Progress Report on
Cloud and Drizzle Retrievals in the Azores

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Bright red trace is a cloud echo in an updraft, ~0.7m/s.
Weak drizzle echo begins at 1 min., increasing to near cloud strength.
Increase in total reflectivity (black) supports microphysical growth.
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Weak drizzle echo begins at 1 min., increasing to near cloud strength.
Increase in total reflectivity (black) supports microphysical growth.
Spectrum alignment, averaging, and decomposition
Retrievals of cloud and drizzle reflectivity

Cloud Reflectivity

Drizzle Reflectivity
Retrieval success fraction

The graph shows the relationship between the distance from the cloud top (in km) and the success fraction. As the distance from the cloud top decreases, the success fraction approaches 0.5 near the cloud top.
Drizzle reflectivity profiles above/below cloud base for four different cloud reflectivity ranges
Mean Doppler velocity and retrieved drizzle velocity

Mean Doppler Velocity

Drizzle Velocity
Measured Reflectivity

Height (km AGL)

Time of Day (hour UTC)

Reflectivity (dBZ)
Retrievals of cloud and drizzle reflectivity

Cloud Reflectivity

Drizzle Reflectivity
Mean Doppler velocity and retrieved drizzle velocity

Mean Doppler Velocity

Drizzle Velocity
Mean Doppler velocity and retrieved drizzle velocity

Mean Doppler Velocity

Drizzle Velocity
Optimal estimation based retrievals

Measured Reflectivity

Retrieved Drizzle Reflectivity

![Graphs showing height vs. reflectivity over time](image)

**APRIORI**
- $Q_c$
- $Q_D$
- $R_c$
- $R_D$

**STATE**
- $Q_c$
- $Q_D$
- $R_c$
- $R_D$

$S_a^{-1}$
Optimal estimation based retrievals

Measured Reflectivity

Retrieved Drizzle Reflectivity

FORWARD MODEL

APRIORI

$Q_c$, $Q_D$, $R_C$, $R_D$

STATE

$Q_c$, $Q_D$, $R_C$, $R_D$

MEASUREMENTS

Z, $<V>$, $V_{air}$, $\Delta Z_V$, lwp, $R_d$

PREDICTED OBSERVATIONS

Z, $<V>$, $V_{air}$, $\Delta Z_V$, lwp, $R_d$
Optimal estimation based retrievals

Measured Reflectivity

Retrieved Drizzle Reflectivity

High-quality input from spectral retrievals

APRIORI

\(Q_c\), \(Q_D\), \(R_C\), \(R_D\)

STATE

\(Q_c\), \(Q_D\), \(R_C\), \(R_D\)

FORWARD MODEL

MEASUREMENTS

\(Z\), \(\langle V \rangle\), \(V_{air}\), \(\Delta Z\), \(lwp\), \(R_{d2}\)

PREDICTED OBSERVATIONS

\(Z\), \(\langle V \rangle\), \(V_{air}\), \(\Delta Z\), \(lwp\), \(R_{d2}\)
Optimal estimation based retrievals

Measured Reflectivity

Retrieved Drizzle Reflectivity

High-quality input from radar/lidar retrievals
High-quality input from spectral retrievals

APRIORI

\[ Q_c, Q_D, R_C, R_D \]

STATE

\[ Q_c, Q_D, R_C, R_D \]

MEASUREMENTS

\[ Z, \langle V \rangle, V_{air}, \Delta Z, IWP, R_{d2} \]

PREDICTED OBSERVATIONS

\[ Z, \langle V \rangle, V_{air}, \Delta Z, IWP, R_{d2} \]
SUMMARY: We are working to close the remaining gaps in the conditions for which we can perform combined cloud/drizzle retrievals, in effect, maximizing the domain covered by the middle column below. We are integrating our recent techniques, and more established ones, into an optimal estimation framework driven by a powerful forward model of cloud processes, to produce a unified best estimate of physical quantities with robust tools for estimating uncertainty.

<table>
<thead>
<tr>
<th>Radar Doppler spectrum parameters</th>
<th>Cloud only ((\chi \rightarrow \infty))</th>
<th>Cloud and Drizzle ((100 &gt; \chi &gt; 0.01))</th>
<th>Drizzle only ((\chi \rightarrow 0))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Z) (Reflectivity)</td>
<td>(f(N_c, r_{o,c}, \sigma_{x,c}))</td>
<td>((1+\chi) \cdot f(N_d, r_o, \sigma_{x,d}))</td>
<td>(f(N_d, r_{o,d}, \sigma_{x,d}))</td>
</tr>
<tr>
<td>(V_D) (Mean Doppler velocity)</td>
<td>(W_{air})</td>
<td>(W_{air} + f(r_o, \sigma_x)/(1+\chi))</td>
<td>(W_{air} + f(r_{o,d}, \sigma_{x,d}))</td>
</tr>
<tr>
<td>(\sigma_D) (Spectrum Width)</td>
<td>(f(\varepsilon))</td>
<td>(f(\varepsilon) + f(\chi, r_{o,d}, \sigma_{x,d}))</td>
<td>(f(\varepsilon) + f(r_{o,d}, \sigma_{x,d}))</td>
</tr>
<tr>
<td>(S_D) (Skewness)</td>
<td>(f(\varepsilon, r_{o,c}, \sigma_{x,c}) = f(\varepsilon))</td>
<td>(f(\varepsilon, \chi, r_{o,d}, \sigma_{x,d}))</td>
<td>(f(\varepsilon, r_{o,d}, \sigma_{x,d}))</td>
</tr>
<tr>
<td>(K_D) (Kurtosis)</td>
<td>(f(\varepsilon, r_{o,c}, \sigma_{x,c}) = f(\varepsilon))</td>
<td>(f(\varepsilon, \chi, r_{o,d}, \sigma_{x,d}))</td>
<td>(f(\varepsilon, r_{o,d}, \sigma_{x,d}))</td>
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