Where has VOCALS left us?

VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Studies) Legacy:

- improved cloud-aerosol-precip parameterizations
- emphasis on understanding climate as a coupled system
- unanswered questions on ocean processes
observational quantification of aerosol indirect effects

cloud albedo effect $-1.8 - -0.3$ W m$^{-2}$ (IPCC 2007)
cloud lifetime effect comparable
(Lohmann&Feichter, 2005; model only)

total aerosol indirect effect $-1.2 - 0.2$ W m$^{-2}$
(Quaas et al., 2009; satellite-constrained model)
Wyoming Cloud Radar (precip, vertical structure)  
Wyoming Cloud Lidar (cloud base)  
millimeter-wave radiometer (lwp)  
broadband visible radiometer (cloud optical depth)  

distance analyzed here ~ 3,500 km from 15° lon by 10° lat area
ACI_\tau = \left. \frac{\partial \ln \tau}{\partial \ln N_a} \right|_{LWP}

30-40 \text{ g m}^{-2} \quad \text{ACI}_\tau = 0.28
90-110 \text{ g m}^{-2} \quad \text{ACI}_\tau = 0.21

McComiskey et al., 2009
model cloud lifetime effect dependent on autoconversion

model autoconversion rates go as $N_d^{-\beta}$

exponent varies from 0.33 (Tripoli and Cotton, 1980) to 3.33 (Beheng, 1994)

Fig. 4. Dependence of the $L-\tau_a$ relationship on the parameterisation of the autoconversion (AU) in the models over land (red) and oceans (blue). In CAM-NCAR, CAM-PNNL, ECHAM5 and GFDL, AU depends on $N_d^{-1.79}$ (Khairoutdinov and Kogan, 2000), in GISS and SPRINTARS, on $N_d^{-1}$ (Rotstayn and Liu, 2005; Takemura et al., 2005), and in CAM-Oslo, CAM-Umich and Hadley, on $N_d^{-0.33}$ (Rasch and Kristjansson, 1998; Jones et al., 2001). In LMDZ-INCA, autoconversion is independent of $N_d$. The results for Hadley and CAM-Umich over land are co-incident.
precipitation closure: \( R \sim f(LWP^\alpha N_D^{-\beta}) \) \( \alpha \sim 1.5 - 1.75; \beta \sim 0.6 - 1.75 \)
precipitation closure: $R \sim LWP^{1.5}N_d^{-0.67}$

$$f(LWP^\alpha N_D^{-\beta}) \quad \alpha \sim 1.5 - 1.75; \beta \sim 0.6 - 1.75$$

$\alpha = 1.5 \beta = -0.67$

Wang & Feingold, 2009
VOCALS observations will ultimately improve model aerosol indirect effect estimates.

\[
\frac{\partial \text{albedo}}{\partial N_d} \bigg|_{LWP} + \frac{\partial \text{albedo}}{\partial \text{LWP}} \frac{\partial \text{LWP}}{\partial N_d} \bigg|_{\text{all else}}
\]

non-precipitating 
precipitating

Quaas et al. 2009
VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Studies) Legacy:

Cloud ‘lifetime’ parameterizations will improve emphasis on understanding climate as a coupled land-ocean-atmosphere system.
SST arguably the most important determinant of subtropical stratocumulus cloud properties

**Abstract.** Satellite observations and meteorological reanalysis are used to examine the transition from unbroken sheets of stratocumulus to fields of scattered cumulus, and the processes controlling them, in four subtropical oceans. A Lagrangian analysis suggests that both the transition, defined as the temporal evolution in cloudiness, and the processes driving the transition, are quite similar among the subtropical oceans. The increase in sea surface temperature and the associated decrease in lower tropospheric stability appear to play a far more important role in cloud evolution than other factors including changes in large scale divergence and upper tropospheric humidity. During the summer months, the transitions in marine boundary layer cloudiness appear so systematically that their characteristics obtained by documenting the flow of thousands of individual air masses are well reproduced by the mean (or climatological) fields of the different data sets. This highlights interesting opportunities for future observational and modeling studies of these transitions.

*Sandu et al., 2011*
Neat Heat Flux at IMET Buoy Site

Annual-mean net heat flux into ocean > 40 W m\(^{-2}\) at 1500 km offshore under persistent low cloud!

How is this net warming at the surface balanced by ocean heat transports?
CGCMs: Surface heat balances along 20S, 75-85W
October-mean de Szoeke et al., J. Climate (2010)

At the ocean surface insolation is too high, evaporation is too high, net heat flux into the ocean is too low, and SSTs are too high.
Fig. 1. Snapshot of simulated surface temperature [°C] in the Fall over the entire model domain (left), with zooms (right) into the subdomains indicated by black boxes in the left panel. Color scales are different for the three subplots.
Hypothesis on the heat budget of the ocean column

Surface flux $> 40$ W/m$^2$ (heating)

Base of mixed layer

250 m

Vertical advection and mixing ($< 1$ W/m$^2$)

(1) Heat transport by turbulence processes
(2) Heat transport by submesoscale eddies
(3) Heat transport by processes such as mixing associated with near-inertial oscillations, with a possible contribution by others such as salt fingering.

Weak horizontal cooling above the thermocline ($\sim 0-10$ W/m$^2$ from current meters and satellite SSTs).

Horizontal advection at and below the thermocline (cooling) due to processes that vary with region; it is partly by transient eddies.
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Tuesday, June 5, 2012
Fig. 3 a) October-mean 17°C-23°C sea surface temperature climatology (2002-2010, TMI, black contour lines, 18-20-22°C lines boldened), 2002-2009 MODIS Terra mean cloud fraction (blue contours span 60-100% cloud cover) and mean aerosol optical depth (yellow-red shading spans 0.05 to 0.25). 'X' mark PIRATA buoys, Sao Tome island (0N, 6.5E), and Ascension island (8S, 14.5W). Boxes indicate KH93 locations. Land topography in 1 km height increments. b) 2002-2010 mean annual cycles in SST, cloud fraction, cloud and aerosol optical depth for the KH93 boxes. Red and black lines indicate SEA and SEP respectively.

more on southeast Atlantic seasonal cycle in Sorel & Zuidema poster: stratus radiative forcing ~ correlated to lower tropospheric stability (SST)
similar climate change issues exist between southeast Pacific and Atlantic.....
...coupled climate models have similar issues w/ SST in Pacific & Atlantic:

Equatorial Atlantic SST gradient
IPCC AR4 models – climate of the 20th century

Richter and Xie (2008)
Do higher resolution, the latest parameterizations, help?

Doi et al., 2012

(b) CM2.1 bias

GFDL

1.0 deg. ocean
2.0 deg atm

(c) CM2.5–CM2.1

0.25 deg. ocean
0.5 deg atm
NCAR model similarly unimproved in the Atlantic

SST Biases
(Pre-Industrial)

CCSM3
mean = -0.76°C
rms = 1.57°C

CCSM4 (2°)
mean = 0.30°C
rms = 1.46°C

CCSM4 (1°)
mean = 0.07°C
rms = 1.11°C

Overall reduction SST bias, all basins
one hypothesis relevant to VAMOS: poor land convection -> weak equatorial trade winds -> insufficient upwelling

Mechanism
MAM

Richter & Xie

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but - CM2.5 precipitation much more realistic than in CM2.1
...drawing attention back to southeast Atlantic ocean mesoscale features....

Ping Chang

Tuesday, June 5, 2012
new US CLIVAR Working Group:

Upper-ocean heat budget synthesis for the eastern equatorial Pacific and Atlantic Oceans

P. Zuidema, S. de Szoeke, R. Mechoso, R. Wood

Working Group Objectives:

1. Promote collaboration between observationalists and modelers, and atmospheric scientists and oceanographers, active in the southeast oceanic basins.
2. Develop a model assessment of surface flux errors similar to deSzoeke et al. (2010) for the equatorial Atlantic, mining all available observations. Models are of current CMIP development age. Observable metrics include shortwave radiation; longwave radiation; turbulent fluxes; wind stress; atmospheric circulation (e.g., location and strength of atmospheric anticyclone); and large-scale ocean circulation (as well as SST). Data sources include the PIRATA buoys at 8E, 8S and 0E, 0S (which includes a subsurface mooring) and research cruises (6) into the Gulf of Guinea as part of the AMMA/EGEE program.
3. Identify recent model improvements and common and persistent model errors, in both CMIP5 and higher-resolution coupled models.
4. Provide recommendations of cases for community simulation and evaluation using eddy-permitting ocean models, sharing specified model conditions and output datasets. The followup to these cases is likely to fall outside the two-year time line of the WG, but attempts will be made to foster this follow-on activity.

Working Group Activities, Timeline, and Outreach:

~6x/yr telecons; active website and email list; annual WG meetings held contemporaneously at ‘meetings of convenience’; BAMS/EOS publication.

Year 1: Establish a website, identify and begin assembling the satellite datasets, buoy and research cruise datasets, begin model assessment. Identify the geographical region/line/point along which to compare observations and models. Identify the anticipated contributions from WG members. (propose to) convene an AGU session with a WG meeting appended (1 day).

Year 2: populate the website, WG meeting (1 day) appended to a meeting of interest. Finalize recommendations for the case specification of a community simulation.