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

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(and many others…)
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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.

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Joint Airborne IASI Validation Experiment (JAIVEx) – April-May 2007

- 8 MetOp cal/val flights
- Sea – Gulf of Mexico
- Land – Oklahoma
- 2 night, 6 day flights
- All MetOp collocated
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$_2$O 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

Flight B285

Brightness temp. (K)

Wavenumber (cm⁻¹)

Residual (K)

Wavenumber (cm⁻¹)
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…)

Endurance 5½ hours
Altitude 20 m – 10.5 km

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
• 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

Combined data from six Jungfraujoch profiles

$C_1$ (20 mb H$_2$O in 1 atm air)

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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