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

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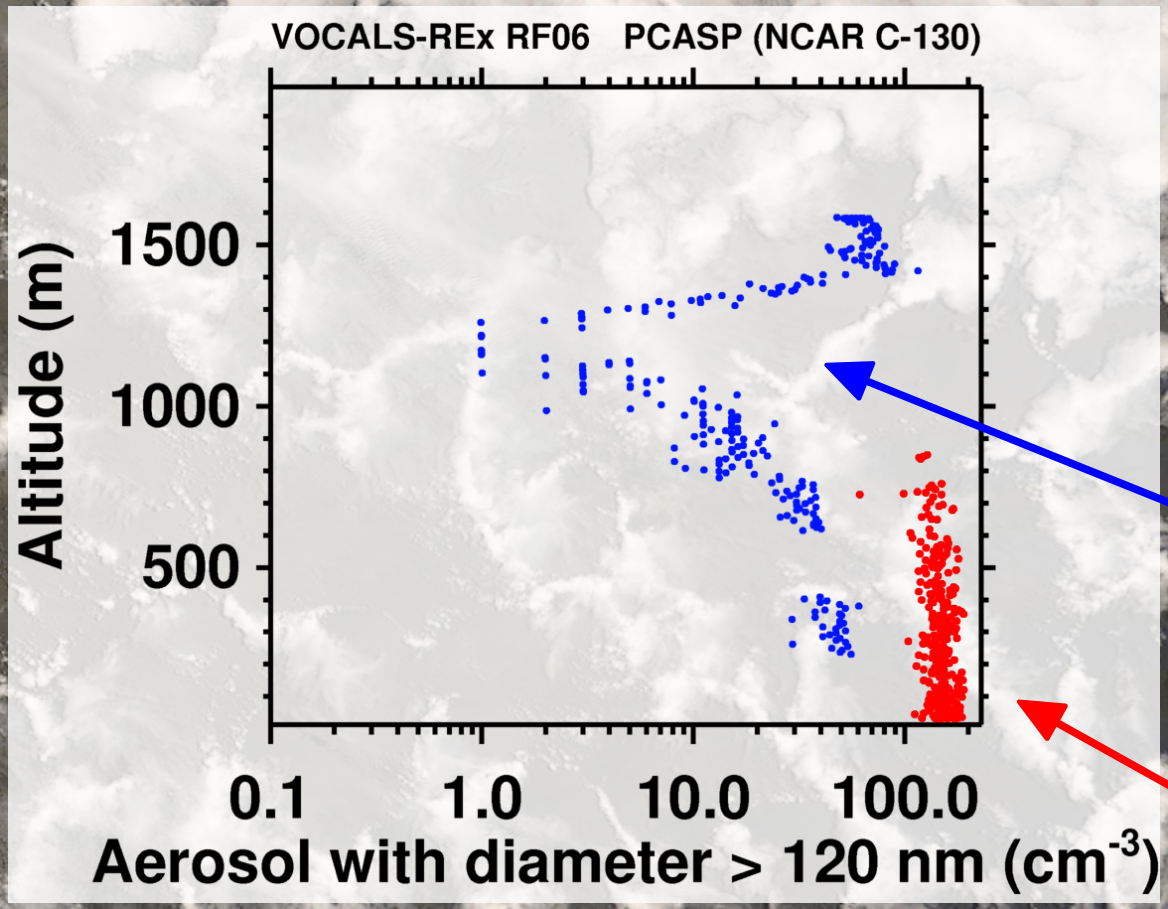
WRF/Chem in LES mode

- Two-moment warm-rain microphysical scheme
- Neutral and charged H_2SO_4/H_2O nucleation
- Size-resolved sea salt emissions
- Full coupling of:
  - Aerosol processes
  - Cloud microphysics
  - Gas and aqueous phase chemistry

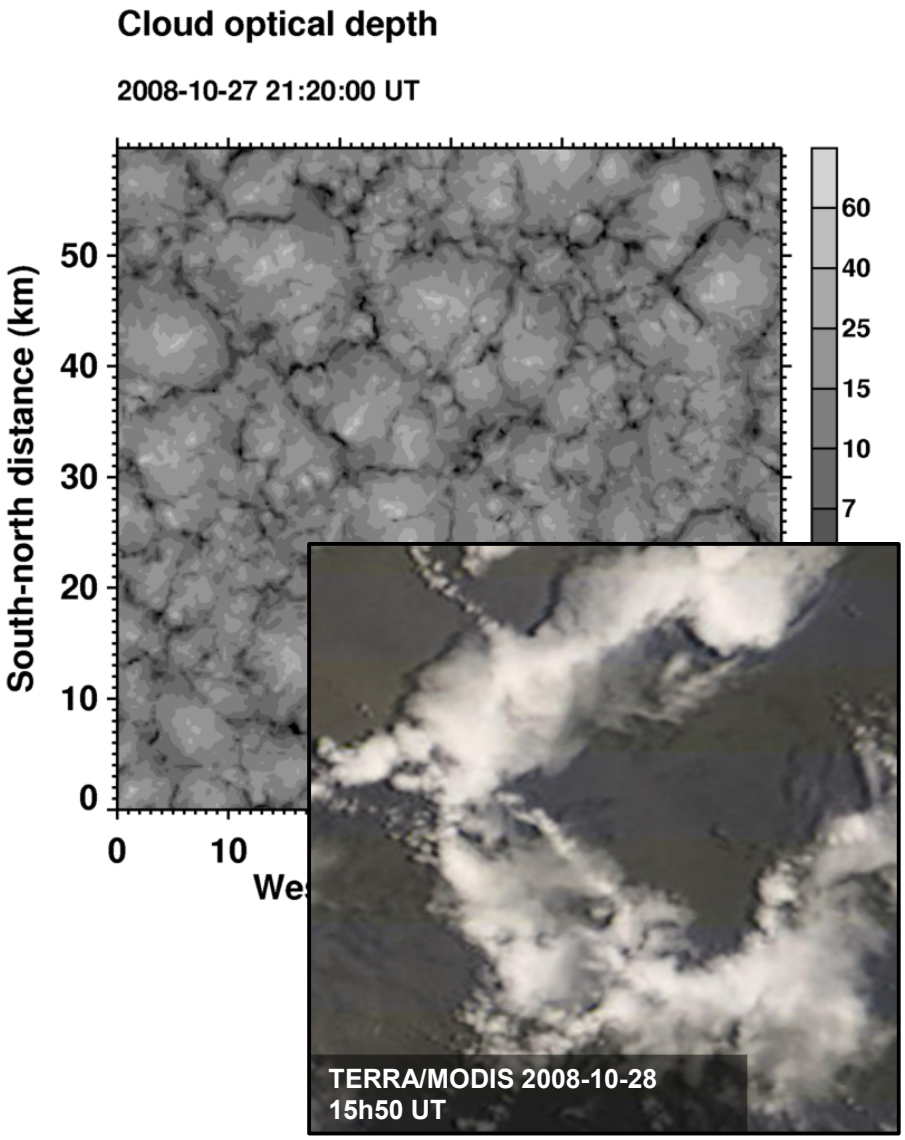
→ **Simulates the aerosol life cycle**

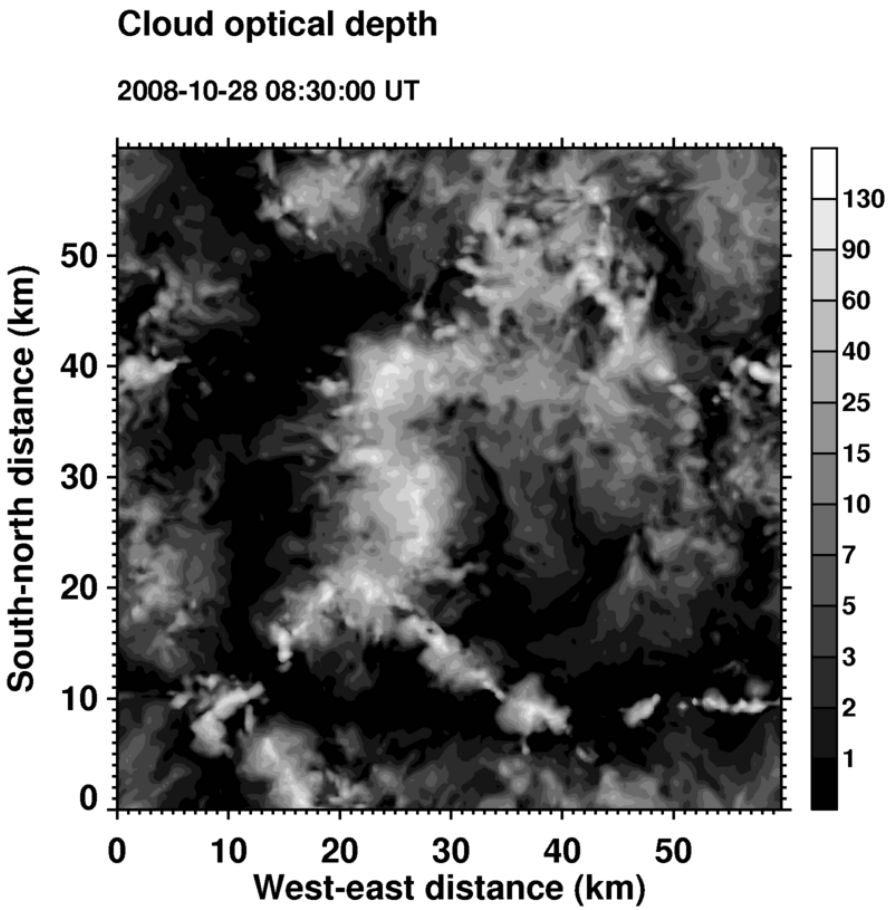
Aerosol in closed and open cells



TERRA/MODIS 2008-10-28 15h50 UT

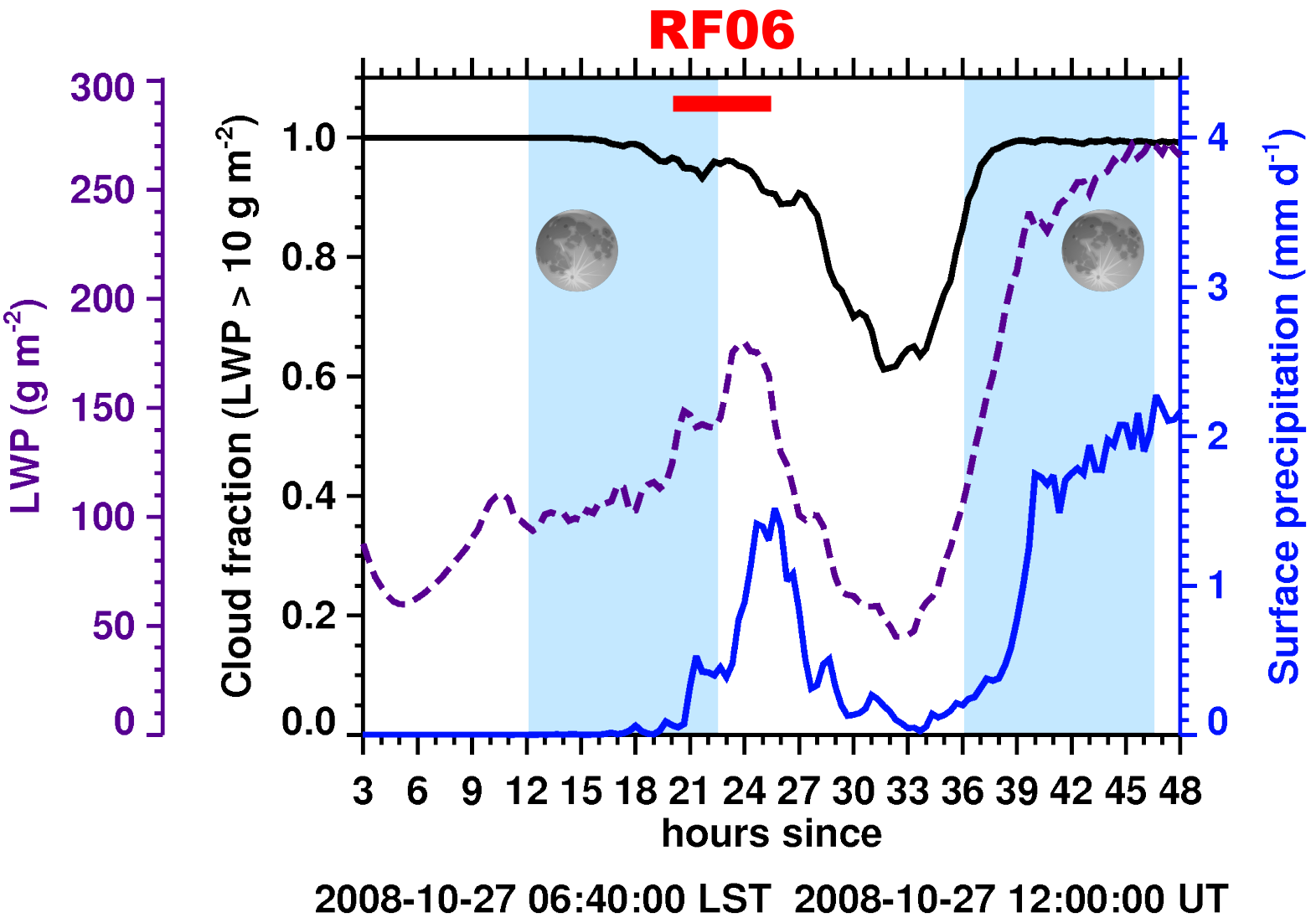
Closed-to-open cell transition



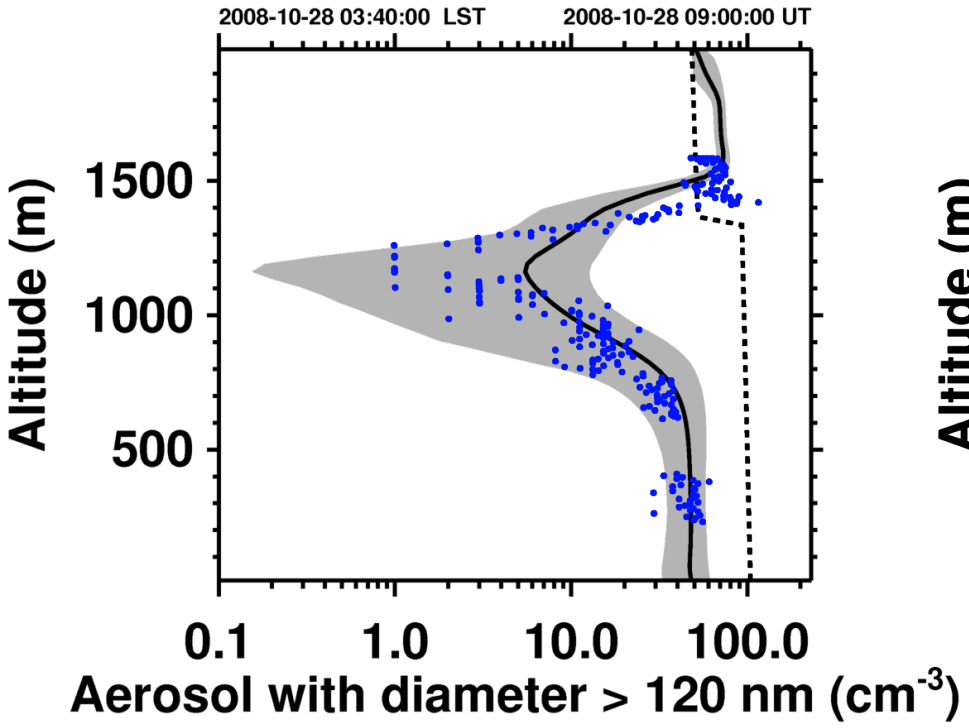


03h10 LST

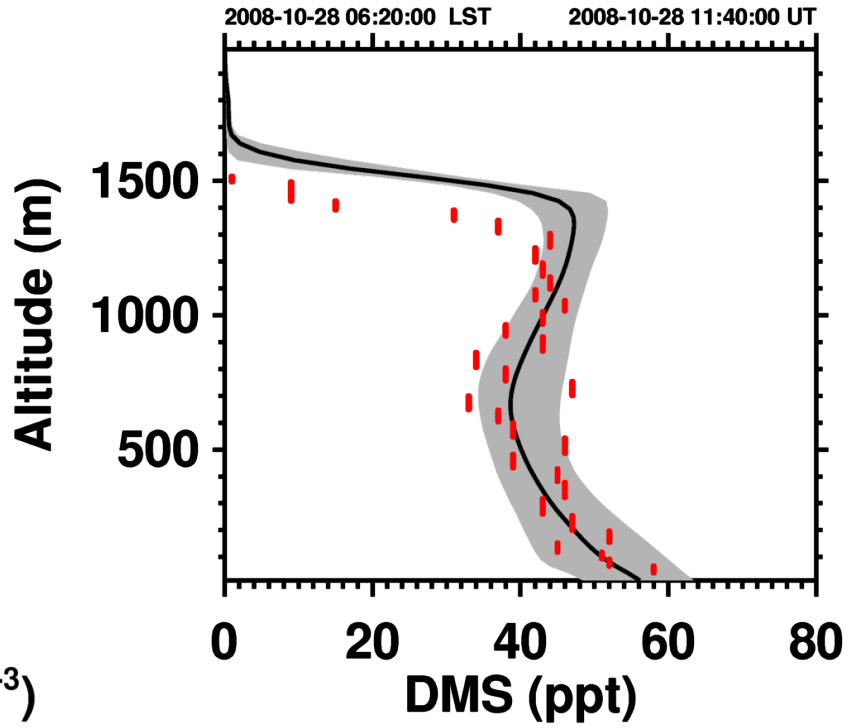
Closed-to-open cell transition



Comparison with RF06

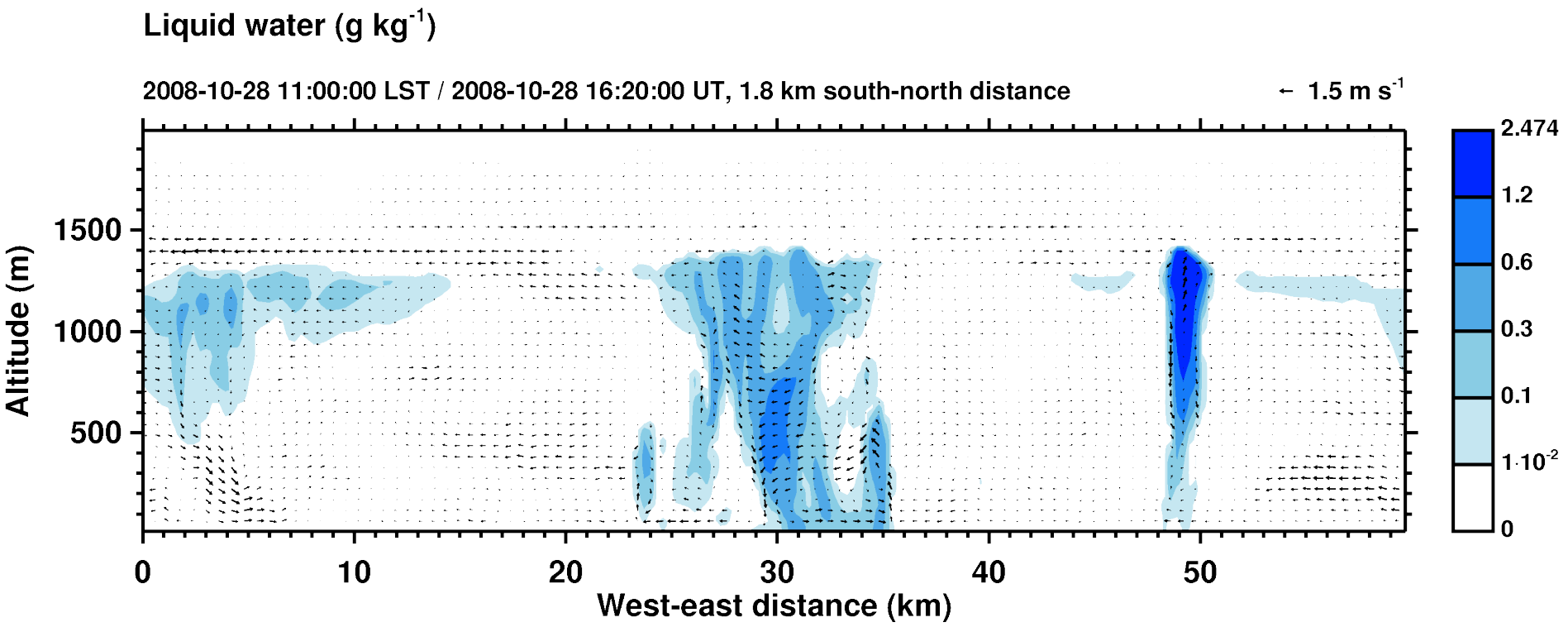


PCASP (NCAR RAL)
VOCALS-REx RF06
NCAR C-130
2008-10-28 09h05 UT

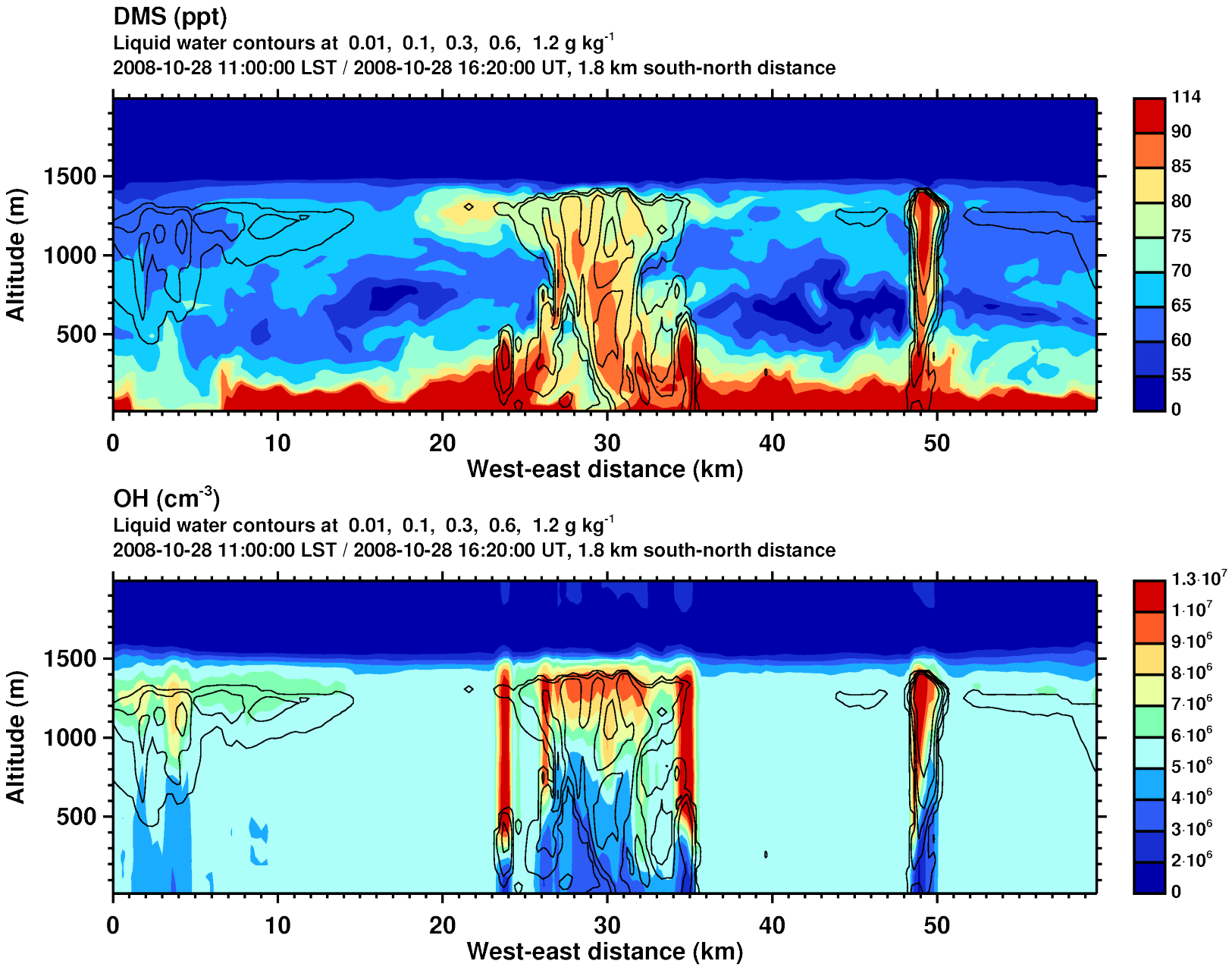


APIMS (Alan Bandy, Drexel U.)
VOCALS-REx RF06
NCAR C-130
2008-10-28 11h36 UT

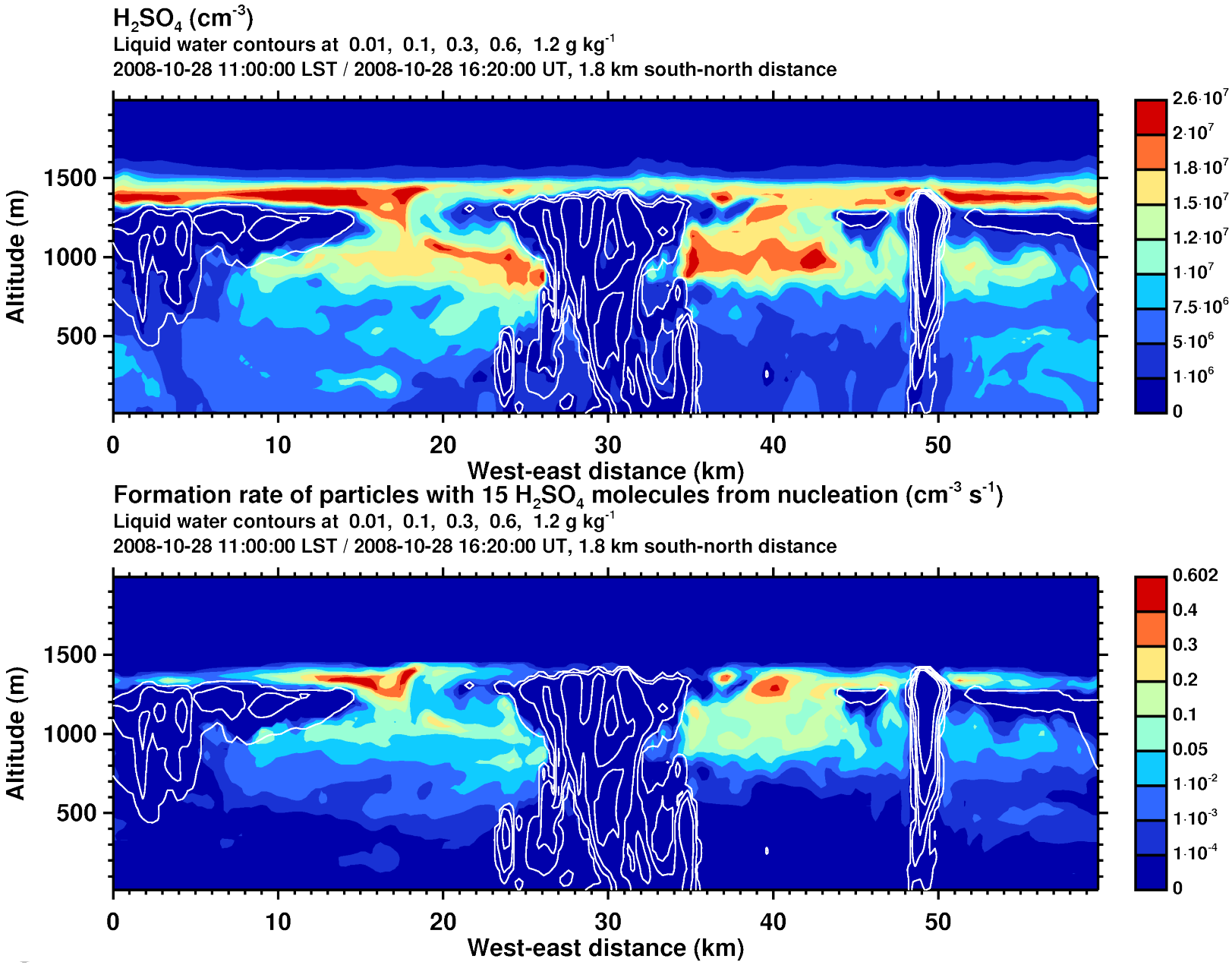
Open-cell convection



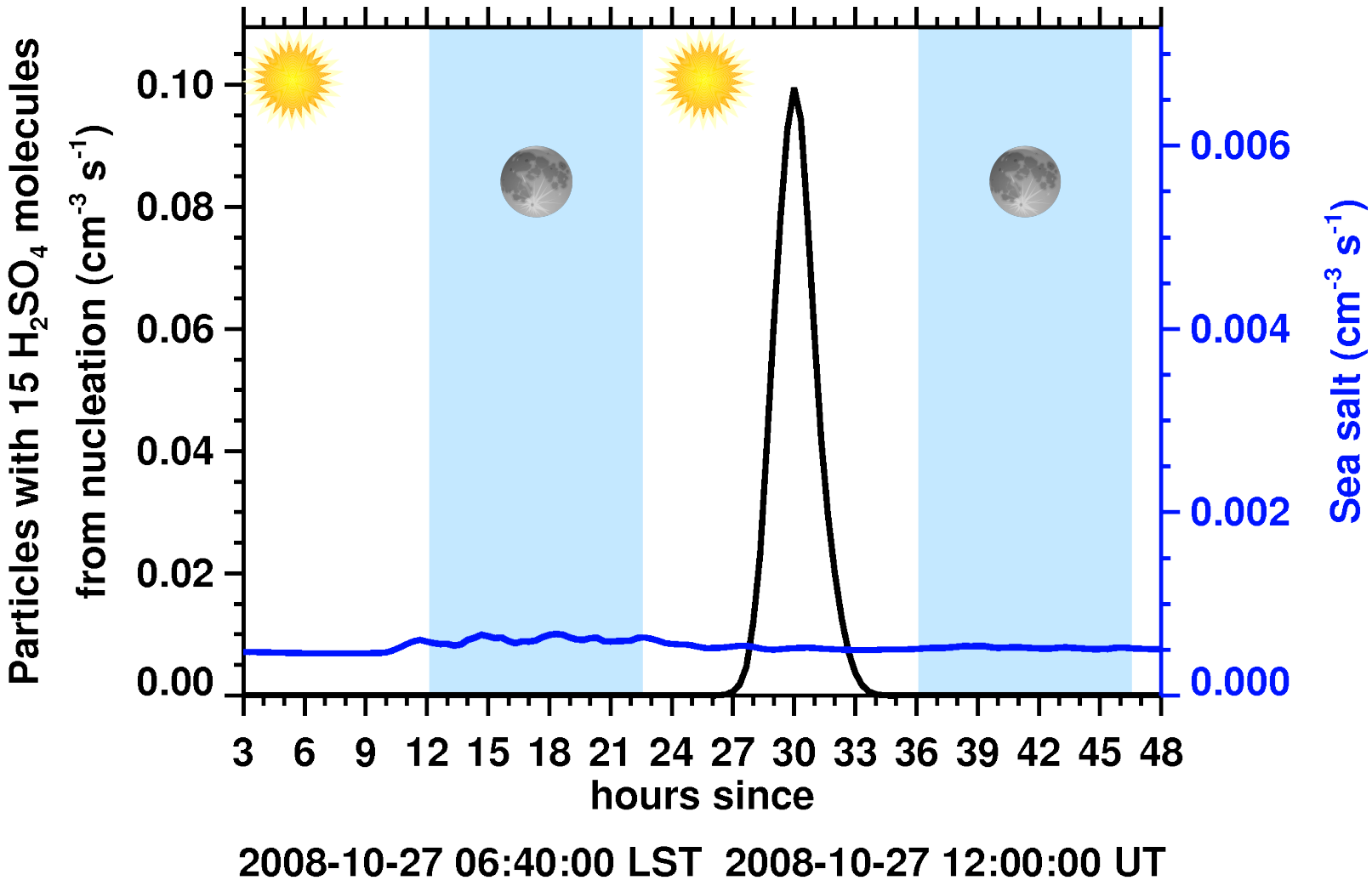
Dynamically driven chemistry



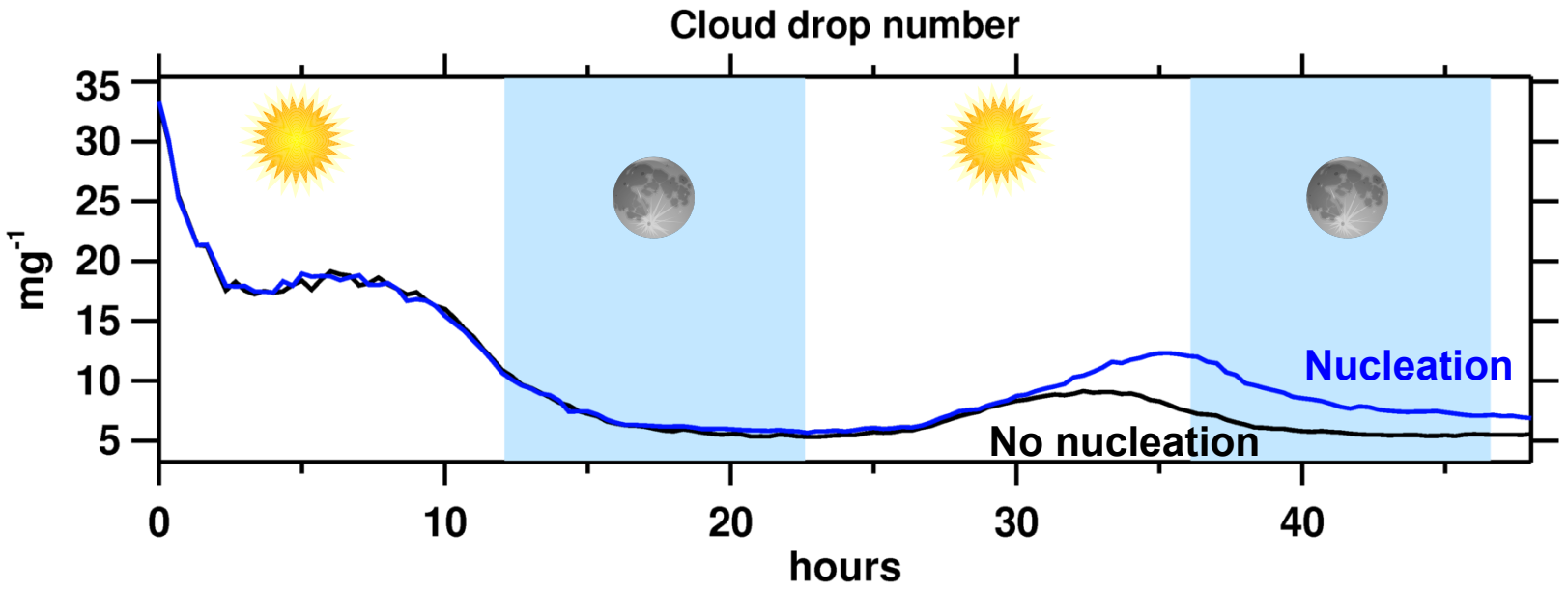
Nucleation

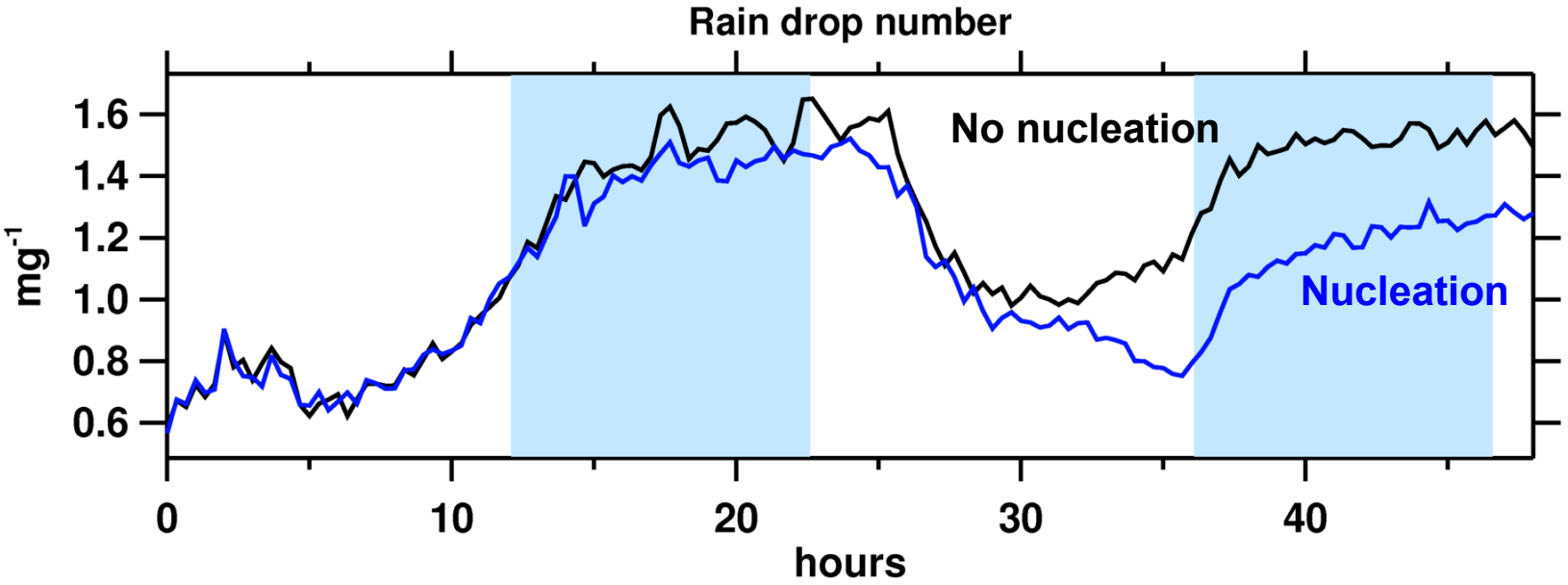

H_2SO_4 (cm^{-3})
Liquid water contours at 0.01, 0.1, 0.3, 0.6, 1.2 g kg^{-1}
2008-10-28 11:00:00 LST / 2008-10-28 16:20:00 UT, 1.8 km south-north distance
Altitude (m)
1500
1000
500
0
10
20
30
40
50
West-east distance (km)
$2.6 \cdot 10^7$
$2 \cdot 10^7$
$1.8 \cdot 10^7$
$1.5 \cdot 10^7$
$1.2 \cdot 10^7$
$1 \cdot 10^7$
$7.5 \cdot 10^6$
$5 \cdot 10^6$
$1 \cdot 10^6$
0
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
Altitude (m)
1500
1000
500
0
10
20
30
40
50
West-east distance (km)
0.602
0.4
0.3
0.2
0.1
0.05
$1 \cdot 10^{-2}$
$1 \cdot 10^{-3}$
$1 \cdot 10^{-4}$
0

Nucleation and sea salt emissions

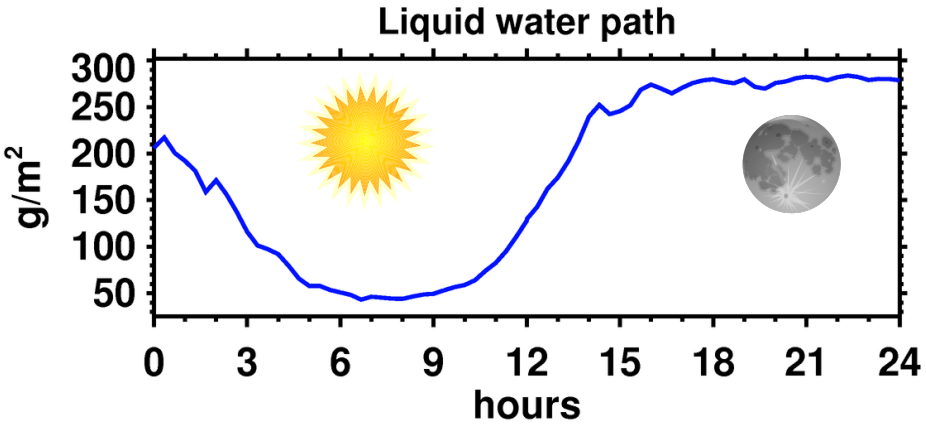


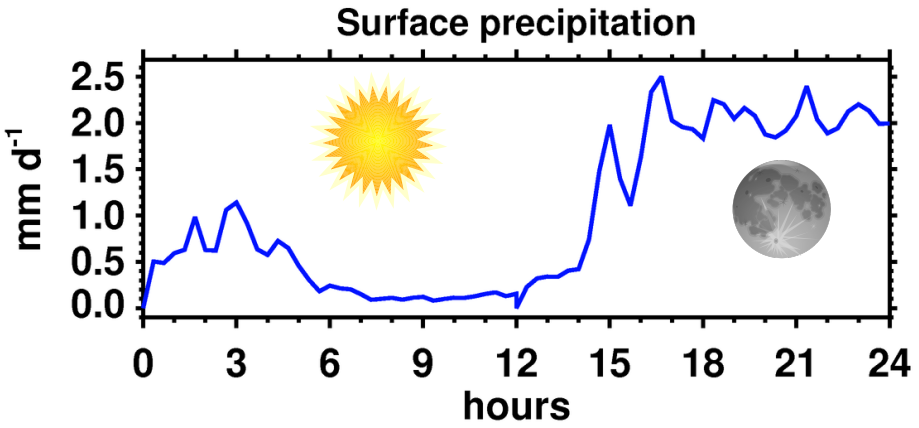
Nucleation and cloud properties

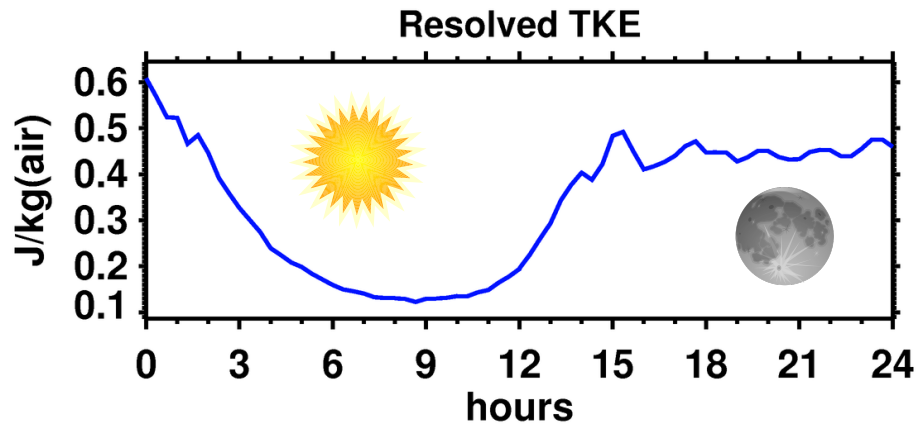


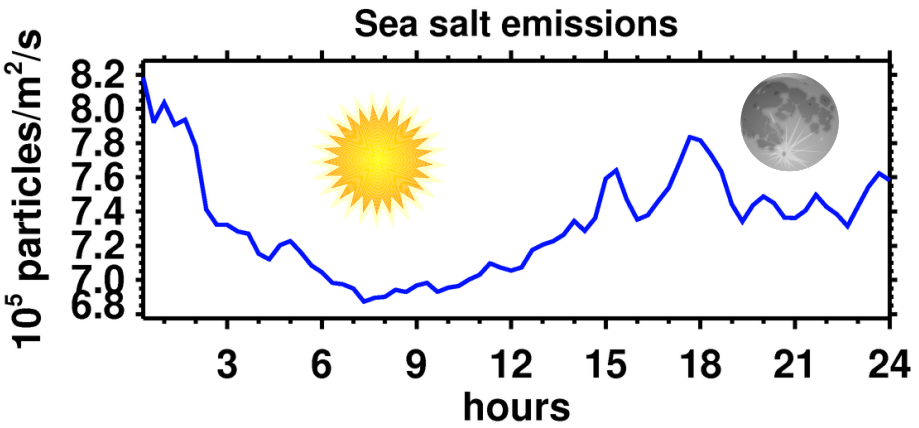


Internal feedbacks (buffers)









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_2SO_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

Model domain

- Dimensions:
  - 48×48 km² × 2000 m
  - 60×60 km² × 2000 m
  - 48 h
- Resolution:
  - 300 m horizontal
  - 30 m vertical
  - 3 s temporal

Simulations

IC and BC from VOCALS-REx observations

- **Vertical profiles:**
  - **θ, q_{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