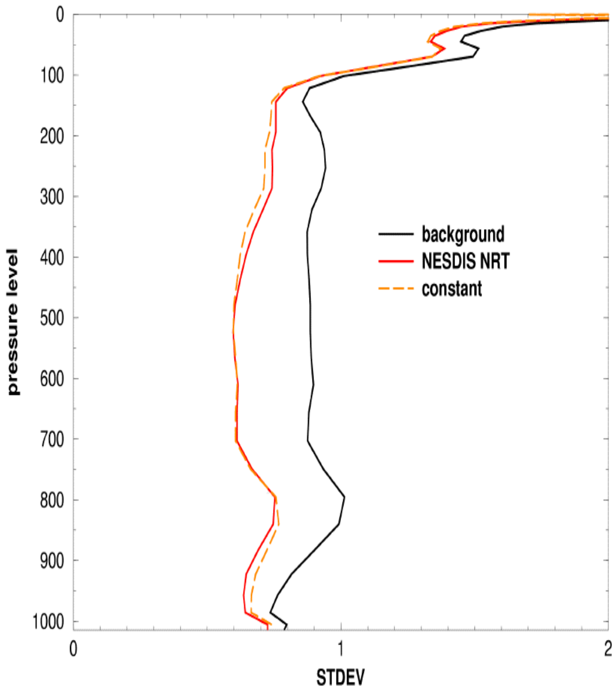


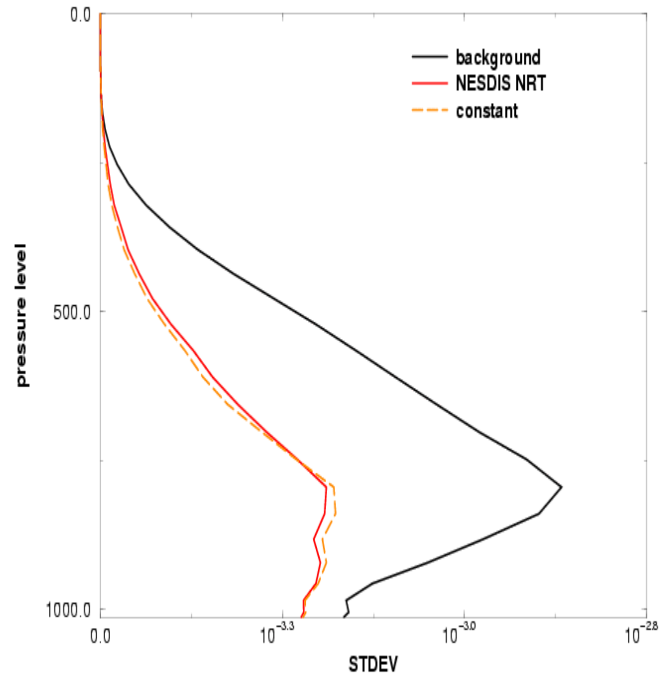
nesdis nrt analysis

Nesdis analysis temperature cors



Is the NESDIS NRT robust to different air-masses?





Even an optimised selection on polar air-masses applied to the same polar air-masses is merely comparable to NESDIS NRT selection

Robustness of the selection to the specification of the background error covariance matrix

- The current background error covariance matrix used at ECMWF only provide a climatology of short-range forecast errors

- On the other hand, previous information content studies have suggested that AIRS/IASI could resolve some of the small scale baroclinic structures that have been identified by sensitivity studies as being crucial to forecast error development (so called key analysis errors)

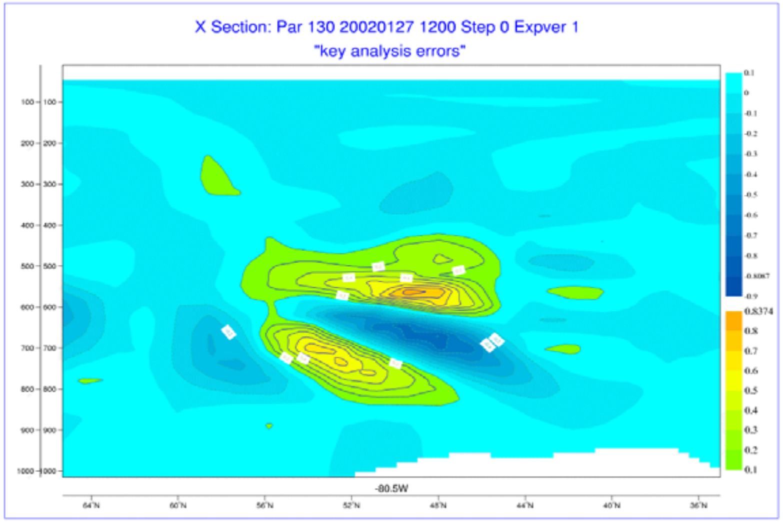
- Among other things (such as cloud correlated), these structures are sharp in vertical and horizontal

- It is therefore interesting to test the robustness of NESDIS NRT selection to cope with such detailed structures

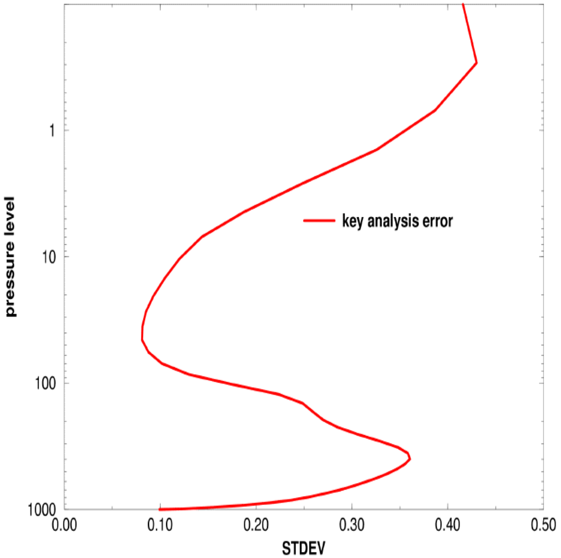
Key analysis error covariance matrix
(one month of high resolution sensitivity experiment)

One key analysis error

Corresponding statistics

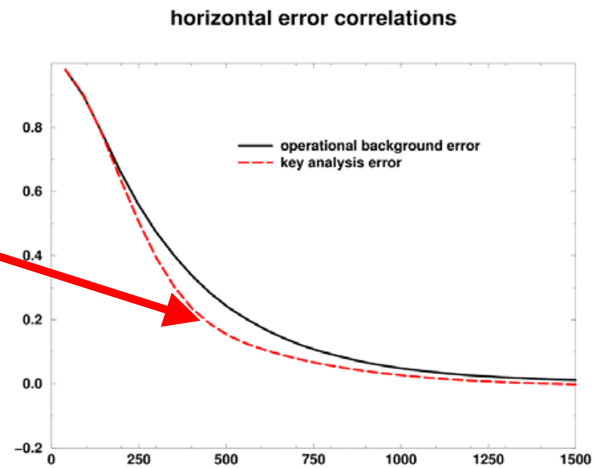


One month of statistics



(relatively) large errors in the troposphere
(spuriously) large errors in the high stratosphere

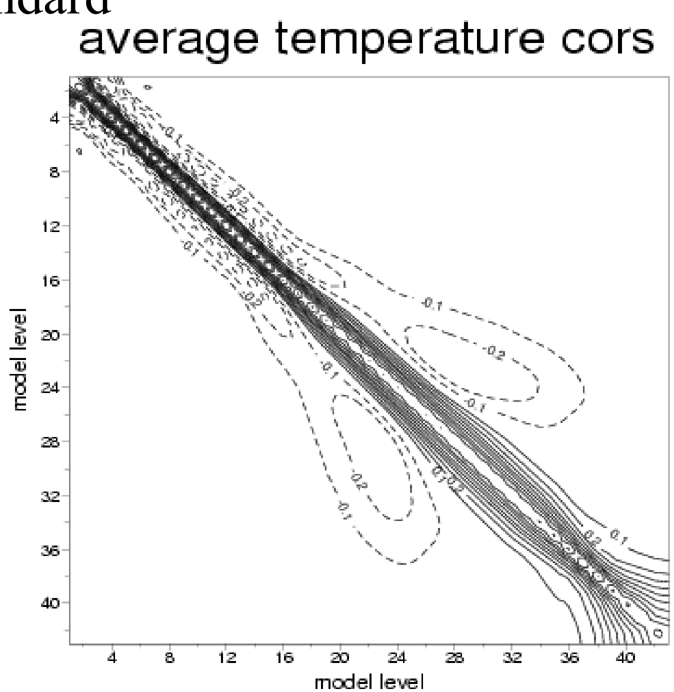
Key analysis error covariance matrix
(one month of high resolution sensitivity experiment)



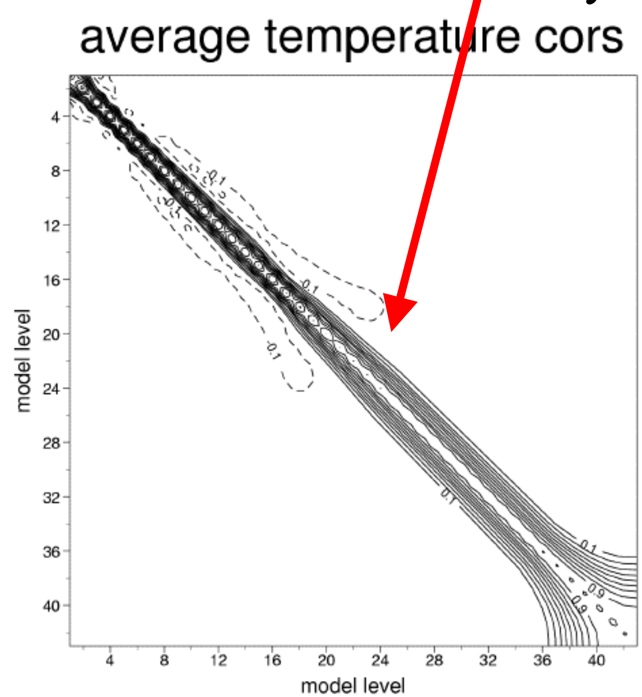
Sharper
In
Horizontal

Sharper in vertical

Standard

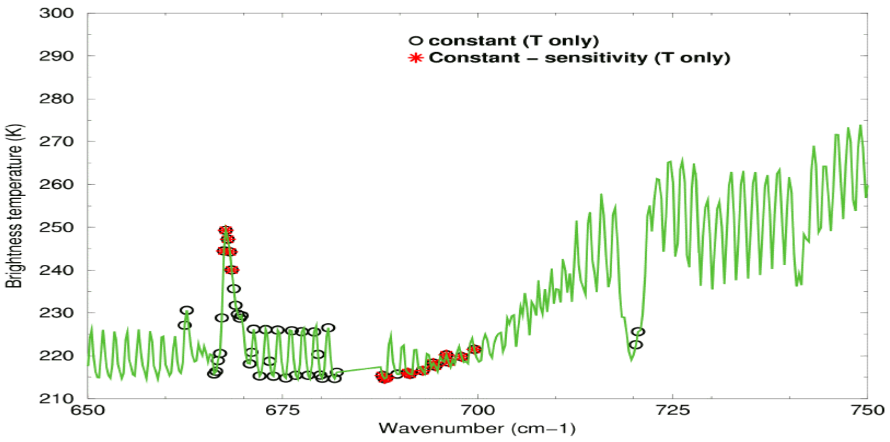


Key analysis error

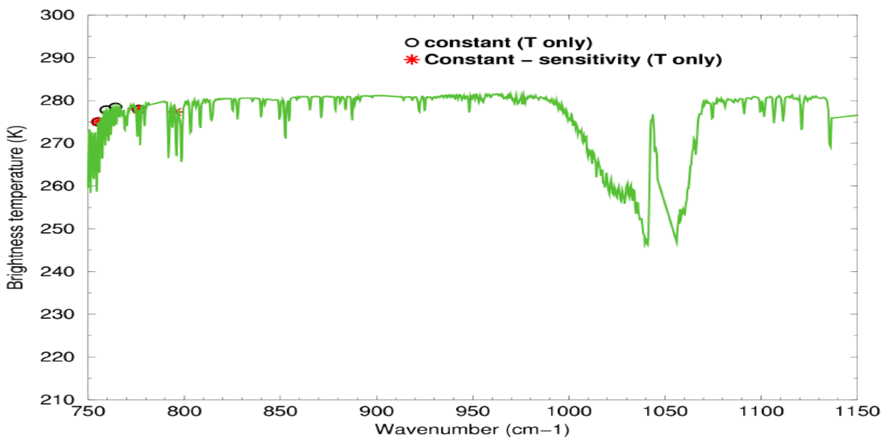


Impact of the background error covariance matrix on the channel selection (T only)

LW 15 µm CO_2 band



H_2O window + 9 µm O_3 band



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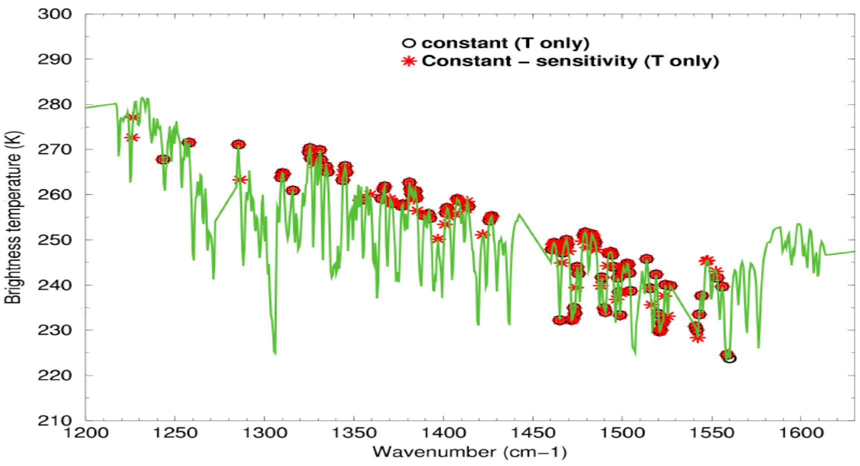

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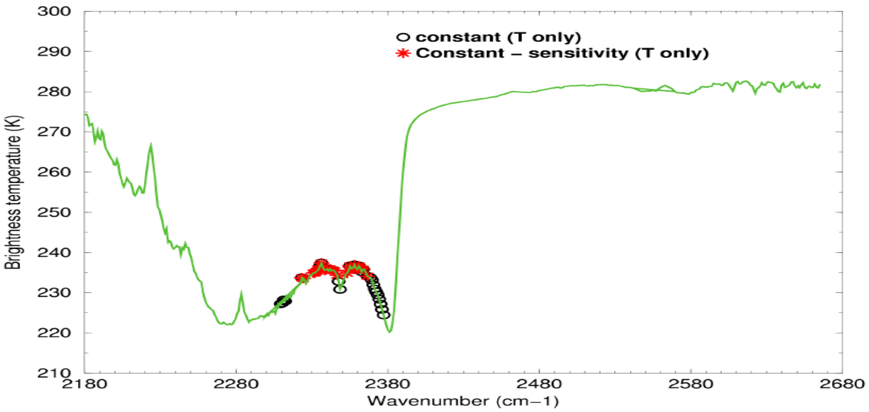

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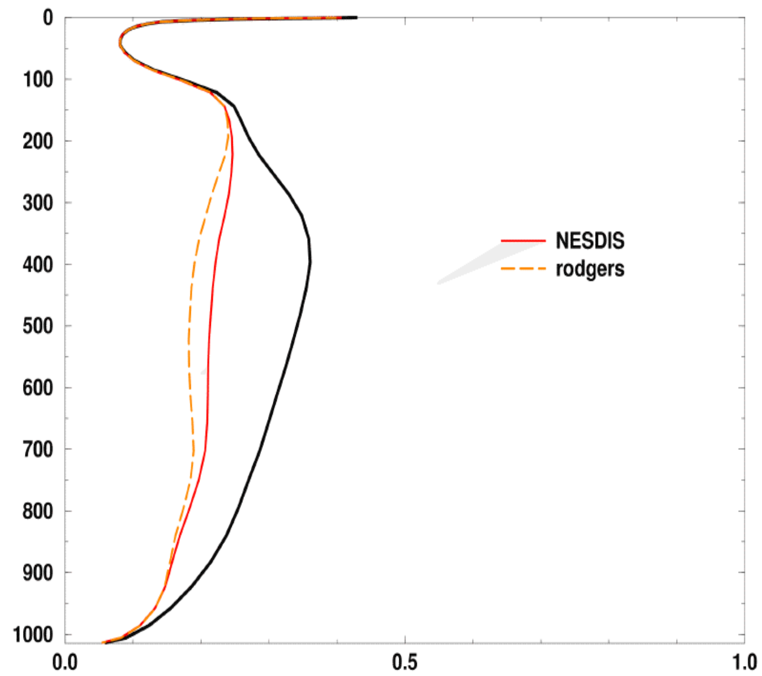

Superiority of a dedicated channel selection over NESDIS NRT…

But…

NESDIS NRT selection is still doing a good job!

Conclusions

- Information Content (IC) and channel selection tools provide some guidance to assess the expected impact of a new instrument
- These tools have been used to evaluate the quality of the NESDIS NRT channel selection versus a more "optimal" approach (sanity check!)

Limits due to linearity and cloud-free assumptions

  - NESDIS NRT channel selection seems very reasonable for NWP applications (as measured by IC indices)
  - NESDIS NRT channel selection is robust to air-masses under consideration
  - NESDIS NRT channel selection is performing well with atmospheric key analysis errors
  - ECMWF is fairly confident with this day-1 strategy
- Optimal channel selection probably remains superior for very specific applications:
  - Cloud detection
  - CO2 estimation,…