SHORTER CONTRIBUTION

Modification of atmospheric tritium and water vapor by Lake Tahoe

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1. Theory

In a parcel of moist air in contact with a lake surface, water molecules, both H_2O and HTO, are transferred both ways between the gaseous and liquid phases. The *net* transfers of H_2O and of HTO are in the direction of decreasing chemical potential of each species. These directions may be opposite. We introduce the following notations:

E_{H_2O}, E_{HTO}	Upward net flux of H_2O, HTO in g cm^{-2} sec^{-1}
q, q_w	Specific humidity (g H_2O/kg air) in free air, at lake surface (saturation)
θ, θ_w	Tritium concentration, in TU, of free air vapor, of lake surface water
t	Time
γ	Fractionation factor (p_{HTO}/p_{H_2O}) at saturation, also ($\theta_{vapor}/\theta_{liquid}$) at equilibrium
a	Transforms specific humidity to height of precipitable water column (g cm^{-2}) in layer affected (sampled)
b	Transforms TU to g HTO/g H_2O
k	Eddy diffusion coefficient of vapor in air, same for both species of water

According to approaches proposed by Bolin (1958), Machta (1969), and others, we can write for the fluxes at the air/lake interface

$$E_{H_2O} = a \cdot dq/dt = a \cdot k\,(q_w - q) \qquad (1)$$

$$E_{HTO} = a \cdot b \cdot d(q\theta)/dt = a \cdot b \cdot k\,(q_w \theta_w \gamma - q\theta) \qquad (2)$$

where we assume H_2O and HTO to have same vertical eddy diffusion coefficient. We divide (1) by (2), whereby a, b, k and t disappear. To describe the changes in humidity and tritium in the air over the lake, we integrate the resulting expression between q_1 and q_2 and θ_1 and θ_2 respectively, and obtain without any approximations

$$\frac{\theta_2 - \gamma\theta_w}{\theta_1 - \gamma\theta_w} = \frac{q_w - q_2}{q_w - q_1} \cdot \frac{q_1}{q_2} \qquad (3)$$

The interesting feature of (3) in our case, is that we can test the validity of the approach, since all parameters can be measured independently of each other.

2. Experimental results

On July 9, 1968, samples of water vapor were collected at selected points around Lake Tahoe, California and Nevada, USA. This was done by using a pump, driven by the battery of a car, to pull about 1 m^3 of air through an absorber, also called a sieve trap, in about 20 min. This technique and the method for measuring tritium were described by Östlund (1968). Air temperature and humidity were recorded and wind observed.

Due to the size of the lake, and having access to only one set of sampling gear, we collected the samples at various times between 08.00 and 16.00 local time (PST). The incoming air was sampled during the afternoon at three points along the western shore, and the most representative point should be Tahoe City, cf. Fig. 1, Pt. 5, where the air comes directly from Truckee Valley. Air leaving the lake was sampled at 09.20 the same morning, when the nightly inversion was just breaking up in a very light

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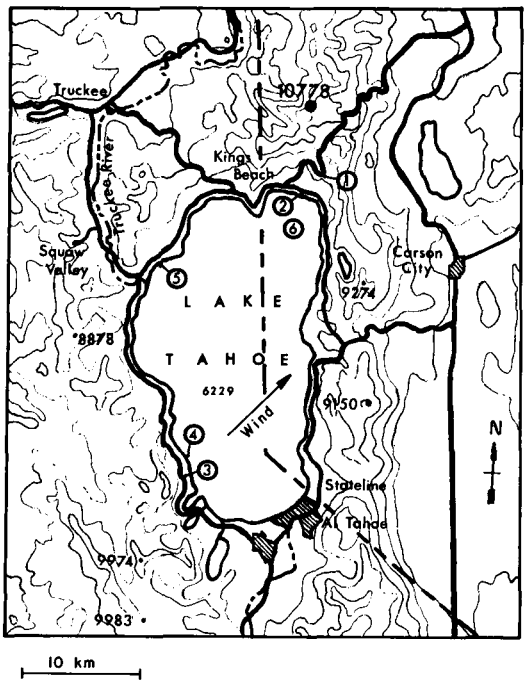

Fig. 1. Map of sampling area (elevations in feet above sea level).

breeze. In addition, the source air was sampled at 400 m above the lake (Pt. 1) at 08.30, before the inversion had broken up.

Sampling points and obtained data are recorded in Tables 1 and 2. It is now obvious that we should have collected at least one more sample of the modified air. The synoptic situation and the small variations in the properties of the source air allow us to assume similar conditions the day before our sampling. From Table 2, we obtain for our calculations:

$$q_1 = 7.1 \pm 0.1 \text{ g m}^{-3};\ \theta_1 = 157 \pm 6 \text{ TU}$$

$$q_2 = 10.4 \pm 0.1 \text{ g m}^{-3};\ \theta_2 = 68 \pm 3 \text{ TU}$$

$$q_w = 14.2 \pm 0.1 \text{ g m}^{-3};\ \theta_w = 29.0 \pm 1.0 \text{ TU}$$

The fractionation factor γ is 0.92, cf. summary by Jacobs (1968). The measured water temperature of 16.7°C is probably slightly high, since it was measured in shallow water.

Left member of Eq. 3 becomes 0.32 and right

Table 1. *Sampling points*

Sampling point numbers refer to Fig. 1. Altitudes in m above lake surface, which itself is at 1 980 m above sea level

Pt. no.	Location	Altitude
1	Look Out Point, Rt. 27, Nev	344 m
2	Incline Village Beach, Nev	5 m
3	Benchmark N 125, California	198 m
4	Lester Beach, Bliss State Park, California	5 m
5	Tahoe City, California	5 m
6	500 m off Incline Village Beach, surface water only	0 m

Table 2. *Sample data*

Meteorological and tritium data. Sampling point numbers refer to Table 1 and Fig. 1. Date: 9 July 1968

Location	Time (PST)	Wind	Temp. (°C)	Spec. Hum. (g kg^{-1})	Tritium (TU)
Source Air					
Pt. 3	13.00	Variable	24.7	7.0	145 ± 4
Pt. 4	14.00	Mostly N.	26.0	7.2	165 ± 3
Pt. 5	16.00	W, 2–7 m sec^{-1}	24.5	7.2	166 ± 5
Pt. 1	08.30[1]	SW 1–3 m sec^{-1}	21.5	6.4	155 ± 3
Modified Air					
Pt. 2	09.30	SW 1–2 m sec^{-1}	20.0	10.4	68 ± 3
Lake Water					
Pt. 6	10.00				28.9 ± 1.1
Pt. 6	10.00				29.5 ± 1.1
Pt. 5	16.00		16.7		28.6 ± 1.0

[1] Above inversion.

member 0.36. The tritium figures carry one standard deviation, which corresponds to ± 0.03 in the left member.

If we instead consider q_w unknown and solve Eq. 3, we obtain $q_w = 13.3 \pm 1.0$ g m^{-3} corresponding to a lake surface temperature of 15.6 ± 1.0°C, which is very close to the measured beach water temperature of 16.7°C. Furthermore, the average lake temperature during the night should be slightly lower than the afternoon beach temperature. The agreement is thus good, and supports the approach that (1) and (2) truly represent the relation between the molecular transfer rates of H_2O and HTO at the lake/air interface. It also illustrates that molecular exchange at the air/sea interface is of great importance in the removal of HTO from the atmosphere to the sea on the open ocean [cf. Eriksson (1965)]. Note that the surface air lost almost half of its tritium content during the night.

Acknowledgement

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