

The Infiltration of Fog Water on Talinay Mountain

Neil Ingraham, Program Director, Hydrologic Sciences Program, Directorate for Geosciences, Earth Science Division, National Science Foundation 4201 Wilson Blvd., Arlington, VA, 22230, USA and Pilar Cereceda Instituto de Geografia, Pontificia Universidad Catolica de Chile, Casilla 114-D, Santiago, Chile

Abstract: Fog, tree water, and spring water was sampled for stable isotopic analysis during two sampling periods in late 1997 and 1998 on Talinay Mountain in Chile. In addition, rain water was collected between December 1998 and December 2000 in integrating collectors. The fog water is isotopically more enriched than the rain water, while the spring waters show two distinct populations. Most trees displayed noticeable lateral variation in stable isotopic composition however; the variation was dampened in the second sampling.

1. INTRODUCTION

The semi-arid, coastal region of Coquimbo, some 350 km north of Santiago, Chile, has virtually no surface water and receives from 100 to 200 mm of rain a year. Vegetation is sparse and consisting of only scattered bushes, and annual grasses. However, at about 5 km from the coast is the relict forest on Talinay Mountain. The mountain has an elevation of 762 masl, and forested above about 600 to 620 meters. The total forest is only about 70 ha and consists of species typical of environments where precipitation is more than 1000 mm per year. The nourishment of these forests may be in the form of fog-drip from the continuous coastal advective fogs.

To understand the effects of fog on the hydrology of the mountain, water from 5 perennial springs, as well as fog and rain was sampled. In addition, a total of 9 trees were sampled during two collection periods, seven during the first collection period in November 1997, and in December 1998, five of the original trees were re-cored and two other trees as well. All of the sampled trees were Olivillo trees (*Aextoxicon punctatum*) except at one location where a Canelo tree (*Drimys winteri*) was sampled, as an appropriate Olivillo tree was not found. Sampling was performed by coring the tree in the manner as described by Ingraham and Matthews [1995] with a standard increment borer. Water was quantitatively extracted from the wood core segments by distillation using toluene as a carrier [Ingraham and Shadel, 1992]

in a still that could accommodate both the wood core and bottle in the boiling chamber assuring that all of the free tree water was collected [Ingraham et al., 1993].

2. RESULTS

The stable isotopic compositions of the fog samples are the most enriched while the spring samples fall in two populations. The rain collected after the second sampling plot between the two populations of spring samples. Unfortunately, some of the hydrogen isotope ratios of the tree cores collected in December 1998 were not credible; thus, the interpretations relating to the tree core water were based on the oxygen isotopic ratios. The stable isotopic results of the fog, rain and spring water samples as well as the water from the complete tree cores (where available) are shown in Figure 1.

3. DISCUSSION

The spring water consistently falls into one of two distinct populations. Most of the springs have compositions of a depleted nature while one spring issues water that consistently has compositions indicating that it is predominately fog water. This spring that issues fog water is located at a considerably higher elevation (570m) than most of the other springs. It is also located near the top of a forested knoll and issues from soil with no apparent lithologic or structural

control. All other springs are lower in elevation, some are at the base of the mountain, and all appear to have a structural control. The observation that there are two populations of springs in terms of water types [probably fog and rain, see Ingraham and Matthews, 1990] requires an explanation that relates to different modes of application, infiltration and deep percolation of water. Fog and rain have different modes of deposition, rain being applied in large doses during short, discrete time frames, whereas fog water is continuously applied in small amounts on nearly a daily basis.

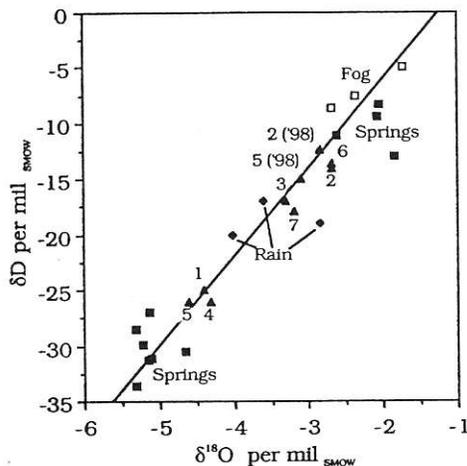


Figure 1. The stable isotopic composition of the rain, spring and fog water samples, as well as the water from the complete tree cores collected in 1997 and the two available cores from 1998 (Trees #2 and 5). The meteoric water line of $\delta D = 8\delta^{18}O + 10$ (MWL, Craig, 1961) is also shown.

3.1 Tree Water

The stable isotopic compositions of the tree water as shown in Figure 1 are the weighted average of the compositions of the segments (when the compositions of an entire core is available). However, the compositions of the individual segments show a large lateral variation within most trees from both collection years as shown in Figure 2. In addition, the lateral variations in each particular tree differ markedly between the two sampling years. The enriched nature of the tree segments collected in 1998 could be due to the enriched nature of the rain as observed subsequent to collection. However, the near complete lack of rain during this period prior to collection suggests that the compositions observed in the trees more likely indicate significant fog water use.

The (unfortunately incomplete, yet useful) data shown in Figure 1 indicate that there are two populations in terms of amount of rain and fog water used. Trees #1, #4, and #5 appear to use considerably more rain than the other trees. However, by close inspection of Figure 2, either the rain water use is not laterally consistent (as with tree #1), or only used after considerable rain as in December 1997 (as with trees #4 and 5).

Tree #7 was sampled near (within 5 - 10 m) the spring issuing water of fog origin, and clearly uses water of a similar isotopic composition. Two other trees (#8 and 9) were also sampled near (also within 5 - 10 m) a structurally controlled spring issuing predominantly what is thought to be rain water. However, both of these trees, as sampled in 1998, also predominantly use fog-derived water as apparently even a close proximity to structurally controlled rain water discharge does not insure a source of water, indeed this spring was observed to be nearly completely dry in late 2000.

All of the trees that displayed a significant content of rain water in 1997 contained significantly less in 1998. Even the large trees respond rapidly to the change in water type by exhibiting a near complete flushing out of the older water. The observations of significant use of fog water, the rapid response of the trees to change in water type emphasizes the importance of fog water to the trees on Talinay.

4. CONCLUSIONS

Fog, tree water, and spring water was sampled during two periods in late 1997 and 1998, whereas rain water was collected between December 1998 and 2000 on Talinay Mountain in Chile. As expected, the fog water is isotopically more enriched than the rain water, while the spring waters show two distinct populations depending whether their source is fog or rain water. The springs discharging rain water are at lower elevations and are structurally controlled. Most trees displayed noticeable lateral variation in stable isotopic composition ranging from using considerable rain to predominantly fog. However; the isotopic variation was dampened in the second sampling when all of the trees appeared to use considerably more fog water. Trees were observed to use fog water even when growing within 5 to 10m of a spring issuing rain water. These observations indicate that the vegetation depends on fog water for nourishment and may not survive without a source of fog water.

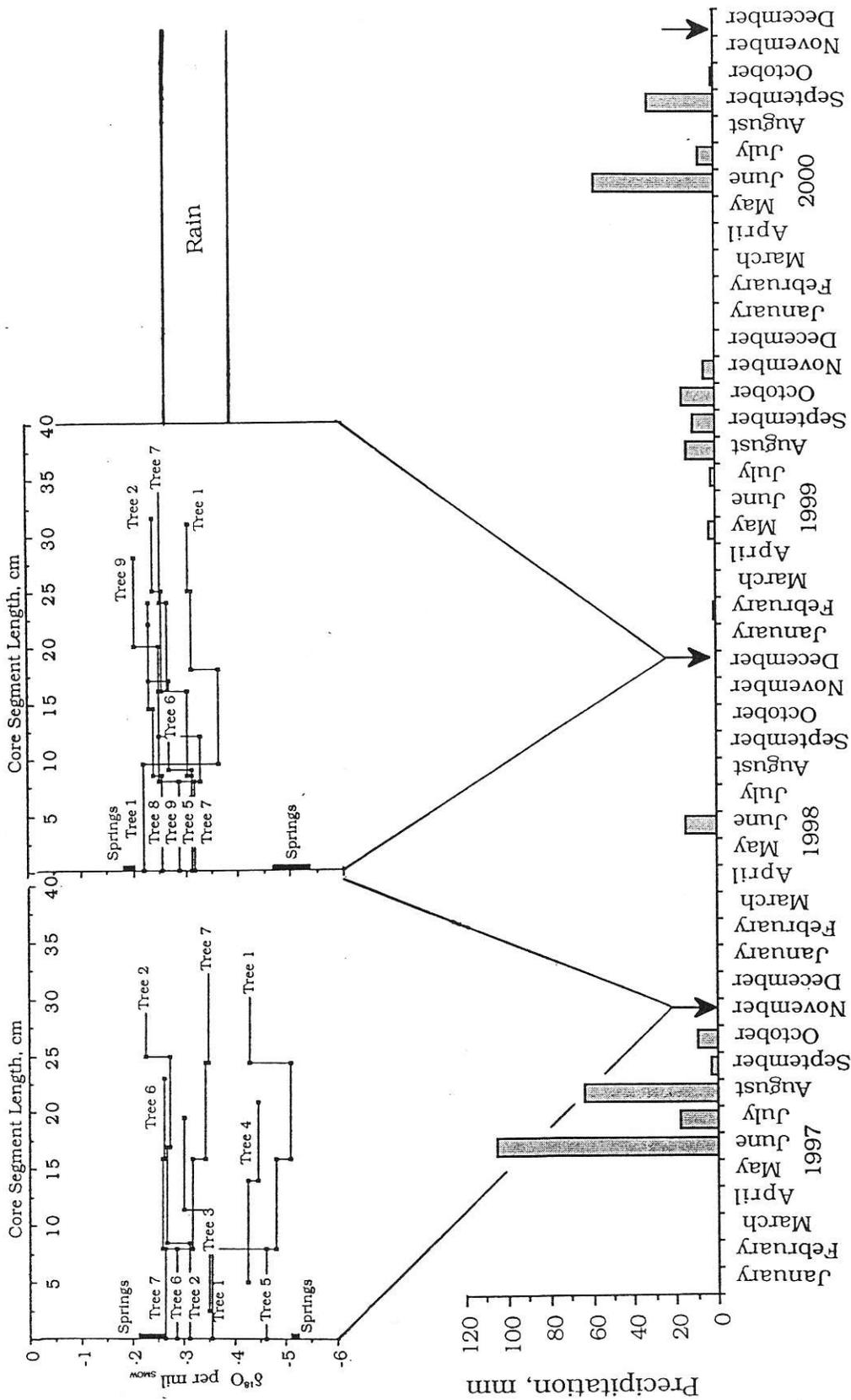


Figure 2. The oxygen isotope composition of all of the tree core segments collected in 1997 and 1998 are shown on the same scale as well as the oxygen isotope compositions of the fog, springs and rain. The dates of collection are identified on the lower scale by arrows along with the recorded amounts of precipitation for the four years at La Serena, 120 km north of Talinay. For reference, the 30-year average (1950 to 1980) for La Serena is 118 mm. The stable isotopic composition of the collected rain is between those of the two populations of springs and considerably more enriched than the rain reported by Aravena et al. [1989; -40 in δD , and -5.6 in $\delta^{18}O$] farther north. The tree core segments show large lateral variation within individual trees, particularly in those collected in 1997. However, the general shape of the lateral variations commonly remains only within a much smaller range in isotopic compositions. The tree segments collected in 1998 show less variation and must be more enriched due to the use of more fog water rather than the use of rain of an enriched composition, as the rain records show that there was simply very little rain prior to sampling to nourish the trees.

5. acknowledgements

We wish to thank Sr. Waldo Canto Vera the Regional Director of the Corporacion Nacional Forestal (CONAF) and Sr. Marcos Cordero for allowing access to the Parque Nacional Fray Jorge. Funding was supplied by Project Fondecyt 1971248 - Comisión Nacional de Investigación en Ciencia y Tecnología (CONICYT)

6. REFERENCES

Aravena, R. O. Suzuki, and A. Pollastri, 1989: Coastal fog and its relation to the groundwater in the IV region of Northern Chile. *Chemical Geology* (Isotope Geoscience Section), Vol. 79, 83-91.

Craig, H., 1961: Isotope variations in meteoric waters. *Science*, Vol. 133, 1702-1703.

Ingraham, N. L. and R. A. Matthews, 1990: A stable isotopic study of fog: the Point Reyes Peninsula, California. *Chemical Geology* (Isotope Geoscience Section), Vol. 80, 281-290.

Ingraham, N. L. and C. Shadel, 1992: A comparison of the toluene distillation and vacuum/heat methods for extracting soil water for stable isotopic analysis. *Journal of Hydrology*, Vol. 140, 371-387.

Ingraham, N. L., R. A. Matthews, and N. Casas, 1993: A Stable Isotopic Study of the Effect of Fog-Drip Water on the Point Reyes National Seashore, California. IN Proceedings of the Fourth Biennial Conference on Research in California's National Parks (S. D. Veirs Jr., T. J. Stohlgren, and C. Schonewald-Cox, edits). Transactions and Proceedings #9, pp. 36-46.

Ingraham, N. L. and R. A. Matthews, 1995: The Importance of Fog-Drip Water to Vegetation: Point Reyes Peninsula, California. *Journal of Hydrology*, Vol. 164, 269-285.