Project Description

Part I. Overview of the EPIC 2001 SE Pacific Stratocumulus Field Study

This 'bundle summary' is an overview of the EPIC 2001 Southeast Pacific Stratocumulus Field Study (EPIC2001Sc), which comprises the stratocumulus component of the EPIC2001 field experiment, and is a part of the project description of all proposals submitted as part of this bundle. This study is based on exploratory shipborne in-situ and remote sensing measurements during a three week cruise of the *Ron Brown* through the SE Pacific stratocumulus region in September 2001. Subtropical stratocumulus clouds have a strong cooling effect both on the ocean (due to reduced incident sunlight) and atmosphere (due to increased longwave cooling from the clouds). Furthermore, seasonal and interannual variations in SE Pacific stratocumulus cloud cover are poorly represented in current GCMs and are a key component for coupled modeling of ENSO (Mechoso et al. 1995). It is a central goal of EPIC to document, understand, and better model the structure of the SE Pacific stratocumulus and its effects on the underlying ocean.

A working hypothesis of EPIC2001 (Raymond et al. 1999) is that the physical processes that modulate the cloud and boundary layer structure, and hence air-sea fluxes, in this region are not very different from in other, better studied, subtropical stratocumulus regions such as the northeastern Pacific and Atlantic Oceans. Indeed, the COADS-derived climatology of this region during September appears analogous to the summertime NE Pacific, with a persistent subtropical high centered at (28°S, 92°W), cold advection to its east and north, subsidence (particularly strong near the coast) and little midlevel and high cloud. The relation between low-lying cloud cover, cloud type, 'lower tropospheric stability', and boundary layer structure (Klein and Hartmann 1993, Norris 1999, Albrecht et al. 1995) is similar to the NE Pacific, with nearly unbroken stratocumulus over the coldest SSTs near the Peruvian coast and more patchy stratocumulus overlying small cumulus clouds west of 95 W. As in the NE Pacific, shipboard reports (Petty 1995) suggest noticeable drizzle at the surface is rare near the coast, but showers are somewhat more common offshore.

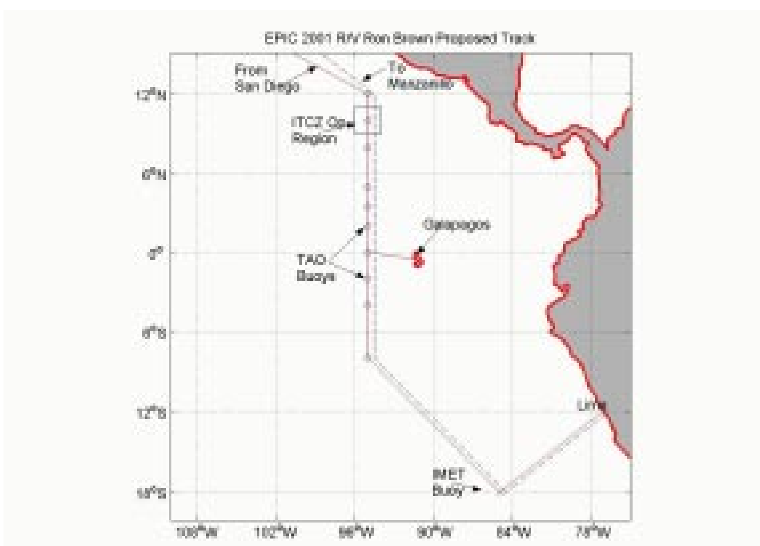
A key scientific and parameterization issue is whether the cloud cover and liquid water path in subtropical stratocumulus regimes is primarily regulated by turbulent entrainment drying at the PBL top, or whether depletion of cloud liquid water by precipitation processes is often also important. The latter is most likely if the above-PBL air is relatively moist, reducing the effectiveness of entrainment drying (Bretherton et al. 1995, Yuter and Houze 2000), or if cloud condensation nucleii (CCN) are relatively sparse (increasing the mean cloud droplet size and promoting precipitation from shallow or short-lived clouds (Albrecht 1989). Neither entrainment nor drizzle in subtropical stratocumulus is fully understood, so these issues have not been answered for any stratocumulus regime.

There are some differences in the above-PBL flow between the SE and NE Pacific that affect above-PBL moisture and aerosol structure, and may therefore affect the stratocumulus. These are due to the uniquely low latitude of the SE Pacific stratocumulus regime and the high topography to the east. During the EPIC2001Sc field operations period (September), there is typically easterly flow above the near-equatorial PBL. This often advects moist air processed by deep convection over (and off) Central and South America over the northern part of the SE Pacific stratus region, such that the above-PBL air may even be moister than the air within the PBL (Bond 1992, Paluch et al. 2000). Further south, above-PBL southerlies and westerlies bring in much drier air.

Similarly large variations in aerosol (CCN) concentrations within the PBL may be anticipated across the SE Pacific stratocumulus region. Biomass burning and other human activities may produce aerosol-rich layers within the near-equatorial easterly flow; this aerosol can then be entrained into the PBL. Further south, pristine marine air over the PBL may induce much lower CCN concentrations in the PBL.

Proposed Measurements

The core aim of EPIC2001Sc is to document the cloud and PBL structure and the surface heat along the cruise track, then to compare these with predictions of large-scale models. Another primary aim is to better understand possible relations between stratocumulus cloud cover and thickness, aerosol, and above-PBL thermodynamics. The region to be sampled typically has 60-80% low cloud cover and PBL depths between 0.5 and 2 km at this season, with somewhat less stratocumulus, more shallow cumulus cloud, and 10-20% lower cloud cover between 0-10 S during the warm phase of ENSO (in which current forecasts suggest EPIC2001 is likely to take place).



The cruise, shown above, will start on 2 Sept. 2001 in the Galapagos Islands, where the *Brown* will briefly stop after its EPIC2001 ITCZ measurement campaign to exchange scientific personnel.

The *Brown* will then steam west to 95°W, south, then southeast to an IMET buoy at 18°S, 85°W, steam into Lima, Peru for a three day port stop (13-15 Sept.), then return along the same track to the 95°W line, steaming across the equator on 22 Sept., arriving at Manzanillo, Mexico on 25 Sept. A formal request to NOAA for the *Ron Brown* ship time for both this and the ITCZ/ABL components of EPIC has been made by Dr. C. Fairall of NOAA/ETL.

Table 1: EPIC2001Sc proposals

P. I.	Institution	Measurement
Fairall et al.	NOAA/ETL	Vertically pointing 35 GHz Doppler radar Boundary layer wind profiler Water vapor and scanning Doppler lidars Laser Ceilometer Microwave radiometer Sensible, latent heat and momentum fluxes Broadband radiative fluxes Surface meteorology, SST
Bretherton/Yuter	U. Wash.	GPS sondes (8 per day) 5 cm scanning Doppler radar Cloud photography Synthesis, model intercomp.
Quinn	NOAA/PMEL	Aerosol size/type

Table 1 indicates the proposed measurements. The *Ron Brown* ship time, many of the major instruments and several key investigators are NOAA-funded, offering considerable leverage to the proposed NSF-sponsored activities. Incremental efforts and costs associated with EPIC2001Sc for NOAA investigators are included in this bundle per agreement between NSF and NOAA.The NOAA/ETL measurements (particularly the surface meteorology, turbulent and radiative fluxes, microwave radiometer, ceilometer, and the ‘cloud’ (35 GHz) radar), and the GPS sondes are required elements of the cruise, without which EPIC2001Sc cannot adequately carry out its central-mission of documenting the clouds, the PBL, and their impact on the underlying surface.

The 8-times daily soundings document the vertical atmospheric structure both in and above the PBL along the ship track, and provide a context for interpreting the cloud observations. The NOAA/ETL shipboard turbulent and radiative flux measurements document all terms of the surface heat budget. The 35 GHz (8 mm) vertically pointing radar, the microwave radiometer, and the profiler operate together as a powerful cloud and drizzle remote sensing system. The radar senses cloud top, drizzle (including fall velocity), and turbulent vertical velocity variance in the cloud layer (i. e. the vigor of the eddies that drive cloud-top entrainment). Cloud base can be difficult to detect even in very light drizzle with the radar, but isunambiguously identified by the ceilometer.

Microwave radiometer measurements of liquid water path are comparable with remote sensing retrievals. Under ideal circumstances, they can also be combined with the radar and ceilometer measurements to retrieve cloud liquid water content and cloud droplet concentration. The scanning Doppler lidar provides subcloud mean velocity and turbulence, while the water vapor lidar provides continuous water vapor profiling below the stratocumulus cloud base, which identify decoupling in the PBL with more better temporal resolution and higher accuracy than radiosondes The lidars may also be used to improve cloud microphysics retrievals (Feingold et al. 1998).

Continuous shipboard measurements of aerosol size distribution and composition, which determine the CCN spectrum, are another important type of documentation, and are central to the goal of understanding cloud microphysics and precipitation processes in the region. Trajectory analysis will be used to correlate aerosol variations with source regions.

The 5 cm Doppler radar is permanently mounted aboard the *Brown* (but requires skilled personnel to operate). It contributes a mesoscale perspective to the precipitation observations and senses the associated horizontal motions). Since both shallow cumulus showers and stratocumulus drizzle tend to be very patchy, this allows a more reliable areally-averaged characterization of the precipitation than provided by the vertically pointing radar. Cloud photography provides a visual context for interpreting the radar and cloud remote sensing data.

A crucial aspect of our overall scientific plan is that these datasets will be analyzed in relation to one another, and that the synthetic view will be compared with large-scale model predictions. This element is woven into all the proposals. In particular, Bretherton's proposal includes an integrative examination of the importance of precipitation processes to the cloud properties and a comparison of the observed PBL properties with reanalyses and the climatology of selected GCMs..

Table 2: Collaborating PIs

P. I.	Institution	Measurements
Albrecht	U. Miami	Satellite retrievals of droplet effective radius, albedo.
Bond	NOAA/PMEL	P-3 overflight
Weller	WHOI	IMET buoy (18 S, 85 W)

Collaborations

The proposed EPIC2001Sc observations will benefit from several collaborations shown in Table 2. Bruce Albrecht, under NOAA PACS funding, is working with Pat Minnis of NASA to provide several-times daily spatially gridded satellite retrievals of cloud fraction, cloud optical depth and albedo, and cloud droplet effective radius over the SE Pacific region from geostationary satellite imagery. These will be compared to the shipboard measurements. The retrievals of cloud droplet effective radius may be valuable to compare with cloud droplet concentrations inferred from shipboard remote sensing and aerosol measurements. Robert Weller maintains a NOAA-funded buoy at 18°S, 85°W which provides a long time series of surface turbulent and radiative fluxes; these can provide a useful comparison with the shipboard measurements as the *Brown* steams by. as part of the EPIC2001 cross-equatorial ITCZ inflow proposal bundle, Nick Bond is proposing many transects by a NOAA P-3 along 95°W down to about 2°S . If there are suitable clouds,one of these flights will overfly the *Brown* as it steams across the equator along 95°W, taking cloud microphysical measurements that can be compared with the shipboard remote sensing systems. At the north edge of the stratocumulus, we can also examine the representativeness of the *Brown* transects compared to Esbensen's proposed aerosonde flights down to 5 S along 95 W (cross-equatorial ITCZ inflow bundle) and surface winds from the TAO buoys along 95 W.

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