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The Atlantic Ocean Acidification Test-bed, La Parguera, PR

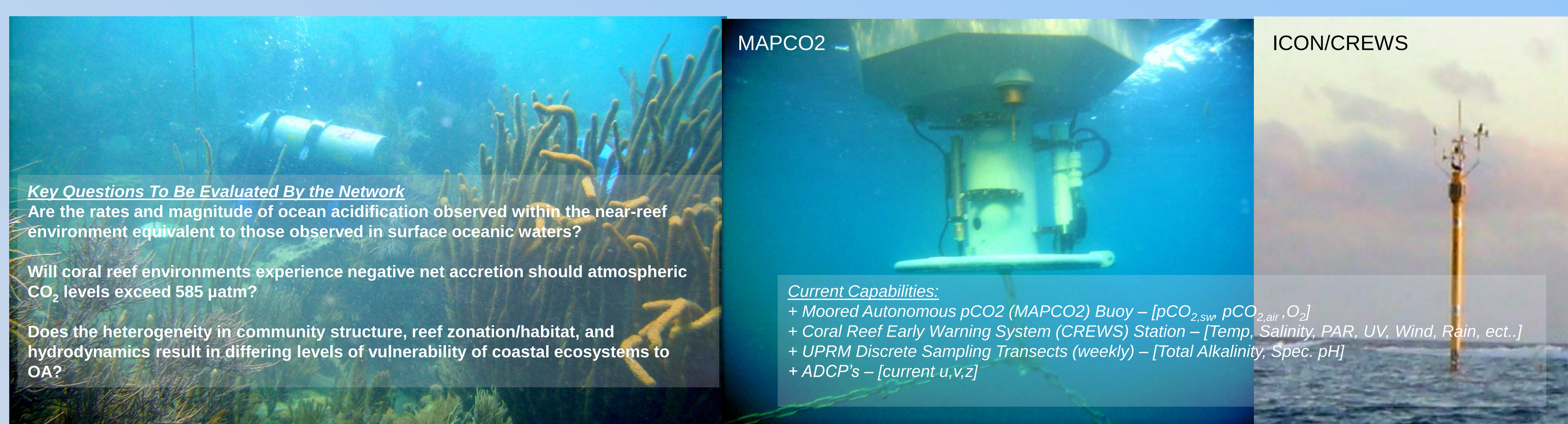
D.K. Gledhill[1,2], Chris Langdon[2], Jorge Corredor[3], Rik Wanninkhof[2], R. Jim Hendee[2], Wade R. McGillis[4].

[1]Rosenstiel School, University of Miami, 2600, Rickenbacker Causeway, Miami, FL 33149; [2]Atlantic Oceanographic and Meteorological Laboratory, National Oceanic and Atmospheric Administration, 4301 Rickenbacker Causeway, Miami, FL 33149; [3]University of Puerto Rico, Mayaguez Campus (UPRM) Magueyes Island La Parguera 908 Lajas 00667-0908 Puerto Rico; [4]Lamont-Doherty Earth Observatory, Geochemistry, Columbia Uni., NY.

INTRODUCTION

Changes in surface ocean chemistry in direct response to rising atmospheric carbon dioxide (CO_2) concentration may pose considerable challenges to a broad range of marine organisms in coming decades[1]. Monitoring this ocean acidification (OA) at regional and local-scales is an important requirement towards improving our understanding of the potential long-term consequences. Coral reef ecosystems are of particular concern given the potential effects OA may have on coral growth rates[2-4] and net community calcification[5].

A satellite-based OA model is now routinely mapping the monthly distribution of surface ocean carbonate chemistry throughout the Greater Caribbean Region (NOAA CRW OAPS v0.4) and reveals considerable spatial and seasonal variability[6]. However, while such models offer an important regional geochemical context, they are applicable only to oceanic settings where coastal processes do not exhibit a significant influence. How OA is manifested within the shallow coastal waters where coral reef ecosystems reside is currently poorly characterized. Community-scale metabolic processes can impart an important control on near-reef carbonate chemistry. Constraining the near-reef variability in carbonate chemistry across diel, seasonal, and annual scales is a critical requirement to evaluating the potential geochemical thresholds of OA. The Atlantic OA Test-bed in the La Parguera Marine Reserve, Puerto Rico seeks to evaluate methodologies and technologies that could be employed to best monitor OA and its impacts within coral reef ecosystems.

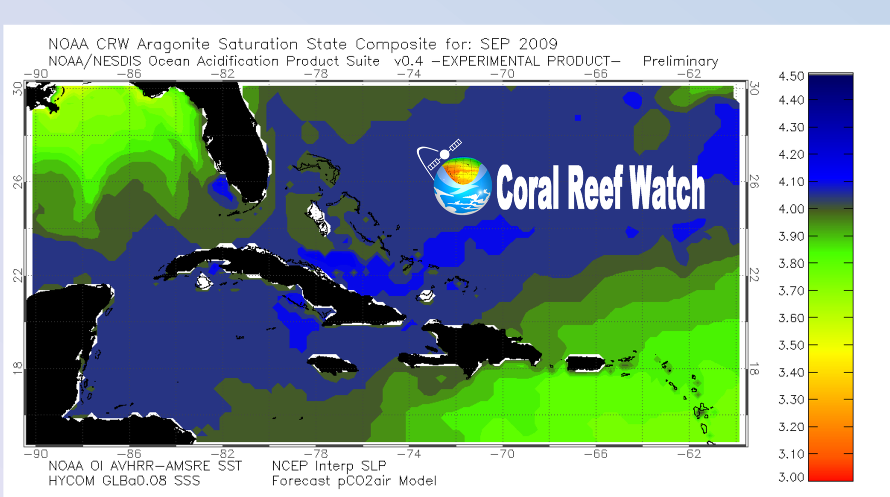


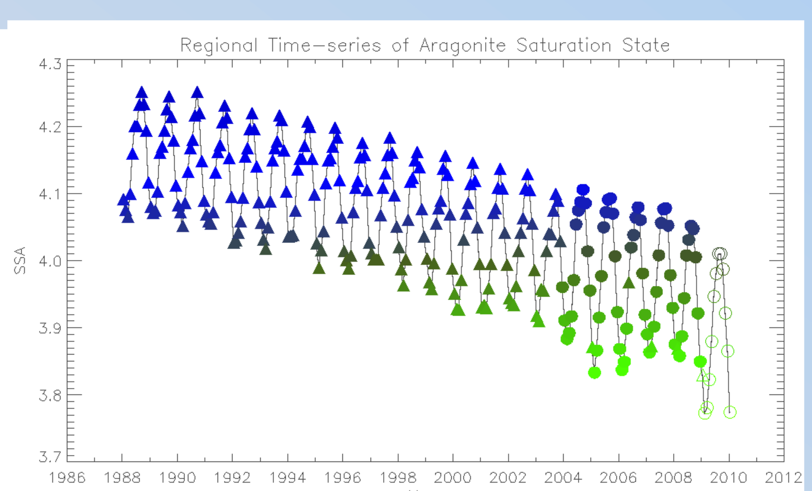
THE ATLANTIC OA TEST-BED

The NOAA Coral Reef Conservation Program has established an Atlantic OA Test-bed (AOAT) within the La Parguera Marine Reserve, Puerto Rico. The test-bed serves as an important prototype towards implementing a Coral Reef Ocean Acidification Monitoring Network. Since January 2009 the AOAT has provided sustained monitoring of near-reef air and sea pCO_2 and ancillary data coupled to weekly discrete geochemical transects across the Cayo Enrique forereef.

La Parguera Marine Reserve

The natural reserve at La Parguera has been identified as a high-priority monitoring site for which on-going habitat characterizations are being conducted by UPRM. Significant reductions of live coral cover have been observed to occur within the reserve over the past several years with a notable decline following the 2005 Caribbean Bleaching Event. The decline of total live coral cover at the community level appears largely driven by mortality of *Montastraea annularis* which has served as the principle reef-building species in Puerto Rico. According to surveys conducted as part of the CCMA-BB's Caribbean Coral Reef Ecosystem Monitoring Project between 2001 – 2006, turf algae accounts for the highest mean percent cover, followed by macroalgae, gorgonians, hard coral and sponges[7].





Ocean Acidification within the Greater Caribbean Region

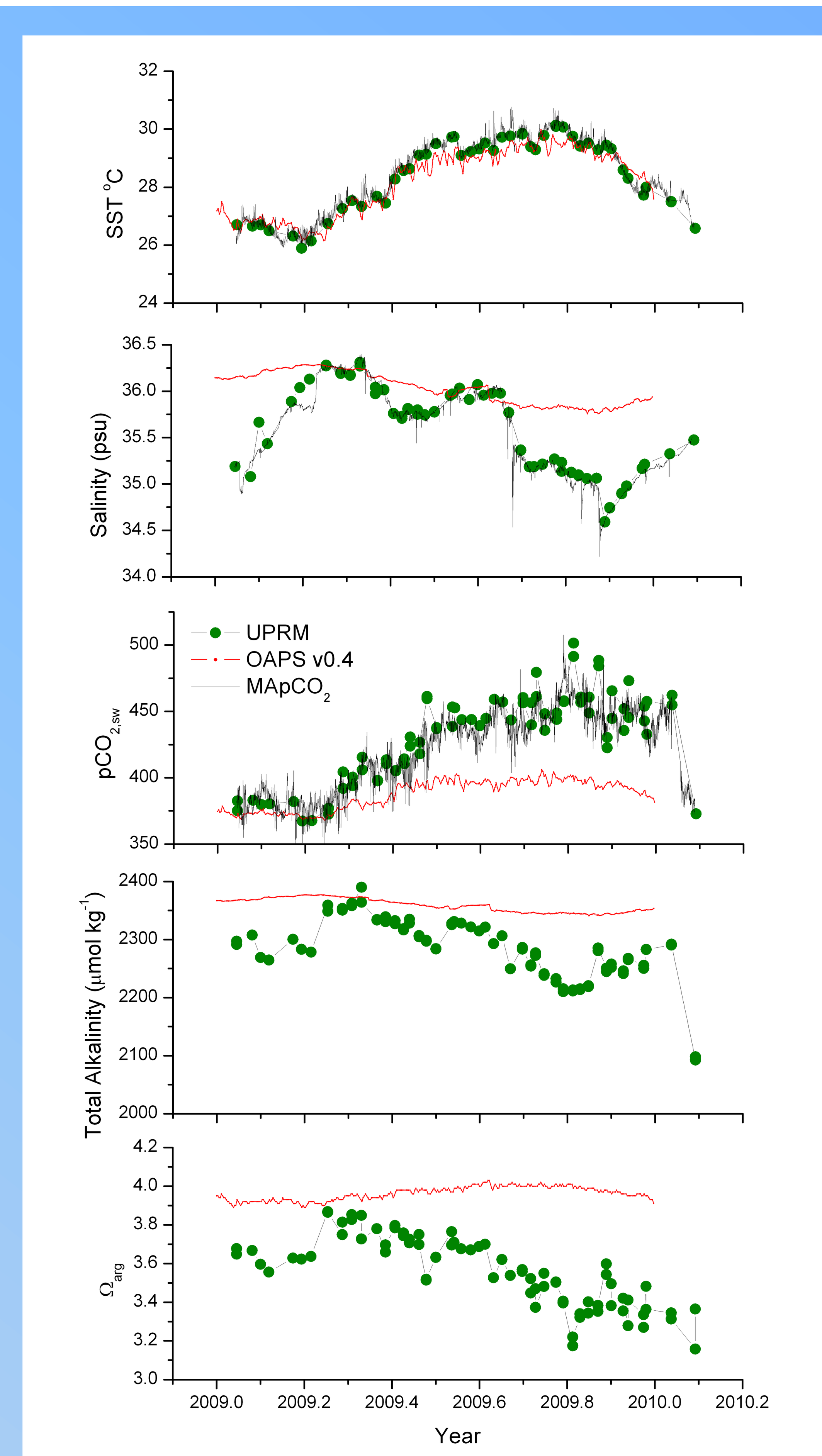
The warm tropical oceanic waters of the South Atlantic and Caribbean exhibit some of the highest carbonate mineral saturation states of global oceans and are expected to remain supersaturated with respect to most carbonate mineral phases for the foreseeable future. However, due to the experimentally demonstrated positive relationship between the degree of supersaturation and calcification rates[2], OA could pose a threat to NOAA living marine resources within the region. Carbonate ion concentrations have already declined in tropical oceanic waters by more than 20% over the industrial period[11] with corresponding changes in carbonate mineral saturation. This degree of saturation is currently decreasing across the SER at a rate of about 3% per decade and exhibits considerable spatial and seasonal variability[6].

Real Time MAPCO2 Data Available From www.pmel.noaa.gov/co2/coastal/LaParguera/data_La_Parguera_30d.htm

Coral Reef Early Warning System www.coral.noaa.gov/crews

OAPS v0.4 Available From www.coralreefwatch.noaa.gov/satellite/oa/

dwight.gledhill@noaa.gov



2009 CO2-SYSTEM TIME-SERIES

Autonomous Measurements

The primary objective of the moored autonomous OA network will be to provide near continuous monitoring of a suite of chemical, physical, hydrodynamic,and meteorological measurements necessary to provide for the monitoring of community scale metabolic performance (net calcification, photosynthesis, respiration). The current test-bed provides a precursor of such a system whereby a Moored Autonomous pCO_2 (MAPCO2) buoy provides continuous 3 hourly measurements of both air and sea mole fraction CO_2 from the prevailing down-current end of Cayo Enrique Reef. The data are transmitted daily along with temperature, salinity and pressure and reviewed for QC by NOAA PMEL and posted to the web. These data are than routinely merged with oceanographic and meteorological data available from the nearby NOAA ICON/CREWS station.

Geochemical Transects

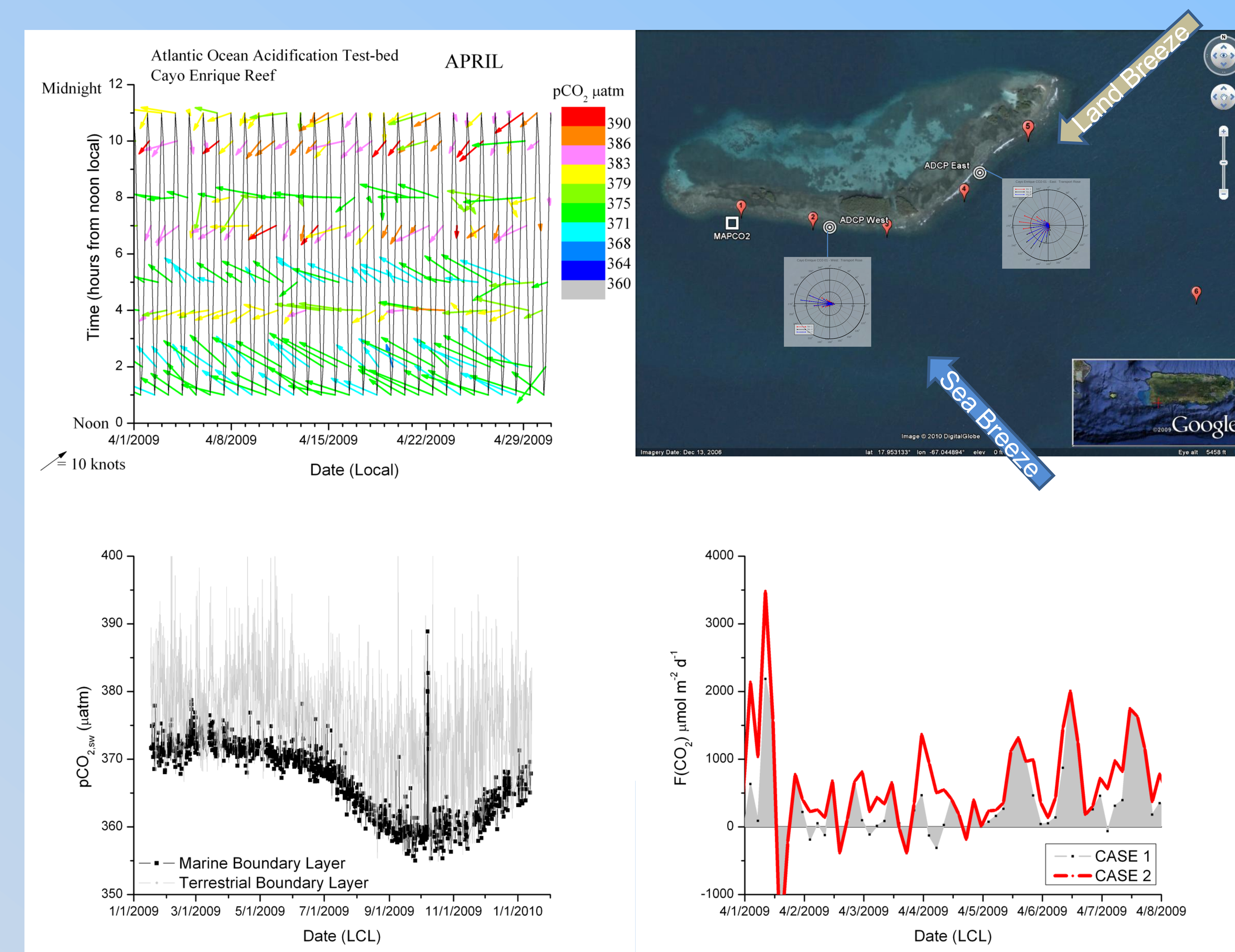
The autonomous observations are validated and supplemented on a weekly basis through a discrete sampling campaign conducted by UPRM. The campaign includes a CTD and water sample transect along the Cayo Enrique forereef, at the MAPCO2, and 0.5 km up-current from the forereef. Water samples are immediately processed at the nearby UPRM lab for total alkalinity (TA) and spectrophotometric pH.

$pCO_{2,sw}$

Discrete measurements of TA and pH obtained weekly by UPRM are coupled to solve for the carbonate acid system and aragonite saturation state using the CO2SYS program[8] applying the K1 ad K2 dissociation constants of Hansson and Mehrbach refit by Dickson and Millero, 1987 using total scale pH. The calculated $pCO_{2,sw}$ (green circles) are in excellent agreement with the autonomous results obtained from the MAPCO2 buoy (grey line). In both cases, $pCO_{2,sw}$ is observed to achieve values well in excess of 450 µatm throughout the summer and rapidly declines in January, 2010. These values are at least 50 µatm higher than that expected in the offshore Caribbean waters based on the OAPS v0.4 (red line). The 3 hourly $pCO_{2,sw}$ measurements obtained at the MAPCO2 reveal considerable diurnal variability which is frequently underappreciated with regards to the effects of OA on coral reefs.

Aragonite Saturation State (Ω_{arg})

Aragonite saturation state (Ω_{arg}) describes the degree to which seawater is supersaturated with respect to the carbonate mineral aragonite of which most coral skeletons and reef structure are composed. Abiotic precipitation is thermodynamically favored at $\Omega_{arg} > 1$ while dissolution occurs at $\Omega_{arg} < 1$. Surprisingly, many laboratory experiments have found a functional relationship between coral calcification rates and Ω_{arg}. Beginning in early April, Ω_{arg} values at Cayo Enrique begin a systematic decline from near 4 to below 3.2. Such a decline is not apparent in the offshore OAPS v0.4 model. While the discrepancy between the OAPS and the test-bed is partly a reflection of coastal and reef processes, there is also reason to suspect based upon historical sampling at the offshore CaTS station (17° 36' N 67° 00'W; 17 miles from the shelf edge) that the HYCOM GLBa0.08 salinity fields used in producing the OAPS fail to capture the seasonal dynamics in the area and will need to be addressed as part of future OAPS development. At least part of the decline observed at the test-bed is related to the increasing $pCO_{2,sw}$ observed at the site along with declining TA and salinity throughout much of the year. The attribution of the declining salinity is believed related to South American river inflow and local rainy season runoff.



SOME KEY FINDINGS SO FAR…

As a result of reef community metabolism, Cayo Enrique (like most other reefs[9]) serves as a net source of CO_2 to the atmosphere (ΔpCO_2 = 47 34 µatm) albeit with a distinctive diel cycle where $pCO_{2,sw}$ increases at night and subsequently declines throughout the day. This air-sea gradient works to drive off CO_2 from the water column according to $F_{CO_2} = ks\Delta pCO_2$ where k is the gas transfer velocity derived from the nearby ICON/CREWS wind measurements and s is temp. & salinity dependent gas solubility[10]. However, within the coastal zone, this gradient can be strongly influenced by considerable variability in $pCO_{2,air}$. A key phenomenon not previously considered in the context of OA is the potential local effect that the terrestrial boundary layer $pCO_{2,air}$ may have on the ability of a reef to off-gas CO_2 built up through metabolic activity. At Cayo Enrique a daily oscillation between the marine and terrestrial $pCO_{2,air}$ boundary layer occurs. During periods when sea breeze conditions dominate (typically around noon time), the $pCO_{2,air}$ is distinctly lower while at night when wind conditions become light and variable the terrestrial boundary layer prevails and elevates the local $pCO_{2,air}$. This terrestrial boundary layer will have a tendency to inhibit CO_2 flux from the water column (CASE 1) relative to what would occur in its absence (CASE 2). Whether such a phenomenon imparts a significant effect to local water chemistry is part of the on-going investigation at the AOAT.

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