Chemical, aerosol, and cloud processes in closed and open cells

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WRF/Chem in LES mode

- Two-moment warm-rain microphysical scheme
- Neutral and charged $\text{H}_2\text{SO}_4/\text{H}_2\text{O}$ nucleation
- Size-resolved sea salt emissions

- Full coupling of:
  - Aerosol processes
  - Cloud microphysics
  - Gas and aqueous phase chemistry

→ Simulates the aerosol life cycle
Aerosol in closed and open cells

TERRA/MODIS 2008-10-28 15h50 UT
Closed-to-open cell transition

Cloud optical depth
2008-10-27 21:20:00 UT

Cloud optical depth
2008-10-28 08:30:00 UT

03h10 LST
Closed-to-open cell transition

RF06

LWP (g m⁻²)

Cloud fraction (LWP > 10 g m⁻²)

Surface precipitation (mm d⁻¹)

hours since

2008-10-27 06:40:00 LST  2008-10-27 12:00:00 UT
Comparison with RF06

PCASP (NCAR RAL)
VOCALS-REx RF06
NCAR C-130
2008-10-28 09h05 UT

APIMS (Alan Bandy, Drexel U.)
VOCALS-REx RF06
NCAR C-130
2008-10-28 11h36 UT
Liquid water (g kg$^{-1}$)

2008-10-28 11:00:00 LST / 2008-10-28 16:20:00 UT, 1.8 km south-north distance

- 1.5 m s$^{-1}$

Altitude (m)

West-east distance (km)

2.474
1.2
0.6
0.3
0.1
$1 \times 10^{-2}$
0

(Noaa)
Dynamically driven chemistry

DMS (ppt)
Liquid water contours at 0.01, 0.1, 0.3, 0.6, 1.2 g kg⁻¹
2008-10-28 11:00:00 LST / 2008-10-28 16:20:00 UT, 1.8 km south-north distance

OH (cm⁻³)
Liquid water contours at 0.01, 0.1, 0.3, 0.6, 1.2 g kg⁻¹
2008-10-28 11:00:00 LST / 2008-10-28 16:20:00 UT, 1.8 km south-north distance
Nucleation

$H_2SO_4$ (cm$^{-3}$)
Liquid water contours at 0.01, 0.1, 0.3, 0.6, 1.2 g kg$^{-1}$
2008-10-28 11:00:00 LST / 2008-10-28 16:20:00 UT, 1.8 km south-north distance

Formation rate of particles with 15 $H_2SO_4$ molecules from nucleation (cm$^{-3}$ s$^{-1}$)
Liquid water contours at 0.01, 0.1, 0.3, 0.6, 1.2 g kg$^{-1}$
2008-10-28 11:00:00 LST / 2008-10-28 16:20:00 UT, 1.8 km south-north distance
Nucleation and sea salt emissions

Particles with 15 H$_2$SO$_4$ molecules from nucleation (cm$^{-3}$ s$^{-1}$)

Sea salt (cm$^{-3}$ s$^{-1}$)

2008-10-27 06:40:00 LST  2008-10-27 12:00:00 UT
Nucleation and cloud properties

Cloud drop number

Rain drop number

Nucleation

No nucleation
Internal feedbacks (buffers)

- **Liquid water path**
  - Units: g/m²
  - Graph shows variation over 24 hours.

- **Surface precipitation**
  - Units: mm d⁻¹
  - Graph shows variation over 24 hours.

- **Resolved TKE**
  - Units: J/kg(air)
  - Graph shows variation over 24 hours.

- **Sea salt emissions**
  - Units: 10⁵ particles/m²/s
  - Graph shows variation over 24 hours.
Summary

- **Sea salt CCN emissions sufficient** to maintain open cell cloudiness (VOCALS-REx RF06 case)
- **Entrainment about half as strong** as sea salt emissions (VOCALS RF06-REx case)
- The closed- to open-cell transition results in
  - DMS conversion to SO$_2$ and H$_2$SO$_4$
  - Aerosol nucleation provides additional new aerosol
- **Nucleation ...**
  - contributes to the cloud drop number
  - suppresses drizzle

➔ CLAW hypothesis?
➔ ...?
Acknowledgments

- Roberto Mechoso, Rob Wood, ...
- Huebert group at the University of Hawaii
- VOCALS science, engineering, and support teams
- NOAA ESRL High Performance Computing Systems team
- **Dimensions:**
  - 48×48 km$^2$ × 2000 m
  - 60×60 km$^2$ × 2000 m
  - 48 h

- **Resolution:**
  - 300 m horizontal
  - 30 m vertical
  - 3 s temporal
IC and BC from VOCALS-REx observations

• Vertical profiles:
  - $\Theta$, $q_{\text{total}}$
  - $O_3$, CO, CCN

• Ocean fluxes:
  - Sensible and latent heat
  - DMS

• Background wind field

• Subsidence rate

→ Simulations start with closed cell circulation
→ Undergo transition into an open cell state
Closed-to-open cell transition

![Graph showing aerosol concentrations and H$_2$SO$_4$ condensation sink over time.](image)

2008-10-27 06:40:00 LST  2008-10-27 12:00:00 UT