Should we use a simple or complex model for atmospheric moisture tracking?

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Introduction
To study the origin of precipitation and the fate of evaporation there exist many numerical moisture tracking models. The assumptions made within these models and their level of detail affects the performance. Comparison studies are rare and the consequences of different assumptions have not been quantified.

Research questions
• How well do a posteriori moisture tracking models perform?
• Which assumptions and circumstances lead to errors?
• How can these assumptions be relaxed in a posteriori moisture tracking models?
• When and where should we apply which moisture tracking model?

Moisture tracking models
• RCM-tag (Knoche and Kunstmann, 2013). Moisture tracking within MMS. Resolves all processes of MMS (transport, diffusion, phase transitions). Complex, but very accurate. Here assumed as ‘virtual reality’.
• WAM (van der Ent et al., 2010, van der Ent and Savenije, 2011, Keys et al., 2012). Quick and simple Eulerian water vapour tracking. Vertically integrated moisture fluxes and ‘well-mixed’ assumptions.
• 3D-T (Tuinenburg et al., 2012). Full 3D Lagrangian method. ‘Well-mixed’ release and recovery of atmospheric water vapour parcels.

Case study Lake Volta (West Africa)
Atmospheric tracking of evaporated water from Lake Volta.

Moisture tracking results in West-Africa

Fig. 1. Winds, evaporation and precipitation
Data from MMS run for August 1998. Rectangle is the tagging source region.

Fig. 2. Tagged precipitation in the original models
The tagged moisture in WAM travels in the wrong direction due to the use of vertically integrated moisture fluxes. The tagged moisture in 3D-T leaves the domain to quickly due to ‘well-mixed’ release and recovery of water parcels.

Fig. 3. Tagged precipitation in the improved a posteriori models
Expanding WAM to track moisture in two well-chosen layers improved the results significantly. In 3D-T, a release of evaporated parcels in the lowest model level, and a recovery of precipitated parcels from cloud levels, led to a much better resemblance of RCM-tag.

Moisture recycling

<table>
<thead>
<tr>
<th>Tracking model</th>
<th>Evaporation of Volta origin that recycles within the domain</th>
<th>Evaporation of Volta origin that recycles in the tagging region</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCM-tag</td>
<td>33%</td>
<td>1.9%</td>
</tr>
<tr>
<td>WAM-1layer</td>
<td>33%</td>
<td>2.0%</td>
</tr>
<tr>
<td>3D-T-Original</td>
<td>12%</td>
<td>3.9%</td>
</tr>
<tr>
<td>WAM-2layers</td>
<td>24%</td>
<td>2.3%</td>
</tr>
<tr>
<td>3D-T-E_low-mixing-Pclouds</td>
<td>24%</td>
<td>2.0%</td>
</tr>
</tbody>
</table>

Global results

Fig. 4. Shear factors of the horizontal moisture flux
The degree to which the system is sheared over the vertical. A value of 0 means a fully sheared system and with a value of 1 there is no shear. West Africa is a worse case scenario for the original WAM and 3D-T methods.

Fig. 5. Continental moisture recycling
The results of WAM-2layers are only slightly different from the results of WAM-1layer. On a global scale, the complexity of the moisture tracking model is less important.

Conclusions and Recommendations
• Original a posteriori models had problems resembling the results of RCM-tag.
• ‘Well-mixed’ assumptions in combination with a sheared wind system lead to moisture tracking errors.
• Simple improvements in the tracking models lead to significantly better results.
• When properly used, a relatively simple 2-layer water vapour tracking model can perform well, even in areas with wind shear.

References
• van der Ent, R. J., and H. H. G. Savenije, Length and time scales of atmospheric moisture recycling, Atmospheric Chemistry and Physics, 11, 1853-1863. 2011.