Options for dealing with clouds in PCA space

Tony McNally and Marco Matricardi

ECMWF

Acknowledge EUMETSAT support for PC work!!

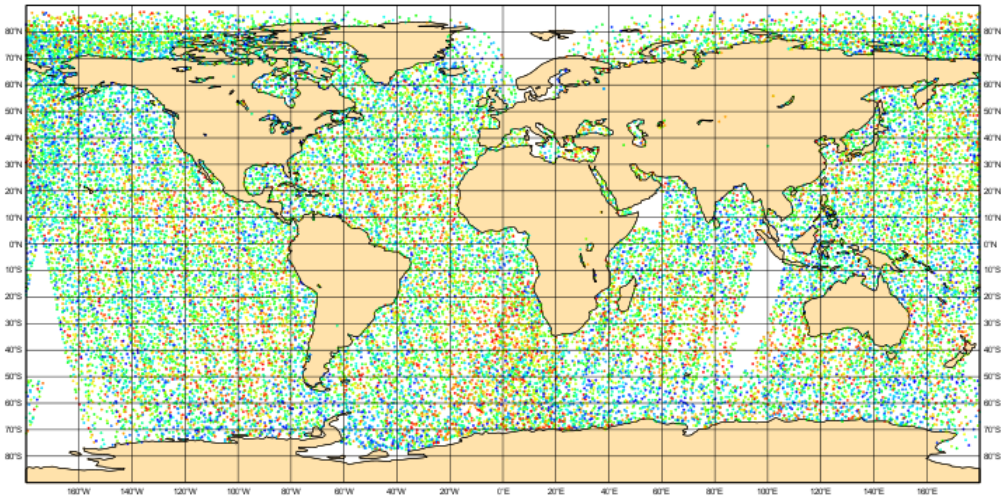
Options for dealing with clouds in PCA space

- What do we do for radiances
- What can we do in PC space
- Future options

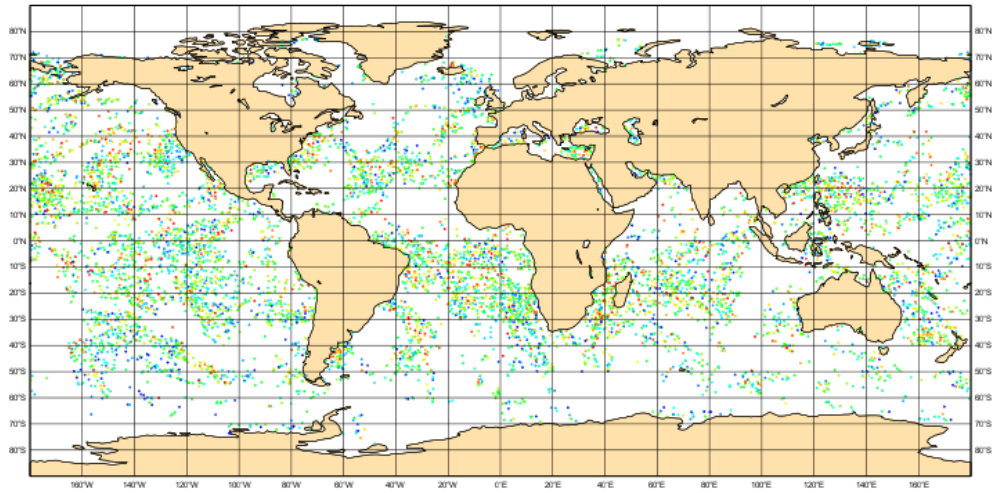
Why do we need to worry about clouds ?

We lose a lot of data due to clouds

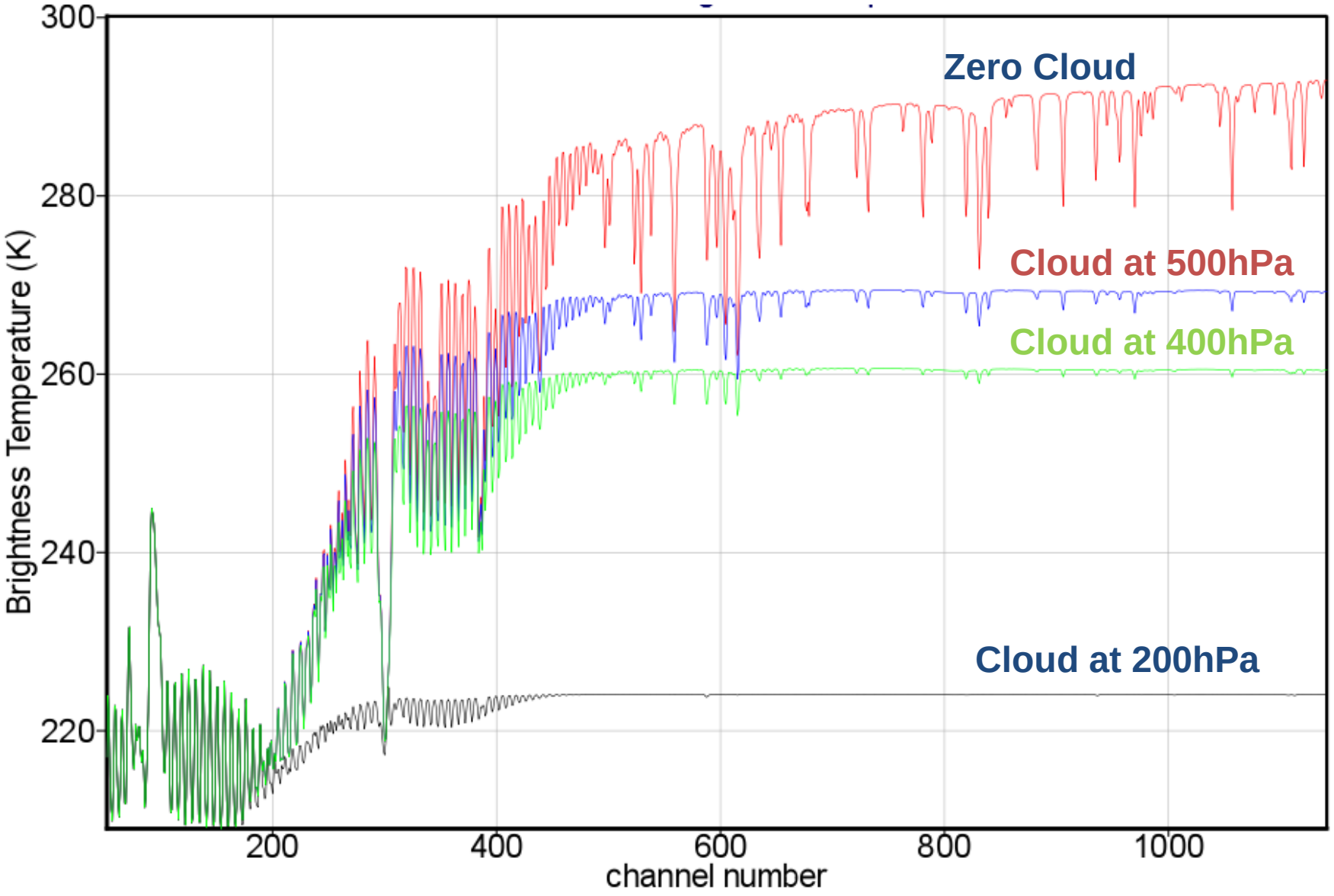
METOP-A + B IASI
ALL DATA



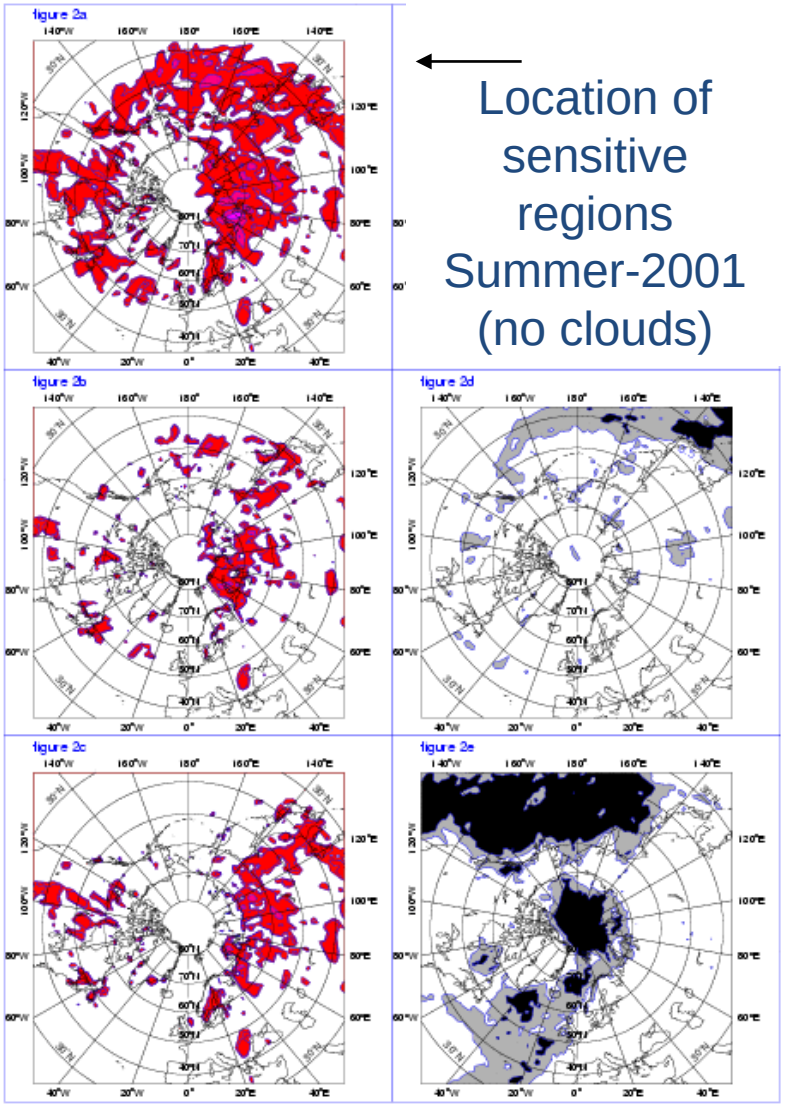
METOP-A + B IASI
CLEAR DATA



Cloud has a very strong IR impact



Cloud occurs in sensitive regions



Location of sensitive regions Summer-2001 (no clouds)

sensitivity surviving high cloud cover

monthly mean high cloud cover

sensitivity surviving low cloud cover

monthly mean low cloud cover

From *McNally (2002) QJRMS 128*

How have we handled clouds in radiance observations

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- Hole hunting (clear pixels)
- Detection and use of clear channels above cloud
- Restricted assimilation of cloudy data (e.g. overcast)
- All-sky assimilation of cloudy data

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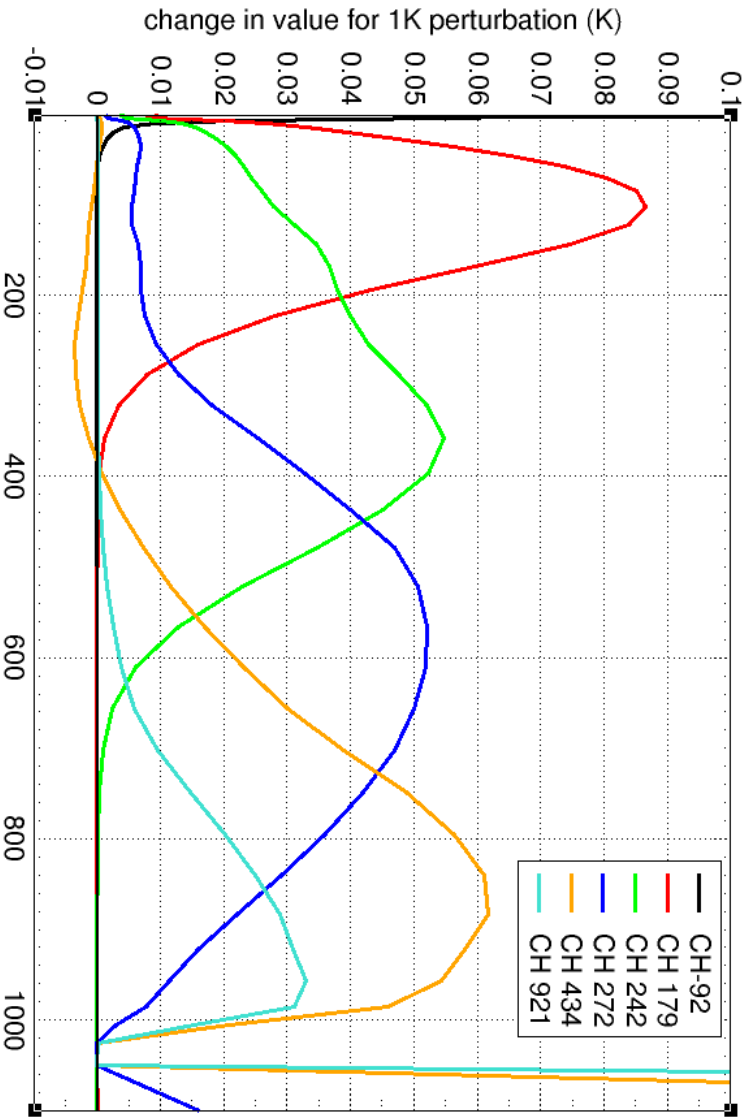
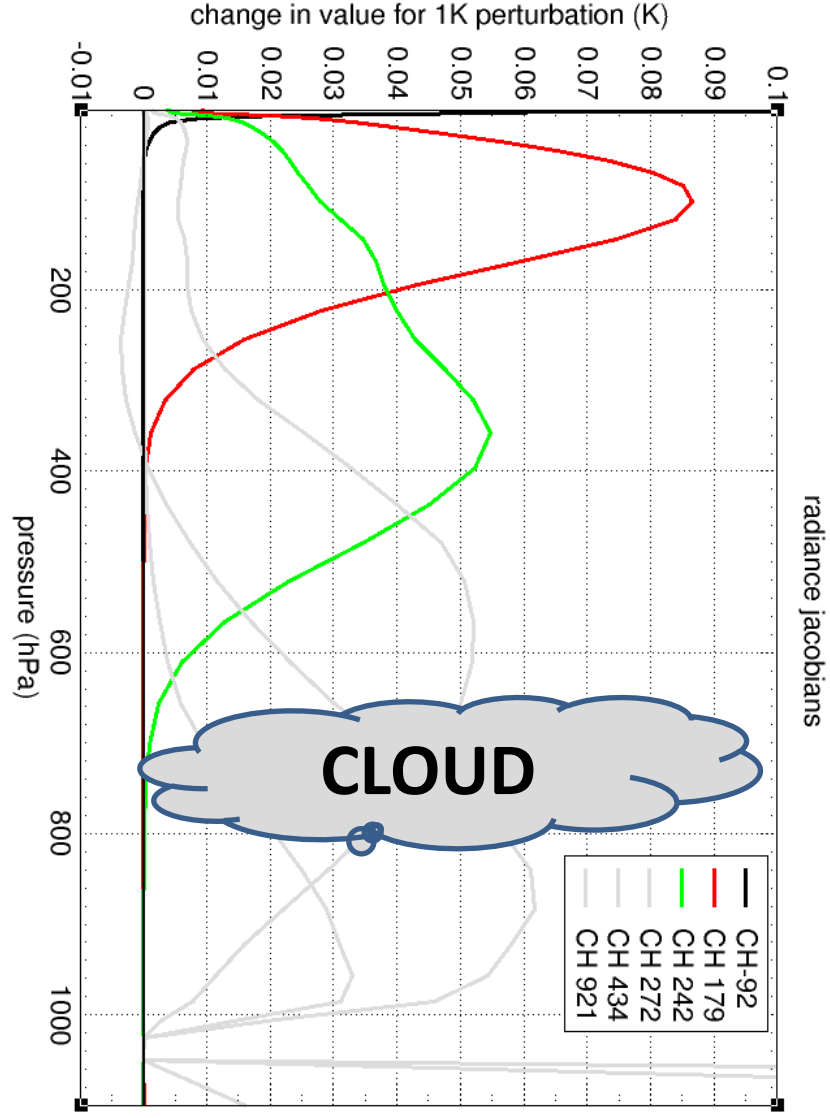
Detection and use of clear channels (above cloud)

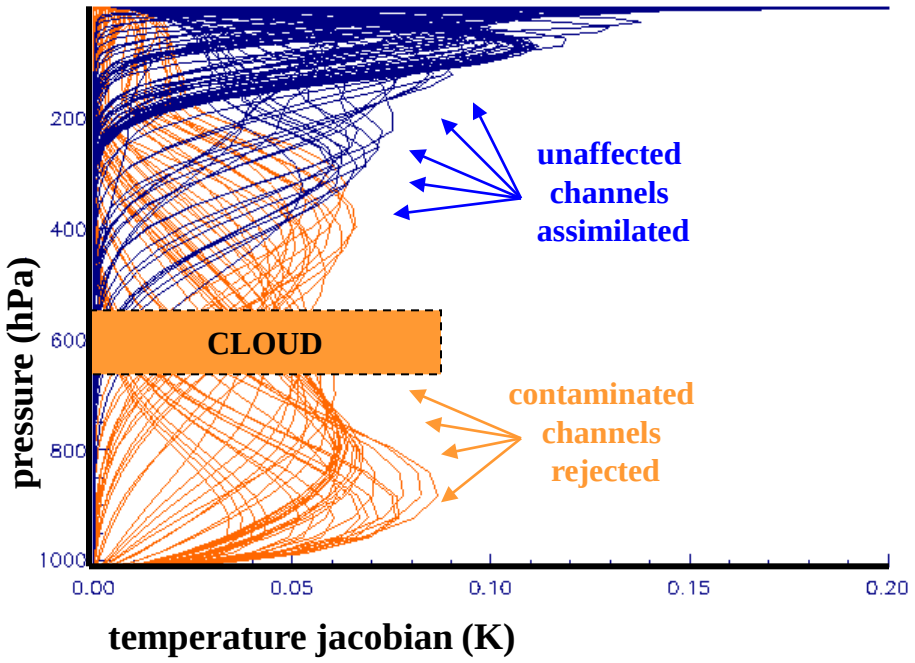
Clear-sky radiance Jacobians

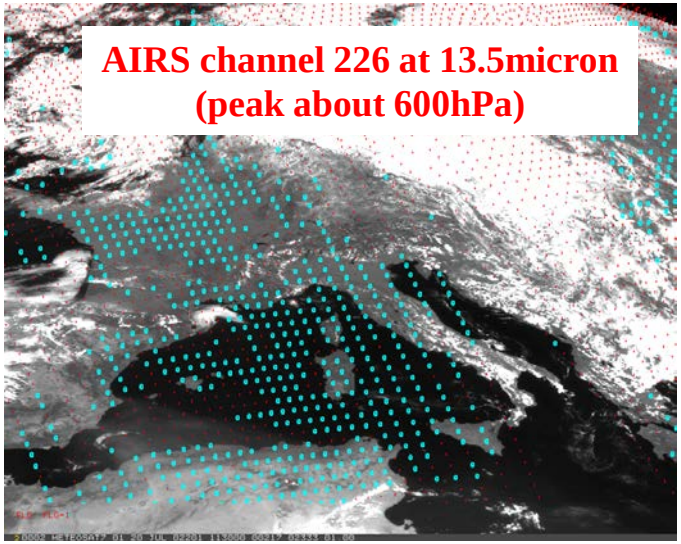


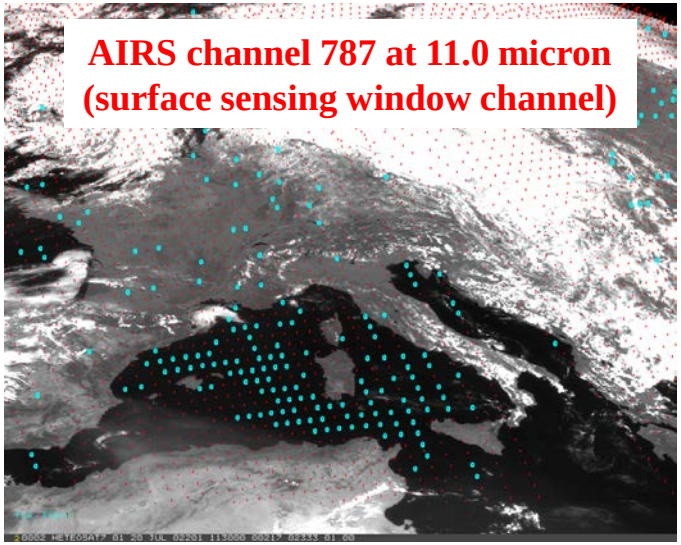


Retaining clear channels above clouds

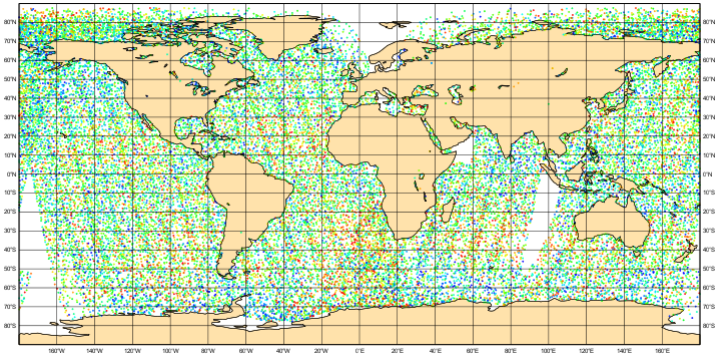
This approach has been used for many years applied to AIRS, IASI and most recently CrIS (see McNally and Watts *QJRMS* 2003)



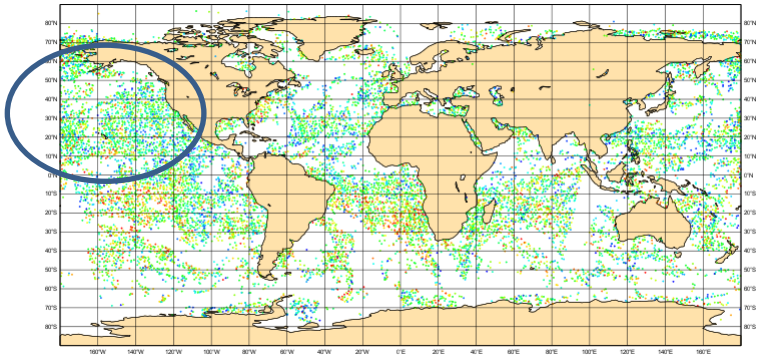




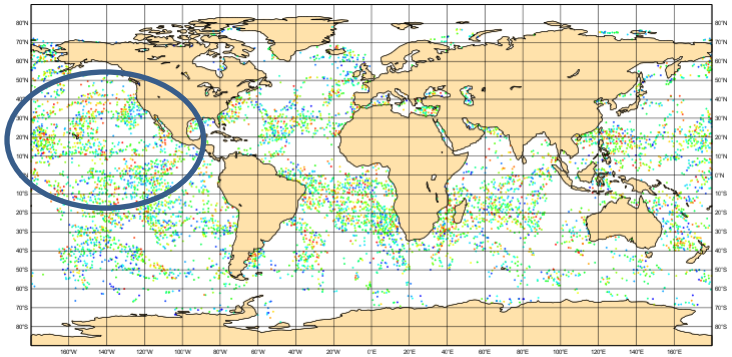
Retaining clear channels above clouds



METOP-A + B IASI
channel 101 (high level)



METOP-A + B IASI
channel 272 (mid-level)

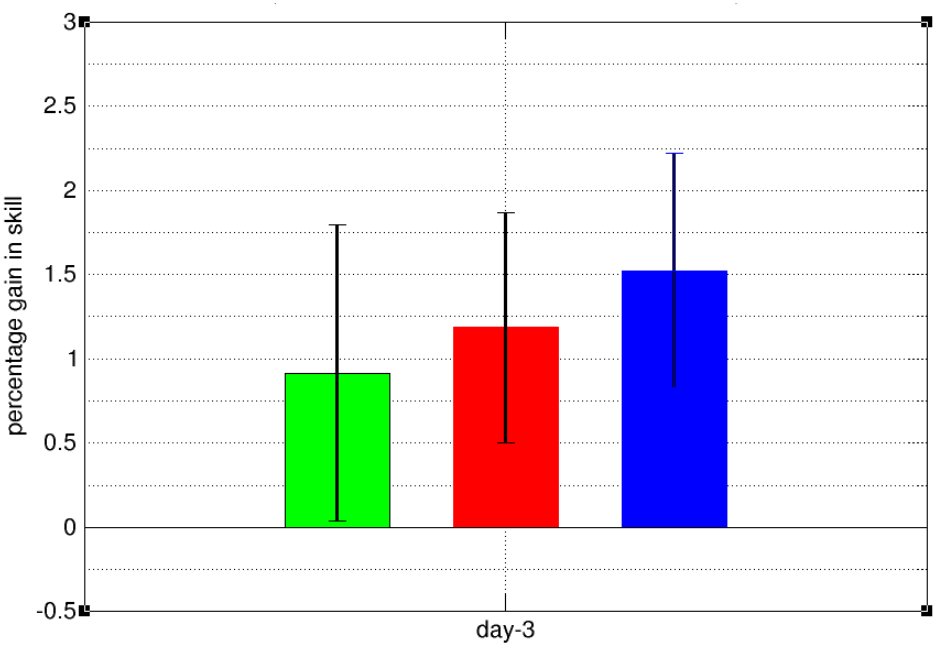


METOP-A + B IASI
channel 921 (window)

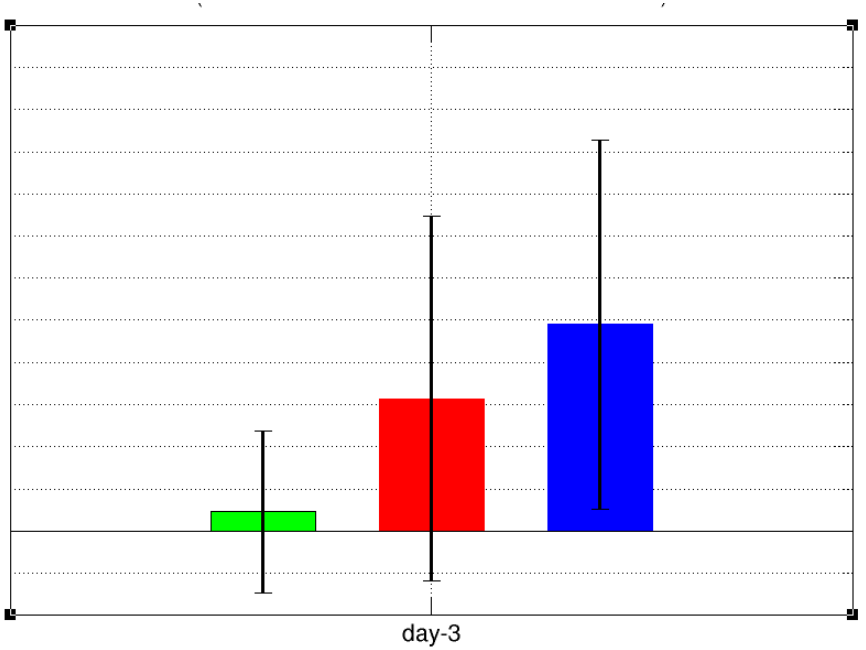
Retaining clear channels above clouds

The plots show the percentage increase in forecast skill (z500) from adding **IASI clear pixels** , **IASI clear channels** and **IASI clear channels + overcast scenes** – all relative to a baseline system that has **no** IASI assimilated.

TROPICS



SOUTHERN MID-LATITUDES

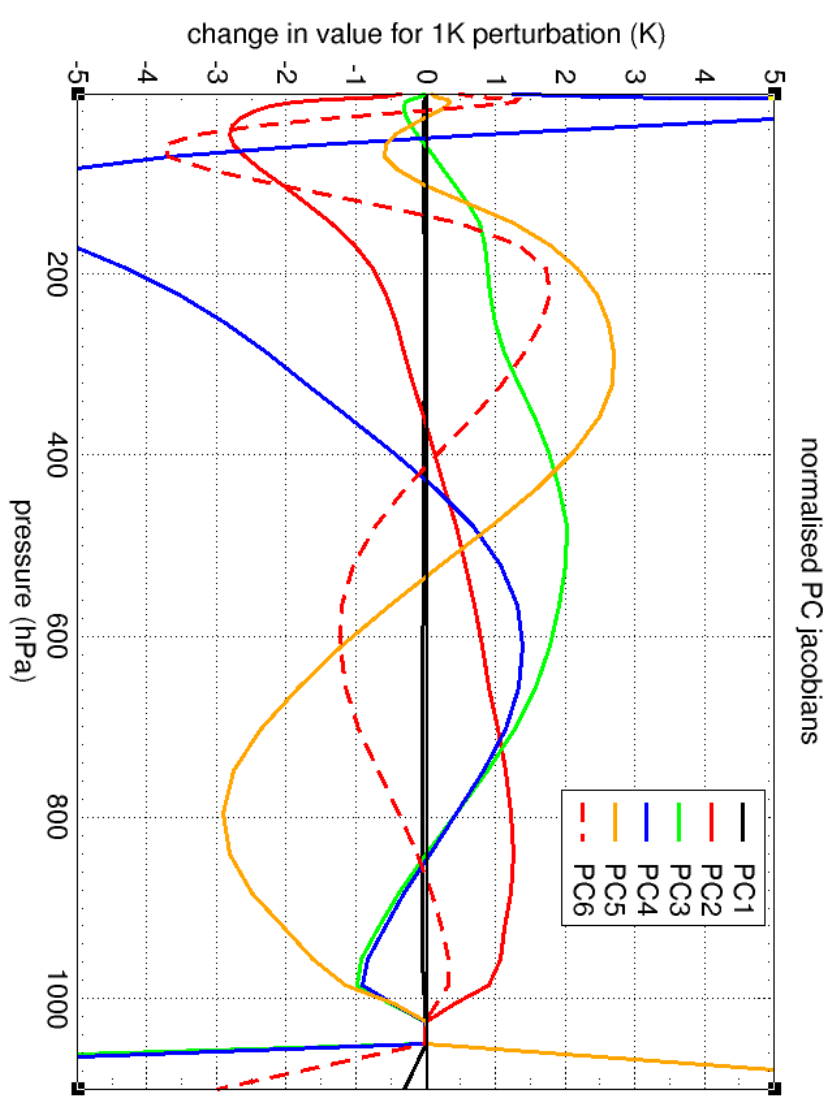


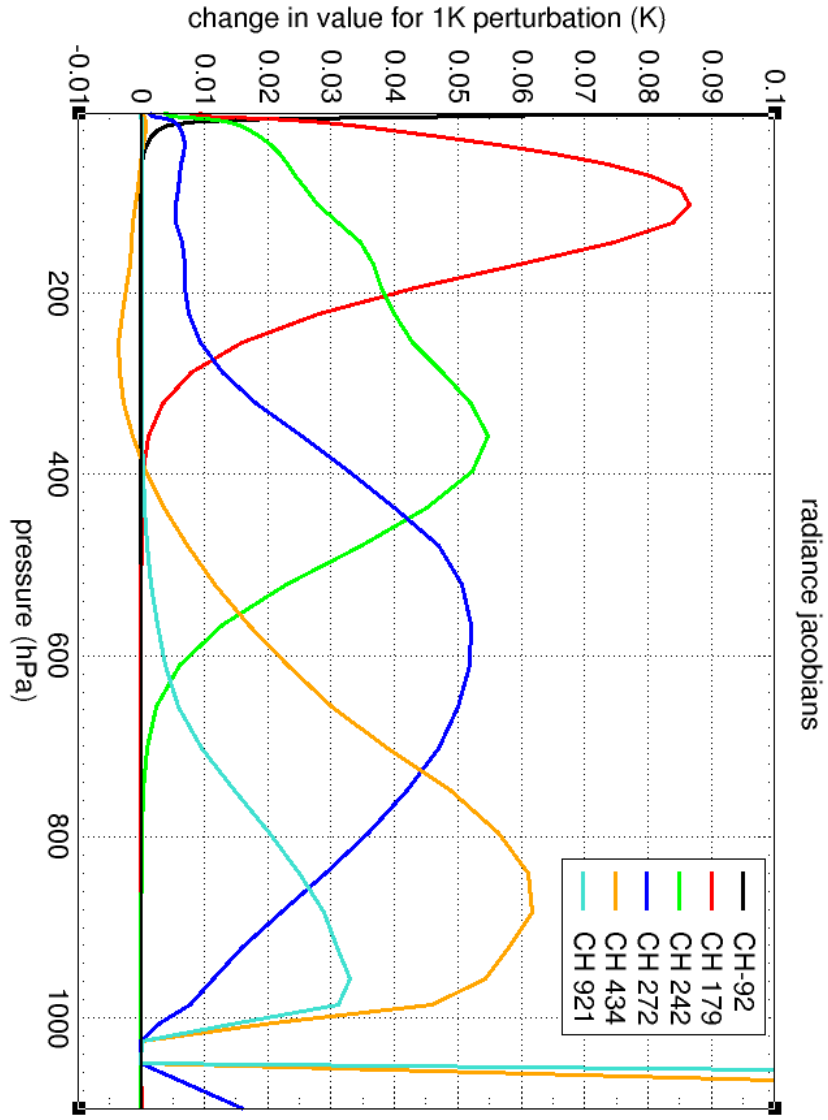
Can we do similar things with PC scores ?

…doing the same for PCA reconstructed radiances is trivial and has been done….

Detection and use of clear PC scores (above cloud)

Clear-sky PC score / radiance Jacobians





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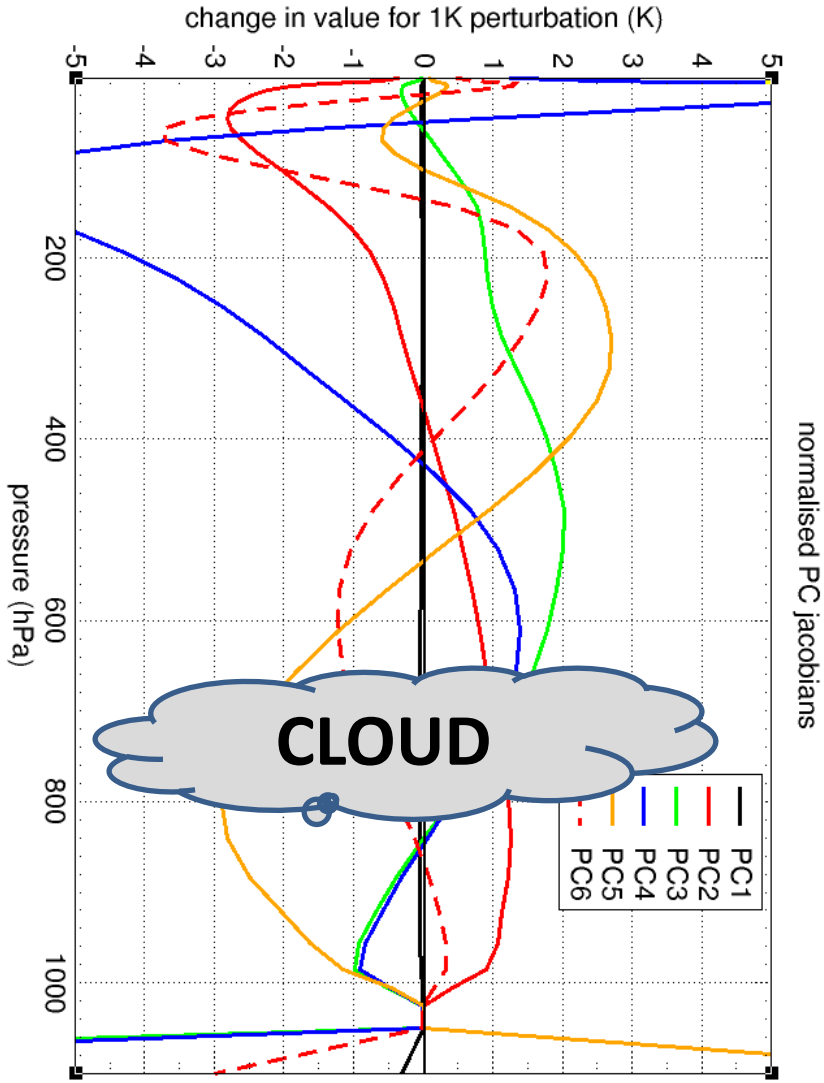
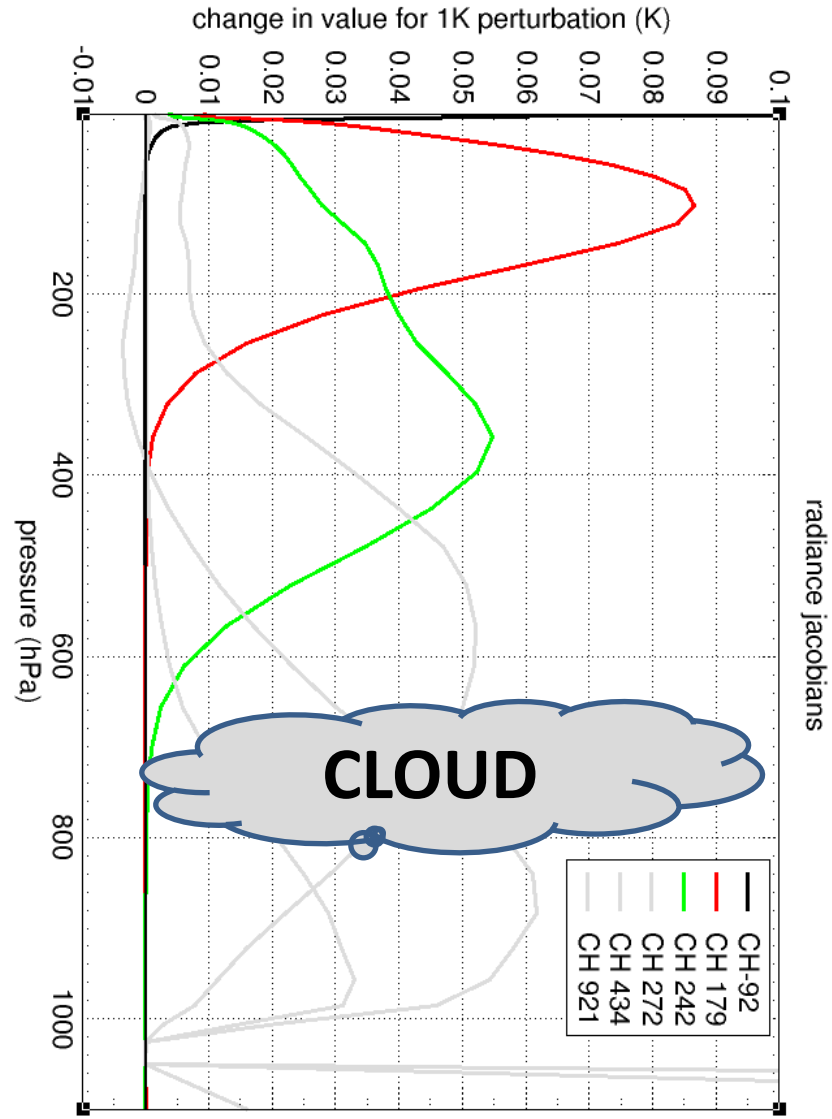
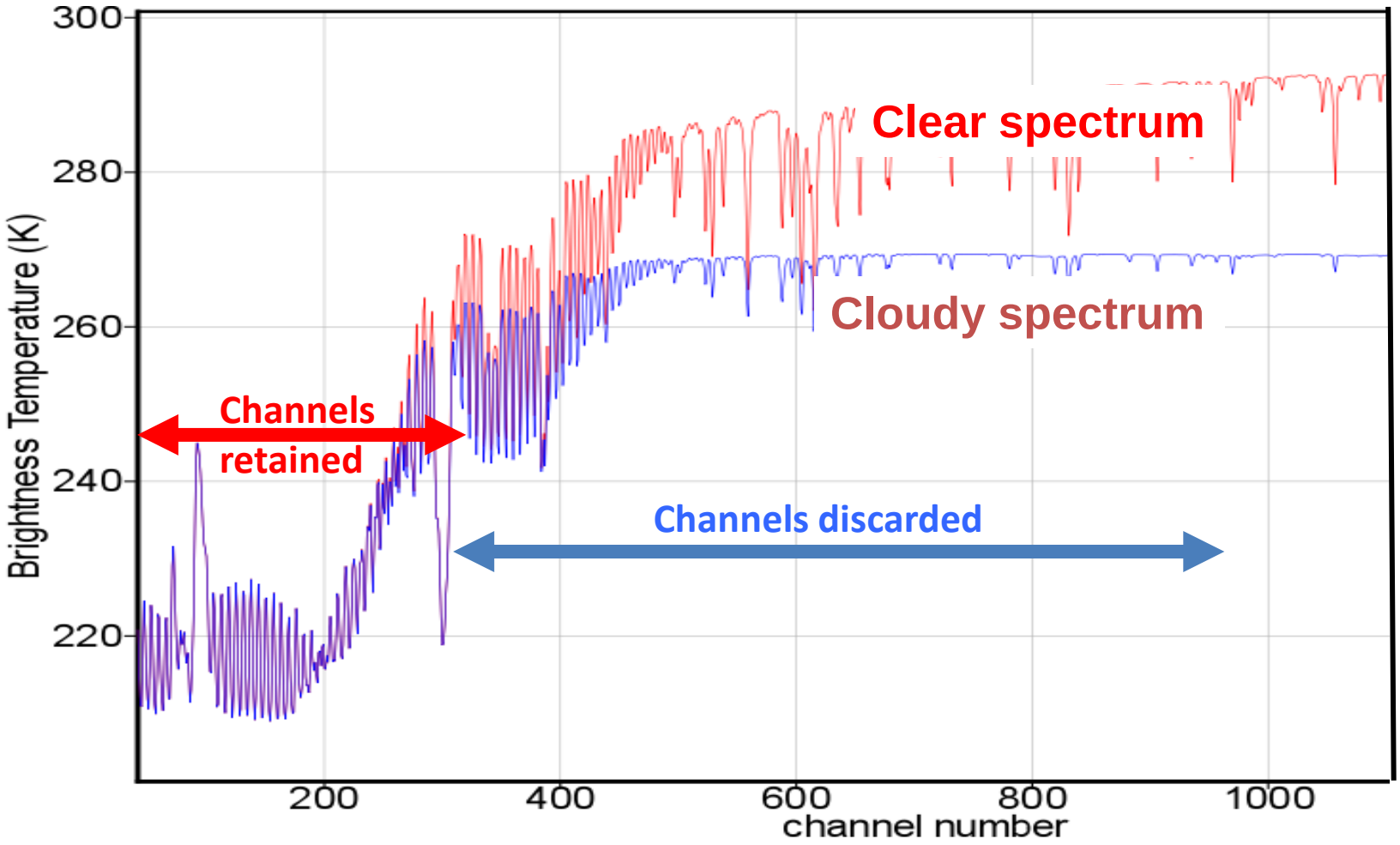




Detection and use of clear PC scores (above cloud)

…must re-compute PC scores from channels set identified as clear….

Re-compute eigenvector projection using only clear channels above clouds



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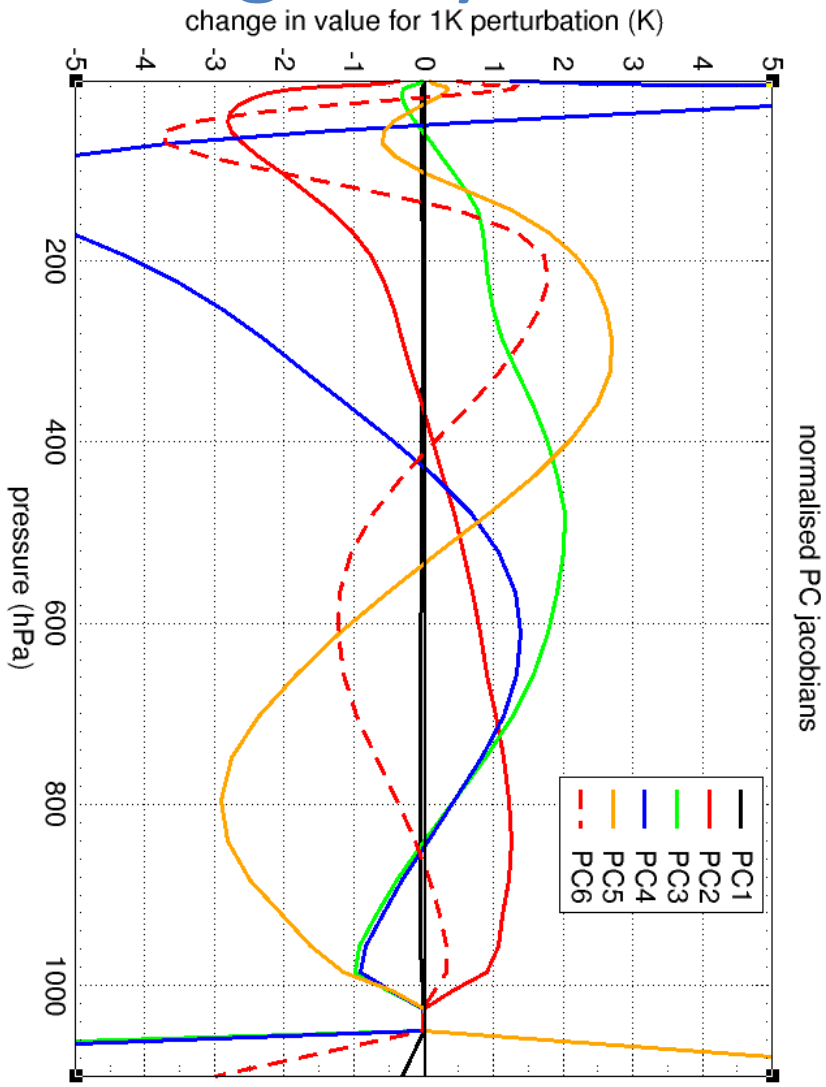

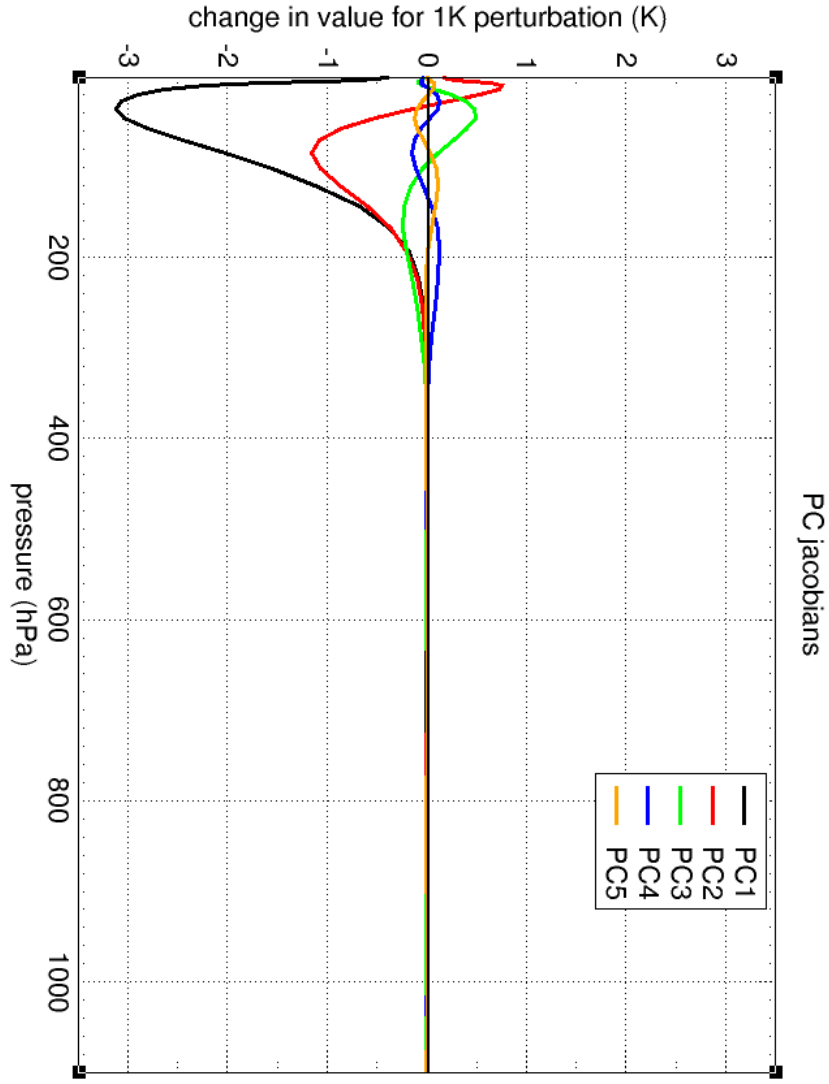

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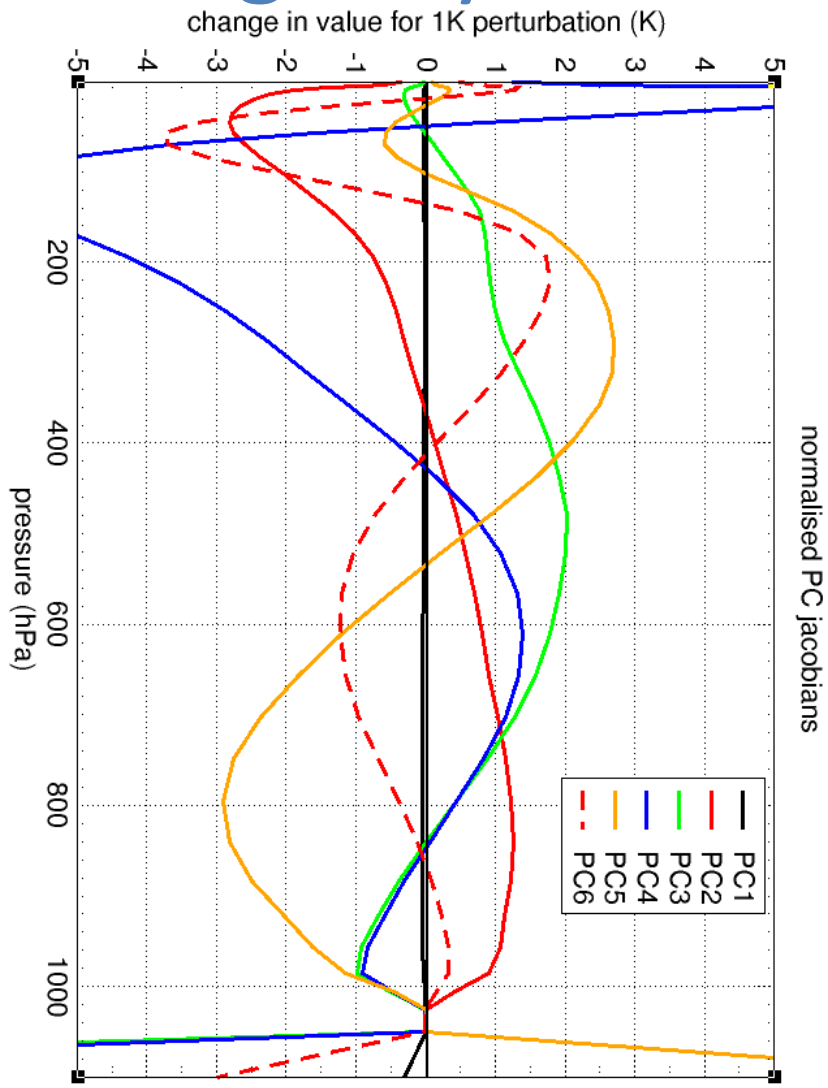

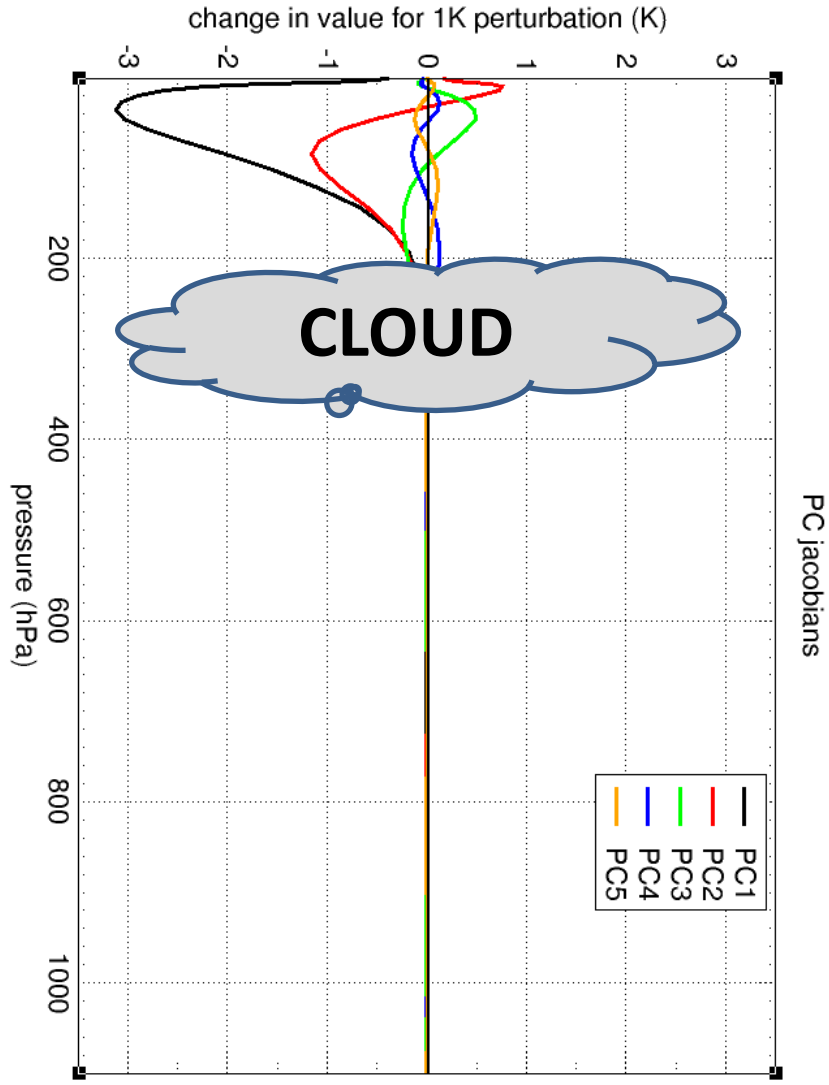

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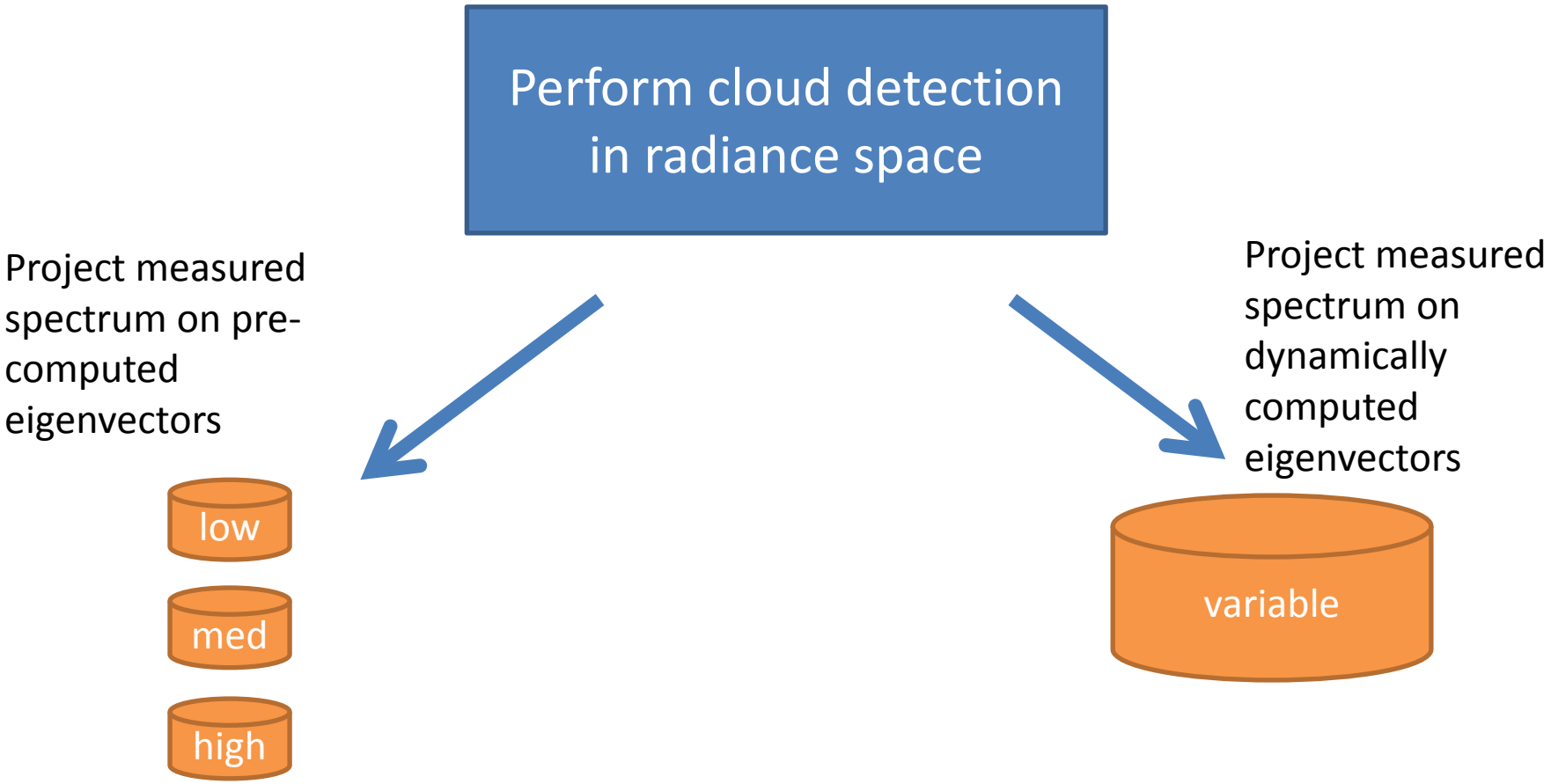
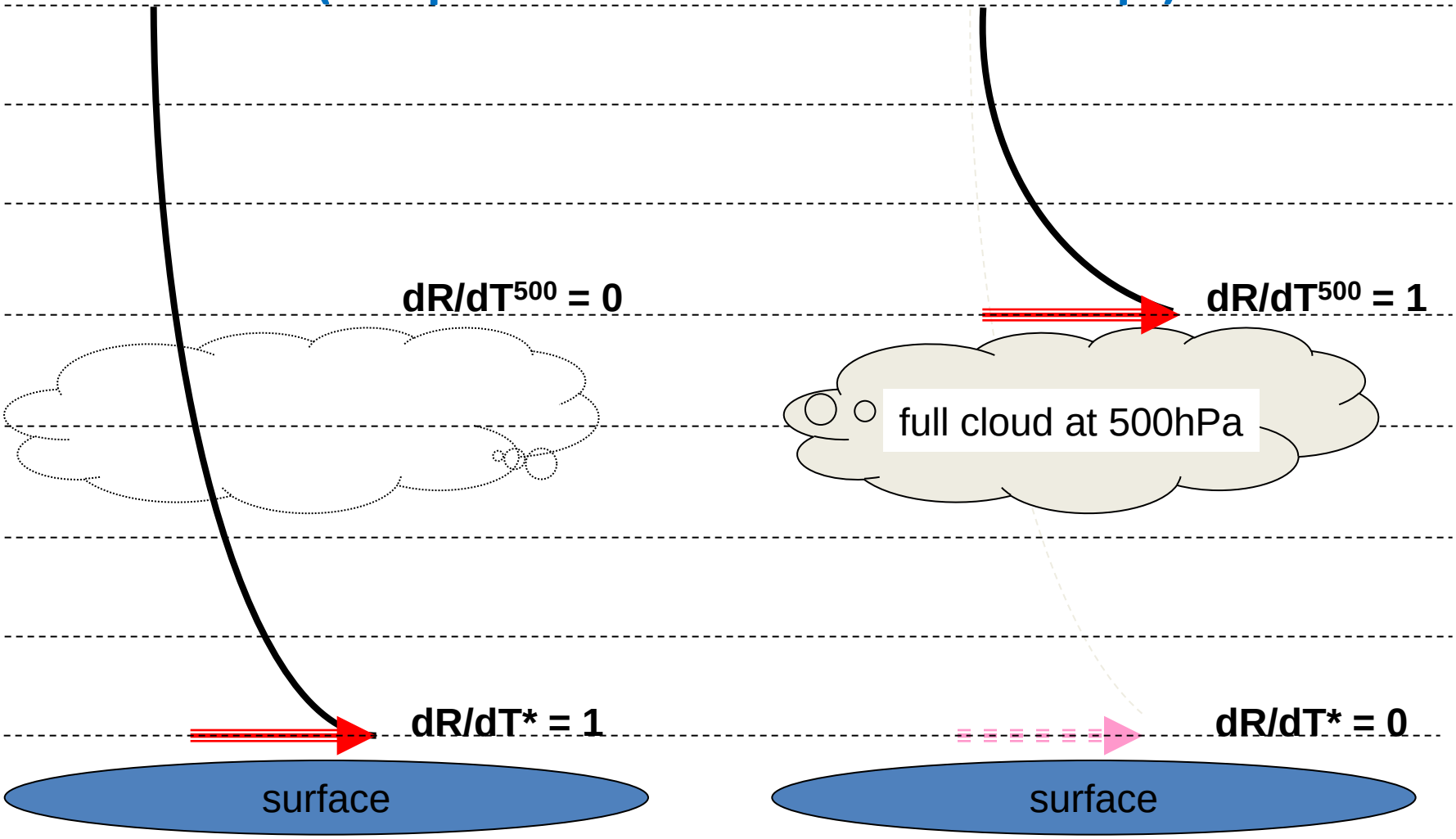


Use of radiances in overcast scenes

Why use radiances in overcast scenes ?

- **Overcast clouds are least ambiguous in the radiance data**
- **Cloud control vector collapses to a single number (cp)**
- **Problems with cloud overlap assumptions vanish**
- **No cross-talk between cloud and surface variables**
- **Termination of jacobians at cloud top provides new high vertical resolution Information on temperature**

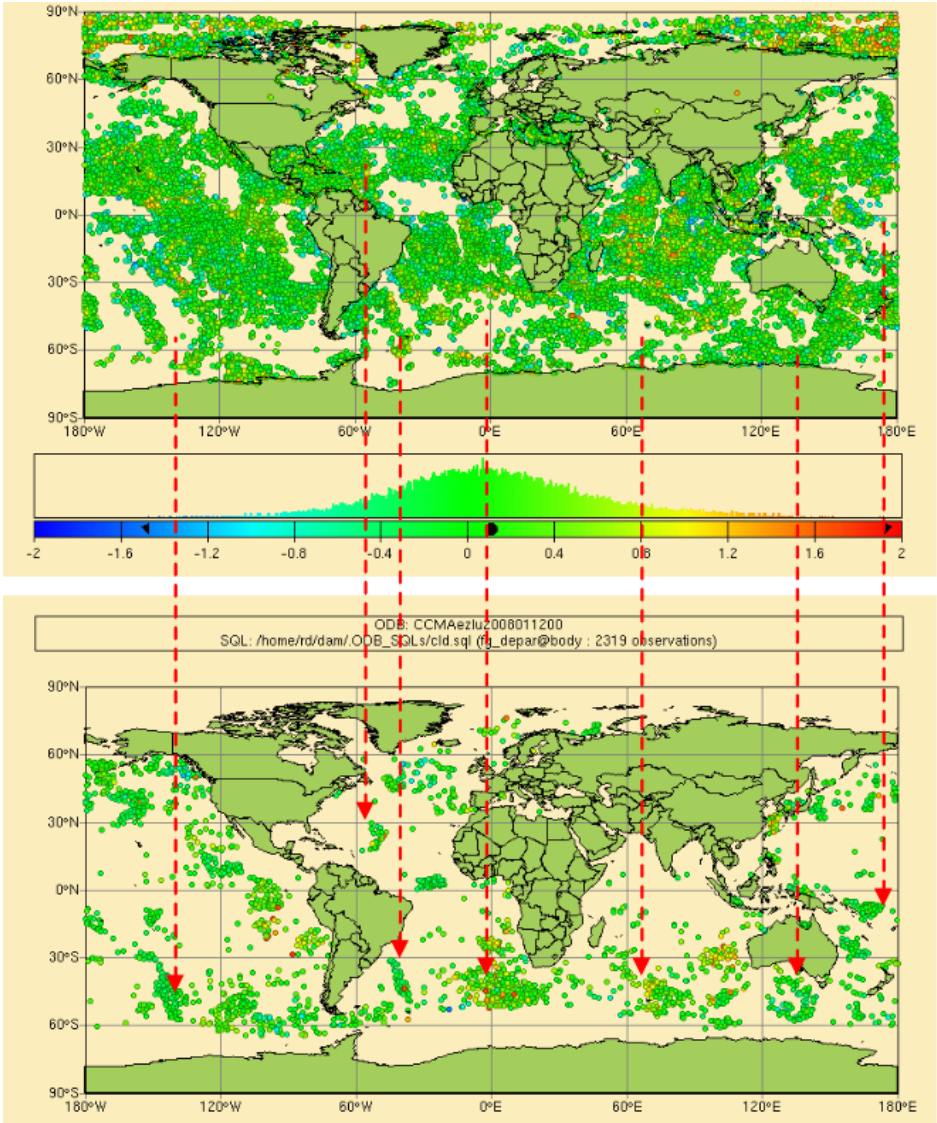
Clear and cloudy Jacobians (impact at the cloud top)



Recovering overcast data

IASI clear channels

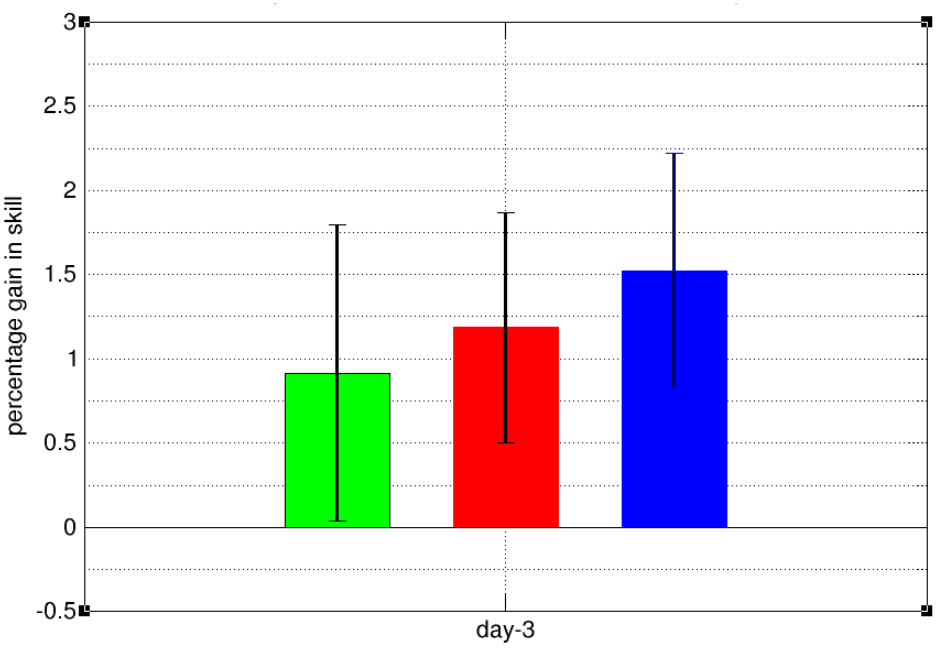
IASI clear channels + OV



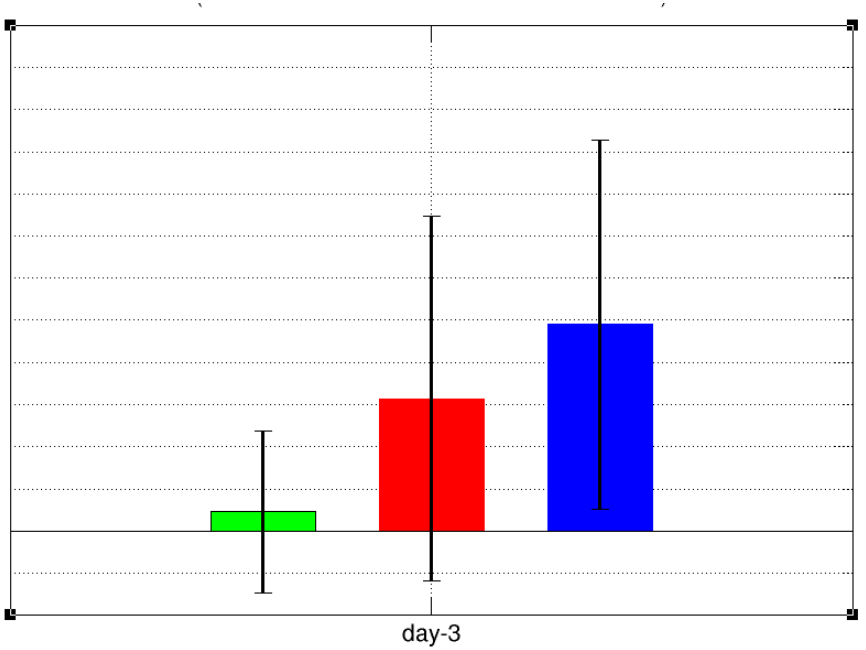
The impact of overcast radiances

The plots show the percentage increase in forecast skill (z500) from adding **IASI clear pixels** , **IASI clear channels** and **IASI clear channels + overcast scenes** – all relative to a baseline system that has **no** IASI assimilated.

TROPICS



SOUTHERN MID-LATITUDES

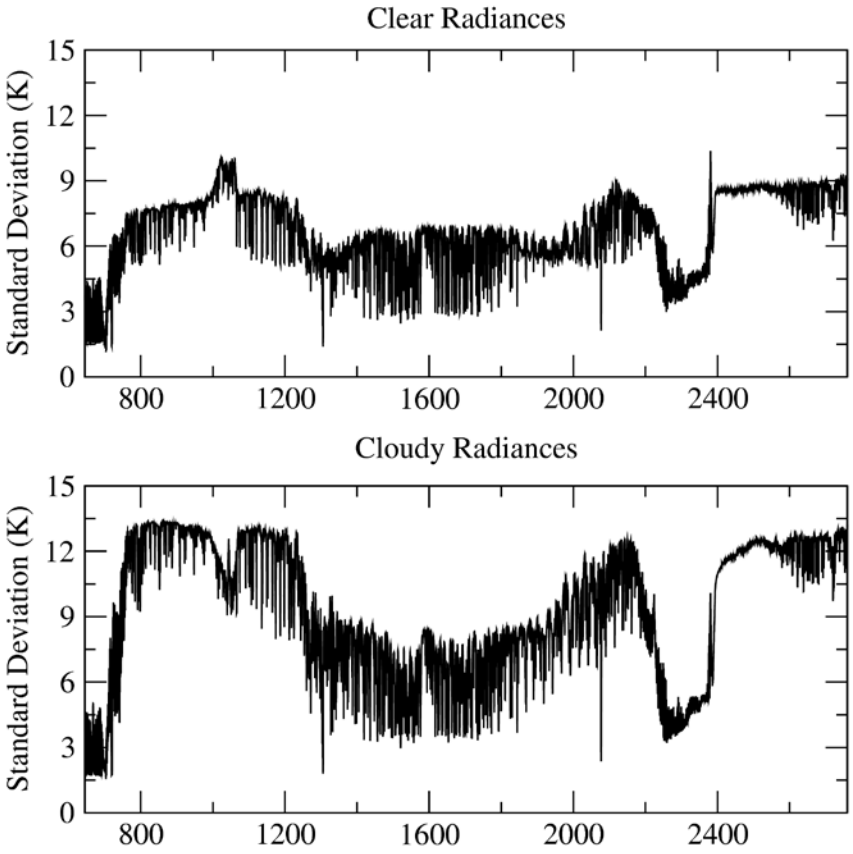


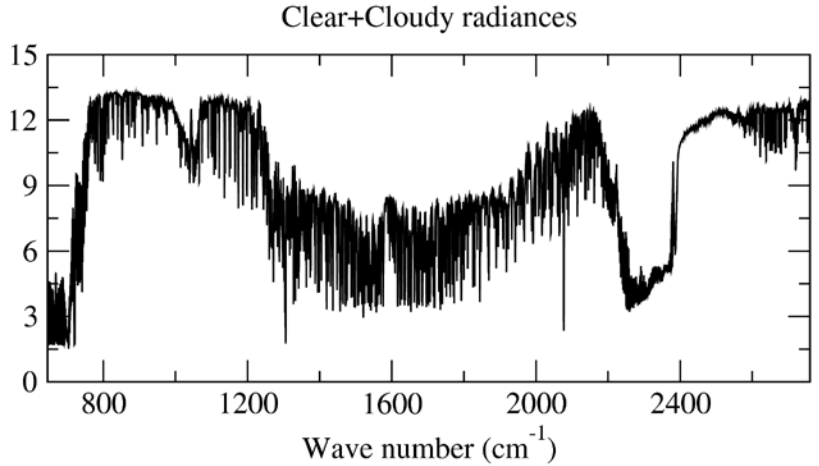
Can we do similar things with PC scores ?

…doing the same for PCA reconstructed radiances should trivial, but has not been done….?

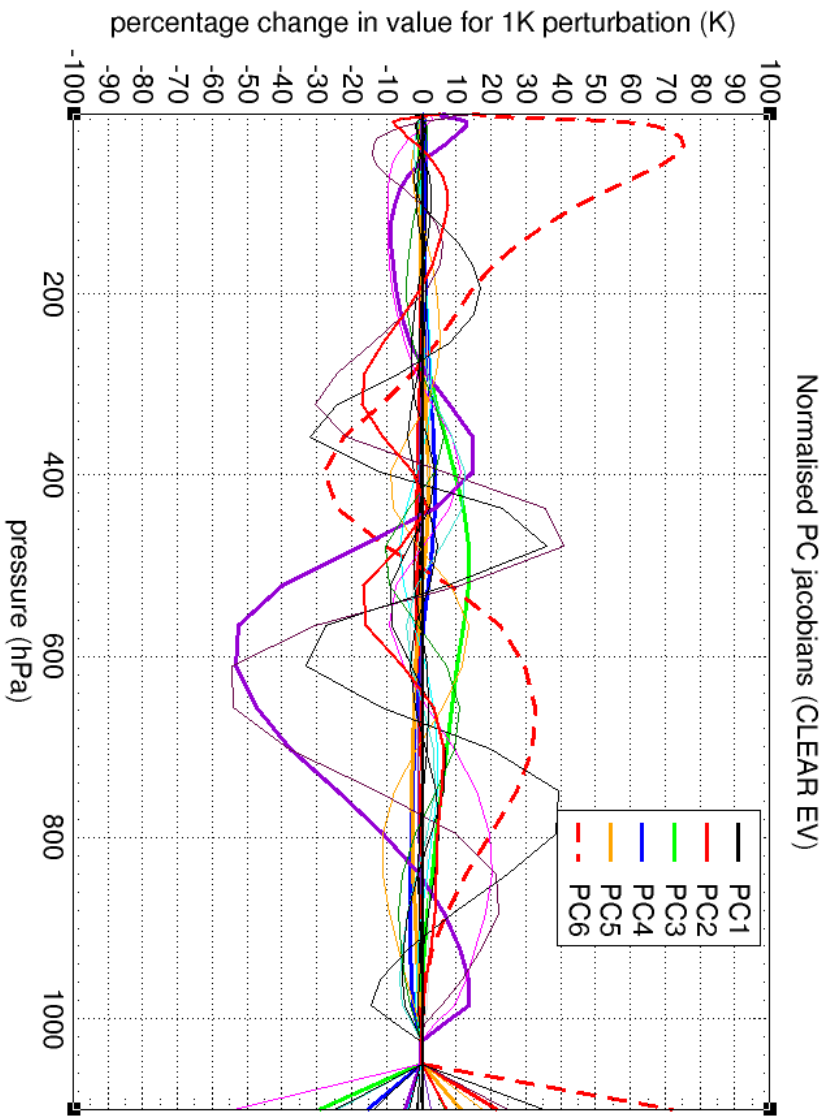
Cloudy PC-RTTOV

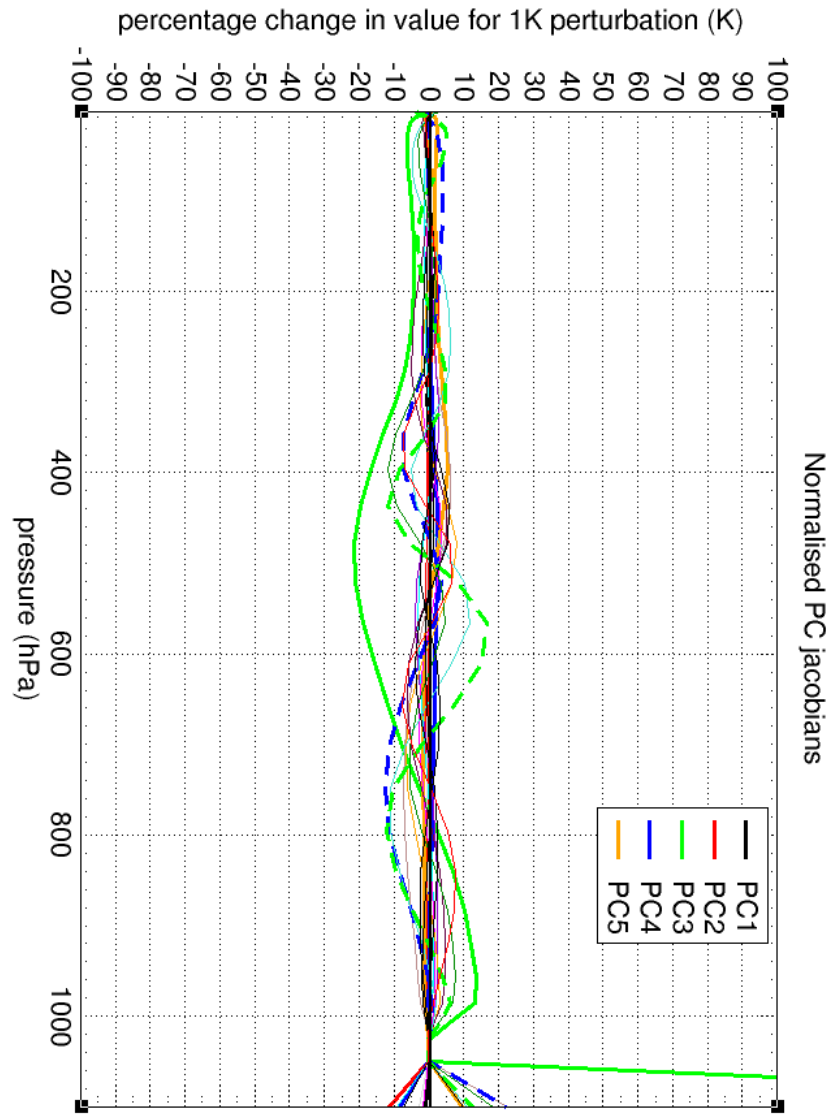
Cloudy PC-RTTOV has been trained on polychromatic simulated radiance spectra





Clear v Cloudy PC score Jacobians





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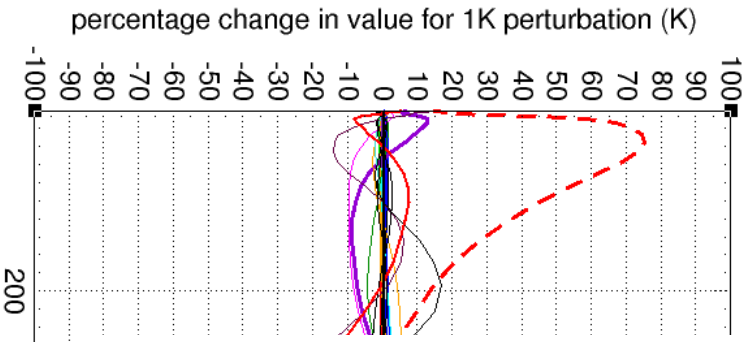
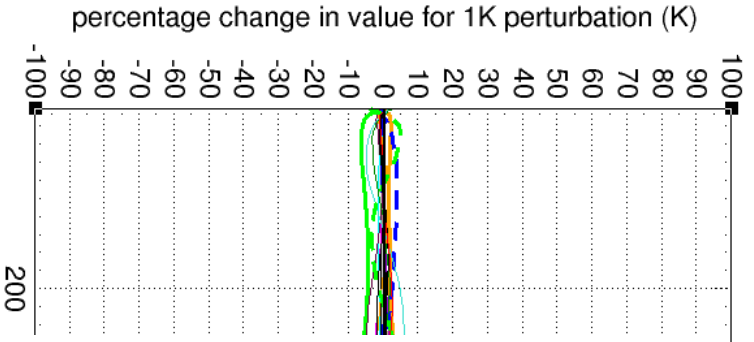
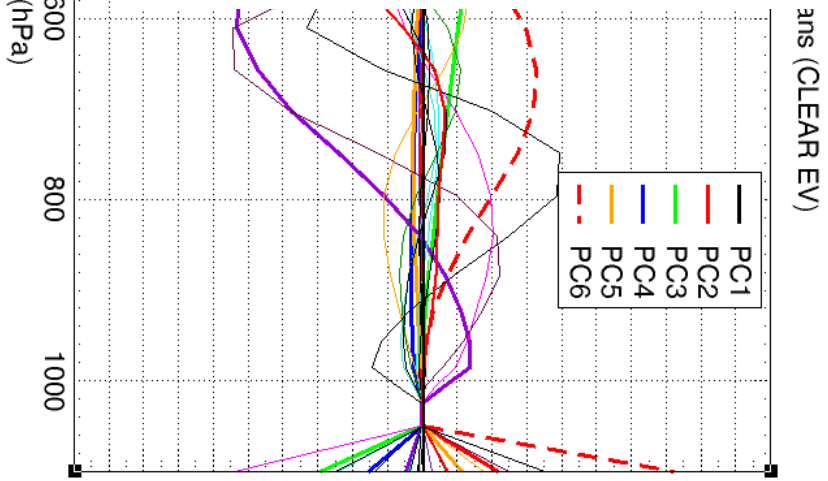
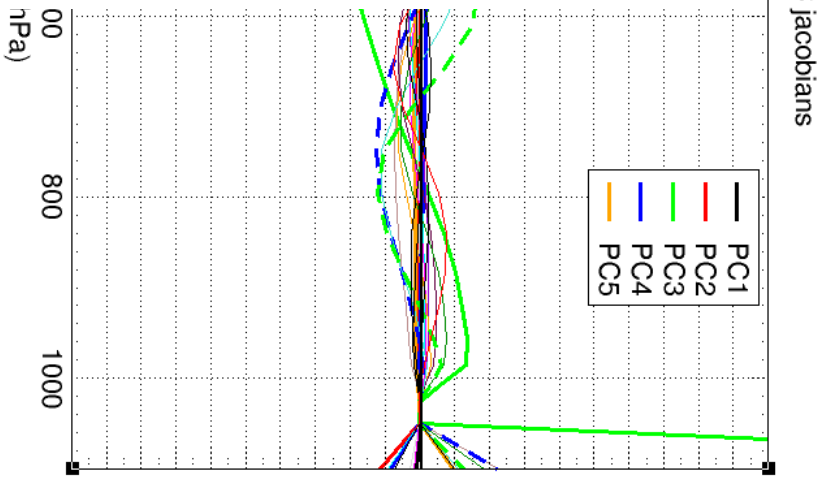


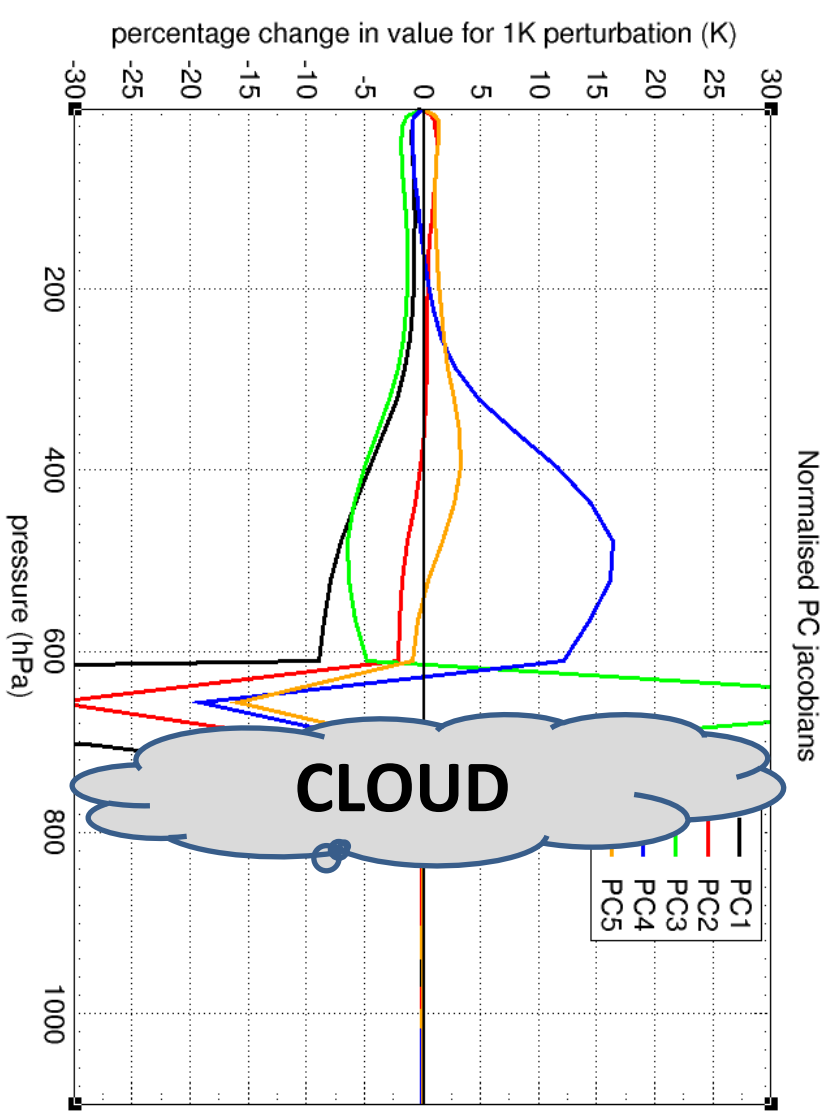


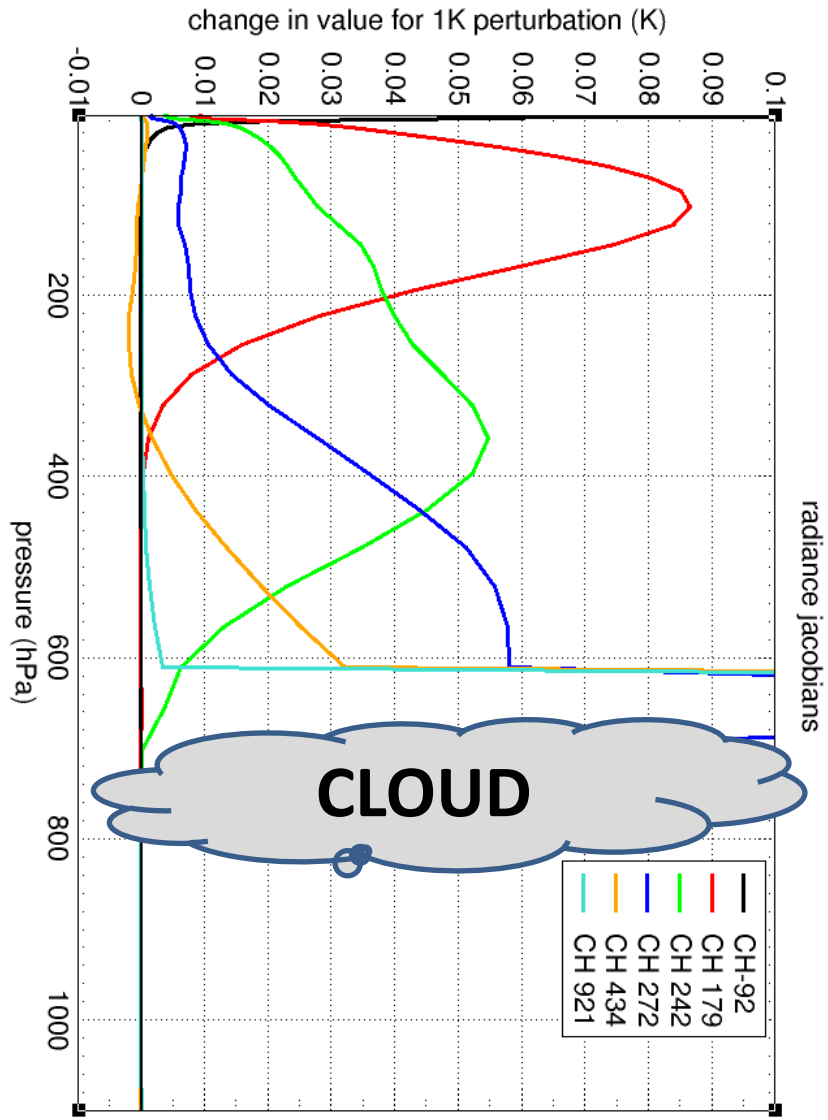
leading eigenvectors explain clouds and lower order T and Q …





Cloudy-sky radiance PC score Jacobians





Assimilating overcast PC scores

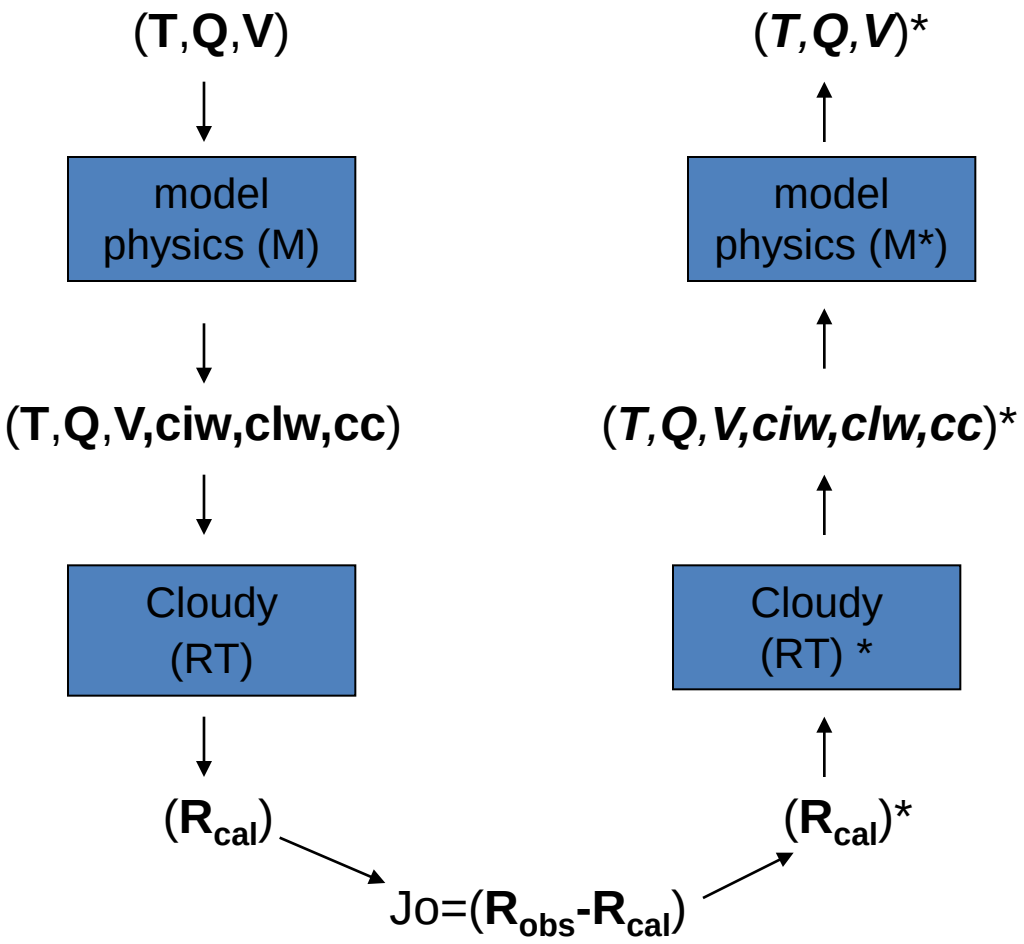
Diagnose overcast cloud height in radiance space

Project measured spectrum on to pre-computed cloudy eigenvectors (with Cf=1 and Cp = height

Assimilate overcast PC scores in the same way as overcast radiances

All sky use of IASI ?

Towards an ALL-SKY Cloudy IR Radiance Assimilation

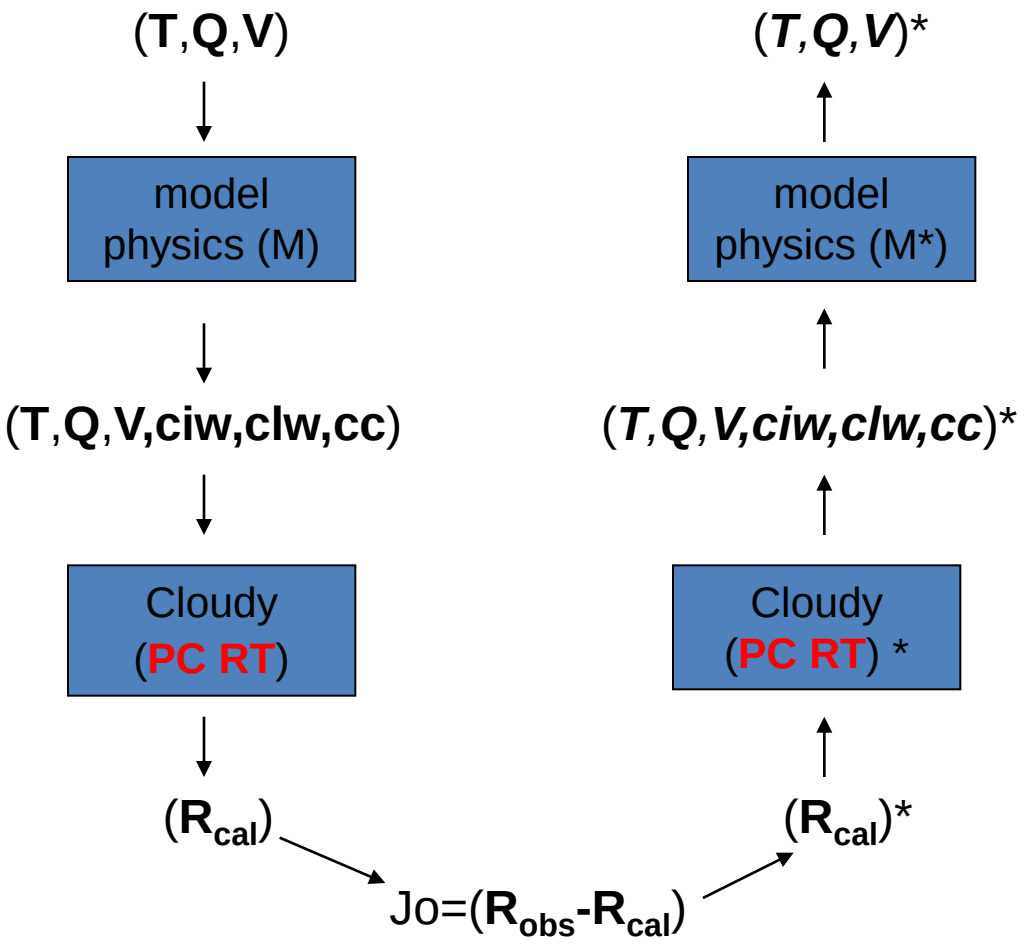


Cloudy radiances $\mathbf{R_{cal}}$ are simulated via a chain of forward operators (M,RT).

The fit of the analysis to the observations is computed (Jo)

Jo is minimized by perturbing the analysis variables according to gradients from a chain of adjoint operators (RT*,M*)

Towards an ALL-SKY PC score Assimilation



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The impact of ALL-SKY radiances / PC scores ?

The plots show the percentage increase in forecast skill (z500) from adding **IASI clear pixels** , **IASI clear channels** and **IASI clear channels + overcast scenes** , and **ALL-SKY** - all relative to a baseline system that has **no** IASI assimilated.

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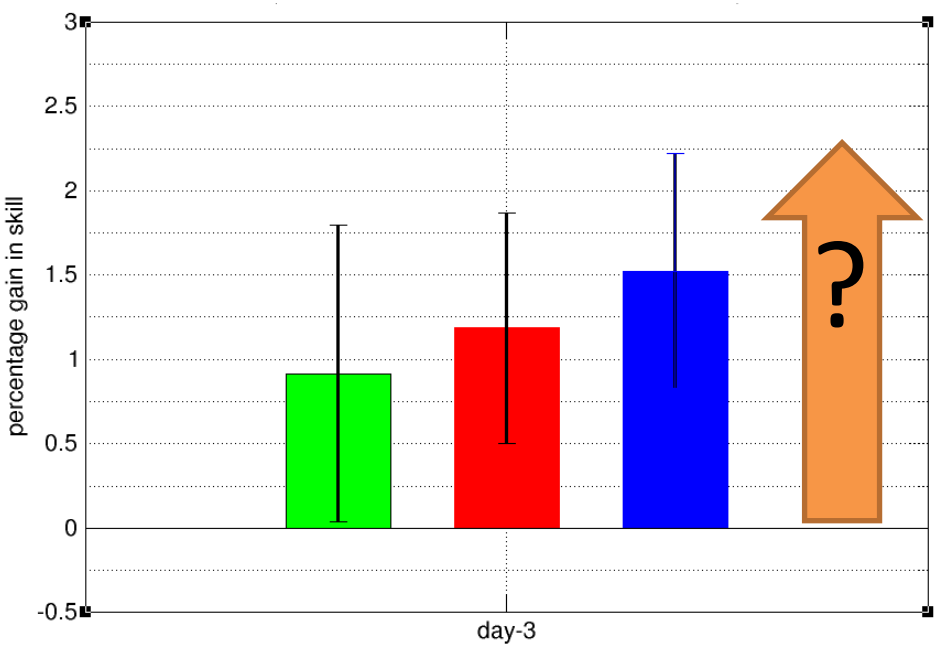

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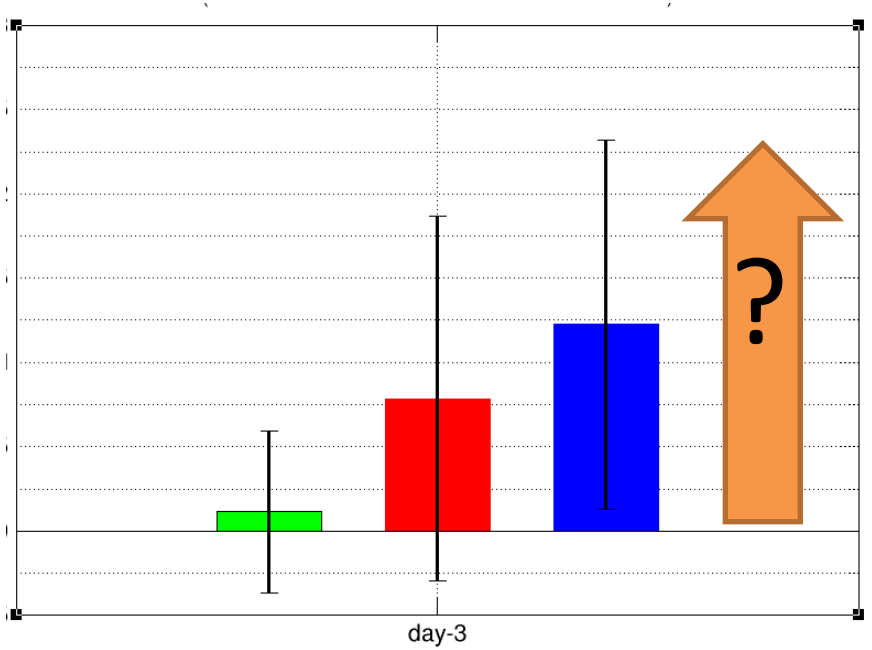

Summary

- All of the approaches developed to handle clouds in IR spectra can be immediately applied to PCA reconstructed radiances.

- These can also be applied to the assimilation of PC scores – though some pre-processing in radiance space is needed and they may be computationally more expensive

- But are there other novel approaches that don't aim to reproduce existing radiance ideas ?