How can we make use of water isotopic observations to better evaluate the representation of moist processes in climate models?

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Thanks to: Obbe Tuinenburg, John Worden, Jean-Lionel Lacour, Sandrine Bony, Françoise Vimeux

Ringberg, March 2014
Water isotopes

- $H_2^{16}O$, $HDO$, $H_2^{18}O$ ...
- fractionation during phase changes
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present-day climate

meteorological variables

isotopic variables

physical processes

future climate

evaluate processes "isotopic test"

evaluate credibility

$H_2^{16}O \rightarrow HDO$
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isotopic proxies

evaluate processes "isotopic test" "paleo-test"
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unsaturated downdrafts, reevaporation
What can we use isotopes for?

- Convective detrainement
  - (Moyer et al. 1996, Webster and Heymsfield 2003)

- Ice microphysics
  - (Bolot et al. 2013)

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convective vs large-scale precipitation
(Lee et al 2009,
Kurita et al 2013,
(Risi et al in prep)

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(Lawrence et al 2004,
Worden et al 2007,
Risi et al 2008,2010)
Recent opportunities

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- More and more GCMs have water isotopes ($\approx 9$), SWING2 intercomparison project
q-δD: moistening and dehydrating processes

100hPa

convective detrainment
convective ascent
large-scale condensation

compensating subsidence
unsaturated downdrafts
reevaporation

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δD (‰)
q (g/kg)

large-scale condensation
subsidence
$q-\delta D$: moistening and dehydrating processes

Diagram showing processes such as convective condensation, detrainment, and subsidence. The graph illustrates the relationship between $q$ (g/kg) and $\delta D$ (permil) across different pressure levels (100hPa and 800hPa). The diagram also highlights large-scale condensation and reevaporation.
q-δD: moistening and dehydrating processes

- Convective ascent
- Convective detrainment
- Large-scale condensation
- Compensating subsidence
- Unsaturated downdrafts
- Reevaporation

$q \ (g/kg)$ vs. $\delta D \ (%)$

- Large-scale condensation
- Detrainment
- Rain
- Subsidence
- Reevaporation

Pressure levels:
- 800hPa
- 100hPa
What causes the moist bias in GCMs?

LMDZ:
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LMDZ sensitivity tests:
- Control
- Excessively diffusive vertical advection
- Excessive condensate detrainment
- Insufficient in-situ condensation

AIRS data

rel. humidity (%) 30°S-30°N
What causes the moist bias in GCMs?

LMDZ sensitivity tests:
- Red: Control
- Green: Excessively diffusive vertical advection
- Cyan: Excessive condensate detrainment
- Blue: Insufficient in-situ condensation
- Black: AIRS/ACE data

(Risi et al 2012)
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- **SWING2 models**

![Diagram showing factors affecting moist bias in GCMs](image)

- 100hPa
- Convective detrainment
- Compensating subsidence
- Unsaturated downdrafts
- Large-scale condensation
- Large-scale ascent
- Vertical diffusion

AIRS data

<table>
<thead>
<tr>
<th>JJA-DJF ΔδD (‰)</th>
<th>400 hPa, 15°N-30°N</th>
</tr>
</thead>
<tbody>
<tr>
<td>relative humidity (%) 30°S-30°N</td>
<td></td>
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Excessively diffusive advection = most frequent bias

(Risi et al 2012)
Convection/ large-scale partitionning

- Deep convection
- Shallow convection
- Large-scale condensation

- Detrainment
- Compensating subsidence
- Unsaturated downdrafts
- Reevaporation

100hPa

Surface
Water isotopes during the MJO

Hoevmuller diagram at 500hPa during Cindy-Dynamo, observed by IASI

δD anomaly (‰)
q anomaly (contours, %)
Water isotopes during the MJO

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mean $q - \delta D$ cycles at 500hPa in the Indian Ocean

Tuinenburg et al in prep
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enrichment by convective detrainment
maximum precip and $q$
deposition by large-scale condensation
deposition by rain reevaporation
Summary/Perspectives

- Lots of measurements exist but are still under-exploited
  - progress in understanding what controls water composition
  - but still a long way to go to exploit this understanding to use water isotopic measurements quantitatively
  - need theoretical/interpretative framework
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- Combine $\delta D$ with other variables:
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  - $q, \delta D +$ chemical tracers: CO, $O_3$, $^{10}Be \Rightarrow$ better characterize air/water fluxes
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- Model intercomparison projects with isotopes:
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  - next CMIP with isotopes? $\rightarrow$ daily outputs, paleo
  - goal: isotopic diagnostics to detect/understand model biases
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- isotopic CRMs to study processes
  - e.g. SAM (Blossey et al 2010, Moore et al 2014)
  - compare with SCMs? e.g. RCE simulations, campaign cases, conditional sampling (e.g. Couvreux et al 2010)