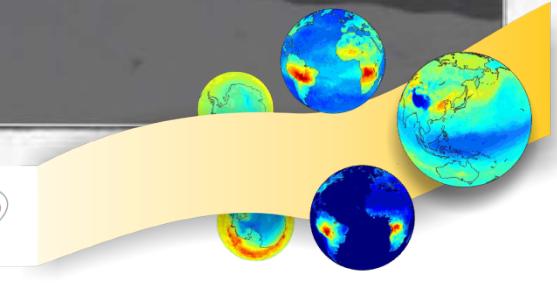
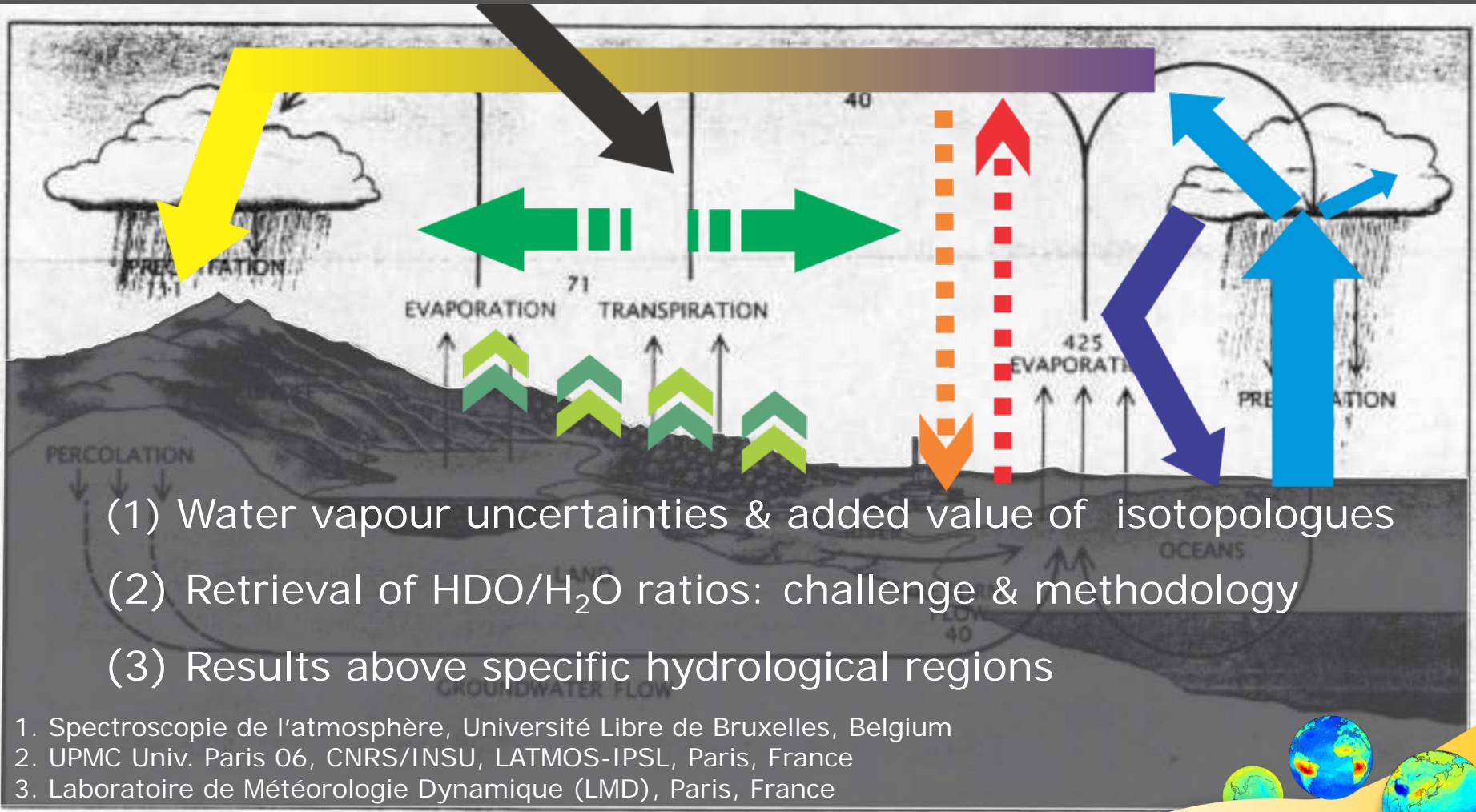


HDO/H₂¹⁶O observations from IASI to investigate hidden humidity tropospheric processes

J.-L. Lacour¹, L. Clarisse¹, D. Hurtmans¹, P.-F. Coheur¹, C. Clerbaux²⁻¹, C. Risi³



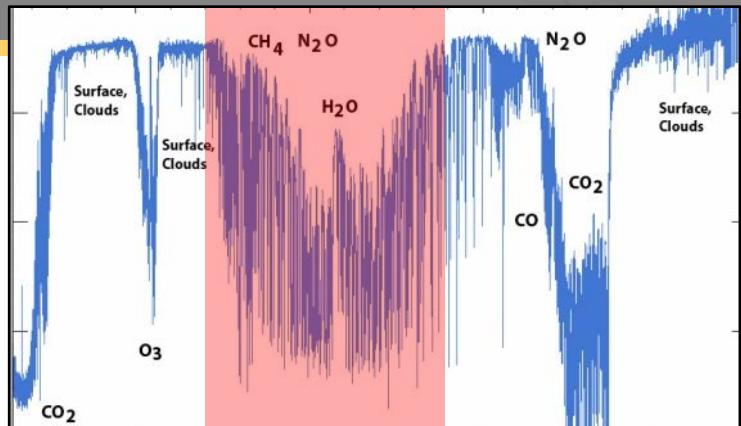
(1)

Water vapour uncertainties & added value of its isotopologues

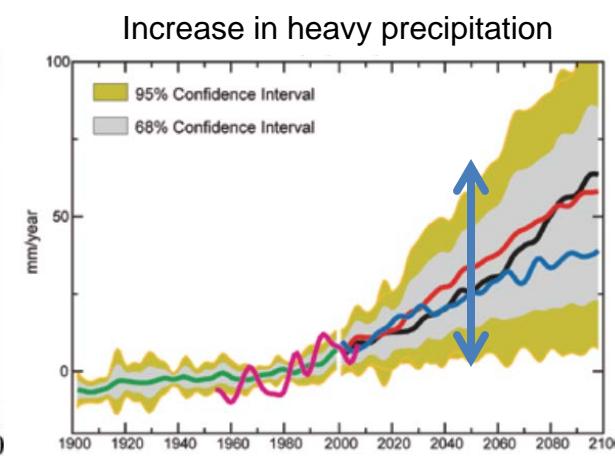
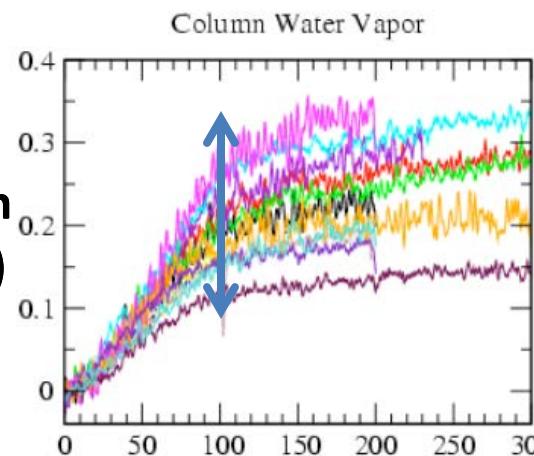
Water vapour uncertainties

Key role of tropospheric water vapour :

- Water vapour feedback:
strongest infrared absorber, main contributor to the GHE
(Schmidt et al., JGR, 2010)
- Clouds feedbacks (Sherwood et al, 2010)
- Deep convection (Derbyshire et al, 2004)



High uncertainties in water vapor in climate models (present and future)
(John and Soden, 2005, Sherwood et al, 2010)



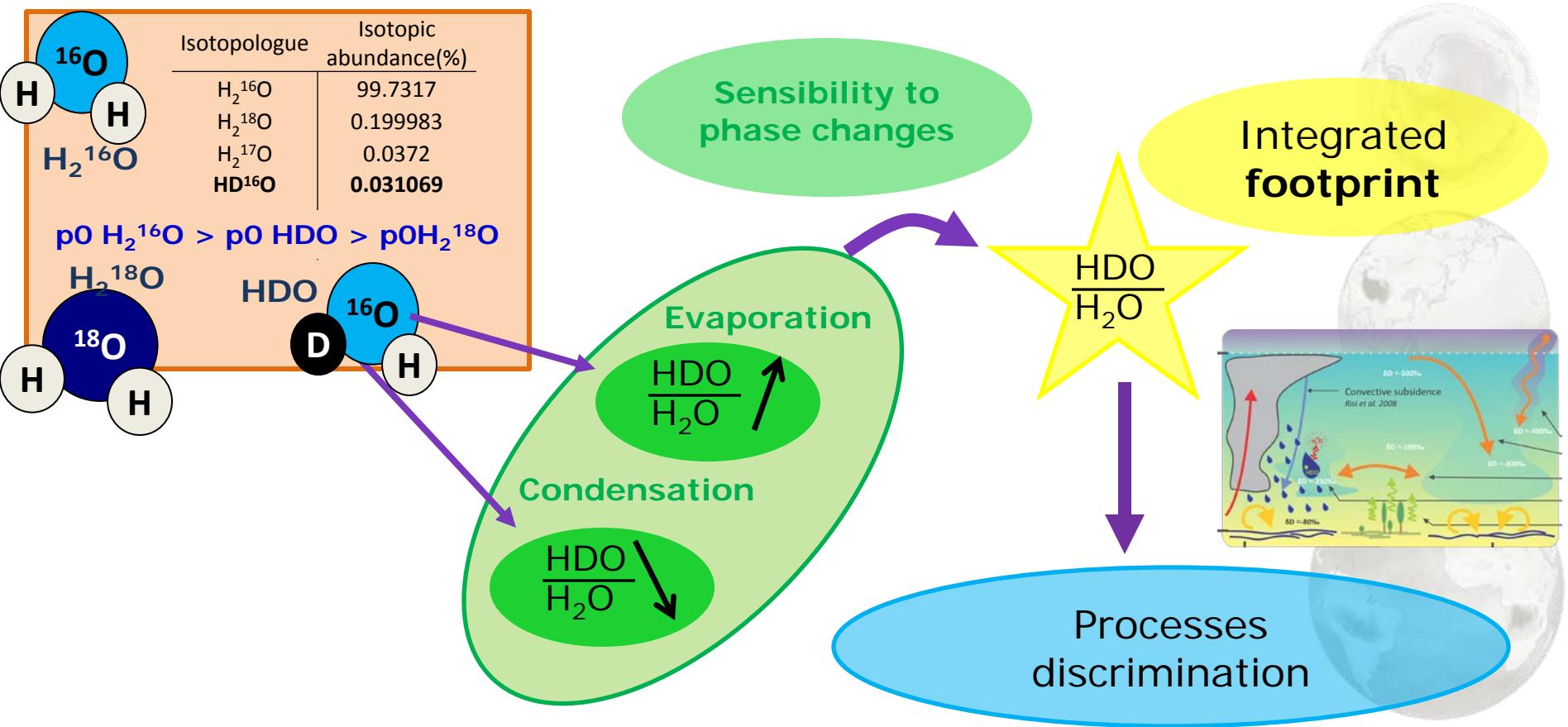
Dispersion due to different ways to represent hydrological processes

Water isotopologues reveal 'hidden' processes

They can serve as diagnostic tool to evaluate processes representation in the models

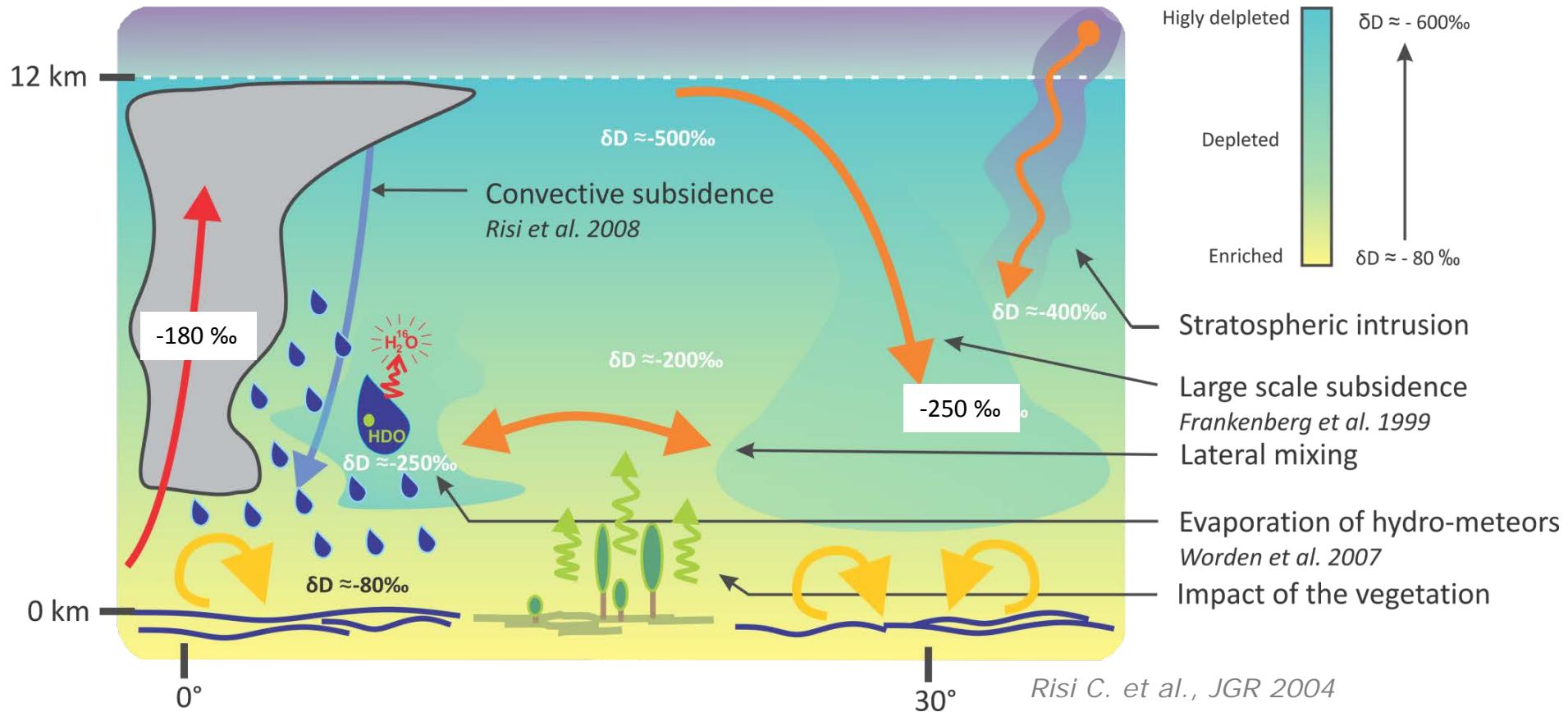


How do water isotopologues reveal “hidden” hydrological processes ?



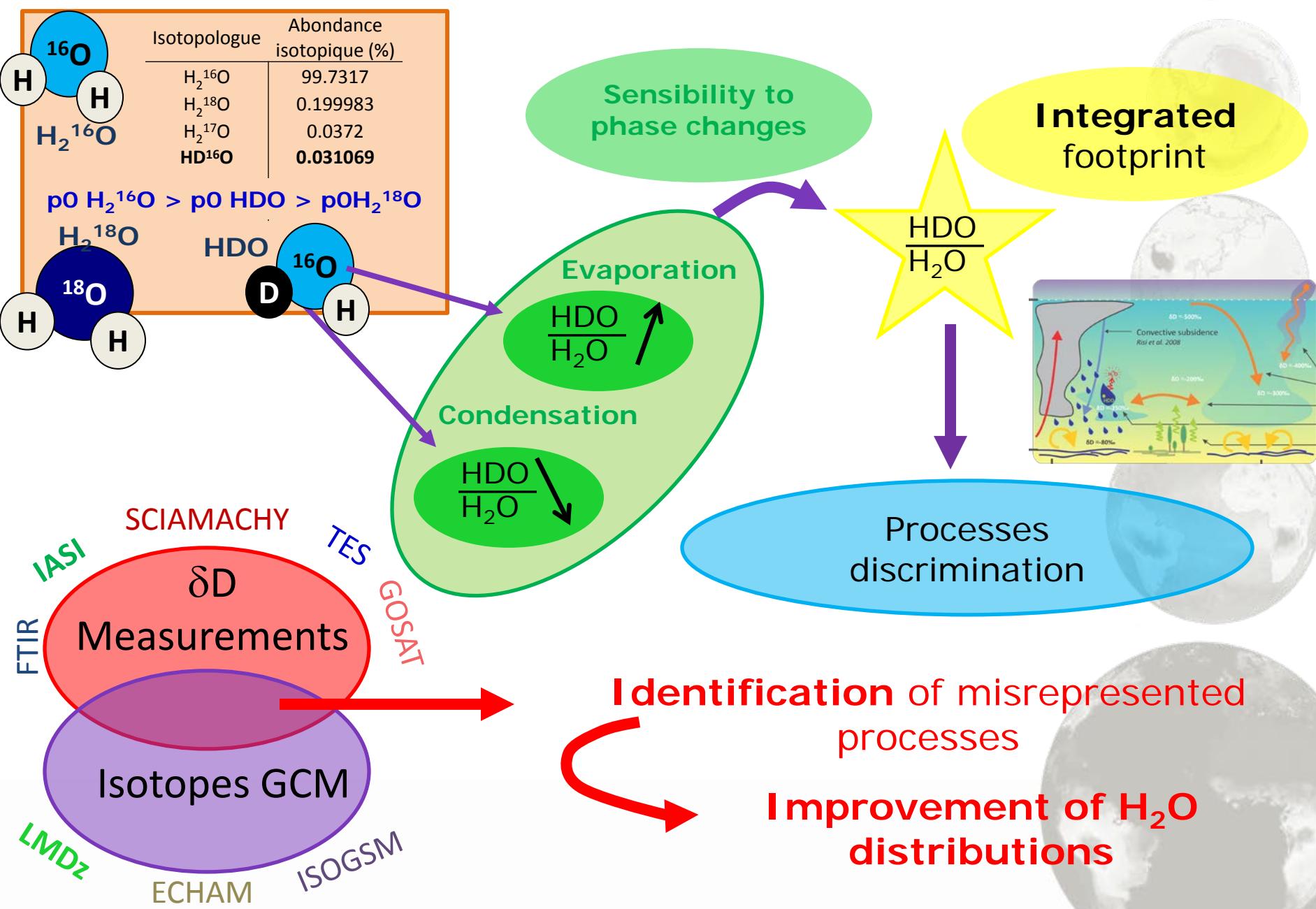
Spatial distribution of δD

Isotope fractionation expressed in δ notation: $\delta D = 1000 \times \left(\frac{HDO/H_2^{16}O}{SMOW} - 1 \right)$

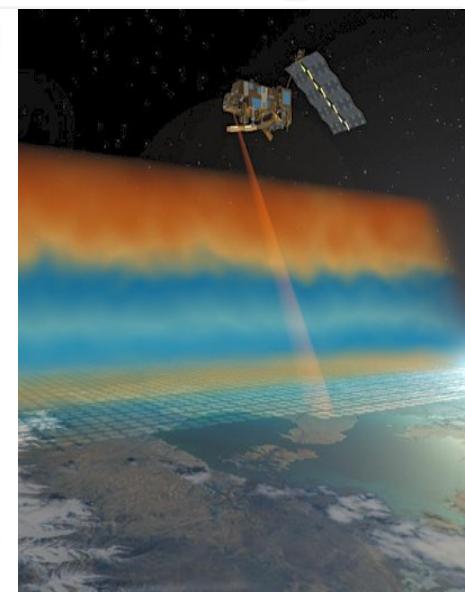
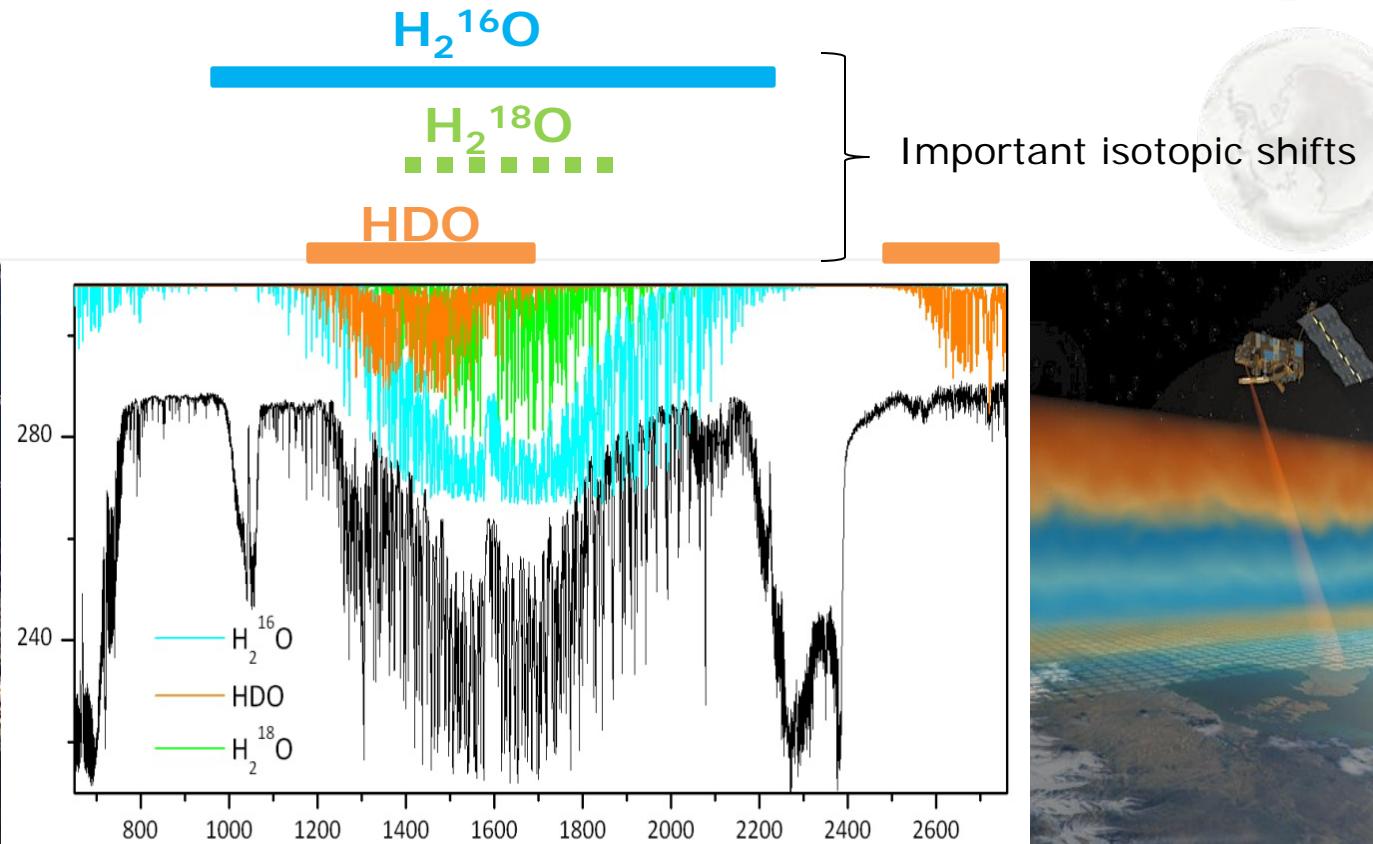


Processes controlling water distribution also control isotopic composition

How do water isotopologues reveal hidden hydrological processes ?



IASI performances for isotopologues applications



- **Spectral resolution = 0.5 cm⁻¹**
Isotopologues spectral signatures well detected
- **Radiometric noise ~ <0.25-0.5 K**
Natural variations of δD > noise Not for $\delta^{18}\text{O}$

★ **IASI sampling characteristics**



(2)

Retrieval of HDO/H₂O ratios: challenge & methodology

Retrieval methodology: adding a constraint in the OEM

Difficulties:

High variability of water, in space and in time.

High precision needed to capture isotopic variations ($\Delta 20\text{\textperthousand} \approx 2\%$)

Original approach:

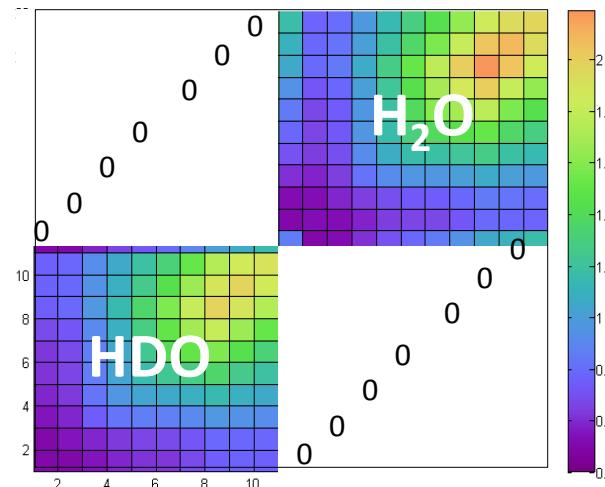
Introduction of correlation information between HDO and H₂O in the retrieval (optimal estimation method)

Schneider et al., ACP, 2006; Worden et al., JGR, 2006

+ retrieval performed on a logarithmic scale

$$\hat{x} = x_a + (\mathbf{K}^T \mathbf{S}_\epsilon^{-1} \mathbf{K} + \mathbf{S}_a^{-1})^{-1} \mathbf{K}^T \mathbf{S}_\epsilon^{-1} (\mathbf{y} - \mathbf{K}x_a)$$

$$\begin{bmatrix} \log \text{H}_2\text{O}_{1\text{ km}} \\ \vdots \\ \log \text{H}_2\text{O}_{10\text{ km}} \\ \log \text{HDO}_{1\text{ km}} \\ \vdots \\ \log \text{HDO}_{10\text{ km}} \end{bmatrix}$$



Retrieval methodology: adding a constraint in the OEM

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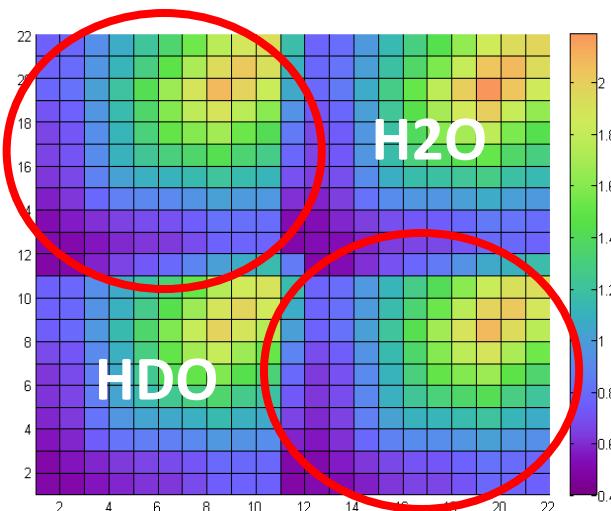
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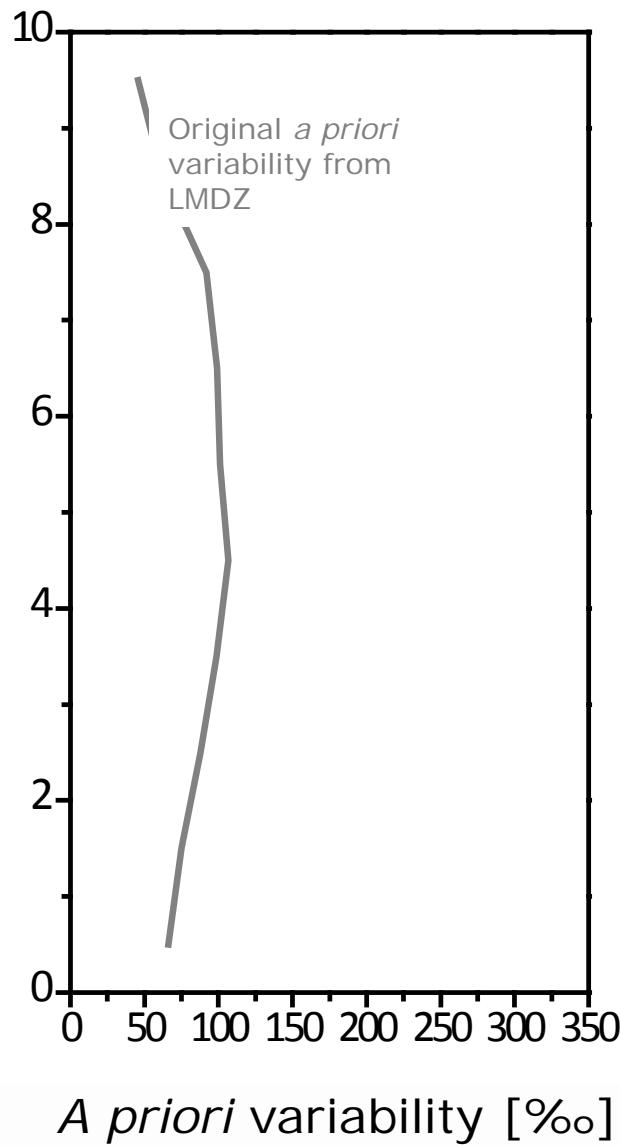
Schneider et al., ACP, 2006; Worden et al., JGR, 2006

+ retrieval performed on a logarithmic scale

$$\hat{x} = x_a + (\mathbf{K}^T \mathbf{S}_\epsilon^{-1} \mathbf{K} + \mathbf{S}_a^{-1})^{-1} \mathbf{K}^T \mathbf{S}_\epsilon^{-1} (y - \mathbf{K}x_a)$$

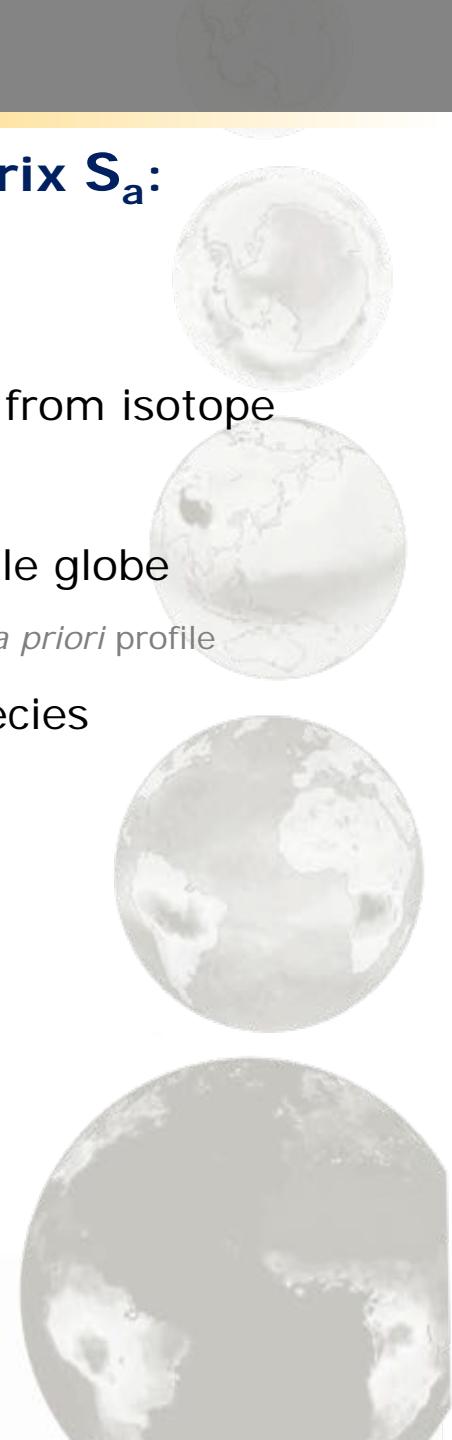
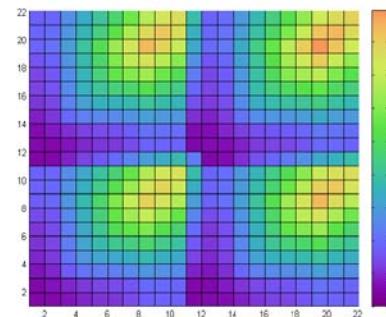
$$\begin{bmatrix} \log \text{H}_2\text{O}_{1 \text{ km}} \\ \vdots \\ \log \text{H}_2\text{O}_{10 \text{ km}} \\ \log \text{HDO}_{1 \text{ km}} \\ \vdots \\ \log \text{HDO}_{10 \text{ km}} \end{bmatrix}$$

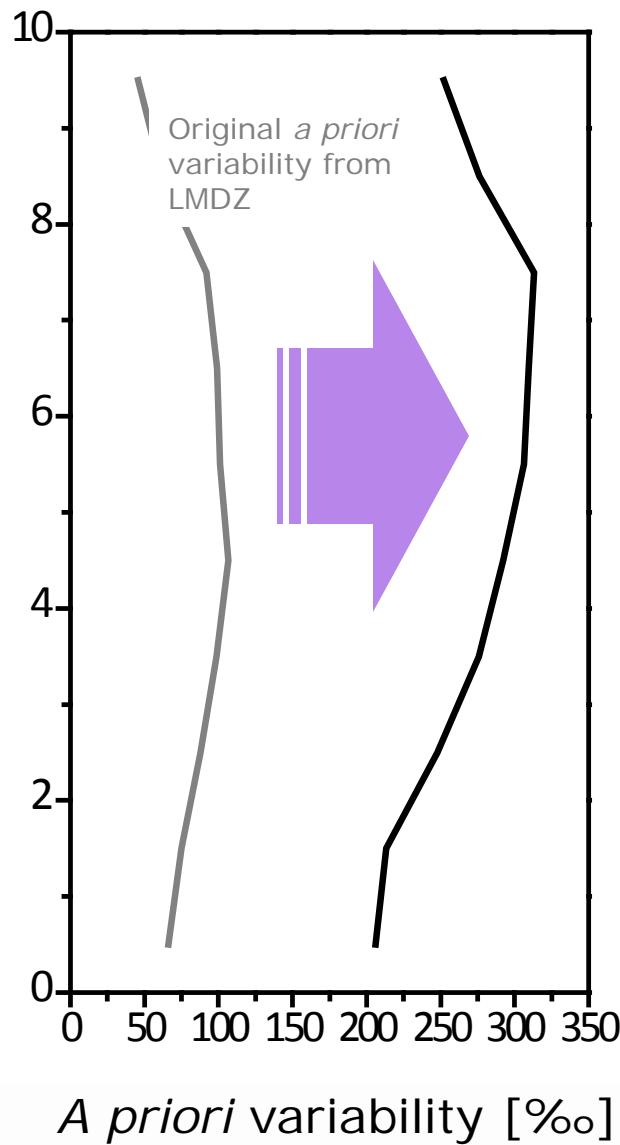




The *a priori* covariance matrix S_a :

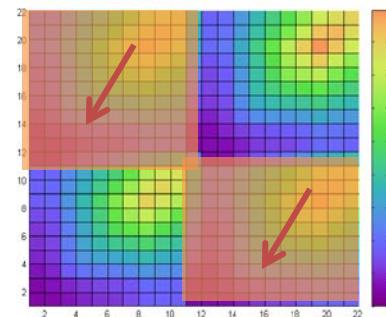
- ◆ Sparse dataset available
 - *A priori* information built from isotope enabled GCM (LMDZ-iso)
 - Covariance from the whole globe and an entire year
 - Decrease of the inter-species elements of the S_a





The *a priori* covariance matrix S_a :

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 - *A priori* information built from isotope enabled GCM (LMDZ-iso)
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Increase of the *a priori* variability of HDO/H₂O ratio

Retrieval choices (2/2)

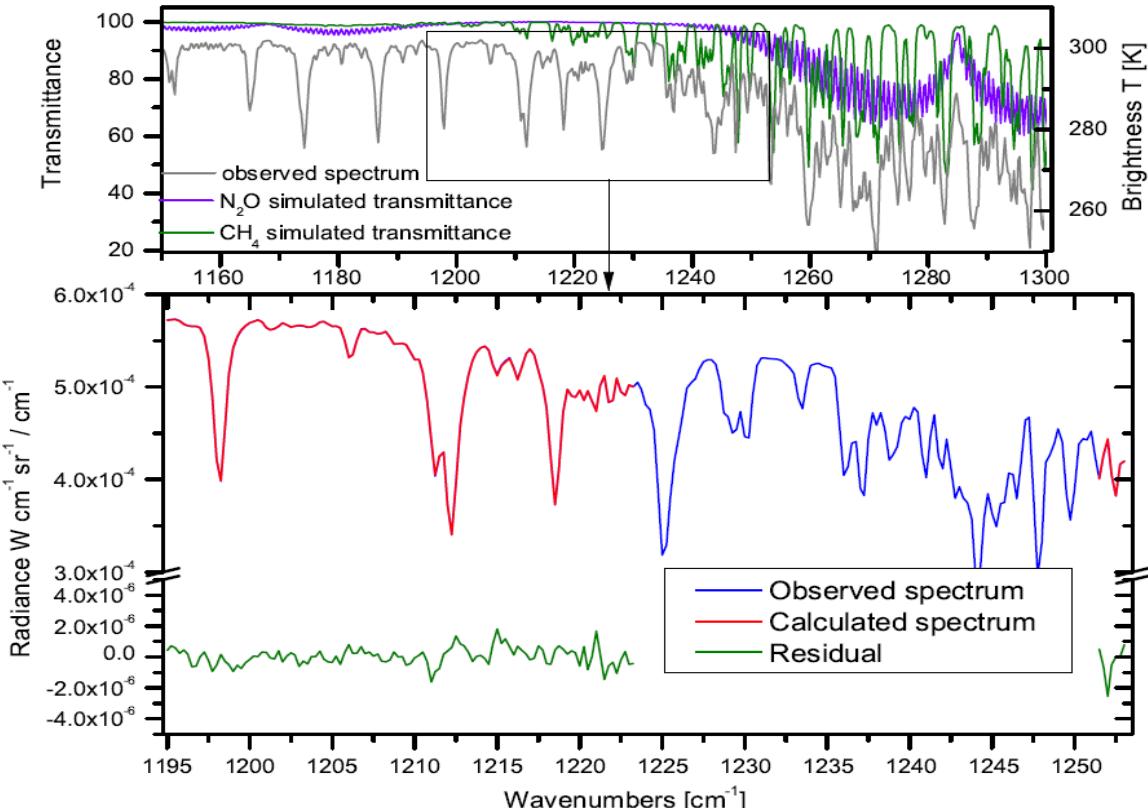
Spectral window:

Small spectral range
from 1195-1253 cm⁻¹

Gap between 1223 & 1251 cm⁻¹
To avoid CH₄ and N₂O interferences

 Short retrieval time

 Fit close to noise level

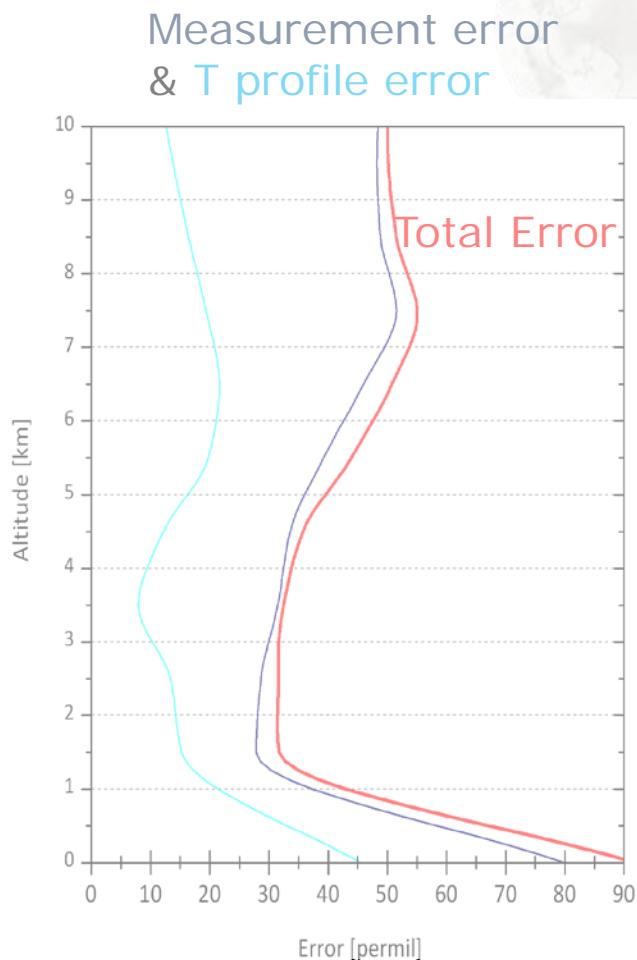
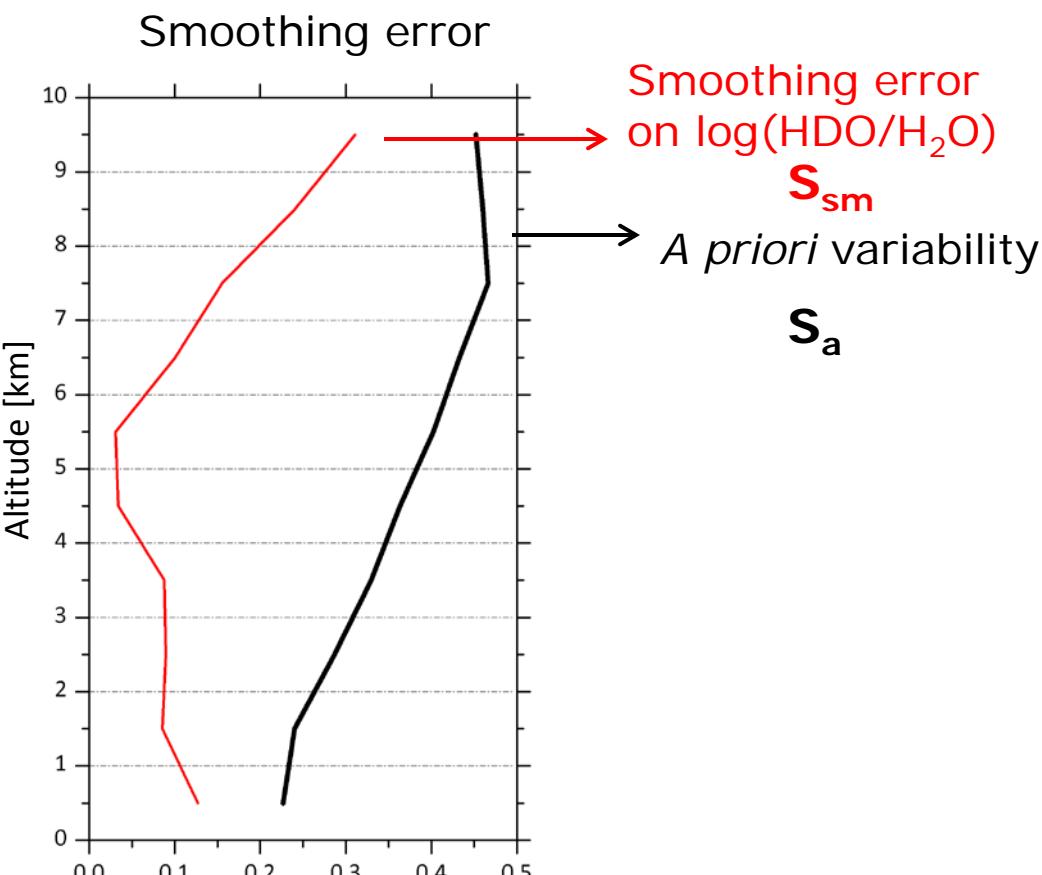


Others:

- Cloud free spectra (\approx EUMETSAT L2 cloud flag $< 10\%$)
- Retrieval on the 10 first kilometers of the atmosphere
- Emissivities climatologies (Zhou *et al.*, IEEE Trans. Geosci. Remote Sens, 2011)

Sensitivity and error characterization

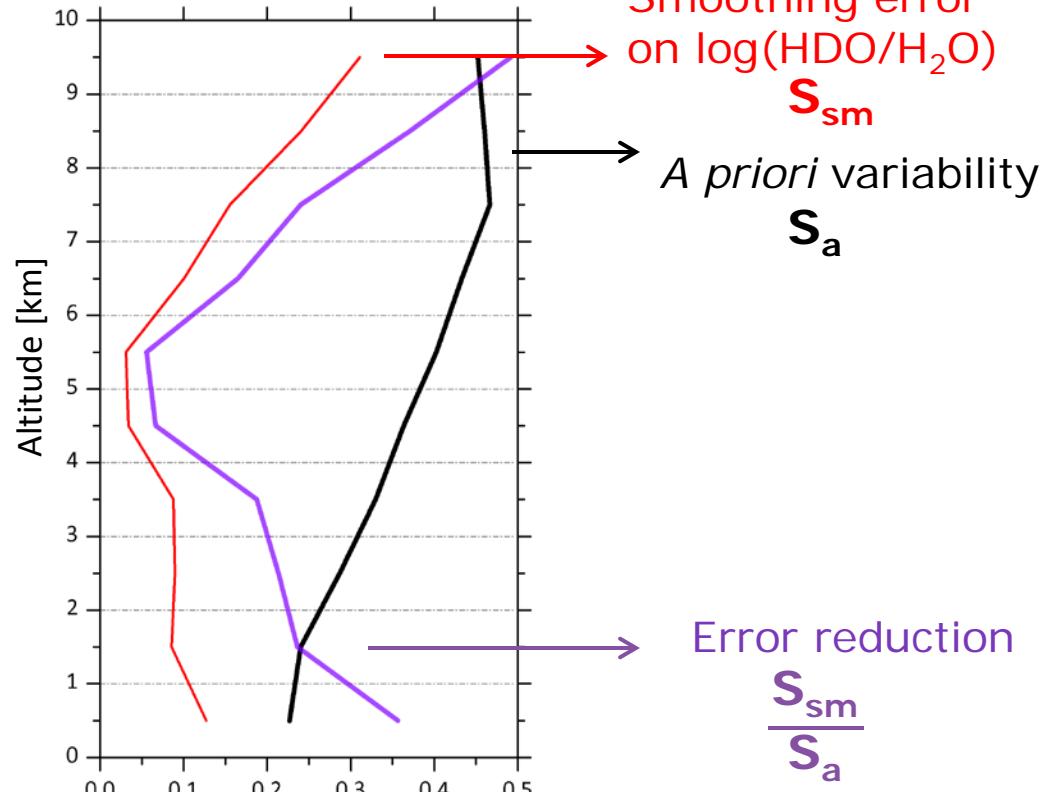
Sensitivity of the retrieval to HDO/H₂O ratio



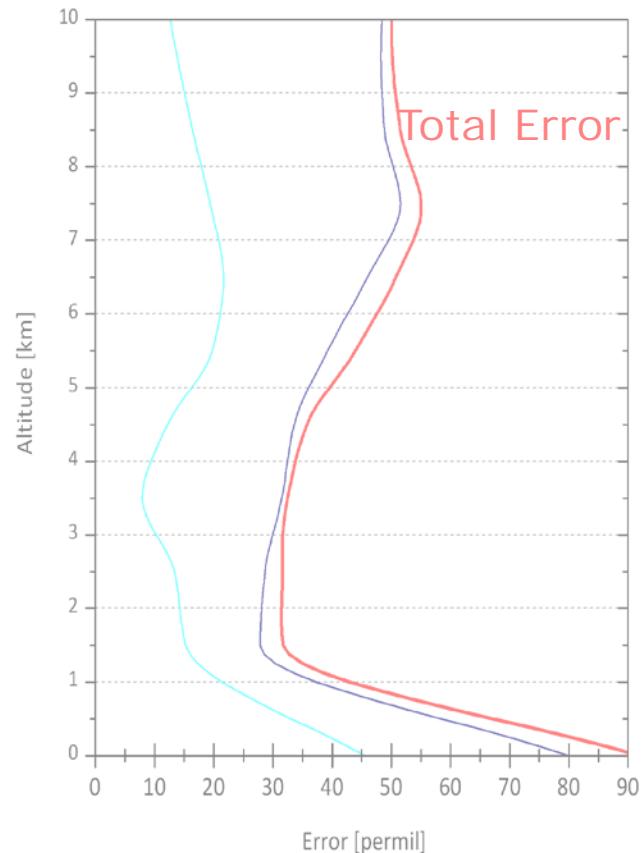
Sensitivity and error characterization

Sensitivity of the retrieval to HDO/H₂O ratio

Smoothing error



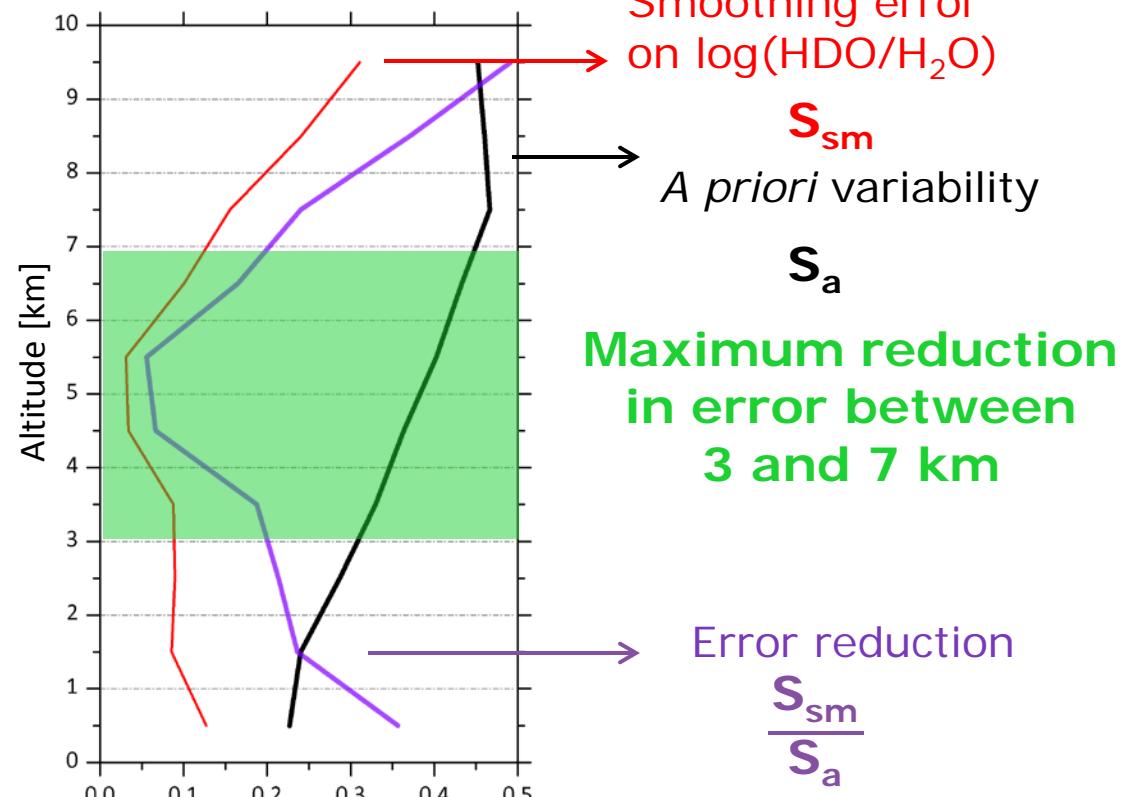
Measurement error & T profile error



Sensitivity and error characterization

Sensitivity of the retrieval to HDO/H₂O ratio

Smoothing error



Smoothing error
on log(HDO/H₂O)

S_{sm}

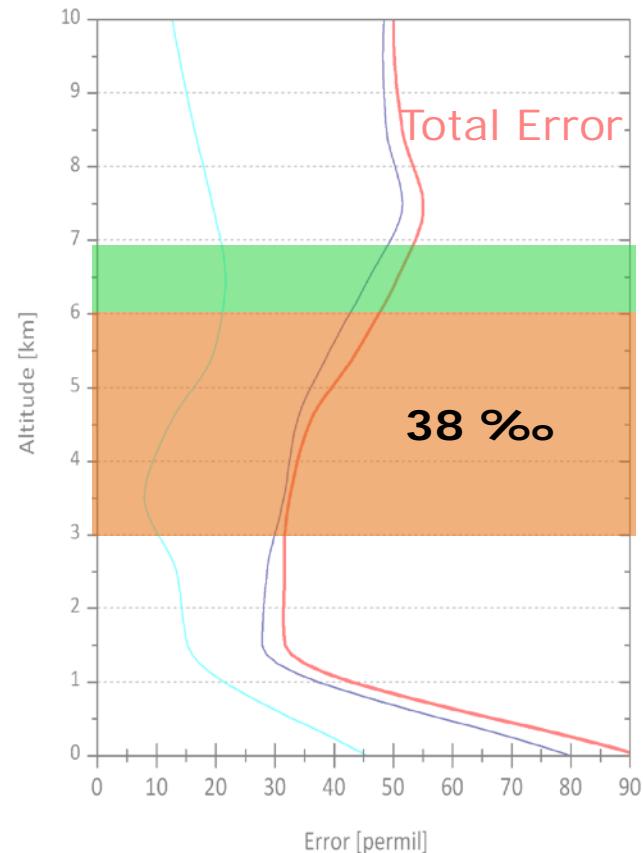
A priori variability

S_a

Maximum reduction
in error between
3 and 7 km

Error reduction
 $\frac{S_{sm}}{S_a}$

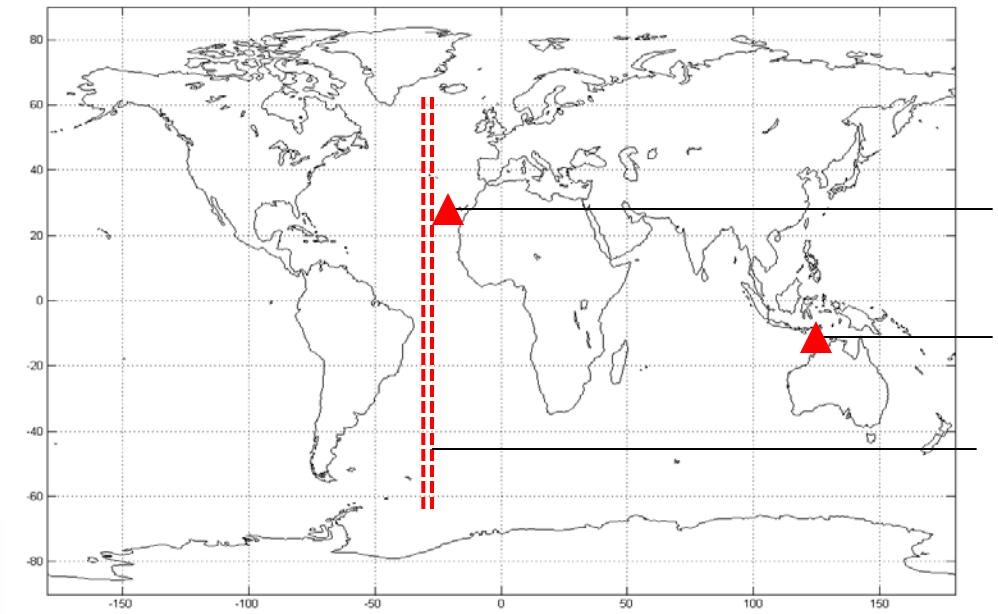
Measurement error
& T profile error



Between 3 and 6 km → Precise and sensitive δD for scientific issues



(3) Results above specific hydrological regions



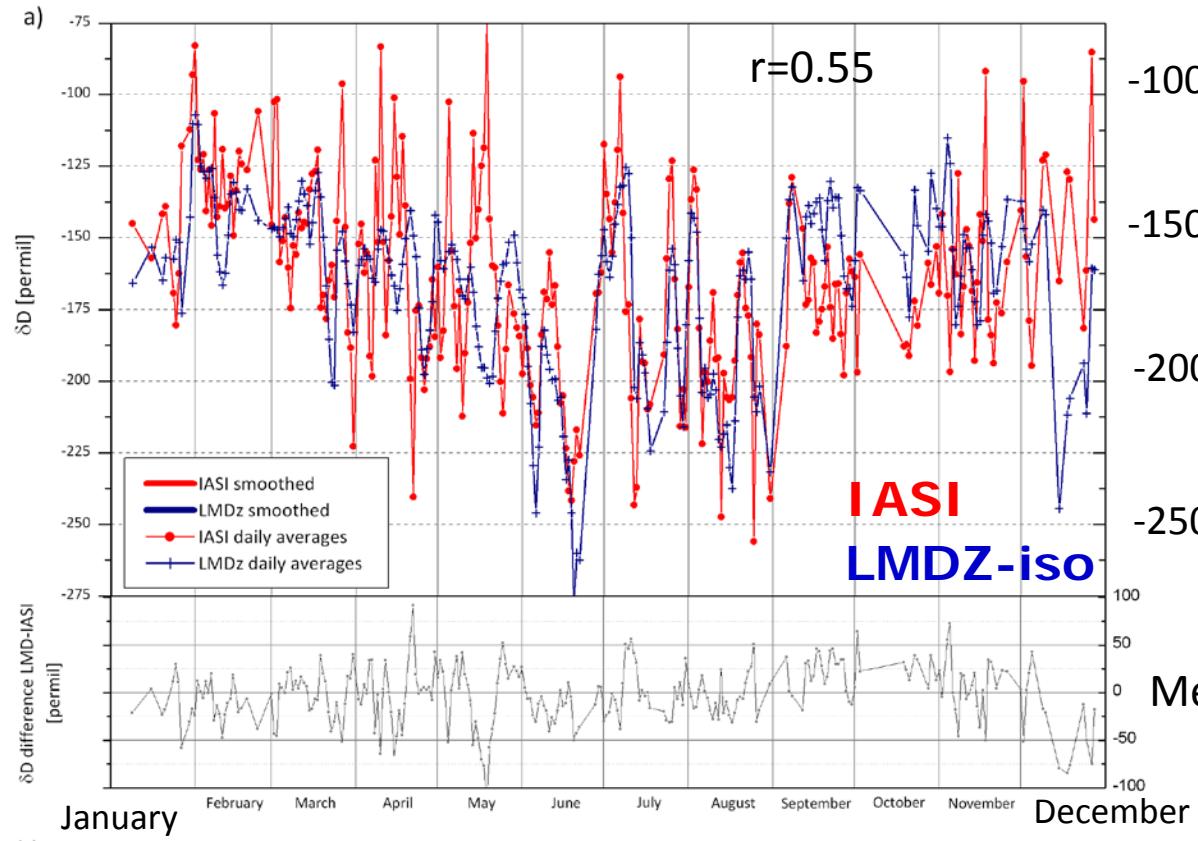
Subsidence site, **Izaña**

Convective site, **Darwin**

Latitudinal gradient

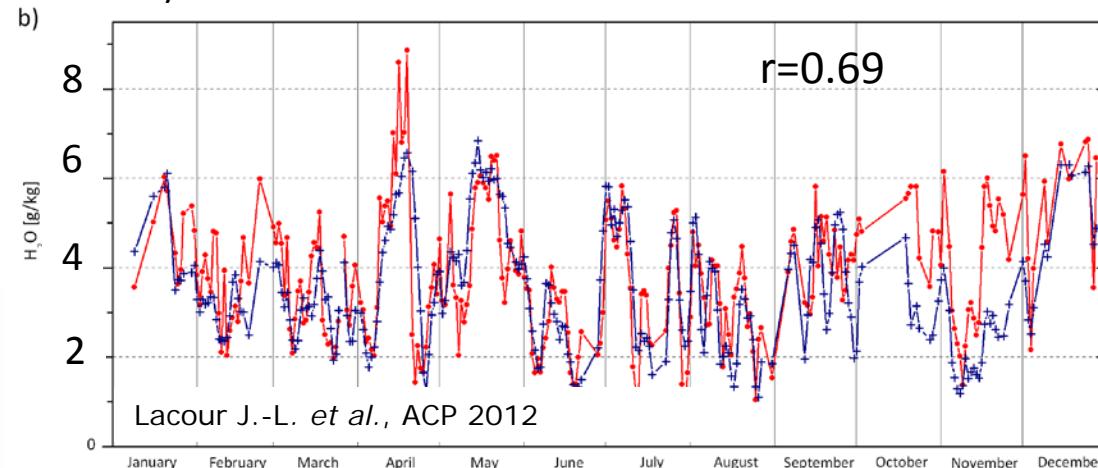
Evaluation of results against model data

Darwin:
Convective site



δD [permil]

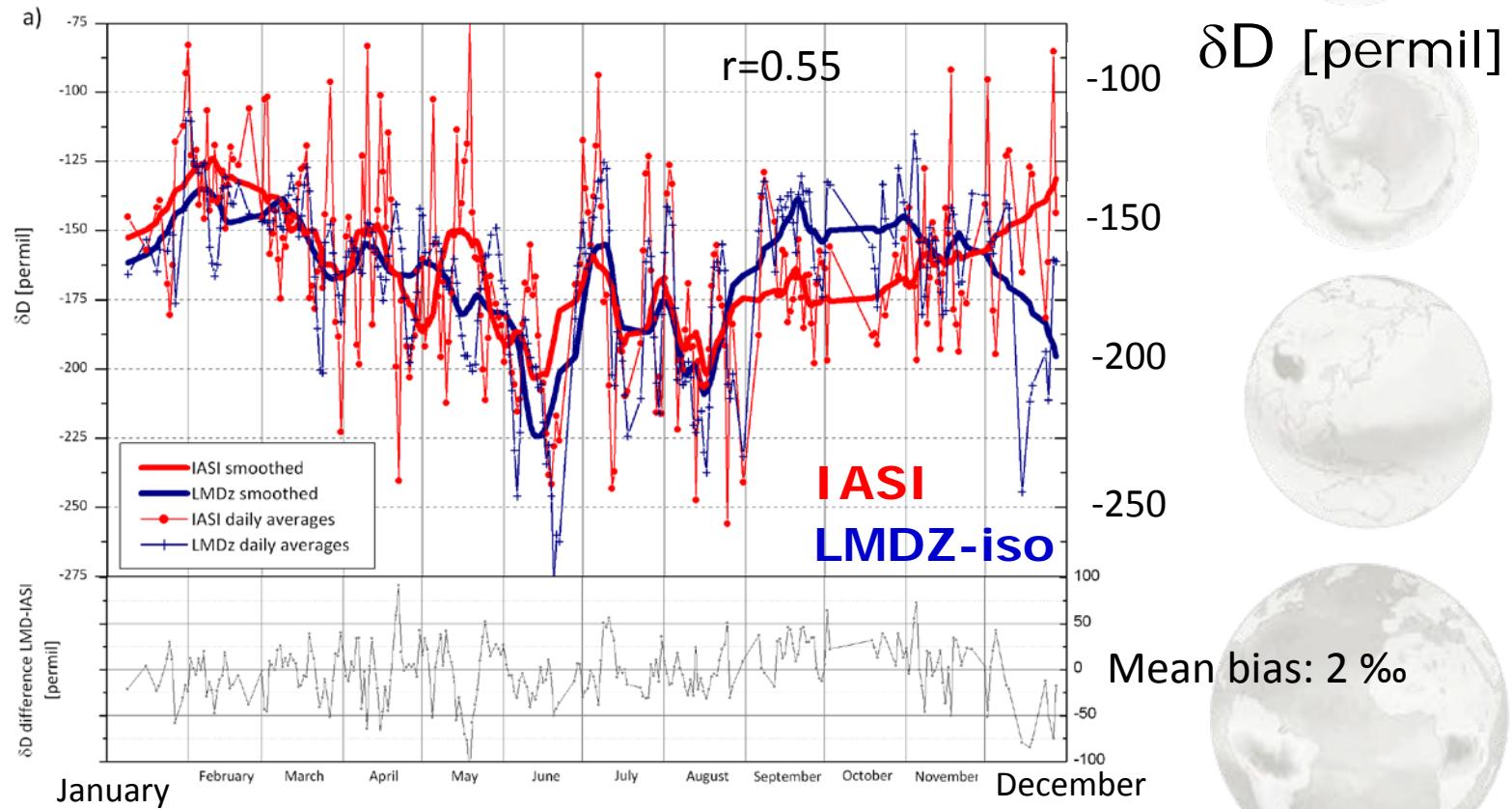
Mean bias: 2 %



H_2O [g/kg]

Evaluation of results against model data

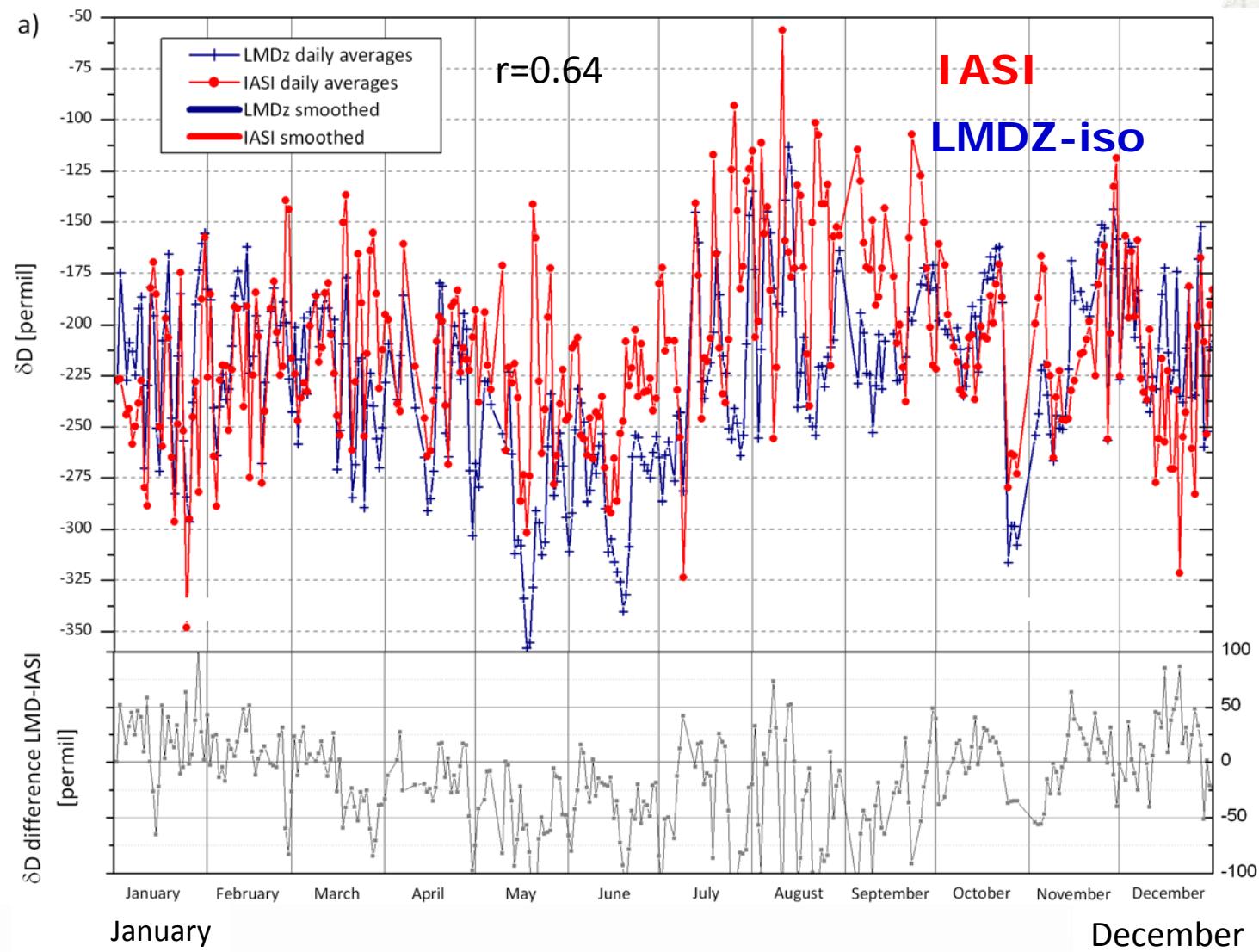
Darwin:
Convective site



Lacour J.-L. et al., ACP 2012

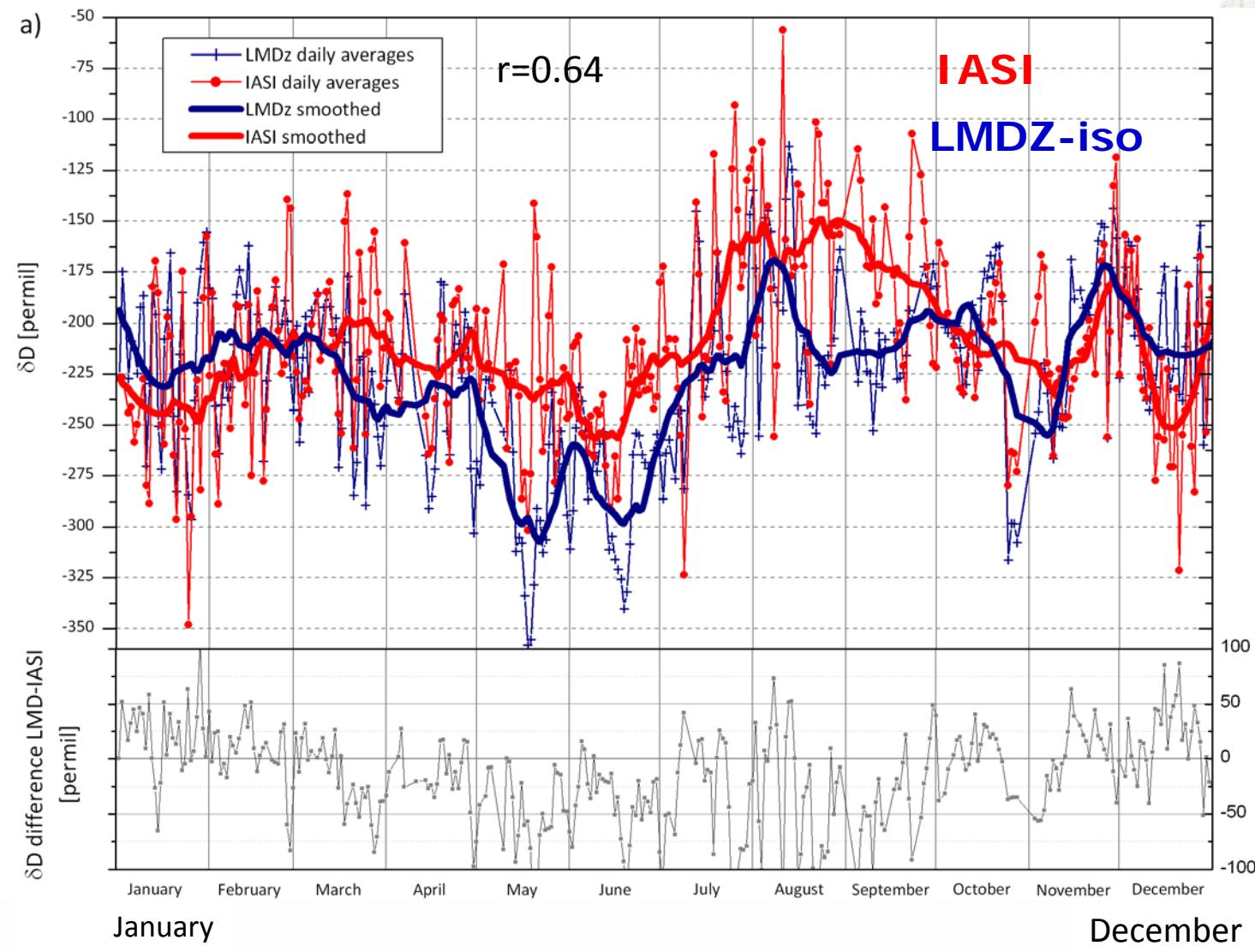
Evaluation of results against model data

Izaña : Subsidence site



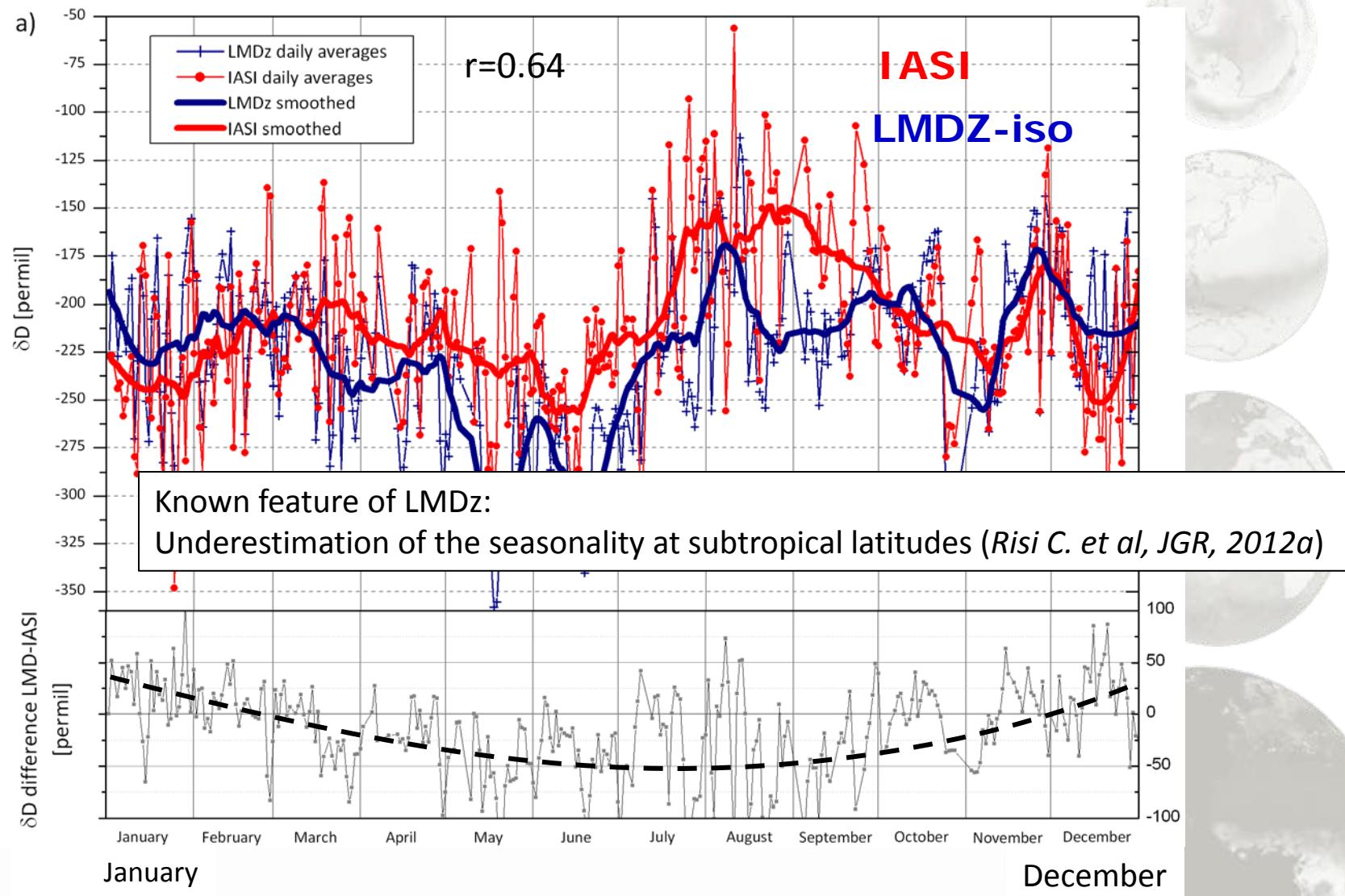
Evaluation of results against model data

Izaña : Subsidence site



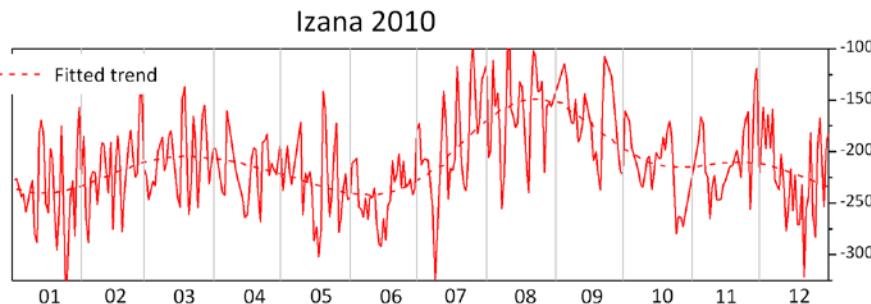
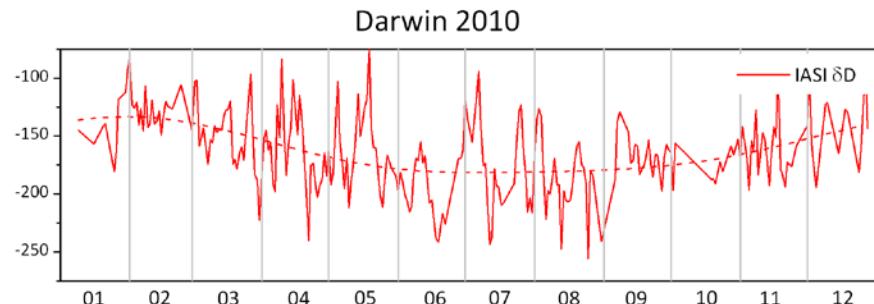
Evaluation of results against model data

Izaña : Subsidence site

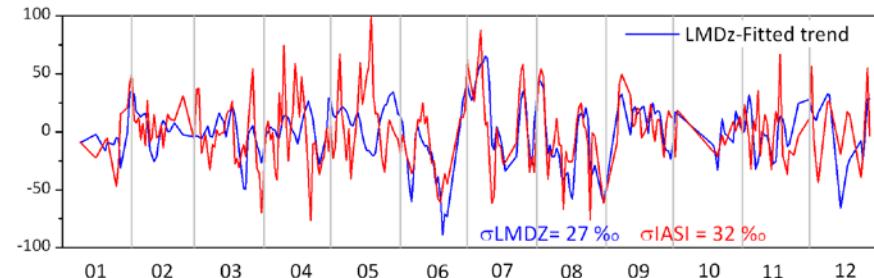
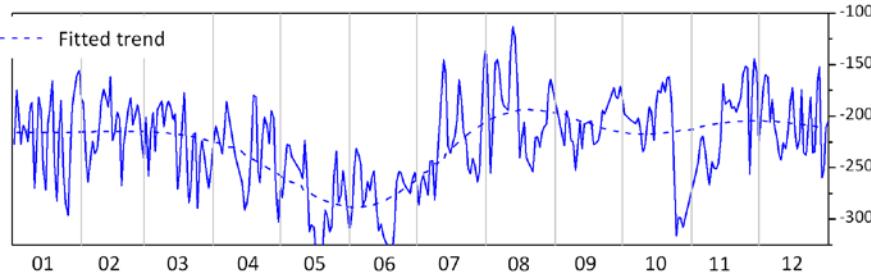
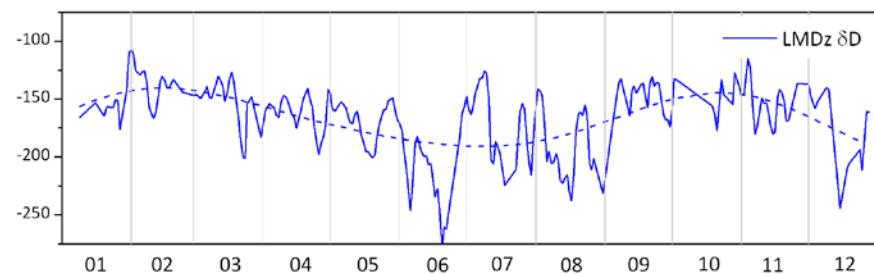


Short term variability - detrended timeseries

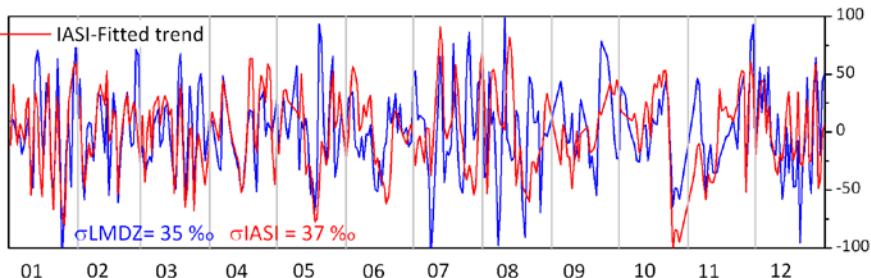
IASI



LMDZ-iso



$\sigma_{IASI} (32\%) > \sigma_{LMDZ} (27\%)$

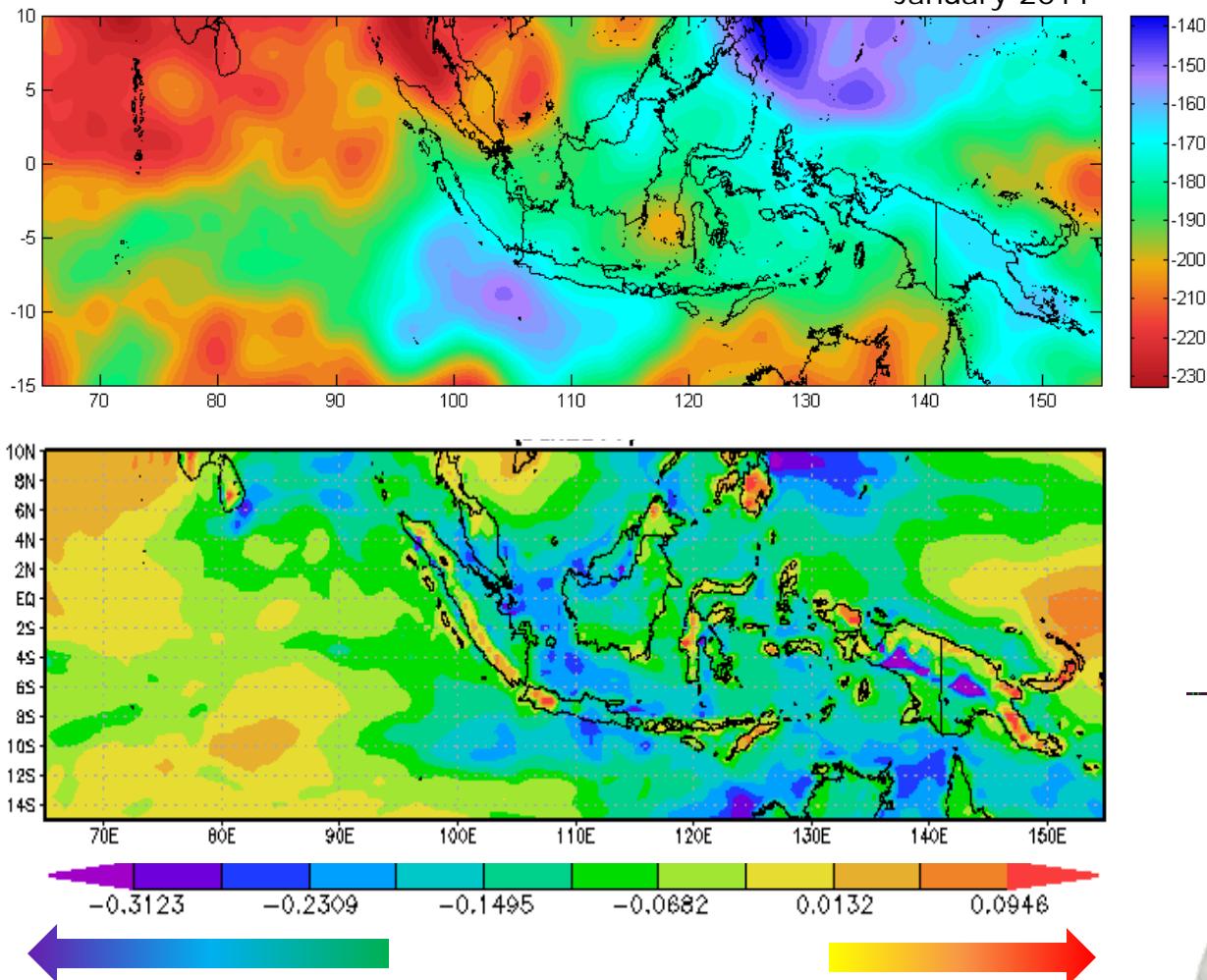


$\sigma_{IASI} (37\%) > \sigma_{LMDZ} (35\%)$

Maritime continent – Dynamic control on δD

Monthly mean

January 2011



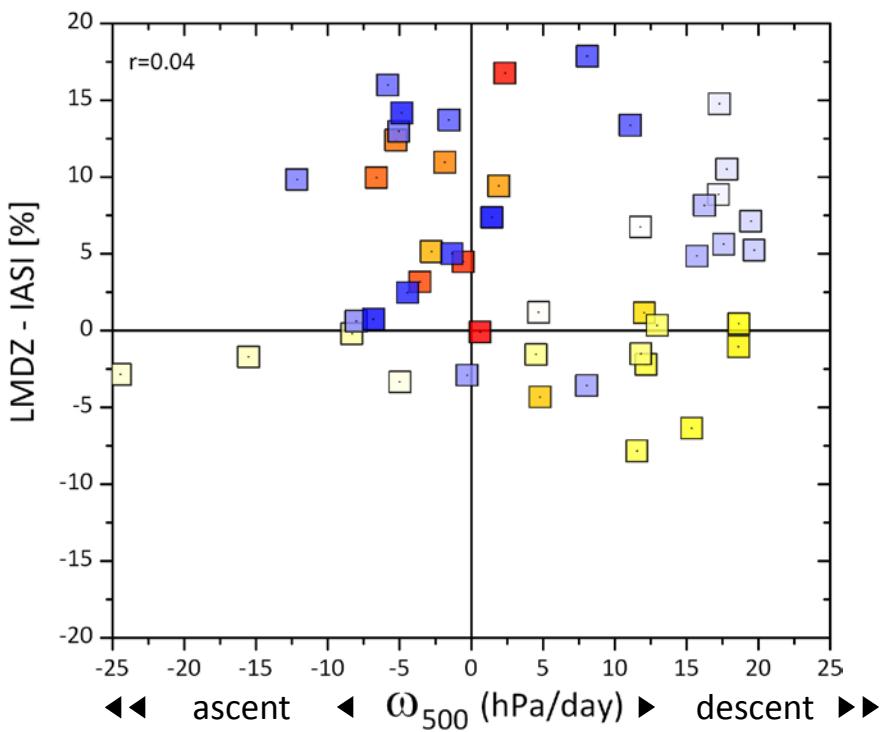
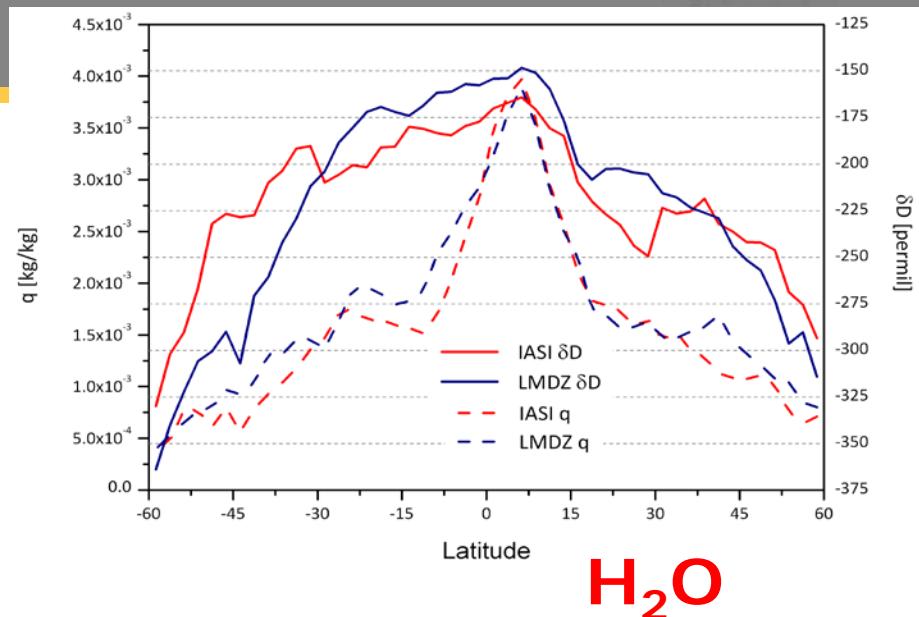
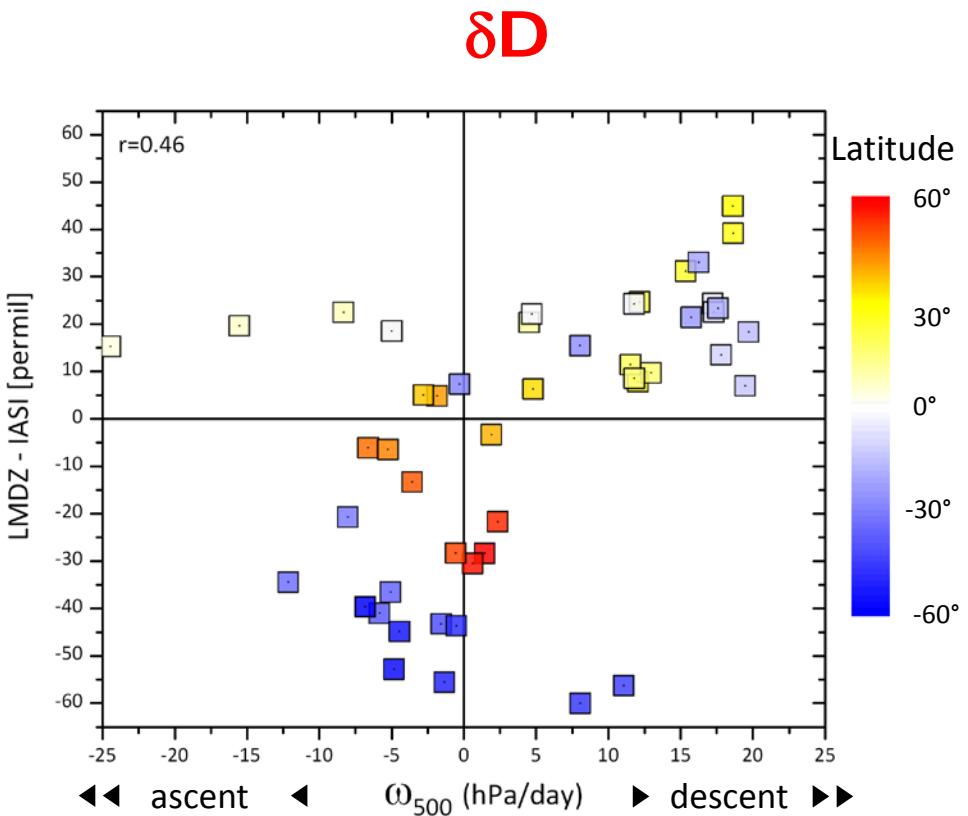
Convection

Subsidence

Latitudinal gradients

Retrievals from 60°N to 60°S above the Atlantic
(short longitudinal extent)

→ Investigating the humidity processes
responsible of the δD latitudinal variability

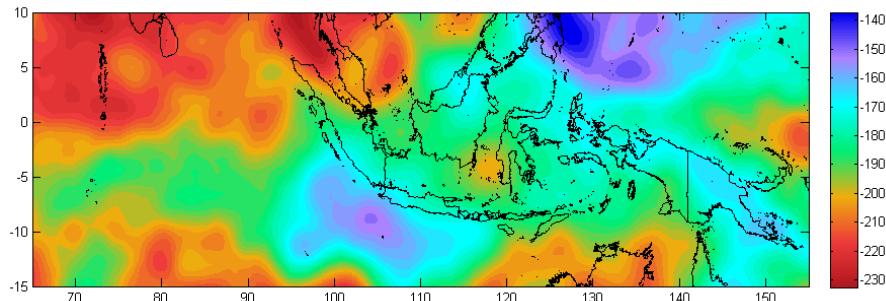


Summary and perspectives

- IASI provides δD precise and sensitive enough for scientific use
- δD retrievals 'evaluation' against LMDZ-iso shows nice agreements
 - ▣ Seasonal -> short term variability in good agreements with LMDZ
 - ▣ Main differences model-IASI have already been identified as model issues
- Growing number of possibilities towards validation
 - ▣ MUSICA project (Schneider et al, 2012)
 - ▣ Airplane δD measurements within HYMEX campaign - cavity ringdown spectrometer (H. Sodemann, EGU 2013)
- CONV-ISO (C. Risi, LMD)

Studying **convective and cloud processes** during the **MJO** and evaluating their representation in climate models by combining humidity, cloud and **water isotopic measurements**

+ TES (J. Worden) , IASI MUSICA (M. Schneider), GOSAT (C. Frankenberg)



Courtesy of H. Sodemann

