Seasonality of vertical structure in radar-observed precipitation over southern Switzerland

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1: Investigate vertical precipitation structure using multiple years of radar data

Most precipitation climatologies are based on surface observations from rain gauges

1: Investigate vertical precipitation structure using multiple years of radar data

A few studies have used multi-year radar data

Does vertical structure also follow an annual pattern?

2: Relate vertical structure to annual precipitation pattern

- Establish link (of lack thereof) between surface precipitation and vertical structure
- Compare our results to MAP case studies

Objectives

Data

Results

Conclusions

Figure 15. Conceptual model of the airflow and microphysics of orographic precipitation mechanisms in MAP cases of (a) unstable unblocked low-level flow, and (b) stable blocked low-level flow (adapted from Medina and Houze, 2003a).

Houze et al. 2001; Medina and Houze 2003; Yuter and Houze 2003
3: Investigate relationship between temperature and vertical structure

Changes in synoptic patterns over the 21st century will increase the proportion of convective precipitation for Swiss river basins

Rudolph et al. 2012, *J. Climate*

Indicator of climate change impacts on the hydrologic cycle?

Giorgi et al. 2011, *J. Climate*
Monte Lema radar
C-band Doppler weather radar
Scans 20 elevations every 5 minutes
2 x 2 km² horizontal resolution
1 km vertical res. (1-12 km asl)
Mar 2004 – Feb 2011

Rain gauges
6 locations in N-S transect
0.1 mm increments
10 min intervals
CFADS: Contoured Frequency by Altitude Diagrams
Individual storm CFAD centroids:
- identified by rain gauges
- ≥ 1 mm in ≤ 24 h
- classified by nearest neighbor

Seasonal CFAD centroids
**Vertical structure relationship to surface precipitation**

<table>
<thead>
<tr>
<th>Precipitation characteristic</th>
<th>DJF</th>
<th>MAM/SON</th>
<th>JJA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (mm)</td>
<td>14.9 [A]</td>
<td>27.2 [B]</td>
<td>21.8 [A]</td>
</tr>
<tr>
<td>Duration (h)</td>
<td>24.2 [A]</td>
<td>24.2 [A]</td>
<td>16.7 [B]</td>
</tr>
<tr>
<td>Interval (h)</td>
<td>95.3 [A]</td>
<td>60.1 [B]</td>
<td>56.4 [B]</td>
</tr>
<tr>
<td>Average rate (mm/h)</td>
<td>0.4 [A]</td>
<td>0.8 [B]</td>
<td>1.4 [C]</td>
</tr>
<tr>
<td>Maximum rate (mm/10 min)</td>
<td>0.5 [A]</td>
<td>1.4 [B]</td>
<td>3.5 [B]</td>
</tr>
</tbody>
</table>

- **MAM/SON** highest total
- **JJA** shortest duration
- **DJF** longest interval
- **JJA** highest rate
- **JJA** highest maximum rate
MAP IOP2b: unstable/unblocked, high Fr


- 10-15 dBZ extends to ~8 km
- 35-40 dBZ at 2-4 km
- Wet snow (0°C) at 3 km
- Riming and graupel formation above 0°C
- Coalescence below 0°C
- Embedded convection
- Intense rainfall
MAP IOP8: stable/blocked, low Fr


- 10-15 dBZ limited to 5-6 km
- 25-30 dBZ at 2-3 km
- Wet snow (0°C) at ~2 km
- Stratiform structure
- Light rainfall
OBJECTIVES
DATA
RESULTS
CONCLUSIONS

Vertical structure and surface temperature

JJA-type storms become more common in late spring

JJA-type storms become less frequent in late fall
Vertical structure and surface temperature

Vector generalized linear model (vglm)

Yee 2008, 2010

\[
\log \left( \frac{P_{\text{MAM/SON}}}{P_{\text{DJF}}} \right) = a_1 + b_1 T
\]
\[
\log \left( \frac{P_{\text{JJA}}}{P_{\text{DJF}}} \right) = a_2 + b_2 T
\]

where \( P_{\text{DJF}} + P_{\text{MAM/SON}} + P_{\text{JJA}} = 1 \),
\( a_1 = -2.31 \); \( b_1 = 0.20 \); \( a_2 = -11.68 \); \( b_2 = 0.70 \).
Monte Carlo simulation of current and future precipitation characteristics

Current: use observed average daily T for 2004-2011
Future: use current + PRUDENCE predicted seasonal change
Christensen and Christensen 2007, Clim. Change
Monte Carlo simulation of current and future precipitation characteristics

Duration: 
↓ summer

Interval: 
↓ winter
↓ summer

Total: 
↑ winter
↓ summer

Rate: 
↑ winter
↑ summer

For each season:
Left – current climate
Right – future climate
Vertical precipitation structure follows a seasonal pattern

- Summer: highest vertical extent and greatest reflectivity near the surface
- Increased convective nature of summer-time precipitation
- Winter CFADs portray a more stratiform character.
- Spring and fall: intermediate values

Vertical precipitation structure is related to surface precipitation characteristics

- JJA-type precipitation events are the shortest and most intense.
- Change in the probability distribution of storm-type classification has implications for surface-based precipitation characteristics.
Vertical precipitation structure is related to surface temperature

- Relevance for climate change – potential for increased probability of convective storms
- No indication of earlier onset of JJA-type in spring or later occurrence in fall (2004-2010)
  - May be interesting to monitor as long-term climate signal

Additional thoughts

Highlights the importance of accurately portraying convection in climate models

Localized impacts of climate change on atmospheric stability, moisture flux, and wind speed and direction
Thank You!