耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

A discussion on the paper "Evidence of deuterium excess in water vapor as an indicator of ocean surface conditions"

By Ryu Uemura et al.，2008

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2015.09.18

Outline

- Background
- Objectives
- Methods
- Results and Discussions
- Conclusions

Background

- The isotopic composition of most of meteoric water is found in a graph of δD versus $\delta^{18}O$ along the "Global Meteoric Water Line": $\delta D = 8*\delta^{18}O + 10‰$; the deuterium excess *d* has been defined as the difference $d = \delta D - 8*\delta^{18}O$. [Craig, 1961 ; Dansgaard, 1964]
- The glacial-interglacial changes in *d* were interpreted as changes in relative humidity and temperatures at the moisture source ocean. [Jouzel et al., 1982; Cuffey and Vimeux, 2001]
- The interpretation of *d* which relies on various models predicts a close relationship between d and ocean surface conditions.
- A few in situ measurements of vapor isotopes in the oceans have been reported, but *d* has not been observed except for subtropical oceans and the Mediterranean Sea. [Craig and Gordon, 1965 ; Gat et al., 2003]
- In this study, we measured isotope compositions of air moisture in the Southern Ocean, then discussed the observation results and simulations from a couple of isotope GCMs.

Simple evaporation model

A global-scale closure assumption ($\delta_{V0} = \delta_E$)

$$\boxed{1 + \delta_{V0} = \frac{1}{\alpha} \frac{(1 - k)}{1 - kh} (1 + \delta_{ocean}) \cdots\cdots\cdots (1)}$$

δ_{V0} — the initial isotope content in the water vapor;

δ_E — the isotope contents of the evaporating water;

δ_{ocean} — an ocean isotope composition;

k — a kinetic fractionation factor;

α — an equilibrium fractionation factor;

h — relative humidity defined as a value normalized on the SST (h^*) in the model.

[Merlivat and Jouzel, 1979]

Objectives

- Showing the isotope ratios of atmospheric water vapor near the ocean surface in middle and high latitudes of the Southern Ocean.

- Showing the correlations between deuterium excess (*d*) versus relative humidity (*h*) and *d* versus sea surface temperature (SST).

- Using atmospheric general circulation models (GCMs) to predict the isotope ratios of marine vapor and validating GCMs through data.

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  - Ship observation
  - A vapor sampling system
  - Isotope general circulation model
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Ship observation

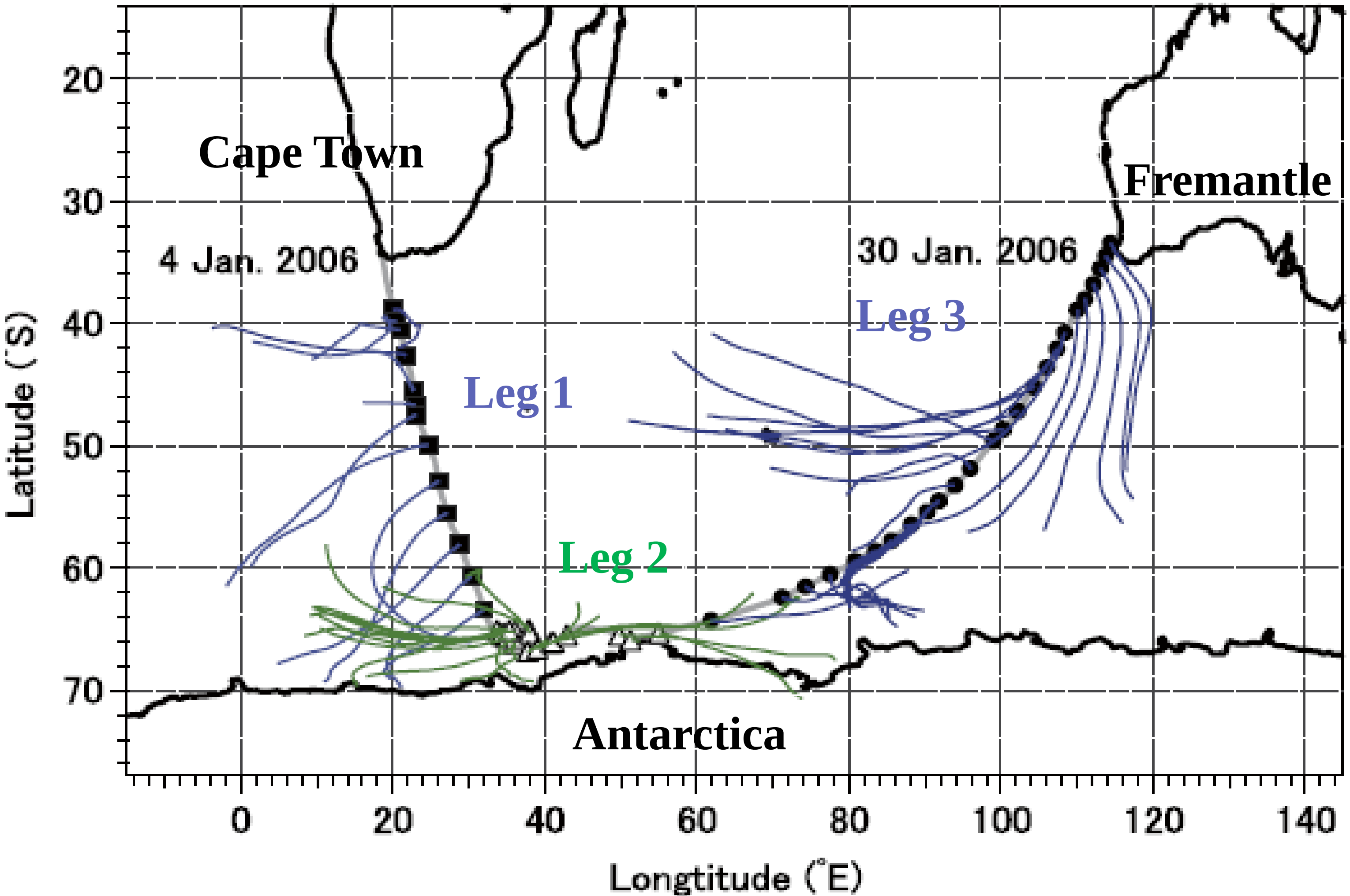

Figure 1. Sampling sites on a map of the ship route (gray).

Frequency
2–3 times per day

Sampling duration
2–12 h

Measurements

Air temperature and relative humidity were measured at 15 m altitude on the ship.

A vapor sampling system

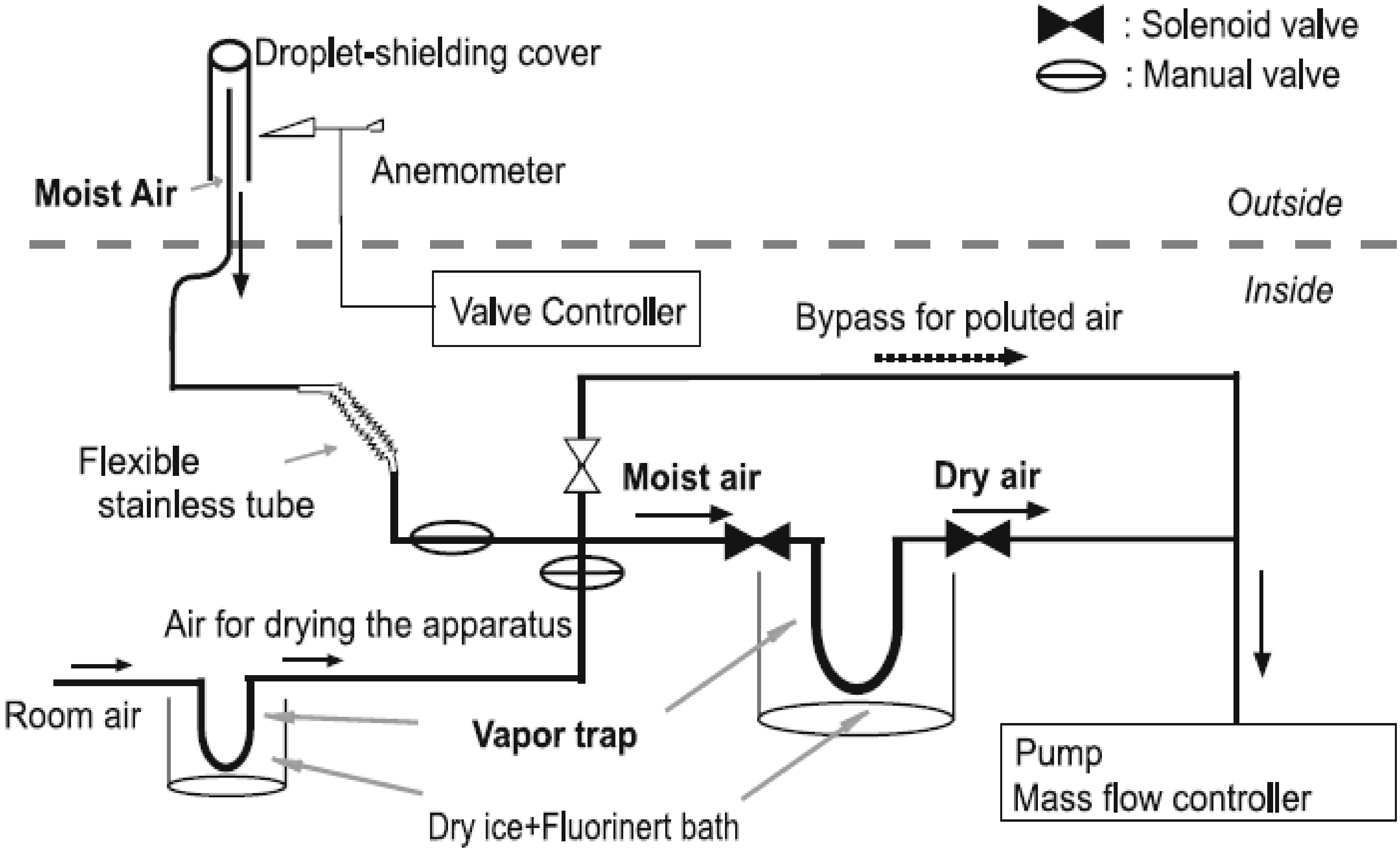

Figure 2. Schematic of the sampling system installed on the ship.

Isotope general circulation model

A global-scale closure assumption $(\delta_{V0} = \delta_E)$

Systematic bias

An atmospheric general circulation models (GCMs)

The GCMs explicitly simulate the global and regional features of atmospheric dynamics and thermodynamics and the detailed hydrological cycles.

1. Isotope Global Spectral Model **(iso-GSM)** [Yoshimura et al., 2008]

   200 km horizontal resolution ＋ 28 vertical sigma levels

2. NASA Goddard Institute for Space Studies **(GISS)** GCM II
   [Jouzel et al.,1987]

   8° × 10° resolution ＋ 9 vertical sigma levels

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- Results and Discussions
  - A. Isotope ratios in vapor
  - B. Deuterium excess in vapor
  - C. Comparison with GCMs
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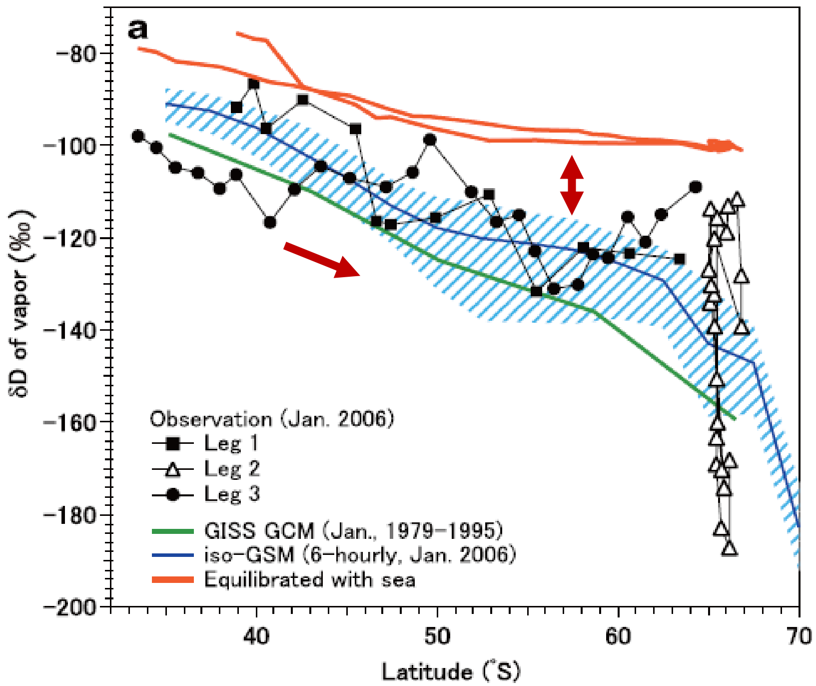
Results and Discussions

Table 1. Isotope Ratios in Water Vapor and Meteorological Conditions Along the Ship Route

Sampling Start Time (UTC)	Sampling Duration (h)	Latitude[a] (°S)	Longtitude[a] (°E)	Atmospheric Pressure (hPa)	Air Temperature (°C)	SST(°C)	*h*(%)	Vapor Isotopes $\delta^{18}O$(‰)	δD(‰)	*d*(‰)
Leg 1 (Cape Town to Antarctica)										
5 Jan. 0413	0142	38.91	20.11	1017	18.3	22.8	63.7	−15.71	−91.7	34.0
5 Jan. 0845	0300	39.86	20.53	1018	19.4	21.5	57.0	−14.56	−86.5	30.0
5 Jan. 1310	0308	40.56	20.93	1016	18.7	21.2	65.8	−14.47	−96.3	19.5
Leg 2 (Antarctic Coastal Area)										
10 Jan. 1745	0840	65.10	33.75	995	−0.3	0.0	80.1	−17.17	−134.0	3.4
11 Jan. 0610	0435	65.32	34.54	994	−0.3	0.1	79.7	−17.24	−132.2	5.8
11 Jan. 1145	0200	65.46	34.55	994	−1.6	0.1	80.7	−19.27	−150.5	3.6
Leg 3 (Antarctica to Fremantle)										
20 Jan. 0540	0902	64.29	61.83	991	0.4	1.0	93.5	−13.27	−108.9	−2.8
21 Jan. 0440	0515	62.39	71.16	995	0.4	1.7	85.4	−15.61	−114.9	10.0
21 Jan. 1110	0650	61.51	74.27	995	0.3	1.8	77.0	−16.41	−120.9	10.4
29 Jan. 1210	0455	33.47	114.35	1022	17.0	19.4	67.3	−14.60	−97.9	18.9

[a]Latitude and longtitude are shown in decimal system.



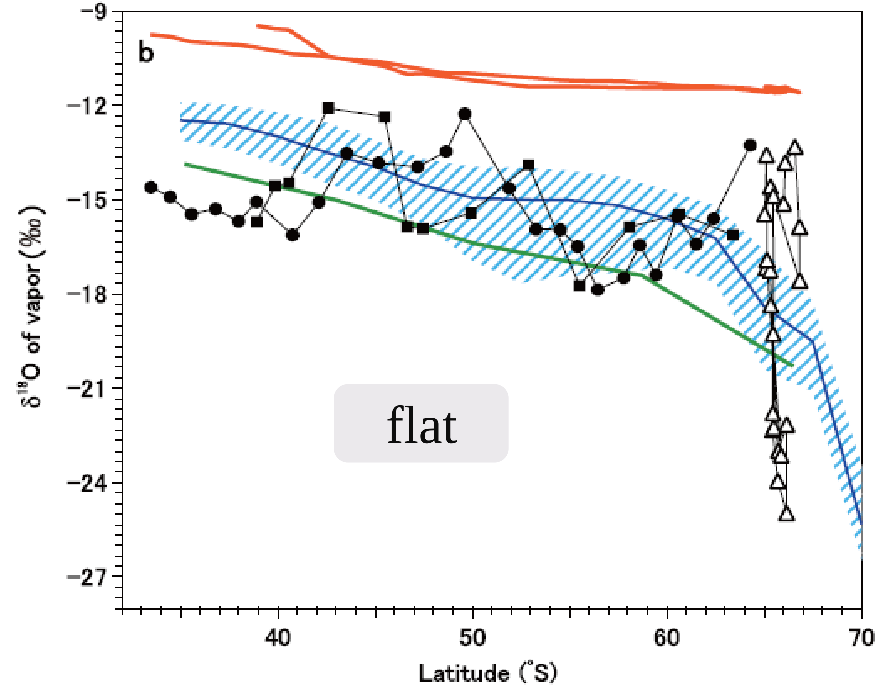
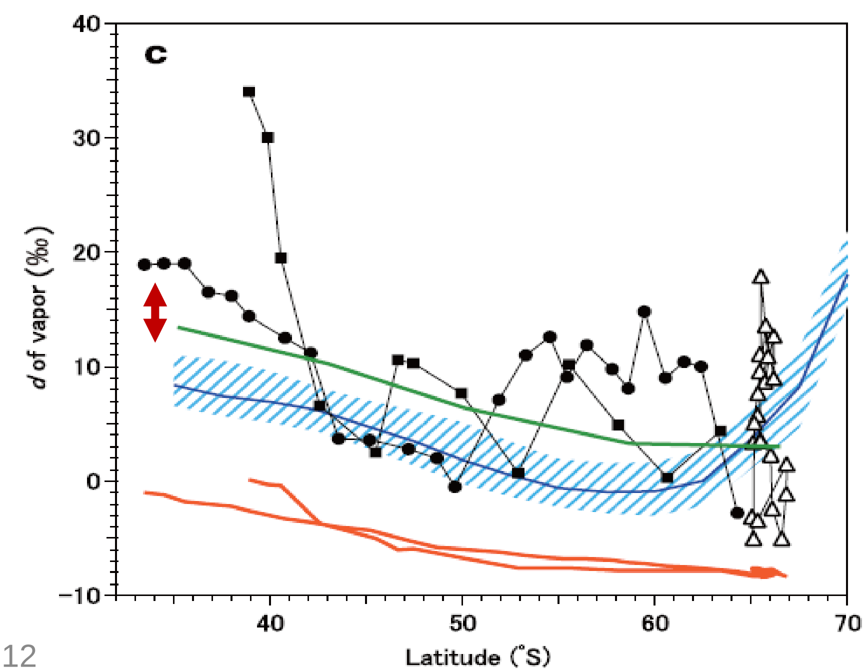


Figure 3. Latitudinal distribution of δD, δ^{18}O and *d* in water vapor.



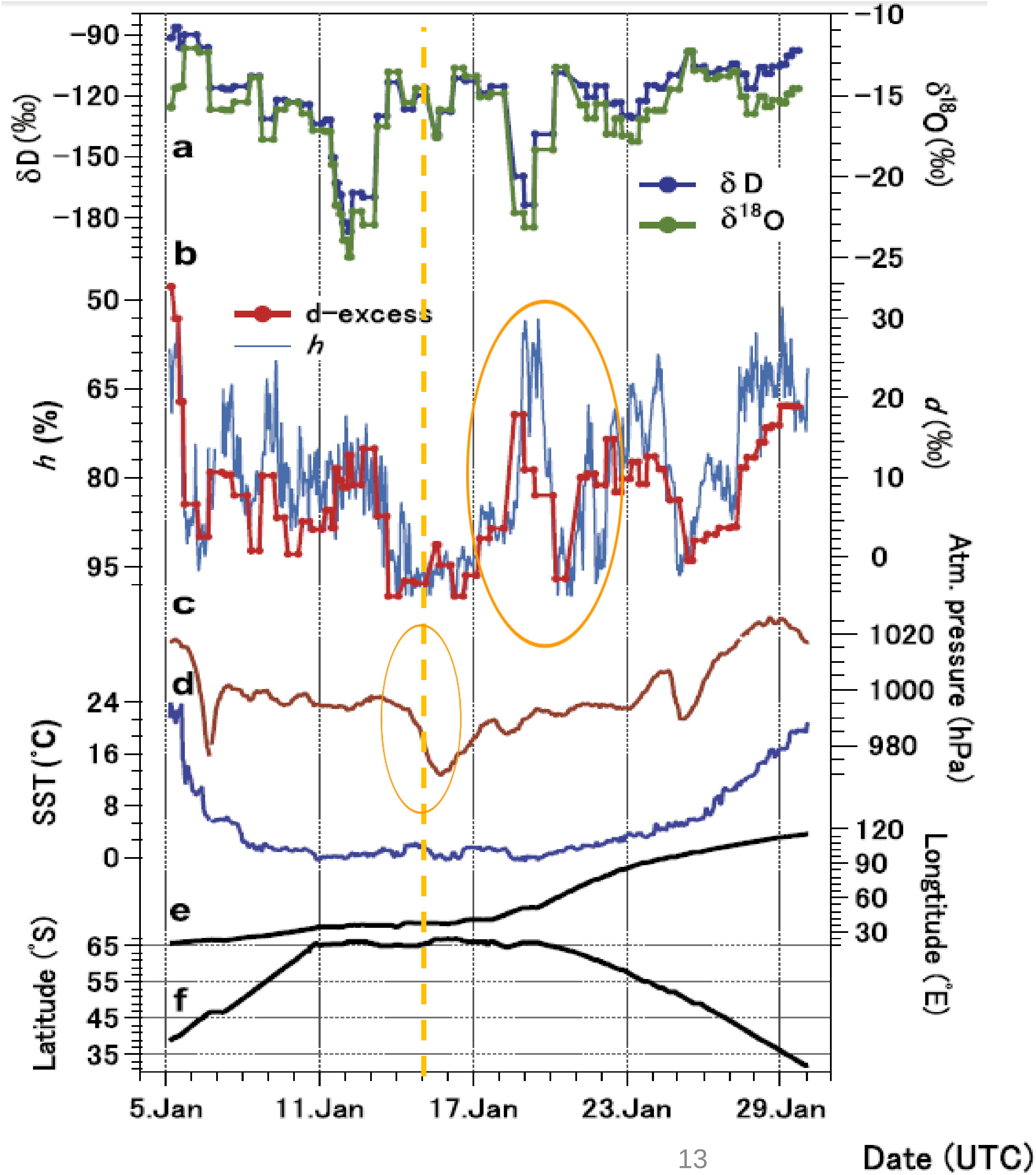


Figure 4.
Time series of isotope compositions and metrological conditions.

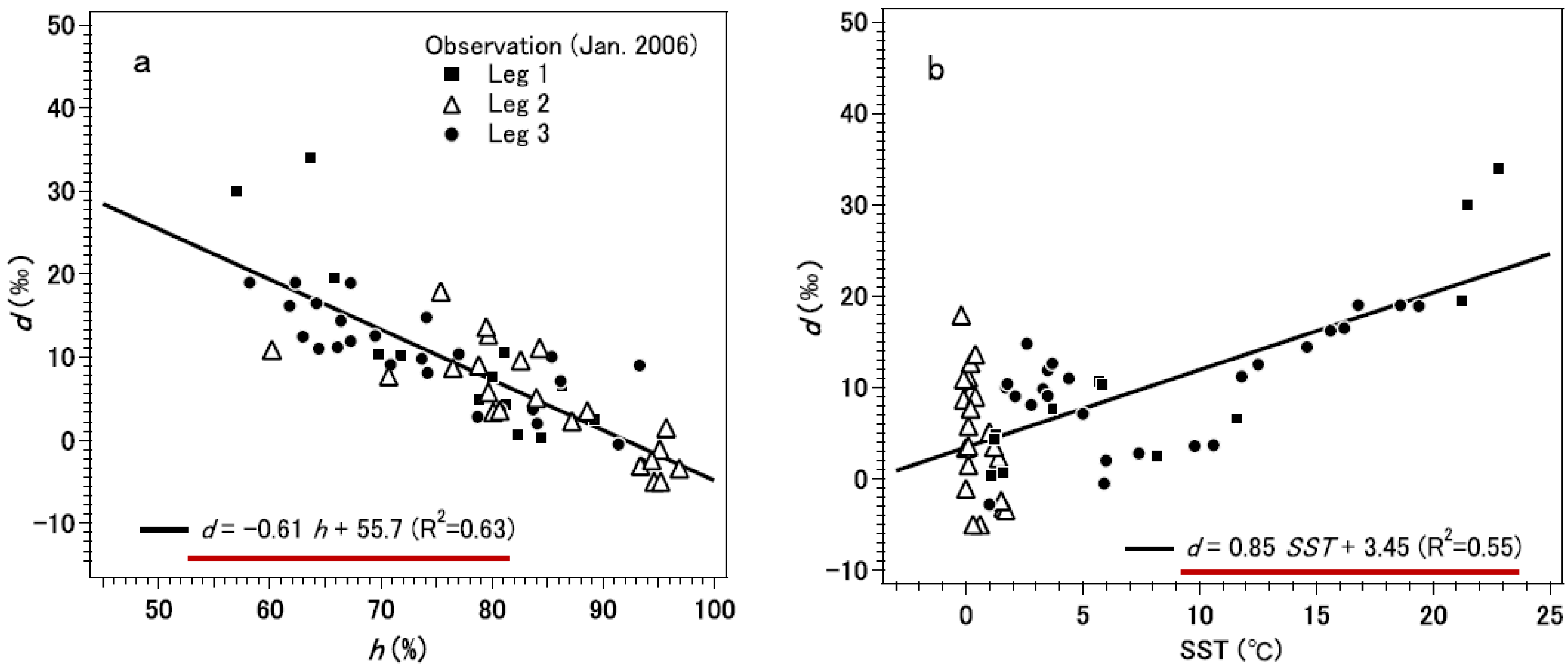


Figure 5. Correlations of *d* in vapor versus relative humidity and SST.

A multilinear regression analysis of *d*, *h* and SST

$$\boldsymbol{d} = \mathbf{0.45\ SST - 0.42}\ \boldsymbol{h} + \mathbf{37.9} \qquad \mathbf{R^2 = 0.73}$$

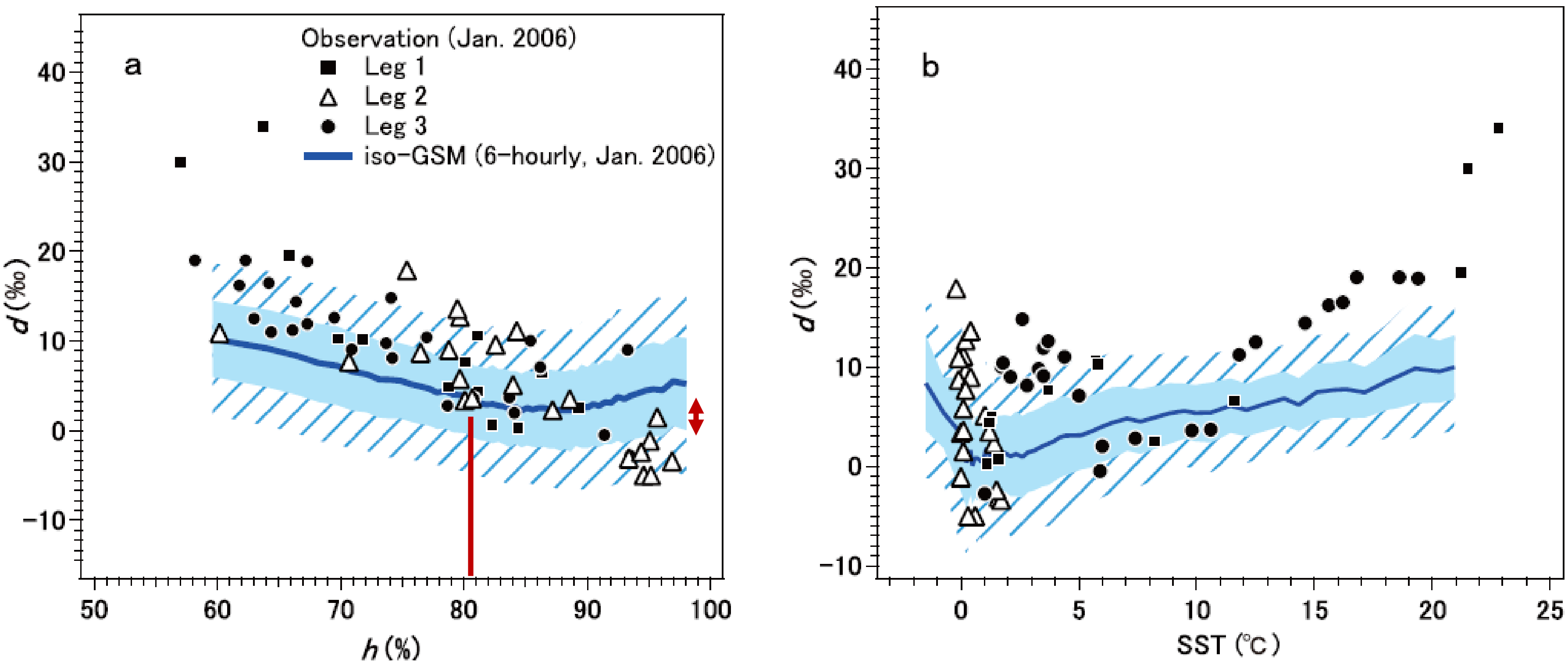


Figure 6. Comparison with GCM.

blue line — the *d* in marine vapor predicted by the iso-GSM

blue shaded area — 1σ slashed area — 2σ

(the standard deviations of the model predicted *d*)

Conclusions

- The large variation of δD and δ^{18}O found south of 65°S is attribute to the mixture of marine and Antarctic vapors.

- The δD in vapor decreases along with higher latitude from 30°S to 60°S, the gradient of δ^{18}O from 30°S to 60°S is flat in comparison to that of δD because of kinetic fractionation during the evaporation.

- The *d* in vapor shows statistically significant correlations with *h* and SST, then provides the first evidence for a close relation between *d* and ocean surface conditions in different southern oceans.

- The observations are consistent with isotope ratios simulated by the iso-GSM, and thus validate the simulation.

THANK YOU