Chemical Evolution in Upper Tropospheric Convective Outflow: Case Study of a Mesoscale Convective System During DC3

Jennifer R. Olson; James H. Crawford; Glenn S. Diskin; Glen W. Sachse; Donald R. Blake; Nicola J. Blake; William H. Brune; Li Zhang; Xinrong Ren; Jingqiu Mao; Ronald C. Cohen; Benjamin Nault; Jack E. Dibb; Christopher A. Cantrell; Alan Fried; Dirk Richter; Petter Weibring; Eric C. Apel; Frank M. Flocke; Samuel R. Hall; Rebecca S. Hornbrook; Kirk Ullmann; Andrew J. Weinheimer; Thomas F. Hanisco; Thomas B. Ryerson; John Crounse; Jason M. St Clair; Paul O. Wennberg; Armin Wisthaler; Tomas Mikoviny; and the DC3 Science Team

NASA Langley, U California – Irvine, Penn State, NOAA ARL, Princeton, U California – Berkeley, U New Hampshire, U Colorado, NCAR, NASA Goddard, NOAA ESRL, CalTech, U Innsbruck

University of Colorado Boulder

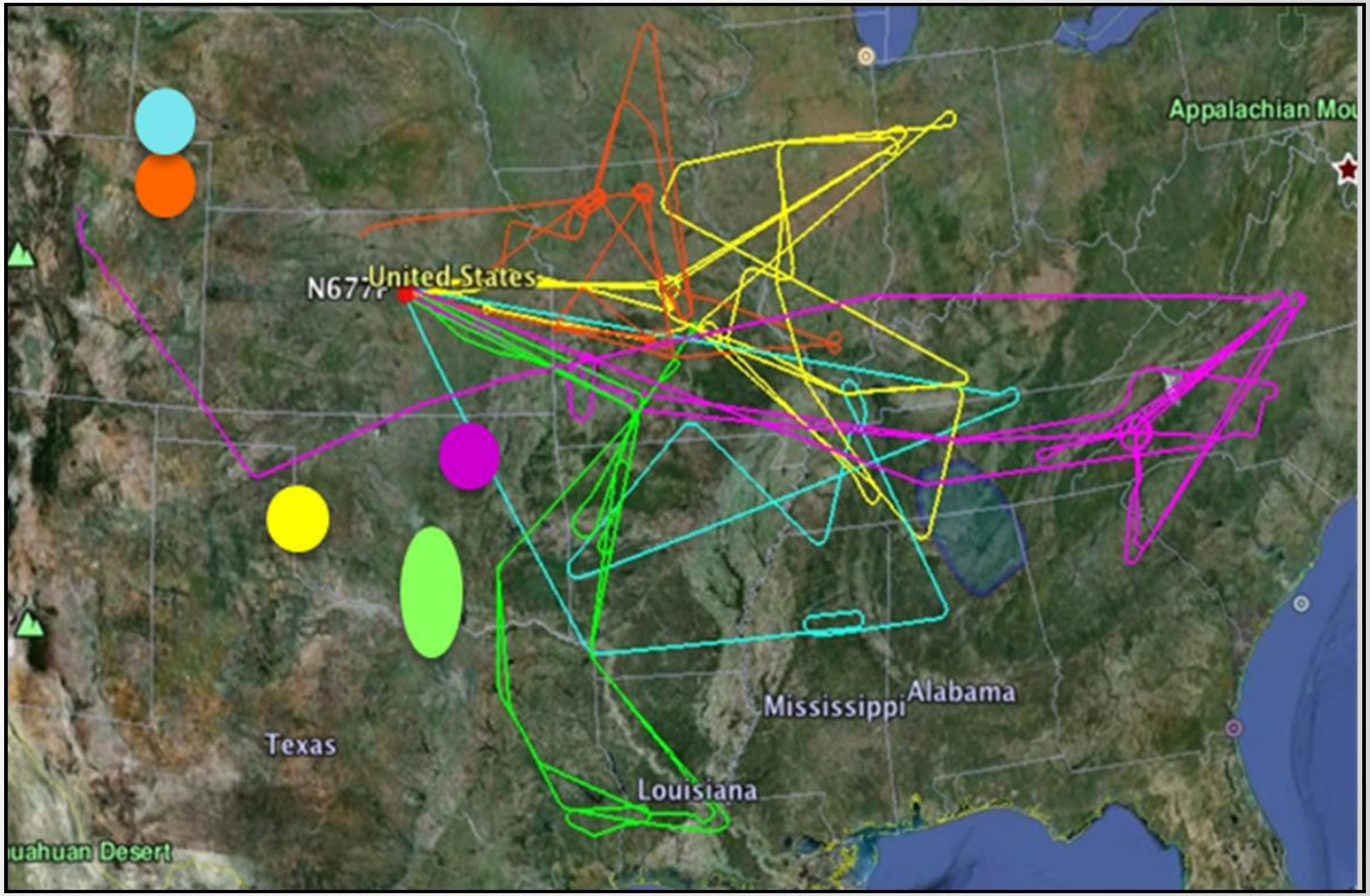
DC3 – Deep Convective Clouds and Chemistry
(goal 1: study of processes in and near active convection)

Goal 1. Quantify and characterize the convective transport of fresh emissions and water to the upper troposphere within the first few hours of active convection, investigating storm dynamics and physics, lightning and its production of nitrogen oxides, cloud hydrometeors effects on scavenging of species, surface emission variability, and chemistry in the anvil.

DC3 – Deep Convective Clouds and Chemistry

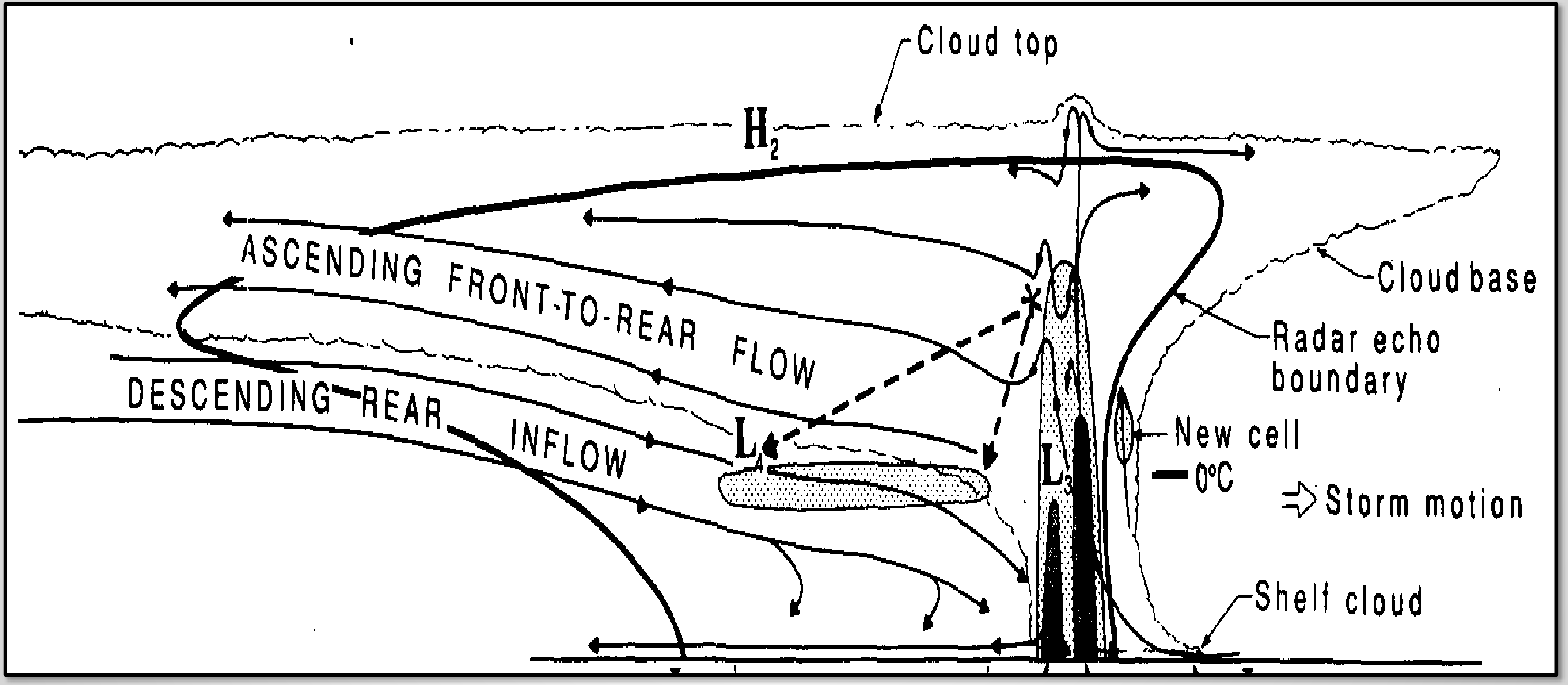
(goal 2: study of outflow aging)

Goal 2. Quantify the changes in chemistry and composition in the upper troposphere after active convection, focusing on 12-48 hours after convection and the seasonal transition of the chemical composition of the upper troposphere.



MCS Schematic Diagram

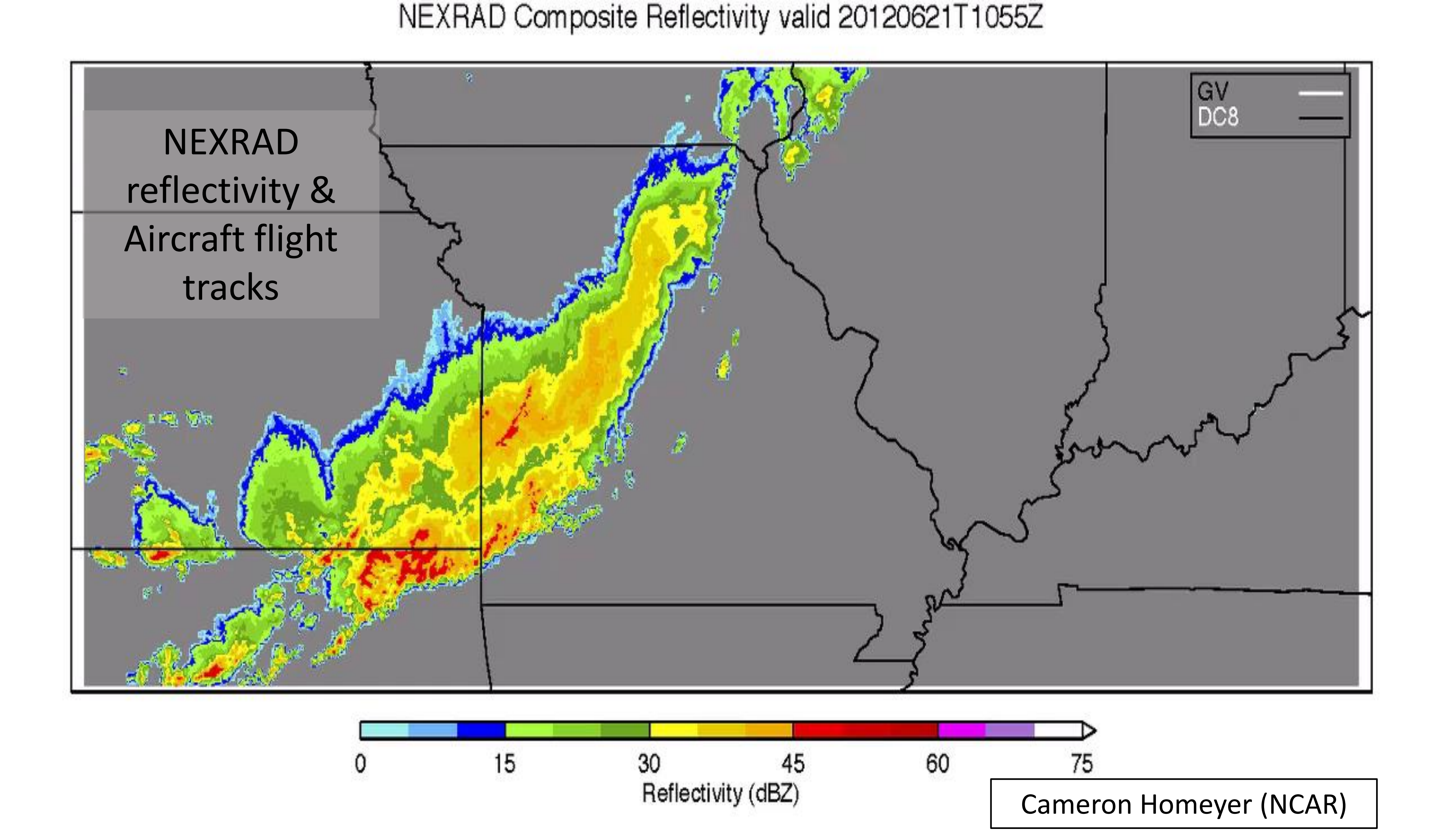
(outflow exits rear of storm)



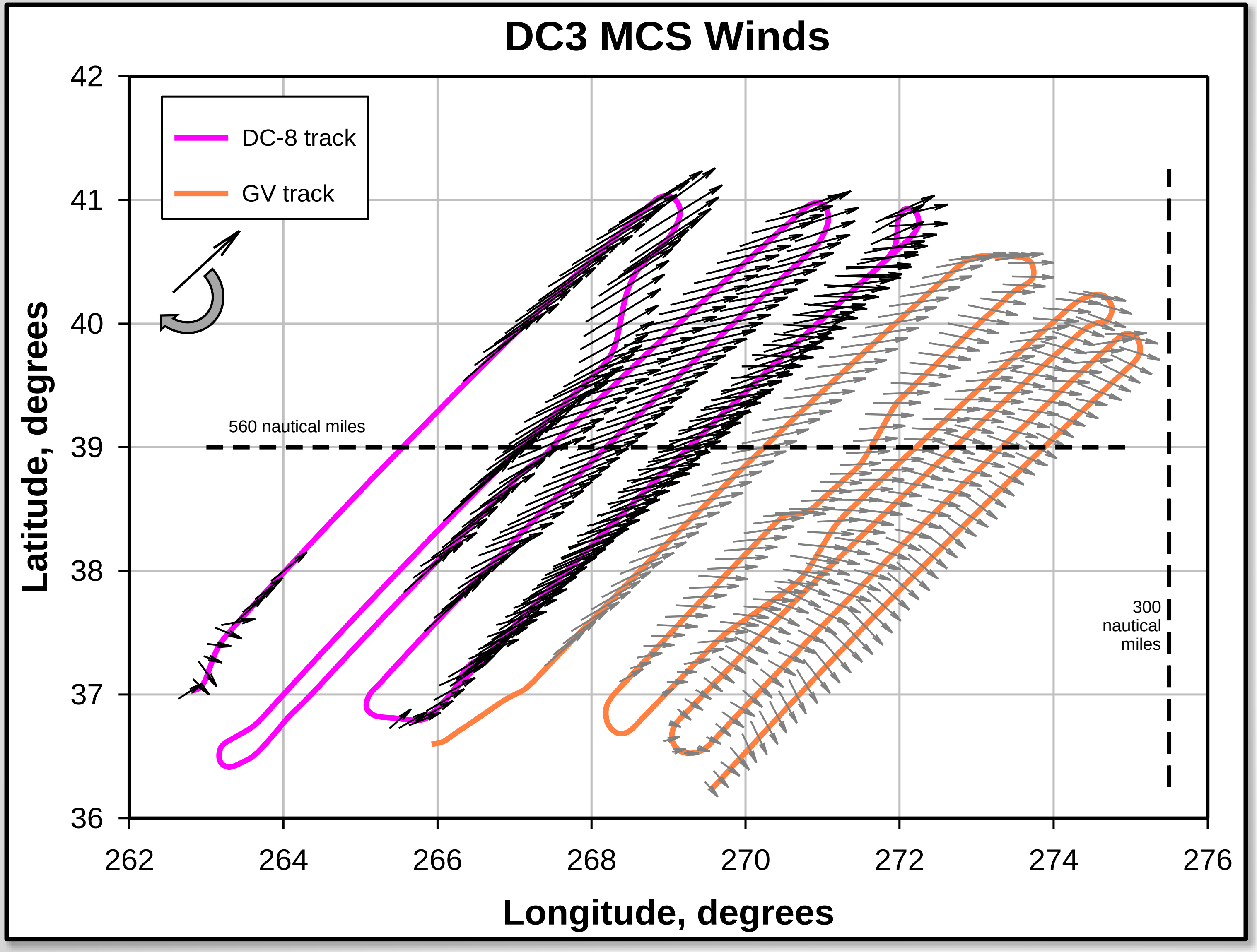
Houze, Rutledge, Biggerstaff, and Smull (BAMS, 1989)

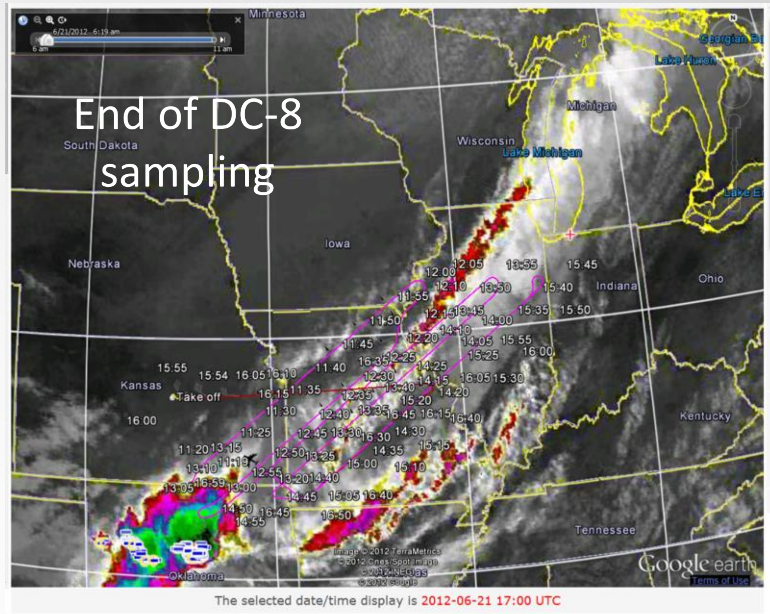
Decaying Nocturnal MCS – 21 June 2012

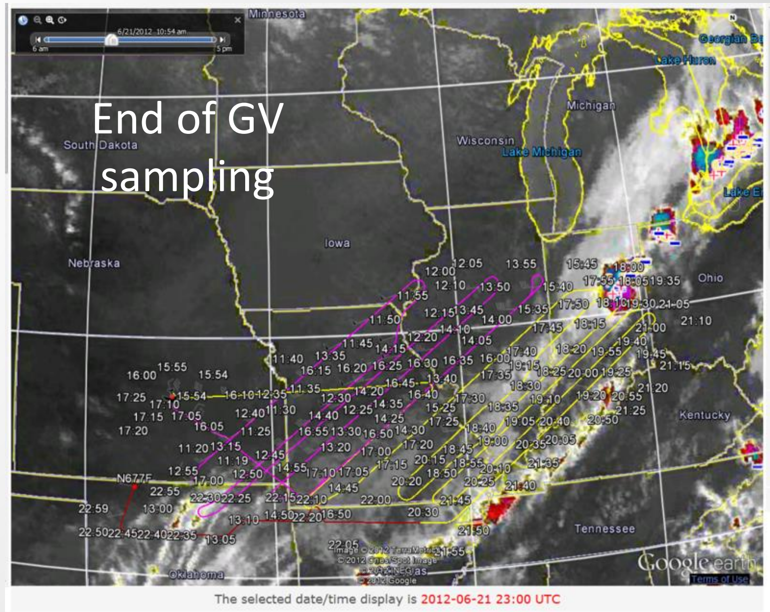
- Started previous evening as line from Wisconsin to Kansas
- Marched southeast through Wisconsin, Iowa, Illinois, and Missouri
- Staged aircraft deployment:
  - DC-8 sampled outflow from 6:00 am to 11:00 am (Local Sun Time)
  - GV sampled outflow from 11:00 am to 4:00 pm
- Each aircraft traversed outflow six times
  - Leg length ranged from about 40 to 60 minutes
- Aircraft flew potential temperature values from 341 to 345 K (about 11.5 km)
- Sampled outflow from eastern Kansas though Missouri, Illinois, and Indiana


NEXRAD Composite Reflectivity valid 20120621T1055Z
NEXRAD reflectivity & Aircraft flight tracks
GV
DC8
0
15
30
45
60
75
Reflectivity (dBZ)
Cameron Homeyer (NCAR)

Aircraft flight tracks & winds

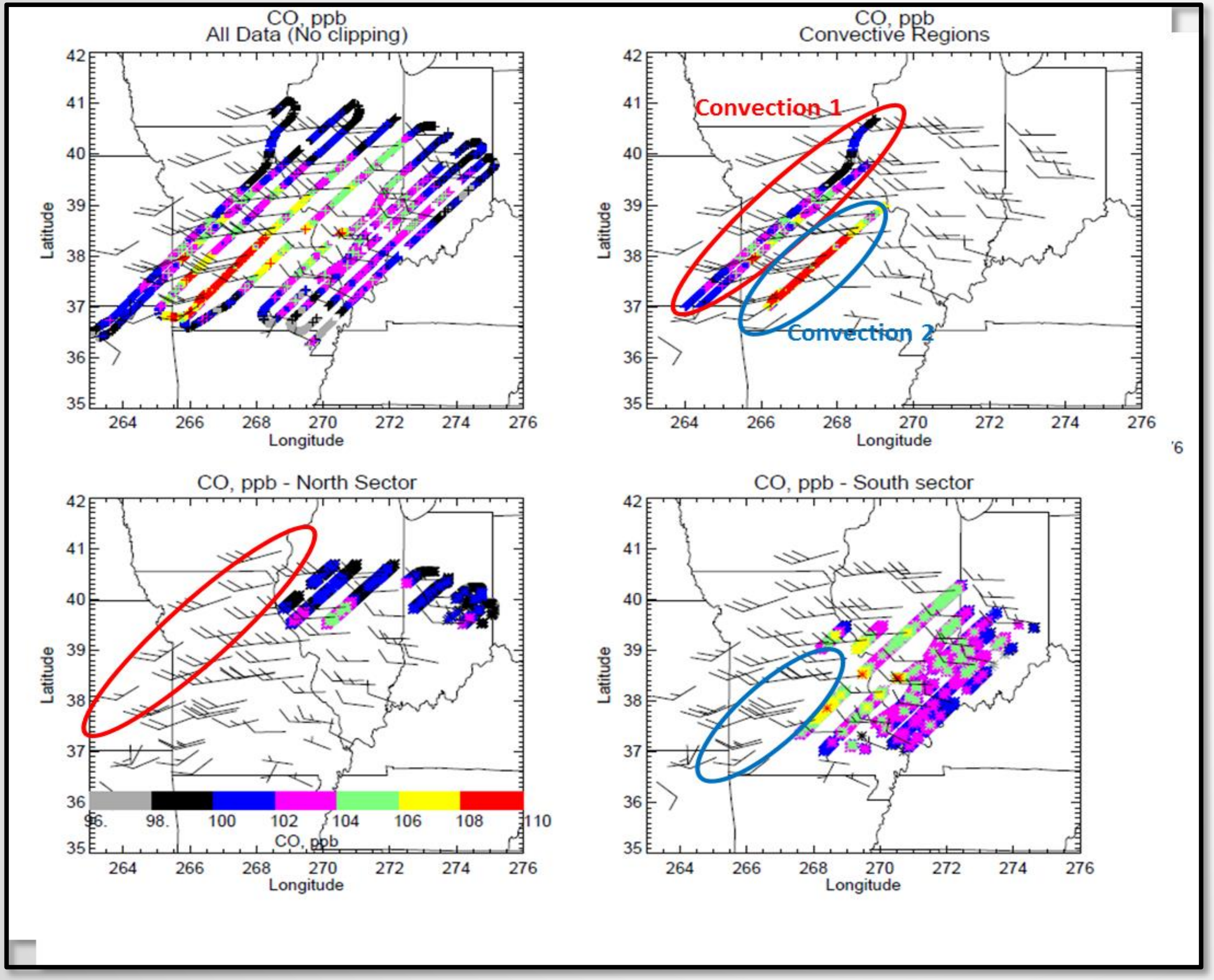






DC-8 data: R. Shetter, E. Buzay; GV data: A. Schanot

Parsing of samples



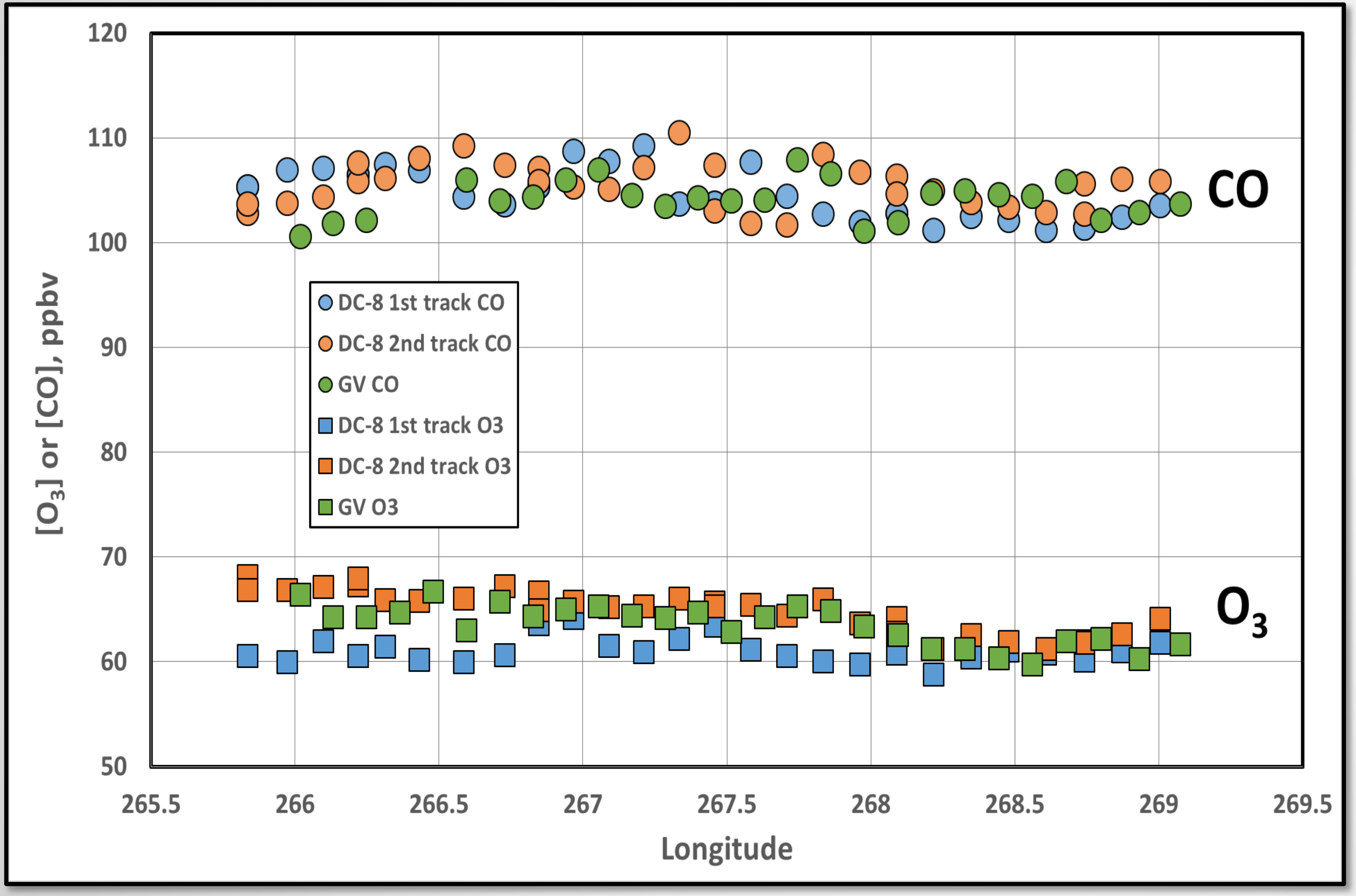
Analysis by Jennifer Olson (NASA Langley)

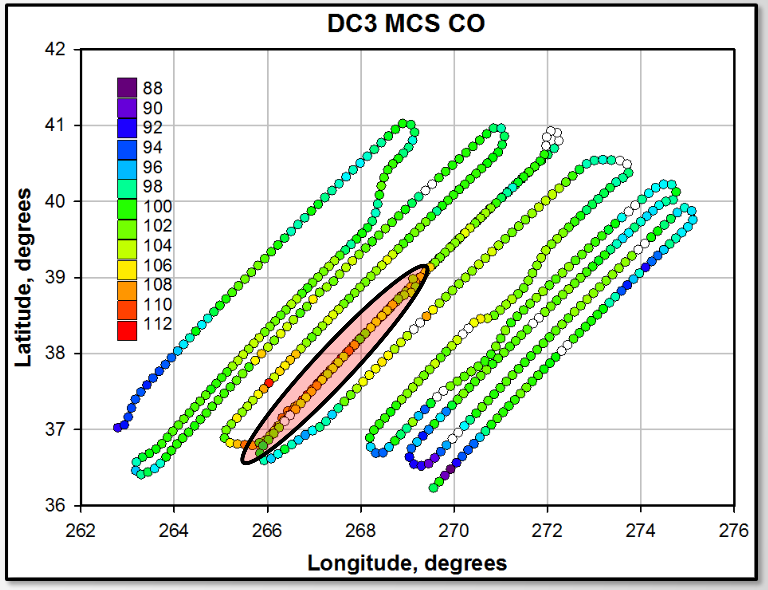
Data parsed into three categories:

1) **Active convection – 2 locations (upper right panel)**
2) **North sector outflow from convection 1 (lower left panel)**
3) **South sector outflow from convection 2 (lower right panel)**

Nearly entire dataset in the proximity of the MCS in upper left panel.

Comparison of observations in overlapping legs





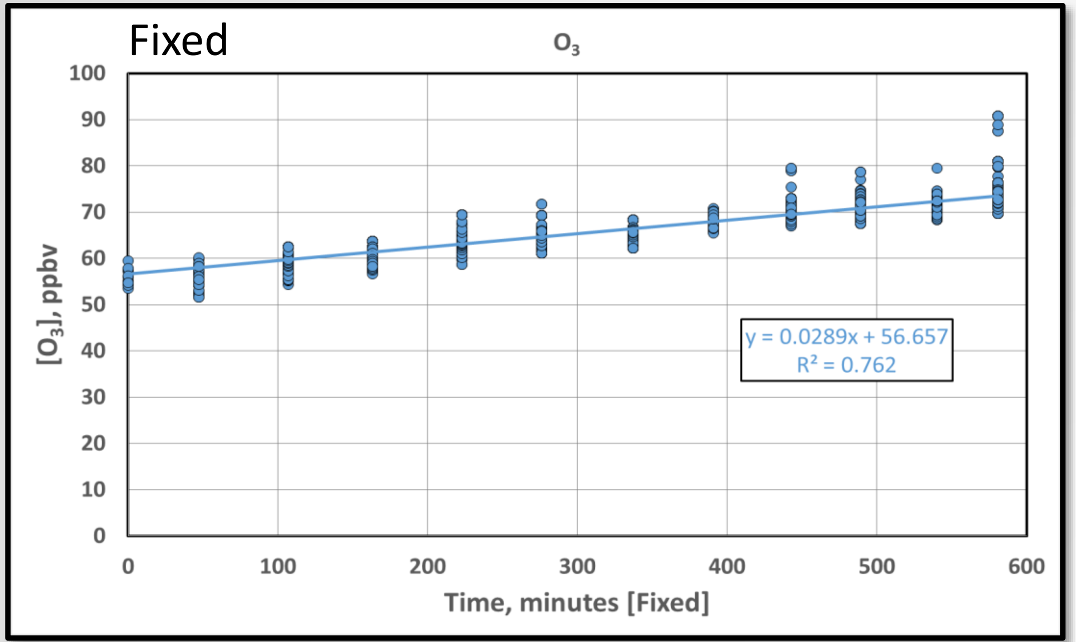
DC-8 O_3: T. Ryerson, I. Pollack, J. Peischl (NOAA ESRL)

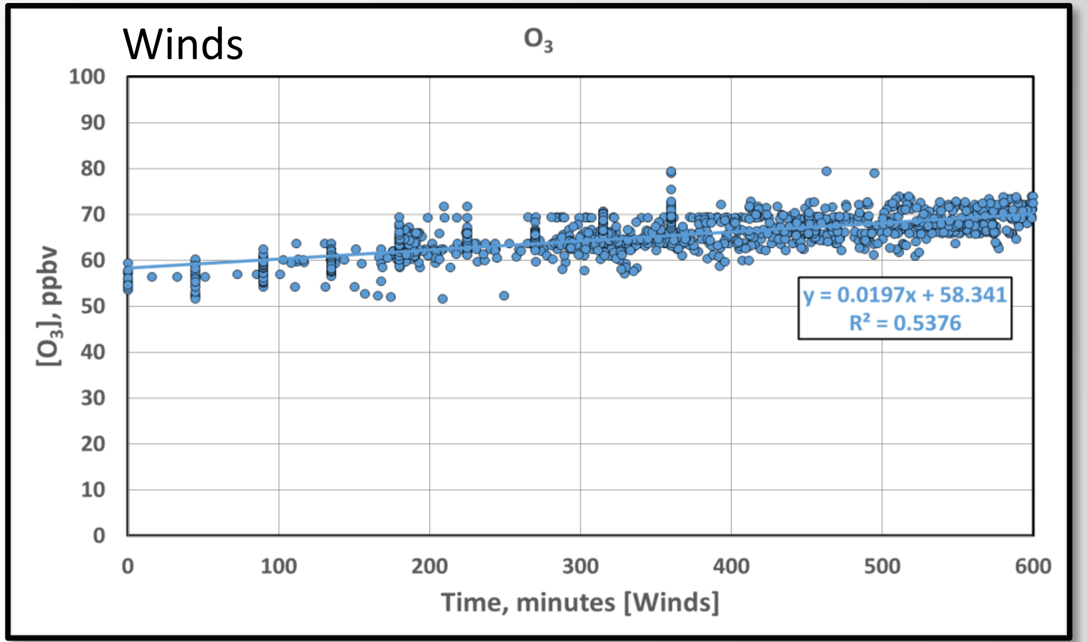
GV O_3: A. Weinheimer, D. Knapp, D. Montzka, F. Flocke, T. Campos (NCAR)

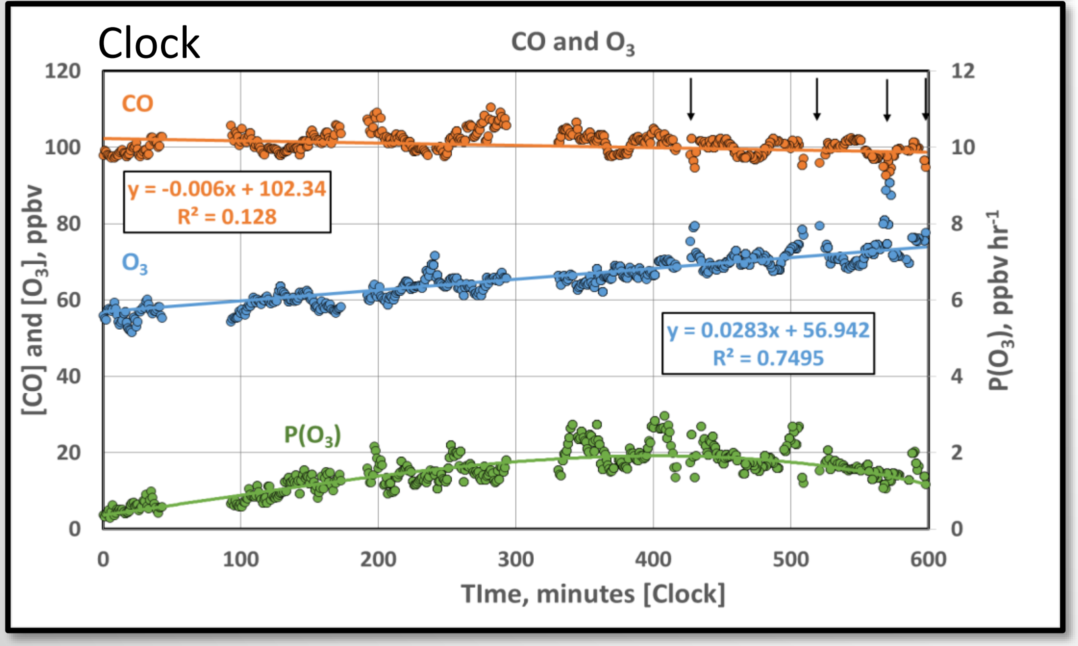
Assigning Photochemical Processing Times

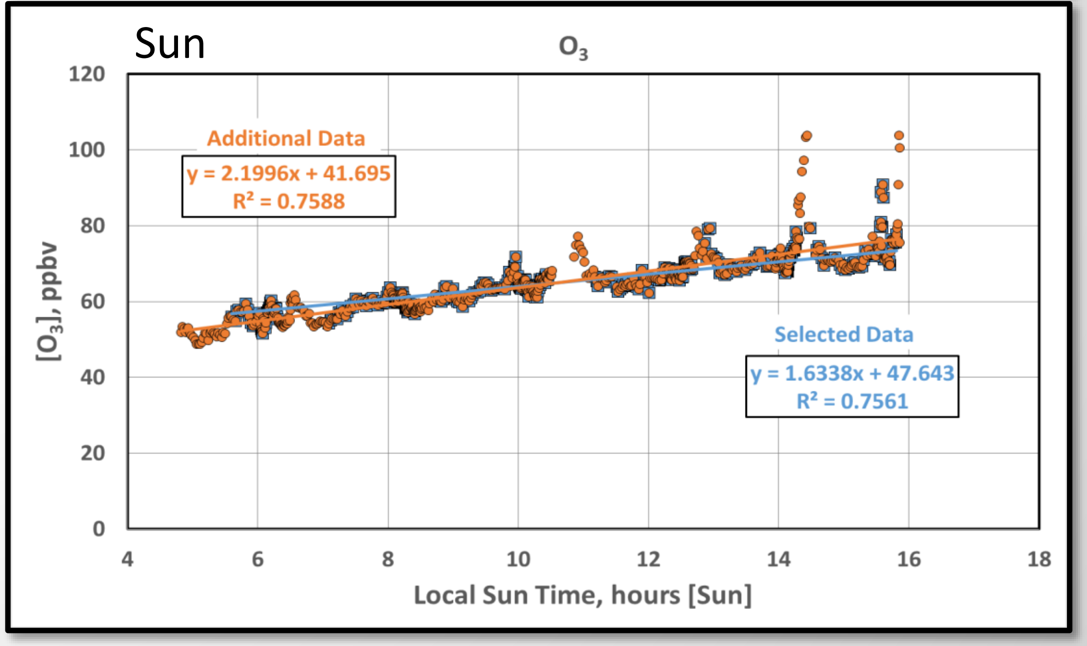
- [Clock] Time of Measurement (UTC) – set 1st point of first leg to 0
- [Wind] Transport time from wind speed, wind direction and distance
  - Can use to filter out trajectories that cannot be sampled later
- [Sun] Local sun time (solar time of day)
- [Fixed] Same time for entire leg = time to sample previous leg (0 for first leg)
- Future: Examine photochemical clocks based on ratios of observed species

Ozone trends using different time estimates

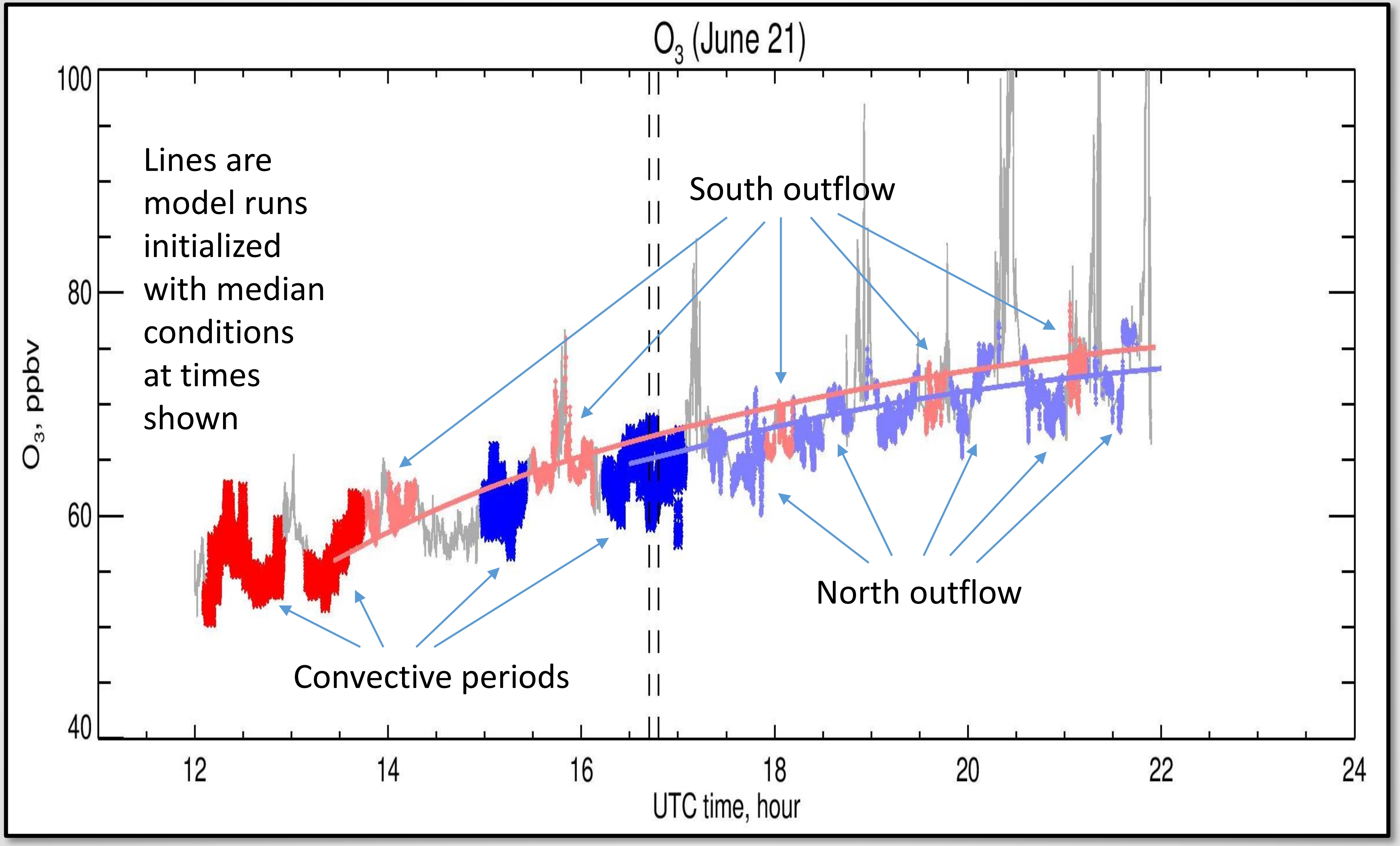








O_3 evolution from Langrangian model & observations



Model runs and plots from Jennifer Olson

O_3 trend estimate summary

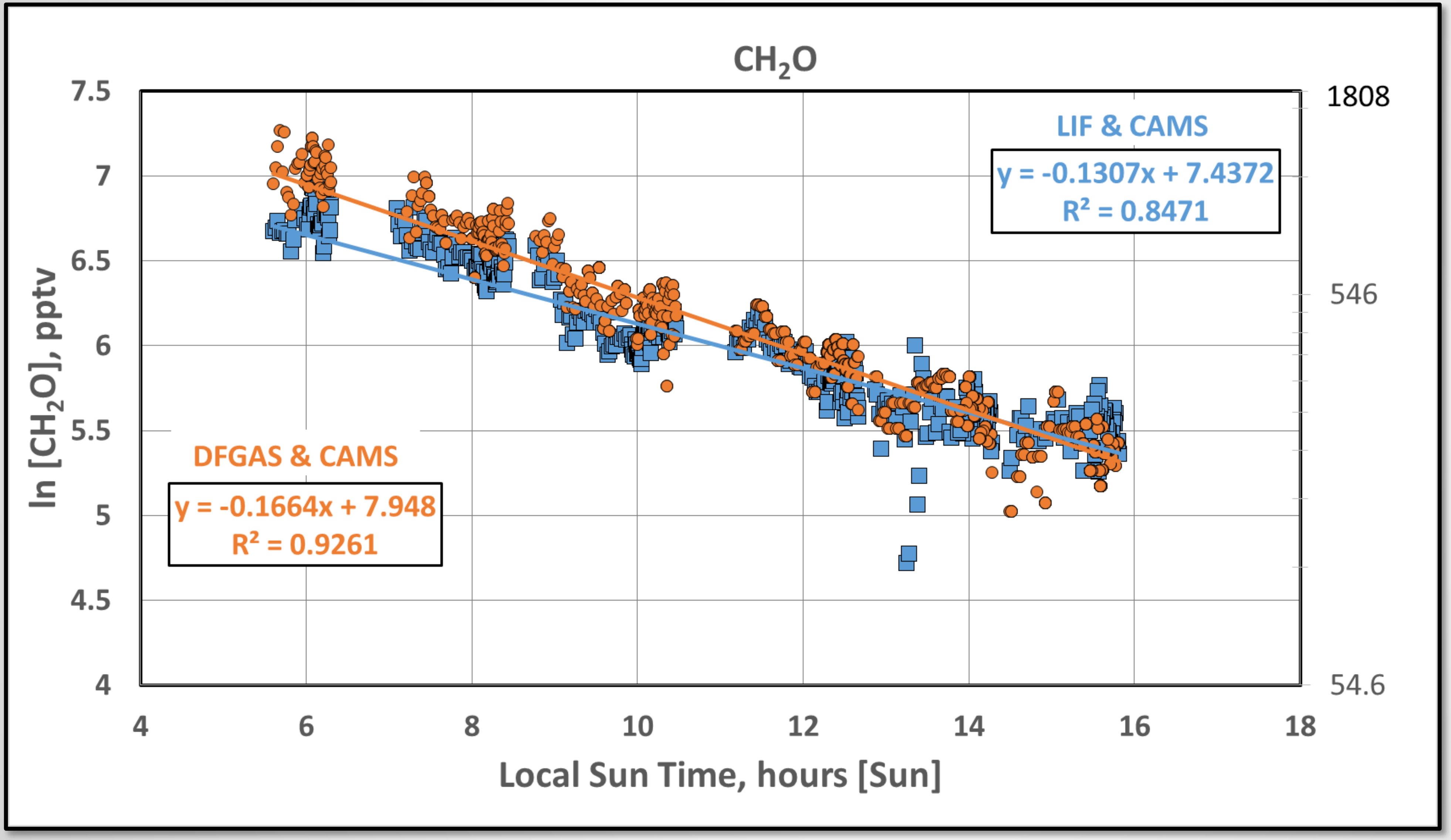
Time Method	Linear Fit Slope, ppbv/hour	$\Delta[O_3]$ in 12 hrs	r^2
Fixed	1.73	20.8	0.76
Winds	1.18	14.2	0.54
Clock	1.70	20.4	0.75
Sun	1.64	19.7	0.76
Calculated $P(O_3)$*	1.62#	19.4	--

*** Based on measured $j(NO_2)$, [NO], $[NO_2]$, $[O_3]$, $[HO_2]$, T, P**

 # average $P(O_3)$ over outflow measurement period

Lagrangian model $\Delta[O_3]$ is about 20 ppbv

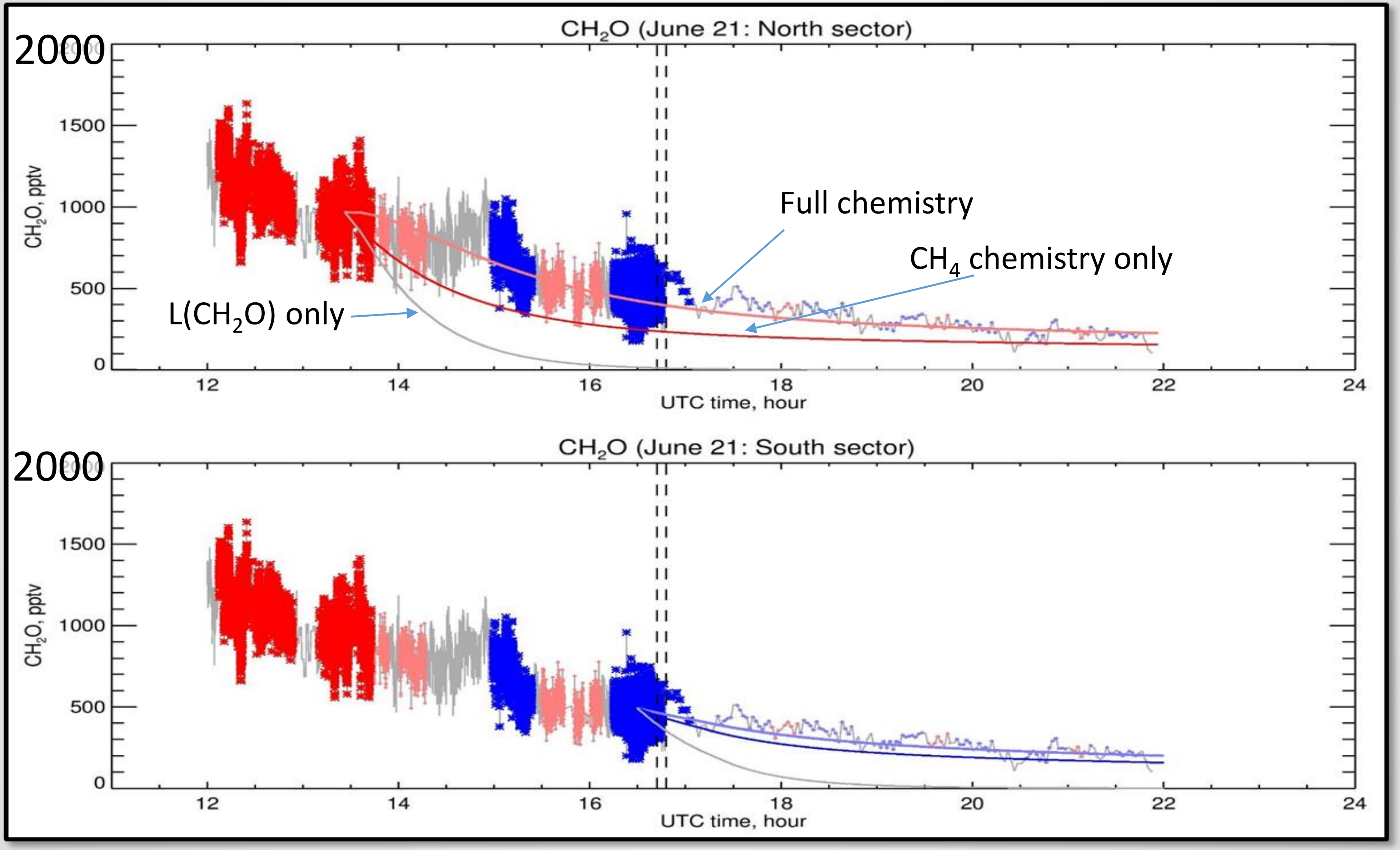
CH_2O trends from observations



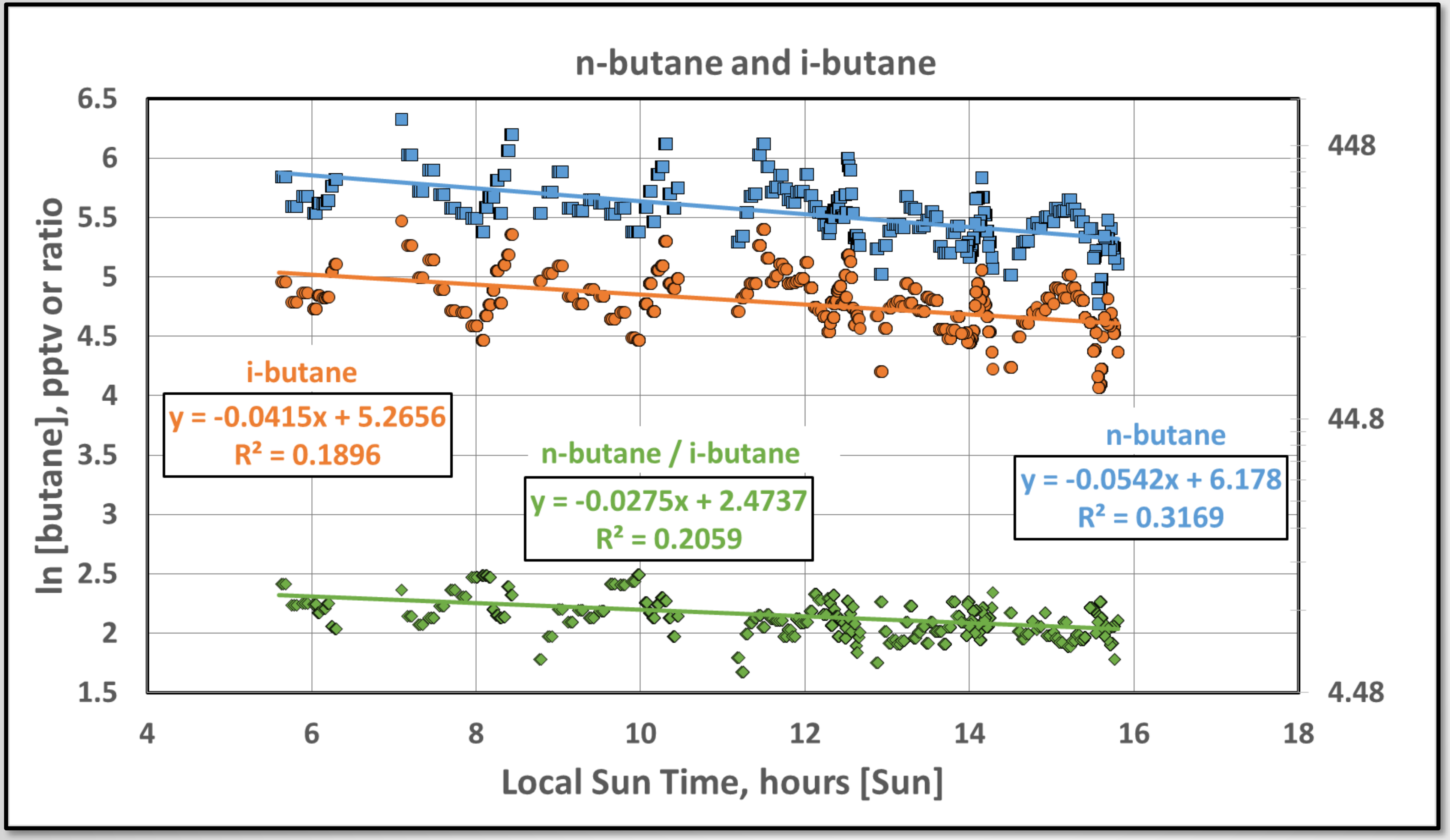
- Observed decay corresponds to lifetimes of about 6 to 7.5 hours
- Lifetime to loss to OH reaction and photolysis is 0.9 hours near midday

DC-8 CH_2O: T. Hanisco (NASA), H. Arkinson (U Maryland); A. Fried, J. Walega (U Colorado)
GV CH_2O: D. Richter, P. Weibring (U Colorado)

CH_2O evolution from Lagrangian model & observations



Butanes trends from observations

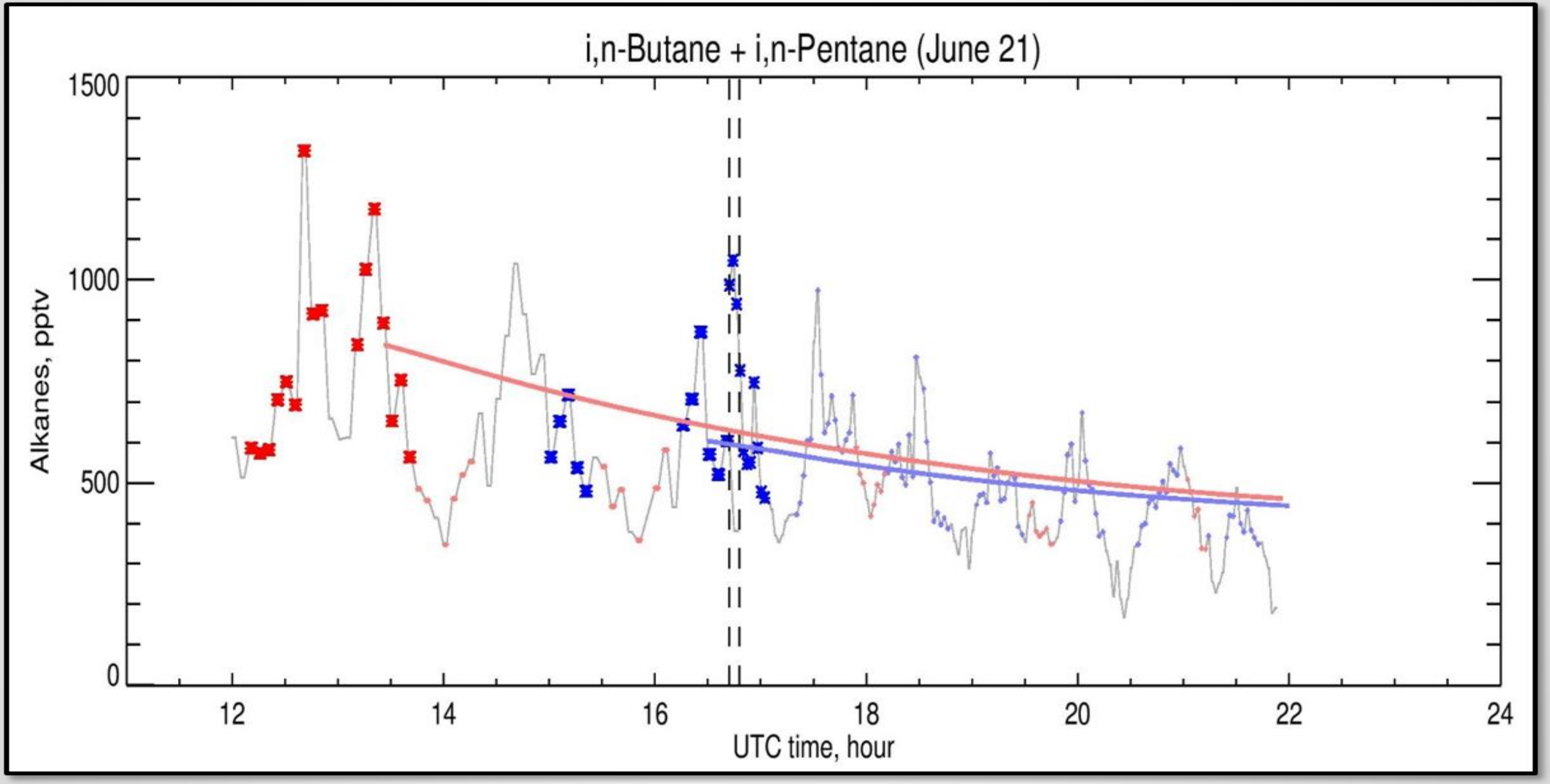


- Observed decay corresponds to lifetimes of about 18 & 24 hours
- Lifetime to loss to OH reaction is 13 & 25 hours near midday
- N-but / i-but ratio tends toward about 2; k(n-but) / k(-i-but) = 1.95

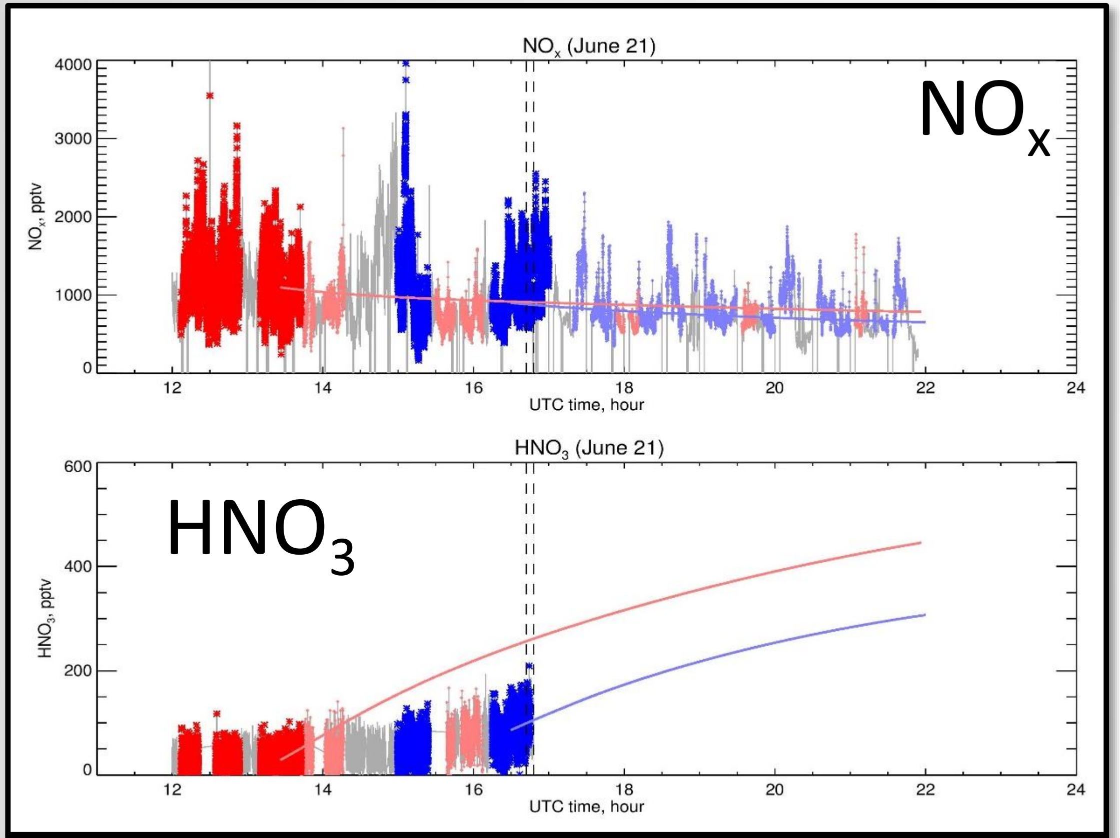
DC-8 HCs: D. Blake, N. Blake, S. Meinardi, B. Barletta (U California-Irvine

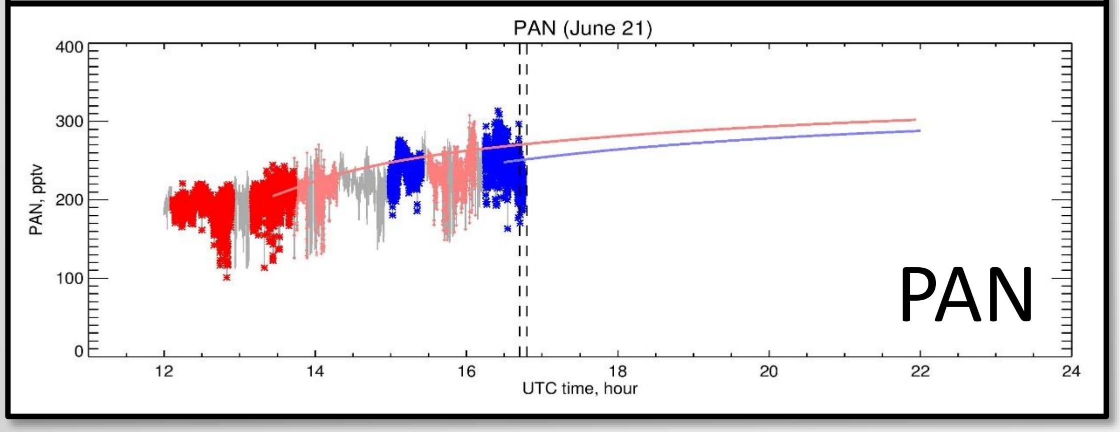
GV HCs: E. Apel, R. Hornbrook, D. Riemer, A. Hills

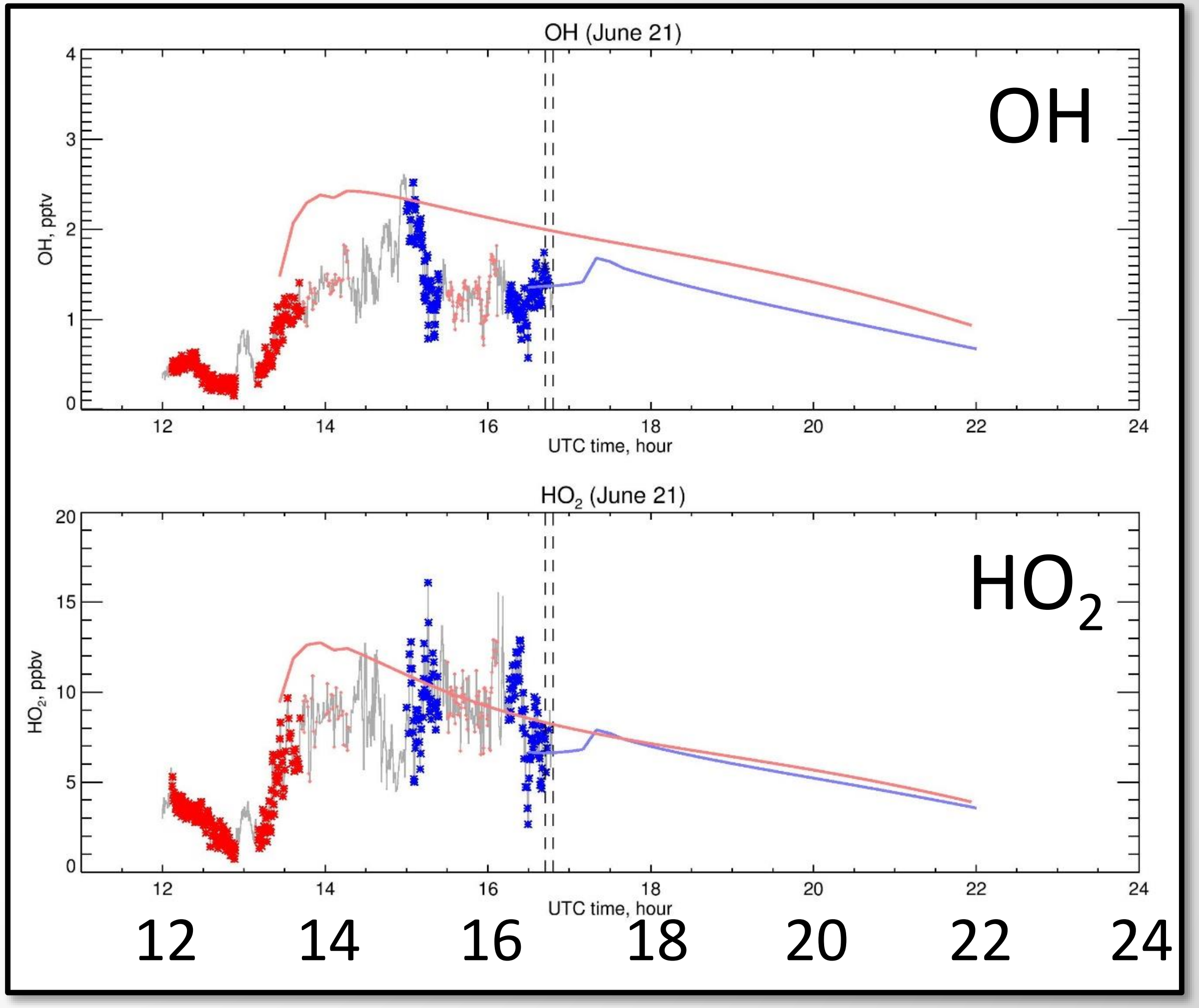
Butanes and pentanes evolution from Lagrangian model and observations



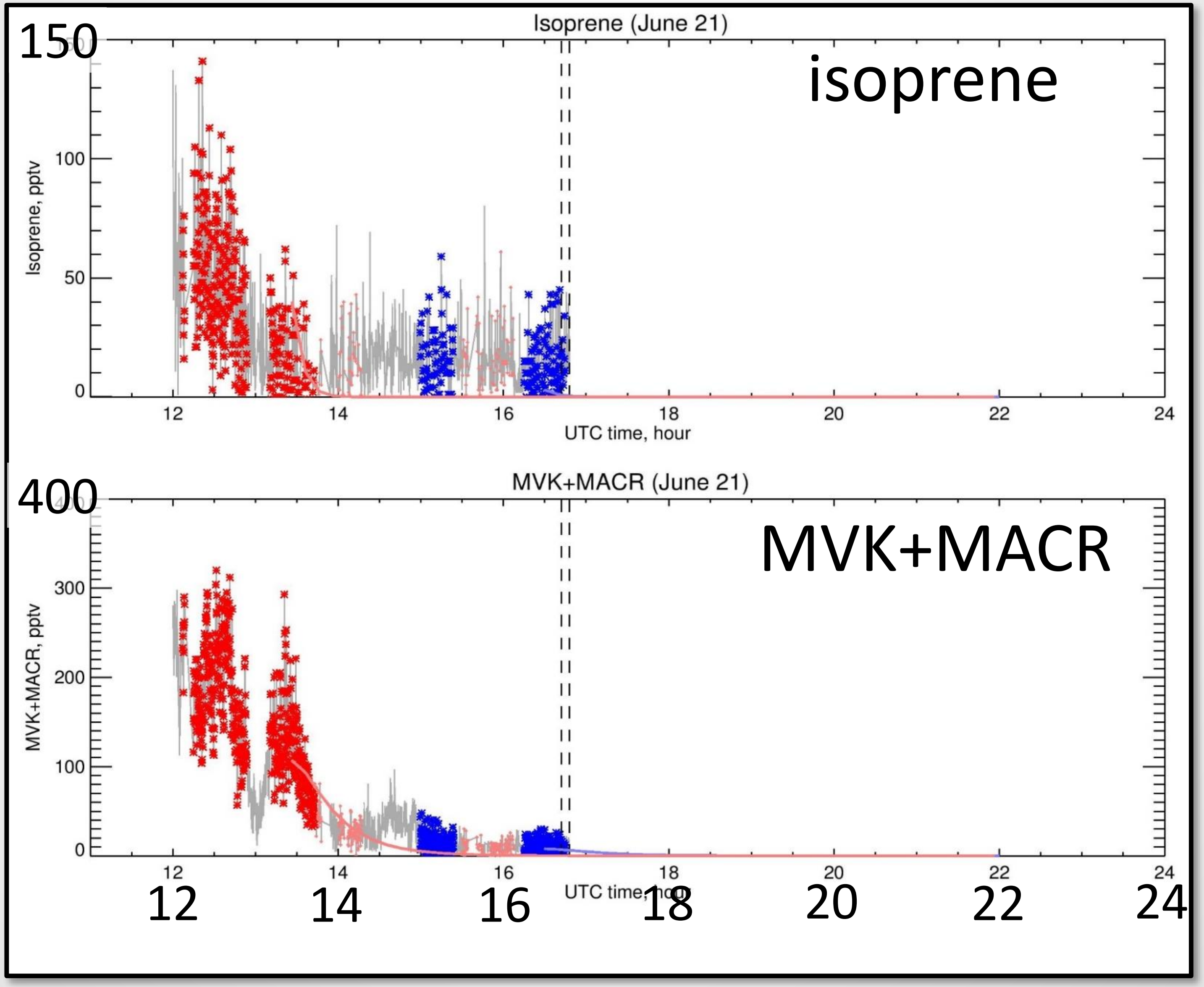
Evolution of other species from Lagrangian model & observations







Isoprene and MVK + MACR evolution from Lagrangian model & observations



DC3 MCS Studies

- Framework developed to assess transport of the outflow of the MCS case study during DC3
- Calculations of species tendencies were made and compared with known chemistry via numerical models and other approaches
  - O_3 growth averages about 1.6 ppbv / hour during the 10 hours of observations => about 20 ppbv in 12 hours
    - DC3 hypothesis of $\Delta[O_3]$ = 8-12 ppbv / day (depends on NO_x and VOCs levels)
    - $\Delta[O_3]$ from model ~20 ppbv
  - CH_2O decay with lifetime of 6 to 7.5 hours
    - Much longer than calculated photolysis and OH reaction lifetime of 0.9 hours at midday
  - Butane decays consistent with known kinetics
- Variety of extensions to NO_x conversion, HO_x radical budgets, SO_2 oxidation, aerosol nucleation and growth, etc.

Thank you to the following…

DC3 Science Team (data, model products, forecasting, planning)

Financial Support:

National Science Foundation (ATC and PDM)

NASA

NCAR

DLR

NOAA

University of Oklahoma

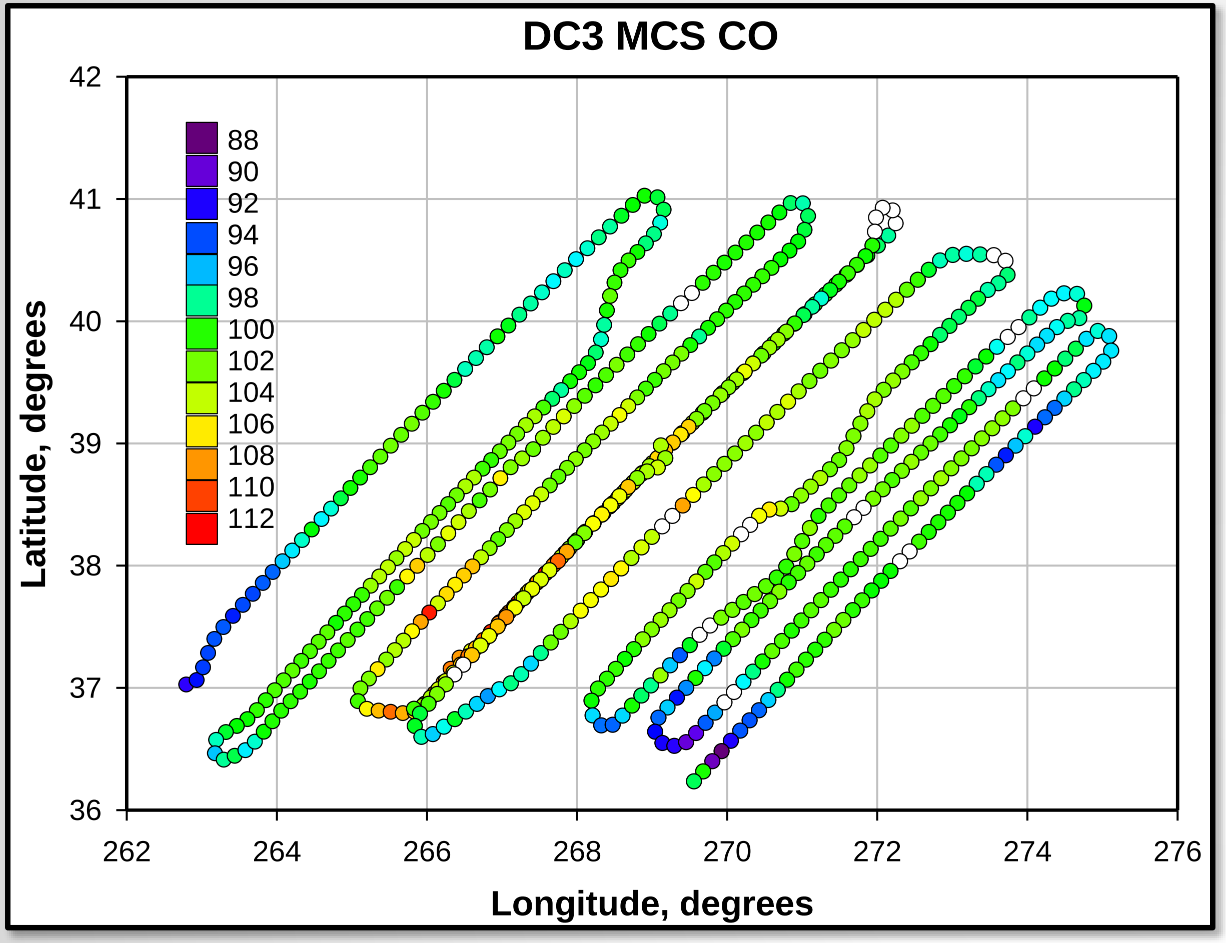
University of Alabama at Huntsville

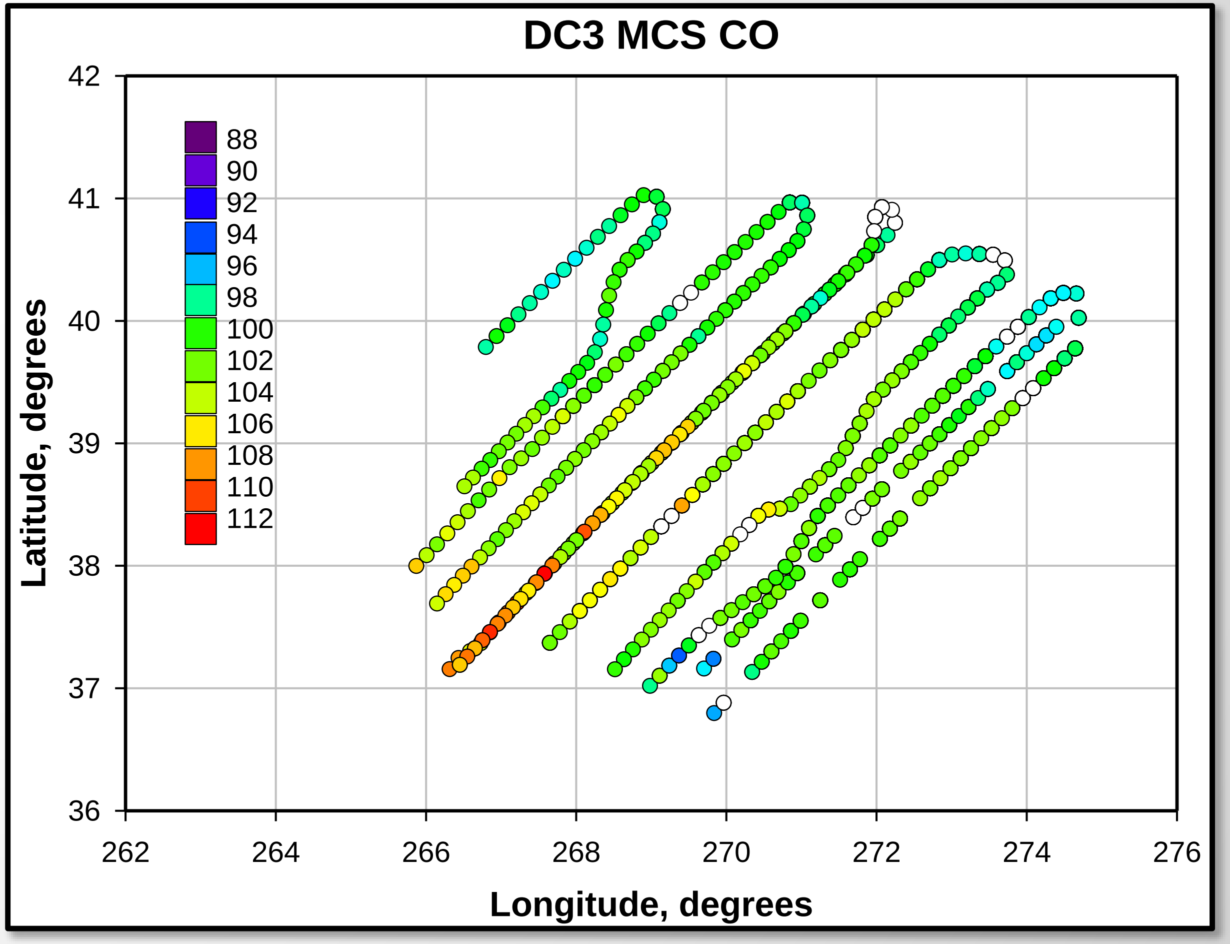
Logistics:

NCAR EOL

Extra Slides

CO Mixing Ratios

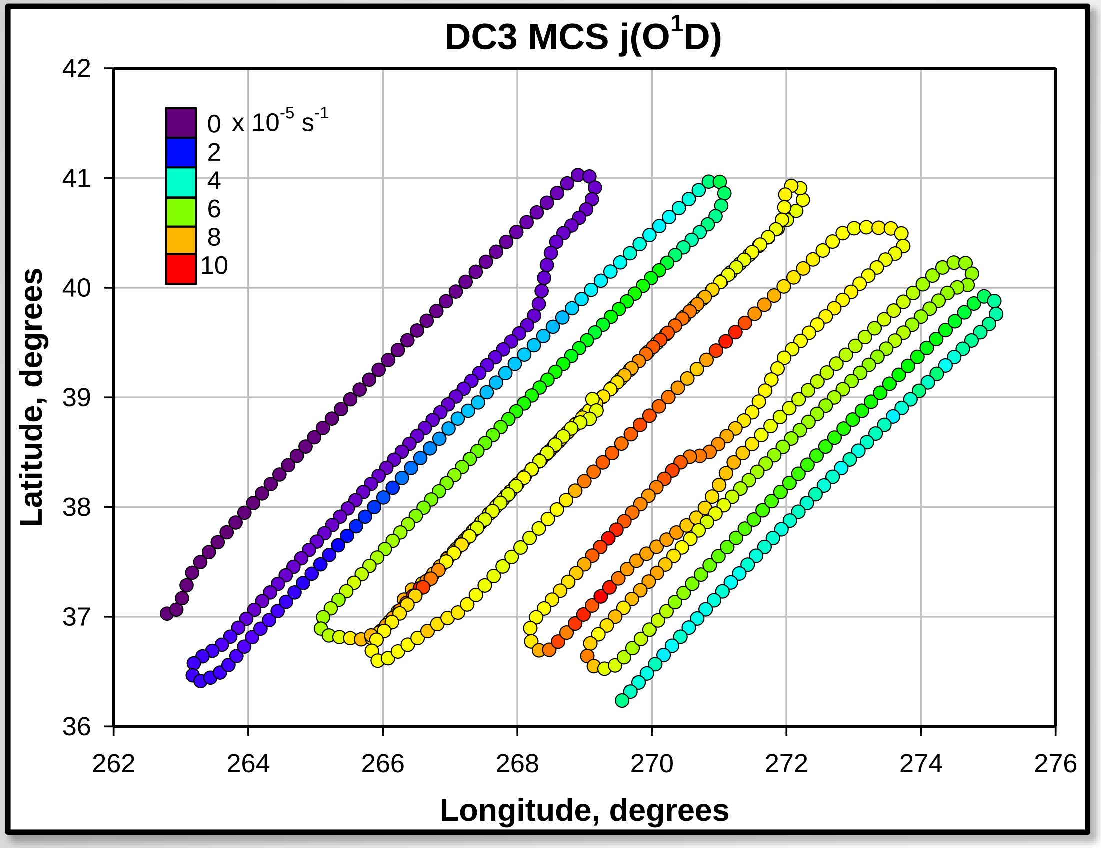


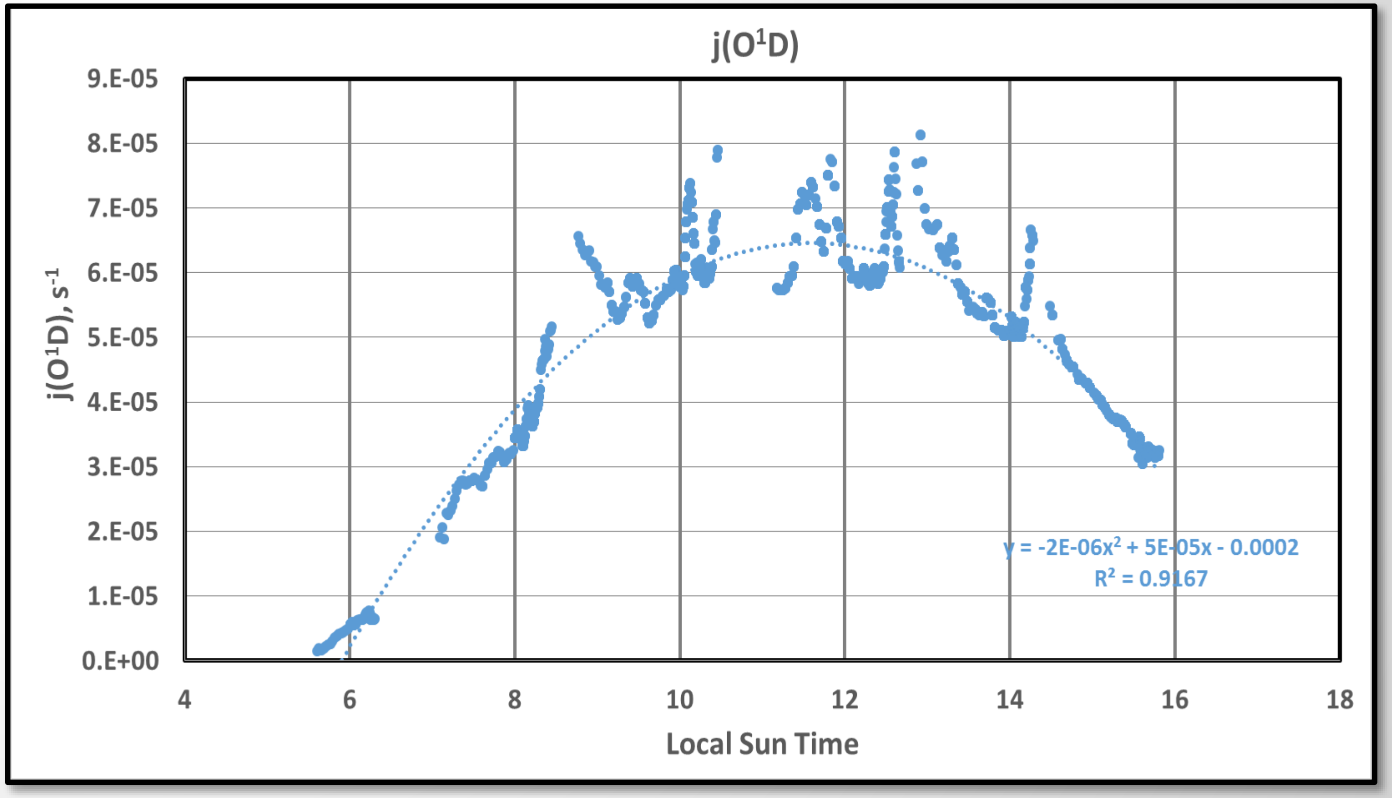


DC-8 CO: G. Diskin and G. Sachse

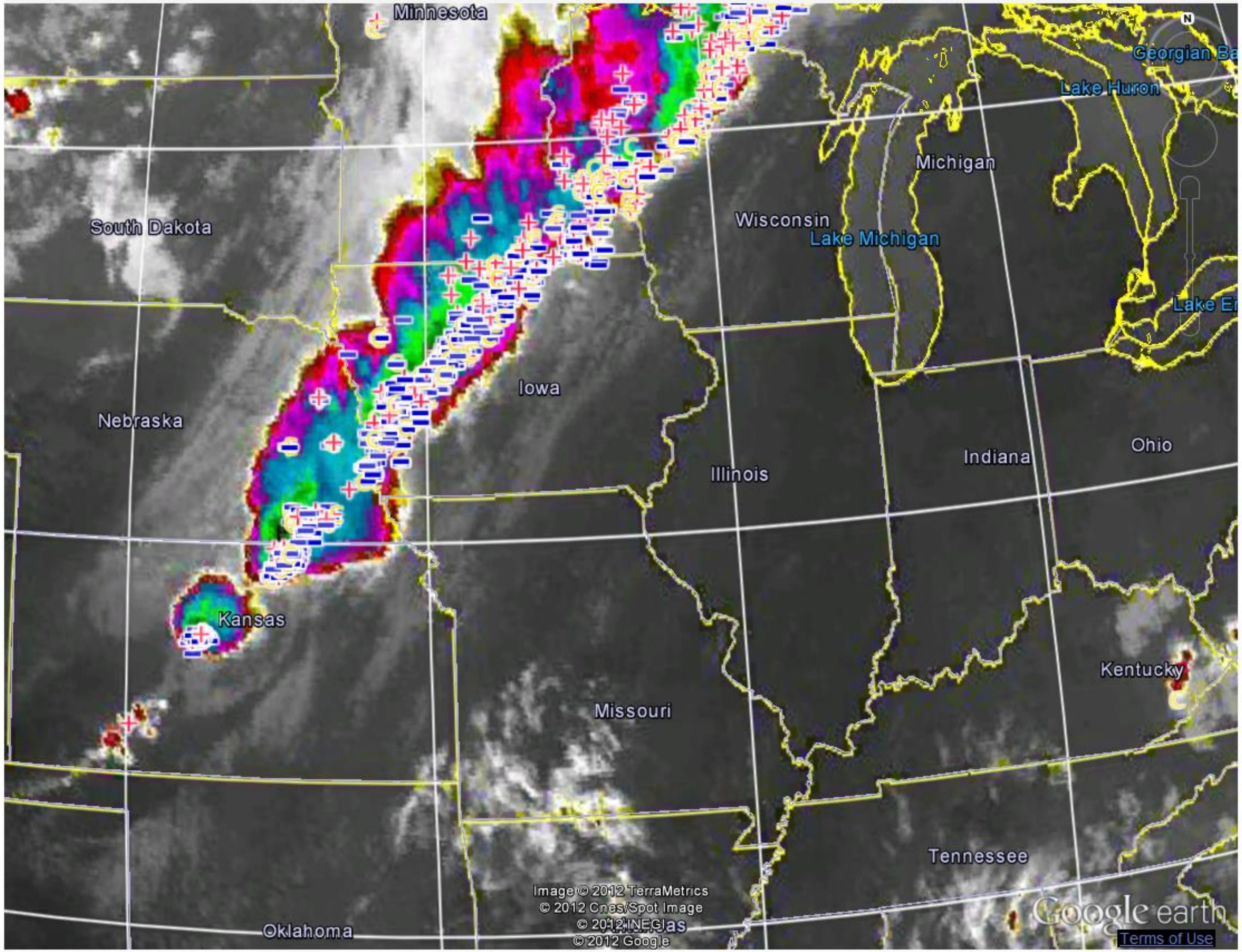
GV CO: T. Campos, F. Flocke, D. Stechman, C. Ferris, M. Rooney

$j(O^1D)$

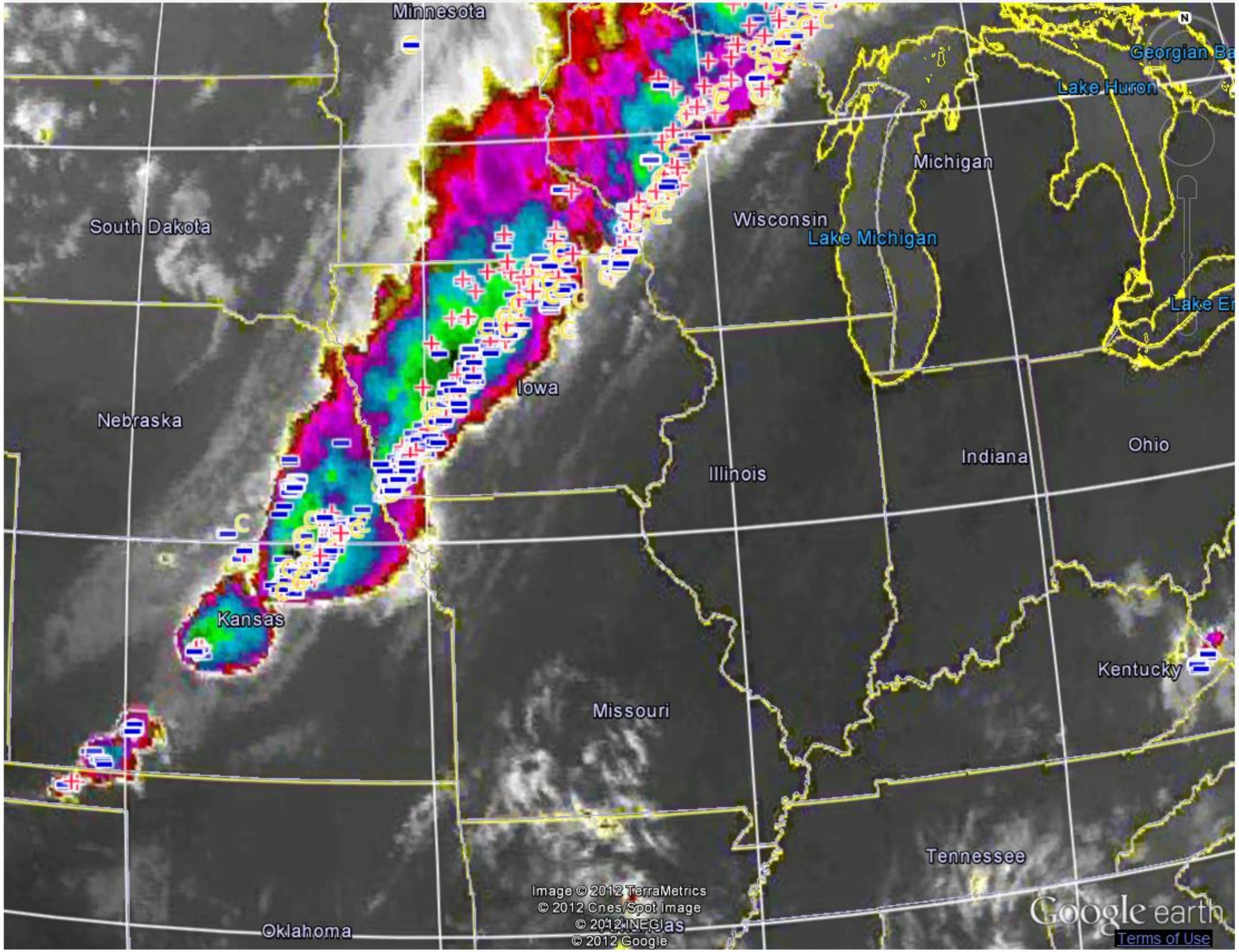




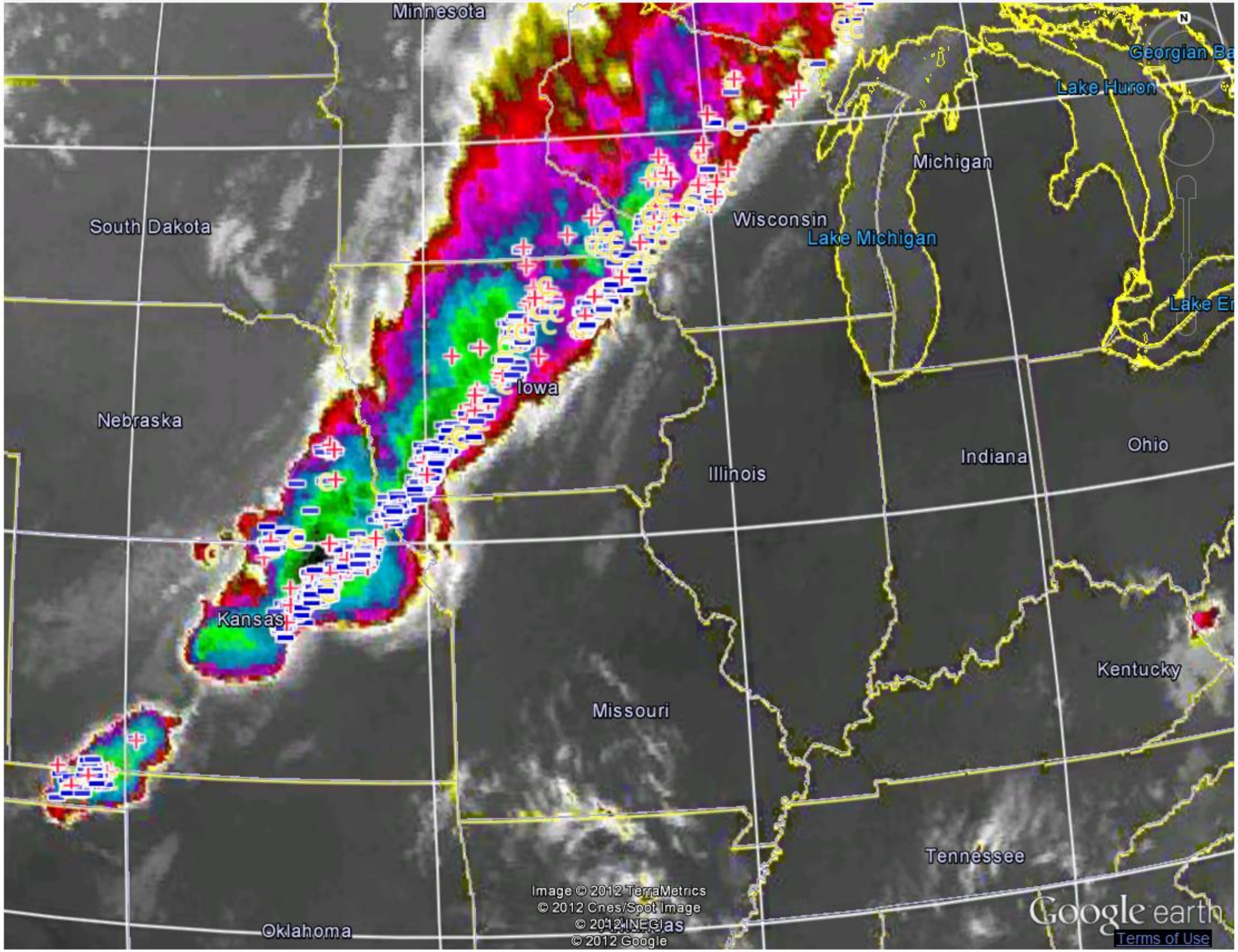
DC-8 and GV j-values: S. Hall, K. Ullmann (NCAR)



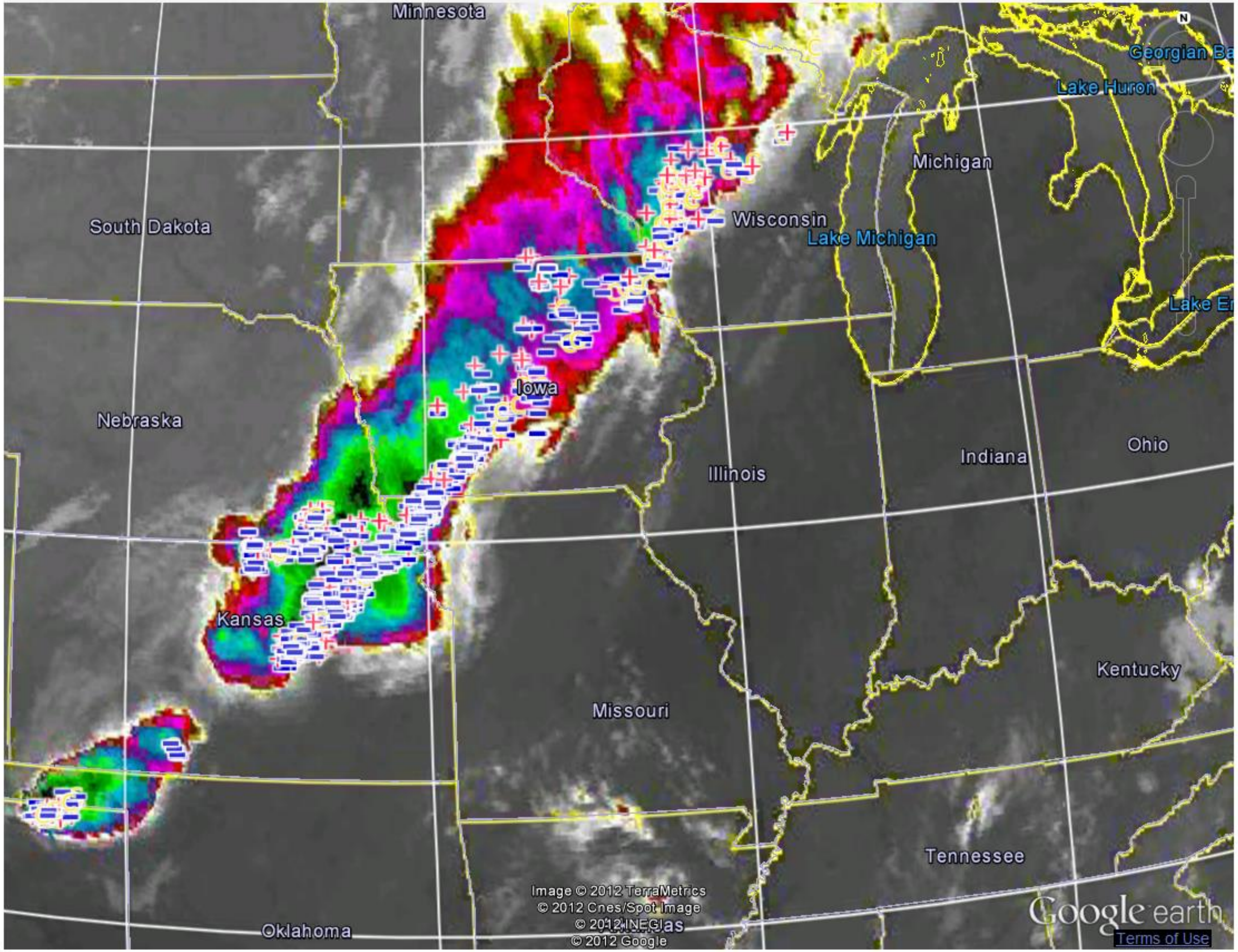
The selected date/time display is 2012-06-21 00:00 UTC



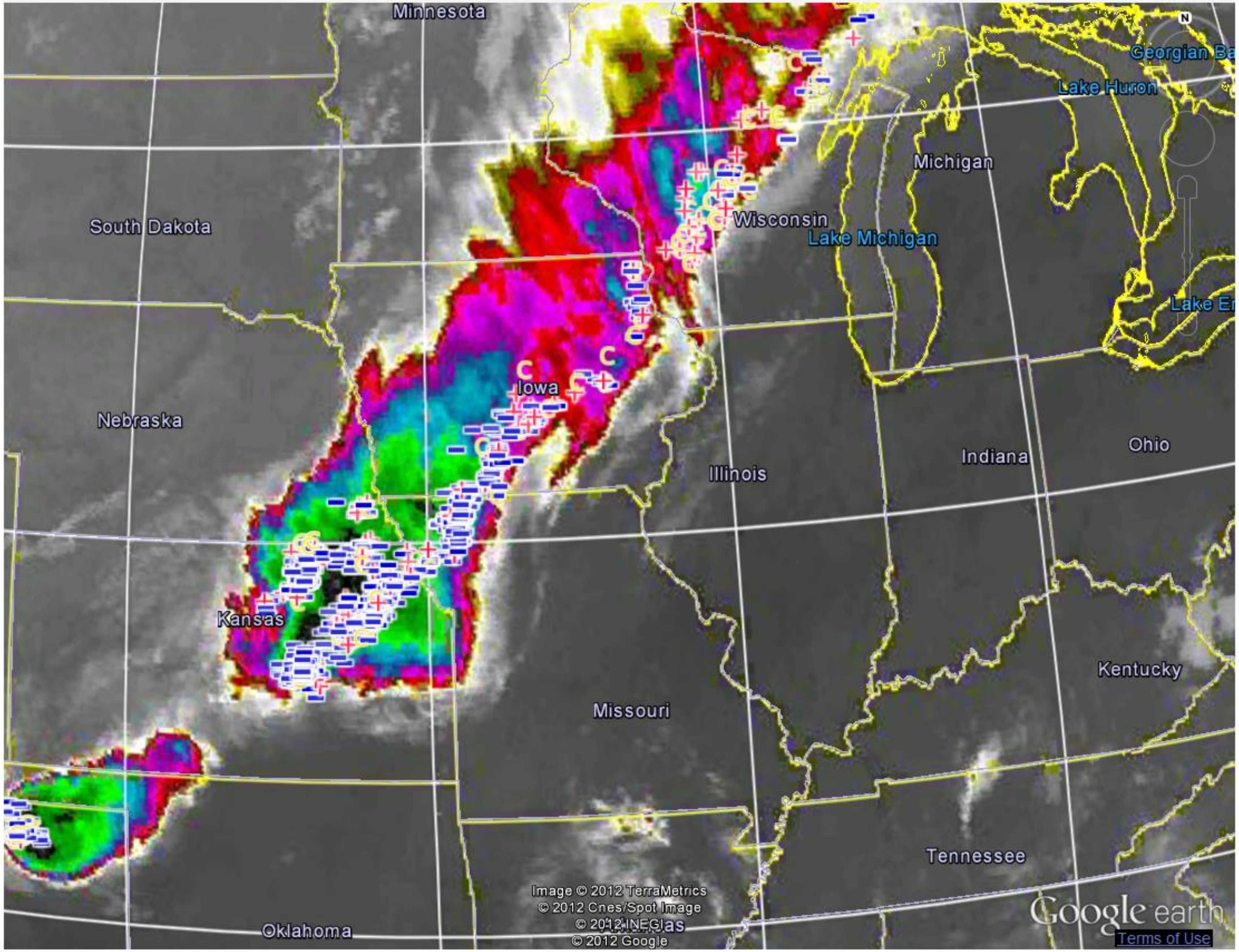
The selected date/time display is 2012-06-21 01:00 UTC



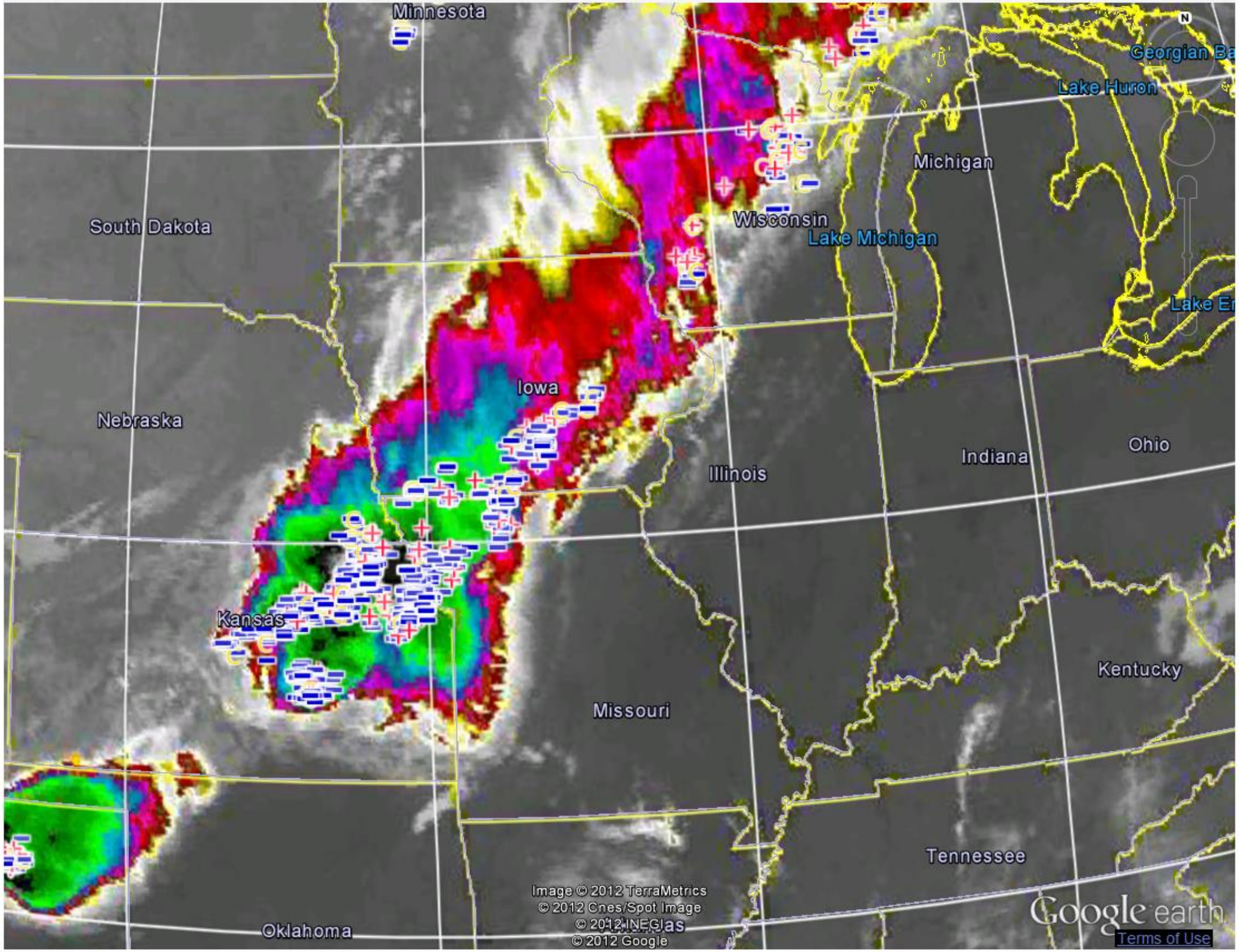
The selected date/time display is 2012-06-21 02:00 UTC



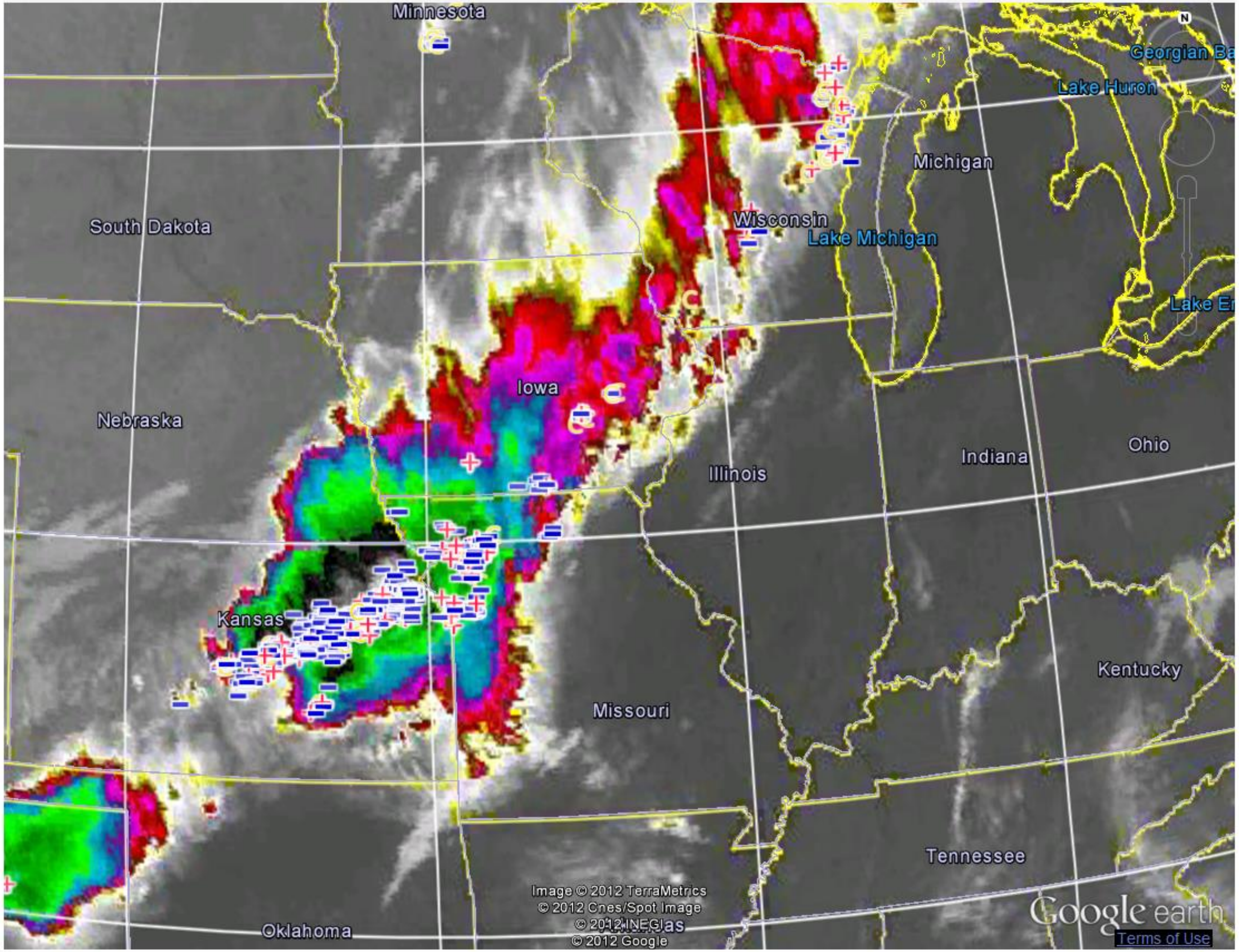
The selected date/time display is 2012-06-21 03:00 UTC



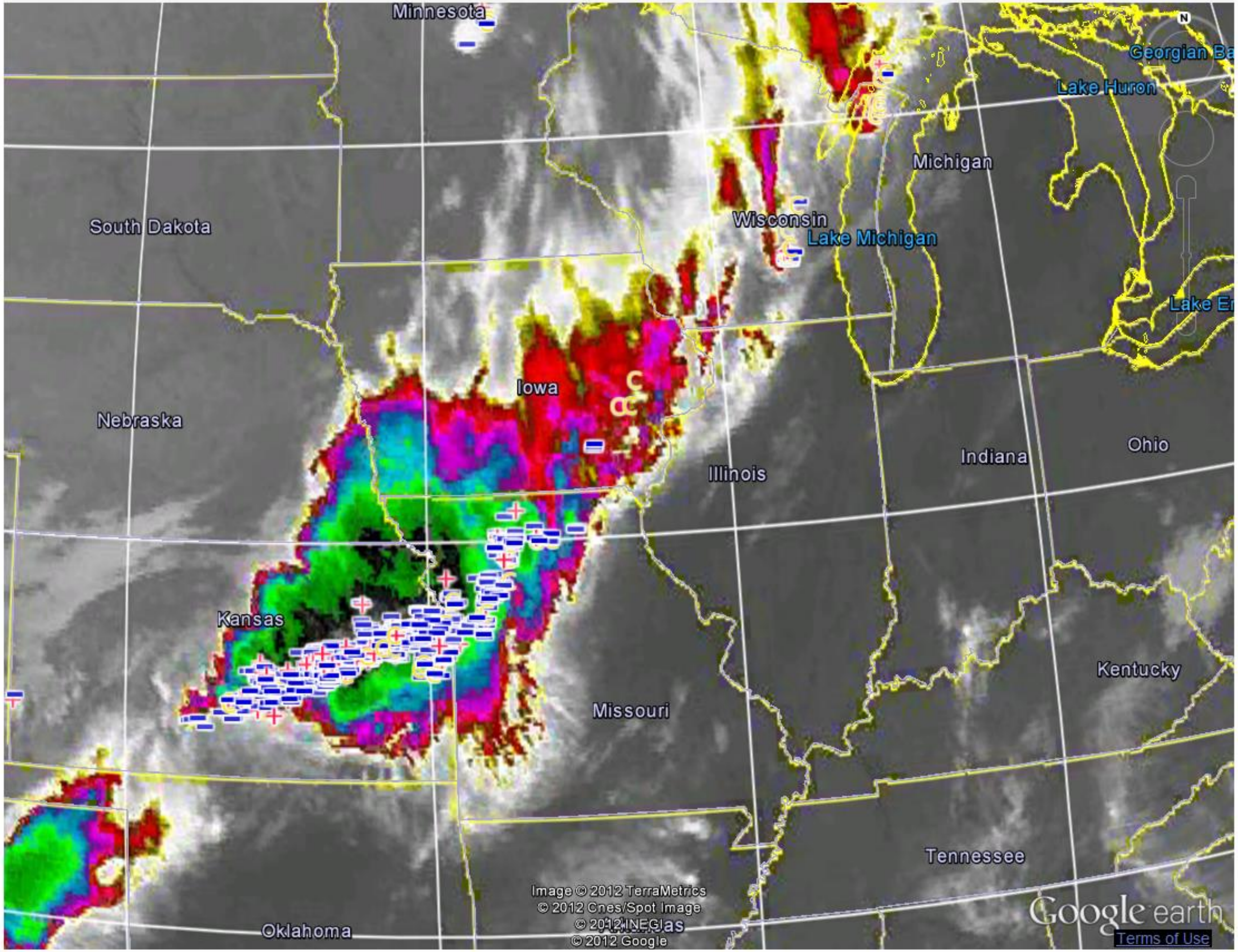
The selected date/time display is 2012-06-21 04:00 UTC



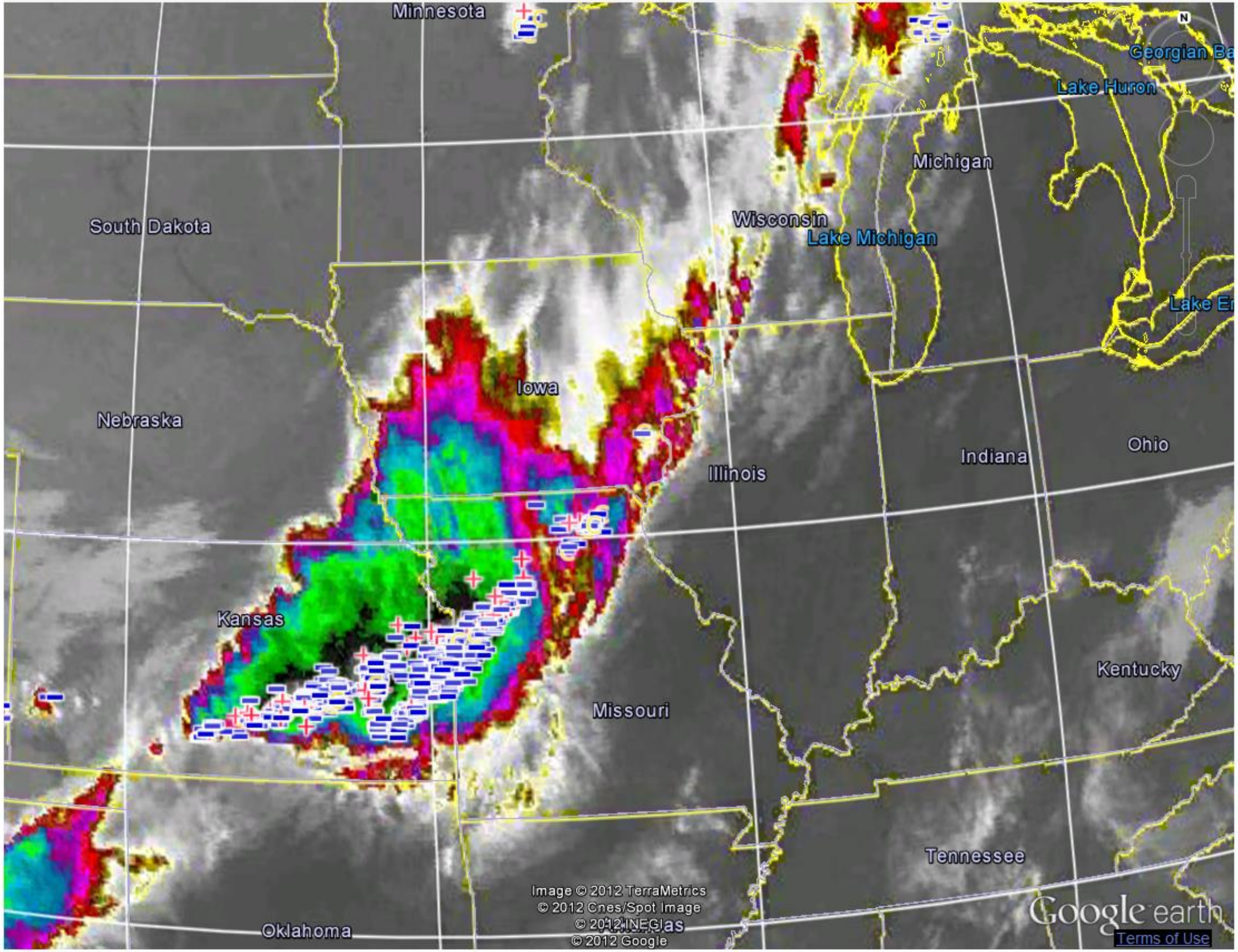
The selected date/time display is 2012-06-21 05:00 UTC



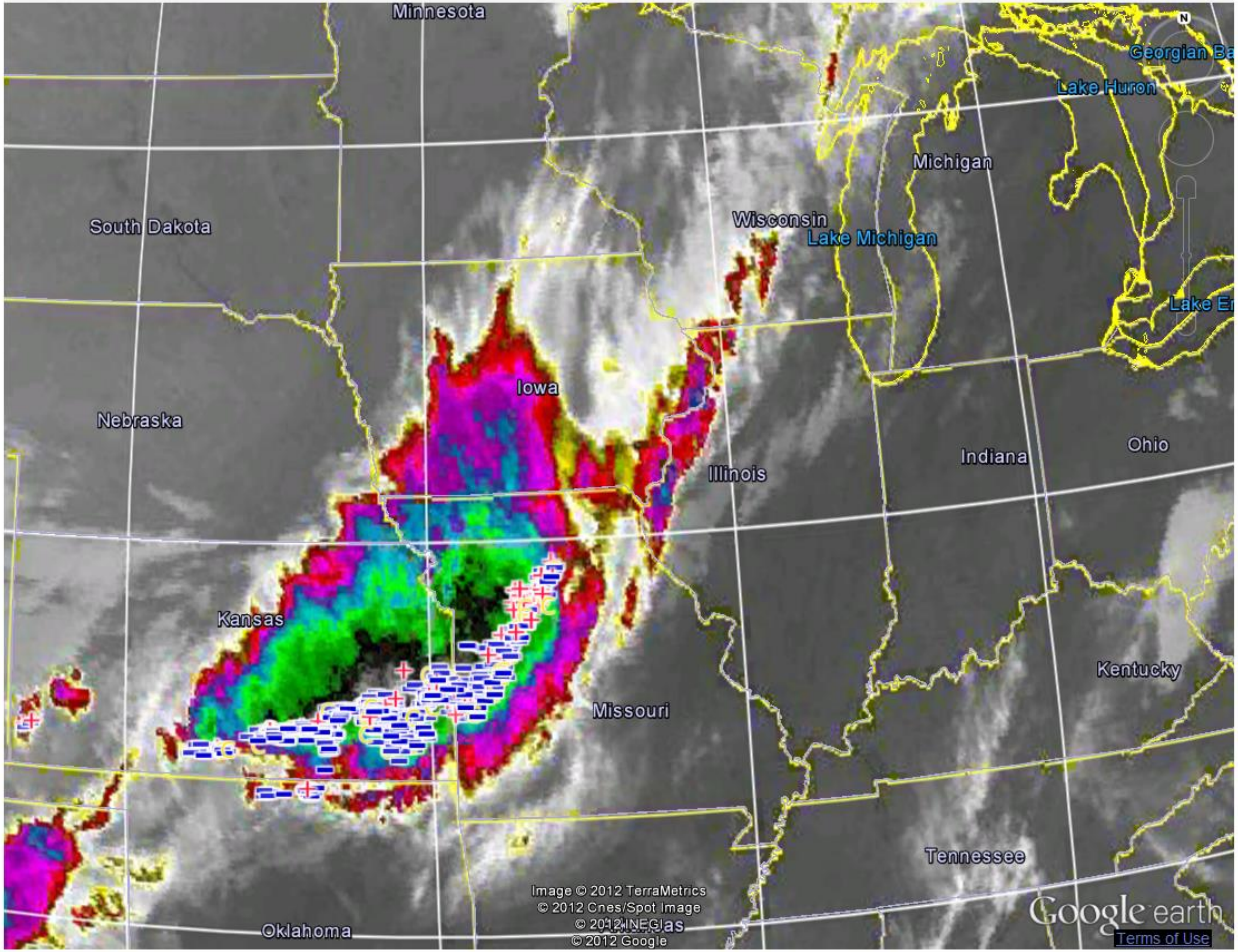
The selected date/time display is 2012-06-21 06:00 UTC



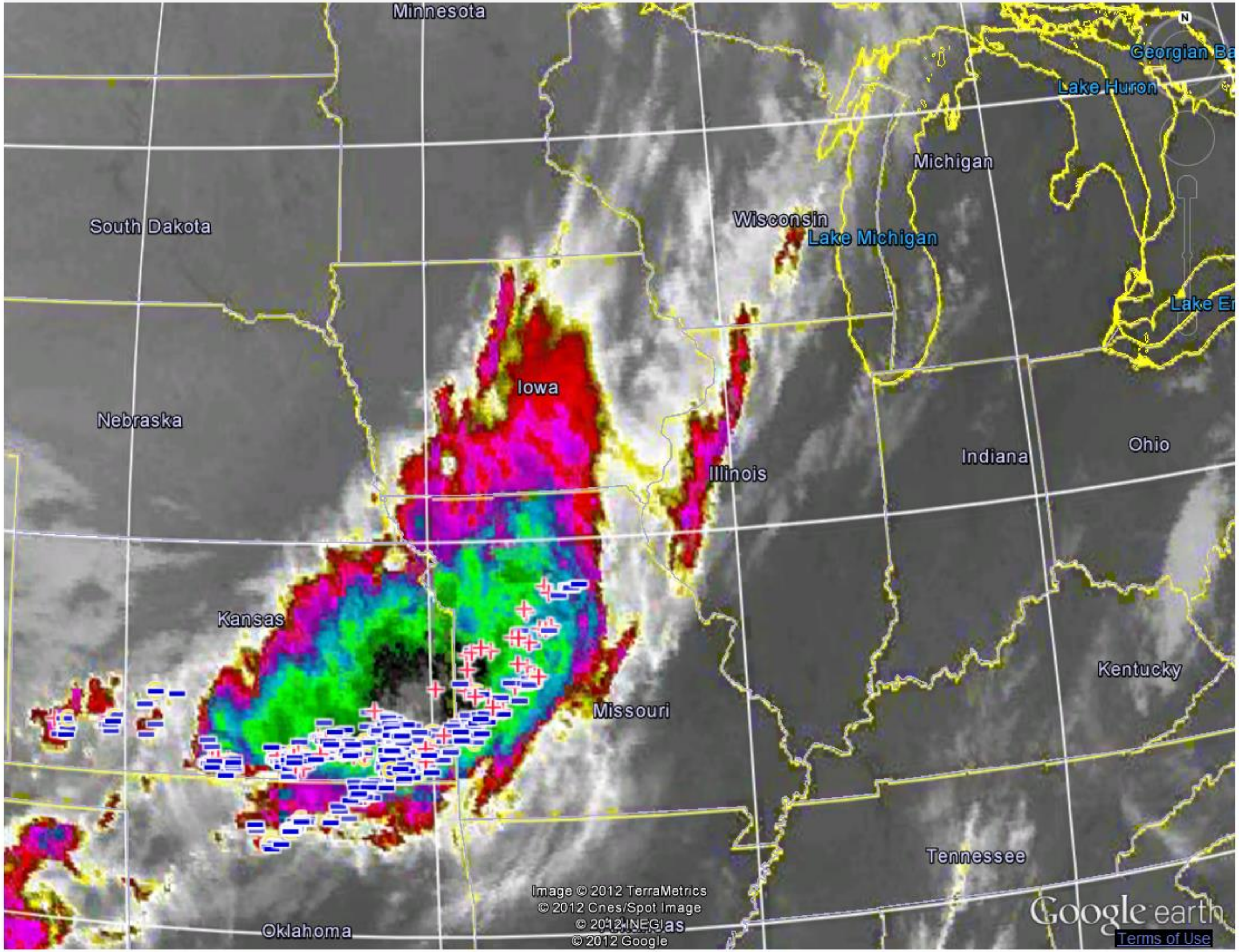
The selected date/time display is 2012-06-21 07:00 UTC



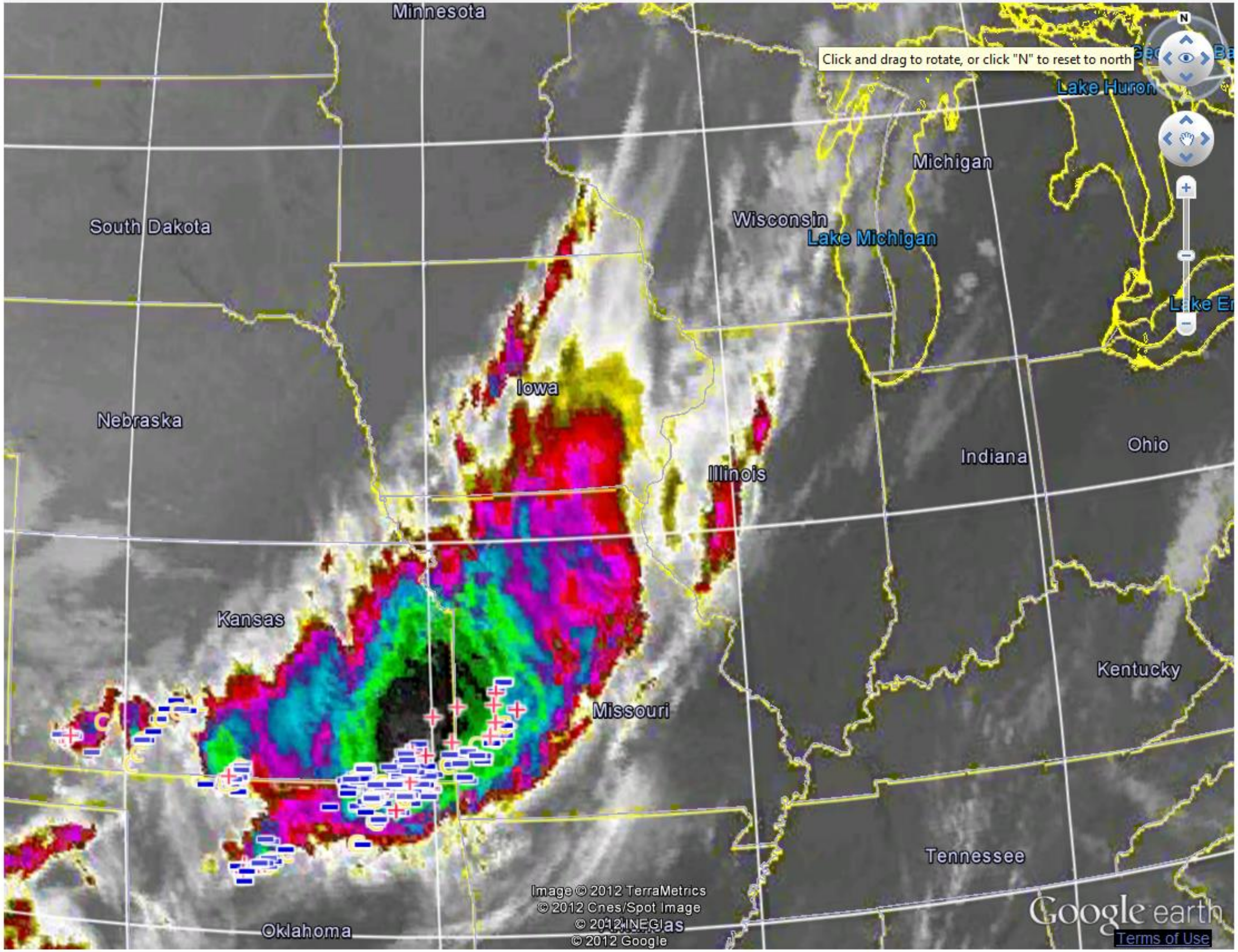
The selected date/time display is 2012-06-21 08:00 UTC



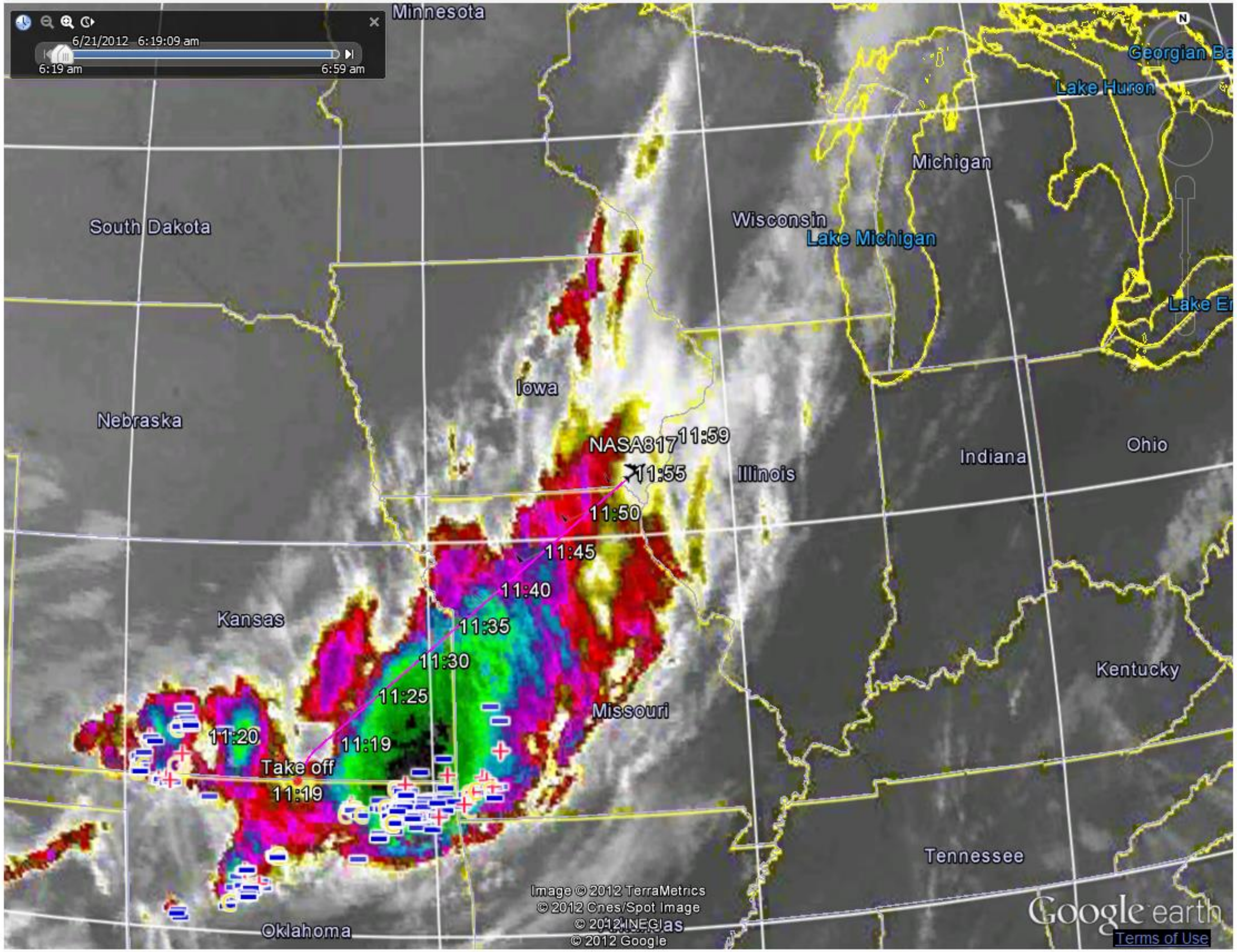
The selected date/time display is 2012-06-21 09:00 UTC



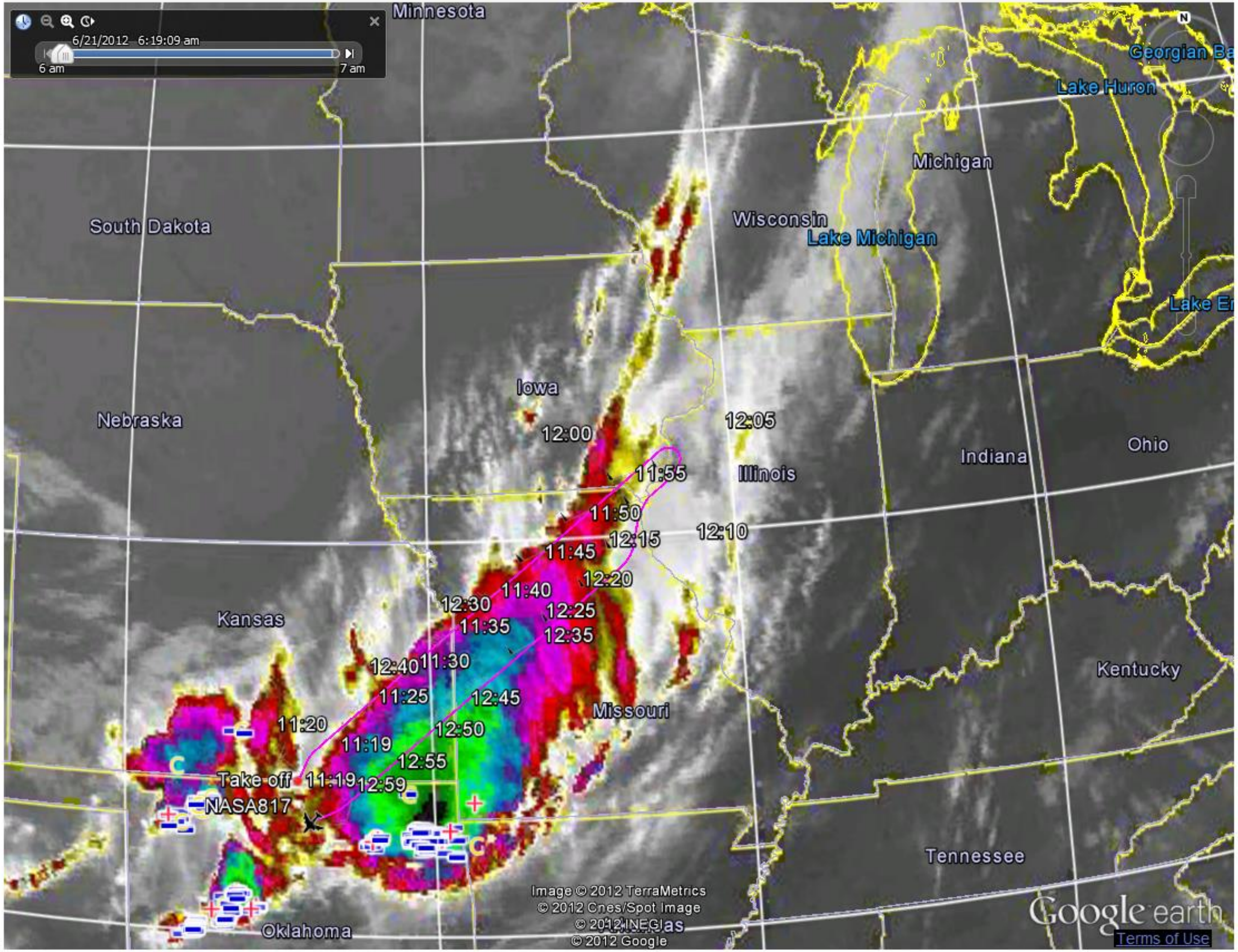
The selected date/time display is 2012-06-21 10:00 UTC



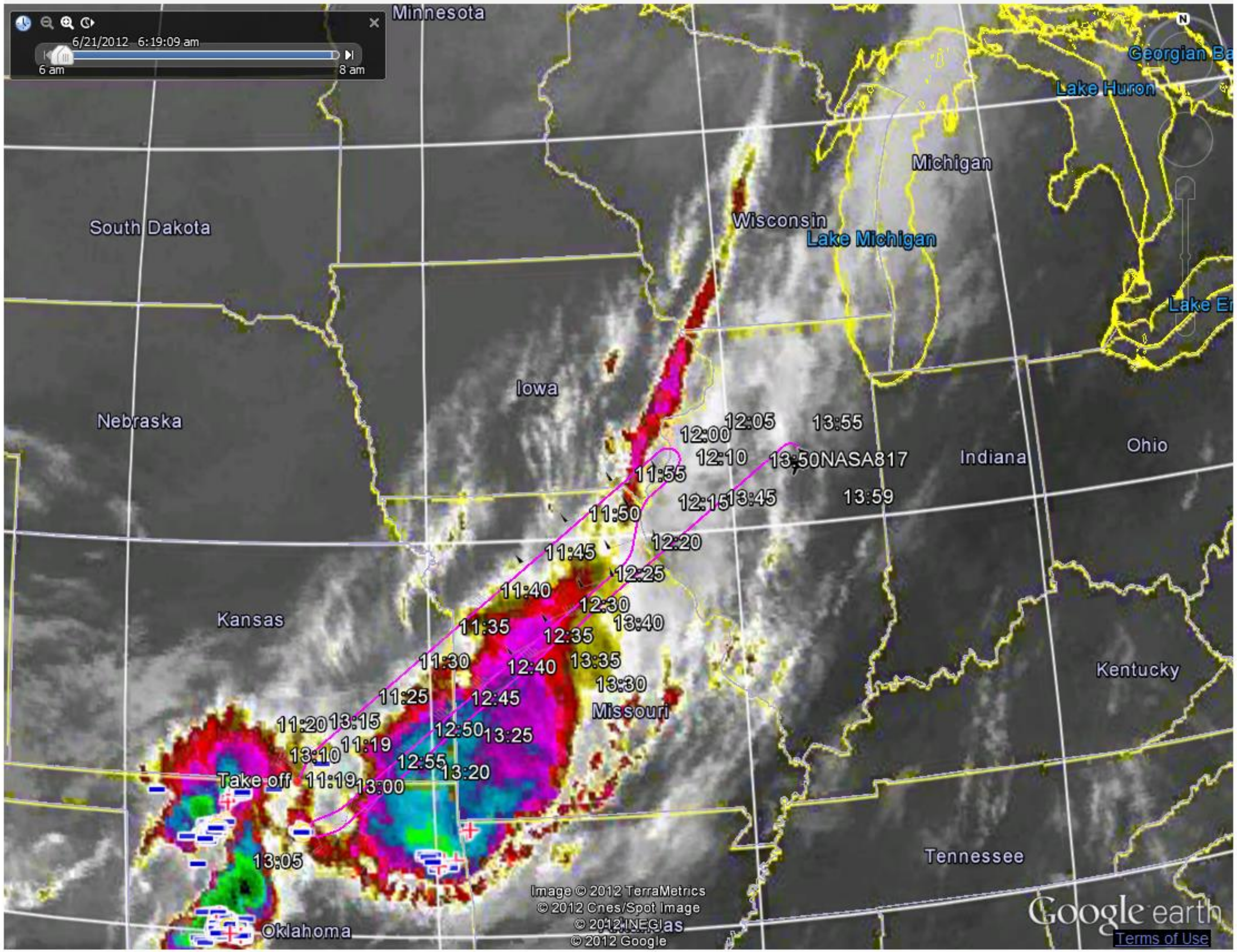
The selected date/time display is 2012-06-21 11:00 UTC



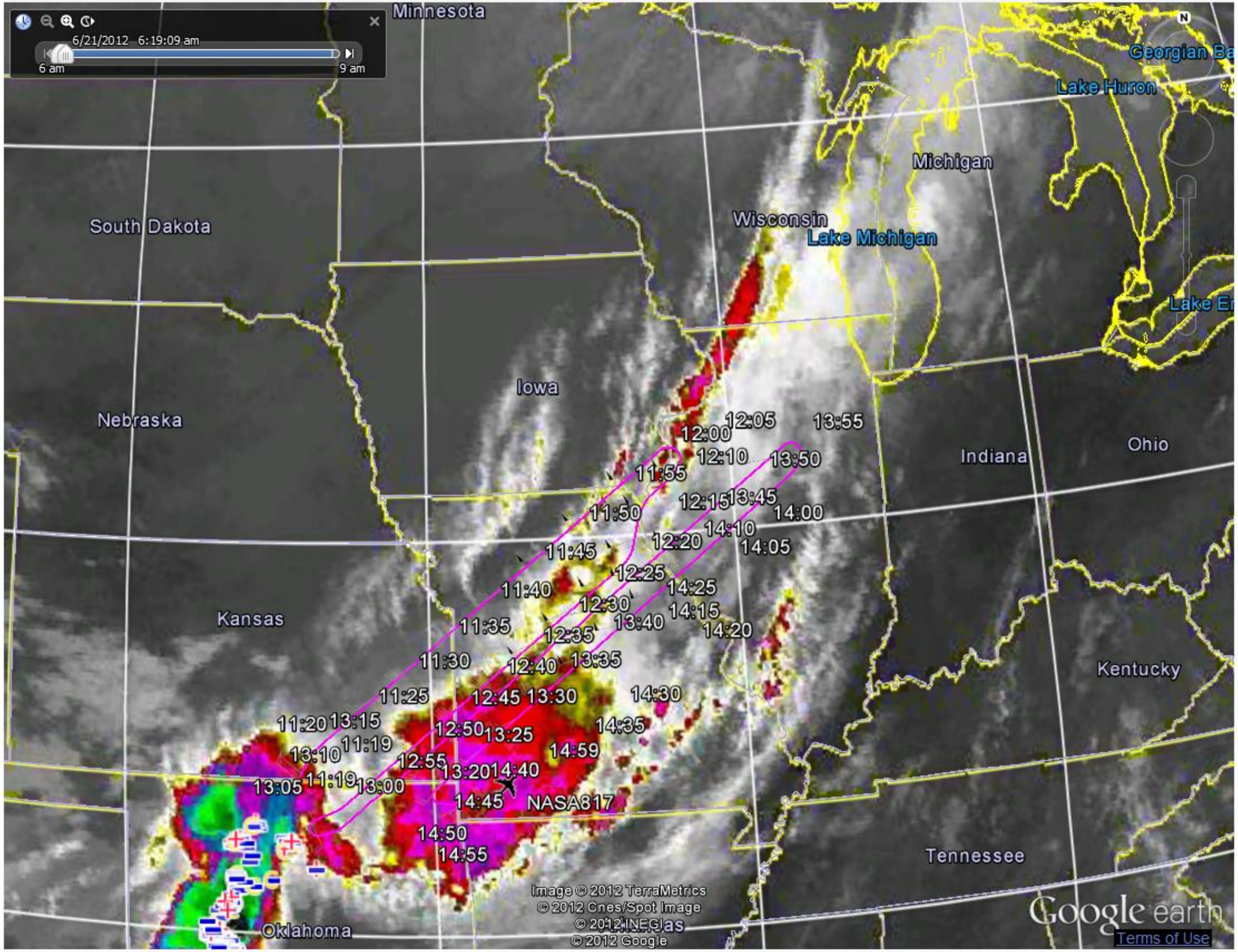
The selected date/time display is 2012-06-21 12:00 UTC



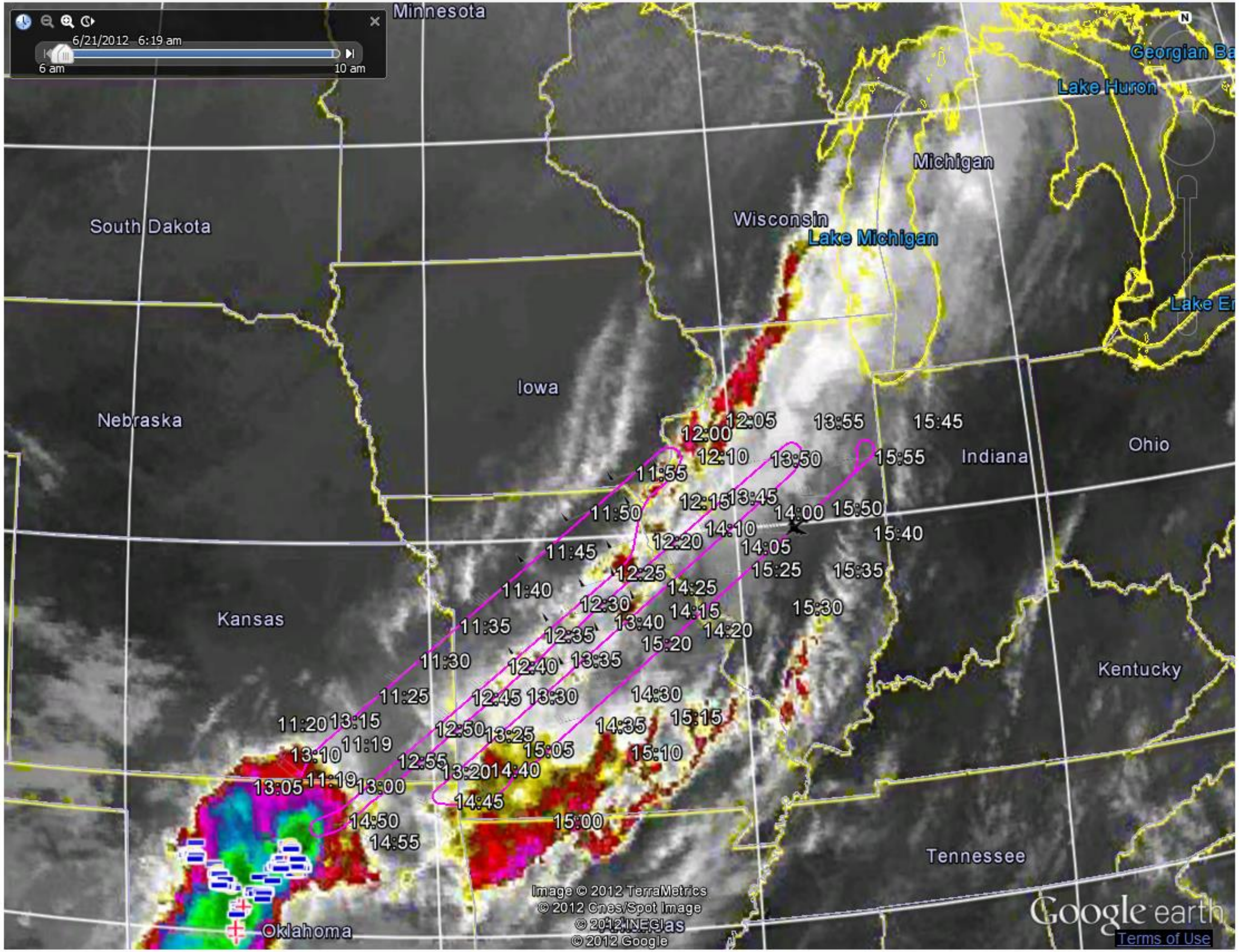
The selected date/time display is 2012-06-21 13:00 UTC



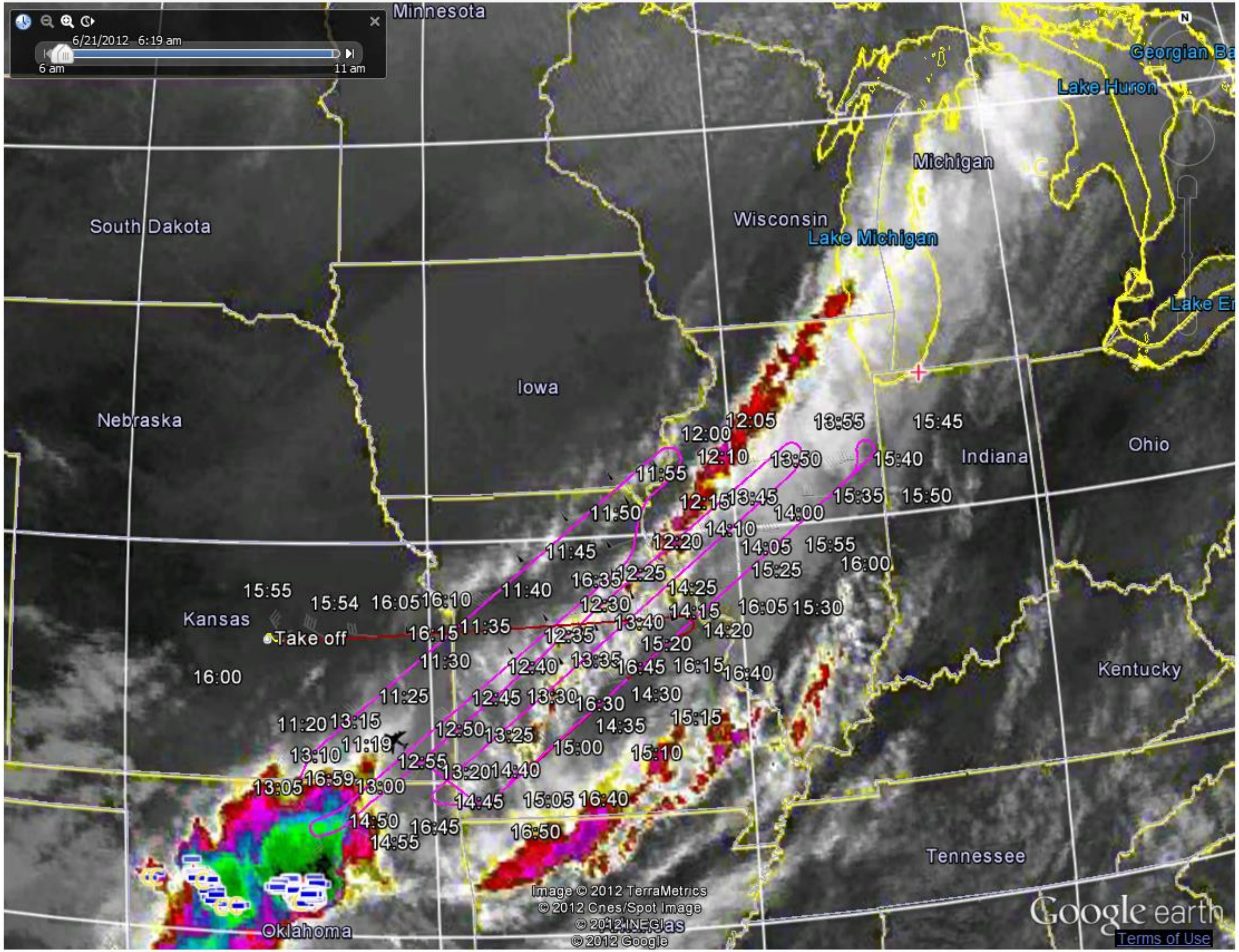
The selected date/time display is 2012-06-21 14:00 UTC



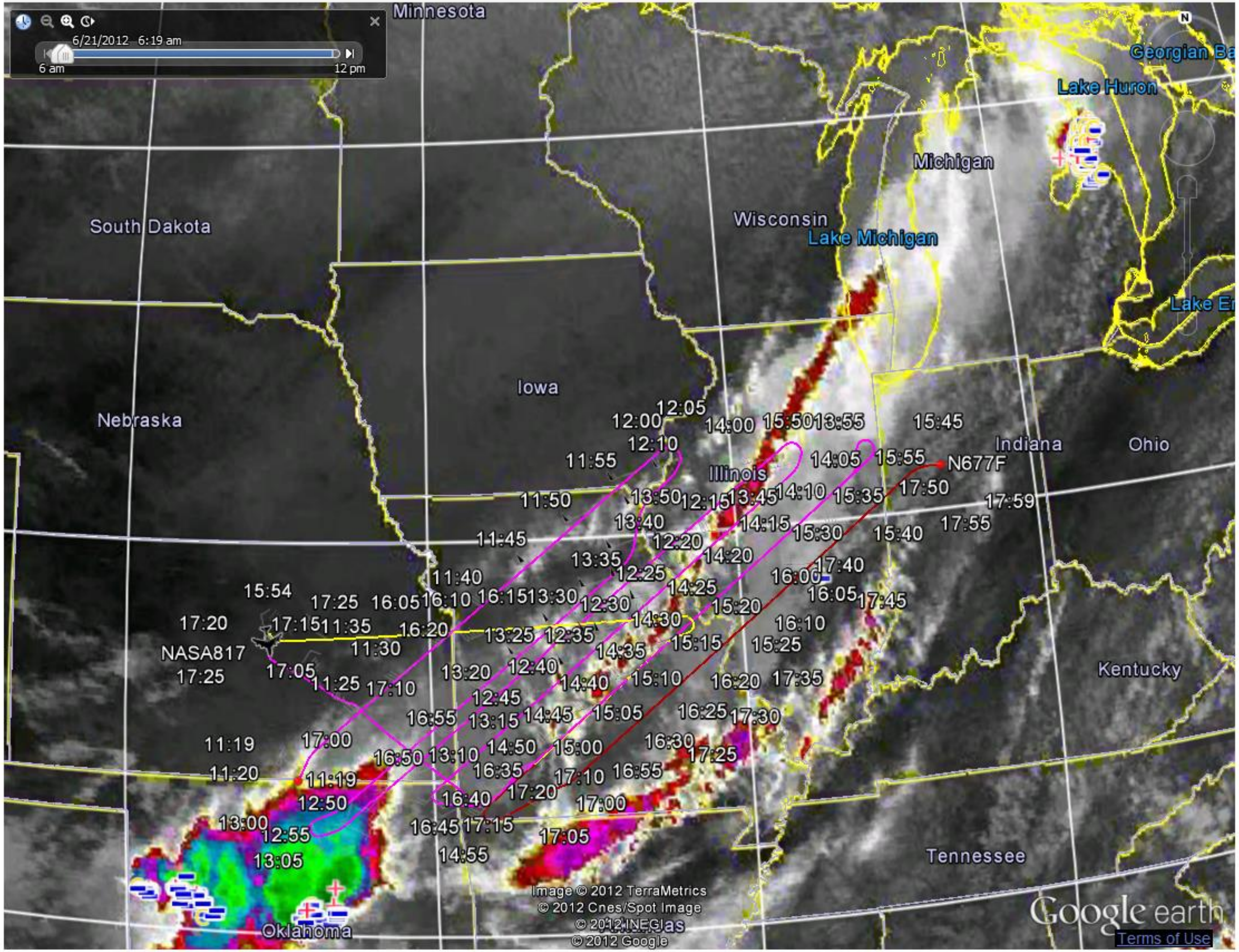
The selected date/time display is 2012-06-21 15:00 UTC



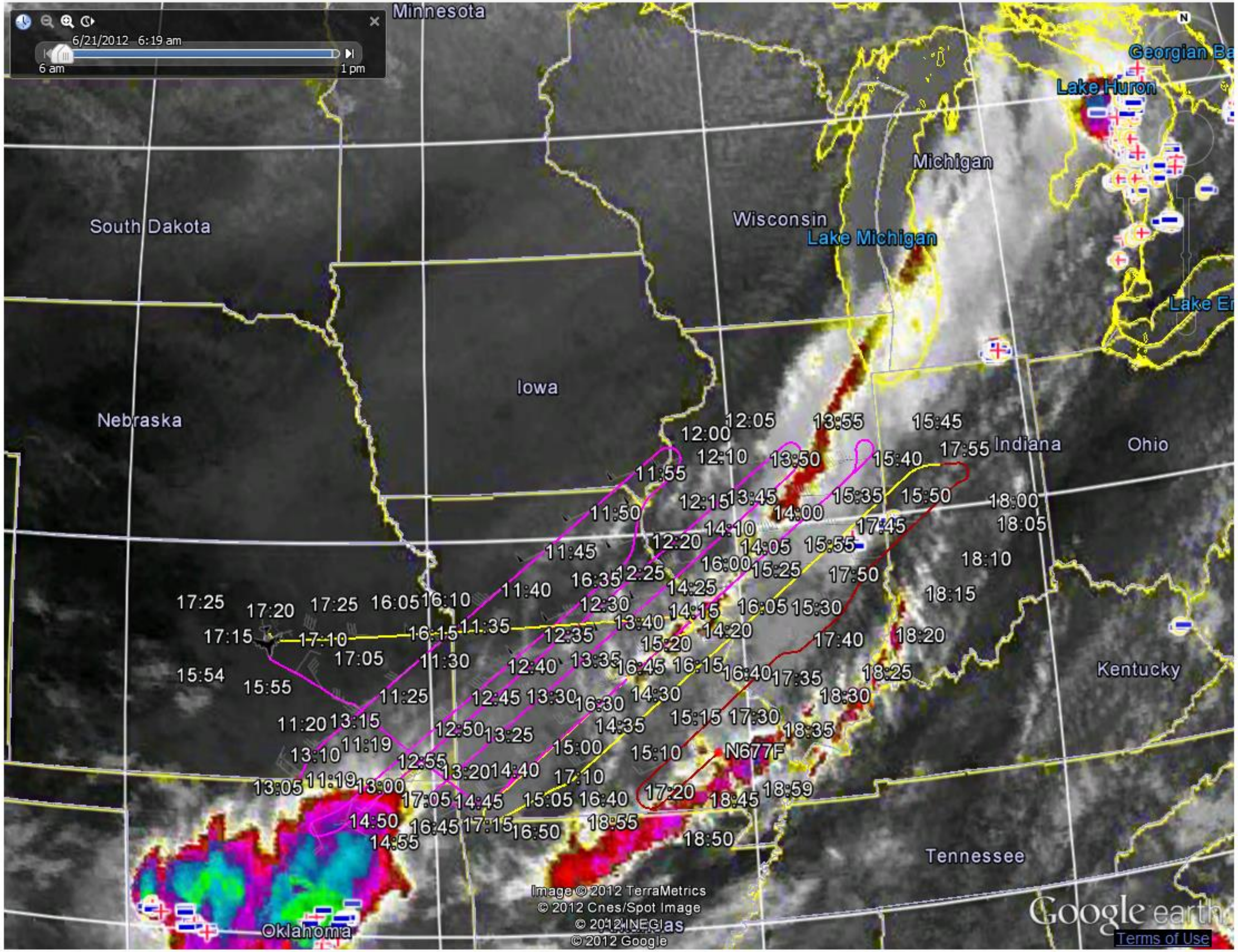
The selected date/time display is 2012-06-21 16:00 UTC



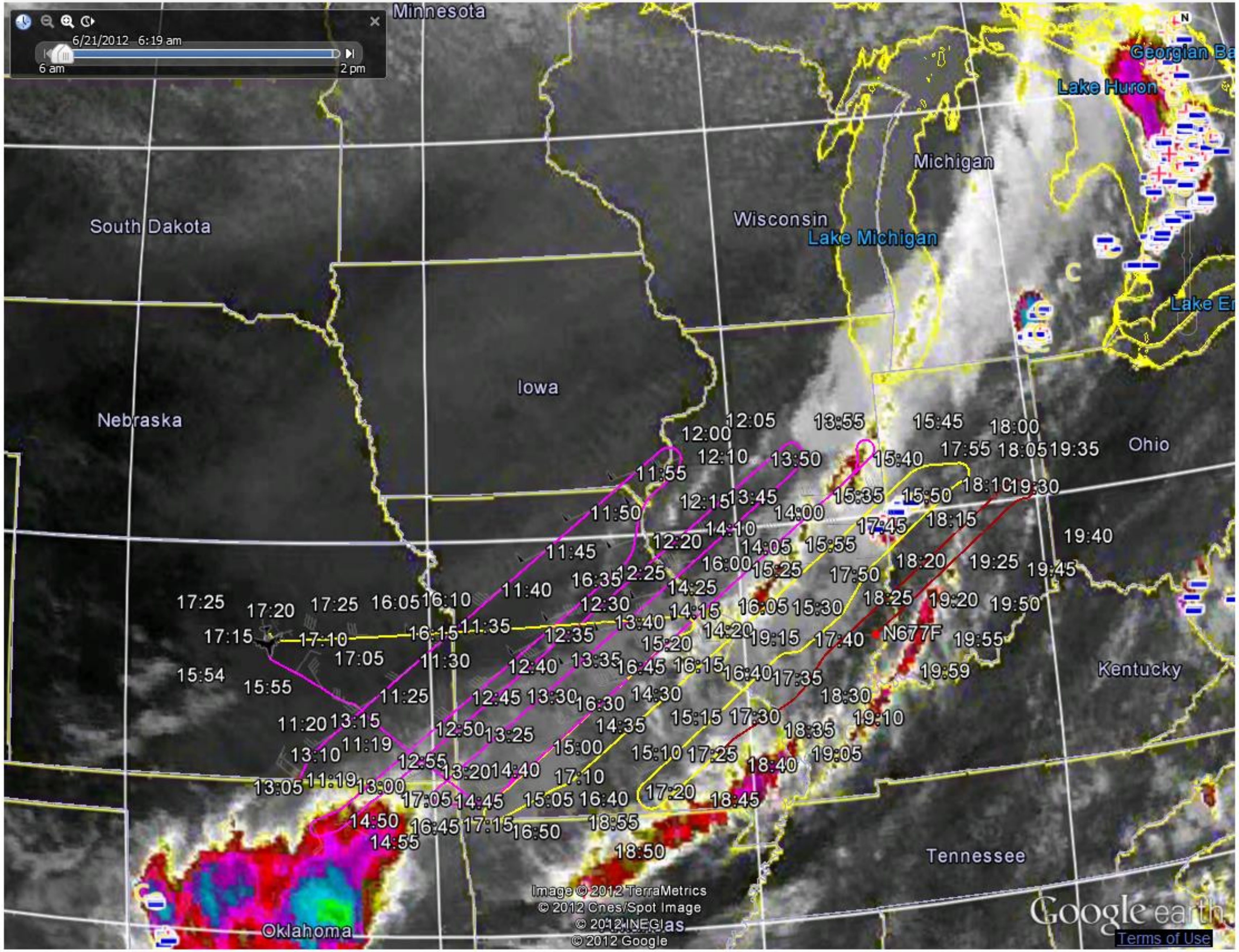
The selected date/time display is 2012-06-21 17:00 UTC



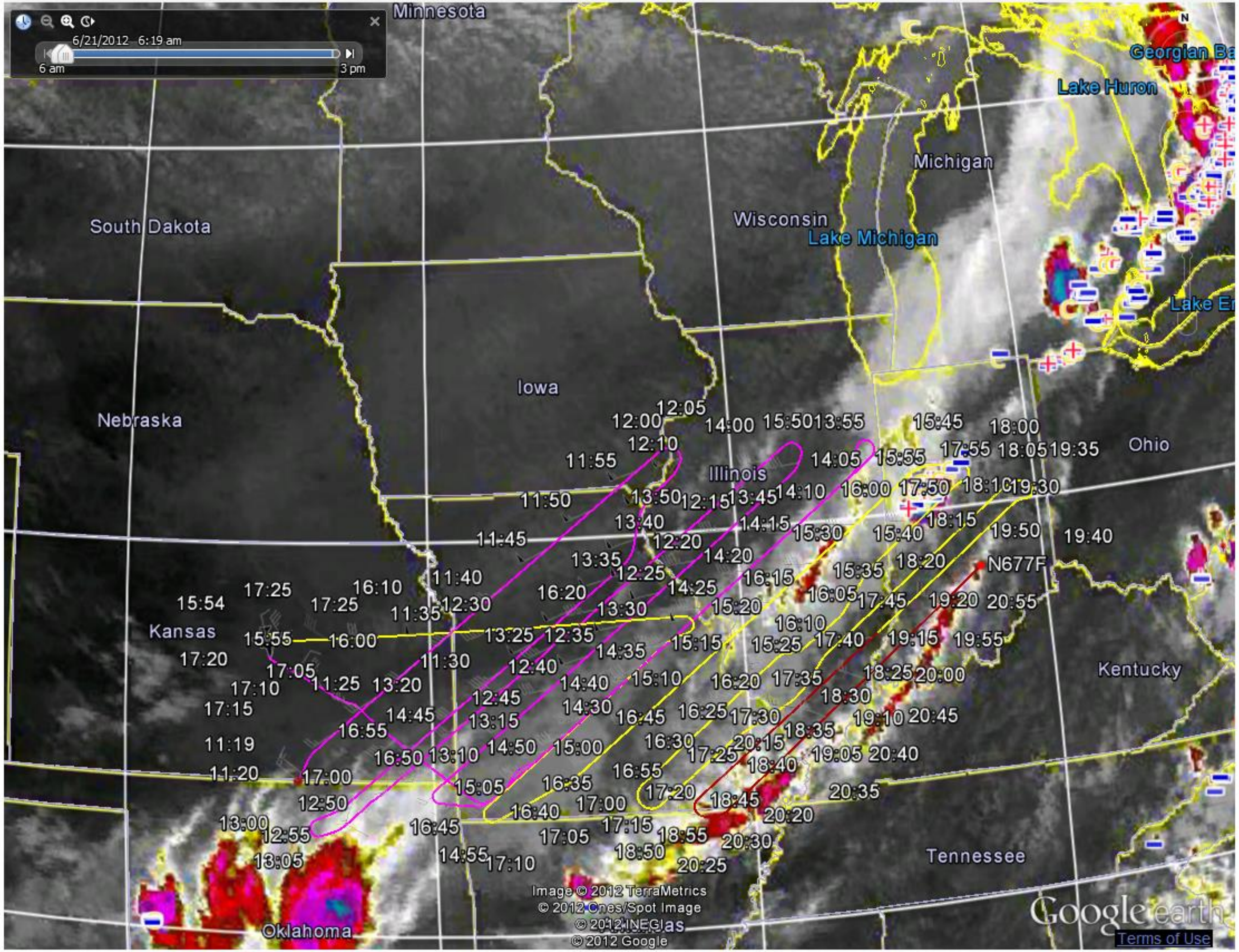
The selected date/time display is 2012-06-21 18:00 UTC



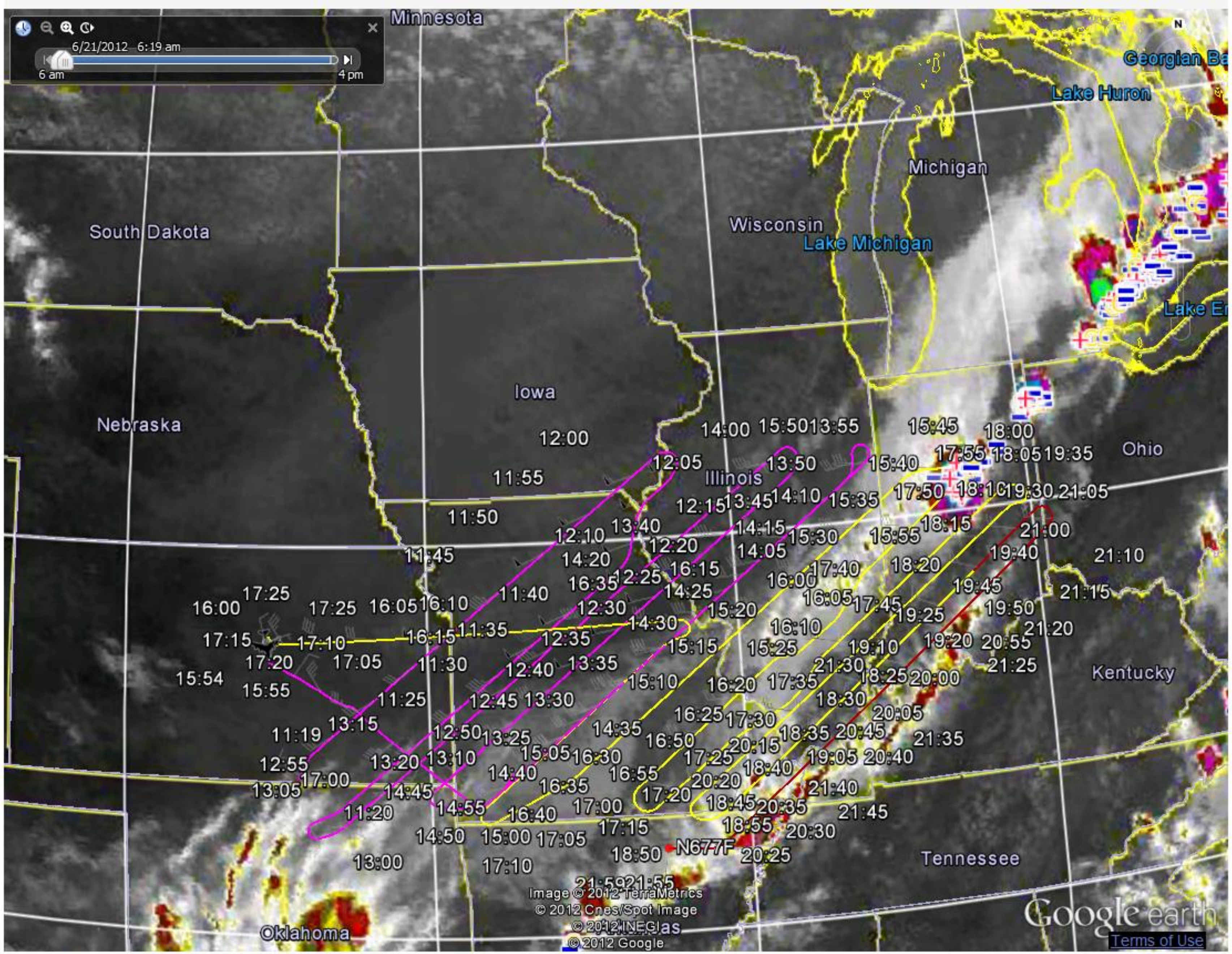
The selected date/time display is 2012-06-21 19:00 UTC



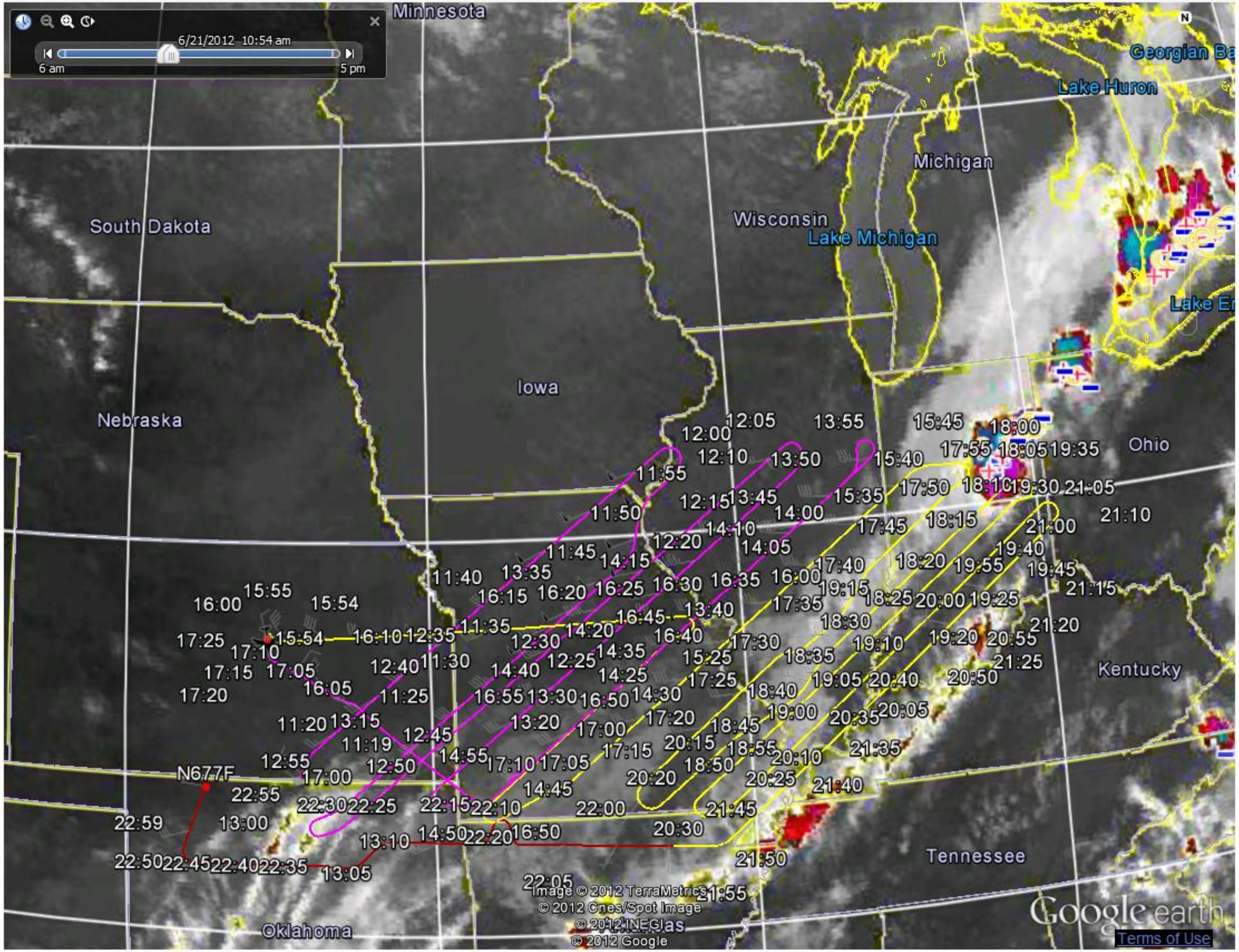
The selected date/time display is 2012-06-21 20:00 UTC



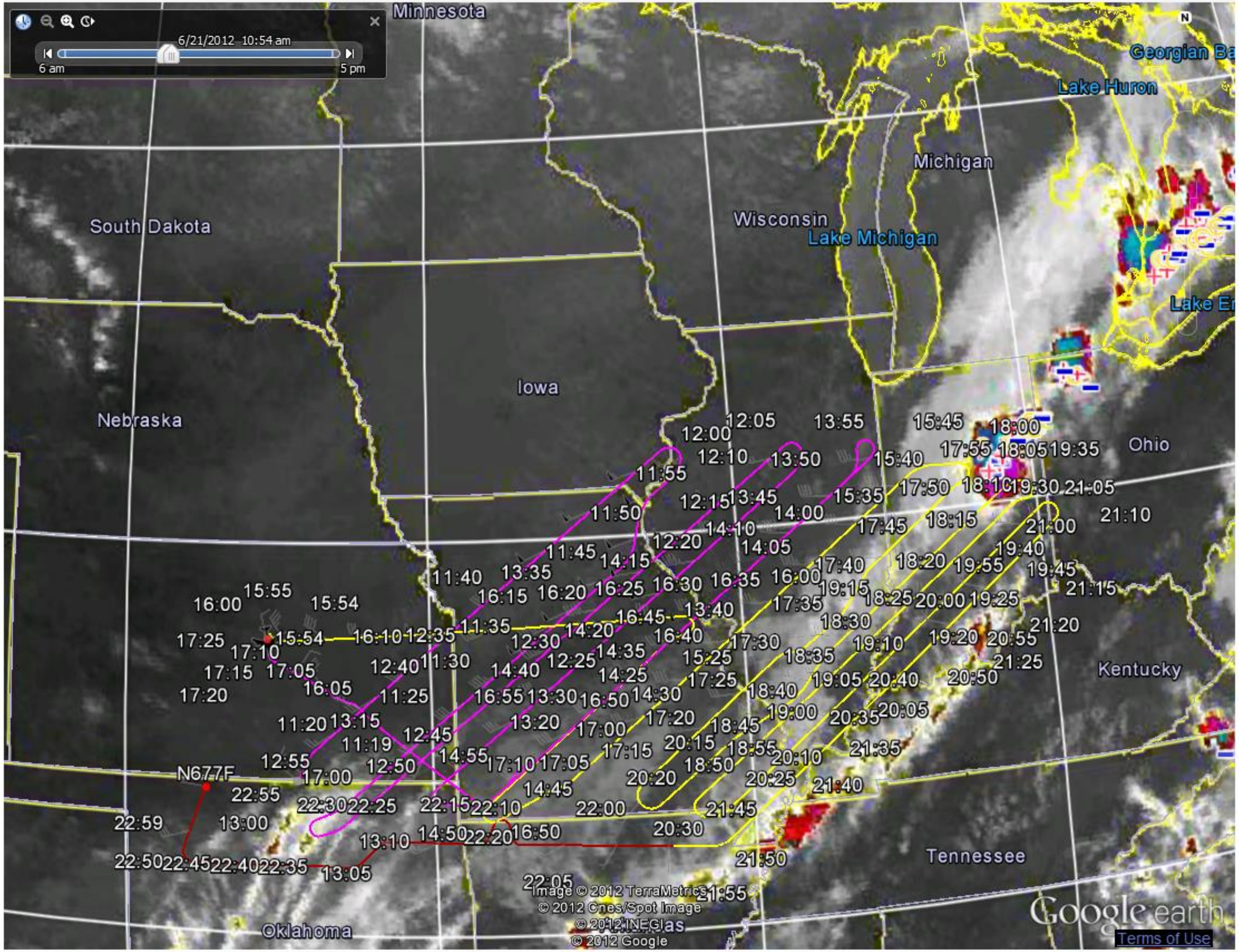
The selected date/time display is 2012-06-21 21:00 UTC



The selected date/time display is 2012-06-21 22:00 UTC



The selected date/time display is 2012-06-21 23:00 UTC



The selected date/time display is 2012-06-21 23:00 UTC

MCS Evolution

Images showing state outlines, visible and infrared satellite images, and DC3 aircraft flight tracks at various times before and during the aircraft sampling.