An Overview of the Meteorological Conditions during MILAGRO

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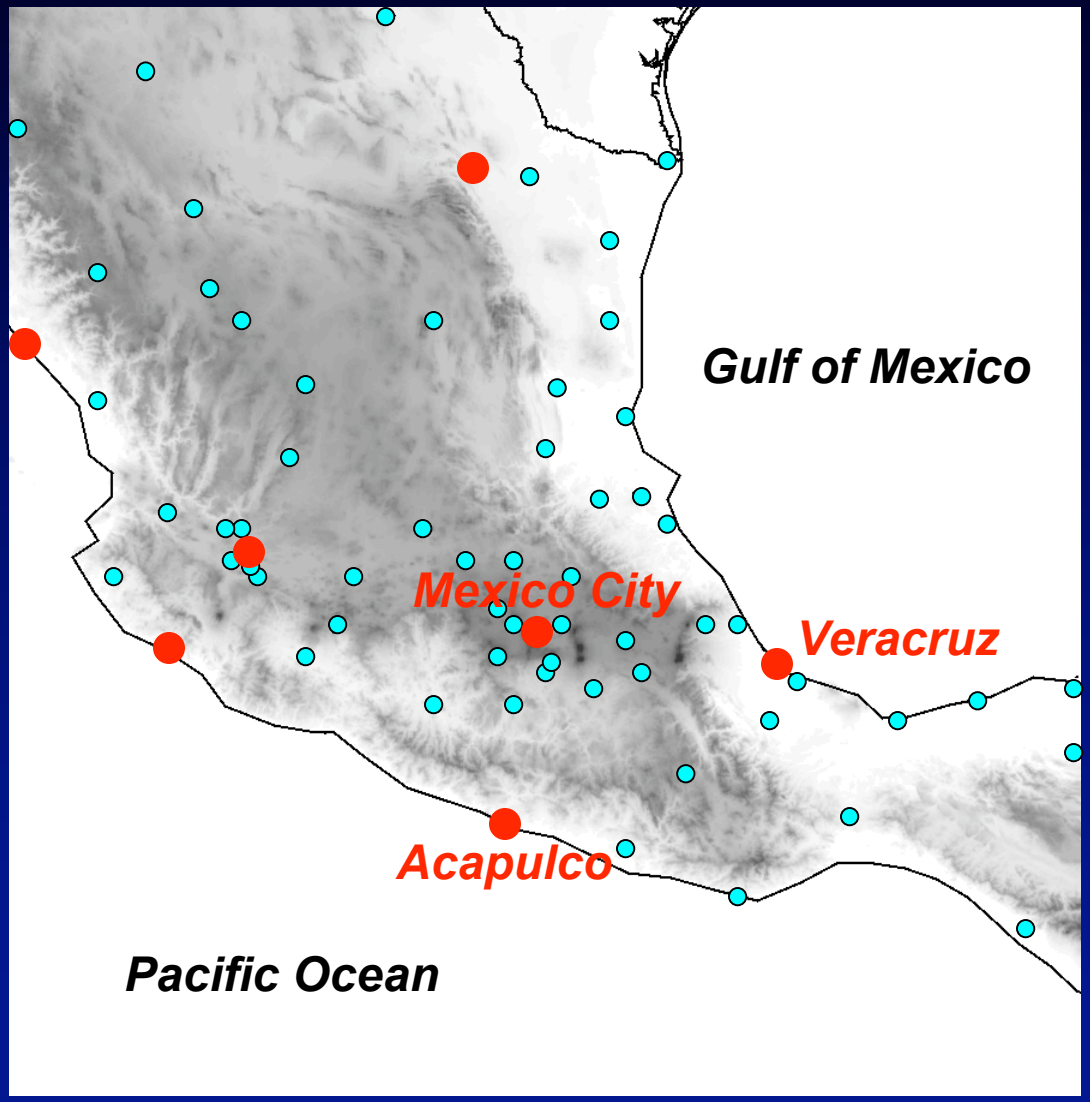
Pacific Northwest National Laboratory

MILAGRO Science Meeting, October 2006, Boulder, CO

Meteorological Instrumentation



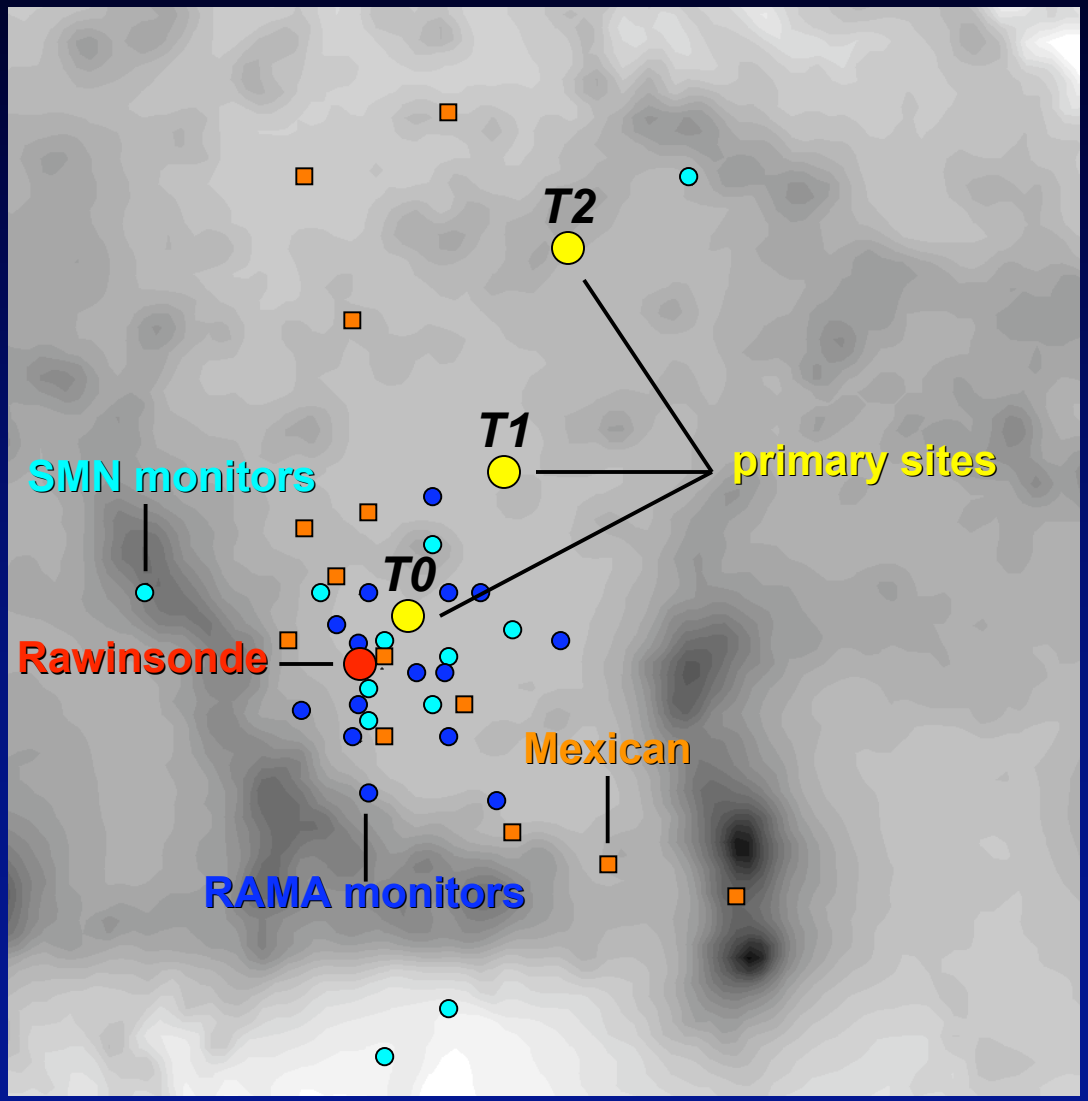
Operational Measurements:

- SMN surface monitors
- Navy surface monitors
- rawinsondes

Supplementary Rawinsondes:

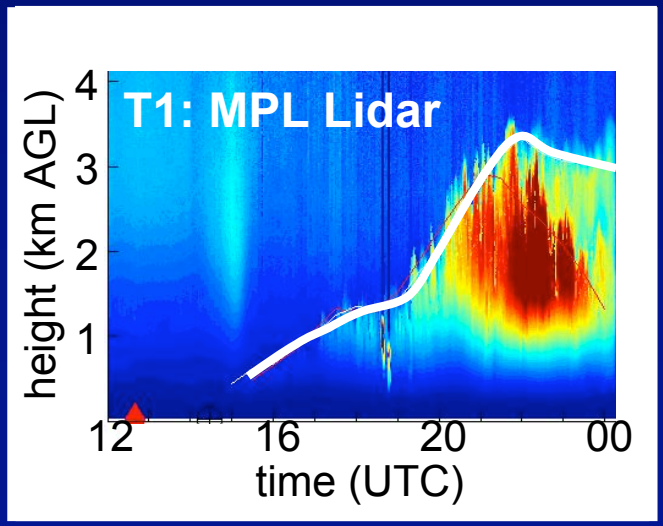
- Mexico City, Veracruz, and Acapulco
- 00, 06, 12, and 18 UTC
- purpose: improve operational forecasts

Meteorological Instrumentation



Field Measurements:

- surface meteorology
  T0, T1, T2
- radar wind profilers
  T0, T1, T2, Veracruz
- radiosondes - T1, T2
- microwave radiometer - T0
- lidars - T0, T1
- tethersonde - T1



from Rich Coulter, Will Shaw, Mikhail Pekour

What Did We Expect?

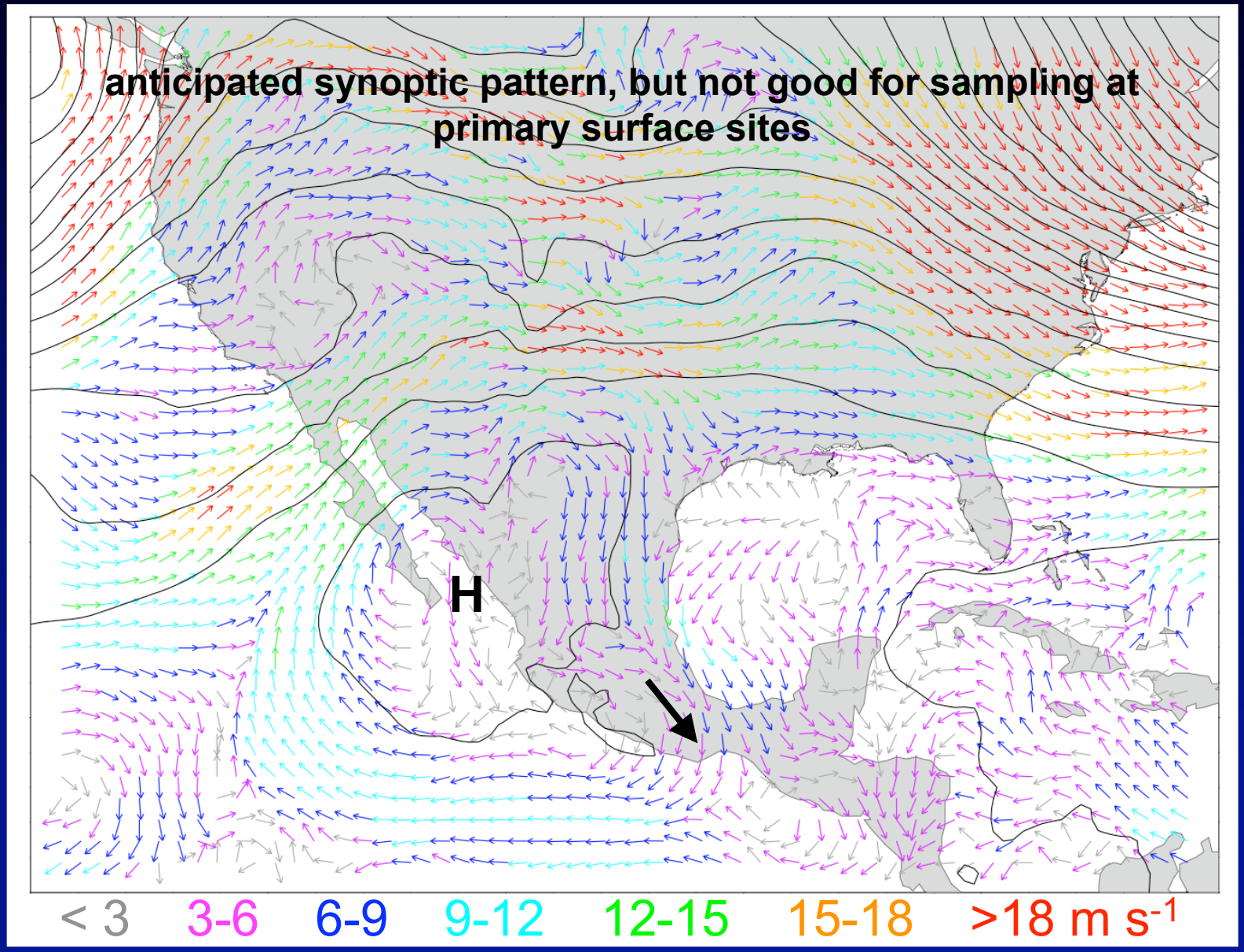
Analyses Prior to the Field Campaign:

- weak synoptic forcing dominated by high pressure systems
- occasional passage of upper-level troughs
- southwesterly near-surface winds 20-30% of the time
- periods of northerly near-surface winds
- low humidity, few clouds, and precipitation

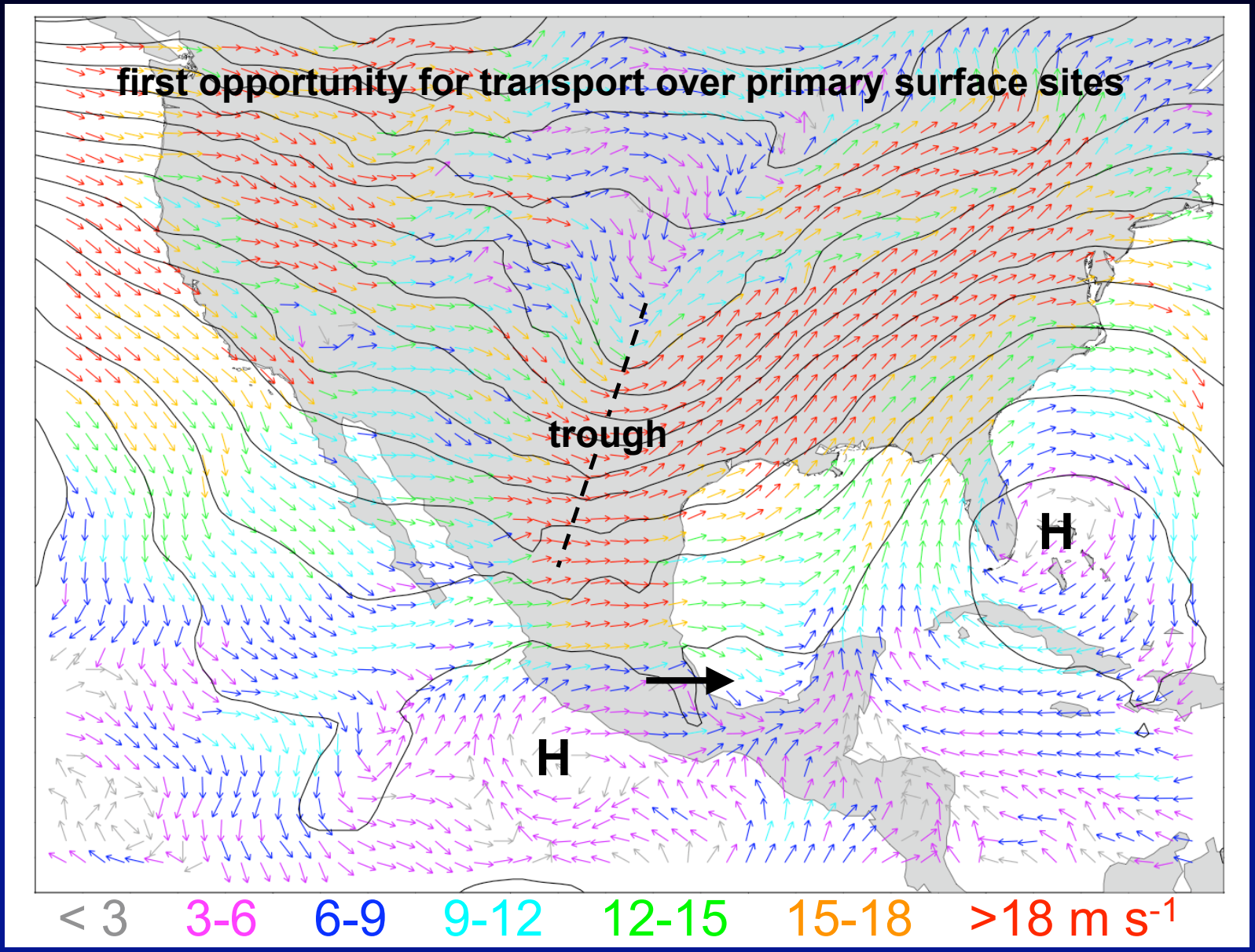
Did This Happen?

Yes and No

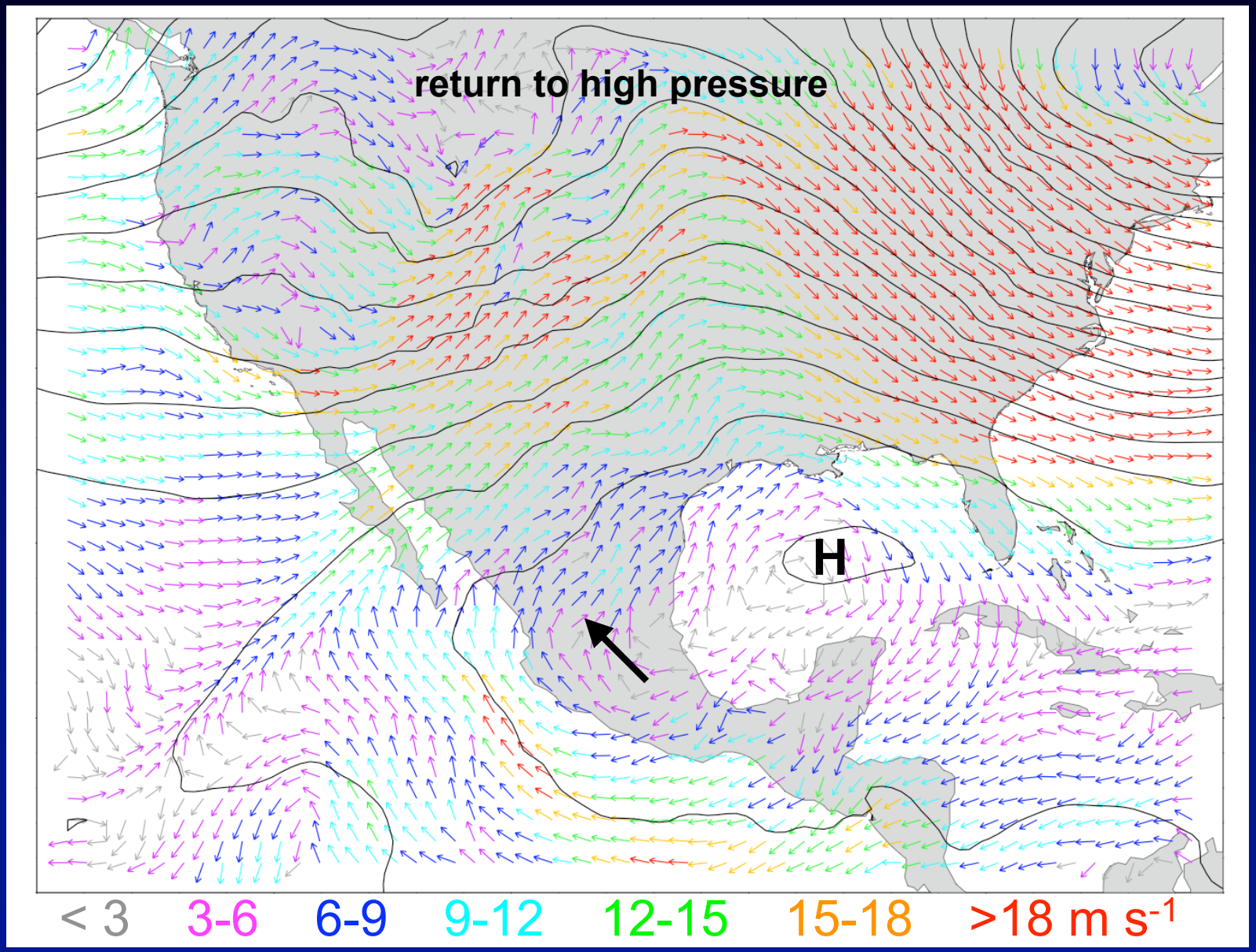
700 hPA 12 UTC March 1



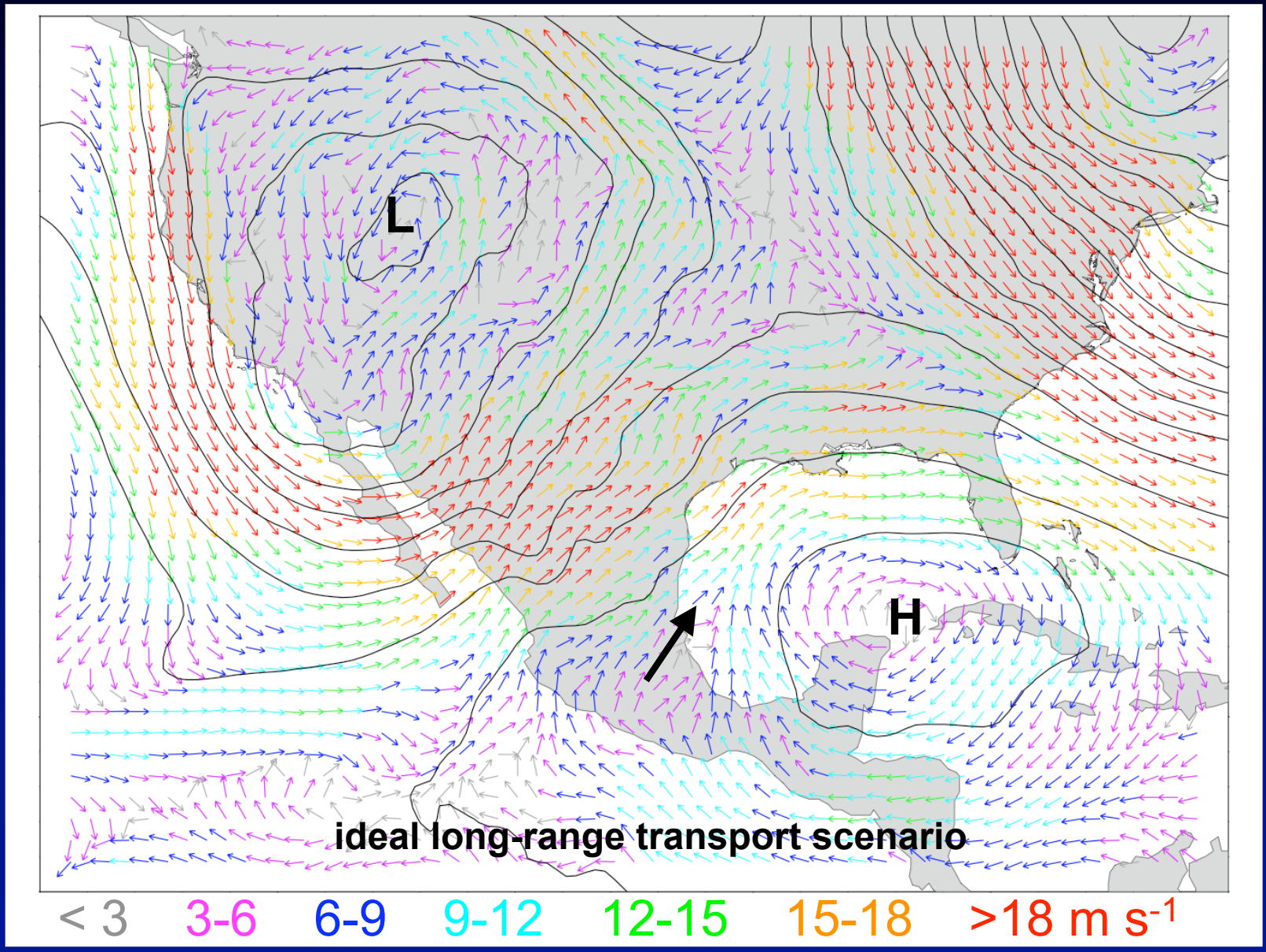
700 hPA 12 UTC March 9



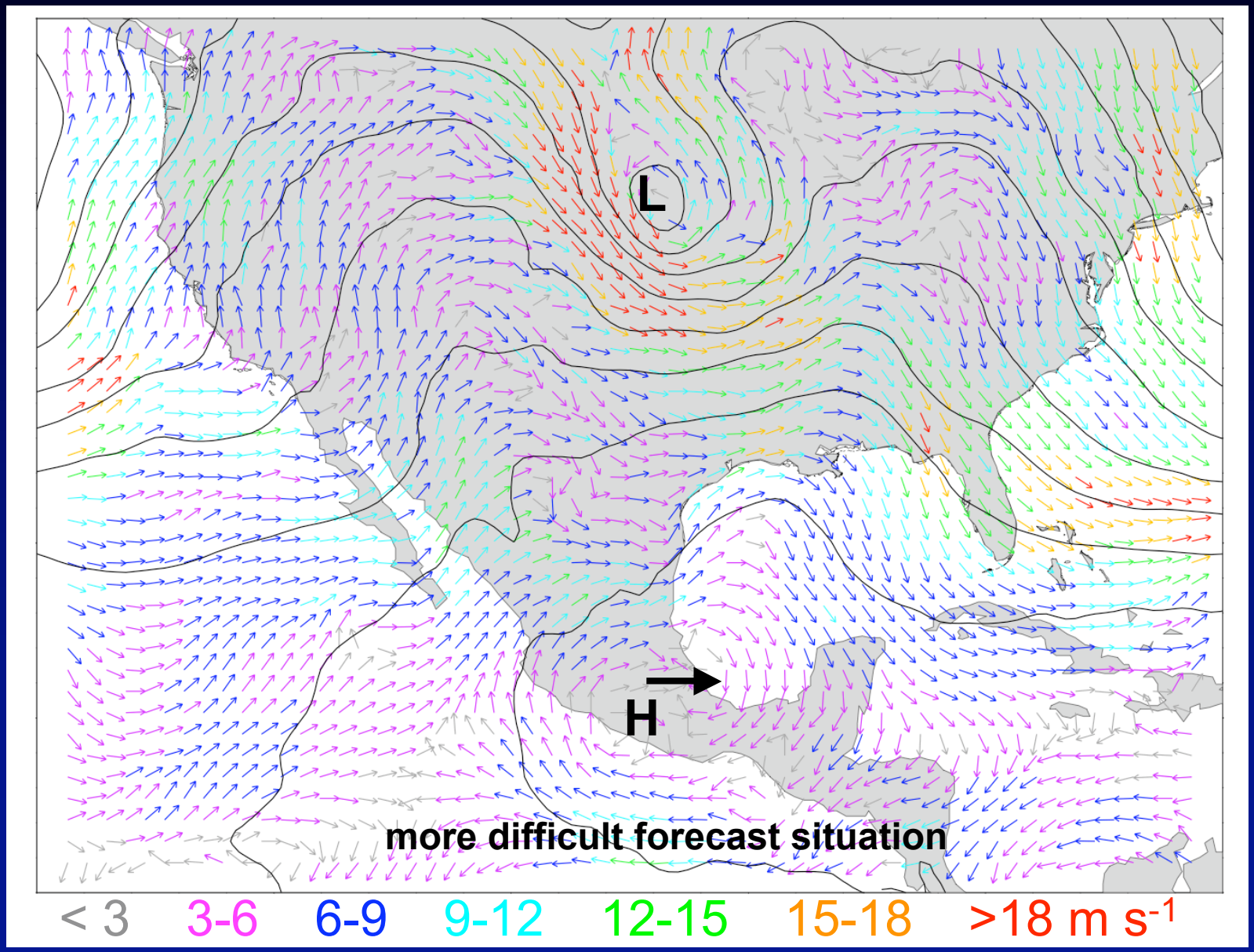
700 hPA 12 UTC March 15



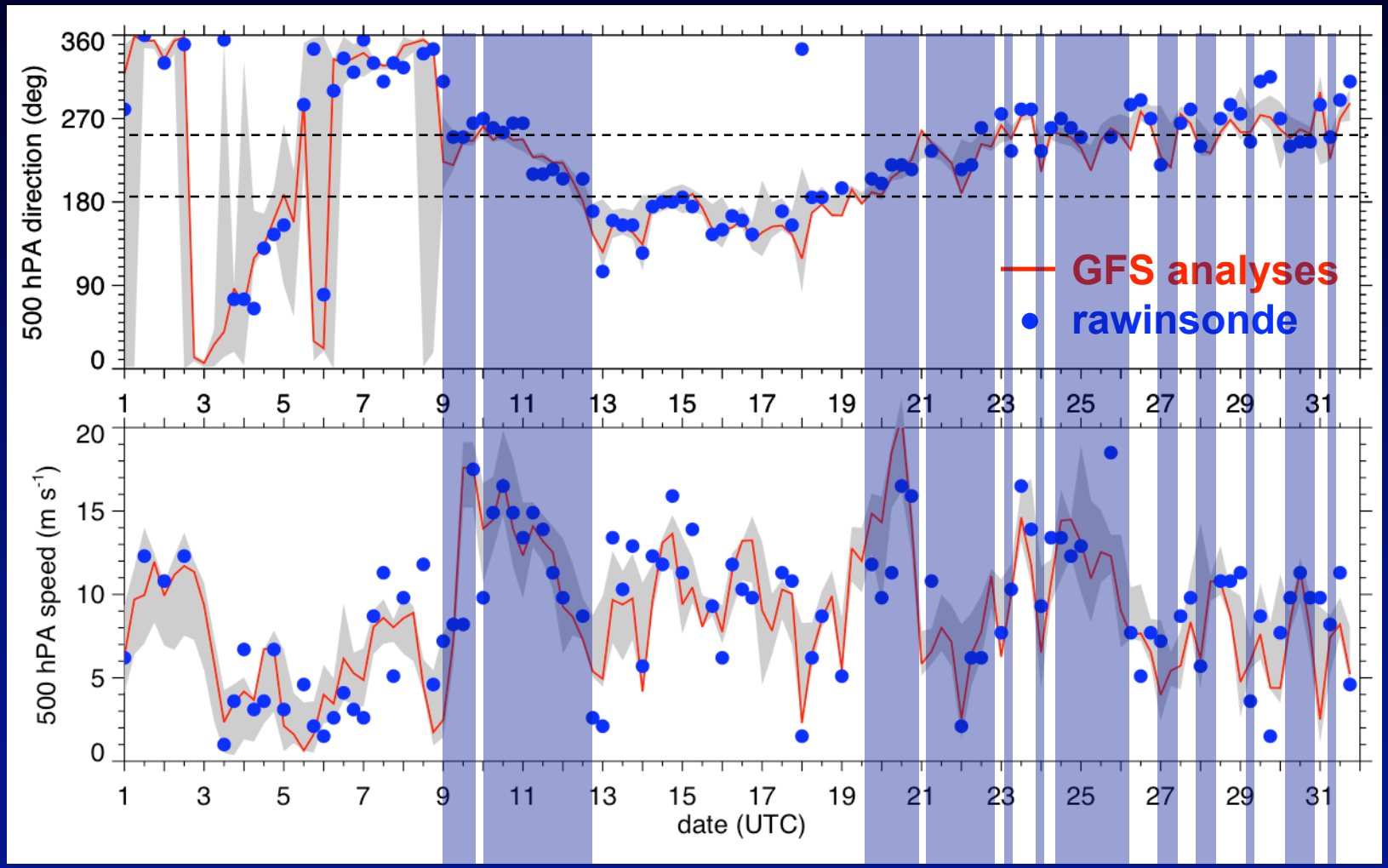
700 hPA 12 UTC March 19



700 hPA 12 UTC March 27

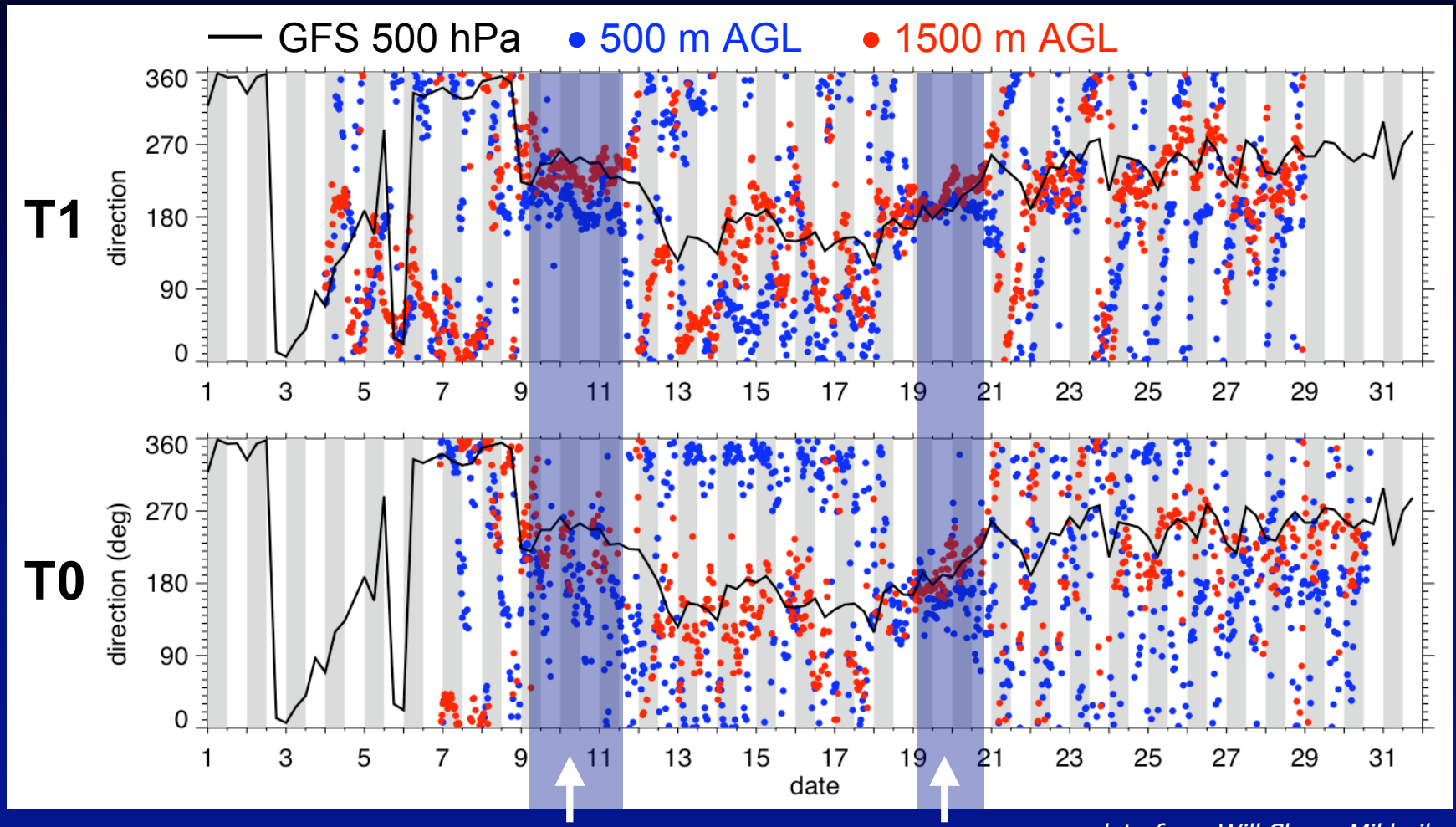


500-hPA Winds over Mexico City



wind directions 195 - 255 degrees favorable for T0 - T1 - T2 transport

Radar Wind Profiler

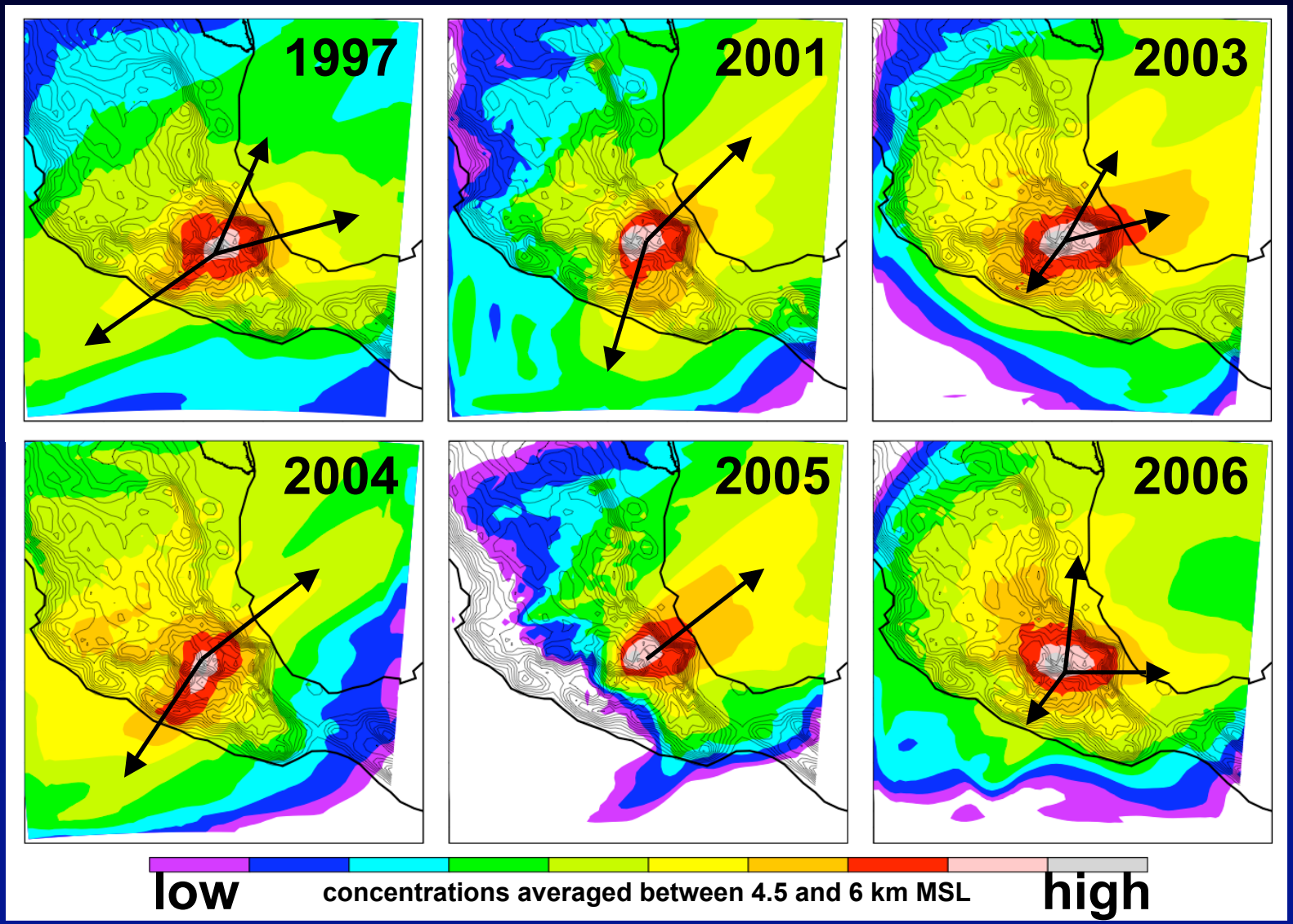


- near-surface winds coupled to synoptic flow aloft
- more variable winds inside basin as a result of thermally-driven terrain circulations

data from Will Shaw, Mikhail Pekour, Justin Walters

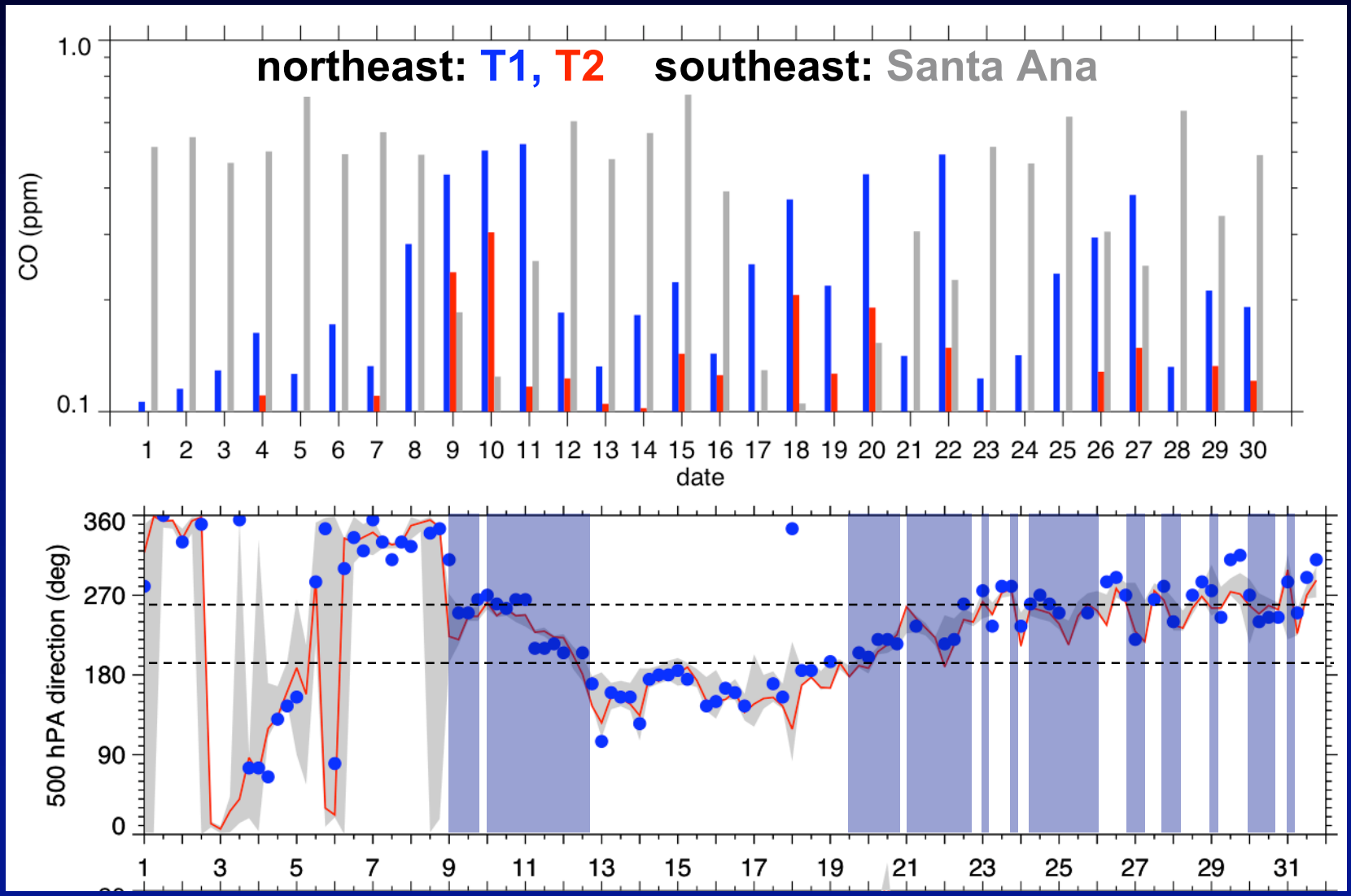
Transport Similar to Other Years?

CO Tracer "Footprint" During March Using WRF-chem (Δx = 22.5 km)



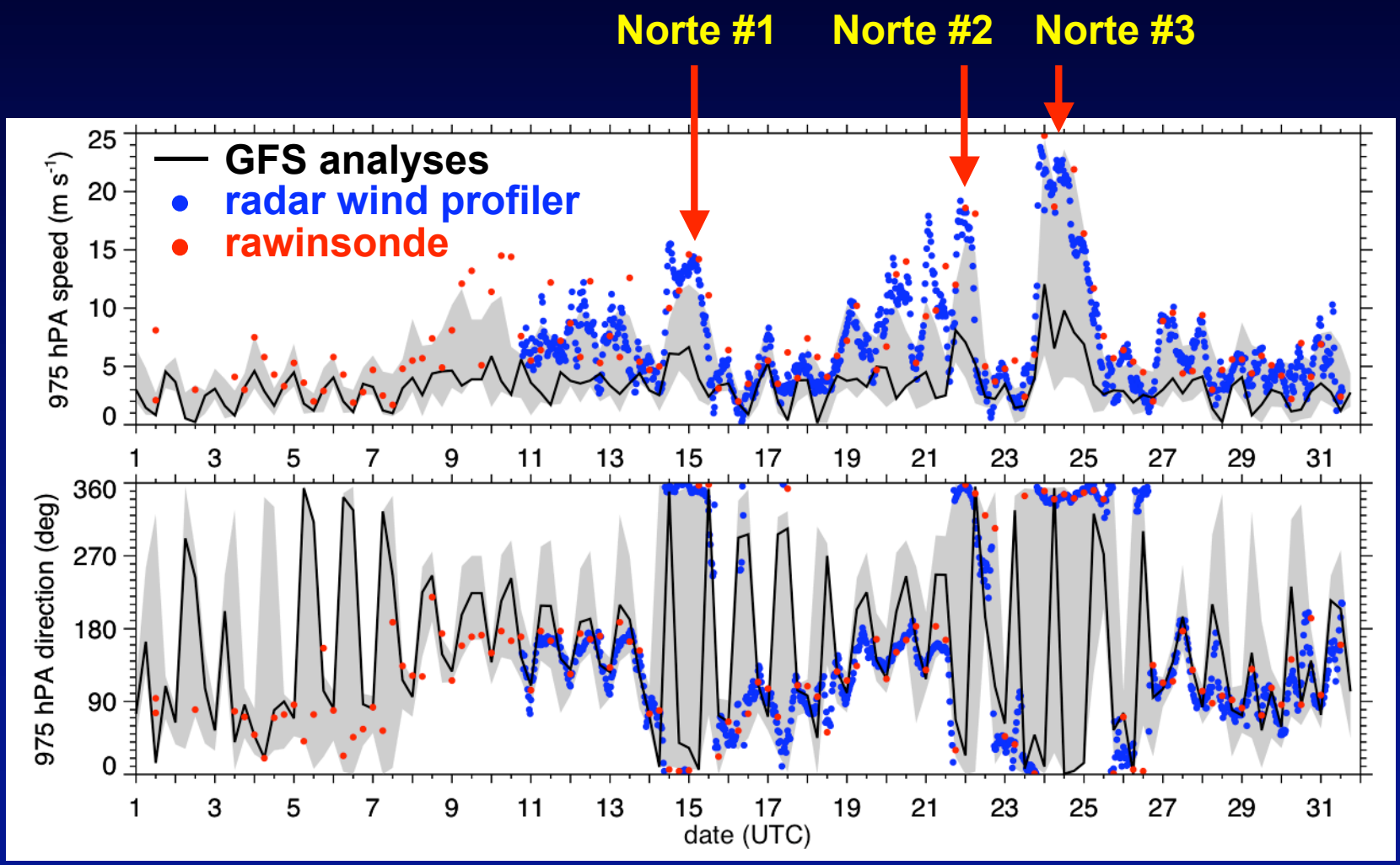
Local Transport over Plateau

Simulated Average Afternoon CO using WRF-chem (Δx = 2.25 km)



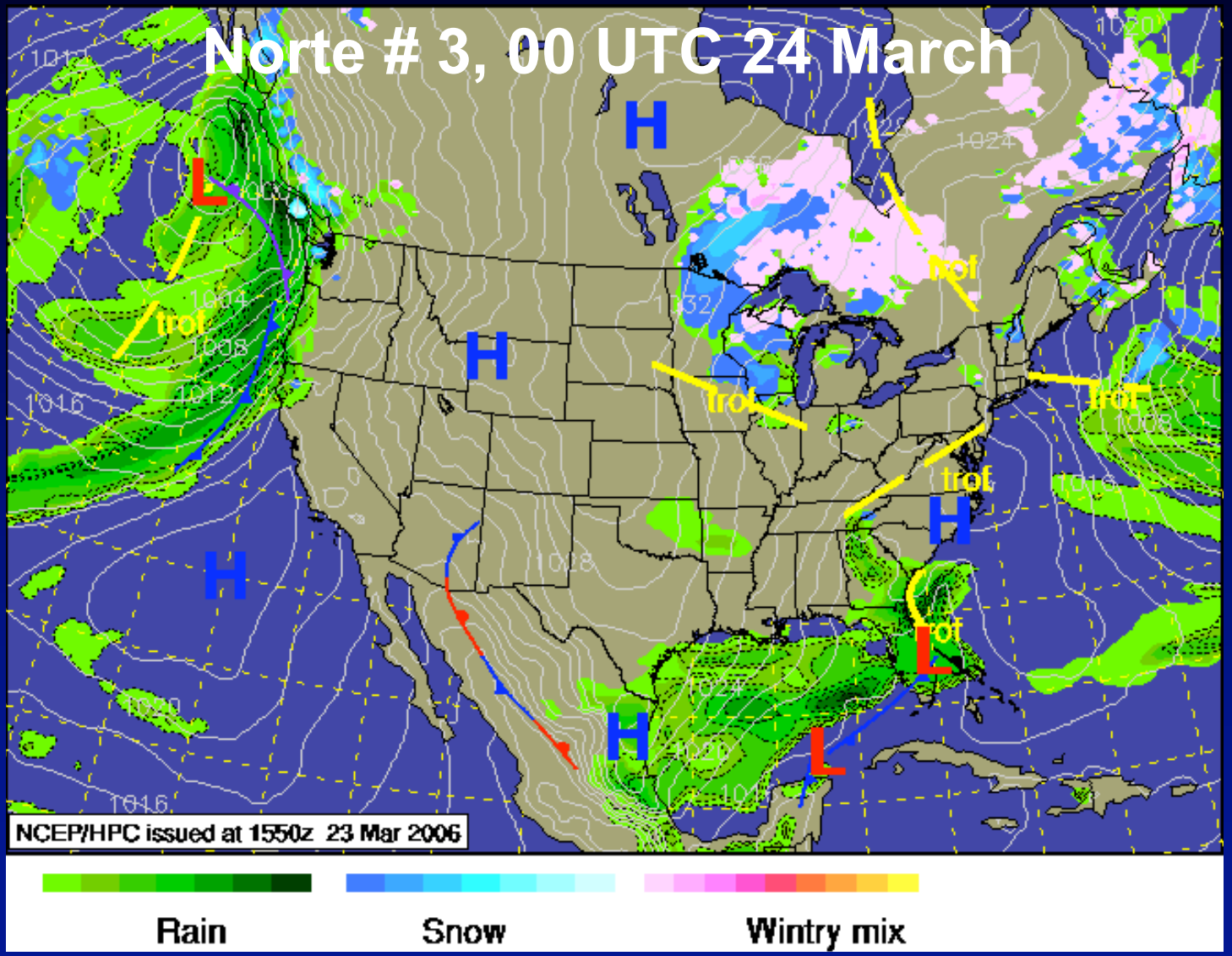
Cold Surge: i.e. Norte

Winds over Veracruz



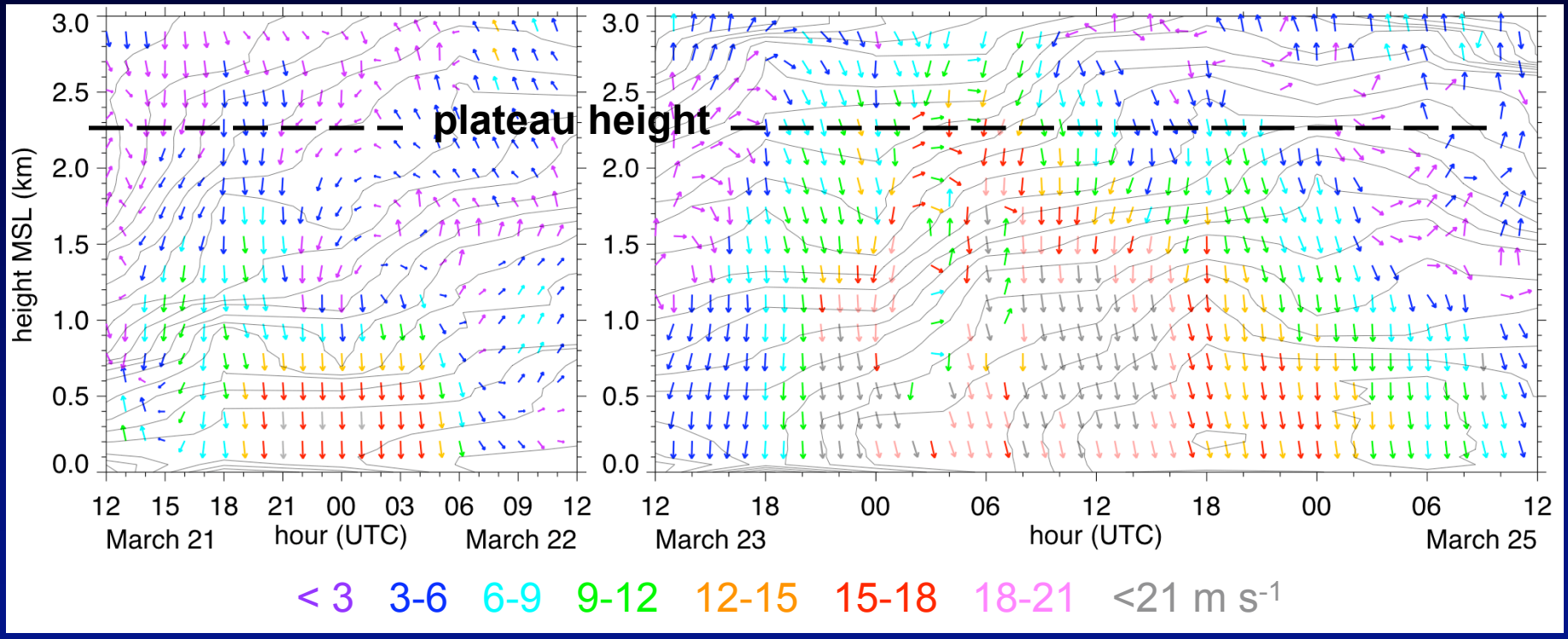
data from Rich Coulter

Cold Fronts


Norte # 3, 00 UTC 24 March
H
H
H
H
L
L
trof
trof
trof
trof
trof
NCEP/HPC issued at 1550z 23 Mar 2006
Rain
Snow
Wintry mix

Veracruz Radar Wind Profiler

Norte #2 Norte #3



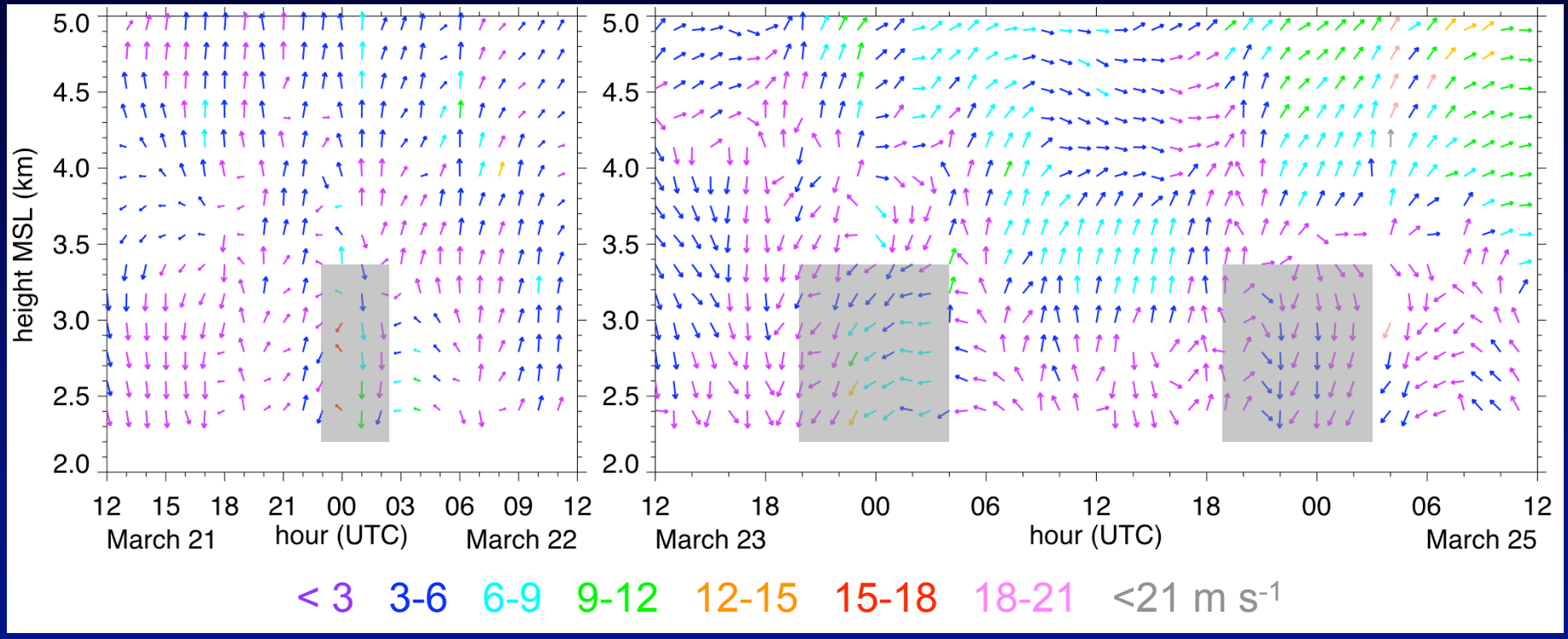
data from Rich Coulter

- brief: duration of a few hours
- shallow: < 1 km
- maximum winds: ~22 m s^{-1}

- long: 2-day duration
- deep: < 2-3 km
- maximum winds: ~26 m s^{-1}

T1 Radar Wind Profiler

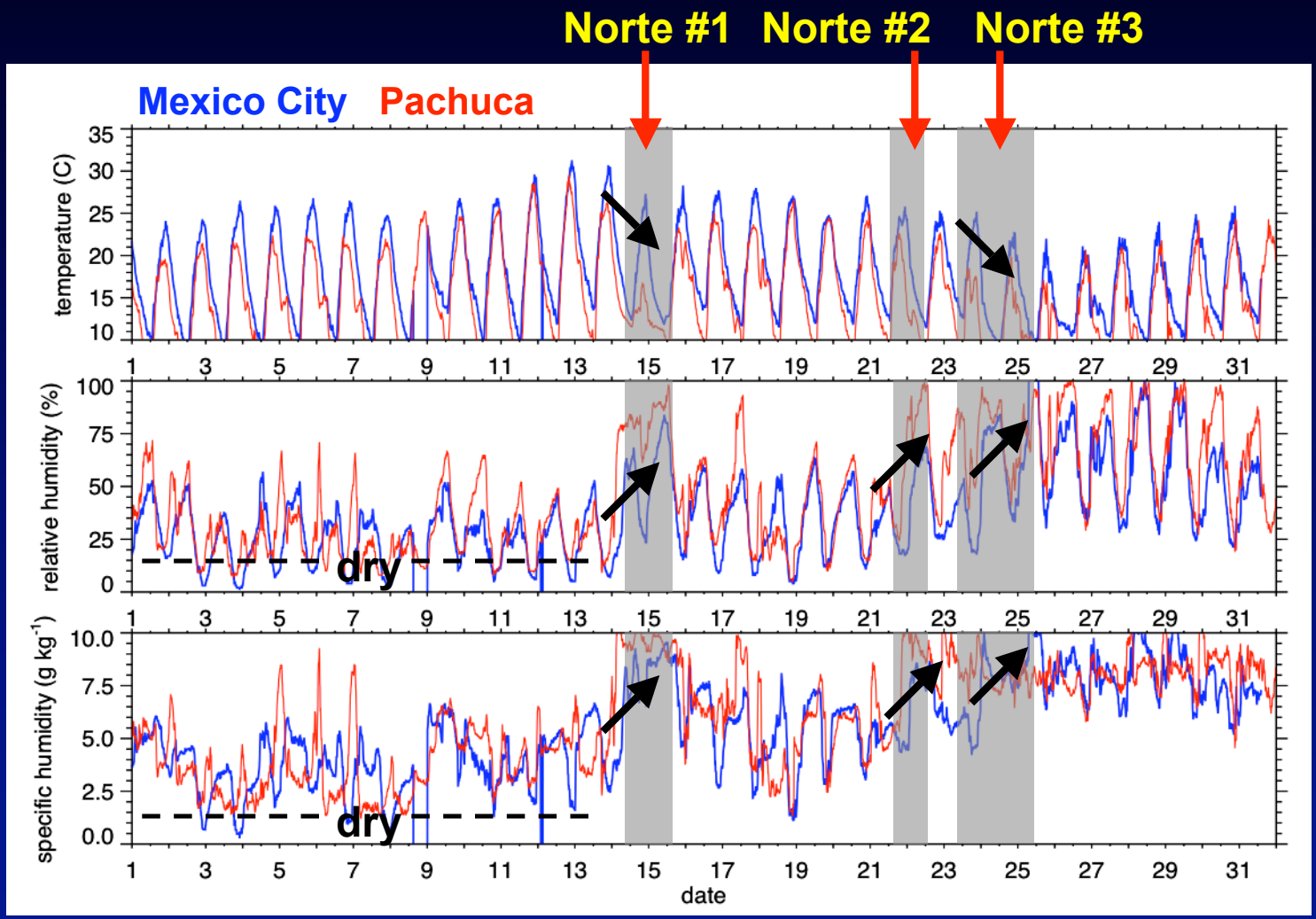
Norte #2 Norte #3



data from Will Shaw and Mikhail Pekour

- weak winds in general during Norte passages
- short periods of moderate northerly winds
- local transport of pollutants likely more complicated than during other periods

Impacts on Temperature and Humidity



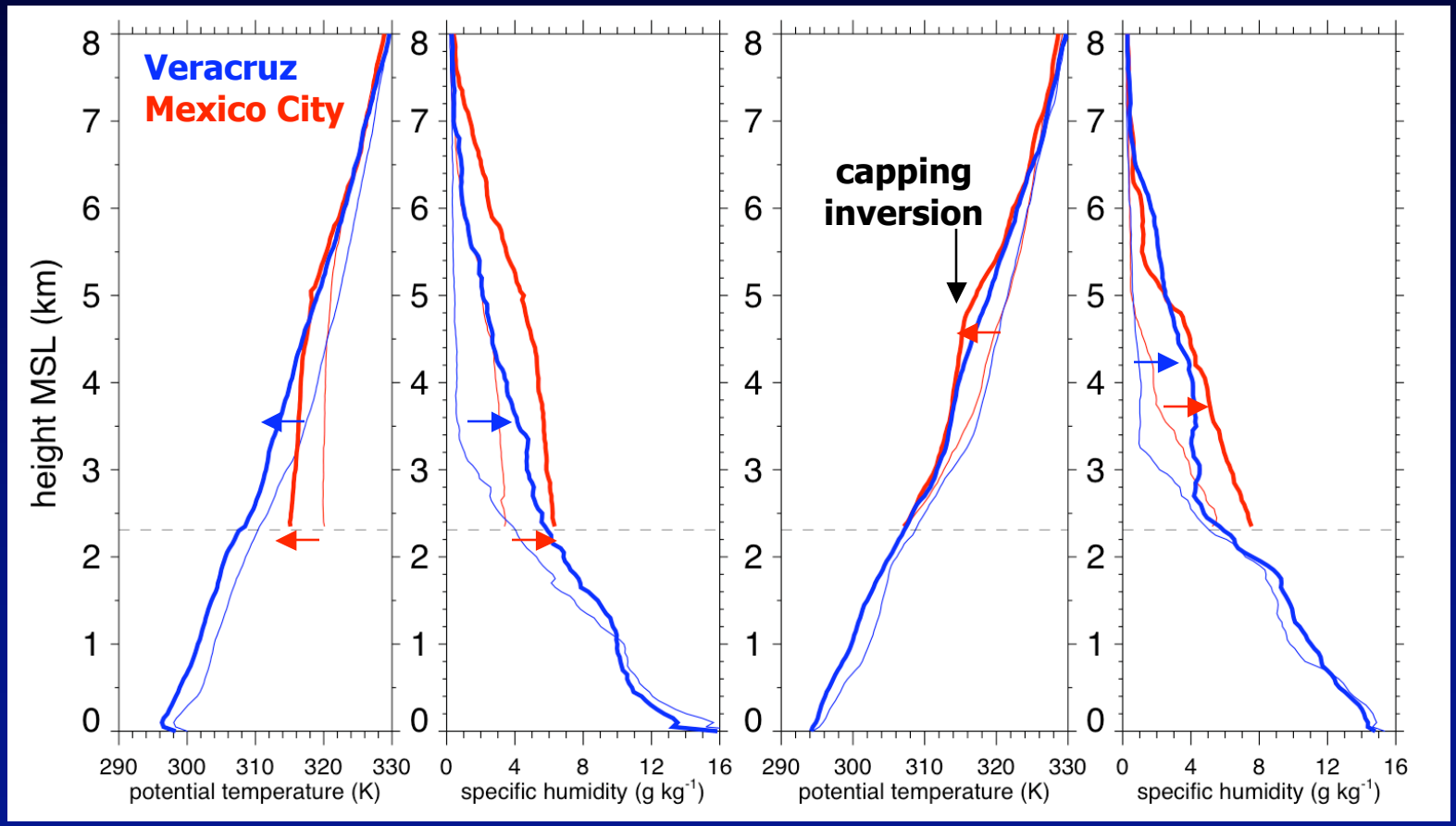
- decreases in temperature and increases in humidity
- how do these changes affect photochemistry and aerosol evolution?

Impacts on Boundary Layer

Averaged Soundings Before (thin line) and After (thick lines) Norte 3

Late Afternoon 00 UTC

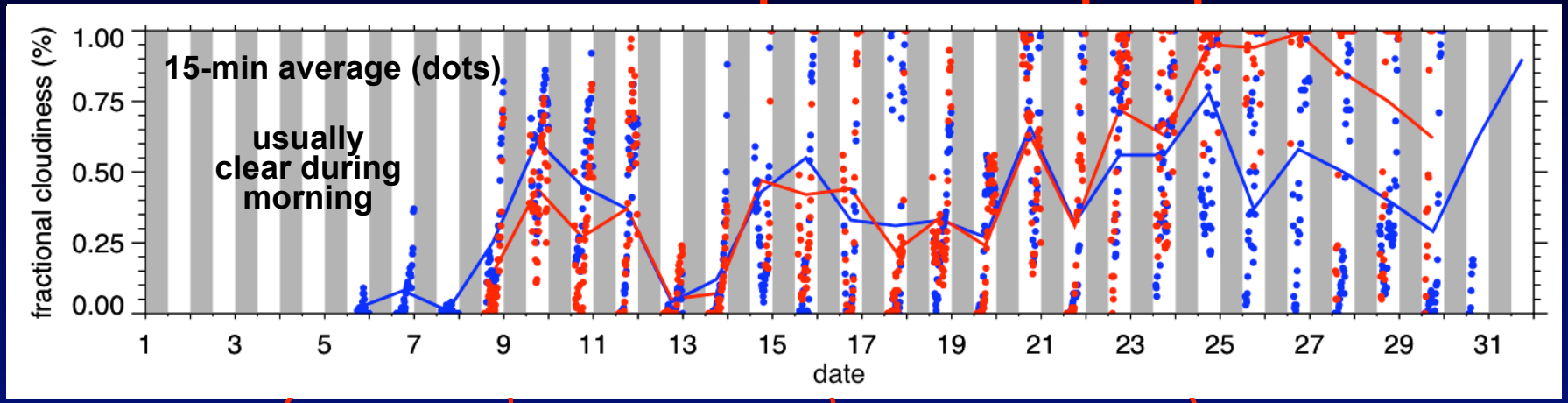
Morning 12 UTC



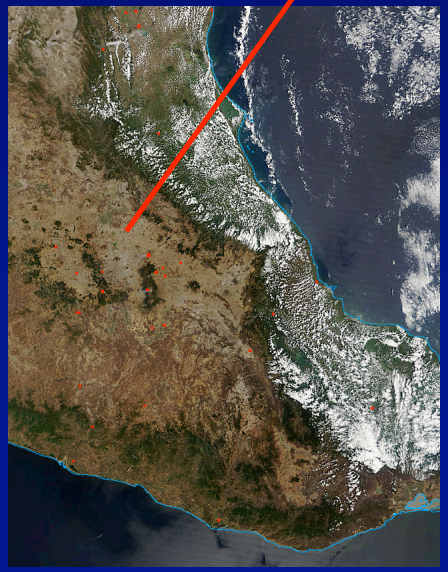
- decrease in temperature and increase in moisture extends several km AGL
- daily variations more complicated

Cloudiness

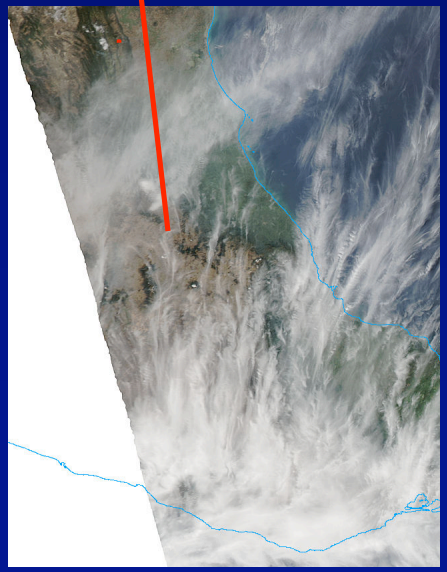
Daytime Fractional Cloudiness Derived from MFRSR



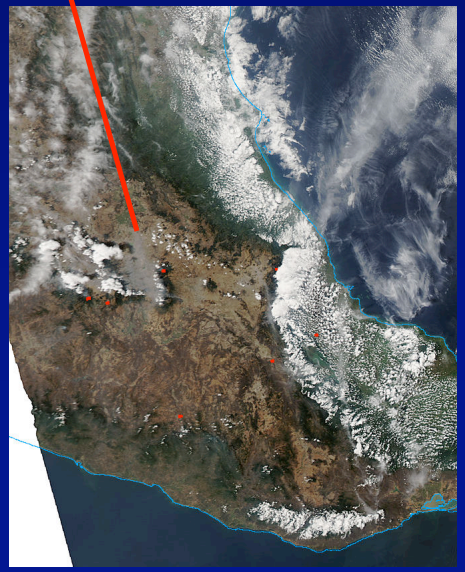
March 5



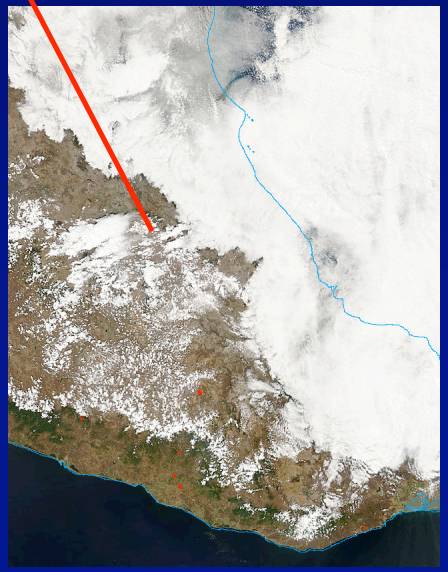
March 9



March 16



March 24



Afternoon Convection

- alter photochemistry
- vertical transport
- cloud chemistry
- cloud-aerosol interactions
- scavenging and removal

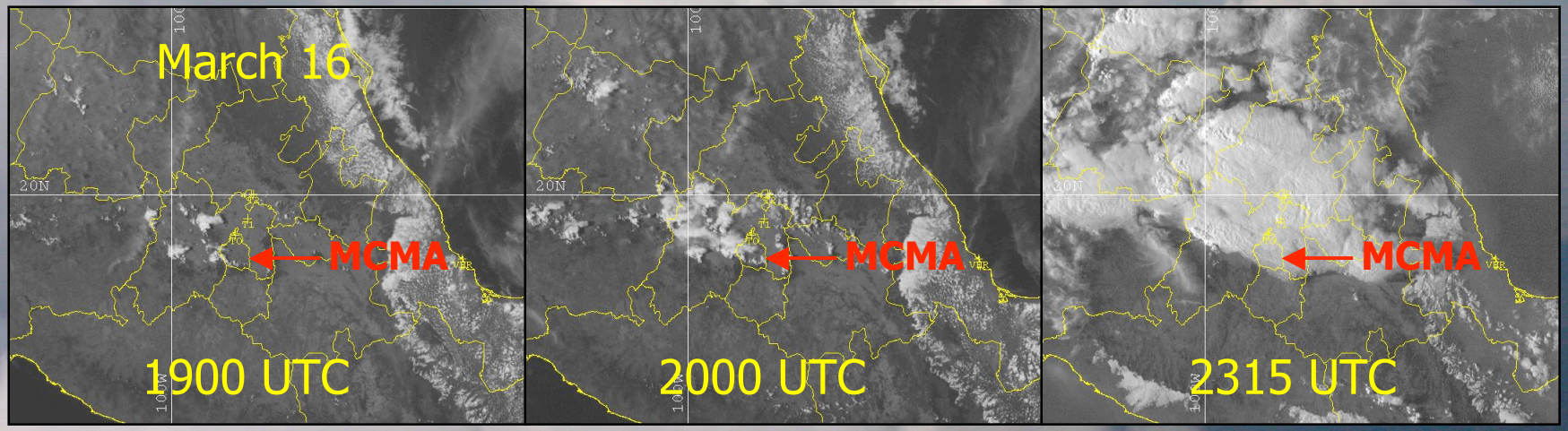
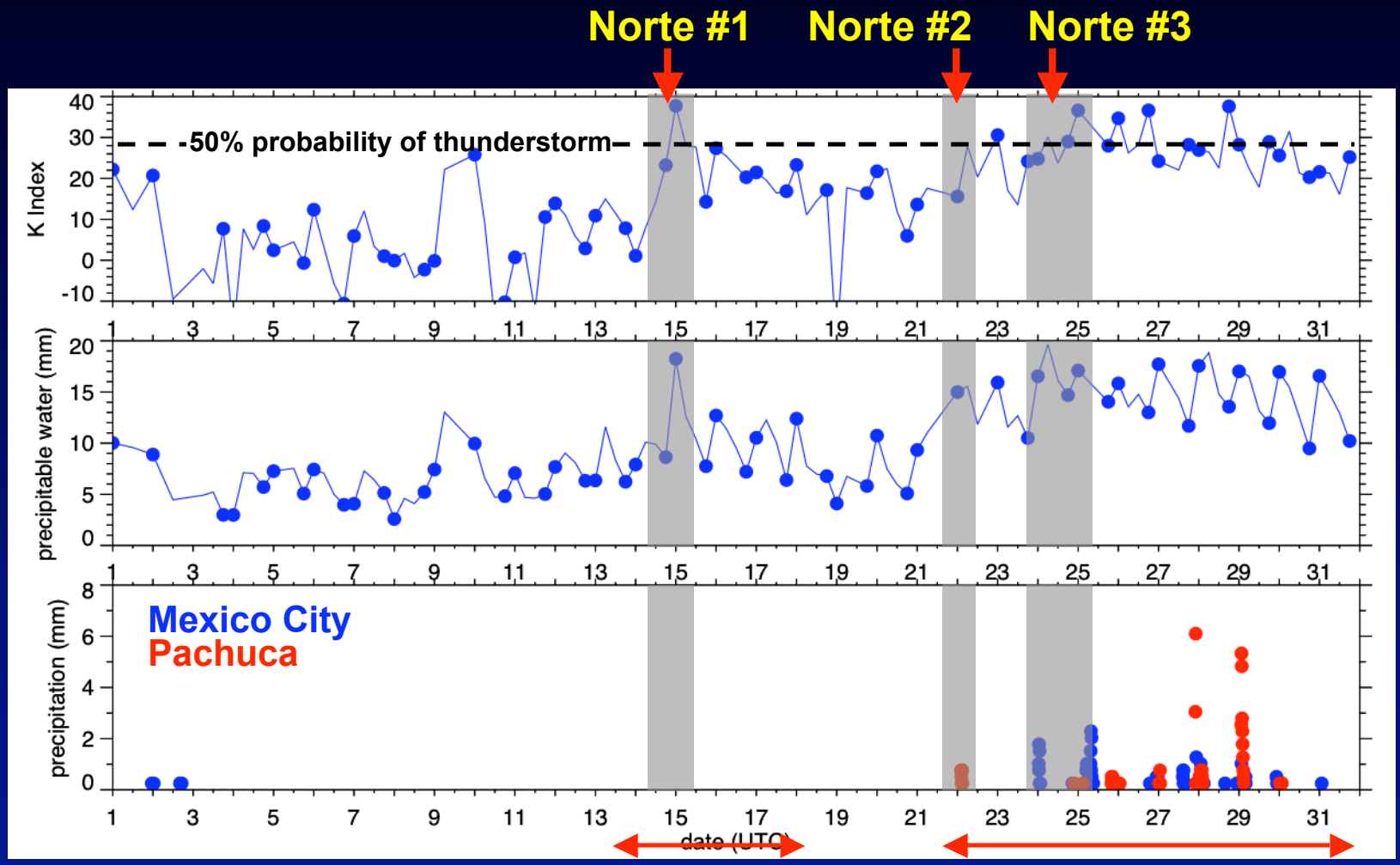


photo from G-1 courtesy of Stephen Springston

Atmospheric Stability



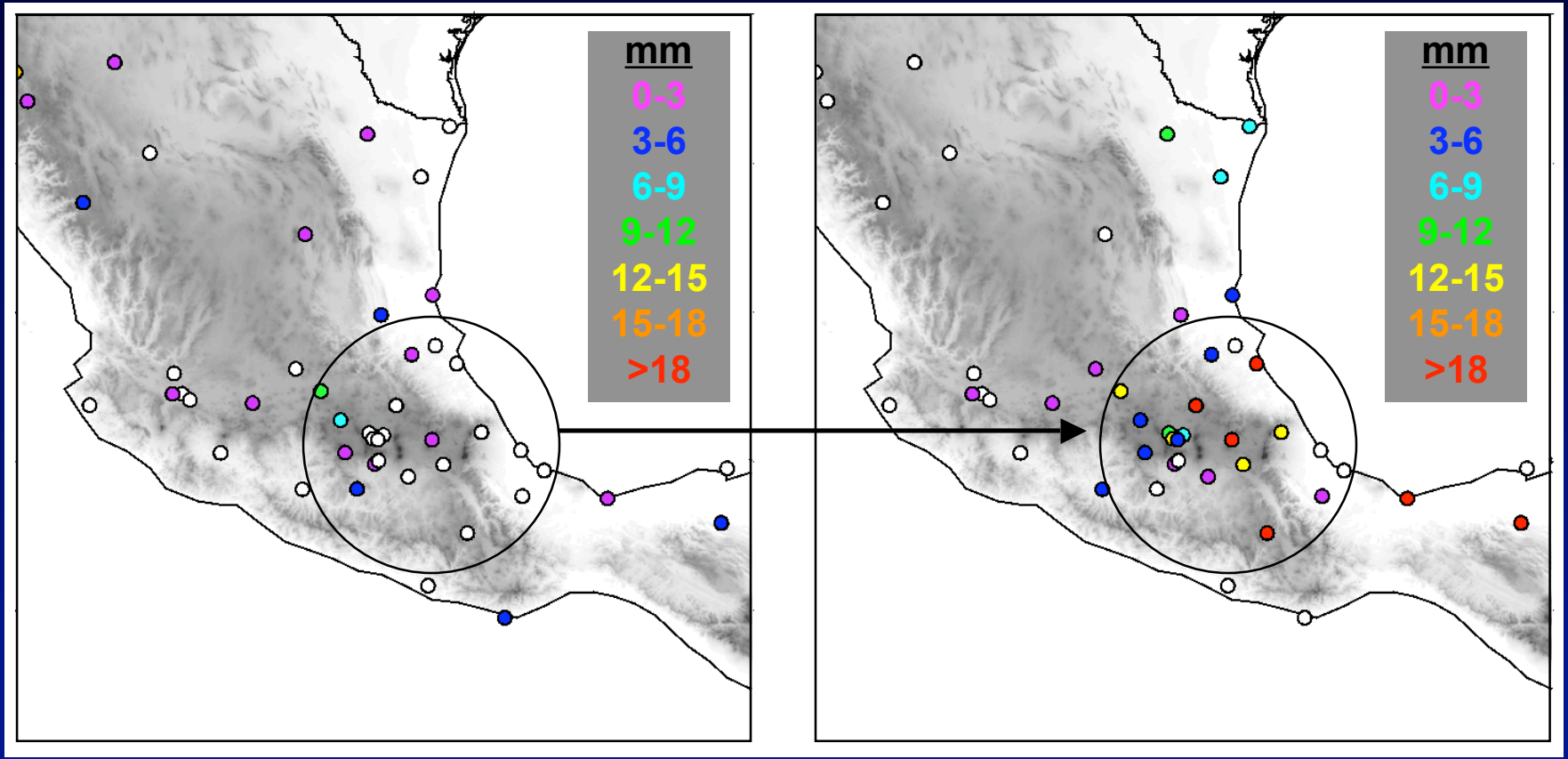
late afternoon convection as seen from visible satellite imagery

- decrease in atmospheric stability and increase in precipitable water
- late afternoon showers over plateau, mostly after Norte #2

Precipitation Distribution

March 1 - 21 (before Norte #2)

March 22 - 31 (after Norte #2)

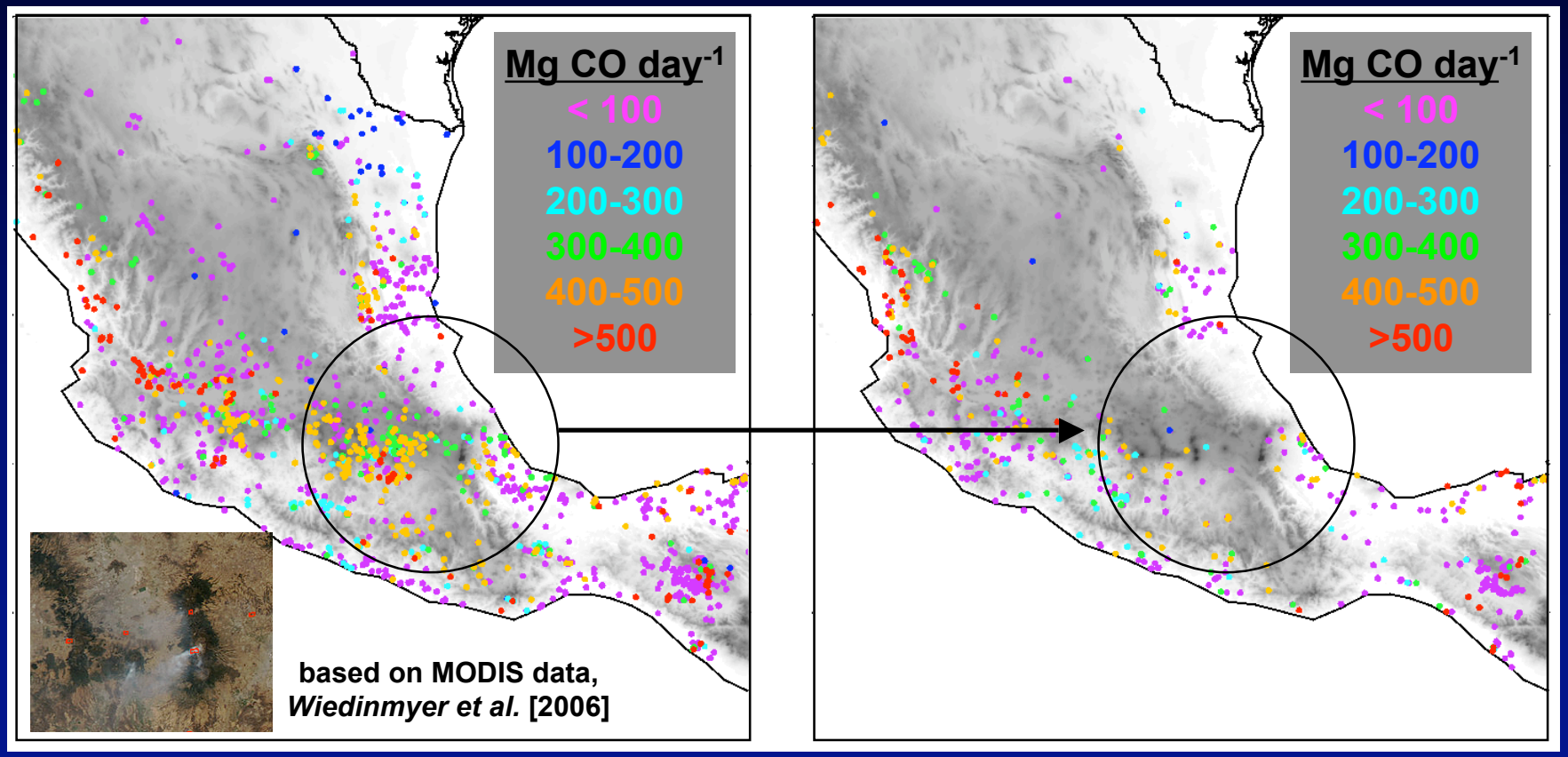


- most precipitation occurred between Norte #1 and #2
- increase in precipitation over central and eastern Mexico

Biomass Burning and Meteorology

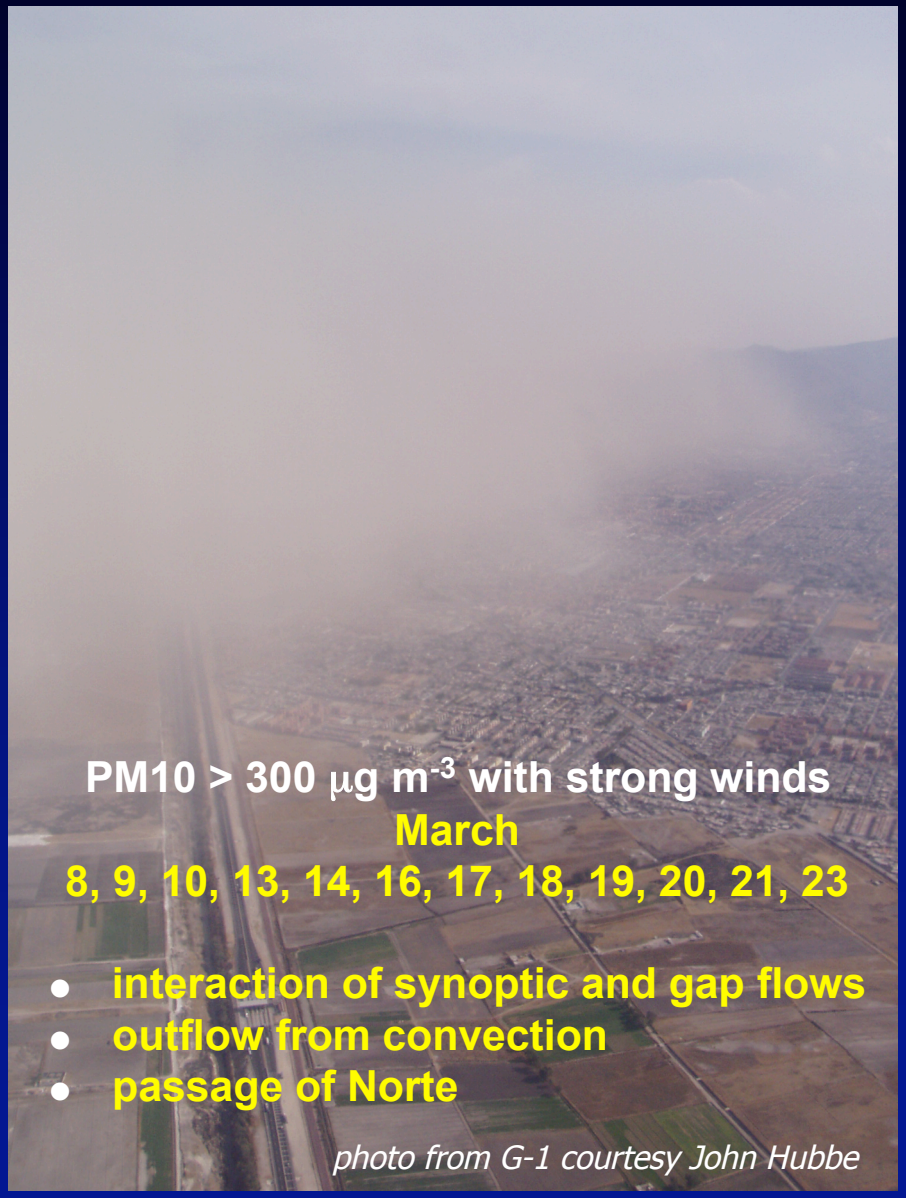
March 1 - 21 (before Norte #2)

March 22 - 31 (after Norte #2)



- dry conditions during first part of field campaign favorable for fires
- few fires over central plateau when clouds and precipitation increased after Norte #2

Dust Associated with Strong Winds



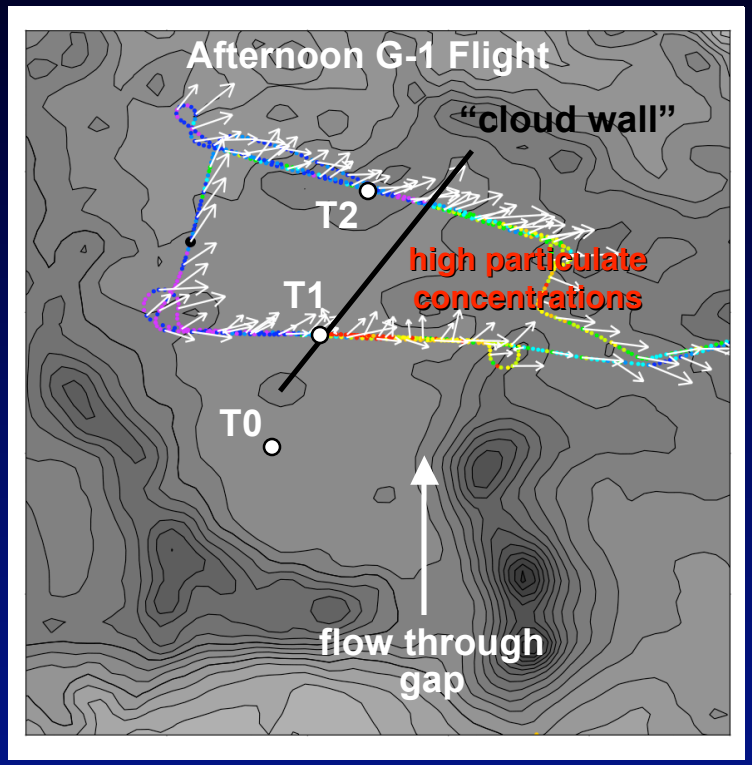
PM10 > 300 μg m^{-3} with strong winds

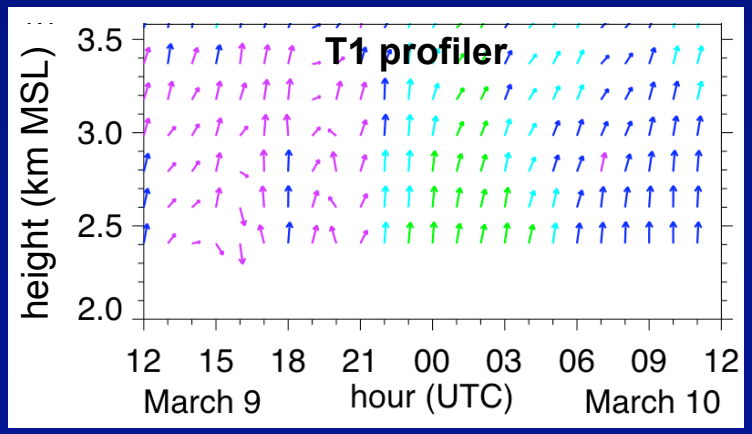
March

8, 9, 10, 13, 14, 16, 17, 18, 19, 20, 21, 23

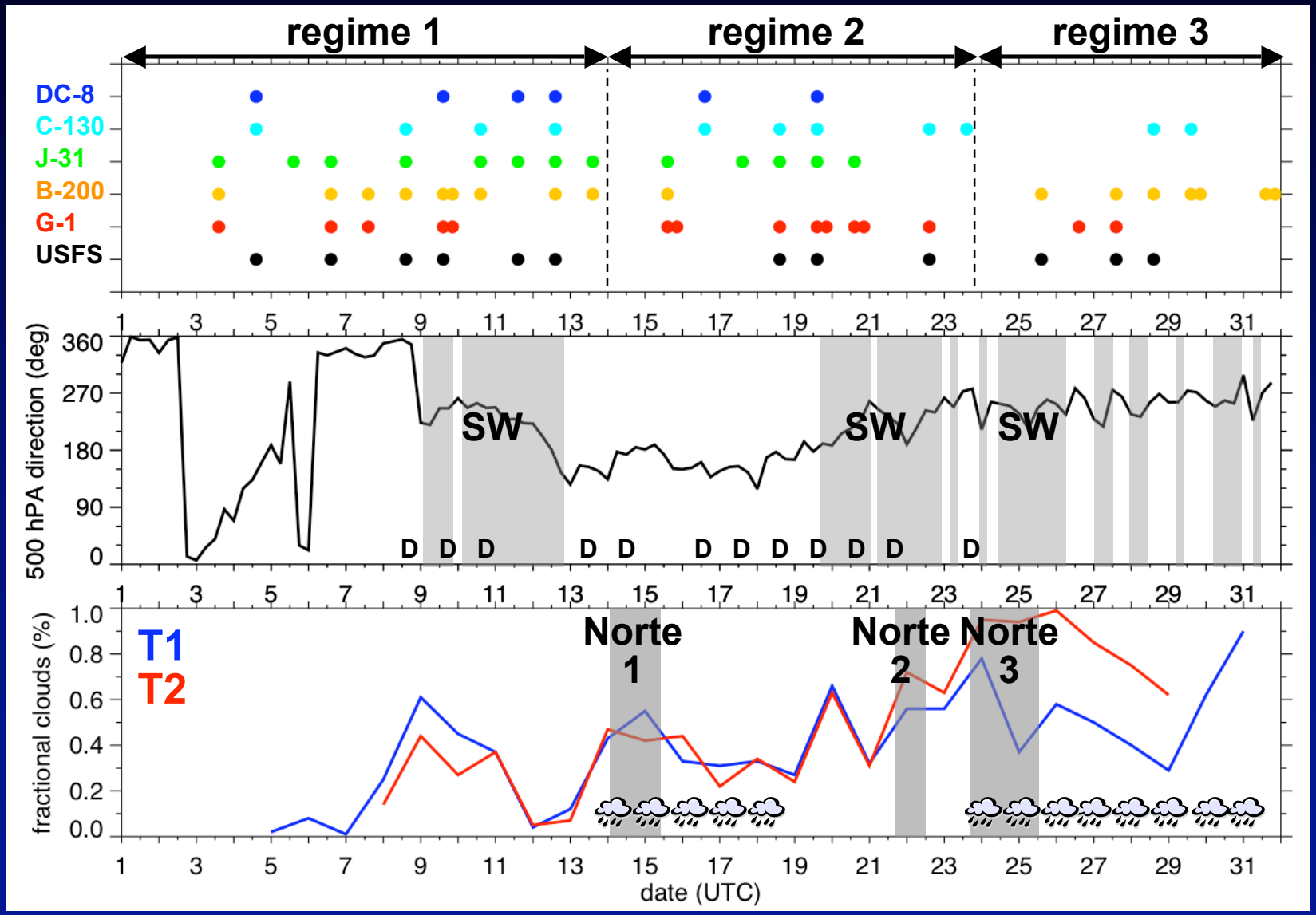
- interaction of synoptic and gap flows
- outflow from convection
- passage of Norte

photo from G-1 courtesy John Hubbe





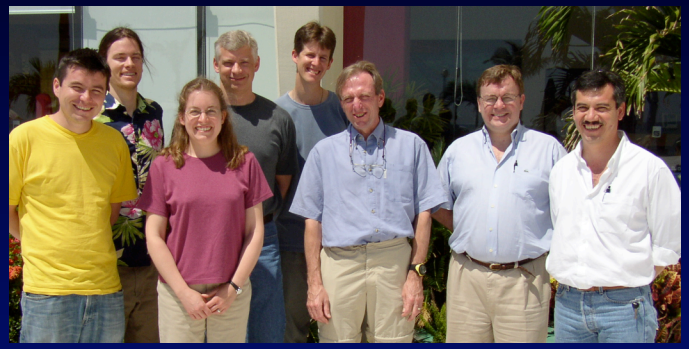
Aircraft Flights



Forecasting

Forecasters and Modelers:

- Jerome Fast, Ernesto Caetano, Federico Acevedo, Greg Carmichael, Ben de Foy, Louisa Emmons, Agustin Garcia, Daniel Jacob, Danny McKenna, Marcelo Mena, Brad Pierce, Bill Skamarock, Andreas Stohl, Youhua Tang, Xuexi Tie
- based in Veracruz center of operations



Daily Weather Briefing:

- focused on supporting aircraft operations, but specialized forecasts were also made
- forecasts, model output, and select measurements were available in real time at http://catalog.eol.ucar.edu/milagro/
- field catalog is still available and documents the thought process of the modeling team during the field campaign

MILAGRO Forecast Models

Model	Organization	Scale	Grid Spacing	Primary Use for Forecasting
MM5-FLEXPART	MC3	local to regional	3, 12, 36 km	meteorology, dispersion
MM5-MCCM	UNAM	local to regional	8, 24 km	meteorology, chemistry
WRF	NCAR	local to synoptic	3, 9 km	meteorology, dispersion
WRF-chem	NCAR	regional	6 km	chemistry, particulates
STEM	Univ. Iowa	regional to synoptic	12, 60 km	chemistry, particulates
MOZART	NCAR	synoptic	~ 2 deg	chemistry
FLEXPART	NILU	synoptic	~ 1 deg	dispersion
RAQMS	NASA	synoptic	~ 2 deg	chemistry
GEOS-CHEM	Harvard	synoptic	50 km	chemistry

most use NCEP's GFS model for boundary conditions

Modeling Summary

Performance of Operational Forecasts:

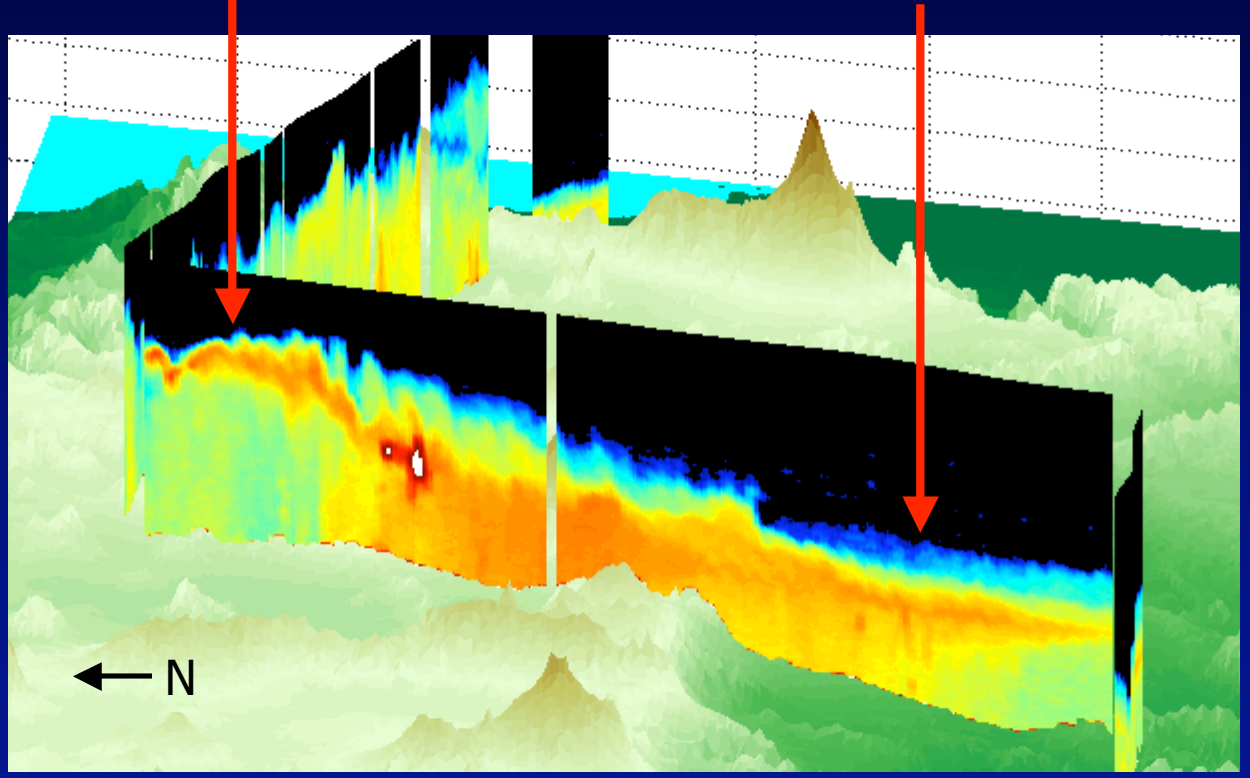
- models usually similar in predicting downwind Mexico City plume
- forecasts usually not change from day to day, except …
- uncertainties in the position of high pressure systems near the end of the experiment caused changes in forecasts from one day to next
- timing and location of afternoon convection most challenging
- inadequate for cirrus forecasting

Future Modeling:

- "reanalysis" simulations being performed to help interpret field data
- issues associated with trace gas and aerosol evolution:
  - interaction of local-regional-synoptic flows
  - same-day & multi-day recirculation
  - lofting, mountain venting, transport and transformation within clouds
  - long-range transport and fate beyond aircraft flights

Example Model Application

What are the processes responsible for particulate layering and how do they affect the fate of particulates?



data from B-200 courtesy Chris Hostetler

Summary

- synoptic transport primarily to the SW prior to March 9
- transport towards the NE and T1 / T2 during 2 periods
- regional circulations more complex during other periods
- three Nortes affected regional meteorology (3rd strongest)
- field campaign can be divided into 3 regimes
  1) < Norte #1: mostly sunny and dry
  2) Norte #1 - #3: increased humidity, cloudiness, and afternoon convection
  3) > Norte #3: further increase in humidity, cloudiness, afternoon convection, and showers

- paper on overview of meteorological conditions during MILAGRO to be submitted soon to ACPD special issue

Acknowledgements

- DOE and NSF: support for meteorological instrumentation that greatly aided forecasting efforts
- forecasting & modeling team
- JOSS - Jose Meitin - field catalog support
- SMN - performing supplementary rawinsondes
- Fernando Acevedo - local forecasting expertise

... and 100% Natural for making life bearable