# Ozone and Air Quality

# Some Selected Research Projects in the Chemical Sciences Division

**Joost de Gouw**
**& Christoph Senff**

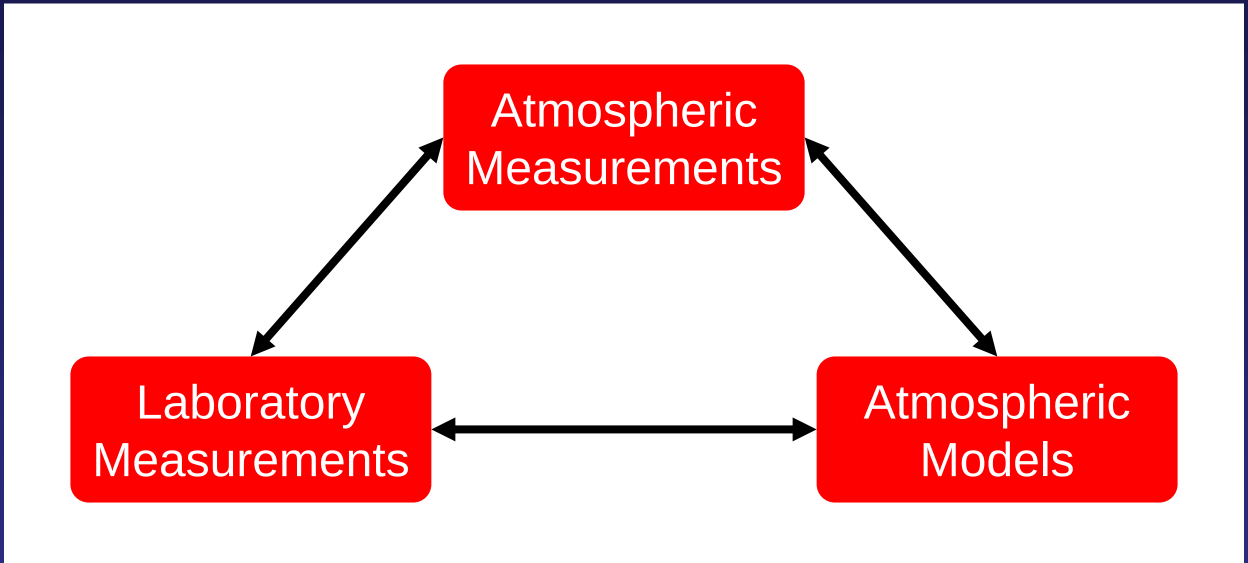
1. Research approach and tools
2. Ozone precursor emissions
3. Nighttime chemical transformation

} Joost

4. Land-sea breeze circulation
5. Ozone regional transport
6. Nighttime transport in low-level jet

} Christoph

# Ozone - Air Quality Research in CSD




- Interplay between different approaches is one of the keys to success
- Collaboration with GSD and PSD on (forecasting) models
- Collaboration with GMD on ozone measurements

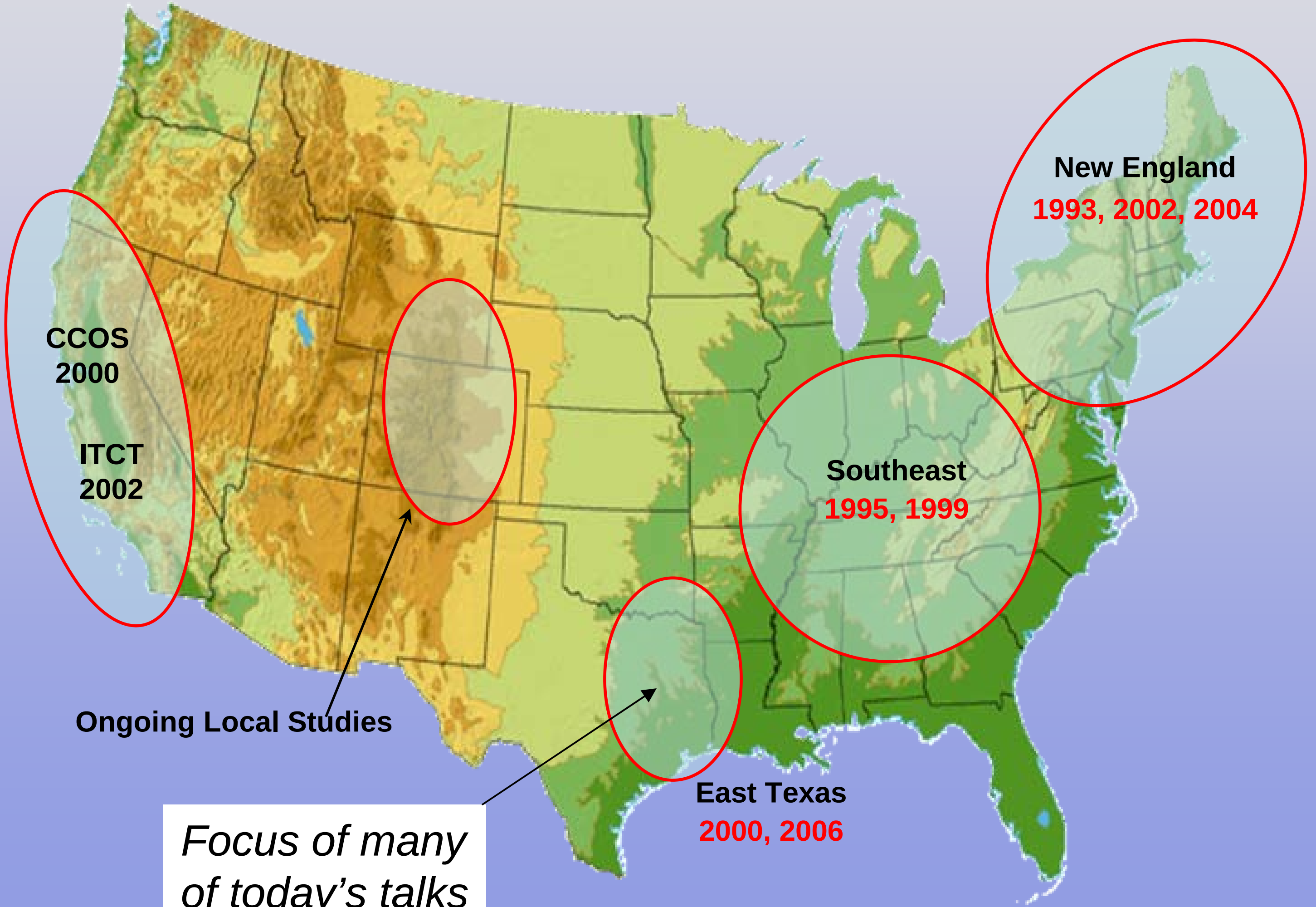
# Tools for Field Measurements Used by CSD

Platforms



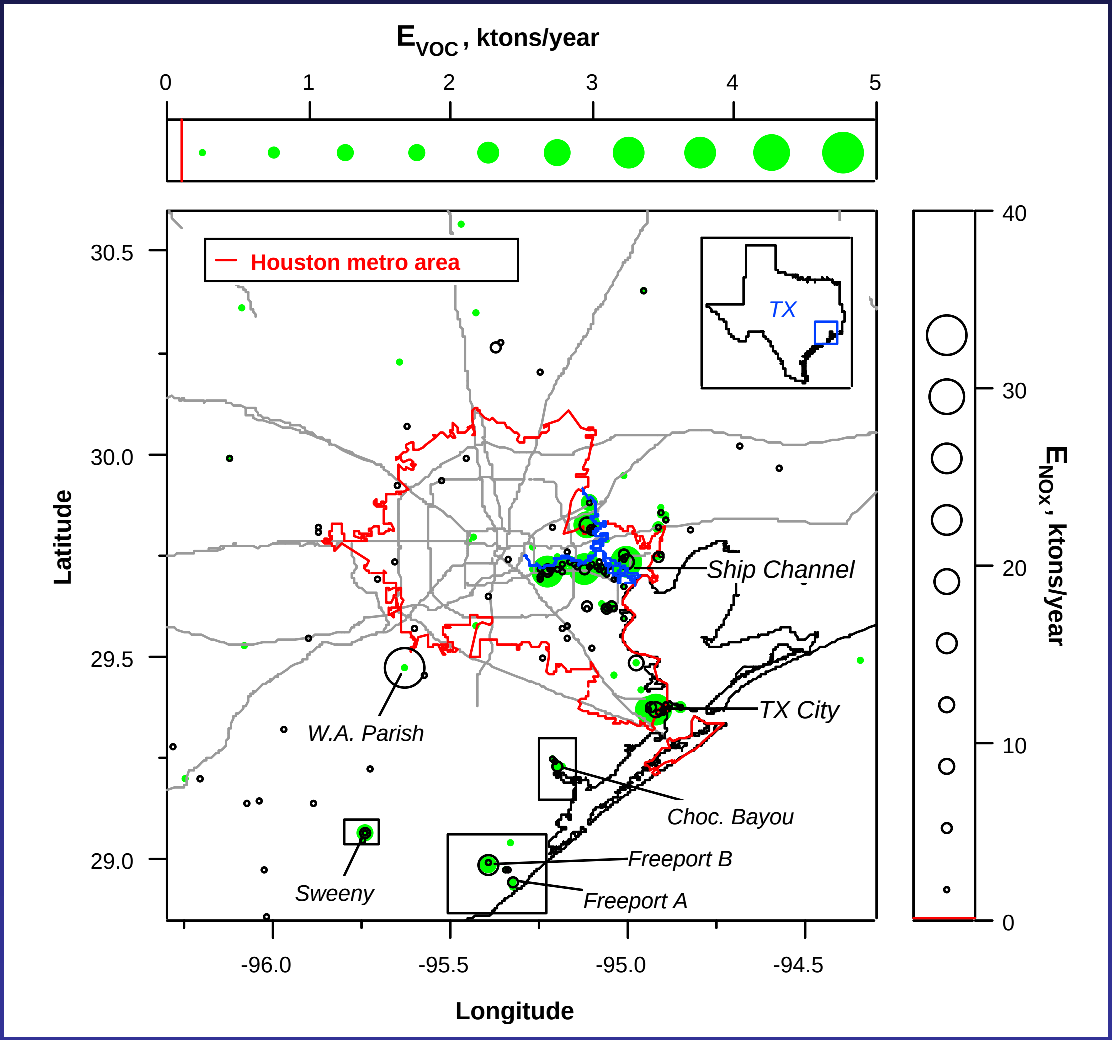

- <u>In-situ Measurements</u> (WP-3 and Ron Brown)
  - Ozone precursors and radiation
  - Radicals
  - By-products of ozone chemistry
- <u>Remote Measurements</u> (Twin Otter and Ron Brown)
  - Ozone lidar
  - Doppler wind lidar

# ESRL Regional Air Quality Field Studies




*Focus of many of today's talks*

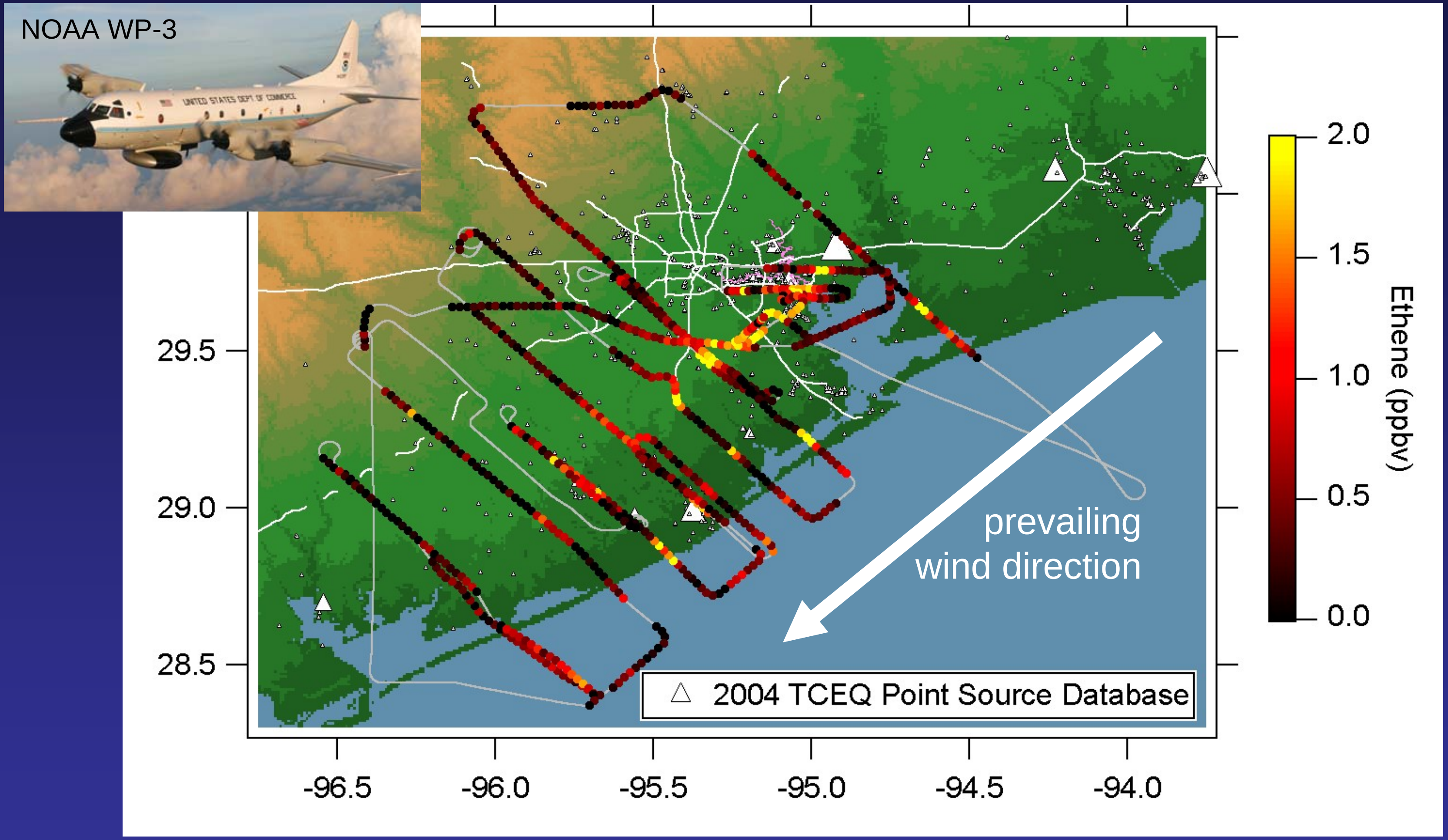
# VOC Emissions from Petrochemical Industries




- Houston has a severe ozone problem due to emissions from the petrochemical industry
- NOAA performed the Texas Air Quality Studies in 2000 and 2006

*Work by: Joost de Gouw, Carsten Warneke, Tom Ryerson*

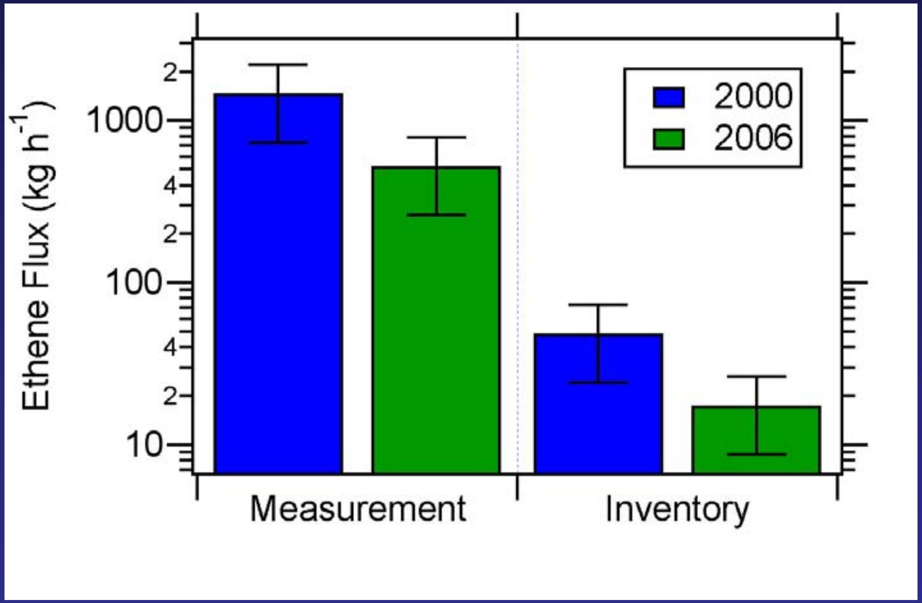
# Ethene Emissions From Industrial Point Sources

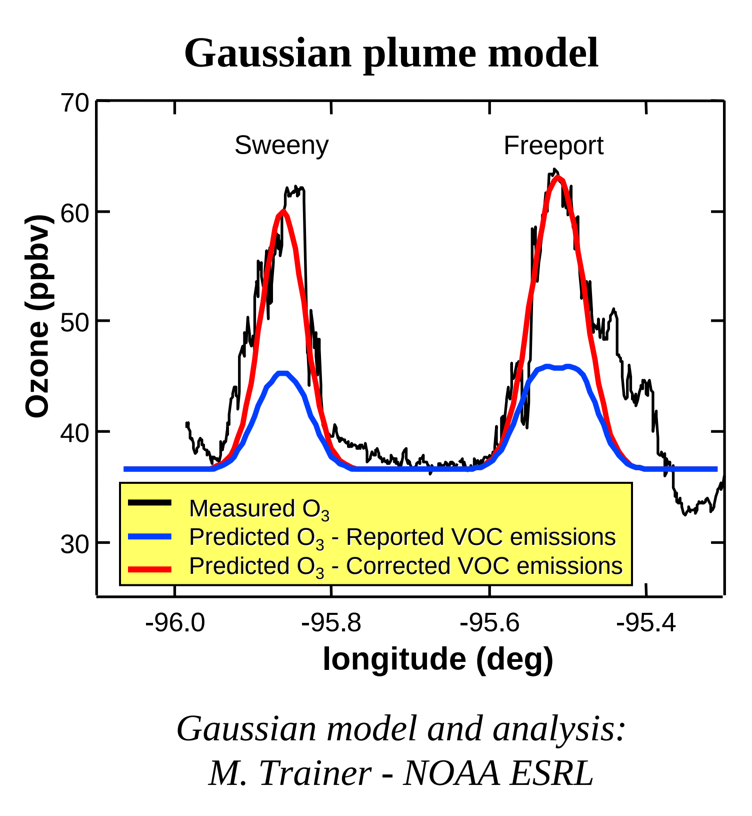



- TexAQS 2000: Ethene is one of the main reactive VOCs
- A laser photo-acoustic instrument was developed for fast-response measurements during TexAQS 2006

# Ethene Emissions From Industrial Point Sources

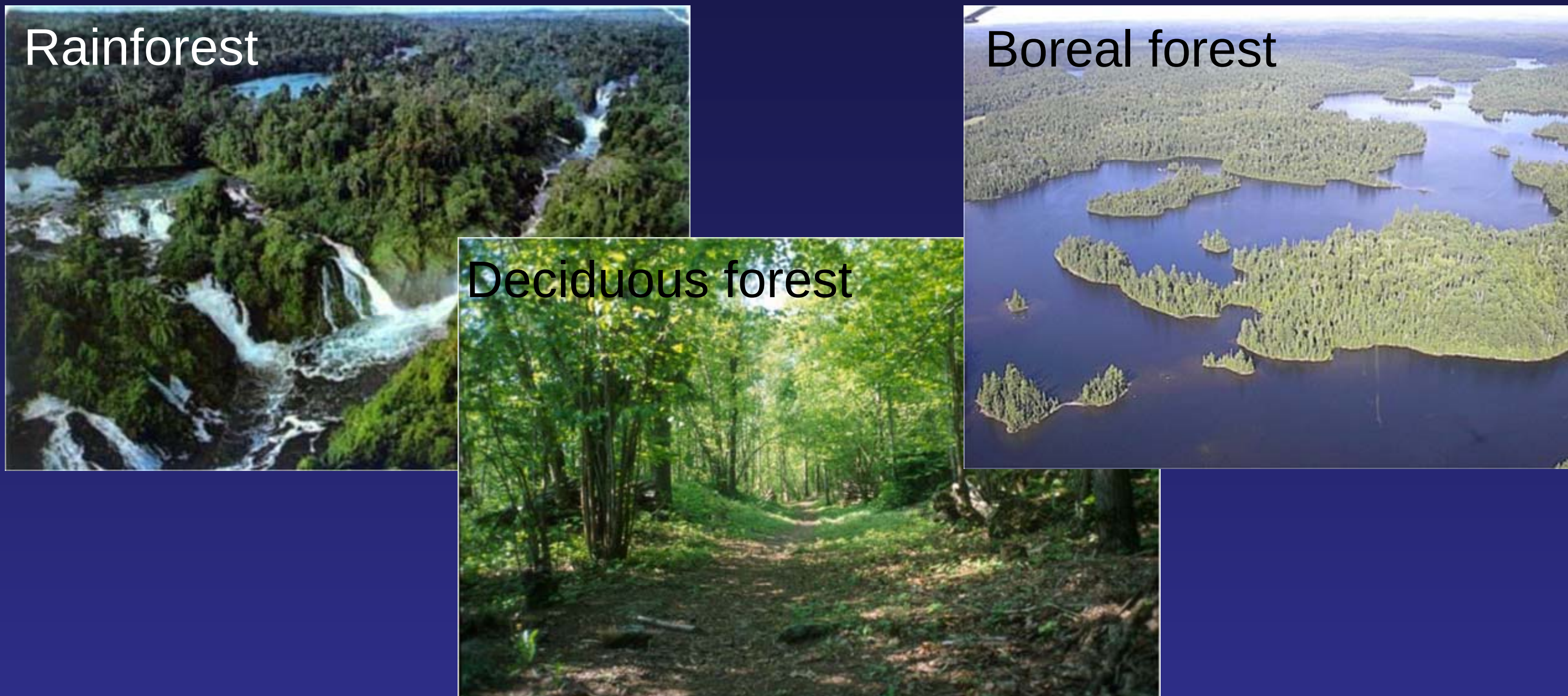
Ethene flux from Freeport:




- ➢ Emissions are severely underestimated in inventories developed by the State of Texas
- ➢ As a result, rapid ozone production in industrial plumes is underestimated by models

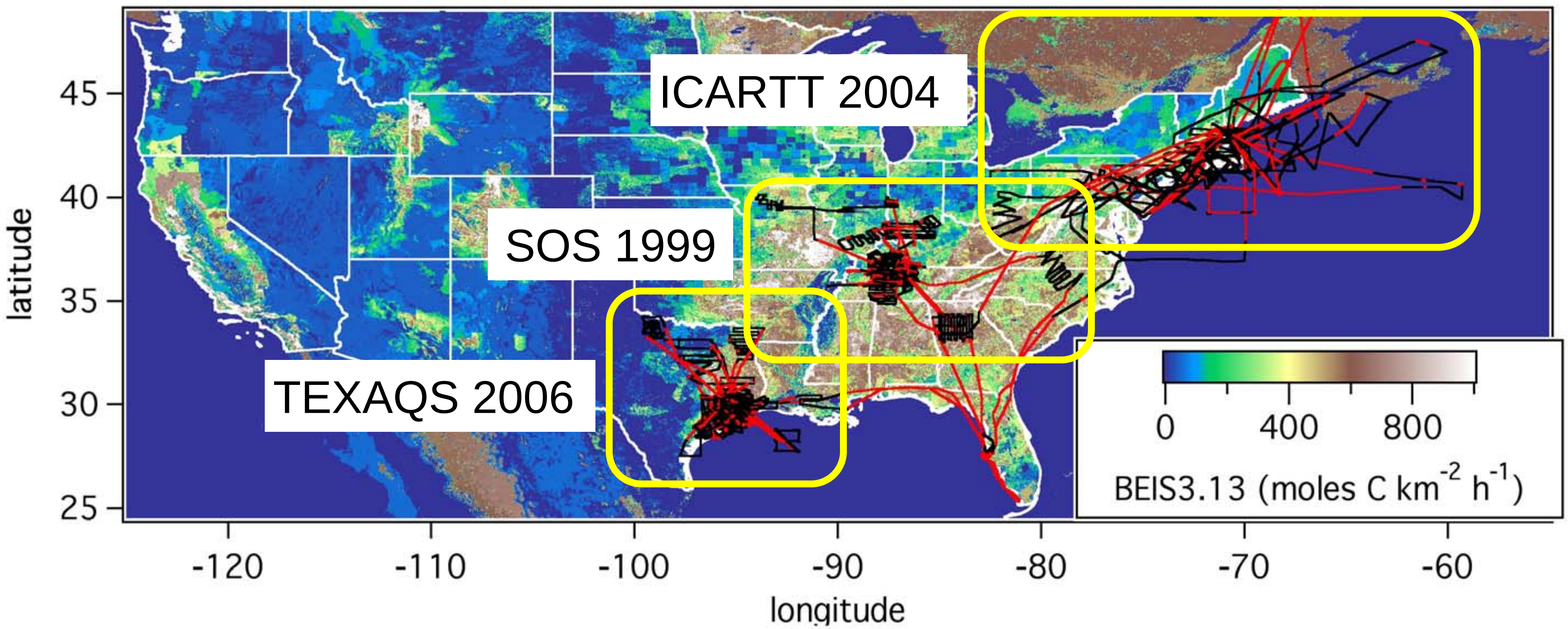
# Verification of Isoprene Emissions Inventories




- Isoprene: large sources ~35% of all VOC emissions
  high reactivity midday lifetime <1 hour
- Reliable estimates of the emissions is key in ozone models

*Work by: Carsten Warneke, Joost de Gouw*

# Validation of Isoprene Emission Inventories

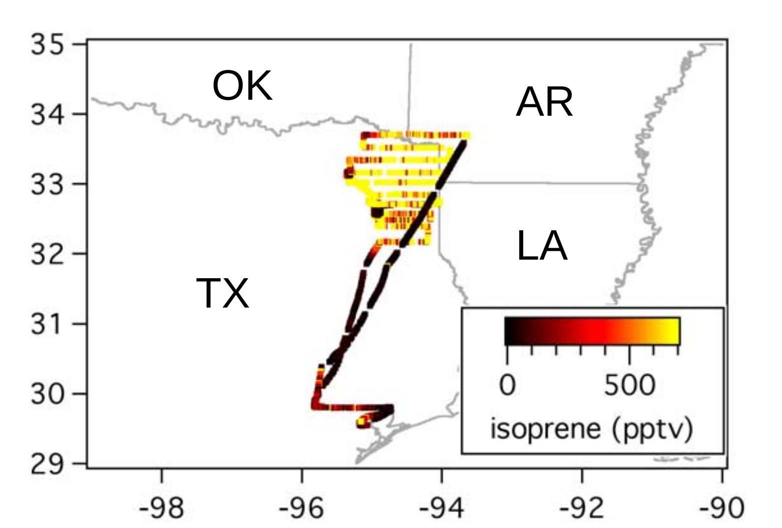


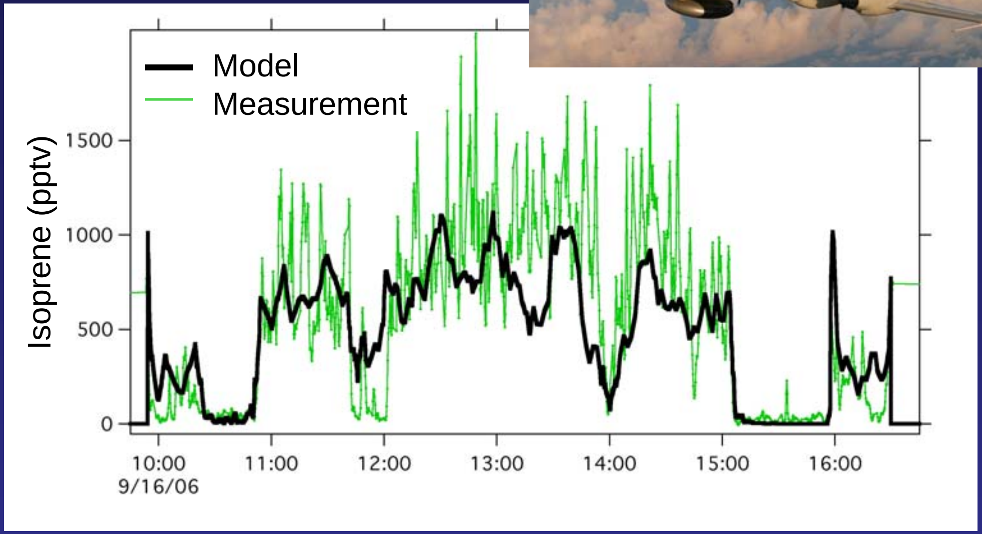

*Warneke et al*. [in preparation]

- Inventories constructed from land-use data and emission factors depending on vegetation type
- Here: validate U.S. emission inventories using aircraft data

# Validation of Isoprene Emission Inventories

Example from 1 research flight over NE Texas:


*Warneke et al*. [in preparation]

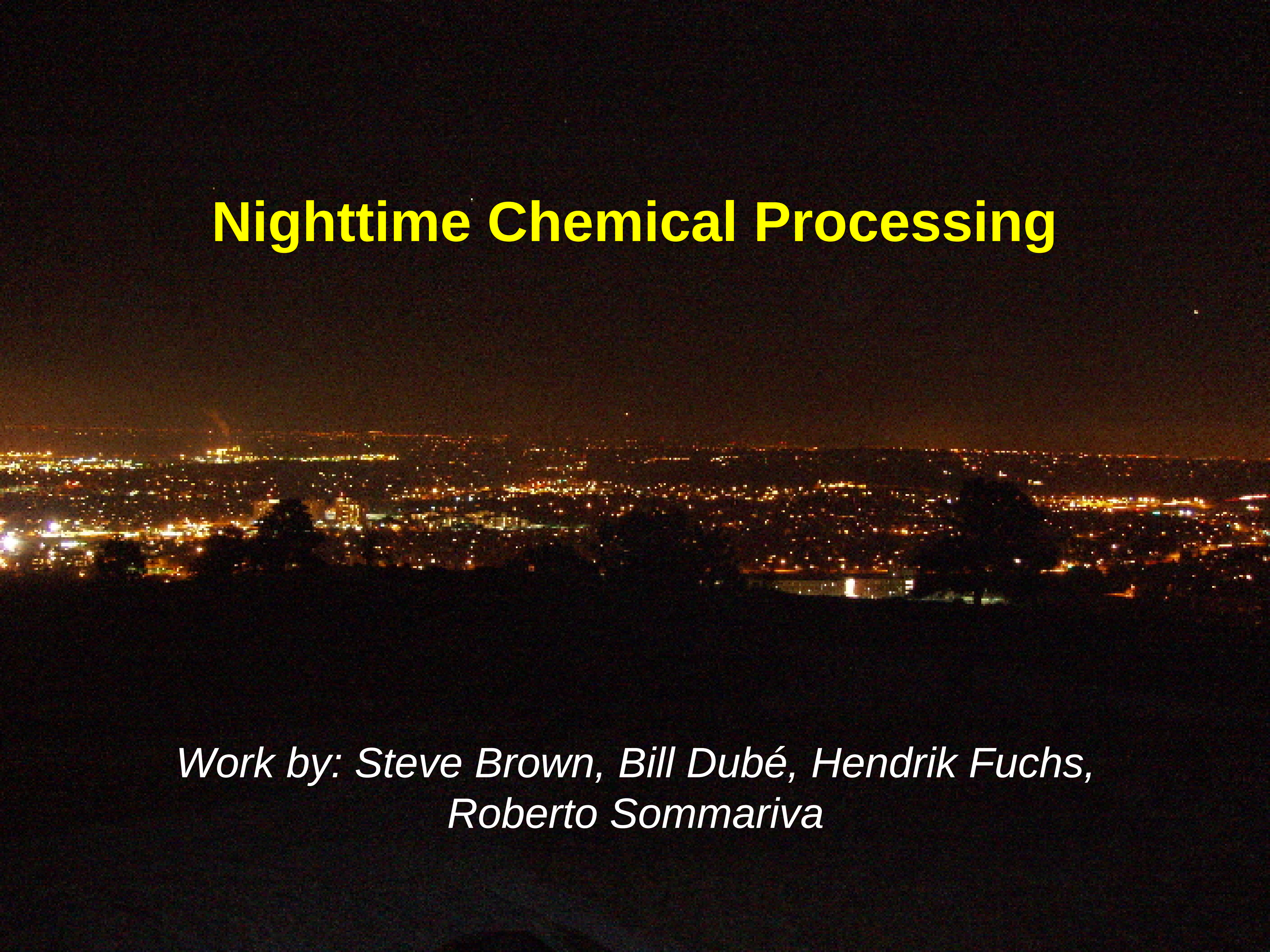
Measurements:

- 1-sec PTR-MS data
- Scatter due to real atmospheric variability

Model:

- EPA BEIS3.13 inventory
- ECMWF temperature and radiation

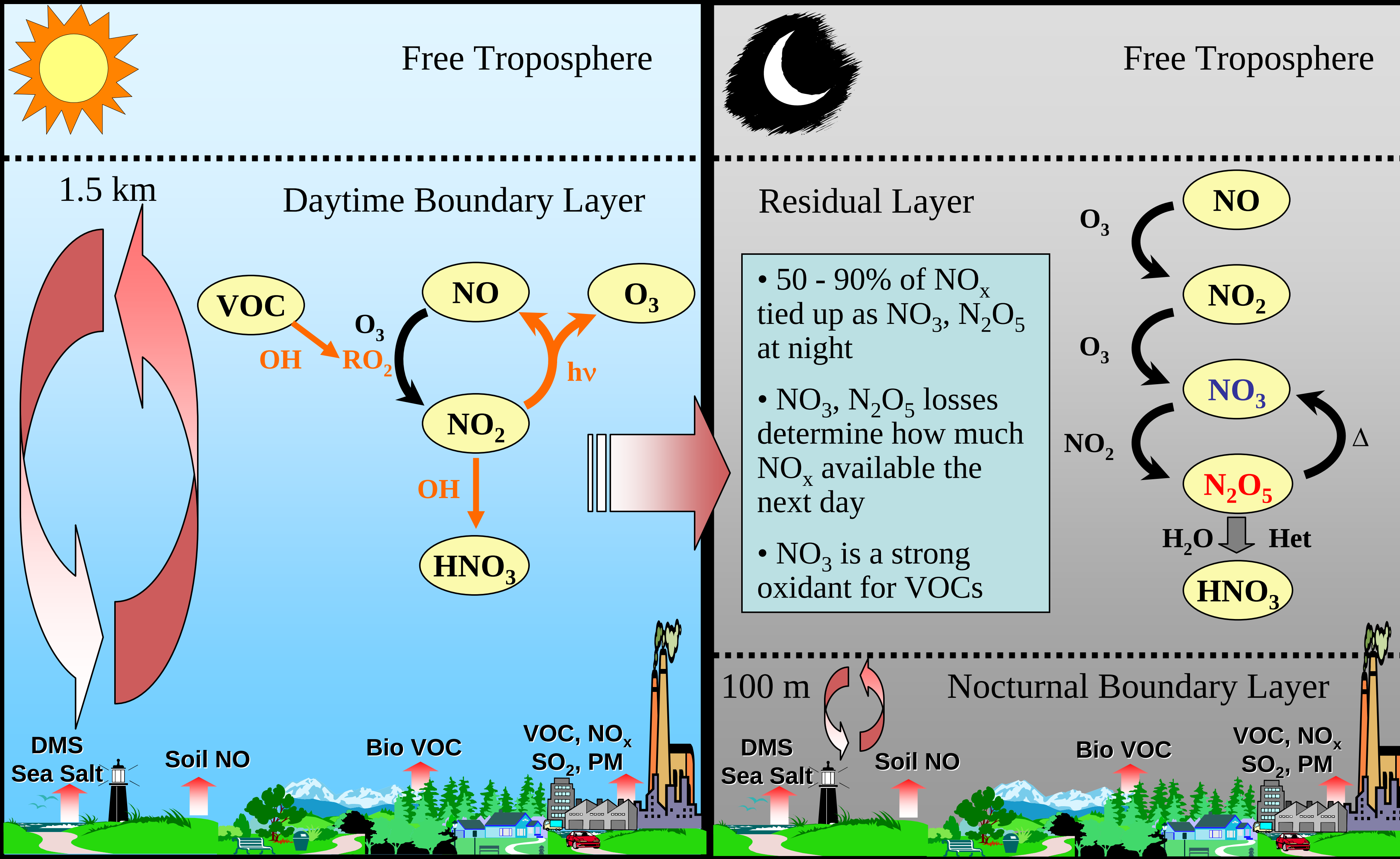
**Measurements agree with inventory within factor of ~2**



# Nighttime Chemical Processing

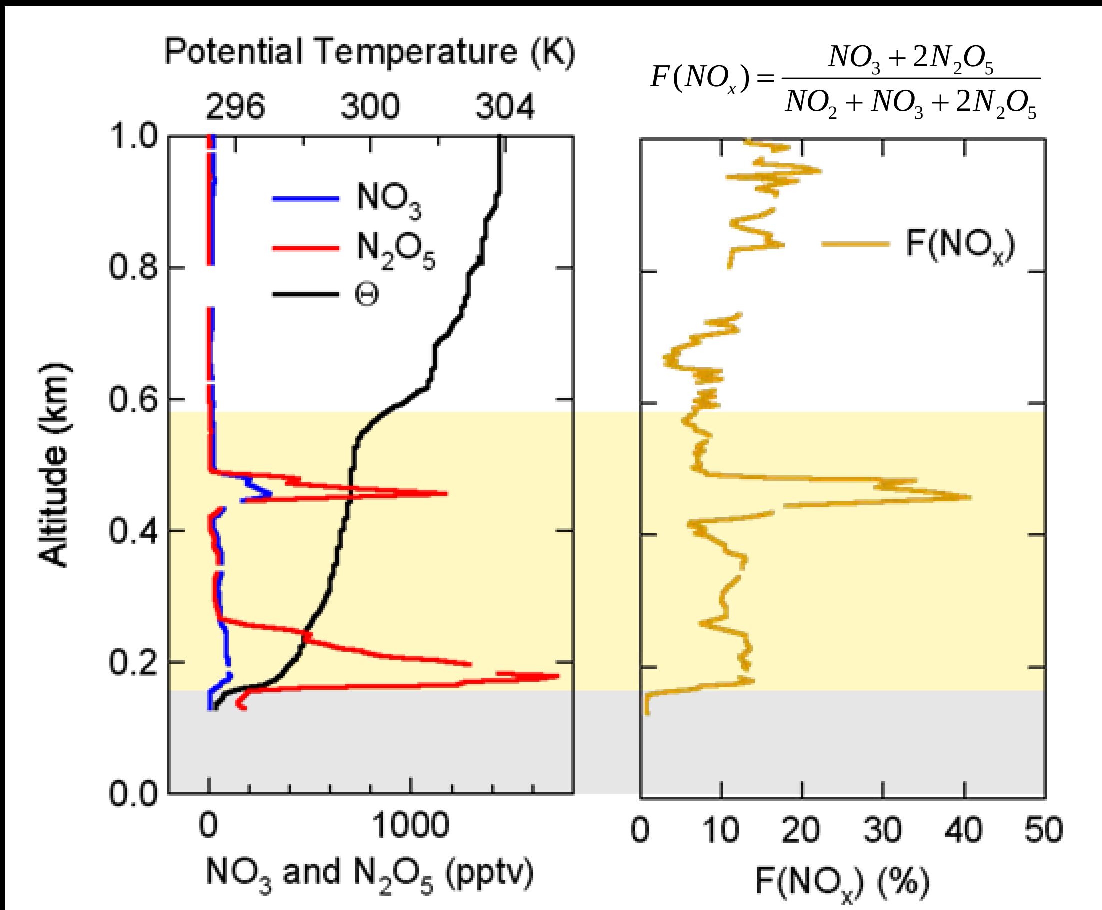
*Work by: Steve Brown, Bill Dubé, Hendrik Fuchs, Roberto Sommariva*

# Diurnal Nitrogen Oxide Cycles




$NO_x$, VOC ,$O_3$ transformed at night

# Vertical Stratification & Nighttime Chemistry

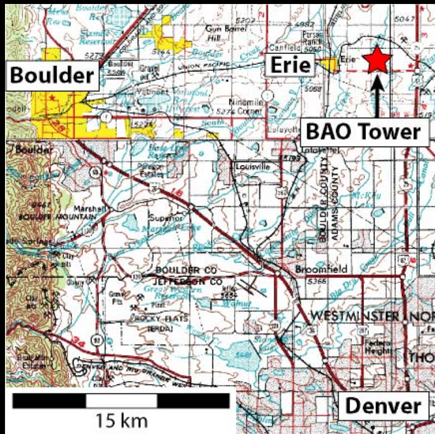

Residual Daytime Boundary Layer

Intermediate Layer

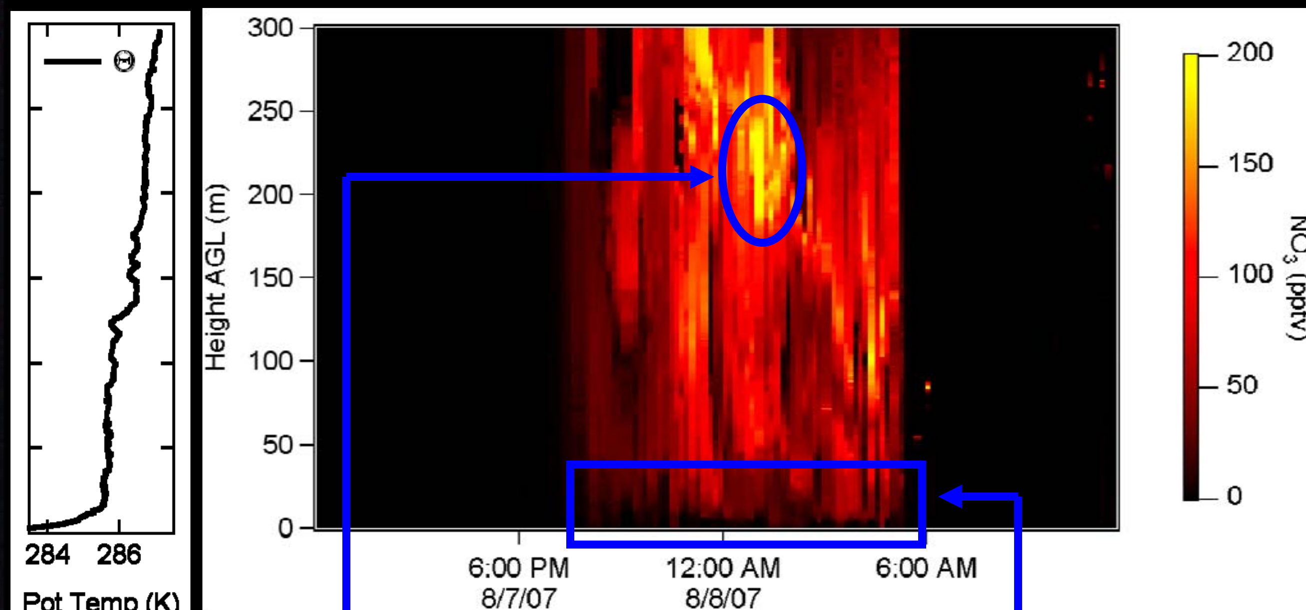
Nocturnal Boundary Layer

- $NO_x$ and VOC plumes occur in discrete layers at night
- Chemical transformation within different layers differs markedly

# Boundary Layer Vertical Profiles Erie (BAO) Tower




- 300 m w/ vertical resolution ~ 0.5 m
- Movable carriage on *outside* with > 1 ton payload
- Studies in 2004 (fall) and 2007 (summer)




- High $NO_3$ routinely observed aloft
- Often associated with complex layering

Surface layer commonly observed

# Ozone Transport and Mixing Processes

- **Local-scale transport:**

  **Land – sea breeze circulation in Houston, TX**

- **Regional transport:**

  **Increasingly important as 8-hour $O_3$ standards are tightened**

- **Nighttime processes:**

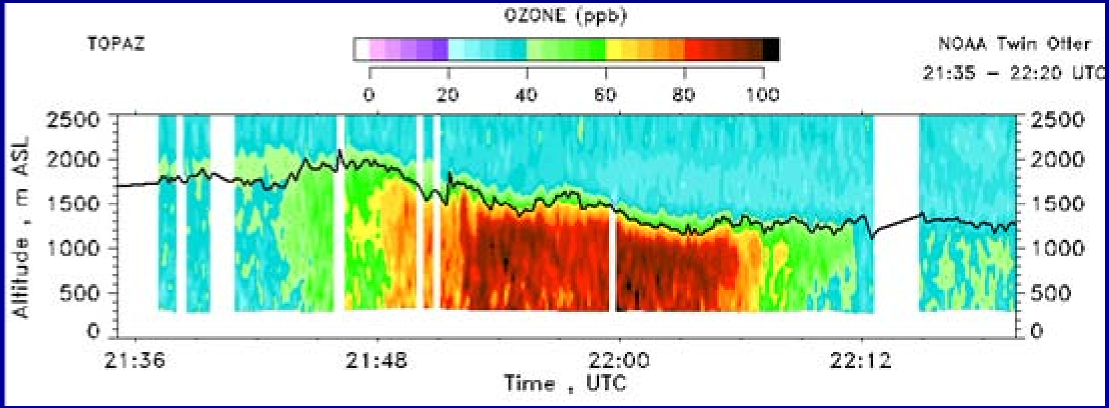
  **Transport and mixing by low-level jet**

# Measurement tools:
# LIDAR & RADAR Remote Sensing

**Ozone Lidar:**

TOPAZ = Tunable Optical Profiler for Aerosol and Ozone

**TOPAZ lidar mounted in NOAA Twin Otter**



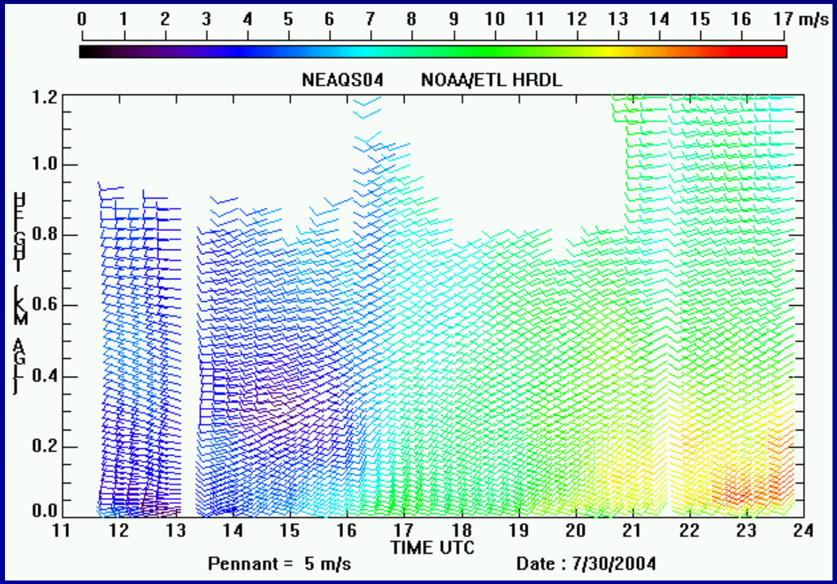

**Ozone profiles & mixed layer height**

R. Alvarez II, C. Senff, et al.

# Measurement tools:
# LIDAR & RADAR Remote Sensing

## Doppler Wind Lidar:

HRDL = High Resolution Doppler Lidar

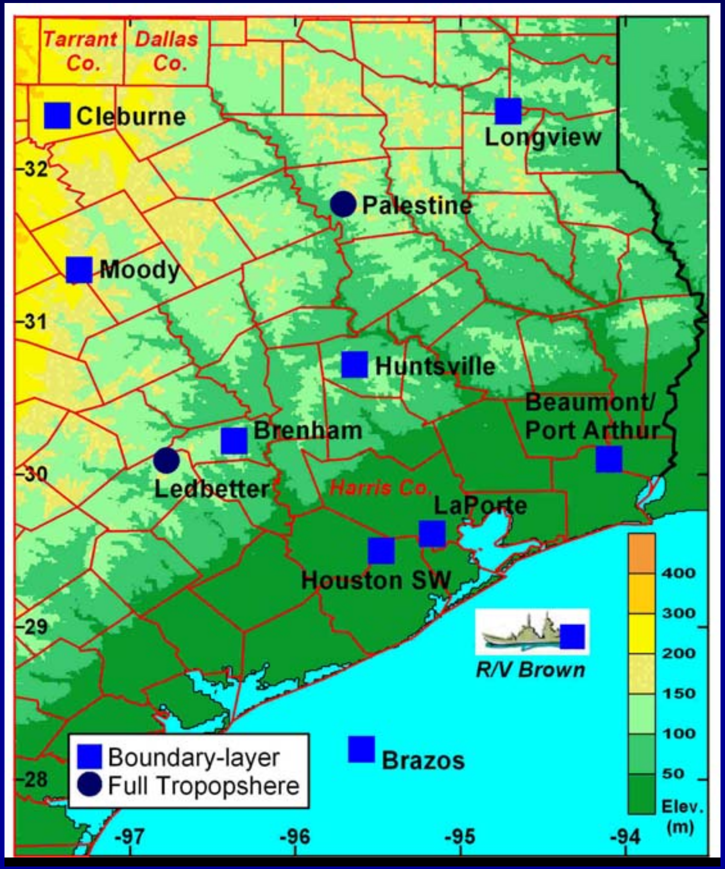



S. Tucker, A. Brewer, et al.

Wind speed & direction profiles

# Measurement tools:
# LIDAR & RADAR Remote Sensing

## Wind Profiler Network (PSD):



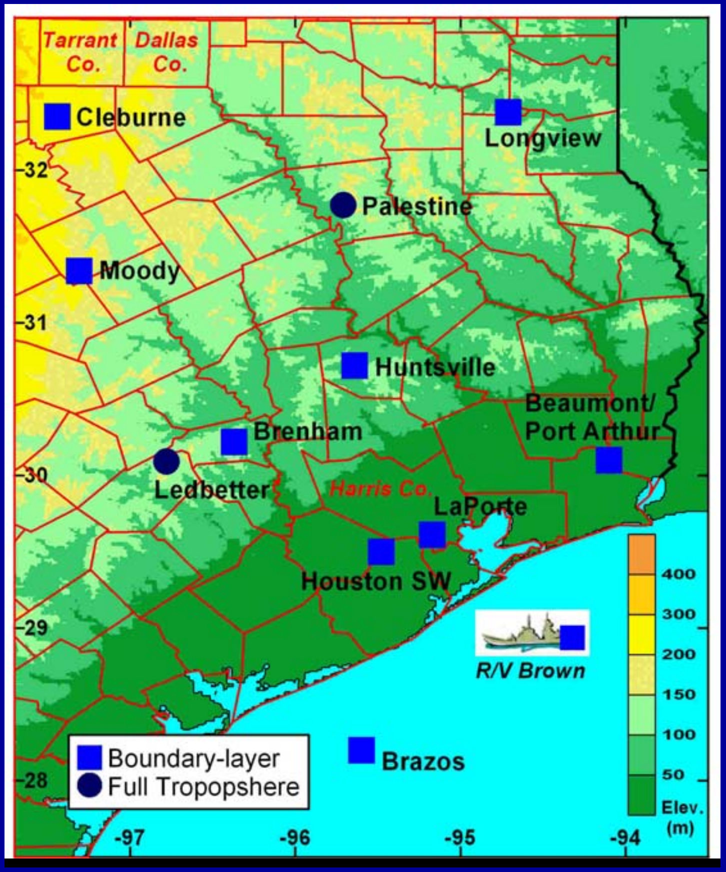

TEXAQS-II East Texas Wind Profiler Network

NOAA/ESRL Integrated Wind Profiler Observing Site

A. White et al.

# Measurement tools:
# LIDAR & RADAR Remote Sensing

## Wind Profiler Network (PSD):

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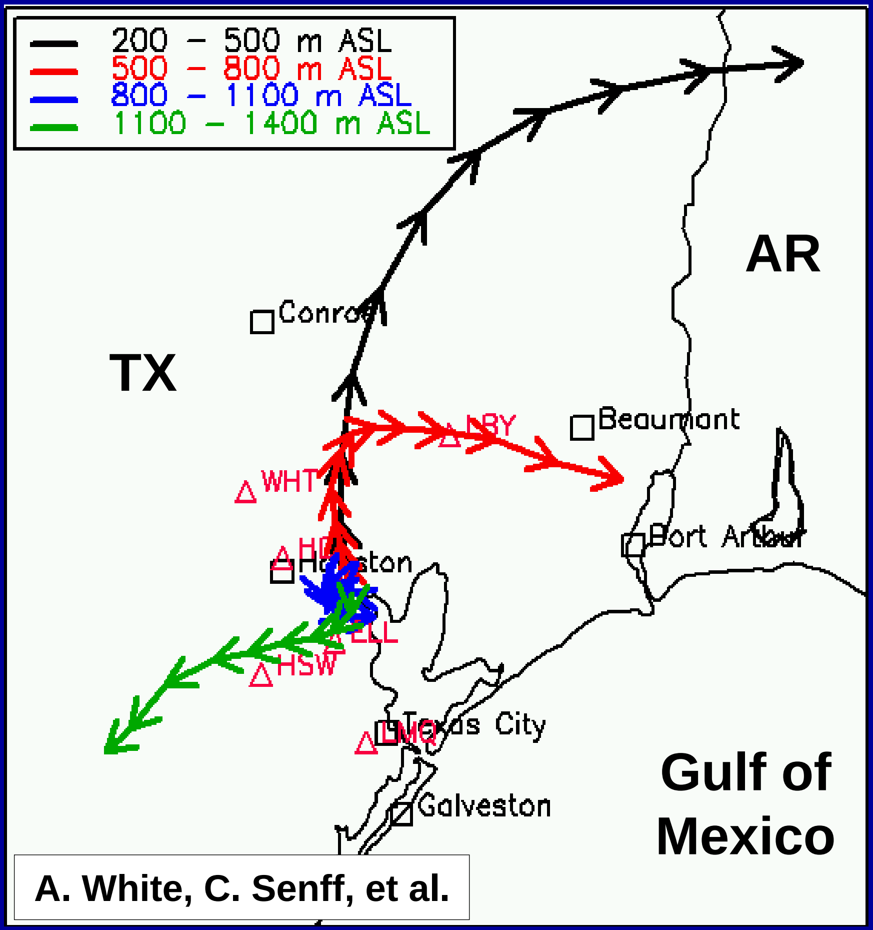
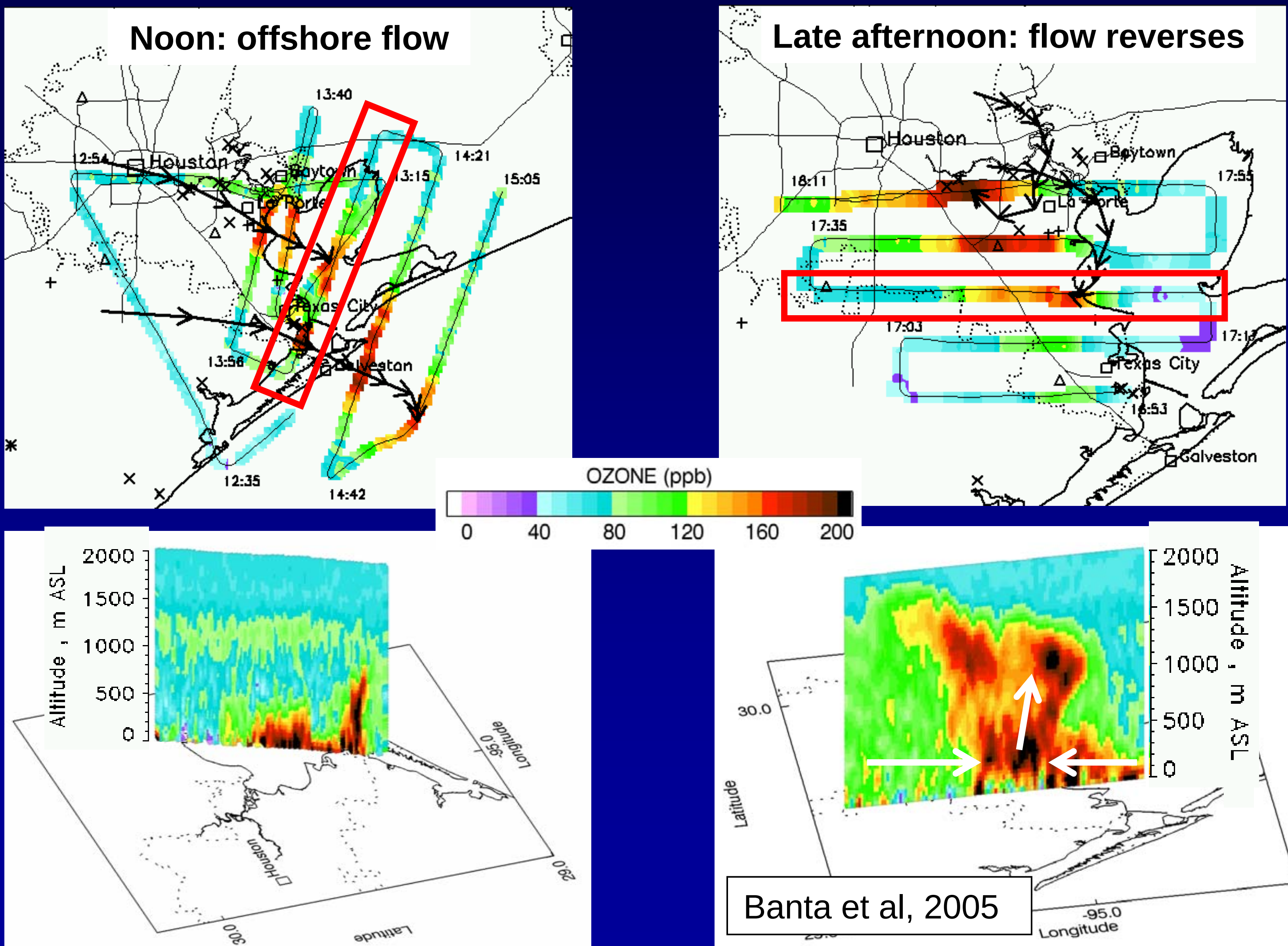


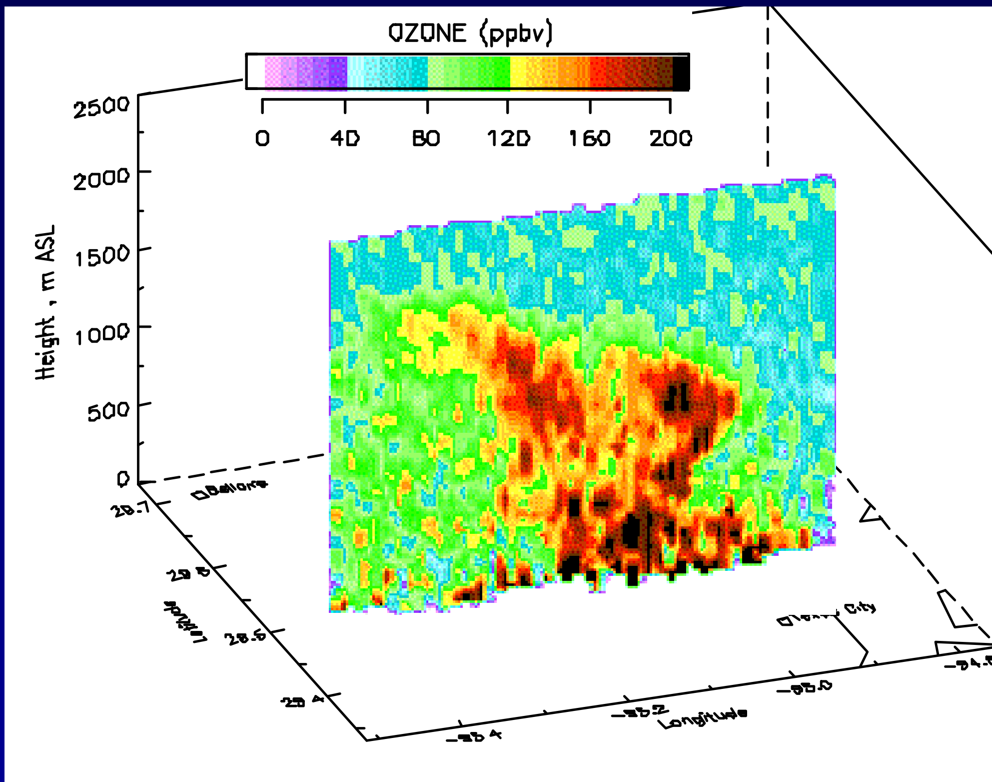

Interactive wind profiler trajectory tool

A. White et al.

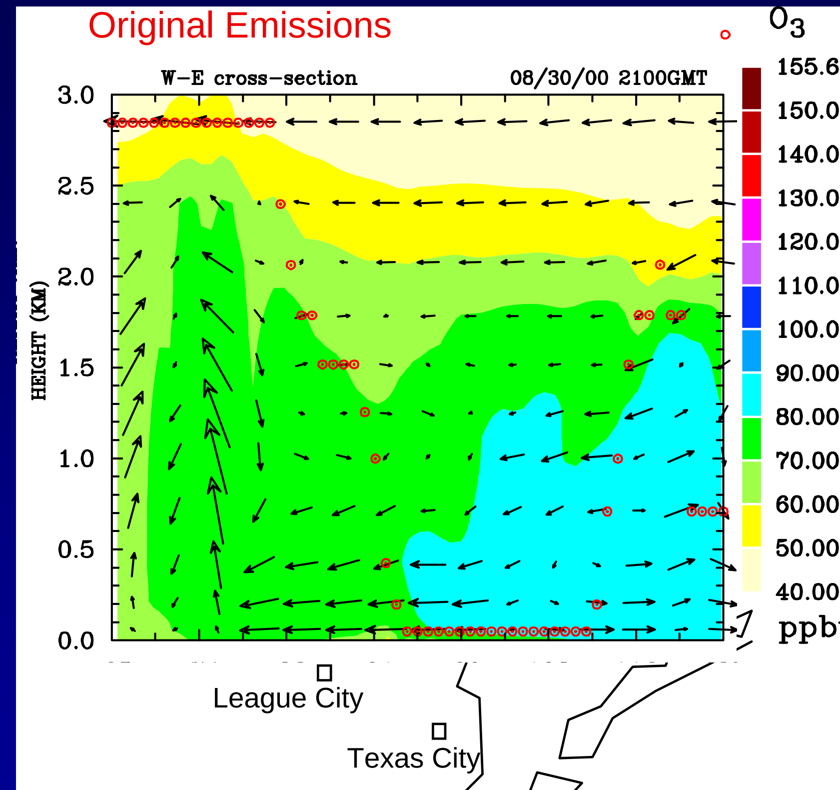
# Local Transport:
# Houston land-sea breeze recirculation



# Air Quality forecast model comparison with lidar




Lidar $O_3$ cross section




MM5/Chem model
(1.7 km horizontal resolution)

J.-W. Bao, G. Grell, S. McKeen

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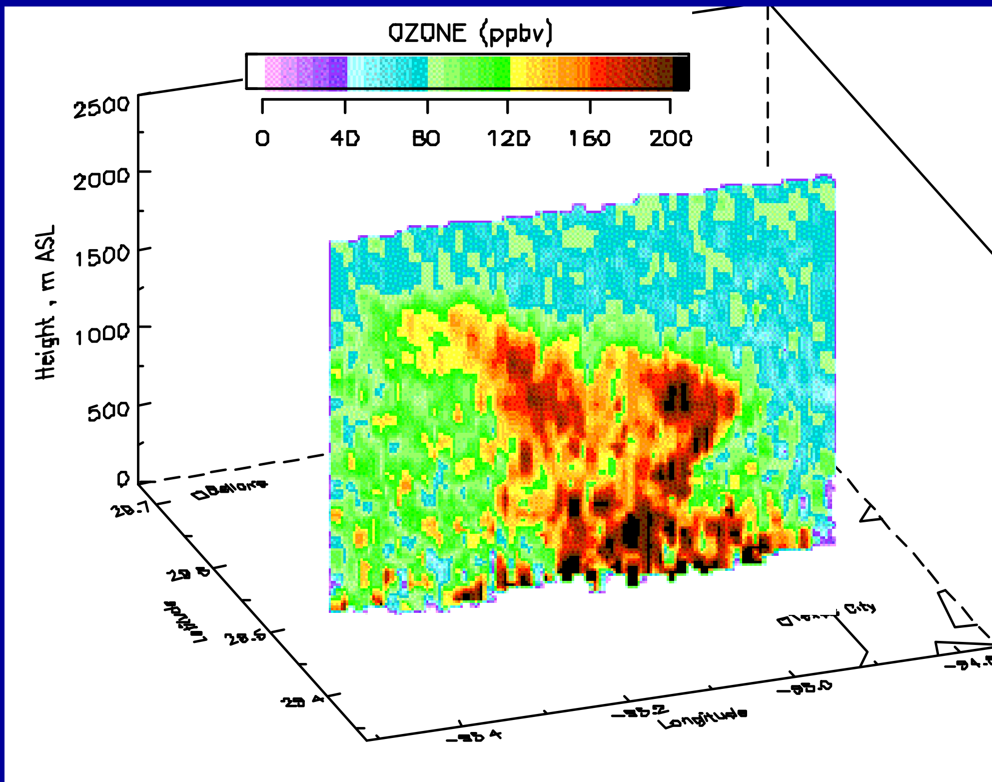
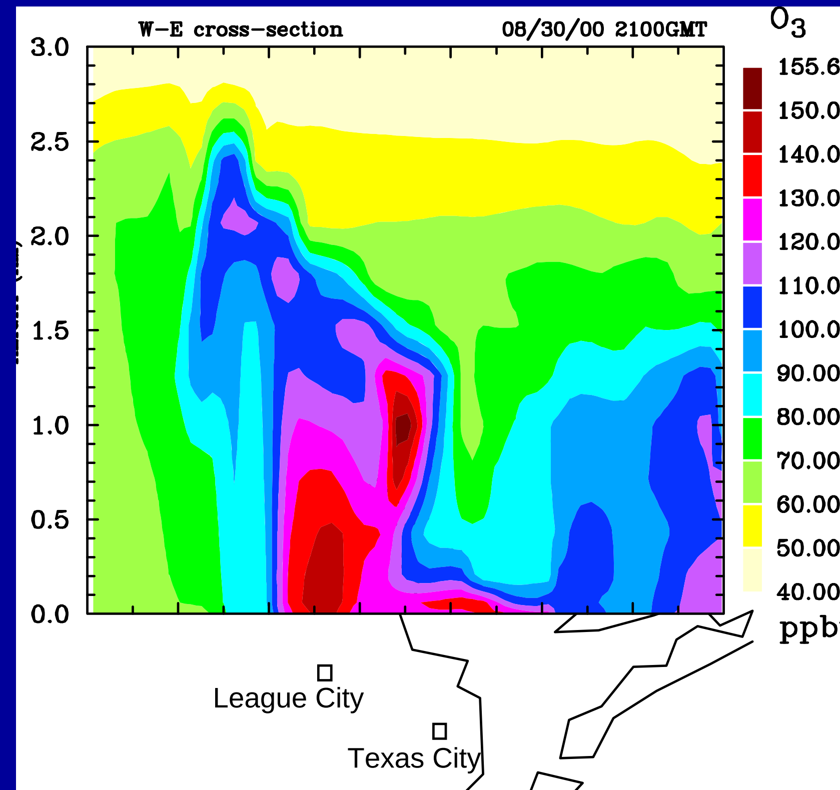



Lidar $O_3$ cross section




MM5/Chem model
(1.7 km horizontal resolution)

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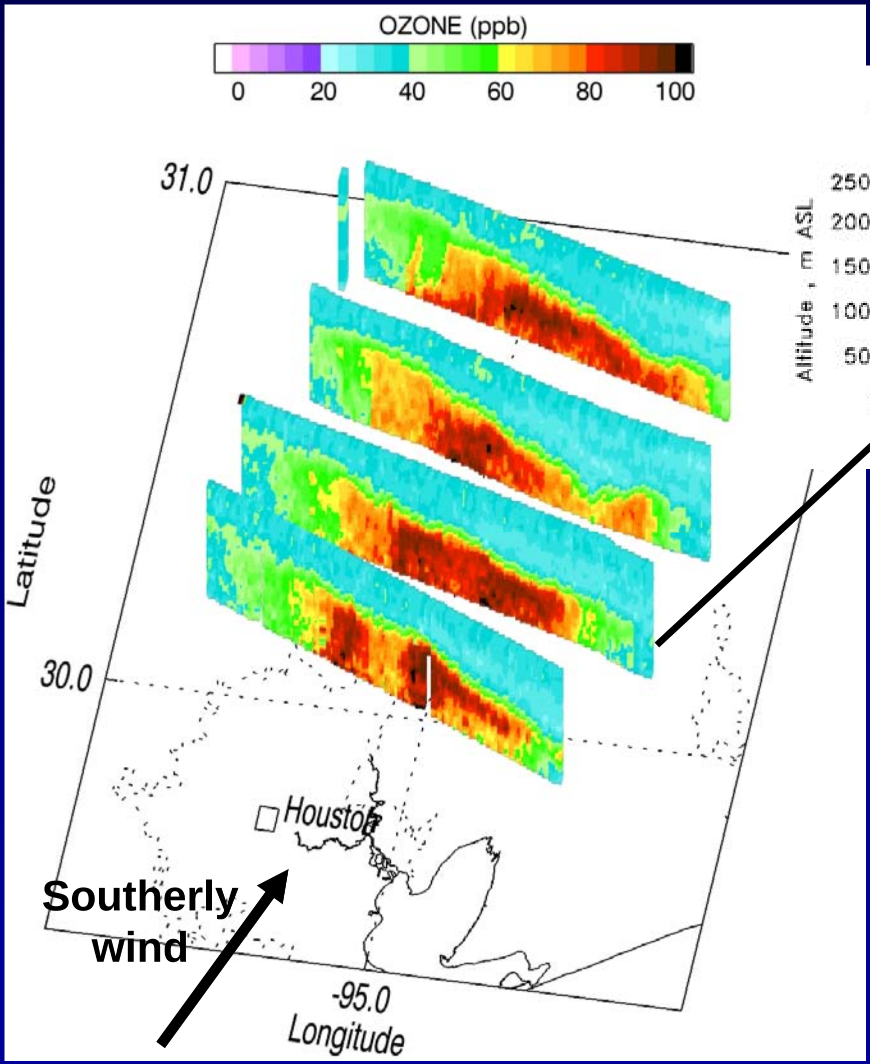
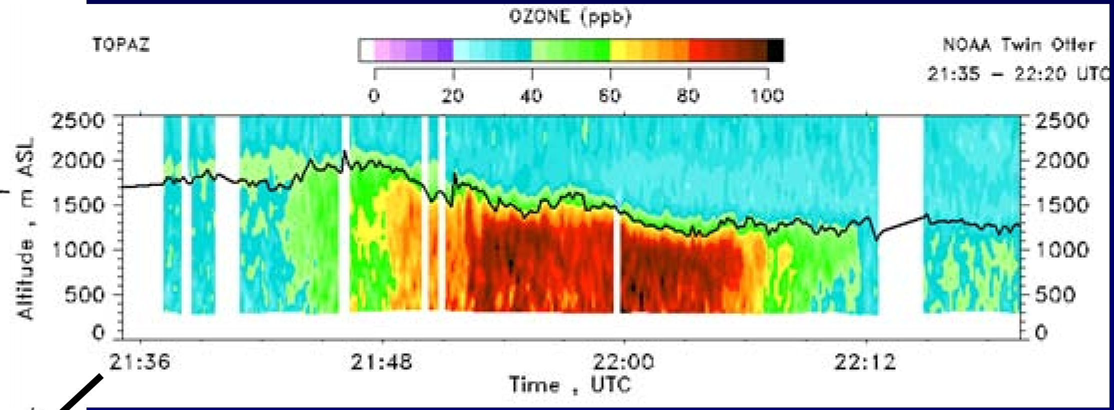
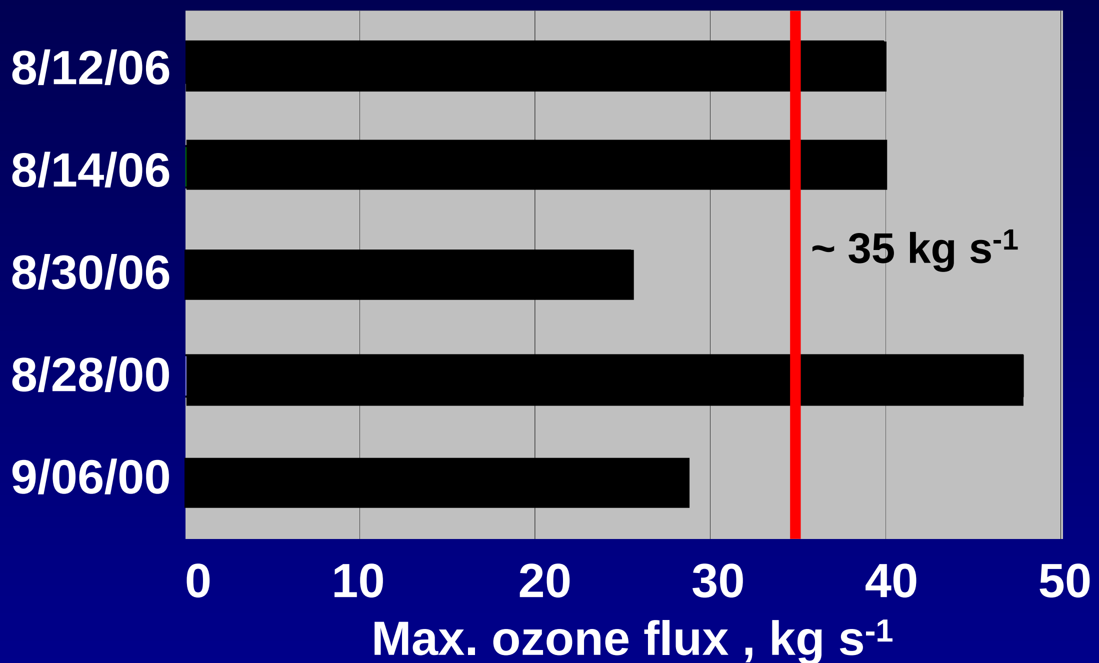
# Regional Transport:
# Estimating ozone exported from Houston



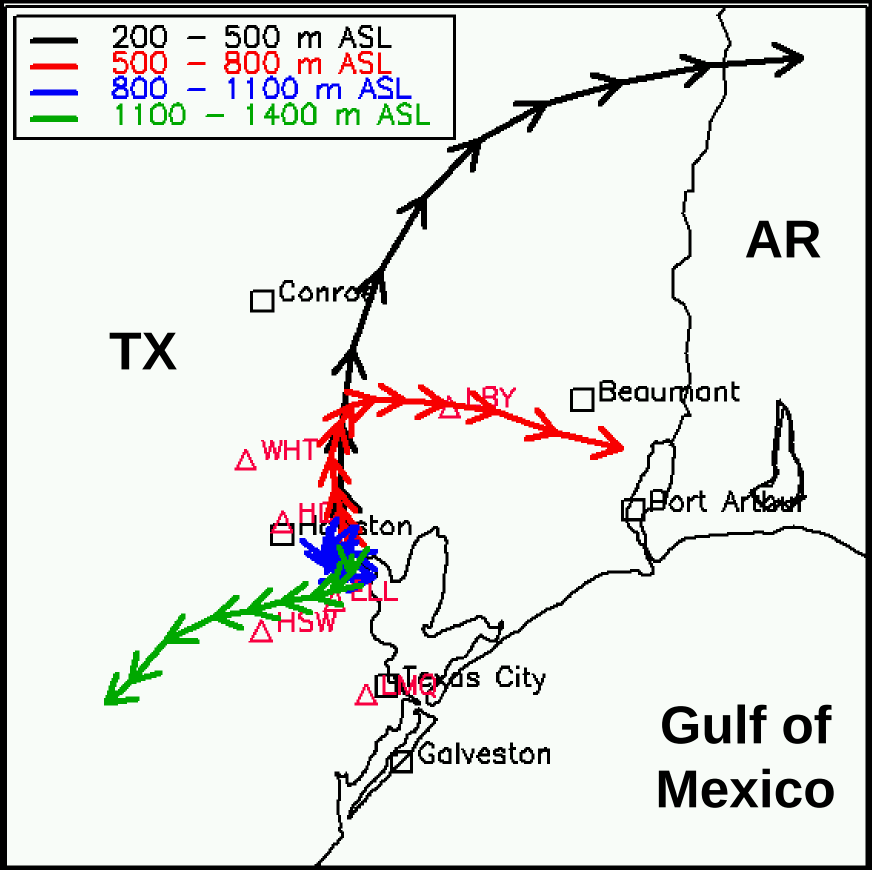

- Integrate excess ozone in plume (plume $O_3$ – background $O_3$).
- Multiply with horizontal wind speed (from wind profiler network) to yield ozone flux for each transect.

# Regional Transport: Houston Ozone Flux




**A flux of 35 kg $O_3$ $s^{-1}$ transported out of Houston over an 8-hour day is equivalent to a 10-ppb increase in ozone over an approx. 10,000 square mile area, assuming a 2-km deep mixed layer.**

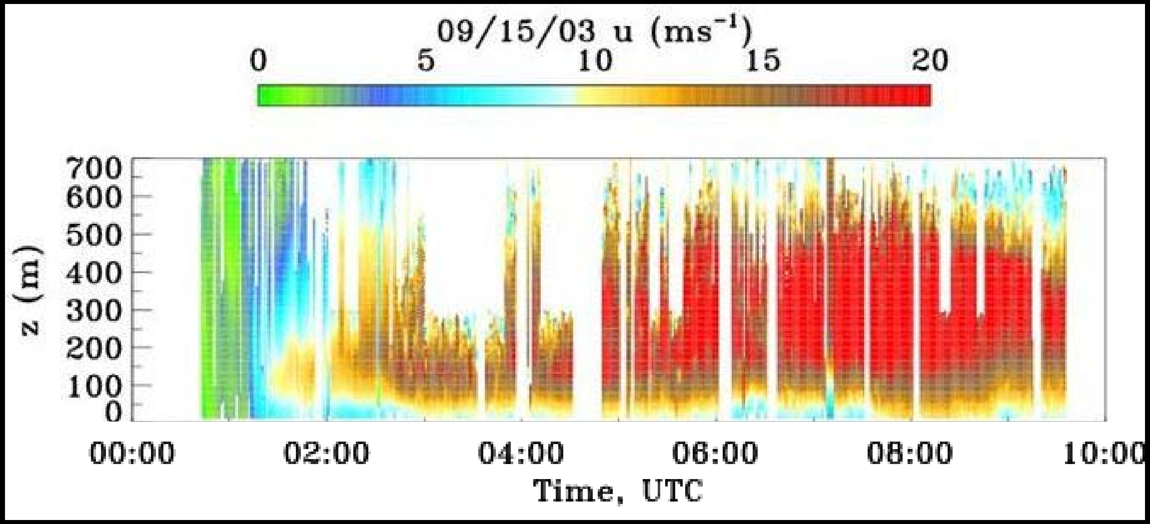
# Nighttime Transport & Mixing




12-hour forward trajectories:
6 PM – 6 AM LST

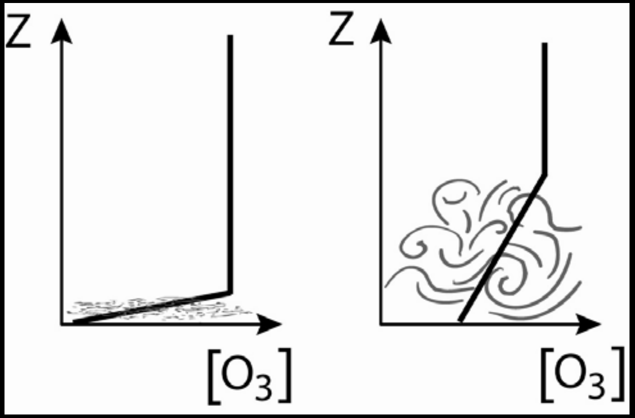
- Nighttime low level jet can transport $O_3$ over long distances.
- Speed and directional wind shear at night are very effective in distributing $O_3$ over large areas.

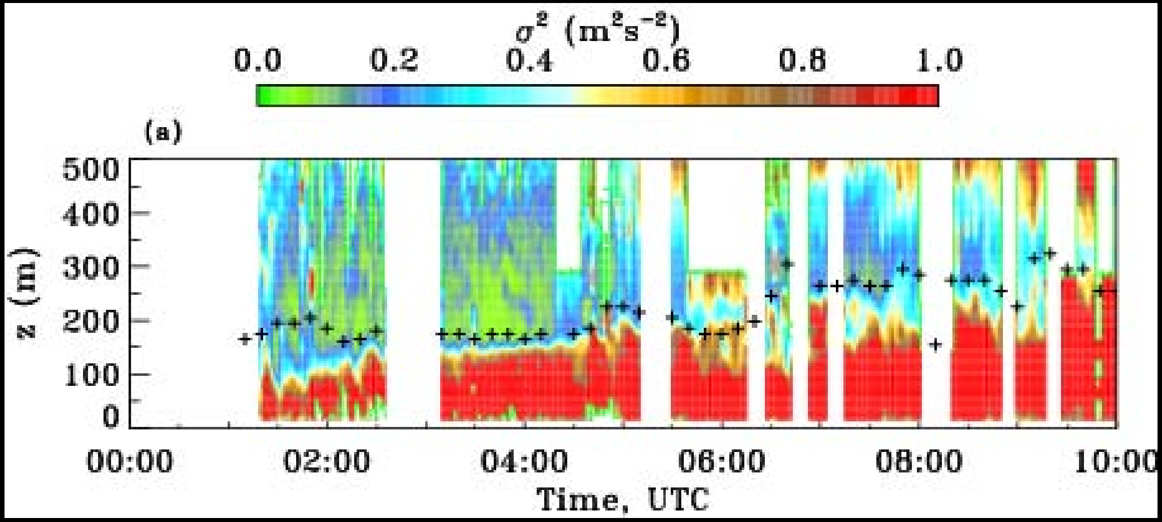
# Nighttime Transport & Mixing




Nighttime low-level jet (LLJ) structure

***w/o LLJ*** ***w/ LLJ***

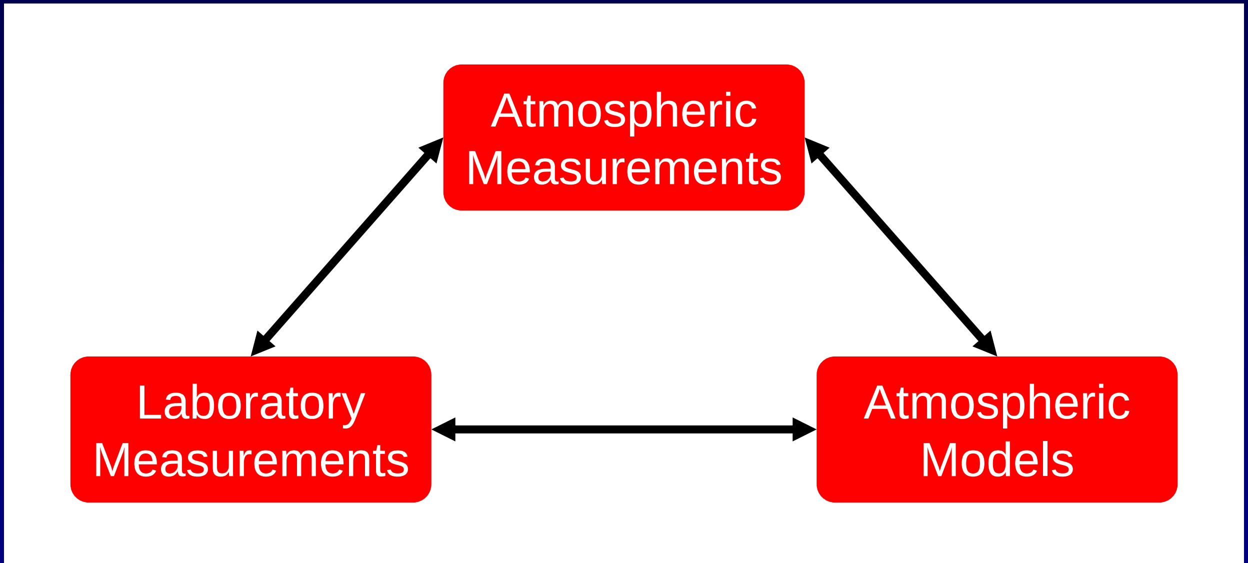



Wind speed variance: $\sigma_u{}^2 \approx$ TKE

R. Banta, Y. Pichugina, et al.

# Summary: Ozone - Air Quality Research in CSD




- Atmospheric measurements of emissions, chemical and dynamical processes are an important cornerstone.
- Laboratory measurements and modeling studies complete CSD's ozone – air quality research approach.