Integrated water vapour time series:
instrumental inter-comparisons and trends

R. Van Malderen[1], H. Brenot[2], E. Pottiaux[3], M. De Mazière[2],
C. Hermans[2], H. De Backer[1], C. Bruyninx[3]

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OUTLINE

1. Instrumental inter-comparison
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2. Time series analysis
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   ii. *Method*
   iii. *Examples*
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What? Inter-comparison between 4 different instruments measuring the same atmospheric variable

Which variable? Integrated water vapour (IWV)

Where? UCCLE (Brussels, Belgium, 50°48'N, 4°21'E, 100m asl) as case study

When? the different instruments cover different observation periods

Aims?

- assess the quality of the different measurements: the precision - accuracy - performance of the instruments
- obtain a better monitoring and understanding of the changing water vapour content in the atmosphere

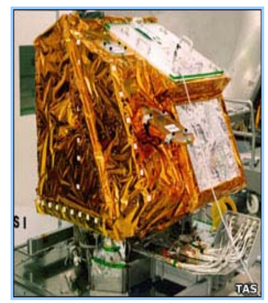
RMI

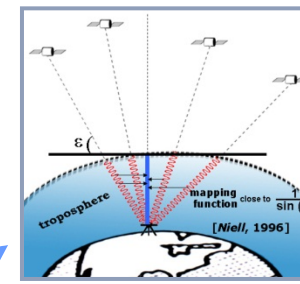
CIMEL sunphotometer

- direct sun measurements @ 940nm (and @ 675 and 870 nm for aerosol correction)
- clear sky only
- level 2 data from the AERONET website

Infrared Atmospheric Sounding Interferometer (IASI)

- Fourier transform spectrometer providing spectra from 3.6 to 15.5 µm with high spectral resolution (0.35 to 0.5 cm^{-1})
- cloud cover is an issue





Radiosondes

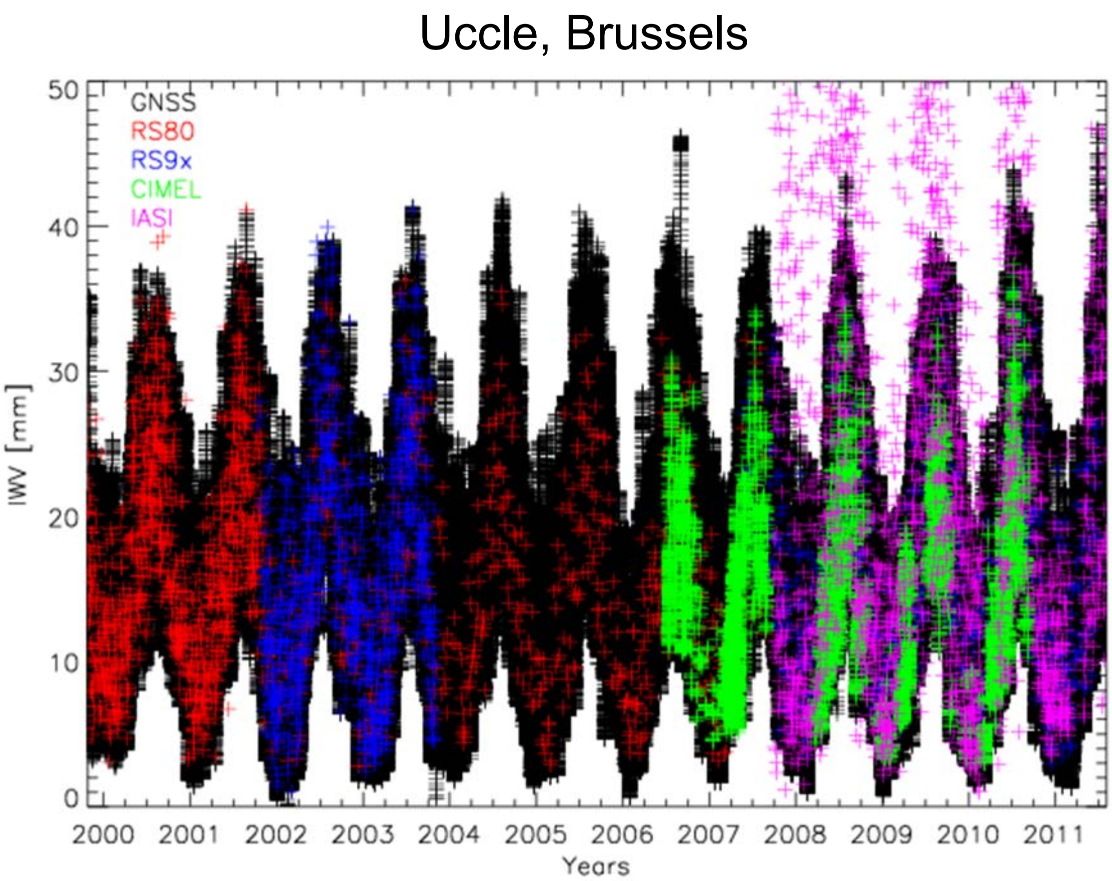
- Vaisala RS80, RS90 and RS92 (=RS9x)
- launched at 12h00 UT, 3 times a week

GNSS system

- Global Navigation Satellite System
- at all weather conditions, always
- T_{surf} and p_{surf} are needed: ZTD → IWV

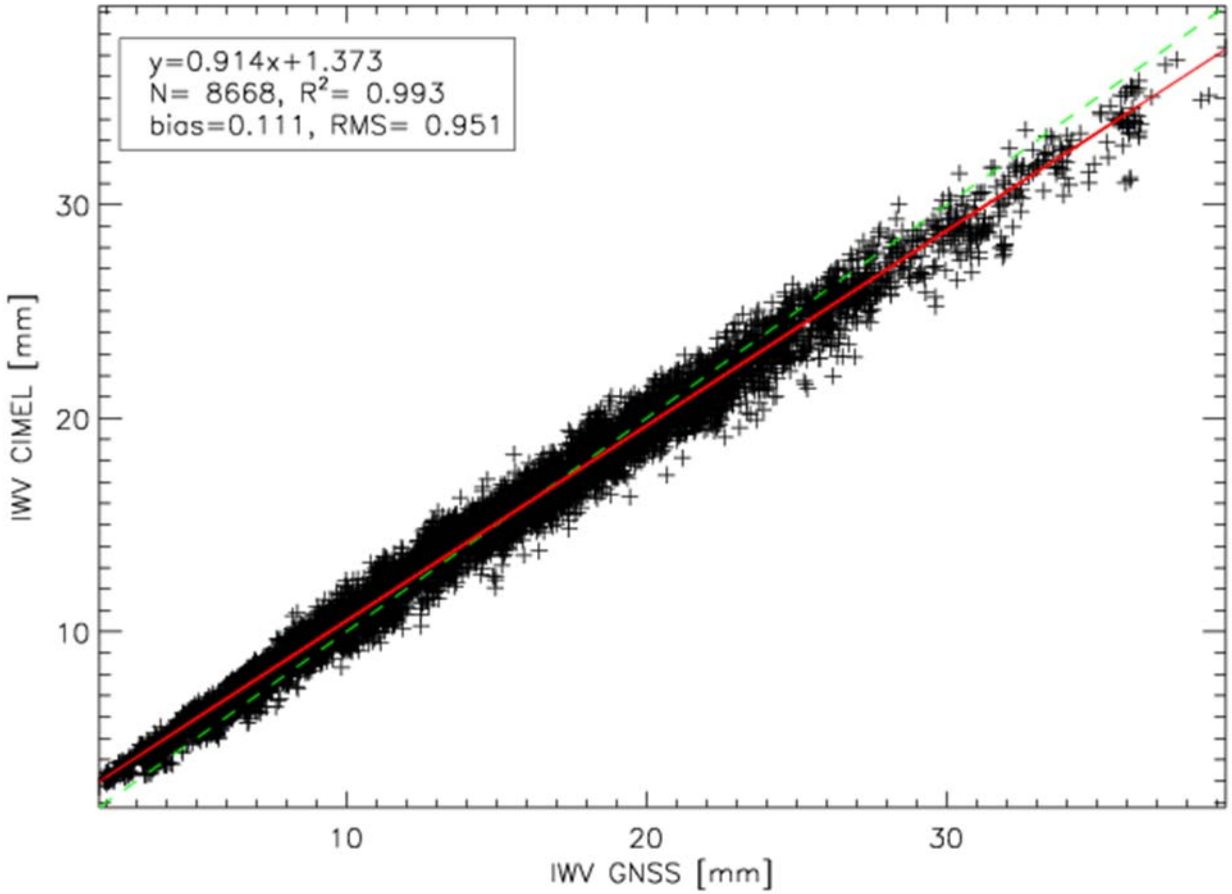
RMI

All measured data…



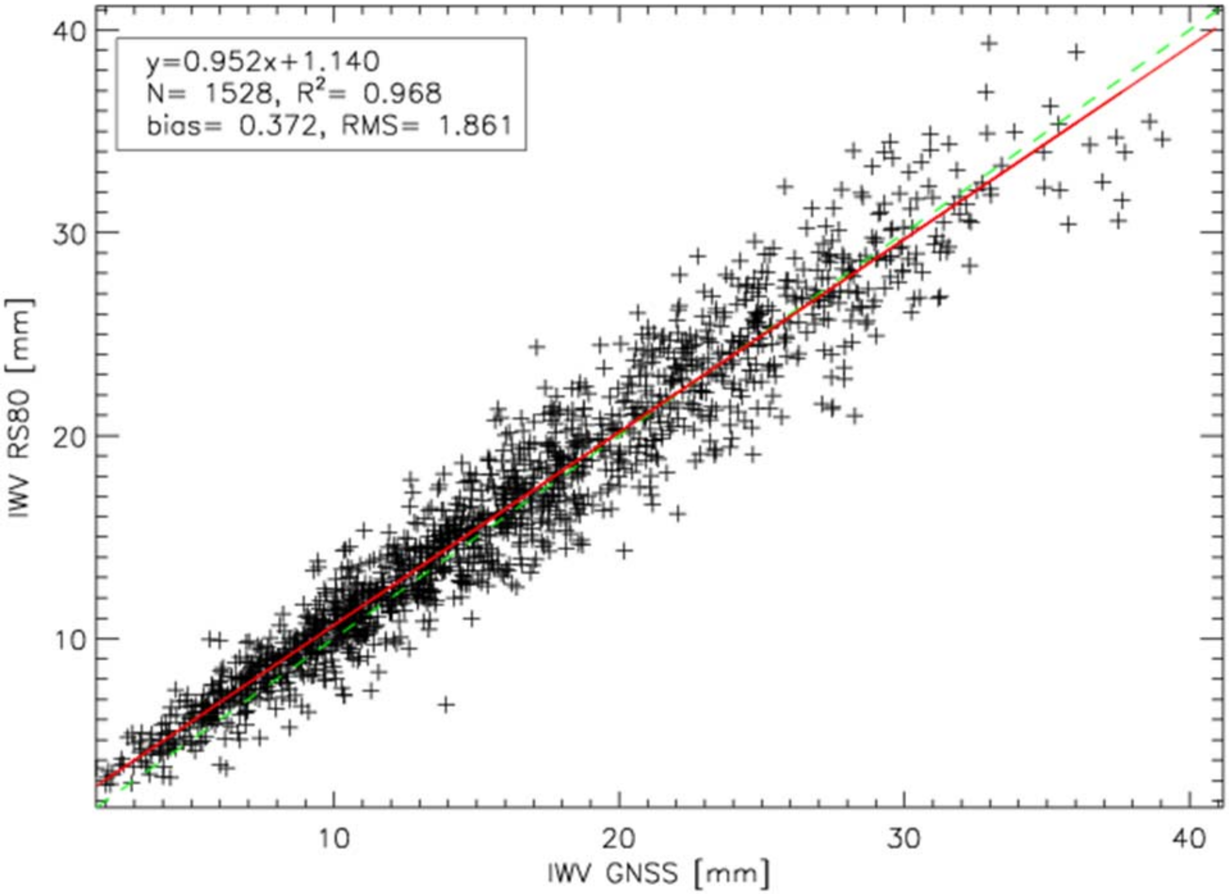
- different instruments = different observation periods
- GNSS data will be taken as reference:
  - ✓ only minor gaps
  - ✓ data every 10 min
  - ✓ data since end 1999 (= launch automatic weather station)
  - ✓ International GNSS Service (IGS) data, ➔ homogeneous reprocessing
- seasonal cycle: max in summer, min in winter

CIMEL vs GNSS



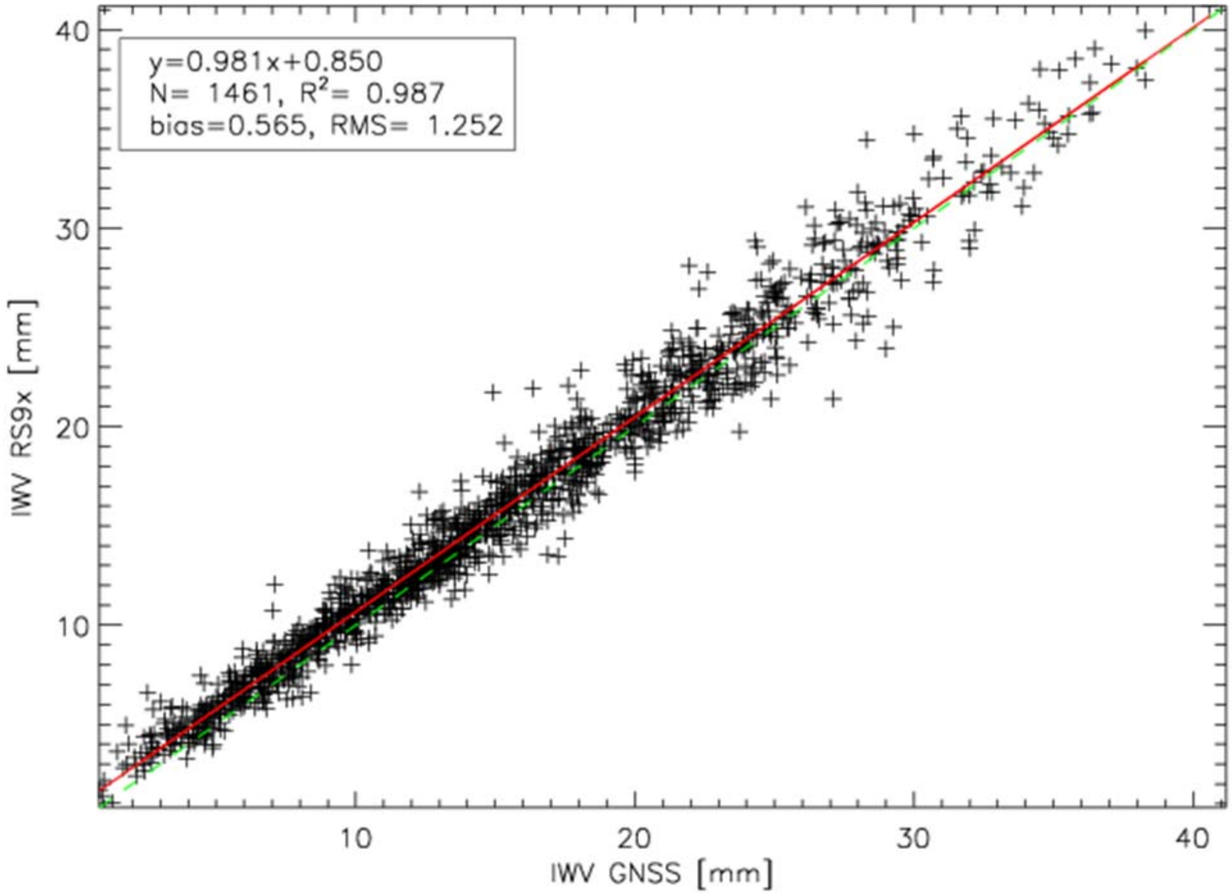
very good agreement
no bias
slope < 1
very small RMS

RS80 vs GNSS



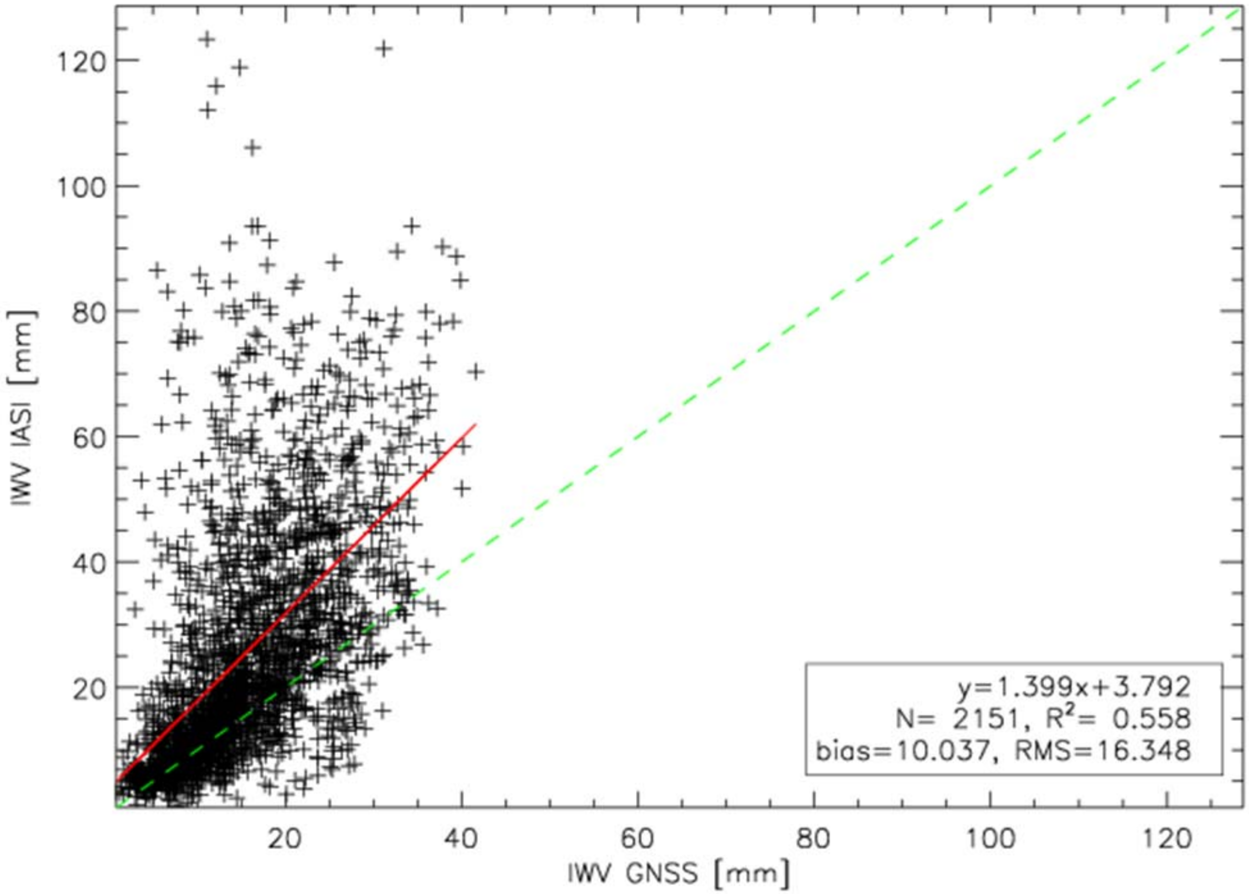
good agreement
very small wet bias
slope < 1
small RMS

RS9x vs GNSS



good agreement
small wet bias
slope < 1, but close to 1
small RMS

IASI vs GNSS

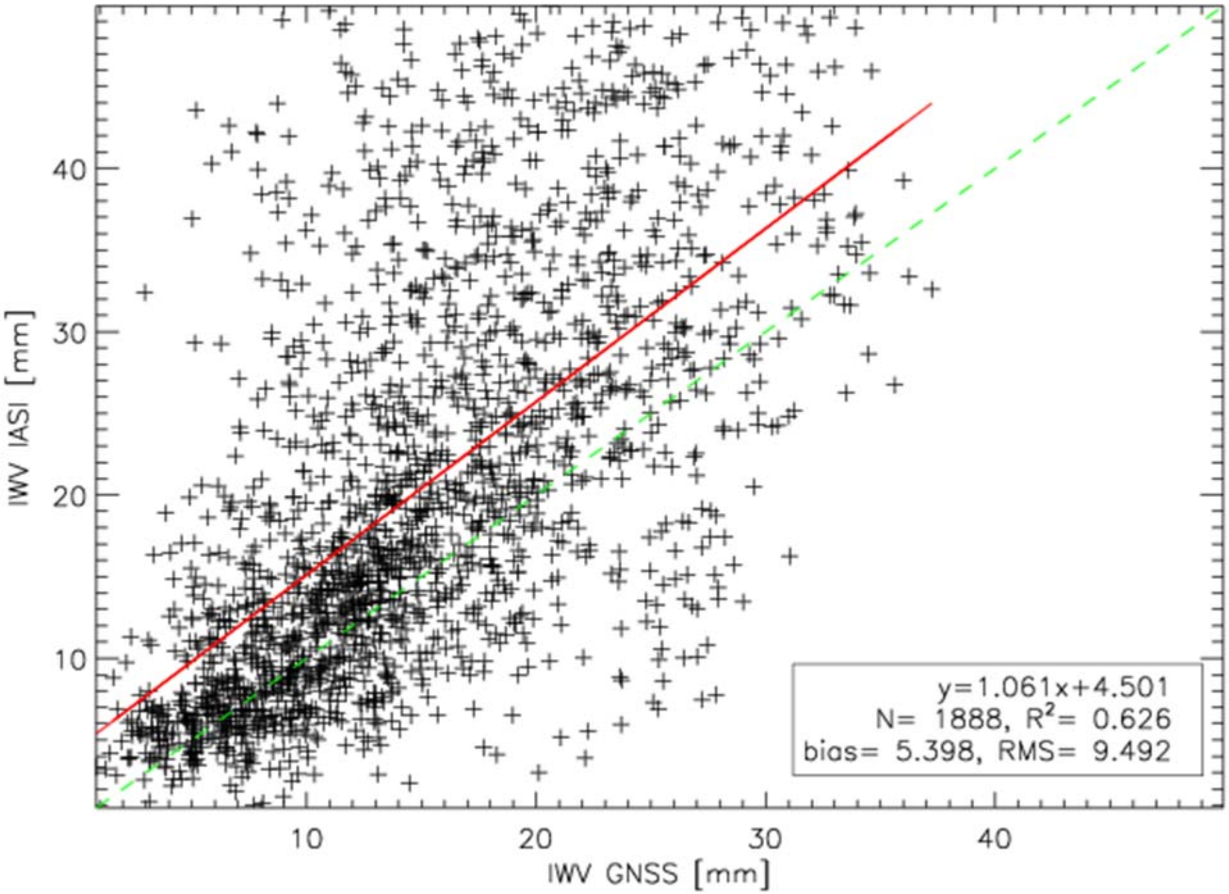


small correlation
large wet bias
slope > 1
high RMS
IASI: cloud cover?
IASI: consider Q flags of data
IASI: closest pixel

RMI

IASI vs GNSS

ZTD < 2.575 m, IWV < 50 mm

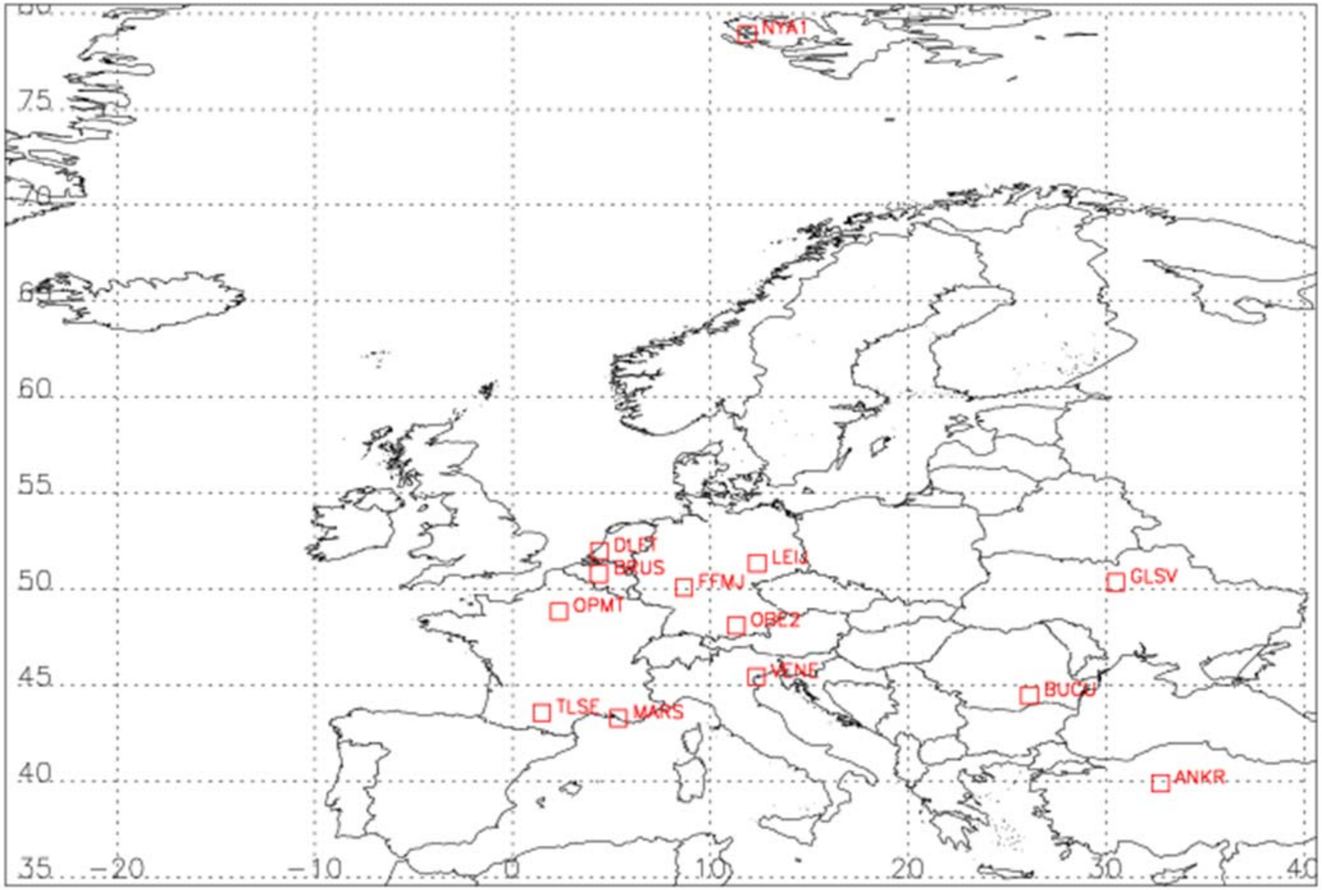


small correlation
large wet bias
slope > 1
high RMS
IASI: cloud cover?
IASI: consider Q flags of data
IASI: closest pixel

Summary

- although originally tracing other slants/directions, very good agreement between the 3 ground-based devices.
- for large IWVs: GNSS IWVs are always larger than the IWVs measured by other ground-based devices (slopes 0.9x), with a max difference of the order of 5 mm
  - ✓ *the larger the IWVs, the higher the probability to have clouds,which might be measured by GNSS but not by CIMEL*
  - ✓ *reason unclear for RS (dry bias for large IWVs/in clouds?)*
  - ➔ *analyze the cloud meteo data?*
- additional data reduction needed for IASI (cloud cover QF) vs. inherent limitation at lower levels

Outlook: extend to other sites



We selected stations with at least 3 instruments (GNSS, RS, CIMEL) at a distance of less than 30 km apart!

Background: IWV trend analysis in literature is based on radiosondes, re-analysis data (ERA40, NCEP), satellite data (SSM I, GOME/SCIAMACHY, …)

➔ problems of homogeneity or limited in time

➔ potential for GNSS data, especially IGS data

- **GNSS:** high time resolution, at all weather conditions, high degree of correlation with other devices
- **I**nternational **G**NSS **S**ervice data**:**
  - ✓ *earliest reprocessing covers about 15 years, for about 150 sites worldwide data starting in 1995/1996*
  - ✓ *high sampling rate: data every 5 minutes*
  - ✓ *state-of-the-art GPS tropospheric delay modelling*
  - ✓ *homogeneous: the re-analysis uses the same analysis strategy over the 15 years*
  - ✓ *no network effect (Precise Point Positioning processing strategy)*

RMI

Method

IGS station

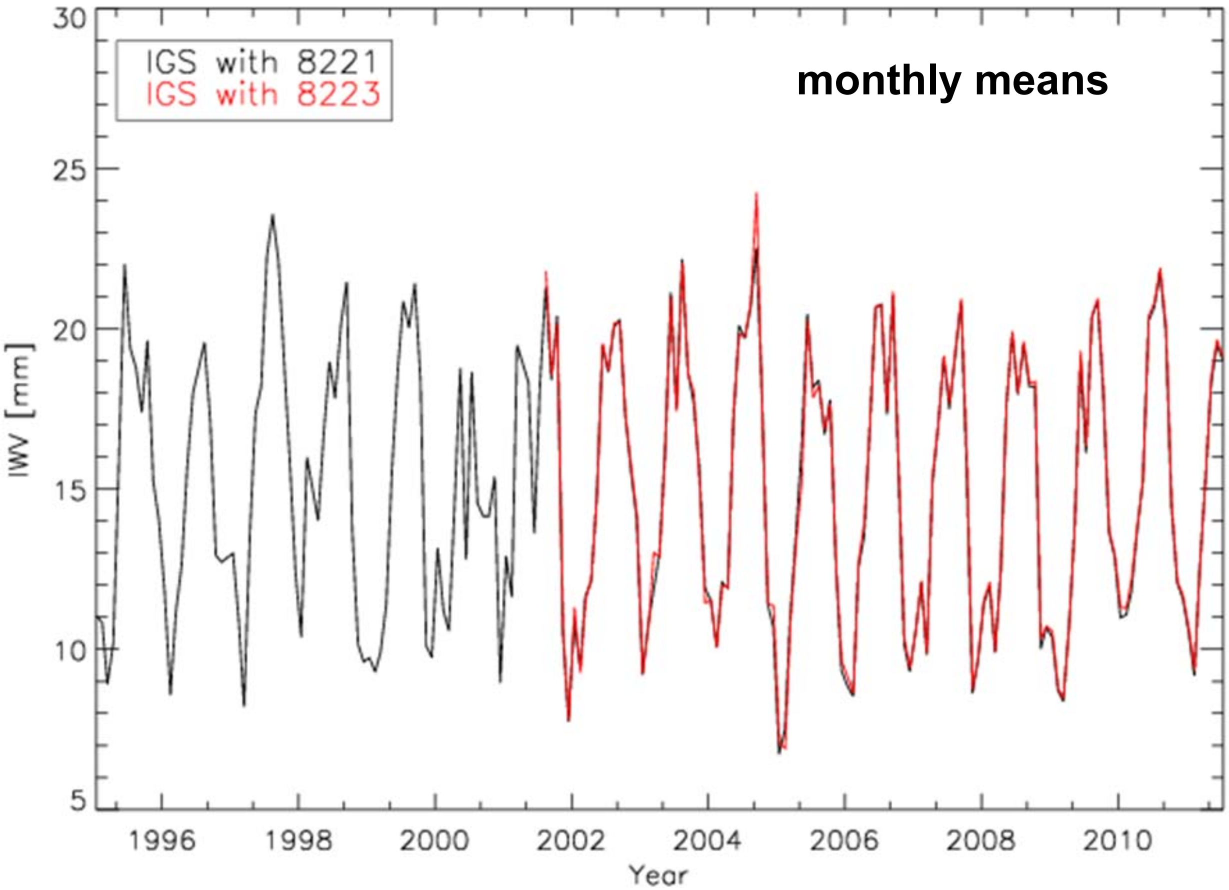
Zenith Total Delay → **IWV**

T_{surf}, P_{surf}

WMO GTS

- nearest meteo station to GNSS station
- correction of T, P (hydrostatic equilibrium) in case of altitude difference between meteo and GNSS station

VILL (Villafranca, Madrid, Spain)

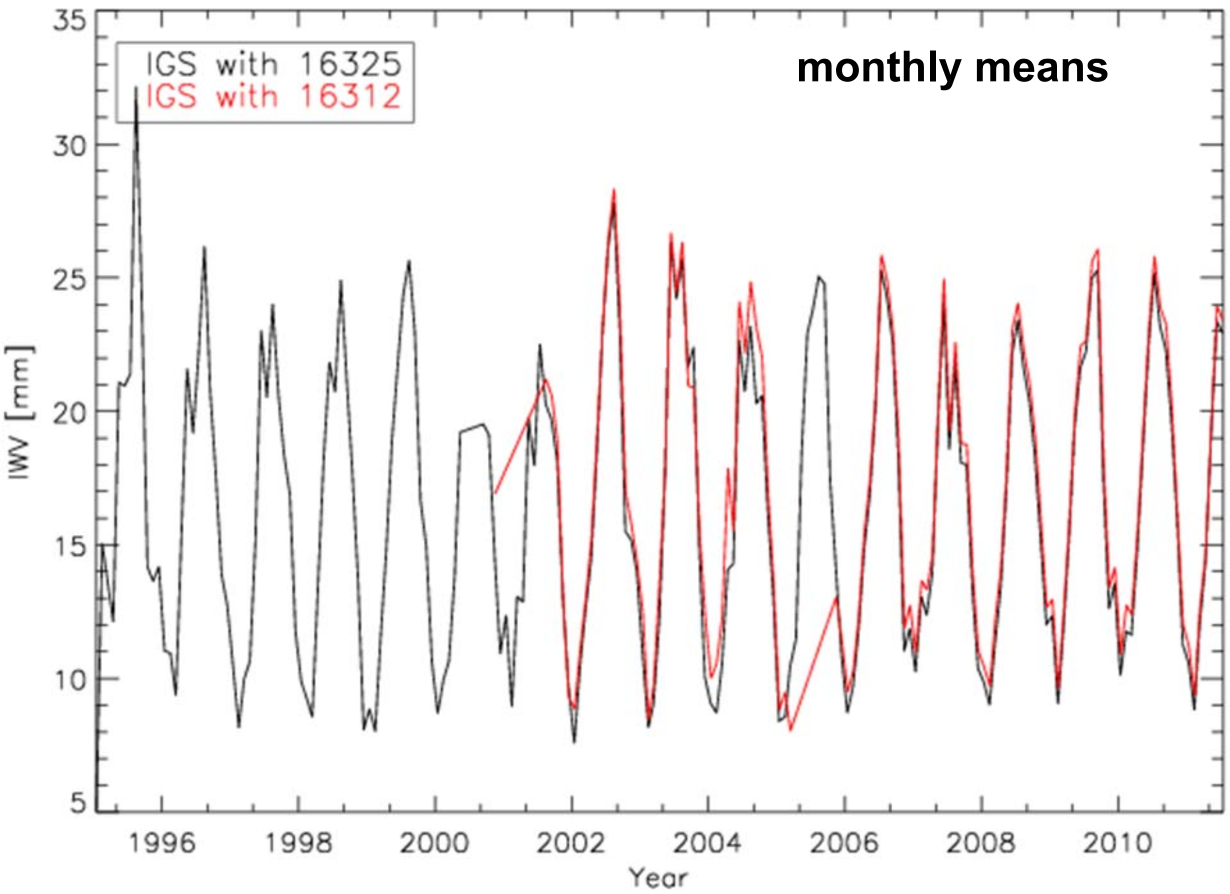


Altitude **Distance**

IGS: 595 m
8221: 609 m, 8221-IGS = 45 km
8223: 690 m, 8223-IGS = 20 km

difference in horizontal distance to the meteo station only gives minor IWV differences

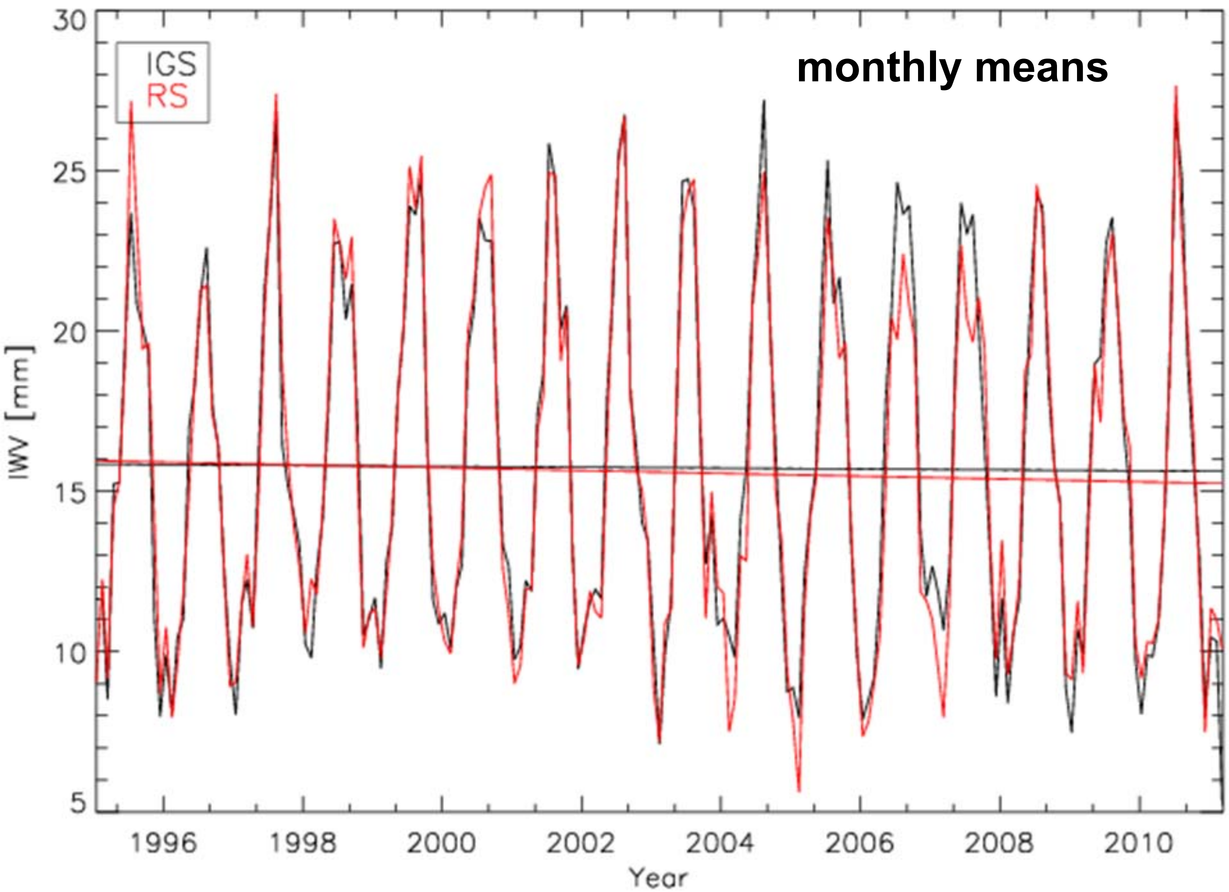
MATE (MATERA, Italy)



Altitude	Distance
IGS: 490 m	
16312: 350 m,	16312-IGS = 27 km
16325: 12 m,	16325-IGS = 27 km

difference in altitude, although corrected for, leads to a small bias between the IWV values

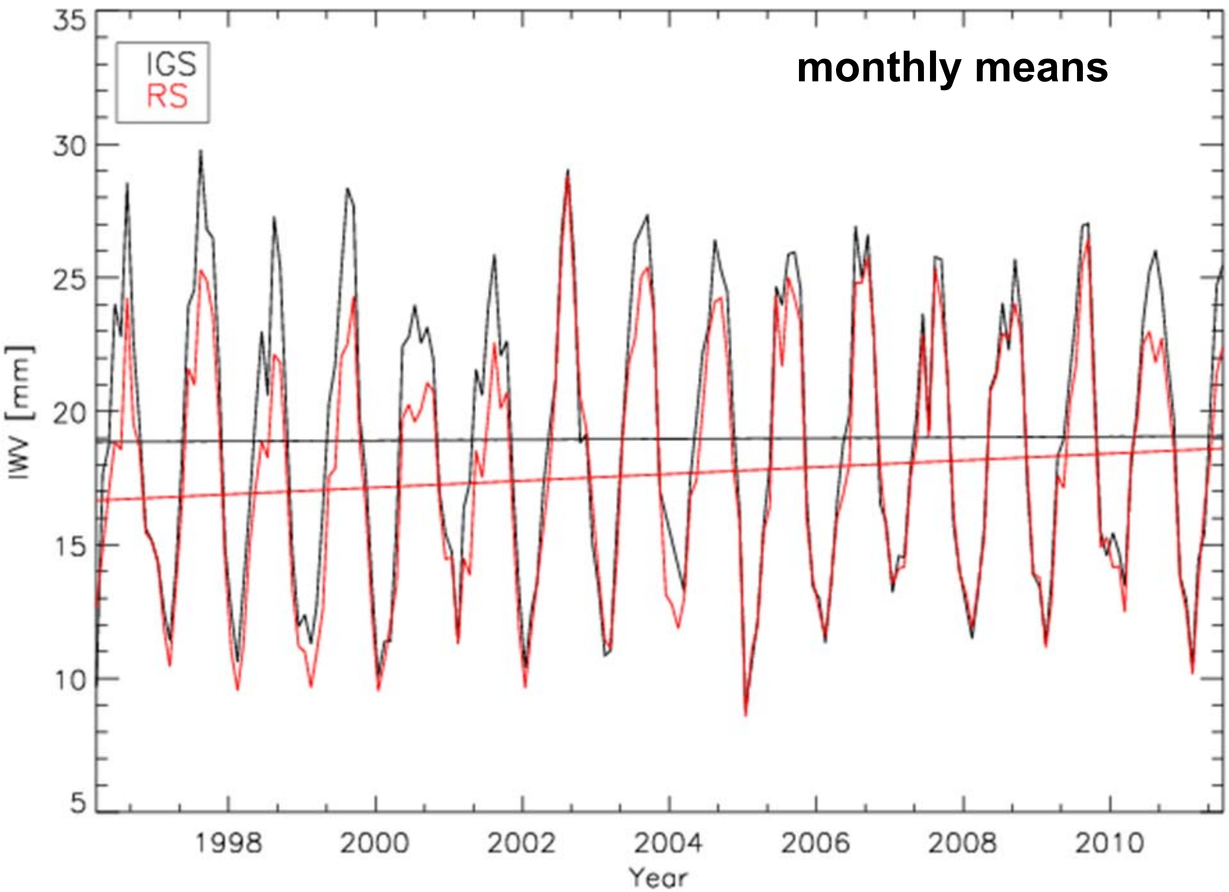
Uccle (Brussels), Belgium



	Altitude	Distance
IGS:	104 m,	IGS – RS = 0 km
RS:	100 m	

although overall good agreement, small difference in trend slope (-0.15 vs. –0.45 mm/dec)

Cagliari, Italy

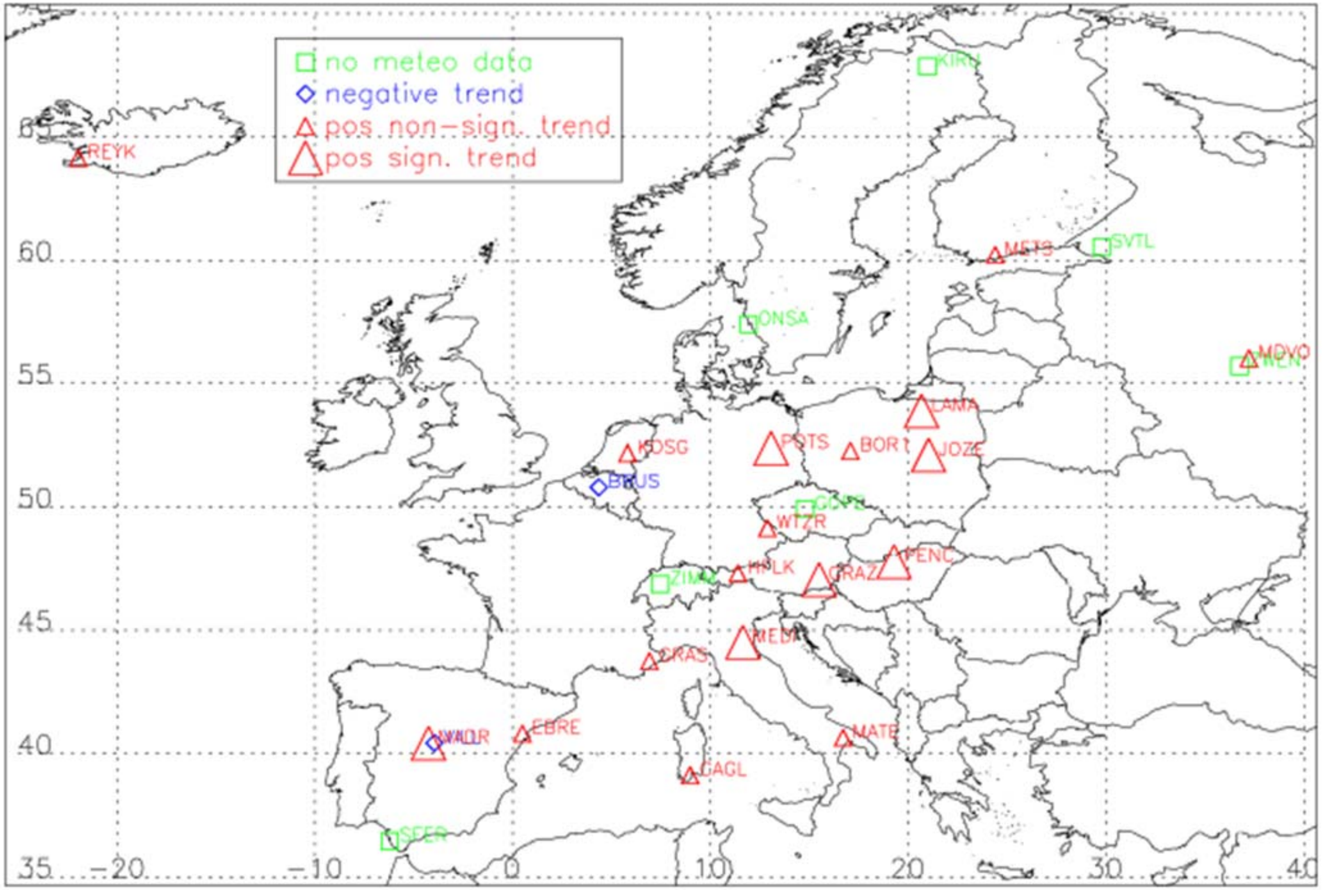


Altitude	Distance
IGS: 192 m,	IGS – RS = 14 km
RS: 5 m	

RS IWV < IGS IWV in early years:

- **not expected**
- **instrumentation change for RS?**
- **large difference in IWV trends (0.16 vs 1.29 mm/dec)**

Summary: all European IGS stations starting in 1995/1996



rather consistent picture: IWV ↑ , most significantly (> 0.5 mm/dec) in central Europe

trend difference in ZTD between 2 IGS stations near Madrid (both use the same meteo station data)

Brussels!

The end