Assessment of Small-Scale Integrated Water Vapour Variability During HOPE

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High Definition Clouds and Precipitation for advancing Climate Prediction

- BMBF funded German-wide research initiative to improve understanding of cloud and precipitation processes and their implication for climate prediction
- Started in 2012, envisioned for 3+3 years
- 20 projects in 3 modules (model, observation, synthesis)

Evaluation concept
- Evaluate obs with obs, models with obs, models with models
- O2: Full domain data
  ➢ WP1: Water vapour
Goals of this study

1. Small-scale variability of IWV
   a) Characterize
   b) Estimate ability of instruments to represent this

2. Provide realistic error estimate for IWV

3. Assess ability of ICON to capture daily IWV cycle
HOPE: HD(CP)$^2$ Observational Prototype Experiment

1. Motivation
2. HOPE
3. Instruments
4. Models
5. Case Study
6. Statistics
4. Summary & Outlook

- Intensive measurement campaign for
  - Critical **model evaluation** at scale of model simulations
  - Providing information on **subgrid-scale variability** which is parameterised even in LES models

- April-May 2013

- Jülich Observatory for Cloud Evolution (JOYCE), Germany

- Community data portal: long-term, short-term, local, and full domain data

Visit [https://icdc.zmaw.de/hdcp2.html](https://icdc.zmaw.de/hdcp2.html)
### Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Temporal Resolution</th>
<th>Spatial Resolution/Representativeness</th>
<th>Uncertainty kg m$^{-2}$ or %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MWR HATPRO</td>
<td>≈2 s</td>
<td>3.5° beam width</td>
<td>0.5 (s)</td>
</tr>
<tr>
<td>GPS sunphotometer</td>
<td>15 min, 10 min</td>
<td>ca. 32 km$^1$</td>
<td>0.5-0.8 (r)</td>
</tr>
<tr>
<td>Graw DFM-09</td>
<td>at least 1 h</td>
<td>drift up to 100 km</td>
<td>1.2 (s)</td>
</tr>
<tr>
<td>MODIS-NIR</td>
<td>≤6 times per day</td>
<td>1 km</td>
<td>1.7 (r)</td>
</tr>
<tr>
<td>MODIS-IR</td>
<td>≤6 times per day</td>
<td>3 km</td>
<td>5-10%</td>
</tr>
</tbody>
</table>
Models

ICON (Zängl et al., 2014)

- Non-hydrostatic modelling framework for NWP and Climate
- High-resolution limited area simulation:
  - Resolution: 156 x 156 m, model top at 21 km
  - Initialization and hourly boundary nudging with COSMO-DE analyses
  - Output every 135 sec

COSMO-DE (Baldauf et al., 2011)

- Non-hydrostatic regional NWP model
- Resolution: 2.8 x 2.8 km, 50 hybrid levels
- Operational:
  - 21 h forecasts
  - Initialized every 3 h from COSMO-DE analyses
  - Hourly boundary nudging with COSMO-EU forecasts
  - 30 min nudging with radar data
  - ¼-hourly output
Case study: 5 May 2013

- IWV ranges from 12 – 18 kgm\(^{-2}\)
- 9 – 15 UTC: High IWV fluctuations (above noise level of MWR)
- MWR & sunphotometer agree well (except for when sun is low)
GPS tends to lie below MWR

Hourly and daily jumps in GPS data

- Reprocessing removes jumps, decreases STD but increases bias.
Radiosondes agree well

Graw Software corrects for daytime dry bias
Case study: 5 May 2013

MODIS-NIR within MWR error

MODIS-IR deviates distinctly

Larger pixel contaminated by clouds?
COSMO-DE does not capture increase of IWV
ICON first captures IWV increase but later deviates from obs.

ICON captures high IWV fluctuations of MWR
Case study: 5 May 2013

MODIS-NIR-FUB within specified error of GPS

But drier than MODIS-NIR
Increased STD due to high IWV fluctuations only captured by high-res. data
Case study: Resolved variability

Correlation/STD decreases/increases with increased mismatch
Spatial mismatch of 10 km corresponds to temp. mismatch of 30 min
STD at 10 km/30 min corresponds to specified uncertainty of obs.
Combined t & s mismatch (as with radiosondes) leads to higher errors
Correl. & STD of MWR decrease similarly as in ICON

Rectangles: ICON high-res. run. Circles: 2 MWRS.
HOPE period

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→ 15 kg m\(^{-2}\) occurs most often in all except sunphotometer

➢ Clear-sky only results in smaller IWVs occurring more often
Multi-instrument comparison

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- **All:** STD $\leq 10 \text{ kg m}^{-2}$, $R \geq 0.98$, mean differs
- **MWR – GPS:**
  - Agree within specified uncertainty
  - Some values 5 kg m$^{-2}$ off due to beginning of day issue
- **Radiosonde – GPS:**
  - RS drier but no day/night difference
- **MODIS – sunphotometer:**
  - IR has double the STD than NIR
  - **MODIS-NIR – sunph.:**
    - Includes less data pairs than MODIS-NIR – GPS
    - Due to sub-satellite-pixel clouds?
- **MODIS-NIR-FUB:**
  - Larger dry bias to sunph. than MODIS-NIR
  - Drier than MODIS-NIR
STD increases with increasing length of time intervals

- Time interval > 1h: All lie close together, within their 25%/75% percentiles
  - 15 min res. sufficient to capture IWV variability

- Time interval < 1 h: very high STDs occur
  - Not captured with low-res. obs.
Temporal variability: STD dependency on time interval

Largest STDs stem from (partially) cloudy situations
Mean diurnal cycle

→ Absolute values differ
→ Same development in all obs., though sunph. has smaller abs. values
→ GPS for MWR cases matches MWR well
→ COSMO-DE shows too small an amplitude; spread highest in afternoon
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Summary

IWV variability – Characterization & Representativity

• STD at 10 km/30 min corresponds to specified uncertainty of obs.
• Combined temporal & spatial mismatch (as with radiosondes) leads to higher errors

Error estimate

• Showed numbers for all obs.
• Time intervals > 1h: 5 min res. sufficient to capture IWV variability
• Time intervals < 1h: still very high STDs, not captured by low res. obs. and model

ICON

• Captures high IWV fluctuations
• Captures daily cycle of case better than COSMO-DE
• Performance very promising
Outlook

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• Full domain comparison of IWV / UTH including
  – Radiosondes
  – GPS
  – MODIS
  – AMSU
  – IASI
  – MSG SEVIRI?

• Utilize full domain observations for evaluating
  – COSMO-REA2
  – COSMO-REA6
  – COSMO-DOWN
  – ICON-DE
Thank you!

References
