Cloud Variability in the Southeast Pacific Stratocumulus Regime from Ship and Buoy Observations—An Overview

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Christopher Fairall (NOAA/ESRL/ETL) and Robert Weller (WHOI)

<table>
<thead>
<tr>
<th></th>
<th>EPIC 2001</th>
<th>Stratus 2003</th>
<th>Stratus 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise Period (Dates)</td>
<td>Oct. 9-25</td>
<td>Nov. 11-24</td>
<td>Dec. 5-23</td>
</tr>
<tr>
<td>Cruise Period (Julian Days)</td>
<td>282-298</td>
<td>315-328</td>
<td>340-358</td>
</tr>
<tr>
<td>Buoy Period (Dates)</td>
<td>Oct. 16-22</td>
<td>Nov. 15-21</td>
<td>Dec. 11-16</td>
</tr>
<tr>
<td>Buoy Period (Julian Days)</td>
<td>289-295</td>
<td>319-325</td>
<td>346-351</td>
</tr>
<tr>
<td>Exact time of Arrival (at the Buoy)</td>
<td>(Oct.) 15.955</td>
<td>(Nov.) 15.781</td>
<td>(Dec.) 11.181</td>
</tr>
<tr>
<td>Exact time of Departure</td>
<td>(Oct.) 22.330</td>
<td>(Nov.) 21.375</td>
<td>(Dec.) 16.250</td>
</tr>
</tbody>
</table>

Crucial Domains for Intercomparisons between the three field experiments:

*Primary - WHOI Buoy Location (20°S, 85°W)*

*Secondary - Common Transect along 20°S*
Ship Instrumentation

<table>
<thead>
<tr>
<th>Remote Sensor</th>
<th>Research Cruise</th>
<th>Technical Specifications</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMCW* radar</td>
<td>Stratus 2004</td>
<td>94-GHz (3.2 mm) – vertically pointing</td>
<td>First three moments of the Doppler Spectrum</td>
</tr>
<tr>
<td>MMCR** pulse radar</td>
<td>All three</td>
<td>35-GHz (8.6 mm) – vertically pointing</td>
<td>First three moments of the Doppler Spectrum</td>
</tr>
<tr>
<td>Brown C-Band radar</td>
<td>EPIC 2001,</td>
<td>5.6-GHz (5.4 cm) – Scanning</td>
<td>Reflectivity and radial velocity</td>
</tr>
<tr>
<td></td>
<td>Stratus 2004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Profiler</td>
<td>EPIC 2001,</td>
<td>915-MHz (32.8 cm)</td>
<td>Time-height profile of wind speed/direction</td>
</tr>
<tr>
<td></td>
<td>Stratus 2004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceilometer</td>
<td>All three</td>
<td>Lidar (Vaisala CT-25K)</td>
<td>Time-height profile of cloud base</td>
</tr>
<tr>
<td>Microwave Radiometer</td>
<td>All three</td>
<td>3-channels: 20.6, 31.6, 90 GHz</td>
<td>Column integrated liquid and vapor amounts</td>
</tr>
</tbody>
</table>

* Frequency Modulated Continuous Wave  
** Millimeter Cloud Radar

Surface meteorology, turbulent and radiative flux measurements as well as aerosol spectrometer measurements

Rawinsondes: During EPIC 2001 -- 8 per day; Stratus 2003 (4 per day); and Stratus 2004 (4 per day; 6 per day while at the WHOI Buoy).
Boundary Layer Structures, Cloud Boundaries and LCL

**EPIC Boundary Layer Structure:**
- Well-mixed stratocumulus-capped boundary layer
- Few broken-cloud and nearly no clear-sky periods.
- Strong diurnal cycle of cloud top.

(Bretherton et al, 2004 and others)

**Stratus 2003 Boundary Layer Structure:**
- Enhanced variability with decoupled layers
- Extensive broken-cloud and clear-sky periods at WHOI
- No signs of pronounced diurnal variability.

**Stratus 2004 Boundary Layer Structure:**
- WHOI Buoy period has BL deepening and a prolonged period of decoupling.
- Two cloud bases--cumulus clouds rising into stratocumulus above
- Pronounced diurnal variability of cloud base.

Serpetzoglou et al. (2008)
Fractional Cloudiness

- Highest fractional cloudiness during EPIC – Lowest during Stratus 2003

- Periods of continuous cloud coverage during EPIC (and Stratus 2004) – extensive clear-sky periods during Stratus 2003
Radar Reflectivity Cross-Sections and Drizzle Occurrence

**EPIC 2001**

**Stratus 2003**

**Drizzle Occurrence**

**EPIC, MMCR reflectivity & Ceilometer cloud base height**

**Stratus 2003, MMCR reflectivity & Ceilometer cloud base height**

**EPIC, Histogram of Drizzle occurrence (from MMCR) - Drizzle defined as returns >10 dBZ of Max Refl.**

**Stratus03, Histogram of Drizzle occurrence (from MMCR) - Drizzle defined as returns >10 dBZ of Max Refl.**
Cloud Macroscopic Properties

Diurnal Variability
Cloud and Large-Scale Controls on Drizzle Occurrence (Non-Aerosol Effects)
WHOI Stratus Ocean Reference Station (WORS)

(20°S; 85°W)

Observations of surface meteorology and fluxes from 2001-2006 to define annual cycle and diurnal variability

(From SST + const RH assumption)
Fractional Cloudiness at WORS

$LW_{dw}$ (LWD) a fractional cloudiness (CF) predictor since to first order

$LWD = CF \times LW_{clld} + (1 - CF) \times LW_{clr}$

Hourly ceilometer estimates of fractional cloudiness compared with those estimated from ship observations of LWD. $LW_{clr}$ is from empirical estimates and $LW_{clld}$ is calculated from $T_{LCL}$. 
Annual cycle of fractional cloudiness from 2001-2006 cloudiness from WORS compare with low and mid+low cloudiness from ISCCP.

Annual cycle of surface latent heat fluxes and Klein stability estimated using 700 mb θ from NCEP reanalysis.
Diurnal Variability in Cloud Fraction at WORS

Min/max in diurnal cycle
Summary

- Radar observations in synergy with other remote and in situ measurements provide a unique characterization of cloud characteristics along with drizzle and boundary layer structures over the eastern subtropical Pacific.

- Extensive observations from three cruises indicate boundary layer structures ranging from well mixed boundary layers with solid clouds to decoupled layers with partially cloudy conditions and cumulus rising into stratocumulus.

- Buoy observations provide a climatology of surface meteorology and fluxes and a cloud fraction that are used to define the annual cycle and diurnal variations that can be used for model and satellite retrieval evaluations.