Validation of radiative transfer models in the highly absorbing water vapor band for hyperspectral infrared sounders

X. Calbet (1), R. Kivi (2), S. Tjemkes (1), F. Montagner (1) and R. Stuhlmann

(1) EUMETSAT, Meteorology, Darmstadt, Germany (Xavier.Calbet@eumetsat.int)

(2) FMI Artic Research Centre
The Atmospheric Sounding Campaign took place in the Finnish Meteorological Institute, Arctic Research Centre (FMI-ARC) during the time period June 4-September 5, 2007.

Surface, ground based remote sensing and balloon measurements were made.

Here we only deal with balloon measurements.
The balloon borne in situ instruments used:
- **RS92-SGP** radiosondes by Vaisala (PTU sondes)
- Reference level cryogenic frost point hygrometers (CFH)
- **ECC** ozonesondes

During the campaign altogether 360 PTU sondes, 40 ozone sondes and 7 frost-point hygrometers were flown.

Of the 7 CFHs, only **4 are useful** (2 are over cloud contaminated scenes and 1 does not have IASI data)
• We will concentrate here on the **RS-92** and **CFH** sondes

• Launches in synchronization with **Metop overpass**:
  - **One hour before overpass**: one **RS-92** + one **CFH**
  - **5 minutes before overpass**: one **RS-92**
Sonde Accuracy

- **TEMPERATURE:** 0.2 K for RS-92

- **HUMIDITY:**
  - **RS-92** from 1 to 3% relative error (Miloshevich et al. 2006) → 0.2-3% error absolute RH
  - **BUT** during **daytime** showing a big **bias**
    between 9 and 50% due to **solar radiation** (Vömel et al. 2007)
  - **CFH** 0.5K error in frost point →
    - **Troposphere** 0.5-5% error absolute RH
    - **Stratosphere** 0.5-0.02% error absolute RH
Sample Sonde (1/2)
Sample Sonde (1/2)

Temperature OK!
Sample Sonde (1/2)

RS92 Moisture above tropopause NOT GOOD

Temperature OK!
Sample Sonde (1/2)

- RS92 Moisture above tropopause NOT GOOD
- CFH Moisture above 40 hPa NOT GOOD
- Temperature OK!
Sample Sonde (1/2)

RS92 Moisture above tropopause NOT GOOD

Temperature OK!

Moisture profiles can vary a lot in 1 hour!

CFH Moisture above 40 hPa NOT GOOD

Temperature OK!
Sample Sonde (2/2)

ECMWF not very accurate in UT/LS
ECMWF AND RS-92 not accurate here

ECMWF not very accurate in UT/LS
Spectral Region of Study

• From **1500 to 1800 cm\(^{-1}\)**
• Water vapour region with its **strongest absorption**
• The atmospheric layers that most greatly contribute to TOA in this spectral region are **mid to high troposphere** and **lower stratosphere**
• These wavenumbers are most **insensitive** to low level clouds and surface properties
• Problem is **simplified** greatly!
IASI noise

- We use the latest **CNES IASI noise**

IASI_NCM_xx_M02_20091217060000Z_20091217060000Z_20091216123652Z_20091216123652Z
RTMs tested

- **OSS** trained with LBLRTM 11.3
- LBLRTM 11.3
- LBLRTM 11.6
Results for OSS and raw Sondes

3 sigma
IASI noise
**Necessary Corrections (1/2)**

- **Dry bias** correction for RS-92:
  - From Rigel et al. (2009) (ala Vömel et al. 2007)
  - From Rigel et al. (2009) + 2%
  - “In situ”: get correction from RS92/CFH comparison launched 1 hour before overpass apply it to RS92 5 min before overpass

- **No space co-location**
Necessary Corrections (2/2)

- **Time interpolation**: ala Tobin et al. 2006

![Graph showing time interpolation](image-url)
Results for OSS and Corrected Sondes
Results for OSS and Corrected Sondes

20070615. OSS

RS92 - 5 min
CFH - 1 hour
RS92 - 5 min in situ bias corrected
Interpolated: CFH & RS92 in situ bias

OBS - CALC (mW/m² srad cm⁻¹)

Wavenumber (cm⁻¹)
We remove this cloud
Contaminated part
Results for OSS and Corrected Sondes

We remove this cloud
Contaminated part

We normalize with IASI noise and squash wavenumbers in a histogram
Results for OSS and Corrected Sondes ("In situ" and Rigel et al.)
Results for OSS and Corrected Sondes ("In situ" and Rigel et al. + 2%)

Chans. wn > 1500 & < 1570 or wn > 1615 & < 1800 cm\(^{-1}\). All days.

In situ bias correction
Rigel et al. bias correction + 2%
Gaussian with sigma=1.0

Relative frequency

IASI instrument noise normalized radiance residuals

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Results for LBLRTM 11.3 and Corrected Sondes ("In situ" and Rigel et al.)

Chans. wn > 1500 & < 1570 or wn > 1615 & < 1800 cm\(^{-1}\). All days

In situ bias correction
Rigel et al. bias correction
Gaussian with sigma=1.0

Relative frequency

IASI instrument noise normalized radiance residuals
Results for LBLRTM 11.6 and Corrected Sondes ("In situ" and Rigel et al.)

Chans. wn > 1500 & < 1570 or wn > 1615 & < 1800 cm\(^{-1}\). All days

**In situ bias correction**

**Rigel et al. bias correction**

**Gaussian with sigma=1.0**

**Relative frequency**

**IASI instrument noise normalized radiance residuals**
Questions (1/2)

- Fit to IASI 1-sigma instrument noise:
  - Is CNES IASI instrument noise too high?
  - Where we just lucky these 4 days?

Chans. wn > 1500 & < 1570 or wn > 1615 & < 1800 cm\(^{-1}\). All days
Questions (2/2)

• Why has the **bias** shifted 1% in Relative Humidity in the **LBLRTM** when going from **11.3 to 11.6**?

  - Because of an **OBS-CALC** exercise similar to the one here?

  - Or because of something more **physical**?
Conclusions (1/2)

- With **IASI** we can differentiate **biases** with a difference of only 2% in absolute terms of relative humidity.
- We need sonde measurements with a low bias < 0.2% in absolute terms and high accuracy of relative humidity in UT/LS → Only **CFH sondes** can provide this.
- **RS92** sondes could be used as a replacement for CFH sondes using a proper bias correction: highly uncertain with this small campaign data sample whether this is achievable, or possibly use **nighttime** observations, but it will **never cover** properly the UT/LS.
- **Spatial co-location** does **not** seem to have a big role in these radiance matching.
- **Temporal co-location** is crucial.
Conclusions (2/2)

• **OBS ↔ CALC** matching is important to:
  - Characterize measurement error covariance matrix for **optimal estimation**
  - Have a representative and quality sample to train statistical techniques (**EOF, ANN, SVM**)

• Ideally: **two CFH** sondes in campaigns launched with some time lag at satellite overpass

• Practical solution: **co-locate** campaign data with **IASI/AIRS/MTG-IRS**
  - GCOS Reference Upper Air Network (**GRUAN**)
  - Future **MTG-IRS** → Have a good collection of co-located radiosonde data