A data assimilation experiment of temperature and humidity profiles from an international network of ground-based microwave radiometers


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Motivations (1/2)

U.S. National Research Council Reports*:

- The planetary boundary layer (PBL) is the single most important under-sampled part of the atmosphere

- The vertical structure of the PBL is not systematically observed
  - Surface → met data
  - PBL → gap
  - Upper air → satellite

- Particularly important in nowcasting and severe weather initiation

- Observing Weather and Climate from the Ground Up; A Nationwide Network of Networks (2009)
Motivations (2/2)

WMO guidance on observations for NWP:

- four critical atmospheric variables are not adequately measured
  - wind profiles
  - temperature and humidity profiles (in cloudy areas)
  - precipitation
  - snow mass

- Ground-based microwave radiometers (MWR) provide T and H profiles
  - High temporal resolution (~1 min)
  - Low-to-moderate vertical resolution
  - Information mostly residing in the PBL

*https://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html*
Approach

- A ground-based MWR network could provide continuous T and H profiling to feed NWP DA 😊

- In the current financial scenario, the deployment of a new dedicated MWR network is not likely 😞

- Several MWR are currently operational:
  - But different organizations and purposes 😞
  - Data under-used 😞
  - No coordination… 😞 ...until MWRnet! 😊😊😊
What’s MWRnet?
http://cetemps.aquila.infn.it/mwrnet
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MWRnet - An International Network of Ground-based Microwave Radiometers
Previous MWR DA experiments (1/2)

Vandenberghe and Ware (2002)

- **Obs:** One single MWR
- **Model:** MM5 (+4DVAR)
- **Period:** One case study (3-hour data assimilation)
  - winter fog event at Denver Airport (**missed by NWP**)
- **Conclusions:** 4DVAR DA assimilation was able to generate fog, though benefits were rapidly lost in the free forecast
Previous MWR DA experiments (2/2)

Otkin et al. (2011); Hartung et al. (2011)

- **Obs:** ~140 MWR (+other instr.)
  - OSSE: Observing System *Simulation* Experiment

- **Model:** WRF (+EnKF)

- **Period:** One case study in continental U.S.
  - winter storm case

- **Conclusions:** reduced errors in the intensity and location of the mesoscale structure, but not in prediction of heaviest precipitation

DA of a real network of ground-based MWR has never been attempted before
Context: HyMeX (1/2)

**HyMeX**: Hydrological cycle in the Mediterranean Experiment

- Water budget
- Hydrological cycle
- Air-Sea interactions
- Heavy rainfalls, floods
- Socio-economic impacts

**Observation Strategy:**

- 10-year Long-term Observation Period (**LOP**)
- 4-year Extended Observation Period (**EOP**)
- Short-term Special Observation Periods (**SOP**)

More info at: http://www.hymex.org/
Context: HyMeX (2/2)

- Work done in preparation to the HyMeX SOP1
  - Sep-Nov 2012

- HyMeX West Mediterranean (WMed) target area

- Arome-WMed NWP system (Météo-France)
  - 2.5 km horizontal resolution
  - non-hydrostatic, detailed physics
  - coupled with global NWP system Arpege (Météo-France)
### Ground-based MWR network

- A network of 13 MWR:
  - H profilers (1)
  - T profilers (4)
  - T&H profilers (8)

<table>
<thead>
<tr>
<th>Station</th>
<th>Institution</th>
<th>Lat</th>
<th>Lon</th>
<th>MSL</th>
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</table>
MWR DA Experiment

- Observations:
  - 13 MWR
  - ~2 months (October-November, 2011)
    - including several heavy precipitation events
    - Over Spain, France, Italy
  - T & H retrievals
    - Retrieval method depending upon site

- Model and Data Assimilation:
  - Arome WMed
  - 3DVAR assimilation of T&H profiles every 3 h
MWR Data Assimilation Experiment

Lampedusa
(Italy, 50 m asl)

Schneeferner glacier
(Germany, 2969 m asl)

October-November, 2011
Other assimilated data in the Control (CTRL) run include:
- radiosondes
- wind profilers
- aircrafts
- ships
- buoys
- automatic weather stations
- satellite radiometers
- weather radars
- ground-based GPS
- GPS radio-occultation

....very little room to make an impact!
MWR Data Assimilation Experiment

- Results:
  - Observation-minus-background (O-B) statistics
    - MWR retrievals minus control run (CTRL) profiles
  - Data assimilation impact:
    - Precipitation (ground truth: rain gauges)
    - Other surface fields (ongoing)
    - Upper air fields (ongoing)
O-B Time series

TEMPERATURE - GRANADA

GRANADA - Temperature (K)

Altitude (m MSL)

OBS

MOD

OBS-MOD
O-B Time series

HUMIDITY - GRANADA

GRANADA - Relative humidity (%)

Altitude (m MSL)

22/10 29/10 05/11 12/11 19/11
date (day of month)

OBS

MOD

OBS-MOD
O-B statistics

Check consistency between MWR products and original CTRL forecast

TEMPERATURE

Lampedusa (Italy)  Potenza (Italy)
O-B statistics

Check consistency between MWR products and original CTRL forecast

**HUMIDITY**

Lampedusa (Italy)                      Potenza (Italy)

![Graph showing relative humidity against altitude for Lampedusa and Potenza](image)

**bias**  **std**  **bias**  **std**
O-B statistics

Conclusions

- Std similar to radiosondes
- Bias much larger than radiosondes
- The large biases are due to a combination of:
  - model bias
  - instrument bias
  - retrieval bias

This needs further investigation
Data assimilation impact

4 runs

- **CTRL**: assimilation of operational data only
- **DA_T**: as CTRL + MWR-derived T
- **DA_U**: as CTRL + MWR-derived U
- **DA_TU**: as CTRL + MWR-derived T&U
Data assimilation impact

Verification w.r.t. **24-h accumulated precipitation** (‘truth’: rain gauges)

CTRL   DA_U   DA_T   DA_TU

2-3 November, Cévennes

26-26 October, Cinque Terre
Data assimilation impact

- **Case #1**: 3-4 Nov, Cévennes (France)
- **CTRL**: precipitation patterns are misplaced and too weak

24-h accumulated precipitation

0 mm where the maximum of observed precipitation is located
Data assimilation impact

- **Case #1**: 3-4 November, Cévennes
- **DA_TU**: more precipitation, good location

24-h accumulated precipitation

Precip maxima are well predicted
Data assimilation impact

- **Case #2**: 4-5 Nov, Genoa (Italy)
- **CTRL**: No precipitation forecast over Genoa

0 mm where the maximum of observed precipitation is located
Data assimilation impact

- **Case #2**: 4-5 Nov, Genoa (Italy)
- **DA_TU**: Better location and intensity, but still drier than gauges

24-h accumulated precipitation

Better location and intensity
Data assimilation impact

Skill scores for 24-h precipitation accumulation (over 2-month period):

<table>
<thead>
<tr>
<th></th>
<th>Bias (mm)</th>
<th>Rmse (mm)</th>
<th>CorrCoef</th>
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</thead>
<tbody>
<tr>
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<td>-0.23</td>
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<tr>
<td>DA_TU</td>
<td>-0.22</td>
<td>6.62</td>
<td>0.64</td>
</tr>
</tbody>
</table>

- MWR DA shows neutral (-to-positive) impact:
  - data are such that can be safely assimilated
  - to be confirmed (w.r.t. surface and radiosonde T&H data)

- More benefit is expected by:
  - improving the data quality (QC + retrieval bias)
  - assimilating brightness temperature (Tb) directly
Results summary

- Results from the first MWR Data Assimilation experiments show neutral (-to-positive) impact

- Possible reasons include:
  - Relatively scarce data (w.r.t. other assimilated sources)
  - Retrieval biases
  - Assimilation of retrievals instead of Tb
Ongoing activities

- Validation with respect to other references:
  - Surface data (T, H)
  - Upper air (radiosonde)

- Towards direct Tb assimilation:
  - TOPROF (EU COST Action)
    - Assessing MWR Tb uncertainties
    - Adaptating fast RTM for ground-based obs
    - Satellite heritage
Summary, conclusions and future plans

- Feasibility demonstration of pseudo-operational DA of a real network of ground-based MWR
- First results show neutral (-to-positive) impact
  - Not great, but encouraging
- Possible reasons:
  - Only few network nodes (13)
  - Retrieval bias
  - Data quality
- On going activities:
  - Complete validation
  - Move towards direct Tb evaluation

Thank you very much for your attention!

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