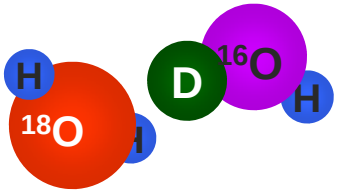


Introduction of Isotope-Incorporated G-RSM

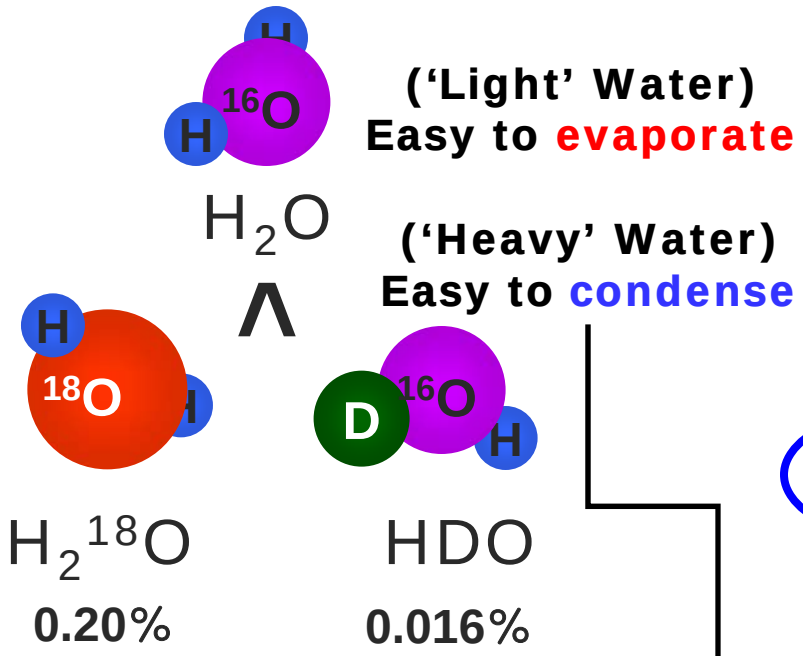
Simulating >100-year isotopic variability by using IsoGSM and 20C Reanalysis (First report)

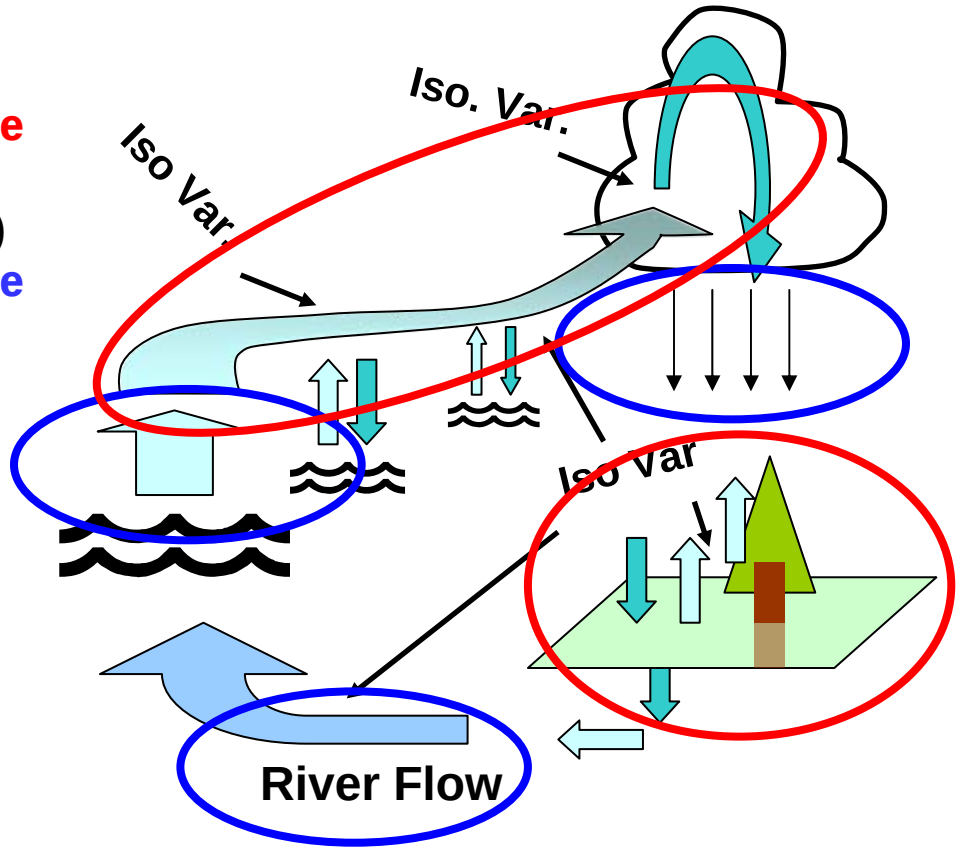
Kei Yoshimura
Atmosphere and Ocean Research Institute

2010/8/9-13 RSM WS in Sapporo

Stable Water Isotopes and Hydrologic Cycle

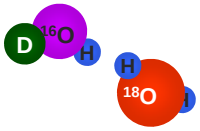
- SWI have integrated records of phase changes during its transport.

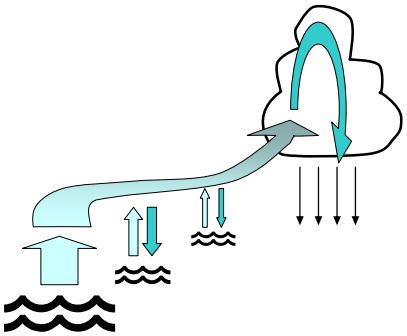




Isotopes are useful…

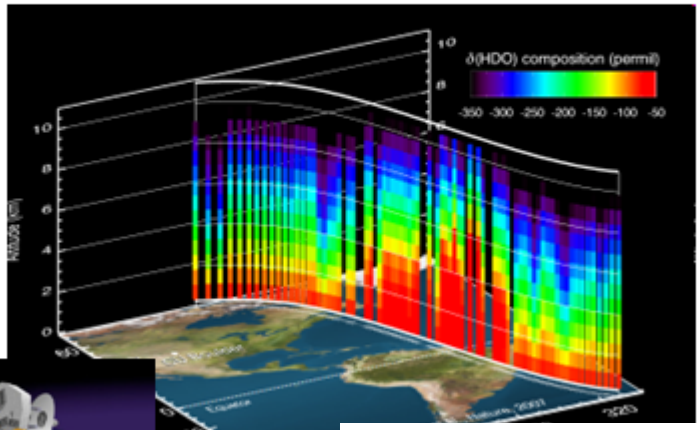
- To interpret past and current isotopic information in precipitation, ice cores, corals, stalagmite, etc., in various spatial/temporal scales.
- To inversely detect an erroneous hydrologic process in the model and/or evaluate the model in an integrated manner.



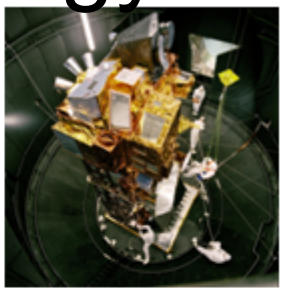


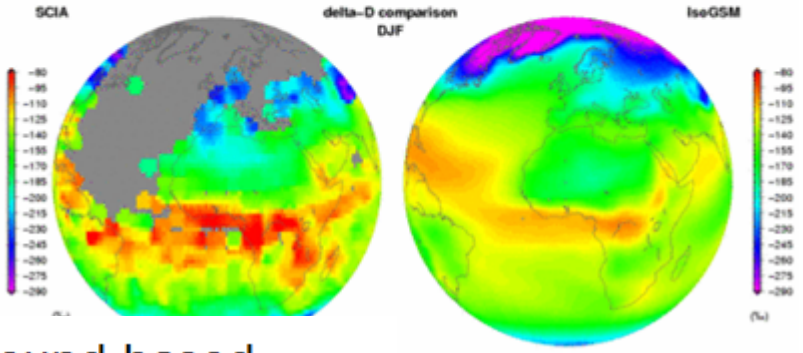
Isotopes are *hot* these days due to new remote sensing technology

TES/Aura: mid troposphere vapor HDO
(Worden et al., 2007, Nature)

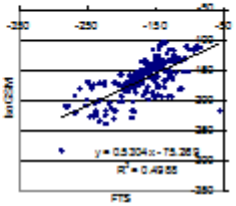


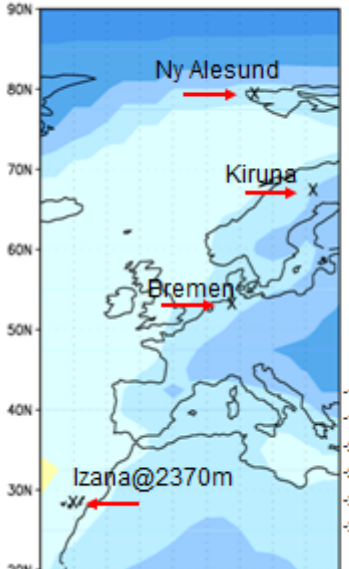
SCIAMACHY/Envisat:
surface vapor HDO
(Frankenberg et al., 2009, Science)

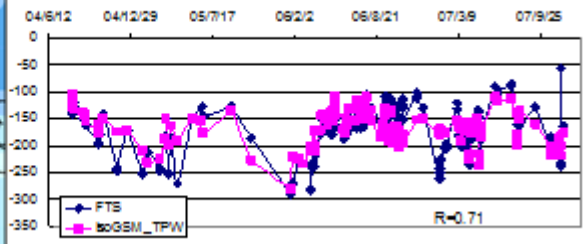




Ground-based
FTS observations







Isotope-incorporated AGCM

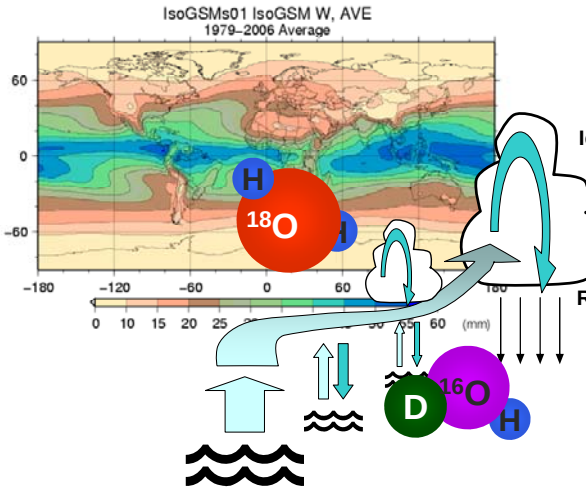
- Pioneered by Joussaume et al. (1984)
- Community effort by SWING

- Kick-off in 17-19 November in IAEA HQ; chaired by C. Sturm, K. Yoshimura & D. Noone.
- More isotopic AGCMs (at least 9) and 2 isotopic RCMs.
- Add nudging experiments to focus on only isotopic parameterizations and on more realistic reconstruction of isotopic variations.
- More focused on hydrologic cycle than climatology

Spectral Nudging + Isotope GSM

– *Poor man's data assimilation for isotopes* –

http://meteora.ucsd.edu/~kyoshimura/IsoGSM1



Surface evaporation (MJ79)

$$R_E = \alpha_{k\_mv}\frac{\alpha_e R_{sea} - hR_a}{1-h}$$

$$\alpha_{k\_mv} = \begin{cases} 1-A & \cdots V < 7(\mathrm{m/s}) \\ 1-(B\times V + C) & \cdots V \geq 7(\mathrm{m/s}) \end{cases}$$

Ice crystal formation (JM84)

$$\alpha_{eff} = \alpha_{k\_jm}\alpha_e$$

$$\alpha_{k\_jm} = \frac{S}{\alpha_e (D/D')(S-1)+1}$$

$$S = 1 - 0.003T \cdots T < -20°C$$

Rain drop evaporation (S75)

$$m\frac{dR_r}{dm} = \beta(R_r - \gamma R_v)$$

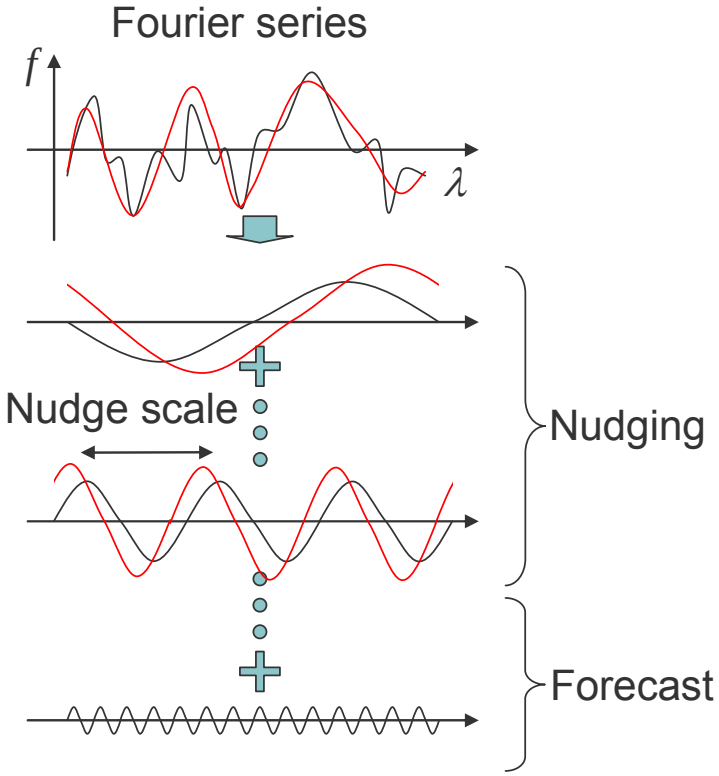
$$\beta = \frac{1-\mu}{\mu},\ \gamma = \frac{\alpha_e h}{1-\mu},\ \mu = \alpha_e (D/D')^n (1-h)$$

$$R_r = \varepsilon\left[(R_{r0} - \gamma R_{v0})(m/m_0)^\beta + \gamma R_{v0}\right] + (1-\varepsilon)R_{r0}$$

$$R_v = \left[q_0' + (m_0' - mR_r)\right]/q$$

IsoGSM

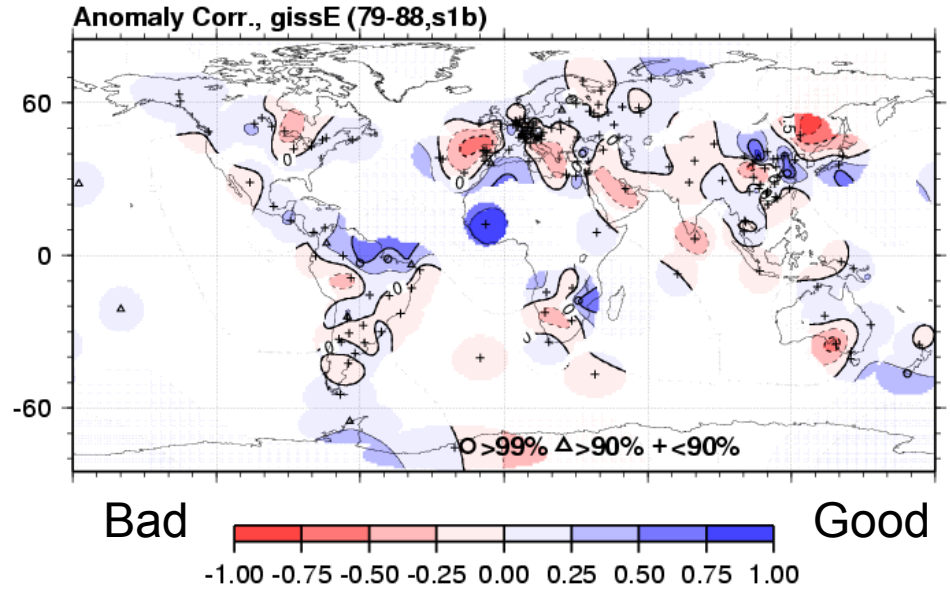
SIO/UT Isotopic Global Spectral Model

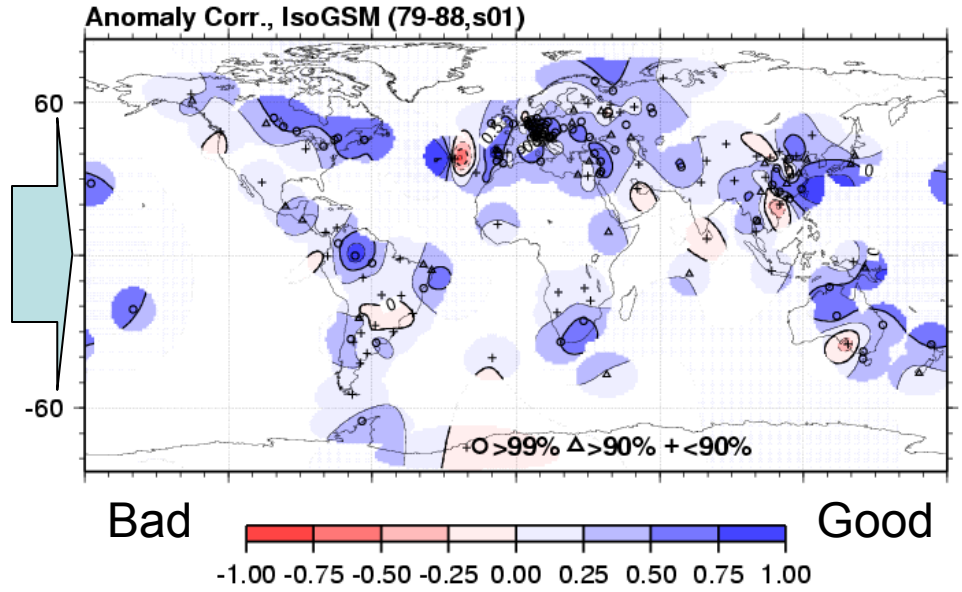


Use large scale (>1000km) winds to constrain dynamical field, so that the isotopic field is also constrained and reproduced in daily to inter-annual time scales.

Yoshimura and Kanamitsu, 2008; Yoshimura et al., 2008

Nudging dramatically improved the isotope simulation





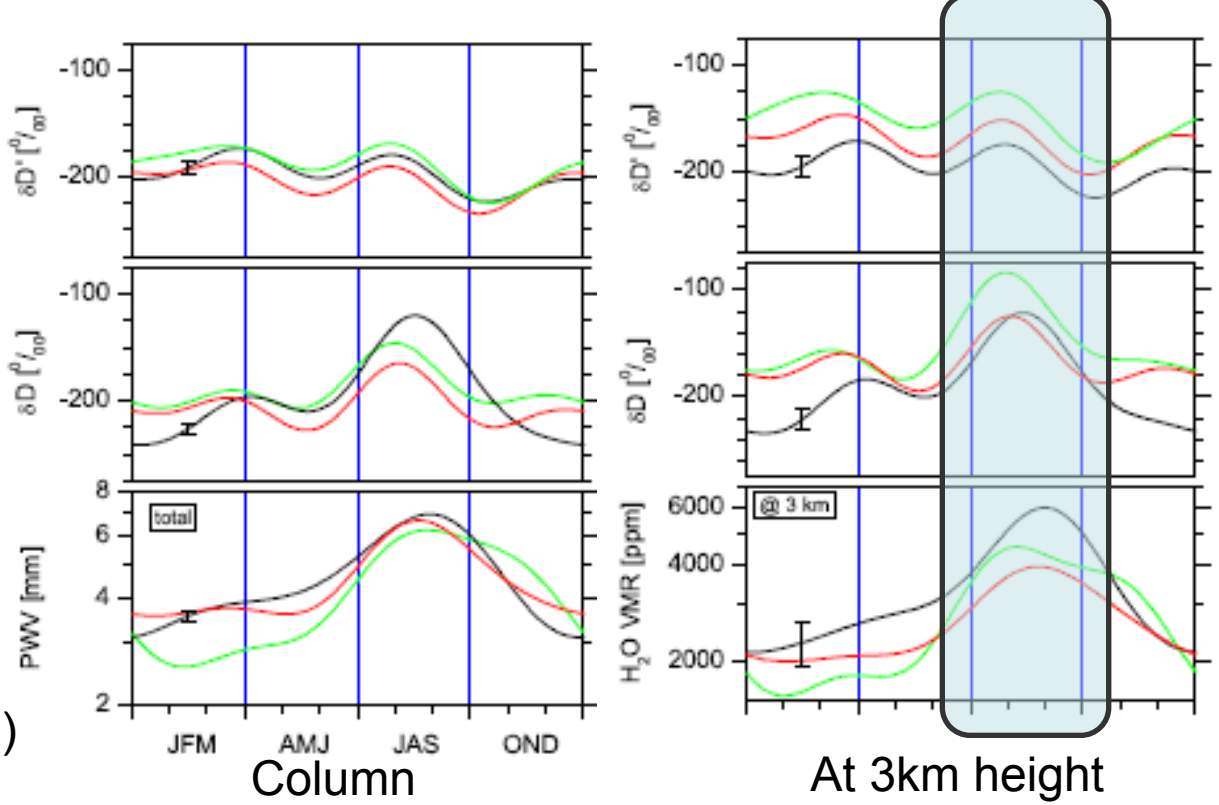
Comparison with GNIP for 1980-1999					
		ECHAM	GISS-E	MUGCM	IsoGSM
Correlation	NH (210)	147	171 (81%)	116	174 (83%)
	Tropics (142)	68	82 (58%)	46	96 (68%)
	SH (37)	22 (60%)	18	16	25 (68%)
Anomaly Correlation	NH (146)	13 (9%)	12	6	114 (78%)
	Tropics (67)	9	12 (18%)	6	32 (48%)
	SH (29)	1	3 (10%)	1	12 (41%)

Yoshimura et al., 2008

vapor δD @Izana by FTIR

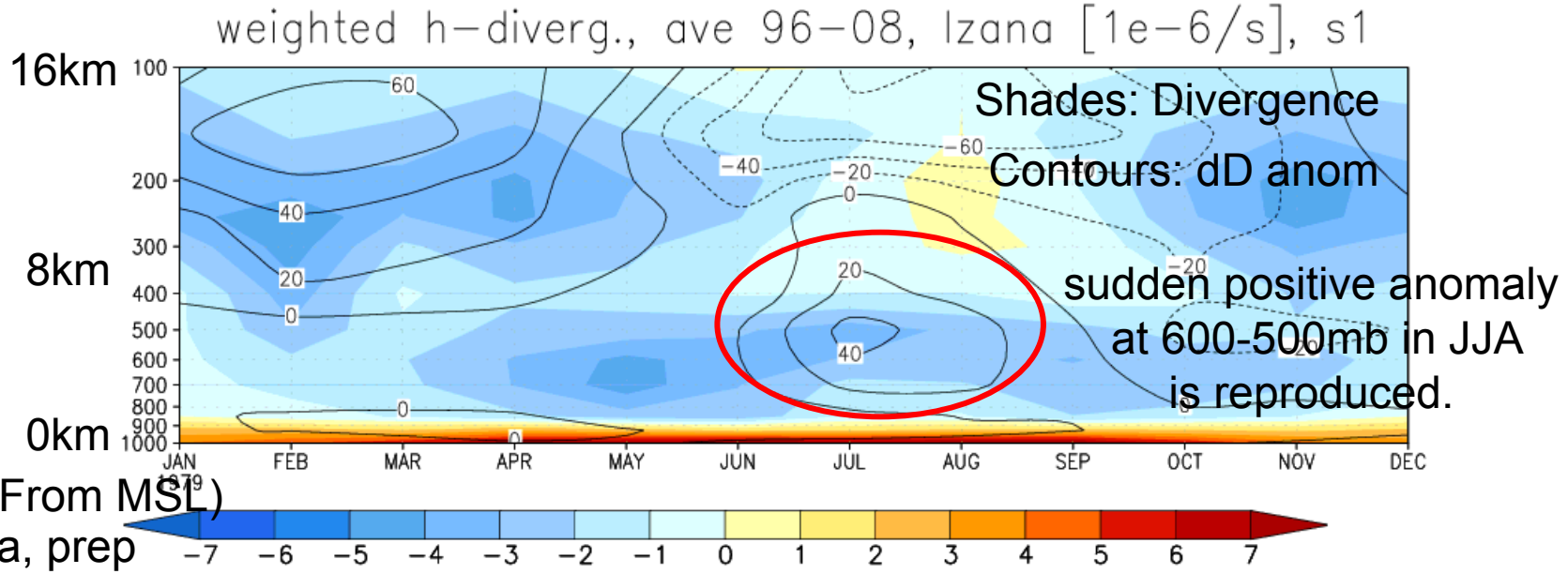
Black: Obs
Red: Nudged
Green: Free

Schneider et al. (2010)



Column

At 3km height

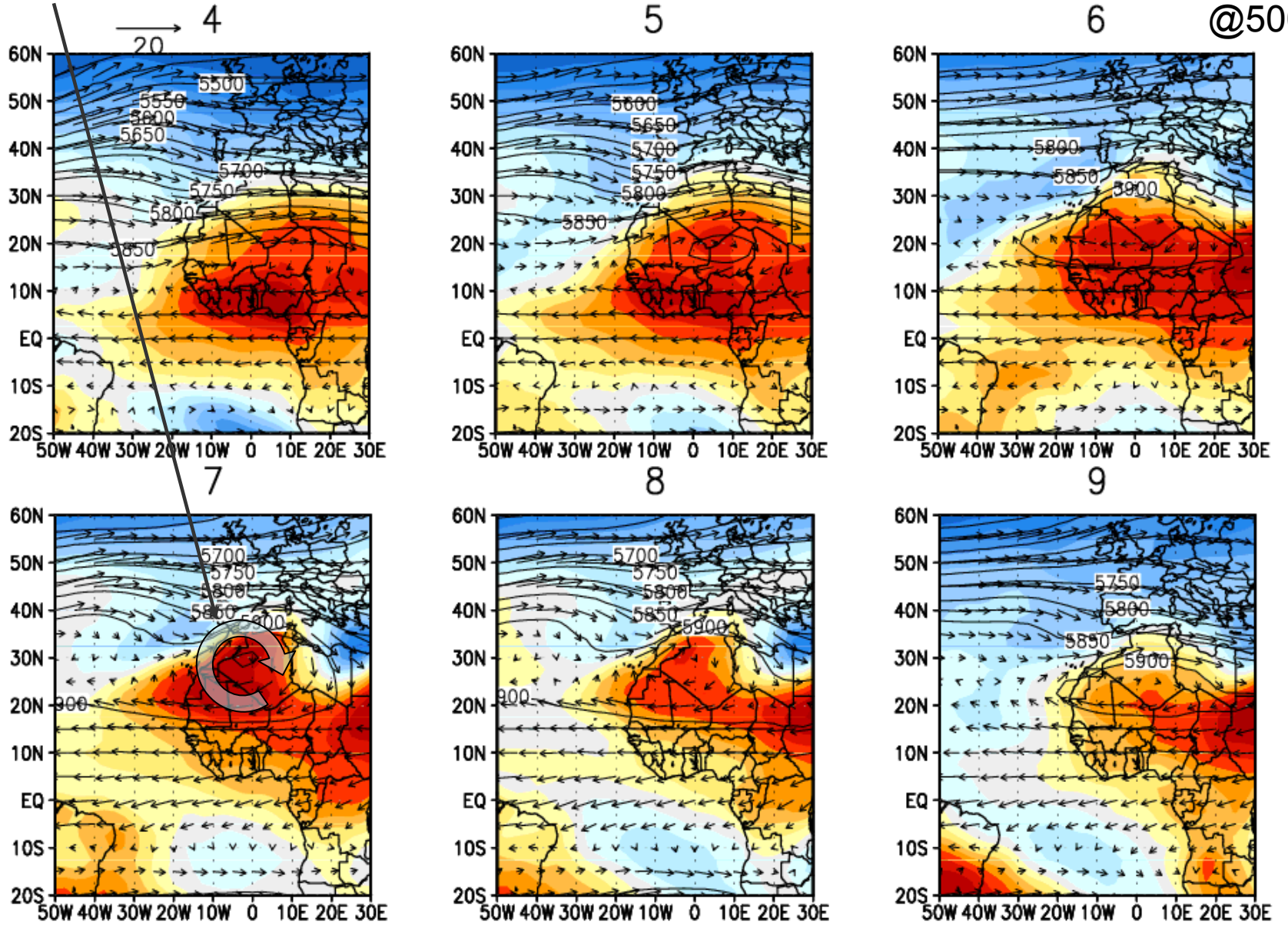


(From MSL)

Yoshimura, prep

High pressure at Morocco; AEJ (Cook 1999) initiated →
ITCZ moves northward → Enriched vapor brought from equator.

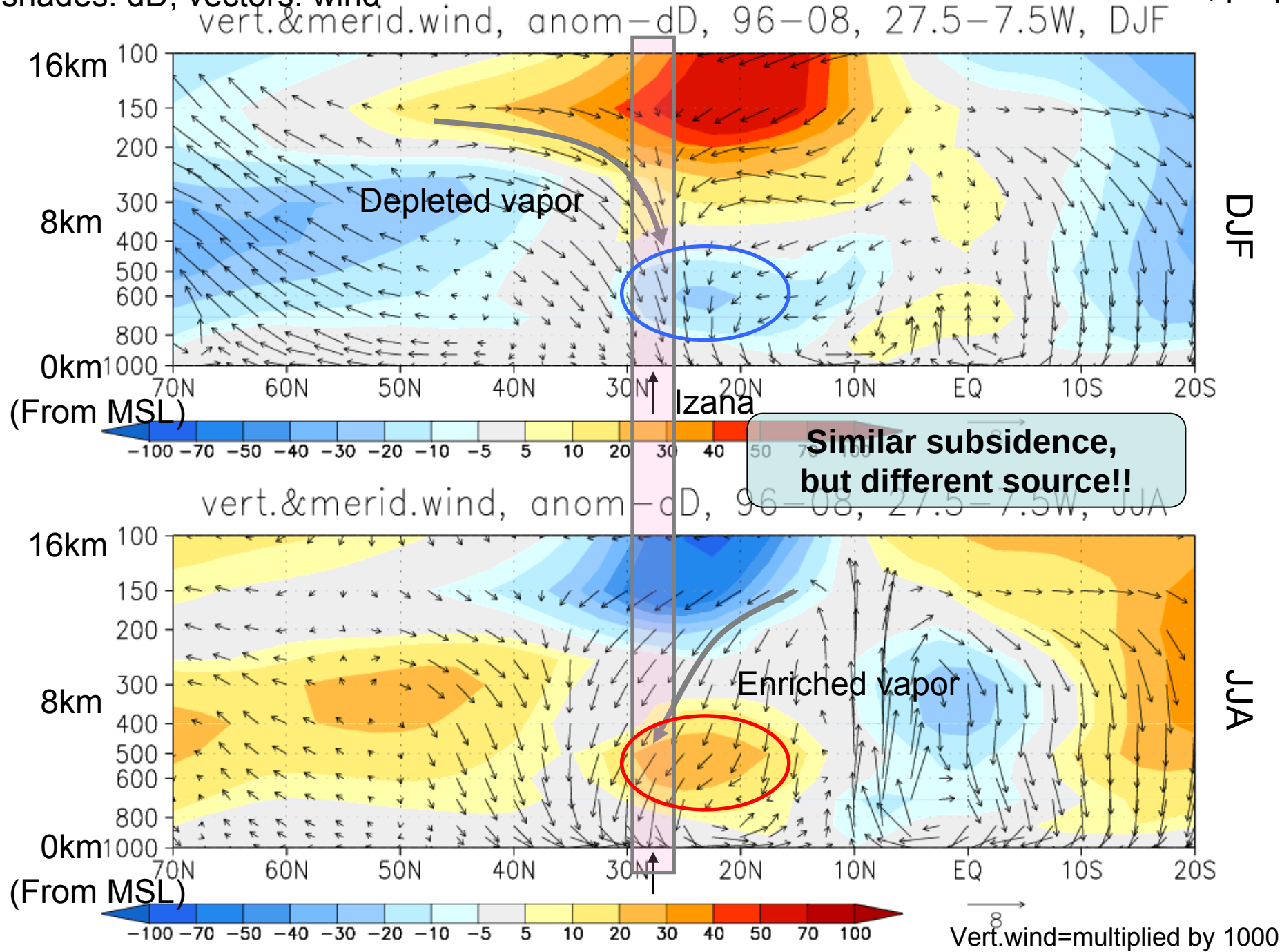
Shades: vapor dD
Contours: GPH[m]
@500hPa



Yoshimura, prep

shades: dD, vectors: wind

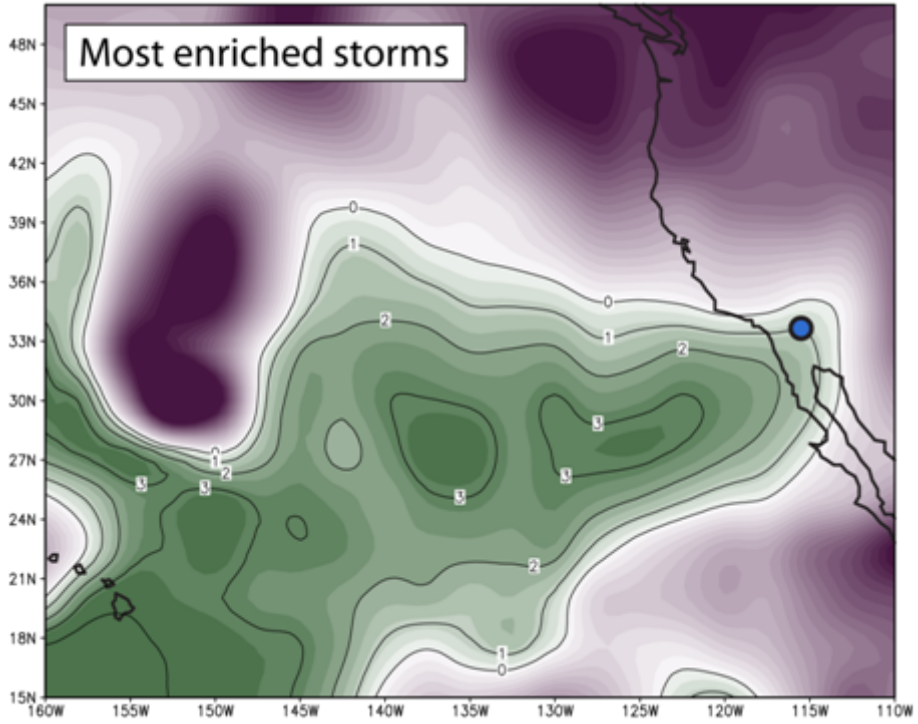
Yoshimura, prep

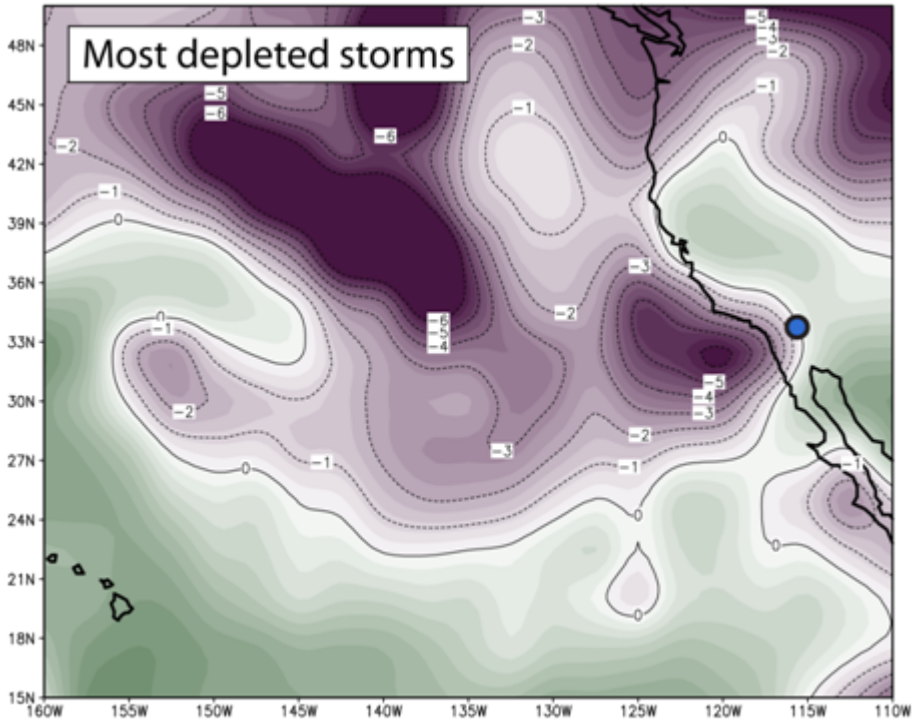


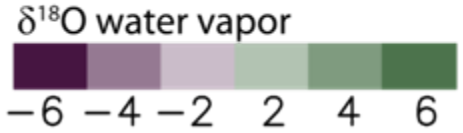
Vert.wind=multiplied by 1000

Model Simulates Individual Storms For the Past 30 Years

- The most enriched isotopic events are associated with southwesterly flow tapping into a “heavy” vapor pool





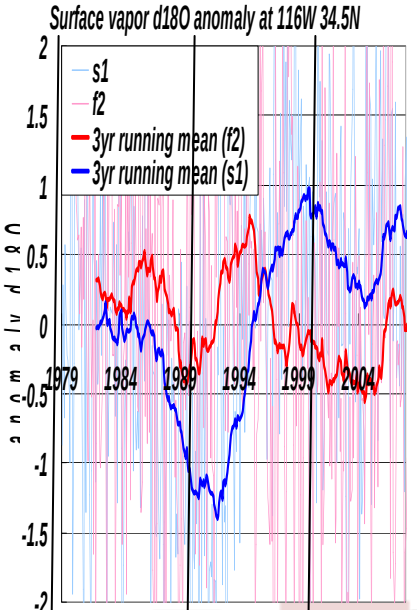


Berkelhammer et al., submitted

Comparison with non-precipitation isotopes

Bristolcone pine tree at SW CA

Extension of simulation needed!!



nudged

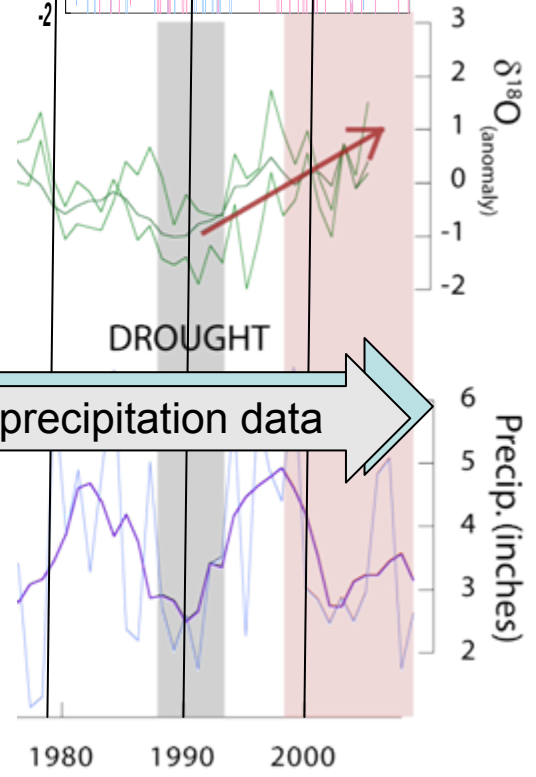
free

$\delta^{18}O$ Cellulos
(White Mts.)

other proxy data (treerings/corals/etc)

precipitation data

Winter Prec
(SE Californ

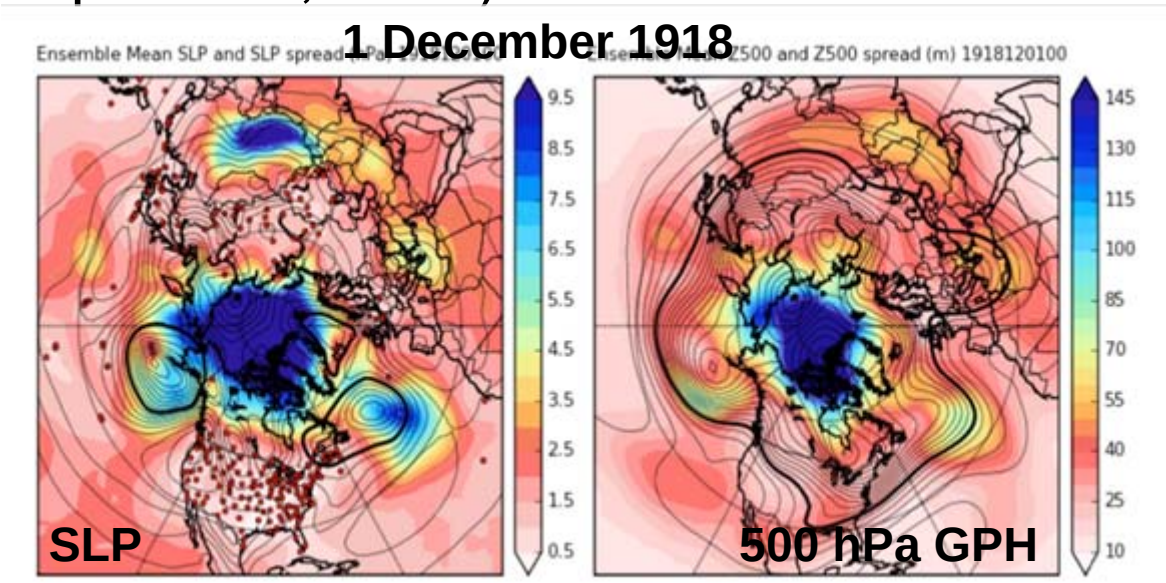


Stott et al., prep

20th century Reanalysis

(Compo et al., 2010)

- Using only surface pressure data historically recorded since 1870's
- Ensemble Kalman Filter for data assimilation (56 member)
- T62L28 GFS with NOAH LSM



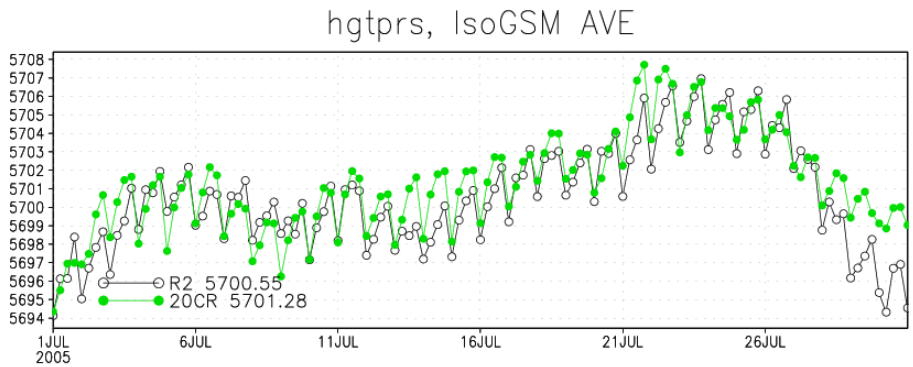
Whitaker et al. (2009)

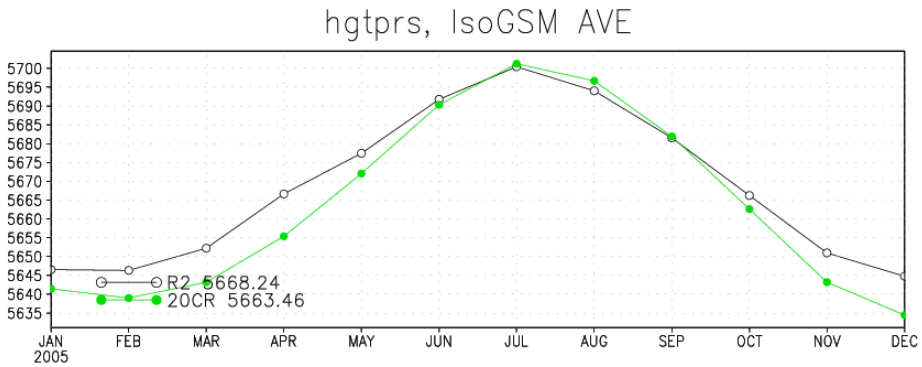
- Reanalysis skill is comparable to current Day-3 forecast skill (Whitaker et al., 2009)

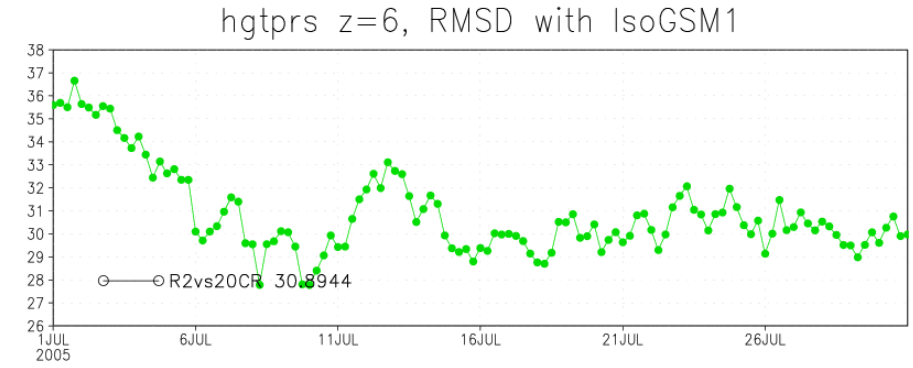
First task: Comparison with IsoGSM-R2 run

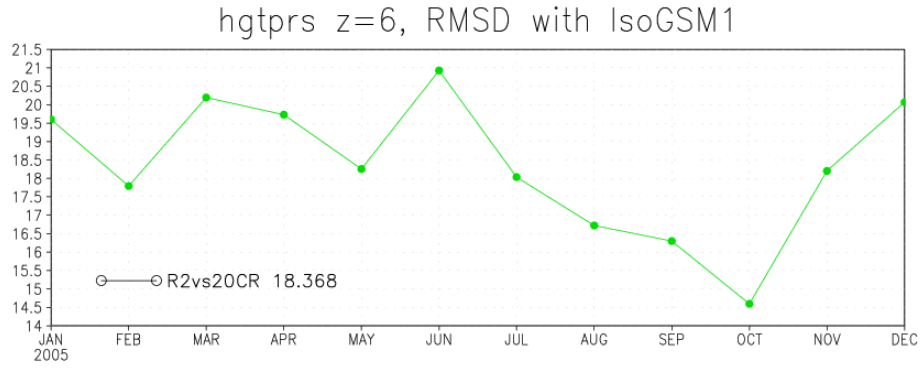
- All of 20thC Reanalysis spectral and surface data (ensemble mean) were copied to ECPC.
- Convert the spectral data into usable format. (NCEP GFS→ECPC GSM)
- Run IsoGSM with spectral nudging as same as Yoshimura et al. (2008).

500hPa Height global mean&rms





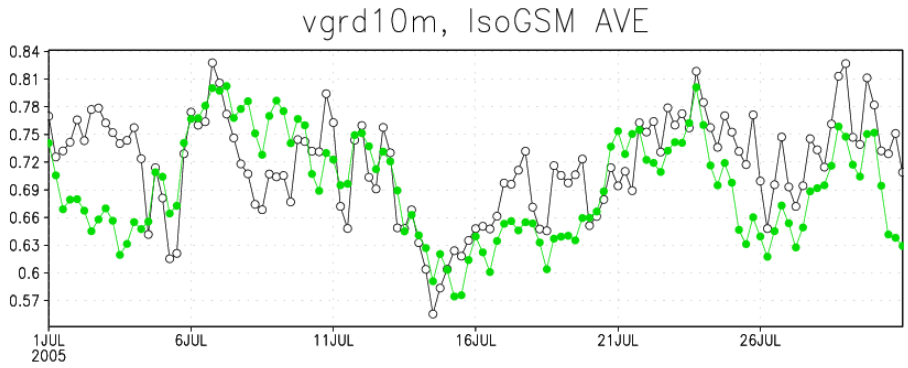


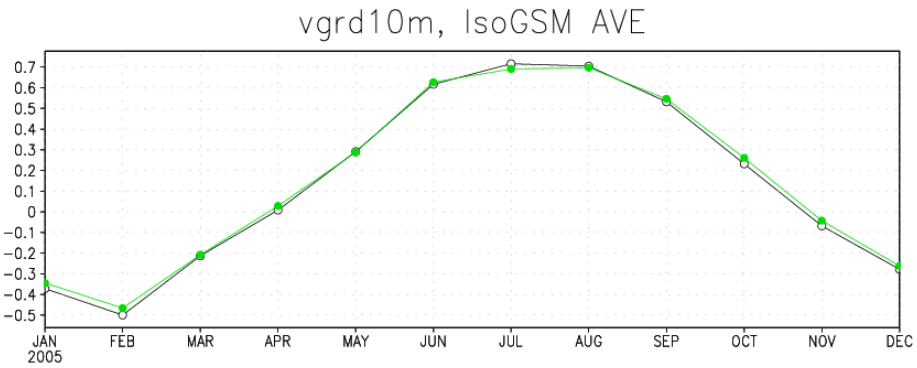


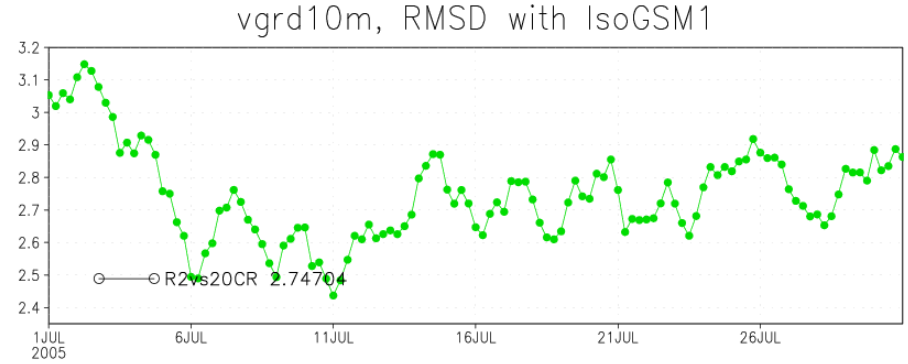
6-hourly snapshot

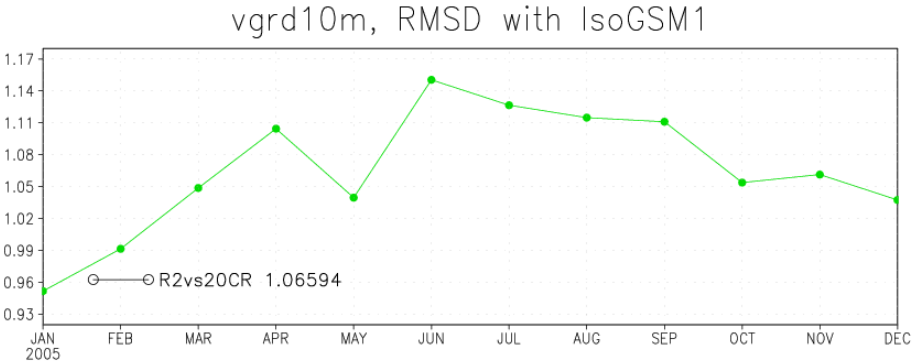
Monthly average

10m V-wind global mean&rms





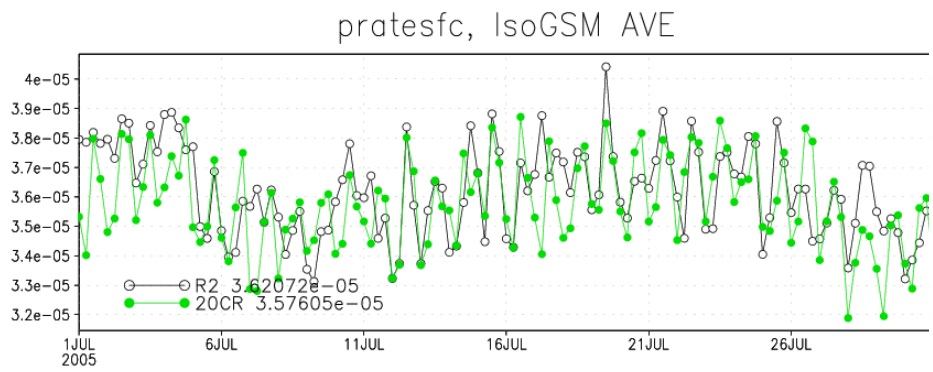


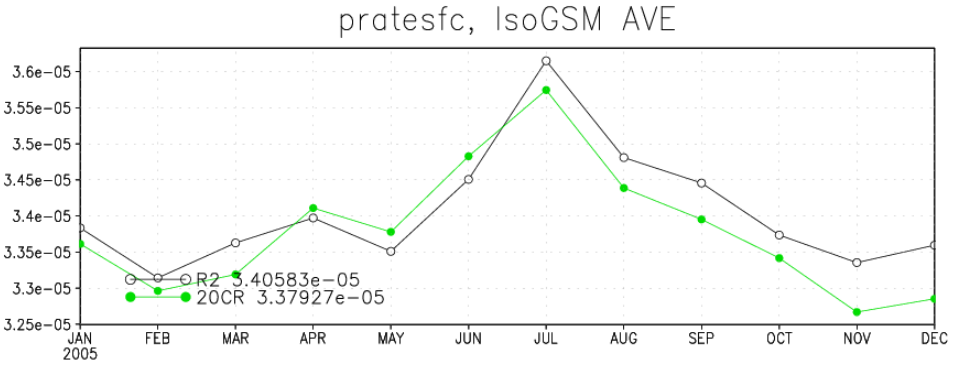


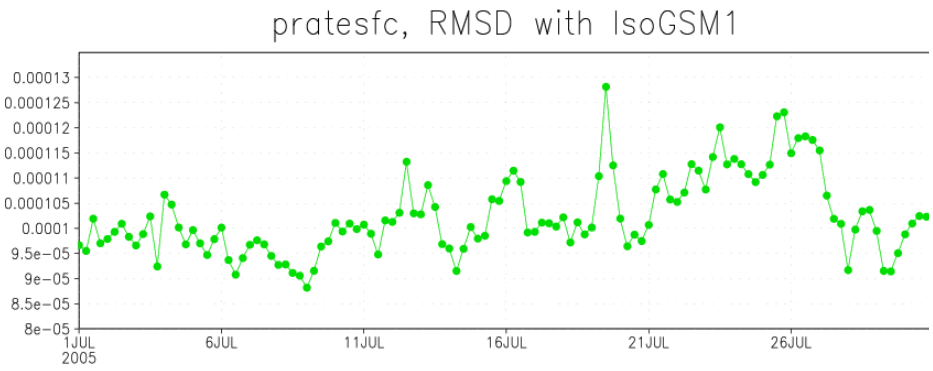
6-hourly snapshot

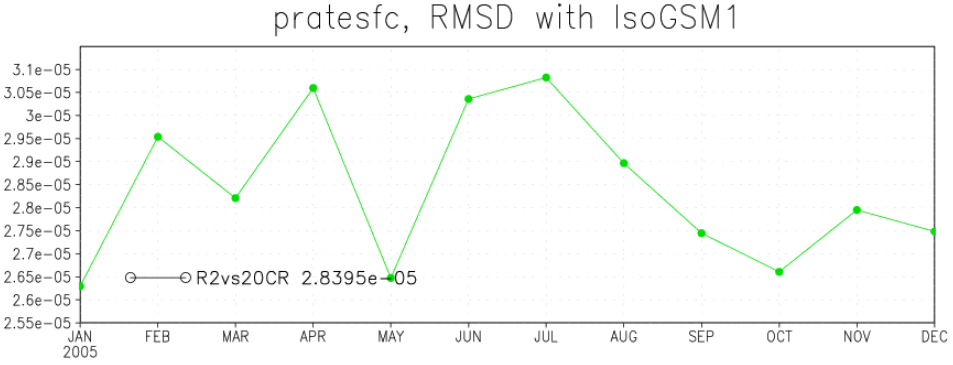
Monthly average

precipitation global mean&rms





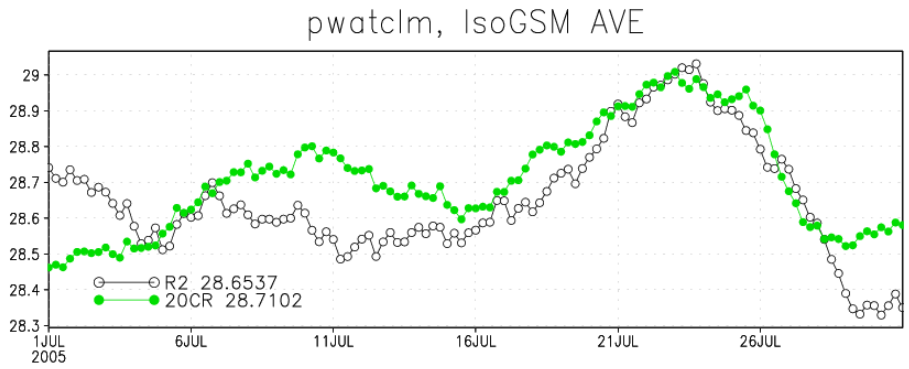


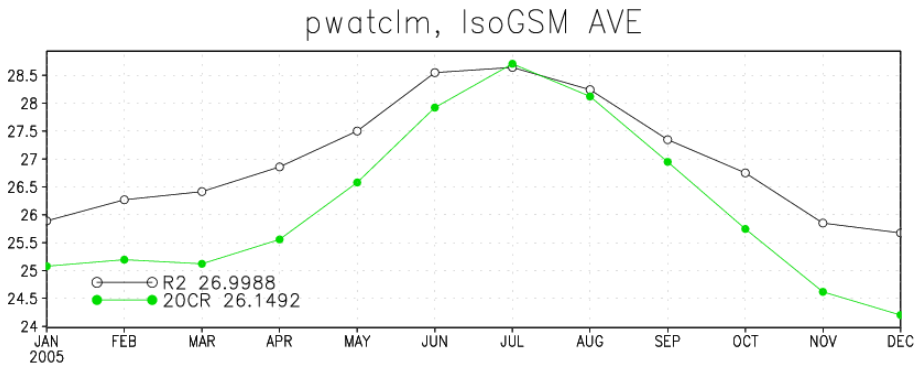


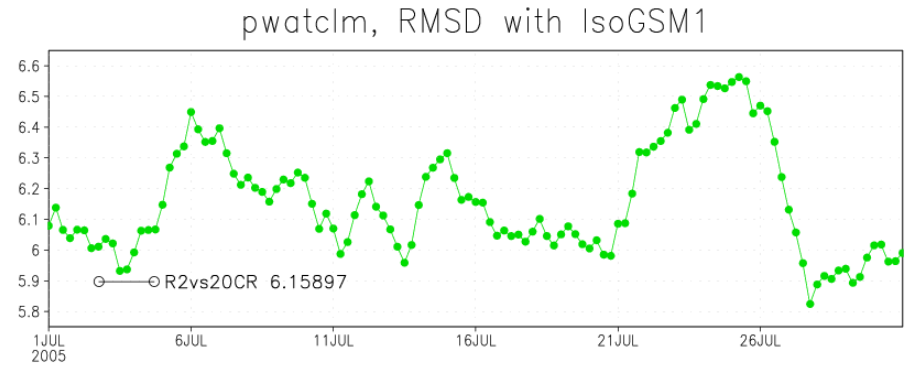
6-hourly snapshot

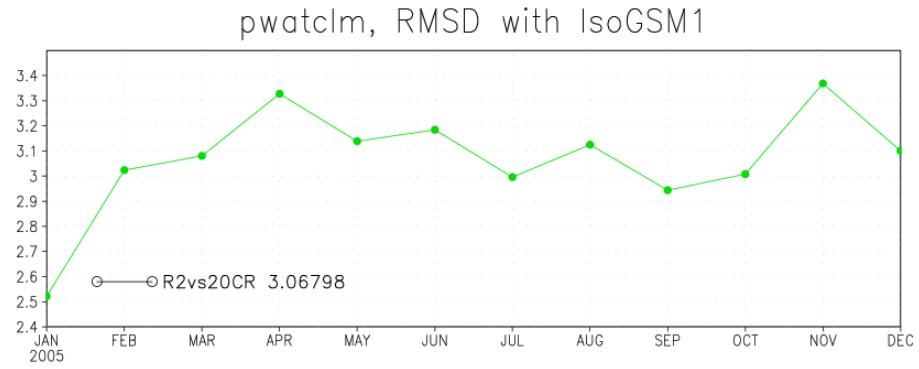
Monthly average

TPW global mean&rms





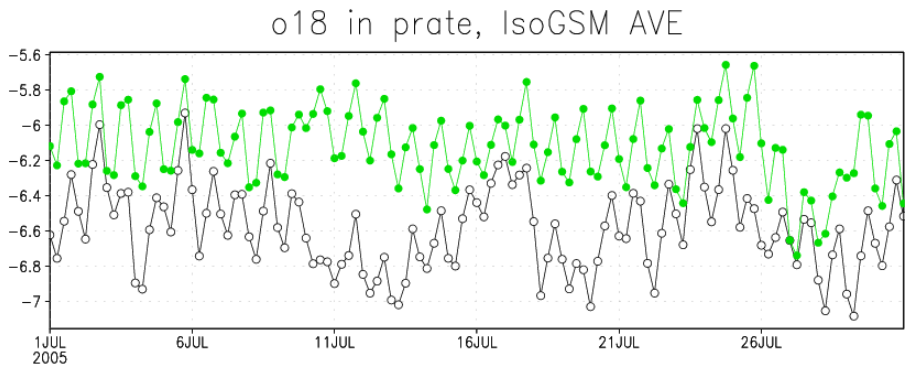


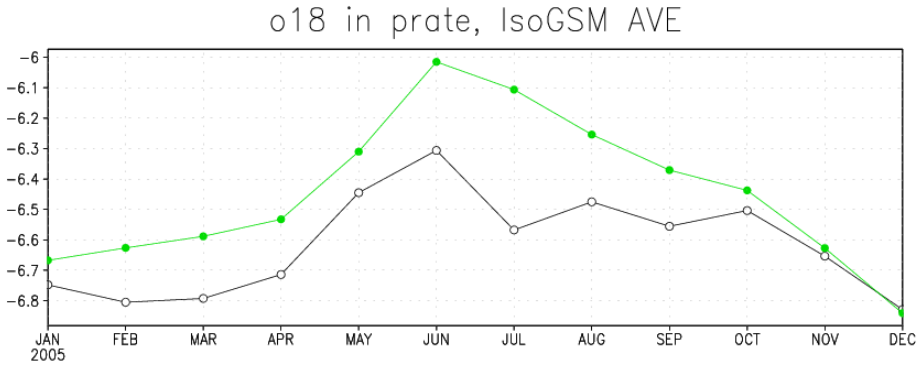


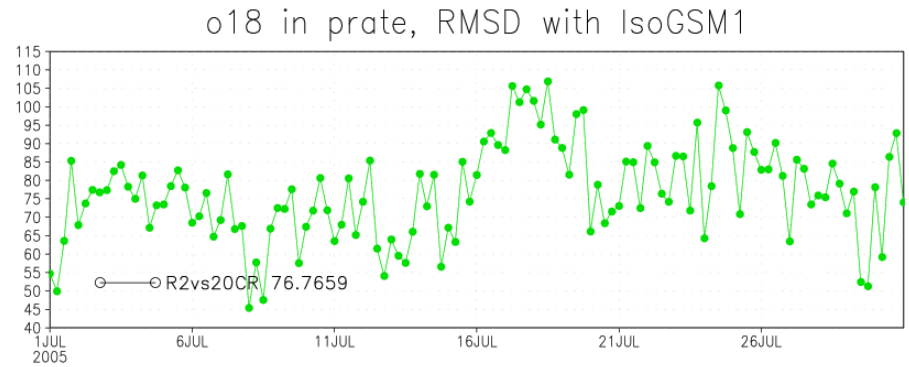
6-hourly snapshot

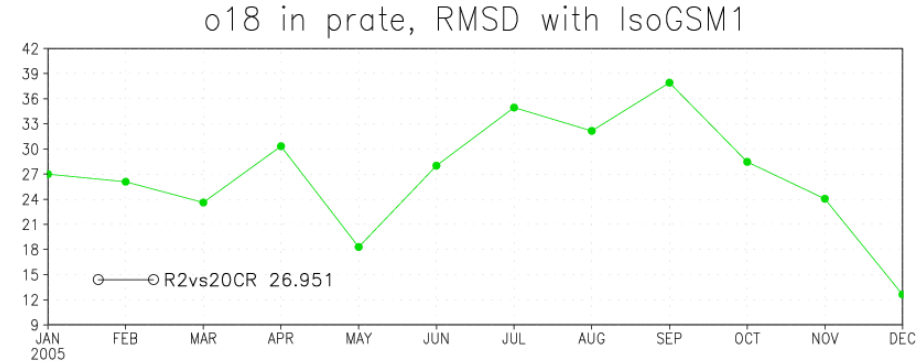
Monthly average

$\delta^{18}O$ in Precip global mean&rms





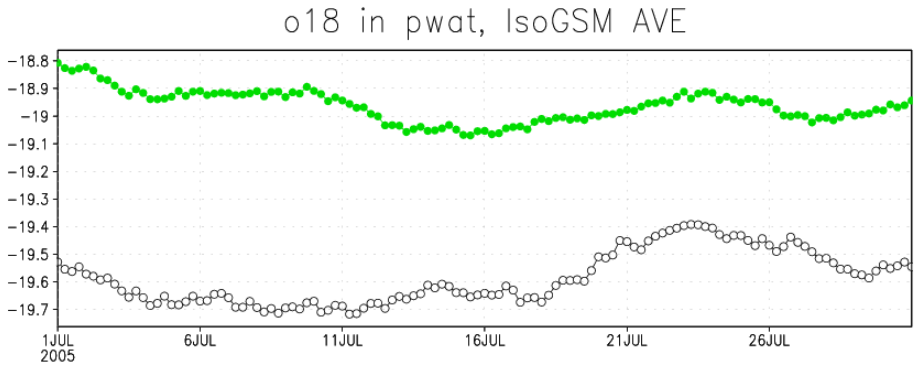


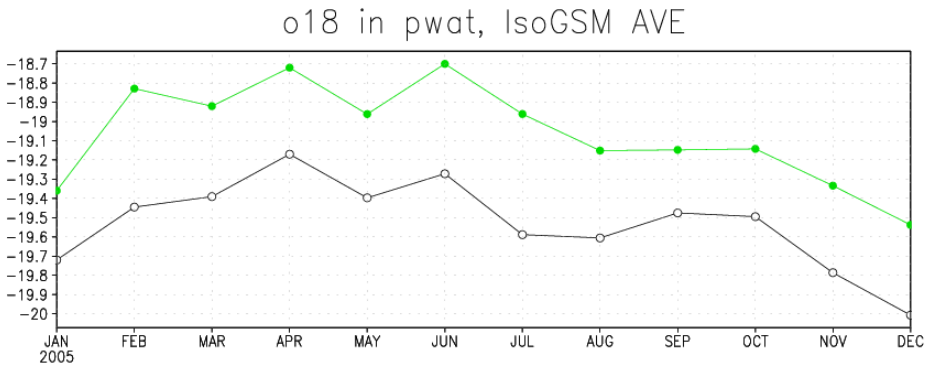


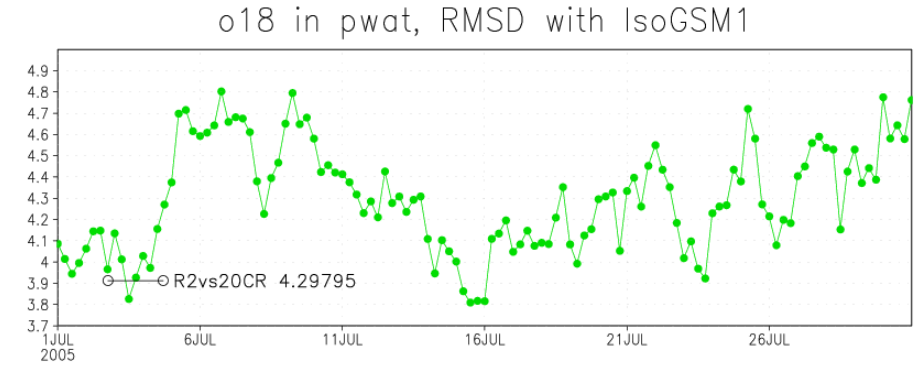
6-hourly snapshot

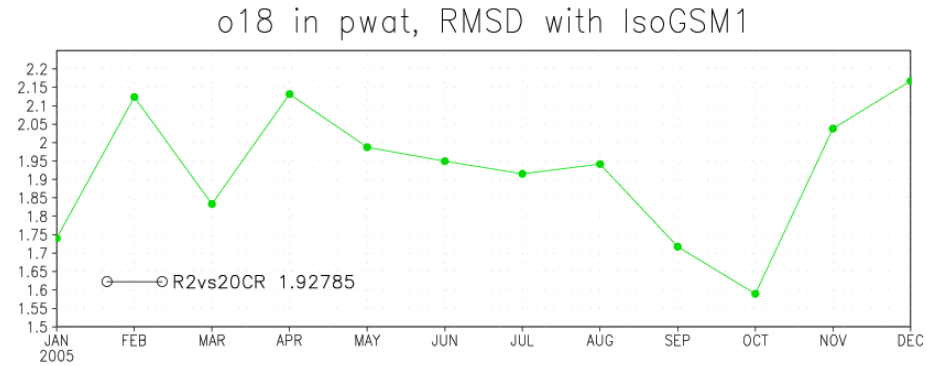
Monthly average

$\delta^{18}O$ in TPW global mean&rms





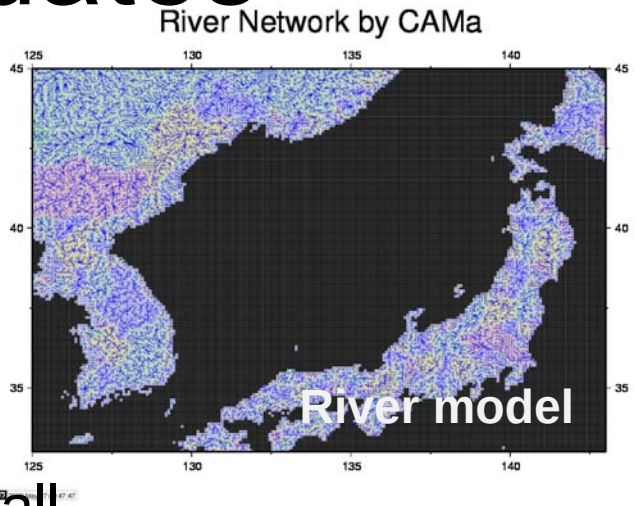




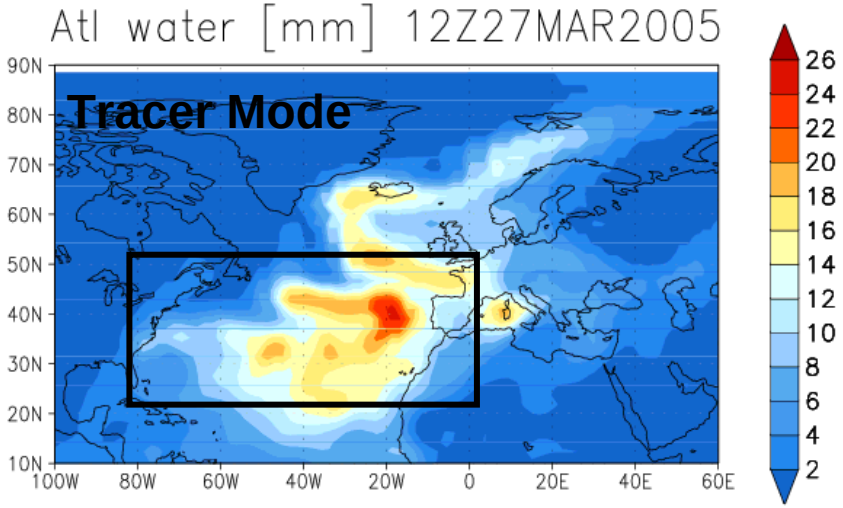
6-hourly snapshot

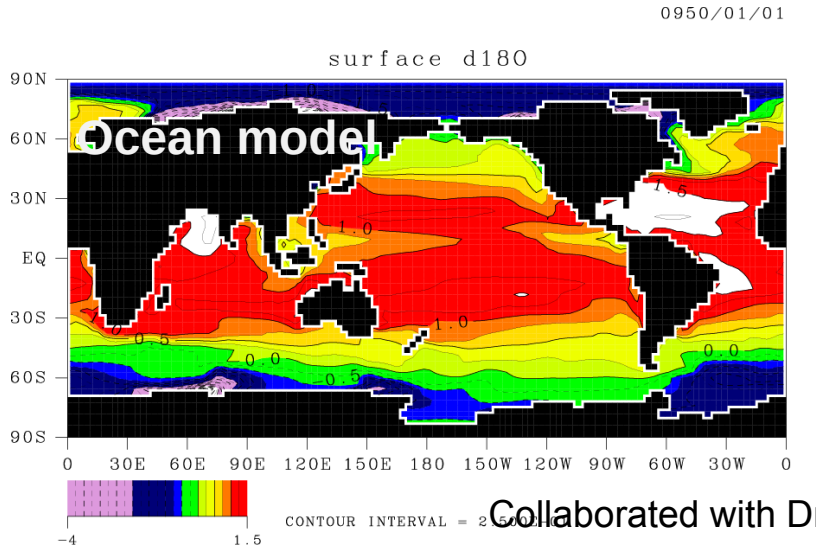
Monthly average

Other Recent Updates



- CVS version available
  ➔ Define “ISOTOPE” when you install.
- Tracer mode available
  ➔ Define “NOFRAC” when you install.
- River routing with isotopes
  ➔ Define “RIV1” or “RIV05” when you install.
- IsoRSM (Yoshimura et al., 2010) available also in CVS
- Offline ocean circulation model with ocean modelers



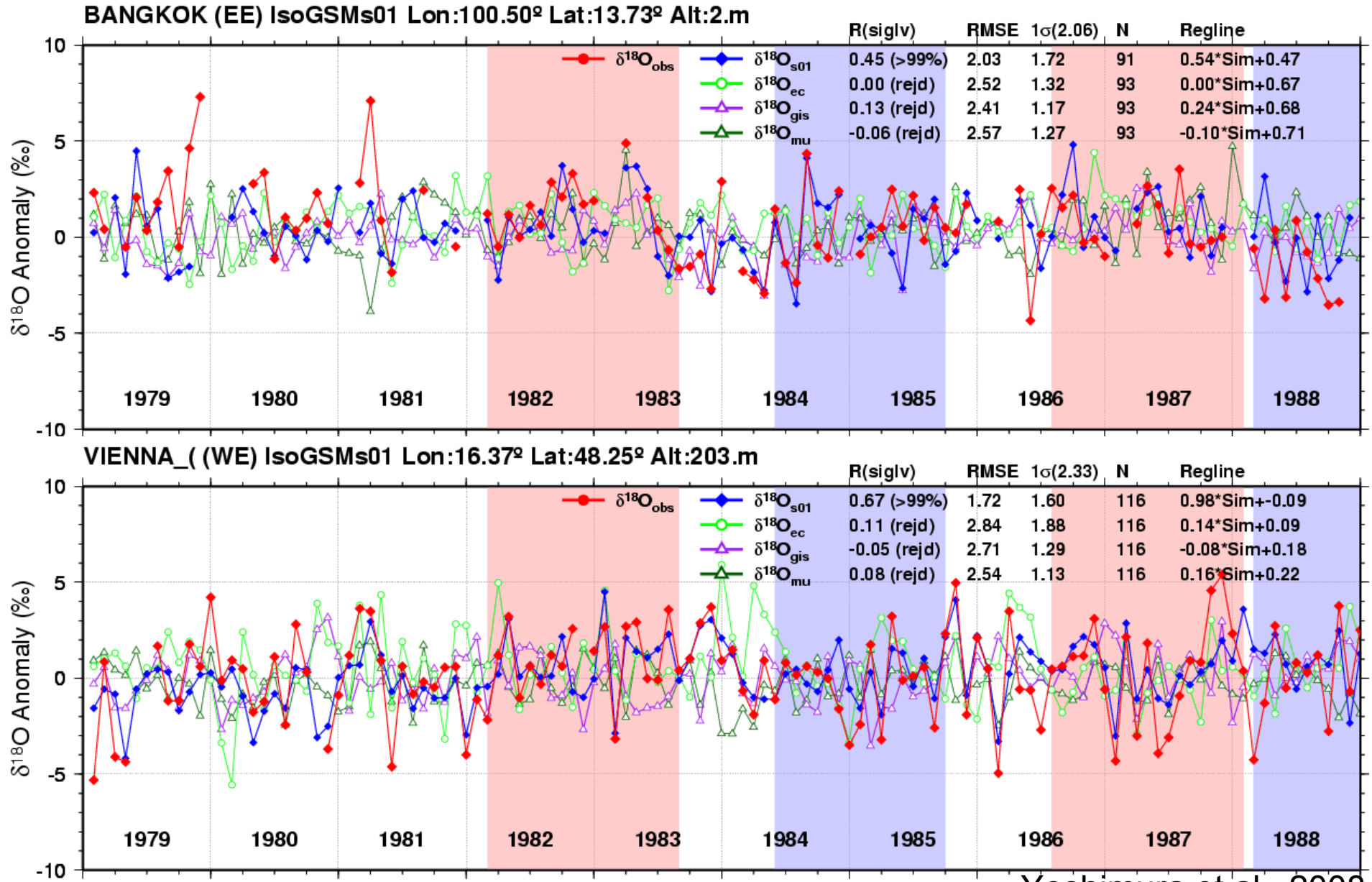


Collaborated with Dr Oka

Thank you!

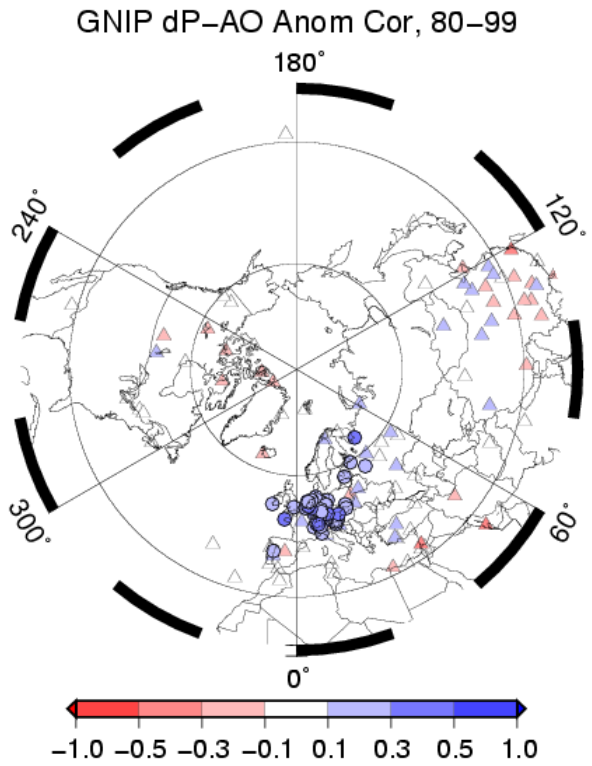
Any comment/question:
keiyoshi08@gmail.com

Monthly anomalies of precipitation isotopes

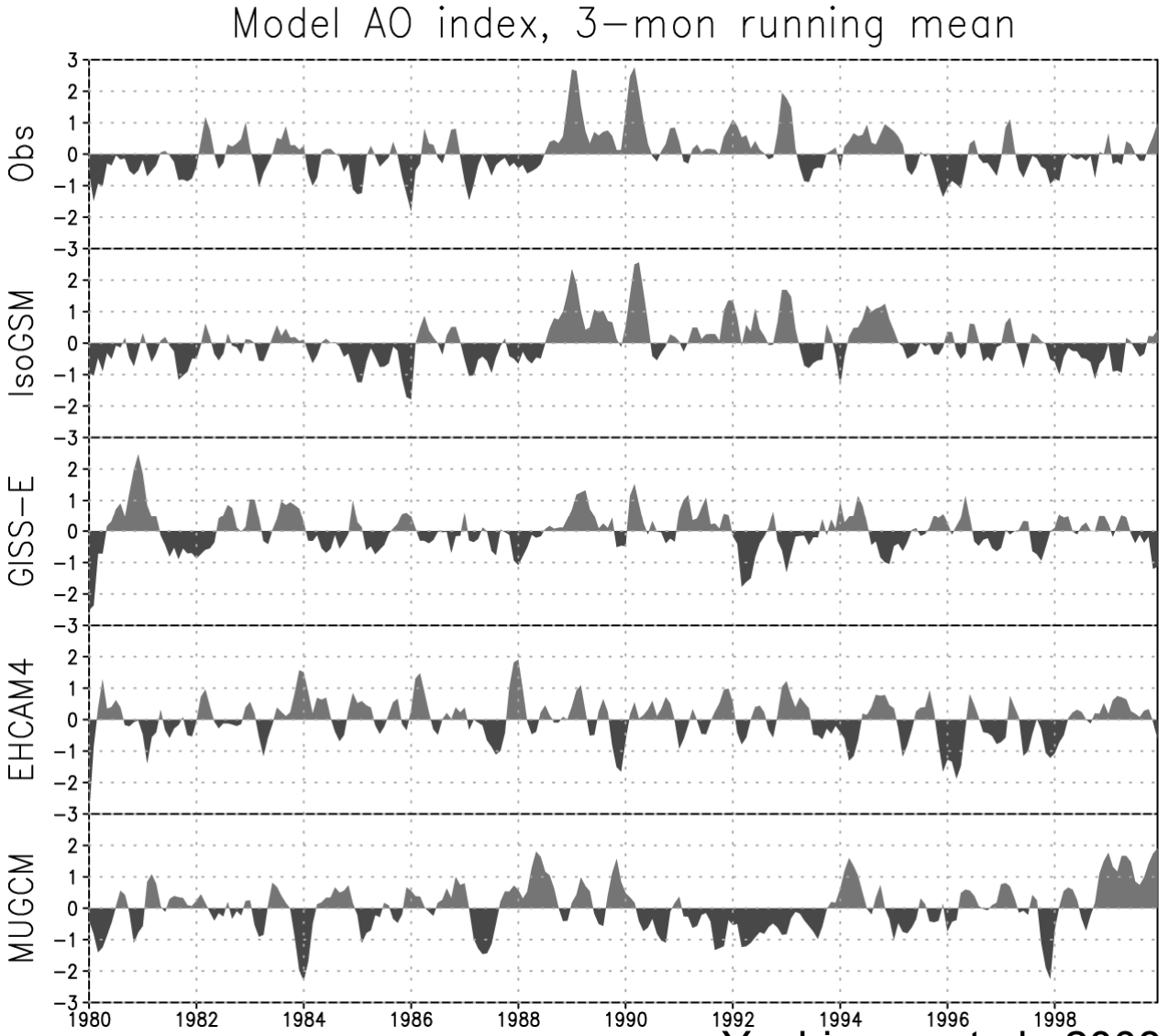


Yoshimura et al., 2008

AO is a key for NH isotopes

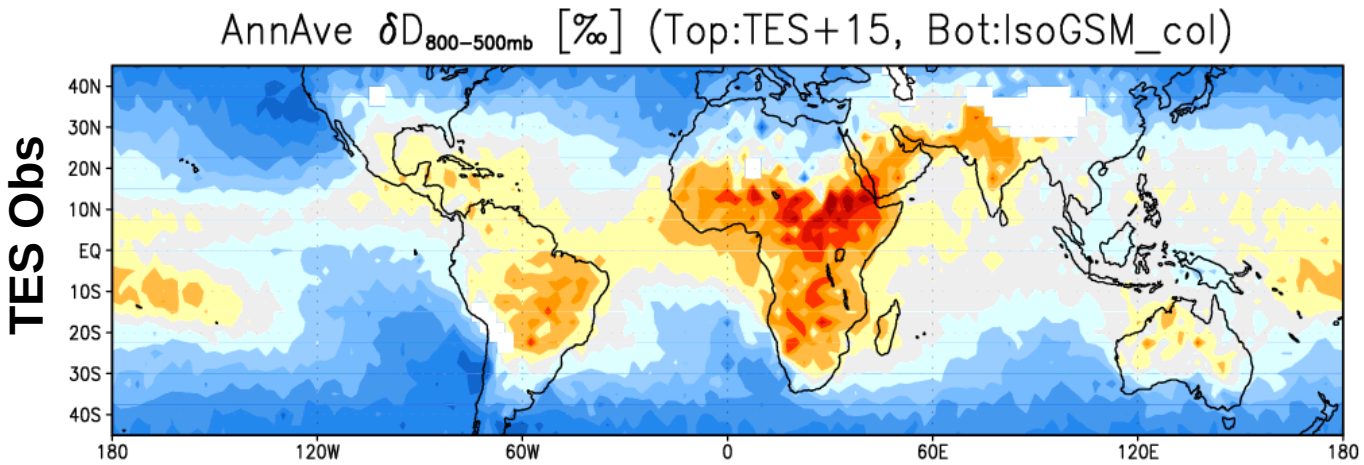


Obs. AO-Isotope correlation



Yoshimura et al., 2008

Yoshimura et al., prep

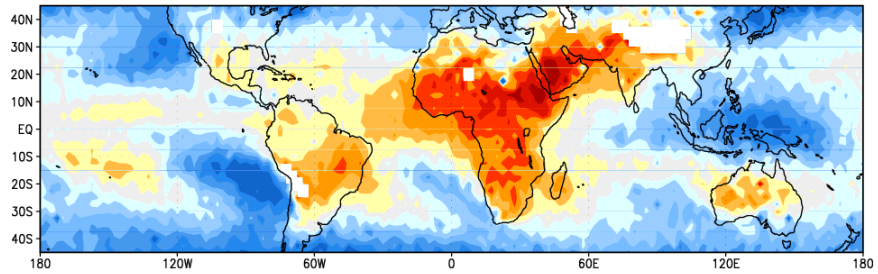


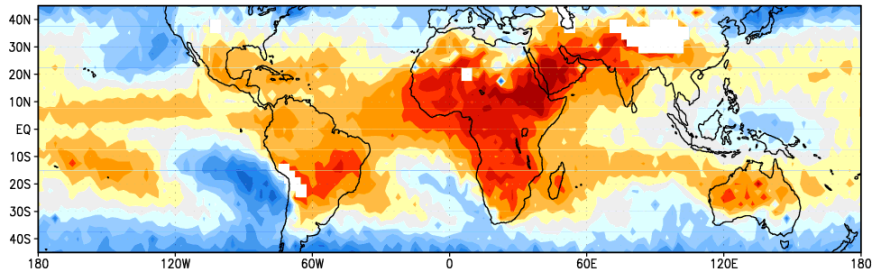
ε: How much fractionation occurs when droplet is falling.

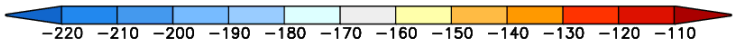
Control

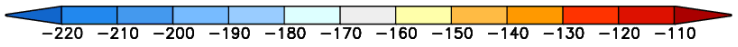
ε=10%

Sim

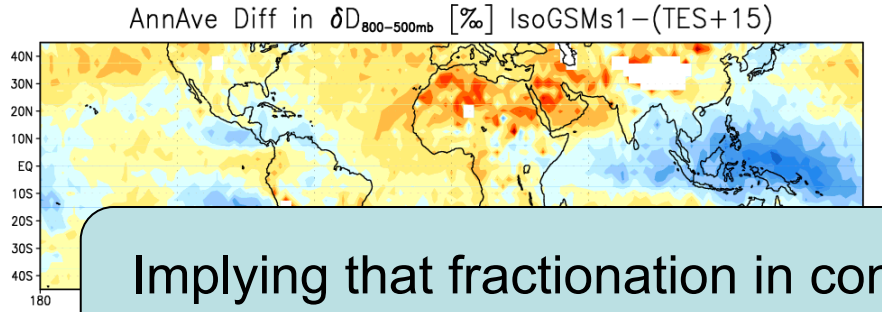


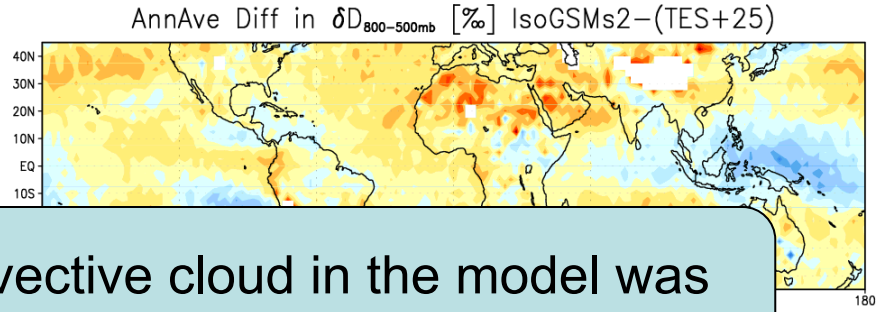






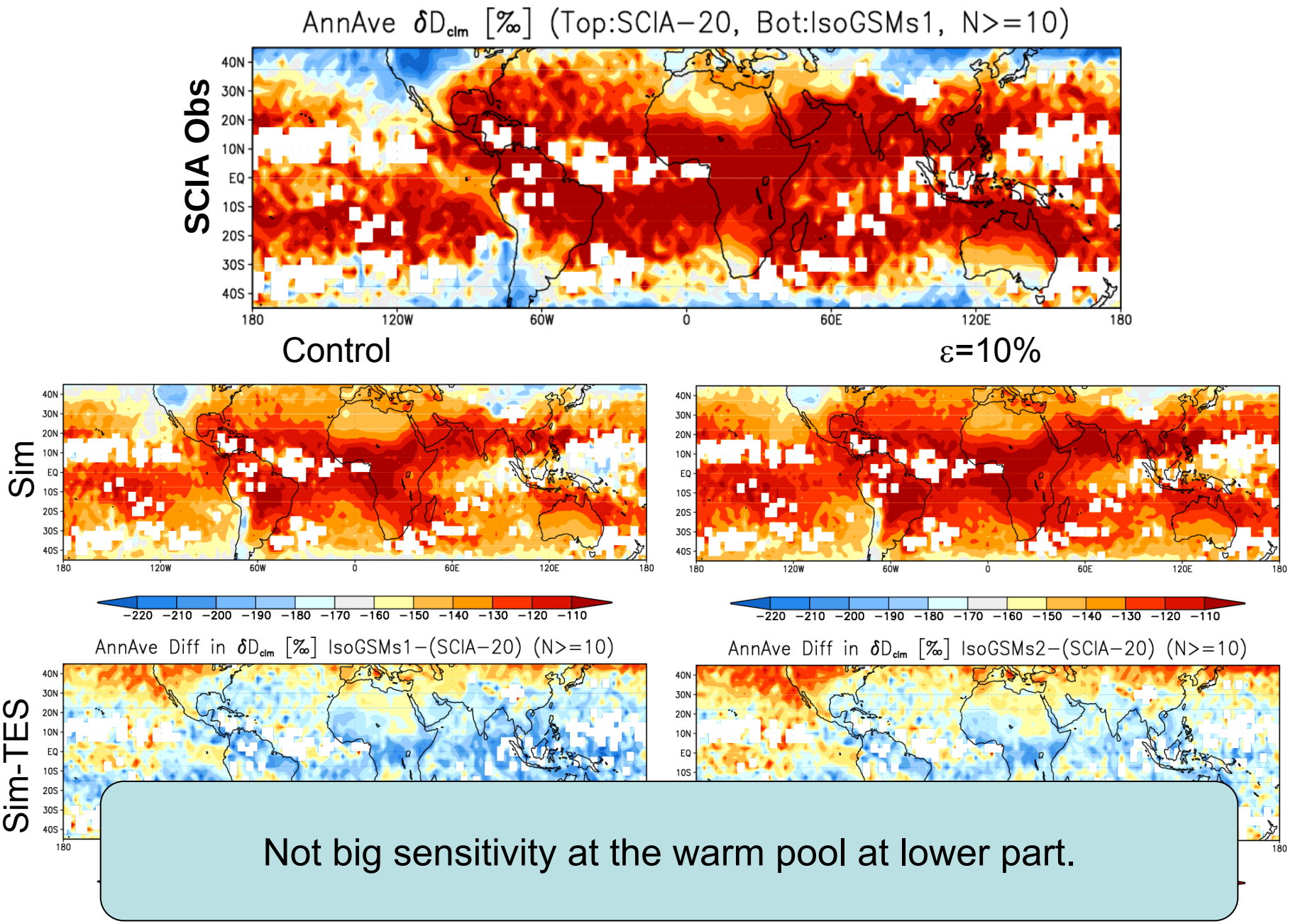
Sim-TES





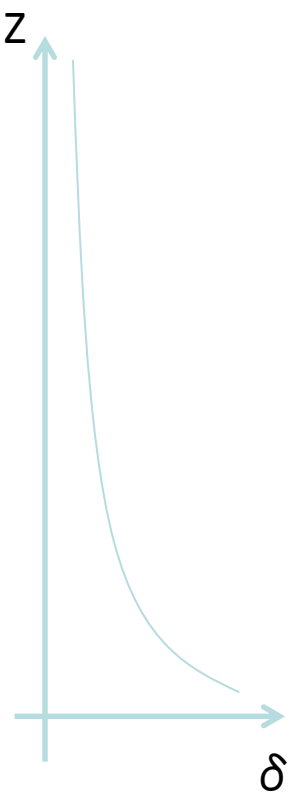
Implying that fractionation in convective cloud in the model was too strong ?? ➔ Further investigation needed.

Yoshimura et al., prep

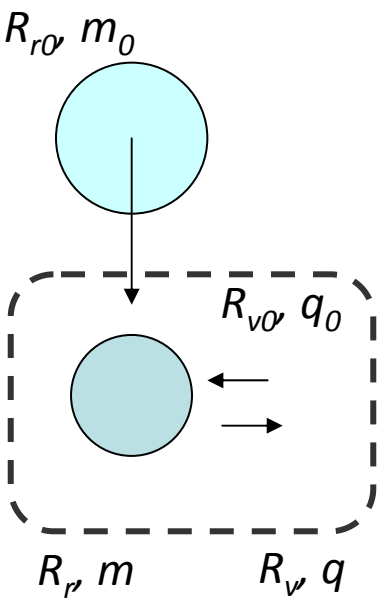


Not big sensitivity at the warm pool at lower part.

Changing equilibrium fraction for convective precipitation

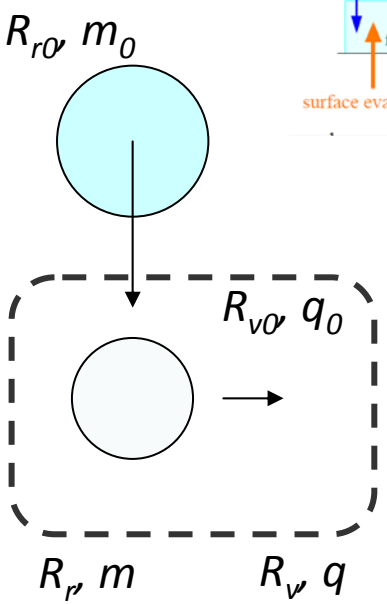


Control (ε =45%)



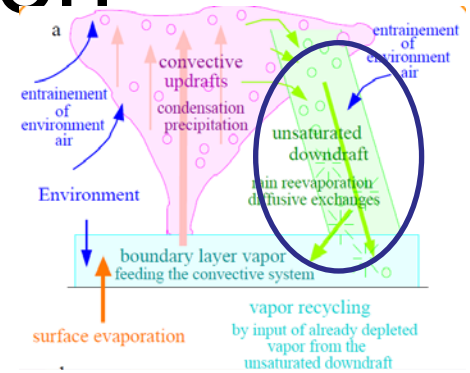
rain isotope ↑
vapor isotope ↓

ε =10%

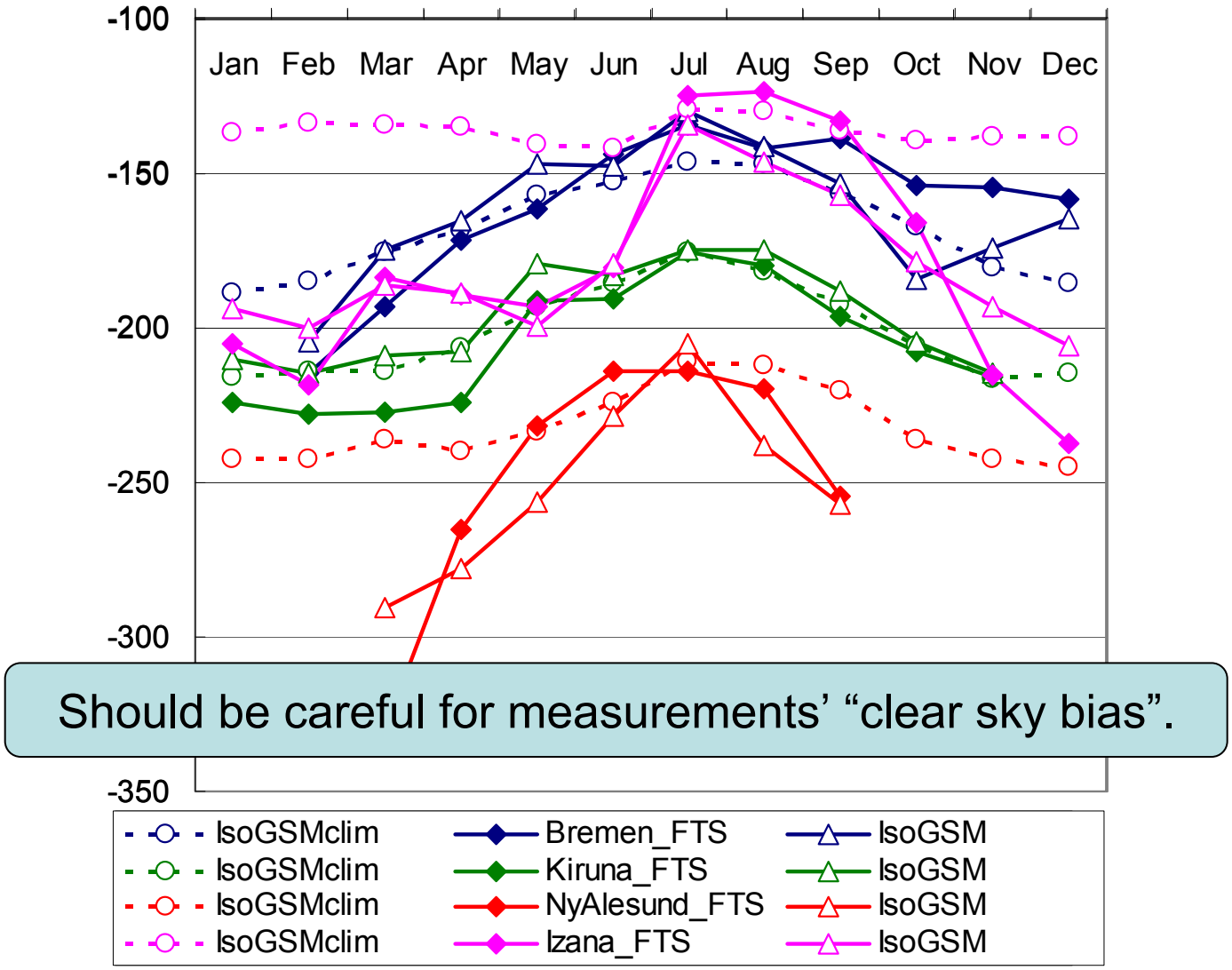


rain isotope →
vapor isotope ?

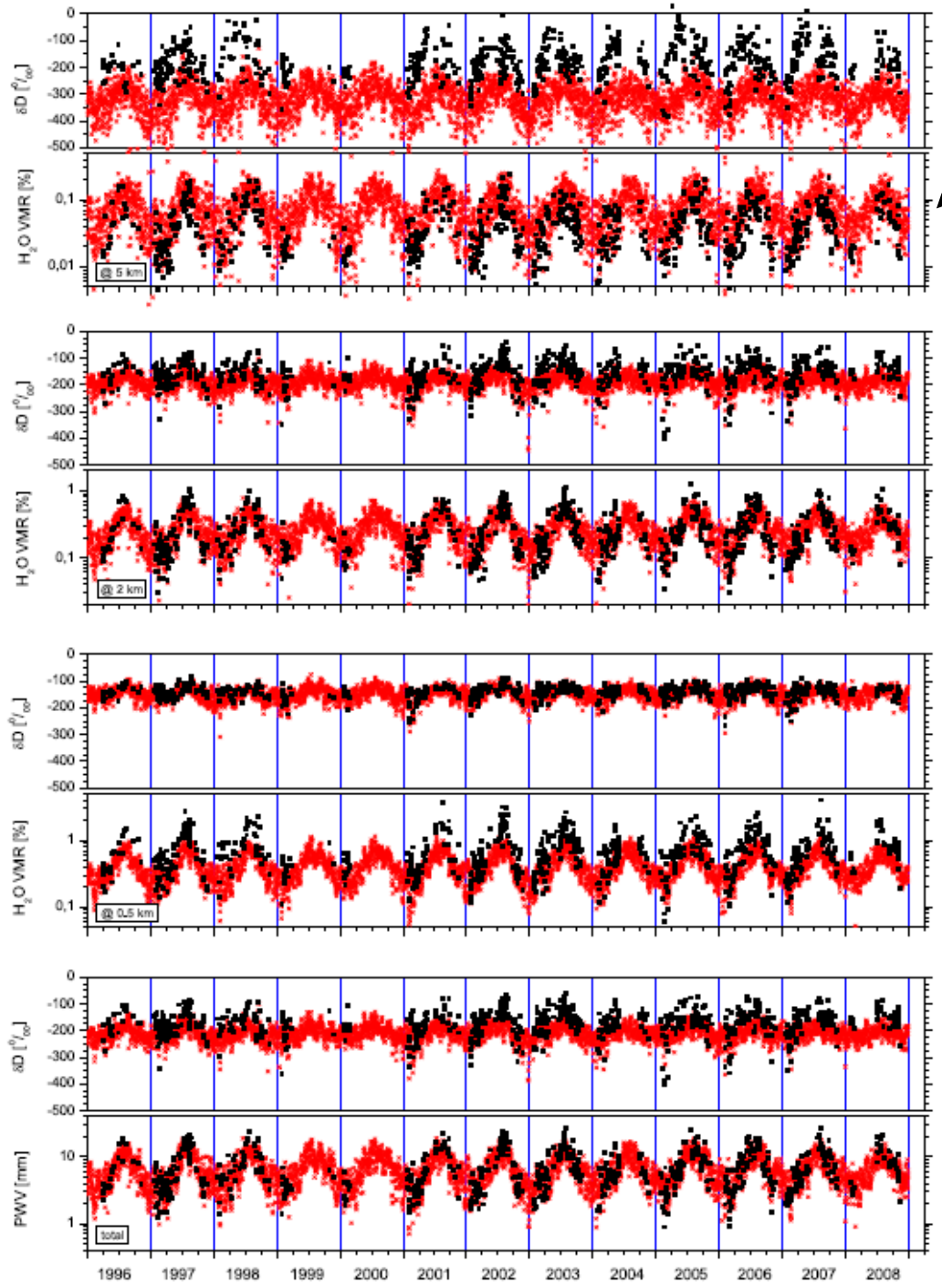
more ice and/or
faster falling speed



Collocated model vs FTS

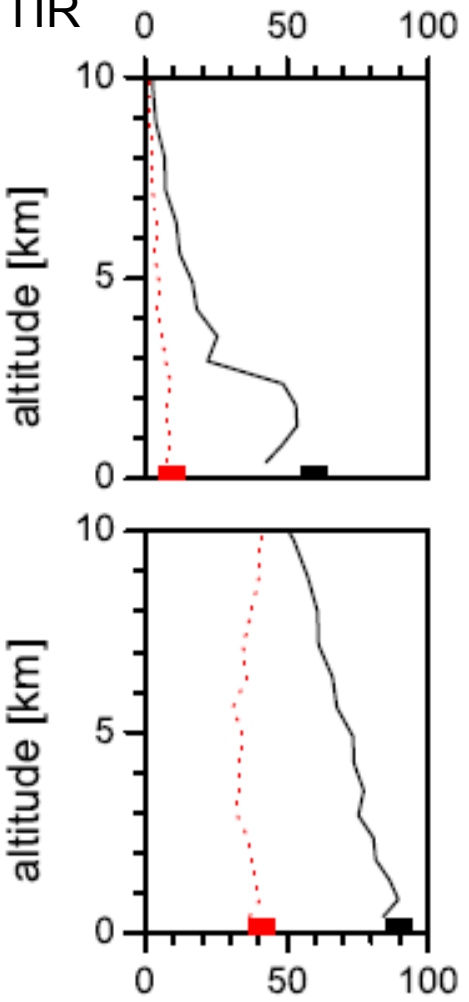


Should be careful for measurements' "clear sky bias".



Red: IsoGSM
Black: FTIR

@Kiruna/Sweden



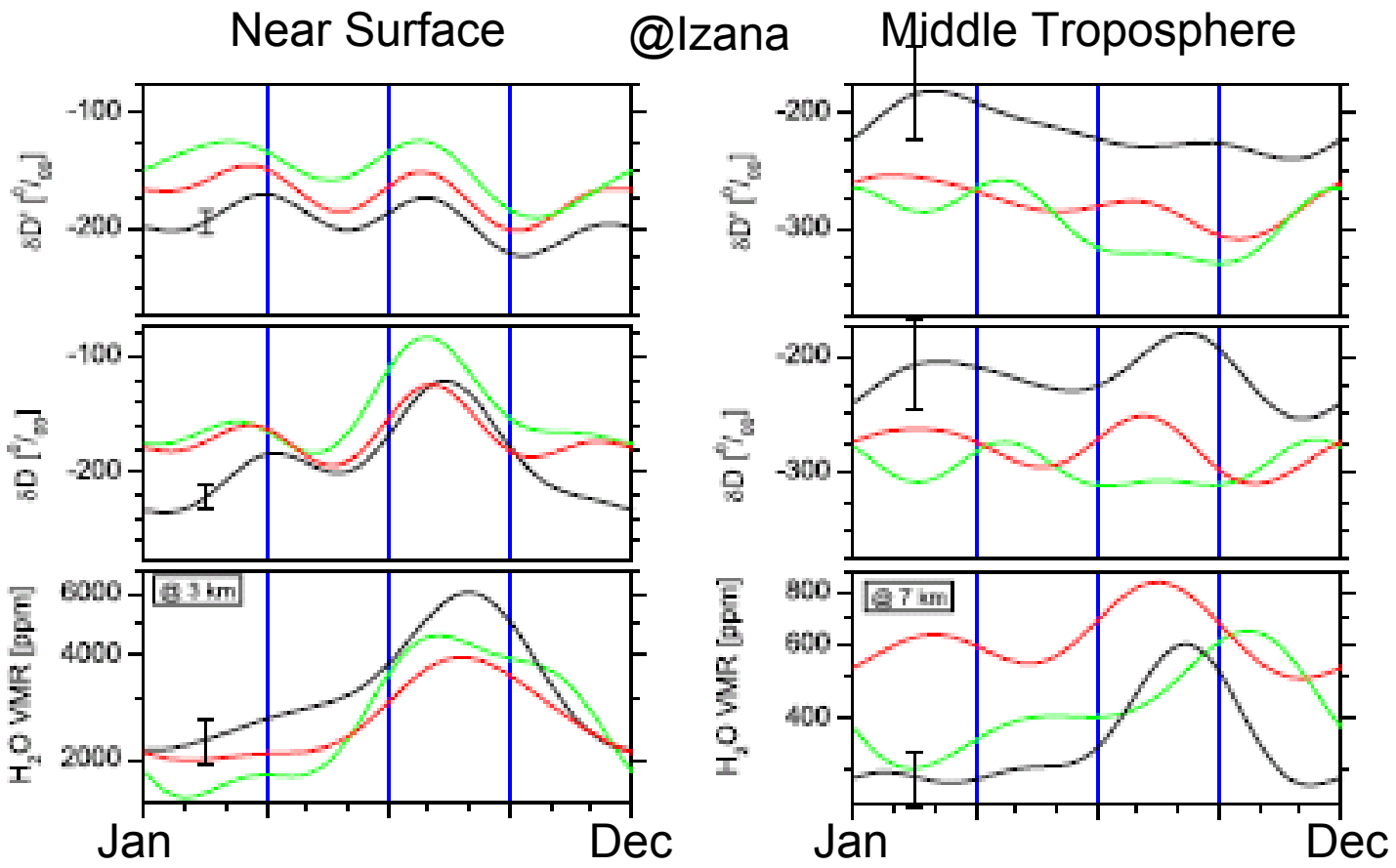
R^2 [%] for raw data

Red: Free run

Black: Nudged run

Schneider et al. (2010)

Limitation of IsoAGCM



Schneider et al., 2010

Black: Obs, Green: Free-run, Red: Nudged run

Simulation accuracy is not good for upper air…

Future direction/strategy

- Isotopes need to be standard output of climate projections for AR6!!
  - Incorporate the isotopes into NICAM
  - Expand to biogeochemical processes
    - IsoMATSIRO needs to be revisited.
    - Tree ring $d^{18}O$, CO_2 $d^{18}O$, ^{13}C, ^{15}N
  - Couple with coast, ocean, sea ice models
    - Prognostic simulation for paleo isotopes.

- Data assimilation
- Longer historical simulations (20C)