Meteosat Third Generation (MTG) IRS

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METEOSAT-1 FIRST IMAGE: 9 DEC 1977 COPYRIGHT ESA
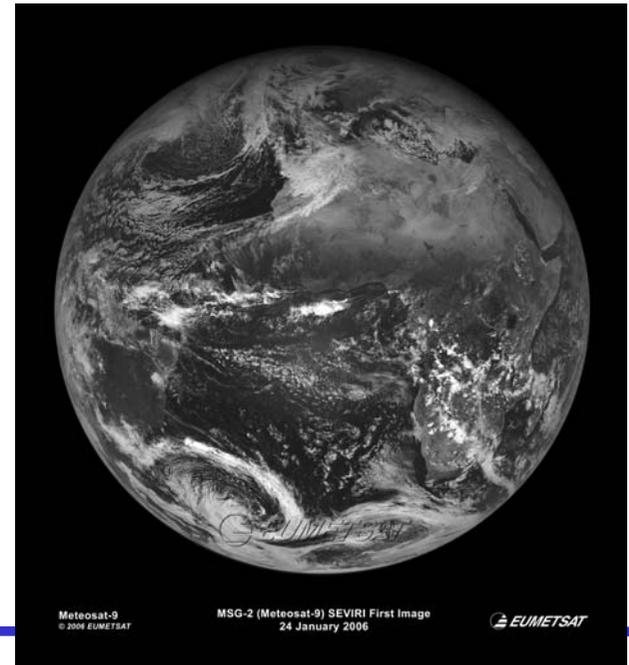
- European organisation for the exploitation of meteorological satellites
- Geostationary Satellite Programme
  - First Image 1st MFG: 9 Dec 1977
  - First Image 2nd MSG: 24 Jan 2006
- MFG and MSG are basic imagers
  - MFG: 3 channels 30 min. cycle
  - MSG 12 channels 15 min. cycle
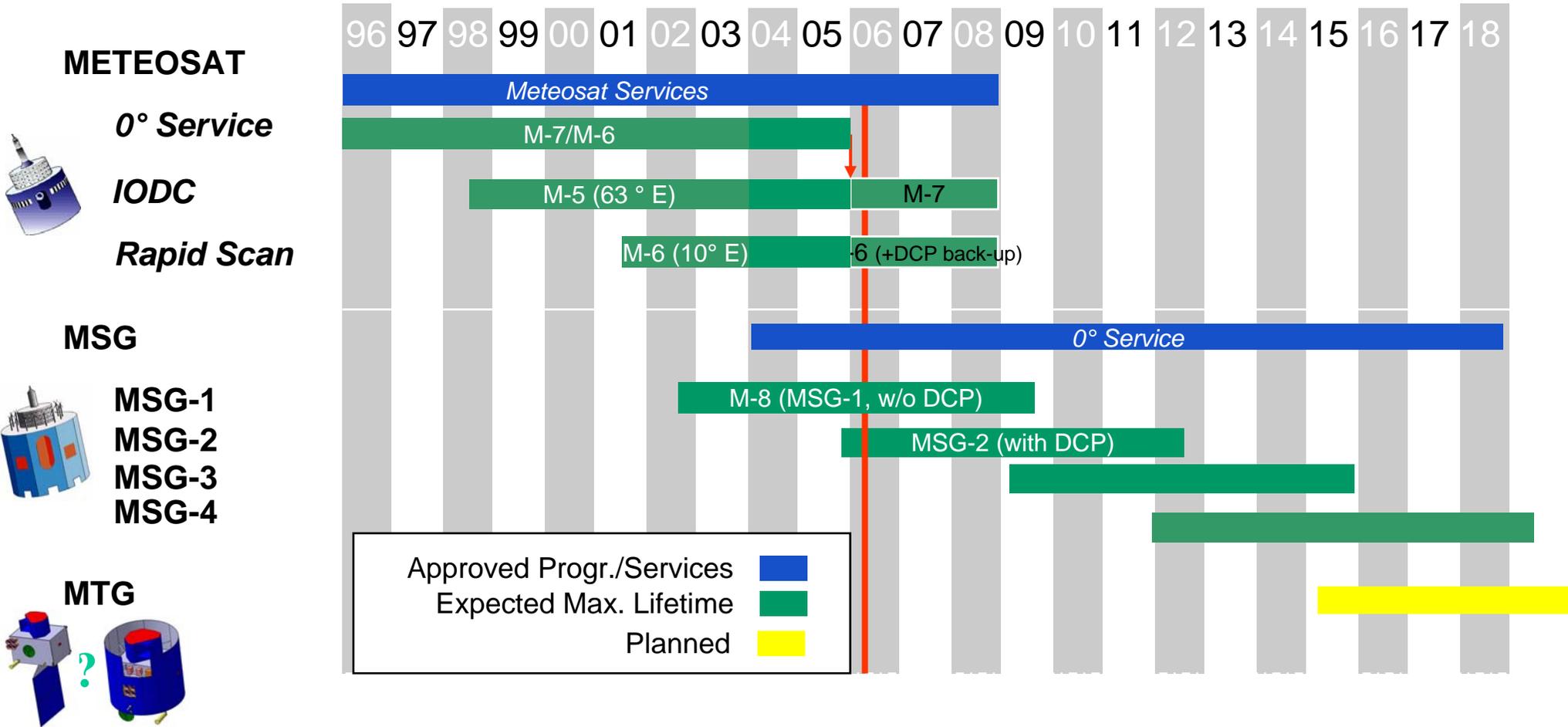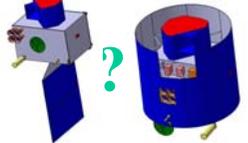

Meteosat-9 MSG-2 (Meteosat-9) SEVIRI First Image 24 January 2006 EUMETSAT

Overview of EUMETSAT Geostationary Programmes

Based on the assessment of observing techniques by remote sensing experts, five candidate observation missions have been identified to meet consolidated user requirements for operational products/services which depend on near real time geostationary satellite observations in 2015-2025.
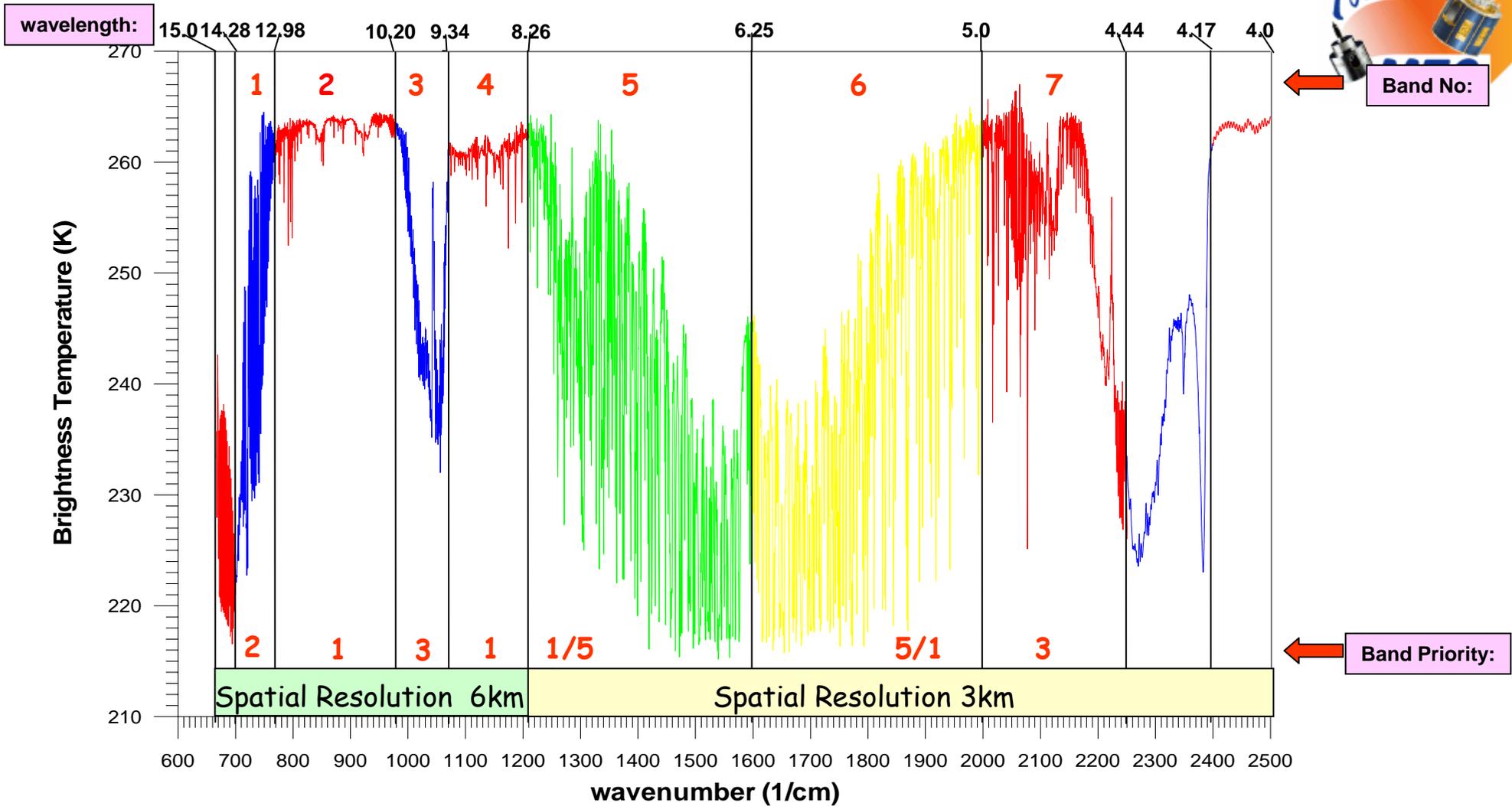
- Three distinct imagery missions dedicated to operational meteorology, with emphasis on nowcasting and very short term forecasting:
  - o The High Resolution Fast Imagery (HRFI) mission, enhancement of the MSG HRV mission;
  - o The Full Disk High Spectral resolution Imagery (FDHSI) mission, successor to the MSG SEVIRI mission;
  - o The Lightning Imagery (LI) mission;

- An Infrared Sounding (IRS) mission focussed on operational meteorology, with some potential relevance to atmospheric chemistry;

- An UV/Visible sounding (UVS) mission dedicated to atmospheric chemistry

MTG Overall Timeline

- **2001-2005:** "USER CONSULTATION PROCESS" & PRE-PHASE A STUDIES *(PHASE 0)*

  - 2001 - 2003: PHASE 1 - HIGH LEVEL USER NEEDS & PRIORITIES AGREED, PREPARATION OF PRE-PHASE A STUDIES
  - 2004 - 2005: PHASE 2 - SYSTEM CONCEPT STUDIES *(PRE-PHASE A)*, EVALUATION/PRE-SELECTION OF MTG MISSIONS

- **2006-2007:** MTG *(PHASE A)* STUDIES OF SELECTED MISSION CONCEPTS

  - APPROVAL PROCESSES: MTG PREPARATORY PROGRAMME

- **2008-2009:** COORDINATED ESA & EUM PROGRAMMES (EUM PREPARATORY PROGRAMME), MTG *(PHASE B)* SYSTEM DEFINITION

  - APPROVAL PROCESSES: MTG DEVELOPMENT PROGRAMMES (ESA & EUMETSAT)

- **2010-2014:** MTG SYSTEM and SEGMENTS DEVELOPMENT/ON-GROUND TEST *(PHASES C-D)*

- **2015 -** NOMINAL NEED DATE FOR MTG *(PHASE E)*

During Pre-Phase A

- Mission requirements based on MRD V1.2 were analysed by industry (ESA Lead activity). Industry prepared 4 baseline concepts.
- During pre-phase A activities some modifications to specifications were agreed.
- The impact of these on the baseline concepts was analysed, and also industry was invited to propose potential de-scoping.
  - Focus on driving requirements (LWIR Radiometric performance)
  - Consider IRS mission objectives and priorities
  - Target an instrument concept compatible with the 2015 launch date
- Resulted in several additional concepts.

wavelength: 15.0 14.28 12.98 10.20 9.34 8.26 6.25 5.0 4.44 4.17 4.0

Band No: 1 2 3 4 5 6 7

Band Priority: 2 1 3 1 1/5 5/1 3

Spatial Resolution 6km   Spatial Resolution 3km

Brightness Temperature (K) — wavenumber (1/cm)

Spectral resolution: 0.5 (outside wv band) – 0.625 (wv band)

Radiometric resolution: 0.2 K at 280

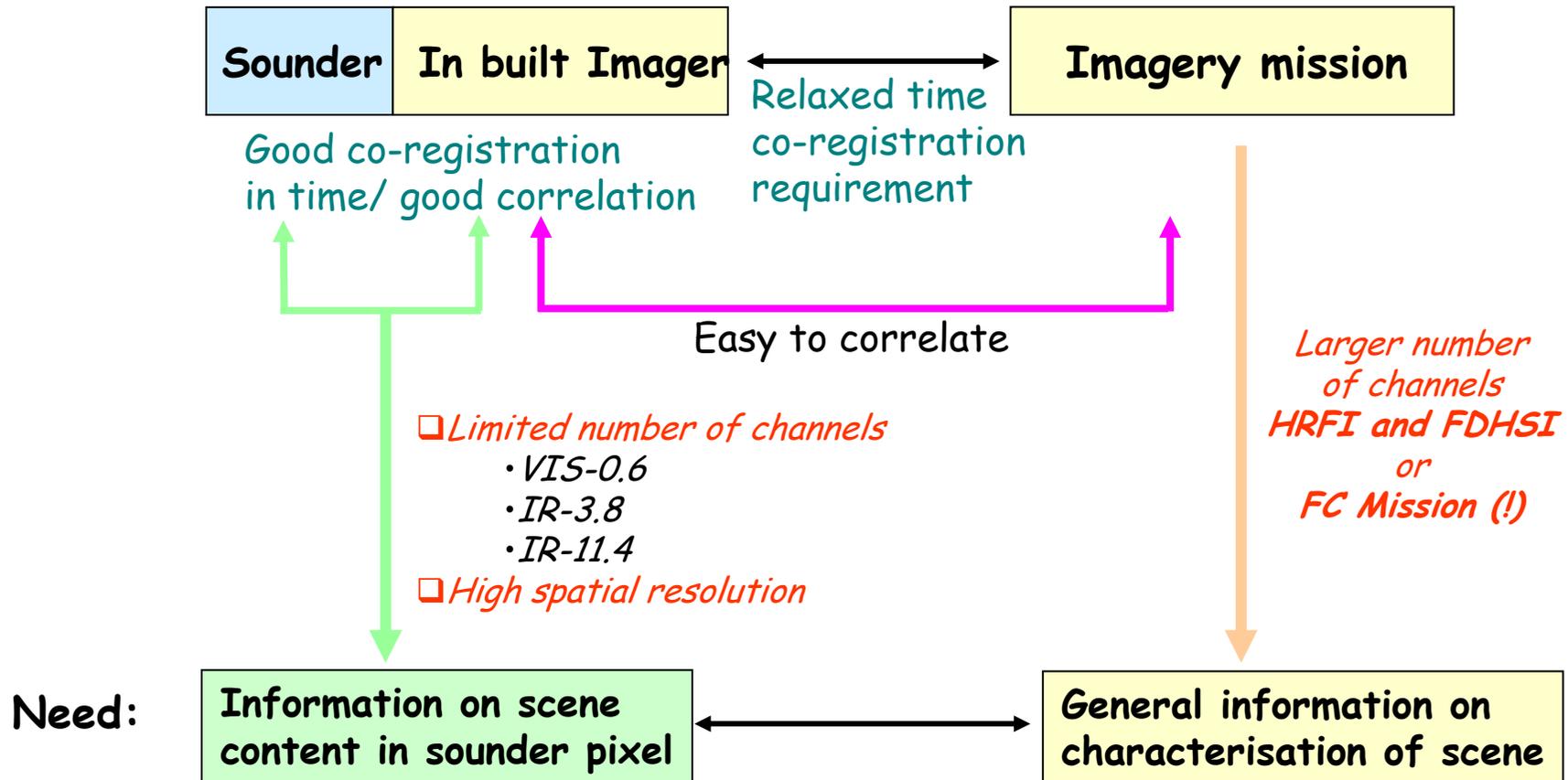|	Coverage	Repeat cycle
Full Disk Coverage	18°x18°	30 min
Local Area Cov.	18°x6°	10 min

Toward

esa

IRS: Synchronous Imaging Requirements

Additional 'high spatial' resolution Imagery is expected to increase the yield of reliable cloud-cleared sounding information in meteorologically active areas where clouds, temperature and moisture gradients exists

Sounder | **In built Imager** ←→ **Imagery mission**

Good co-registration in time/ good correlation

Relaxed time co-registration requirement

Easy to correlate

❑ *Limited number of channels*
- *VIS-0.6*
- *IR-3.8*
- *IR-11.4*

❑ *High spatial resolution*

Larger number of channels HRFI and FDHSI or FC Mission (!)

Need: | **Information on scene content in sounder pixel** ←→ **General information on characterisation of scene**

Summary of pre-phase A results
Driving requirements

- ## The large spectral range, high spectral resolution
    - large number of FPA
    - Large datavolume (160-190 Mbps DS and FTS after onboard FFT)
- The long wavelengths (IRS 0,1, 2)
    - Operating temperatures at 45 K to meet nedt
- The inter channel registration
- Stringent LOS

- Results indicate an expensive instrument with several critical pre-developments, which is different for the different concepts (DS/FTS).

Pre-Phase A
Close-out Questions

- Do we need anything else besides IRS 5 or IRS 6?
- 14 micron (IRS 1)?
    - If yes: can we stop at eg. 730, or 800?
    - No: Can we trade IRS 1 against observations in IRS 7 + IRS 8
- IRS 7:
    - Can we stop IRS 7 at 2150 cm-1
- Where in the spectrum can we accept non-compliance to radiometric specifications
- Where in the spectrum do we have to insist on compliance to radiometric specifications
- Do we need spatial sampling of 3 km for IRS 5 – 7 and 6 for IRS 1 – 4
- Do we need a spectral over sampling of 2
- IRS 5 or IRS 6?
- DS or FTS?
- Effect of clouds?
- Spectral Calibration: Can we use IRS 7, but at higher spectral resolution

The Main Objective: IRS

Several studies were conducted towards answering the questions

Main objective of the studies: to consolidate the requirements without sacrifice the Main mission objective

Mission Objective: to derive atmospheric motion vectors in clear sky areas from displacement of water vapour features.

Methodology:
1. Start with a q-retrieval
2. Derive the MV from sequence of q-images

Candidate MTG IR Sounding Mission
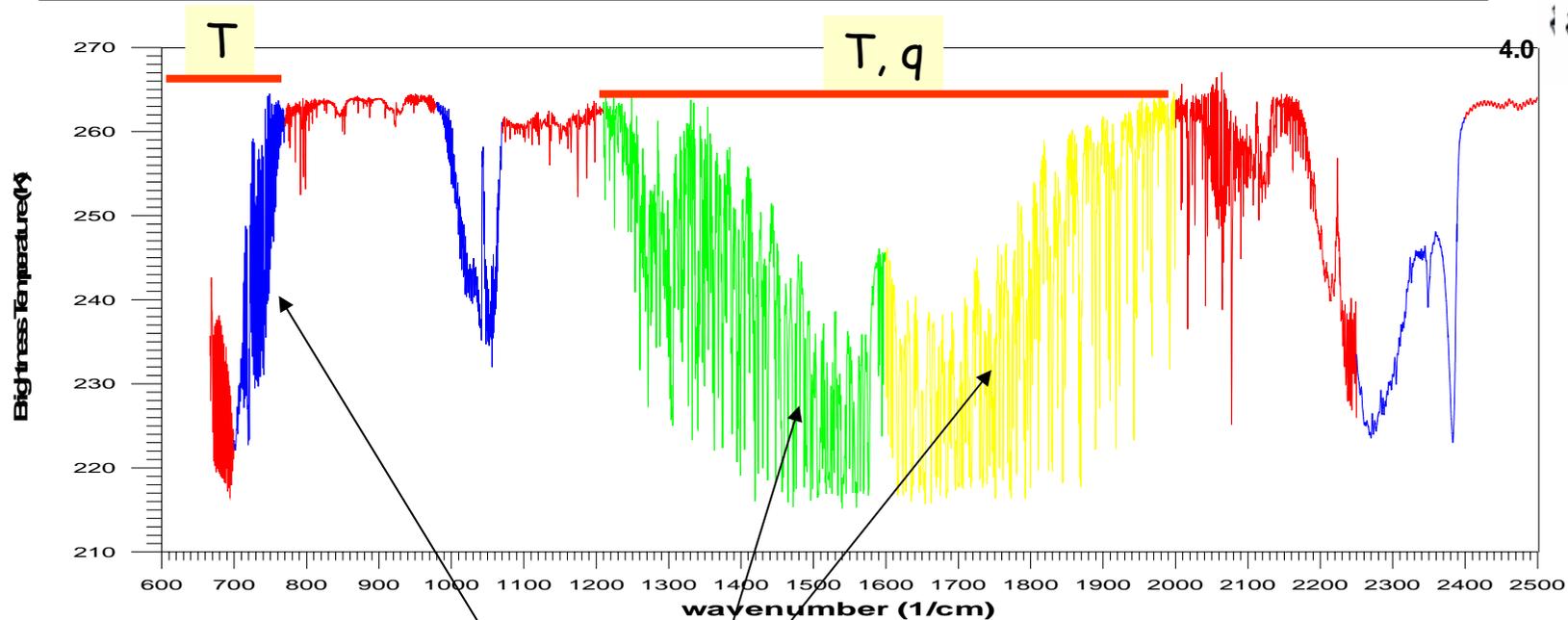
Traditionally observations 14 and 6.3 micron are used used to retrieve T and q

Using IC analysis and retrieval simulations tested the dependency
of the q-retrieval on instrument specifications

Information Content

- Knowledge of the atmospheric state (x) can be expressed as a pdf, of which we have prior knowledge, with associated error covariance Sx

- The objective: for a given observation (y) and error covariance Sy, derive new state (x^o) by minimisation of the posterior error covariance, linear error analysis yield posterior error covariance Sx^o.

- Information Content is related to the of prior and posterior error covariance.

- Positive: No need for a retrieval, can analyse in systematic way.

- Negative: Optimistic results

Information Content: Result
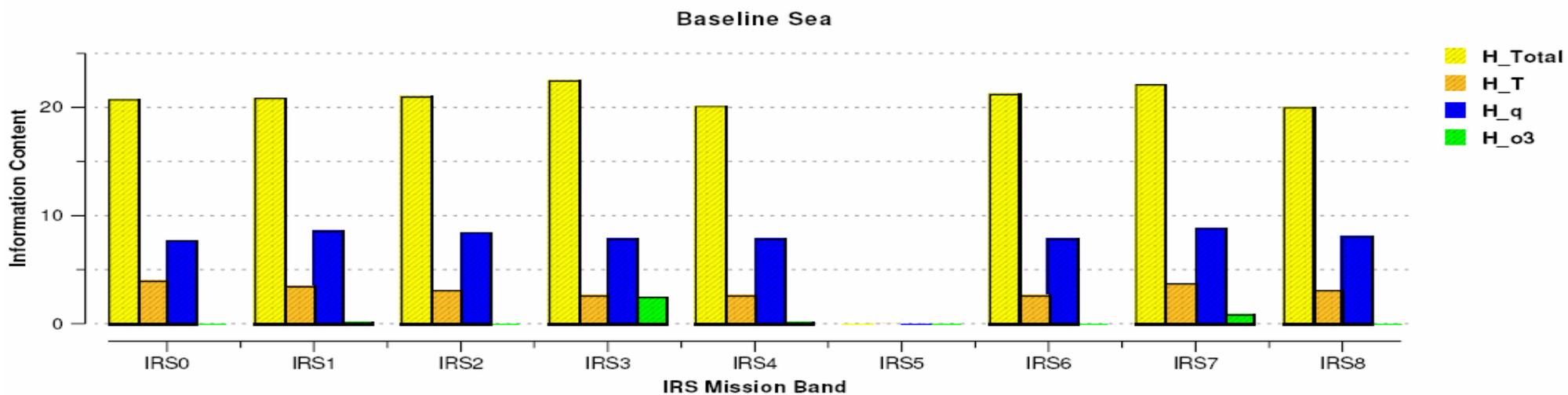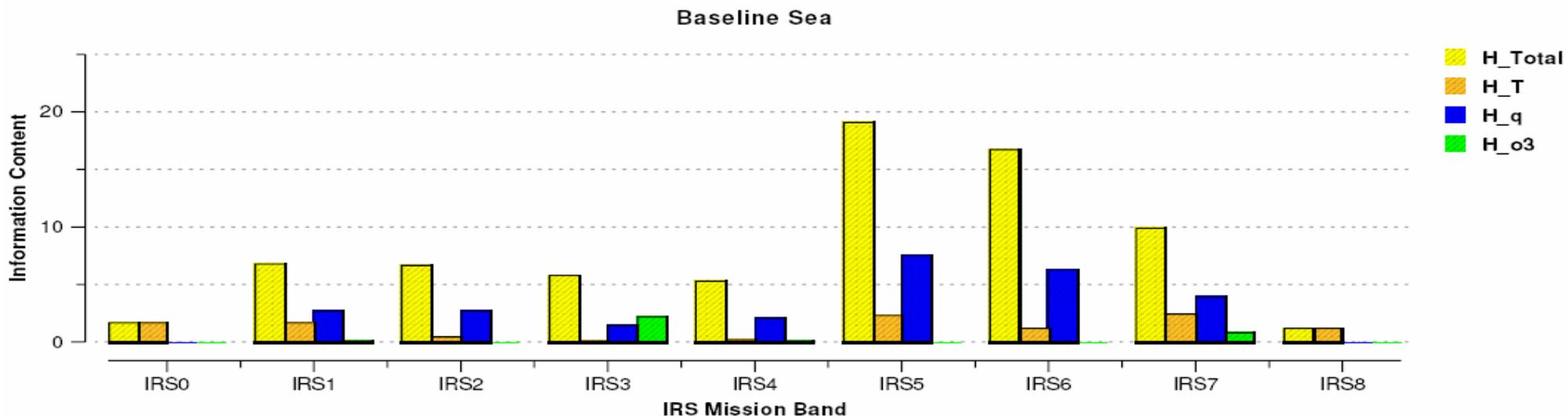
Retrieval Studies

- Full 1-D var by Met Office (Eyre, English and Pavelin)
  - Era 40 dataset, NWP error co-variance, AIRS simulations
- EOF and physical iterative method by C. Serio
  - Era 40 dataset, climatological error co-variance
- EOF and physical method by Li.
  - Era 40 and Regional dataset from Limited Area Model
- EOF and physical retrieval by X. Calbet
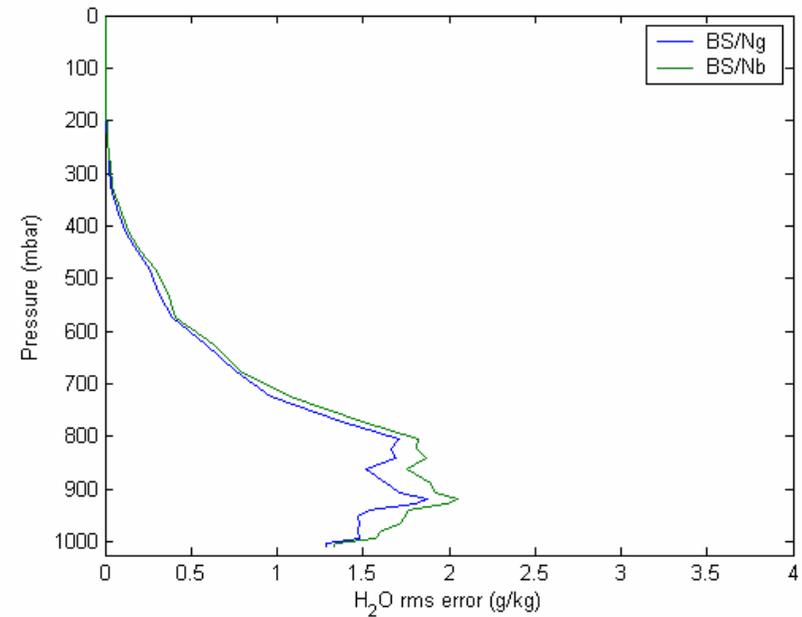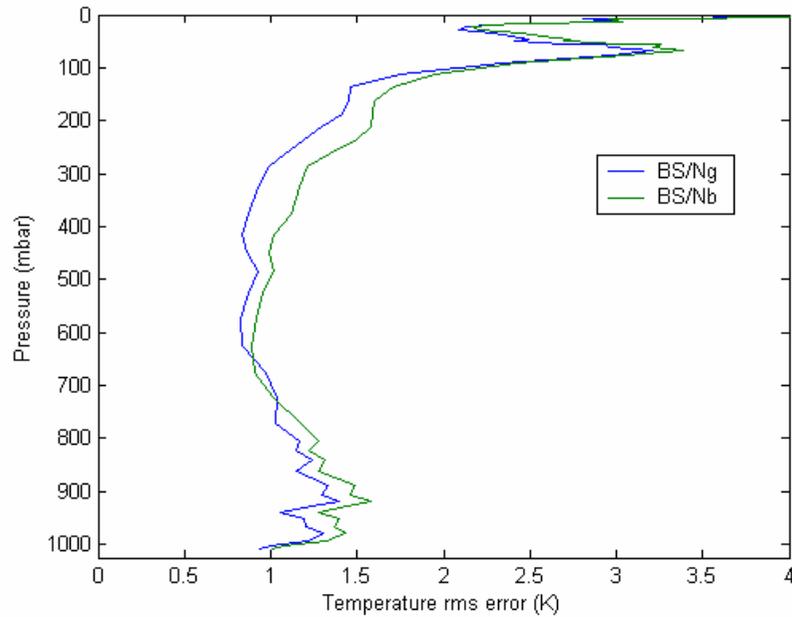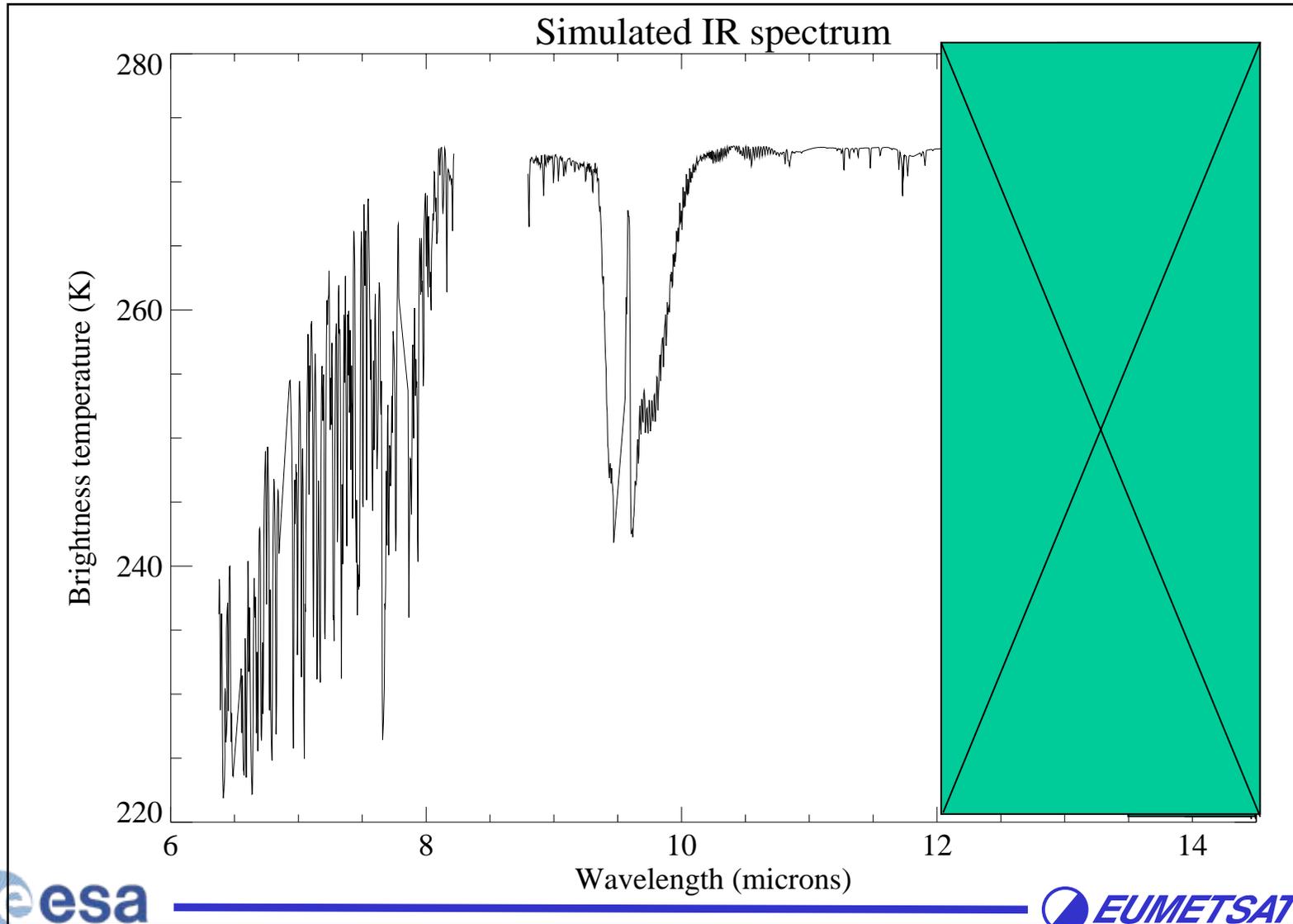 - Airs data

Noise Models

Noise

Compromise
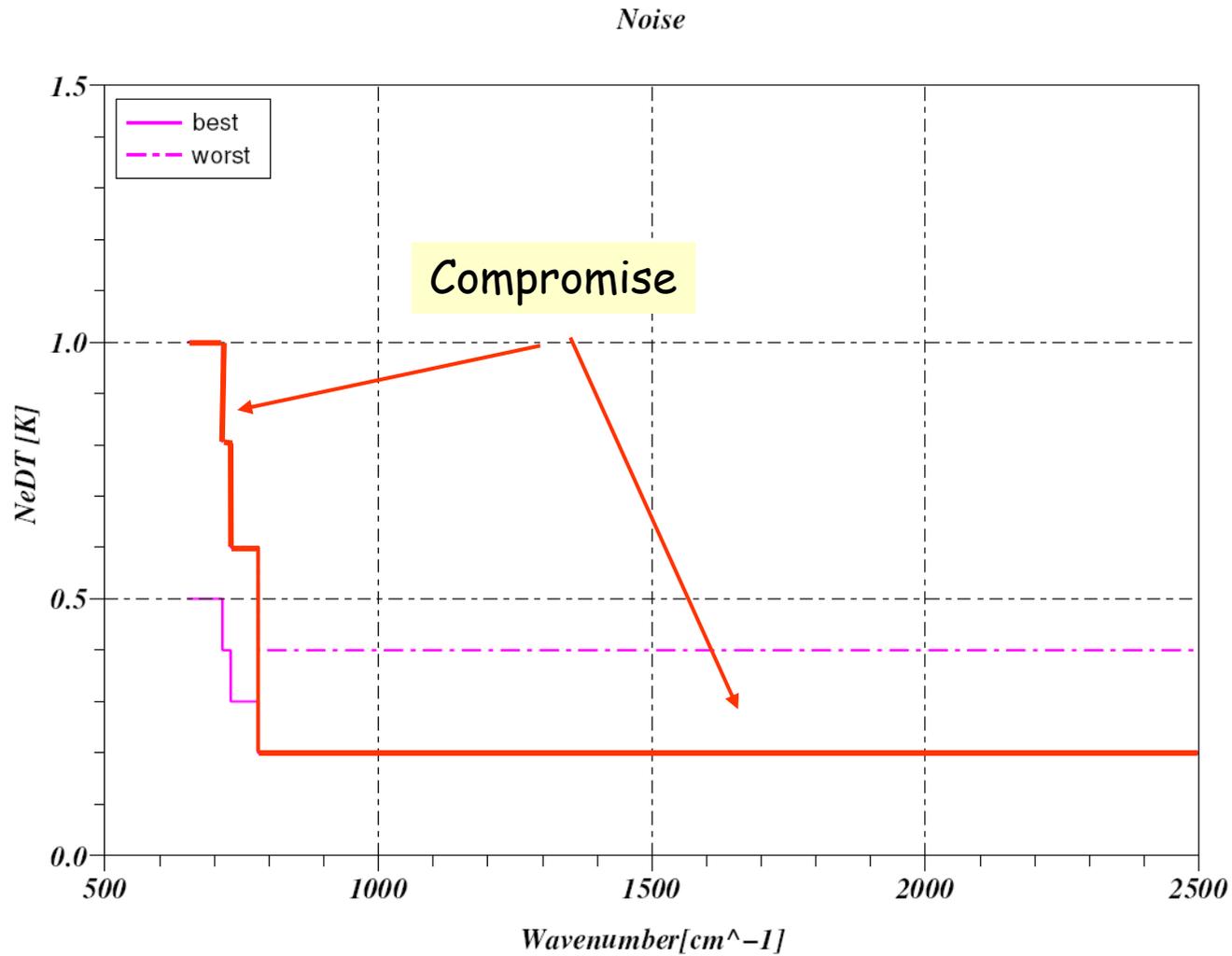
Met Office Results: Noise scenario
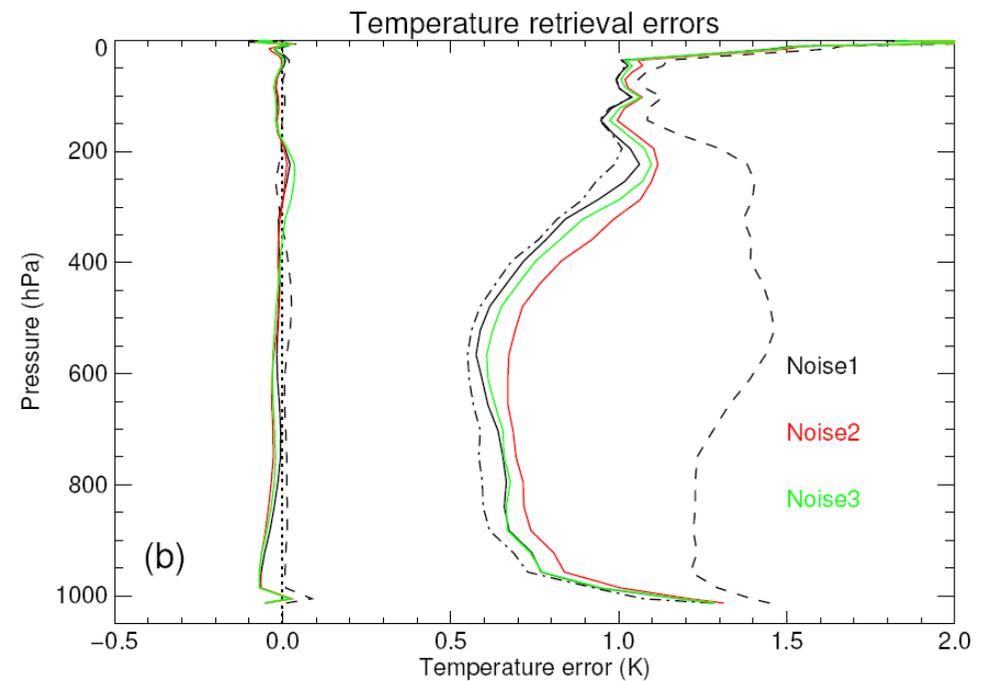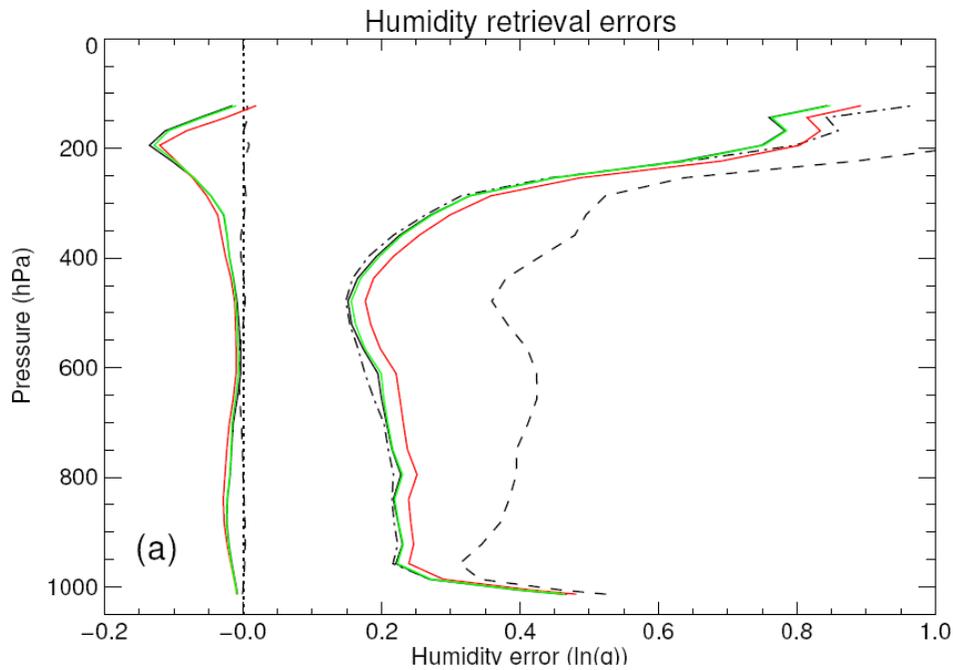
Simulated retrieval results (C. Serio)
Noise Scenario

Denial

Simulated IR spectrum

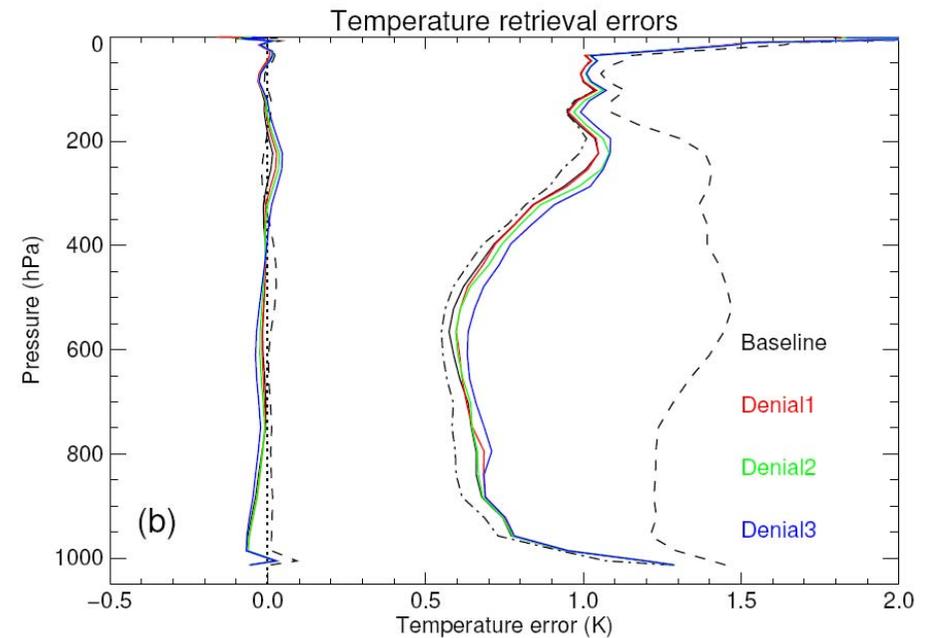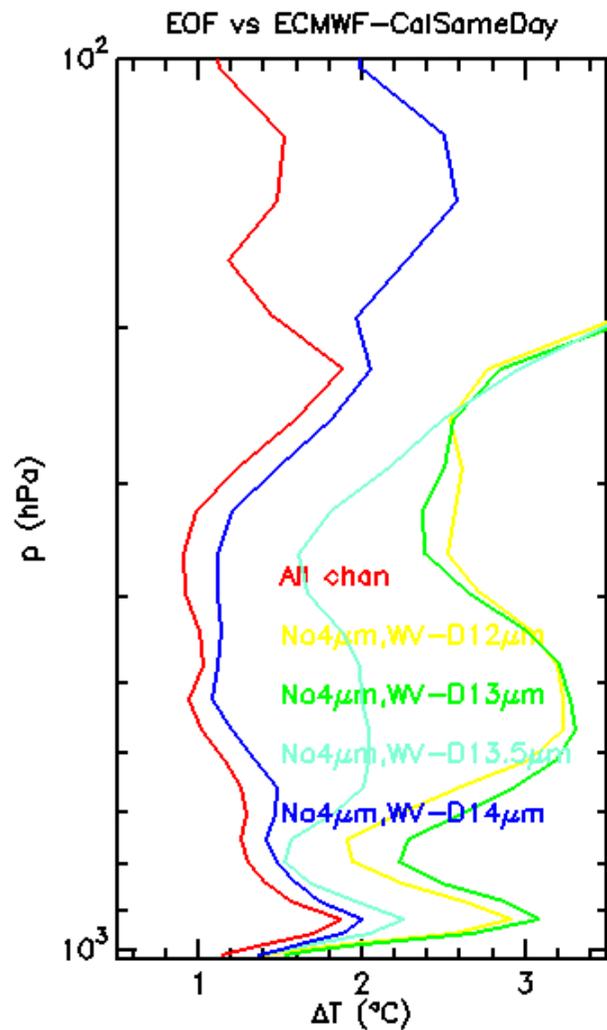Brightness temperature (K) vs Wavelength (microns)

Met Office Results:
Denial Experiment
Simulation results

Exp.	Range (cm^{-1})
Bas.	710 – 1560
1	715 – 1560
2	730 - 1560
3	780 - 1560
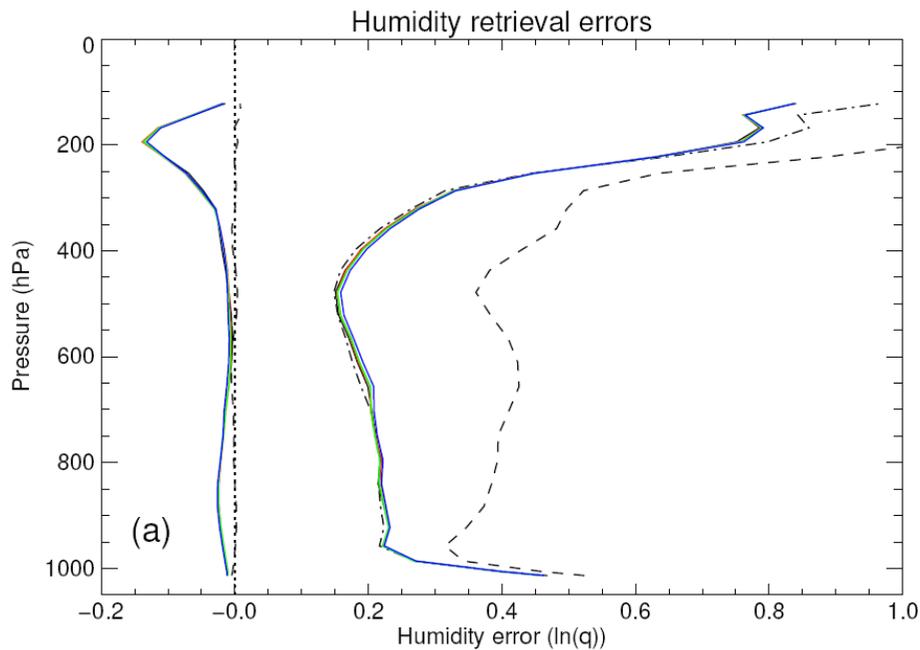
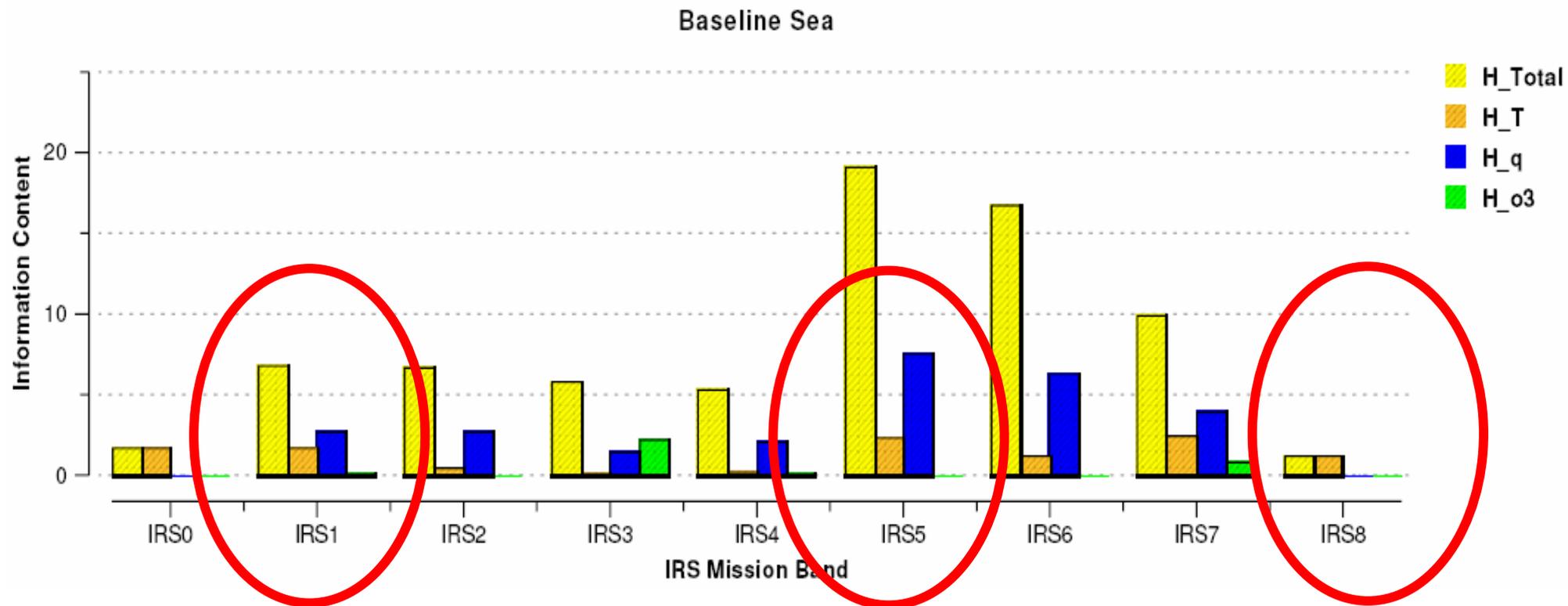# Denial results
AIRS retrieval
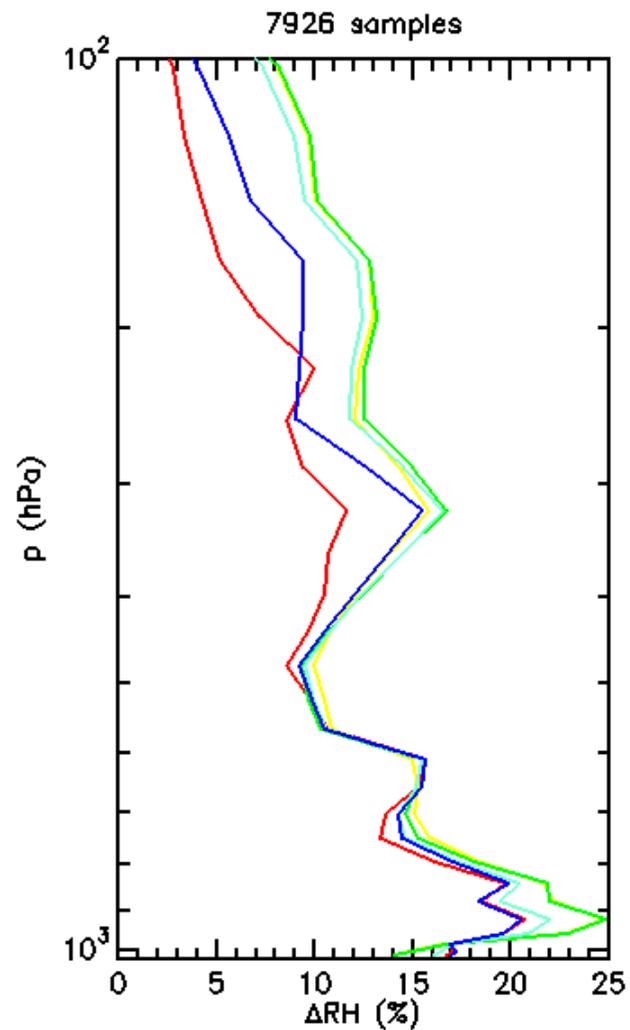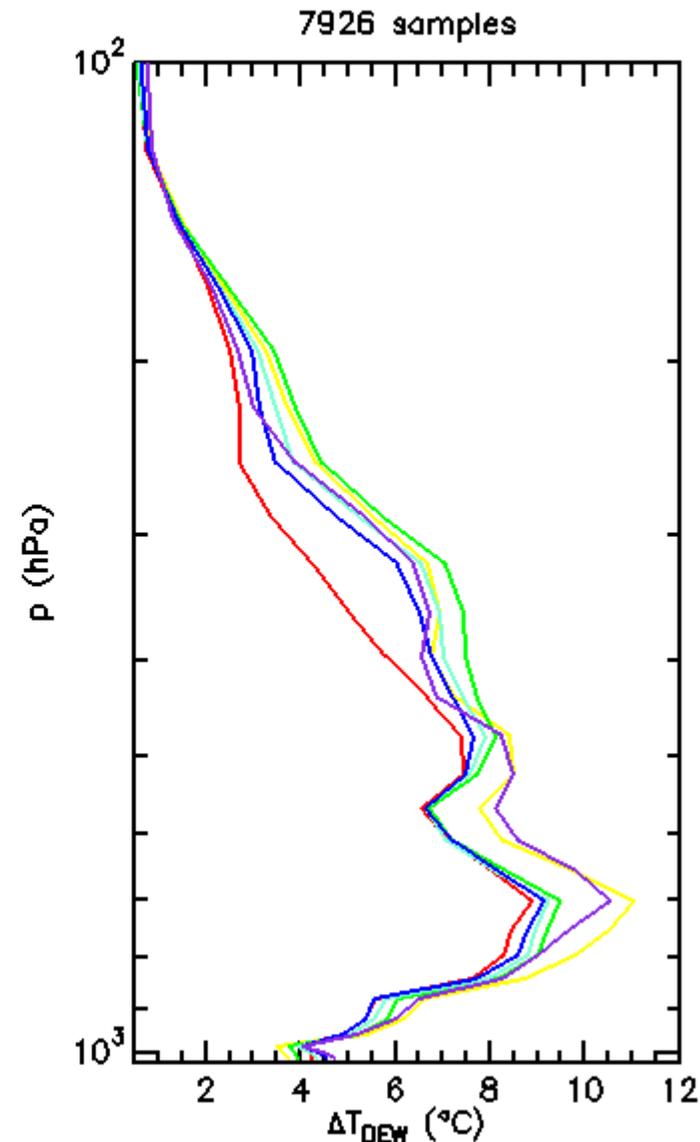
Summary

- Results show a sensitivity to the noise
- Sensitivity to the denial experiment (T more than Q)
- Suggests to be sufficient T-information in the WV region to allow a good q-retrieval

- Are we looking at the right signal?
- How confident are we in the results?

Information Content: Result

Baseline Sea

Sample AIRS retrieval
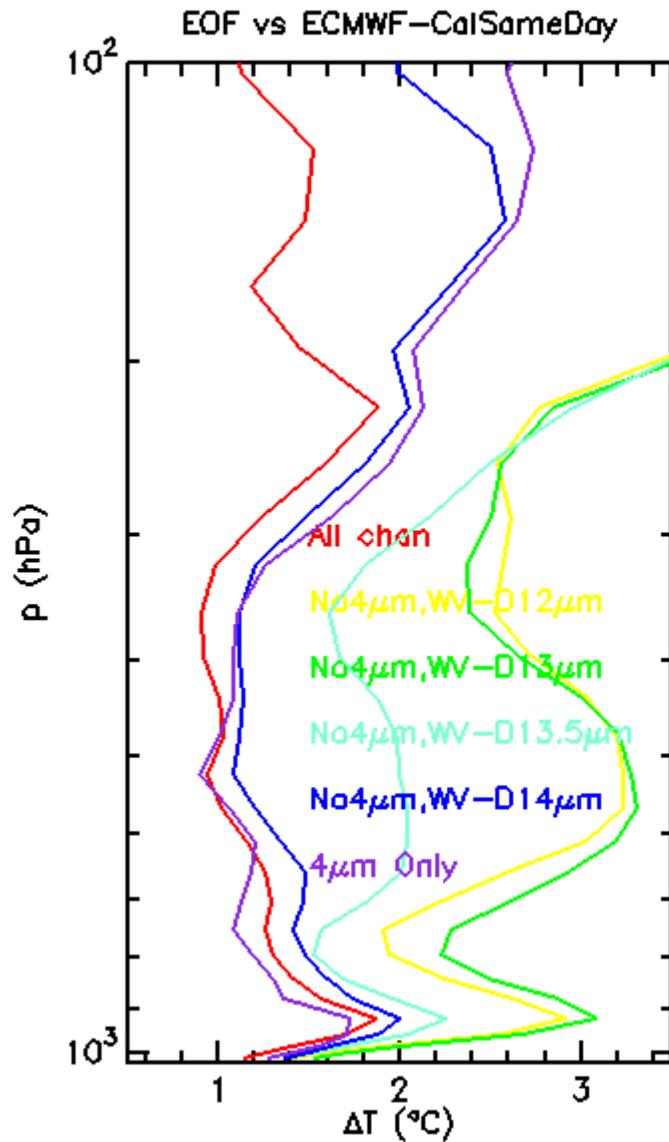
Results EOF J.Li: ERA
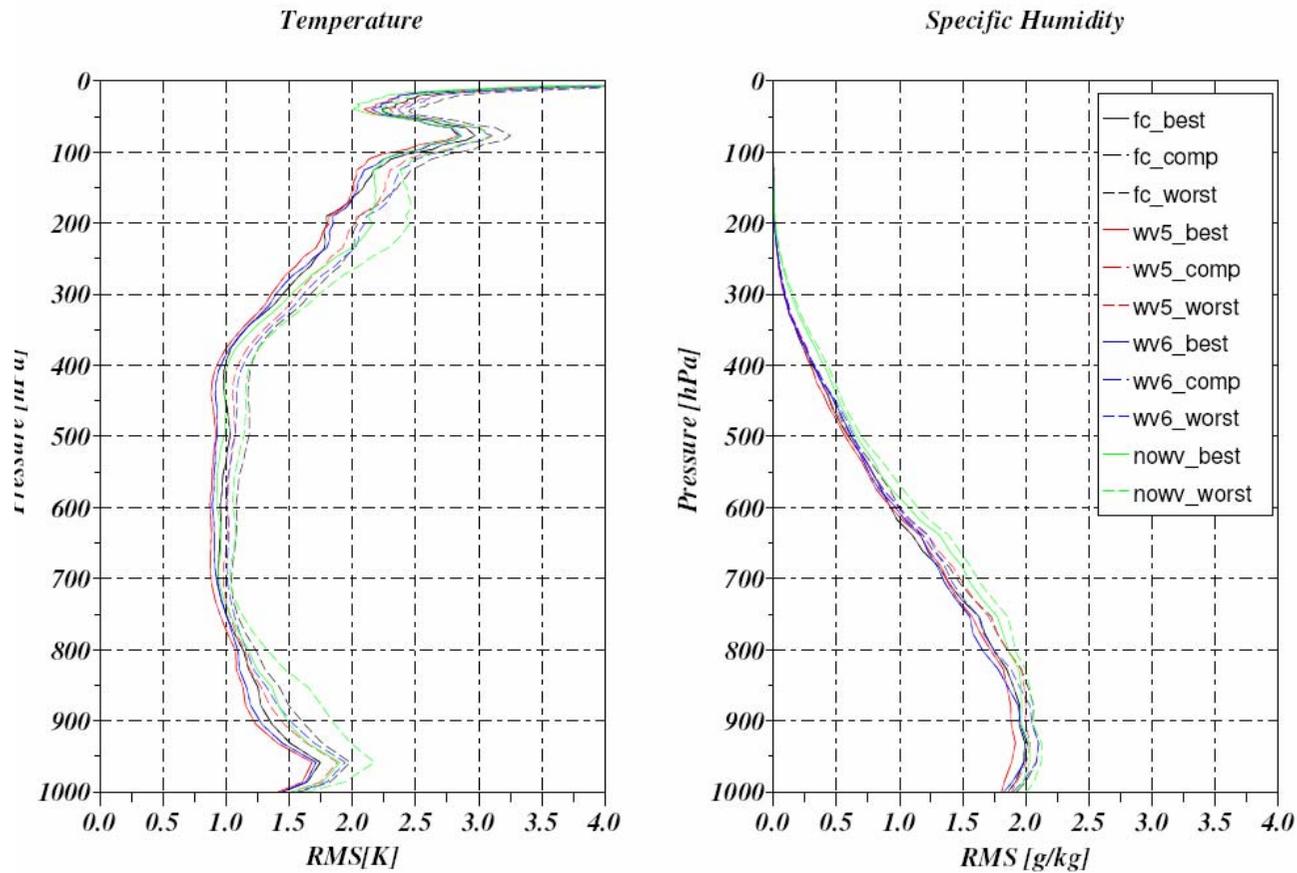
Concern!

- EOF retrievals show 'reasonable' q-results even if there is no q-information in the observations
- Result of the statistical relation between T and q in the training dataset.

Not only Meteorolgy!

- **Capabilities of IRS-MTG to sound ozone, CO and methane**
    - C. Clerbaux, J. Hadji-Lazaro, S. Turquety, D. Hurtmans, P. Coheur, R. Van Oss
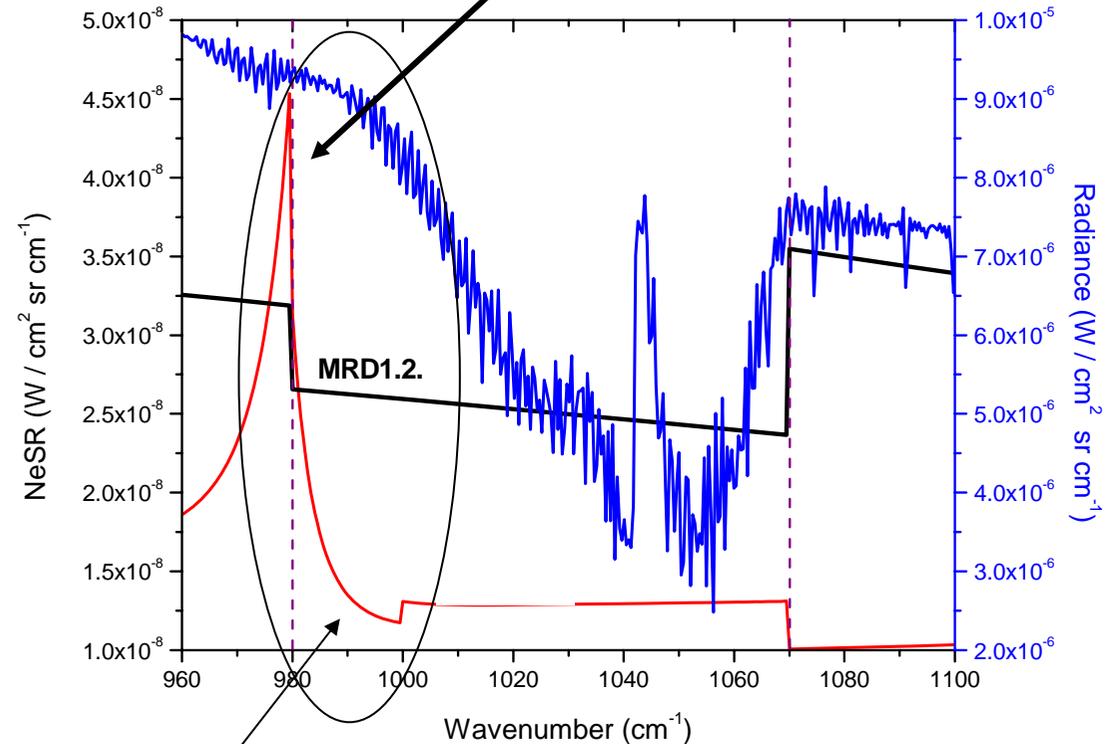
Not only Meteorology!

- ## Capabilities of IRS-MTG to sound ozone, CO and methane

  - C. Clerbaux, J. Hadji-Lazaro, S. Turquety, D. Hurtmans, P. Coheur, R. Van Oss

- Information content analysis on the effect of different noise performance for the retrieval of tracegases from IRS.

Important ?

Example of noise performance

▸ **At best :**
- - 4 independent pieces of information
- - 1 % accuracy on the ozone total (0-60 km) column
- - 10 % accuracy on tropospheric column = *threshold chemistry requirements*

▸ **Different tradeoffs between "band centres / band width" enable reaching the chemistry requirements.**
  ▸ **At the SHORTWAVE END (980 cm^{-1}) of IRS-3**

Total error (%) on TROP. column

~102 cm^{-1}

IRS-3

$S_{tot}^{(0-12\ km)} = 10\ \%$

Band width (cm-1)

Band centre (cm-1)
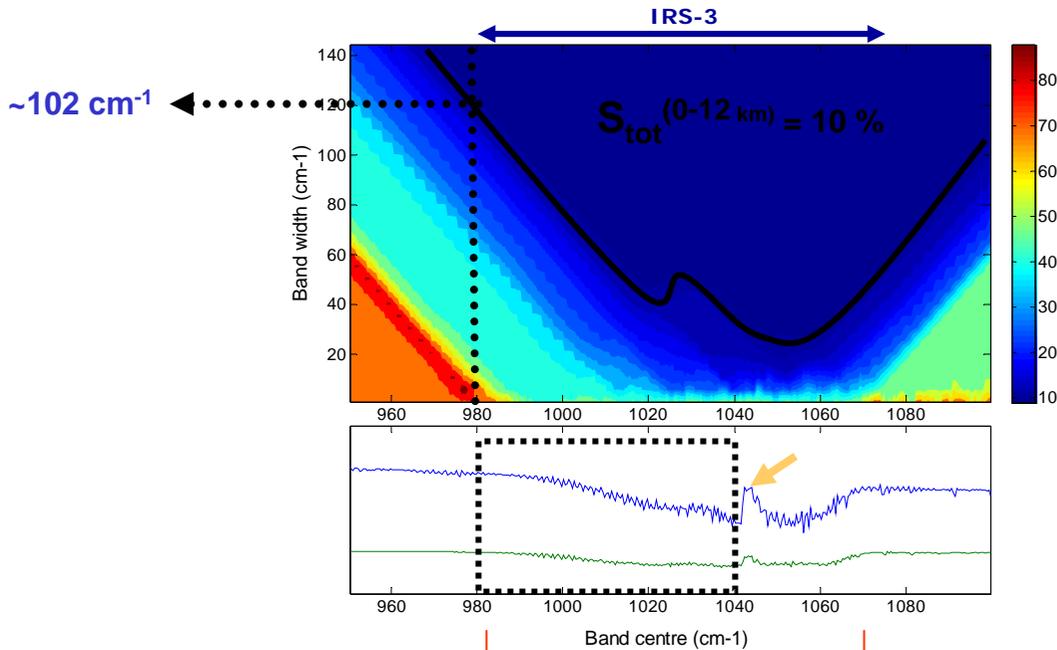
At least 120 /2 = 60 cm^{-1}
away from IRS-3 origin:

▸ **980-1040 cm^{-1}**

Note:
980-1045 cm^{-1}
recommended to add
baseline information

Limit of band 3   Limit of band 3

MTG-IRS expert meeting
24-25 april 2006

- 24-25 april 2006 and expert meeting to consolidate the MRD-IRS requirements and to answer the open questions

- The experts made several recommendations (shown next), which needs to be translated into requirements and then needs to be agreed.

Trade 5/6 Trade

Recommendation 1: confirm IRS-6 only - following study conclusions
and preferable to IRS-5 as cleaner better RTM
CH4 in IRS-5 not highest priority from GEO
no need to implement IRS-5
=> no impact in IRS-7

FTS/DS Concept

Recommendation 2: FTS shall be the baseline concept with the understanding
that the updated MRD gives specifications for
the baseline configuration
(the understanding is that in case industry proposes
to deviate from the baseline concept need
to be confirmed by users/MMT)

Spatial Sampling

Recommendation 3: AMV still highest priority but not yet demonstrated.
4 km spatial sampling still compliant with AMV retrieval.
T(p) / H2O(p) retrieval as well as identification of 'not cloud affected radiances' (currently applied at ECMWF) would benefit from having same spatial resolution for Group I and II (would also be a relaxation following GIFTS)

IE

Recommendation 4: confirm that IE @ 4km >= 67% for the $11\mu m$ channel in IRS-2 accepting non-compliance above (long-wave CO2 band)

Basic repeat cycle

Recommendation 5/6: As a goal the IRS shall scan FD in 30min
with a threshold scan time FD of 60 min
and confirmation of MRD requirement IRS-100
('rapid scan' mode over selectable areas over
complete lifetime)

Spectral Coverage

Recommendation 7: confirm priority of bands - 1st IRS-6/4/2
2nd IRS-1/7
3rd IRS-3
confirm not to explicitly to relax IRS-1 to above 700 cm-1 but
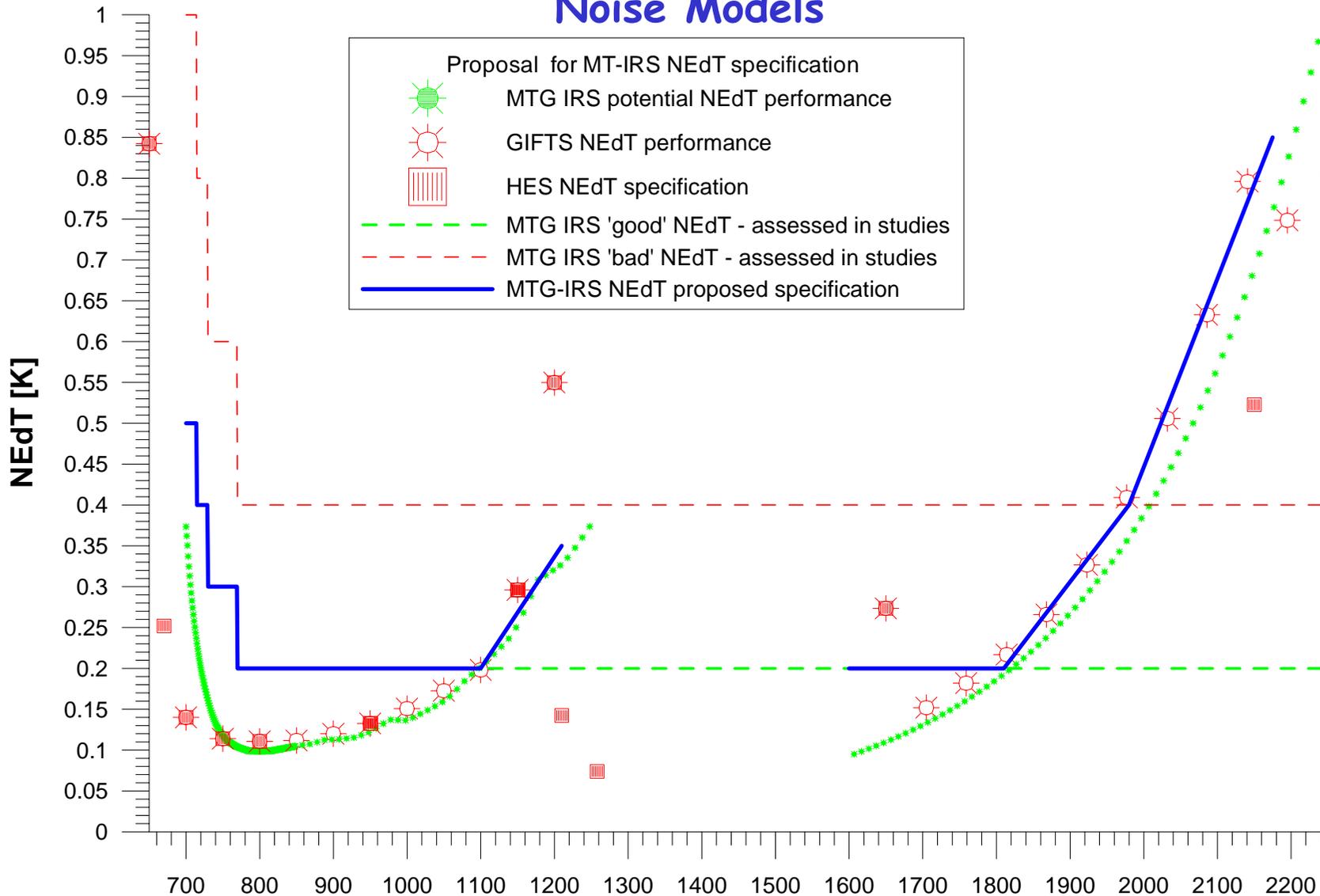to relax NEdT according to NG noise proposal (in line with detector
lambda cut off at 14 μm)
confirm to band IRS-7 at 2175 cm- 1 compliant with CO retr.

Spectral Resolution

Recommendation 8: As FTS has been proposed as baseline spectral sampling (1/2MOPD) should be specified instead of spectral resolution through FWHM

recommended IRS-MOPD = 0.8 cm

Noise Models

Legend:
- Proposal for MT-IRS NEdT specification
- MTG IRS potential NEdT performance
- GIFTS NEdT performance
- HES NEdT specification
- MTG IRS 'good' NEdT - assessed in studies
- MTG IRS 'bad' NEdT - assessed in studies
- MTG-IRS NEdT proposed specification

Y-axis: NEdT [K]
X-axis: wavenumbers cm⁻¹

Recommendation 9: accept propsed specification (blue line)

Build-in Imager

Recommendation 10: to discard the BiI

Revised Priorities

Revised priorities:

        1st radiometric accuracy (except IRS-1 longwave side)
        2nd spectral resolution
        3rd spatial resolution
        4th temporal resolution

Comments regarding implementation scenarios?

operability of IRS mission:
        lower than imagery mission - no hot back up required accepted

Summary

- Able to solve critical issues and define a way forward