Use of isotopes for process-oriented diagnostics

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Added value of water isotopes

$H_2O$

$HDO$
Added value of water isotopes

\[ H_2O \quad \rightarrow \quad HDO \]

- Physical processes
- Meteorological variables
- Isotopic variables
Added value of water isotopes
Controls on water vapor isotopic composition

- Mixing
- Rayleigh

- Subsidence
- Detrainment
- Reevaporation
- Large-scale condensation
- Large-scale drying and depletion
- Vertical diffusion
- Moistening and enrichment
- Large-scale ascent
- Large-scale subsidence
- Unsaturated downdrafts
drying and depletion
- Detrainment moistening and enrichment
- Reevaporation moistening and depletion

Graph showing mixing and subsidence processes at different pressure levels.
Example: cause of moist bias in GCMs?

Sensitivity tests:
with LMDZ:
- Control
- Excessively diffusive vertical advection
- Excessive condensate detrainment
- Insufficient in-situ condensation
- AIRS/ACE data

(Risi et al 2012b)
Example: cause of moist bias in GCMs?

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SWING2 models:
- ECHAM
- CAM2
- MIROC
- GISS
- HadAM
- GSM

400 hPa, 15°N-30°N mean

▶ frequent reason for moist bias=excessively diffusive advection

(Risi et al 2012b)
Water isotopes during Cindy Dynamo

- Hovmuller diagrams at 500hPa, 10°S-10°N average
Cycles $q - \delta D$

650–500 hPa at Gan Island

Composite MJO Phase Diagram (isotope space)

Berkelhammer et al 2012

- IASI
- LMDZ SP
- LMDZ NP

- pre–MJO: 13–15 nov
- coeur MJO: 24–25 nov
- fin MJO: 29–30 nov
Cycles $q-\delta D$

650–500 hPa at Gan Island

- $\delta D$ (%)
- $q$ anomaly (%)

Berkelhammer et al 2012

600 hPa

Composite MJO Phase Diagram (isotope space)

- $\delta D$ (%)
- $q$ (g/kg)

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▶ depends on location/season? altitude? type of event?
Cycles $q-\delta D$

650–500 hPa at Gan Island

Composite MJO Phase Diagram (isotope space)

600 hPa

-17.5 days
+17.5 days
+12.5 days
+7.5 days
-12.5 days
-7.5 days
-2.5 days
+2.5 days

Berkelhammer et al 2012

-180
-190
-200
-210
-220
-230
-240
-250
-260
-270

$\delta D$ (%) vs $q$ anomaly (%)

-155
-160
-165
-170
-175
-180

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

-10
-5
0
5
10
15
20
25
30

60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10

-10
-5
0
5
10
15
20
25
30

$\text{IASI}$

$\text{LMDZ SP}$

$\text{LMDZ NP}$

depends on location/season? altitude? type of event?

use sign/shape as a process-oriented diagnostic?
Tendances from different processes

LMDZ SP, lower troposphere

- total
- dynamics
- large-scale condensation
- convective detrainment
- compensating subsidence
- convective evap
Convection vs large-scale schemes

deep convective parameterization

shallow convection parameterization

large-scale parameterization

downdrafts

unsaturated detrainment

compensating reevaporation

subsidence

large-scale condensation

100hPa surface
Convection vs large-scale schemes

- deep convective parameterization
- shallow convection parameterization
- large-scale parameterization

- conv vs large-scale precip arbitrary

- detrainment
- unsaturated downdrafts
- reevaporation
- compensating subsidence

100hPa

large-scale condensation

surface
Why is the conv vs LS partitioning important?

arbitrary but affects:

- simulated climate and variability
  - heating rate large-scale circulation
  - cloudiness radiative effects
  - intra-seasonnal variability (Kim et al)
  - humidity transport
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→ difficult to evaluate directly or too many factors at play
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- things that can be used for model evaluation
  - chemical tracer transport
  - water isotopes
Tendencies from conv. vs large-sc. precip

$dq/qdt$ (%/day)

large-scale ascent
large-scale condensation
convective detrainment
compensating subsidence

$\frac{d\delta D/dt}{dq/qdt}$ (%/%)
Sensitivity tests in LMDZ

Amazon, DJF-JJA (wet-dry)

- **TES data**
- **control**
- **vertical advection more diffusive**
- **stronger condensate detrainment**
- **less in-situ condensation**
- **less in-situ precipitation**
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Amazon 600hPa

TES data

ΔδD (‰)

Δq DJF-JJA (g/kg)

ΔP_{LS}/ΔP_{tot} DJF-JJA
Conclusion

Summary

- $\delta D$ informs about moistening and dehydrating processes
- $q - \delta D$ during MJO informs about relative timing of processes
- precipitating events deplete the tropospheric vapor all the more as it is associated with large-scale precipitation

$\Rightarrow$ use it more quantitatively to evaluate conv vs large-scale precip partitionning and underlying heating profiles
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More generally

- lots of measurements exist but are still under-exploited
- progress in understanding what controls tropospheric isotopic composition, but still work before we can reverse this understanding to use isotopic measurements quantitatively
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Perspectives

- Link with degree of organization?
- Combine $q$, $\delta D$ + cloud ⇒ better constrain large-scale precip
- Combine $q$, $\delta D$ + chemical tracers: CO, $O_3$, $^{10}Be$ ⇒ fluxes
- Comparisons with CRMs