COMPARISON AND ACCURACY OF INTEGRATED WATER VAPOUR FROM GROUND BASED GPS

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Mathematical Geodesy and Positioning

Comparison and accuracy of integrated water vapour from ground based GPS

- GPS Water Vapour Meteorology Project
- GPS network and processing strategy
- Conversion of ZWD into integrated water vapour (IWV)
- Comparison with radiosonde, radiometer and model forecasts
    - day break problem
    - diurnal trends
- Alternative processing schemes
    - using predicted orbits with orbit relaxation
    - comparison with Bernese software

GPS Water Vapour Meteorology Project (1)

- Supported by Netherlands Remote Sensing Board (BCRS)
- Objectives
  - set up of an infrastructure for the acquisition, storage and processing of GPS-IWV data in the Netherlands
  - make an assessment of the accuracy of GPS-IWV data
  - investigate the usefulness of GPS-IWV data for weather forecast models and climate research
  - study the feasibility of real-time processing of GPS-IWV data
- Started 1996, completed in 1998 (final report January 1999)
- Database continues to be filled

GPS Water Vapour Meteorology Project (2)

Participants

- Royal Netherlands Meteorological Institute (KNMI), De Bilt

  Henk Klein Baltink, Henrico Derks*), Andre van Lammeren

- Delft University of Technology (TUD), Delft

  Andre van der Hoeven, Ronald Stolk*), Boudewijn Ambrosius

  Hans van der Marel, Frank Kleijer

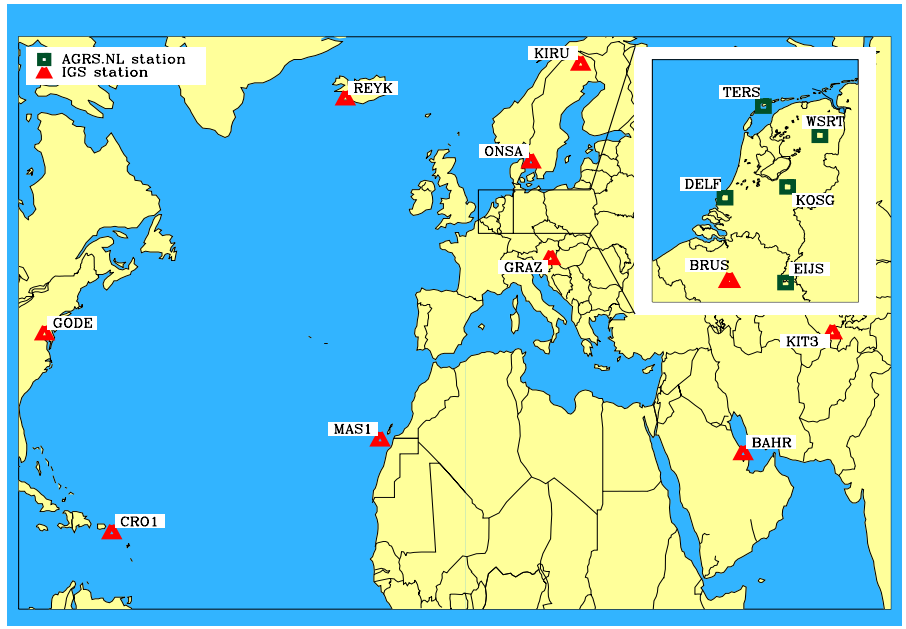
- Survey department of Rijkswaterstaat (MD), Delft

  Anton Kosters

The data from the radiometer were processed by Suzanne Jongen (Eindhoven University of Technology)

GPS Network and processing strategy (1)
- the GPS network -

The GPS network has at its core the AGRS.NL network extended with Brussels.

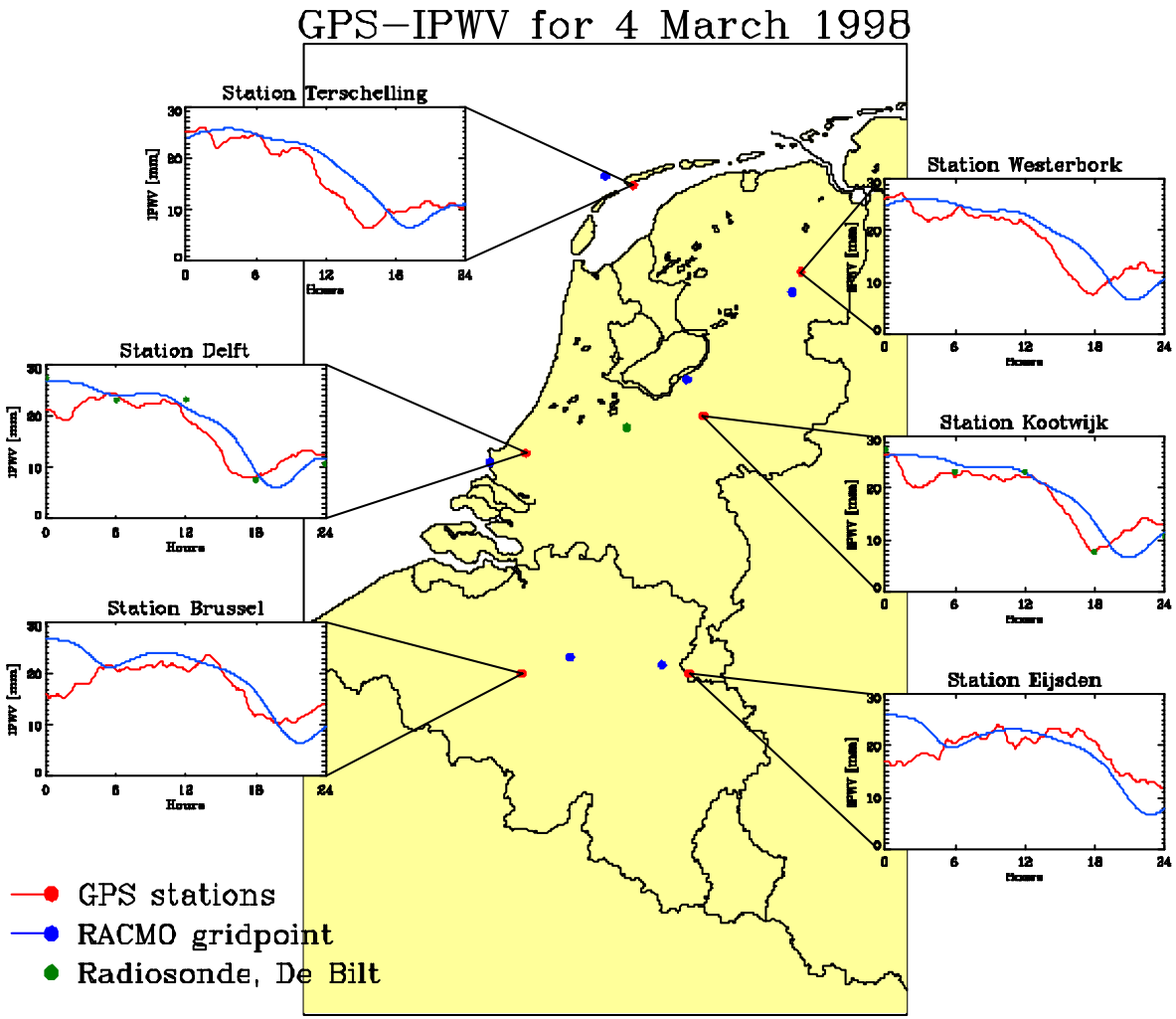


The purpose of the distant IGS stations is to facilitate:
1. Absolute IWV estimation
2. Orbit relaxation for the near real-time processing

GPS Network and processing strategy (2)
- GPS processing strategy -

- GPS data is processed by Delft University of Technology using the GIPSY software of JPL
  - 10^0 elevation cut-off angle
  - IGS stations at periphery fixed (during orbit estimation)
  - orbit strategies
    - CODE rapid orbits w/ 2 day fit
    - predicted orbits w/ and w/o orbit estimation
  - 6 minute interval (24 hour batches, with 1-2 days delay)
  - residual troposphere zenith delays estimated every 6 minutes
    - random walk process with 0.17 mm/$\sqrt{s}$ for the drift parameter
    - using Lanyi mapping function
- The estimated total zenith delay is converted to IWV at the KNMI using surface pressure and temperature

GPS Network and processing strategy (3)
- Display of IWV results on internet -



http://www.knmi.nl/onderzk/atmoond/GPS

Conversion of ZWD to integrated water vapour (1)
- the conversion factor Q(Tm) -

The zenith total delay (ZTD) is converted to integrated water vapour (IWV) using the surface pressure and mean temperature T_m

$$ZWD = ZTD - ZHD(P_s, \varphi, h)$$

$$IWV = ZWD / Q(T_m)$$

with

$$Q(T_m) = 10^{-6} \rho_w R_v (k_3 / T_m + k_2^{'})$$

and

$$T_m = 0.673 T_s + 83.0$$

derived from the surface pressure temperature T_s. The accuracy of the conversion factor (~6.5) is 2% if computed from surface temperature.

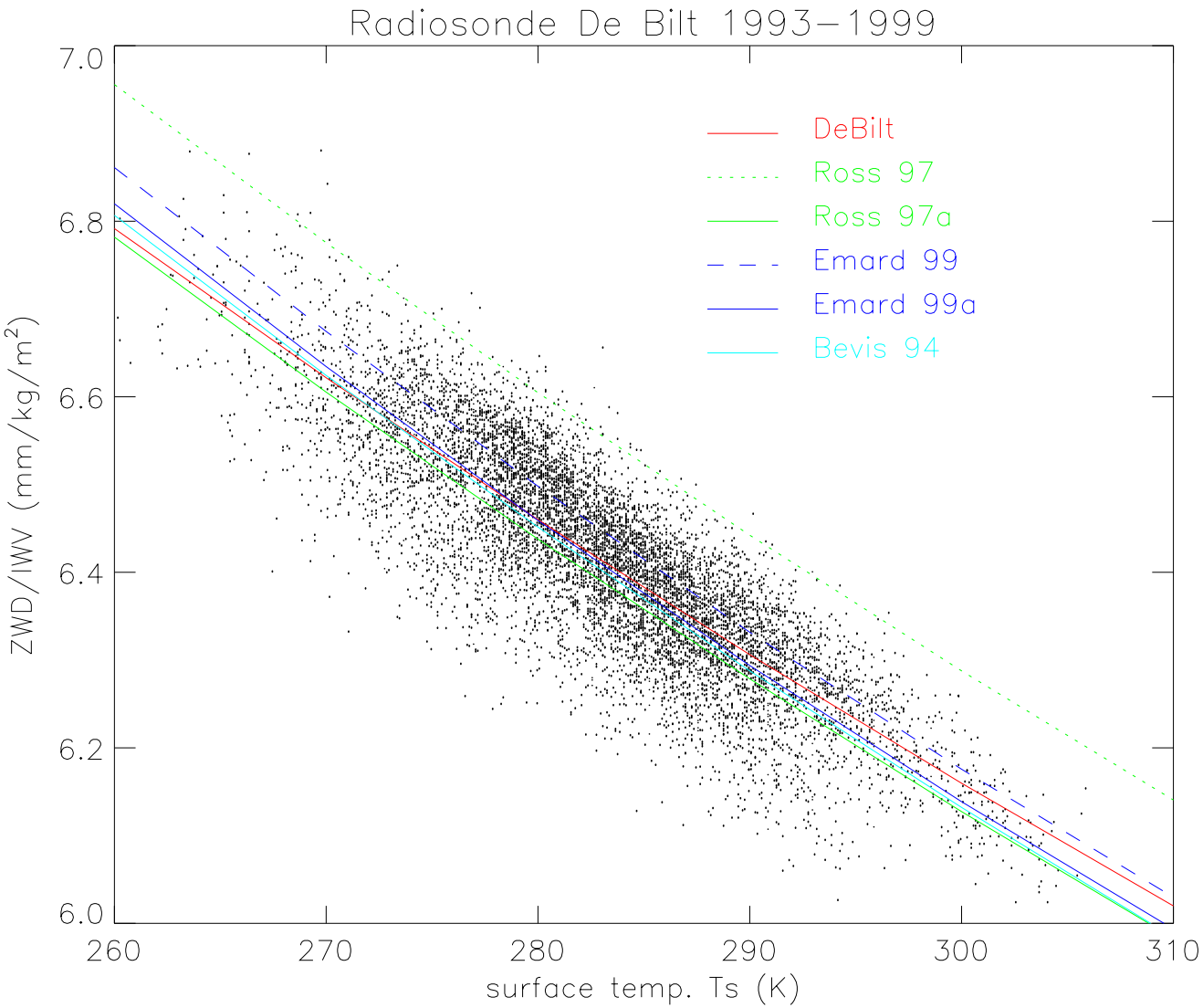
The mean temperature relation is different from Bevis et al. (1992)

Conversion of ZWD to integrated water vapour (2)
- analysis of radiosonde data at De Bilt -

- Radiosonde at De Bilt
  - Vaisala RS80 (accuracy 0.2^0C in T, 0.5 hPa in P and 2% in RH)
  - launched four times daily (approximately 0h, 6h, 12h, 18 h UTC)
  - data stored at 10s intervals (resolution in lower atmosphere 60-70 m)
- The radiosonde profile data is integrated to obtain the zenith wet delay (ZWD), integrated water vapour (IWV) and mean temperature (Tm)
- Q(Tm) from De Bilt agrees well with other published results
- Diurnal cycle present
- Reduction in the scatter can be achieved if Tm is related to the surface temperature at 80 m

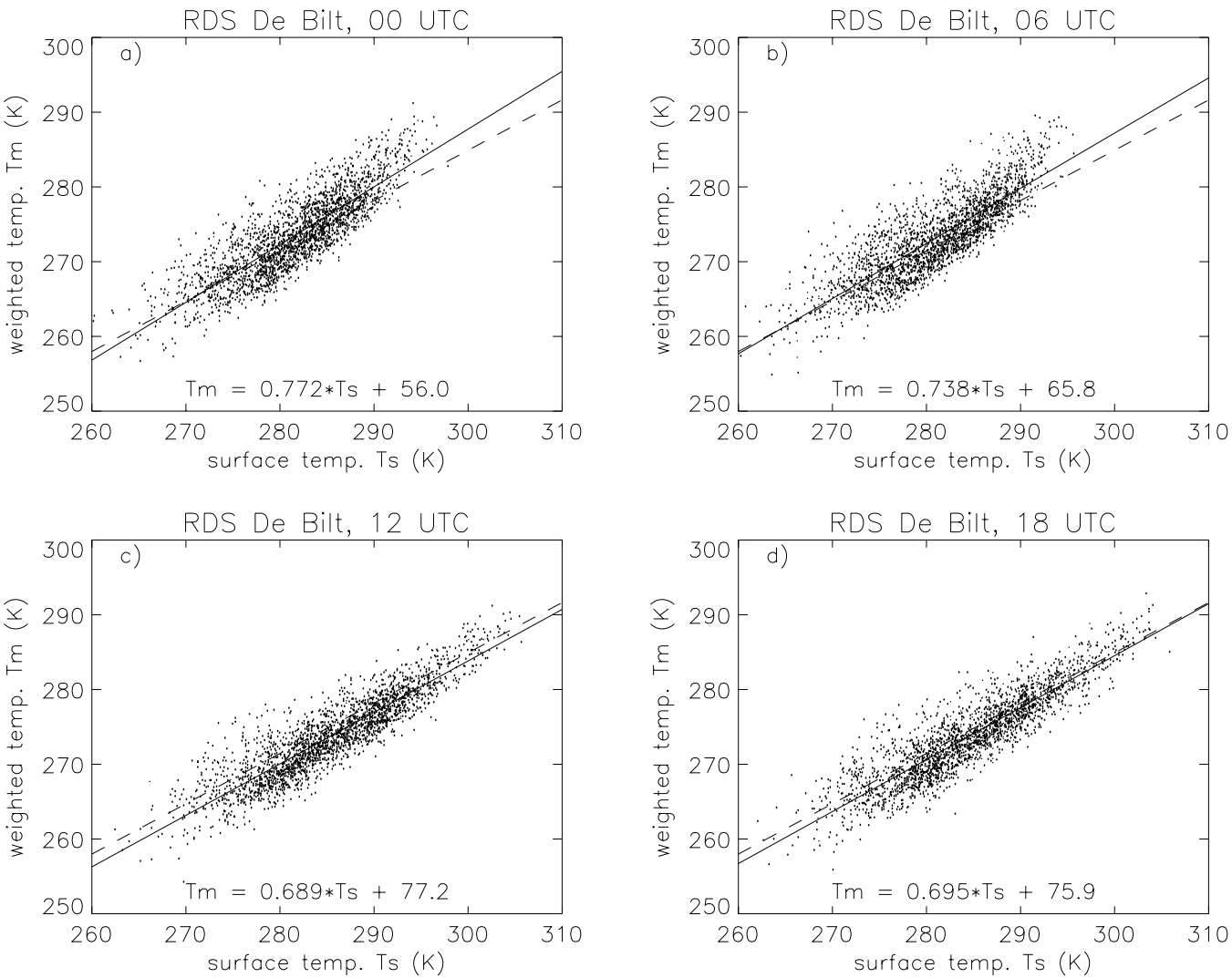
Conversion of ZWD to integrated water vapour (3)

ZWD/IWV from radiosonde data De Bilt 1993-1999

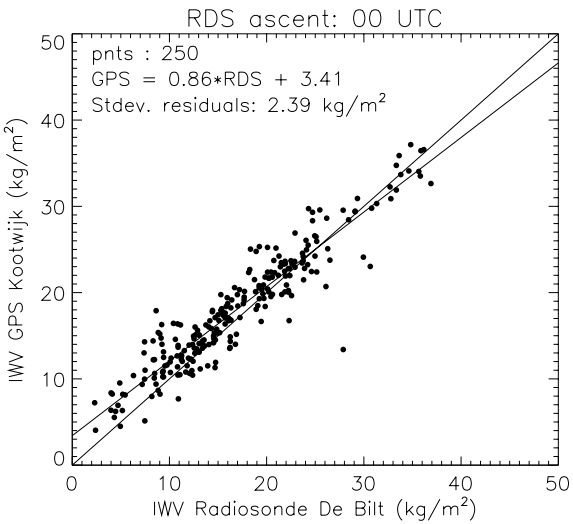


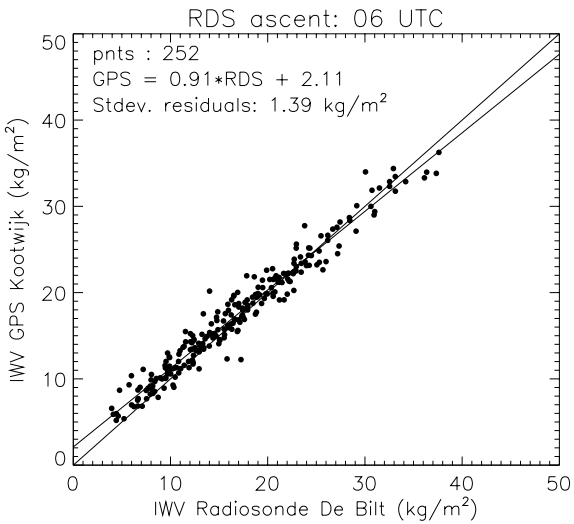
Conversion of ZWD to integrated water vapour (4)

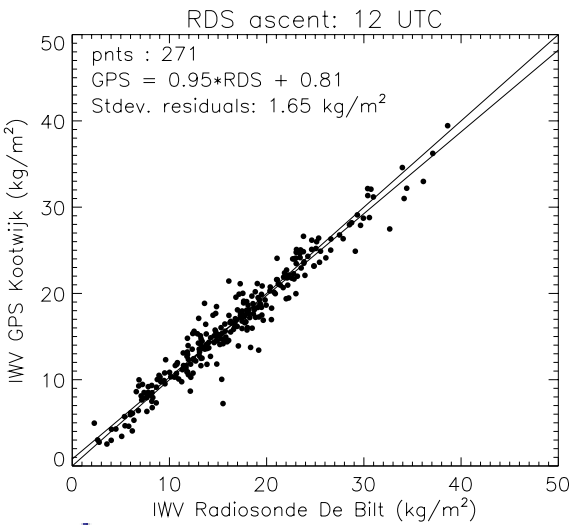
Tm from radiosonde data De Bilt 1993-1999

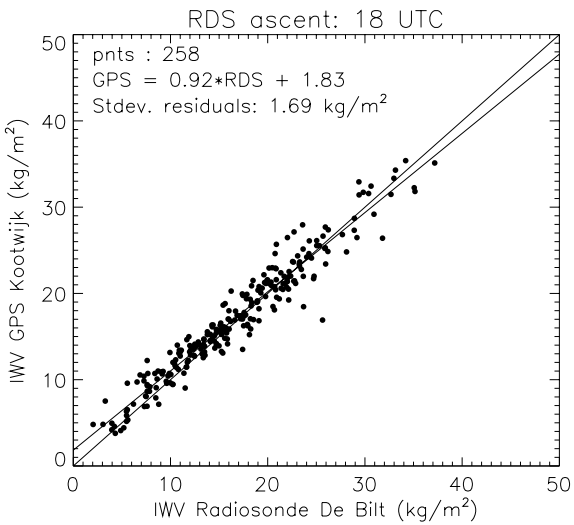


Comparison of GPS-IWV with radiosonde data (1)
Kootwijk(GPS) - De Bilt(RDS)









Operational processing (1998)

Radiosonde De Bilt
- Kootwijk 42 km NE
- Delft 56 km SW

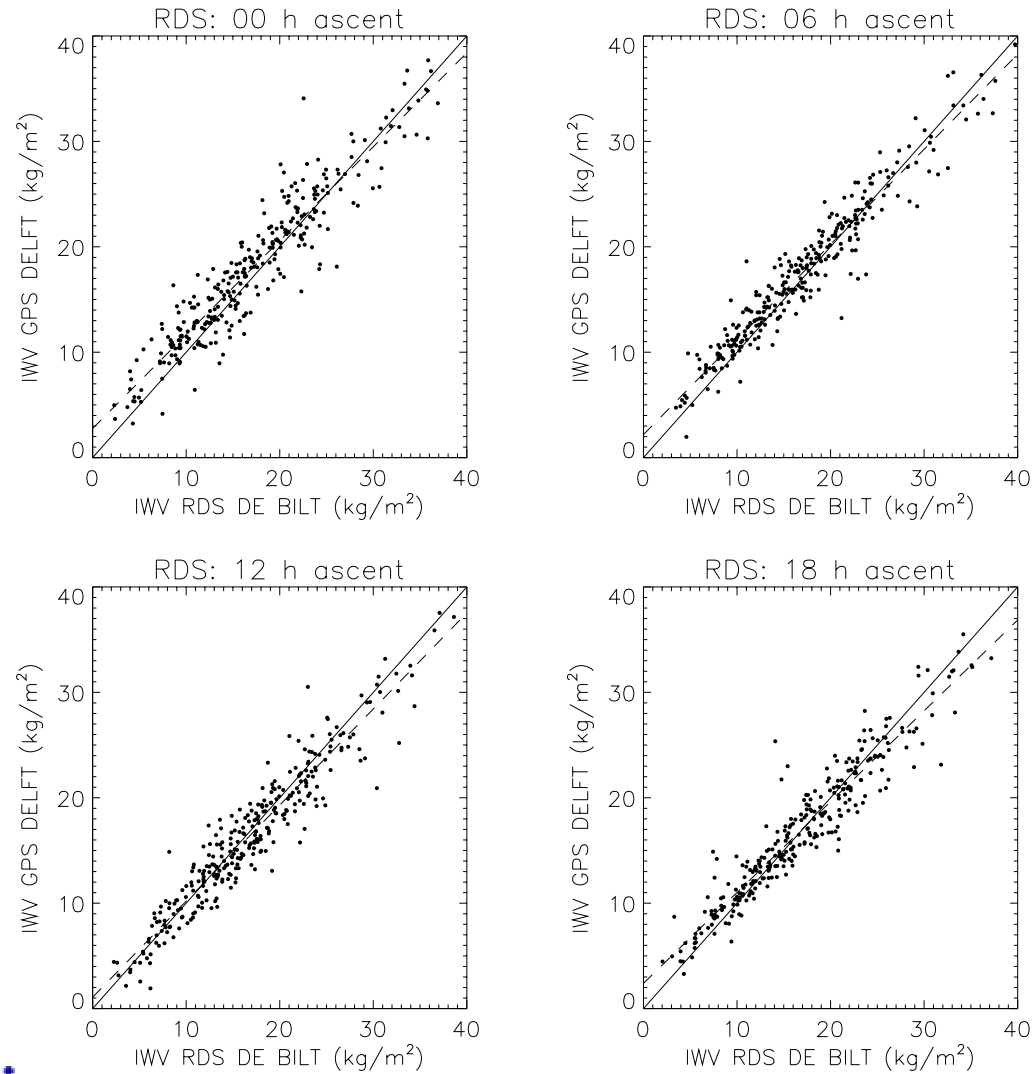
Launches at 0h, 6h, 12h and 18h UTC

St.dev. 1.4-1.7 kg/m^2 , except at 0h launch (23:30 UTC) 2.4 kg/m^2

Problem at day-break

Comparison of GPS-IWV with radiosonde data (2)

Delft(GPS) - De Bilt(RDS)



Operational processing (1998)

Radiosonde De Bilt

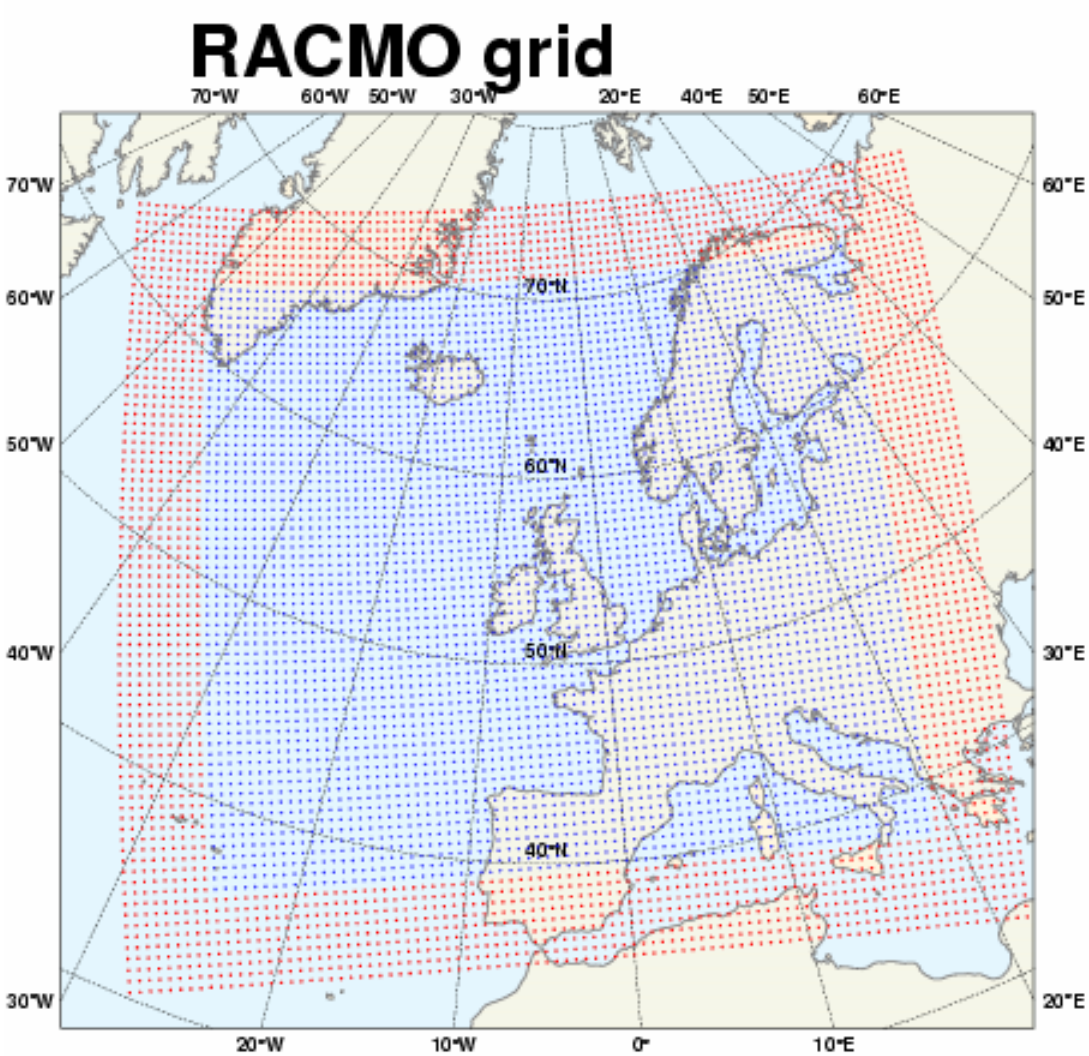
- Kootwijk 42 km NE
- Delft 56 km SW

Launches at 0h, 6h, 12h and 18h UTC

St.dev. slightly higher due to proximity to sea and larger distance to De Bilt

Confirms previous results

Comparison with RACMO model (1)
- RACMO model -

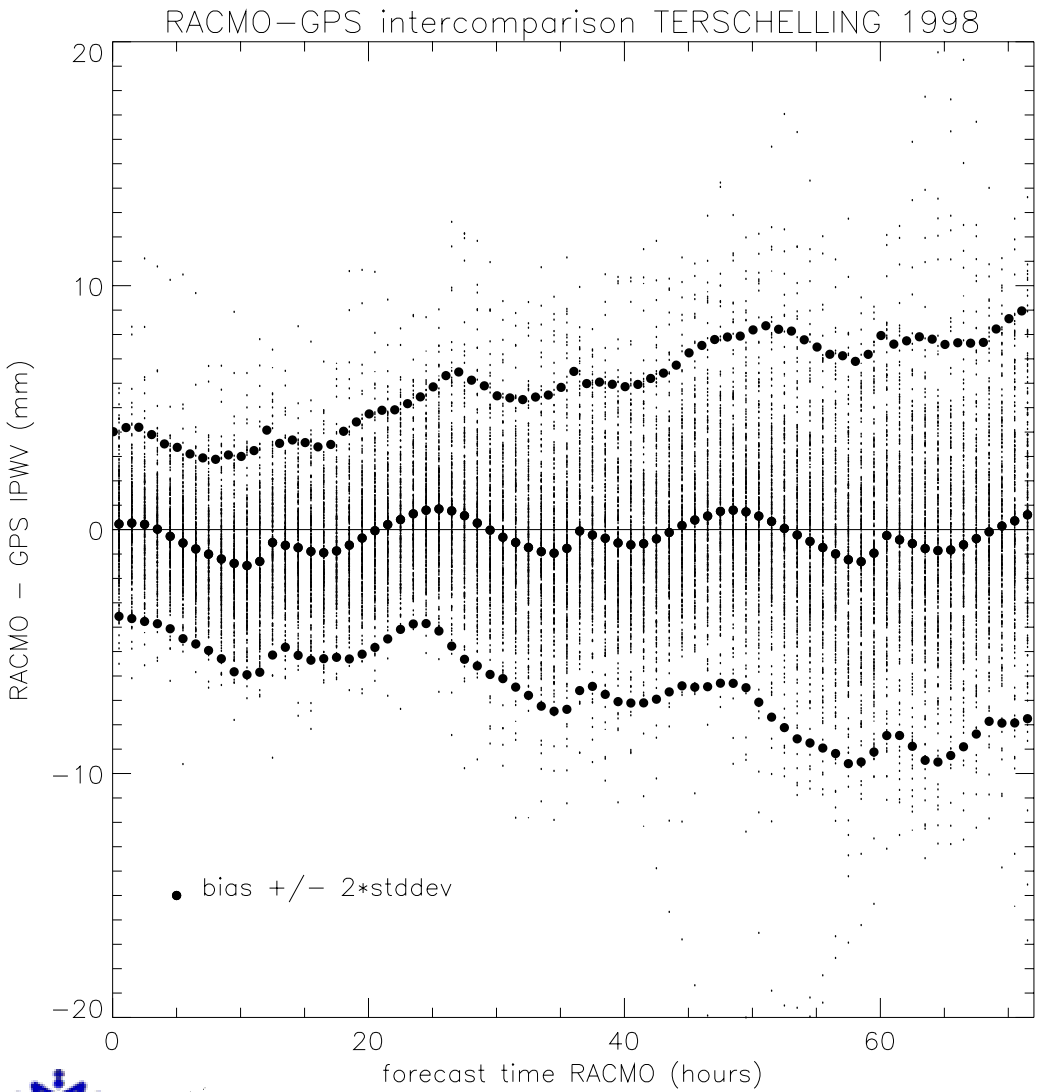


Regional Climate Model (RACMO)

- run once daily in forecast mode for a 72 hour period
- approx. 55 km grid size
- boundary and initialisation fields from ECMWF global model
- IWV calculated at 5 min interval

Comparison with RACMO model (2)

- as function of forecast time -

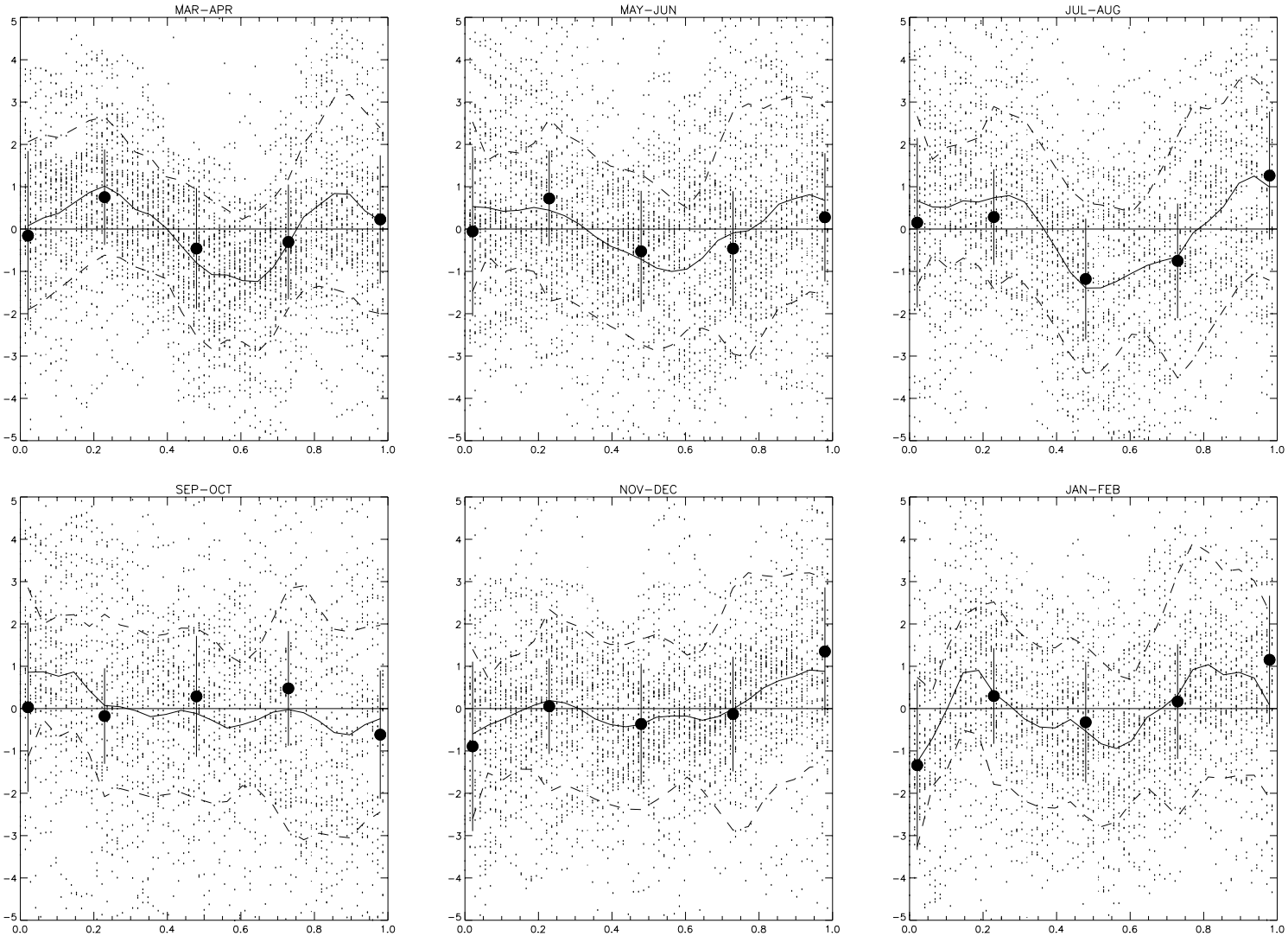


Comparison of GPS-IWV and RACMO-IWV

- hourly averaged data
- analysis as function of
  - forecast time
  - season
  - location
- standard deviation
  20min. averages:
  2.76 kg/m^2
  6 hour averages:
  2.45 kg/m^2

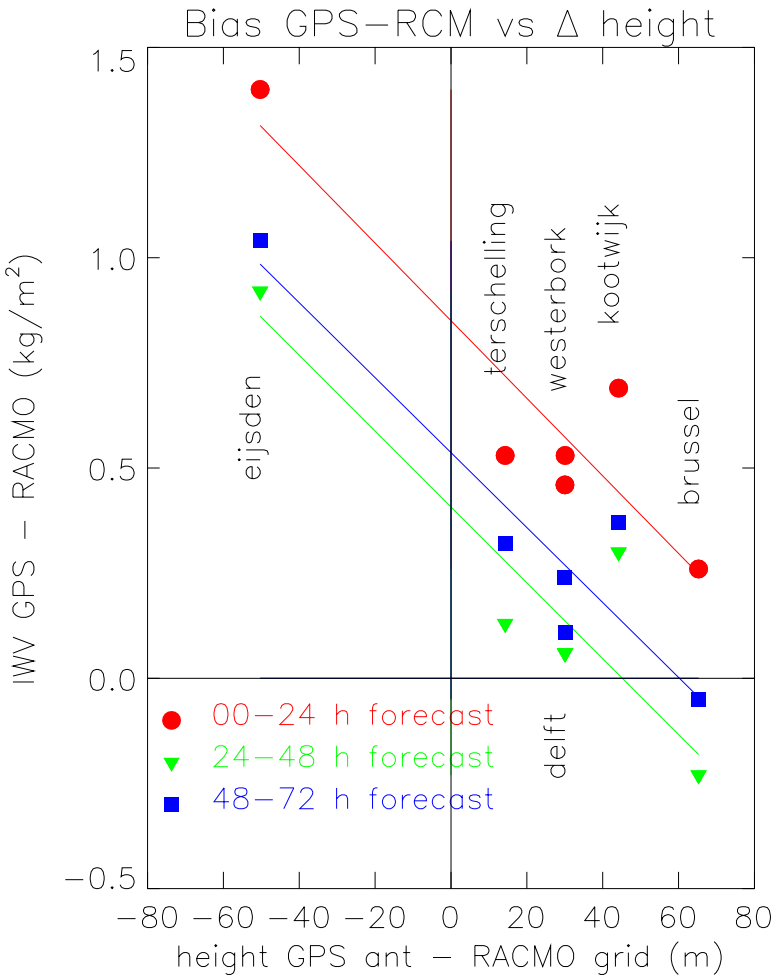
Comparison with RACMO model (3)

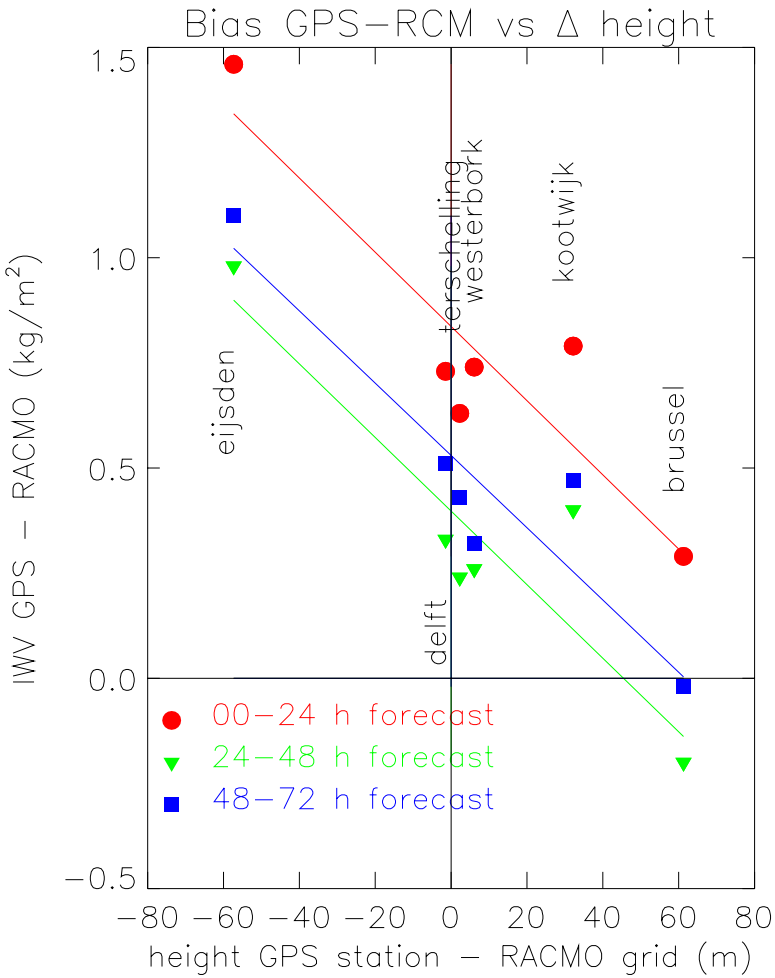
- as function of season and time of day -



Comparison with RACMO model (4)

- as function of location -

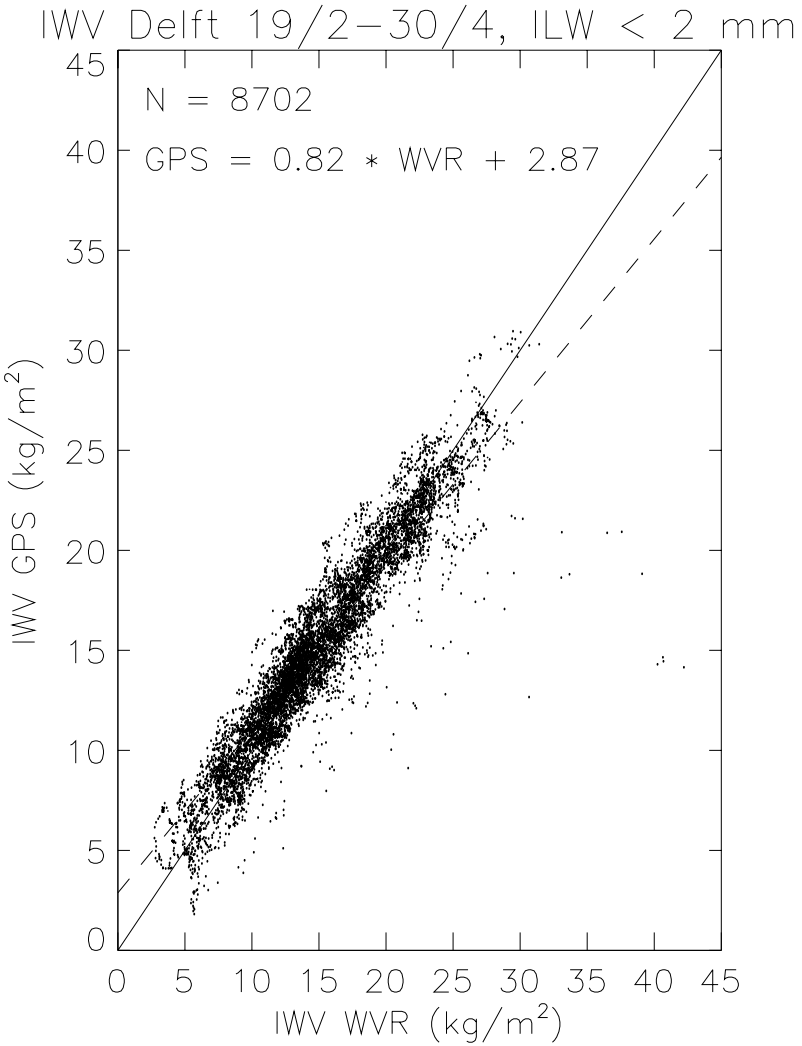


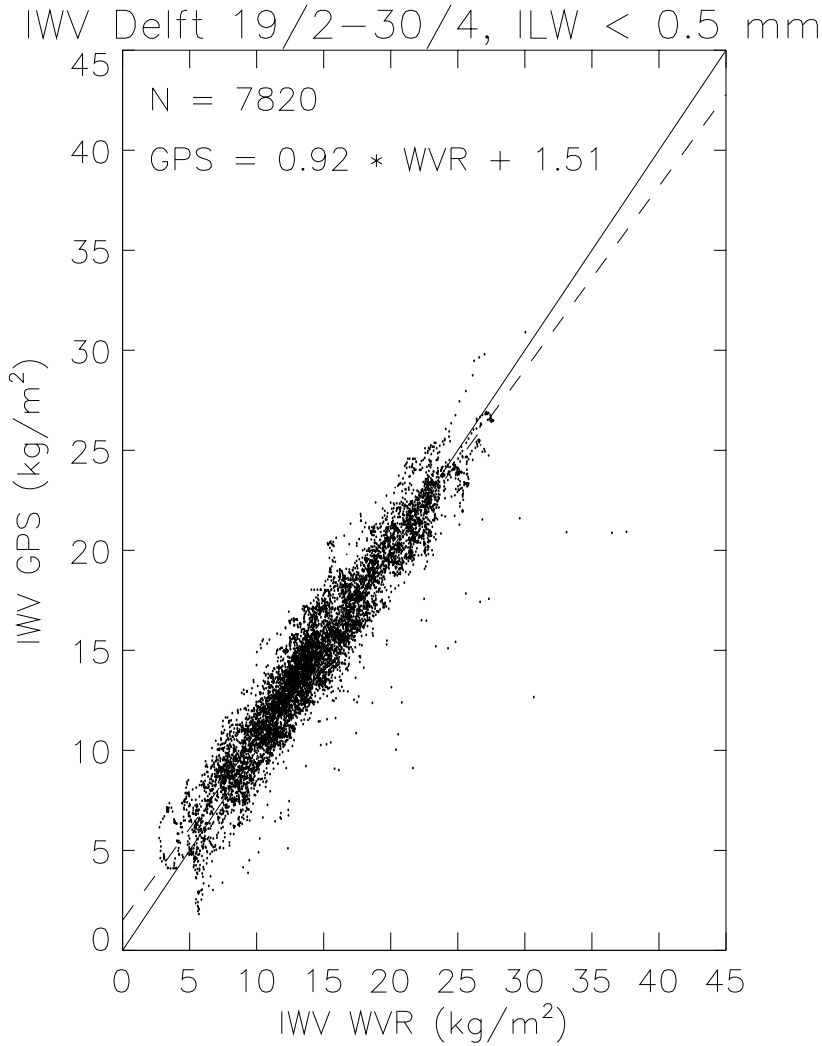


Comparison with radiometer data (1)

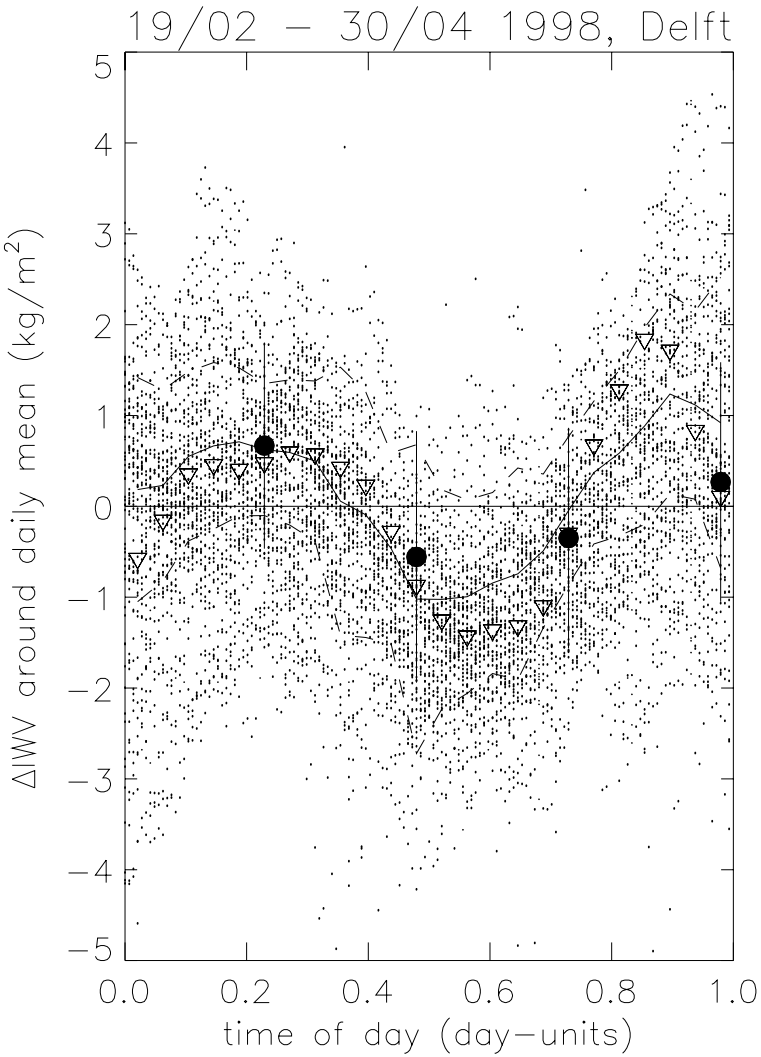
- Rescom Ka-1 21.3/31.7 GHz water vapour radiometer
- Located in Delft, at 1.5 km from GPS antenna, during
  - three CLARA-campaigns in 1996
  - two and half month period in 1998 (19 Feb. - 30 April)
- WVR-IWV data retrieved by TU Eindhoven
  - two different processing methods
    - linear regression method with manufacturer's constants (not used)
    - non-linear matched atmosphere using surface meteo and, if available, information on cloud base and height (best results)
  - WVR sampled at 1 sec, averaged over 60 sec
  - 0.5 mm threshold for liquid water content
  - tipping curve calibrations performed

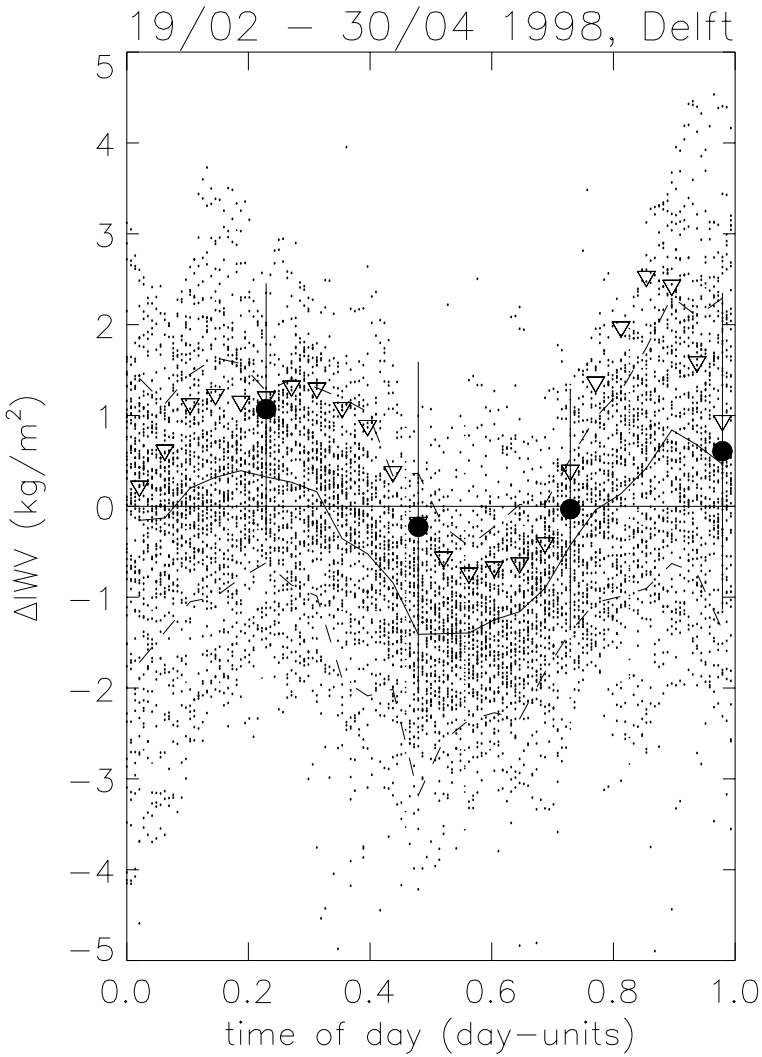
Comparison with radiometer data (2)



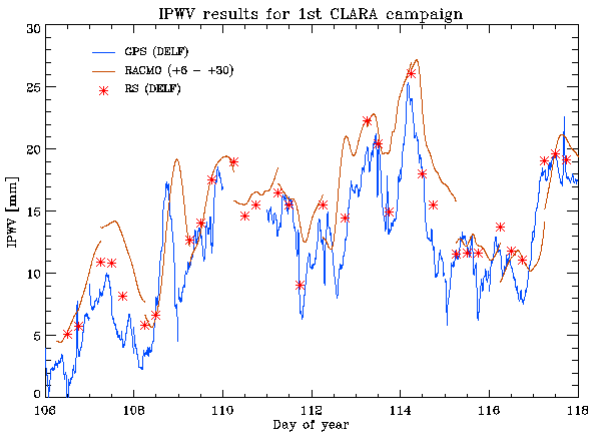


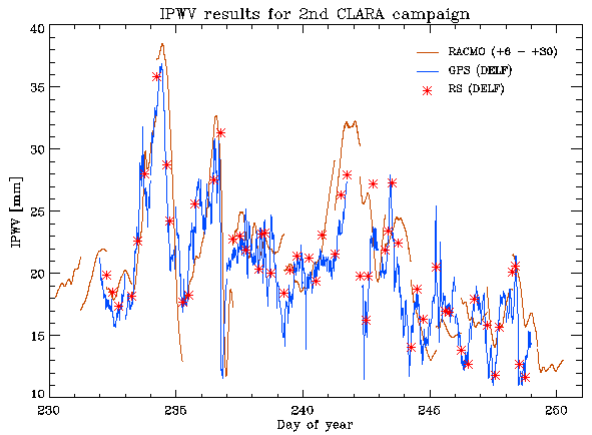
Comparison with radiometer data (3)

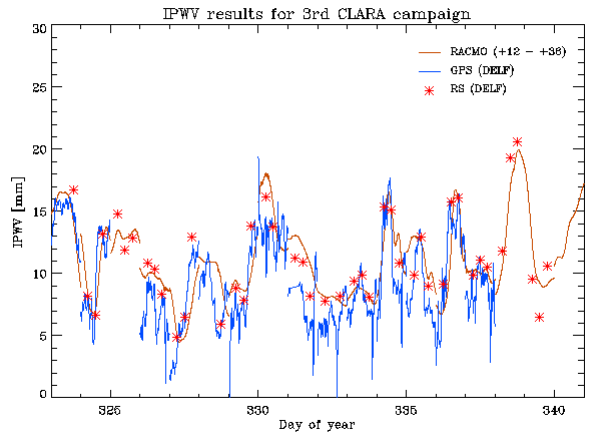


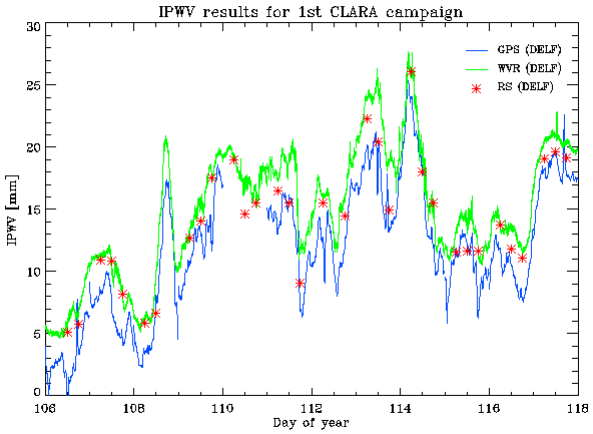


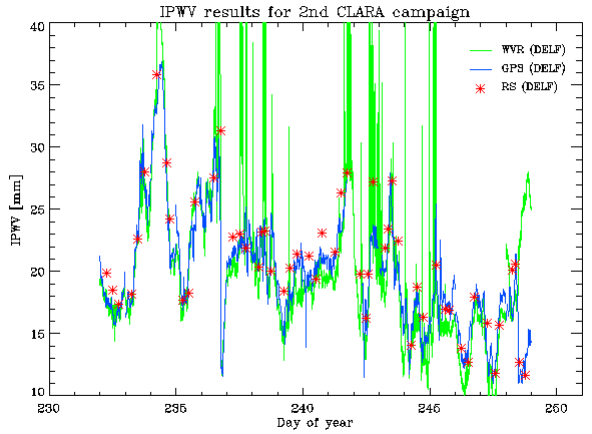
Comparison with radiometer data (4)
- CLARA campaigns -

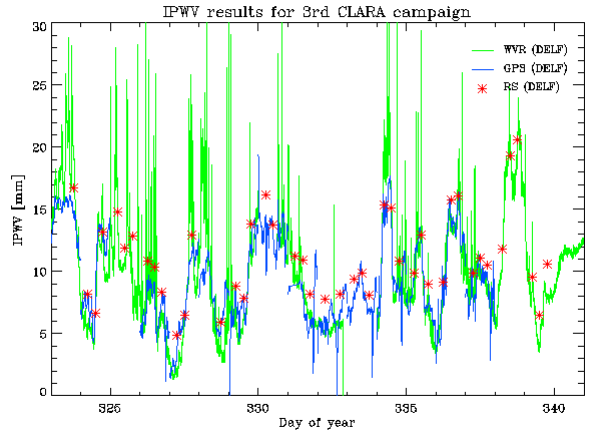












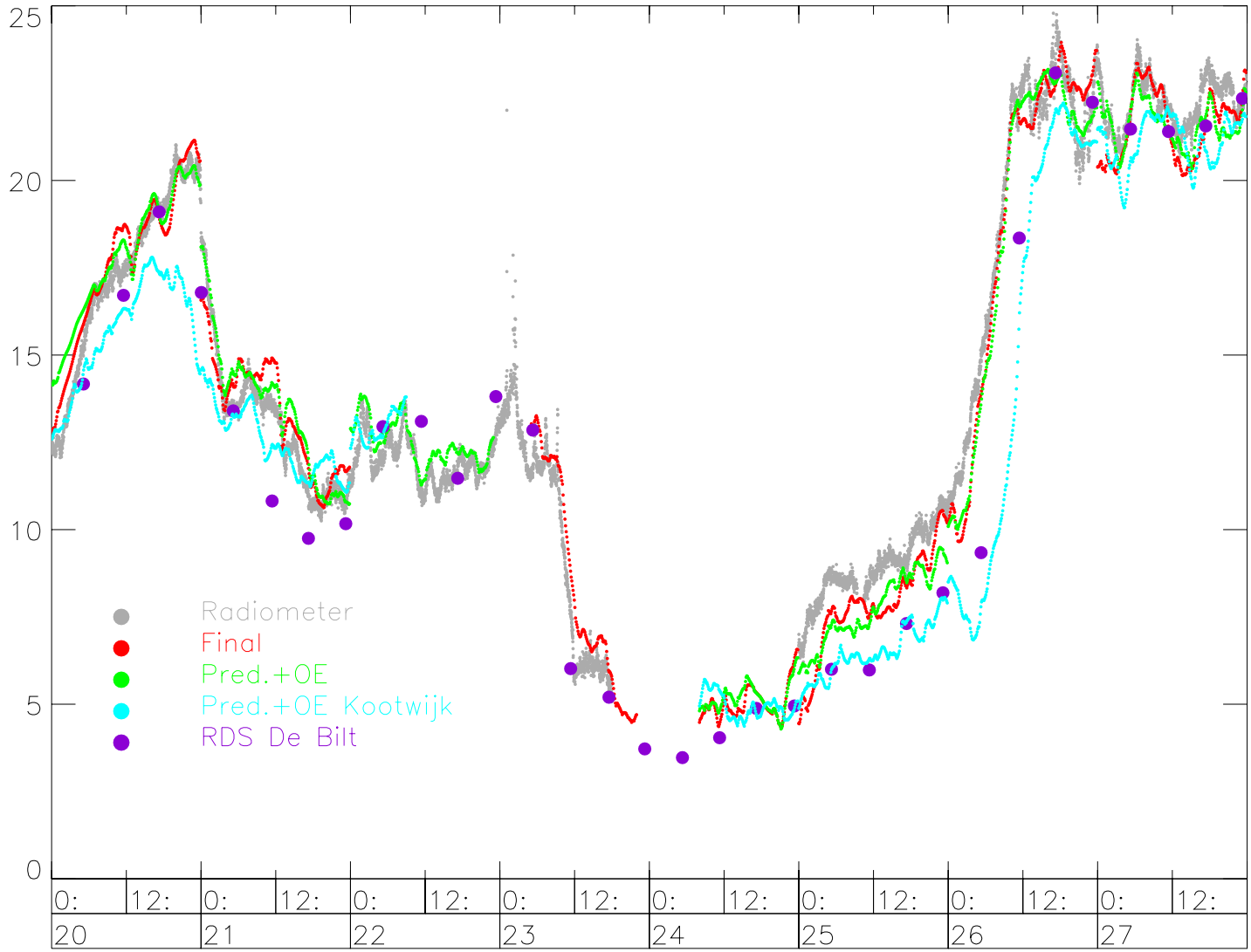
Alternative processing schemes (1)
- GPS testweek -

- Comparison of the operational processing with radiosonde, radiometer and RACMO model showed
  - jumps at the day-break
  - daily, season dependent, trend
  - GPS underestimates IWV by a factor 0.92, which is partially compensated by a positive bias of 1.5-1.6 kg/m^2

- A special week (20-27 March 1998, day 79-85) was selected to
  - study the day break (and other) problem(s)
  - study the feasibility of near real-time estimation using predicted orbits and orbit relaxation
  - compare GIPSY and Bernese software v4.0

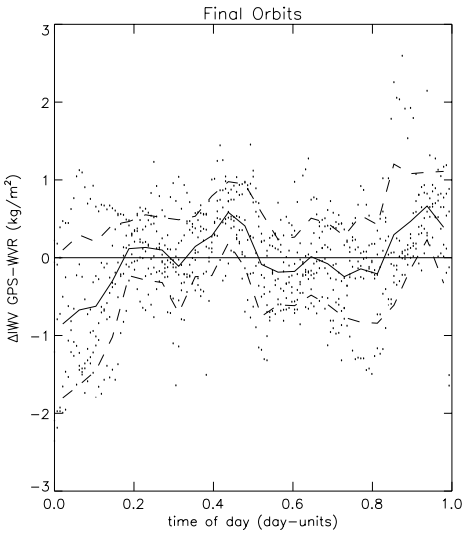
Alternative processing schemes (2a)

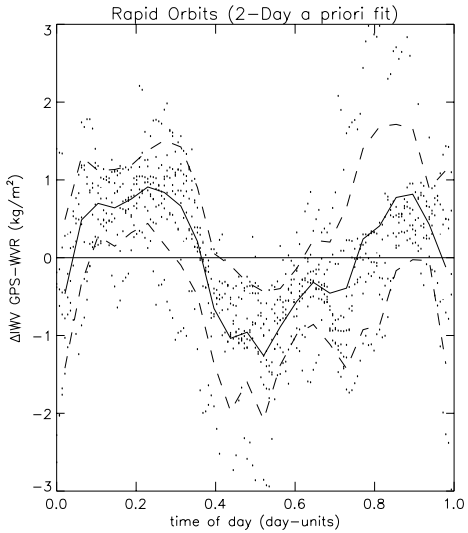
- improvement by orbit relaxation -

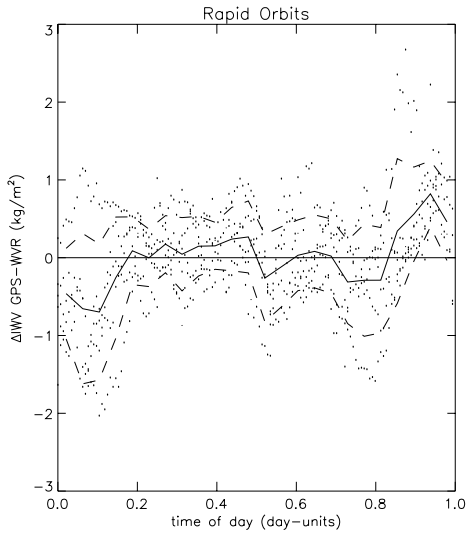


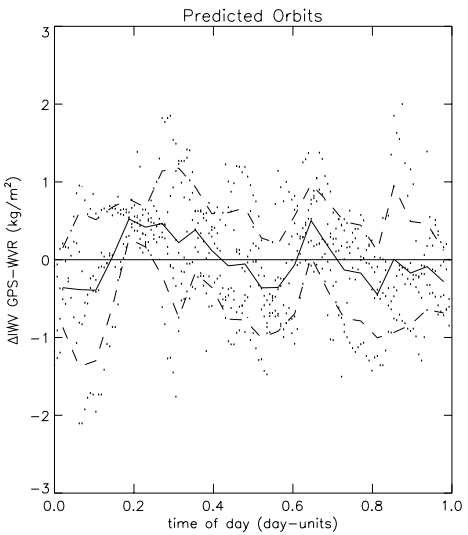
Alternative processing schemes (2b)

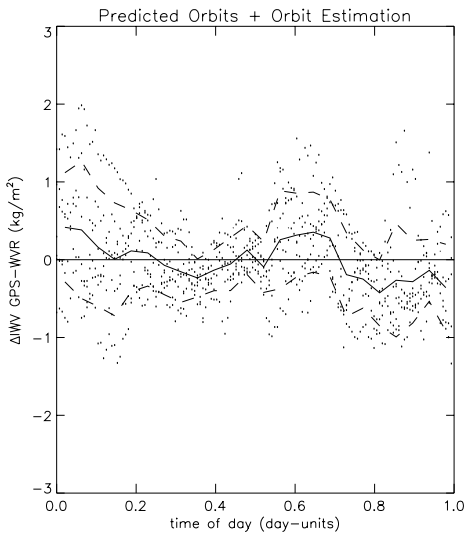
- comparison of various orbits -











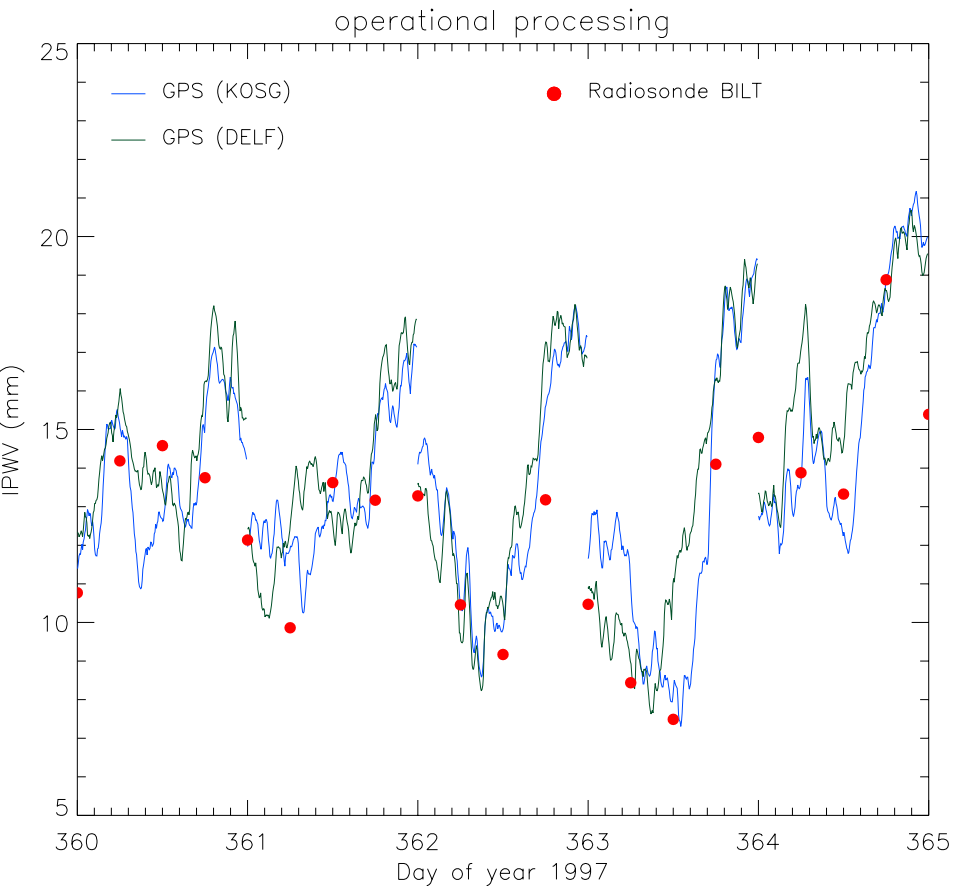
ΔIWV around daily mean difference

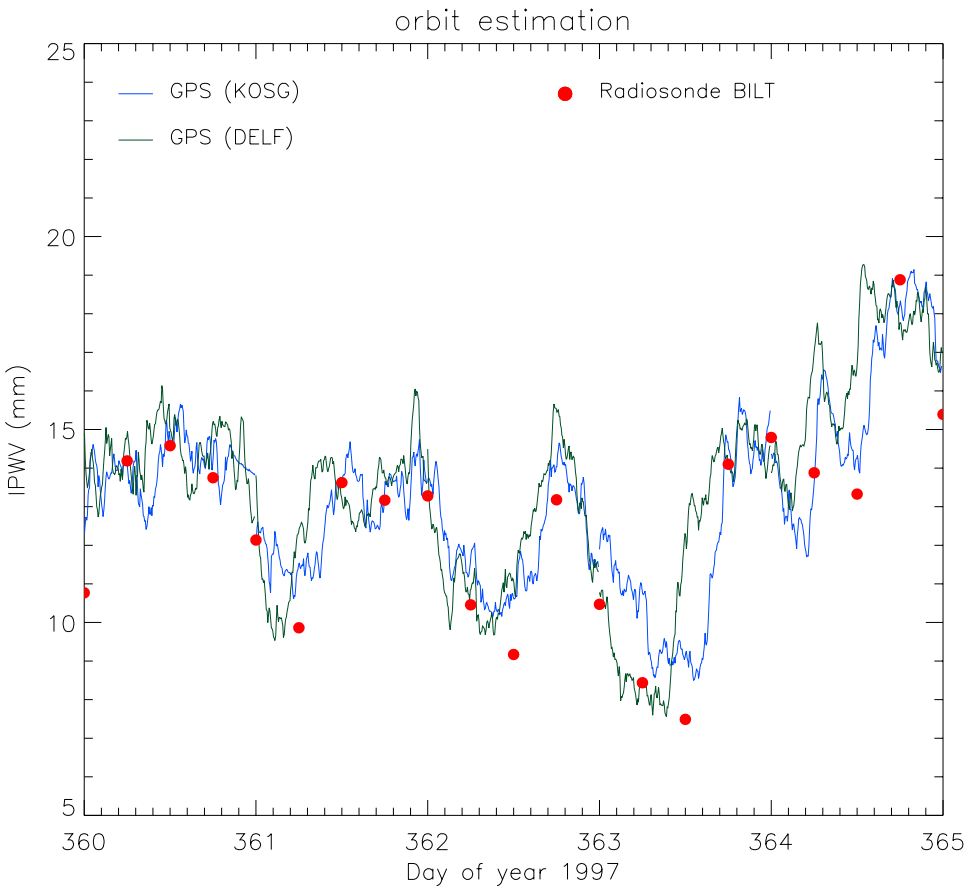
GPS and WVR: 10 minutes averaged data

Location Delft, 20−27 March 1998

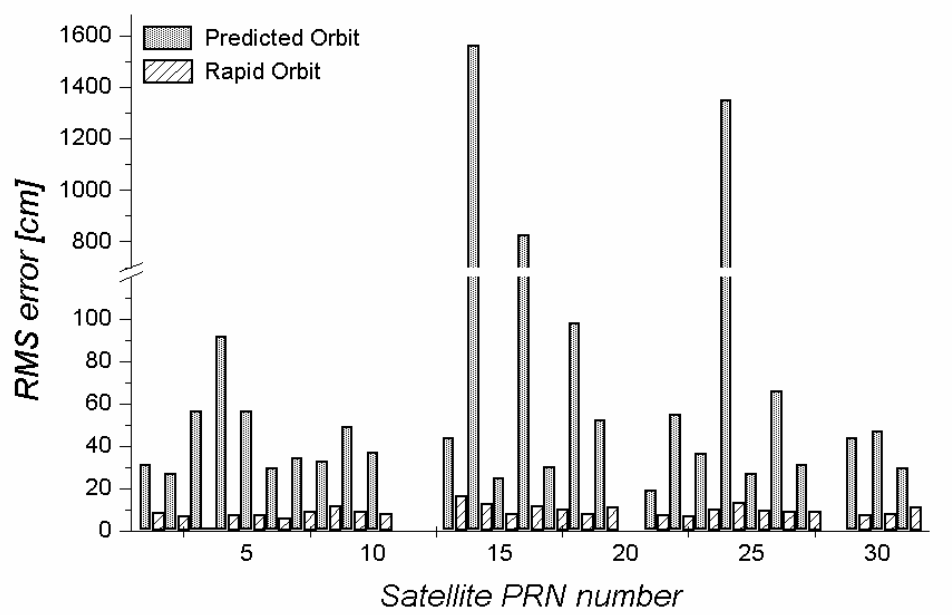
Alternative processing schemes (2c)

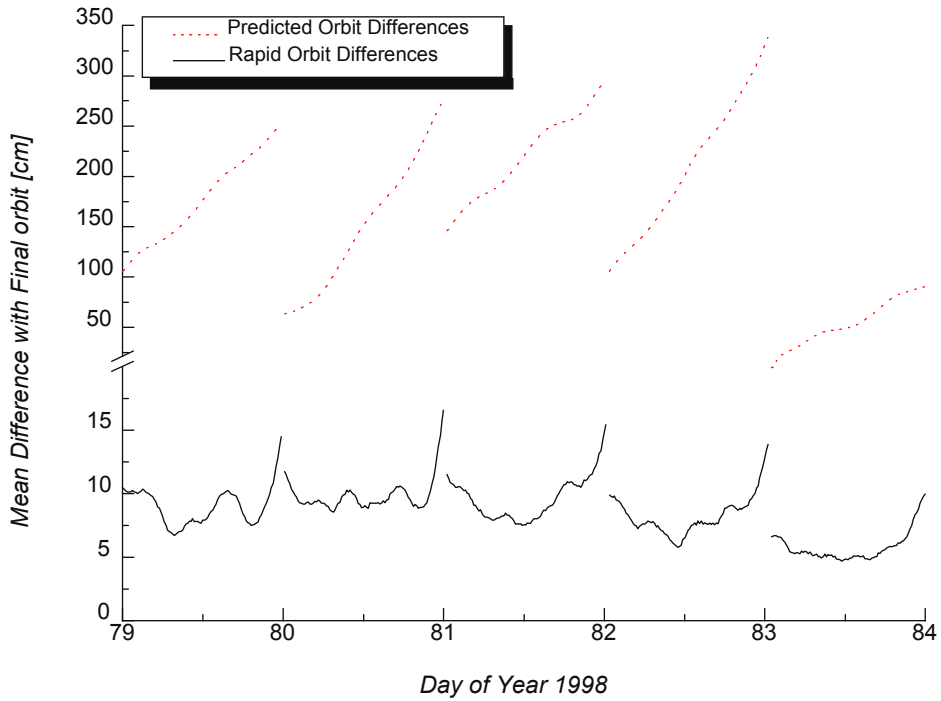
- extreme case of day breaks -



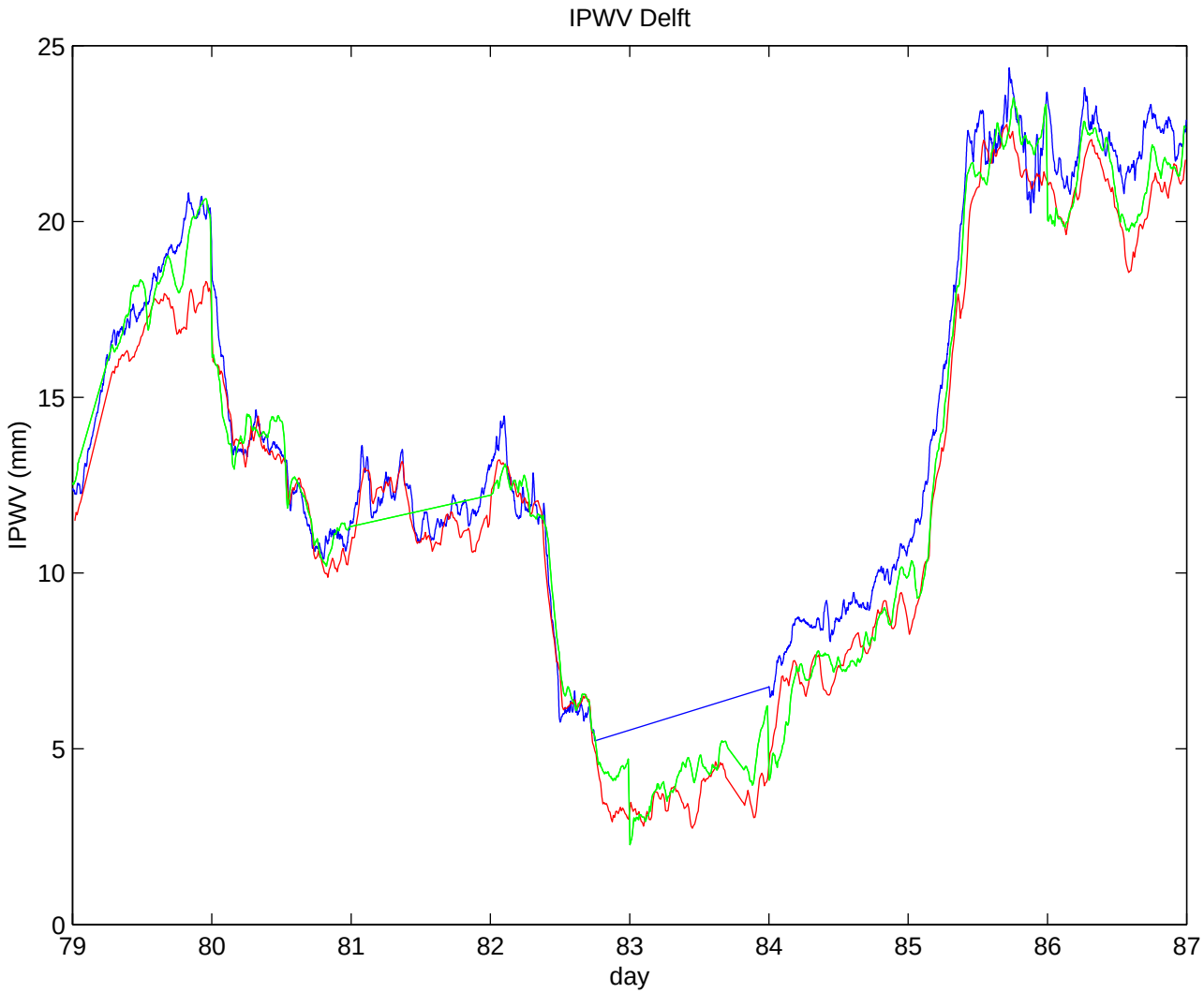


Alternative processing schemes (2d)
- Orbit accuracy -





Alternative processing schemes (3)
- comparison with Bernese s/w -



Conclusions

- Comparison of the operational processing with radiosonde, radiometer and RACMO model showed
  - jumps at the day-break
  - daily, season dependent, trend
  - GPS underestimates IWV by a factor 0.92, which is partially compensated by a positive bias of 1.5-1.6 kg/m^2
  - st.dev. of the difference is 1.4-1.7 kg/m^2 (except at 0h UTC)
- The main cause for the day breaks and the diurnal trend is the way in which we processed the (rapid) orbits
- Experiments using predicted orbits with orbit relaxation showed
  - improvement in the day breaks and diurnal trends (under further investigation)
  - feasibility of near real time estimation