IASI validation studies

Stuart Newman and co-workers

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Acknowledgements

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- JAIVEx science team

  Bill Smith, Allen Larar, Dan Zhou, Hank Revercomb, Xu Liu
- EUMETSAT support

  Peter Schlüssel
- ECMWF

  Andrew Collard
- Met Office

  Jonathan Taylor, Fiona Hilton, Sid Clough

  (and many others…)

Contents

This presentation covers the following areas

- Principles of airborne validation campaigns (JAIVEx)
- IASI spectral calibration
- IASI direct radiance validation
- Cross-validation with AIRS
- Identification of model biases
- Summary

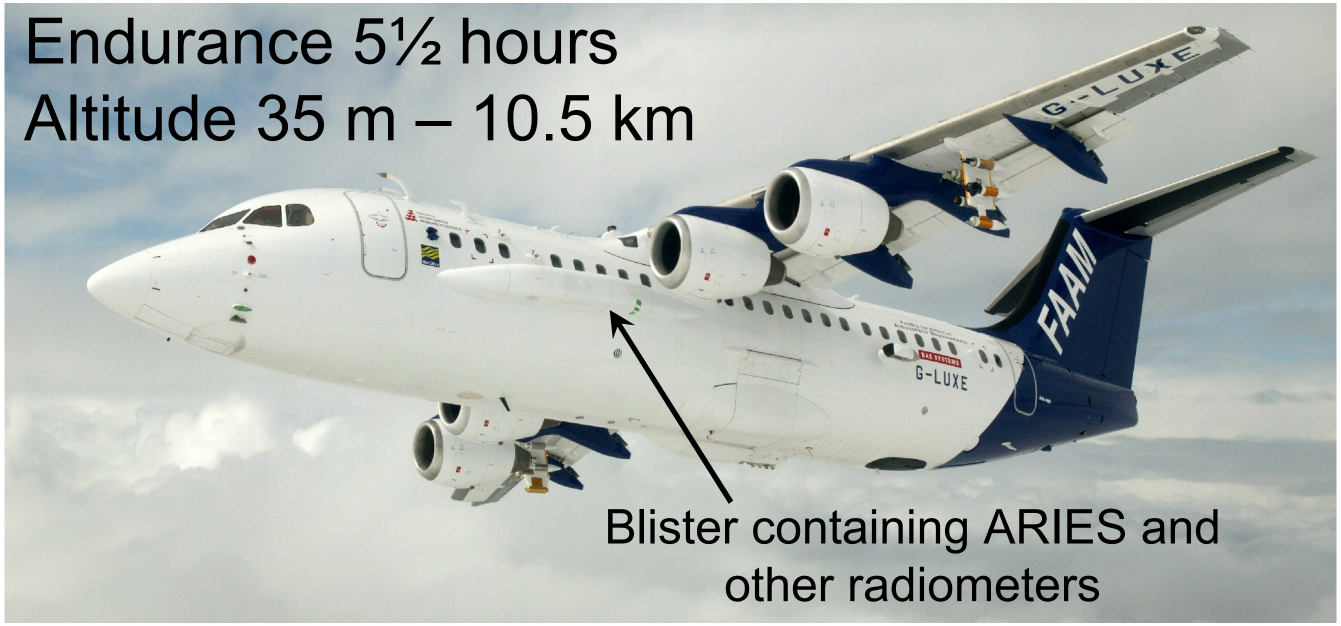
Airborne validation

Principles of airborne validation campaigns

- Aim to collect high-quality case studies during underflights of spaceborne instruments
- Hyperspectral sensors on research aircraft are used for direct radiance comparison (radiometric calibration)
- Collocated in situ measurements of atmospheric structure (temperature, humidity, trace gas species) and surface emission for radiance simulation (spectral calibration, spectroscopy, Level 2 product validation)
- Can be considered complementary to global studies using nearest radiosondes or model fields (statistical weight versus in-depth case studies)

Met Office

FAAM BAe 146-301 capability

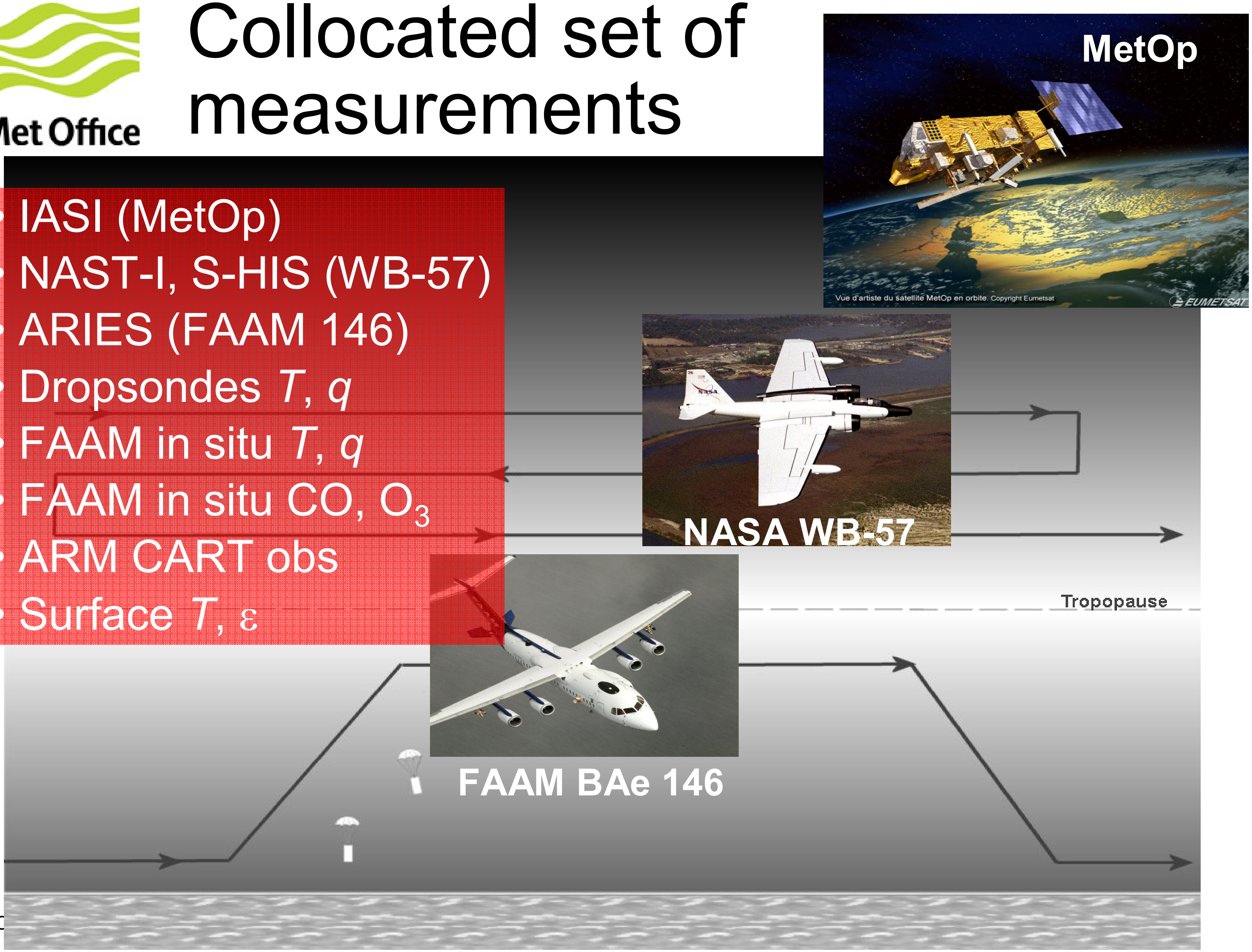


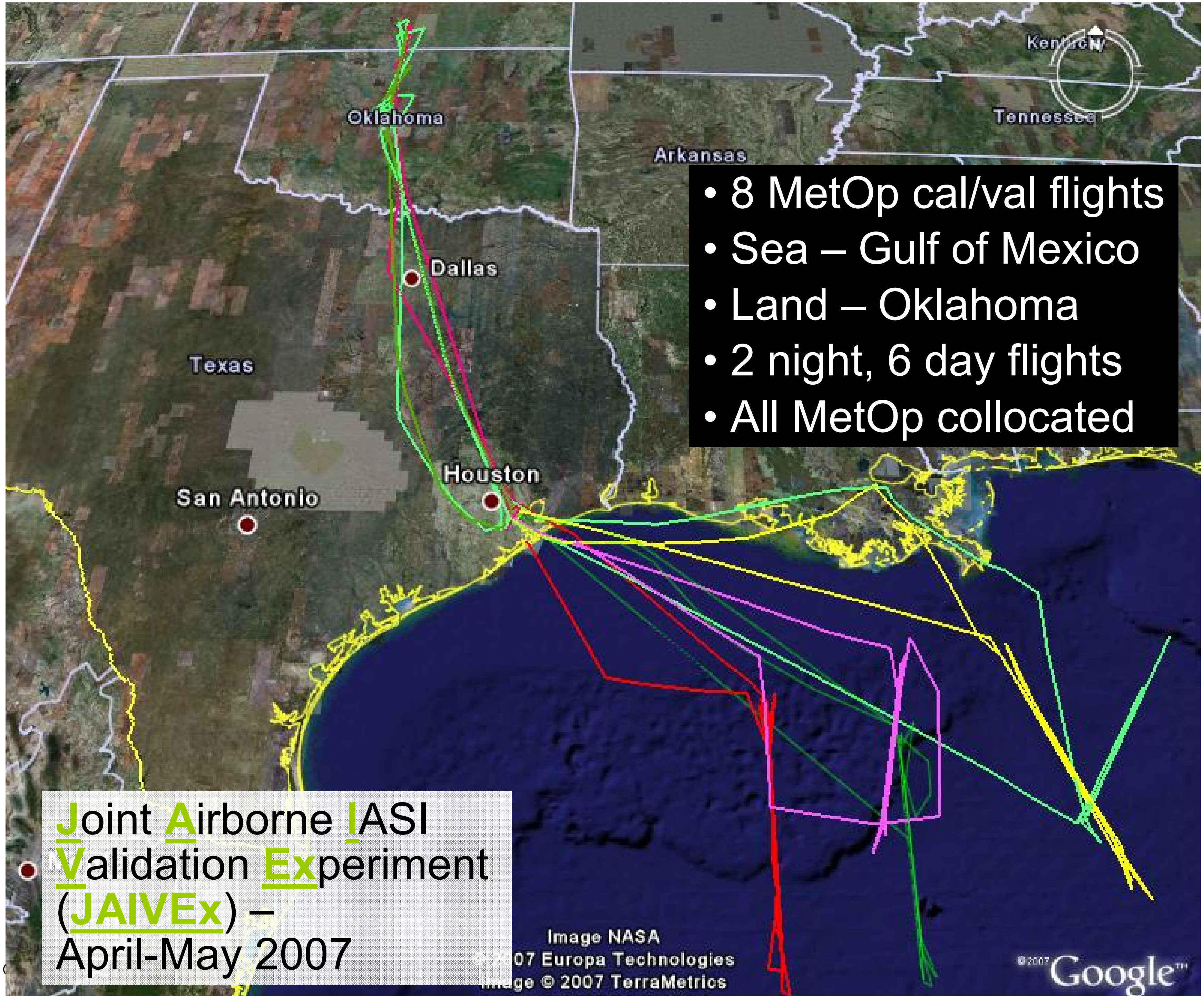
- Dropsondes
- Core chemistry (ozone and CO)
- Temperature and humidity probes
- Multi-spectral shortwave radiometer
- Microwave radiometers
- Particulates (aerosols and cloud particles)
- Winds (and more…)

ARIES interferometer (Bomem MR200)
Spectral range 550-3000 cm^{-1}
LW (HgCdTe) and SW (InSb) detectors
Max. resolution 1 cm^{-1} (0.5 cm^{-1} sampling)
Multiple viewing geometries (up and down)
Field of view 44 mrad (full angle)

Collocated set of measurements

- IASI (MetOp)
- NAST-I, S-HIS (WB-57)
- ARIES (FAAM 146)
- Dropsondes *T*, *q*
- FAAM in situ *T*, *q*
- FAAM in situ CO, O_3
- ARM CART obs
- Surface *T*, ε





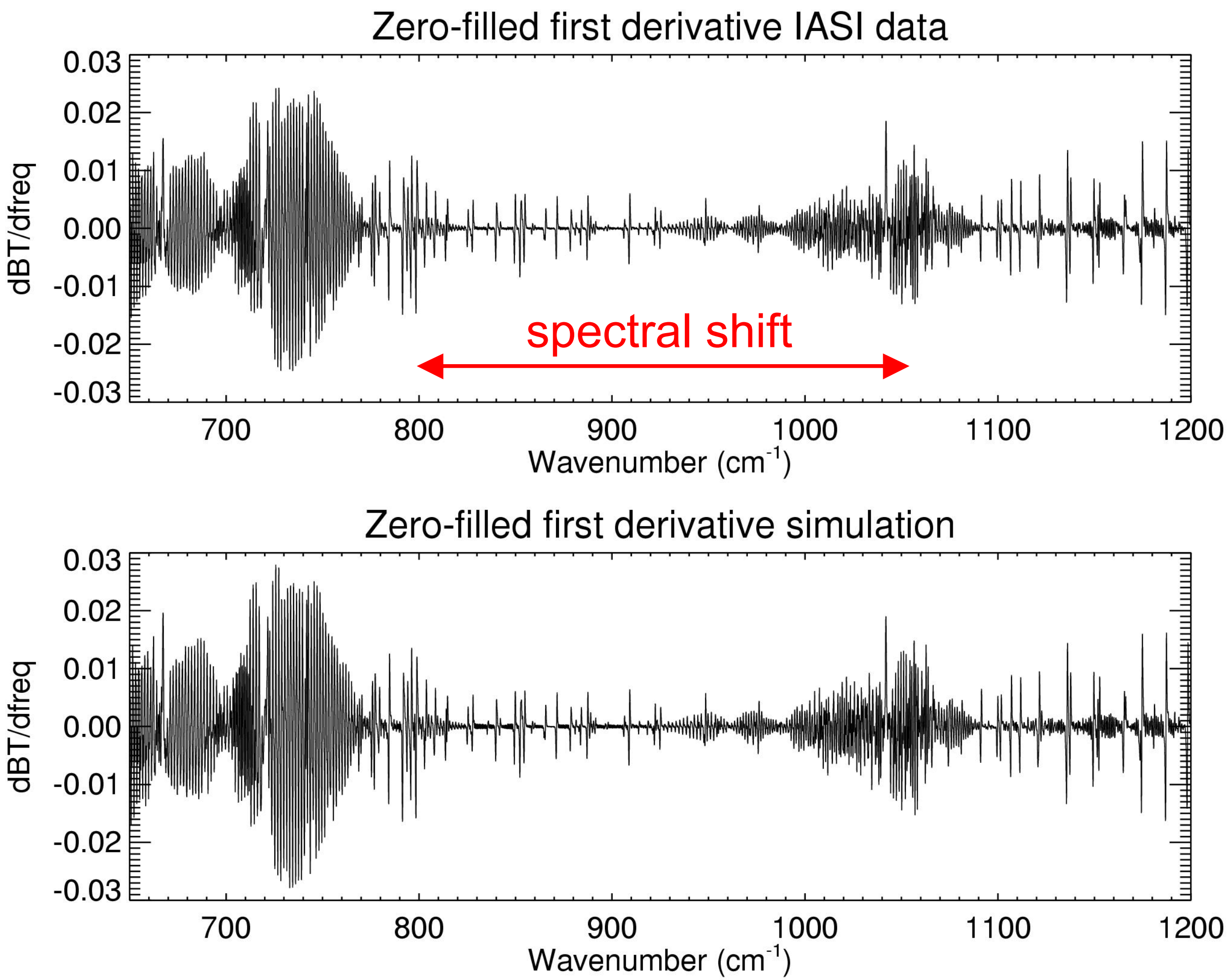
- 8 MetOp cal/val flights
- Sea – Gulf of Mexico
- Land – Oklahoma
- 2 night, 6 day flights
- All MetOp collocated

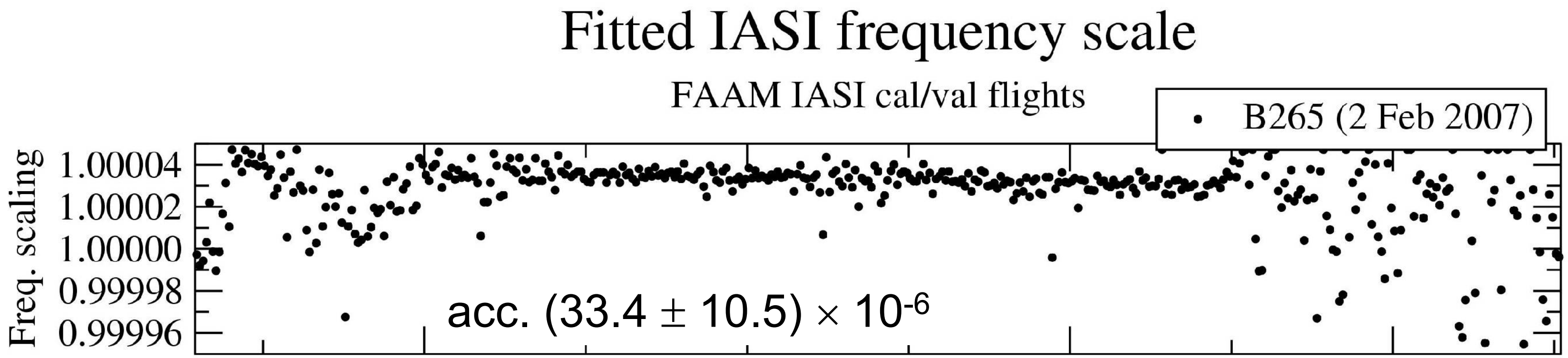
Joint **A**irborne **I**ASI **V**alidation **Ex**periment (**JAIVEx**) – April-May 2007

IASI spectral calibration

Spectral calibration

Compare first derivatives (observed and simulated spectra) and compute correlation coefficient





Maximise spectral correlation by applying a scaling to the nominal frequency array such that

$$\nu_{shifted} = c \times \nu_{IASI}$$

where $c \approx 1.00003$ for case study on 2 Feb 2007. This accuracy of 3×10^{-5} compares to the IASI specification of 2×10^{-6}.

L. Strow and S. Hannon, *"Initial IASI Validation"*, UMBC, showed a similar result.

This was anticipated by the Technical Expertise Centre, and was followed by a routine correction to the configuration file parameters.

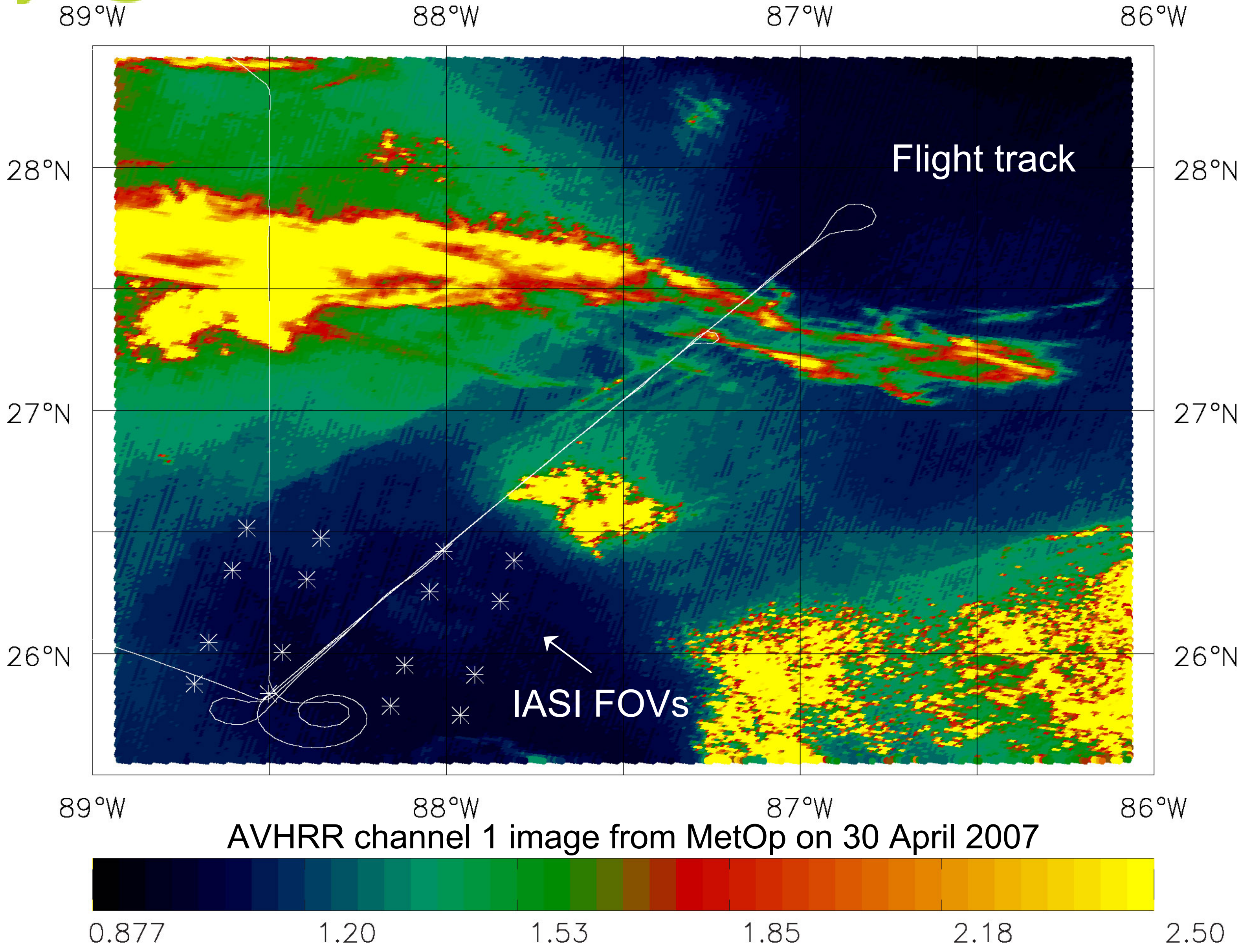
IASI direct radiance validation

Met Office

JAIVEx case studies

- Best clear sky cases over ocean where the uncertainties in radiative transfer modelling and surface emission are minimised
- Optimise collocation of sensors (satellite and two aircraft) with simultaneous measurements of the atmospheric state
- FAAM aircraft measurements from low level retrieve surface temperature and emissivity
- Cases over Oklahoma ARM site present more complicated situation (variable surface emission), but useful for validation of IASI exploitation over land (e.g. 1d-var retrieval techniques)

Gulf of Mexico 30/4/2007



Radiative transfer simulations

Met Office

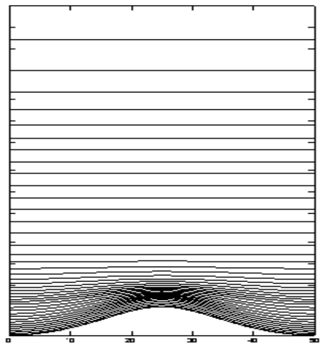
- For case study select dropsondes released closely in time and space with clear-sky interferometer FOVs

- Construct profiles of temperature and humidity etc. for input to line-by-line radiation code; top-up above aircraft profile with NWP model fields

- Output line-by-line infrared simulated spectra for hyperspectral sounders

- Compare observed with simulated spectra

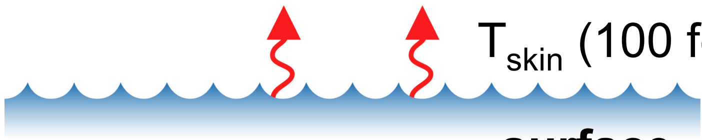
top of atmosphere (MetOp)



Model fields from Met Office UM and ECMWF analyses

BAe 146 max alt.

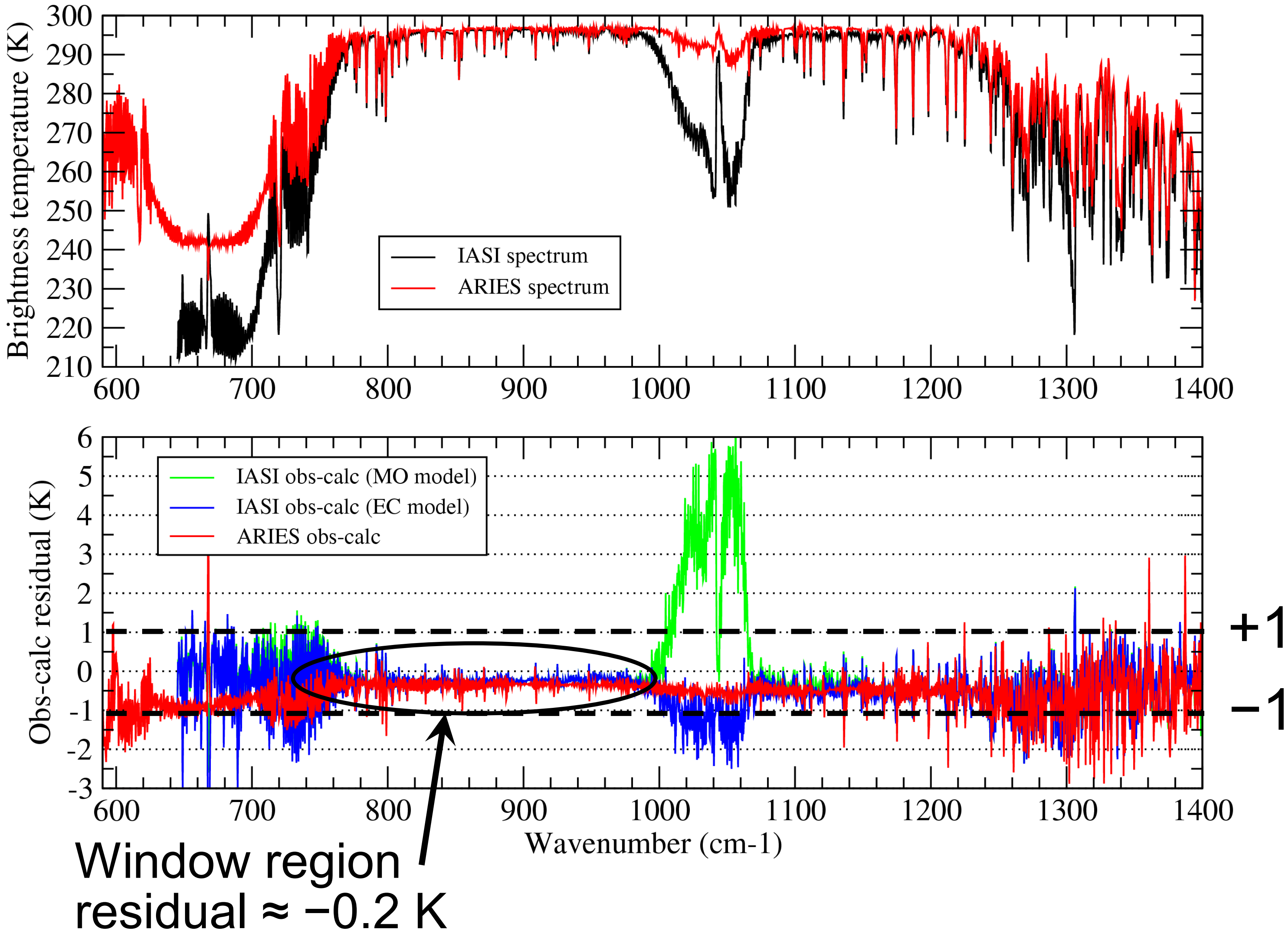
Dropsondes and FAAM 146 in situ measurements



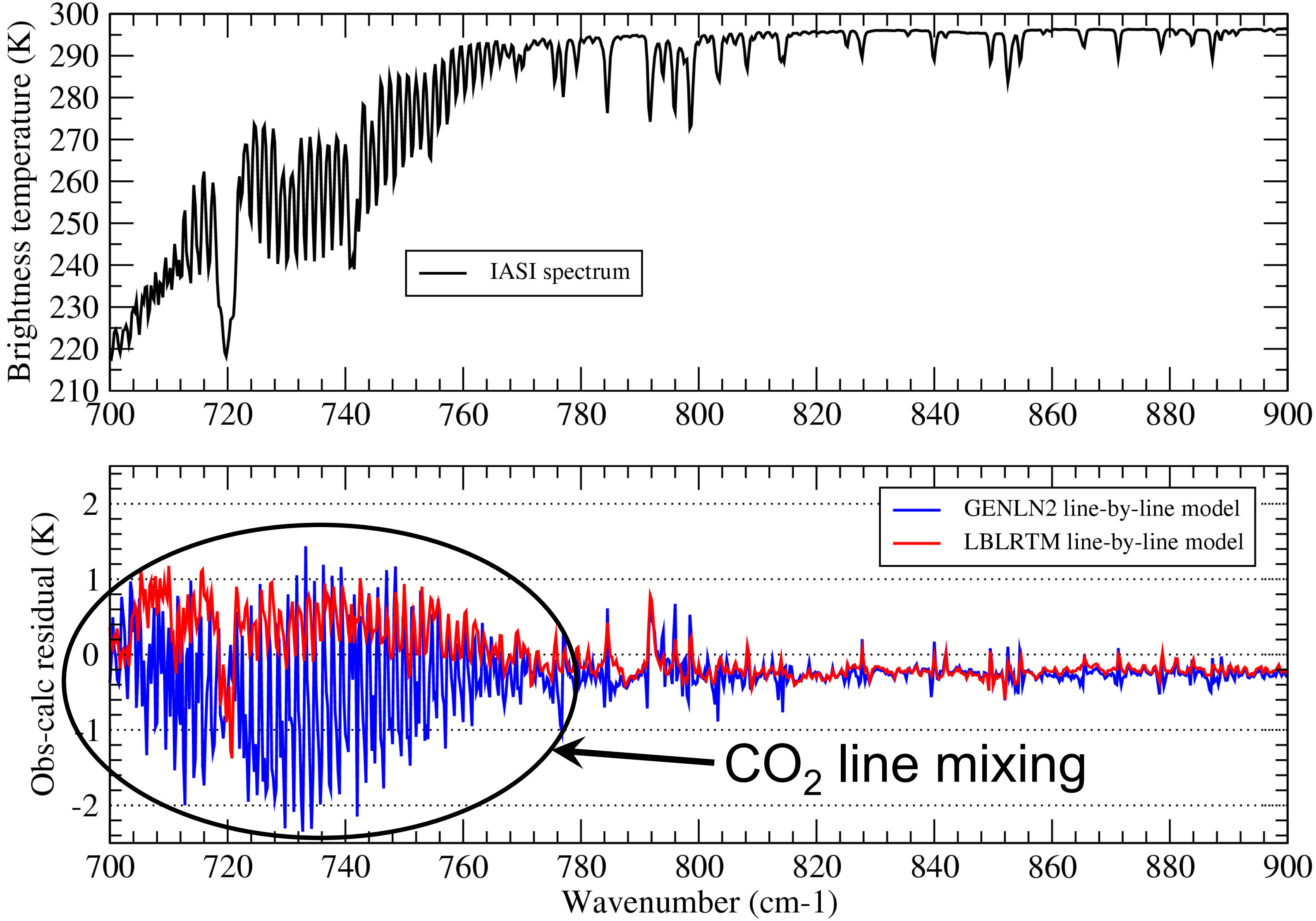
T_{skin} (100 feet)

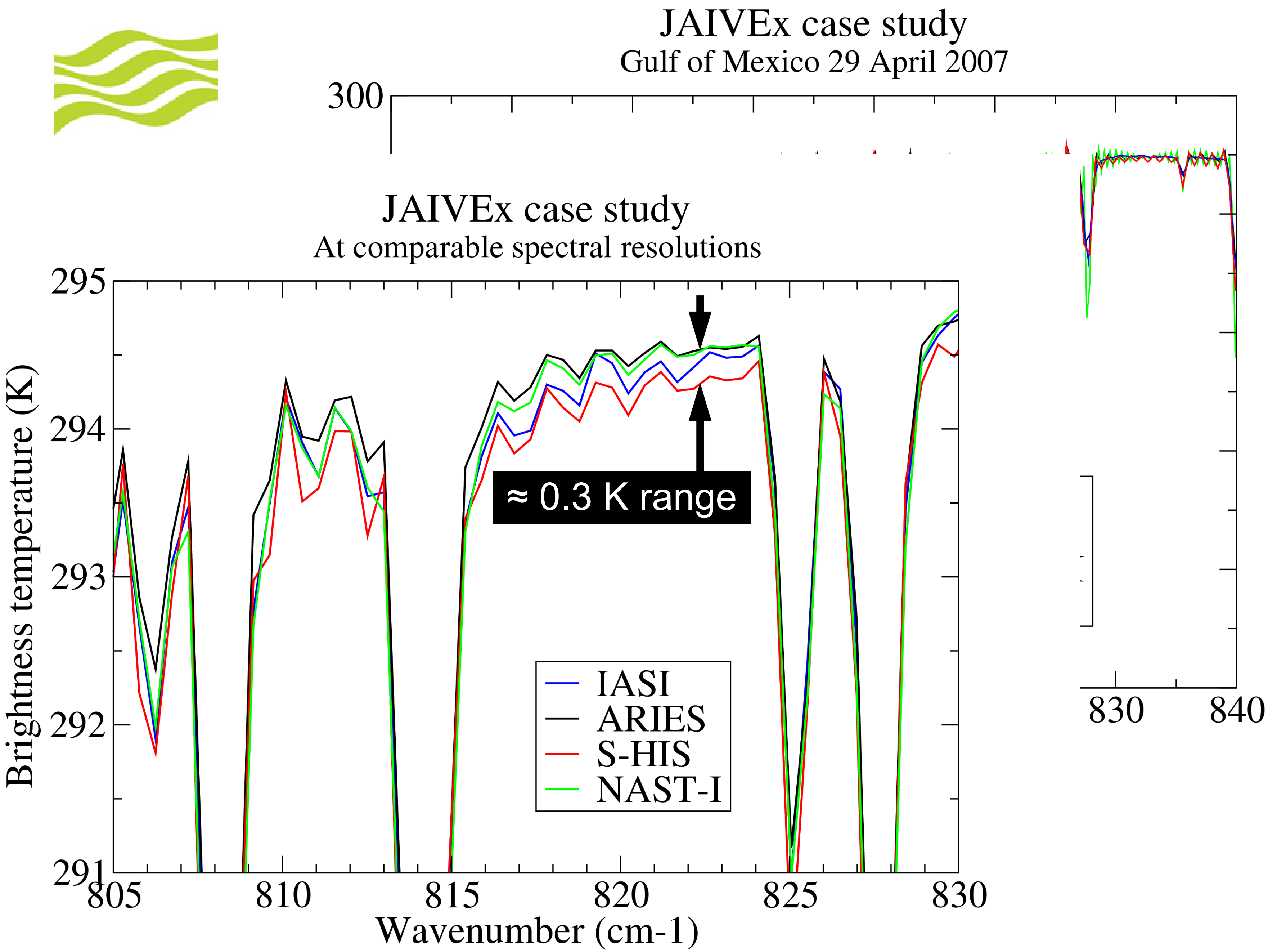
surface

Radiance validation 30/4/07

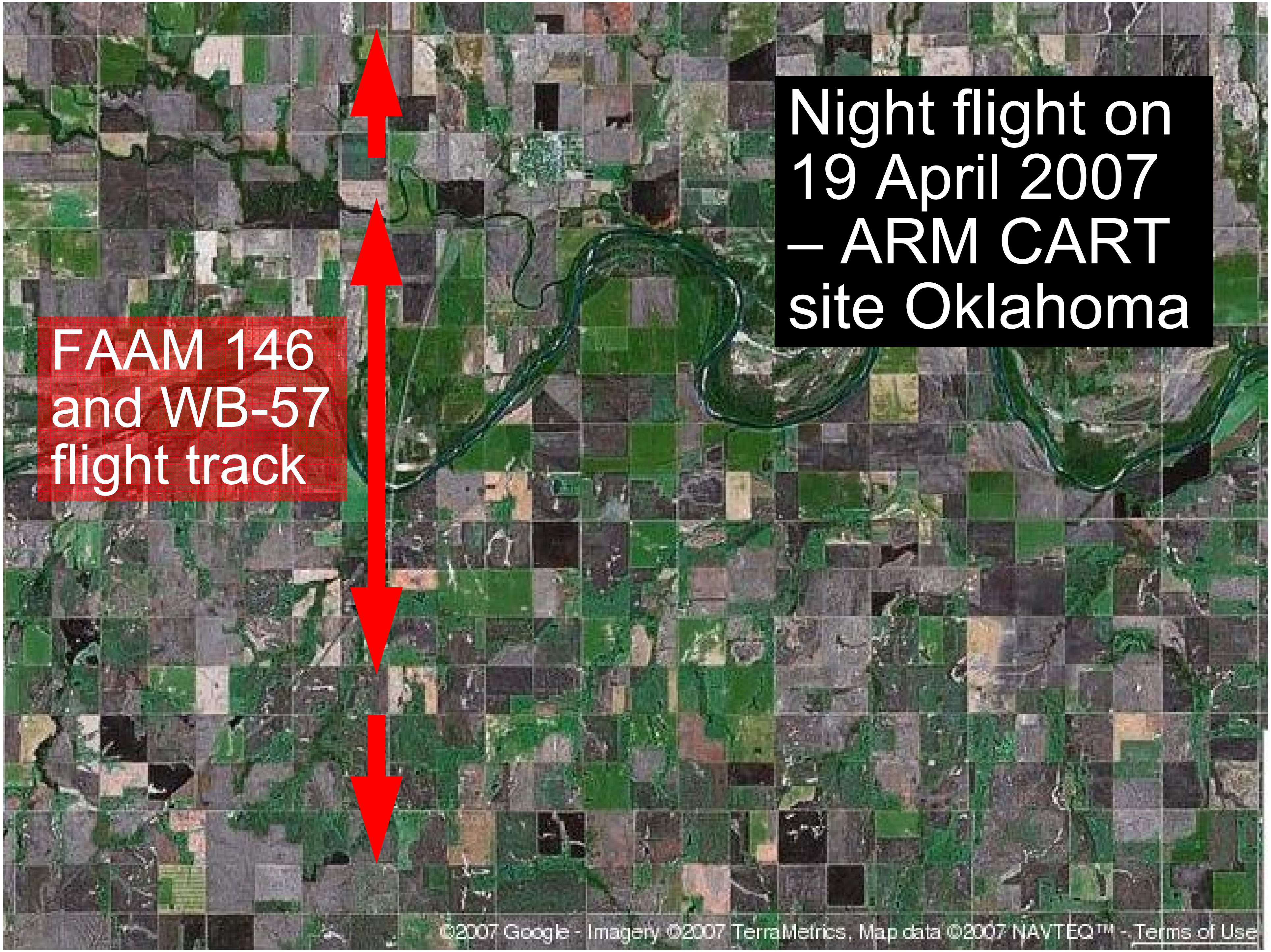


RT code differences

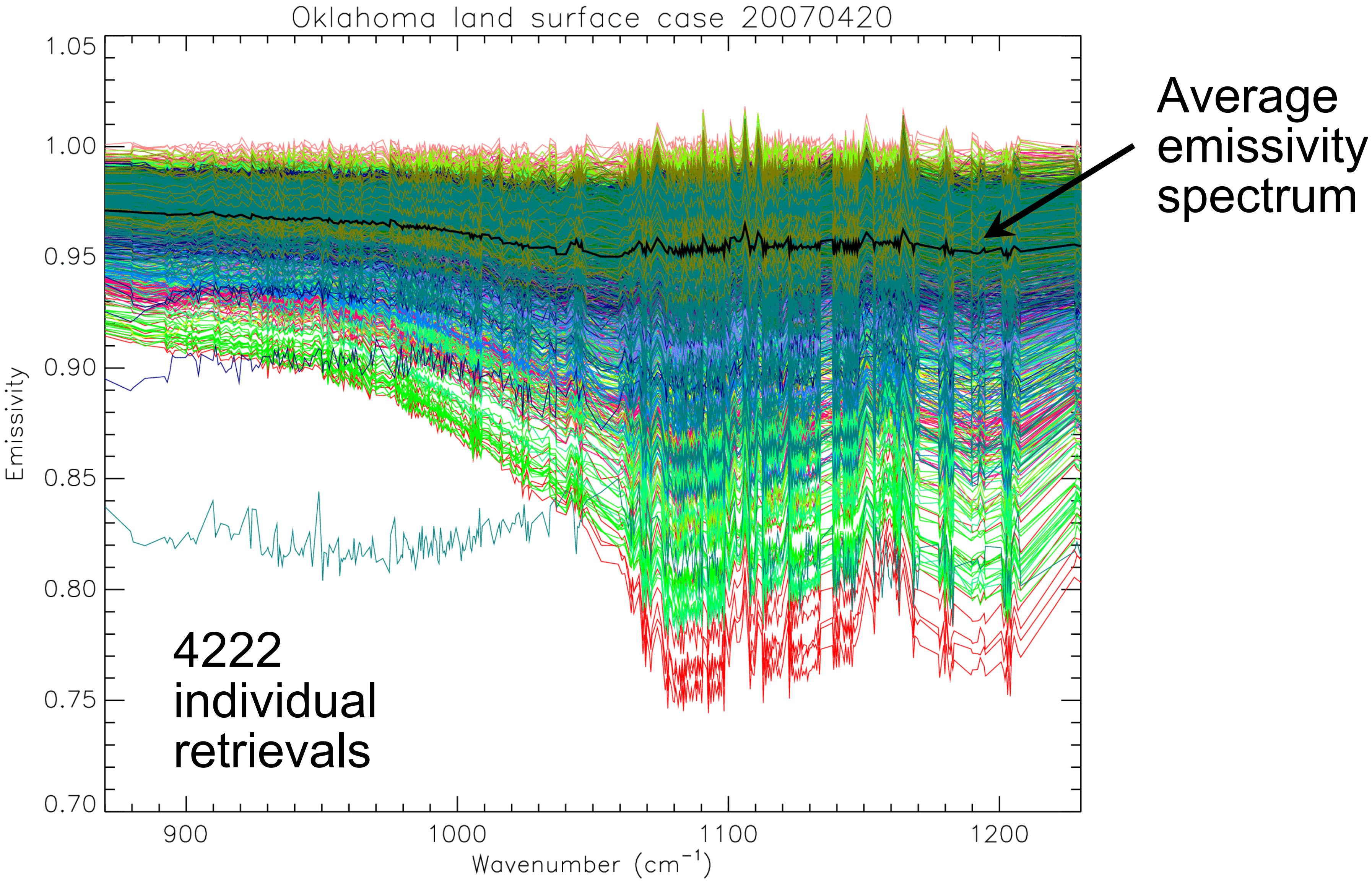




JAIVEx case study
Gulf of Mexico 29 April 2007
300
830
840
JAIVEx case study
At comparable spectral resolutions
295
294
293
292
291
805
810
815
820
825
830
Wavenumber (cm-1)
Brightness temperature (K)
≈ 0.3 K range
IASI
ARIES
S-HIS
NAST-I

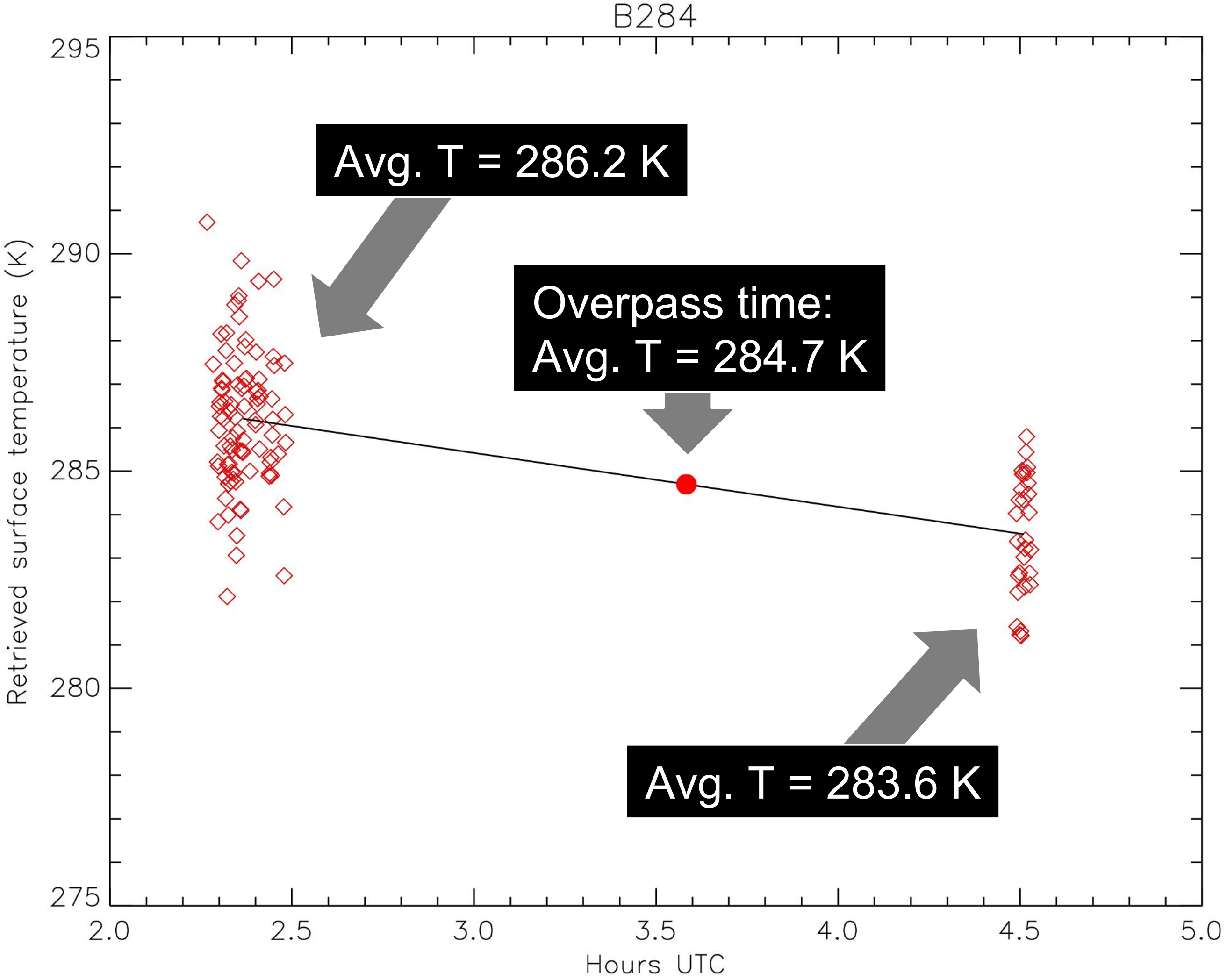

Night flight on
19 April 2007
– ARM CART
site Oklahoma
FAAM 146
and WB-57
flight track
©2007 Google - Imagery ©2007 TerraMetrics, Map data ©2007 NAVTEQ™ - Terms of Use

Oklahoma emissivity

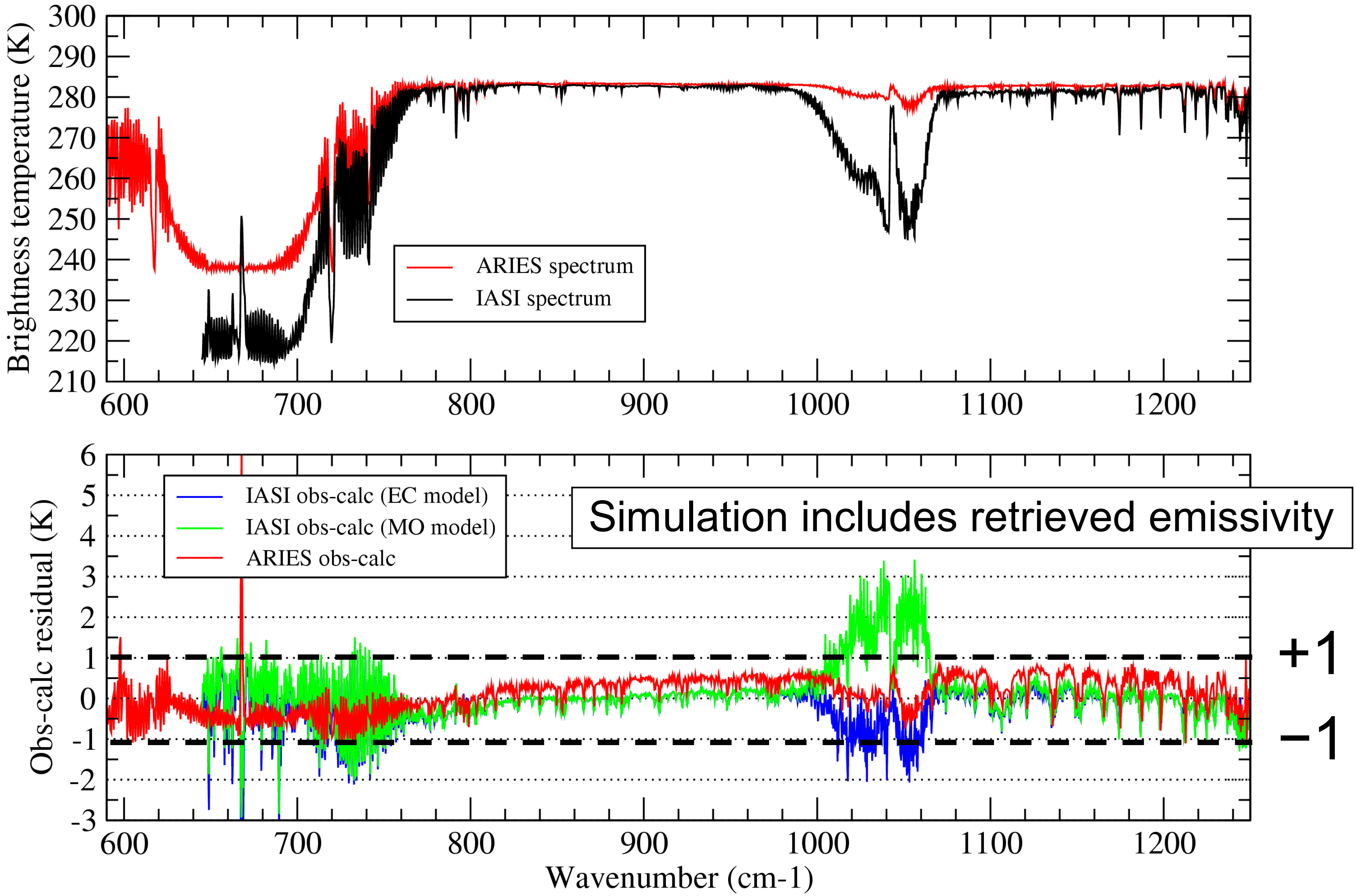


Oklahoma, 19 April 2007 (surface retrievals)

ARIES retrieved surface temperature from runs at 3000 feet

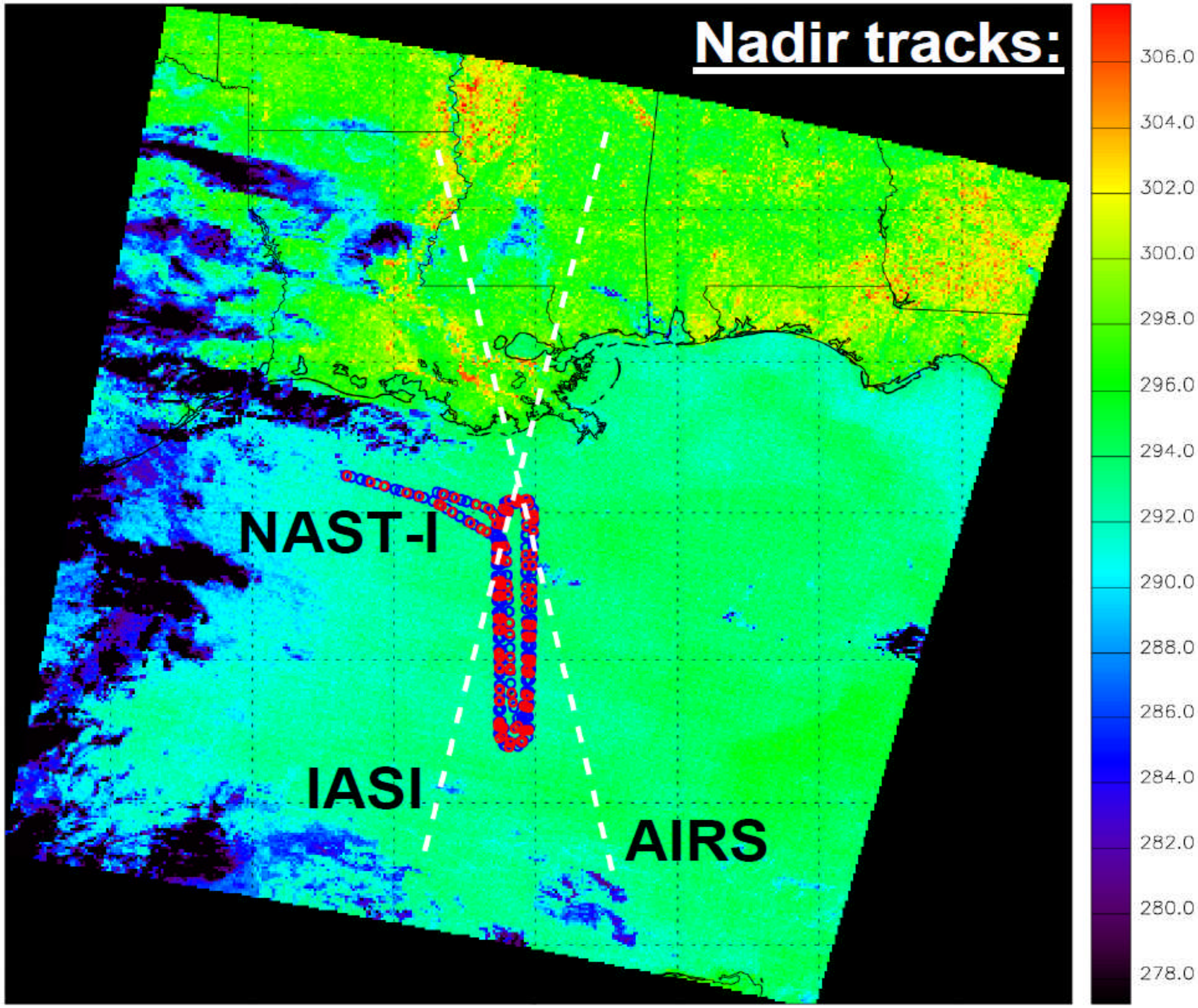


Radiance validation 19/4/07



Cross-validation with AIRS

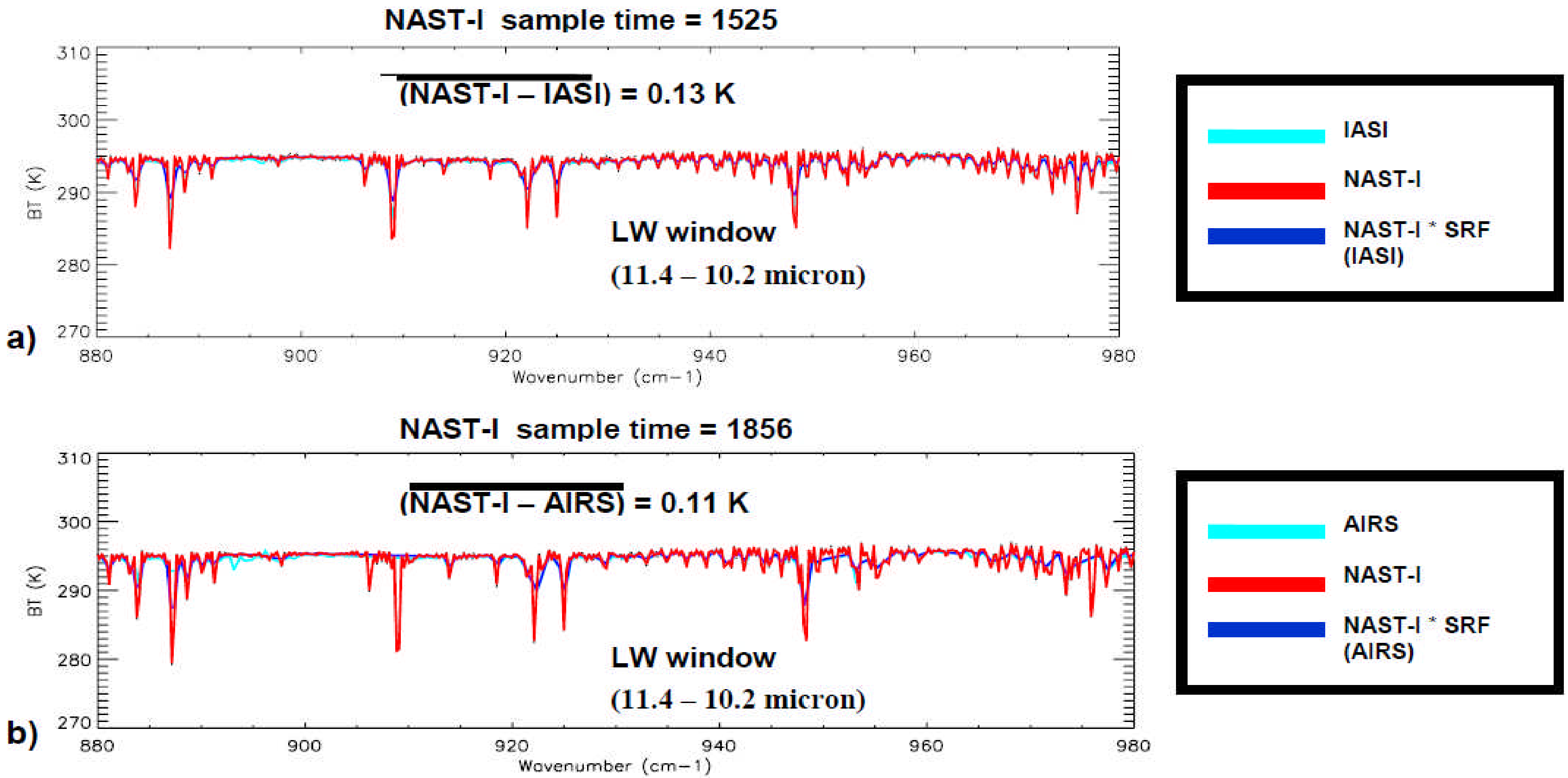
IASI vs AIRS



IASI imager

- Case study of 29 April 2007 over Gulf of Mexico
- MetOp overpass at 1550 UTC followed by Aqua at 1919
- NAST-I on WB-57 provides continuous time coverage, for direct comparison with IASI and AIRS
- Spectra matched in space and time

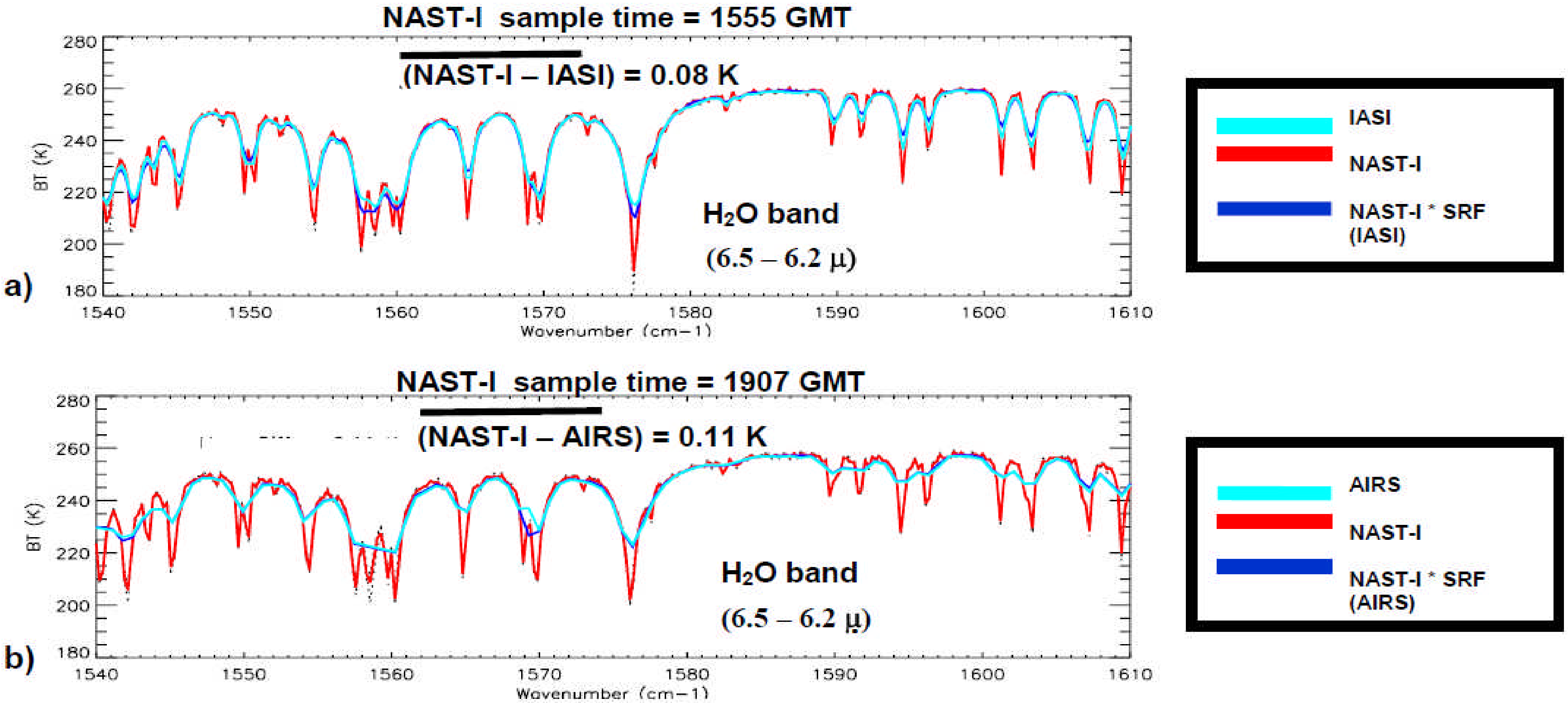
IASI vs AIRS



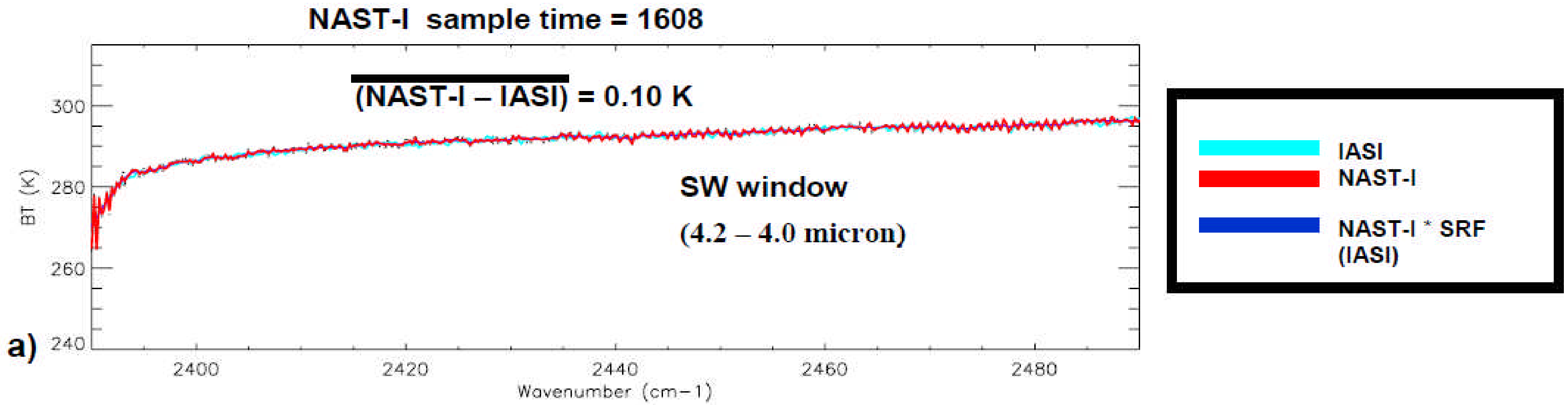
IASI calibration linked to AIRS via collocated NAST-I observations

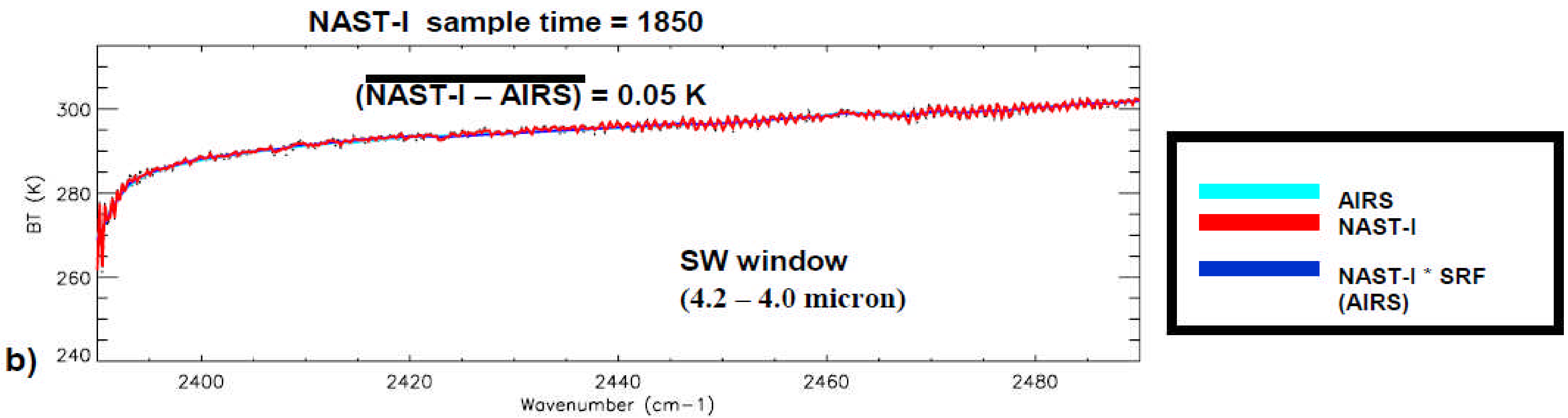
See Larar *et al.*, 'IASI spectral radiance performance validation: case study assessment from the JAIVEx field campaign' submitted to *Atmospheric Chemistry and Physics*

IASI vs AIRS


NAST-I sample time = 1555 GMT
(NAST-I – IASI) = 0.08 K
H2O band
(6.5 – 6.2 μ)
BT (K)
Wavenumber (cm−1)
a)
IASI
NAST-I
NAST-I * SRF
(IASI)
NAST-I sample time = 1907 GMT
(NAST-I – AIRS) = 0.11 K
H2O band
(6.5 – 6.2 μ)
BT (K)
Wavenumber (cm−1)
b)
AIRS
NAST-I
NAST-I * SRF
(AIRS)

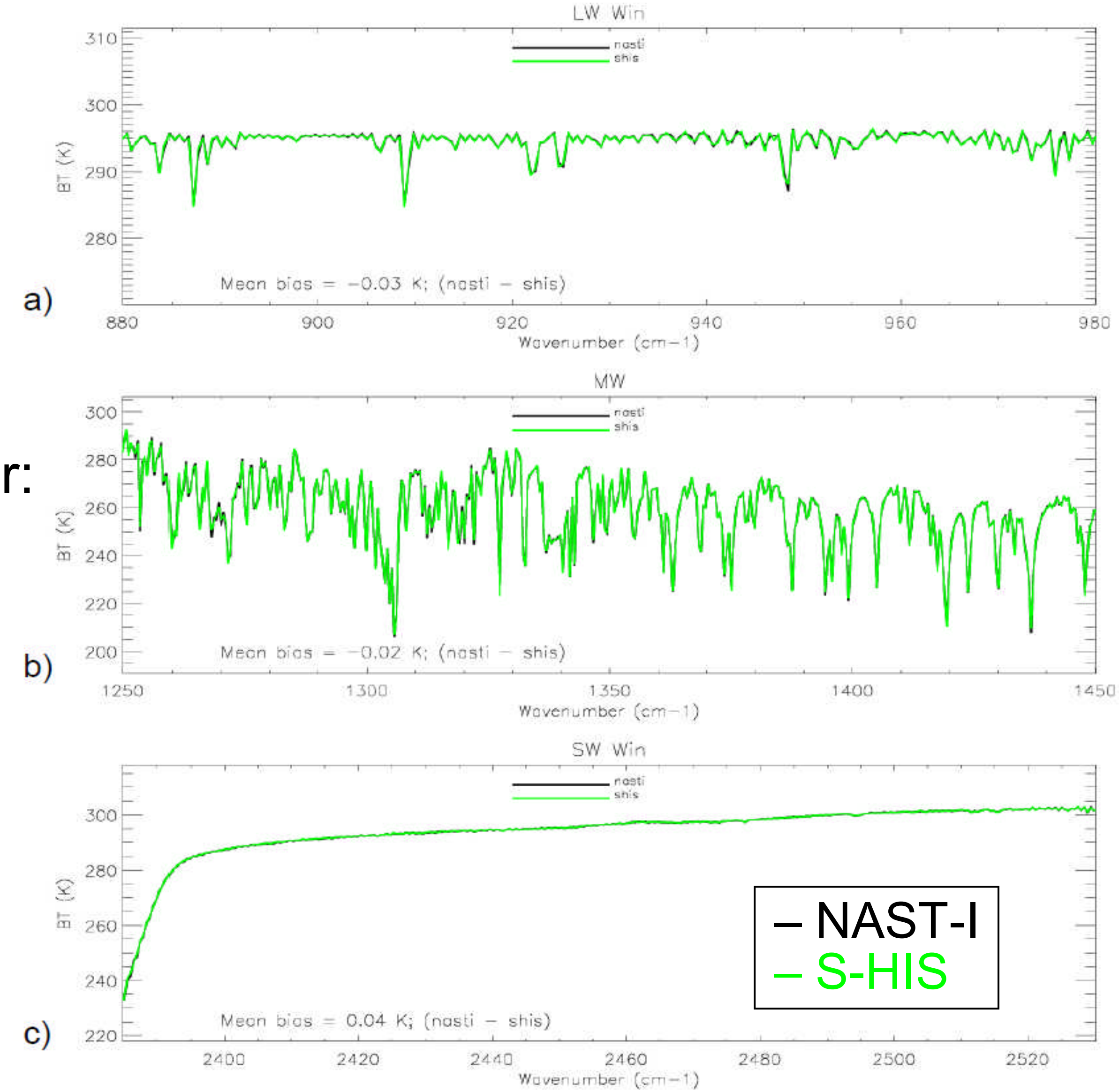
IASI vs AIRS


NAST-I sample time = 1608
(NAST-I – IASI) = 0.10 K
SW window
(4.2 – 4.0 micron)
BT (K)
300
280
260
240
2400
2420
2440
2460
2480
Wavenumber (cm−1)
a)
IASI
NAST-I
NAST-I * SRF
(IASI)


NAST-I sample time = 1850
(NAST-I – AIRS) = 0.05 K
SW window
(4.2 – 4.0 micron)
BT (K)
300
280
260
240
2400
2420
2440
2460
2480
Wavenumber (cm−1)
b)
AIRS
NAST-I
NAST-I * SRF
(AIRS)

Intra-platform consistency

- LW window:
  bias of -0.03 K
- MW water vapour:
  -0.02 K
- SW:
  +0.04K



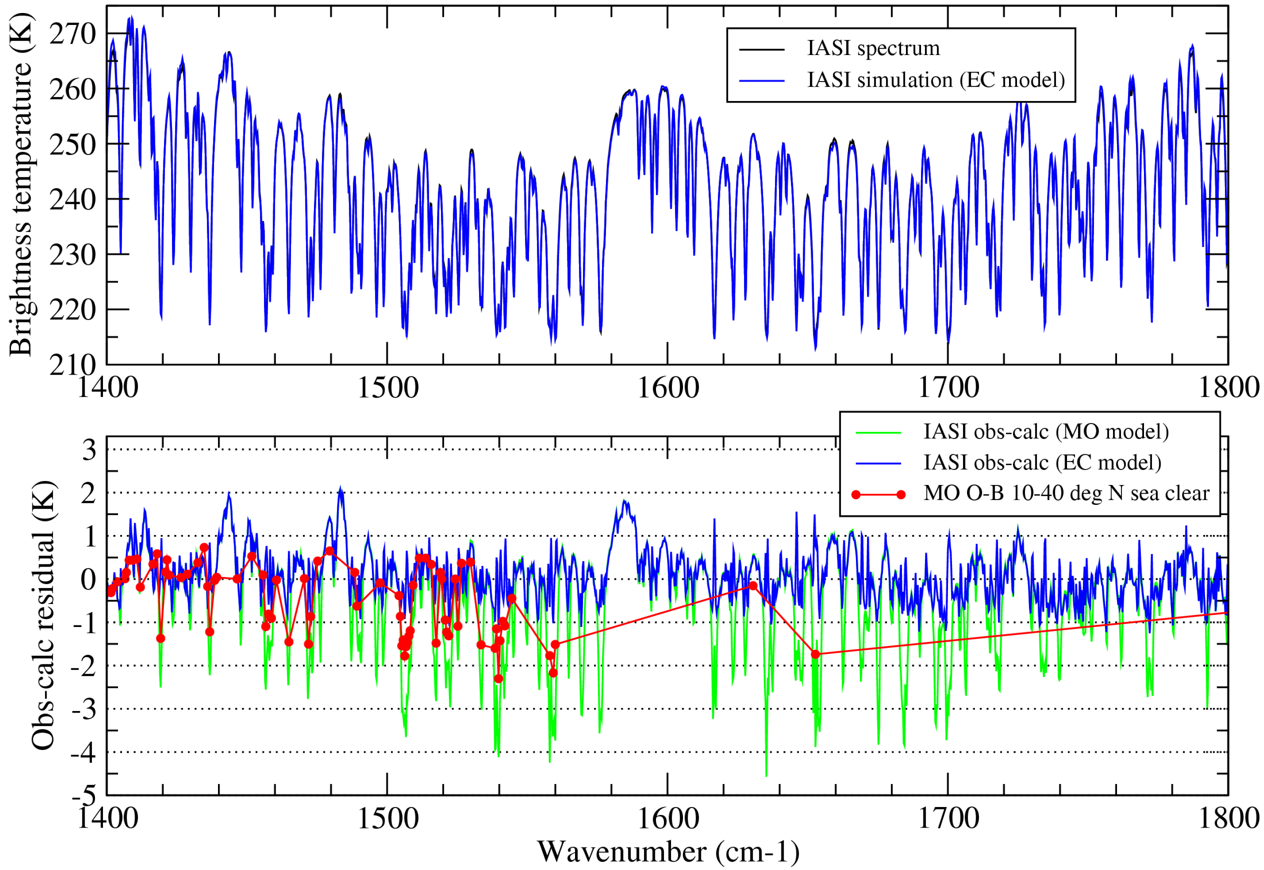
Cross-validation results

- Across all three IASI spectral bands cross-validation using NAST-I as reference gives excellent agreement between IASI and AIRS
- Level of agreement is to within 0.13 K (absolute with NAST-I) and 0.05 K (IASI relative to AIRS)
- NAST-I itself is calibrated relative to S-HIS to within 0.04 K and both are ultimately referenced to national standard blackbody source, i.e. traceable chain of calibration

Identification of model biases

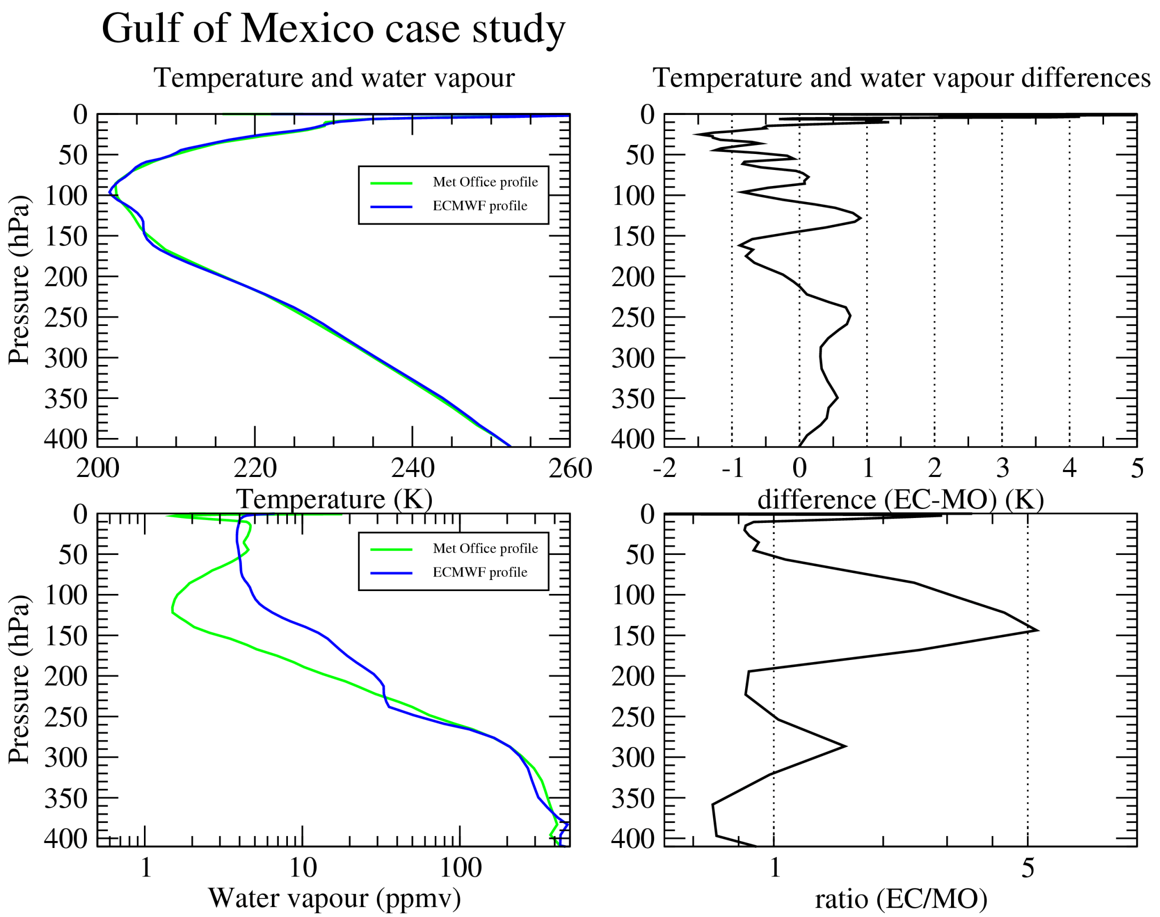
Case study 30 April 2007

Gulf of Mexico over ocean



- Water vapour band less well fitted than longwave band
- Larger (negative) residuals with Met Office model fields c.f. ECMWF fields used in simulation
- Met Office O-B data match negative residuals well

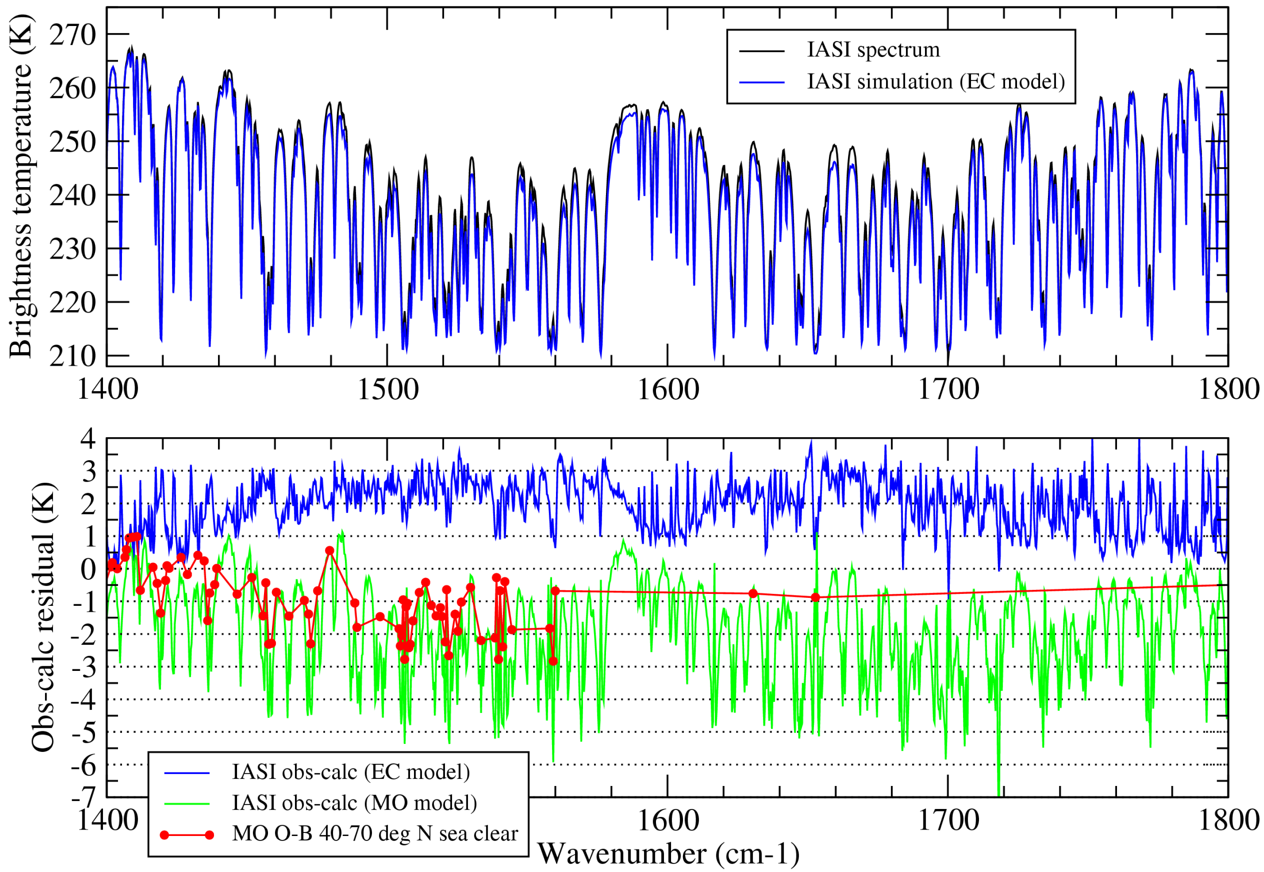
Profile comparison



- Met Office and ECMWF temperature fields show good consistency
- Met Office humidity profile for case study shows significant dry bias relative to ECMWF

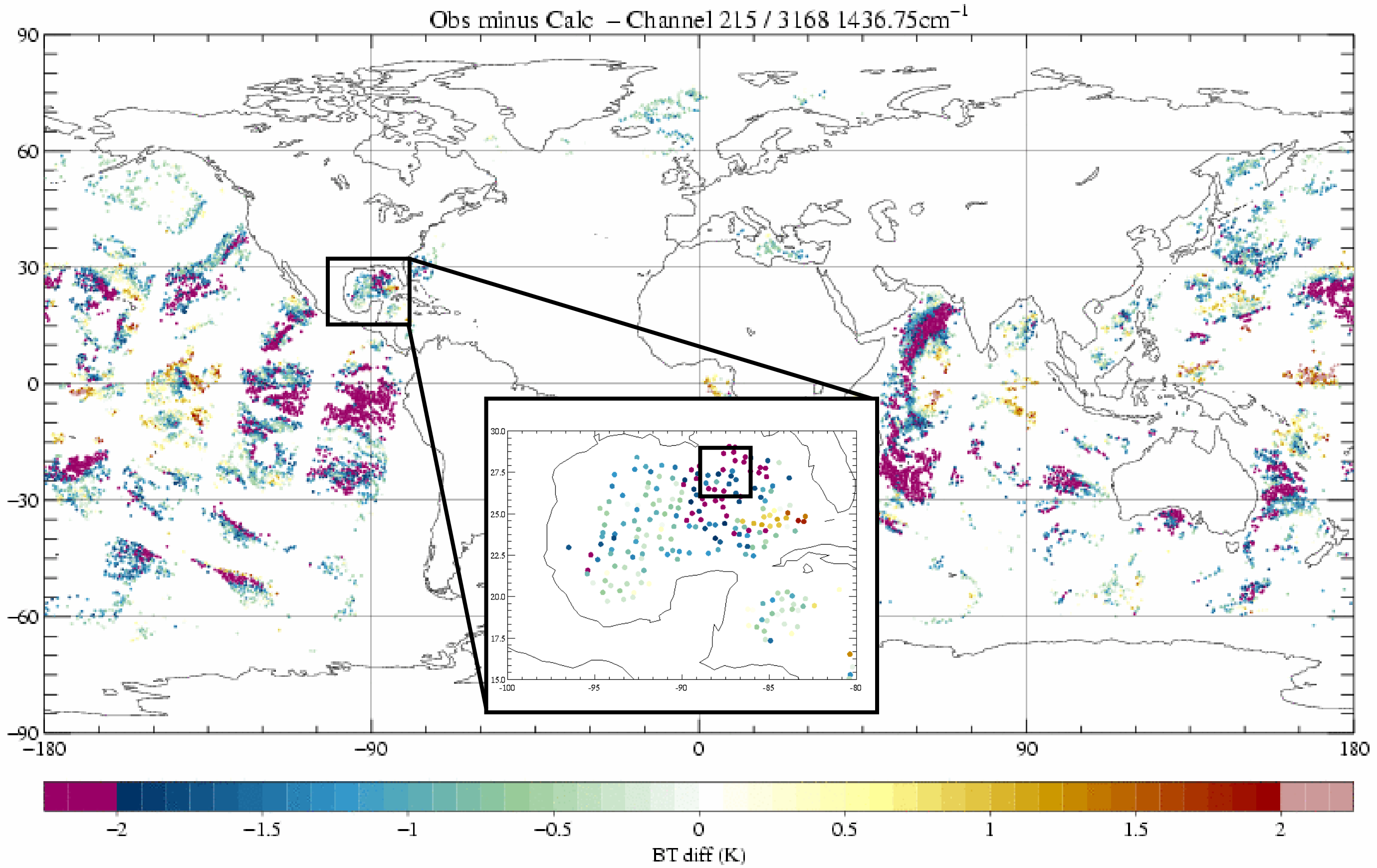
Case study 12 December 2007

UK ocean area (North Sea)



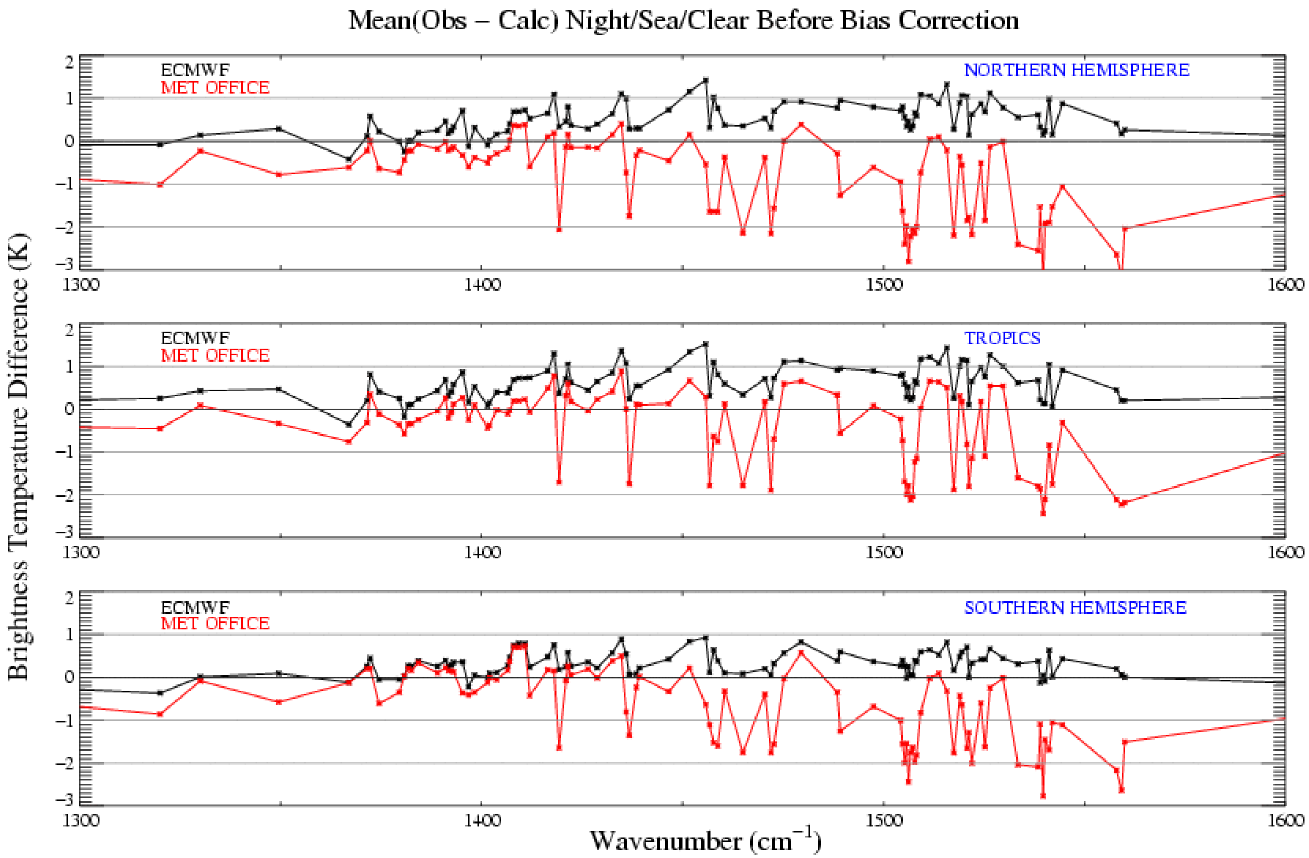
- In this case the large negative bias from Met Office fields persists
- By contrast there is a smaller positive bias using ECMWF profile data
- Met Office O-B data match residuals

How representative are the case studies?



- Met Office obs-calc difference for 18 hours of observations on 30/4/07
- Most of the globe shows a negative bias

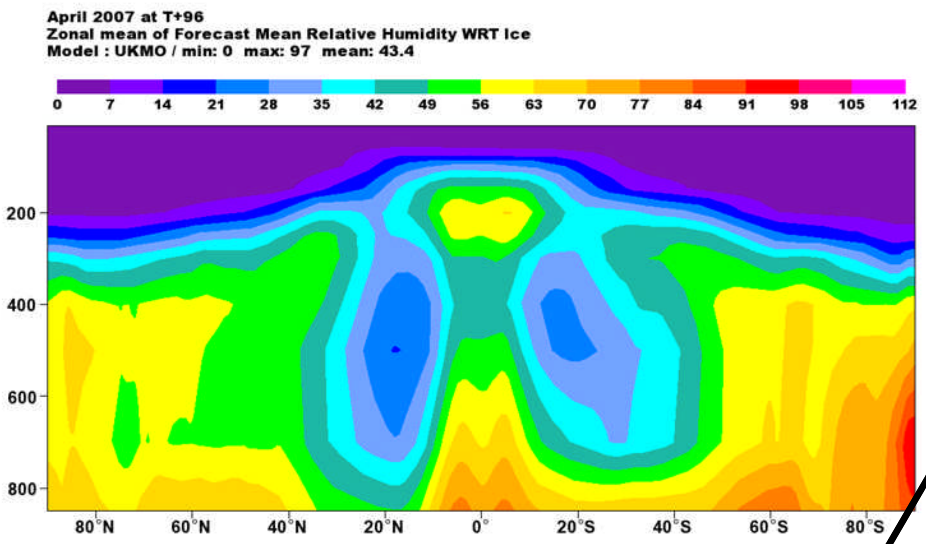
Comparing the Met Office and ECMWF obs-calc departures

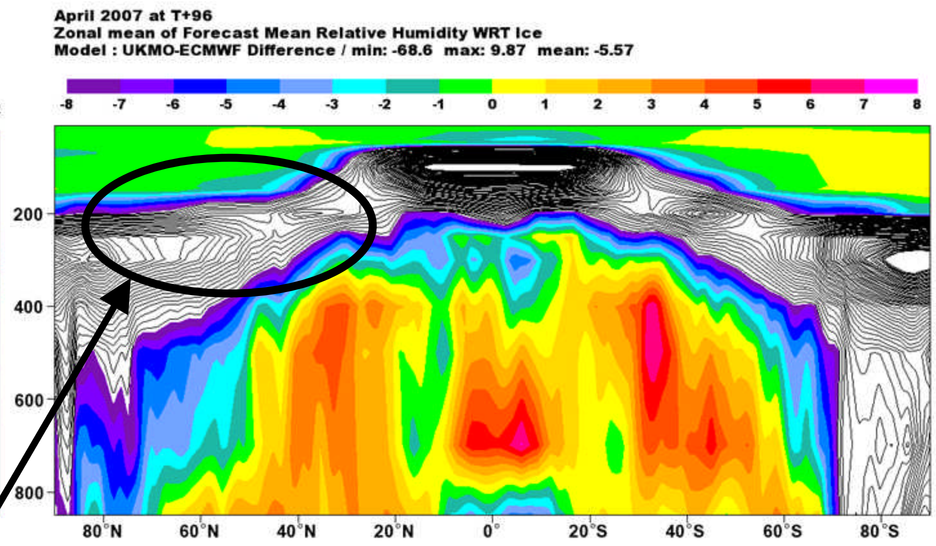


- Met Office has a large negative bias for the high-peaking channels for all latitude bands
- ECMWF shows a smaller positive bias

Thanks to Fiona Hilton and Andrew Collard

Can we see a bias in the model water vapour fields?





Tropopause level humidity is consistently moister for ECMWF

Thanks to Sid Clough

Model bias issues

Met Office

- Comparisons between IASI data and Met Office and ECMWF model profiles have helped to identify a large and previously unreported dry bias in the Met Office global model near the tropopause. In contrast, the ECMWF model tends to show a small moist bias. There is no evidence of significant IASI instrument biases in this spectral region.

- This has prompted the following changes for inclusion in the new Met Office 70-level model trial:

  (1) More conventional water vapour observations assimilated by changing radiosonde upper threshold limits

  (2) Changes to satellite biases in absence of water vapour obs aloft

  (3) New 4D-Var definition of tropopause

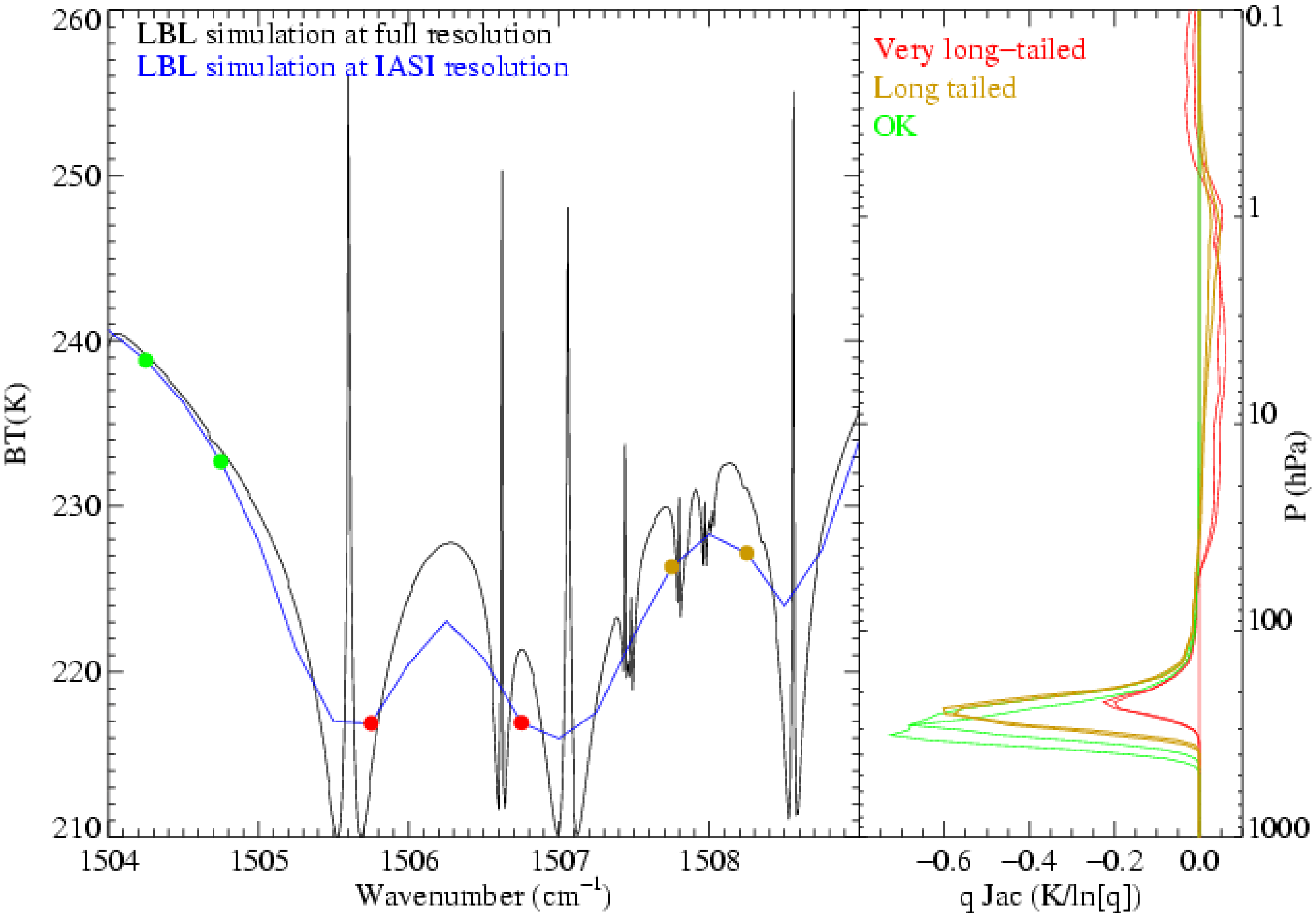
  (4) Humidity increments set to zero above the tropopause rather than allowing them to reset to a negative increment

Summary

- The JAIVEx campaign has produced a comprehensive data set for IASI validation and testing of retrieval algorithms
- Adjustments to the IASI spectral calibration parameters since launch have been successful
- IASI absolute radiance validation achieves agreement to within 0.3 K brightness temperature (total spread of measurements by four co-viewing interferometers) and less than 0.2 K compared to best line-by-line simulations
- Cross-validation studies show both IASI and AIRS agreement with reference measurement of less than 0.2 K
- Limiting factor in observed – background departures in strong water vapour band appears to be model treatment of stratospheric humidity, which has helped to identify a dry bias in the Met Office global model

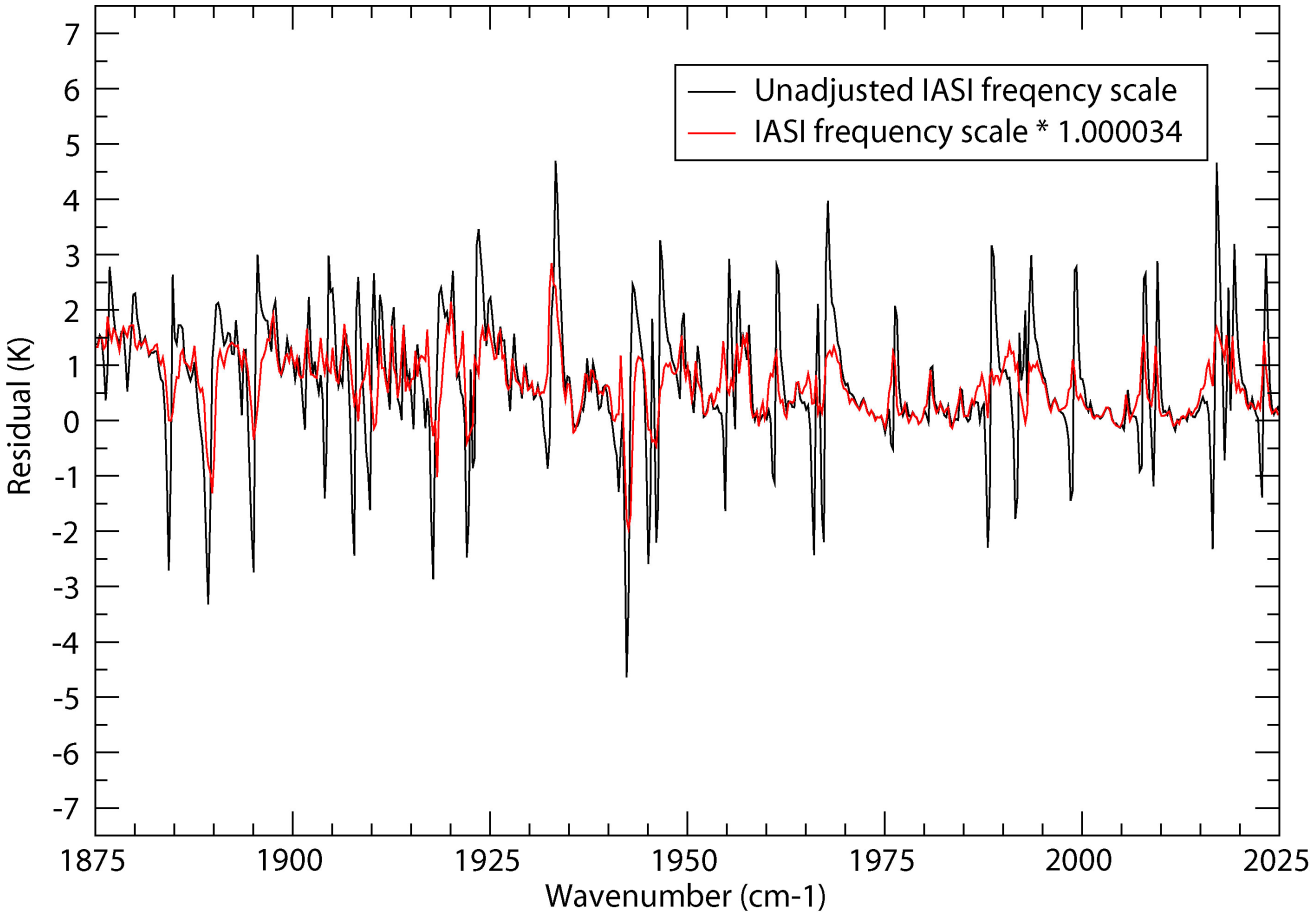
Questions and answers

High-peaking water vapour channels



- The channels which show the worst bias are typically close to line centres
- Although assimilation of IASI data could help to correct the model bias, these channels cause problems for operational assimilation
- Their Jacobians show that they are sensitive to water vapour throughout the atmospheric column
- A large model bias in the stratosphere leading to an observation-background difference can result in an erroneous humidity increment in the mid-troposphere

IASI spectral calibration



- Improvement in residuals (February 2007 case) through scaling of nominal IASI frequency scale