Overview
Deep Convective Clouds and Chemistry (DC3) Field Experiment
Science Plan & Experimental Design

NCAR

NCAR is funded by the National Science Foundation

History & Principal Investigators

- UTLS Workshop 2003 – first discussed idea
- September 2005 – initiated planning the experiment
- April 2006 – 1st planning workshop
- August 2008 – 2nd planning workshop
- January 2009 – submitted proposal to NSF & request for facilities
- May 2011 – DC3 Test Flights
  - Test new instruments on GV, practice flight patterns, exercise daily briefing

- Principal Investigators:

  Mary Barth, Chris Cantrell, Steve Rutledge, Bill Brune

DC3 Steering Committee

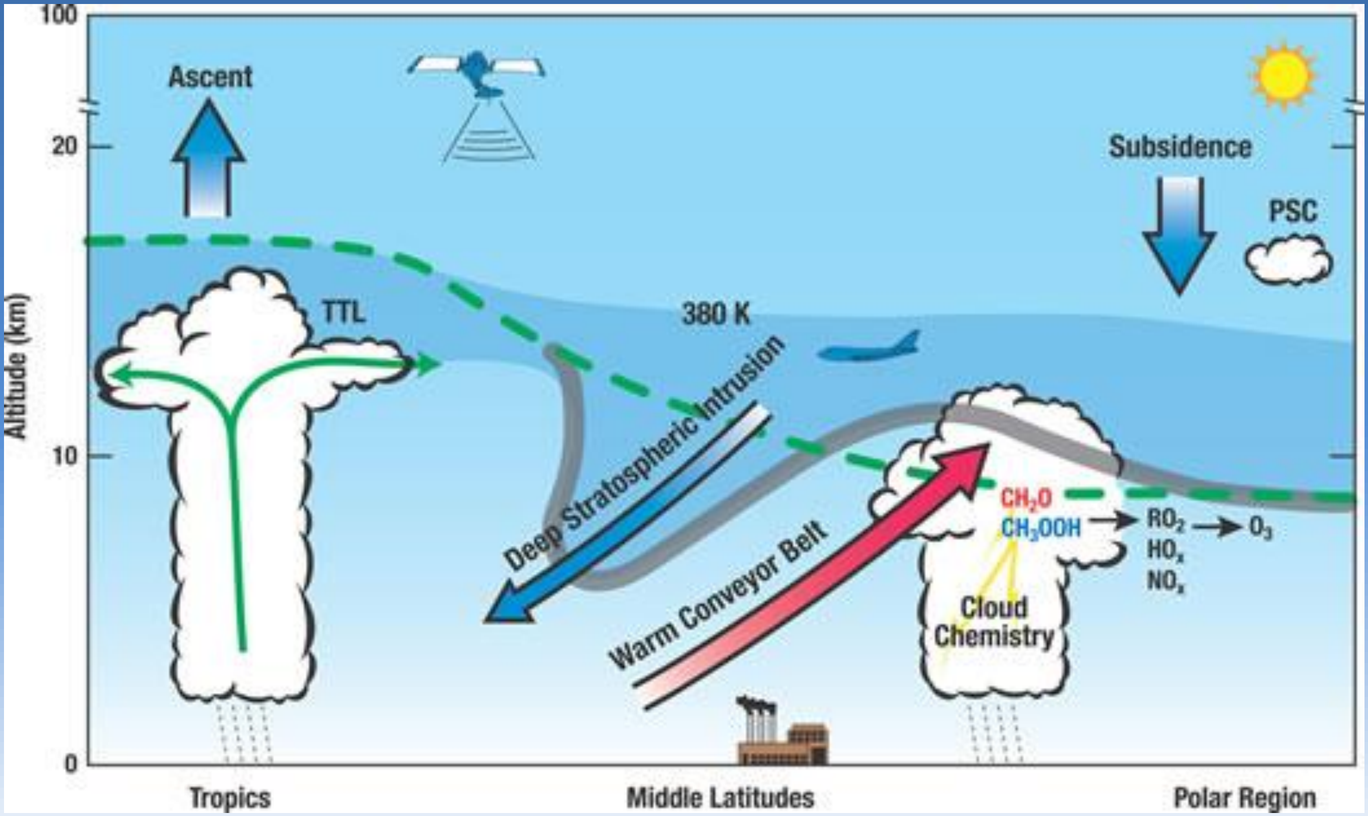
- Mary Barth, Chris Cantrell, Steve Rutledge, Bill Brune
- Owen Cooper
- Alan Fried
- Paul Krehbiel
- Laura Pan
- Ken Pickering
- Andy Weinheimer
- Jim Crawford
- Andrew Heymsfield
- Don MacGorman
- Larry Carey
- Jeff Stith

Support Personnel

- Logistics Support: Vidal Salazar, Jim Moore
- GV: Allen Schanot DC-8: Rick Shetter
  DLR: Heidi Huntrieser Falcon: Andrea Hausold
- http://www.eol.ucar.edu/projects/dc3

Motivation

- Ozone in the UTLS region is important for climate change and for affecting the UV radiation reaching the Earth's surface



UTLS = upper troposphere & lower stratosphere

Motivation

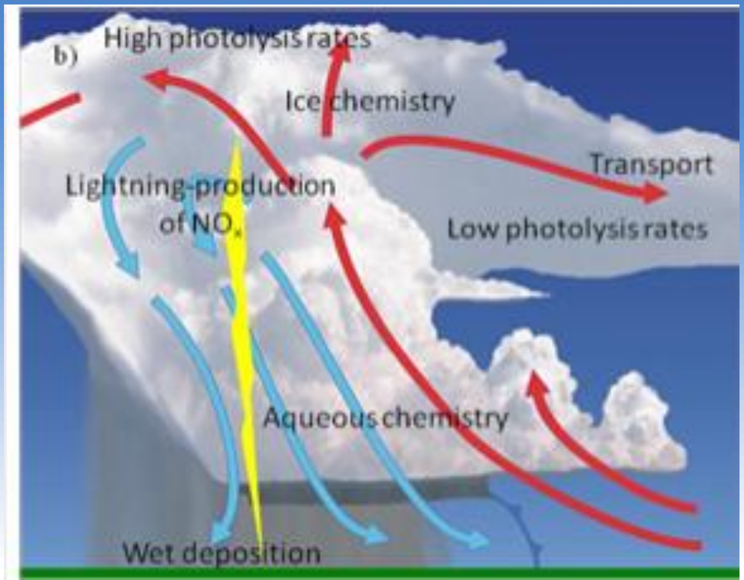
- Ozone in the UTLS region is important for climate change and for affecting the UV radiation reaching the Earth's surface
- How much does deep convection alter the composition of the UTLS region?
  - Transport of BL species from the surface to the UT → hydrogen oxide radicals (HO_x)
  - Lightning production of nitrogen oxides (NO_x)
  - $HO_x + NO_x$ → Ozone (O_3)

UTLS = upper troposphere & lower stratosphere
BL = boundary layer

DC3 Goals

1. *To quantify and characterize the convection and convective transport within the first few hours of active convection, investigating:*

- *storm dynamics and physics,*
- *lightning and its production of nitrogen oxides,*
- *cloud hydrometeor effects on wet scavenging of species,*
- *chemistry in the anvil*

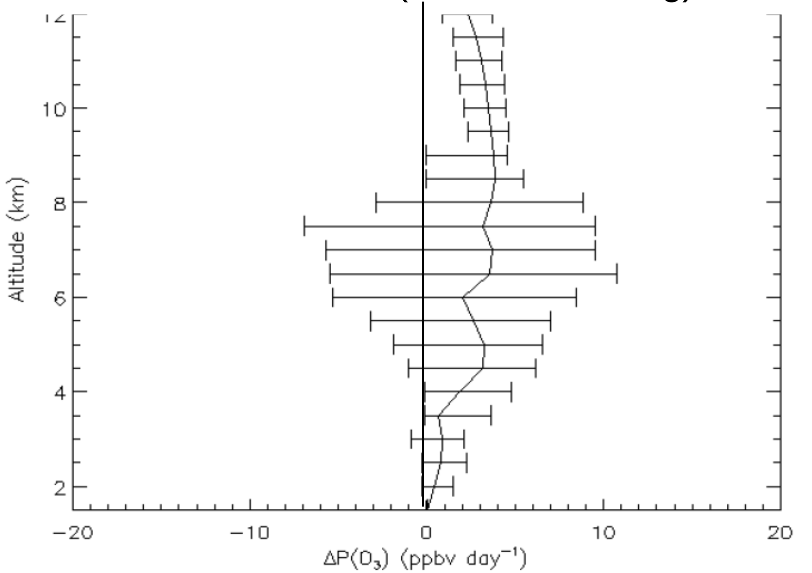


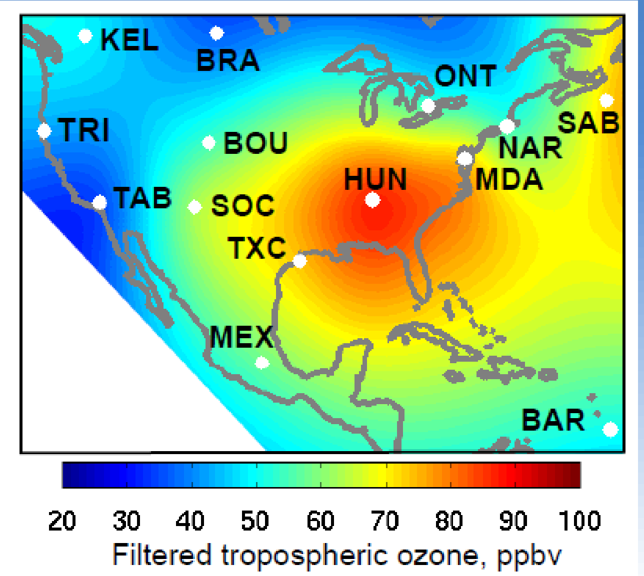
DC3 Goals

2. *To quantify the changes in chemistry and composition after active convection, focusing on*

- *12-48 hours after convection and*
- *the seasonal transition of the chemical composition of the UT*

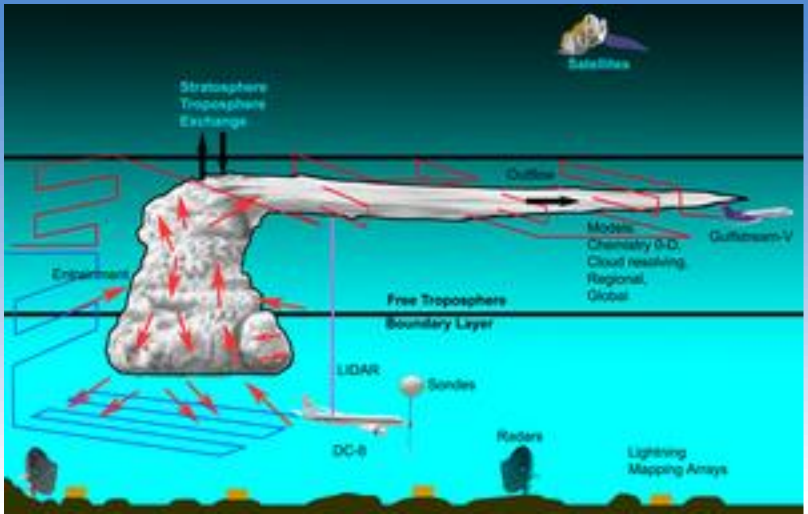
Change in Ozone Production Due to Lightning During 24-hr Period Following July 10, 1996 STERAO Storm (from K.Pickering)





DC3 Field Campaign Strategy

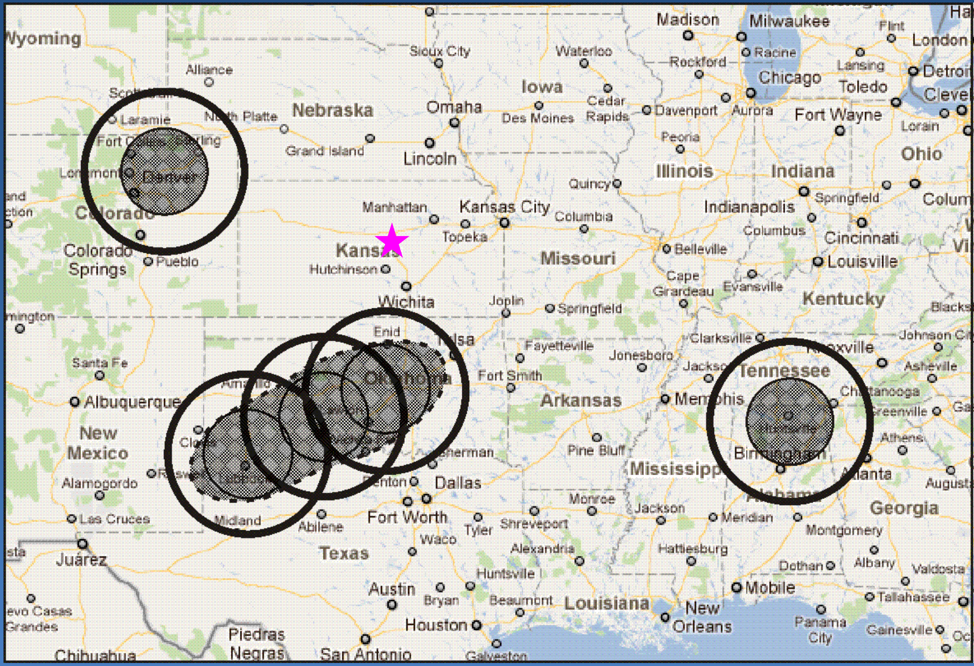
- Get comprehensive chemistry on board two aircraft
- Get comprehensive storm information from ground-based Doppler and polarimetric radars
- Add detailed information on lightning location from lightning mapping arrays
- Include sondes, satellites, and other data to provide further context for the study
- Forecast where storms will occur, and where the UT convective outflow will be the next day



May and June 2012

~7 week period

Northeast Colorado and
Central Oklahoma / West Texas
and Northern Alabama



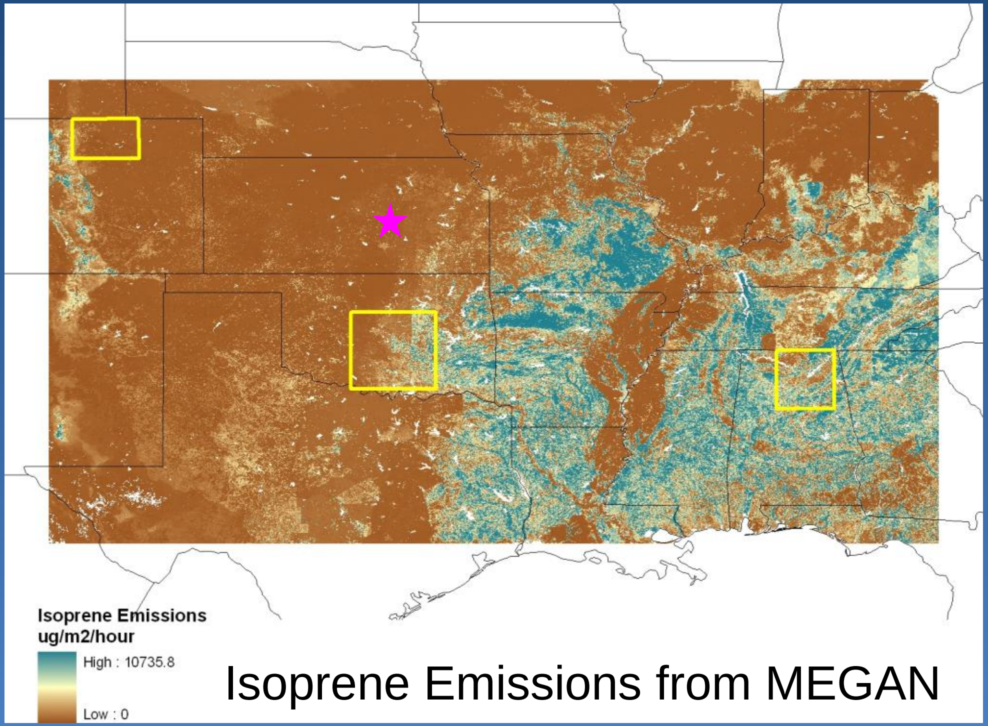
– Sufficient ground-based facilities
– Likelihood of convection occurring in one of the three places is good
– Contrast different environments

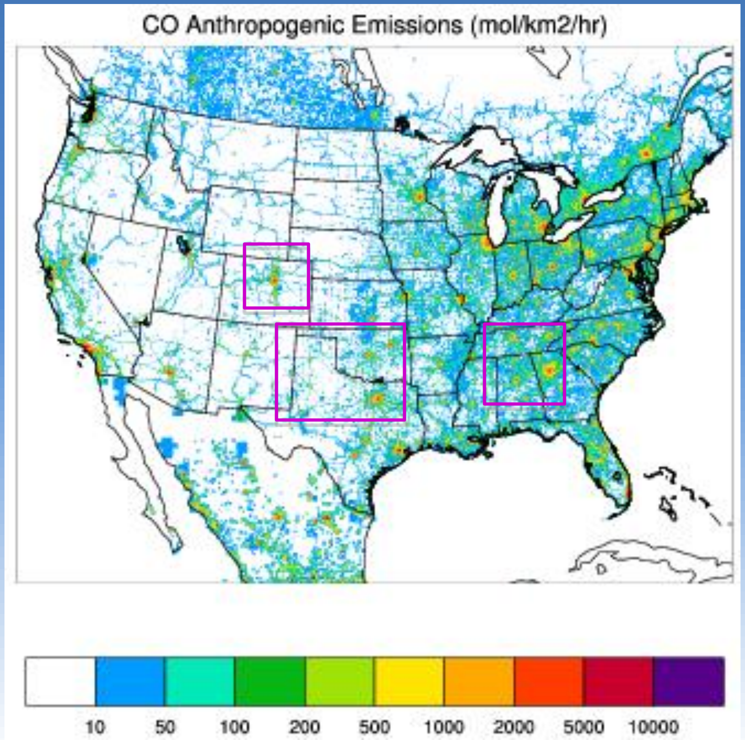
★Operations Base, in Salina, KS, centrally located to reach all 3 regions

May and June 2012

~7 week period

Northeast Colorado and Central Oklahoma / West Texas and Northern Alabama



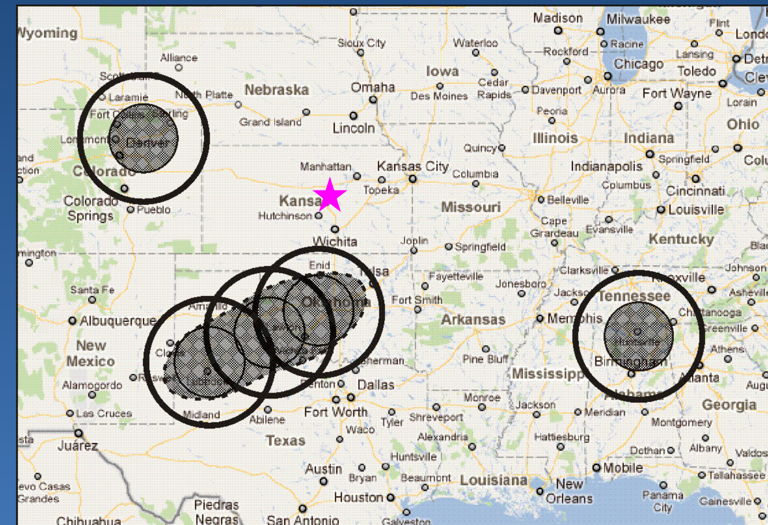


- Biogenic emissions gradient, esp. for isoprene
- Anthropogenic emissions higher east of Mississippi River

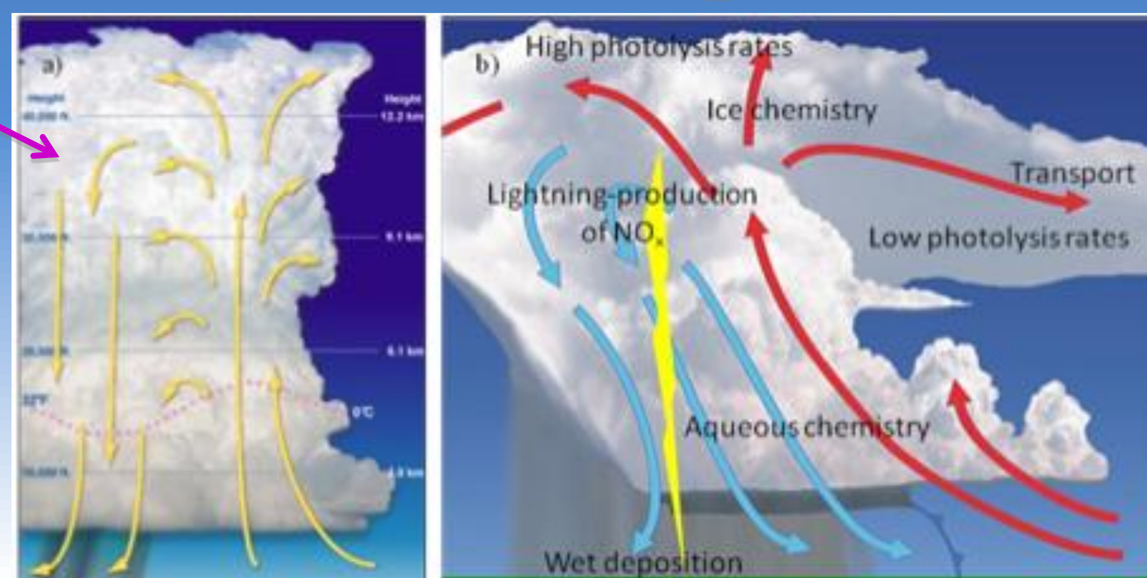
➢ Contrast different chemical environments

May and June 2012

~7 week period

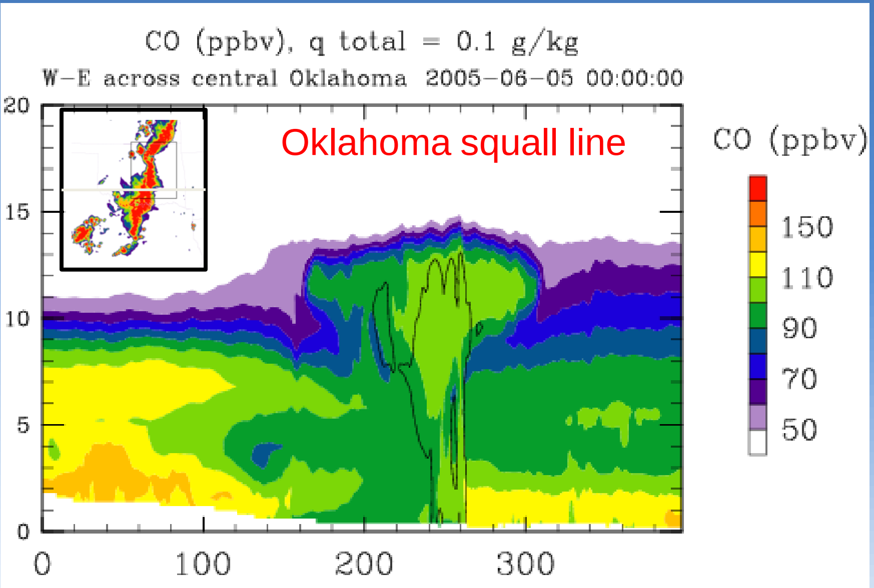


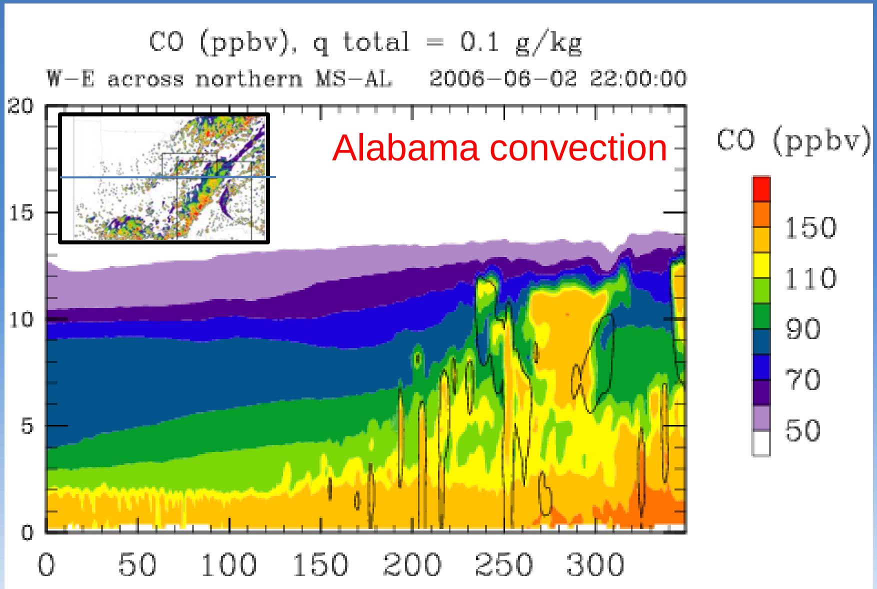
- High cloud bases (CO)
- Shear-driven storms (CO, OK, TX)
- Low shear environment (esp. in June; AL)
  - Air mass thunderstorms



DC3 Hypotheses

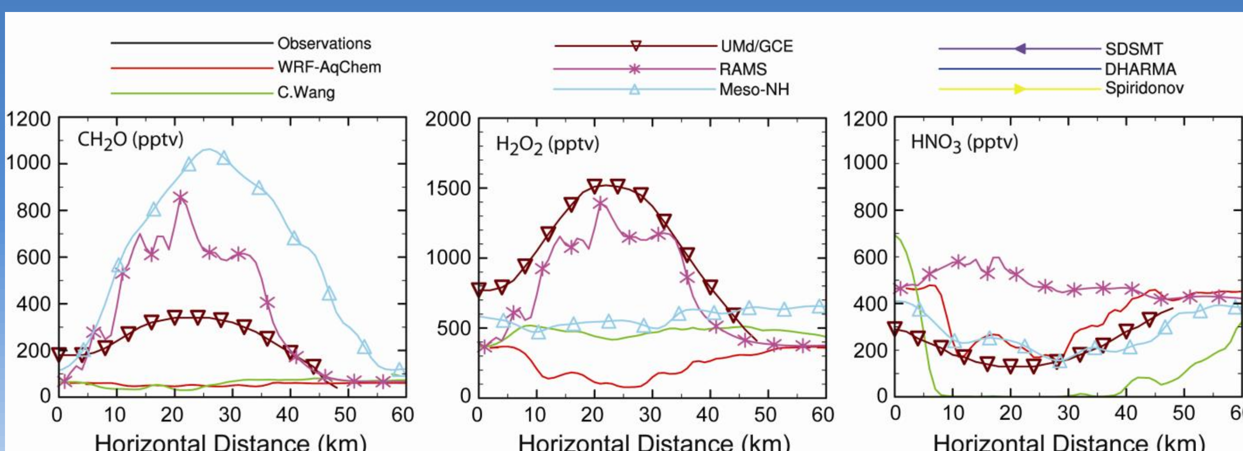
1. *Quantify transport of tracers from the BL to the UT*

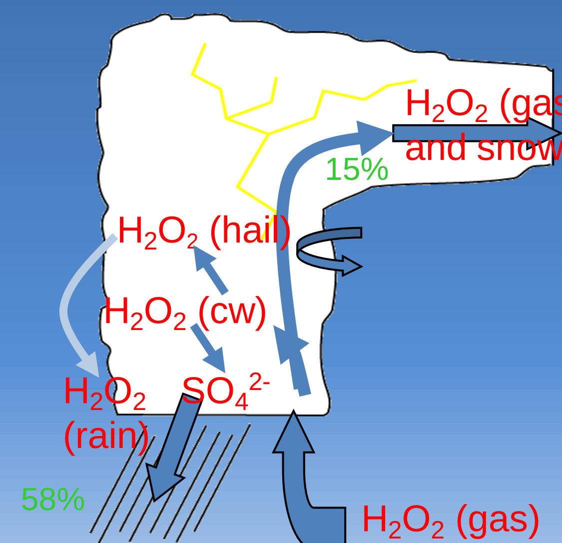




DC3 Hypotheses

2. *Scavenging of soluble species and the role of the ice phase*

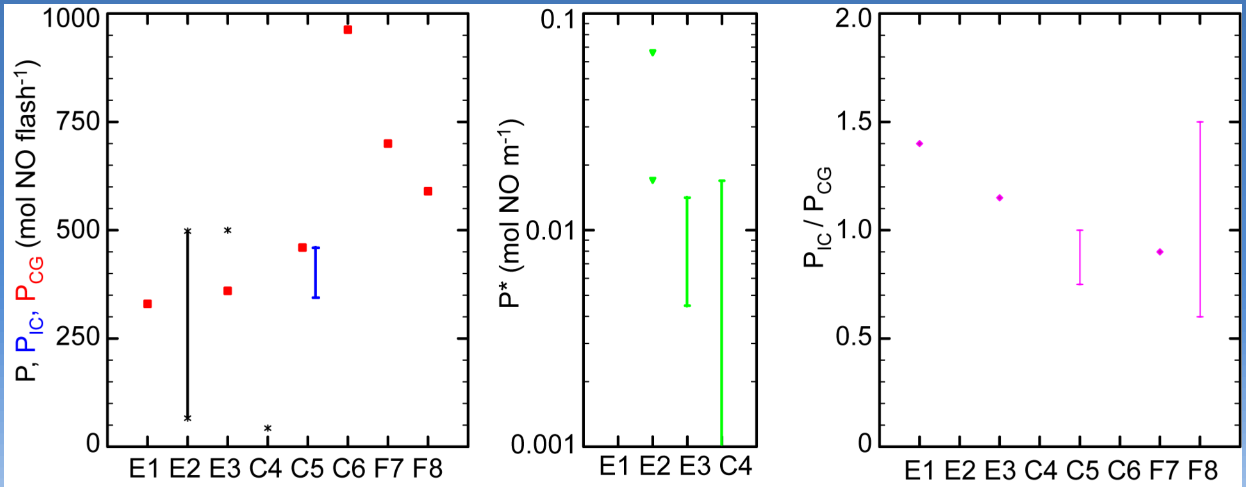




Barth et al., 2007

DC3 Hypotheses

3. *Production of NO_x from lightning;*
   NO_x produced per IC flash compared to CG flash



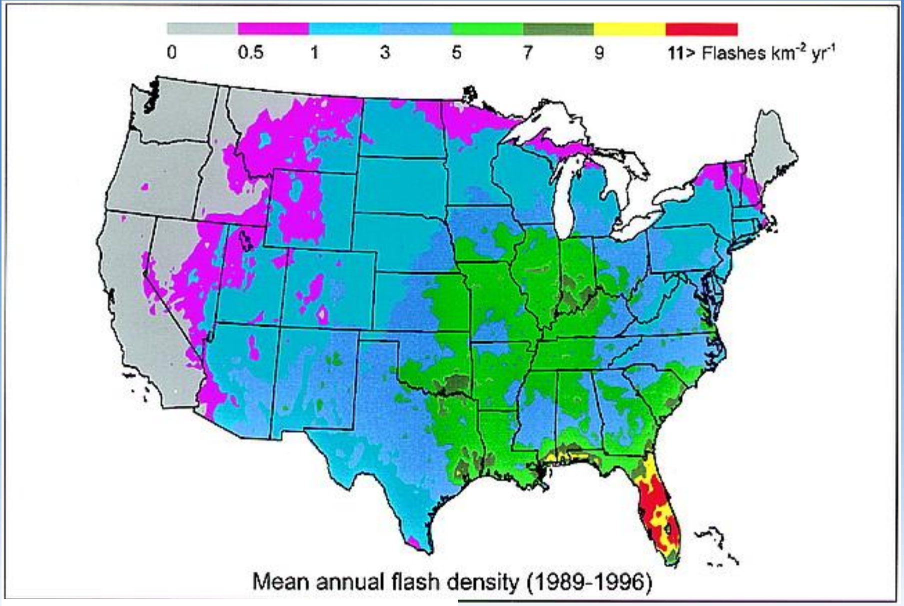
European, Colorado, Florida storms

Courtesy K. Pickering

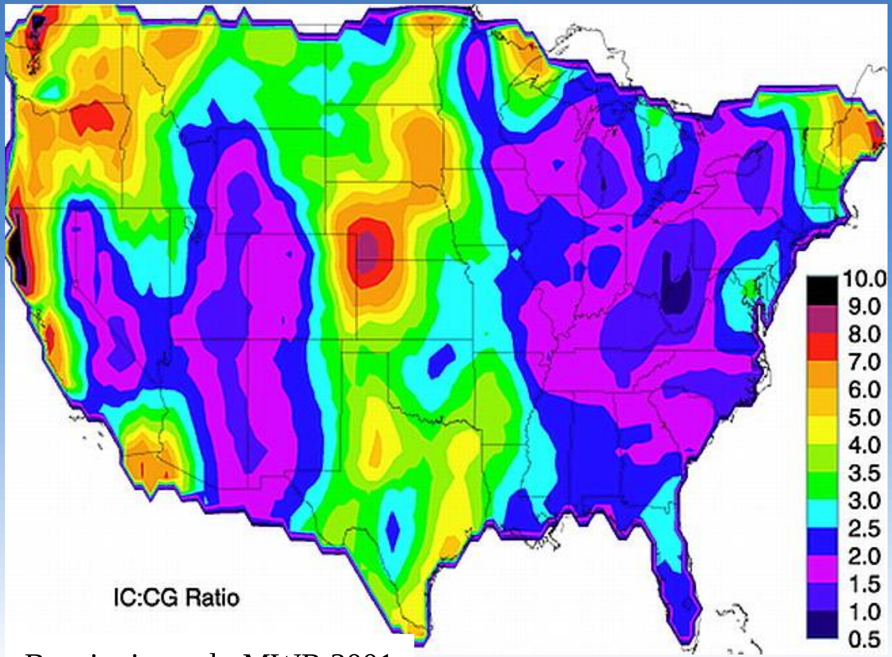
DC3 Hypotheses

4. *Flash rates correlations with storm parameters, e.g. amount of graupel*

   Examine whether cloud-to-ground lightning occurrence is inhibited in storms that produce little precipitation.



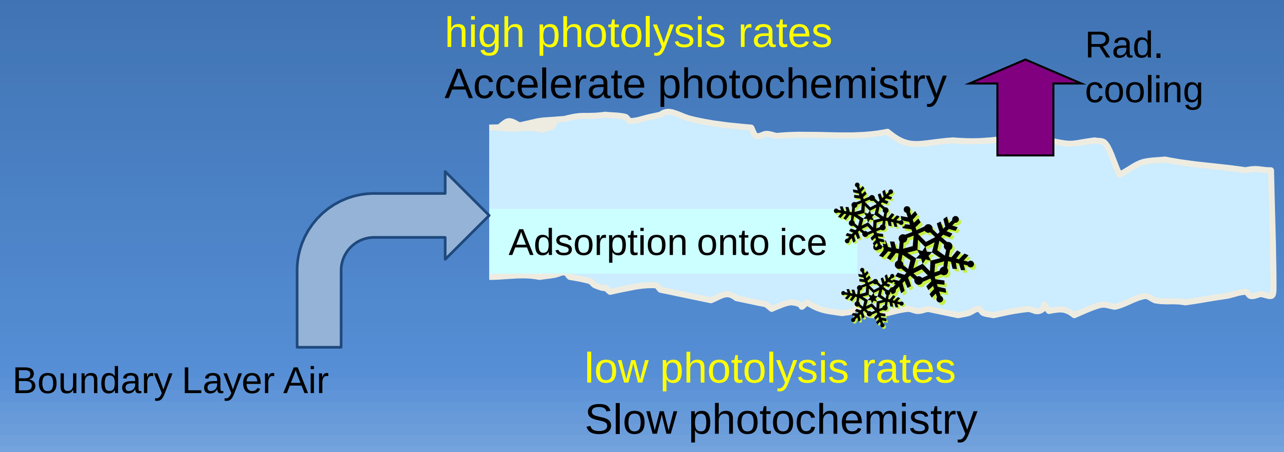
Huffines and Orville, JAM 1999



Boccippio et al., MWR 2001

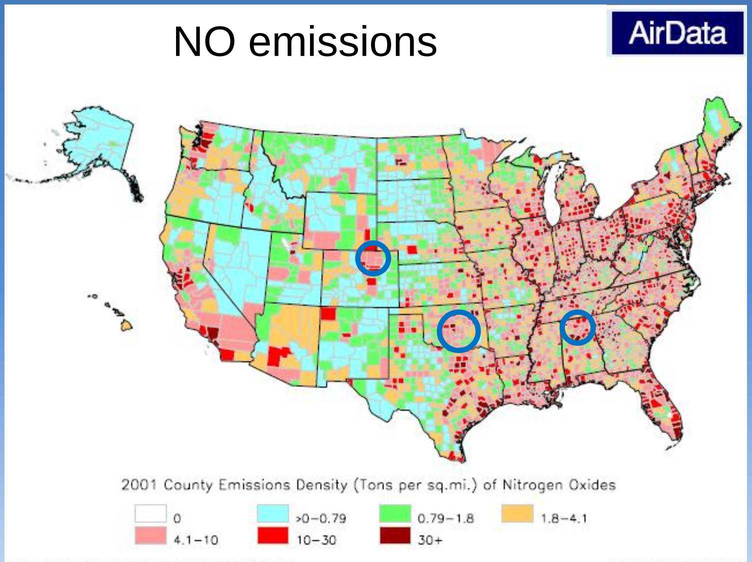
DC3 Hypotheses

6. Chemistry in the anvil

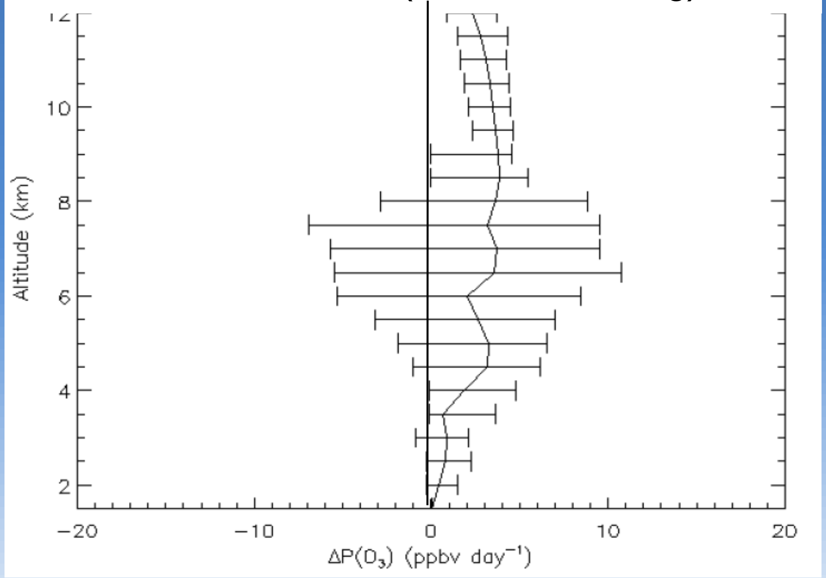


DC3 Hypotheses

7. Chemical aging in the UT convective outflow plumes
-- dependence on the chemical composition of the BL where the storm occurred



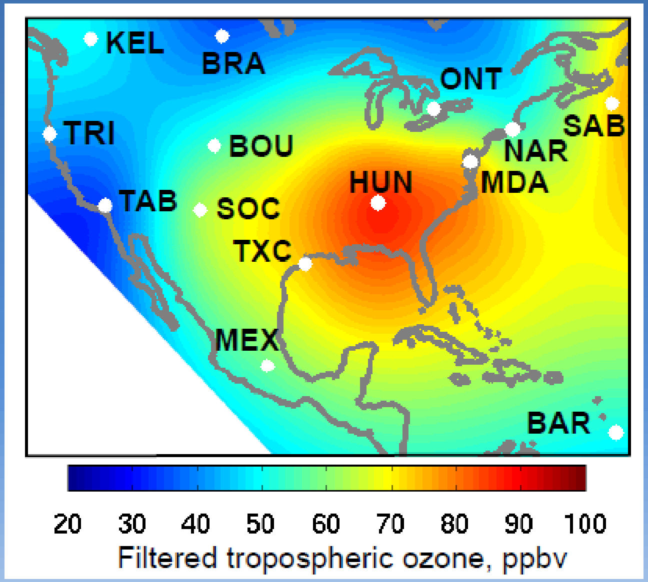
NO emissions



Change in Ozone Production Due to Lightning During 24-hr Period Following July 10, 1996 STERAO Storm (from K.Pickering)

DC3 Hypotheses

8. *Survey flights at the end of June from the central U.S. to the northern Caribbean will find the greatest UT ozone and NO_x mixing ratios above the Gulf of Mexico and Florida*



average UT O3 during August 2006
(Cooper et al., 2007)

Ancillary Goals

- *Convective Processing of Aerosols*
  - Characterize the aerosol number and mass concentrations in the inflow and outflow regions of the storms, including CCN measurements in the inflow region
  - Obtain ice concentration measurements in the anvil of the storms
- *Transport of Halogens*
  - Measure organic halogen source gases and at least one inorganic bromine and chlorine containing compound (e.g. BrO and HCl) to calculate inorganic halogen amount and the partitioning among various reactive and reservoir species

Aircraft facilities for the field campaign

- NSF/NCAR G-V for sampling in upper troposphere

  (8-15 km)
- NASA DC-8 for sampling inflow and mid- to upper troposphere (0.5-12 km)
- DLR Falcon for sampling in upper troposphere (8-13 km)
  - Will be at DC3 for ~3 weeks

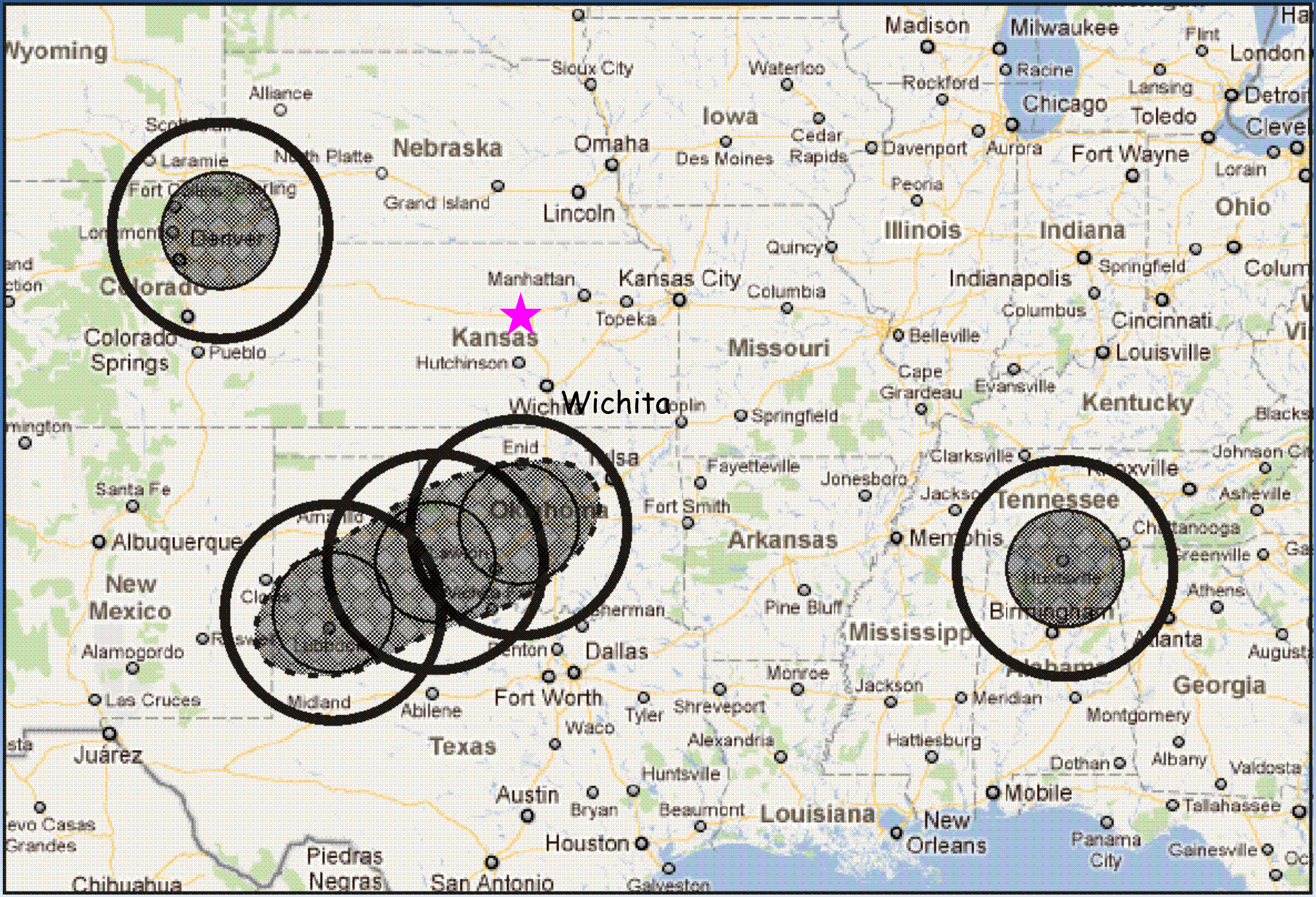
Aircraft Measurements for Hypotheses

- CO, O_3, non-methane hydrocarbons (NMHCs)
  - Transport from BL to UT
- HNO_3, HNO_4, H_2O_2, HCHO, SO_2, CH_3OOH, CH_3CHO
  - Scavenging of soluble species
- NO, NO_2
  - Production of nitrogen oxides by lightning
- OH, HO_2, above species
  - Photochemistry in upper troposphere

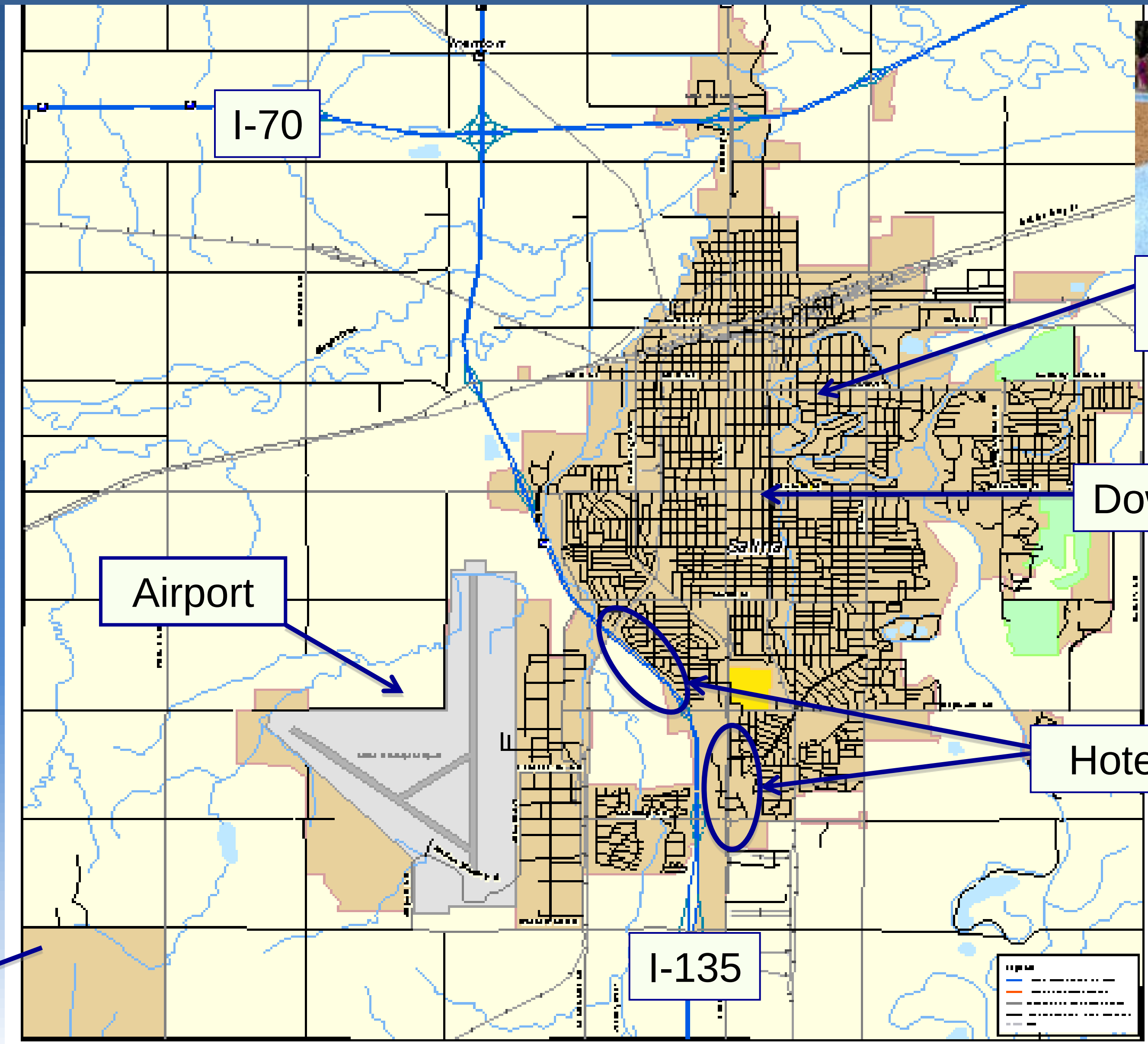
Aircraft Measurements for Hypotheses

- Aerosol size distributions, CCN in inflow region, ice particles
  - Cloud processing of aerosols
- Organic halogens, HCl
  - Transport of halogens

Operations Base – Salina, Kansas



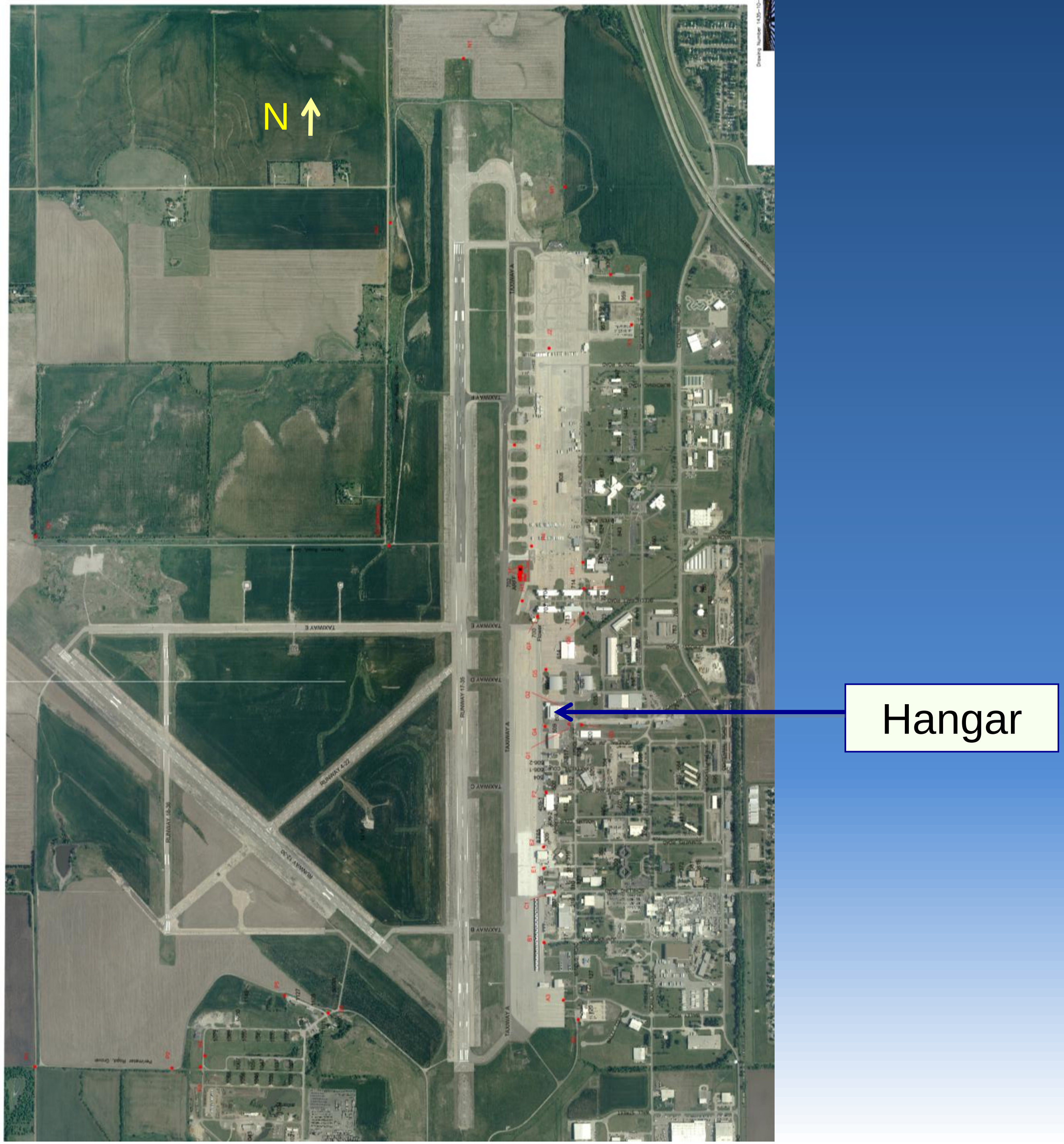
Operations Base – Salina, Kansas



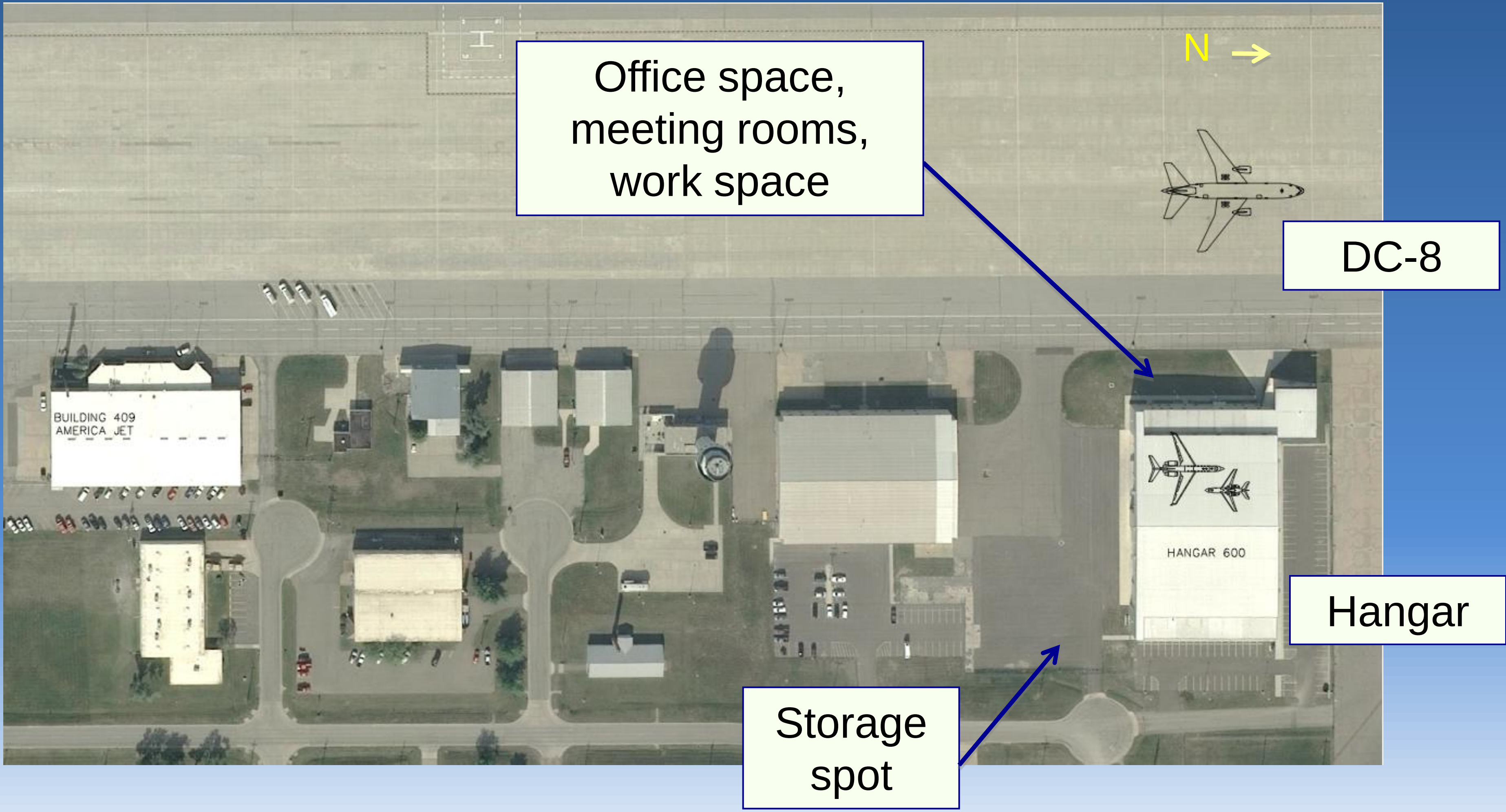
Kenwood Cove Water park

Source (ESRI, Tele Atlas NA)

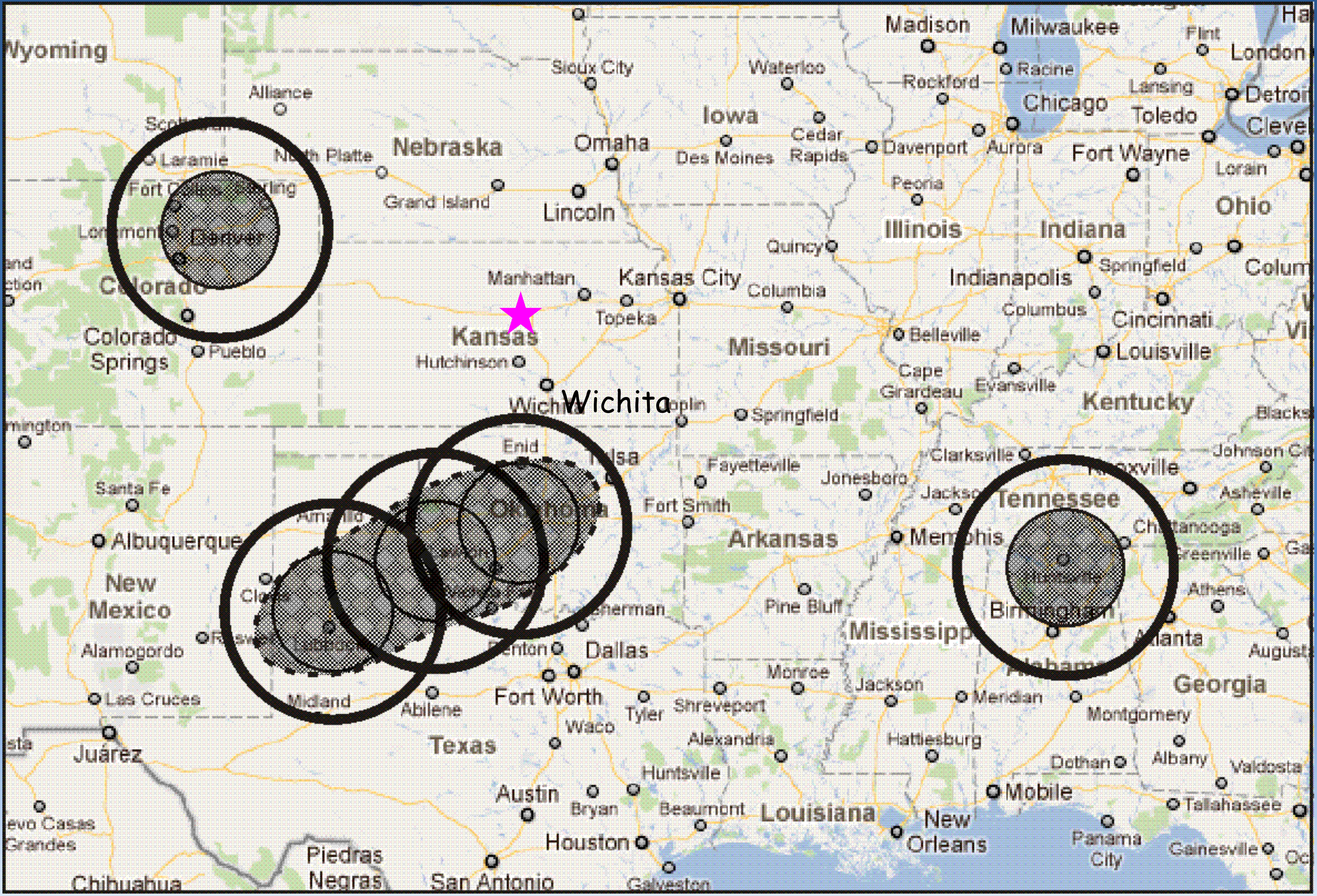
Kanopolis State Park



N
Hangar


Office space, meeting rooms, work space
N
DC-8
BUILDING 409
AMERICA JET
HANGAR 600
Hangar
Storage spot

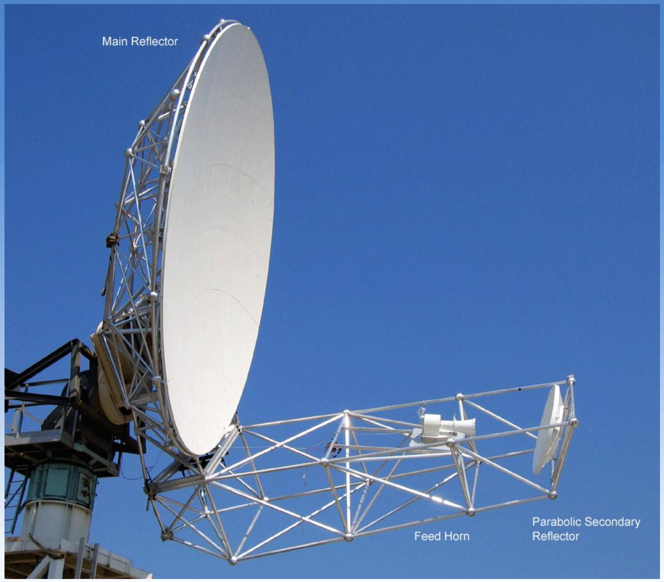
Map of DC3 Sampling Regions



Thanks to Don MacGorman for this map

Ground facilities for the field campaign

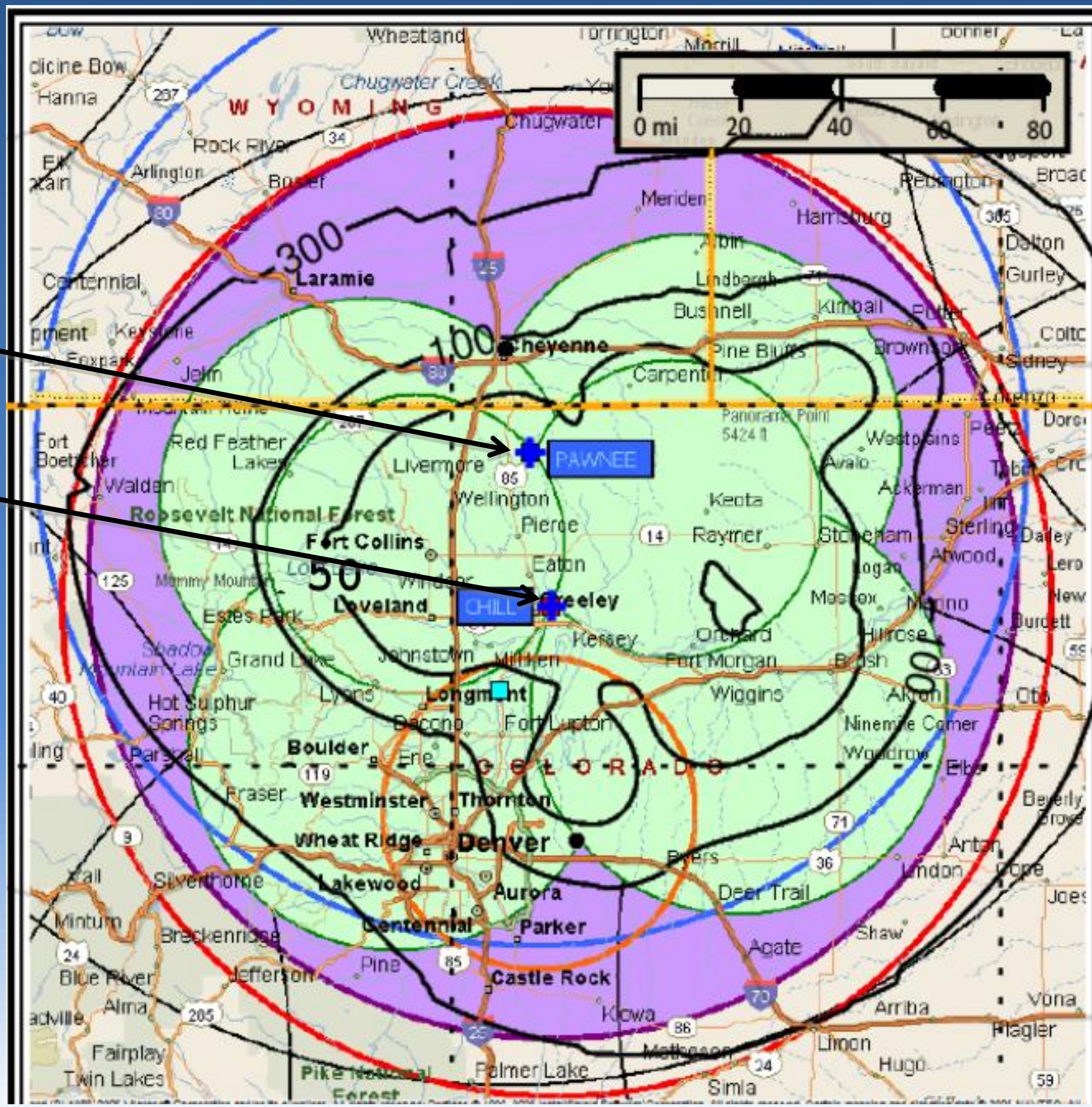
- Northeast Colorado
  - CSU CHILL radar for sampling storms in NE Colorado
  - PAWNEE radar for dual-Doppler
  - MGAUS for soundings in NE Colorado
  - Lightning Mapping Array (LMA) consisting of 15 stations



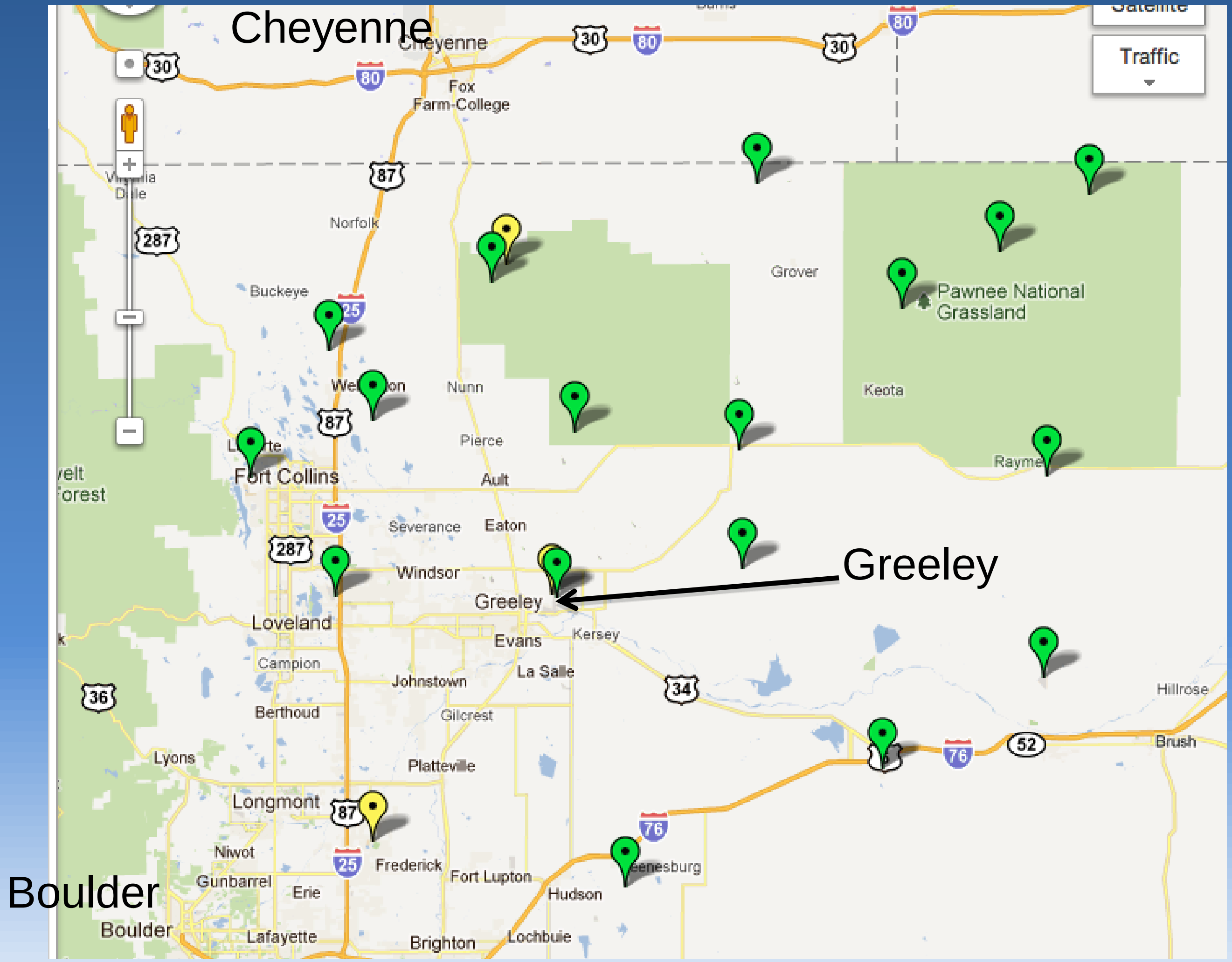
Map of NE Colorado Ground Facilities

PAWNEE radar

CHILL radar



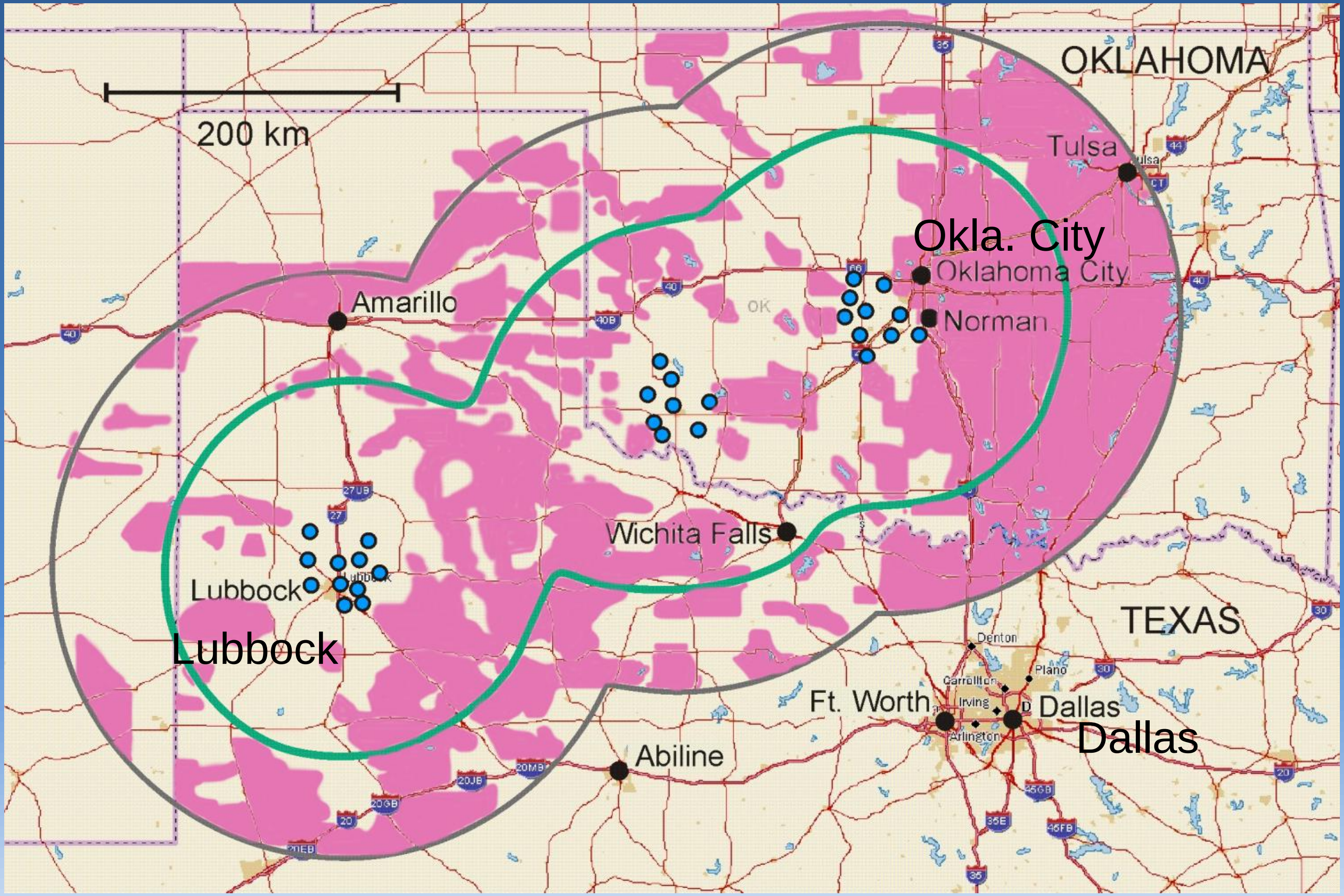
LMA Stations in NE Colorado



Ground facilities for the field campaign

- Oklahoma / West Texas
  - SMART radars, OU PRIME radar, KOUN radar
  - Lightning Mapping Arrays in central OK, SW OK, W. TX
  - OK soundings
  - Balloons for electrical measurements

Map of Oklahoma and West Texas Ground Facilities



Blue dots: LMA stations; pink shading: regions where SMART-R likely cannot set up

Ground facilities for the field campaign

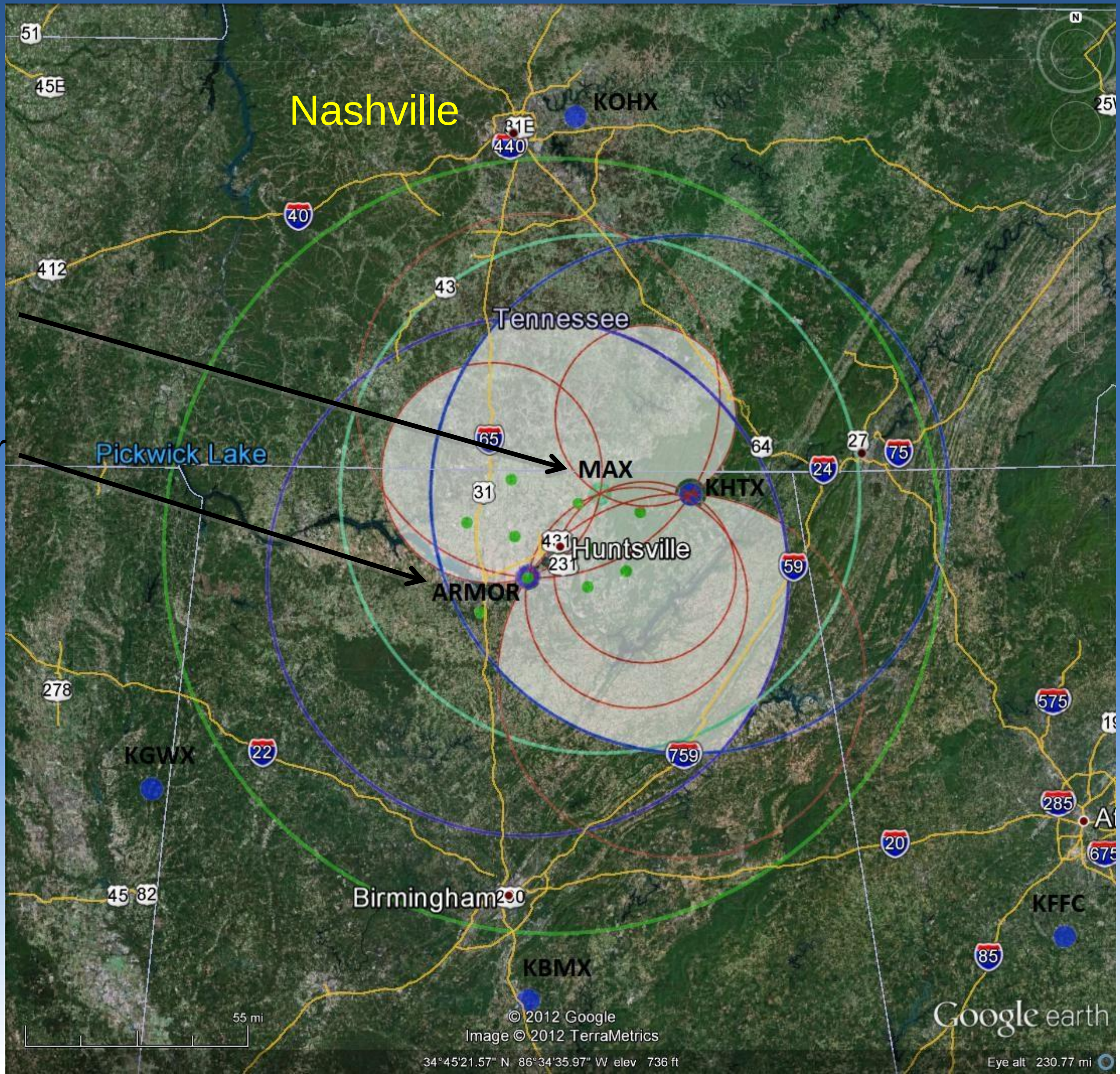
- Alabama
  - ARMOR and MAX radars,
  - N Alabama LMA,
  - MIPs profiler, ozonesondes

Map of Northern Alabama Ground Facilities

MAX radar

ARMOR radar

Green dots = LMA stations

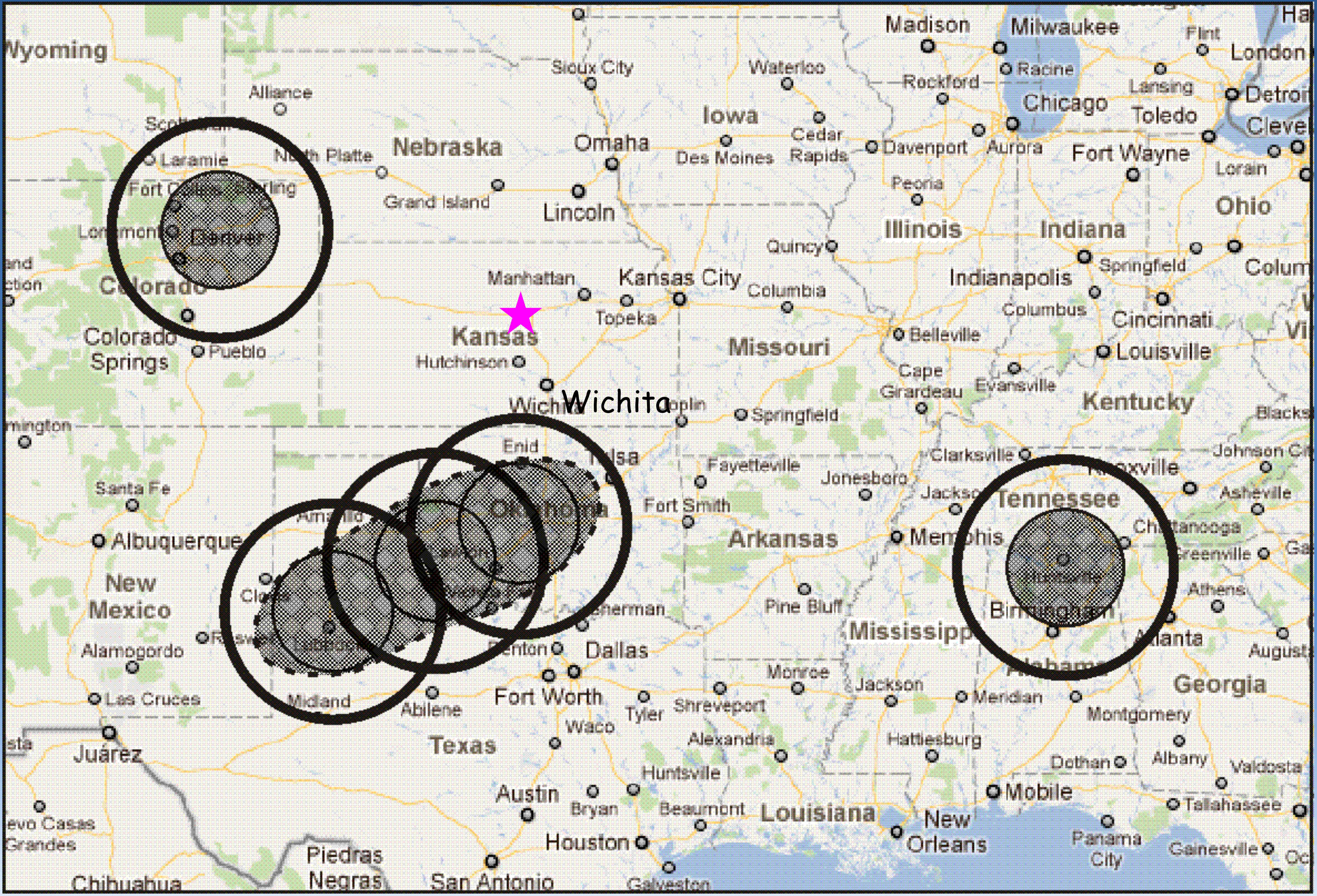


Atlanta

Ground-Based Measurements for Hypotheses

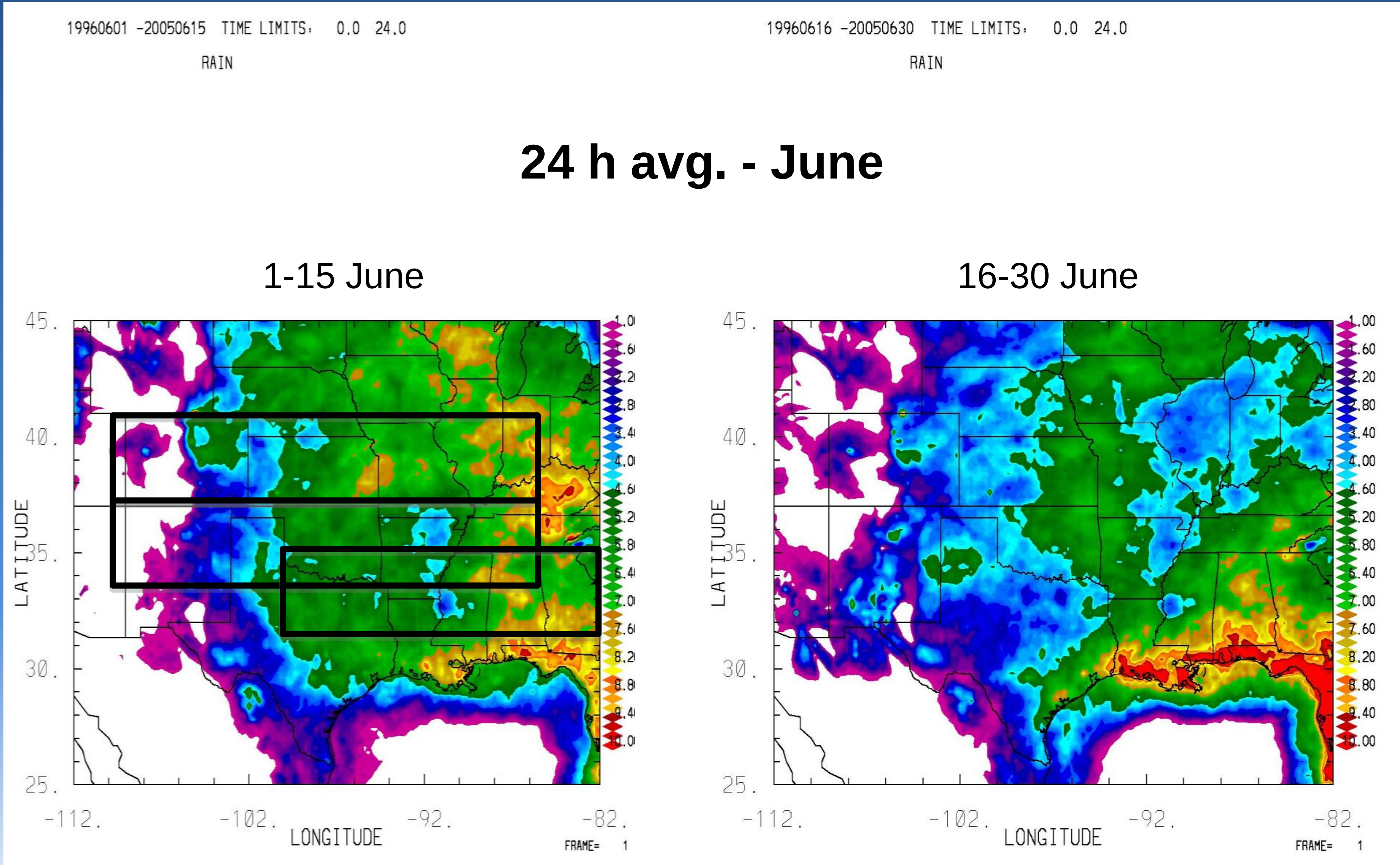
- Dual-Doppler Radar → u, v, w
  - Transport from BL to UT
- Polarimetric Radar → storm hydrometeors
  - Scavenging of soluble species
- Lightning Mapping Array (LMA)
  - Production of nitrogen oxides by lightning
- LMA + Radars
  - Flash rate correlations with storm parameters
  - Inverted polarity flashes

Thunderstorms in DC3 Sampling Regions



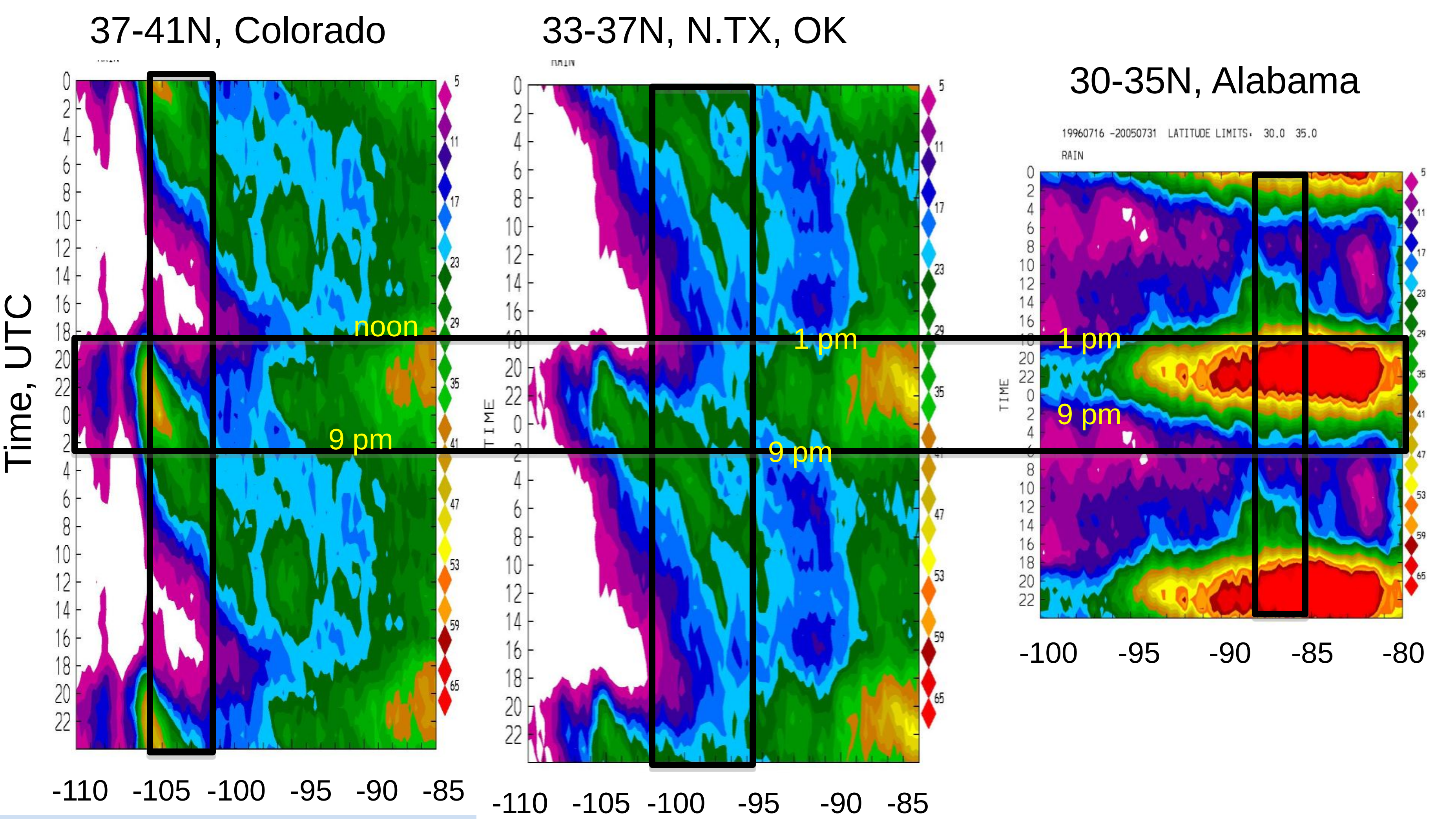
Courtesy Don MacGorman

Climatology of Storms



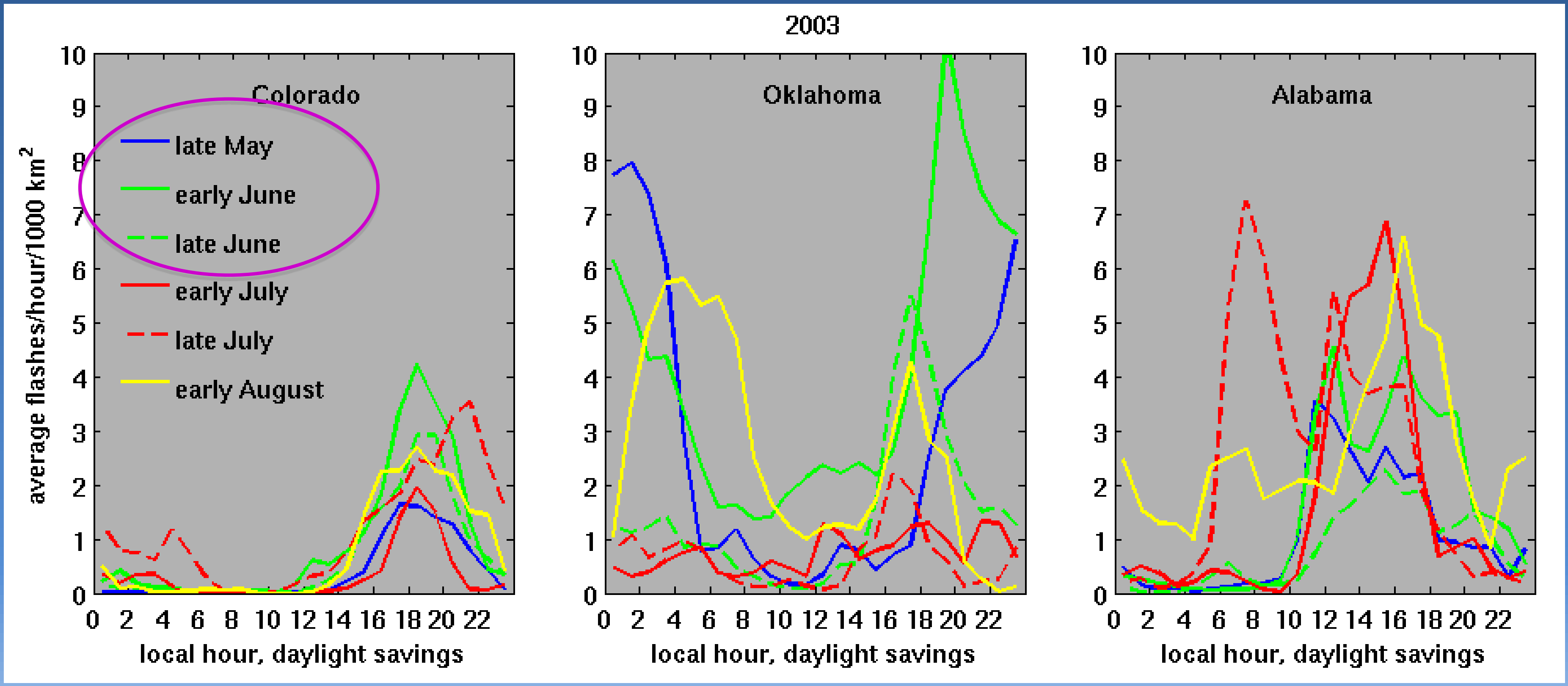
Courtesy R. Carbone, NCAR

Diurnal Variation of Storms for 1-15 June



Courtesy R. Carbone, NCAR

Diurnal cycle of NLDN detected cloud-to-ground flashes



Courtesy O. Cooper, NOAA/U.Colorado

Forecasting Storms and Downwind UT Plumes

Name	Run time	Update time	Time available to community	Observations used
3 km WRF-ARW Weather & tracer forecasts	2 48-hr sims run daily	00Z 12Z	13Z = 0800 CDT 01Z = 2000 CDT	
3 km WRF TTU Weather forecasts	4 60-hr sims run daily	00Z, 06Z, 12Z, 18Z	10-13Z = 0500-0800 CDT	
4 km WRF NSSL Weather forecasts	1 36-hr sim run daily	00Z		
FLEXPART Particle dispersion model Trajectory fore-casts in UT	1 48-hr run after flight completes	~02Z		Aircraft lat & lon GFS winds
0.5x0.6° MOZART Chemical forecasts	1 5-day run	00Z	14Z = 0900 CDT	
Decision making algorithm (A. Small, H. Verlinde)				

DC3 Field Campaign Strategy

- Comprehensive chemistry on board 2-3 aircraft
- Comprehensive storm information from ground-based Doppler and polarimetric radars and lightning mapping arrays
- Sondes, satellites, and other data to provide further context for the study
- Forecasting, Nowcasting, an

Good coordination among facilities to produce a successful campaign → Operations Plan