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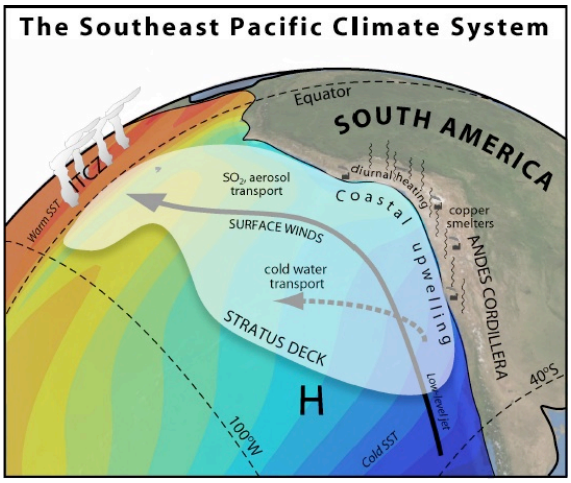
From VOCALS to action: studying the mysteries of clouds and the ocean in the Southeast Pacific 19.06.2007

The Southeast Pacific, the marine area off the South American west coast, bears signatures of a tightly coupled system involving poorly understood interactions between clouds, aerosols, upper ocean dynamics and thermodynamics, coastal currents and surfacing of deep water, and regional circulations influenced by the Andes Mountains. This climate system has proven difficult to simulate by state-of-the-art Coupled Atmosphere-Ocean General Circulation Models (CGCMs) used for climate change projections and El Niño forecasting. The system variability has impacts on the global climate (rainfall and temperature patterns in far-distant parts of the world are influenced by the ocean-atmosphere coupling in the tropical Southeast Pacific). There are also severe impacts on the regional economy (regional fisheries account for one-fifth of the worldwide marine fish catch).



The great height and extent of the Andes Mountains are sharp barriers to the circulation in the lower atmosphere, resulting in strong winds parallel to the coasts of Chile and Peru. These winds push the warmer surface waters off the coast to the open ocean, bringing cold, deep, nutrient-rich waters to the ocean surface (a process known as coastal upwelling) that feed one of the most productive marine ecosystems in the world.

The extensive cold ocean surface temperatures, in combination with warm and dry air aloft helped by orographic effects of the Andes, support the largest and most persistent subtropical sheet of stratus and stratocumulus clouds in the world. The massive sheet of stratocumuli at an altitude of below 2,400 m (8,000 ft) covers the sky nearly all year round.

In the Southeast Pacific, CGCMs show systematic errors in the form that the ocean surface waters are represented too warm and the marine stratocumulus clouds too thin. The cloud deck greatly restricts the amount of solar energy reaching the ocean beneath and, by doing so, has a large impact upon the Earth's radiation budget. The cloud layer helps maintain the cool ocean surface temperatures resulting in tight couplings between the upper ocean and the atmosphere. VOCALS posits that oceanic eddies shed from the region of coastal upwelling also contribute to maintaing a cool ocean surface, in a process that is poorly captured by ocean models. These errors challenge the CGCMs ability to predict climate change and forecast El Niño.

The formation and persistence of the stratocumulus sheet are influenced by atmospheric aerosols from both natural and anthropogenic sources. Along the Peruvian and Chilean coast an array of copper smelters directly inject sulfur emissions into the atmosphere from their locations at various altitudes from close to sea level to nearly 3000 m on the Andean slopes. The combined sulfur emissions are comparable to the entire sulfur emissions from large industrialized nations such as Mexico and Germany. High cloud droplet concentrations (leading to the formation of clouds) close to the coast provide potential evidence of anthropogenic

influence. Further offshore, extremely low cloud droplet concentrations are found in the clean southern hemisphere.

Generally, stratocumuli bring either no precipitation or only drizzle (light rain). But with low concentrations of atmospheric aerosols in the area far off the coast the physics and chemistry of the persistent cloud deck is likely to be different from more polluted regions that have been the focus of many previous field campaigns. In fact, there is evidence that enhanced drizzle formation with lower aerosol concentrations can drastically reduce the coverage of the stratocumulus cloud deck. The presence of this low cloud sheet and the (yet almost unknown) dynamical and microphysical processes controlling its thickness and coverage are cornerstones of the climate in the Southeast Pacific and have strong implications for the global climate system.

Despite its great importance to the Earth's climate system, the ocean-cloud-atmosphere-land system in the Southeast Pacific has yet been sparsely observed and fundamental processes are not well understood. To close the gaps in our understanding of coupling processes and to achieve great advances in global climate modelling, the VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS) is being developed by the World Climate Research Programme (WCRP) and partners. The WCRP projects on Global Energy and Water Cycle (GEWEX) and on Climate Variability and Predictability (CLIVAR) and the (co-sponsored) Surface Ocean-Lower Atmosphere Study (SOLAS) strongly co-operate in VOCALS. In fact, the CLIVAR Variability of the American Monsoon Systems (VAMOS) programme takes the lead of VOCALS, but scientific and technical expertise are also provided by the GEWEX Cloud System Study (GCSS) group and SOLAS.

Main research foci for VOCALS are (1) to improve regional and global climate models; (2) to study aerosol effects on cloud (and drizzle) formation; and (3) to improve the accuracy of weather predictions in coastal areas dominated by such low and persistent cloud covers.

VOCALS is organized around two major components: a Regional Experiment (VOCALS-REx) with extended observations of one month duration (October to November 2008) including aircraft-, ship- and land-based operations, ocean buoy measurements, and satellite observations, and a Modelling Programme (VOCALS-Mod) for numerical modelling from process models to global models.

VOCALS-REx will focus upon understanding the processes that control precipitation, including the role of atmospheric aerosols, their transport from the land to the ocean, and their depletion by the clouds themselves, in other words: the aerosol-cloud-drizzle interaction will be investigated. Further, an unparalleled combination of in-situ and remotely sensed cloud measurements will be used to tackle outstanding satellite remote sensing problems and shed light into coupling processes between ocean, atmosphere and land. VOCALS-Mod will help to improve model simulations of key climate processes using the Southeast Pacific as a challenging test-bed, particularly in coupled models.

VOCALS has plans for collaborative training between US/UK and Chilean/Peruvian early-career oceanographers and students as part of the programme's capacity building remit. This includes hand-on use of new technologies (such as coastal radars, gliders etc) in advance of the field campaign and later during the VOCALS experiments as well as the processing and analysis of data and the preparations of joint publications. Further, bilingual web-based outreach activities in Spanish and English are being planned.

The budget for the VOCALS project is estimated to be 16-18 Million US$. However, funding options are still being sought. VOCALS is sponsored by NOAA and its Climate Prediction Programme for the Americas (CPPA), the US National Science Foundation (NSF) and the US National Center for Atmospheric Research (NCAR). Other contributors are the US Department of Energy (DOE) and Office of Naval Research (ONR). VOCALS is an important activity for the World Climate Research Programme that has been fostered by CLIVAR/VAMOS and GEWEX as well as SOLAS. VOCALS is an interdisciplinary, multi-agency project bringing together atmospheric and coupled modellers, weather forecast and climate scientists, aerosol and

aerosol-cloud interaction specialists as well as cloud physicists from various agencies in the US, UK, Chile and Peru. [*ca*]

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Links and Reference

VOCALS website http://www.eol.ucar.edu/projects/vocals/

VAMOS website http://www.clivar.org/organization/vamos/vamos.php

VOCALS-REx Experimental Design Overview (2006)
http://www.eol.ucar.edu/projects/vocals/documentation/vocals_overview.pdf

VOCALS Science Plan (2006)
http://www.eol.ucar.edu/projects/vocals/science_planning/VOCALS_SPO_rev_aug06.pdf

VOCALS Programme Summary (2007)
http://www.eol.ucar.edu/projects/vocals/documentation/vocals_overview.pdf

Wood, R., C. R. Mechoso, C. Bretherton, B. Huebert, and R. Weller (2007) The VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS) U.S. CLIVAR Variations Vol. 5, No. 1: 1-5.
http://www.usclivar.org/Newsletter/VariationsV5N1.pdf.