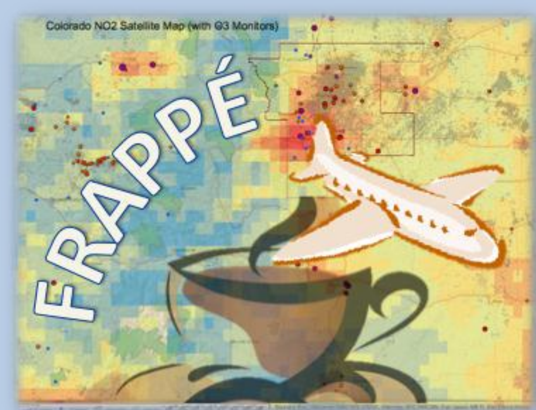
FRONT RANGE AIR POLLUTION AND PHOTOCHEMISTRY ÉXPERIMENT

National Center for Atmospheric Research (NCAR-ACD, MMM),
NASA Airborne Science Program
Colorado Department of Public Health and Environment (CDPHE),
Colorado State University (CSU), University of Colorado Boulder (CU),
CU Institute for Arctic and Alpine Research
Environmental Protection Agency (EPA) Region 8,
National Oceanic and Atmospheric Administration (NOAA ESRL),
National Park Service (NPS), Regional Air Quality Council (RAQC),
Storm Peak Laboratory (DRI), UC Berkeley, U of Wisconsin,
U of Maryland, U of Cincinnati, Georgia Tech, UC Riverside, Aerodyne Inc.

Northern Front Range Metro Area (NFRMA)

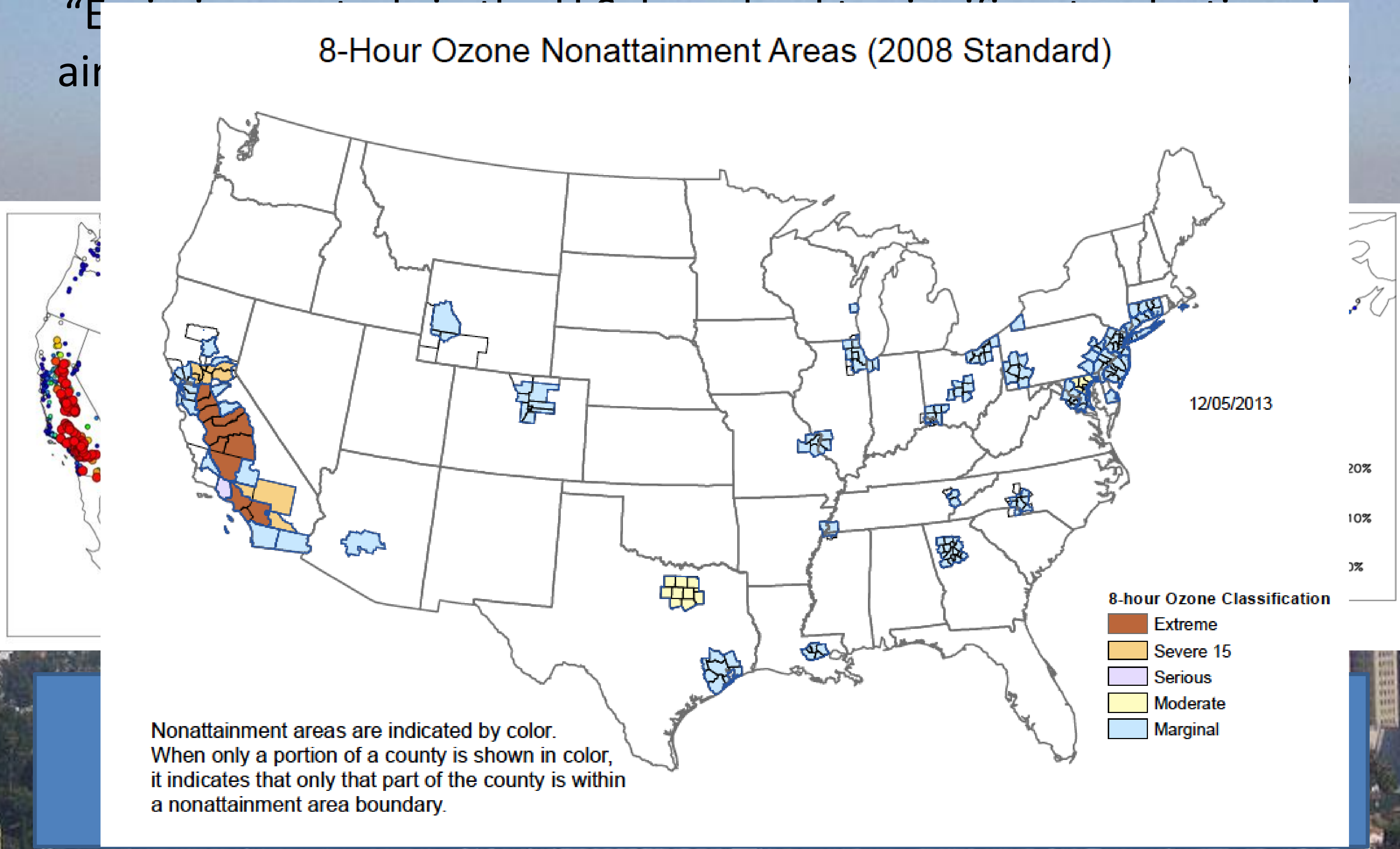
July 13-August 16, 2014

http://www2.acd.ucar.edu/frappe
http://discover-aq.larc.nasa.gov/



Air Quality – a solved problem?

Not really…

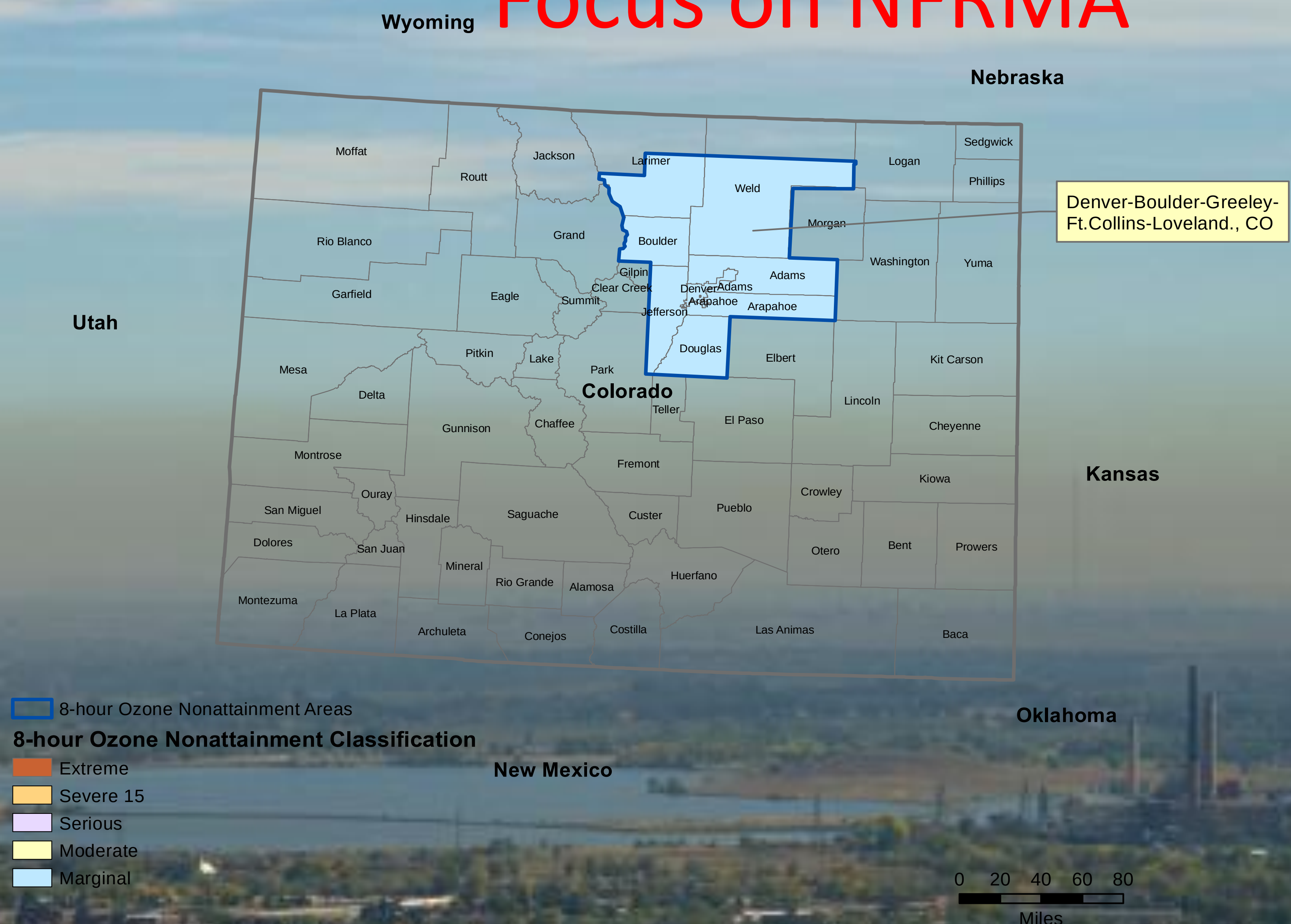


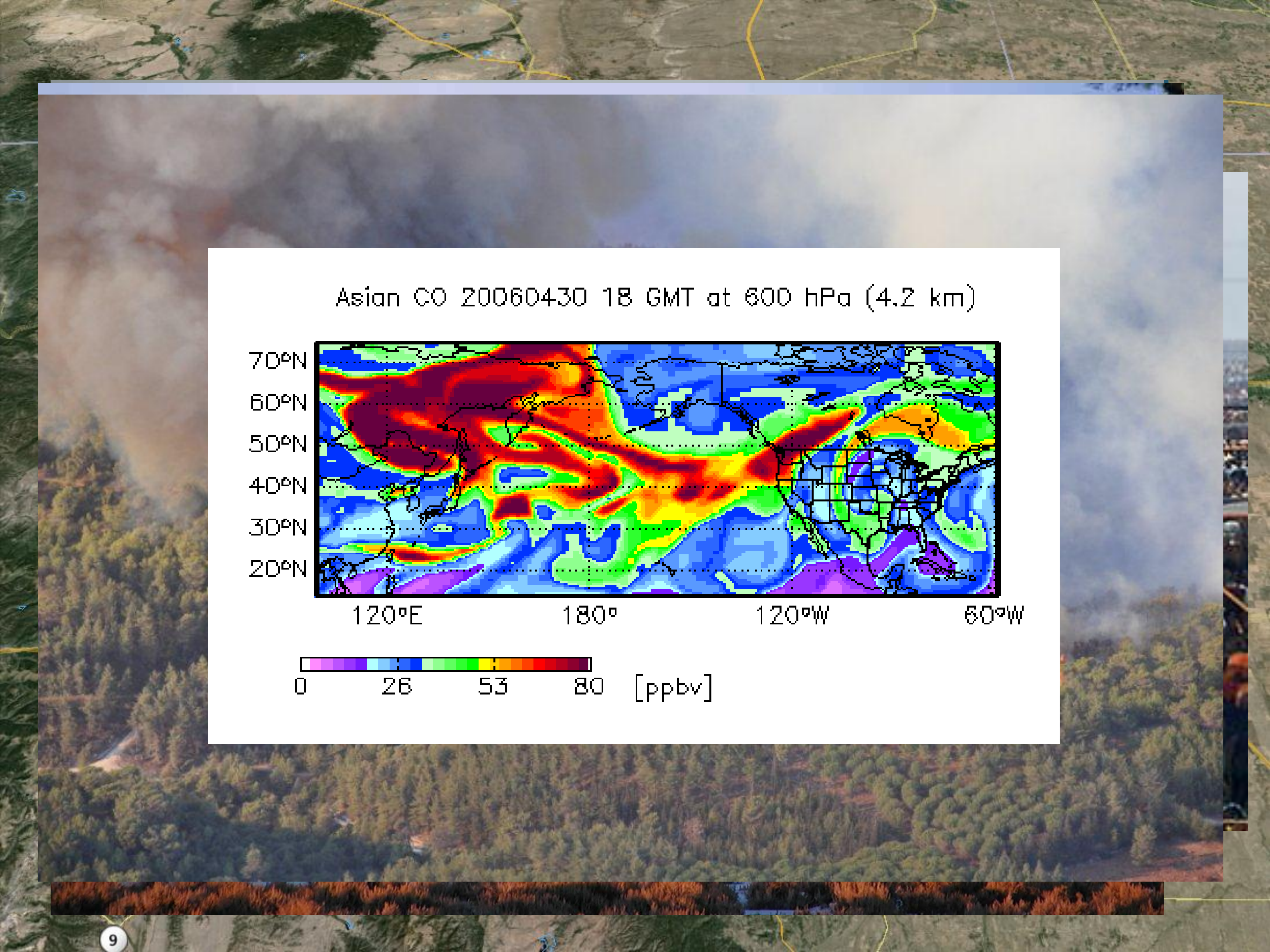
8-Hour Ozone Nonattainment Areas (2008 Standard)
12/05/2013
8-hour Ozone Classification
Extreme
Severe 15
Serious
Moderate
Marginal
Nonattainment areas are indicated by color.
When only a portion of a county is shown in color,
it indicates that only that part of the county is within
a nonattainment area boundary.

Colorado 8-hour Ozone Nonattainment Areas (2008 Standard)

12/05/2013

Focus on NFRMA

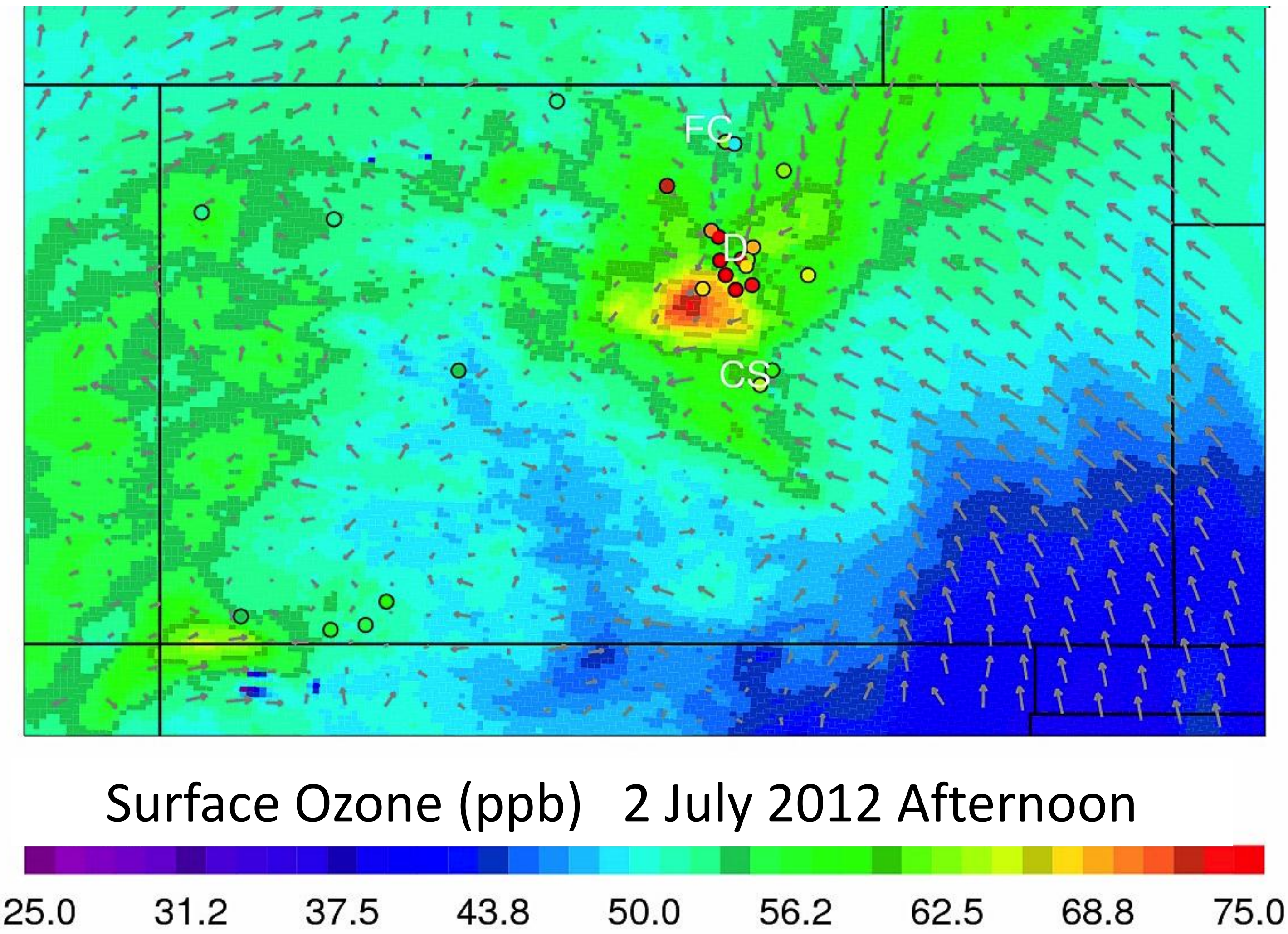



Asian CO 20060430 18 GMT at 600 hPa (4.2 km)
70°N
60°N
50°N
40°N
30°N
20°N
120°E
180°
120°W
60°W
0
26
53
80
[ppbv]

Air Quality Improvements ?

- We have done all the “easy” things
  - Catalytic converters, emission equipment on vehicles
  - Combustion efficiency, vapor recovery systems
  - Emission reductions for EGUs
  - Industry emission reductions
- Have mostly addressed VOC, starting to address NO_x
  - NO_x (or VOC) reductions can reduce or increase O_3 depending on the “chemical regime.”
- Need for “smarter”, better informed solutions
  - Houston AQS 2000, 2006
- Need for more comprehensive measurements
  - Air quality models mostly informed and “validated” by sparse ground-based observations of very few “criteria pollutants”
  - Pollutants move around horizontally and vertically
  - Spatially separated emissions come into play during different meteorological situations; recirculation effects
  - Climate change impacts

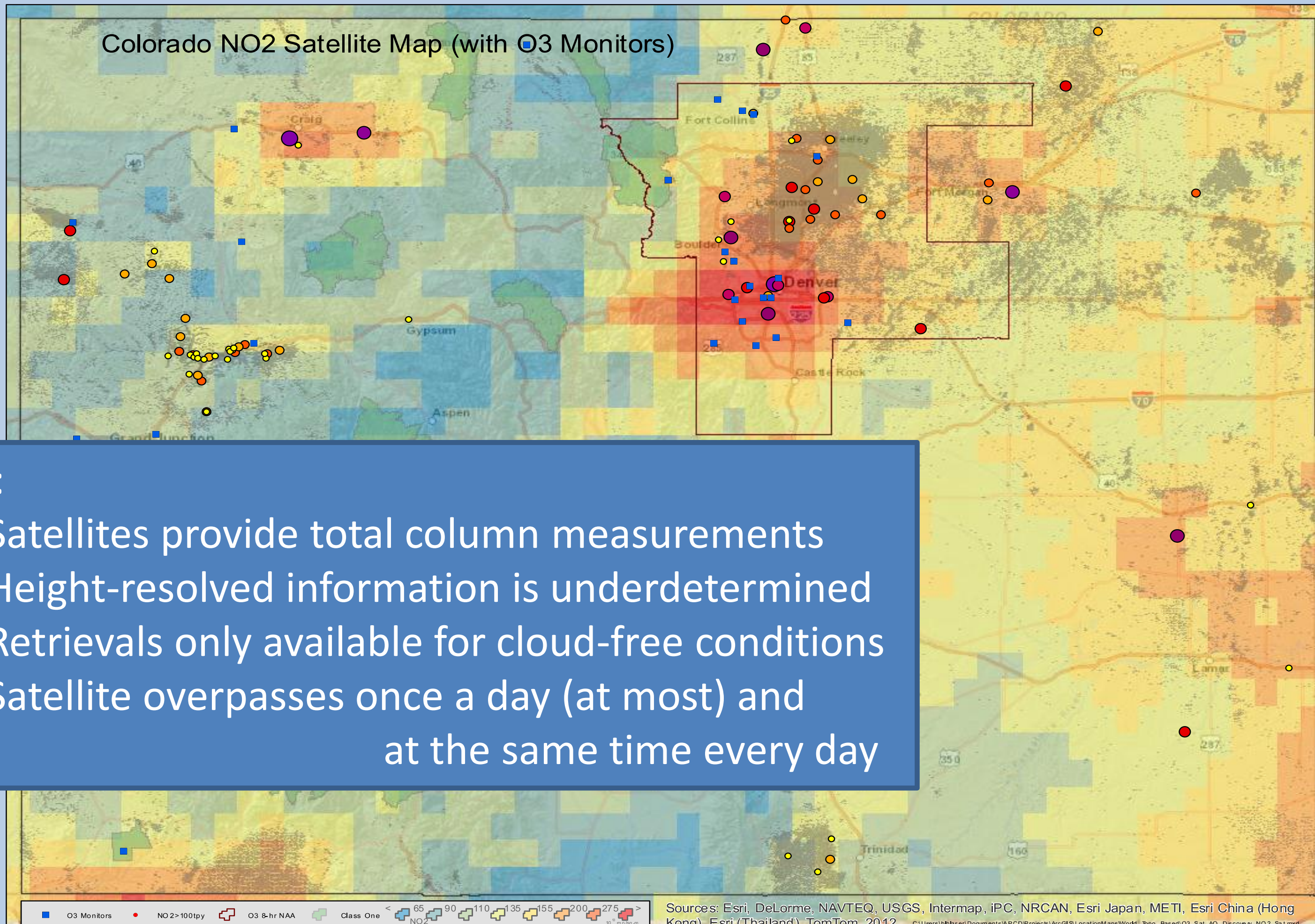
Air Quality Improvements ?



Surface Ozone (ppb) 2 July 2012 Afternoon

We can now measure some pollutants from space

- NO_2, CO, CO2, CH2O, others-



But:

- Satellites provide total column measurements
- Height-resolved information is underdetermined
- Retrievals only available for cloud-free conditions
- Satellite overpasses once a day (at most) and at the same time every day

DISCOVER-AQ

Deriving **I**nformation on **S**urface Conditions from **Co**lumn and **VER**tically Resolved Observations Relevant to **A**ir **Q**uality

(NASA Earth Venture mission)

How can satellites be used to inform about AQ?

1. *Relate column observations to surface concentrations for aerosols and key trace gases*

2. *Characterize differences in diurnal variation of surface and column observations*

3. *Examine horizontal scales of variability affecting satellites and AQ modeling*

Deployments and key collaborators

Maryland, July 2011 (EPA, MDE, UMd, UMBC, Howard U.)
California, January 2013 (EPA, CARB, UC-Davis & Irvine)
Texas, September 2013 (EPA, TCEQ, U. of Houston)
Colorado, Summer 2014 (EPA, NSF, NOAA, CDPHE)

DISCOVER-AQ

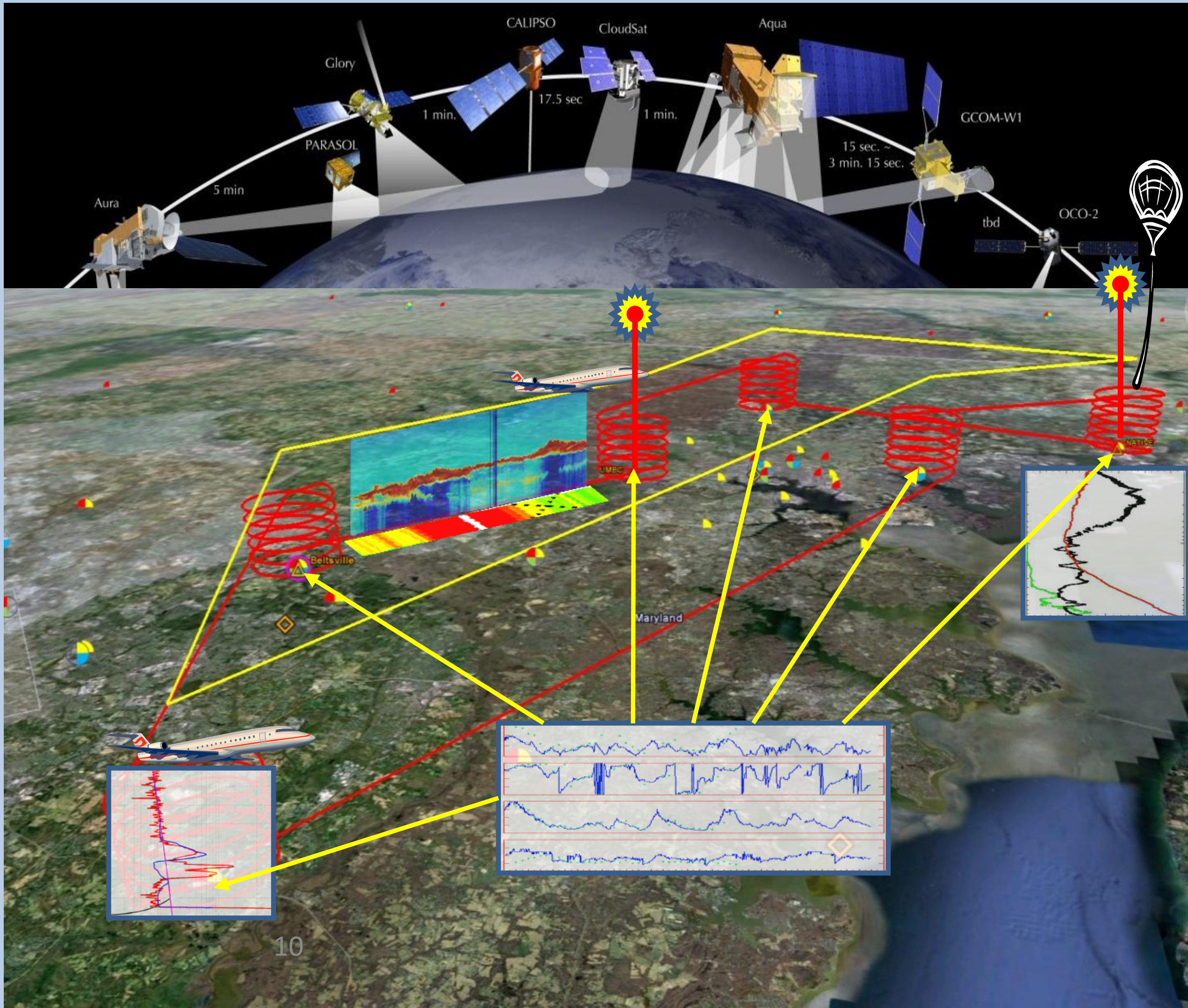
- **Trace Gases and Aerosols**
- **Column, surface, and vertical profiling**
- **Diurnal Evolution**
- **~15 flights over 4 weeks**

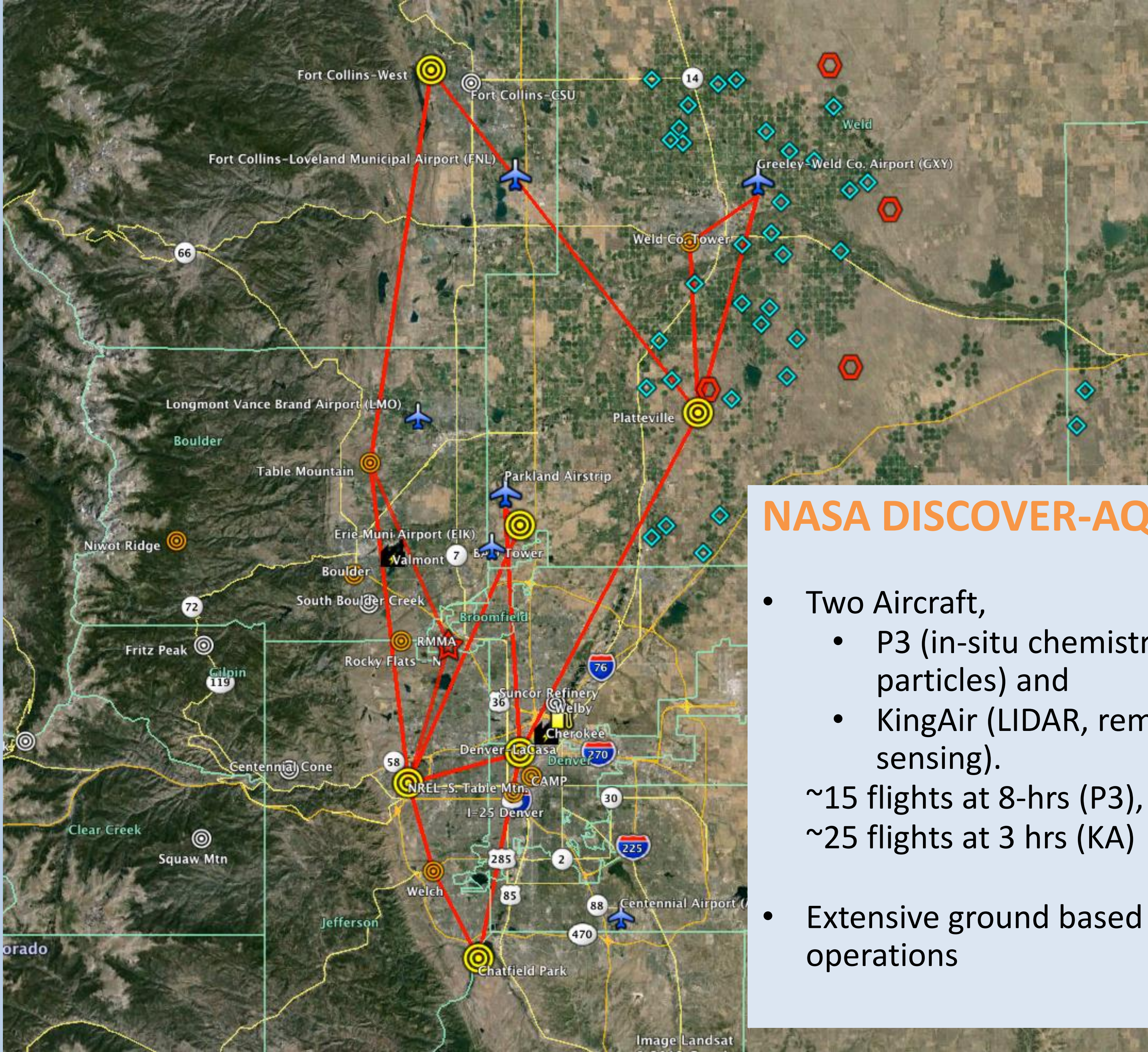
NASA King Air
Column Measurements
Integrated from surface – 8 km

NASA P-3B
Vertical Profiling
Altitude Range: 500ft AGL – 5 km

Surface
In situ
Remote sensing
Ozonesondes
Aerosol lidar
~ 4-6 ground sites

Key Measurements:
NOx, Ozone, CO, CO2, CH4, Alkanes, Alkenes, Alkynes, CH2O, Aldehydes, Aromatics, Oxygenates, halogenated VOC, OH and HO2 radicals. Aerosols: Type, Size, Chem. Composition, hygroscopicity

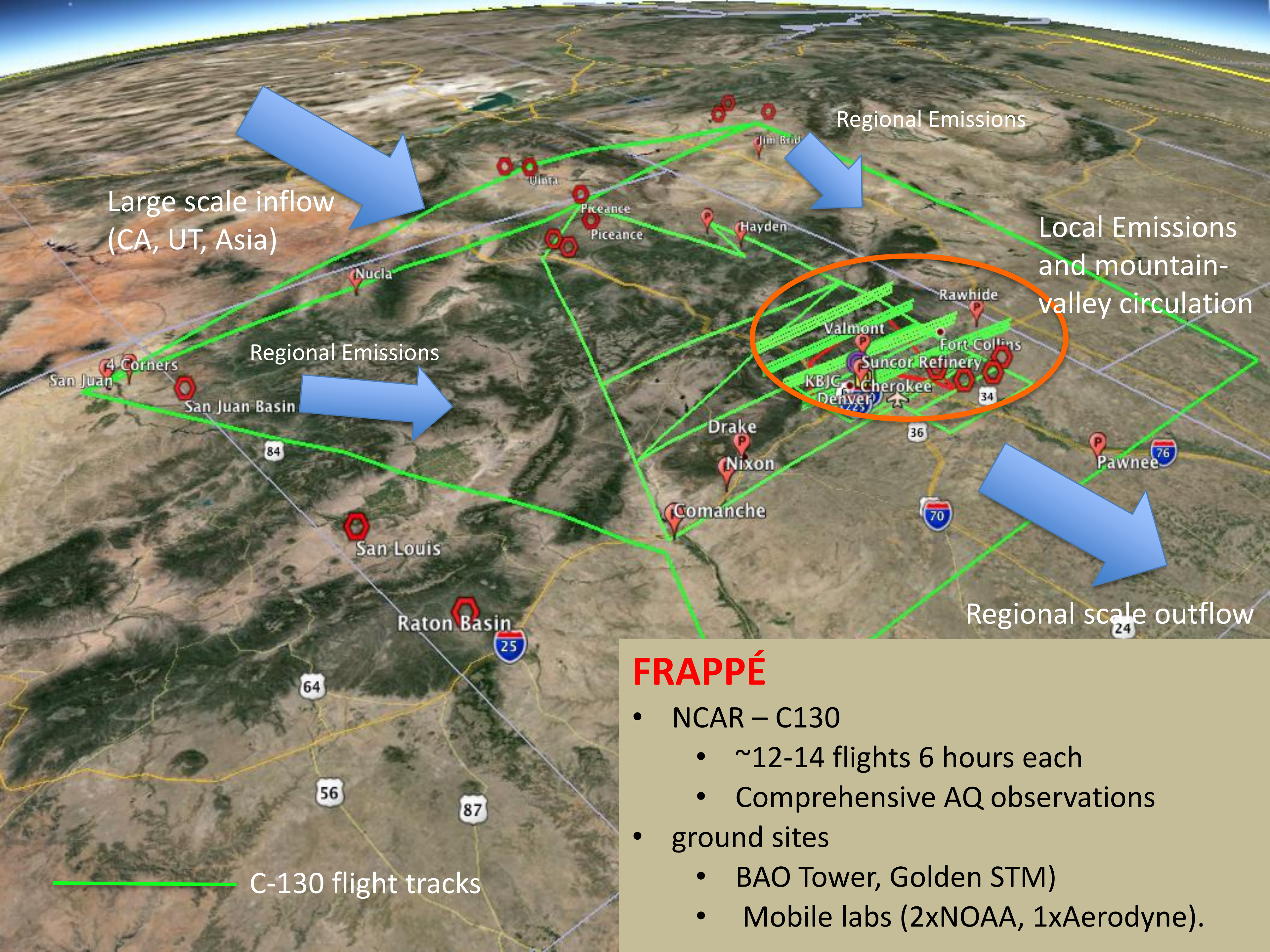




NASA DISCOVER-AQ

- Two Aircraft,
  - P3 (in-situ chemistry and particles) and
  - KingAir (LIDAR, remote sensing).

  ~15 flights at 8-hrs (P3),
  ~25 flights at 3 hrs (KA)
- Extensive ground based operations



FRAPPÉ

- NCAR – C130
  - ~12-14 flights 6 hours each
  - Comprehensive AQ observations
- ground sites
  - BAO Tower, Golden STM)
  - Mobile labs (2xNOAA, 1xAerodyne).

- Understanding AQ requires understanding the ***WHOLE ATMOSPHERE and its variability*** – chemically, dynamically, physically.
- Vertical structure and mixing of emissions into the boundary layer and its evolution during the day is critical information – ***surface measurements are rarely sufficient to gain full picture*****.**
- Complicated flow structure due to mountain induced circulation ***make aircraft measurements critical***.
- Measurements and results from FRAPPÉ and DISCOVER-AQ will ***add significant value*** to air quality model performance and thus provide ***input to policy/decision making***.

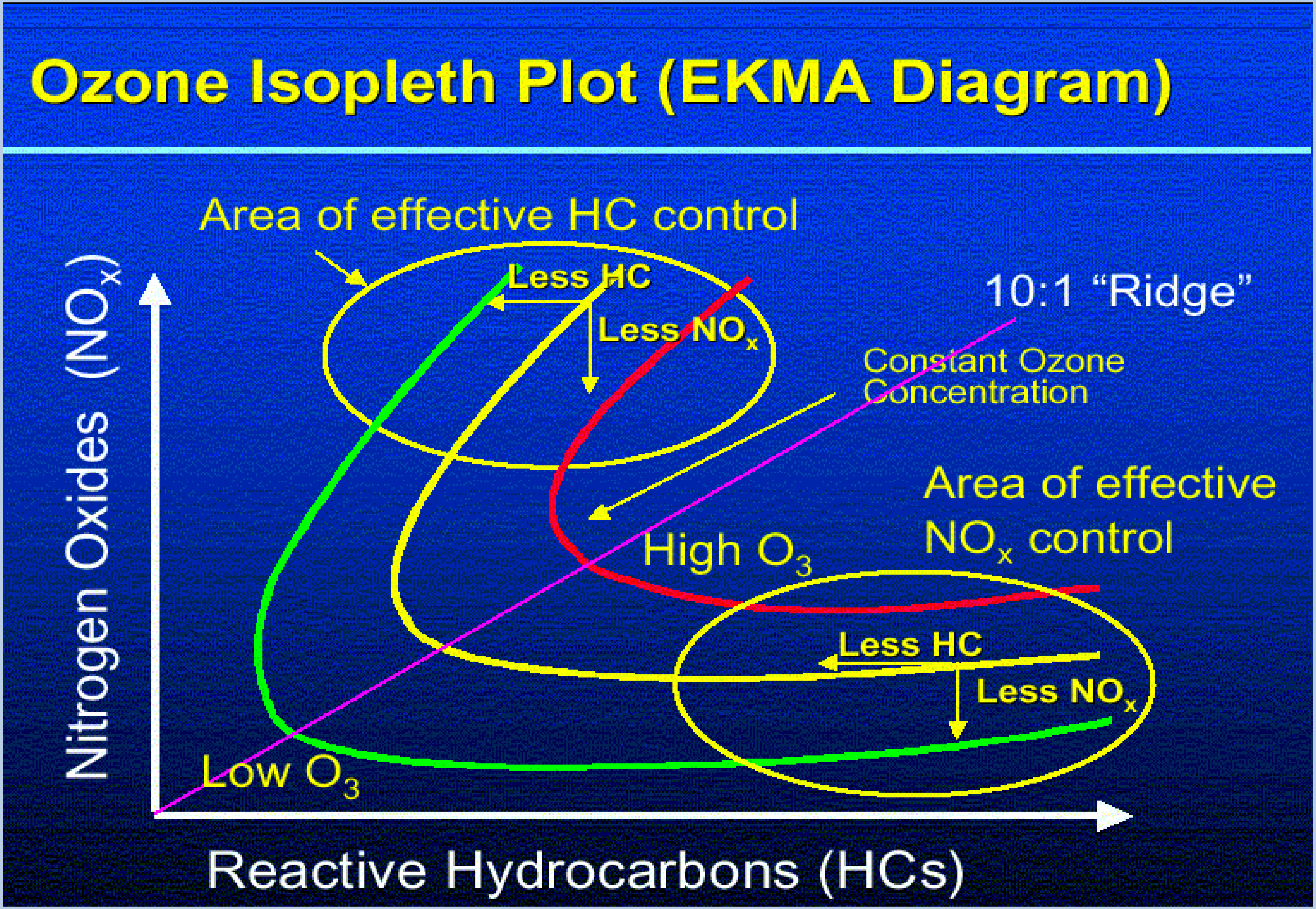
FRAPPÉ still has some funding needs:

- Education and Outreach program (before, during & after deployment)
- Data analysis support for University partners (2015/6)
- Please let us know if interested in supporting this effort

extras

Ozone / photooxidant formation: a highly non-linear system

VOC + NOx + hv → Ozone



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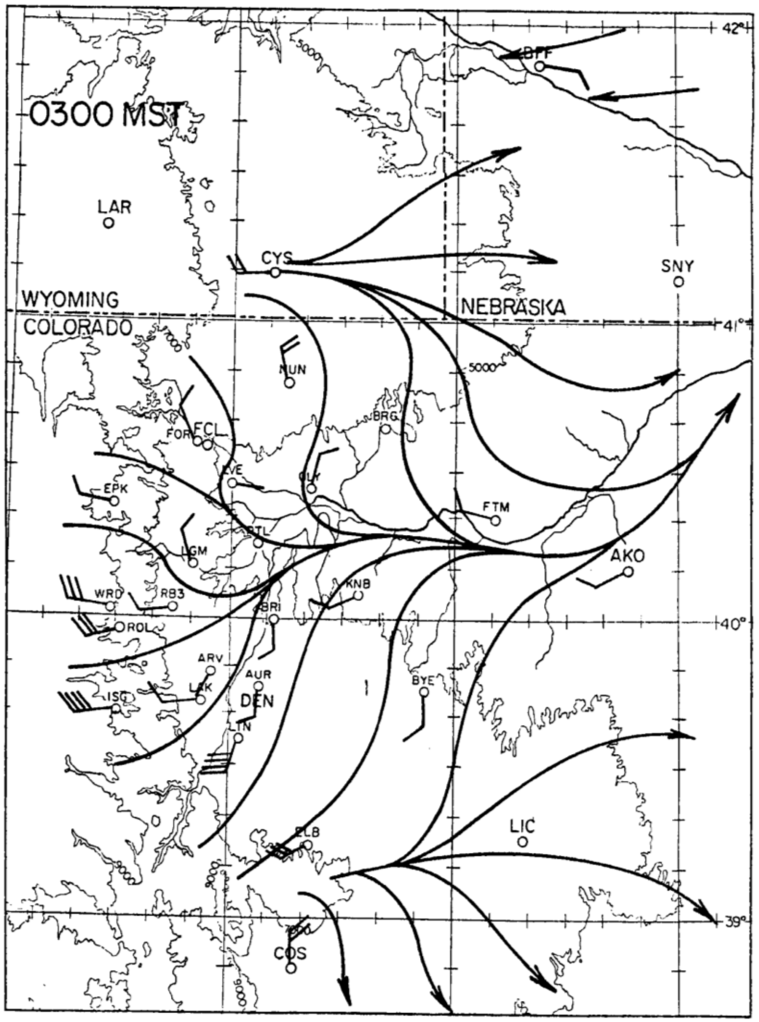


Fig. 5. As in Fig. 2, except for 0300 MST.

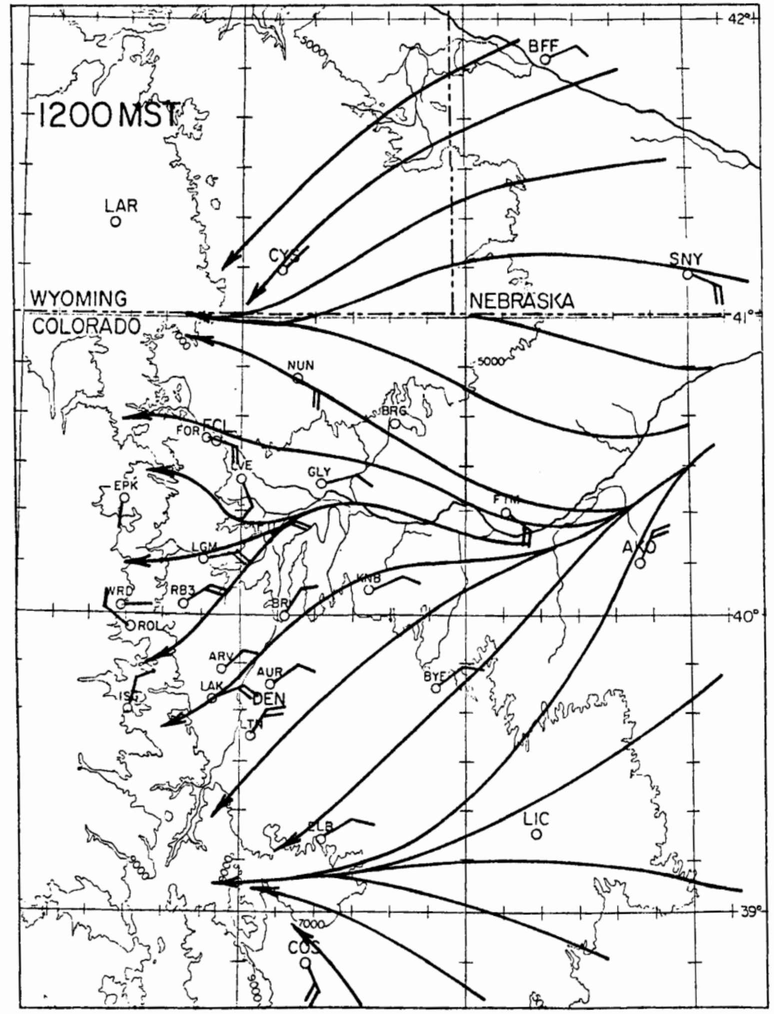
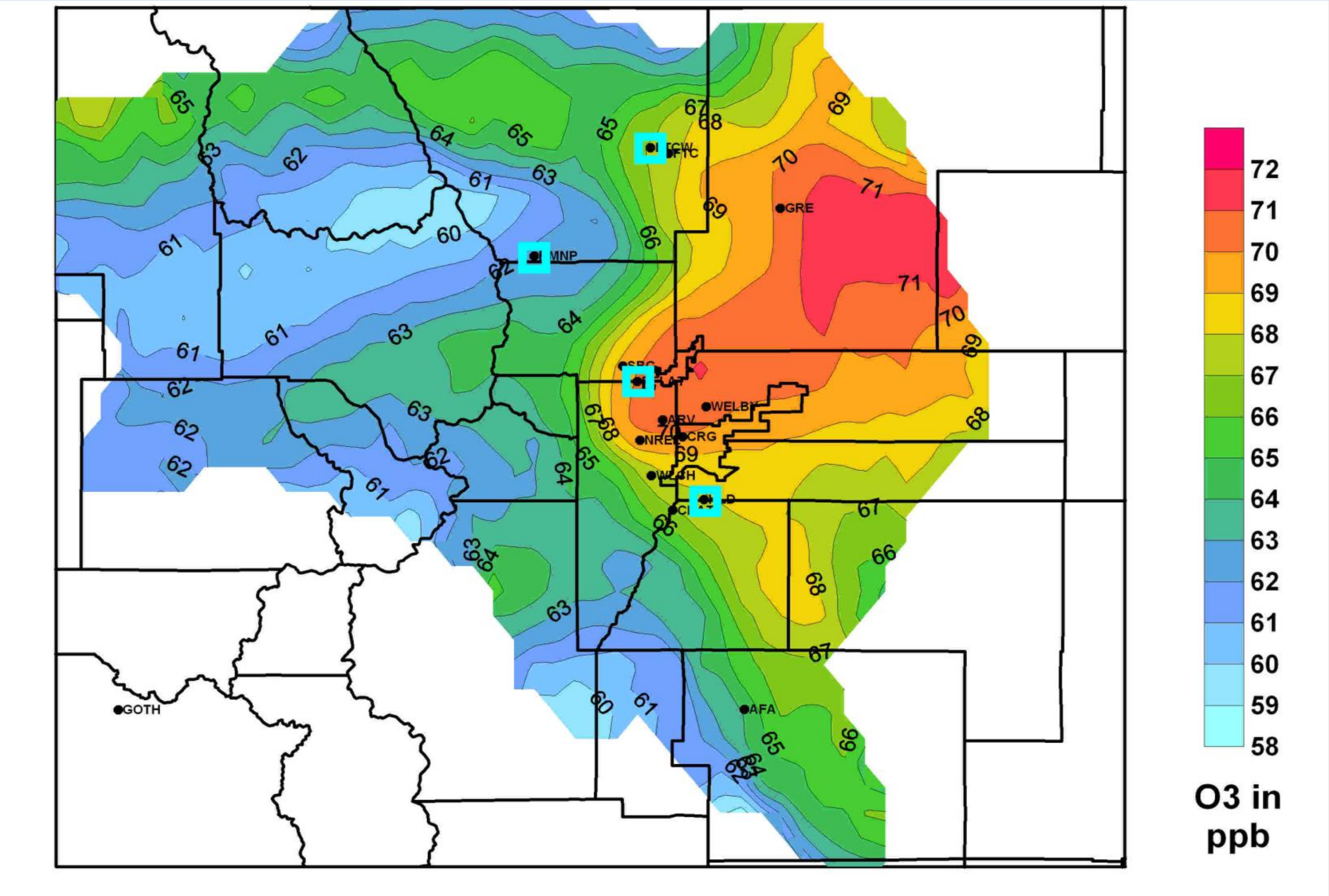


Fig. 14. As in Fig. 2, except for 1200 MST.

From Johnson and Toth, (1981)

FRAPPÉ 2014

Rawhide
Rocky Mtn NP
Fort Collins
Feedlot
Feedlot
Feedlot
Pig Farm
NOAA Platteville Site
Fritz Peak Observatory
Valmont
Erie Tower
KBJC
36
Cherokee
Suncor Refinery
58
70
270
6
Denver
KDEN
470
285
225
Centennial
287
Castle Rock



A map of the average daily max 8-hour O3 associated with air parcels arriving from source regions in and near the Front Range (based on HYSPLIT back trajectories for FTCW, RMNP, RFLAT, and HLD monitoring sites, Summer 2006).

This shows what concentrations are caused at these monitors by air originating in a given area. Urban sources and oil and gas activities are in the key source region.

Courtesy P. Reddy, CDPHE, Air Pollution Control Division

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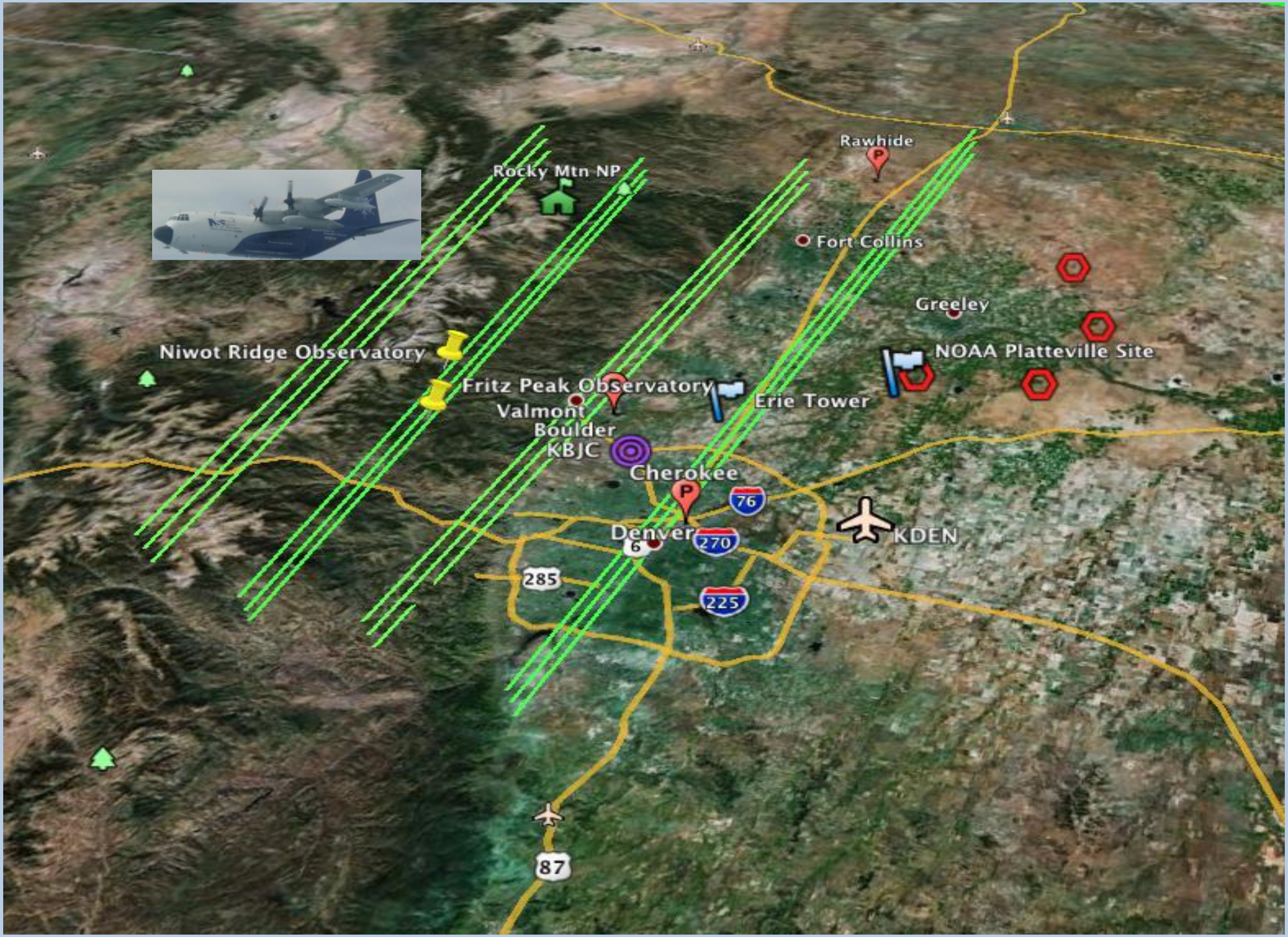
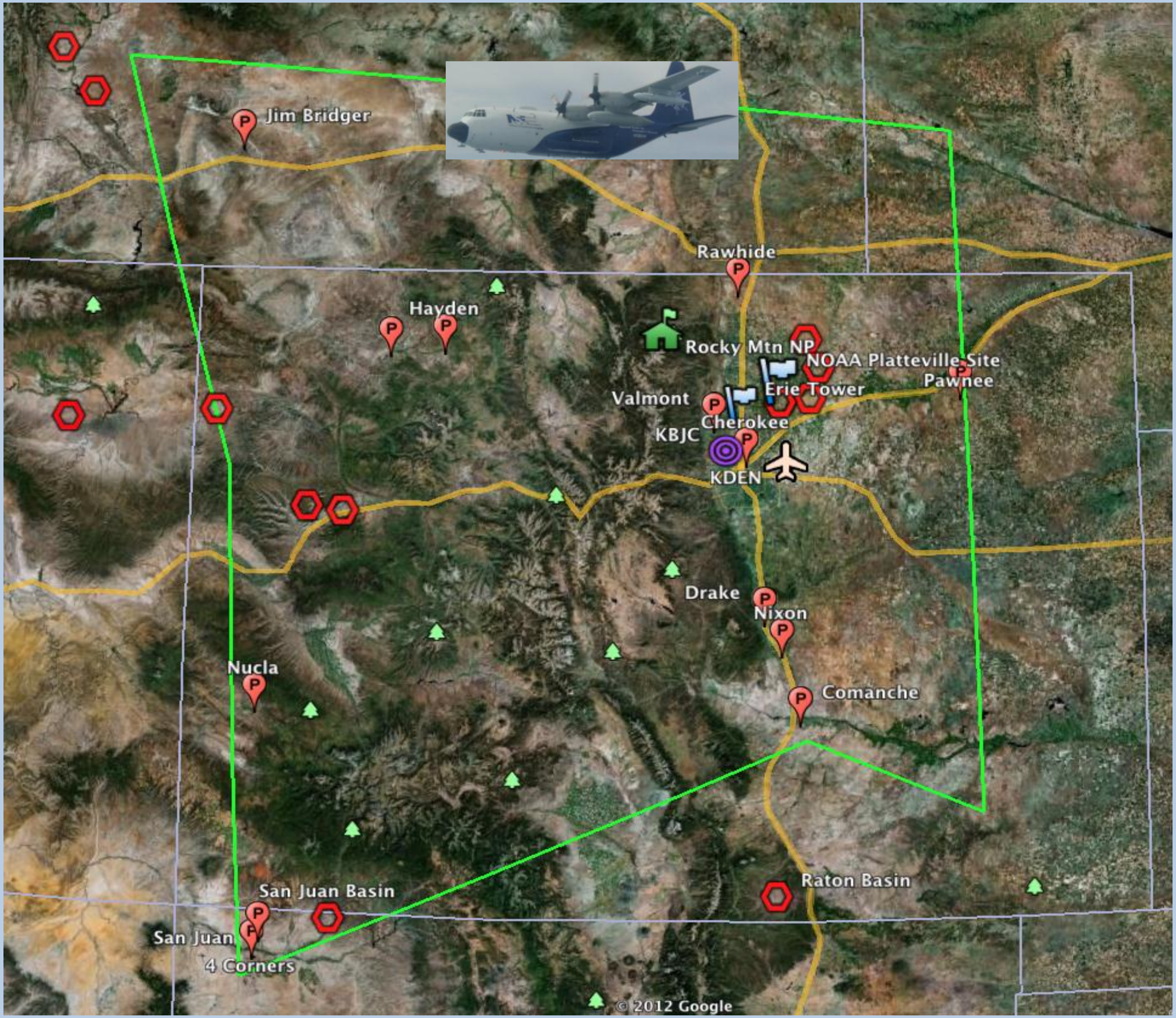


Rawhide
Rocky Mtn NP
Fort Collins
Greeley
NOAA Platteville Site
Niwot Ridge Observatory
Fritz Peak Observatory
Erie Tower
Valmont
Boulder
KBJC
Cherokee
76
Denver
6
270
KDEN
285
225
87

FRAPPÉ 2014


Jim Bridger
Rawhide
Hayden
Rocky Mtn NP
NOAA Platteville Site
Pawnee
Erie Tower
Valmont
Cherokee
KBJC
KDEN
Drake
Nixon
Comanche
Nucla
San Juan Basin
San Juan
4 Corners
Raton Basin
© 2012 Google

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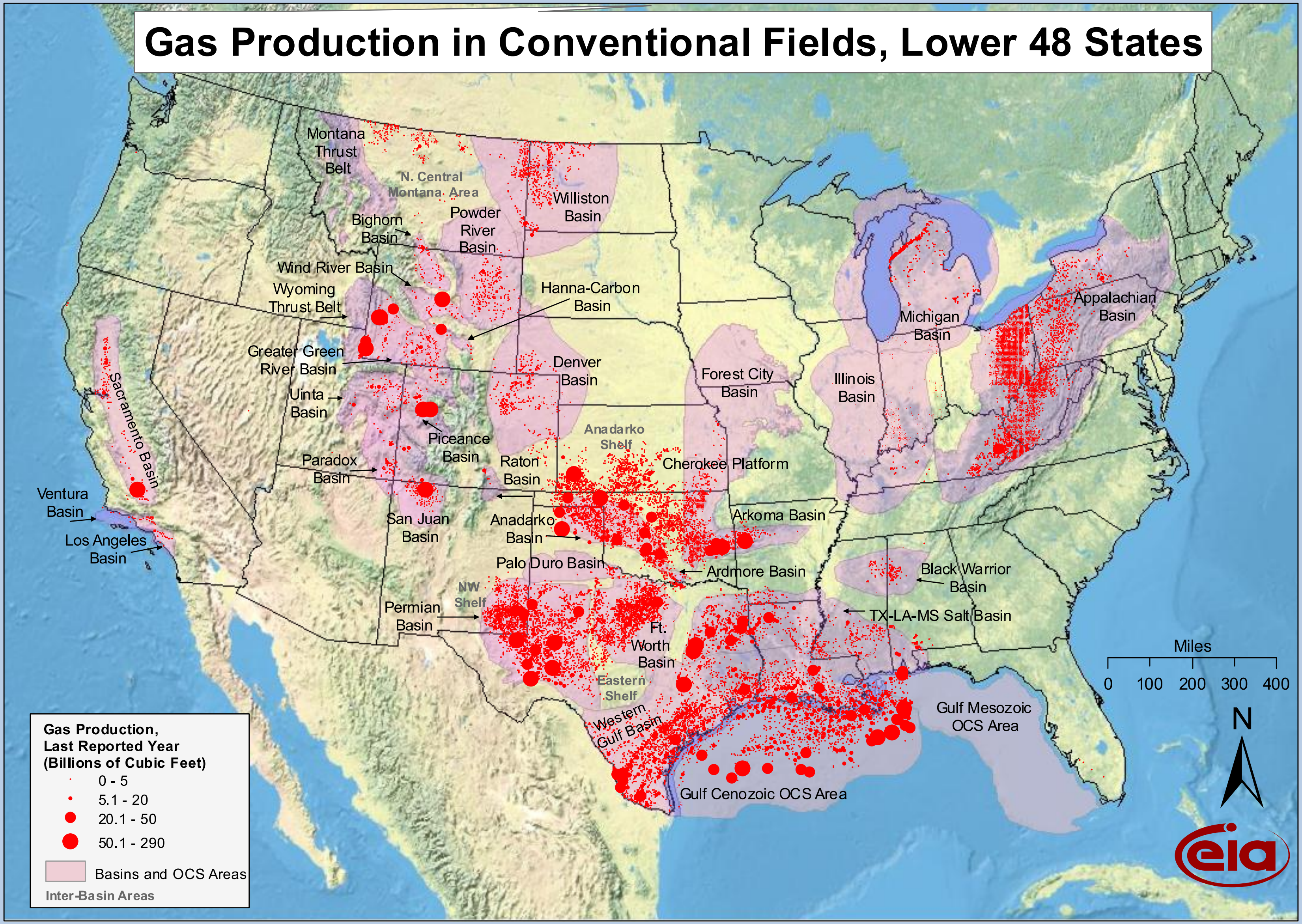

Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009

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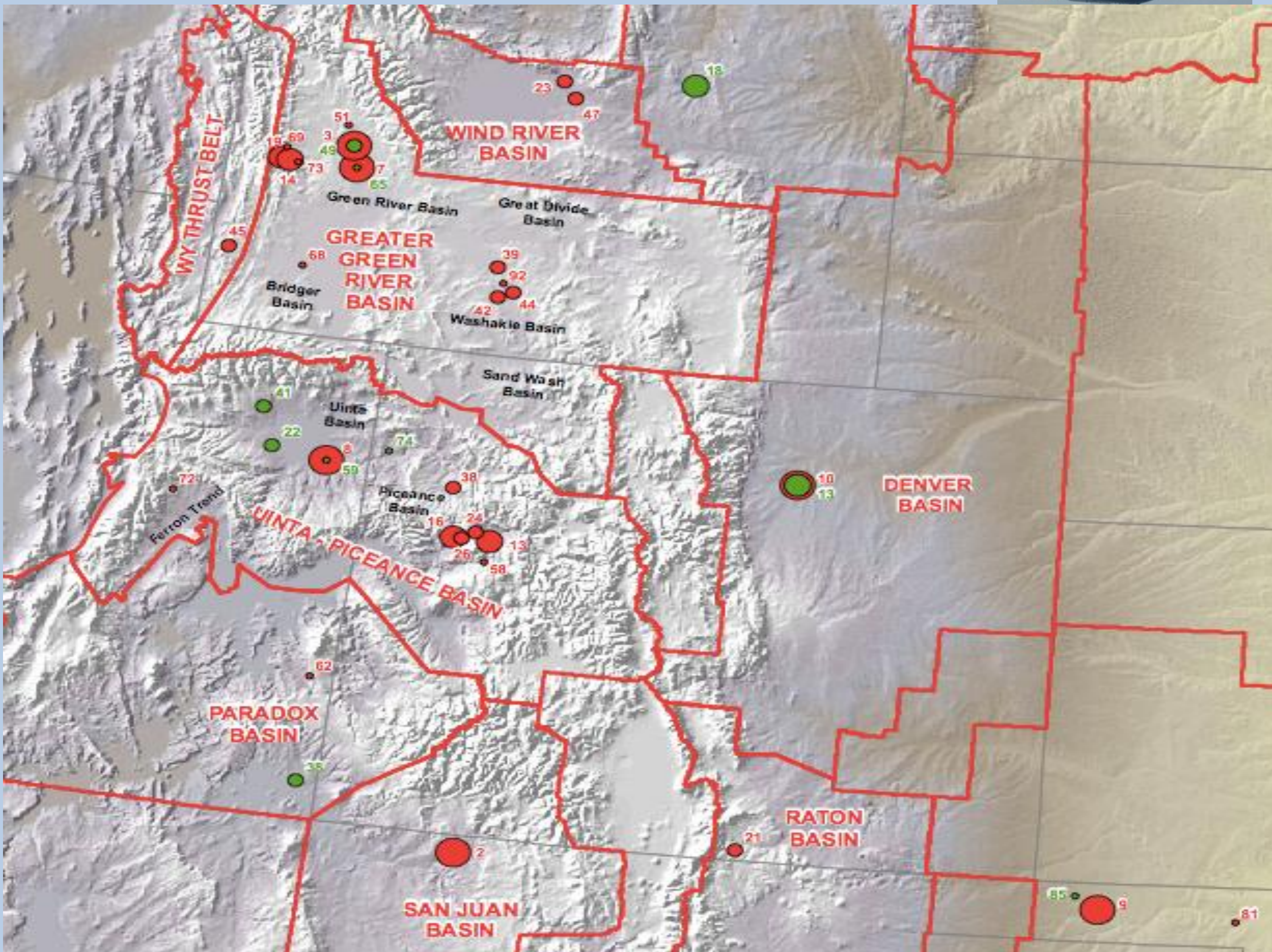

WY THRUST BELT
WIND RIVER BASIN
Green River Basin
Great Divide Basin
GREATER GREEN RIVER BASIN
Bridger Basin
Washakie Basin
Sand Wash Basin
Uinta Basin
Piceance Basin
Ferron Trend
UINTA - PICEANCE BASIN
DENVER BASIN
PARADOX BASIN
SAN JUAN BASIN
RATON BASIN

FRAPPÉ will

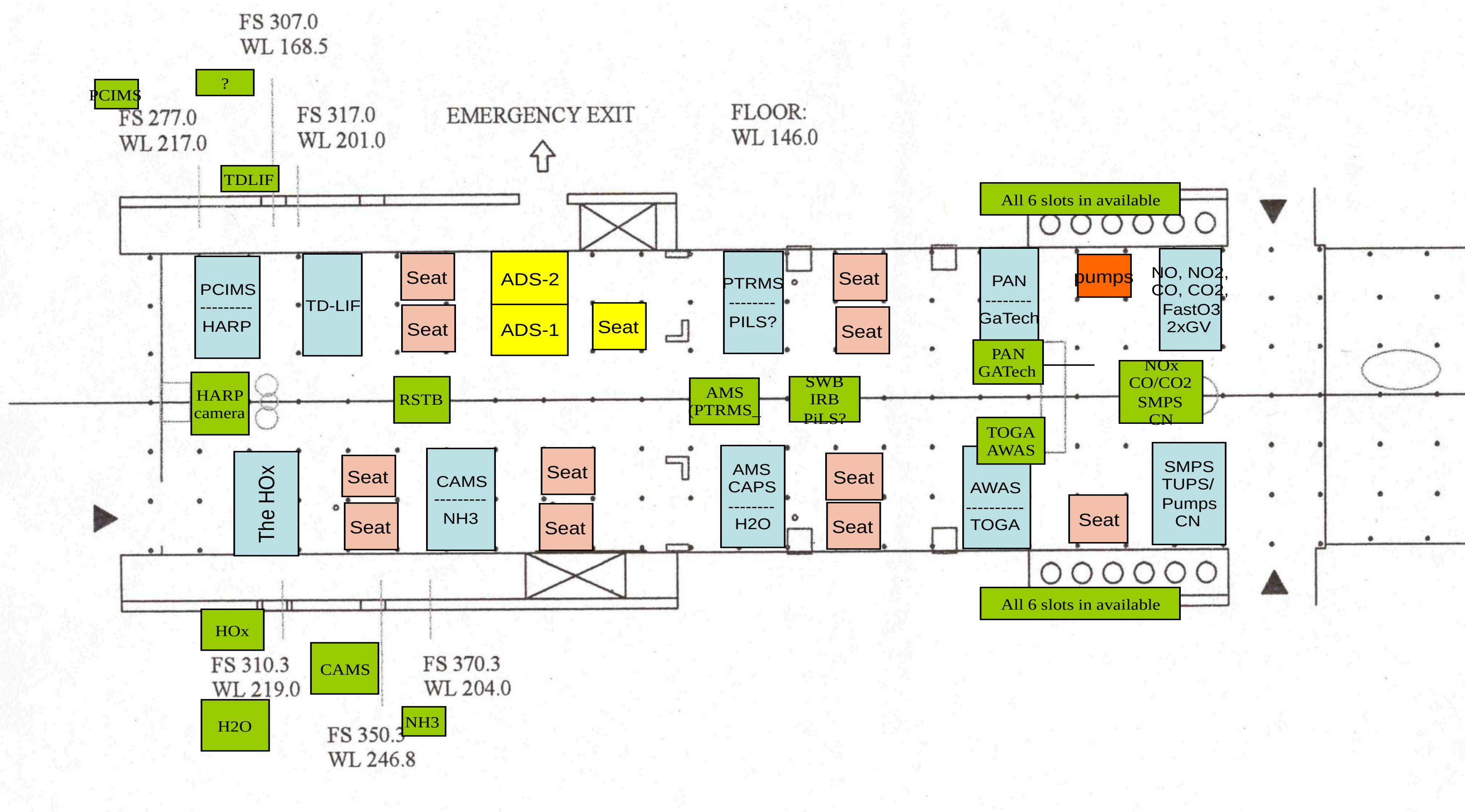
- **Quantify emissions of trace gases from**
  - Oil and gas extraction and related activities
  - Transportation
  - Power generation
  - Agricultural activities
  - Vegetation
- **Quantify the interaction and the overall impact of these emissions on local and regional air quality**
  - Air mass composition (organics, oxidants, NOx)
  - Climate impact
  - Ozone and oxidant formation
  - Formation and evolution of particulates
  - Mountain induced recirculation – accumulation of pollutants
- **Quantify import of larger scale emissions and impact on local air quality**
  - UT and WY oil and gas extraction and power generation
  - California
  - Asian emissions
  - Potential wildfires
- **Develop strategies to reduce oxidant formation and improve air quality**

FRAPPÉ Measurements/Modeling

- Aircraft: Ozone, NO, NO_2, HNO_3, HNO_4, PANs, Alkyl Nitrates, CO, SO_2, CO_2, Methane, Ethane, Alkanes, Alkenes, Alkynes, Oxygenates, CH_2O, Aldehydes, CH3CN, HCN, NH_3, OH, HO_2 and RO_2 radicals, Halogenated tracers, Particles: size distr., type, chemical composition, physical parameters, met. and aircraft state parameters.
- Surface Sites: Photochemical tracers (depends on site), mobile vans with photochemical and emission tracers, vertical profiles (Erie Tower), column integrated measurements of aerosol parameters, vertically resolved measurements of ozone, particles (LIDAR).
- Mobile Labs: Two mobile laboratories (by NOAA and Aerodyne) - and maybe a third mobile lab – will be deployed in the region
- Air Quality Modeling: CMAQ and WRF-Chem at 3km or higher spatial resolution, CAM-Chem (large scale background)

C-130 Payload

Draft C-130 LAYOUT FOR FRAPPÉ
02/03/14



FRAPPÉ Outreach

- Schools: GO3 project; teacher and student involvement in campaign and post-campaign analysis (NSF RETI, NCAR SPARK)
- Opportunities for educators, media people etc. to be on board during flights
- NCAR/Airplanes Open House
- Denver Museum for Nature and Science – “Scientists in Action”
- Nat. Park Service – RMNP staffed real-time displays
- DIA – real time display or experiment video?
- Documentary about Denver brown cloud (James Balog)
- Summer classes at CSU
- NCAR Significant Opportunities in Atmospheric Research and Science (Undergrad Summer Program)

FRONT-PORCH 2014 (NCAR RAL/MMM)

- June to mid-Aug 2014
- Thunderstorm Initiation study
- Radars (fixed and mobile) and integrated sounding systems (ISS)
- High resolution Met-Forecasting (WRF)