Aircraft and satellite hyperspectral measurements investigating the radiative impact of atmospheric water vapour

Stuart Newman and co-workers

ITSC-17, Monterey, 14-20 April 2010

Acknowledgements

Many thanks to colleagues involved in collaboration

- JAIVEx science team

  Bill Smith, Allen Larar, Dave Tobin, Dan Zhou, Hank Revercomb, Xu Liu

- EUMETSAT support

  Peter Schlüssel

- University of Reading

  Keith Shine, Igor Ptashnik

- Met Office

  Jonathan Taylor, Fiona Hilton, Andrew Collard

  (and many others…)

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This presentation covers the following areas

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- JAIVEx case studies
- CAVIAR water vapour continuum research
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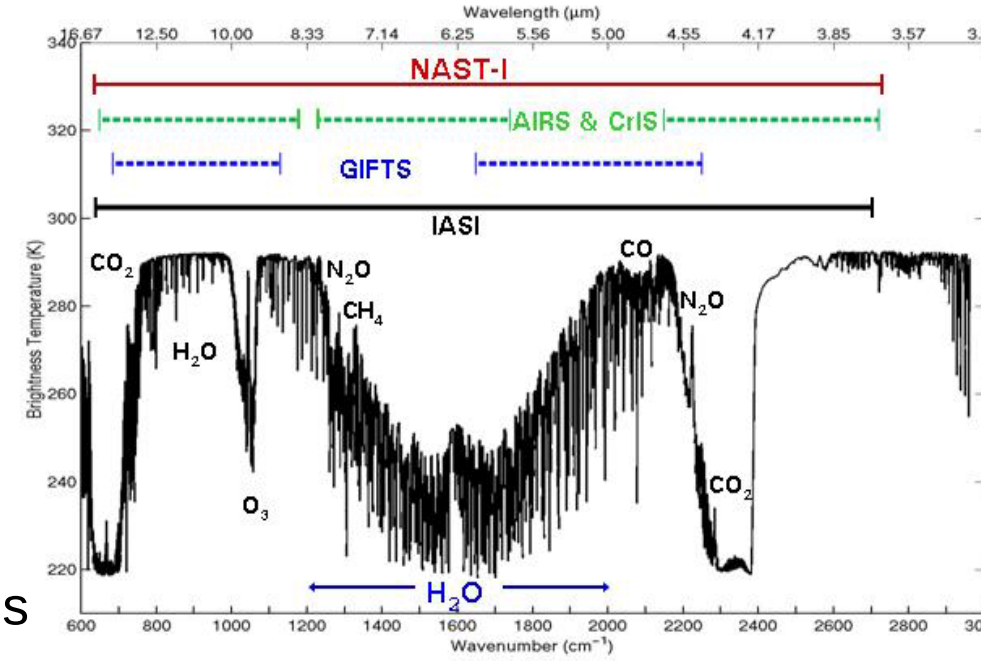
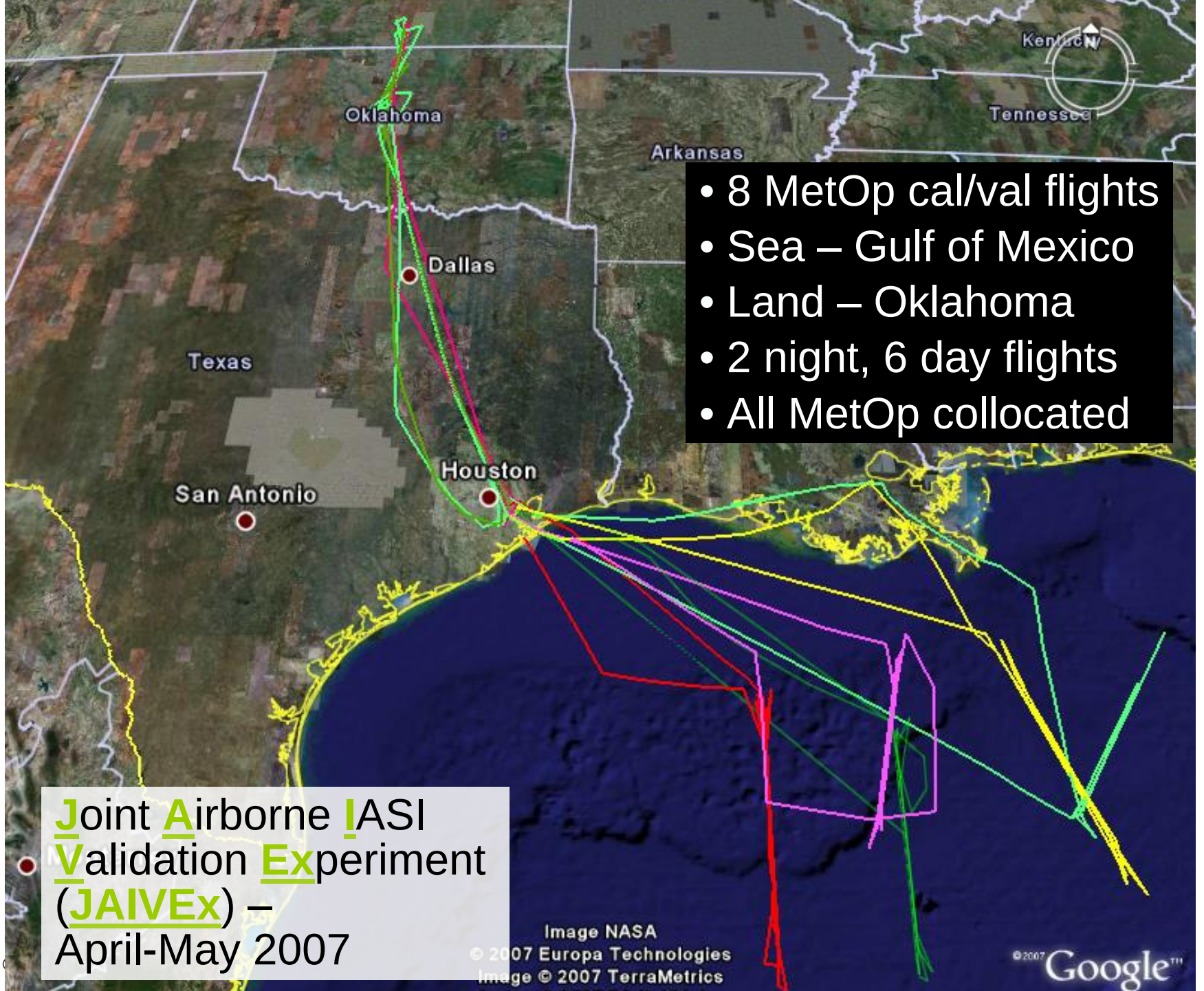
Motivation

- IASI temperature sounding channels have been exploited successfully, with water vapour channels increasingly used by NWP centres
- ECMWF/NWP-SAF workshop on the assimilation of IASI in NWP recommended improvement in RT models – potential to use upper tropospheric humidity channels as anchoring observations
- Hyperspectral satellite observations of water vapour channels rely on good knowledge of the spectroscopy and continuum

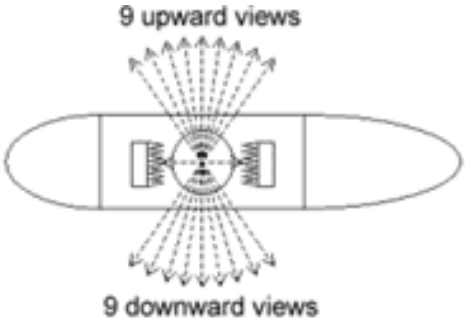


JAIVEx

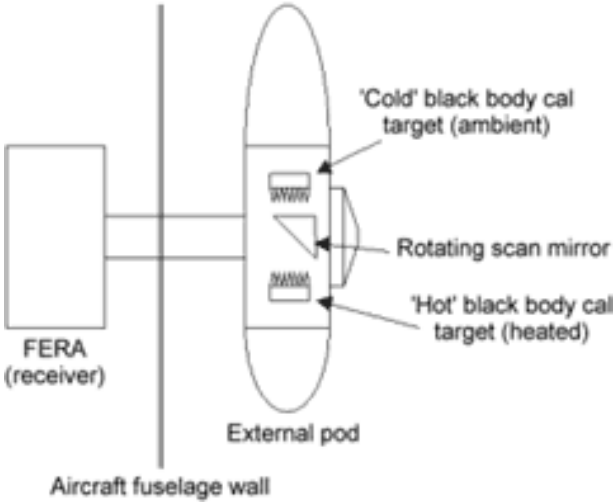

Oklahoma
Arkansas
Tennessee
Dallas
Texas
Houston
San Antonio
• 8 MetOp cal/val flights
• Sea – Gulf of Mexico
• Land – Oklahoma
• 2 night, 6 day flights
• All MetOp collocated
Joint Airborne IASI Validation Experiment (JAIVEx) – April-May 2007
Image NASA
© 2007 Europa Technologies
Image © 2007 TerraMetrics
Google

Best estimate of atmospheric state
JAIVEx flights

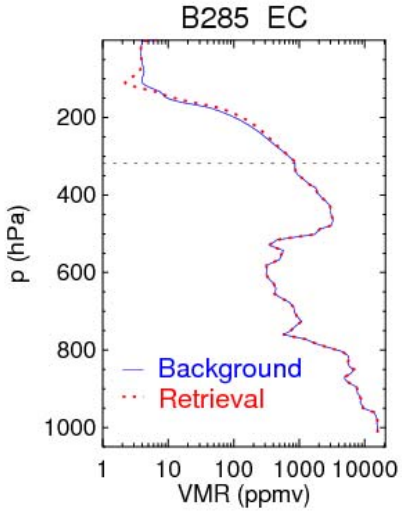
- Dropsondes closely coincident in time and space with IASI satellite overpass give temperature and humidity below 10 km
- FAAM aircraft probes give additional *T, q* profiles as well as trace gas concentrations
- ECMWF model fields (*T, q,* O_3) above maximum aircraft altitude
- Helpful to constrain humidity above the aircraft using microwave observations at 183 GHz

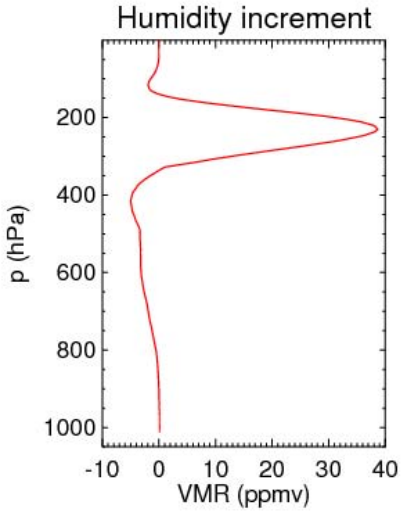


Microwave Airborne Radiometer Scanning System (**MARSS**)

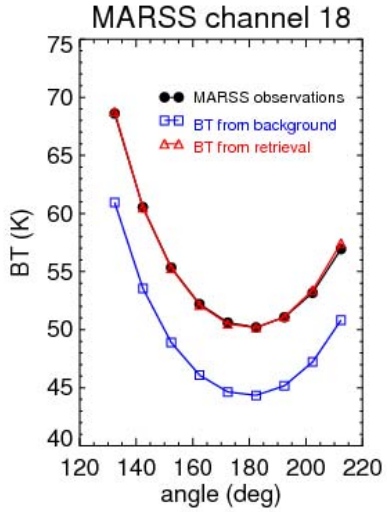


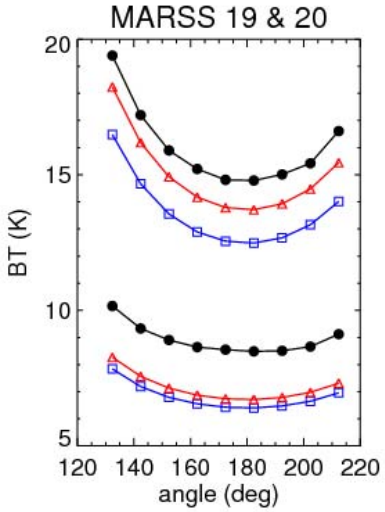
Microwave retrieval of H_2O profile
Flight B285, 19/20-Apr-2007

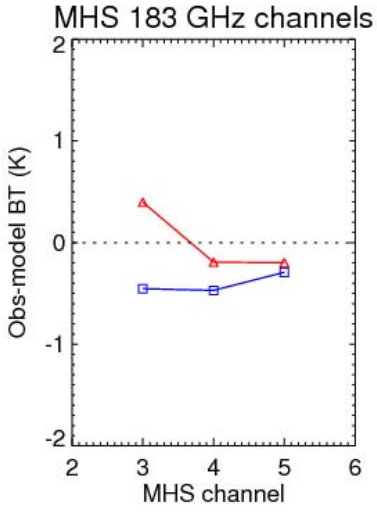




- Dropsonde profile topped up by ECMWF upper atmosphere
- Simplified retrieval of humidity using aircraft (MARSS) and satellite (MHS) radiances at 183 GHz
- AER's MonoRTM used for microwave Jacobian calculations

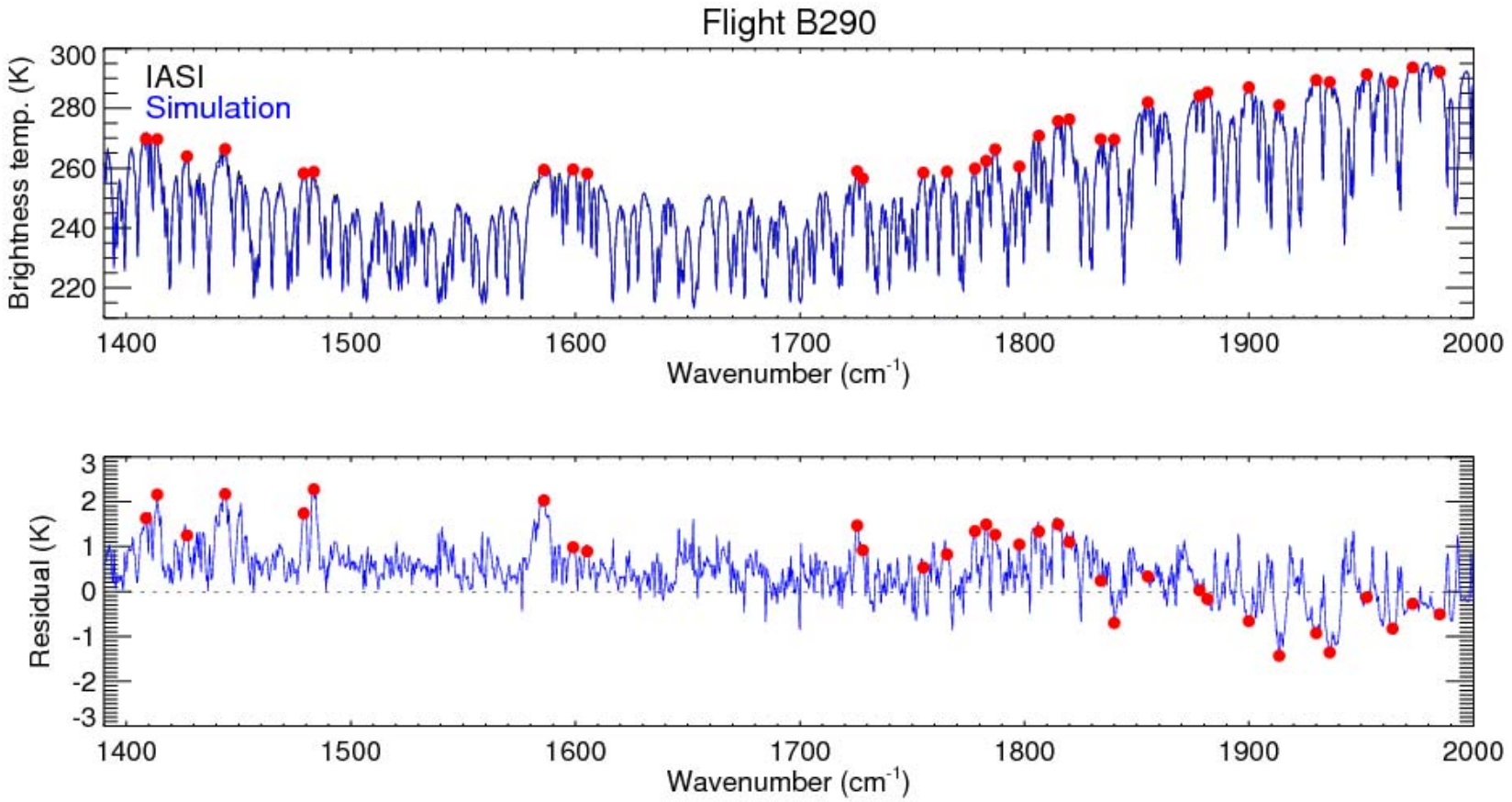






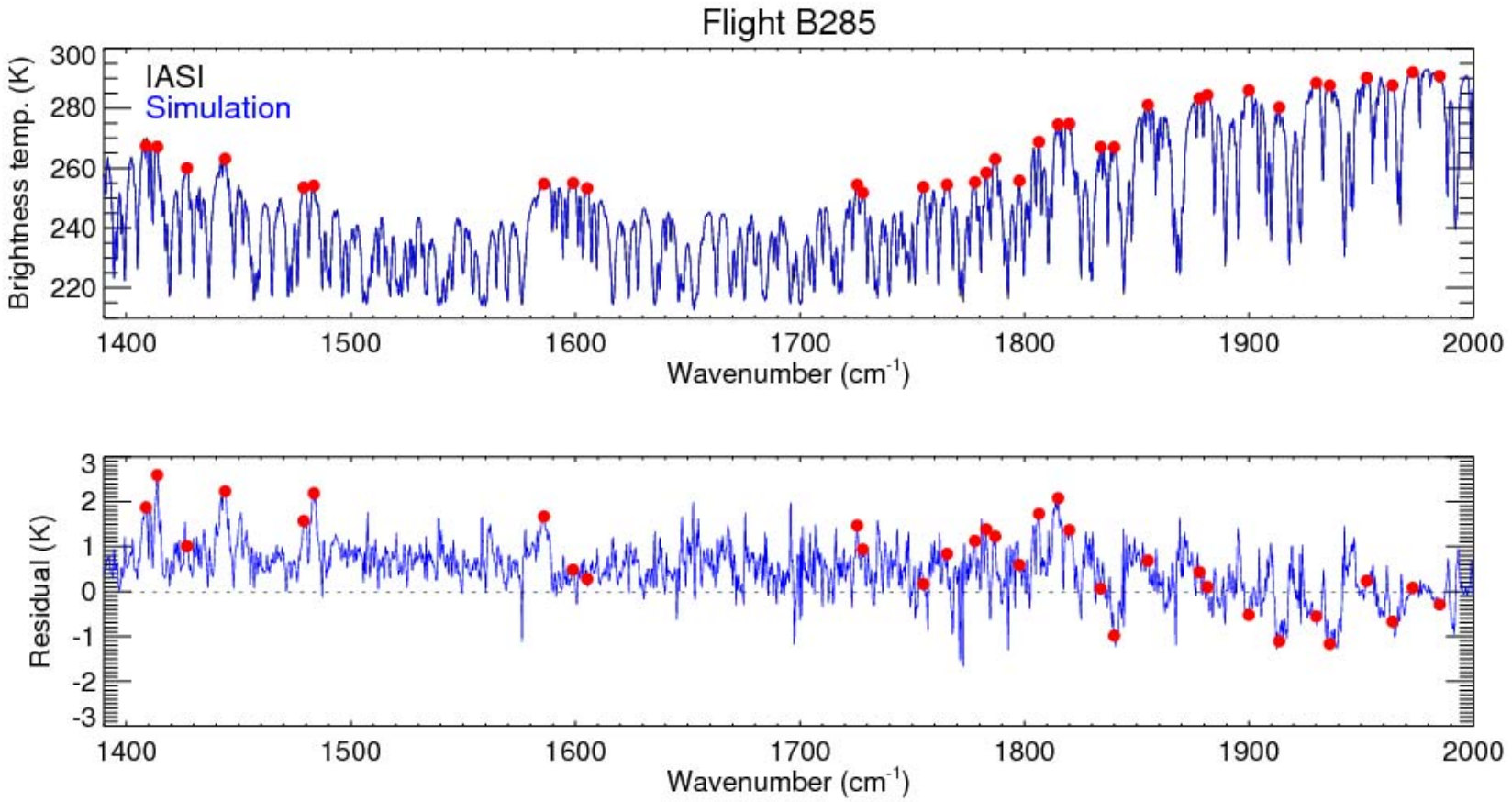
IASI water vapour band

Flight B290, 30-Apr-2007

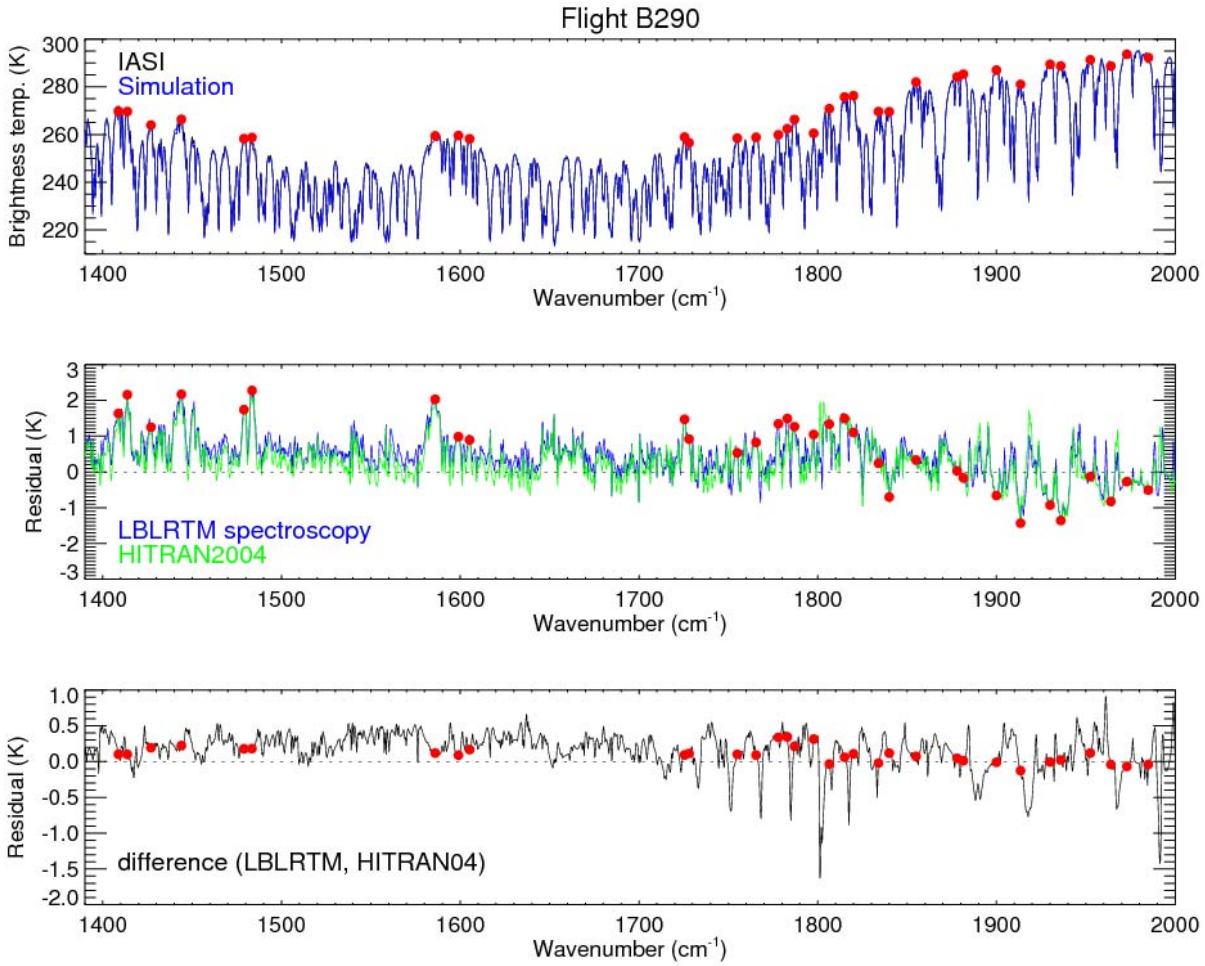


IASI water vapour band

Flight B285, 19/20-Apr-2007

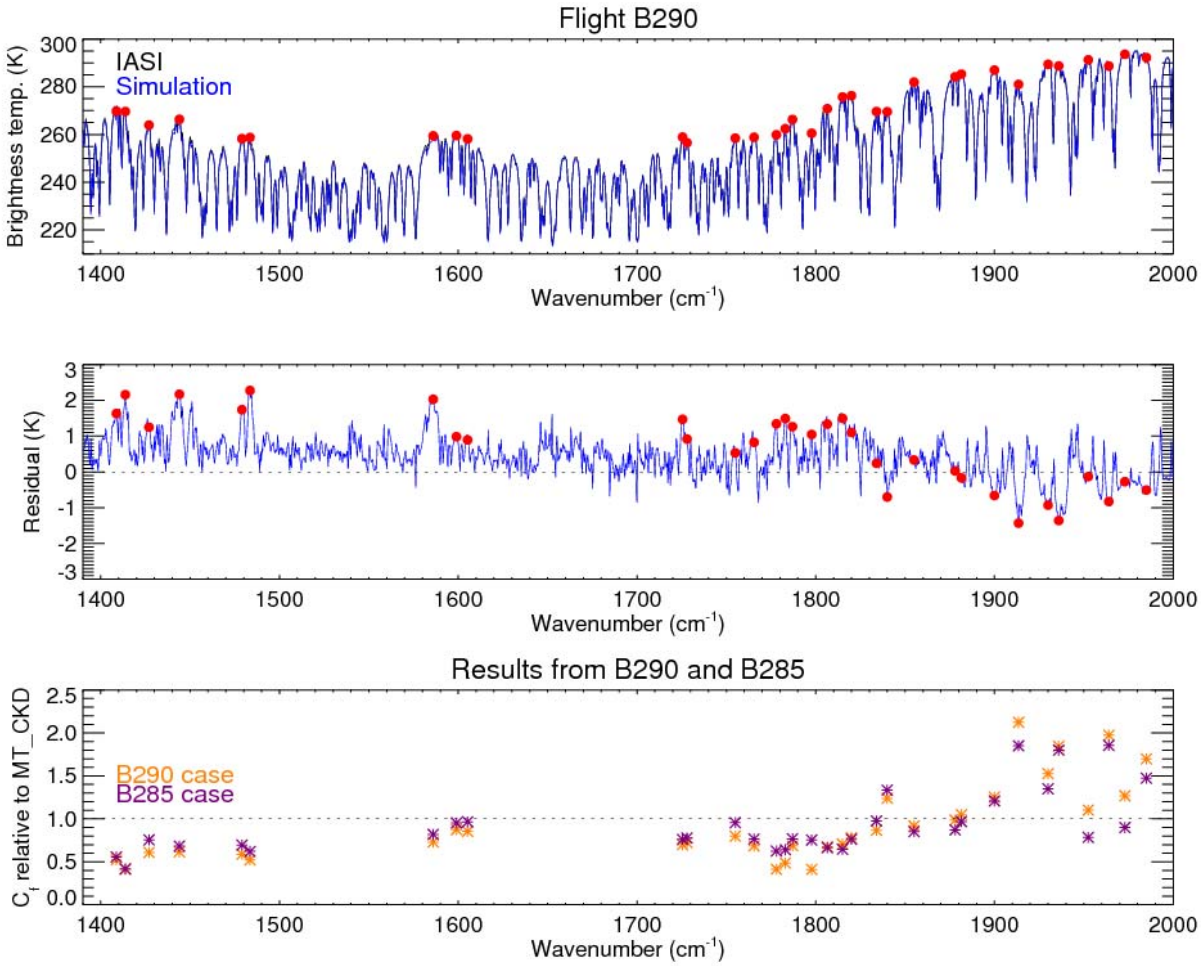


IASI water vapour band
Flight B290, 30-Apr-2007



- Coudert et al. water vapour spectroscopy updates since HITRAN2004
- MT_CKD_2.5 in LBLRTM_v11.7
- Continuum channels relatively insensitive to spectroscopic database

IASI water vapour band
Flight B290, 30-Apr-2007



- Implied continuum strength is less than MT_CKD < 1500 cm^{-1}, but greater than MT_CKD > 1900 cm^{-1}
- Retrieved continuum is sensitive to uncertainties in atmospheric profile

CAVIAR

CAVIAR consortium

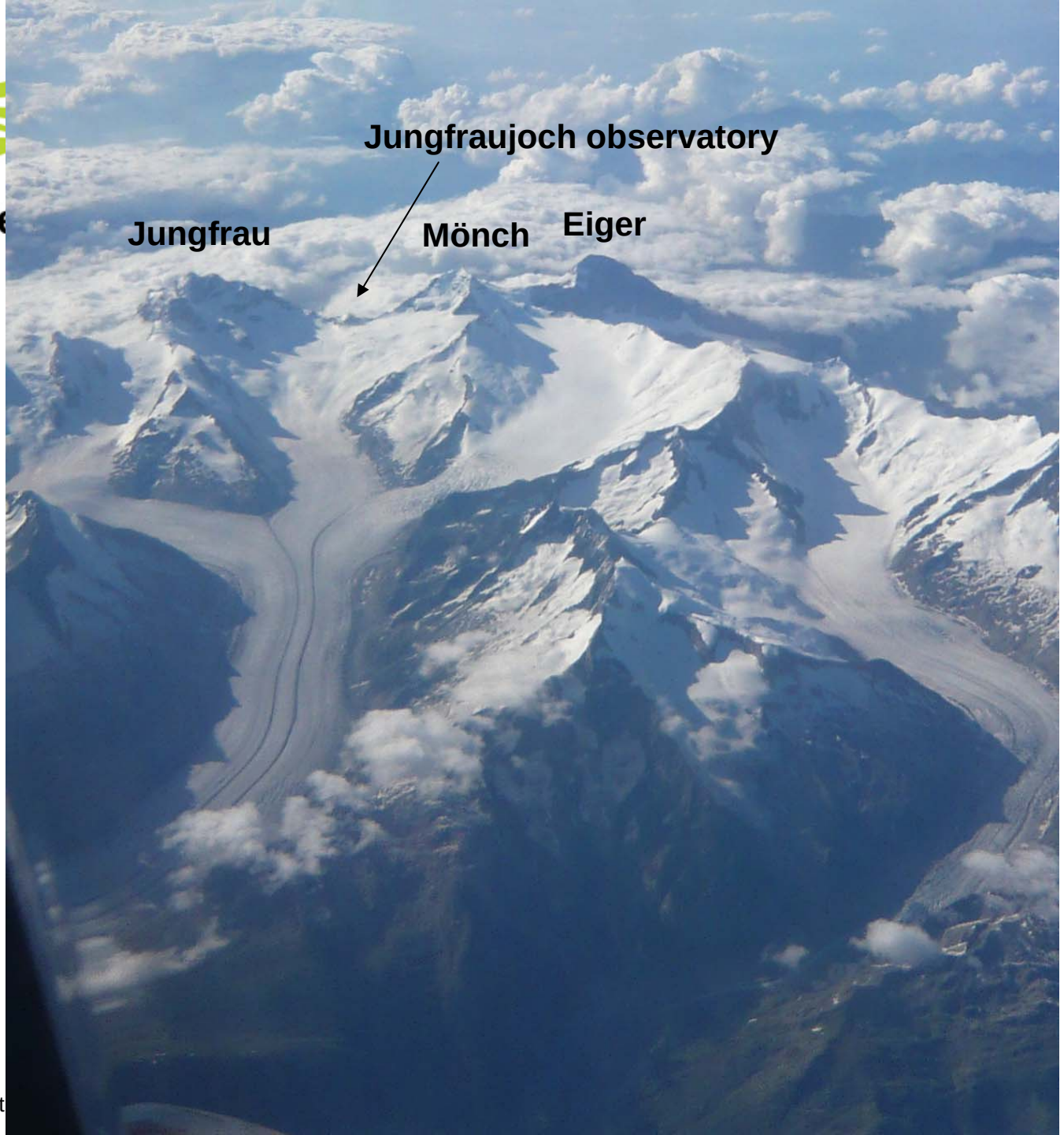
- **CAVIAR** – **C**ontinuum **A**bsorption at **V**isible and **I**nfrared wavelengths and its **A**tmospheric **R**elevance
- NERC- and EPSRC-funded consortium
- Theoretical calculations, laboratory measurements and field campaigns aim to improve understanding of, and reduce uncertainties in, the water vapour continuum

FAAM BAe 146-301 capability

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

ARIES interferometer (Bomem MR200)
Spectral range 550-3000 cm^{-1}
TAFTS interferometer (Imperial College)
Spectral range 80-800 cm^{-1}

Both instruments view upwelling and downwelling radiances

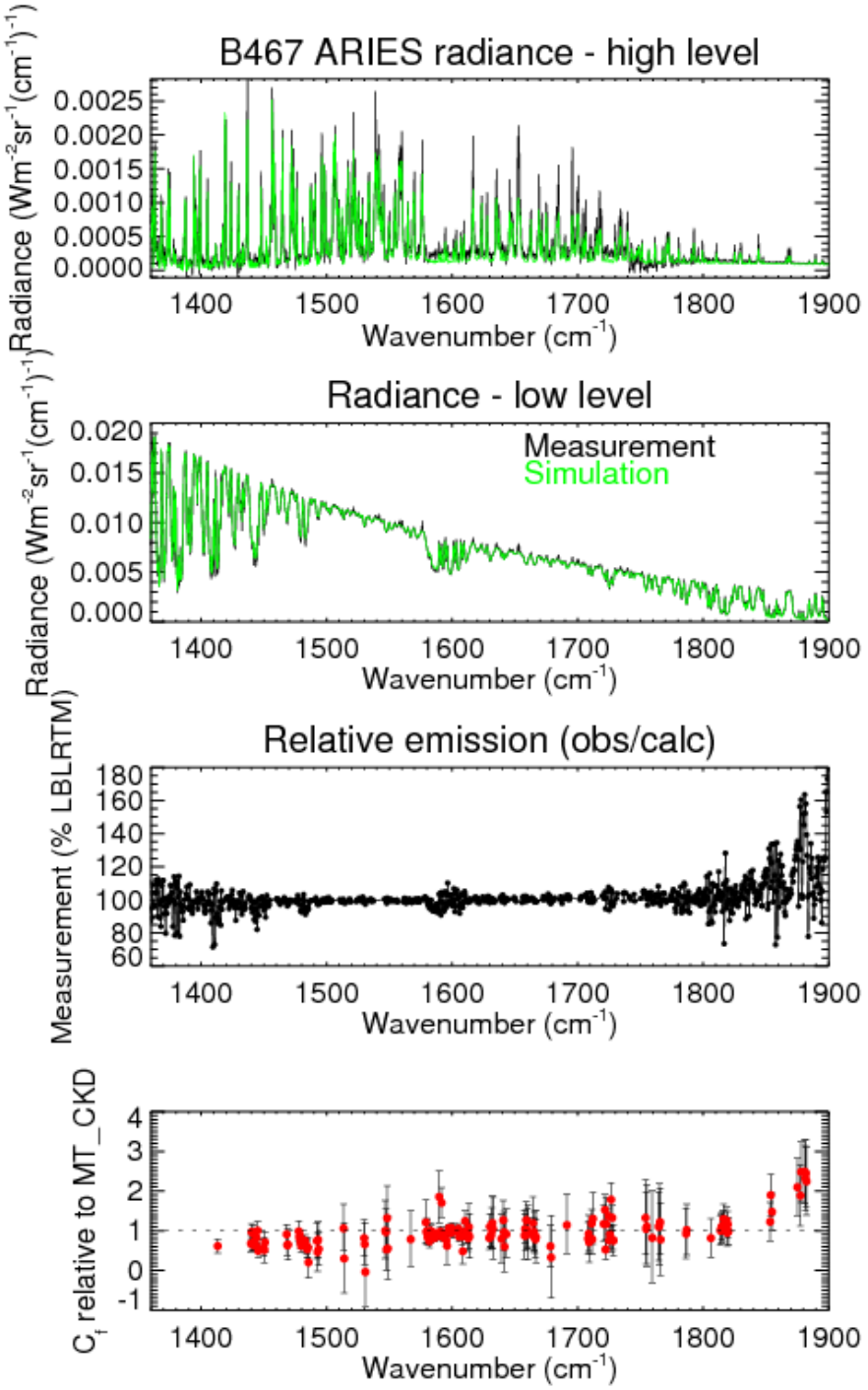


CAVIAR: Jungfraujoch High Altitude Observatory (Switzerland) campaign July-August 2009

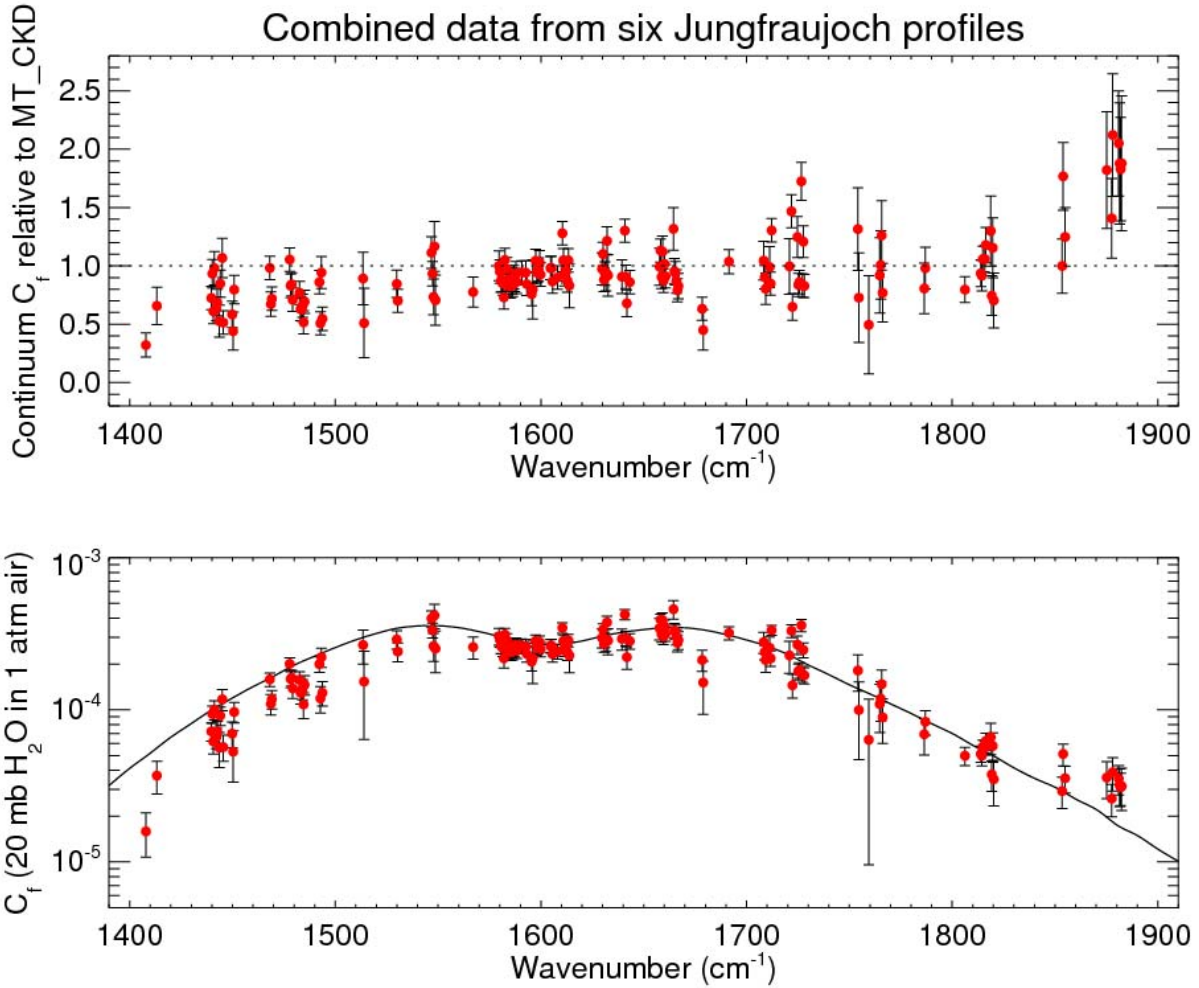
- 9 FAAM research flights
- Runs between 15,000 – 35,000 feet
- Spiral descents over Jungfraujoch for in situ water vapour characterisation
- Dropsondes from high level
- ARIES, TAFTS infrared observations from the aircraft, NPL's high resolution sun-tracking FTS data from the observatory

CAVIAR example
B467 19-Jul-2009

- Initial run at high level for radiance measurements (here looking up)
- Spiral descent over Jungfraujoch observatory measuring in situ water vapour (rapid response FWVS probe used here)
- Subsequent run at lower level for radiance measurements (here looking up)
- Determine change in radiance due to water vapour in atmospheric path
- Derive continuum strength, compare to MT_CKD model in LBLRTM



Preliminary results
Selected data from flights B467-B474

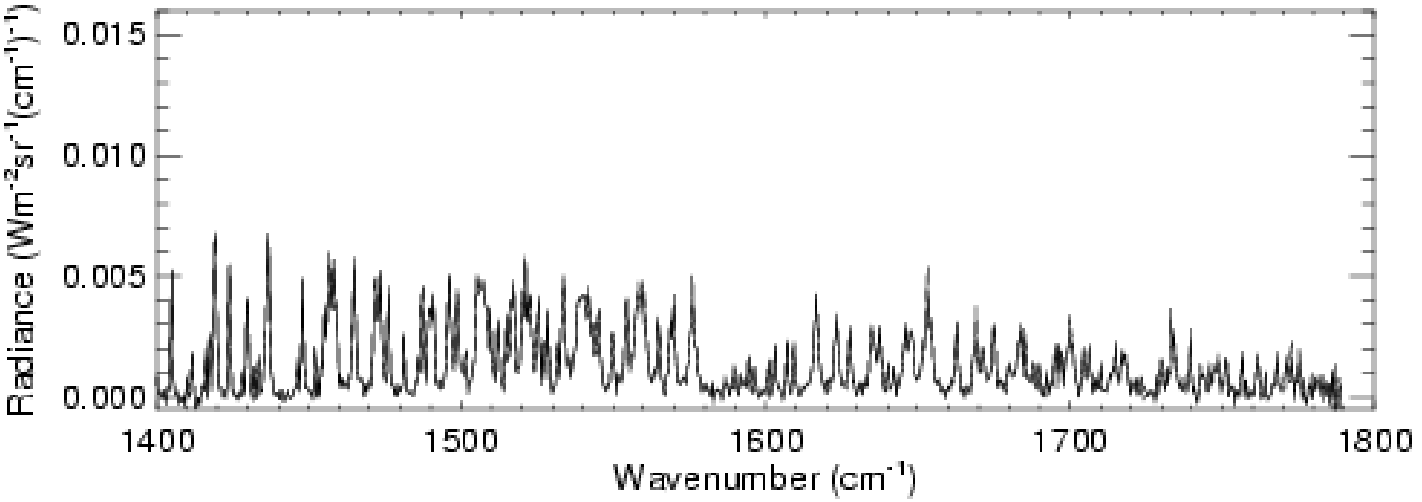


Summary

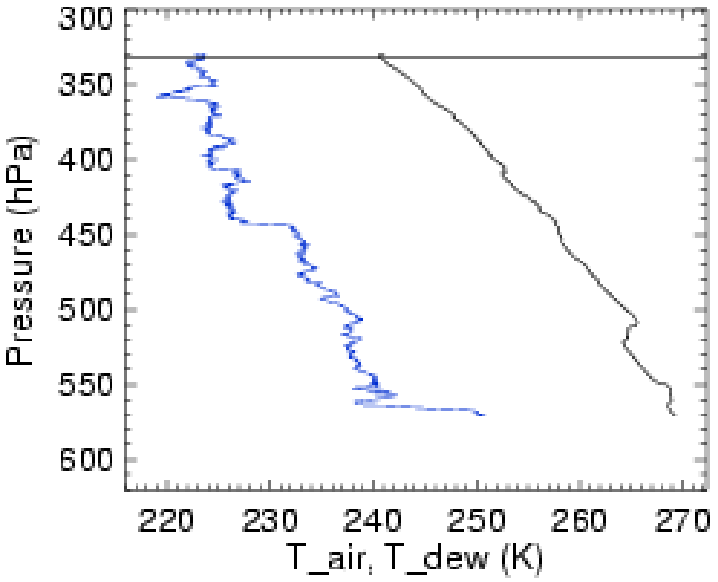
- A combination of satellite, aircraft and ground-based measurements is being used to investigate the infrared water vapour spectrum, its spectroscopy and continuum
- Spectroscopy updates (some strong water vapour transitions increased in strength by 5-10%) are significant, but residual differences still seen in case studies from JAIVEx and CAVIAR
- Simulated IASI spectra from JAIVEx agree with measurements largely to within 2 K, with largest magnitude residuals for channels sensitive to the water vapour continuum
- Preliminary results from recent CAVIAR campaign allows foreign-broadened continuum coefficients to be constrained, showing frequency-dependent departures from MT_CKD
- CAVIAR consortium continues to investigate the continuum and its causes through a combination of theoretical calculations, laboratory measurements and field campaign data

Questions and answers

ARIES data: B471 spiral descent



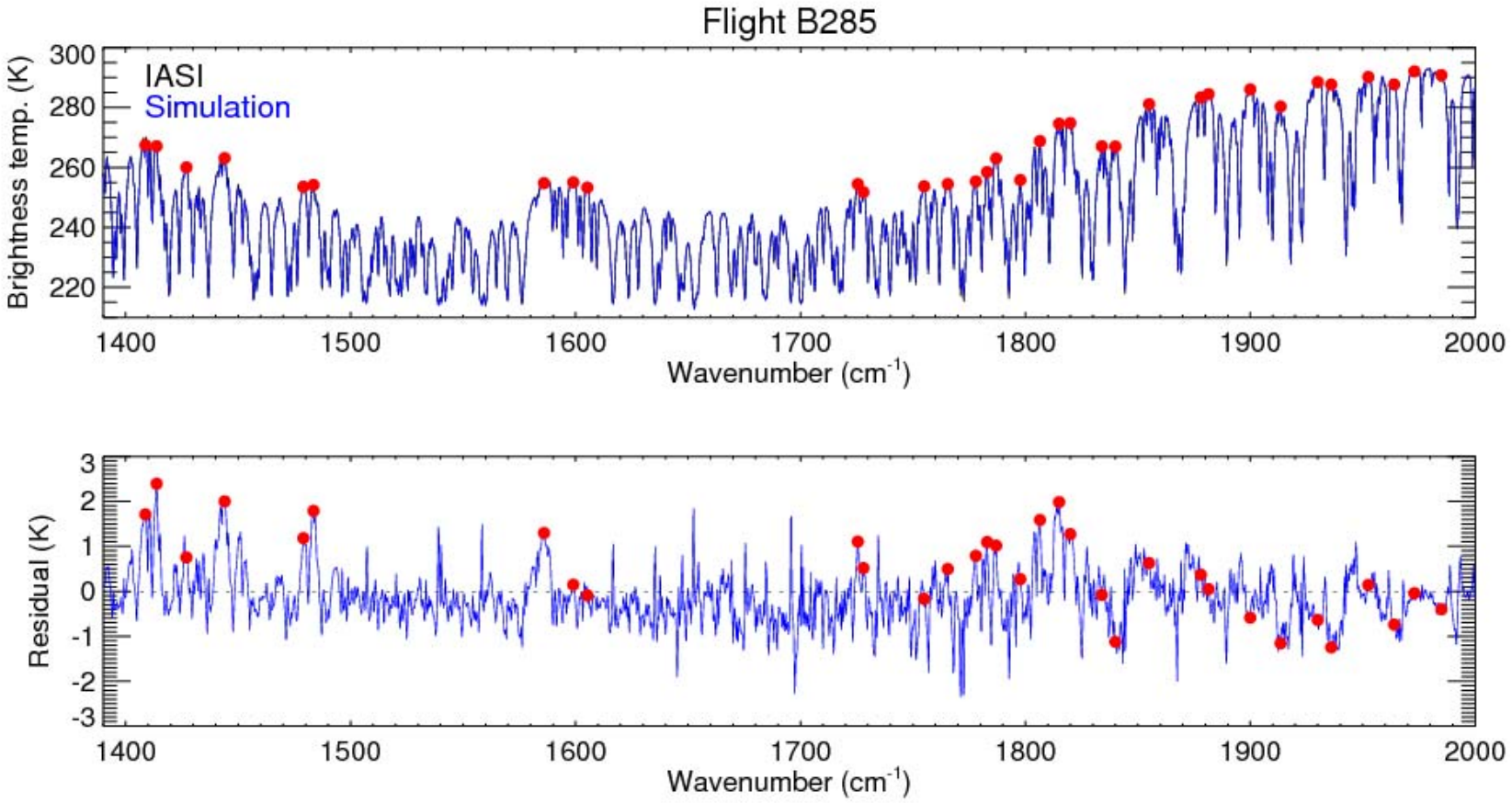
ARIES zenith data during spiral descent over Jungfraujoch



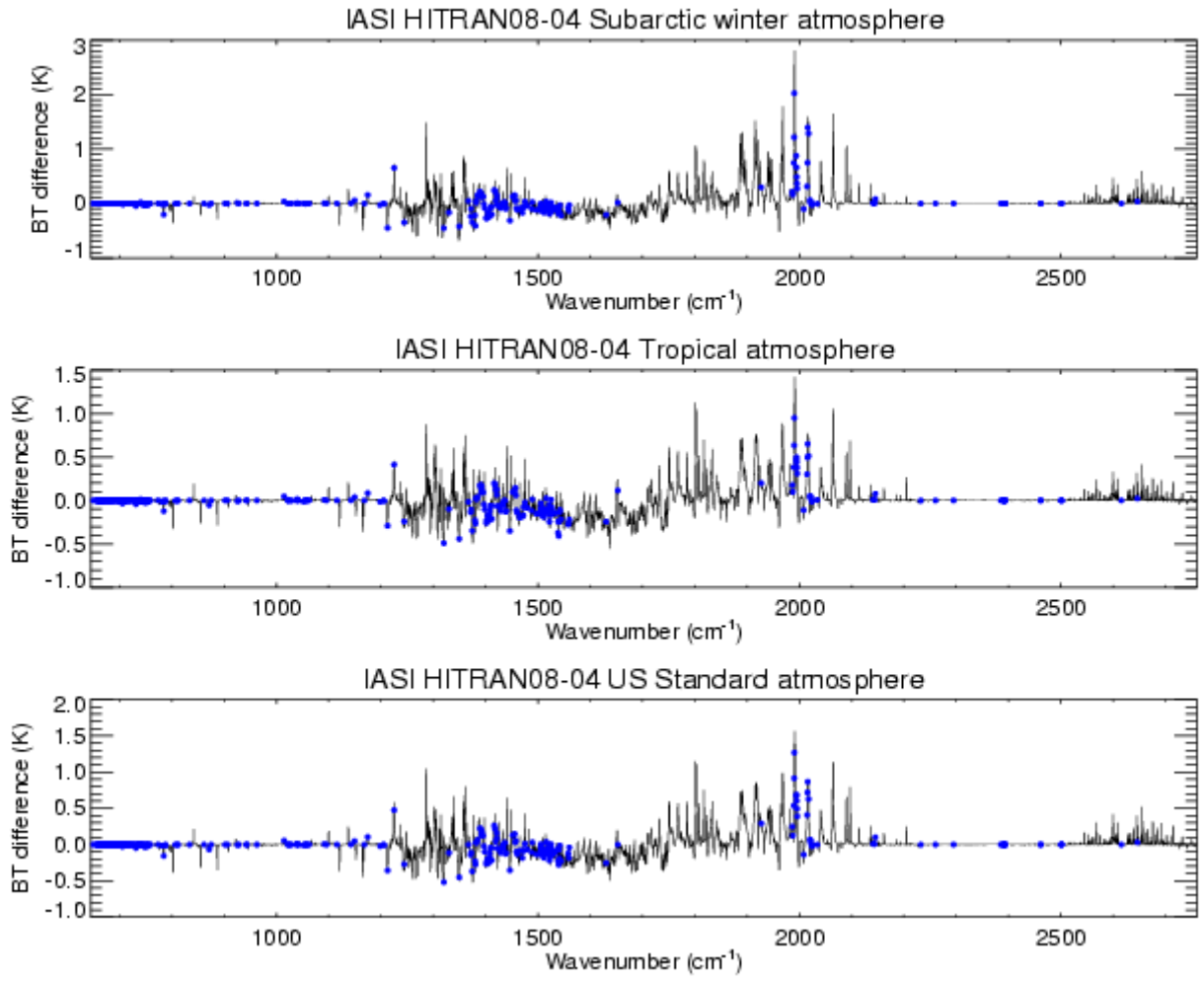
FAAM spiral descent measurements of temperature (Rosemount de-iced probe) and dew point (FWVS)

IASI water vapour band

Flight B285, 19/20-Apr-2007 **(unmodified profile)**



HITRAN updates



- Brightness temperature differences resulting from updated spectroscopy in HITRAN 2008
- Highlighted are the operational Met Office monitored channels