Error diagnostics for PC scores assimilation

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Introduction

- **Specifying errors is essential for the assimilation of any observation.**
- **Simpler error characteristics were a key argument for moving to the assimilation of raw radiances.**

- **What are the characteristics of observation and background error in PC-space?**
- **In radiance space, representativeness, RT, and QC errors are correlated between channels – what do they look like in PC-space?**
- **For a given assumed observation error in PC-space, what is the equivalent error in radiance space?**

- **PC-truncation is not addressed in this talk.**

Observation error in PC-space

- **When PCs are calculated from noise-normalised radiances, the observation error is:**

$$\mathbf{R}_{PC} = \mathbf{I} + \mathbf{F}_{PC}$$

I – Identity matrix

$\mathbf{F}_{PC}$ – "other errors" (e.g., forward model errors, representativeness errors, QC errors, etc)

- **What does F look like in PC space?**

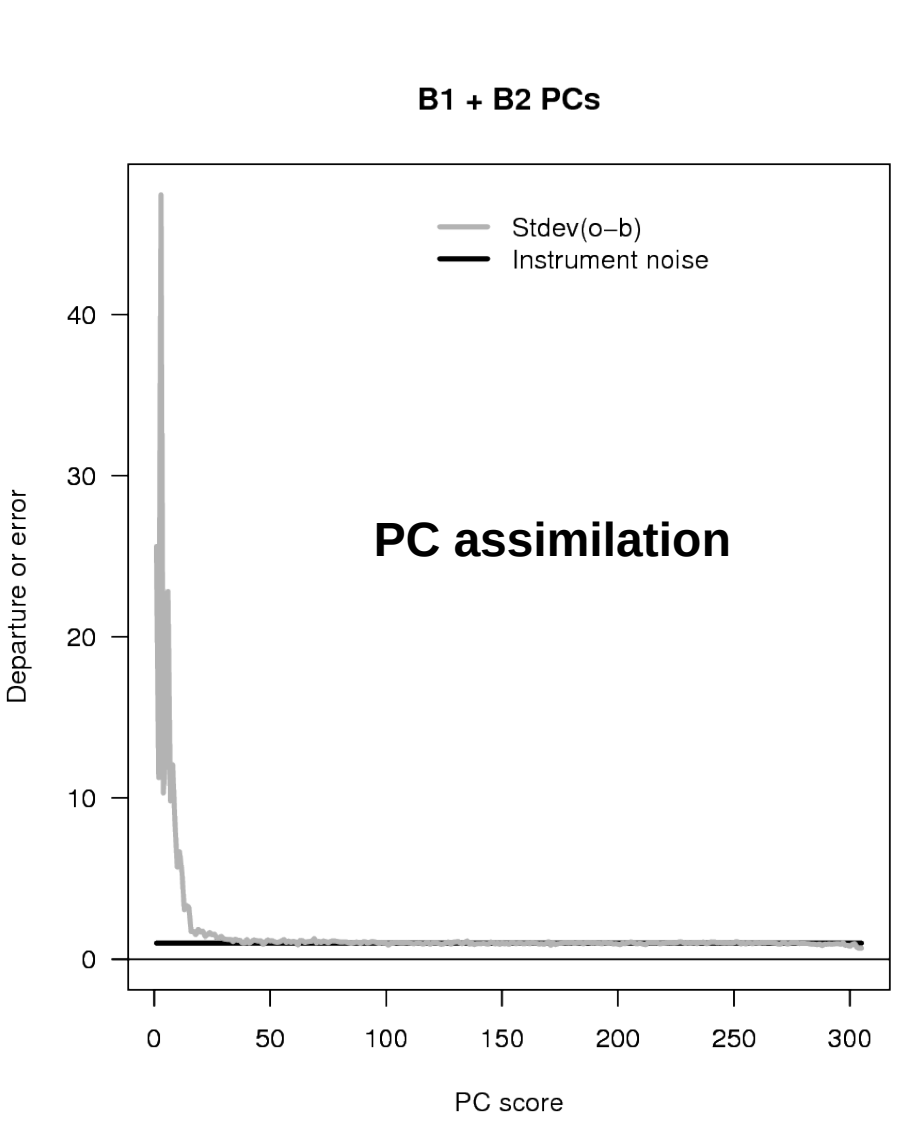
- **→ Observation-space diagnostics**

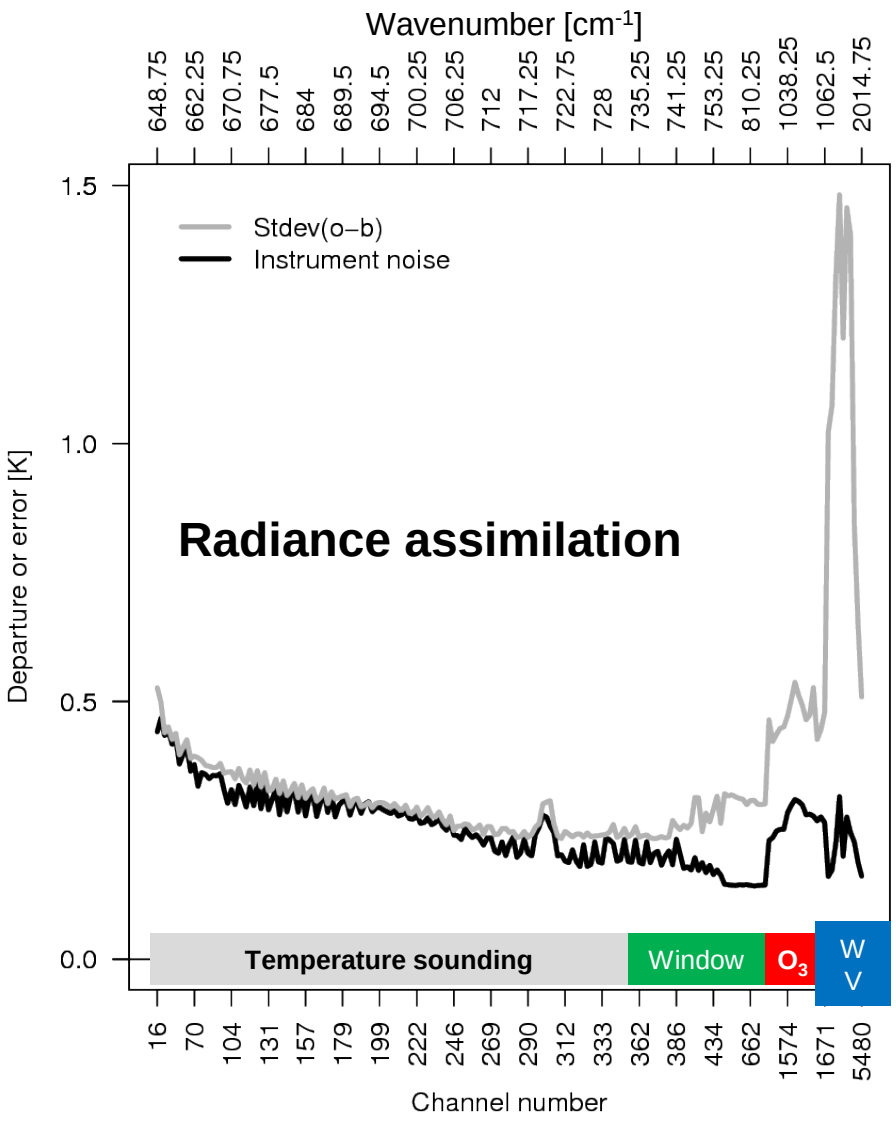
Experiments

- **Diagnostics taken from assimilation systems with the full observing system (19 June – 19 July 2012):**
  - **PC-scores assimilation:**
    - **Assimilation of 305 PC-scores derived from 305 channels from IASI bands 1 & 2**
    - **Assimilation of completely clear scenes only; new cloud detection**
    - **→ Marco Matricardi's talk yesterday**
  - **Radiance assimilation:**
    - **Assimilation of brightness temperatures from 191 channels (as performed in operations).**
    - **Assimilation of clear channels and overcast scenes**

- **Error diagnostics with Hollingsworth/Lönnberg method from completely clear scenes (Desroziers gives qualitatively similar results).**

Background departures





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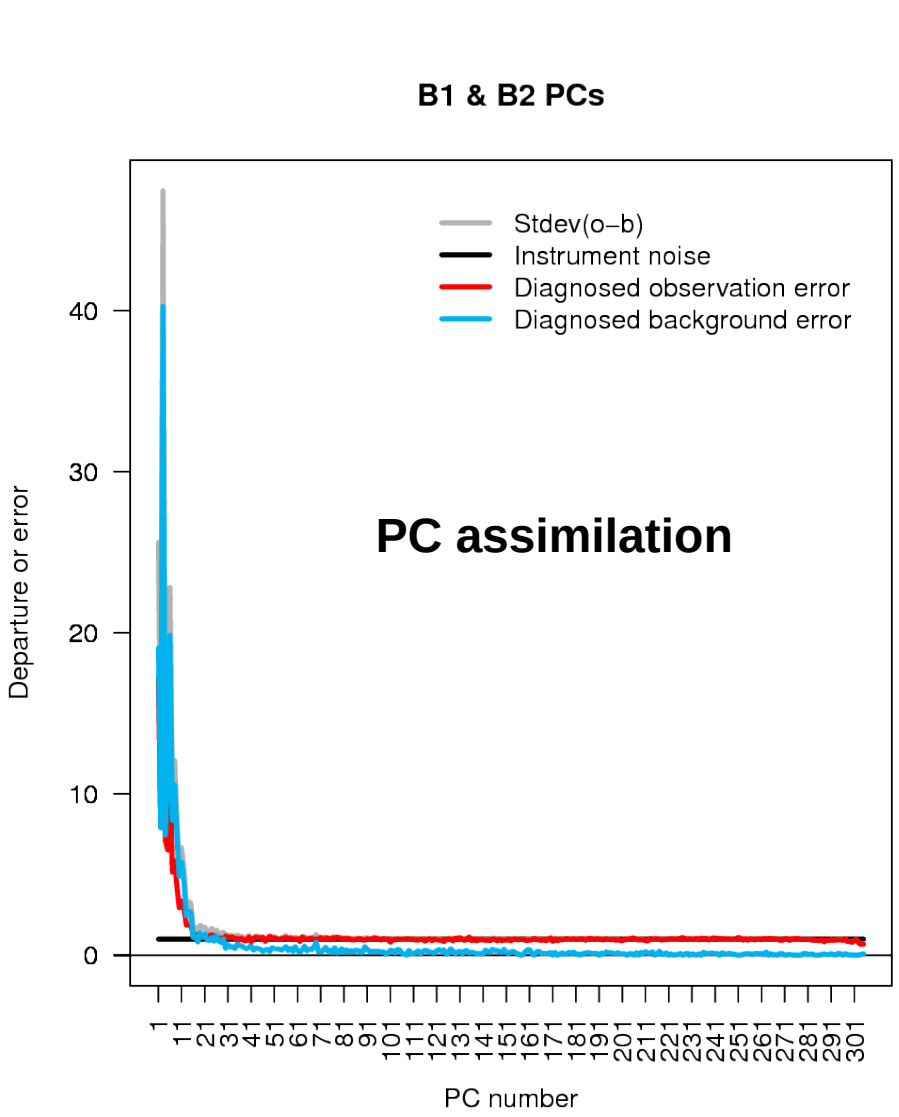
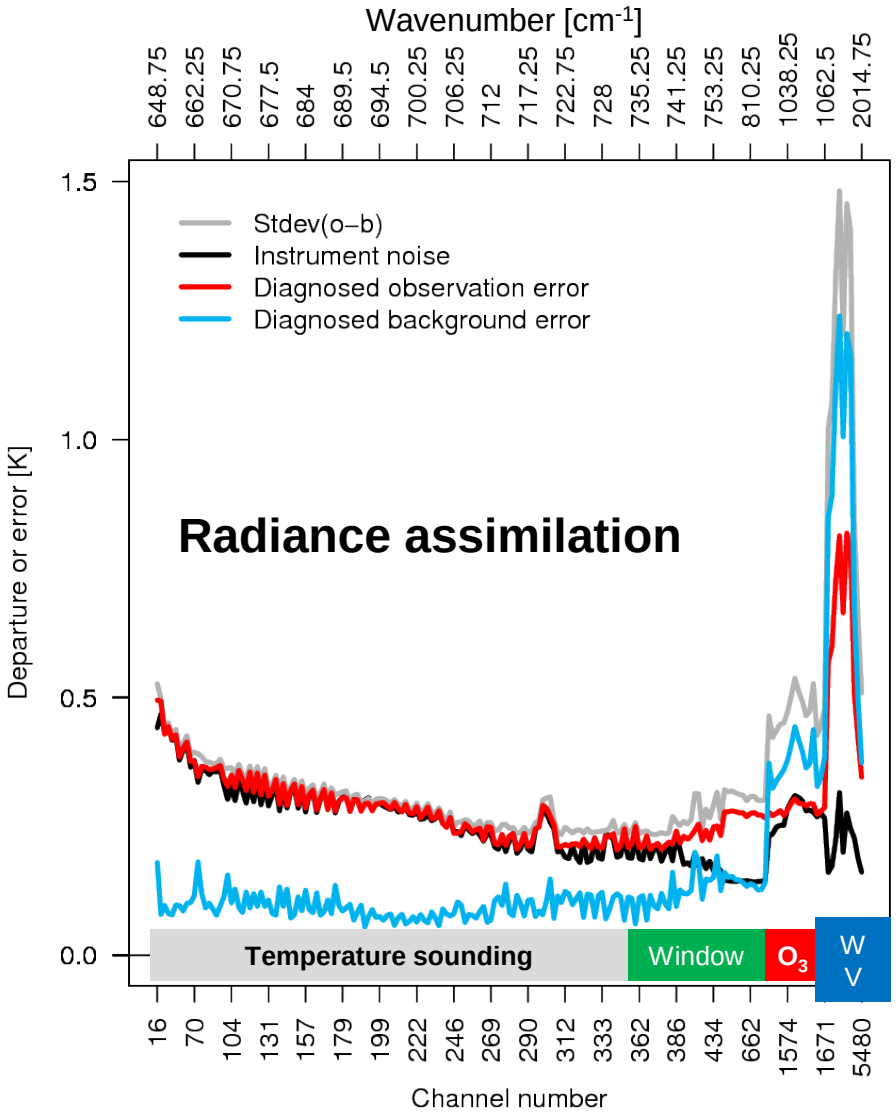
Diagnosed background and observation error





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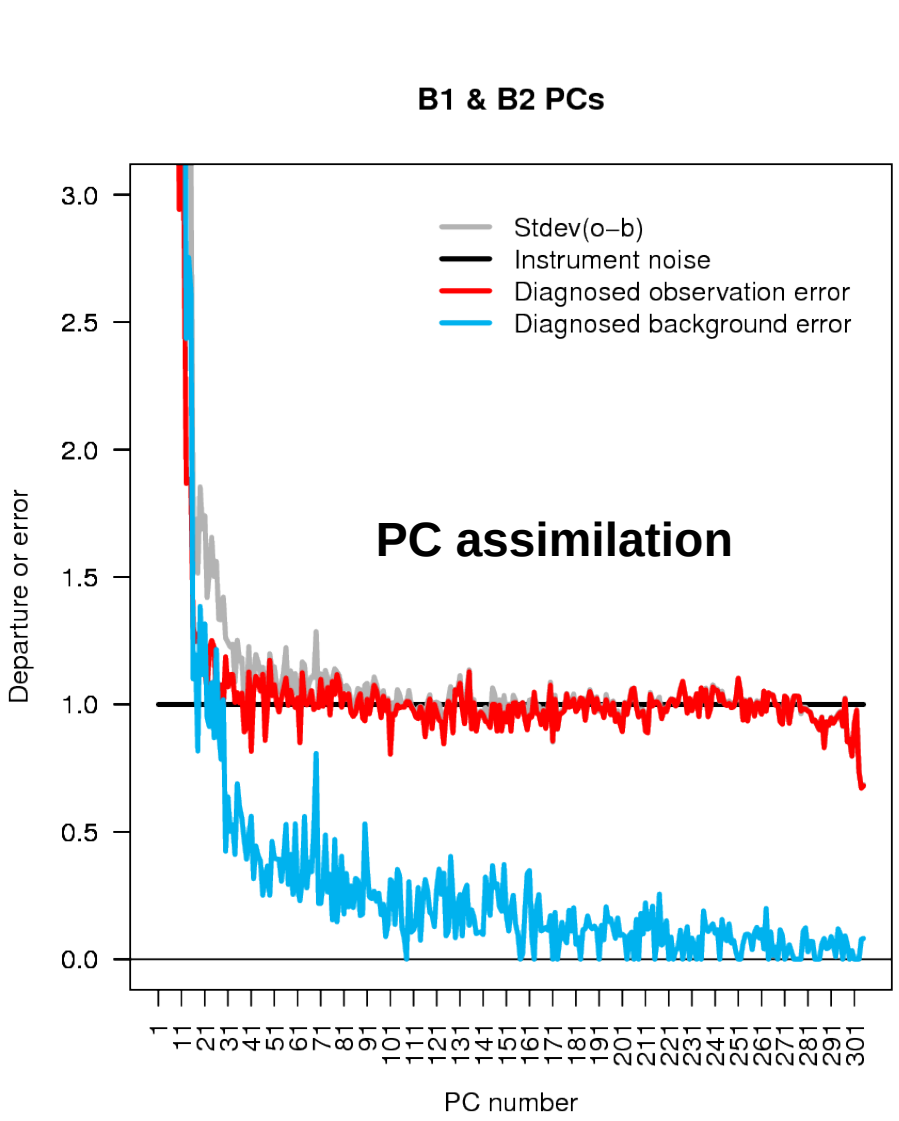
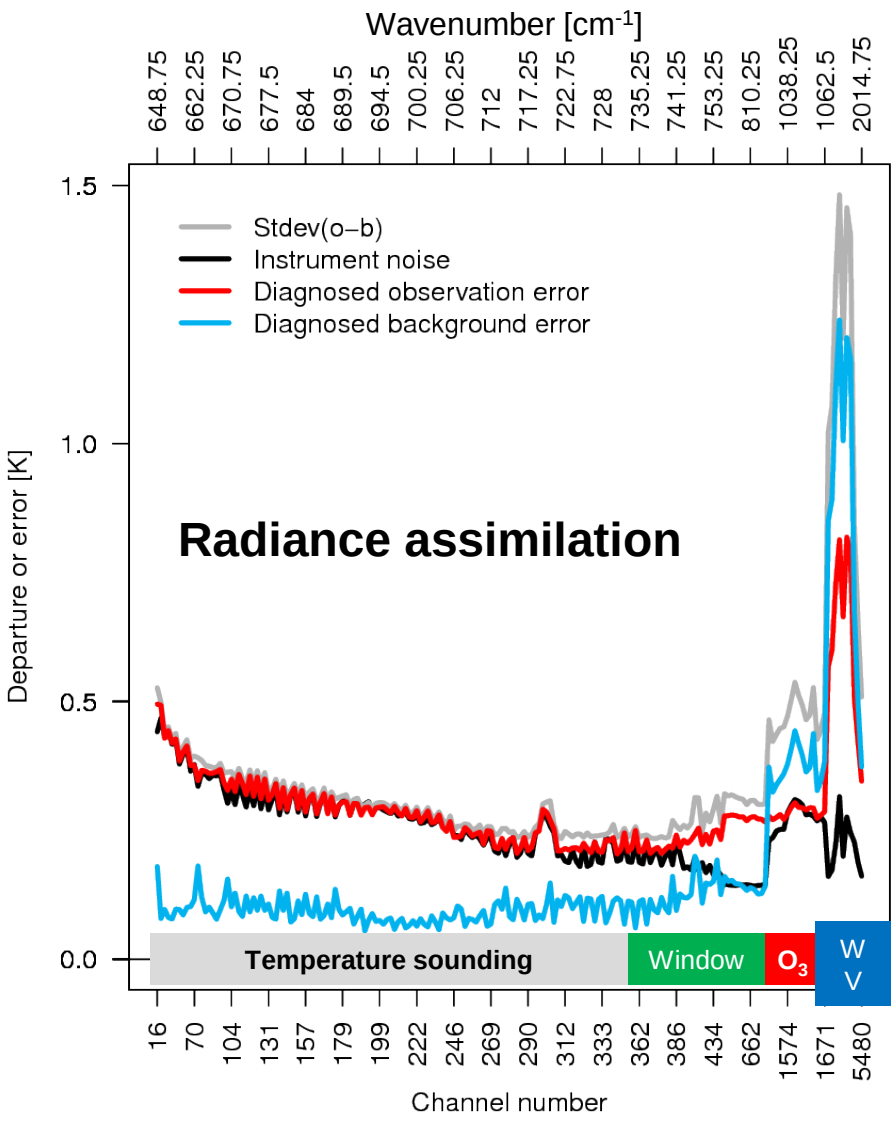
Diagnosed background and observation error





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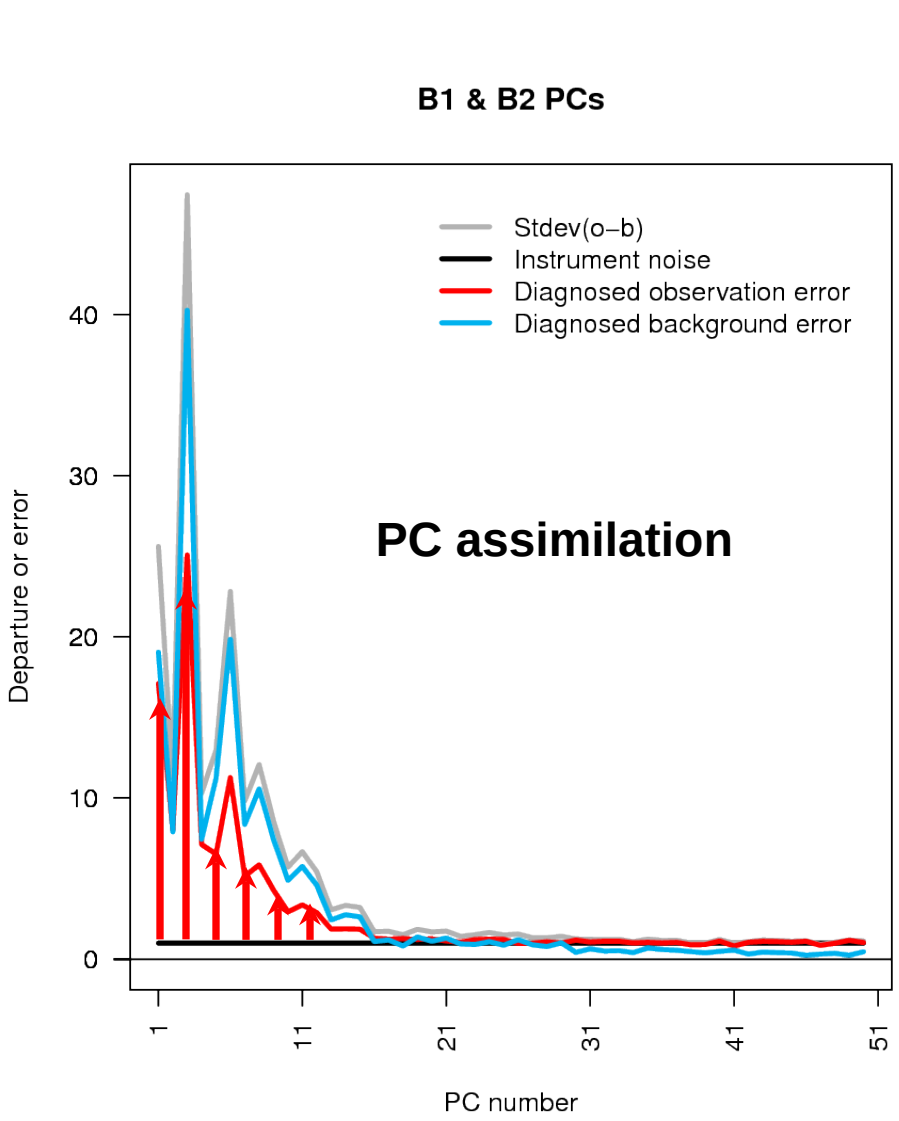
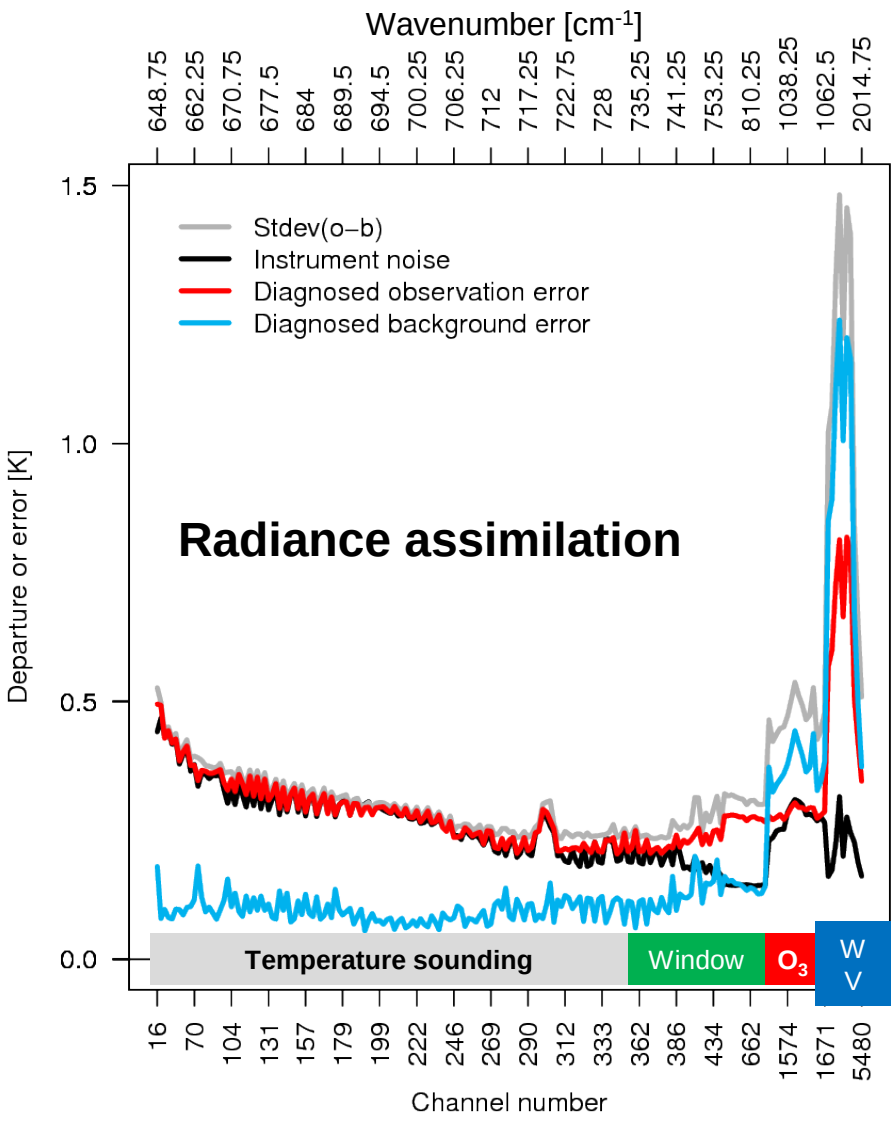
Diagnosed background and observation error





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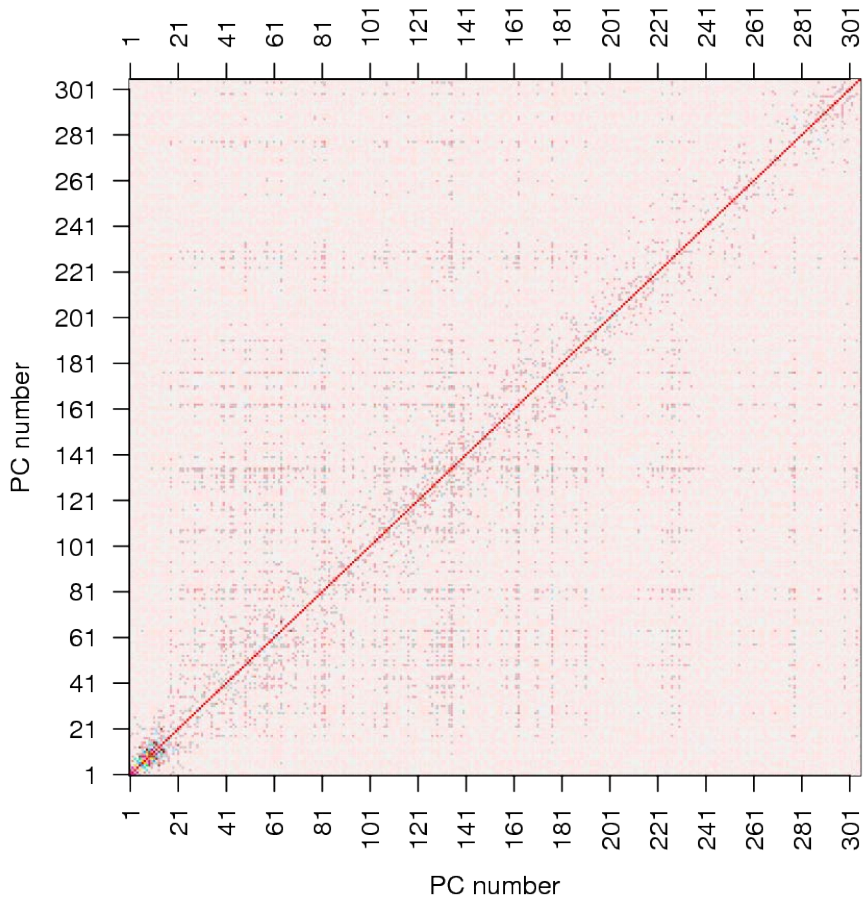
Diagnostics: Some points

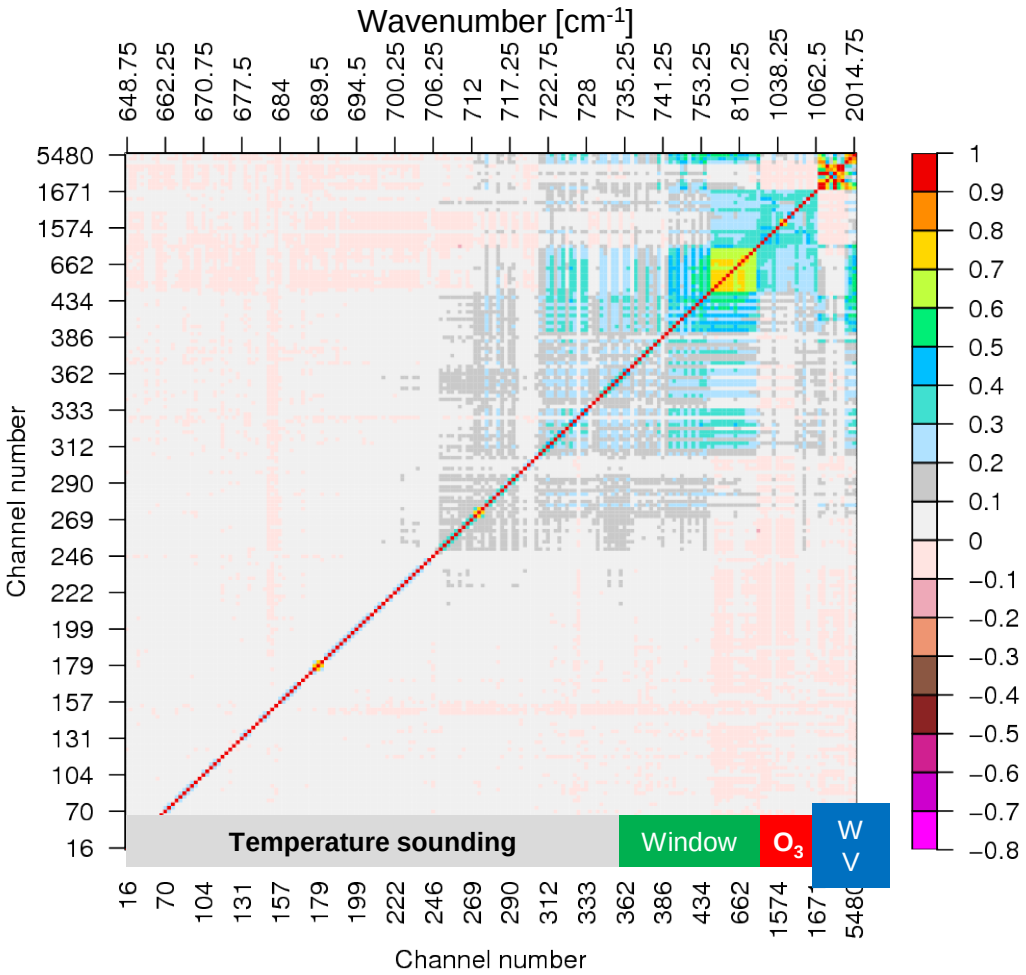
- **For raw radiance assimilation:**
  - **Background error small for T-sounding; instrument noise dominates observation errors.**
  - **Significant contribution from "other" errors for window channels, H_2O, O_3.**
  - **Background errors larger than observation errors for window channels, H_2O.**
- **For PC-scores assimilation:**
  - **Background and observation error comparable for leading PC-scores.**
  - **Significant contribution from "other" errors for leading PC-scores.**
  - **Instrument noise dominates for higher-order PC-scores.**

Diagnosed observation error correlations

PC assimilation



Radiance assimilation



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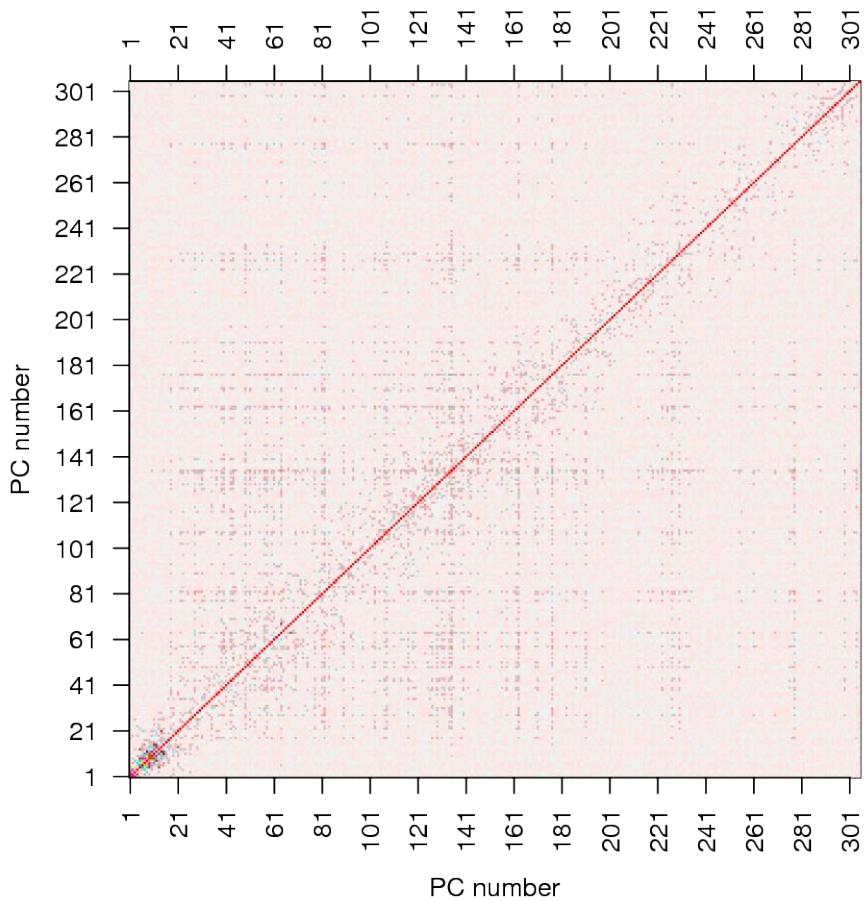
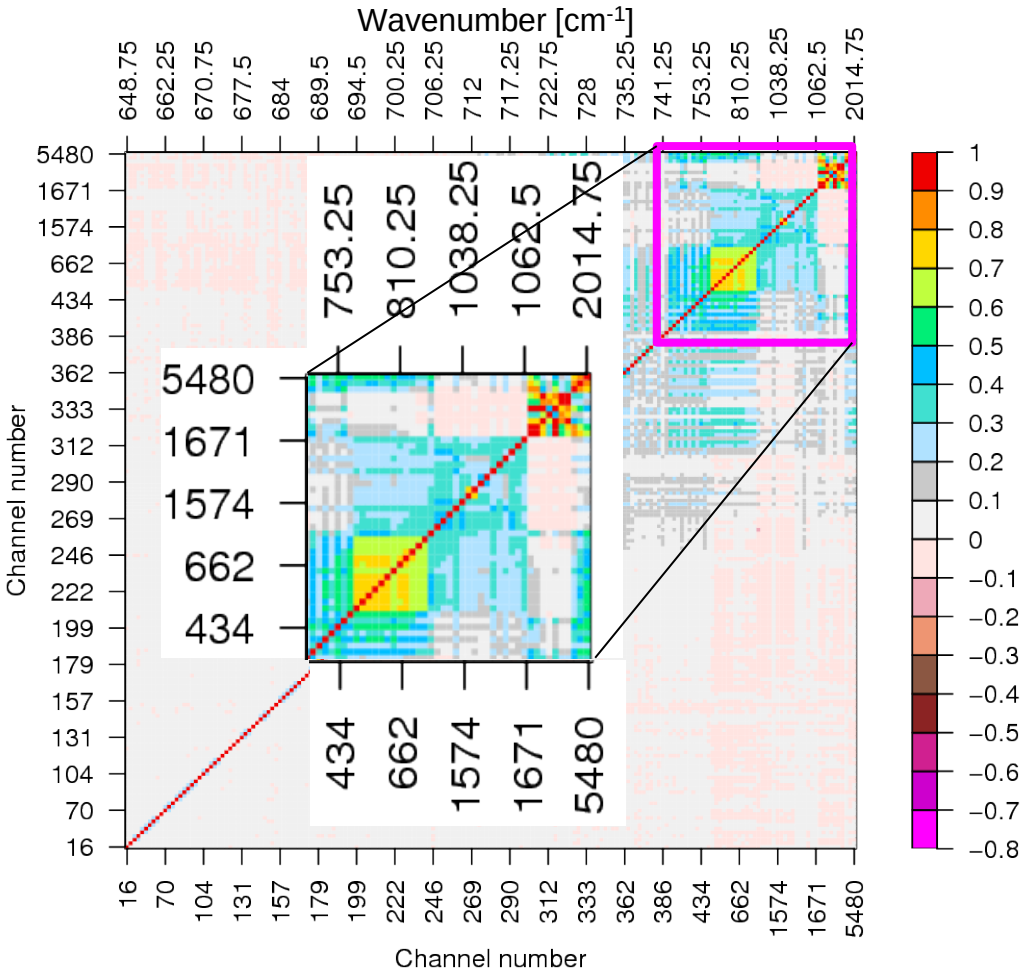
Diagnosed observation error correlations

PC assimilation

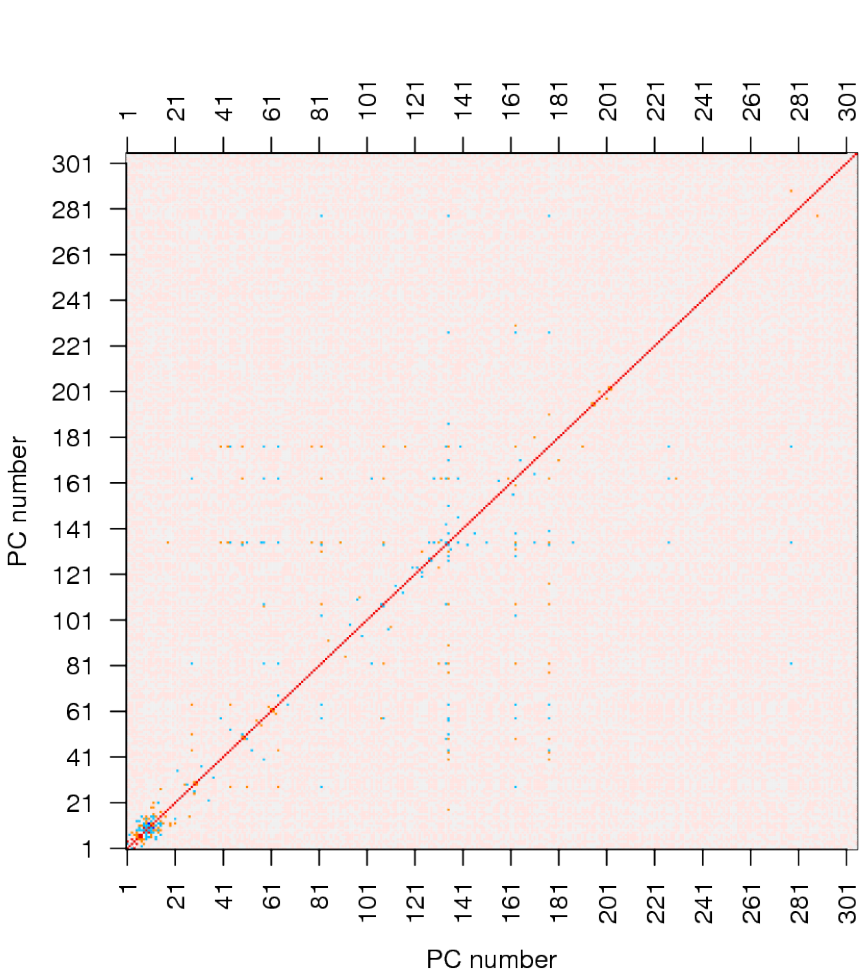


Radiance assimilation

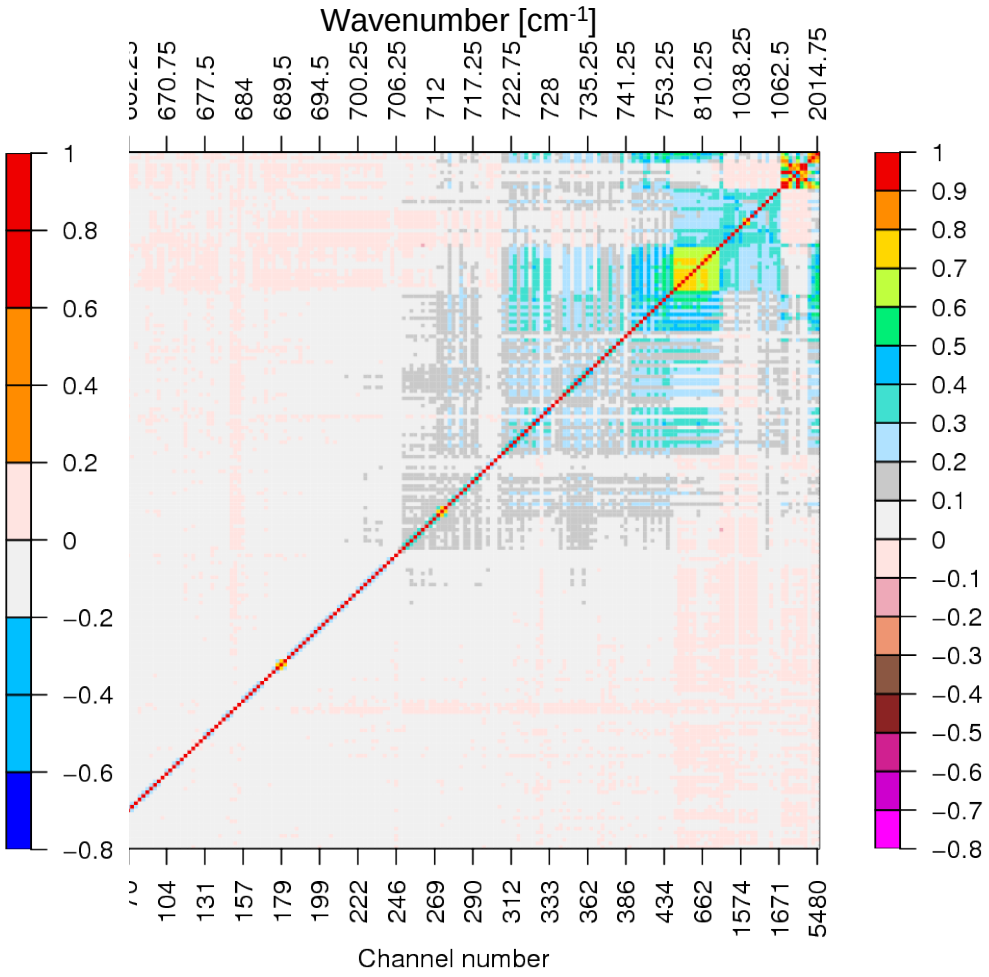


Diagnosed observation error correlations

PC assimilation

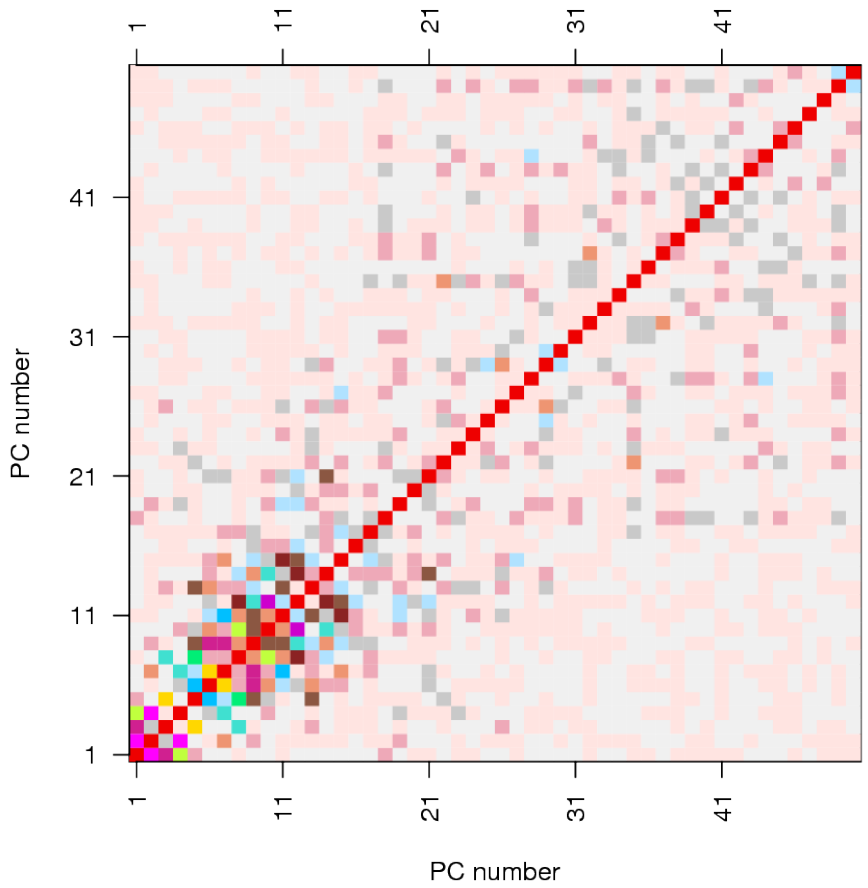


Radiance assimilation

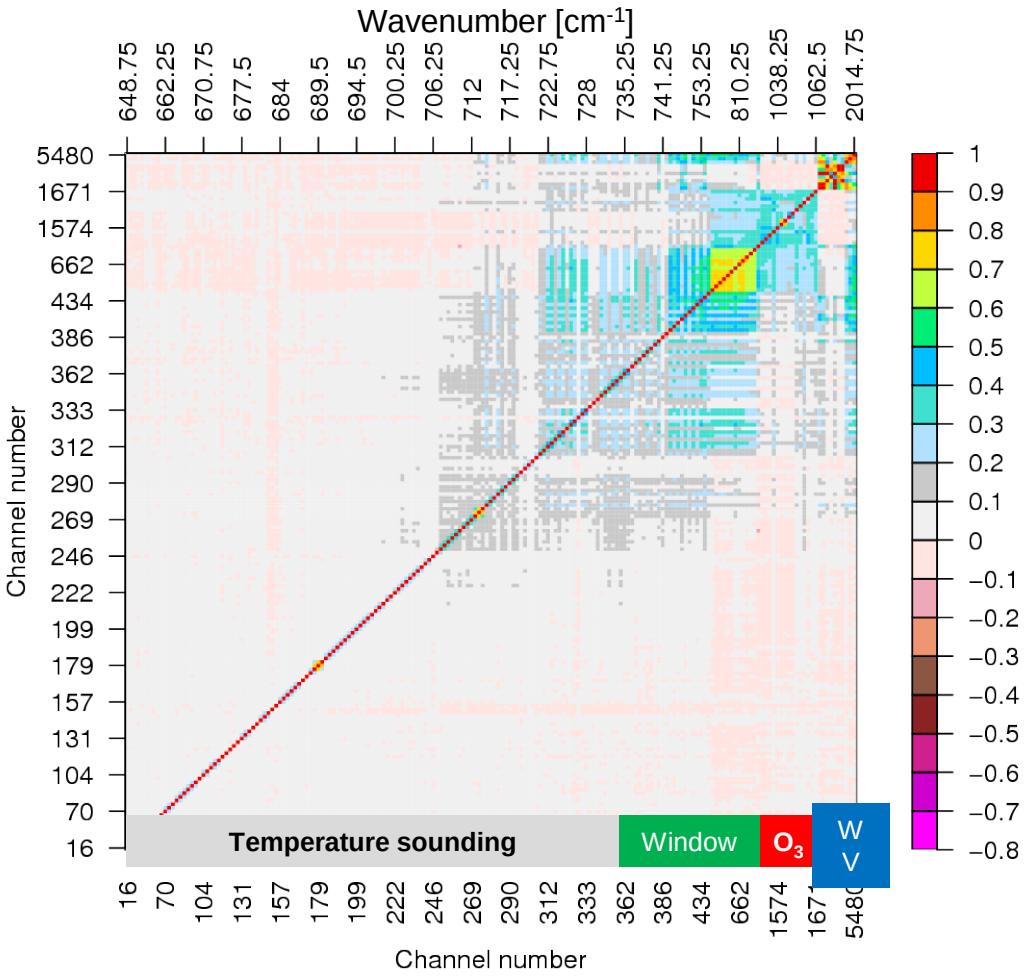


Diagnosed observation error correlations

PC assimilation



Radiance assimilation



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How do the *diagnosed* observation errors compare in brightness temperature space?

Conversion PC scores ↔ brightness temperatures

- **From radiances to PC-space:**

$$\mathbf{y}_{PC} = \mathbf{U}\,\mathbf{N}^{-1/2}\,(\mathbf{y}_{Rad} - \overline{\mathbf{y}_{Rad}})$$

  - **y** – observations
  - **U** – matrix with rows of eigenvectors of covariance matrix
  - **N** – covariance of instrument noise

- **Convert observation error covariance R diagnosed in PC-space to radiance space:**

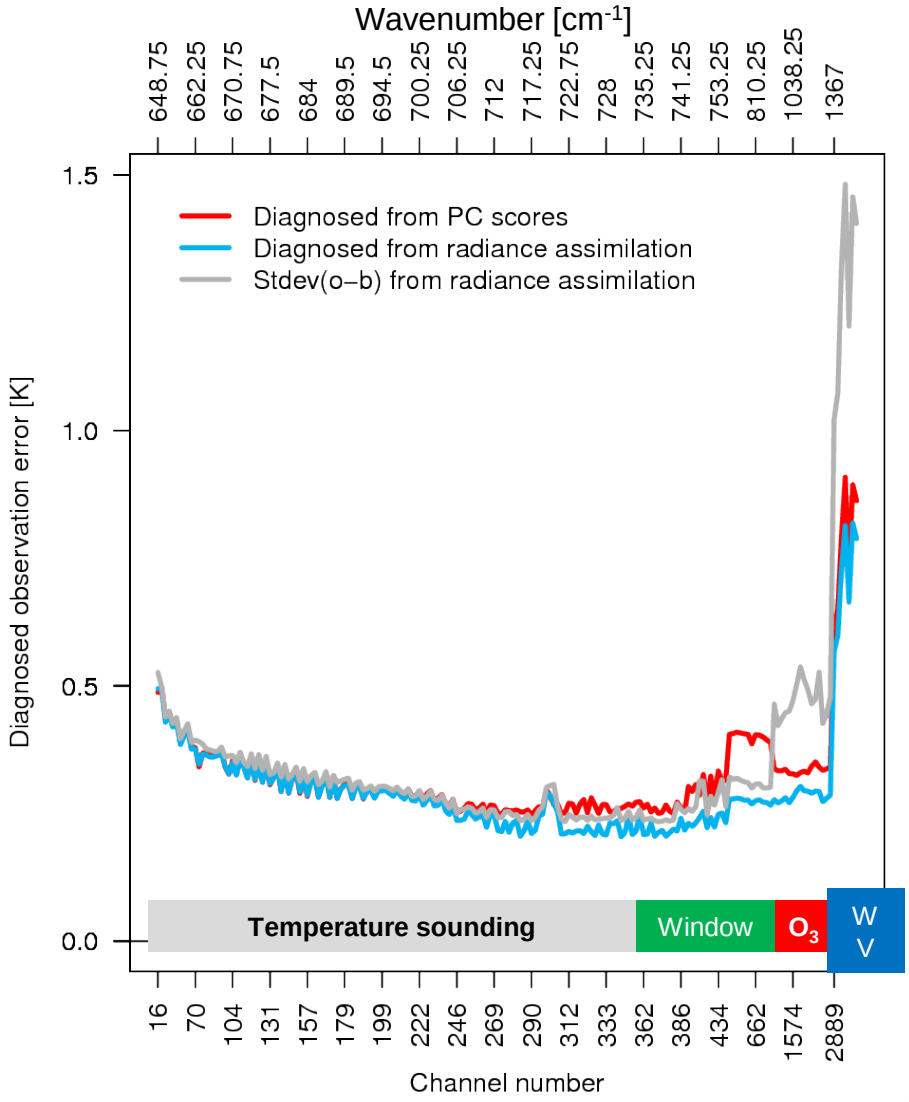
$$\mathbf{R}_{Rad} = \mathbf{U}^{T}\ \mathbf{N}^{-1/2}\ \mathbf{R}_{PC}\ (\mathbf{N}^{-1/2})^{T}\ \mathbf{U}$$

- **Conversion to brightness temperature space:**

$$\mathbf{R}_{BT} = \mathbf{P}\,\mathbf{R}_{Rad}\,\mathbf{P}^{T}$$

P – Jacobian of the inverse Planck function at mean scene temperature

Diagnosed observation errors, subsampled for common channel set



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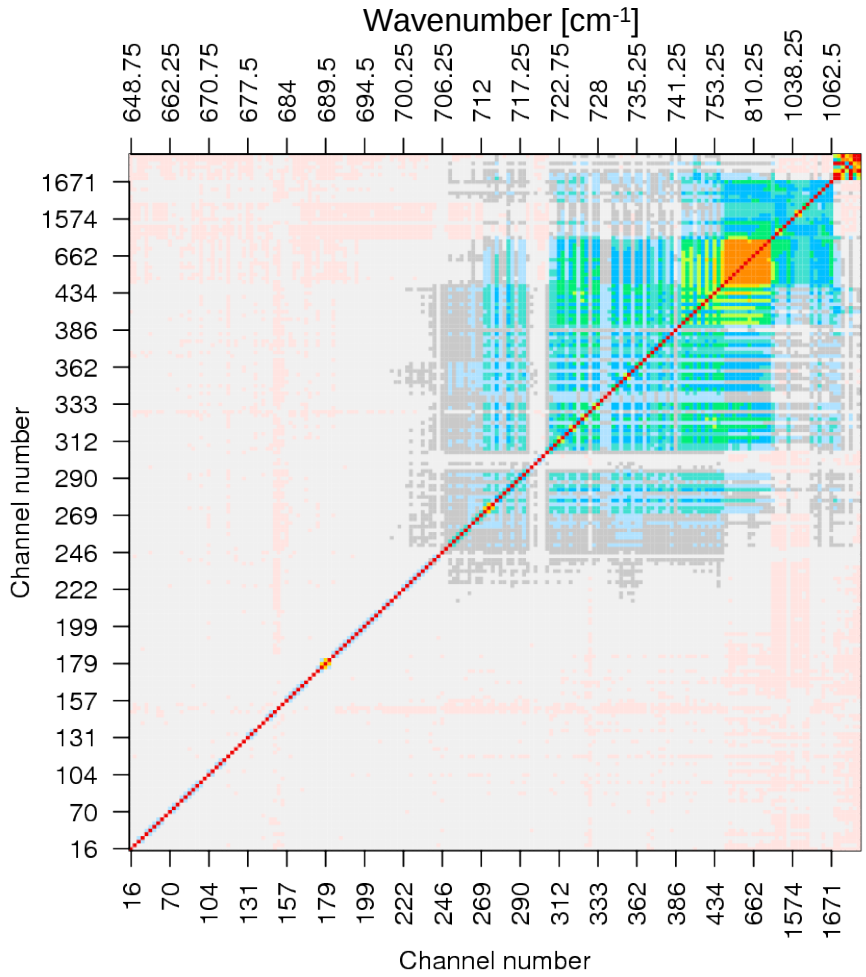
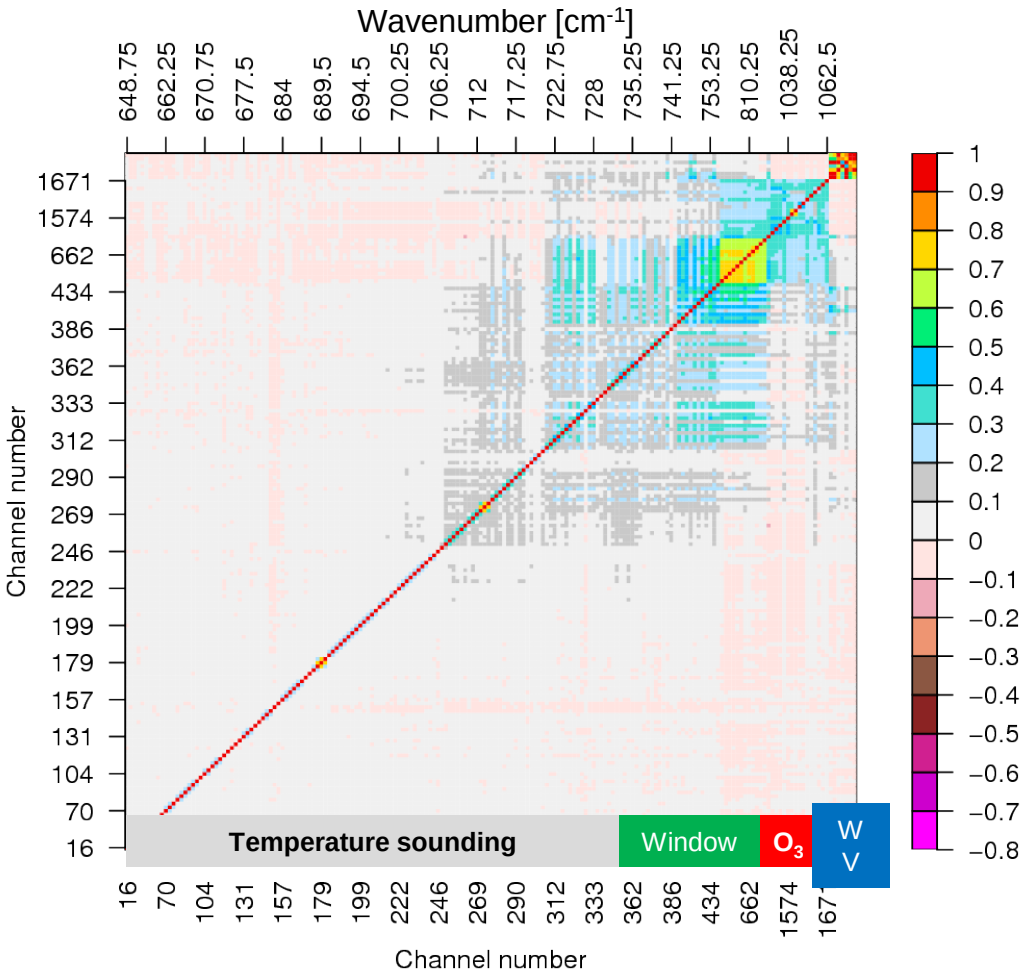
Diagnosed observation error correlations, subsampled for common channel set

PC assimilation, converted to radiance space



Radiance assimilation, common channels only



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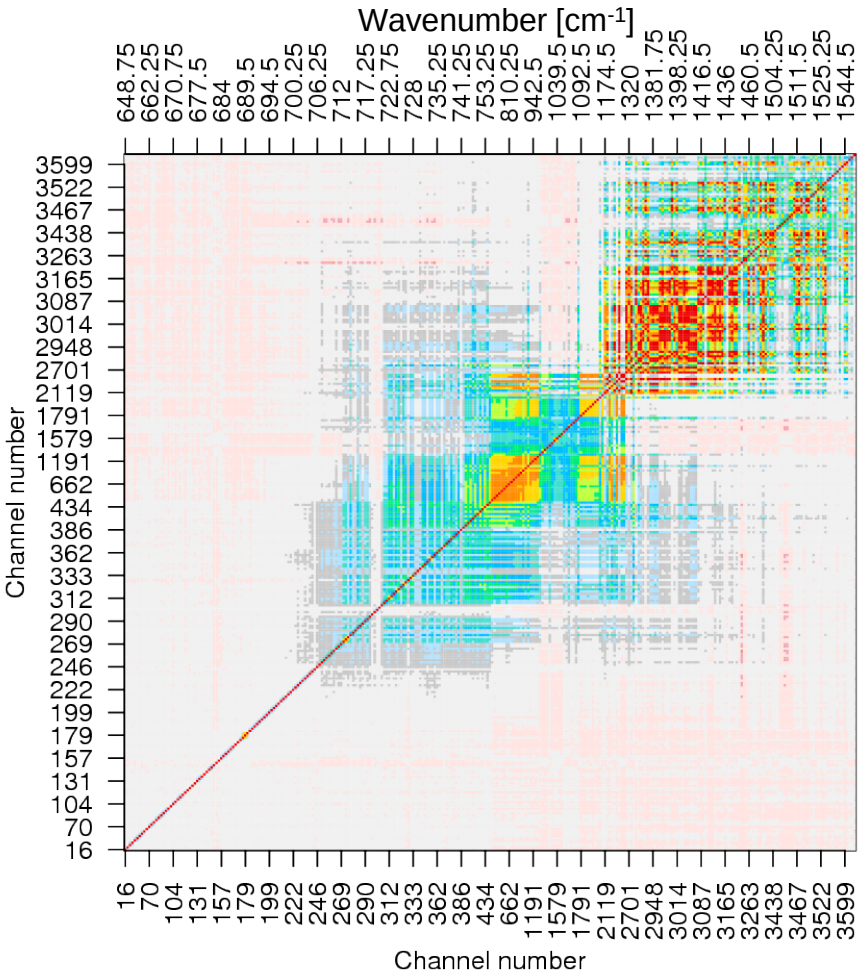
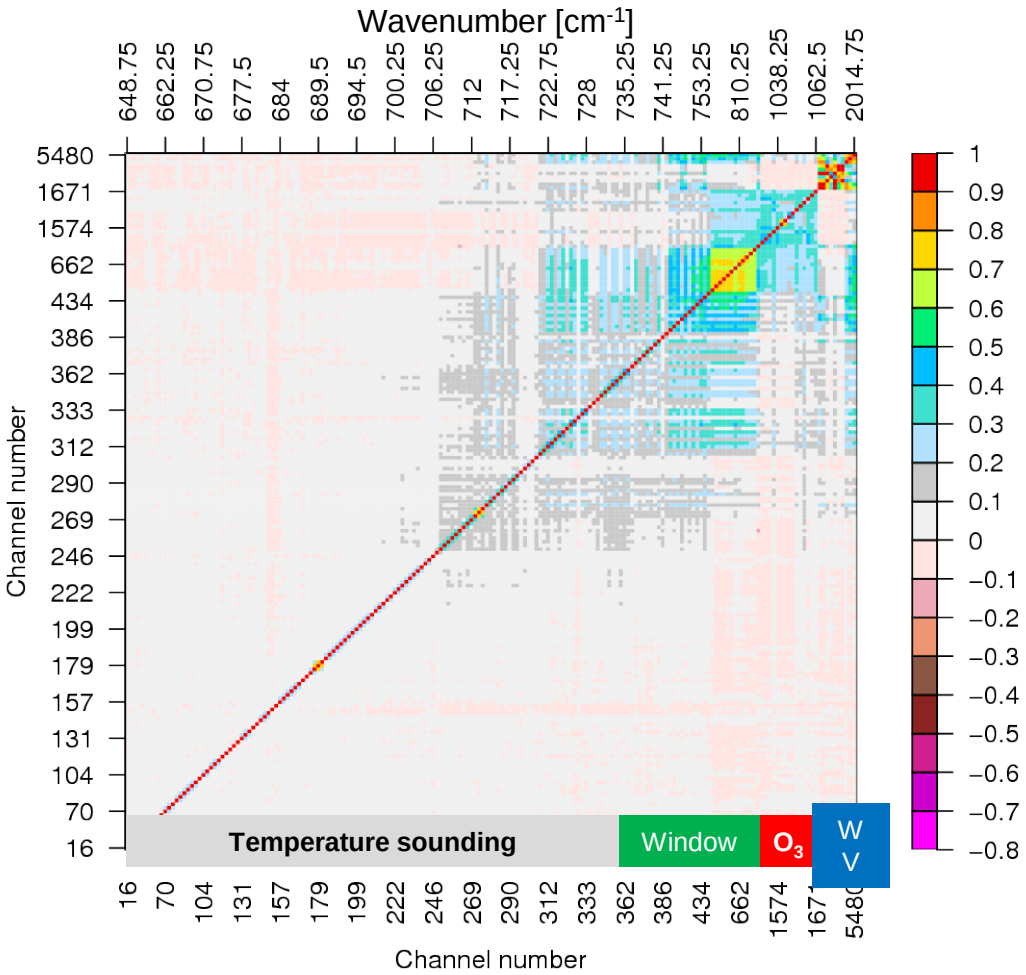
Diagnosed observation error correlations

PC assimilation, converted to radiance space



Radiance assimilation



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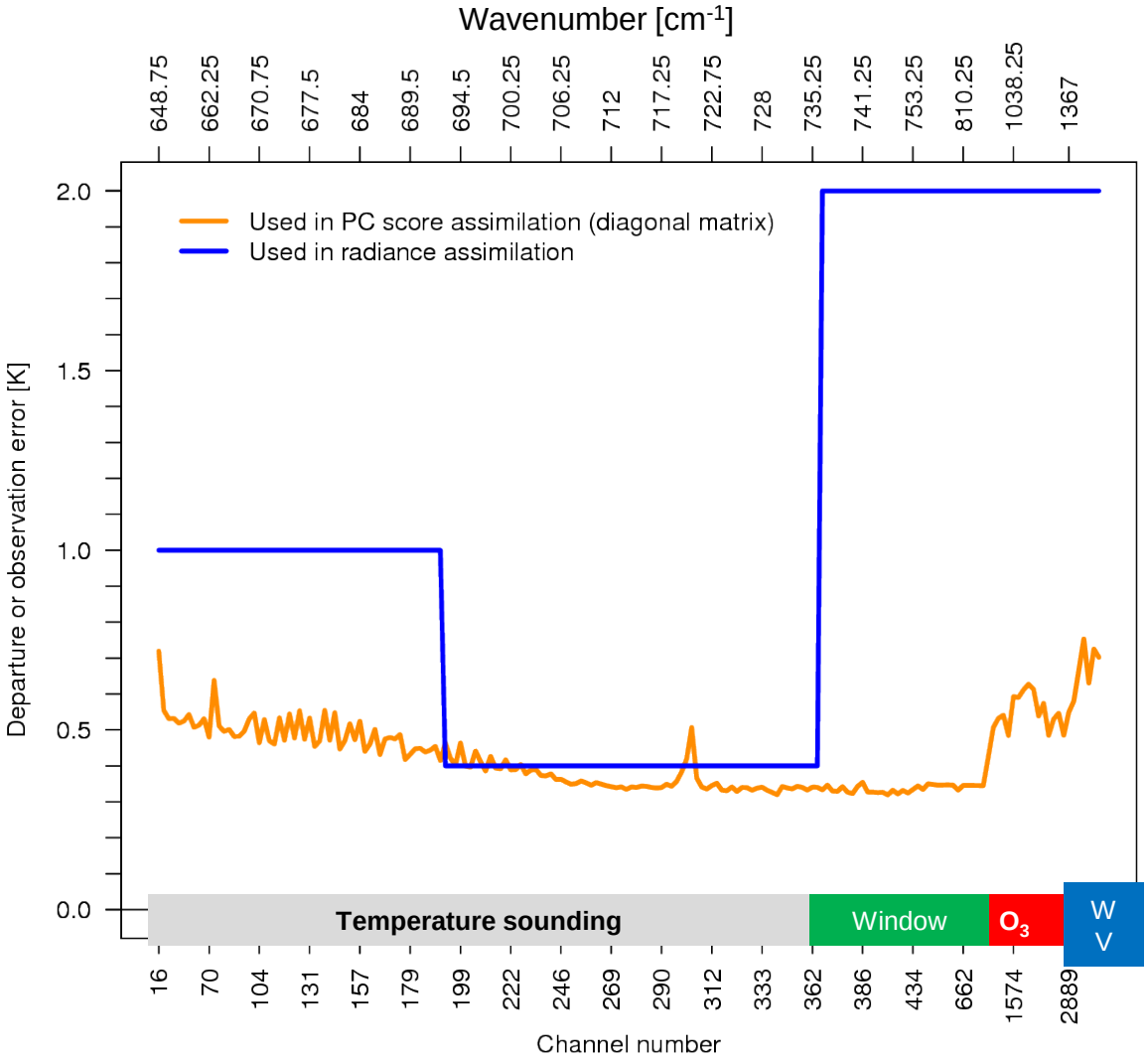
What do the *assumed* observation errors from the radiance and the PC experiment look like in brightness temperature space?

Assumed observation errors

(subsampled for common channel set)



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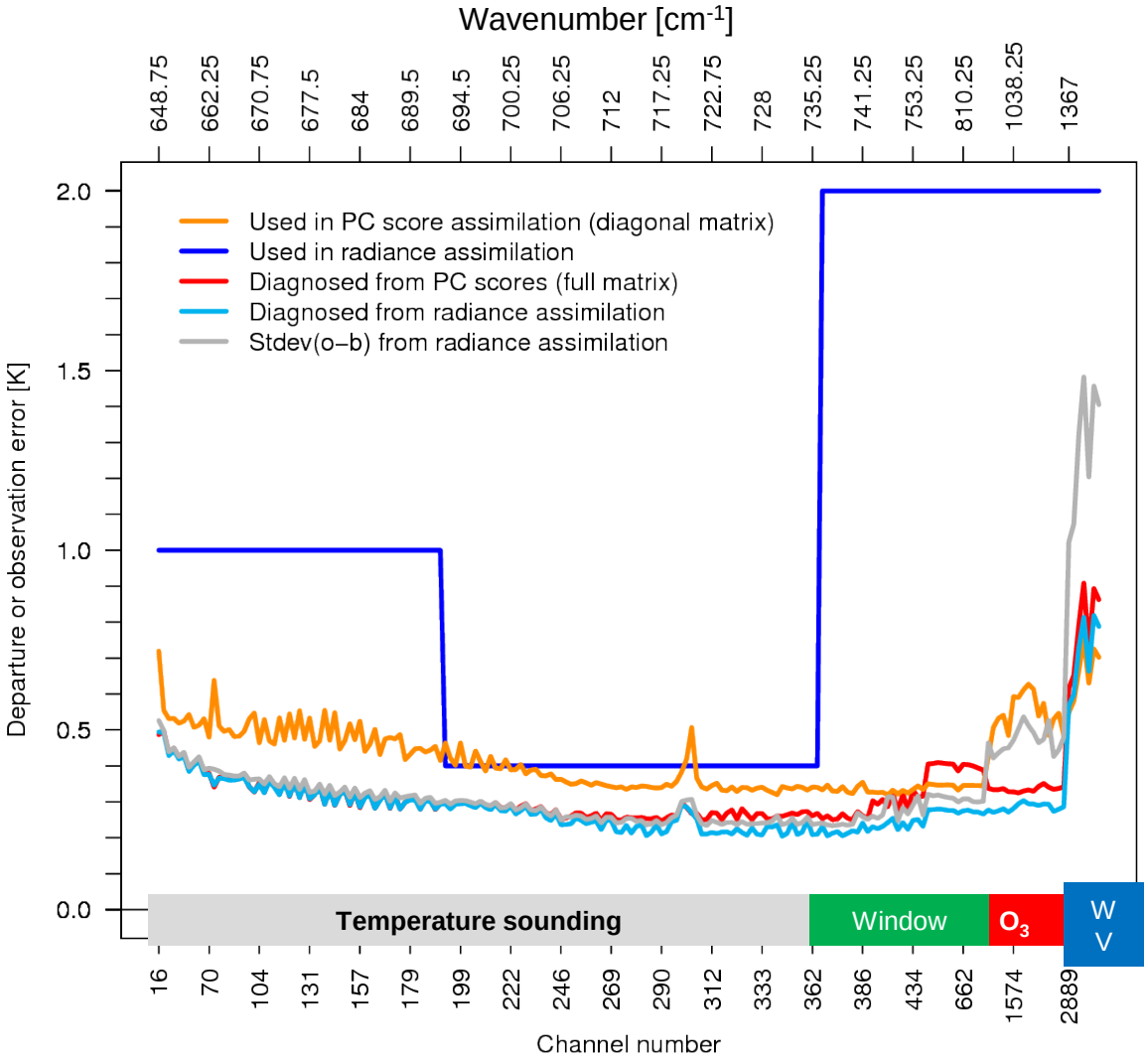
Assumed observation errors

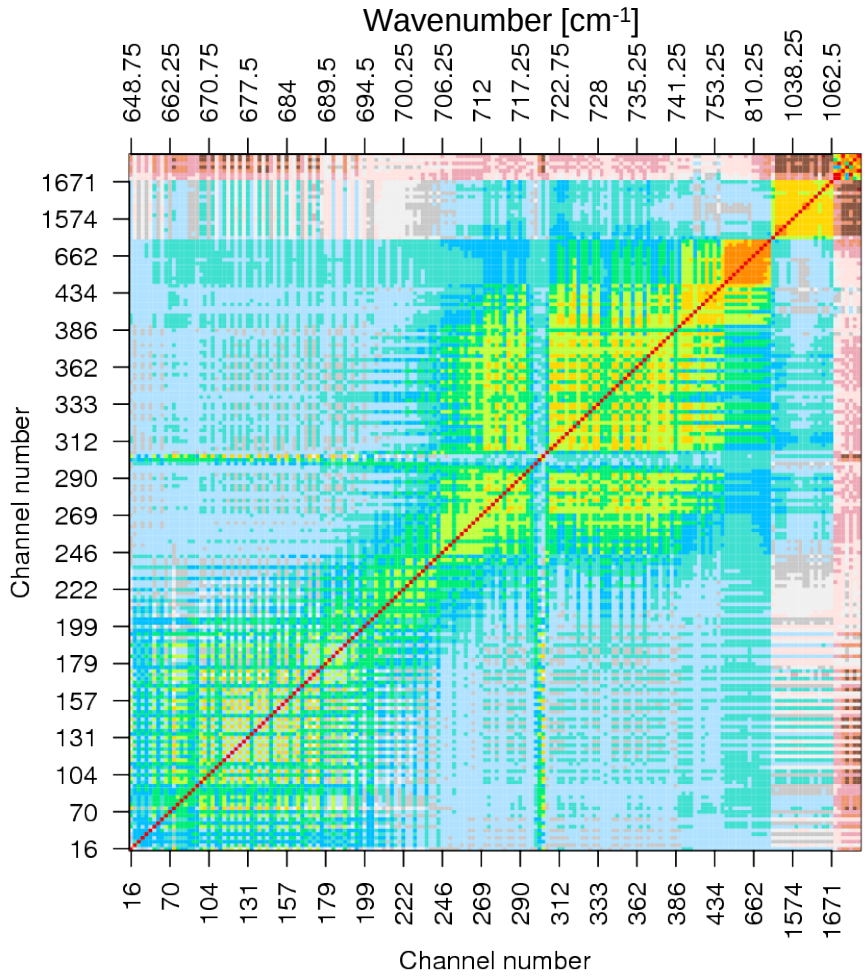
(subsampled for common channel set)



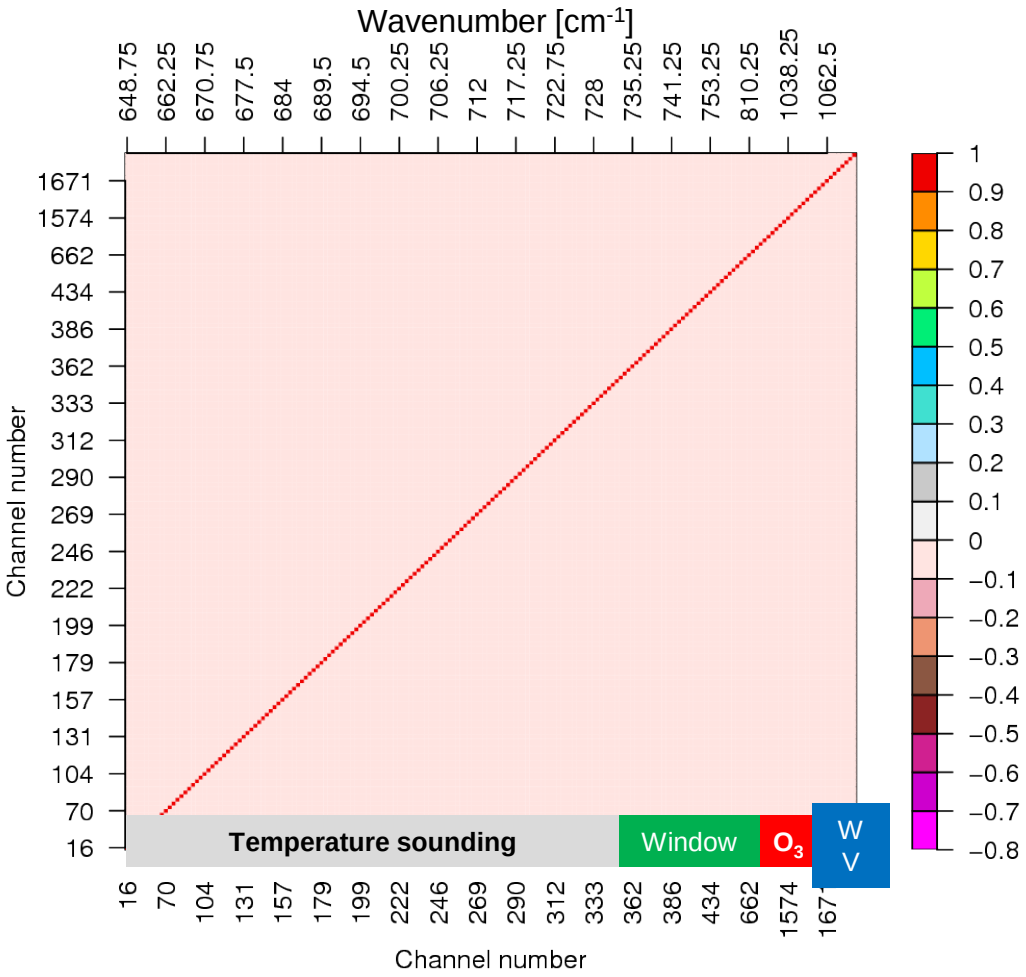
Assumed observation error correlations

(subsampled for common channel set)

PC assimilation, converted to radiance space



Radiance assimilation



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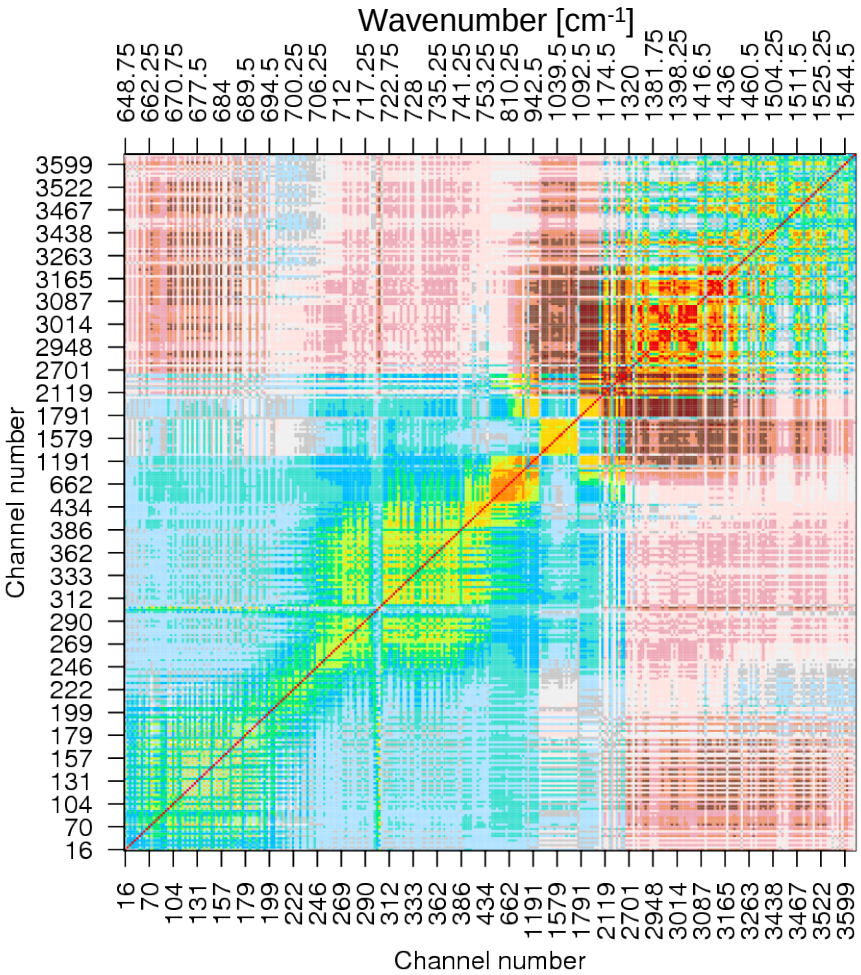
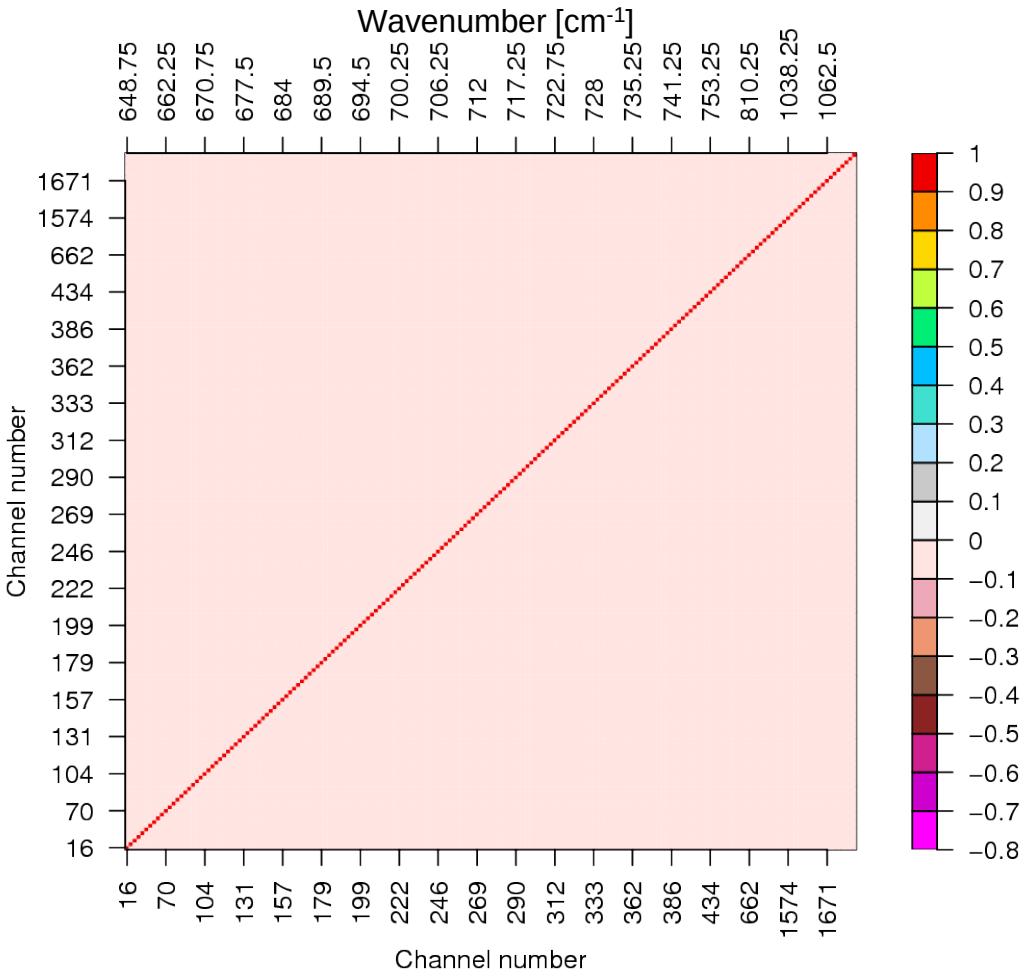
Assumed observation error correlations

PC assimilation, converted to radiance space



Radiance assimilation



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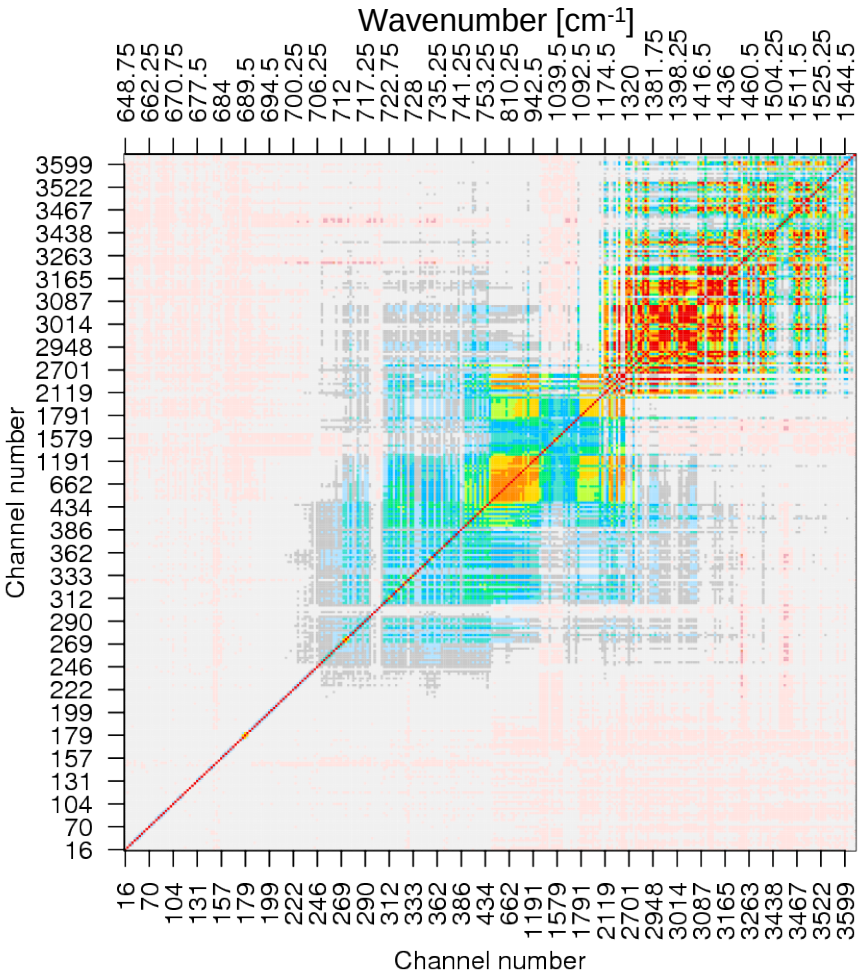
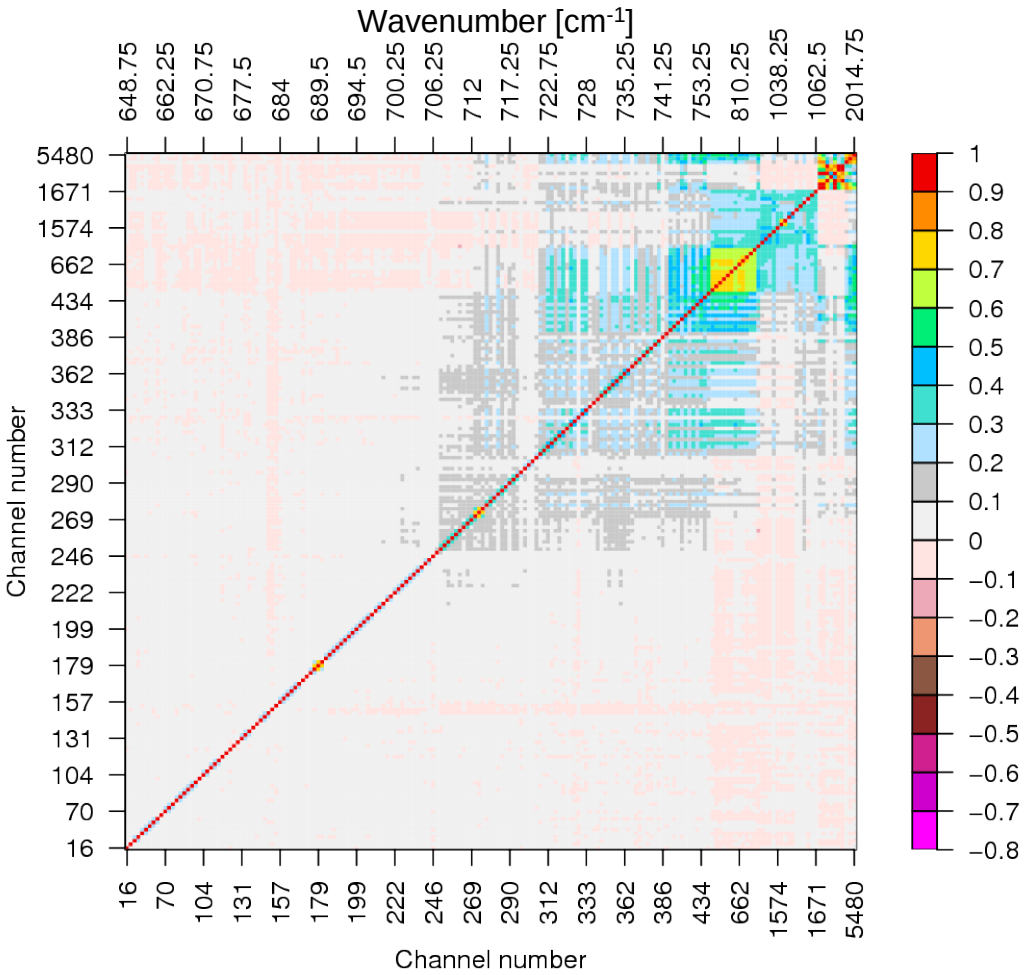
Diagnosed observation error correlations

PC assimilation, converted to radiance space



Radiance assimilation



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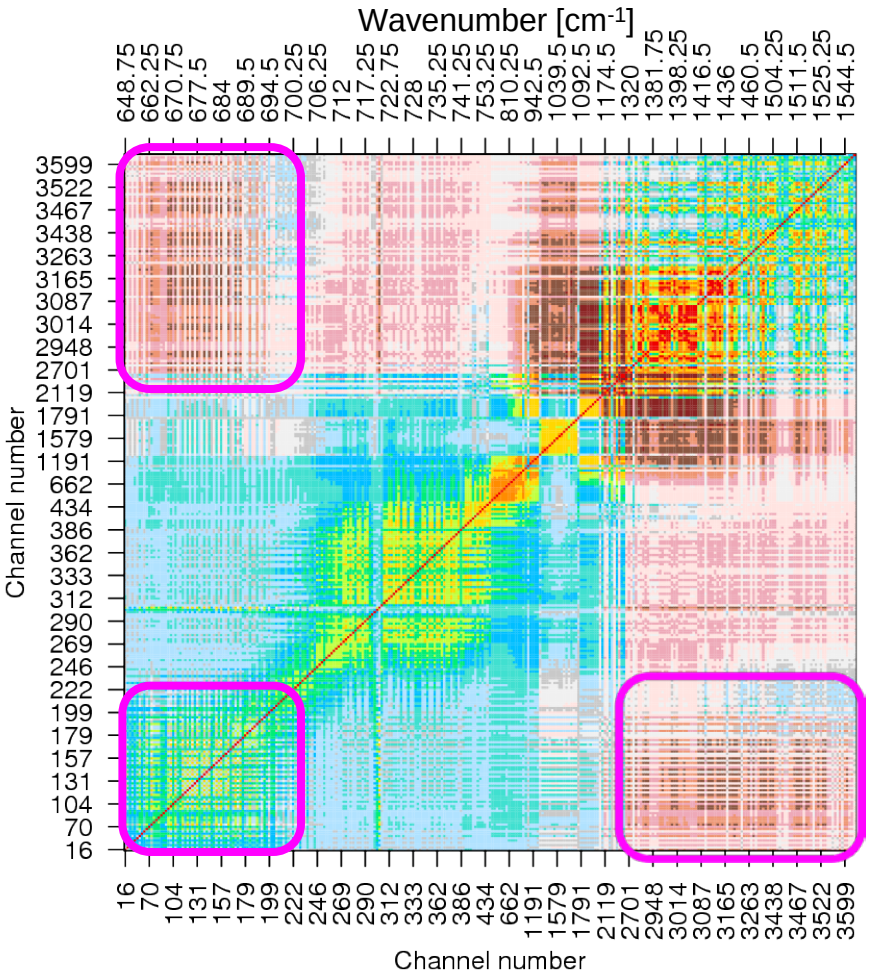
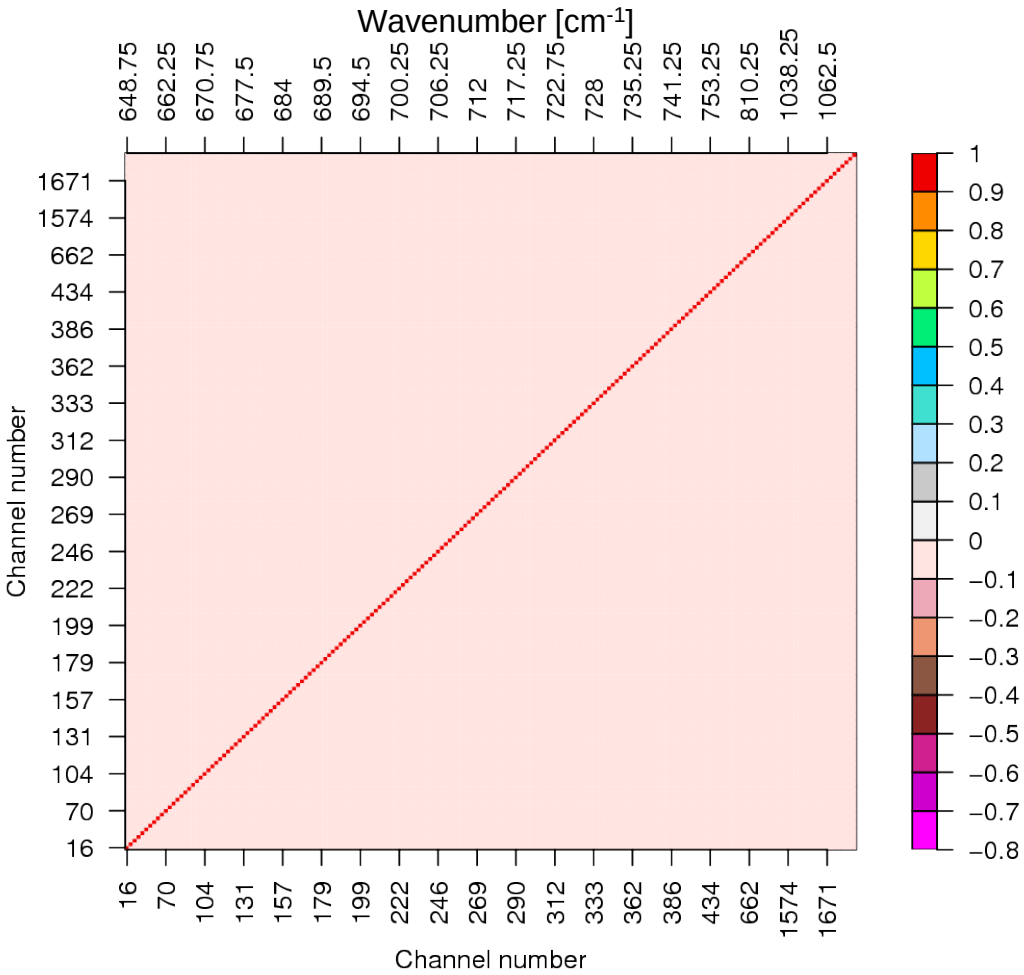
Assumed observation error correlations

PC assimilation, converted to radiance space



Radiance assimilation



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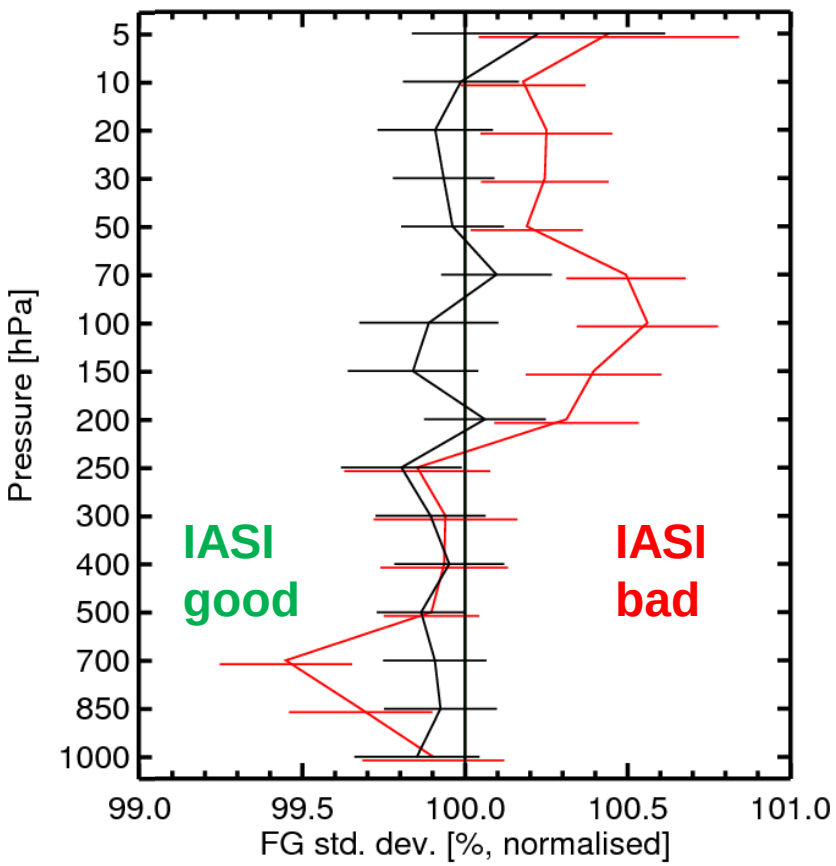
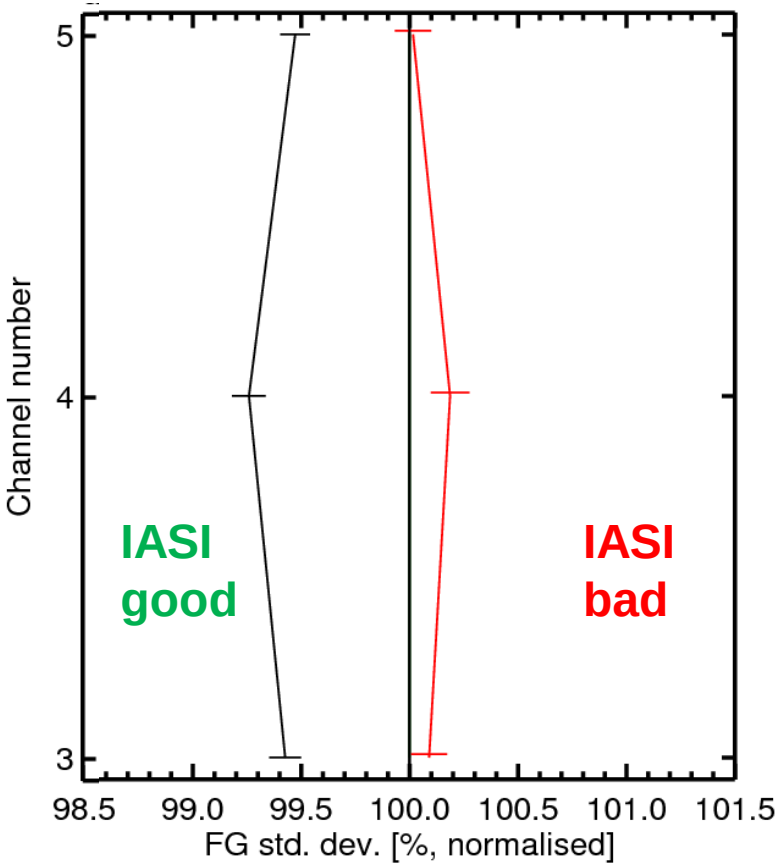
Background departure statistics

(normalised to no-IASI experiment)

Radiosonde temperature, global



MHS, global



Radiance assimilation (191 channels, operation obs errors)

PC-assimilation (305 PCs, diagnosed diagonal obs errors)

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Summary

- **Diagnostics suggest F introduces error correlations for PCs as well as radiances.**
- **Observation error covariances diagnosed from the PC-assimilation and the radiance assimilation are qualitatively consistent.**
- **The diagonal observation error covariance used in the PC assimilation implies:**
  - **Some inter-channel error correlations when converted to radiance space,**
  - **with some of them qualitatively consistent with the diagnosed error correlations,**
  - **but with some spurious inter-channel error correlations (e.g., between stratospheric and humidity channels).**
- **There is scope for improved observation error specification for PC (and radiance) assimilation.**

Assumed errors in PC-space (B1 only)