An Analysis of Convectively Sourced Water Vapor in the Overworld Stratosphere at Northern Midlatitudes: An Update with Data from SEAC4RS

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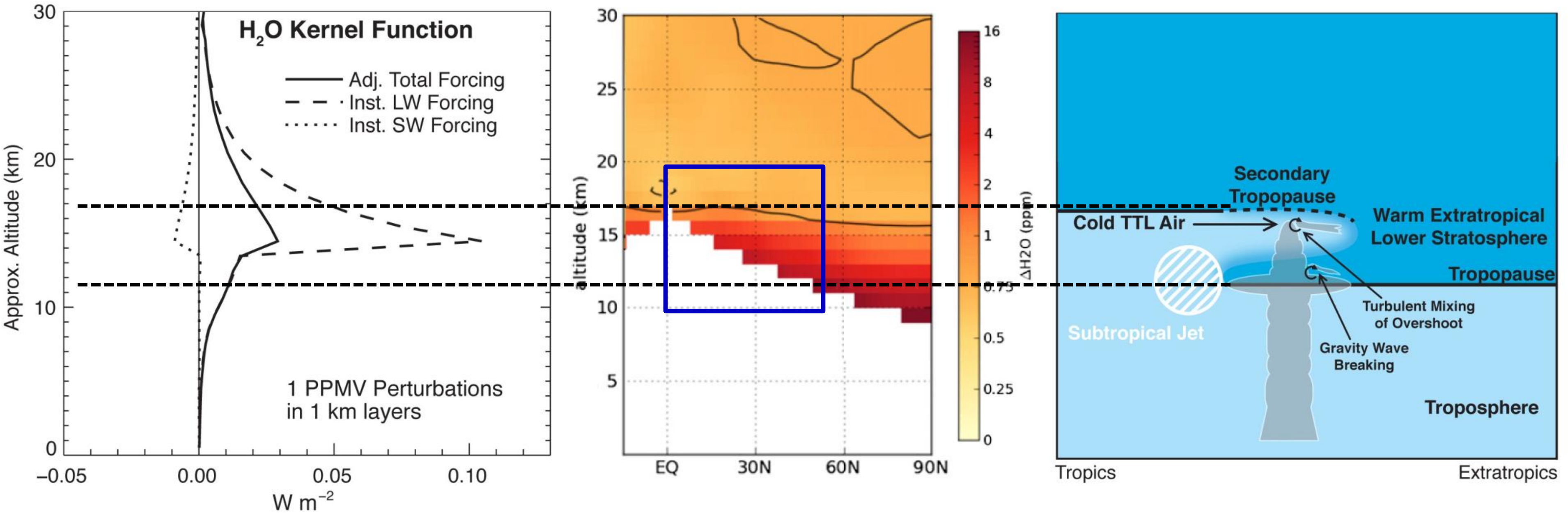
Scientific Motivation I

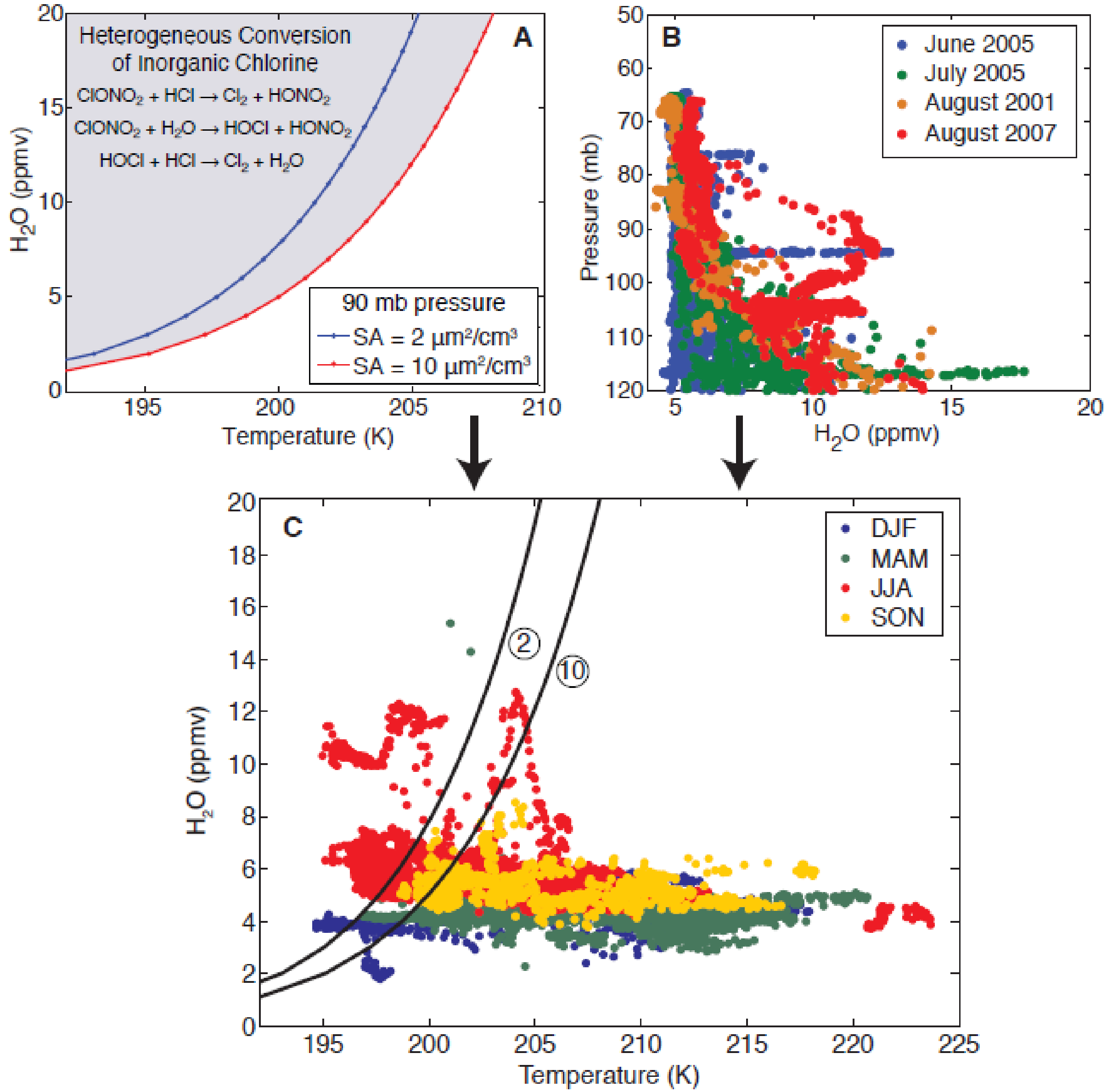
Water Vapor, Radiative Forcing & Climate Feedback



- Radiative impact significant even for ~1 ppmv changes in strat. H_2O
- As temperatures rise, water vapor in UT/LS increases --> +Feedback
- Convective contribution least well understood
- **How will the mechanisms that determine UT/LS H_2O change in response to climate forcing?**

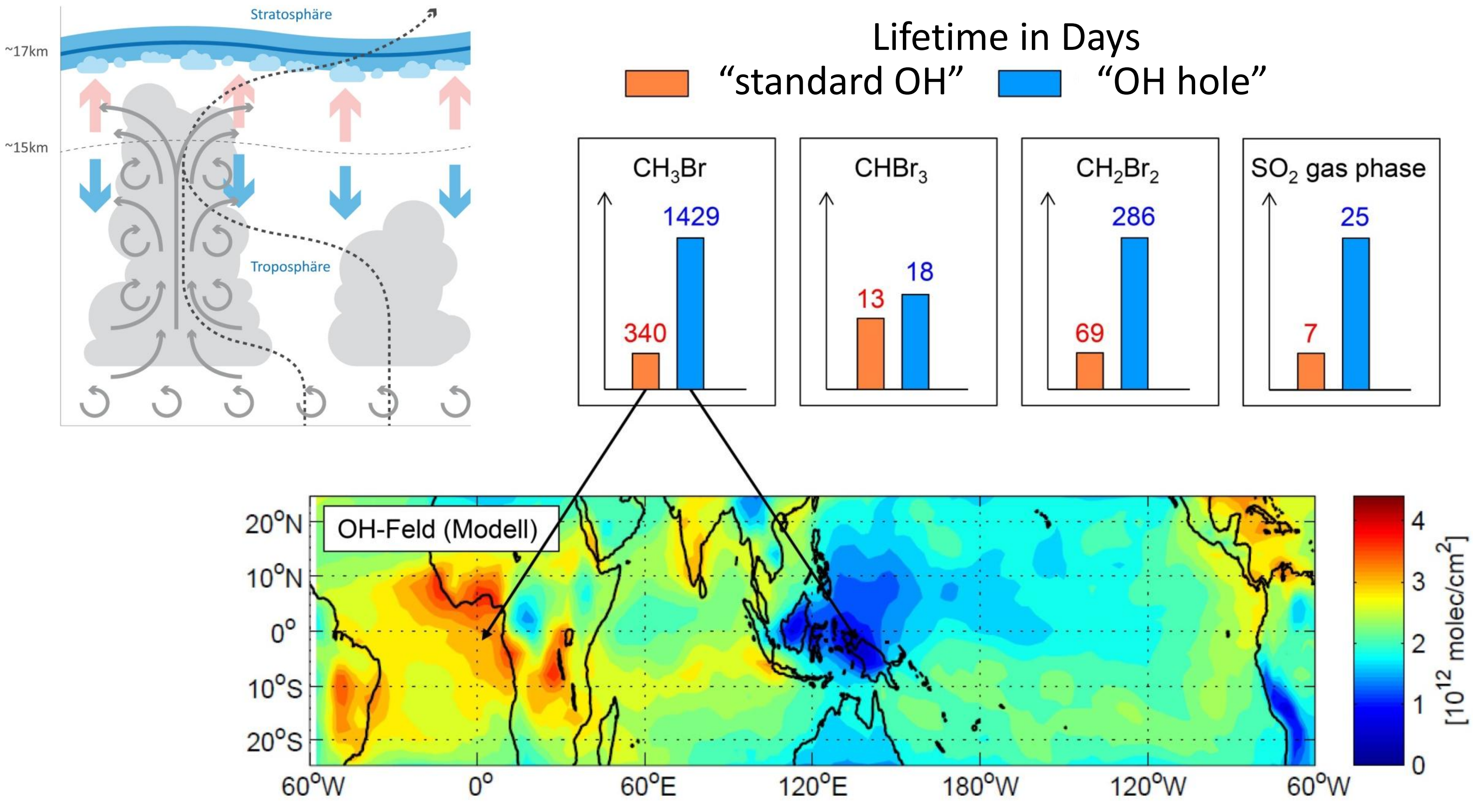
Scientific Motivation II

Convection, Water Vapor & Potential for Ozone Loss



Scientific Motivation II+

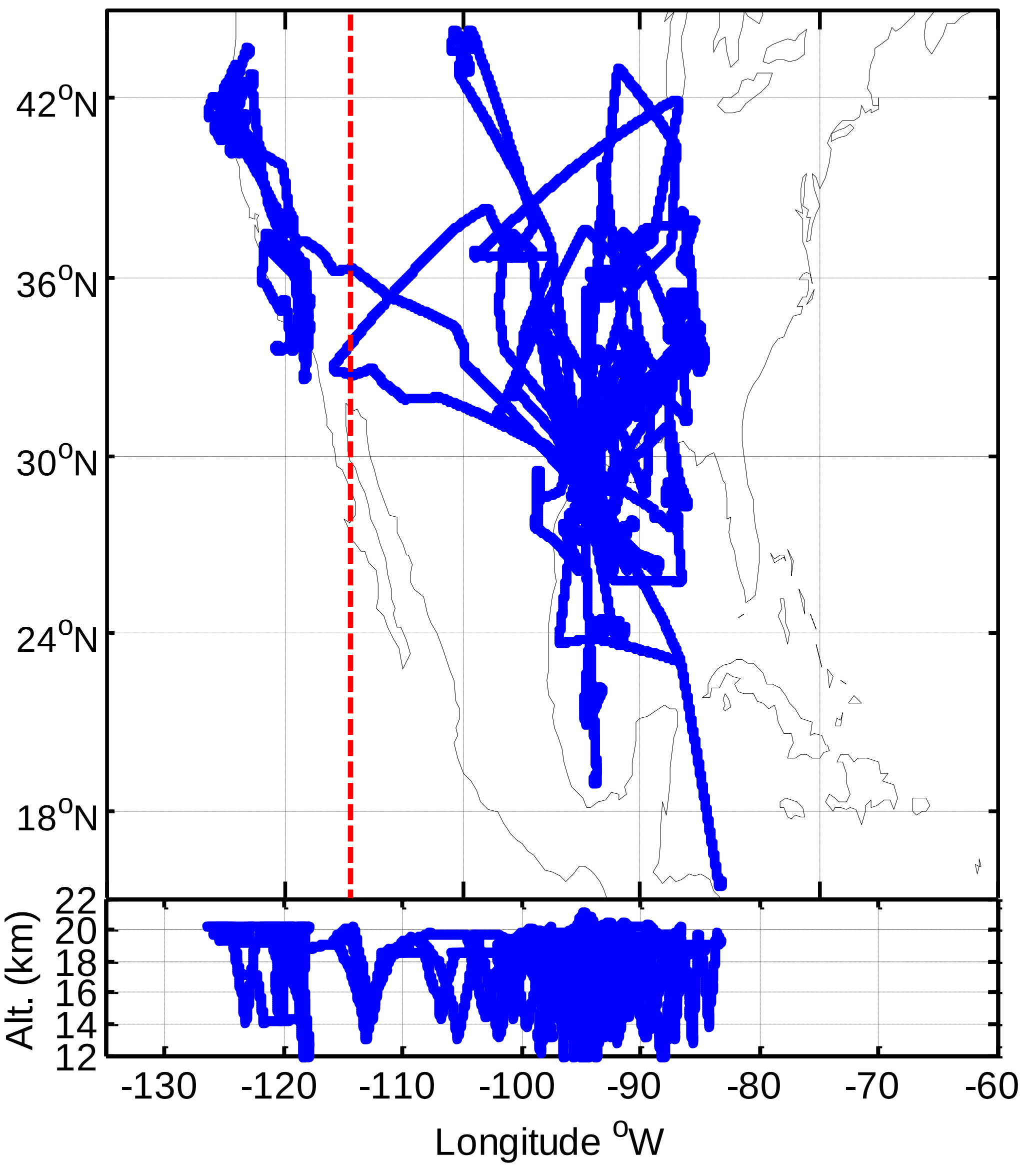
Convection, Chemical Transport & Potential for Ozone Loss



Adapted from http://www.awi.de/en/news/press_releases/detail/item/pm_rex_englisch/

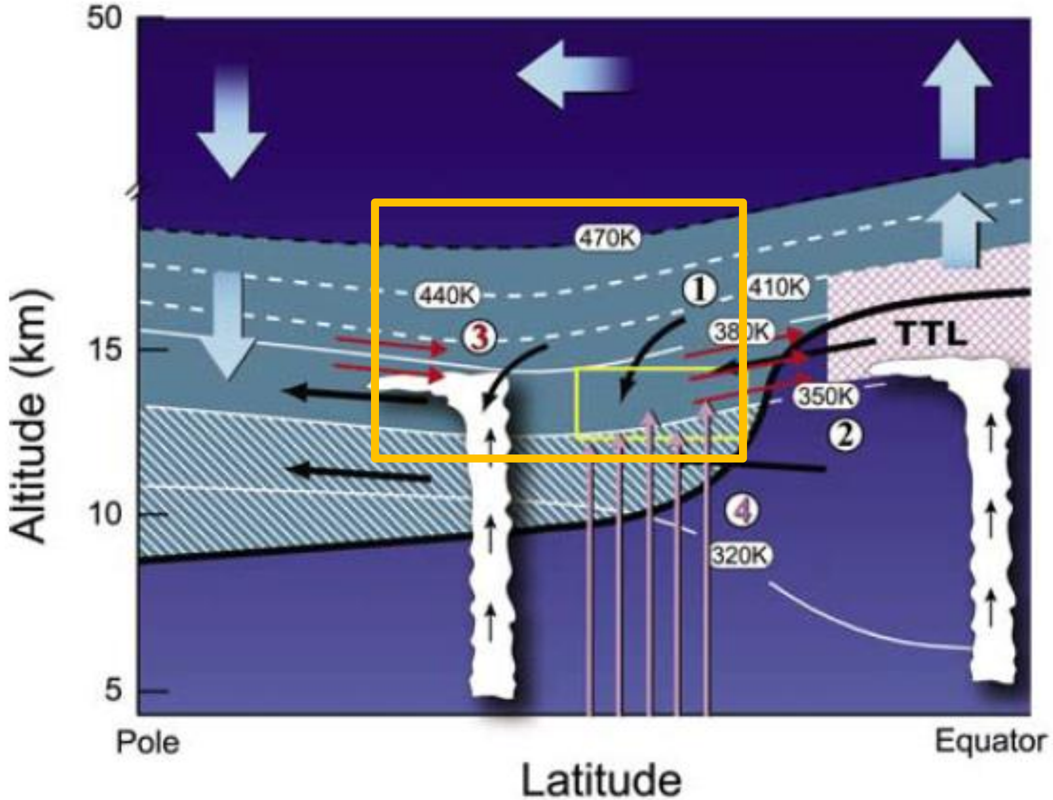
SEAC4RS – Aug. & Sep. 2013, Houston TX

ER-2 Flight Tracks & Vertical Profiles



SEAC4RS – Aug. & Sep. 2013, Houston TX

Pathways for Air Into UT/LS Study Region

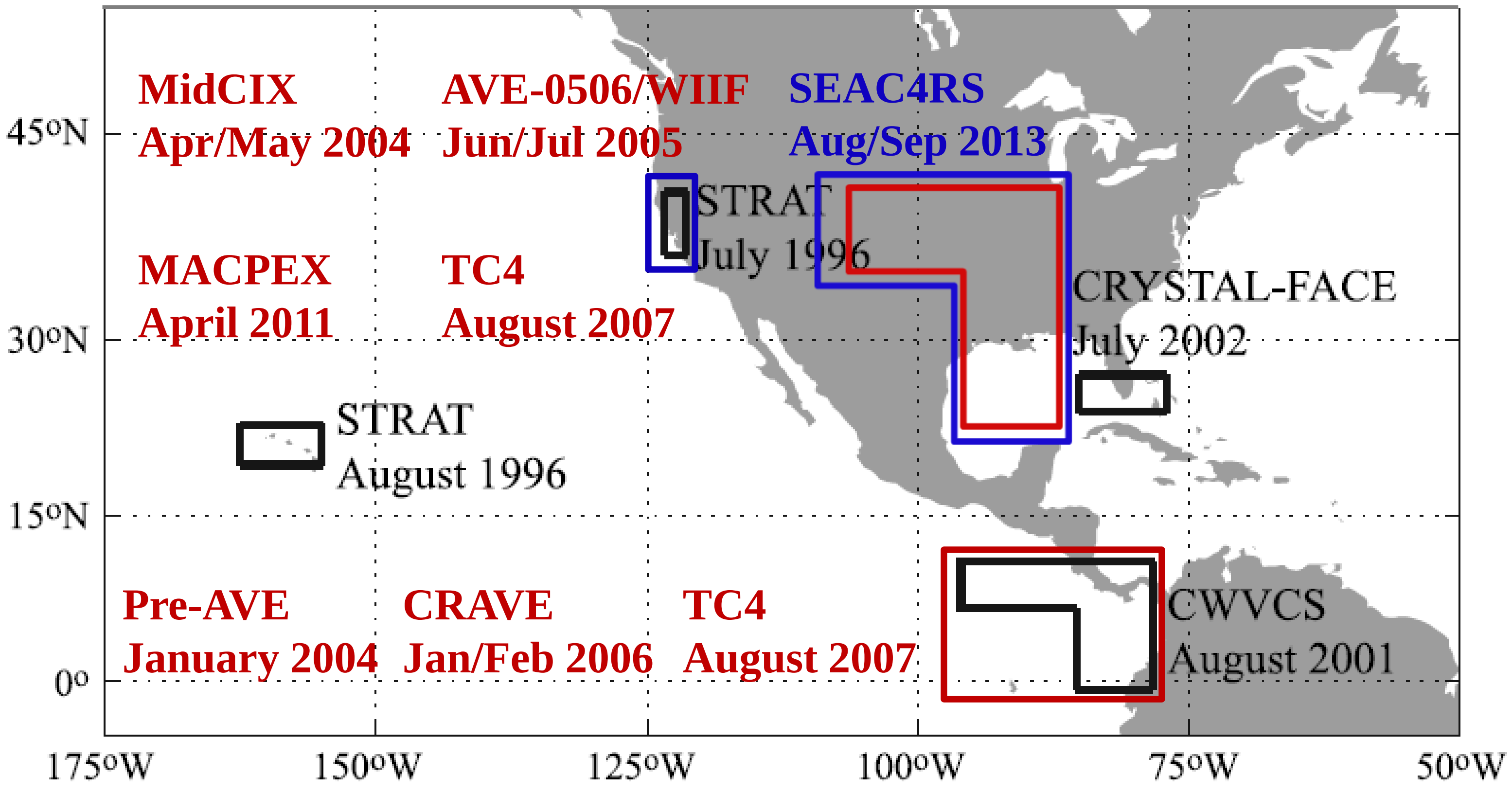


1. Young Stratospheric Air from Tropics/Subtropics
2. Isentropic Transport from TTL/Upper Tropical Troposphere
3. Older Stratospheric Air that has been transported in via NAM Circulation
4. **Local Convection over the Continental U.S.**

Adapted from Weinstock, et al., 2007

Mission Coverage in Past Decade

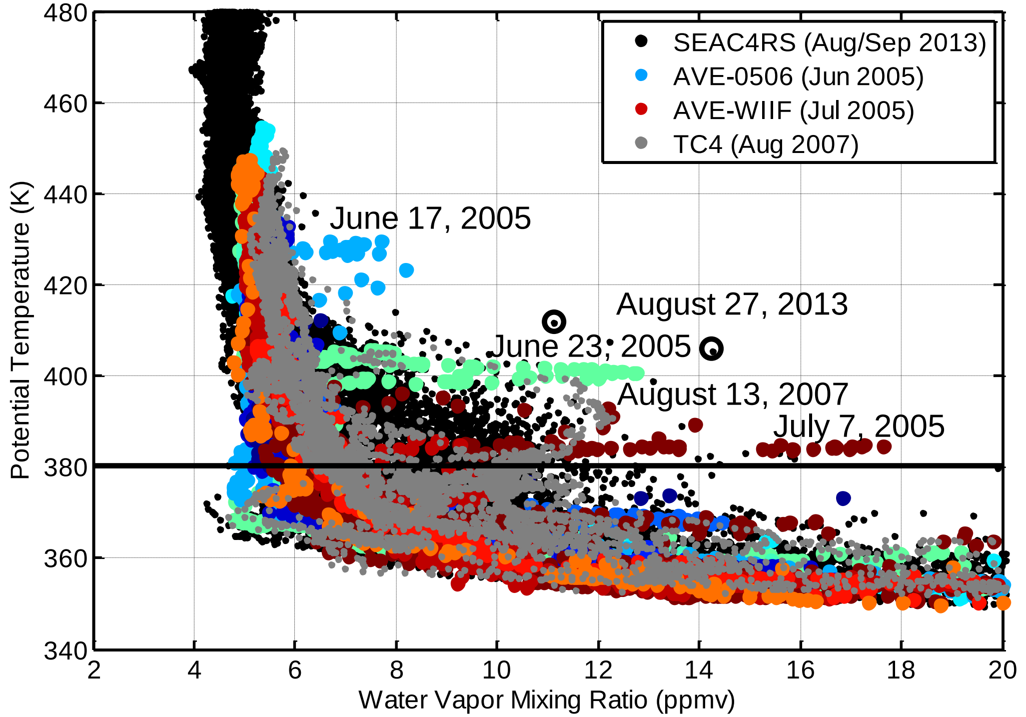
Constrains Source Regions, Variability by Season and Year, etc.

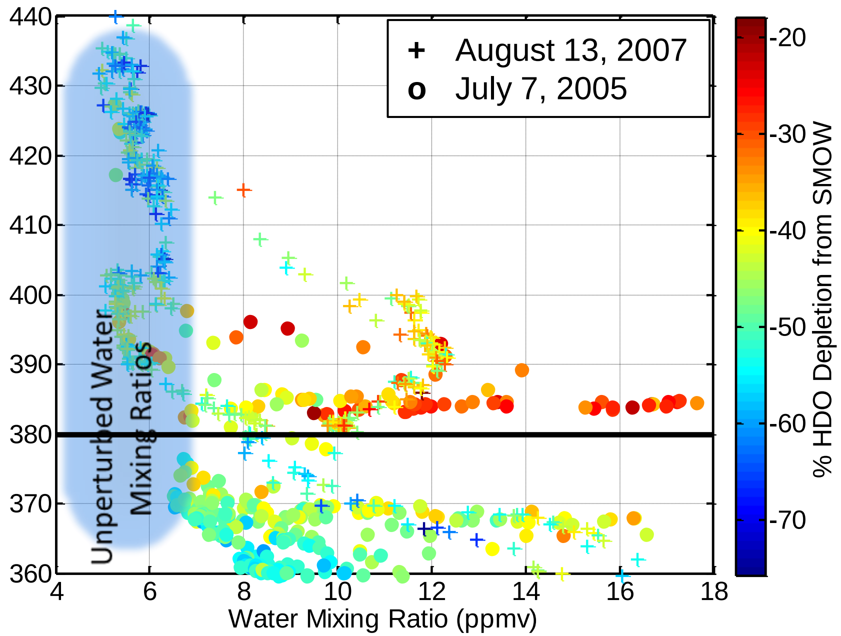


Adapted from Pittman, et al., 2007

Evidence of Direct Convective Injection of H_2O

Harvard Water Vapor & Isotopologue Data

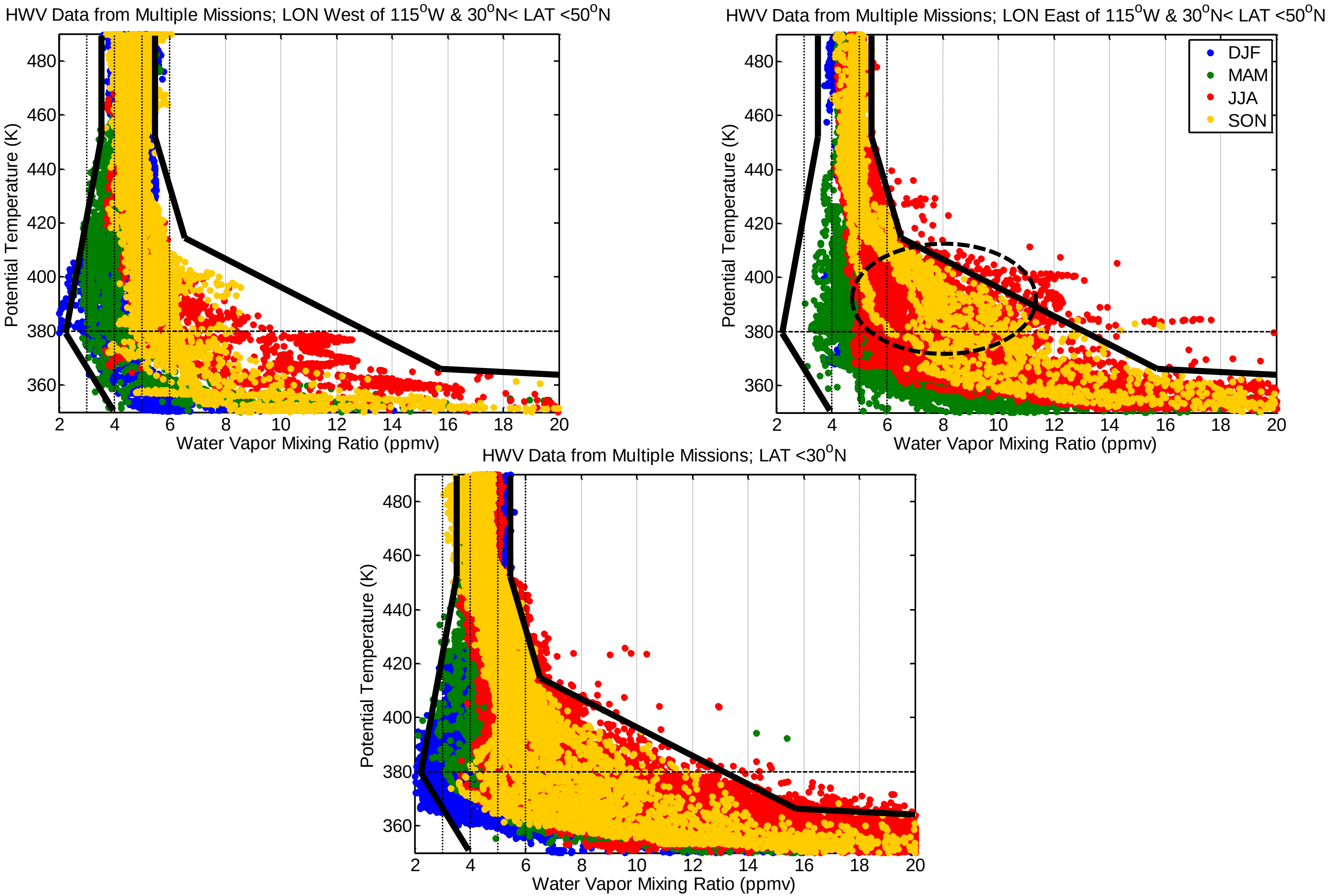




- ❖ Summertime convective plumes observed over Continental U.S.
- ❖ Hydration plumes observed to add up to ~12 ppmv above 380 K
- ❖ Hydration plumes evident up to ~440 K
- ❖ **These events circumvent temperature control of tropopause**

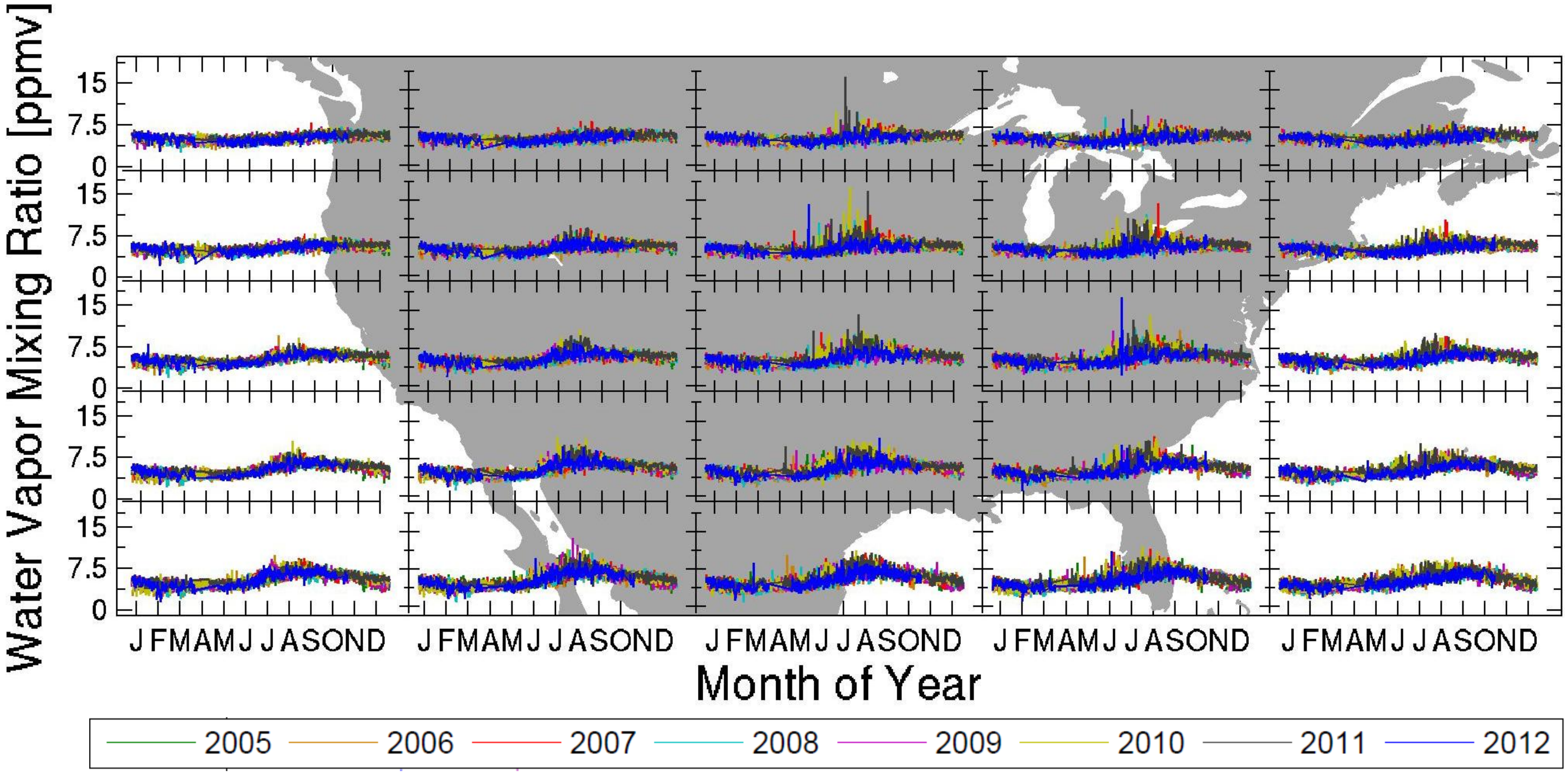
HWV In Situ Data by Season

Seasonal & Regional Differences, Summer Plumes over U.S.



MLS Satellite Data at 100 hPa

Inter-annual & Seasonal Variability in High Water Events

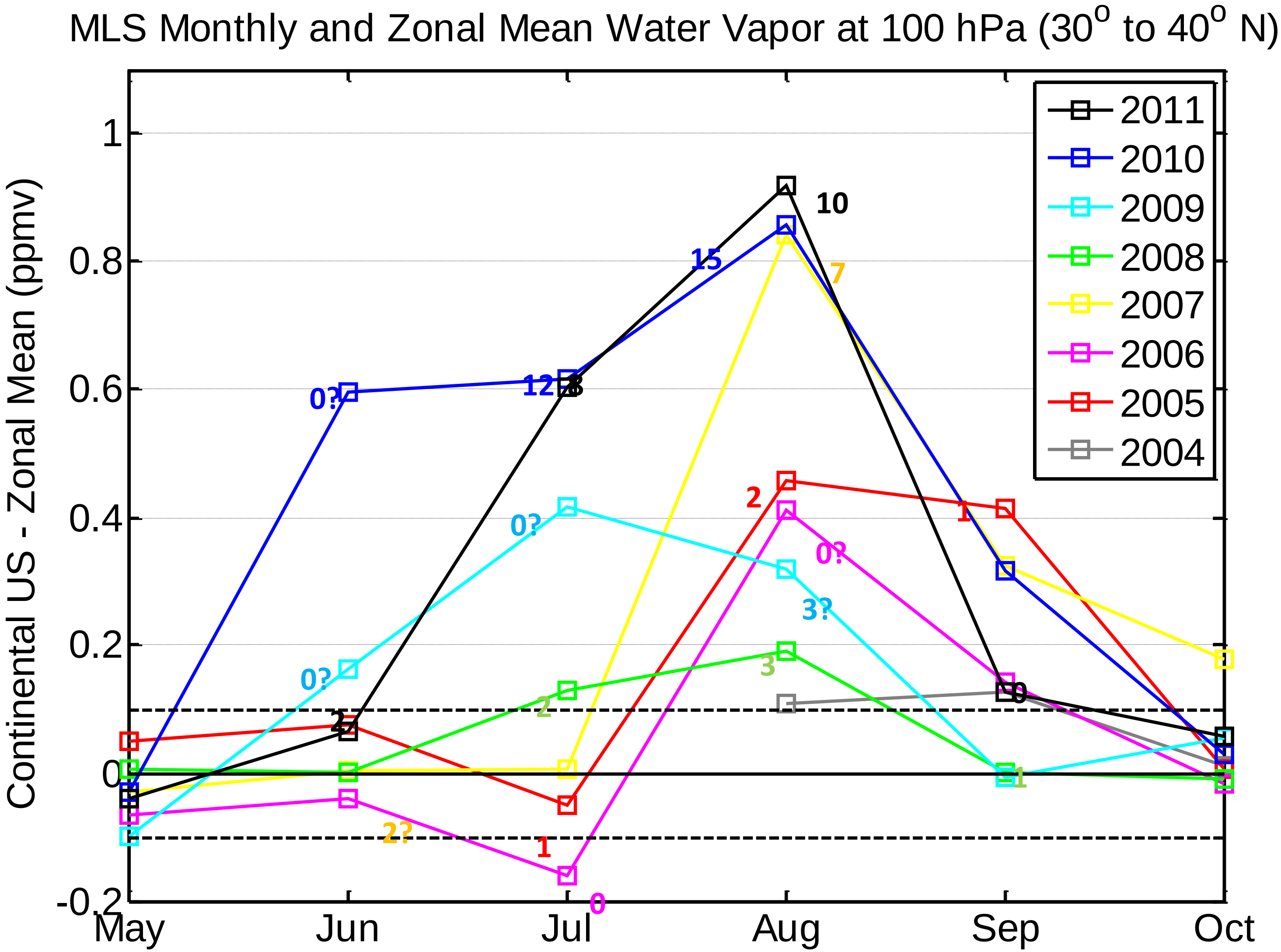


- Seasonal and regional localization of water vapor enhancements
- Transient events of 15 ppm or more are observed, even as far north as 45°
- MLS events similar to enhancements observed in situ by HWV

Dykema, et al., *in preparation*, 2014

MLS Satellite Monthly Mean Measurements

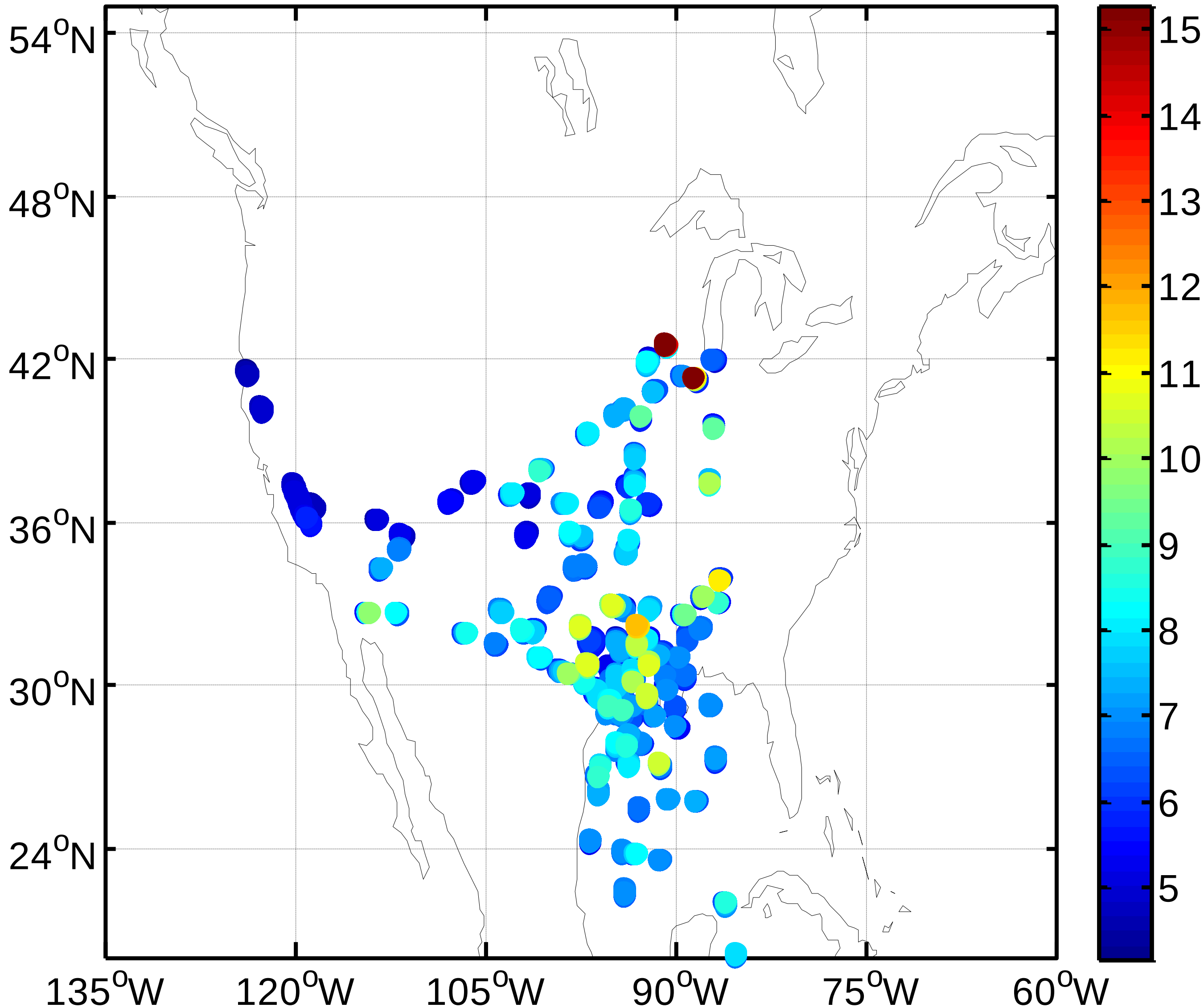
ΔH_2O = Con. U.S. – Zonal Mean at 100 hPa



*Numbers refer to estimated # of MLS events with >9 ppmv over CONUS per month

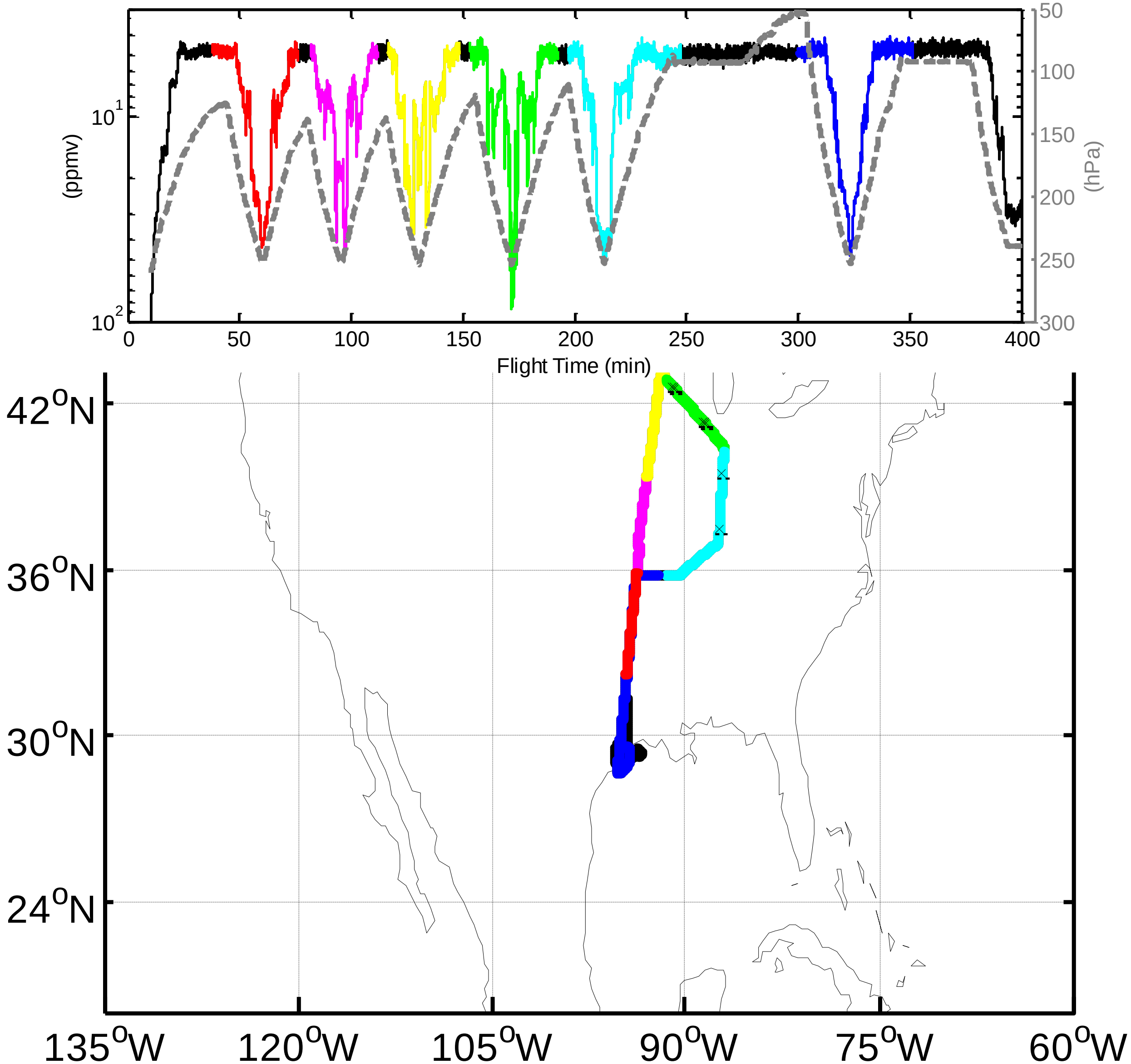
SEAC4RS Water Vapor at 90 (±5) hPa

Plume Evident off the Southern Tip of Lake Michigan @ 42°N



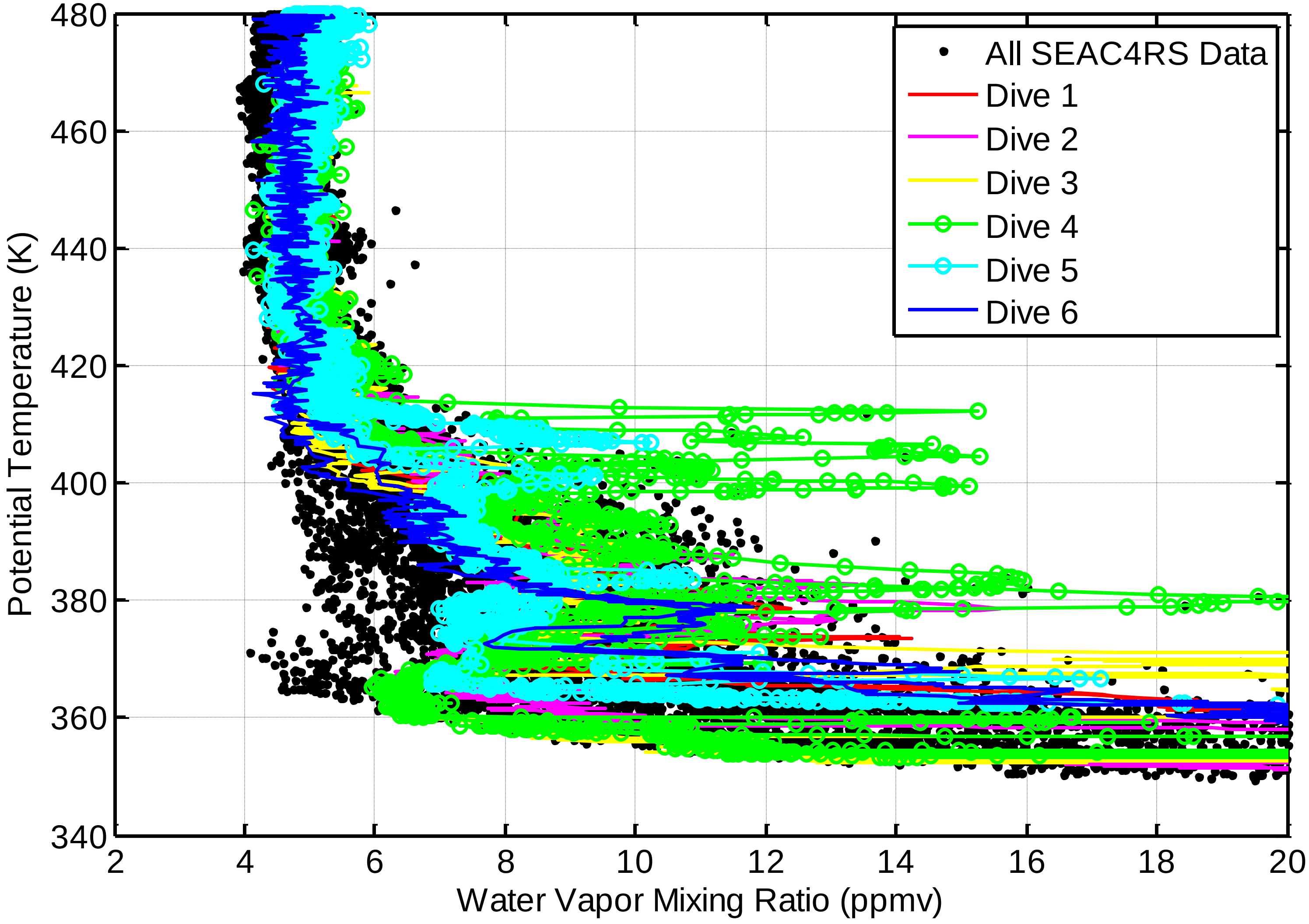
Flight of August 27, 2013

Sample MCS Outflow over Great Lakes Region



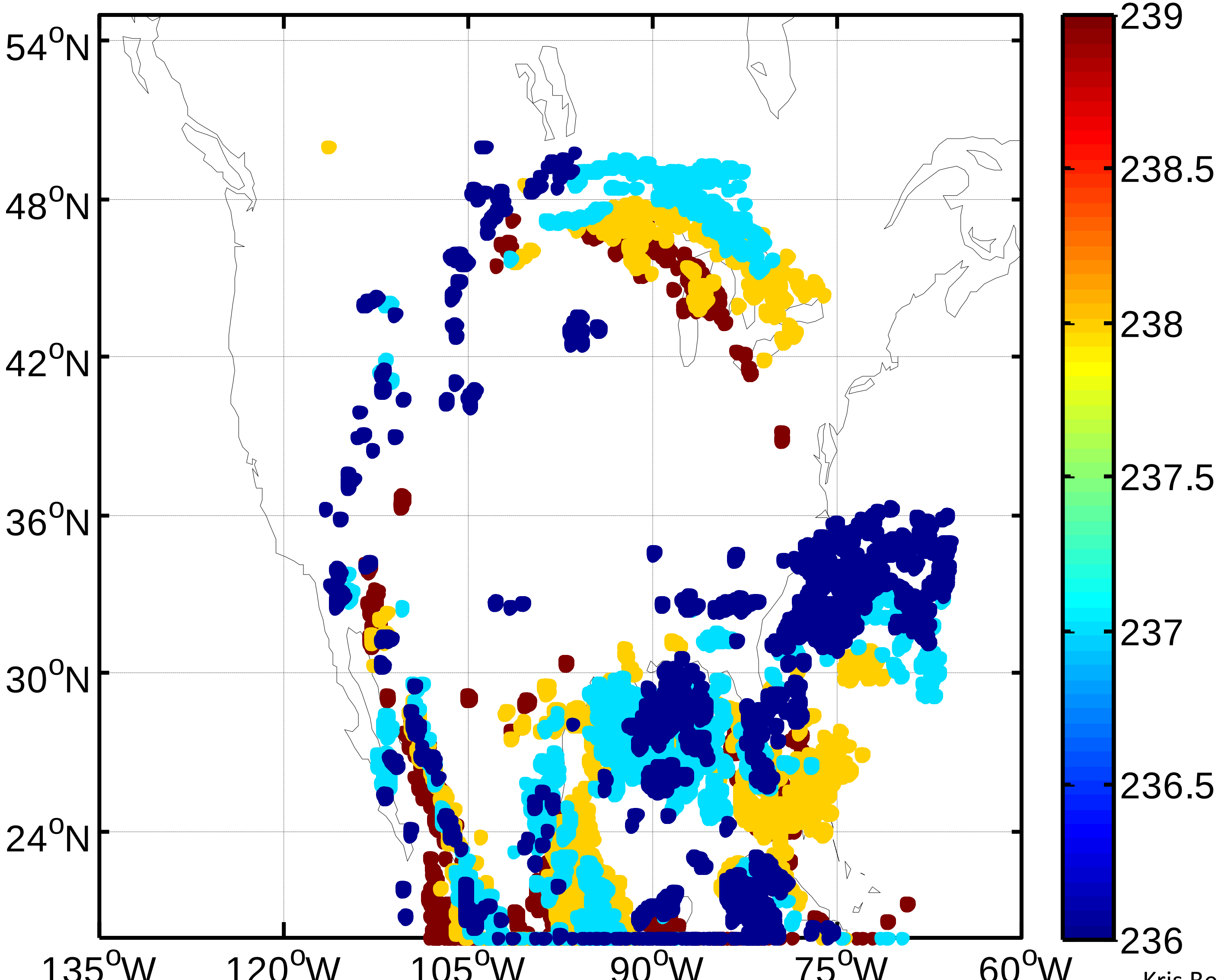
Convectively Sourced Plume in SEAC4RS

Plume in Overworld Stratosphere Observed on Aug. 27, 2013



Overshooting Top Detections Using GOES-IR

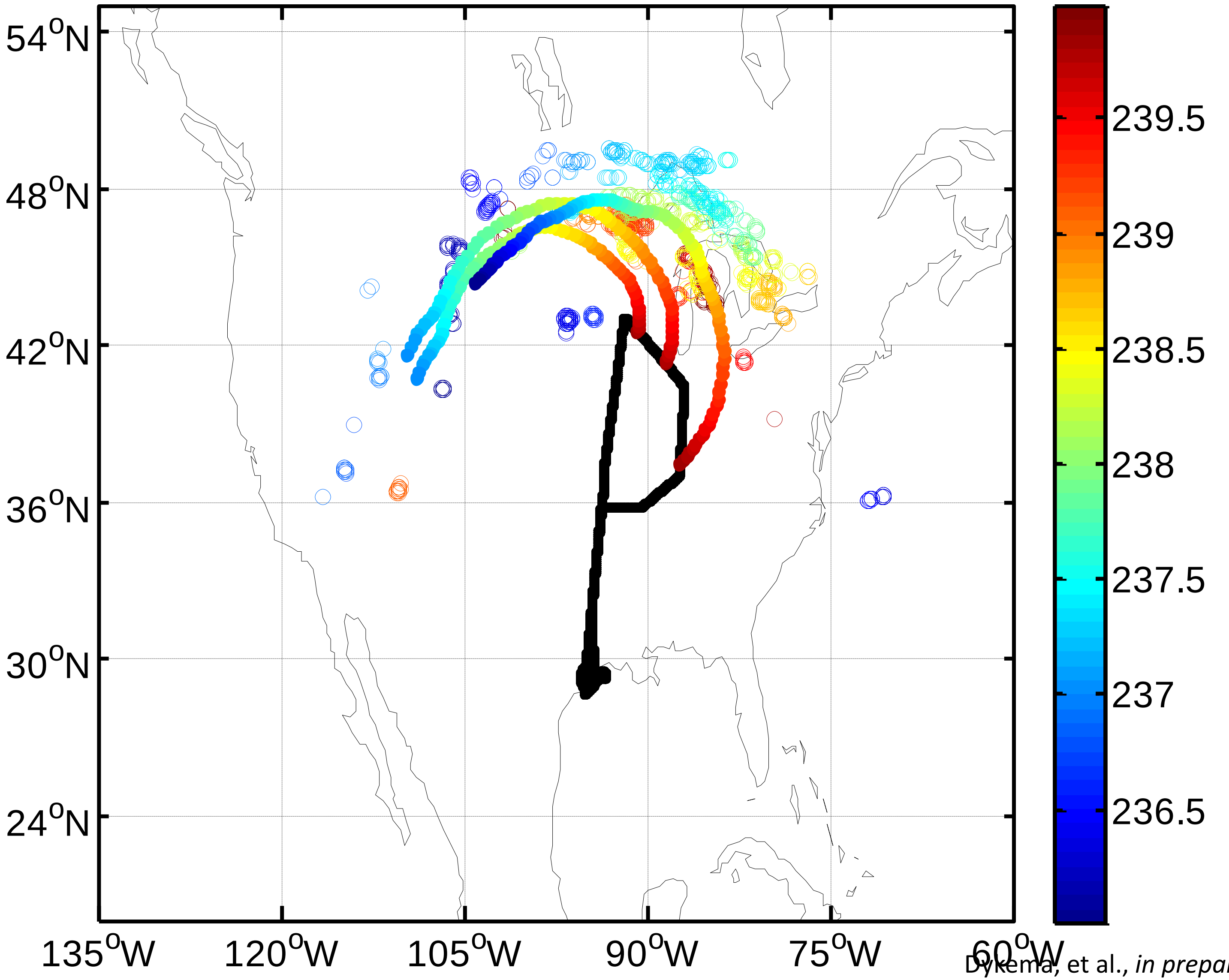
Selected OT Detections in 4 Days over North America



Kris Bedka, OT Analysis

Linking Aug. 27, 2013 Plume to Storm System

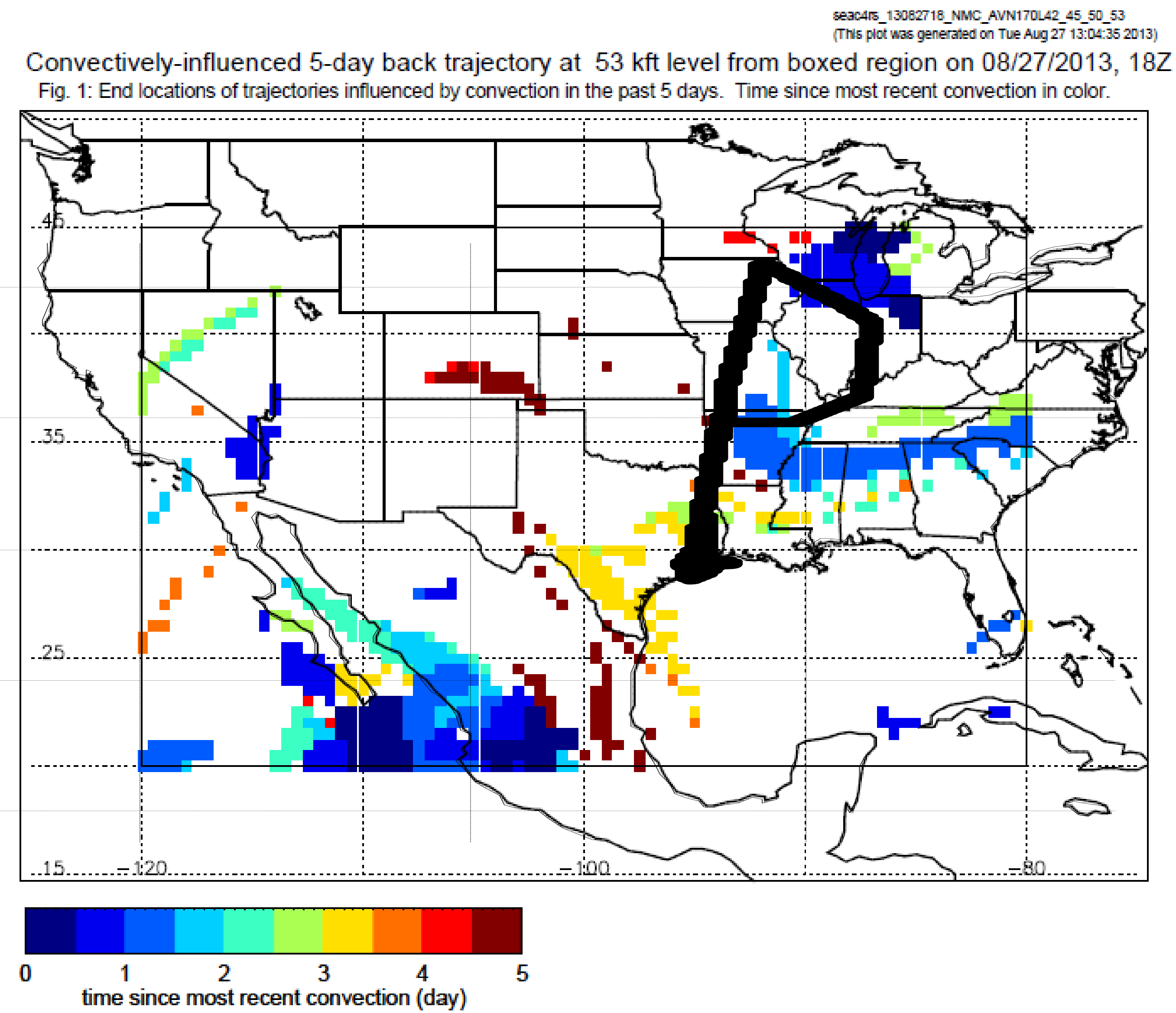
Flight Track, OT Detections & Back-trajectories



Dykema, et al., *in preparation*, 2013

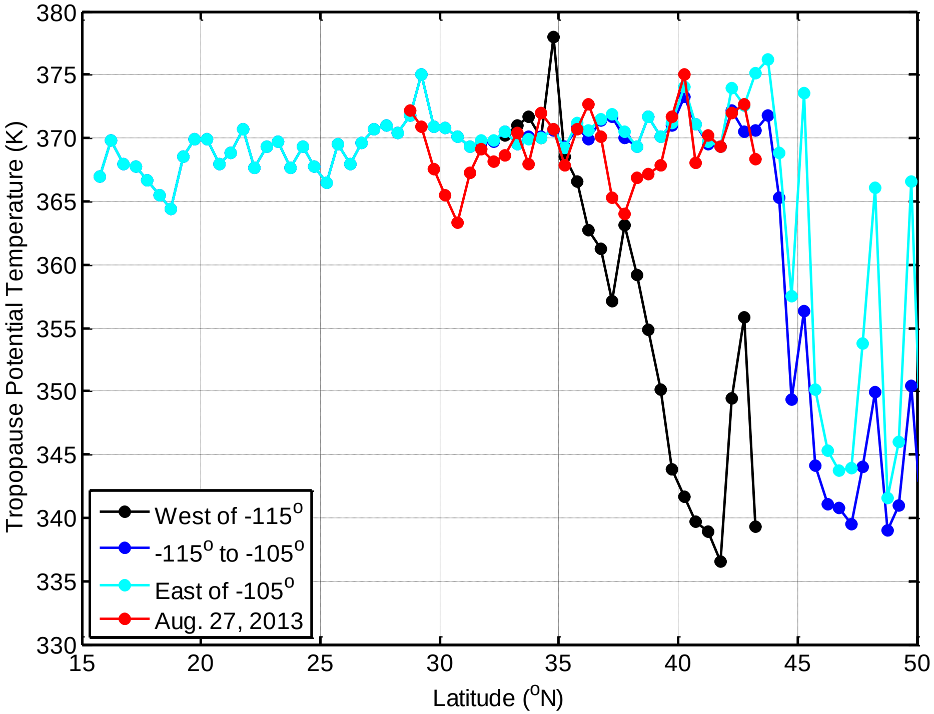
Results from Lenny Pfister's CI Forecast

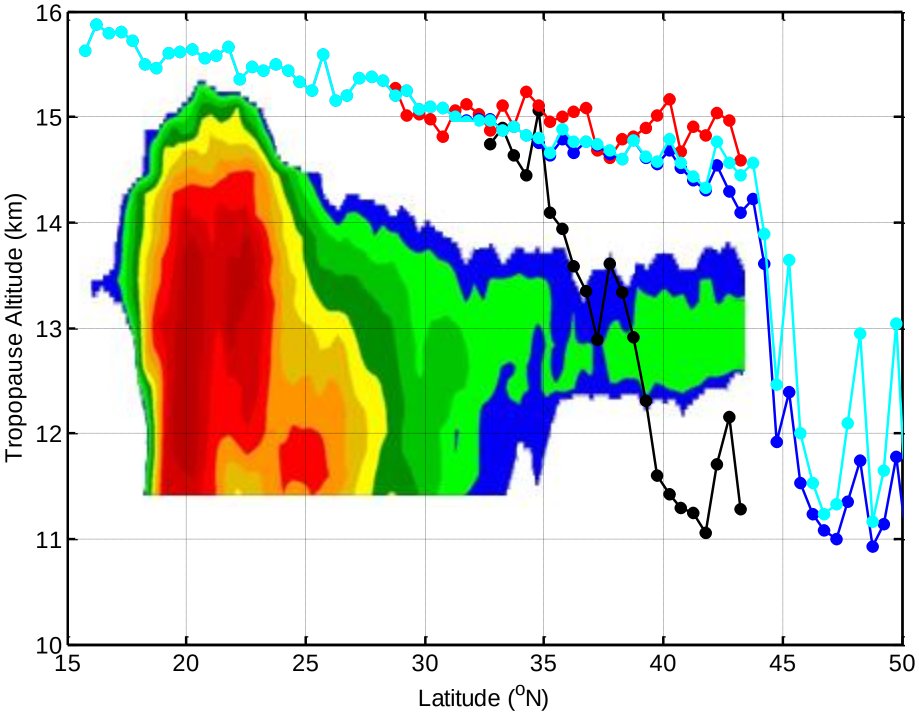
Air Parcels Showing CI at 53 kft for Aug. 27, 2013



Dynamical Context – Tropopause Level

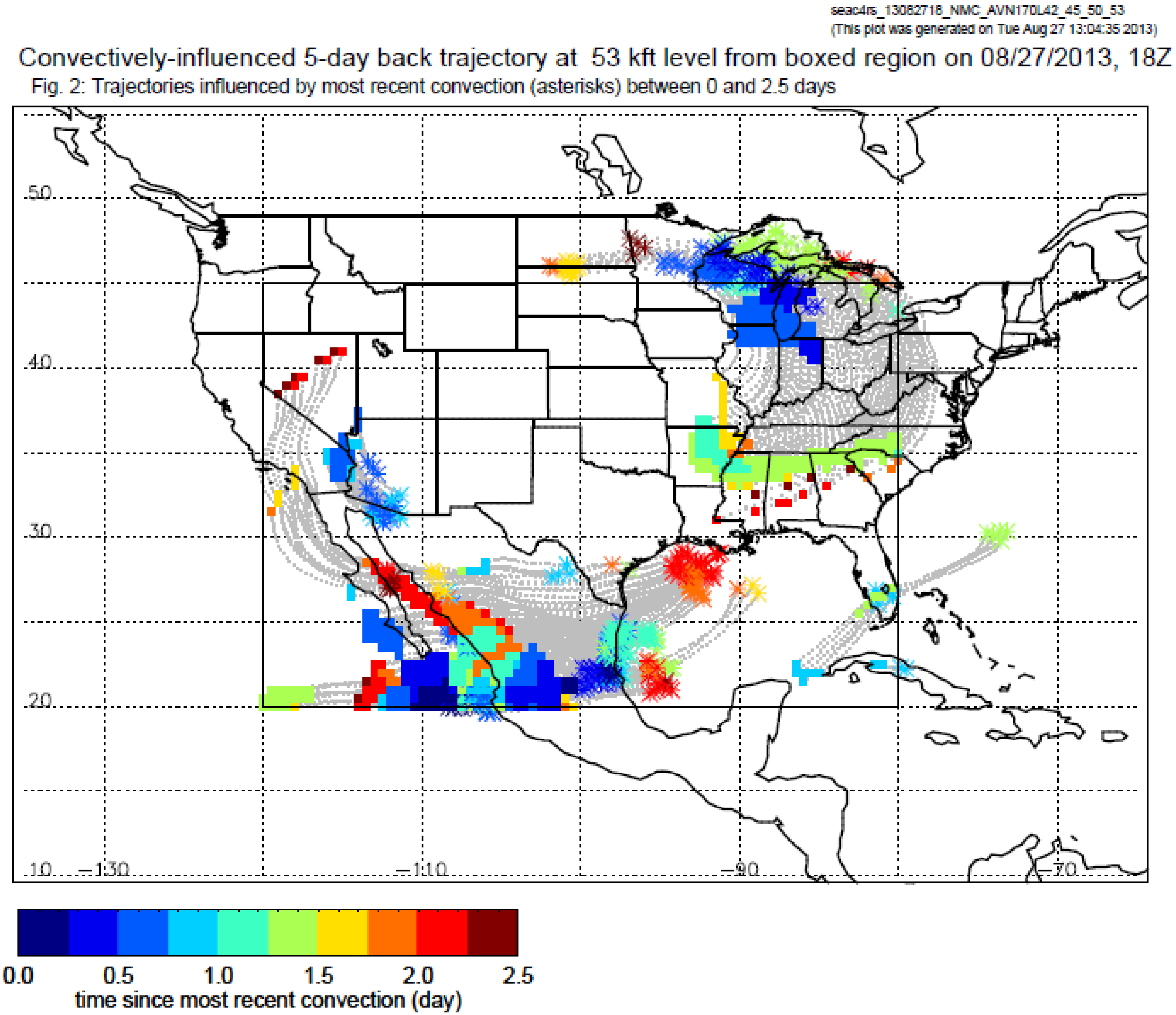
High Tropopause for Most of Mission, Sharp Break at ~45°N





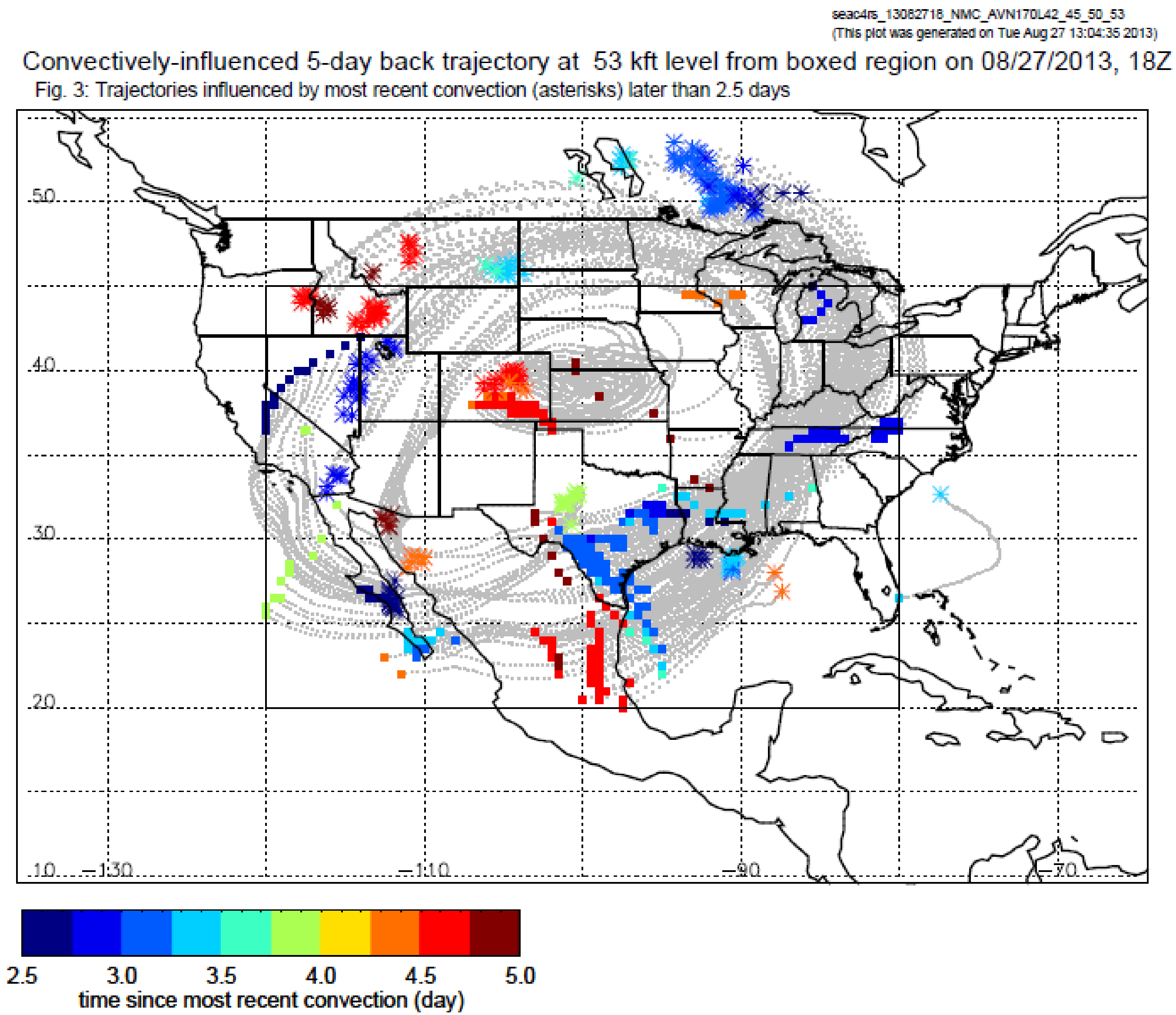
Dynamical Context – Lenny's Analysis

Convective Storms, 0 – 2.5 Day Trajectories & CI at 53 kft



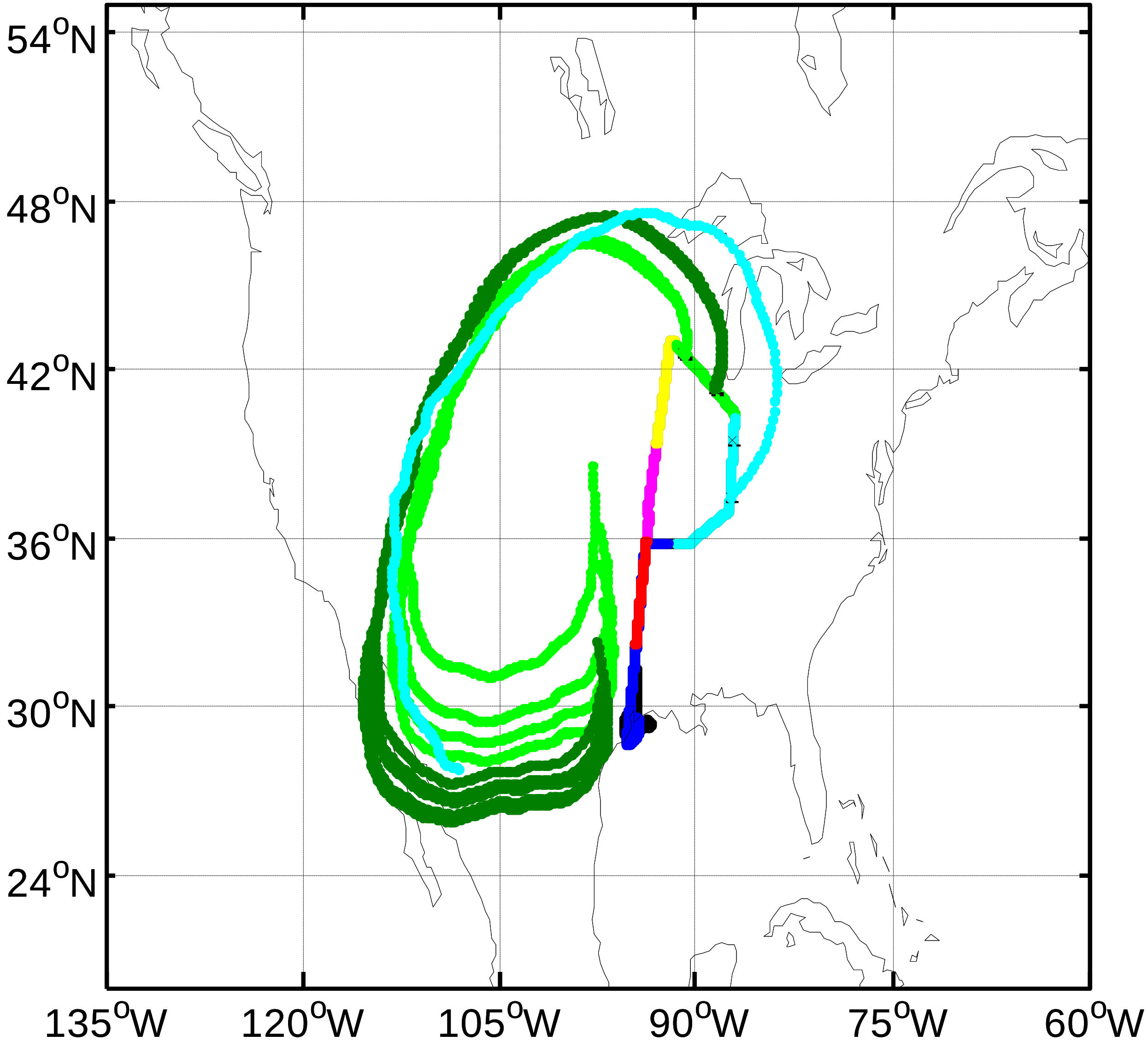
Dynamical Context – Lenny's Analysis

Convective Storms, 2.5 – 5 Day Trajectories & CI at 53 kft



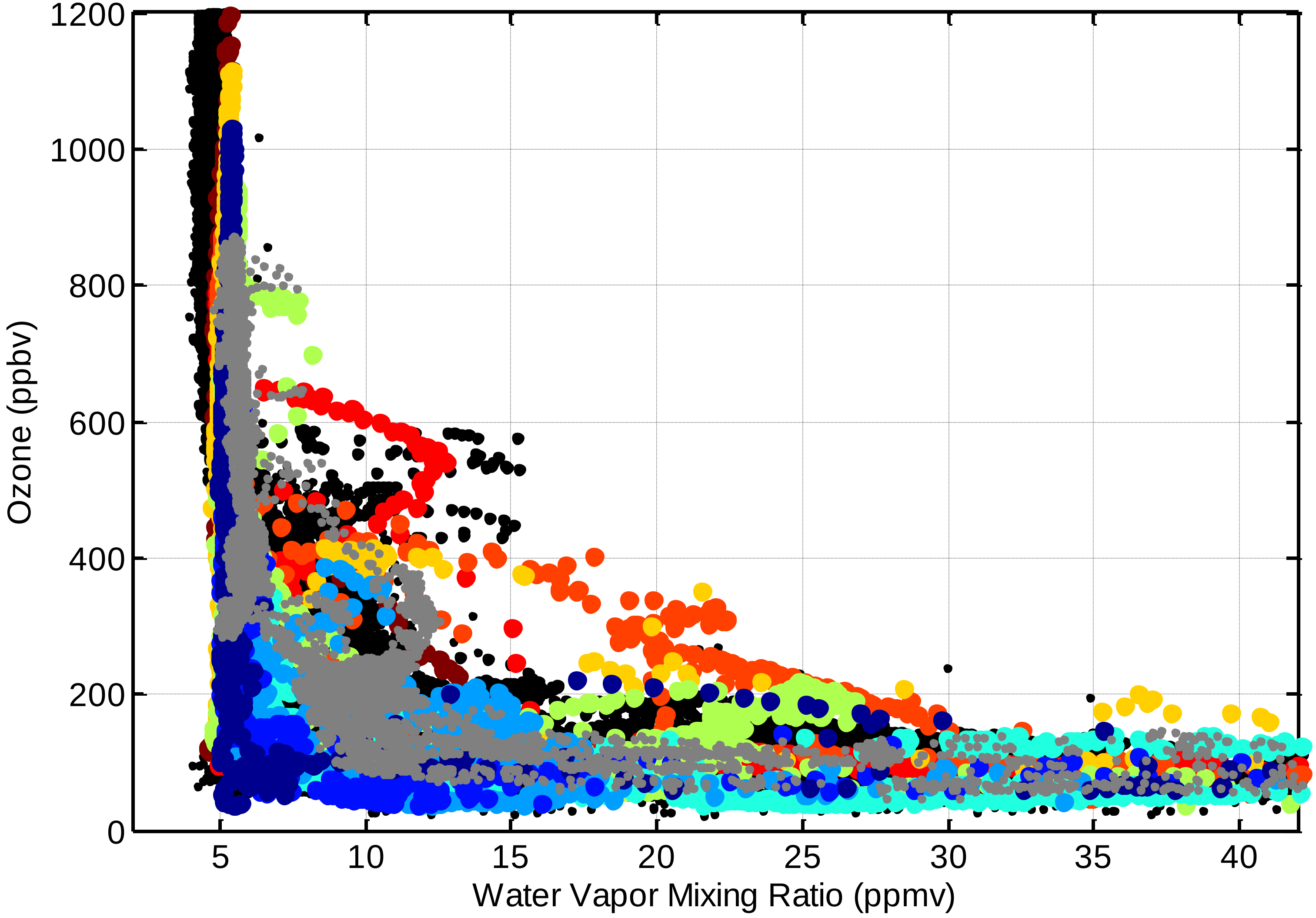
Dynamical Context – Back-trajectories

10-day Back-trajectories from Stratospheric Plume Locations



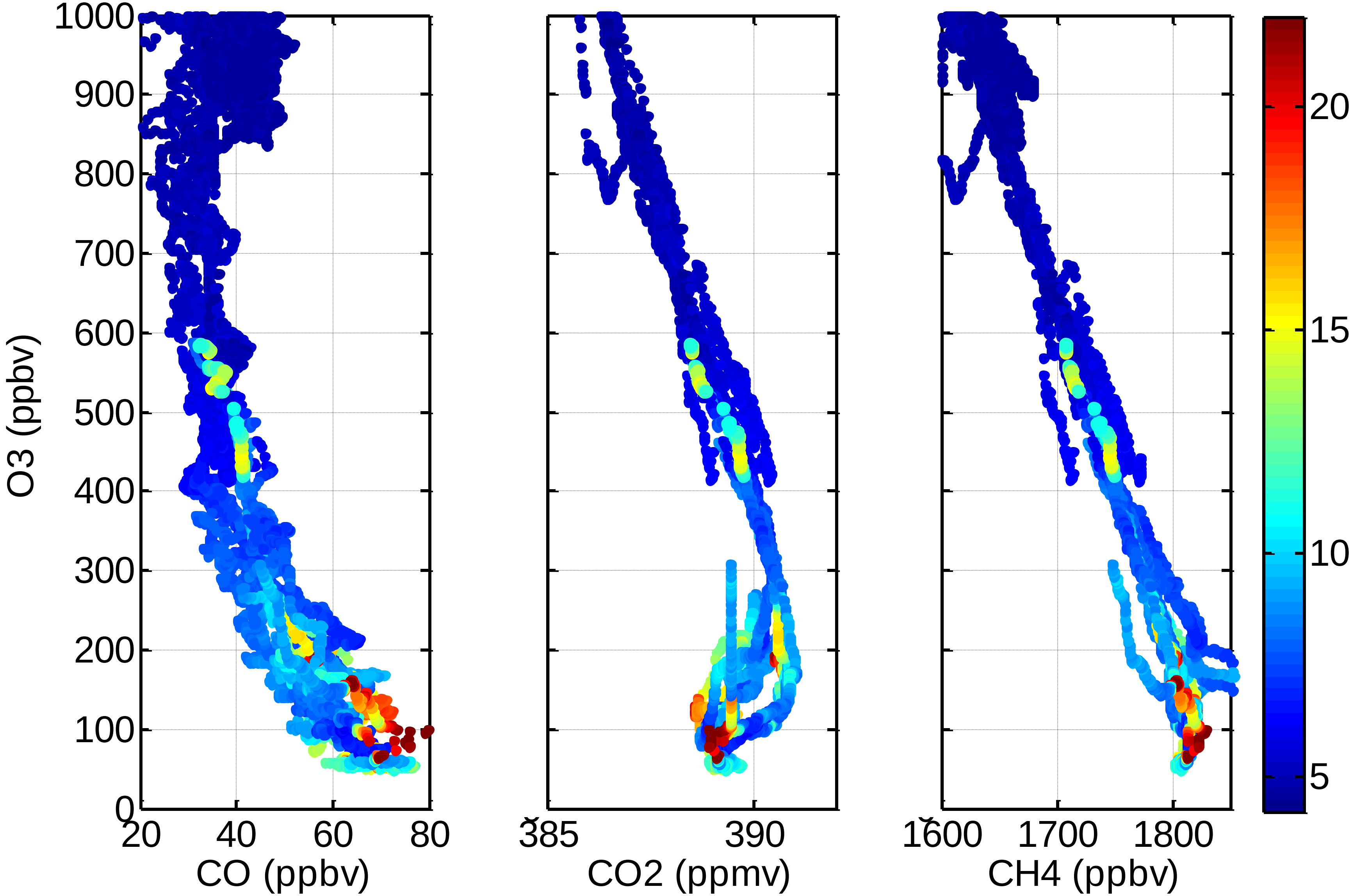
Chemical Context

Tracer-Tracer Correlation – H_2O vs. O_3



Chemical Context

Tracers Plotted vs. O_3 & Color-coded by Water VMR



Summary

Complementary Data Sets – Aircraft, Satellite, Radar

Summary

- ❖ Convection can deliver large quantities of water directly to the lowermost and overworld stratosphere (up to ~440 K)
- ❖ This mechanism bypasses the thermal control of the tropopause
- ❖ Plumes are evident in both high-resolution aircraft and global satellite data
- ❖ GOES IR imagery is useful for identifying potential storm candidates
- ❖ OT algorithm and back trajectories can be used to confirm storm source
- ❖ Trajectories show that stratospheric air over central U.S. has a relatively long lifetime

Future Work

Complementary Data Sets & Case-study Comparison

Future

- Radar data are expected to provide additional information about storm evolution and structure
- Additional tracer from SEAC4RS data will be used to provide more information on the amount of near surface boundary layer air that is transported via this mechanism
- Further analysis of this and of four other similar plume case studies will provide insight into the details of the convective source term

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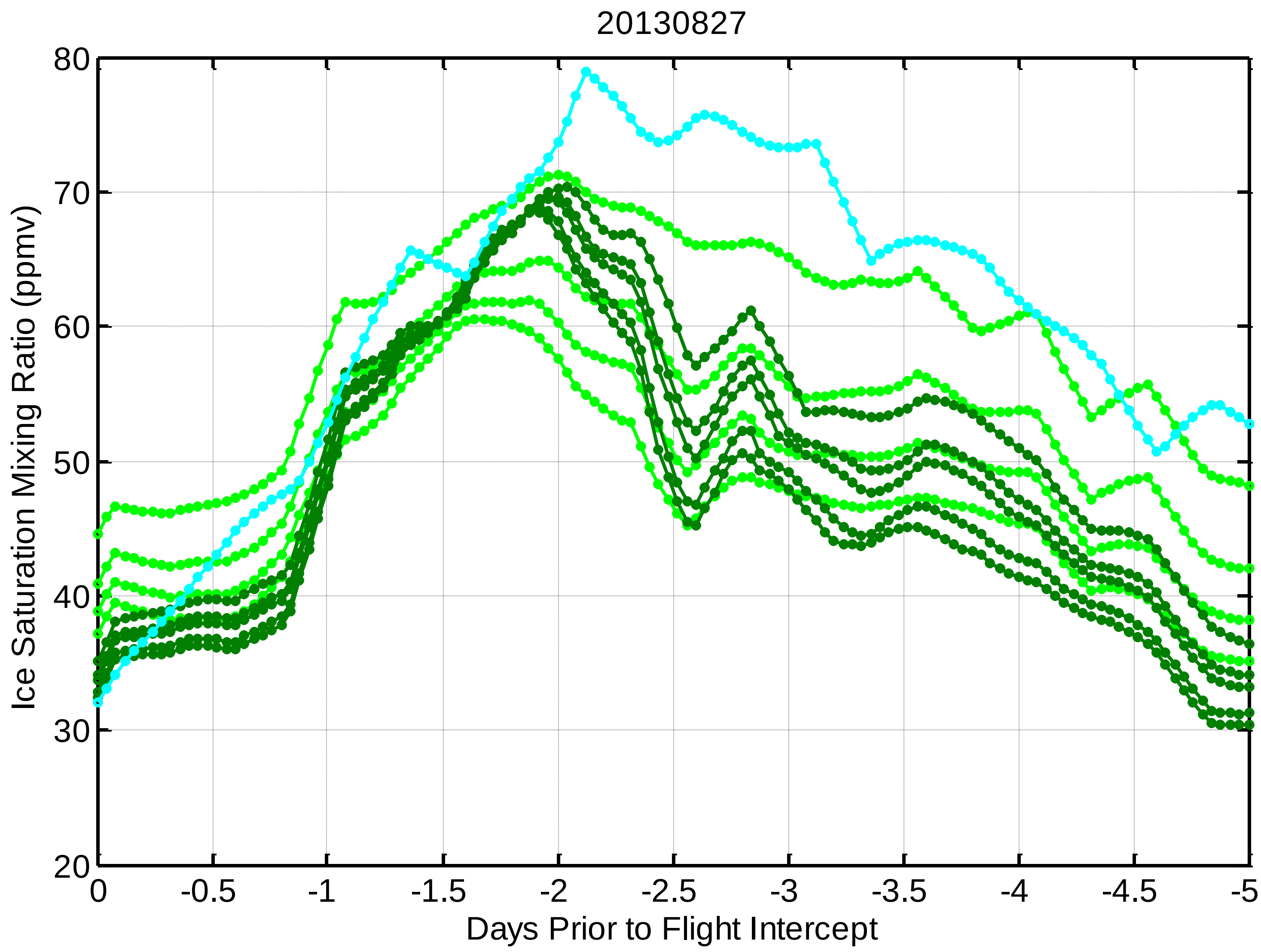
- The impact of these events may increase in response to climate forcing and higher low-level moisture

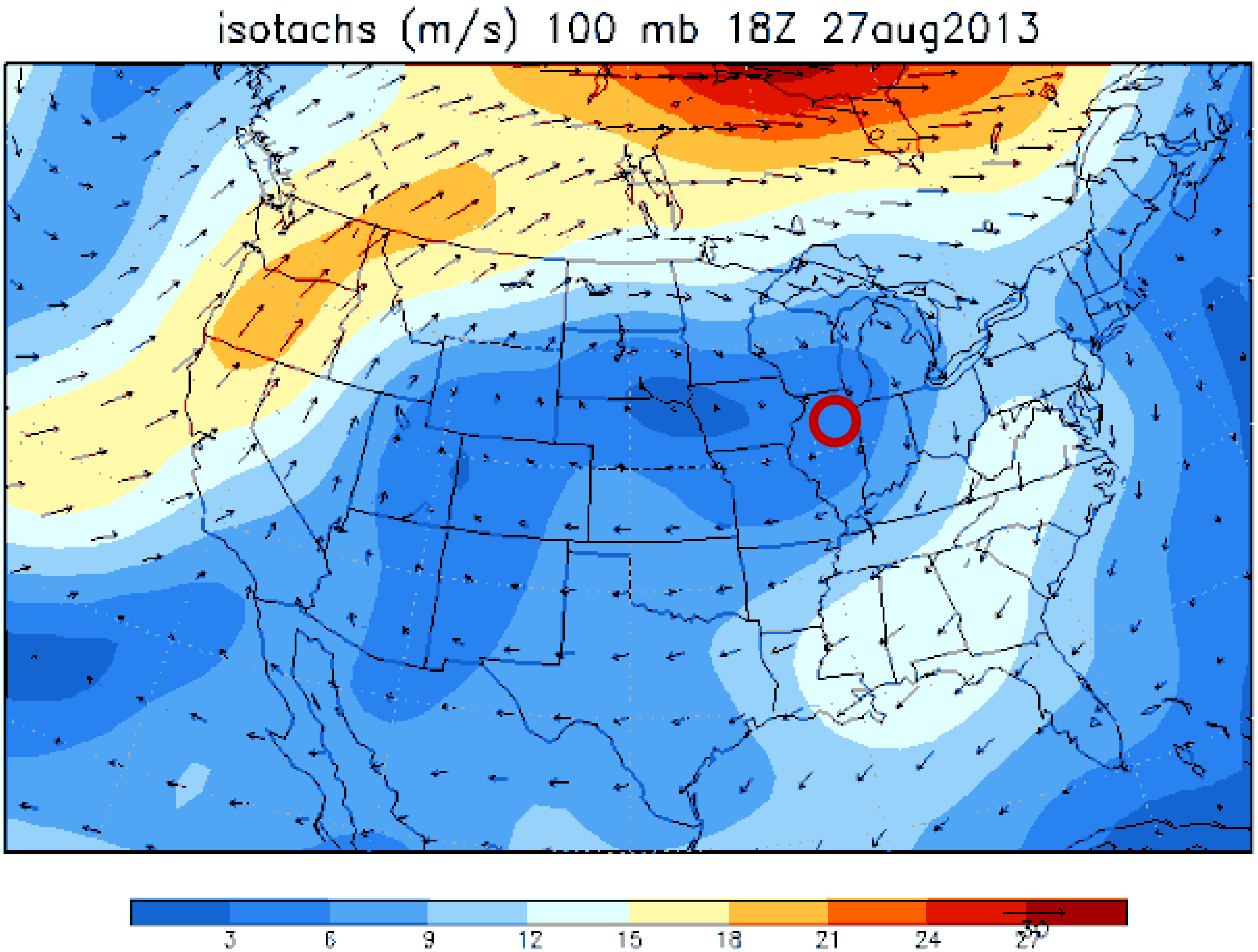
Rough Bound of Max. Water at t = 0

Ice Saturation Mixing Ratios Calculated Along 10-day BTs



Dynamical Context – Zonal Wind Fields

Westerly Flow Associated with Jet & Stratospheric Easterly Flow



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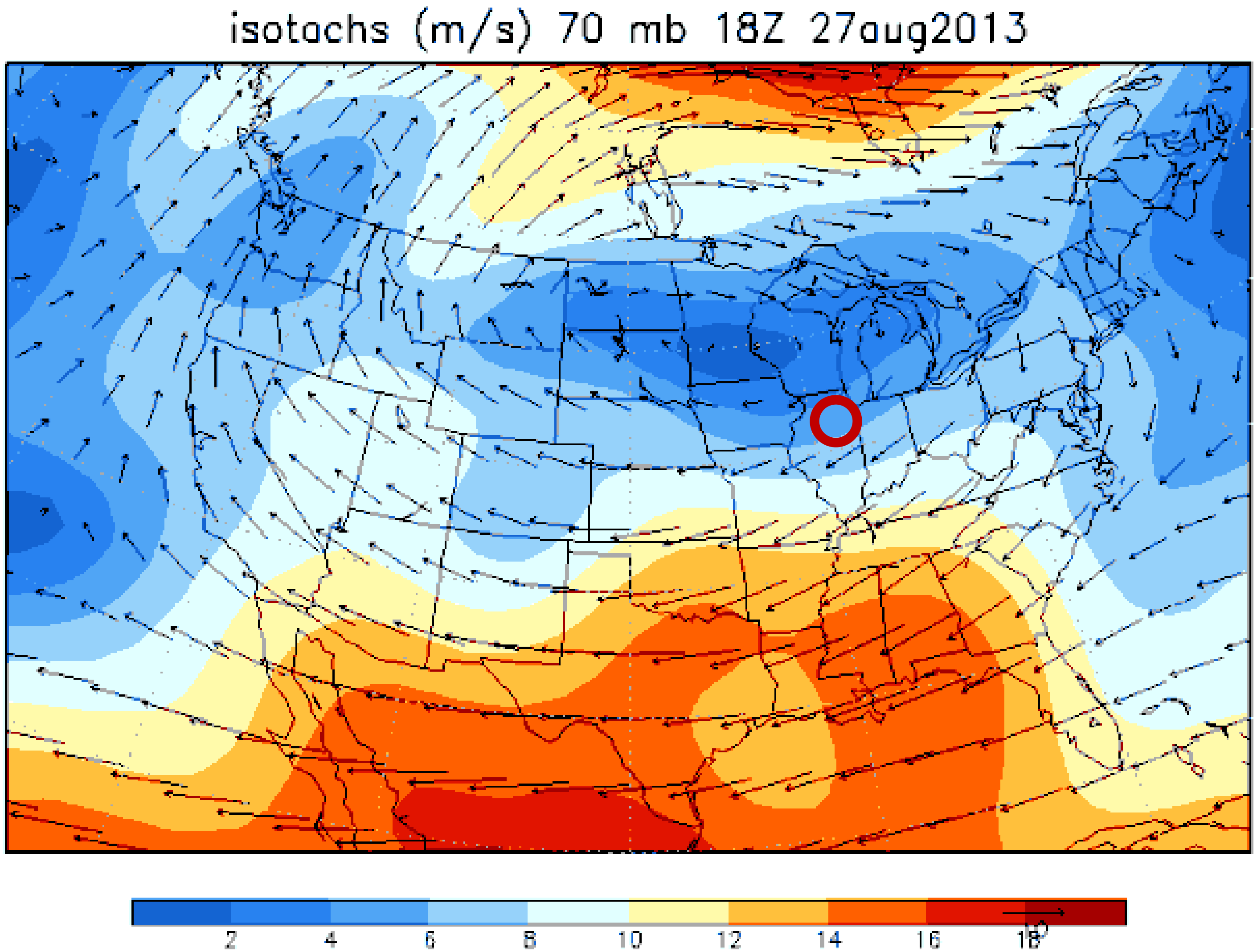

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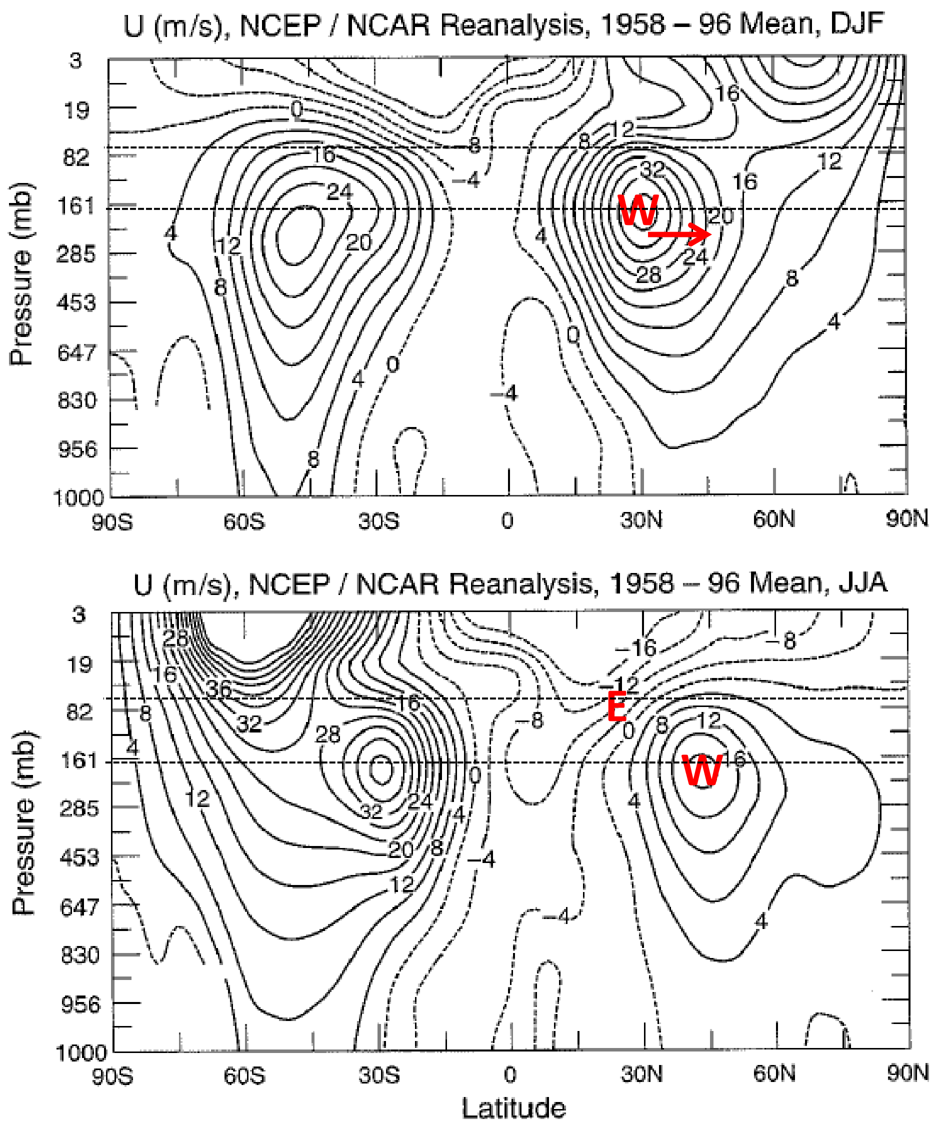
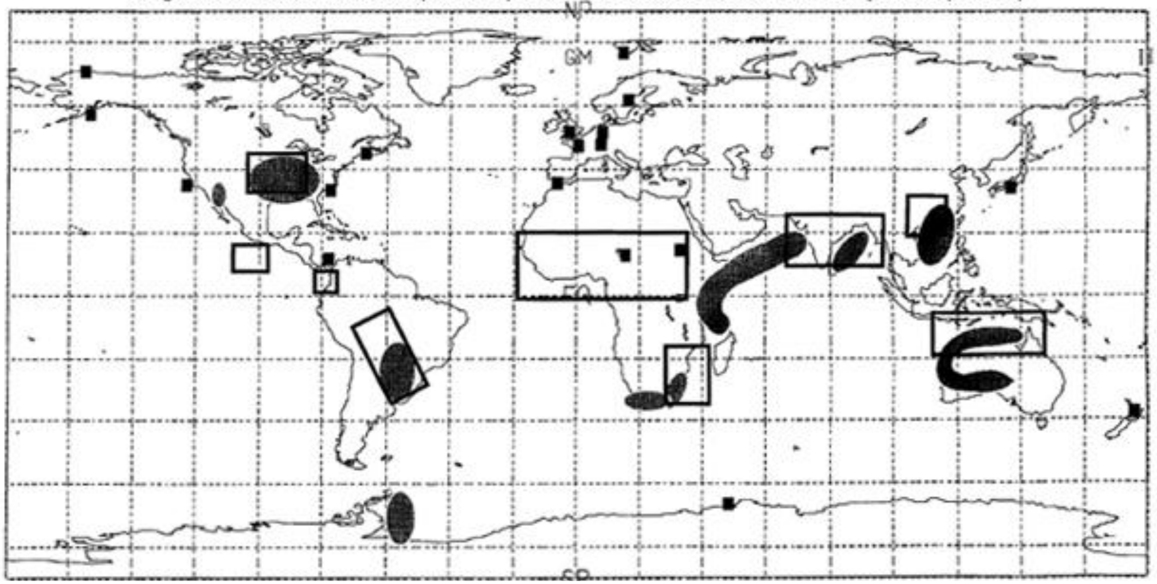


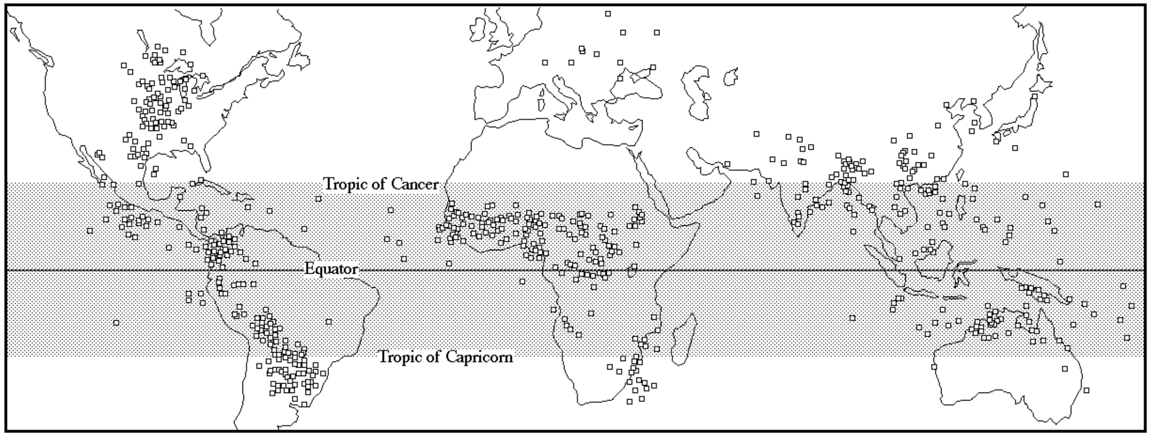
Global Distribution of MCCs in Literature

Continental US is Notable for Convection at Mid-Latitudes

Regions of Low-level Jets (shaded) and Mesoscale Convective Complexes (boxes)



http://www.goes-r.gov/users/comet/tropical/textbook_2nd_edition/media/graphics/low_level_jets_convection.jpg - From Stensrud, 1996

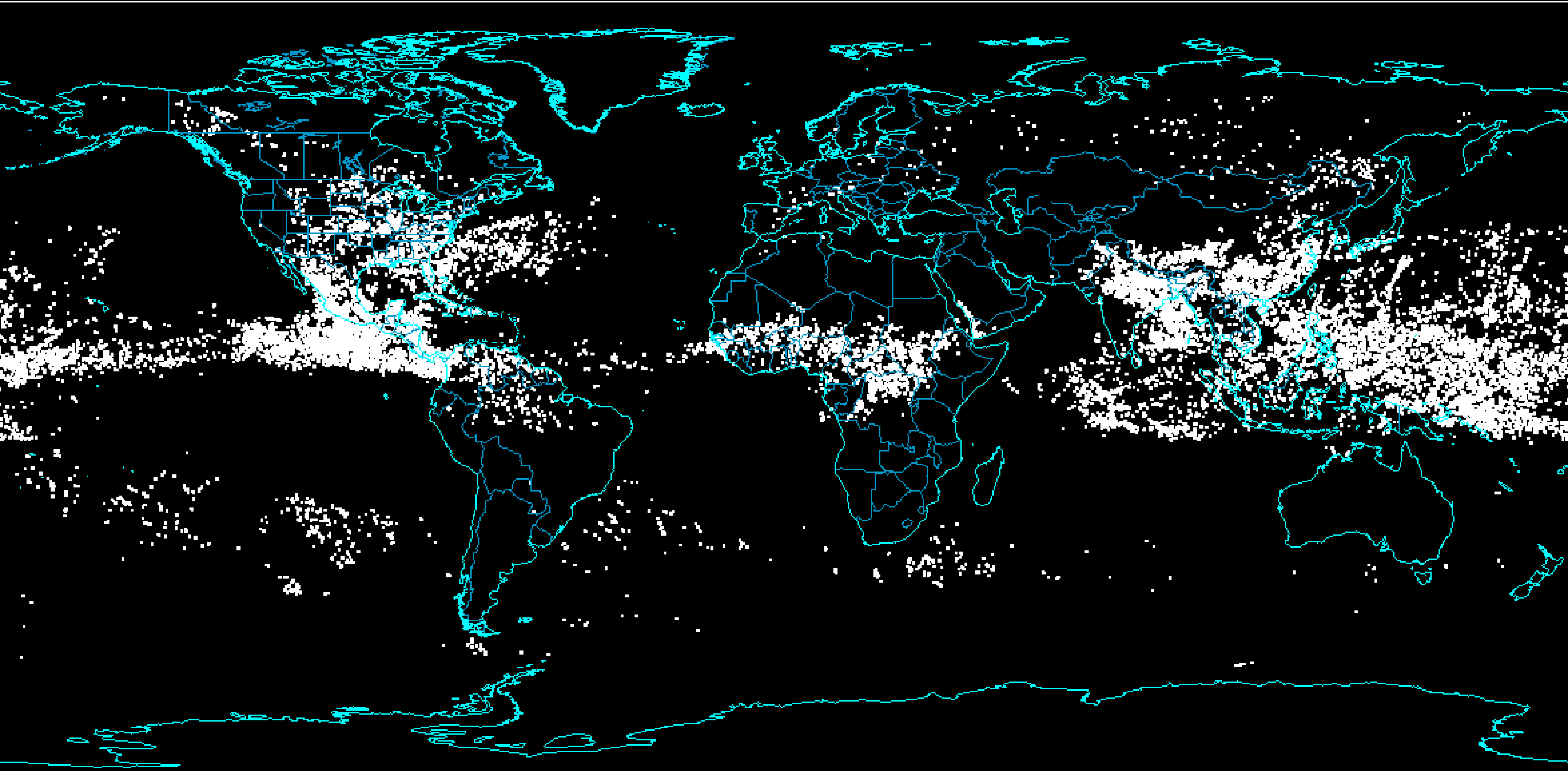


The global distribution MCCS based on satellite imagery as described in Laing and Fritsch (1997). Figure 5 from "Extratropical Synoptic-Scale Processes and Severe Convection" by Charles A. Doswel III, in *Severe Convective Storms* A Meteorological Monograph to be published by The American Meteorological Society

Snapshot of Summertime Convective Hotspots

Global Overshooting Top Detections – July 1986

As part of a Cloud Property Climate Data Record being developed for NOAA NCDC at NASA LaRC, OT detections will be produced for all AVHRR observations from 1978-present



NOAA-9 AVHRR July 1986 Overshooting Top Detections, Analysis by Kristopher Bedka