17A.5 WATER RECYCLING AND WATER VAPOR TRANSPORT IN THE VICINITY OF TROPICAL CYCLONES FROM STABLE ISOTOPE RATIOS

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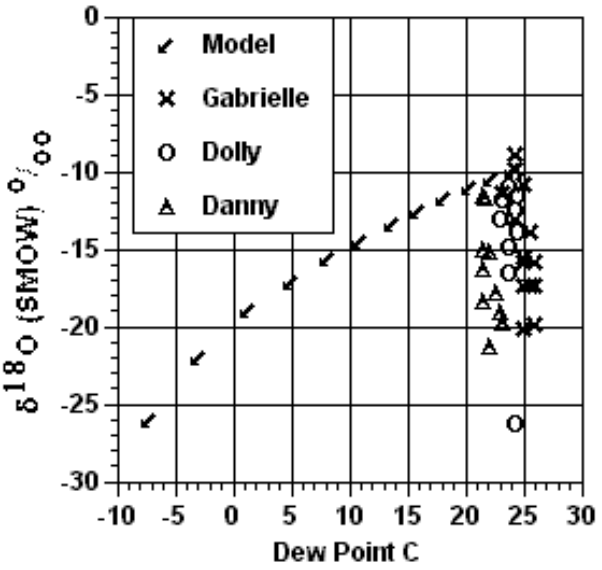
1. INTRODUCTION

The stable isotopic composition of water vapor evaporated from the sea surface is controlled by relative humidity and sea surface temperature. At isotopic equilibrium the isotope ratio ($H_2{}^{18}O$/ $H_2{}^{16}O$) is about 1% lower in the water vapor phase relative to the liquid phase. Over the tropical oceans this results in oxygen isotope values ranging from –9 to –12 per mil relative to ocean water. As air parcels rise in the atmosphere and rain is produced as a result of moist adiabatic accent the oxygen isotope value of the remaining water vapor decreases as the dew point drops as shown in Figure 1.

Figure 1



This isotopic decrease is commonly known as “Raleigh Distillation” and is used to describe the isotopic variation of water vapor and precipitation in the atmosphere. The initial oxygen isotopic composition of vapor is about –10 per mil whereas that of the precipitation is close to that of seawater (0 per mil). As condensation progresses the isotope values of the remaining water vapor (see Figure 1) and the precipitation (not shown) decrease.

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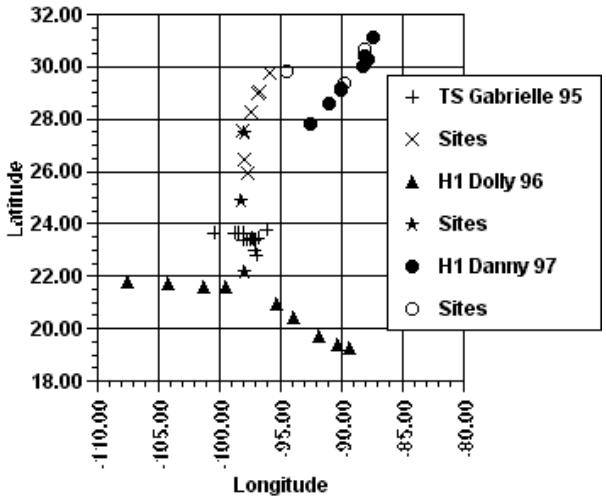
Water vapors in the vicinity of tropical cyclones have oxygen isotope values that range from –9 to –26 per mil. The lower isotope values in this range represent air parcels that were exposed to rainfall. Tropical cyclones have high condensation efficiency that results in low isotope values for rain. Isotopic exchange between inflowing vapor and falling rain lowers isotope values. The isotopic values of vapor from three tropical cyclones are shown in Figure 1.

2. DESCRIPTION OF THE TROPICAL CYCLONES

Five tropical cyclones were studied. They include Tropical Storm Gabrielle (1995), Hurricane Dolly (1996), Hurricane Danny (1997), Hurricane Luis (1995) and Hurricane Bonnie (1998). Gabrielle formed as a tropical depression on August 9, 1995 in the Gulf of Mexico off the coast of Mexico, strengthened to a tropical storm and moved very slowly westward into the coast of Mexico where it dissipated on August 12. Dolly formed on August 19, 1996 in the northwest Caribbean Sea as a tropical depression, strengthened to a hurricane, weakened as it moved across the Yucatan Peninsula and strengthened again into a hurricane before making landfall south of Tampico, Mexico. Danny formed in the northwest Gulf of Mexico on July 16, 1997 strengthening into a hurricane in about 24 hours as it moved across the Mississippi Delta to Mobile Bay where it hesitated in the vicinity for two days finally dissipating to a tropical storm and moving inland. The tracks of these three storms and the sampling locations where water vapors were collected are shown in Figure 2.

Figure 2



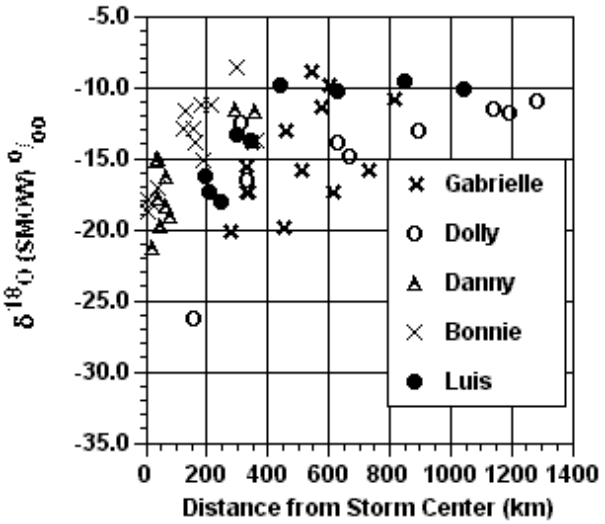
Luis formed on August 28, 1995 as a wave off the coast of Africa and quickly intensified from tropical storm to category-4 hurricane in the course of 2 days. It tracked eastward into the northern most islands of the lesser Antilles. Samples were collected from September 4 to 7 from two locations in close proximity on the northeast coast of Puerto Rico as Luis passed to the northeast as a category-3 hurricane. Bonnie formed on August 19, 1998 east of the lesser Antilles and moved northwestward to the North Carolina coast increasing steadily in strength to a category-3 storm. Water vapor samples were collected in New Bern, North Carolina where the storm passed directly overhead on August 27.

The storms exhibited considerable differences in size, strength, and organization. Gabrielle was a moderated sized, weak and poorly organized tropical storm. Dolly was a large category-1 hurricane that varied in its degree of organization. Danny was very small category-1 storm with good symmetry. Both Luis and Bonnie were large category-3 storms with beautiful symmetry and a high degree of organization.

3. WATER RECYCLING AND WATER VAPOR TRANSPORT

Water vapor in an air parcel entering a tropical cyclone assuming it has evaporated from the sea surface and has not been exposed to rainfall should have a relatively high isotope value. As this air passes through rain-bands evaporation of rain and isotopic exchange between rain and vapor lower isotope values because rain has a lower isotope value than seawater. These effects lead to a lowering of isotope values of water vapors inwardly as can be seen for all five tropical cyclones (Figure 3).

Figure 3



However, the decrease in isotope values per kilometer for each storm reflects the size, strength and degree of organization of each storm. Danny had low isotope values only very close to the storm center reflecting its small size. In contrast to this Gabrielle and to a lesser degree Dolly exhibited low isotope values at considerable distances from their centers. This probably indicates that water vapor was ejected from these two storms at low levels during their weakened and disorganized stages. Remember, all of the air samples had high water vapor pressures meaning the air could not have been derived from aloft where low isotope values prevail. For both Luis and Bonnie the high degree of organization reflected by beautiful symmetry prevented significant low level expulsion of water vapor as occurred in Gabrielle and Dolly fitting the idealized model of well organized tropical cyclones " in at the bottom and out at the top".