A novel approach to Lagrangian sampling of marine boundary layer cloud and aerosol in the northeast Pacific: Case studies from CSET

Johannes Mohrmann1, Robert Wood2, Christopher Bretherton3, Bruce Albrecht2, Pauquita Zuidema2, Virendra Ghate3
1University of Washington, 2University of Miami, 3Argonne National Laboratory

Summary
- A semi-Lagrangian approach for sampling of marine boundary layer (MBL) clouds was developed for the Cloud System Evolution in the Trades (CSET) campaign.
- MBL airmasses were sampled on outbound flights from California to Hawaii and resampled two days later, using forecast-based trajectories to track sampled airmasses and plan return flights.
- Forecast trajectories used for return flights were accurate at 24 hours lead time; comparison with analysis trajectories showed a mean forecast error of 58 km (± 39 km) over 48-hour trajectories.
- Mean resampling error (average distance between research plane and airmass at resampling time) over 47 resampled trajectories was 27 km.

CSET Background
The Cloud System Evolution in the Trades field campaign took place July/August 2015.

Motivation:
- Characterize the evolution of clouds, precipitation, and aerosol fields in the stratocumulus-to-cumulus transition region of the northeast Pacific.
- Provide comprehensive case studies of the SC-Cu transition to help test and improve cloud process models and GCMs.
- Exercise new airborne sensing equipment on board the NSF/NCAR G-V HIAPER jet, including HIAPER Cloud Radar (HCR) and HOLODEC.

Flight strategy:
16 research flights (7 Lagrangian mission pairs + 2 unpaired flights) were carried out between Sacramento, CA and Kona, Hi. Each flight consisted of circa 2000 km of MBL sampling, following the sequence shown in Fig. 2.

Data and Methods
Trajectory setup:
- Trajectories were run with the HYSPLIT air parcel model.
- Datasets for wind fields were NCEP GFS 0.25° (forecast) and NCEP GDAS 0.5° (analysis).
- Trajectories initialized at 500 m along outbound flight path and advected isobarically for 48 hours.

Flight resampling error is the minimum distance between plane and analysis-based airmass trajectory, averaged over 47 resamplings.

Forecast error is calculated by comparing endpoints of 48-hour trajectories using forecast data to trajectories based on analysis (this neglects errors in analysis), averaged over 56 trajectories. Forecast lead time is relative to trajectory end time.

Results
Forecast error:
- 215 km forecast error at 72 hours lead time meant that outbound flights could be planned with good approximate knowledge of return flight path.
- 58 km forecast error at 24 hours lead time meant that accurate return flight plans could be filed by FAA deadlines.

Flight resampling error:
- Mean flight resampling error was 27.3 km; more than half of all resampled trajectories were interpolated within 20 km of analysis airmass location.

Discussion
CSET was successful and the sampling strategy worked reliably, given the practical constraints of flight planning. Flight resampling error was generally less than the trajectory error at 24 hours (when return flight plans were finalized); this is due to flight path often crossing near the ‘actual’ analysis airmass location en route to the forecast location.

Despite significant observed vertical wind shear throughout the boundary layer, the choice of 500 m initialized isobaric trajectories was validated through visual inspection of cloud features using visible and infrared imagery from the Geostationary Orbiting Environmental Satellite (GOES-15); the trajectories tracked large-scale cloud features well over 2 days.

Application of mission pair matching and trajectories has been preliminary; Fig. 7 shows one such application of matching data from an outbound flight to data from a return flight. Other applications include tracking GOES VIIRS products (produced by P. Minnis at NASA Langley Research Center) along trajectories.

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Contact: Johannes Mohrmann, jcm@atmos.washington.edu