



Question 1: How are current hyperspectral IR sounders such as the NASA JPL AIRS and CNES & EUMETSAT IASI used (in NWP)?

Stephen English

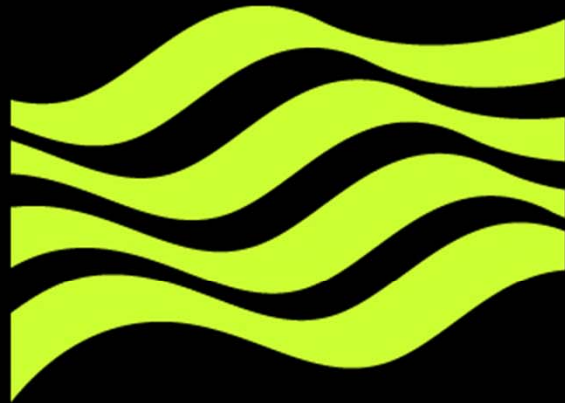
CPTEC (Brazil) and Met Office (UK)

WWW.CPTEC.INPE.BR

Brazil
United Kingdom



CENTRO DE PREVISÃO DE
TEMPO E ESTUDOS CLIMATICOS



Met Office



1. How are current hyperspectral IR sounders such as the NASA JPL AIRS and CNES & EUMETSAT IASI used (and in future NPP and JPSS CrIS)?
 - What are the deficiencies?
 - What improved information is needed by the user?

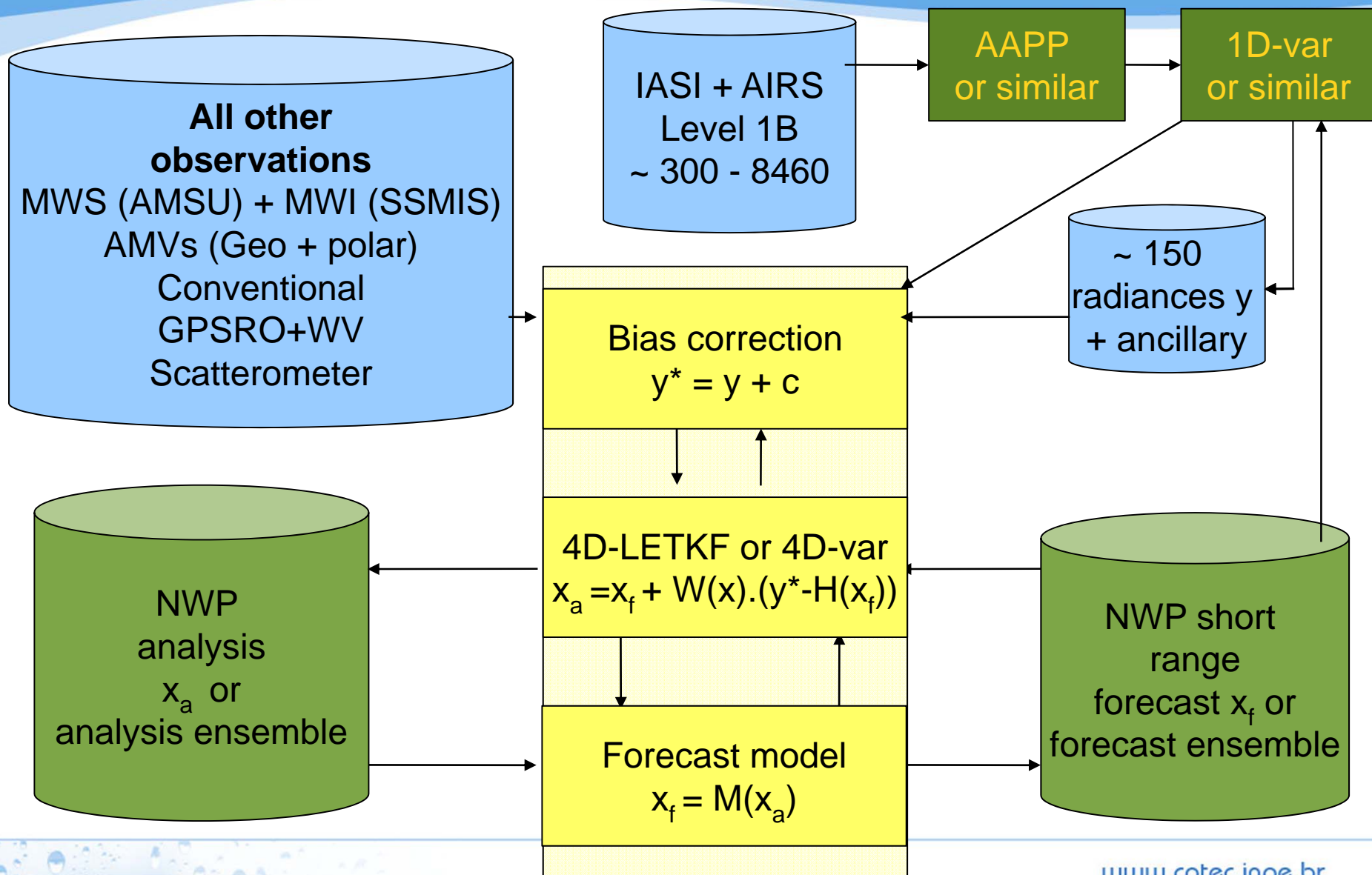
- IASI, AIRS (...and CrIS)
- How are hyperspectral sounders used in operational weather forecasting?
 - 4D-var and LETKF
- Deficiencies in use of hyperspectral sounders
- Current value in NWP
- What improved information is needed?

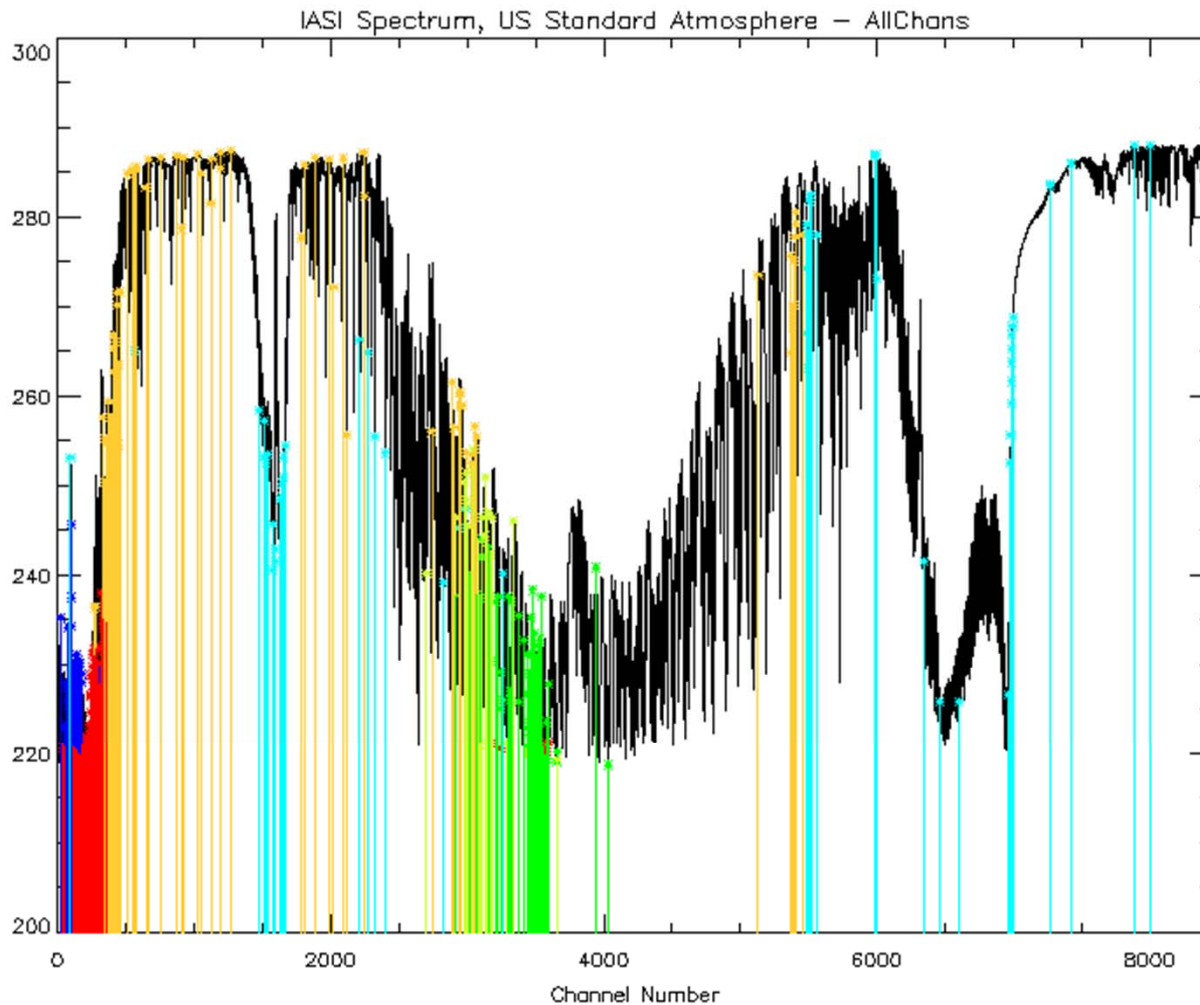
AIRS and IASI

“...whichever NWP centre uses these new data most quickly will gain a significant advantage”

Philippe Courtier (Météo-France) shortly before launch of AIRS, 2001
(at a time when AMSU-A impact was grabbing the headlines)

2011: IASI impact larger than AMSU-A





Red – Used (Sea/Land, Clear/MWcloud)

Yellow – Used (Sea/Clear only)

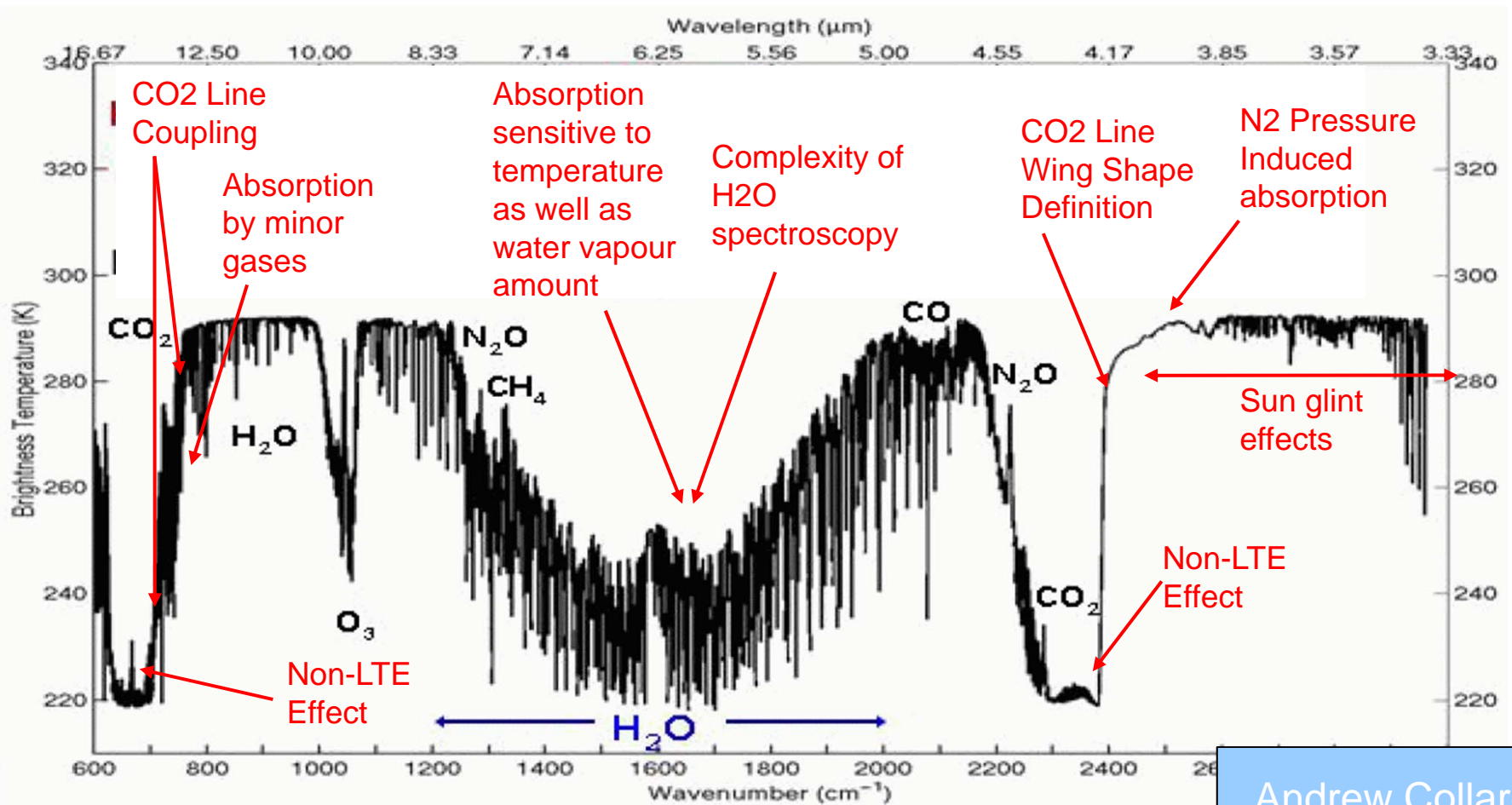
Blue – Used (1D-Var preprocessor only)

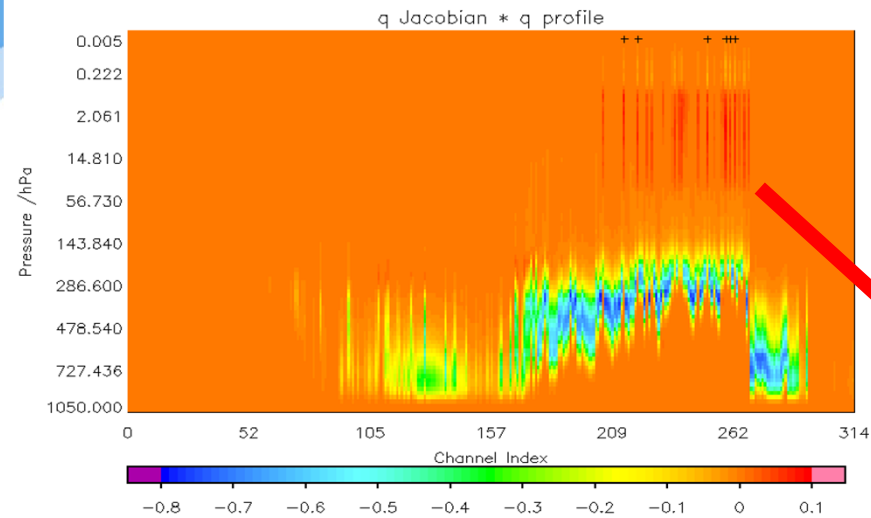
Cyan – Rejected

Green / Lime – Rejected water vapour channels

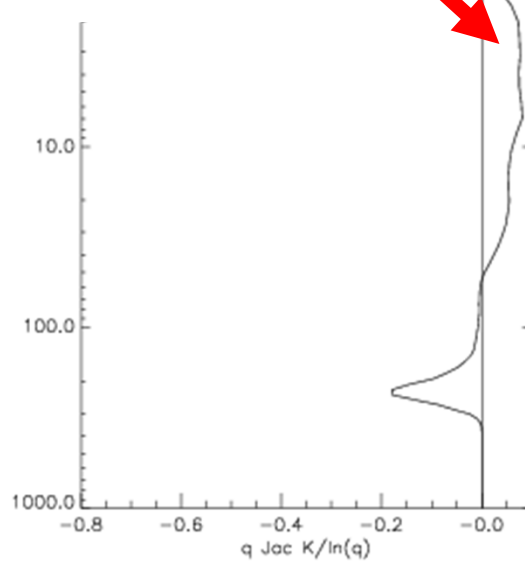
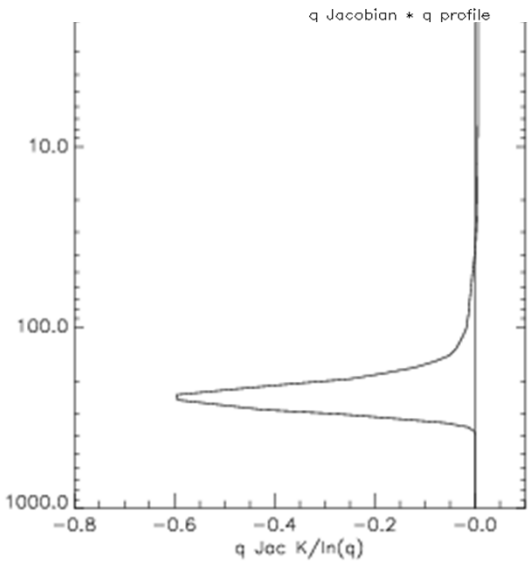
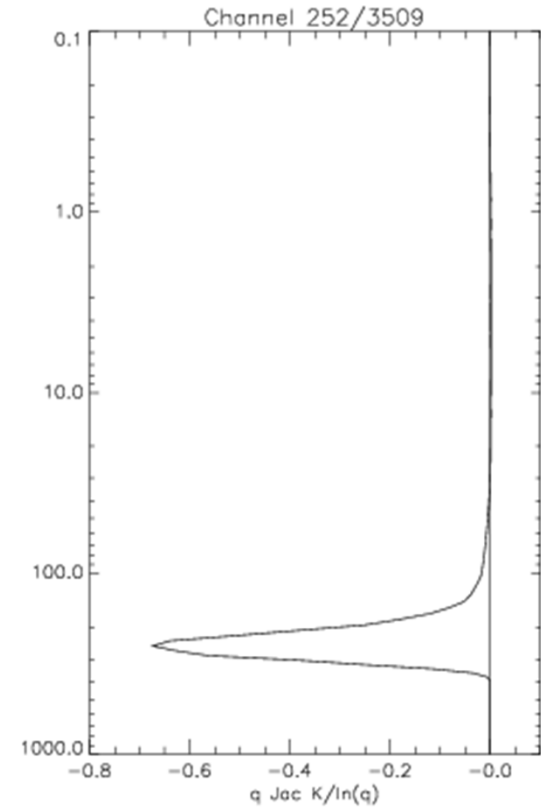
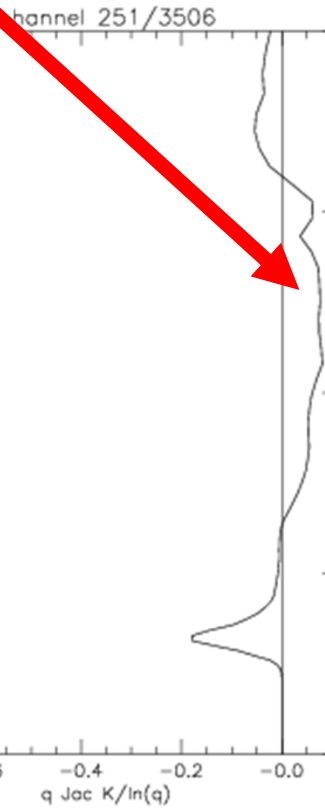
- Need care with words like deficiency!
- So why do we not use all the channels?
 - Complex radiative transfer
 - Observation correlated error
 - Computational cost
 - Forecast model bias (especially for moisture)

The radiative transfer is affected by a multitude of factors, which may affect our ability to use parts of the spectrum. For example:



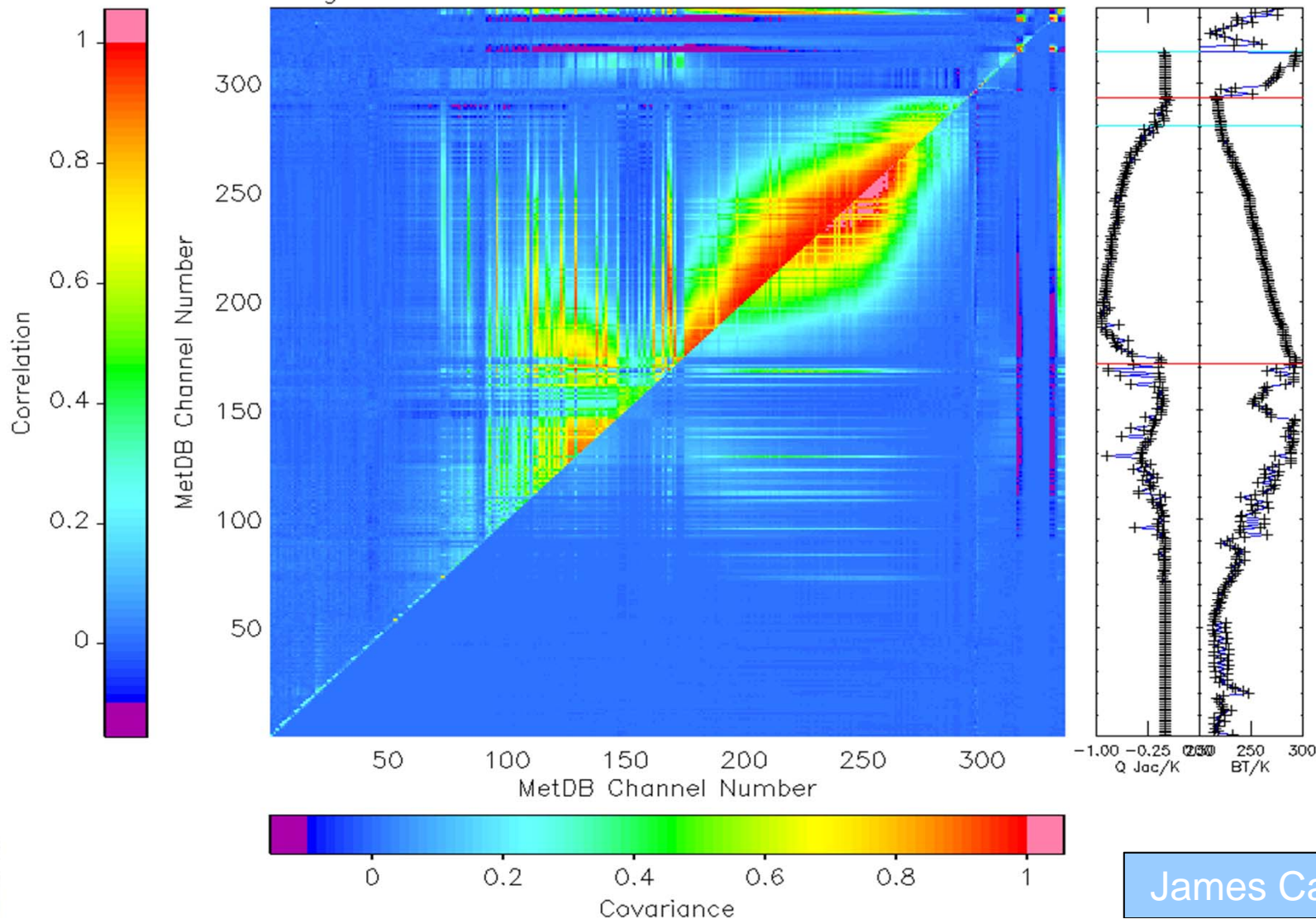


High-peaking water vapour

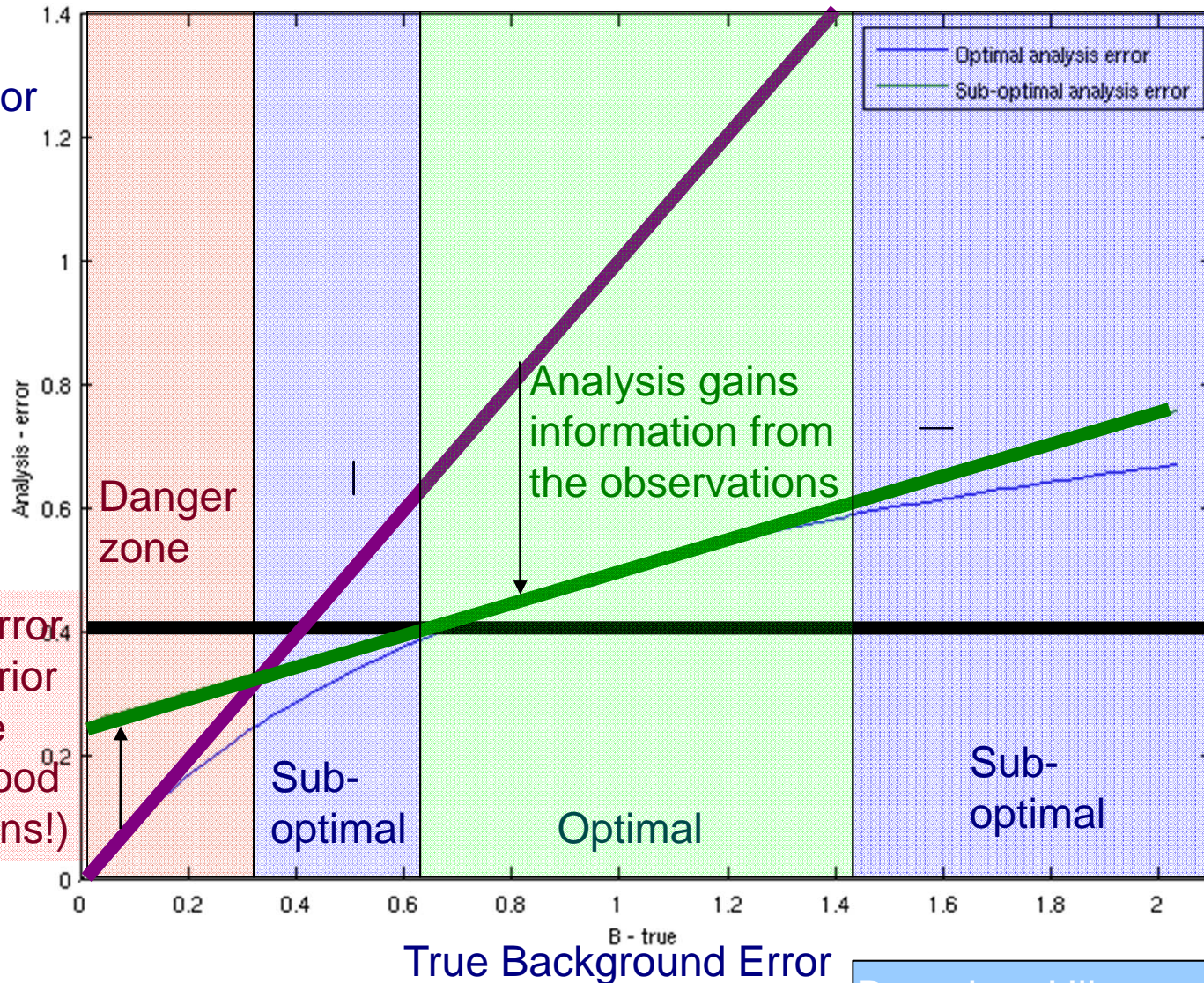


LW CO₂ Window LW H₂O SW CO₂ MW

Diagnosed IASI Observation Error – Rank Raw BT



Analysis error



Using fixed
B = 1

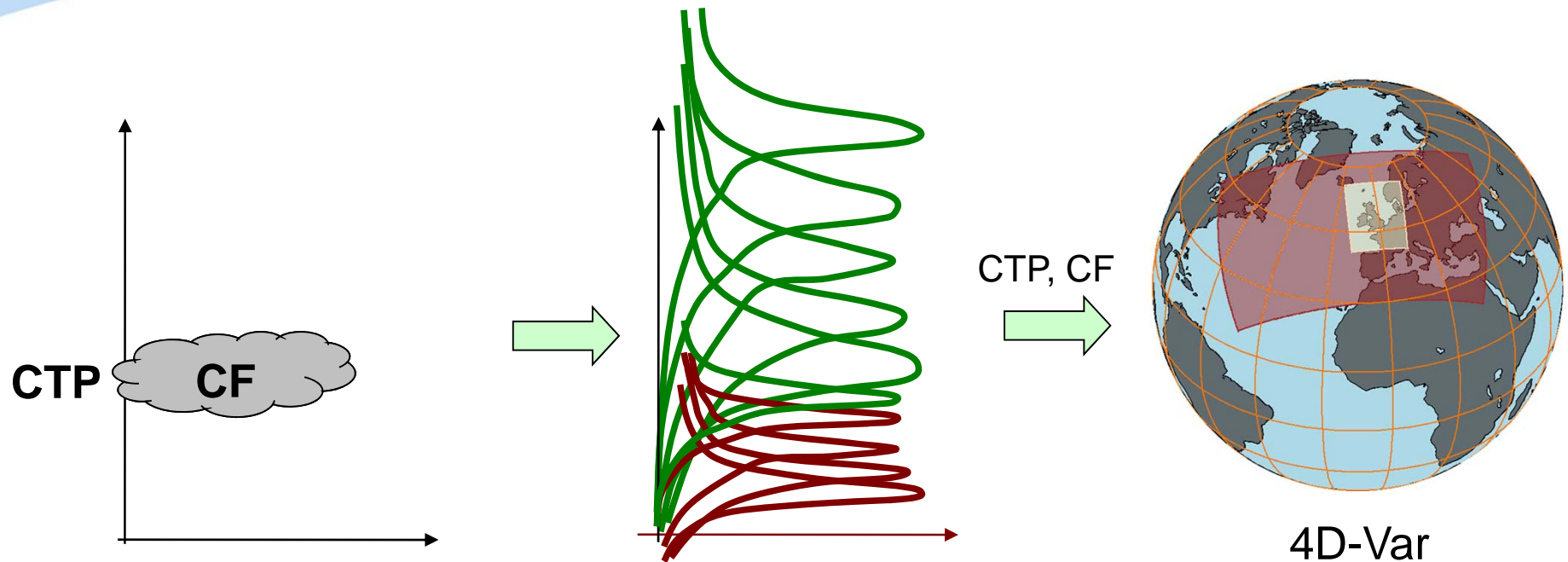
Using true B

Analysis error exceeds prior knowledge (despite good observations!)

True Background Error

Based on Hilton and Eyre 2010

- Assimilation of observations can make analysis worse if errors are not well known.
 - When prior knowledge is underestimated
 - But if prior knowledge overestimated we fail to exploit the observations fully
 - Note that underestimating observation errors is equivalent to underestimating prior knowledge
- Peril of defining requirement in EDR
 - Can give opposite impression to reality
 - Better to define requirement in terms of “value added”



- Retrieve cloud parameters in 1D-Var

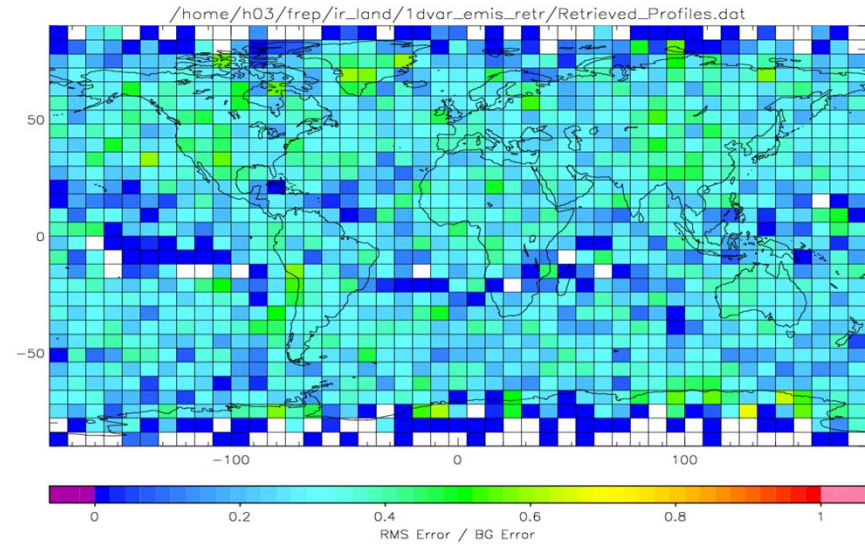
- Choose channels with minimal sensitivity below cloud top

- Pass cloudy radiances, retrieved CTP and CF to 4D-Var

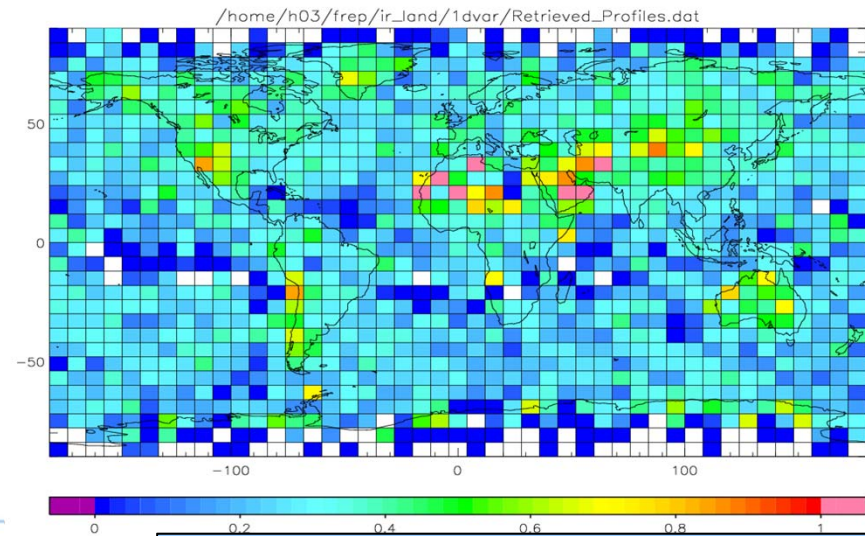
This approach does not gain information below cloud in partly cloudy scenes. Why? Because the single level grey cloud model is not realistic enough.

- Other main issue for hyperspectral sounders is the surface...
 - IR surface emissivity has large spectral variability
 - Retrieving emissivity in n channels adds n unknowns to state vector
 - Use **principal component analysis** to compress the emissivity spectrum
 - Use prior knowledge of spectral variation of emissivity (from lab measurements)
 - Constrains solution to realistic values
 - Retains realistic correlations between channels
- **Helps to separate T_{skin} and $\epsilon(\lambda)$**

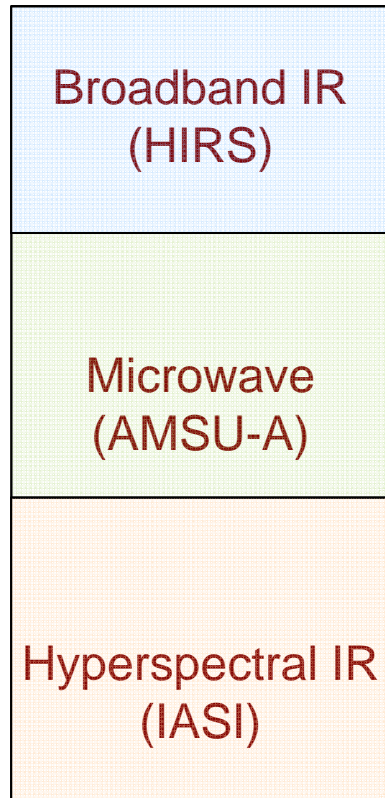
**Without emis
retrieval**



**With PC based
emis retrieval**



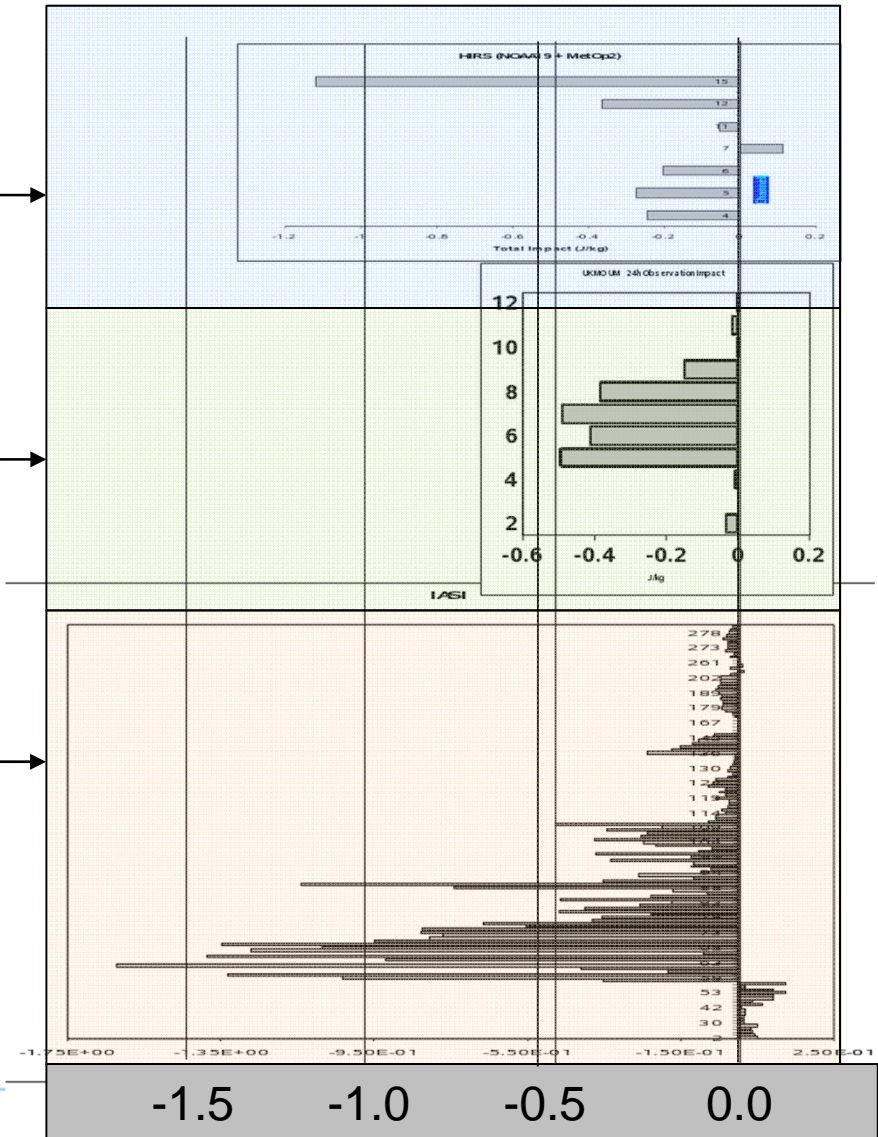
From Ed Pavelin, Met Office



Best -1.1 J/kg

Best -0.5 J/kg

Best -1.7 J/kg



Adjoint sensitivity is a measure of the ability of each observation to reduce forecast error for a specified metric.

From Richard Marriot, Met Office

- JPSS-1 satellite fixed price contract: **\$248M** for 6 year mission
 - Every year late starting to use data wastes **\$40M** per year
 - Cost is \$40M but the benefit is even larger... in US current value of NWP current total value of NCEP forecasts are ~\$10B and Riishojgaard calculated savings of **\$200M** per hour gained in advanced warnings.
 - Fourth WMO Workshop on the Impact of Various Observing Systems on NWP Geneva, Switzerland, 19-21 May 2008 summary and conclusions: AIRS and IASI each ~6 hours gain
 - **So total benefit of AIRS, IASI and CrIS ~ \$1B per annum to US each**
 - If benefit scales with GDP (i.e. assuming similar investment in effort to use data, and access to data):
 - UK, France, Brazil ~ \$150M each

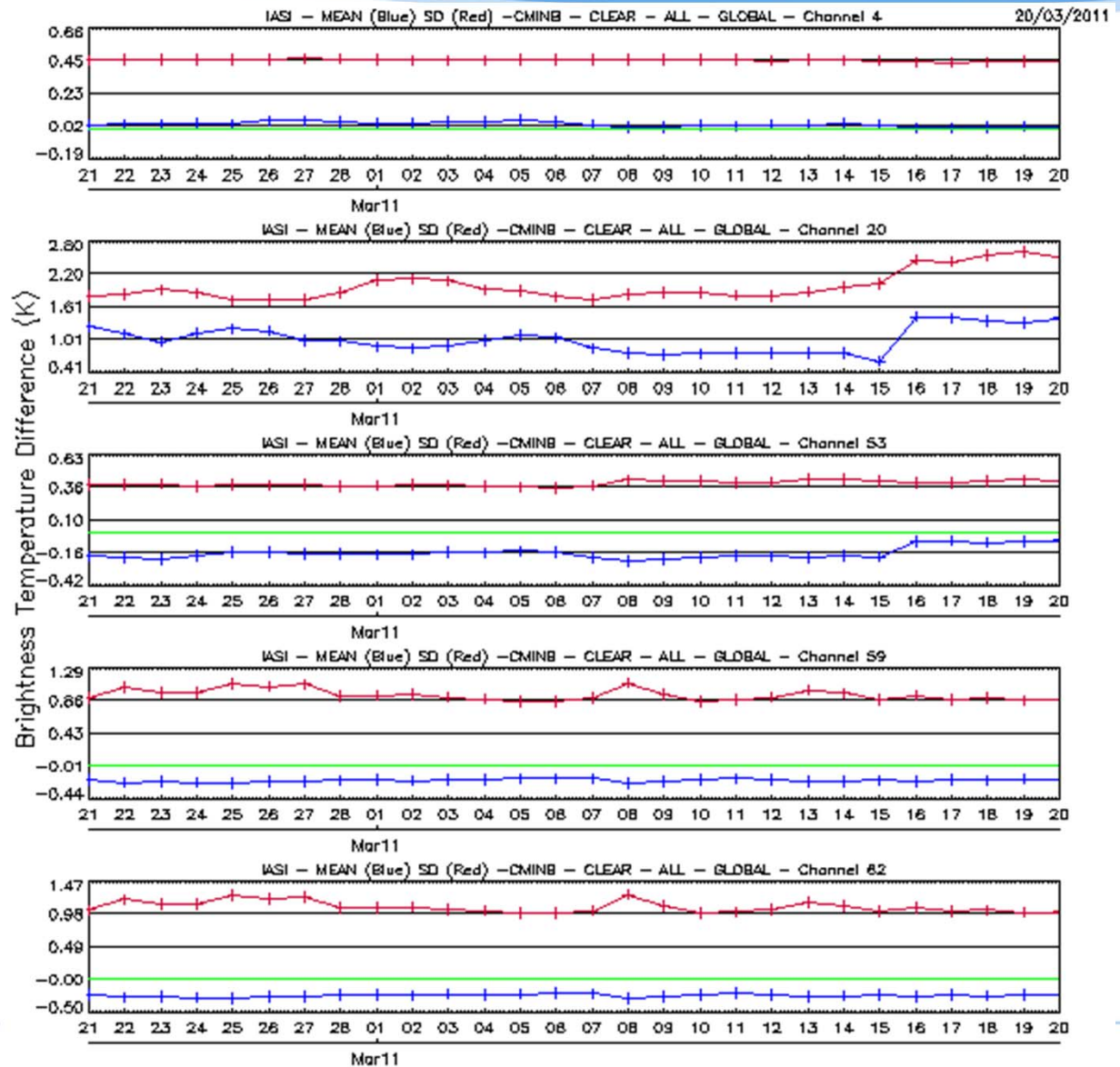
- Data can start saving lives and money **sooner** if:
 - Satellite agencies send **simulated data** for a year, resolving problems of telecommunications, handing formats, errors in BUFR etc....*the technical stuff.*
 - *Work with NWP and climate centres to ensure they have all information needed to assimilate (in research mode) the simulated data – instrument response functions etc.*
 - Send real data as soon as instrument switched on *to resolve the science and data quality in partnership between satellite agencies and NWP/climate centres.*
 - Monitoring begins immediately and assimilation of data within 2-3 months of launch.
 - NWP/climate centres need huge computer processing power to fully exploit – but delaying wastes money.

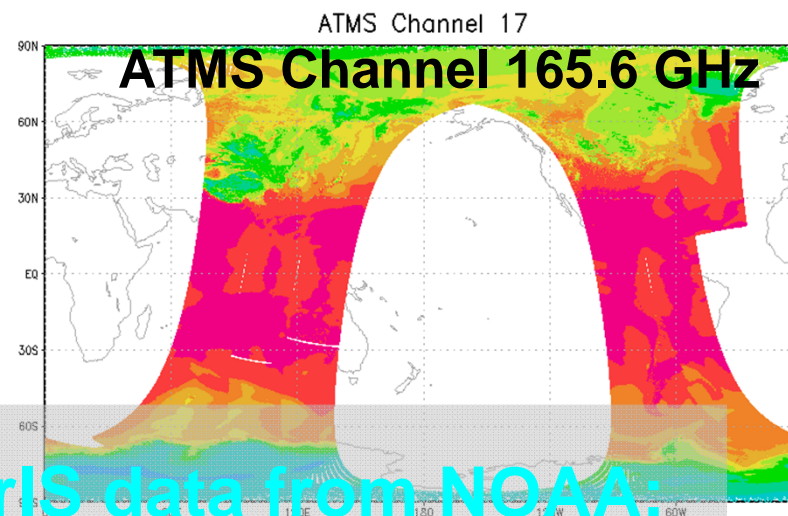
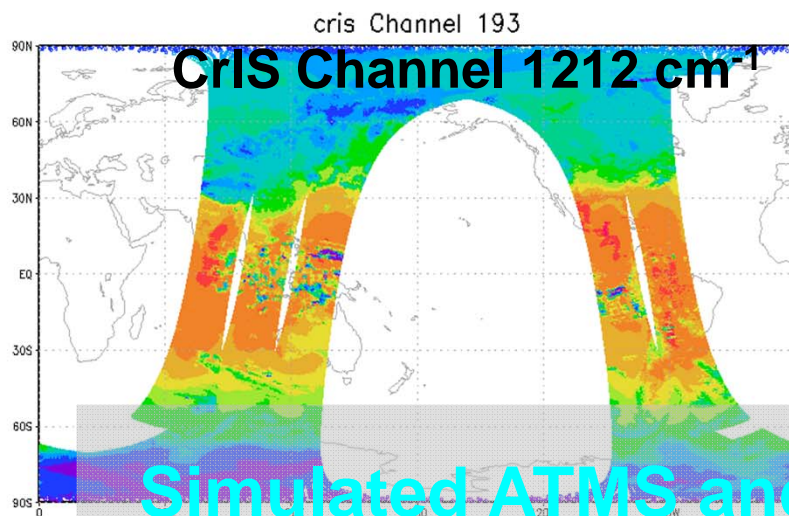


Example IASI monitoring (Met Office)

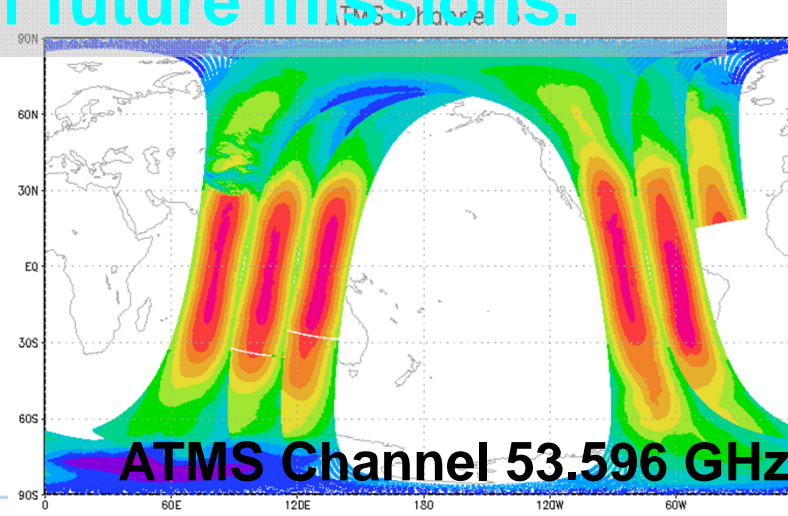
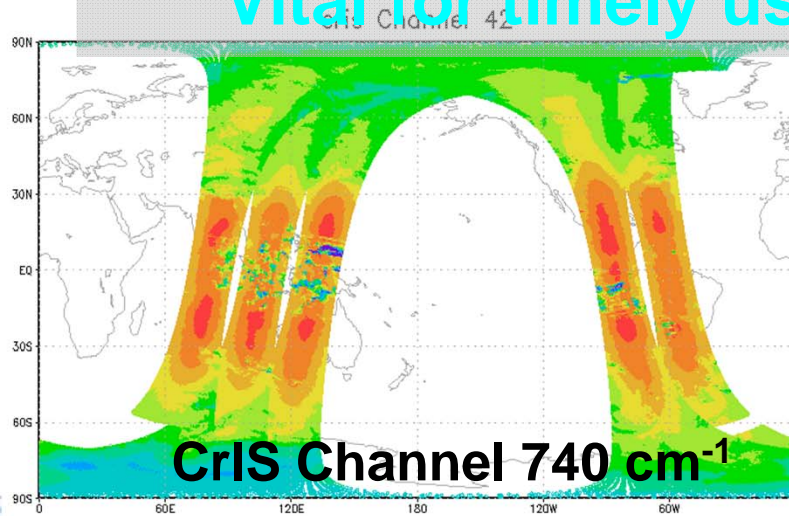


NWP centres share monitoring to show if problems are local or with data itself.





**Simulated ATMS and CrIS data from NOAA:
Vital for timely use of future missions.**



0.0195 0.026 0.0325 0.039 0.0455 0.052 0.0585 0.065 0.0715 0.078 0.0845 0.091

216 220 224 228 232 236 240 244 248 252 256 260

- Hyperspectral sounders have a very high information content – around 30 pieces of independent information for temperature and humidity.
- Despite using few channels, and a very simple treatment of clouds and surface, the data already has an important impact in NWP.
- **1 IASI > 1 AMSU** but we have AMSU on N15-19, MetOp, Aqua and only 1 IASI, 1 AIRS! **Therefore overall MW still dominant.**
- But we are only just beginning....it took 20 years to learn how to use TOVS!

- **Observations**
 - IASI quality hyperspectral sounder data with:
 - Better traceable calibration.
 - Raw radiance data or well characterised PCs.
 - Ancillary data e.g. on clouds from imager.
 - Better characterisation of **errors**, including **random error**, **correlated error**, **systematic error**, **biases**.
- **Radiative transfer models**
 - Emissivity databases – they exist but have conflicting results? Need to resolve with **high spatial resolution**.
 - More testing of simplified (**affordable**) cloud models.
 - Spectroscopy – eliminate remaining uncertainties.
 - **Support JCSDA's CRTM and NWPSAF's RTTOV!**
 - Better characterisation of errors.

- **Advanced data assimilation systems**
 - In NWP/climate centre's court! Many issues and areas of research which will lead to better exploitation of hyperspectral sounders....
 - better characterisation of model and background error; merging of variational and ensemble DA techniques; allowing for model error (weak constraint 4D-var); linearisation; variable transforms for gaussian errors. Note DA is not just for NWP – its for climate too.
- **Pre-launch characterisation, provision of information**
 - Much of this is now happening very effectively. e.g. simulated data for CrIS and ATMS! ISRFs, formats, errors....
- **Ground segment**
 - **The 1b radiances are the “product”** and we want the best quality, best characterised 1b radiance product possible.
 - Rapid dissemination: **goal timeliness 30 minutes** and send data to NWP centre partners as soon as available to Sat Agencies so **cal/val is partnership between NWP/climate centres + Sat Agencies.**

- Use of hyperspectral sounders is successful at NWP centres.
 - But research into using data more effectively is well underway
- Microwave observations remain overall the most important datatype and their value and importance must not be neglected.
- Plans are well advanced in NWP centres for use of CrIS radiances
 - Thank NOAA for provision of simulated pre-launch BUFR datasets for testing. Invaluable!
 - These efforts are immensely important.
- Plans for MTG-IRS and/or GIFTS/STORM
 - High vertical resolution feature tracking?
 - We support these missions strongly, but there is a lot of work to do to prepare for them