Atmospheric chemical transformation (oxidation) determines many of the impacts of primary emissions

- Cannot understand chemical transformation unless you understand the night
- CSD is a recognized leader in nighttime chemistry

CSD research topics for this review:
1. Nighttime oxidation of biogenic hydrocarbons
   - The influence of anthropogenic emissions on aerosol from biogenic emissions
2. Heterogeneous reactions of nitrogen oxides
   - A better understanding of the influence of $\text{NO}_x$ on tropospheric ozone
Nocturnal Biogenic VOC Oxidation

Scientific Problem: Enhanced organic aerosol of biogenic origin in regions of high anthropogenic emissions (Spracklen, ACP 2011; Xu, PNAS 2015)

Pye et al., Atmos. Chem. Phys. 2010

CSD Approach: Extensive laboratory and field studies, including the most comprehensive current database of nighttime aircraft measurements

Night Flights of NOAA P-3 Aircraft

Aircraft probes vertical structure in stratified nighttime atmosphere for complete picture of nighttime oxidation
Nocturnal Biogenic VOC Oxidation

Key Scientific Result: Quantitative measure of the competition between NO$_3$ (anthropogenic) and O$_3$ (natural, background) oxidation of biogenics at night

SENEX 2013: A CSD aircraft campaign in the southeast U.S. designed to understand anthropogenic – biogenic interactions

Despite recent reductions in U.S. emissions, NO$_x$ still dominates nighttime oxidation in the summertime residual layer in the Southeast
Heterogeneous Reactions of Nitrogen Oxides

Scientific Problem: Nitrogen oxide reactions on aerosols are complex and uncertain, but important to understanding regional and global tropospheric ozone.

\[ \text{NO}_2 + \text{Cl}^- \rightarrow \text{ClNO}_2 \]
\[ \text{ClNO}_2 \rightarrow \text{Cl} + \text{NO}_2 \]
\[ \text{up to 50\% of tropospheric NO}_x \text{ loss} \]
\[ \text{10\% of tropospheric O}_3 \text{ and OH} \]

\[ \text{N}_2\text{O}_5 \text{ uptake is variable} \]
\[ \text{ClNO}_2 \text{ recently discovered, highly uncertain yield} \]

CSD Approach: Laboratory, field and model studies, including the largest current database for paired measurements of N\textsubscript{2}O\textsubscript{5} and ClNO\textsubscript{2}

Combination of ground, ship and aircraft measurements

Domestic and international partnerships
**Heterogeneous Reactions of Nitrogen Oxides**

**Key Scientific Result:** Demonstration of ubiquitous production of ClNO$_2$ from N$_2$O$_5$, even in continental interior regions

**ACCRONiM 2009:** Activation of Continental Chloride by Reactive Oxides of Nitrogen in Midwinter, A CSD ground based intensive

Continental U.S. Cl production

3 - 8 Tg yr$^{-1}$

Global Cl production

8 - 22 Tg yr$^{-1}$

30 – 90% of total tropospheric budget

New paradigm for tropospheric halogens & NO$_x$

Thornton *Nature*, 464, 271-274