MWR data processing - from raw data to meteorological products

EG-CLIMET Sub Working Group (SWG) meeting
14-16 March, 2011 - Zülpicher Straße 49a, Universität zu Köln, Köln, Germany

Rationale:
This SWG meeting aims at providing indications on best practice procedures for the processing of microwave radiometer (MWR) and MWR profiler (MWRP) data. In particular, this SWG introduces software tools developed at University of Cologne for reprocessing MWR data and providing quality flagged MWR observation and retrieval data sets.

List of attendees:

	Name	Acr.	Status	Funding	Country
1.	CIMINI Domenico	(CD)	MC-substitute member	yes	IT
2.	CZEKALA Harald	(CH)	MC-substitute member	not needed	DE
3.	ENGELMANN Ronny	(ER)	Expert	yes	DE
4.	FERRARIO Massimo Enrico	(FM)	Expert	yes	IT
5.	GUELDNER Juergen	(GJ)	WG member	yes	DE
6.	HAEFELE Alexander	(HA)	MC-substitute member	yes	CH
7.	KLEIN-BALTINIK Henk	(KH)	Expert	yes	NL
8.	LOEHNERT Ulrich	(LU)	MC member	not needed	DE
9.	MARTELLUCCI Antonio	(MA)	Expert	yes	NL
10.	PACE Giandomenico	(PG)	WG member	yes	IT
11.	POSPICHAL Bernhard	(PB)	Expert	yes	DE
12.	SEIFERT Patrick	(SP)	Expert	not needed	DE
13.	MEUNIER Veronique	(MV)	Expert	not needed	CA
14.	MASCHWITZ Gerrit	(MG)	Expert	not needed	DE

Agenda:

Day 1. 14 March h 13:00-18:00

a. Brief introduction
b. The MWR_PRO concept
    i. Reading of raw data formats
        1. currently supported: RPG, RESCOM
        2. planned: Radiometrics, Kipp&Zonen (review of raw data examples)
    ii. Quality control flagging
    iii. Multilinear regression retrieval application
    iv. Output data format

Day 2. 15 March h 09:00-18:00

a. Review and consolidation of MWR_PRO concept
b. Practical examples: reprocessing of real radiometer data
    i. Processing of user data.
c. On-line processing and quicklooks

Day 3. 16 March h 09:00-13:00

a. Review of achievements and results
b. Future needs and developments
c. Wrap-up and adjorn

INTRODUCTION

This is the second meeting related to MWRnet. 14 people from 5 countries attended. Minutes from MWRnet meetings will be made available on the EG-CLIMET (www.eg-climet.org) as well as MWRnet (http://cetemps.aquila.infn.it/mwrnet) websites.
Brief update on the MWRnet status: Since the last meeting, new members have joined MWRnet (from USA, Sweden, etc). A MWRnet presentation was given by Fabio Madonna at the GCOS Reference Upper Air Network (GRUAN) ICM3 meeting. GRUAN community showed large interest in MWRnet initiatives. Main questions from the GRUAN community were related to the products delivered in MWRnet and to the establishment of a network database. This clear interest has been shown an invitation to the MWRnet coordinators in joining the Task Team 5 of GRUAN (TT5) related to ancillary (to radiosondes) measurements. Moreover, a colleague from the GRUAN site in Beltsville (Maryland, USA) applied for joining MWRnet. Beltsville was one of the 4 GRUAN sites not part of MWRnet yet.

THE MWR_PRO CONCEPT

Ulrich Loehnert (University of Cologne) introduces MWR_PRO, a tool for processing MWR data from "raw" Tb to quality flagged Tb and retrieved atmospheric products.

MWR_PRO main features:

- Ingest MWR data (time, Tb, azimuth, elevation)
    1. So far: HATPRO, RESCOM
    2. Plans for: MTP5, MP3000
- Apply quality control and output quality flagged Tb (level 0)
    1. Manual filtering
        a. A manual edited file contains information periods that cannot screened otherwise (radome obstructions, radio-frequency interferences (RFI), mis-calibration,…)
    2. User defined thresholds
        a. Thresholds for unphysical Tb, IWV, LWP, Tz
    3. Rain flag
    4. House keeping
        a. Gives back one flag coming from internal sanity checks
        b. Channel checks (this rely on, e.g., response to noise diode input)
        c. Channel thermal stability
        d. Hot load sensors difference larger than 0.3K
    5. Plans for: channel cross-correlation
- Apply multi-linear regression (MLR) and output quality flagged retrievals (level 1-2)
    1. Simple and robust scheme: MLR based on radiosonde dataset with synthetic LWC(z)
    2. Data levels numbering (1-2) depends on the dimensionality of the retrieved variable
    3. MLR coefficients are pre-computed (currently not within MWR_PRO), relying on radiosonde climatology (~site specific)
    4. Options for bias correction (based on LWP<0 or clear-sky radiative transfer (RT) comparison, else…)
    5. Surface measurements can or cannot be included in the observation vector.
- Output
    1. Store level 0-2 data in NetCDF format
    2. Graphic quicklook of quality flagged

MWR_PRO suggested changes:

- Data levels

1. Level 0: raw data (uncalibrated voltages)
2. Level 1: calibrated Tb
3. Level 2: retrieval products
4. Level 2a: integrated values (IWV, LWP, ATT, WD)
5. Level 2b: profiles at single azimuth/elevation
6. Level 2c: boundary layer profiles

- NetCDF format
  1. Comply with the NetCDF Climate and Forecast (CF) Metadata Convention (http://cf-pcmdi.llnl.gov/)
- Quality Flag (QF)
  1. Include instrument as well as retrieval QF
  2. Maintain all QF throughout the processing, plus produce a lumped QF
  3. Add radiosonde-to-retrieval (including documented RT)
  4. Include channel cross-correlation; this could help identifying erroneous channels (as for example RFI which usually occur not to all channels)
- Quicklook graphics
  1. Avoid showing RH profiles, as these often show inconsistency with LWP
  2. Add another colour to the QF graphics, so to distinguish problems related with K- and V-band only
  3. Quicklook now are static; it would be useful to have dynamical zooming in/out (low priority)
- Towards OpenSource
  1. make a sharable version that can run without the need of IDL licence

OTHER PRESENTATIONS

Massimo Errico Ferrario (ARPAV, Italy)

- 5 years operational use of 4 radiometers (3 MTP5, 1 HATPRO) in Northeast Italy for
  - Meteorological weather forecast
  - Air quality monitoring and prediction
- Annual-mean data availability from 40% for HATPRO to nearly ~100% for MTP5
- Several method to verify quality MWR data (Thermal Homogenous Conditions in Po Valley, Daily Check, Pseudo Profiles with weather stations)
- Examples of
  - Data quality check methods (thermal homogenous conditions, daily check, pseudo profiles with weather stations)
  - combined plot of T(z) and RH(z) to help estimate type precipitation (rain/snow)
  - plot of dHinv (inversion altitude) and dTinv (inversion strength) to help air quality and pollutant dispersion
  - comparison with PM10 concentration
- Stability index (at different layers) computed with Brunt-vaisala frequency (BVF)
- Data from HATPRO and SODAR are coupled and ingested into RAOB software for forecast indices computation
- A case study to evaluate the ability to detect atmospheric lids by MWR
- use of MWR data for comparison with NWP model (COSMO) output
- use of MWR data for mixing layer height calculation and comparison with radiosonde data

Juergen Gueldner (DWD, Germany)

- Long-term (~10 years) observations at Lindenberg (D)
- Retrieval method used: Neural Network (NN), best linear unbiased estimation, observation-based statistical regression

- Observation-based statistical regression (OSR). Applied to:
  - MWRP (12-chan from 22-59 GHz); FTIR
  - Results from about 3 years (10-min mean values are archived)
  - rms with respect to radiosondes (~600 cases)
  - OSR shows the minimum bias (for both T(z) and WV(z))
- Channel biases:
  - Channel biases range from -5 to 2 K
  - Possible reasons: different altitude of MWR/radiosonde, absorption model, instrument calibration, etc…
- Results from LUAMI (Lindenberg Upper-Air Method Intercomparison)
  - Motivation of LUAMI
    - Get NWP people interested and trustable about a MWR network
    - Demonstrate comparable results at different sites and site-independent information
  - 8 stations took part to LUAMI for 1 month
  - Difference between MWRP and Local model
    - IWV (also from GPS)
    - T(z) and WV(z) at 500-1000-2500 m
  - Harmonized retrieval
    - A regression based on NWP forecast-data (REGmod)
    - COSMO was used as the NWP model (COSMO data are virtually available for anytime, anyplace in Europe).
      - REGmod effectively eliminates problems such as
        - Biases in MWRP channels
        - Absorption model uncertainty
        - Site climatology
      - But on the other hand, REGmod could
        - Mask atmospheric features may be missed by NWP, as for example:
          - Persistent temperature inversions
          - Temp/IWV/LWP biases in NWP

Ulrich Lonhert (University of Cologne, Germany)

- Reprocessing of MWRP data in Payerne (CH)
  - 3 years of data (including 5-6 liquid nitrogen (LN2) calibrations)
  - Biases detected by comparing Tb with simulations from clear-sky sondes. Biases show jumps after each LN2 calibration
  - A different Tb bias is removed for each channel and each period between LN2 calibration.
  - Removing the Tb biases reduces the T(z) biases significantly, but not completely
    - There seems to be a residual bias in the upper air
    - There seems to be a residual bias peak between 300-1000 m. This feature seems to be common in Cabauw and Lindenberg.
      - AH points out that it may related to the smoothing error (see discussion section).

Alexander Haefele (MeteoSwisse)

- Report on two papers (JTECH 2009, ATMD 2011)
- Retrieval based on OEM – averaging kernel
- Following results based on a MW spectrometer (16000 channels over 21.735 to 22.735 GHz; bins of 20 MHz width were used for the retrieval)
- Results on error budget

    - measurement-smoothing-total error
    - smoothing error dominates over the measurement error
- Information content with respect to height
    - correlation coefficient with respect to radiosondes profiles
- Time series (1 year) of WV mixing ratio at 3 different pressure/height
- The second paper is on discussion on ATM: comments are welcome.

DISCUSSIONS

- Several RT models are documented and freely available
    - MonoRTM: http://rtweb.aer.com/monortm_frame.html
    - ARTS: http://www.sat.ltu.se/arts/
- Infrared (IR) RT should be included soon, as MWRP are starting incorporating 1 or 2 IR channels
- MWR_PRO currently provide QF based on HATPRO house keeping data (see LU presentation for the data being used). House keeping data are probably stored in Radiometrics units as well.
- The "rain flag" provided by some MWR (as HATPRO, MP3000) should be taken with care, as it was shown that there are cases in which this fails in one way or the other.
    - LU showed cases in which the rain flag missed to detect residual water over the radome
    - PG showed cases in which the rain flag was set to on while was not raining (as judged by infrared temperature (Tir) sensor and eye witness)
- LU: Quicklook graphics help indicating rain period boundaries that need to be flagged out. LWP increase before and after rain: after rain, spots of water may persists until it evaporates; before rain, it may be rain falling down but not actually reaching surface.
- LU: Webcams helps in monitoring radome integrity
- LU: Azimuth scan quicklook (hh vs azimuth); this is done every 10 minutes, it would take too long to do continuously.
- CH: Elevation scans is faster than azimuth, because elevation scanning moves the mirror only. Keep this in mind when scheduling the elev/azimuth scan.
- Surface measurements can be included in the MWR_PRO retrieval. CH points out that it not always a good idea to include them, because the T/RH nearby the radiometer may not be really representative of the surrounding (e.g. concrete vs. grassland floor) and you may be driving the T/RH profile with this strong constraint. Surface measurements can be used, but proper error (related to representative) should be associated to those.
- CH points out that quality flags are important for retrievals as well as for measurements, because you could have questionable retrievals in case of MWR proper functioning (as for example high LWP, without rain at surface, leads to unreliable WV profile). Thus, two kind of QF should be made:
    - Instrument sanity
    - Environment conditions

  It is recommended to have different levels of flagging contributing to one lumped QF, indicating that more investigation is needed.
- FM/HA: RH plots may be misleading since T and WV may concur to give unrealistic data (e.g. RH<95% with LWP>0). CH suggests to use K+V bands to retrieve directly RH. HA proposes to either avoid the use of RH or use K+V bands for direct RH retrievals. RH is the most interesting moisture variable for users; however, everybody agrees that maximum 2 degrees of freedom are available: thus the question is should we provide the RH profile or not? RH profiles are easy to criticise, but users would not give that up easily.

- CH: central frequency could easily be off by 10-30 MHz (for HATPRO generation 1, partly compensated with a filter-shift patch); this should be within 1 MHz in HATPRO generat. 2.
- UL: data from RHUBC are being carefully investigated, concerning central frequency, equivalent monochromatic frequency, and oxygen absorption model.
- UL: the most important problem with lover V-band is the absolute calibration.
- CH: recommend to switch off the sky-dip calibration, because even in perfect conditions consecutive sky-dips may give jumps of about 1 K in calibration. UL agrees, but points out that LN2 calibration should be careful characterized (observe LN2 before and after the calibration).
- MA: we should cope with the fact that the network will include newer and older MWR, so we should not focus on newer technology only.
- CD: MWRnet does accept non-commercial radiometers. There are a few already in (e.g. University of Bern). For NWP application they have to show high reliability. For NWP, MWRnet should start from well calibrated Tb. Non-commercial MWR that provide this reliably are OK.
- MA: MWRnet cannot compete with GPS receiver networks on IWV. LWP and profiling are of course added values. LU says satellite community always search for other sources of information for comparison and validation, so IWV from MWRnet may still be interesting.
- LU: We should not think to replace radiosonde with MWR (no hope) but rather to fill with MWR data the gap between the radiosondes.
- LU: an outcome of this meeting should be that NWP application may rely on NWP model regression, but any climate application should rely on careful calibration monitoring, which includes close maintenance and RT comparison.
- KH: concerning the NetCDF, we should try to comply with the CF convention. That should facilitate the interchange of data files.
- HA: can MWR_PRO be compiled and made available to all? IDL has stand-alone compiling, but was not tried yet. IDL has also licence-free versions that allow certain, but not all, features. Therefore, sharing MWR_PRO without IDL licence may be feasible but it would need testing.
- A radiosonde to retrieval files module should be added to MWR_PRO. This would require:
  - RT code (including documentation)
  - Radiosonde screening (based on existing tools from MA (t.b.c.))
- Instrument characteristics should be taken into account
  - Channel beamwidth (maybe important just for <15°). This needs to be quantified.
  - Channel bandwidth (especially important for lower V-band channels)
- HA suggests to add AVK profile information to retrieval as these information may add to the bias related to persistent features
- HA points out that low level T biases that are seen in Payerne (and maybe in Lindenberg and Cabauw as well) may be related to the smoothing error (i.e. MWRP low resolution). In fact, if a persistent feature, such as a temperature inversion, is present and not resolved by the MWRP retrievals, this could lead to a vertical bias feature.

RECOMMENDATIONS

#	What	Why	Who
R1	Level 0 data should always be stored	Level 0 data allow for: - Off line quality controls - Future reprocessing (i.e. recalibrat.)	ALL
R2	MWRP climate application should rely on careful calibration monitoring (including RT comparison and close maintenance)	Calibration uncertainty can exceed the accuracy required by climate applications.	ALL
R3	Gain calibration should be performed once every 3-5 minutes for some 5-10 sec integration time.		HATPRO operators
R4	Always store data even if quality flags (e.g. rain flag) are on. Never delete data!	Rain sensor may be wrong either way (in presence of water/salt/dirt)	ALL
R5	Avoid RH profiles computed from T and WV retrieved profiles.	Errors in T and WV retrieved profiles concur to result in unrealistic RH values	ALL

ACTIONS

#	What	Why	Who
A1	Check if house keeping data are stored in Radiometrics MWRP	Implement instrument QF for Radiometrics radiometers	GJ
A2	Implement MWR_PRO suggested changes		LU
A3	Add radiosonde-to-retrieval module (including documented RT)	Allow MWR_PRO users to develop their own retrieval coefficients	PB
A4	Quantify channel beamwidth contribution		HA
A5	Provide instrument characteristics and contacts for Toulouse MWR operators		MA
A6	Compare RH as obtained from direct inversion of K- and V-band channels and computed from T and WV retrievals		t.b.d.
A7	Join MWRnet		MV, SP, ER, PB
A8	Set FAQ section (+ logbook) up on MWRnet website	Allow MWRnet members to access our answers to FAQ	CD
A9	Fill MWR section on EG-CLIMET wiki		ALL(*)

(*) Actions for EG-CLIMET wiki-page on MWR

Introduction		CD, LU
Fundamentals	Theory of operations, Products, Applications	CD
Operational use	Scanning strategies, Automatic data transfer	CH, GJ,…
Error characteristics	rms profiles, Information content, AVK, Tb and retrieval bias, Central frequency and bandpass	LU, HA, GJ
Practical aspects	Tips and recommendation on calibration, RFI mitigation, Instrument setup (obstructions, location, etc.), Water/ice/dirt detection over the radome, Maintenance and surveillance (webcam experience), Adverse atmospheric conditions	PG + ALL, including manufacturers