Thermal Infrared Surveys and Nutrients Reveal Substantial Submarine Groundwater Discharge Systems Emanating from the Kona Coast of Hawaii

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Introduction:
Local accounts of cold water spots and previous qualitative infrared (IR) imagery have indicated several locations where groundwater is discharging from coastal embayments of the west coast of Hawaii. We conducted high resolution aerial IR surveys, using a spectrometer having 0.1°C sensitivity, to map surface water temperatures and identify spatial extents of numerous submarine groundwater plumes emanating from coastlines surrounding Kalokelani and Honokohau-Kahauloa areas. We combined our IR imagery with ground-based measurements of nutrients, salinity, and Ra and Ru isotopes to assess the submarine groundwater discharge (SGD) in the area.

1. Study Areas: Kalokelani Bay and embayments in Kaloko-Honokohau National Historical Park area were our first study sites. These occur on the arid, desert-like western coast of the Big Island where fluvial inputs are virtually nonexistent. Submarine groundwater exiting at the coastal zone thus controls practically all freshwater delivery to this wide region.

2. Previous Studies: Past aerial infrared images taken in 1992 (Georgy Wilkins) along west coast of Hawaii using handheld camera. Although resolution is poor, the images show plumes of cool freshwater (white) emanating out across the surface of relatively warmer marine (dark) waters.

3. Methods: Our aerial surveys are conducted using the University of Hawaii’s Airborne Hyperspectral Imager (AHI) Infrared system. The AHI sensor collects 256-pixel wide swath images containing long-wave infrared (LWIR) data, so multiple overlapping flights are required to survey each area. Each pass is flown unidirectionally so that the plane’s orientation remains consistent from pass to pass. The sensor is internally calibrated to a blackbody before and after every individual pass of data acquisition. Post-processing LWIR data involves averaging over the spectral range of 8-12 microns and converting to temperature. Each flight swath is geo-rectified based on the plane’s altitude, speed, pitch, yaw, and roll. Further ground-truthing by correlating specific pixels in the IR images to their corresponding pixels on base maps is also required. Individual flight swaths are combined to produce a near complete IR image of each area. Results are cross-checked with high accuracy against multiple simultaneous ground-based observations.

Salinity, temperature, nitrogen, phosphorus and silica concentrations were simultaneously determined from surface waters, upwelling blackwater, and tidal ponds. These are coupled with Ra-223 and Ra isotopes as tracers of groundwater inputs and importantly, flux.

4. Results: Submarine groundwater discharge is clearly delineated by aerial LWIR imagery. Color-enhanced infrared images show plumes of fresh water (dark blue color ~22.5 - 24.5°C) emanating out across the surface of marine waters (red color ~25 - 27°C). Due to substantial freshwater inputs, much of the surface water funneling out Honokohau Harbor is less than 22°C (black). Kaloko (north) and Aimakapa (south) Ponds in Kaloko National Park also show substantial groundwater buildup and leakage to the ocean.

5. Conclusions: Aerial infrared imaging is a novel method for collecting precise, high-resolution surface temperature data and quantitatively identifying freshwater plumes over extensive areas. As demonstrated here, combining this with ground-based determinations of nutrients (and other effluents), salinity, temperature and Ra and Ru tracers produces a new integrated multi-faceted approach to quantitative assessment of the effects of SUBMARINE GROUNDWATER DISCHARGE.