Wet Scavenging of Soluble Trace Gases in Deep Convective Clouds: A Comparison of SEAC4RS and DC3 Sampling Strategies

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Instrument Teams: DACOM, ESRL, CAMS, DFGAS, P-CIMS, S-CIMS, GT-CIMS, VCSEL, DLH, CDP, 2D-S
O$_3$ formation in UT controlled by HO$_x$ and NO$_x$; many HO$_x$ precursors are soluble.
Scientific Questions

- How much does wet removal of soluble species vary in deep convective storms in different regions?
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• How well does WRF-Chem represent this wet removal?
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• How much does fractional removal vary when calculated from anvil vs. core observations?
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Fraction Removed (FR) measures net transport of chemical species from storm inflow to outflow

Mean \( \frac{[S_x]}{[CO]} \) in outflow

Mean \( \frac{[S_x]}{[CO]} \) value in inflow

Bela et al. (2015), in prep.
Fraction Removed (FR) measures net transport of chemical species from storm inflow to outflow.

Mean $[S_x]/[CO]$ in outflow

$w \sim 35-45 \text{ m s}^{-1}$

$H \sim 10 \text{ km}$

$t \sim 4-5 \text{ min}$

Mean $[S_x]/[CO]$ value in inflow

Bela et al. (2015), in prep.
Fried et al. (2015) extrapolates CH$_2$O observations in anvils to storm cores.

Mean [S$_x$]/[CO] in outflow

Mean [S$_x$]/[CO] value in inflow

Fried, “Formaldehyde Scavenging Efficiency Determinations in Convective Clouds: Comparisons of Select SEAC4RS Data with DC3 Results,” Th. 9:15 am
Comparing WRF-Chem simulations at top of storm core produces similar scavenging efficiencies (SE)

Mean $[S_x]/[CO]$ in outflow

Mean $[S_x]/[CO]$ value in inflow

WRF-Chem
40-dBZ SE: 0.51

Observed CH$_2$O
3-component SE: 0.40-0.57

Fried, “Formaldehyde Scavenging Efficiency Determinations in Convective Clouds: Comparisons of Select SEAC4RS Data with DC3 Results,” Th. 9:15 am
Do fractions removed vary significantly among storms in different regions?

Bela et al. (2015), in prep.
Do fractions removed vary significantly among storms in different regions?

multi-cellular system, Oklahoma
May 29, 2012

Bela et al. (2015), in prep.
Do fractions removed vary significantly among storms in different regions?

Airmass storm, Alabama
May 21, 2012

Bela et al. (2015), in prep.
Do fractions removed vary significantly among storms in different regions?

Severe storm, Colorado
June 6, 2012

Bela et al. (2015), in prep.
Do fractions removed vary significantly among storms in different regions?

Multi-cellular storm system with smoke ingestion, Colorado, June 22, 2012

Bela et al. (2015), in prep.
Bela et al. (2015), in prep.
“Fraction removed” of CO is an indication of amount of entrainment

Bela et al. (2015), in prep.
OK/AL storms remove more CH$_2$O and CH$_3$OOH than those in Colorado

Bela et al. (2015), in prep.
Colorado storm cases remove more HNO$_3$ than OK/AL storms

Bela et al. (2015), in prep.
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How well does WRF-Chem simulate severe storm dynamics and transport?

- RRTMG radiation
- Lightning Data Assimilation
- NAM-ANL
- YSU PBL
- Noah LSM
- Morrison microphysics

Δz ~200 m

Δx = Δy = 1 km

Δz ~100 m
WRF-Chem Simulates Location, Timing, Structure of May 29, 2012 Severe Storm in Oklahoma

Bela et al. (2015), in prep.
WRF-Chem Simulates Location, Timing, Structure of May 29, 2012 Severe Storm in Oklahoma

Bela et al. (2015), in prep.
How well does WRF-Chem simulate wet removal of soluble species?

PR1992/Decaria lightning NO\textsubscript{X}  

MOZART chemistry  

TUV photolysis  

GOCART aerosol  

MOZART, DC-8 Obs.  

Neu and Prather wet scavenging  

NEI 2011

FINN

MEGAN v2.04
Neu and Prather wet scavenging does not track dissolved species.

Bela et al. (2015), in prep.
Neu and Prather wet scavenging does not track dissolved species

\[ \text{dissolution} \ (K_H) \]
\[ \Downarrow \]
\[ \text{cloud water} \rightarrow \text{gas} \]
\[ \text{deposition} \ (HNO}_3 \]
\[ \text{rain hail snow} \]
\[ \Downarrow \text{evaporation} \]
\[ \text{gas} \]

\[ r_f = 0.5 \text{ for } HNO}_3, \]
\[ \text{else } r_f = 0 \]

Bela et al. (2015), in prep.
Neu and Prather wet scavenging does not track dissolved species.

Bela et al. (2015), in prep.
Bela et al. (2015), in prep.
For CH$_2$O, $r_f=0$ within error bars of observations, versus expected $r_f=0.64$

Bela et al. (2015), in prep.
For HNO$_3$, $r_f$ value has small impact on fraction removed

Bela et al. (2015), in prep.
Scientific Questions

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• WRF-Chem represents wet removal of soluble species for a severe storm in Oklahoma

• How much does fractional removal vary when calculated from anvil vs. core observations?
Scientific Questions

- Wet removal of soluble species varies significantly among deep convective storms in different regions.
- WRF-Chem represents wet removal of soluble species for a severe storm in Oklahoma.
- How much does fractional removal vary when calculated from anvil vs. core observations?
How does wet removal compare in convective core sampling from SEAC4RS?

multi-cellular system, west Texas
Sept. 18, 2013

Alan Fried
Less removal of CH$_2$O and H$_2$O$_2$, more of HNO$_3$ in Sept. 18 than OK May 29 storms
Conclusions

• Wet removal of soluble species varies significantly among deep convective storms in different regions.

• WRF-Chem represents wet removal of soluble species for a severe storm in Oklahoma.

• Less removal of CH$_2$O and H$_2$O$_2$, more of HNO$_3$ in Sept. 18 than OK May 29 may be due to anvil vs. core sampling.
Thank you!

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