GISS lunch talk Seminar@09 March, 2009

Diagnosis of the present hydrological cycle using isotope GCM

Naoyuki Kurita
(Visiting Scientist from JAMSTEC)

ateau

H_2O 99.7% HDO 0.016% $H_2{}^{18}O$ 0.20%

Outline

1. New water isotopes dataset in Asia
2. Findings of new dataset
3. Factors controlling the isotopic variation using isotope GCM
4. How to use the isotope tracer to diagnosis of the hydrological cycle

2005.09.05

Borneo island

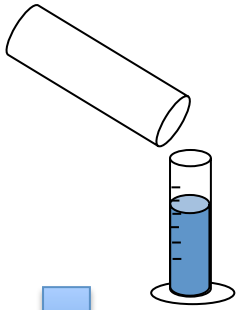
Indian Ocean

Water Isotope Sampling Procedure

1. Collect rain samples

Russian station

2. Measure the amount of precipitation

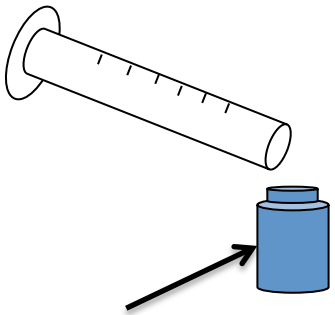


3. Send to WMO through the telecommunication network system

WMO (WWW)

World Meteorological Organization

3. Replace rain water to glass bottle (6ml)

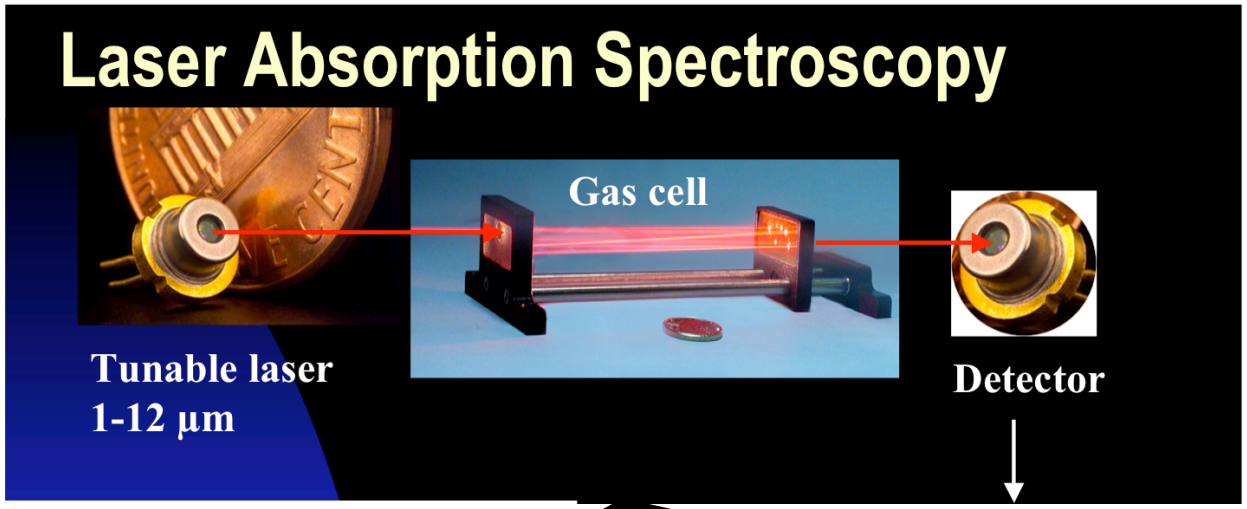


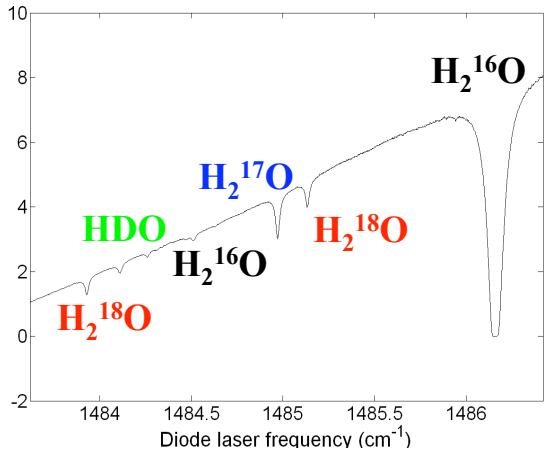
6ml Bottle

Ship to Lab.

4. Measure the isotopic content of prec.

New Measuring Technique





In-situ observation

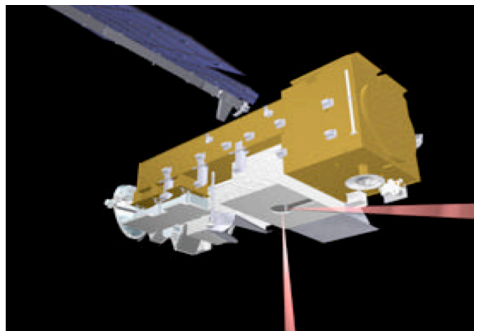
Airplane

NASA WB-57

Balloon

TETHEO campaign

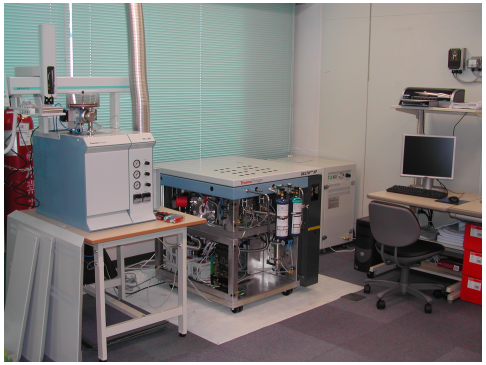
Satellite



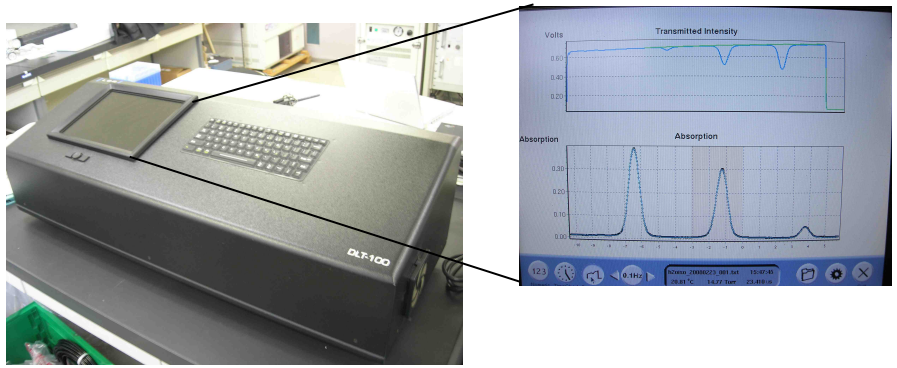
AURA/TES

New Measuring Technique

Laboratory → Reduce the measuring time



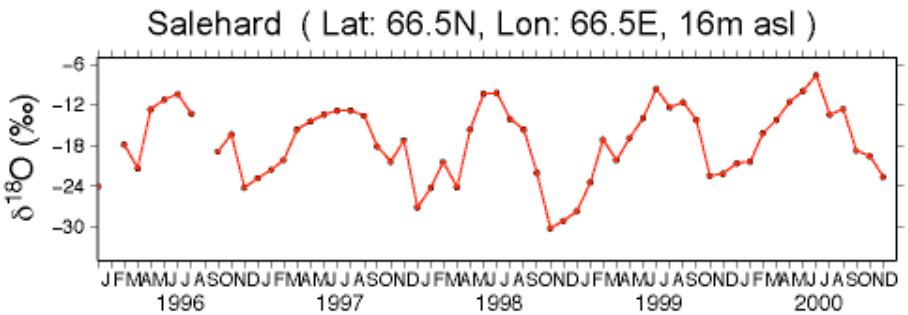
CF-IRMS



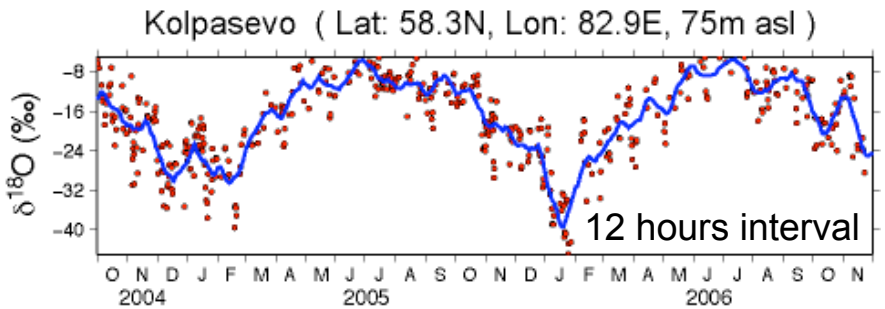
Laser mass spec.

Monitoring datasets

Monthly archive → Event sampling

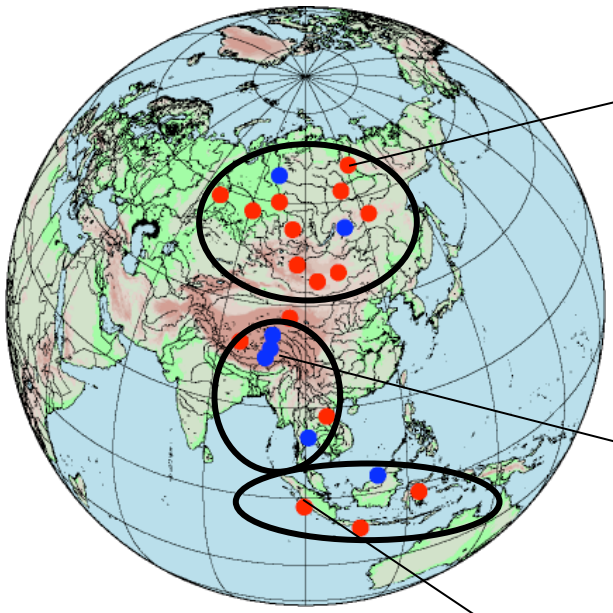


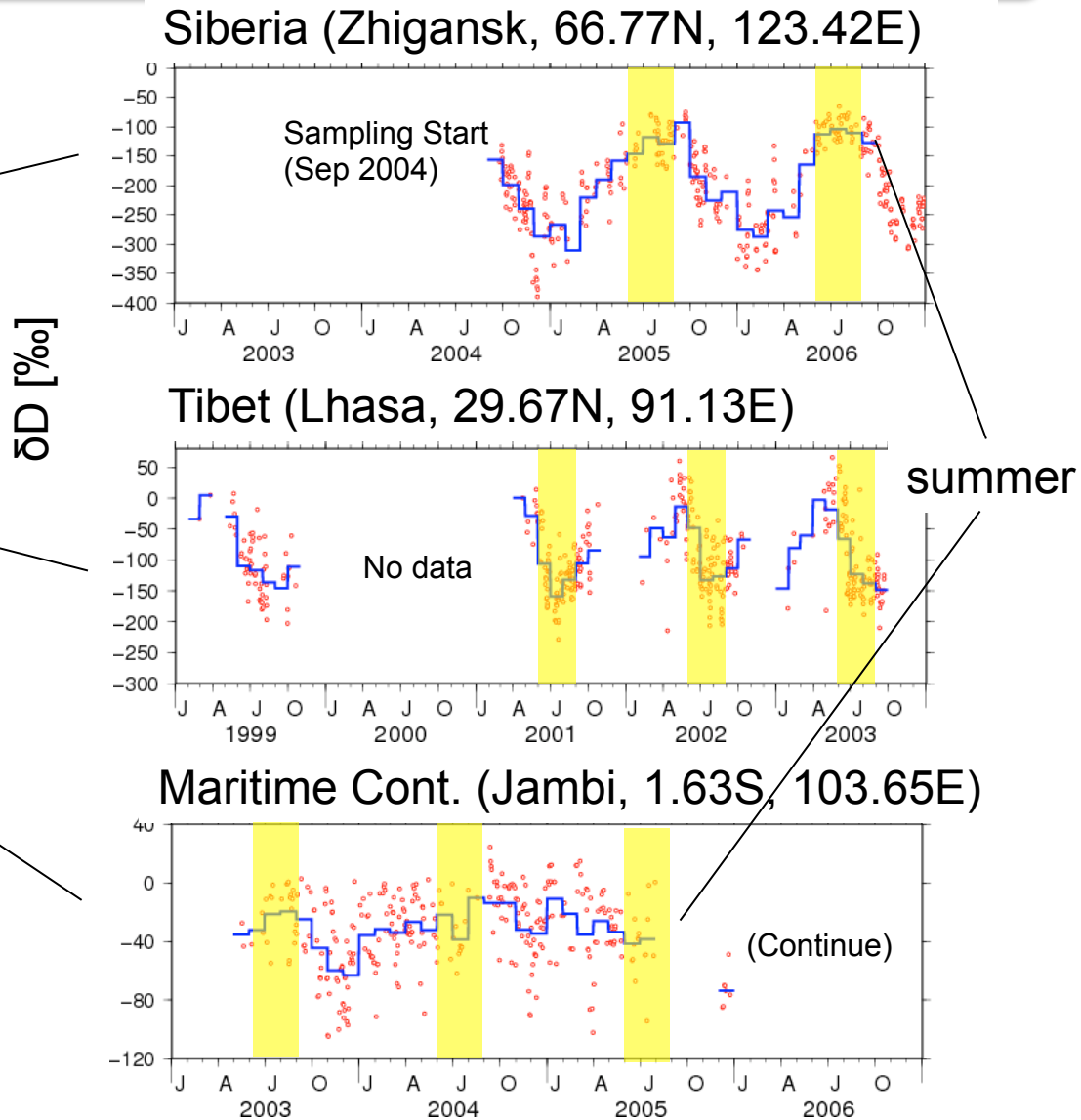
(Kurita et al., 2004)



(Kurita et al., 2009 in preparation)

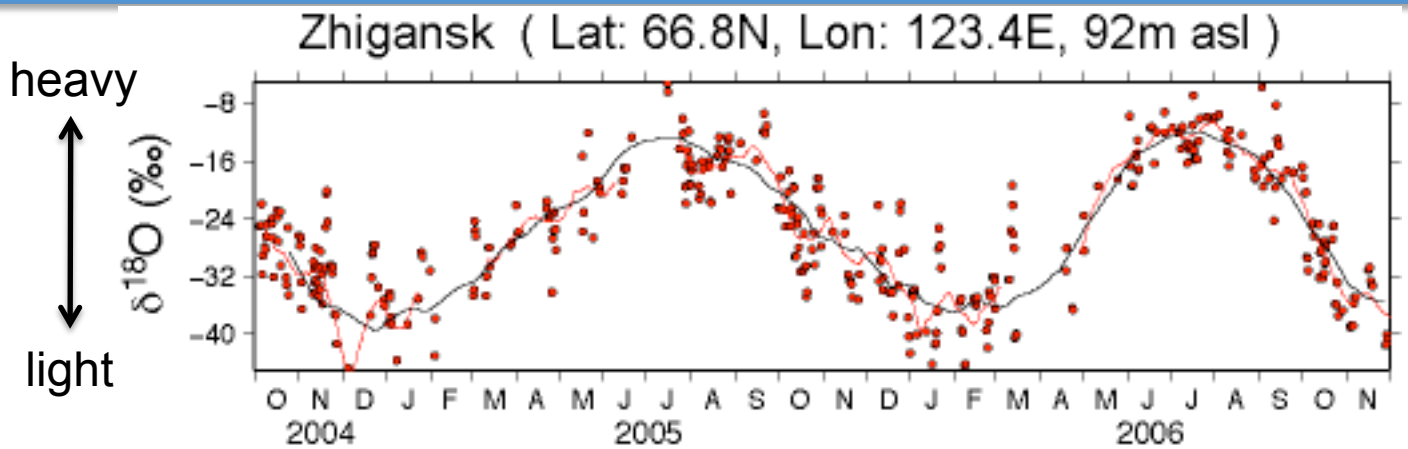
Water Isotope Monitoring in Asia



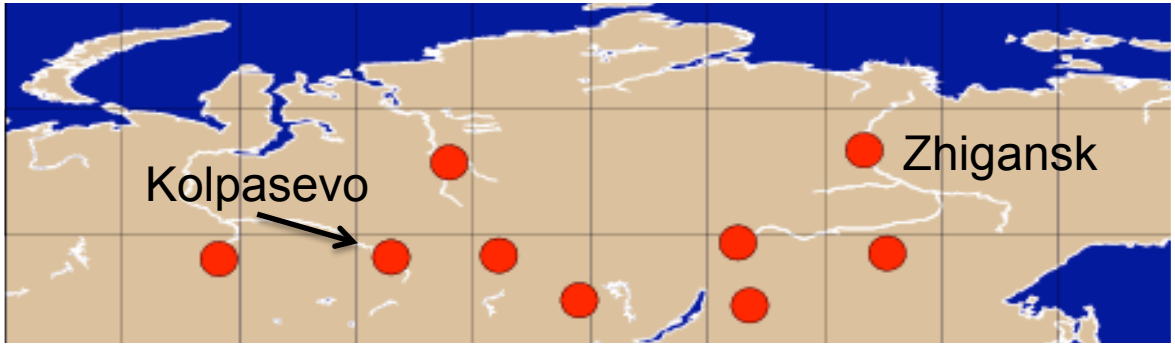


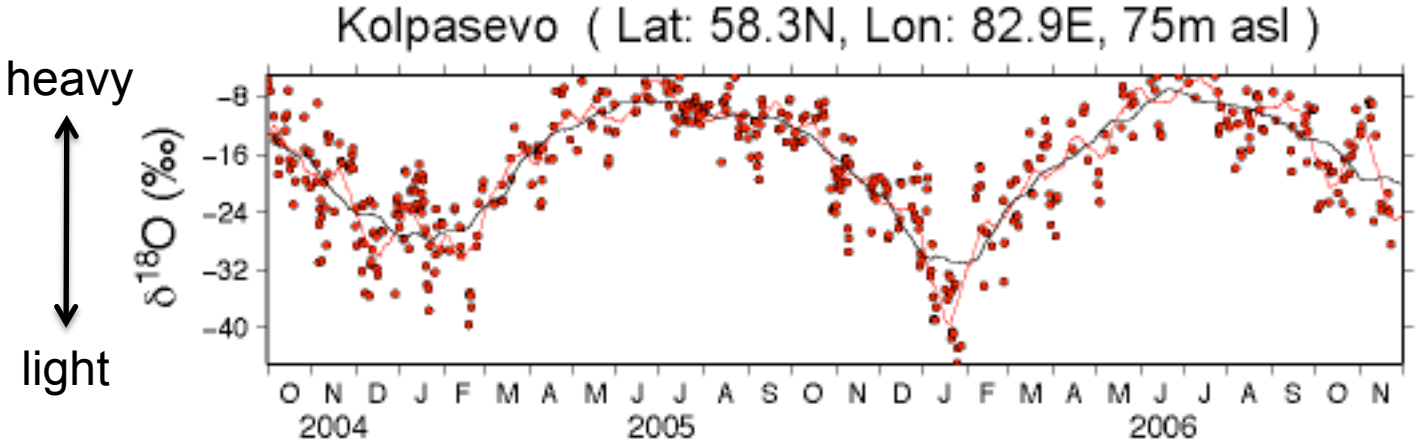
What can we get from these high frequency monitoring datasets?

Time series of $\delta^{18}O$ in precipitation in Siberia



Eastern Siberia

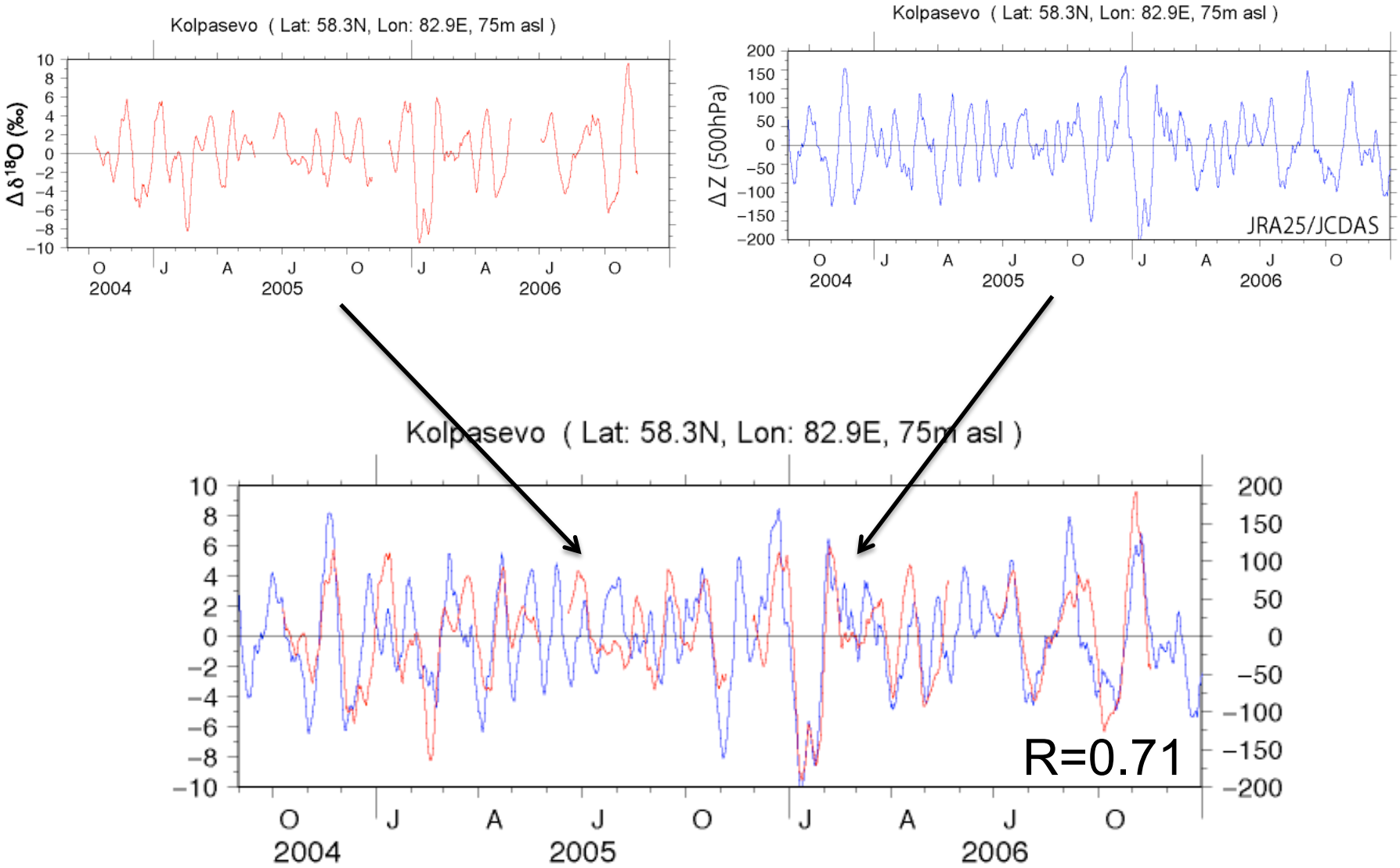




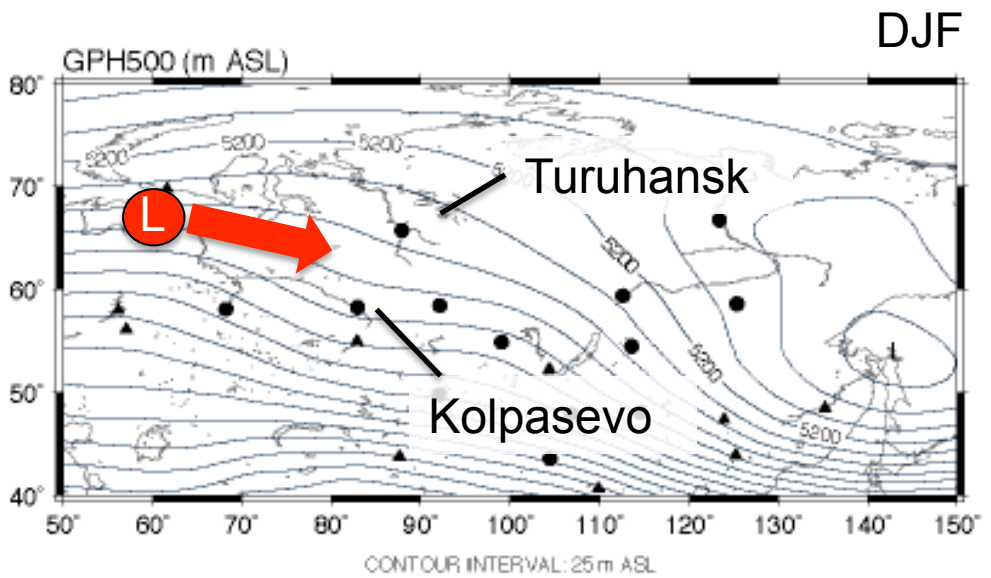
Western Siberia

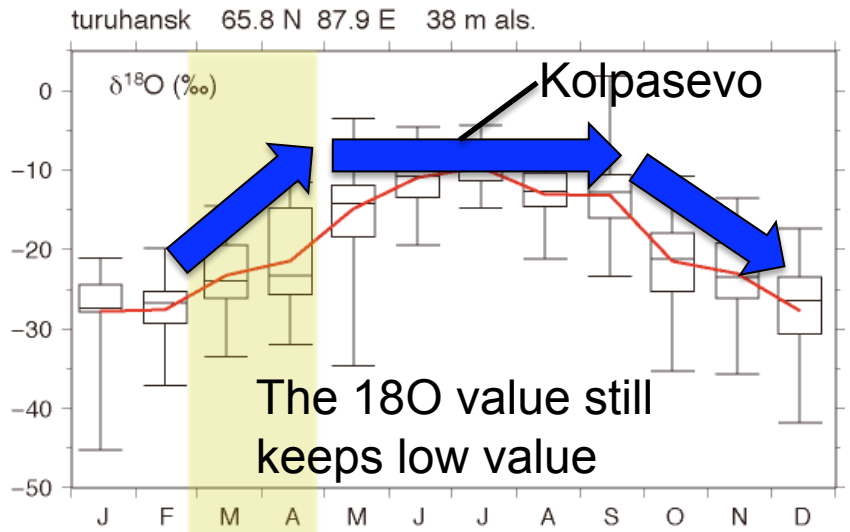
Intra-seasonal variability of $\delta^{18}O_{pre}$ in Siberia

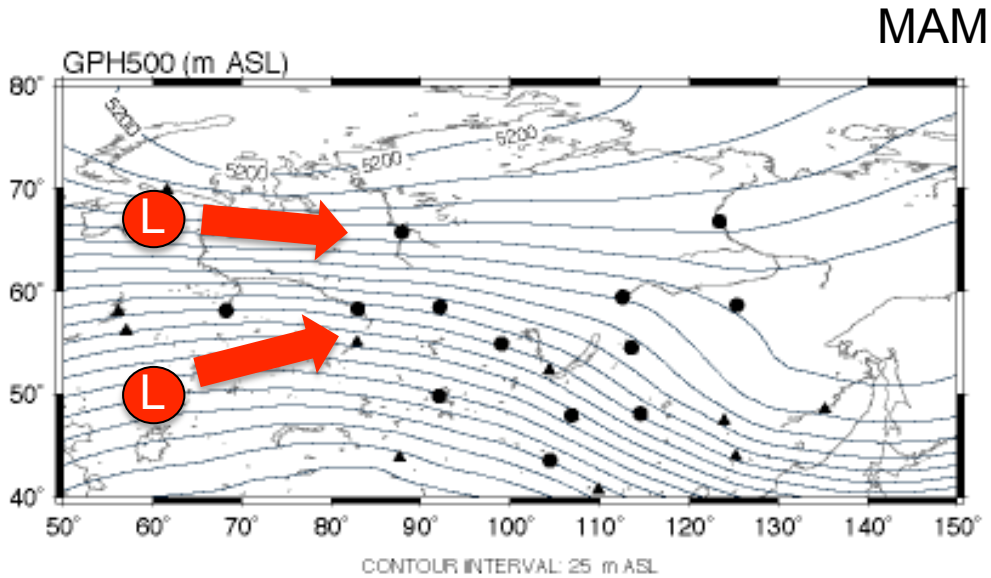
10-30 day band passed filtered anomaly

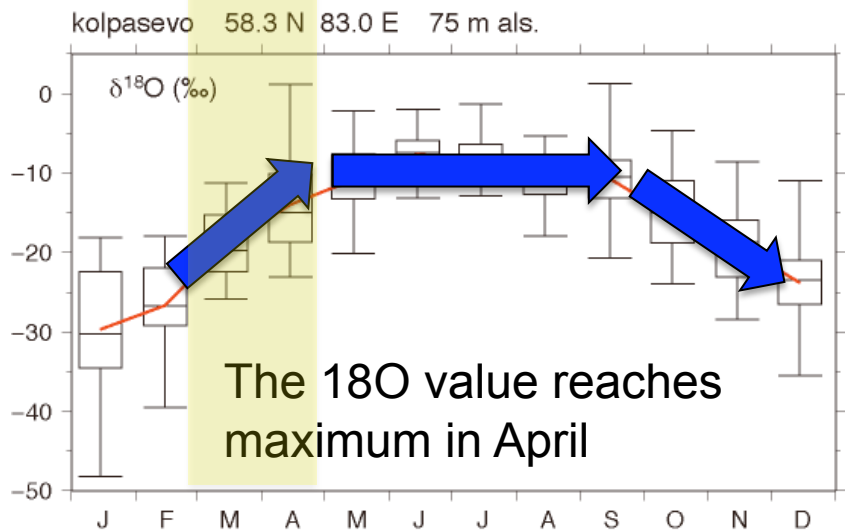


Seasonal cycle of $\delta^{18}O_{pre}$ in Siberia



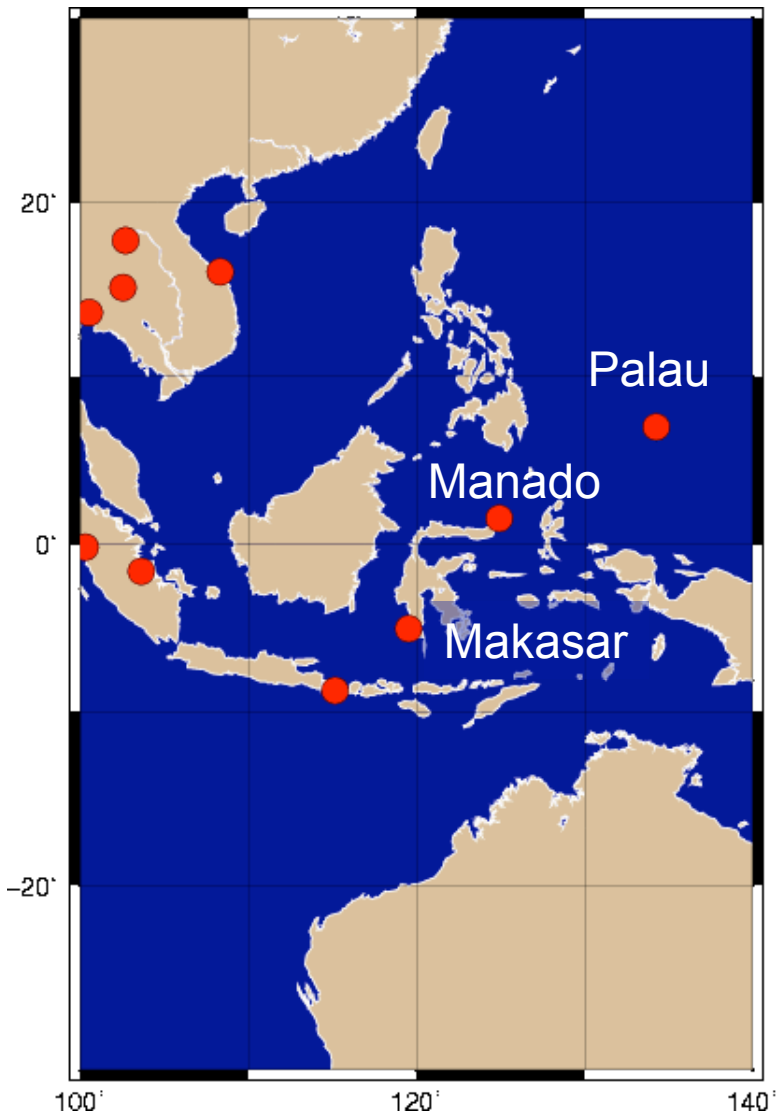


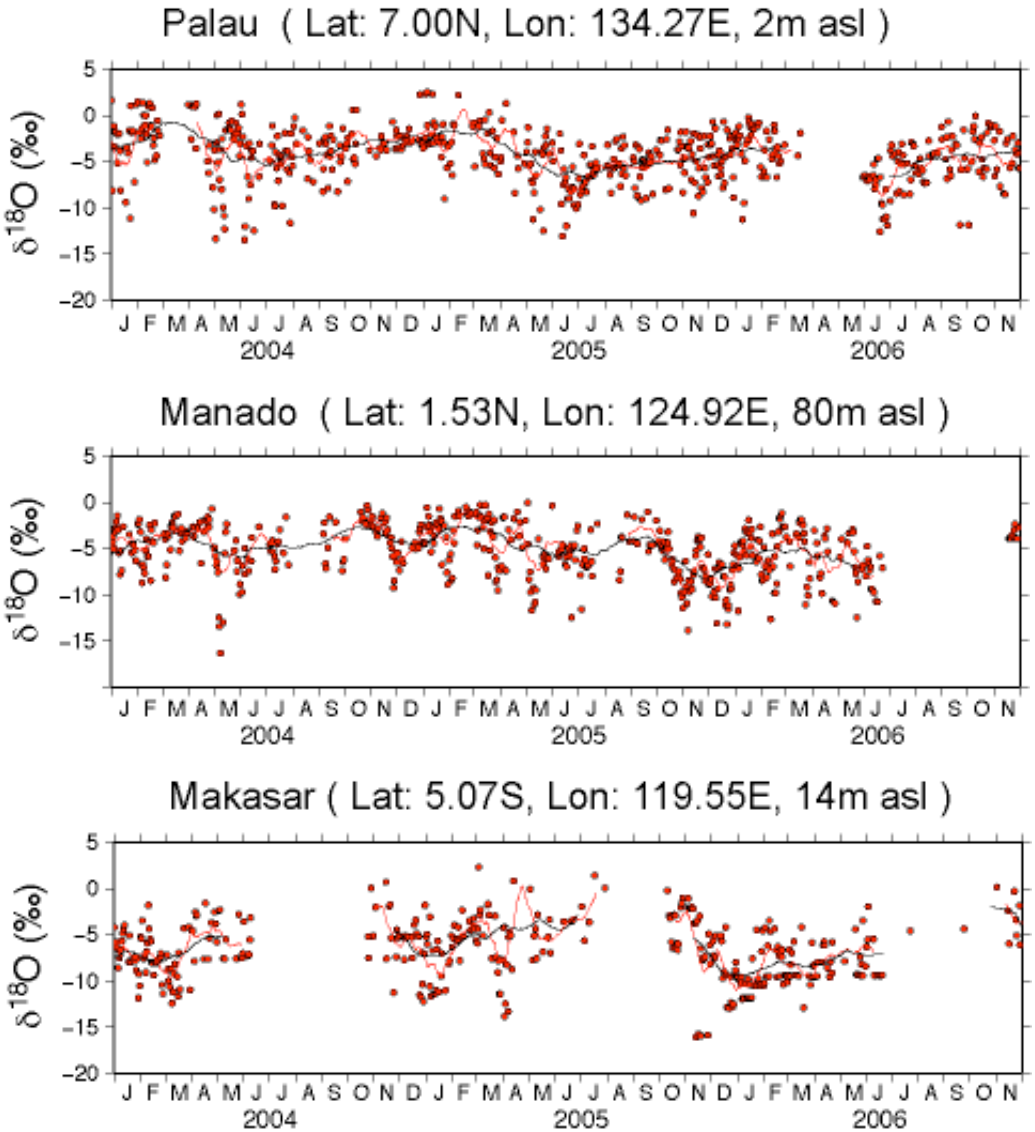




Time series of $\delta^{18}O$ in precipitation in Tropics

Intra-seasonal $\delta^{18}O$ variation >> Seasonal $\delta^{18}O$ variation

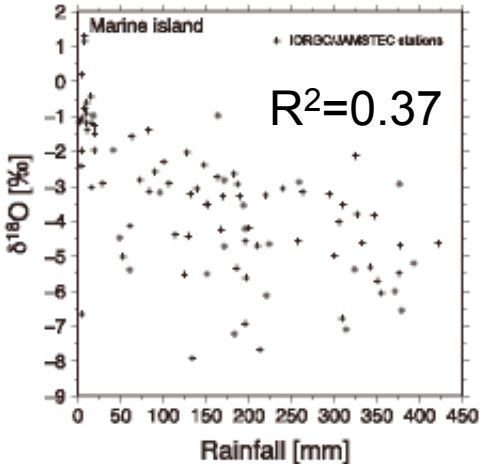




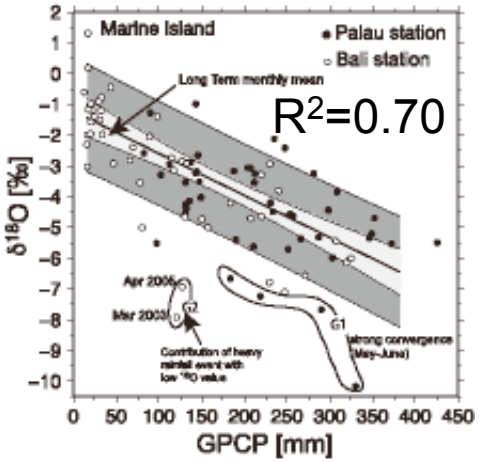
Isotope/Rainfall amount relationship (monthly)

Sub-tropical region

Local Rainfall



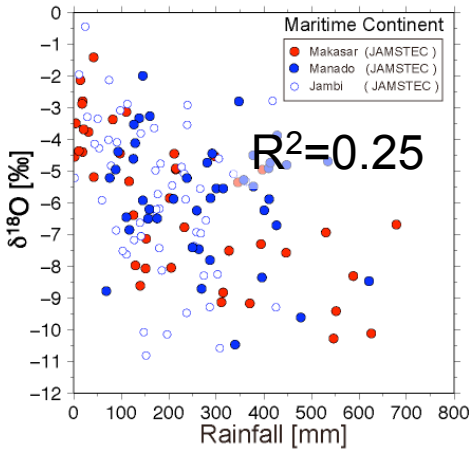
Regional Rainfall



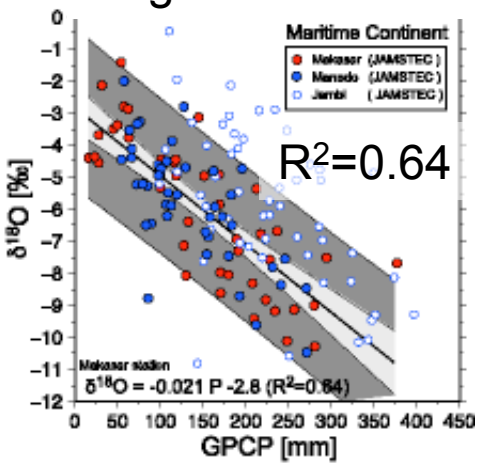
On a monthly timescale, the correlation of $\delta^{18}O$ value with regionally averaged precipitation amount was much higher than that with station based precipitation.

Maritime Continent region

Local Rainfall



Regional Rainfall



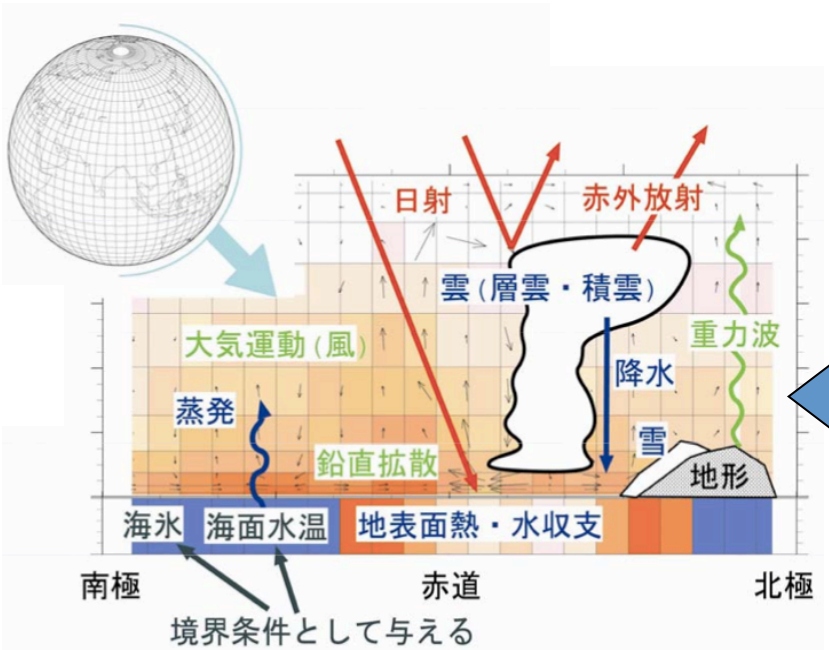
The variability of $\delta^{18}O$ values observed at a station is related with the regional scale hydrological circulation.

(Kurita et al., 2009)

Water Isotope GCM

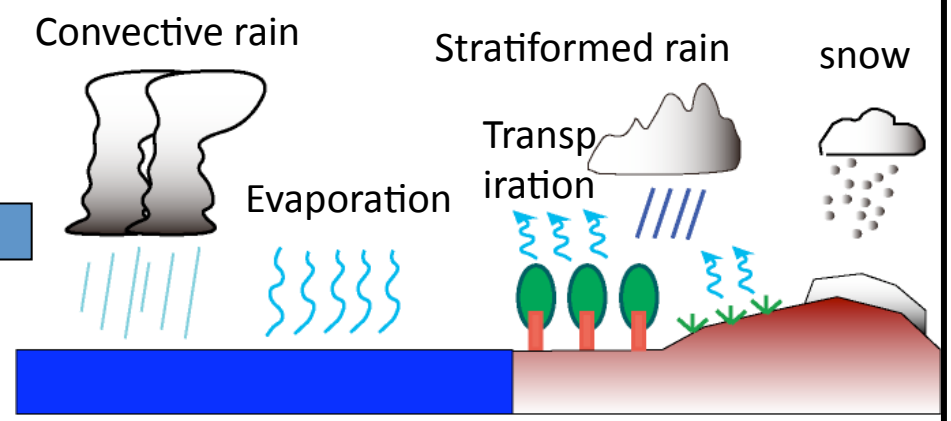
Isotope scheme is incorporated into the physics scheme of GCM

MIROC ver3.2(IPCC AR4)



Isotope physics

Isotope changes only occurs at condensation and surface flux scheme

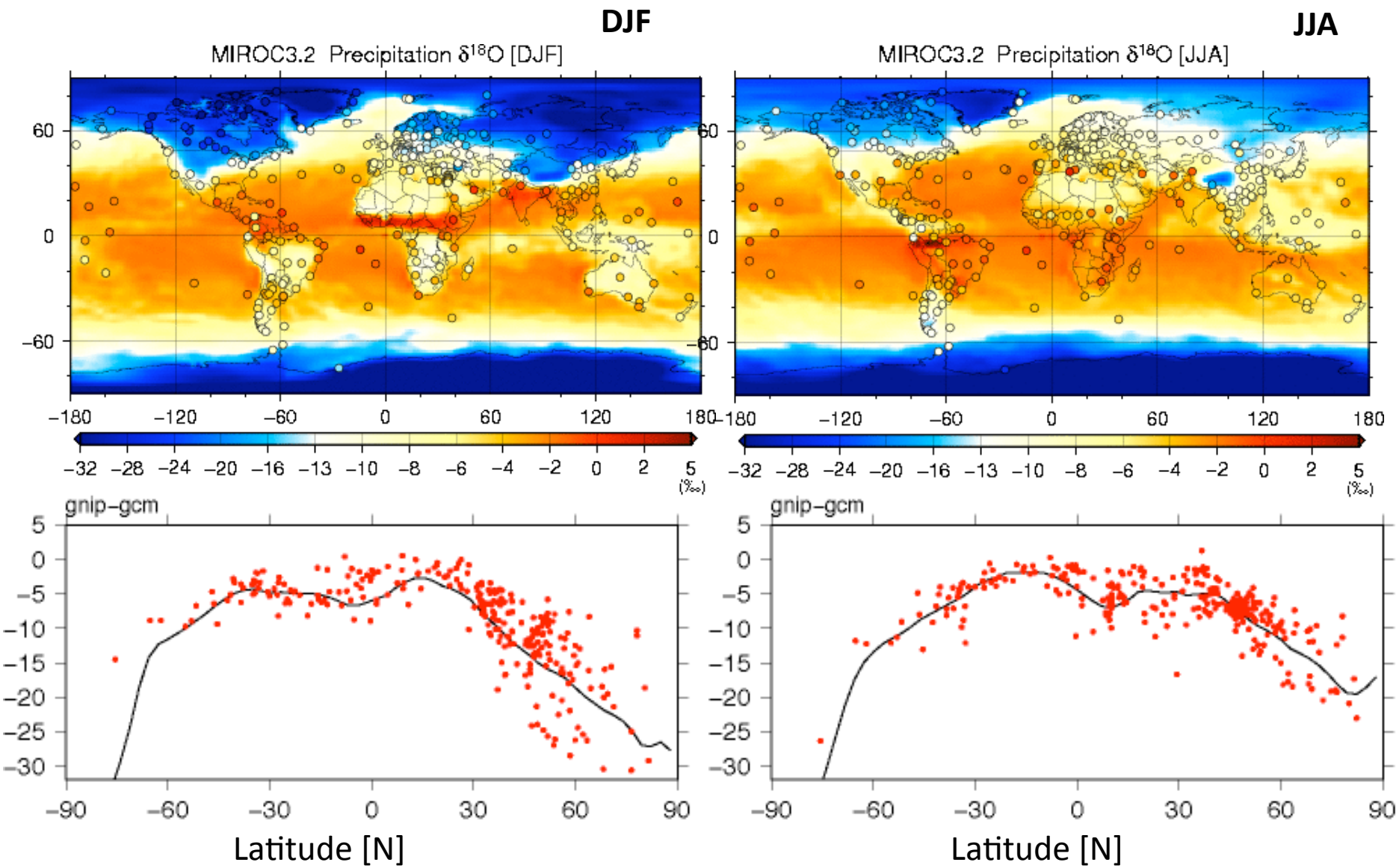


Definition of Isotope value

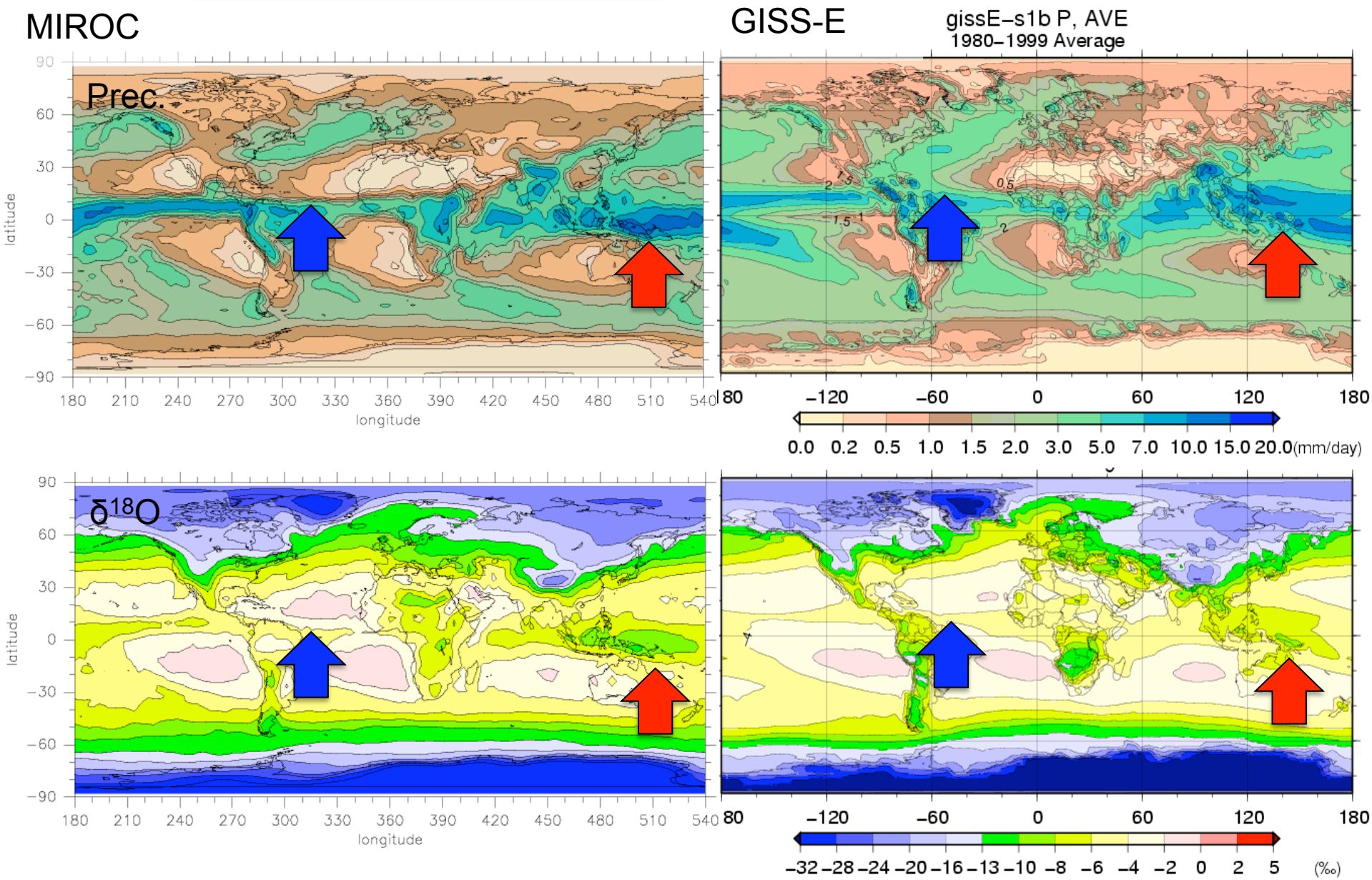
$$\delta^{18}O = \left(\frac{Q(H_2{}^{18}O)}{Q(H_2O)} - 1 \right) \times 1000$$

Q(TH2O):Total moisture
(vapor+cloud liquid)

Model performance ($H_2{}^{18}O$)



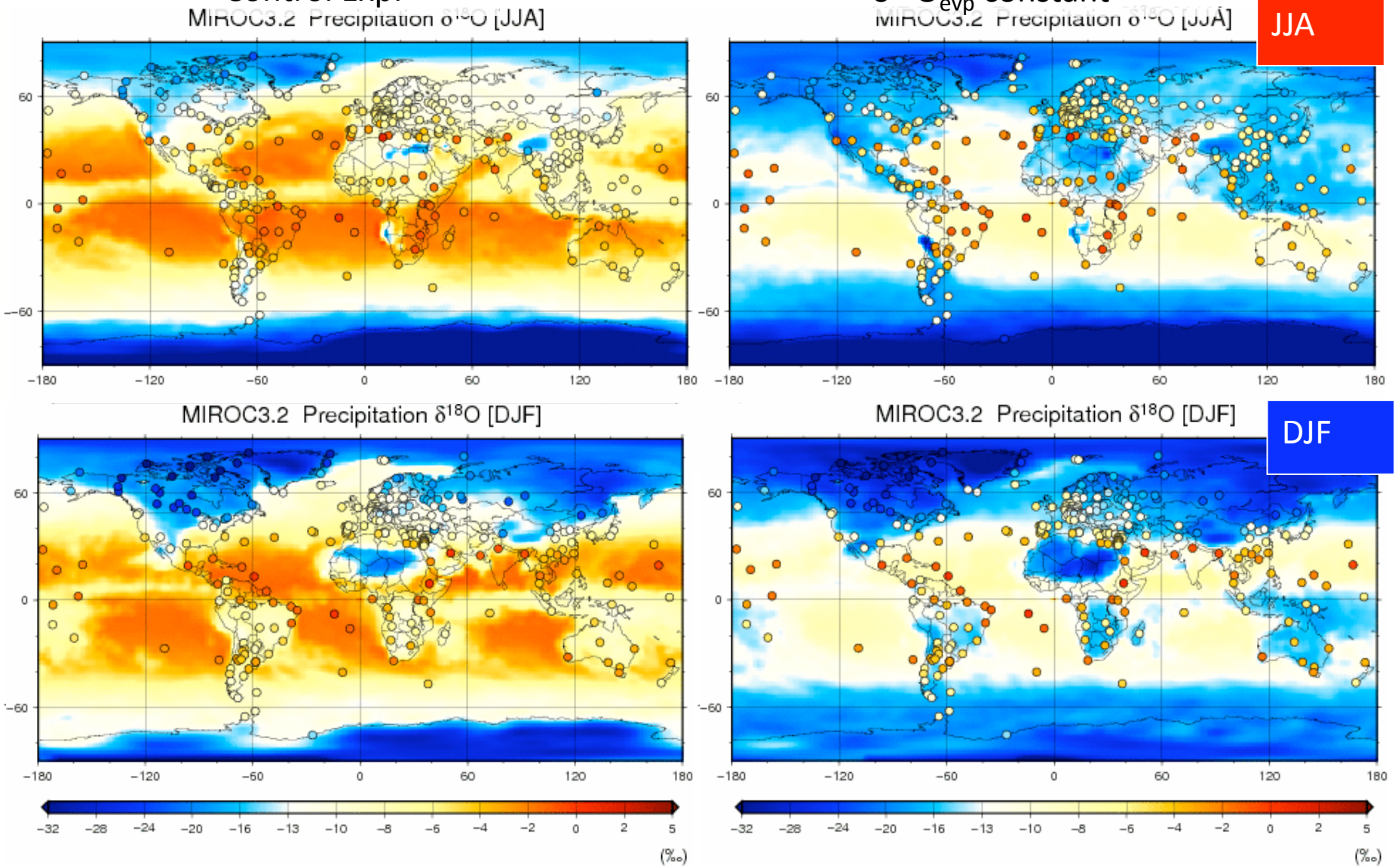
Comparison between GISS-E and MIROC



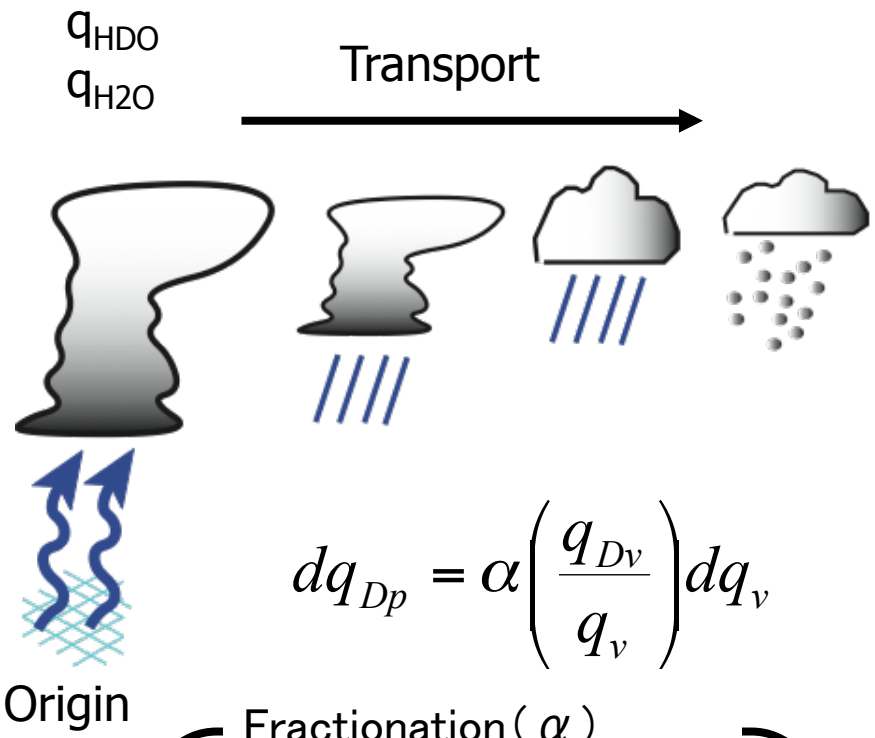
Sensitivity Test (Source effect)

Control Exp.

$\delta^{18}O_{evp}$ constant



Rain-out effect

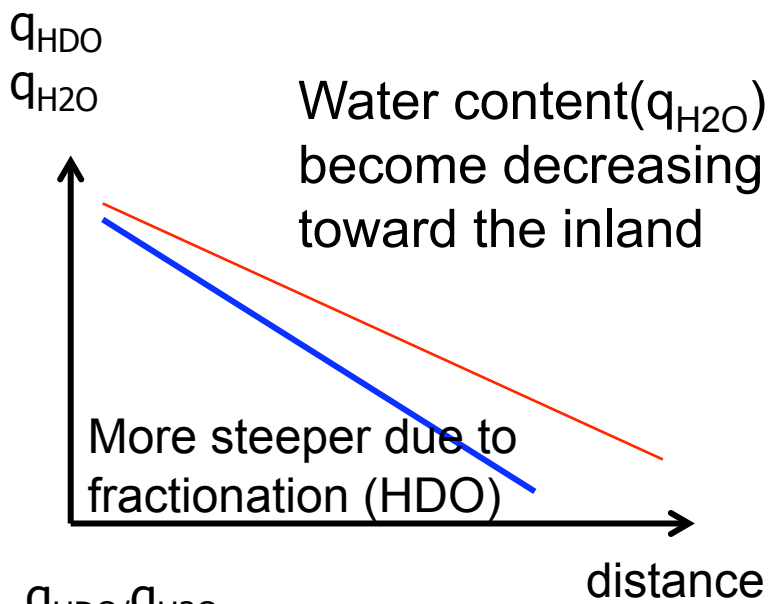


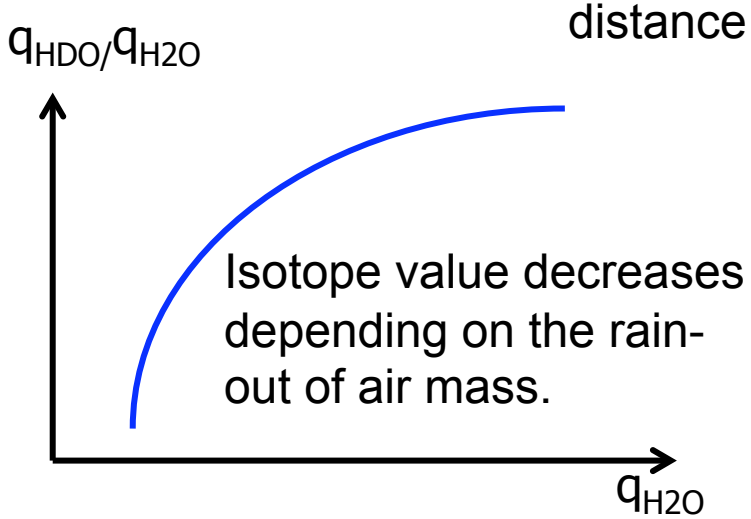
$$dq_{Dp} = \alpha \left(\frac{q_{Dv}}{q_v} \right) dq_v$$

Fractionation (α)

heavy isotopes tend to enriched in condensation phase

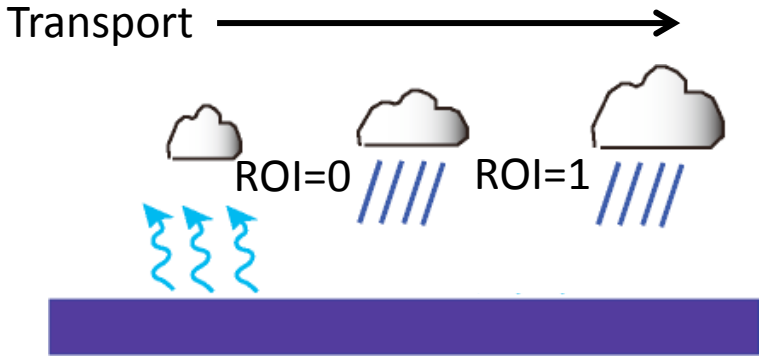
δD (liquid) > αδD(vapor) α＞1





Rain-Out Index (ROI)

What is the ROI?



The concentration is set to zero at the time of evaporation from the ocean, and then is forced to increase the amount of precipitation at each time step.

Basic Equation for water vapor

Precipitation flux

$$\frac{\partial q^t}{\partial t} = -v\nabla q^t - \frac{1}{\rho}\frac{\partial}{\partial z}(F^D + F^C - F^P)$$

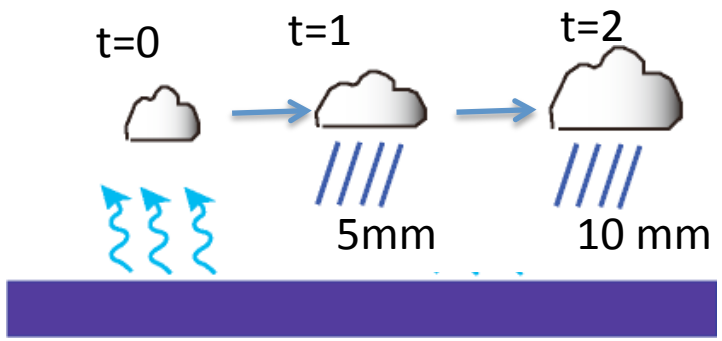
The Equation for tracing water vapor

$$\frac{\partial}{\partial t}(xq^t) = -v\nabla(xq^t) - \frac{1}{\rho}\frac{\partial}{\partial z}(F_x^D + F_x^C - F_x^P) + q_P^t$$

Precipitated water vapor

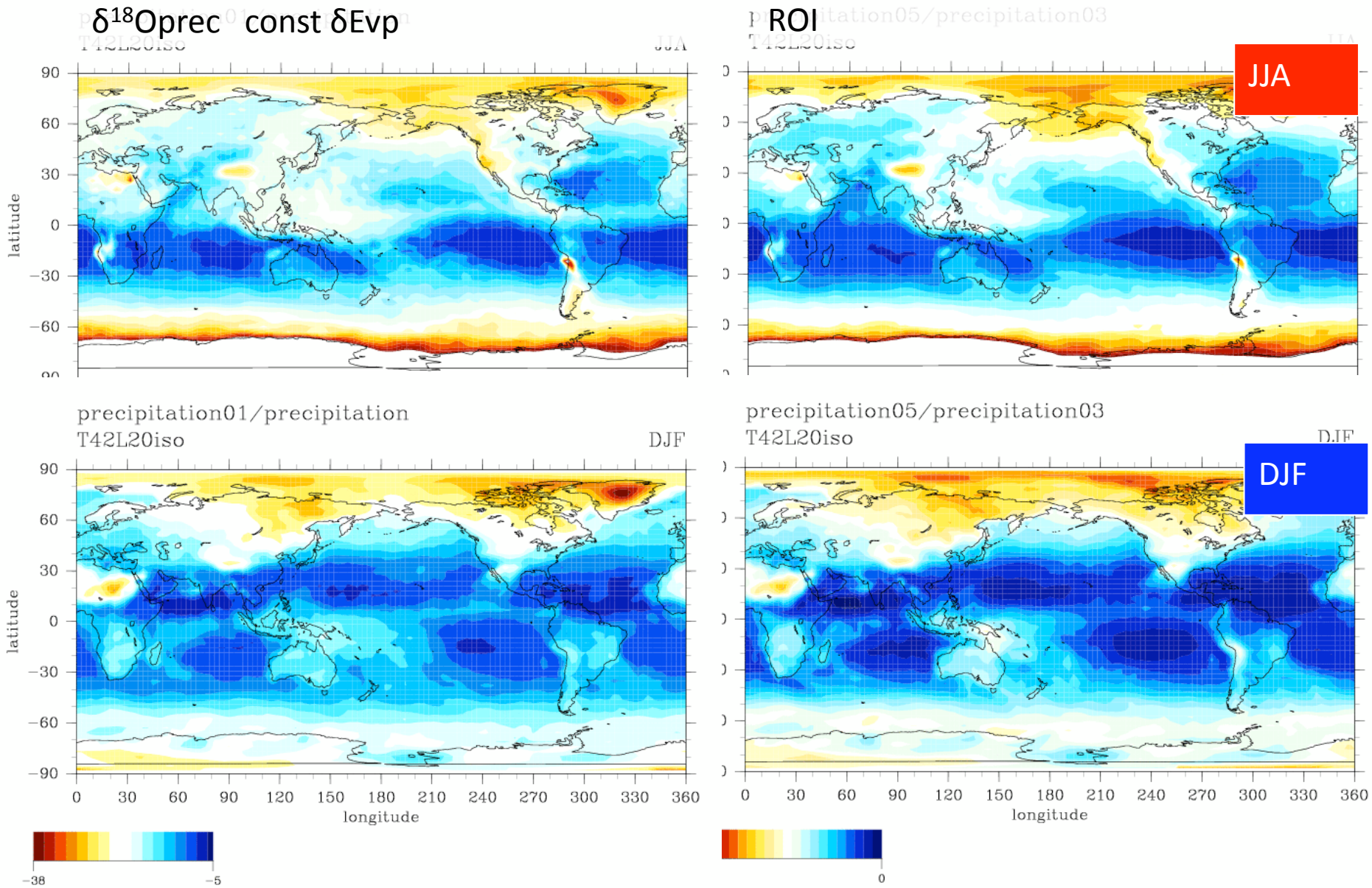
$$ROI = P_{xq}^t / P_q^t$$

For Example

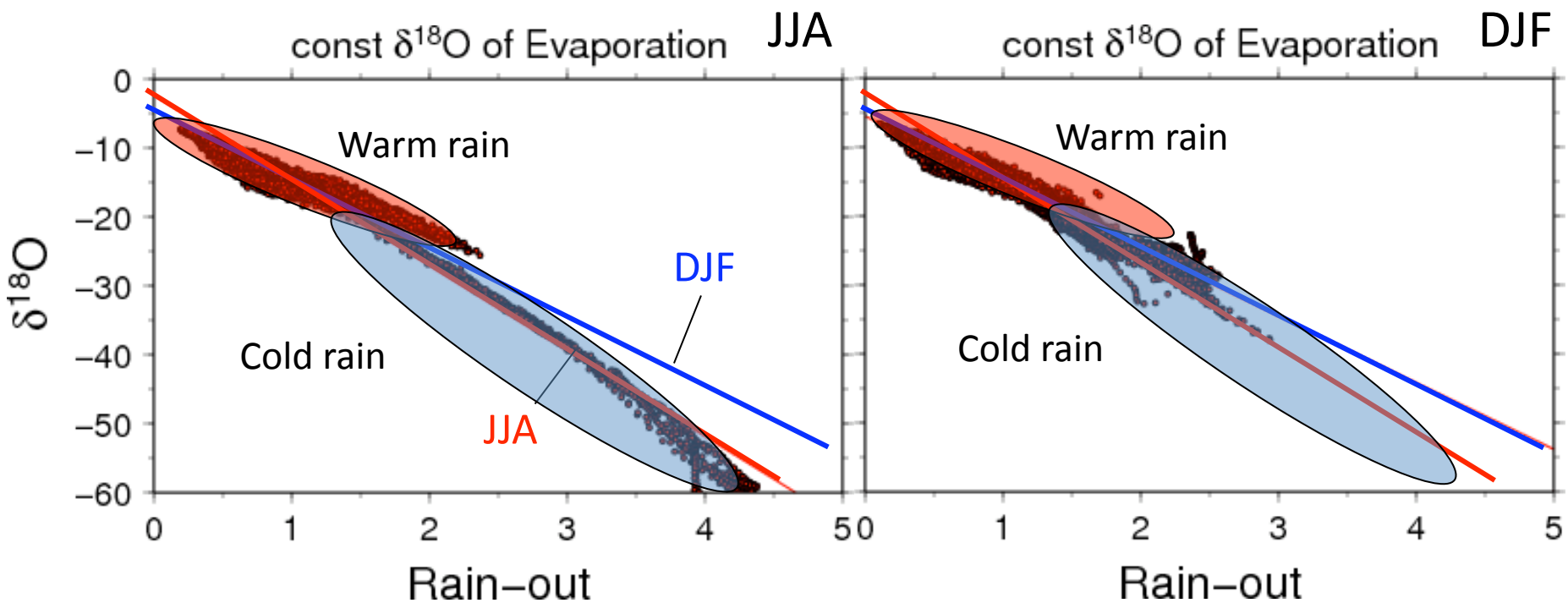


$P_1 / P_2 = 5/10 \rightarrow ROI=0.5$

Rain-out effect



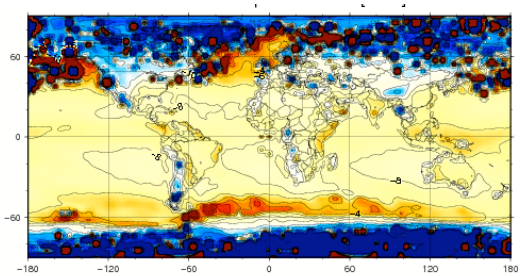
ROI vs $\delta^{18}O$ (const. δE)



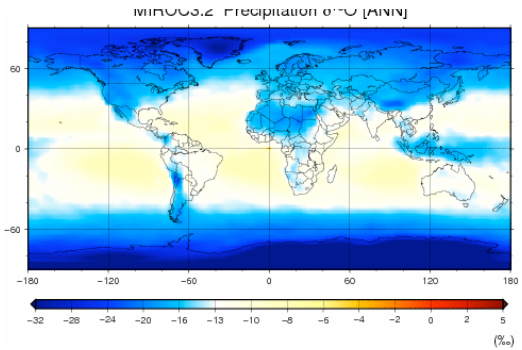
Global isotopic pattern seems to be controlled by the rain-out history from the source region.

Factors controlling isotopic value

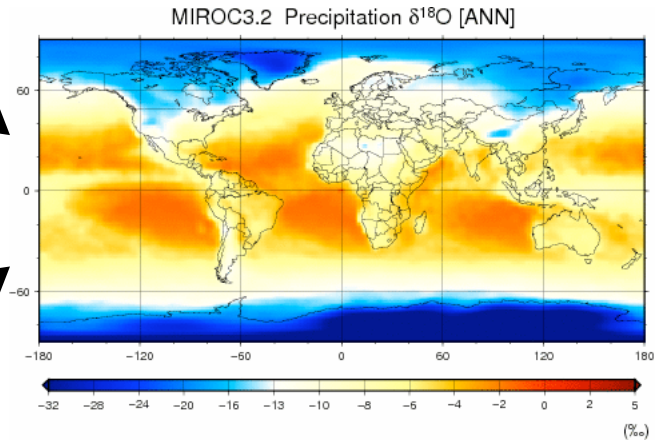
Surface Isotopic distribution



Isotopic variability due to rain-out



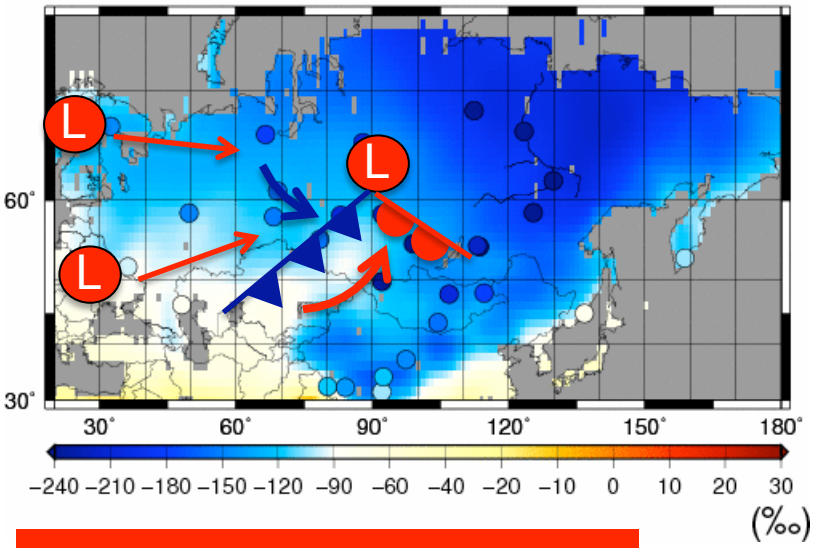
Isotopic field of precipitation



$$\delta(\text{prec}) = \delta(\text{source}) + \varepsilon \times \text{ROI} \quad (\varepsilon\text{:fractionation factor})$$

Key factor for isotopic variation

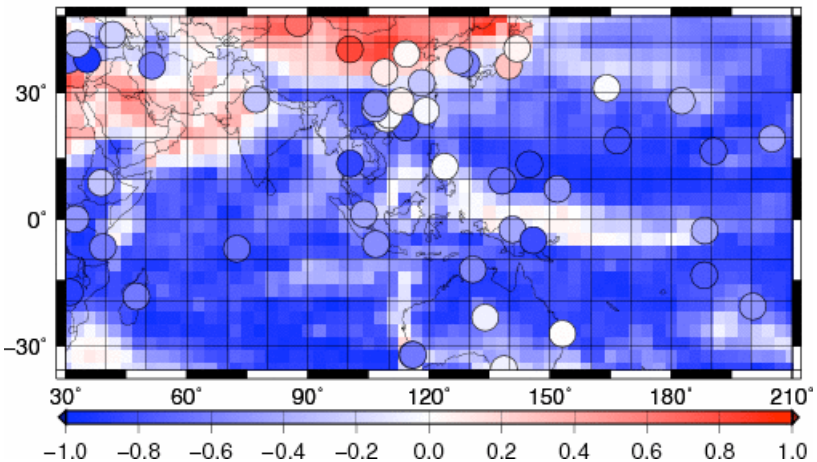
Middle & High latitude region



Isotopic variability of precipitation is related with moisture transportation pattern associated with low pressure system.

Moisture source contribution

Tropics & subtropics region



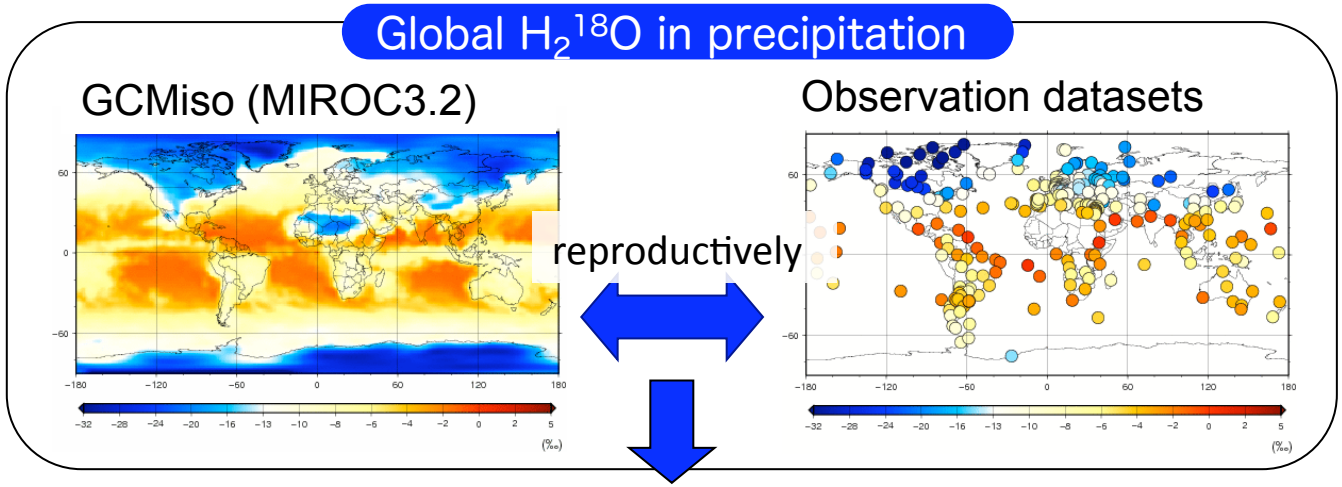
Correlation between $\delta^{18}O$ and rainfall

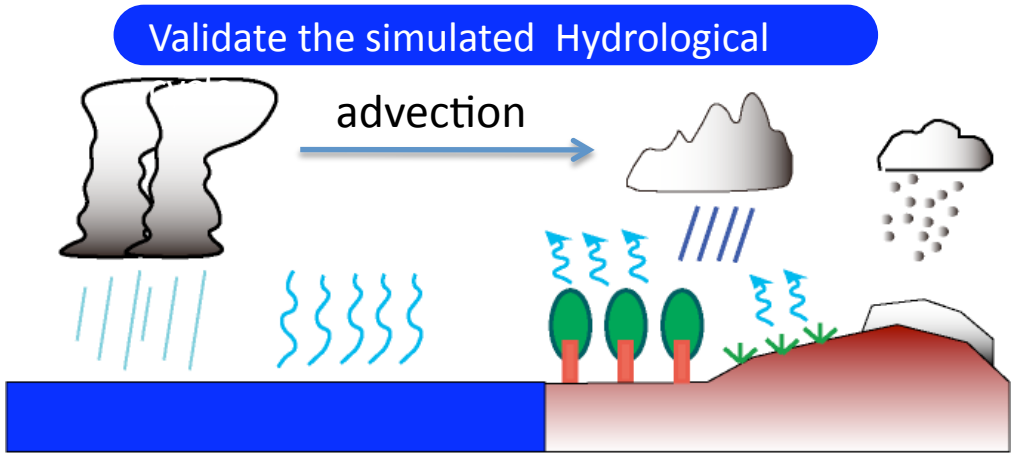
Isotopic variability of precipitation has negative correlation with rainfall amount.

Regional rain-out contribution

Diagnosis of the simulation

Isotopic variability in the atmospheric water is closely related with integrated history during transportation from source region. Thus, good reproducitivity of water isotope field results in the model can successfully simulate the hydrological cycle in the atmosphere.





Thank you for your attention!
September 2008@ Arctic Ocean