Basic Meteorology

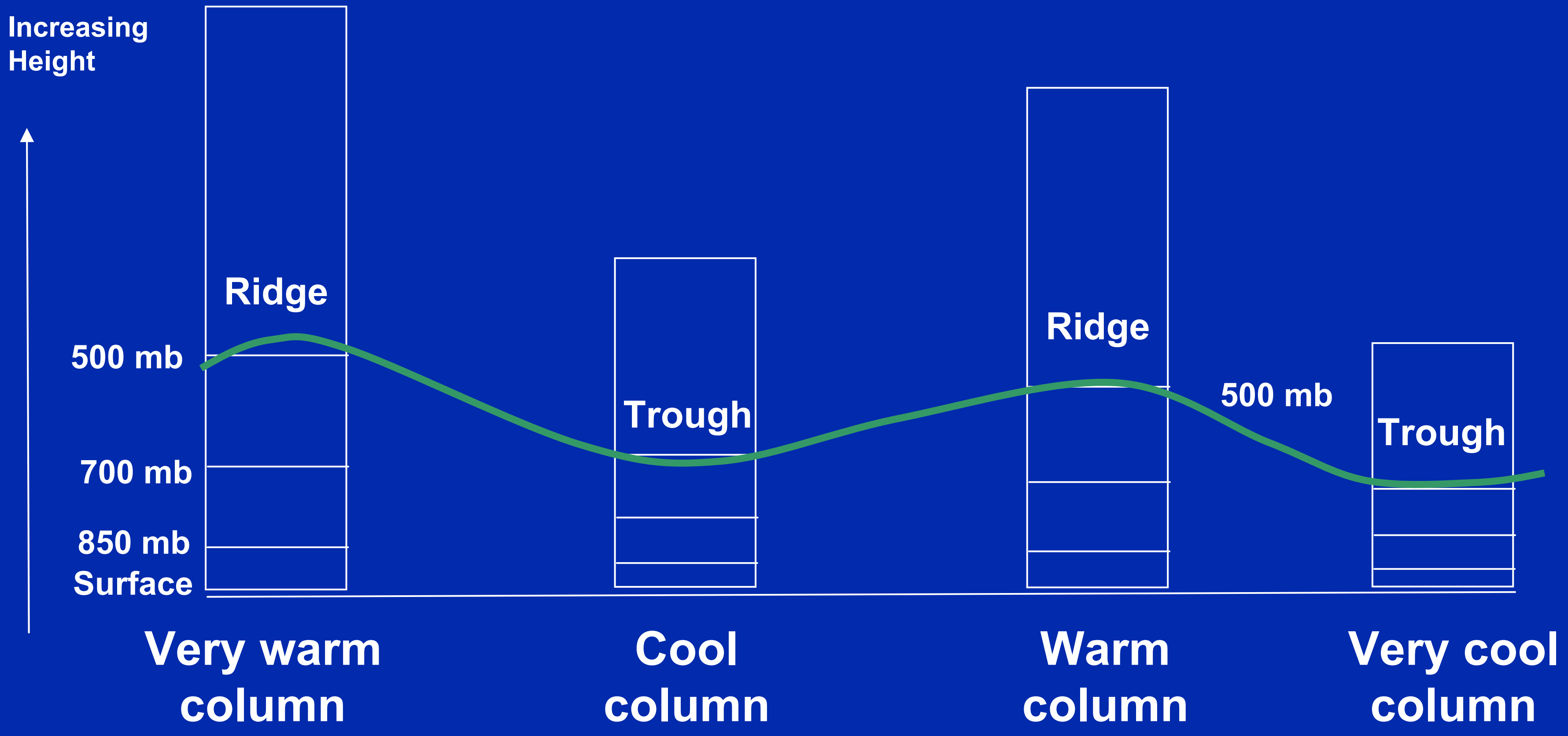
- Processes that influence air quality
  - Sunlight
  - Horizontal dispersion
  - Vertical Mixing
  - Transport
- Large scale to local scale

Basic Weather

- Aloft ridges and troughs
- Rising and sinking air
- Surface highs and lows
- Vorticity
- Mixing and temperature soundings
- Ridges, troughs, and temperature soundings
- Winds
  - Synoptic scale
  - Meso/Urban scale
- Transport (surface and aloft)

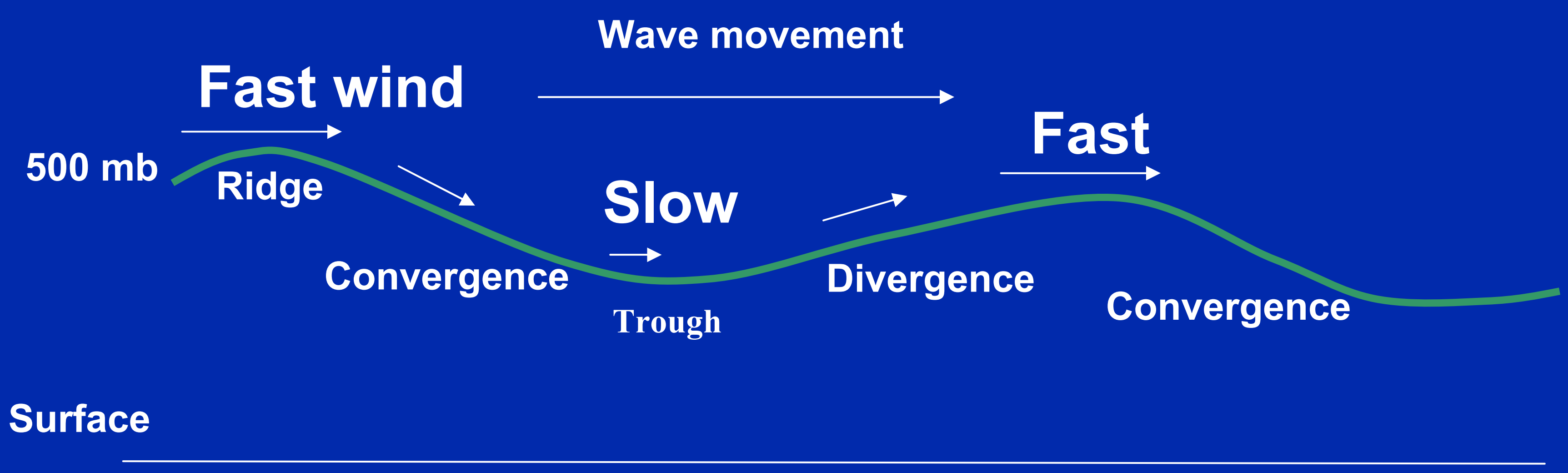
Aloft Ridges and Troughs

- Mountains and valleys of warm and cool air
- The height of the 500-mb pressure altitude depends on the relative temperature of the column



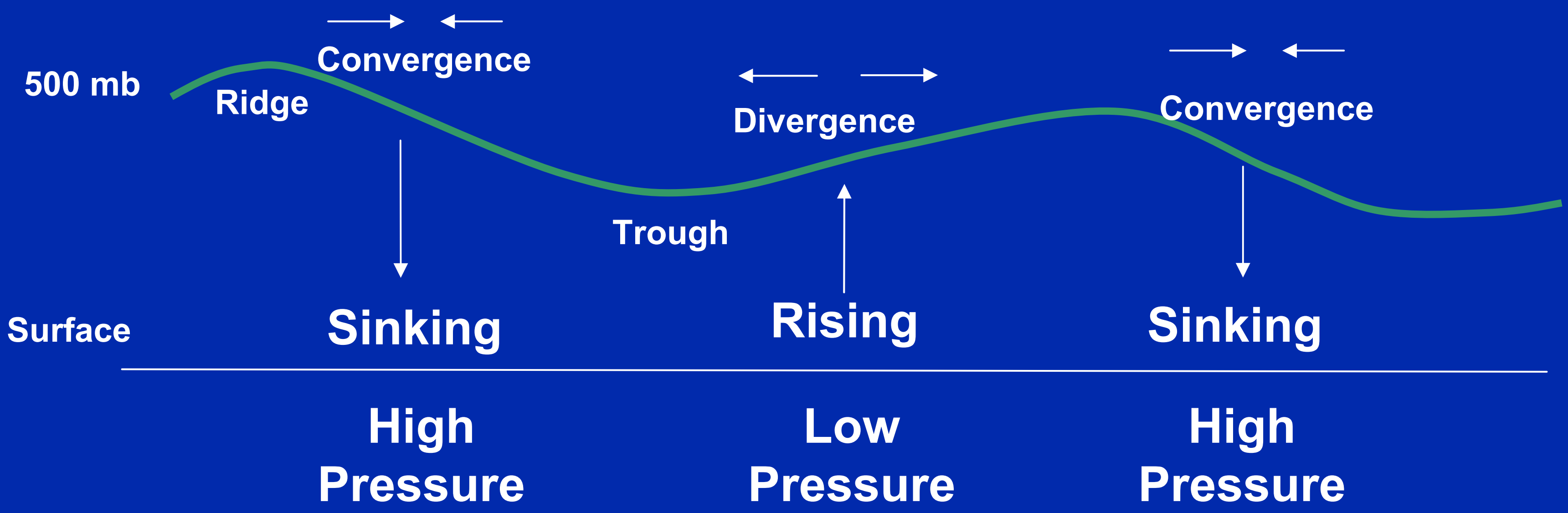
Aloft Ridges and Troughs

- Air travels faster around ridges and slower around troughs
- Areas of aloft convergence and divergence
- Waves (ridges and troughs) generally move west to east



Aloft Ridges and Troughs

- Aloft divergence causes rising motion and surface low
- Aloft Convergence causes sinking motion and a surface high
- Surface pressure patterns are offset from aloft patterns

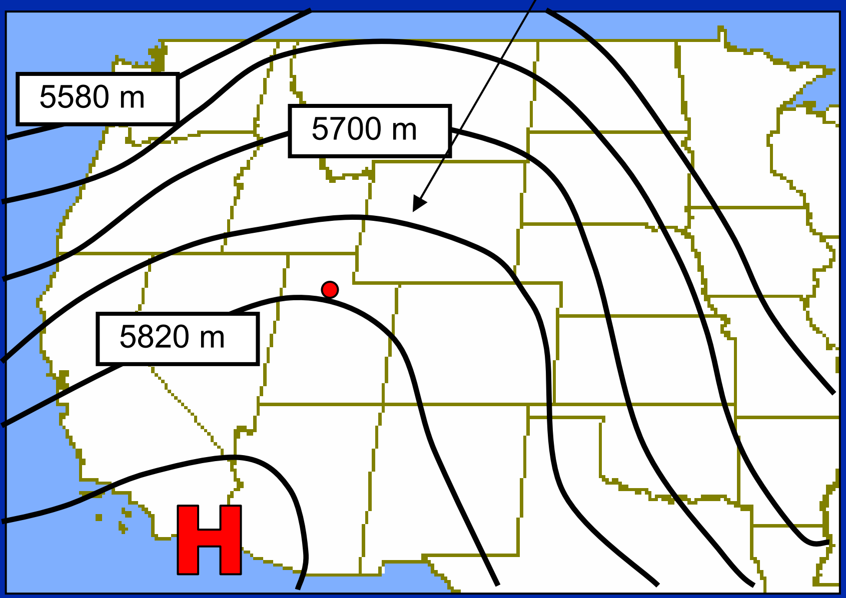


Rising and Sinking Air

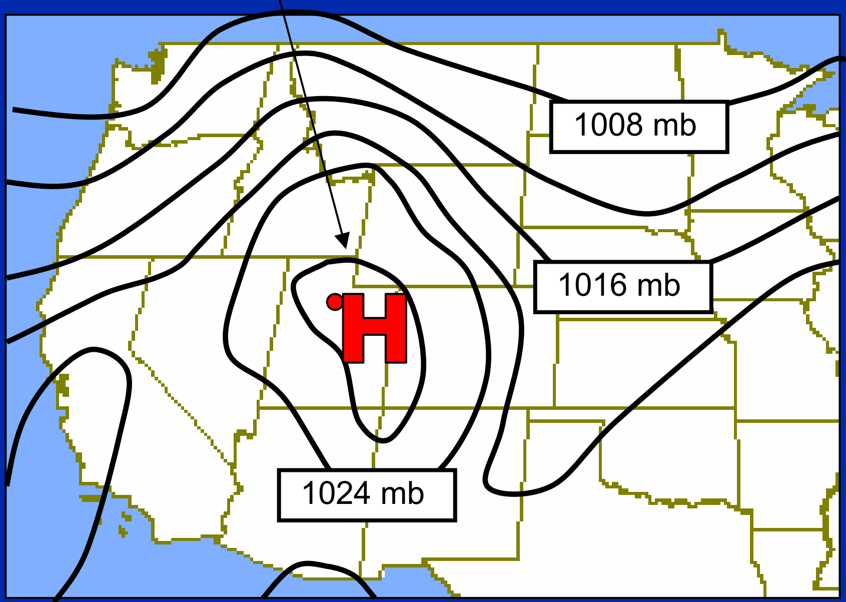
- Sinking motion
  - Warms the air
  - Creates a temperature inversion
  - Reduces vertical mixing
  - Creates clear skies
  - Associated with poor air quality
- Rising motion
  - Cools the air
  - Breaks inversions
  - Increases mixing
  - Causes cloud cover
  - Associated with good air quality

Surface Highs and Lows – Relationship to Aloft Pattern

Ridge = Sinking = Surface high



500 mb heights on the afternoon of January 7, 2002 (00Z Jan 8)

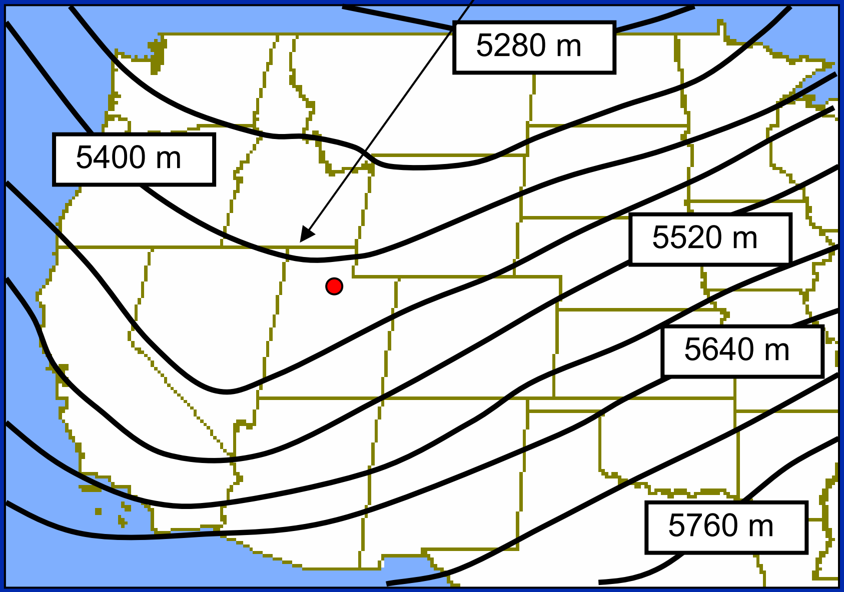


Surface pressure on the afternoon of January 7, 2002 (00Z Jan 8)

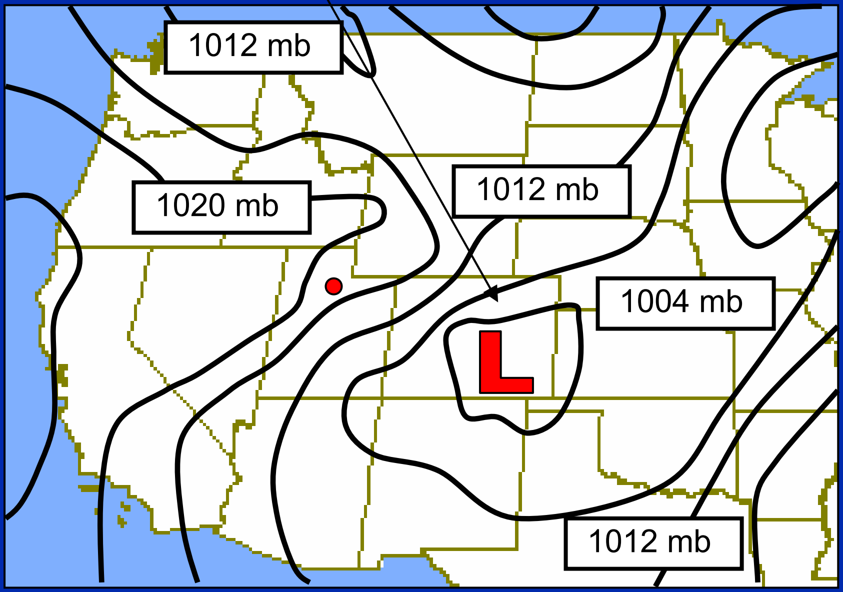
High $PM_{2.5}$ in Salt Lake City, Utah

Surface Highs and Lows – Relationship to Aloft Pattern

Trough = Rising = Surface low



500 mb heights on the afternoon of January 22, 2002 (00Z Jan 23)



Surface pressure on the afternoon of January 22, 2002 (00Z Jan 23)

Low $PM_{2.5}$ in Salt Lake City, Utah

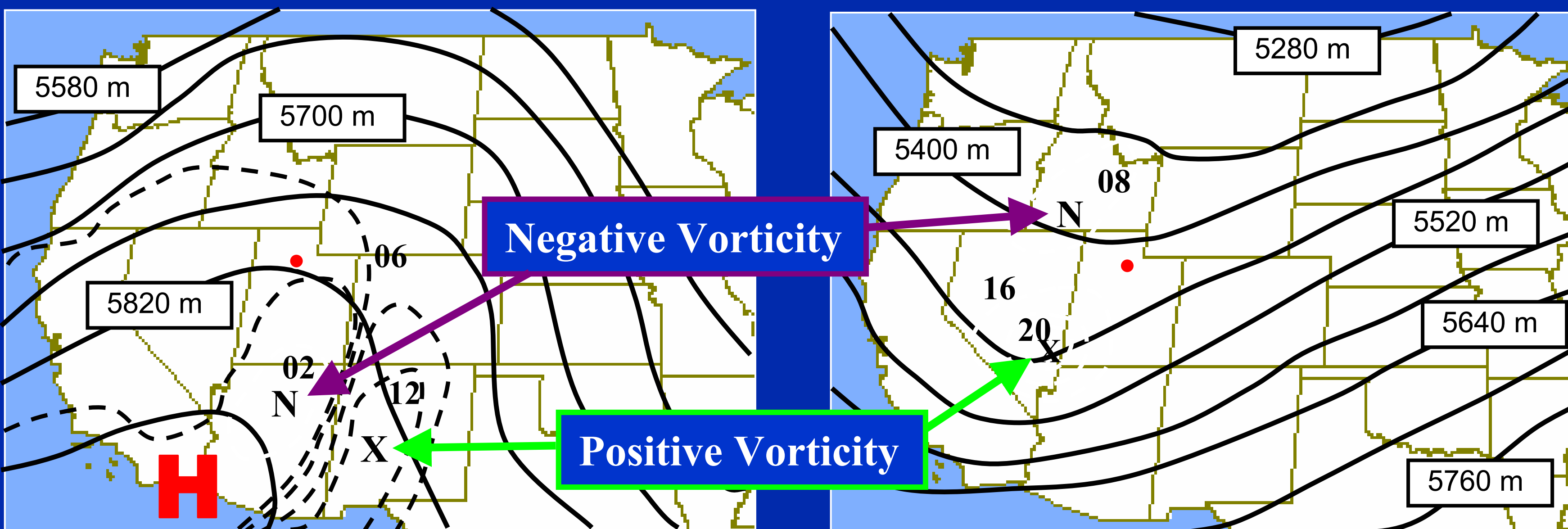
Vorticity – Subtleties of Ridges and Troughs

- Vorticity is the measure of rotation
- Captures smaller-scale aloft features within larger patterns
- Subtle changes in an upper-level pattern can have a large influence on air quality
- Negative vorticity is associated with sinking motion (Less than 10 $1 \times 10^{-5}\ s^{-1}$ on charts)
- Positive vorticity is associated with rising motion (Greater than 10 $1 \times 10^{-5}\ s^{-1}$ on charts)
- Movement of vorticity is what is important

Vorticity – Example of Negative and Positive

Ahead of **Negative Vorticity** = Sinking Motion = Reduced Vertical Mixing = **Poor AQ**

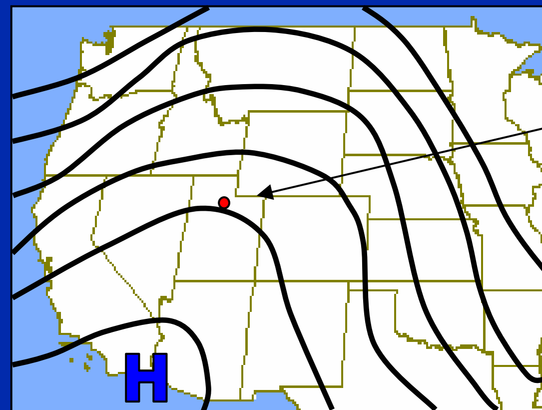
Ahead of **Positive Vorticity** = Rising Motion = Good Mixing = **Good AQ**



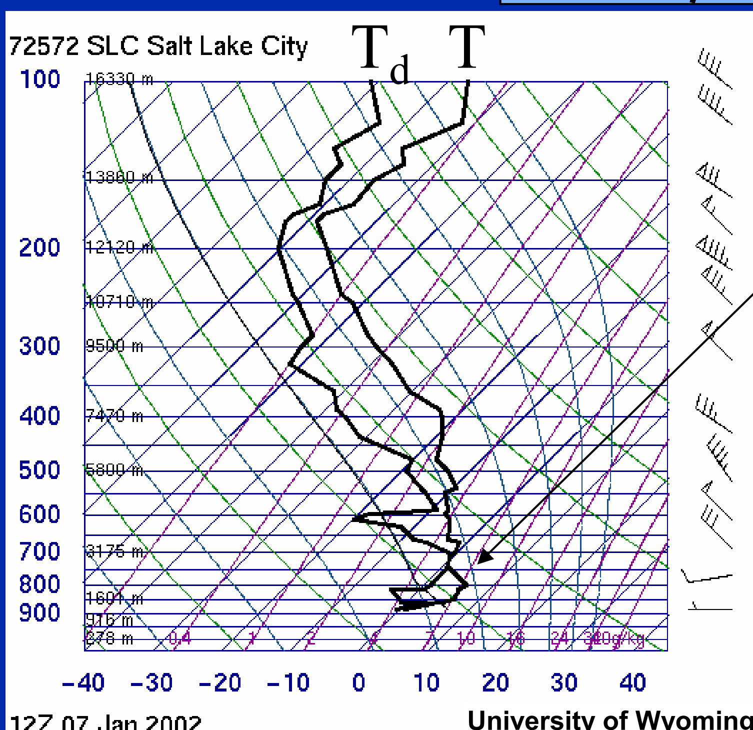
500-mb heights and vorticity for January (00Z Jan 8). Heights are in meters vorticity is in 1x10^{-5} s^{-1} (dashed). The local vorticity minimum and the "X" vorticity maximum.

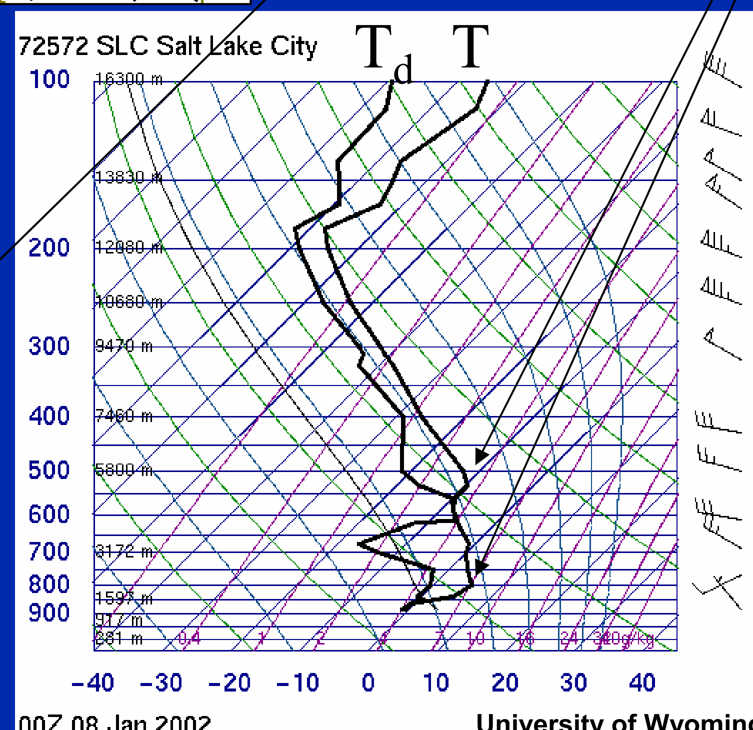
500-mb heights and vorticity for January 22, (00Z Jan 23). Heights are in meters (solid) vorticity is in 1x10^{-5} s^{-1} (dashed). The "N" local vorticity minimum and the "X" denotes vorticity maximum.

Ridges and Temperature Soundings

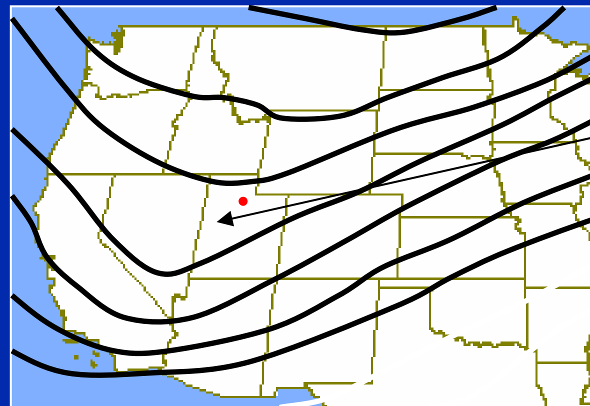


Ridge =
Sinking =
Strong Inversion =
Poor AQ

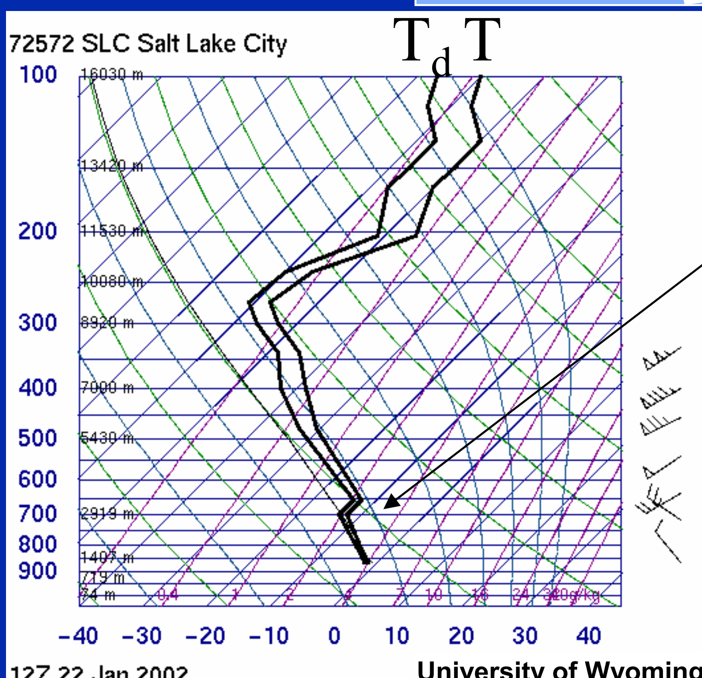


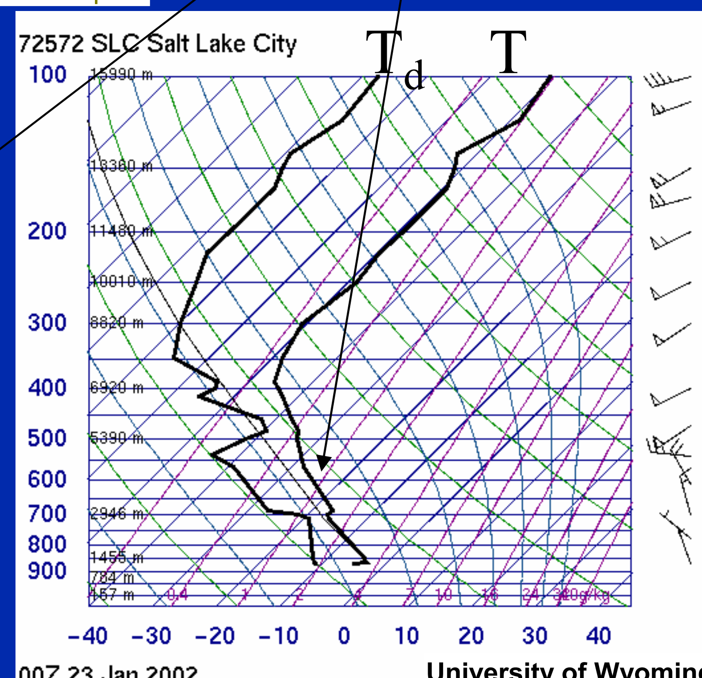


Troughs and Temperature Soundings



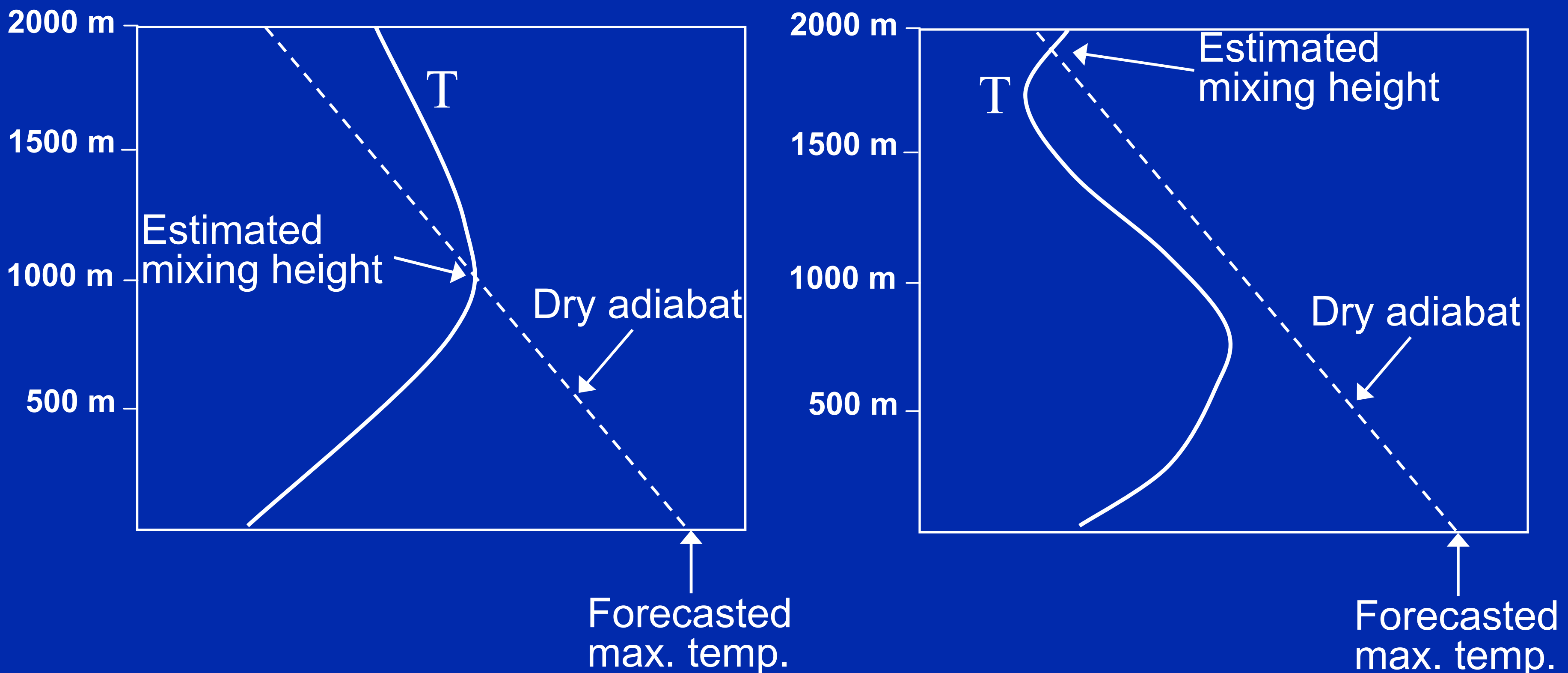
Trough=
Rising =
Weak Inversion=
Good AQ



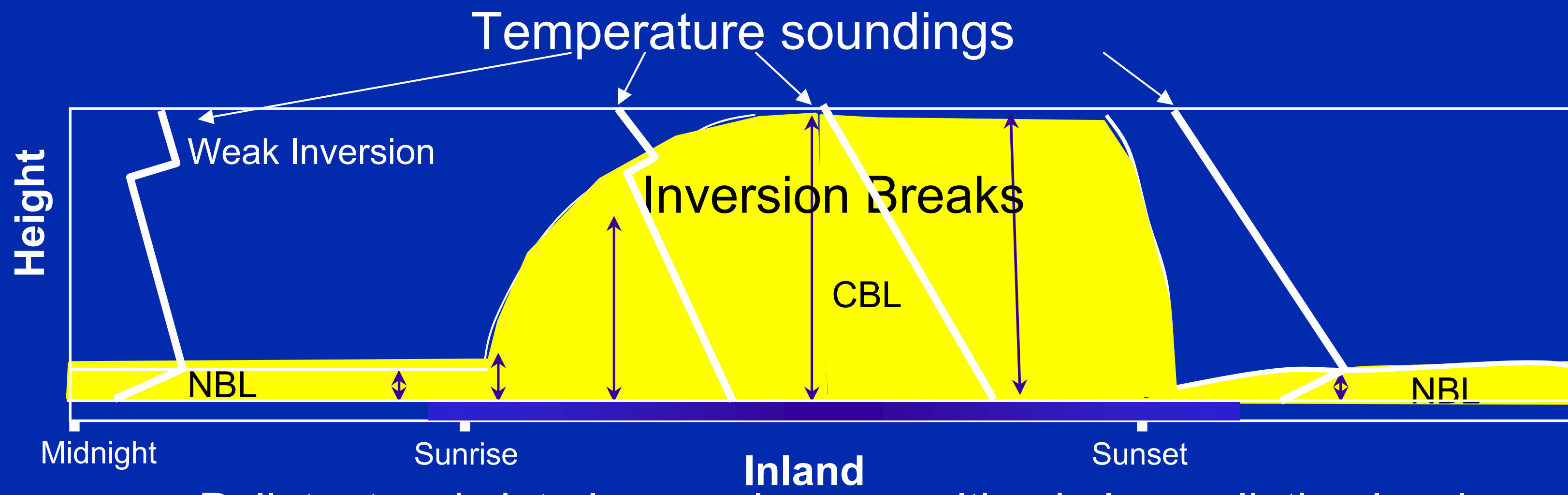


Mixing and Temperature Soundings – Estimating Mixing Height

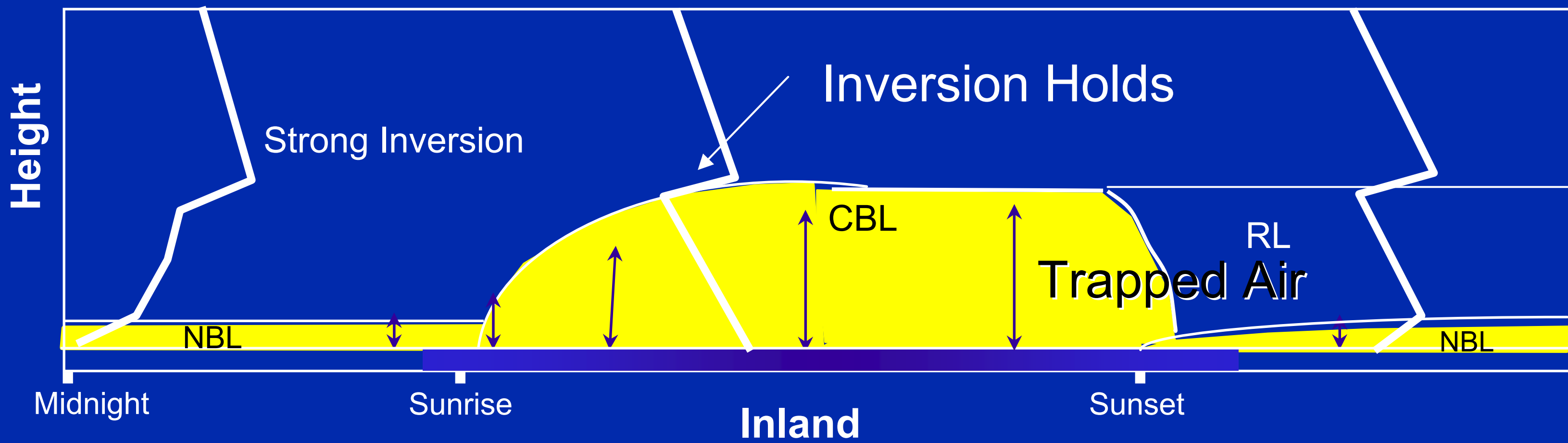
- Holtzworth Method – Starting at the forecasted maximum temperature, follow the dry adiabat (dashed line) until it crosses the morning sounding. This is the estimated peak mixing height for the day.
- The dry adiabatic rate is how an unsaturated air parcel cools as it rises. It is defined as -9.8 ºC per km.



Mixing and Temperature Soundings



Pollutants mix into large volume resulting in low pollution levels



Pollutants mix into smaller volume resulting in high pollution levels

RL = Residual Layer
CBL = Convective Boundary Layer
NBL = Nocturnal Boundary Layer

= Surface-based mixing depth

= Surface-based vertical mixing

Winds

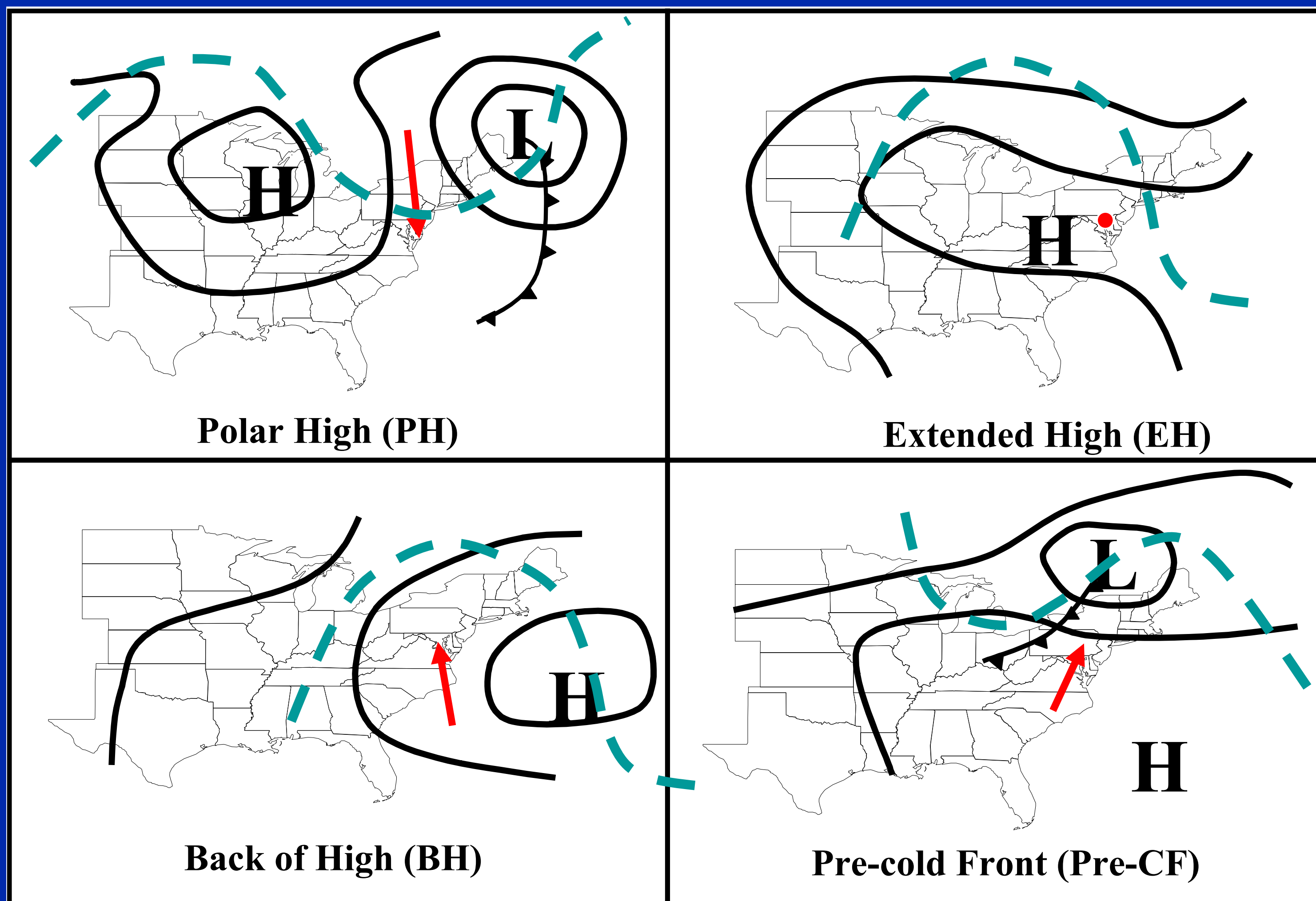
Horizontal dispersion and transport

- Synoptic scale
  - Winds driven by large high- and low-pressure systems
- Meso-scale
  - Land/sea or lake breeze
  - Mountain/valley
  - Terrain-forced
- Surface vs. boundary layer
  - Transport at different levels
  - Mixing during the day

Winds – Examples of Synoptic Patterns and Wind Flow

Low ozone

High ozone



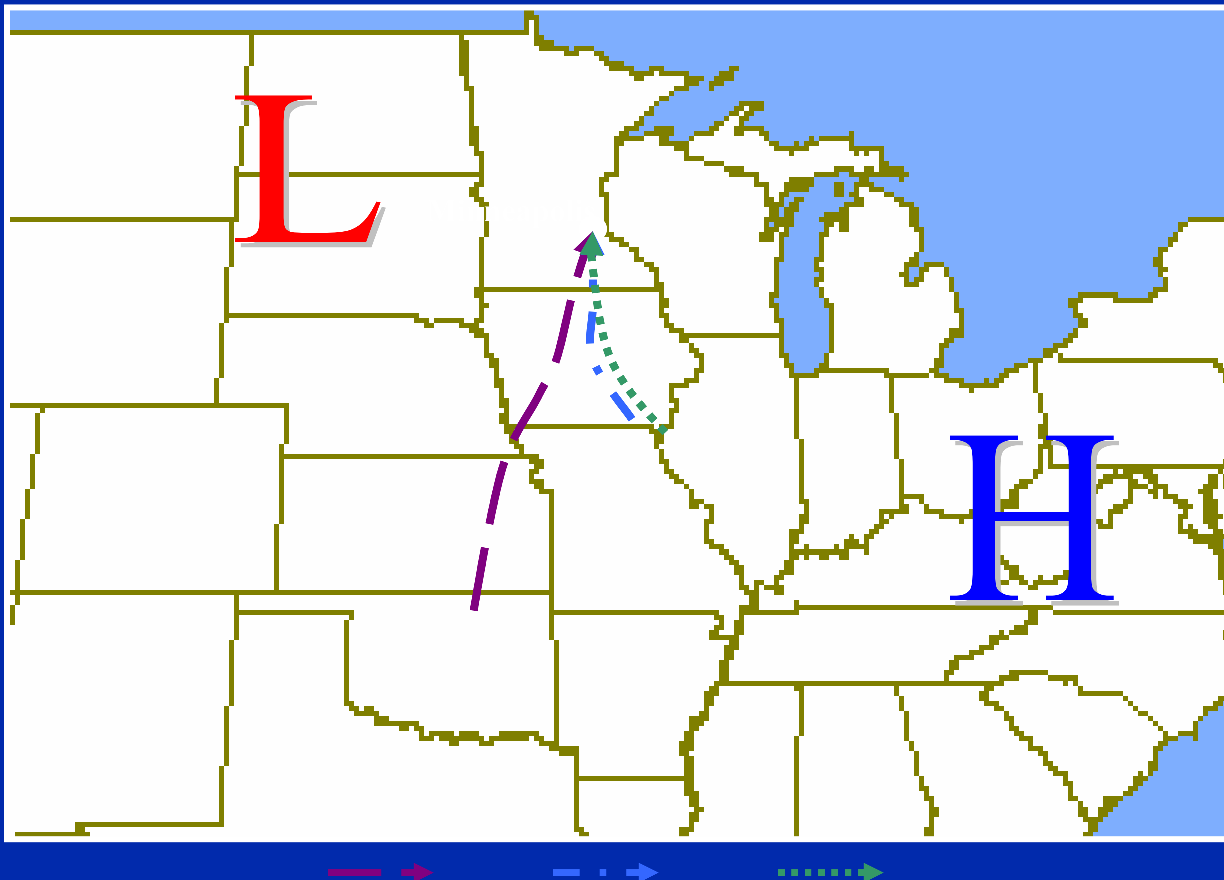
Moderate ozone

High ozone

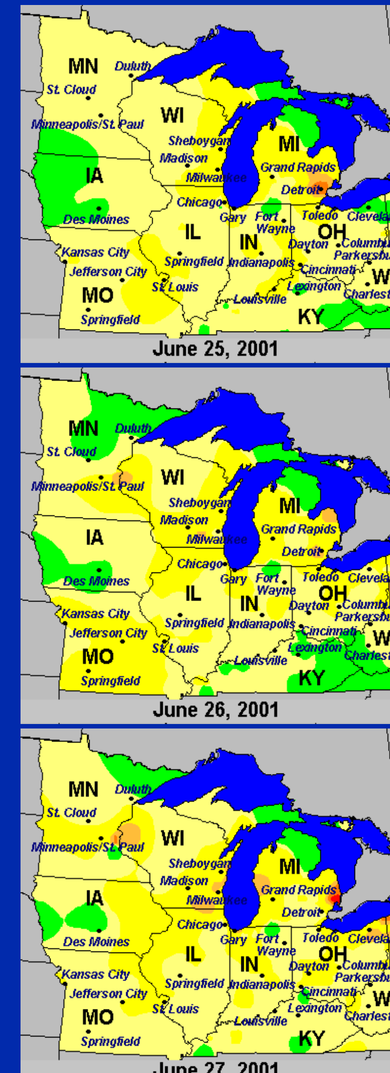
Lines of constant surface pressure
Line of constant 500-mb height
Wind speed and direction

MacDonald et al, 1998
Comrie and Yarnal, 1992

Winds – Transport



24-hr air parcel paths for a June 2001 ozone episode based on NOAA's Hysplit Trajectory Model.



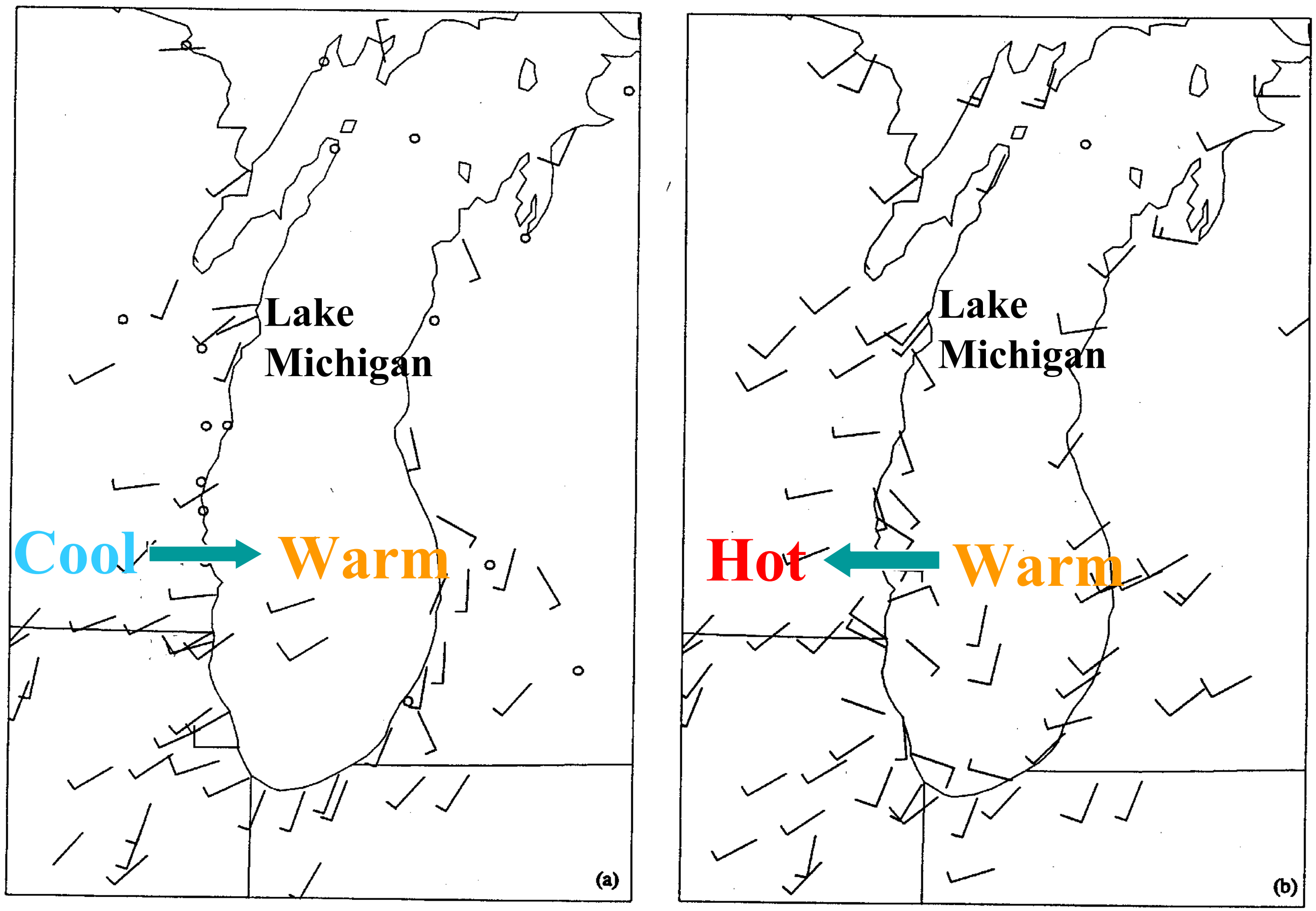
Peak 1-hr ozone (AIRNow)

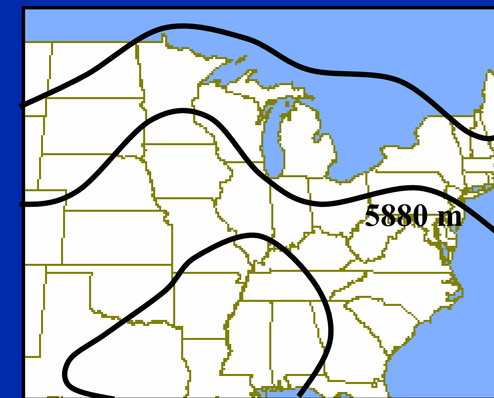
Winds – Meso and Urban Scales

- Meso/urban scales = regions, bays, metropolitan regions, terrain
- Local flows (stagnation, recirculation) are very important for air quality predictions
- Local forcing can dominate flow patterns when synoptic pressure gradients are weak
- Local flows often follow diurnal heating and cooling cycles
- Local flows are often difficult for weather models to predict but can be predicted by forecasters with knowledge of the area

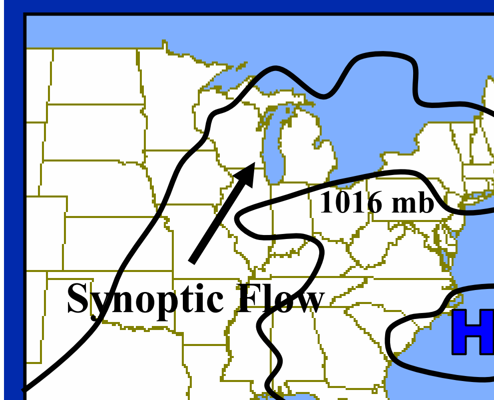
Winds - Land/Lake Breeze

Land Breeze | **Lake Breeze**





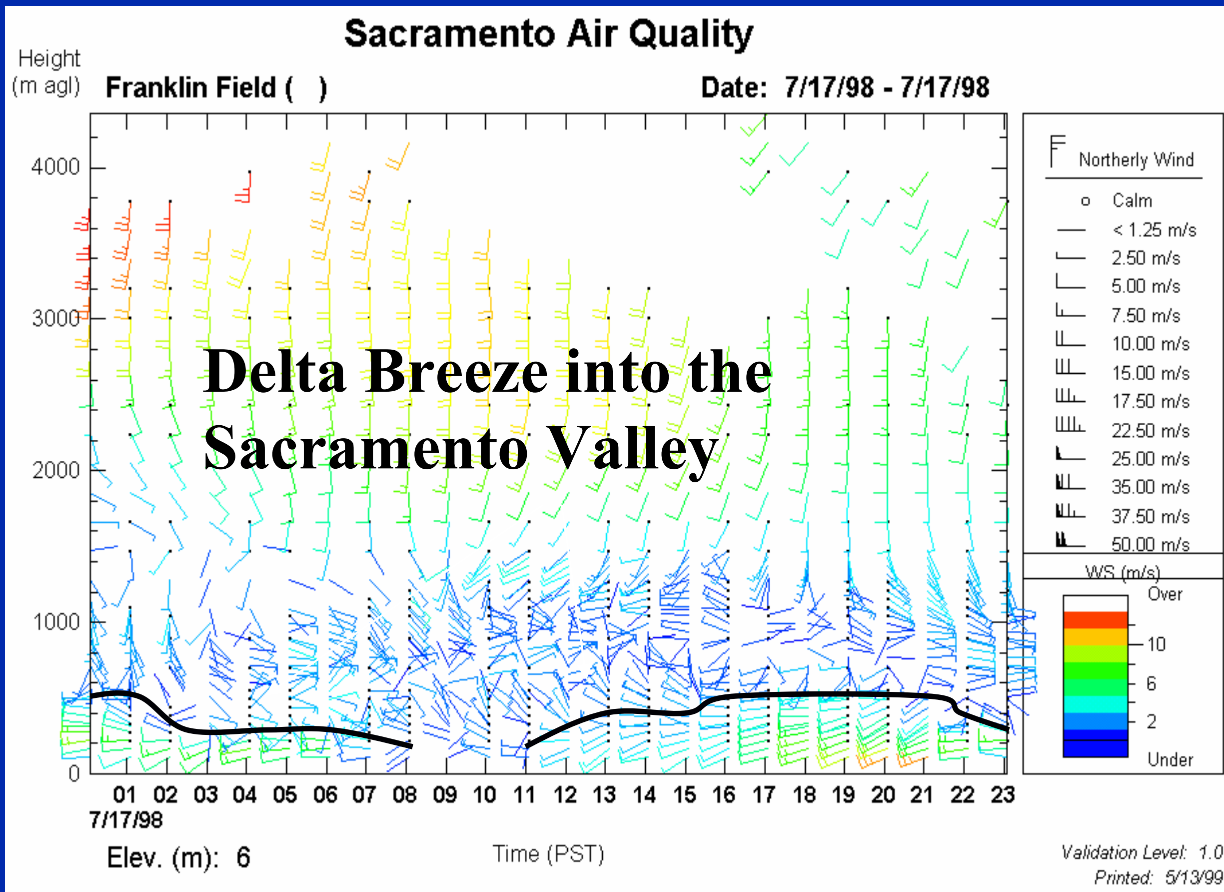
500 mb heights on July 18, 1991

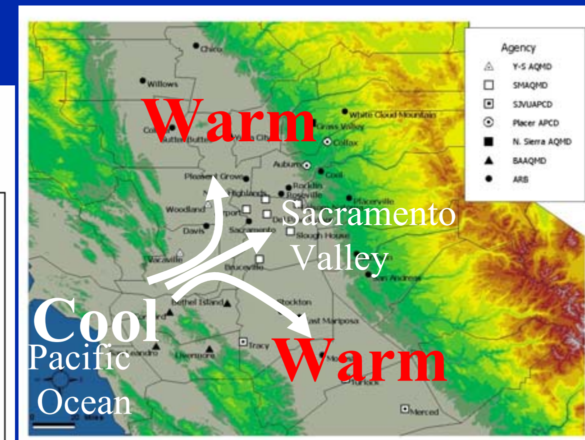


Surface pattern on July 18, 1991

Surface winds on July 18, 1991 at (a) 0600 CDT and (b) 1500 CDT. Peak ozone concentrations on this day were about 170 ppb. (Dye et al., 1995).

Winds - Trough and a Persistent Delta Breeze

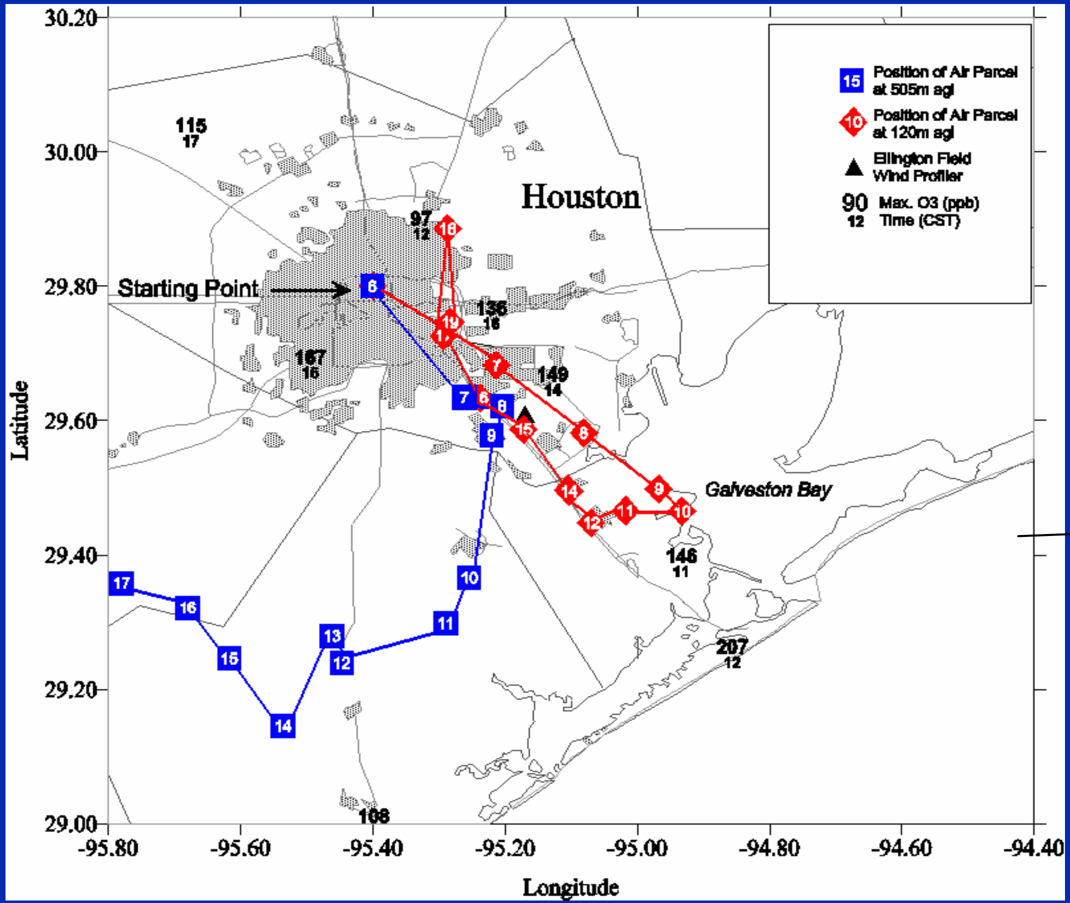




Radar profiler wind data at Franklin Field, California, on July 17, 1998. Notice the demise of the delta breeze at about 0800 PST and the return of the delta breeze at about 1100 PST below about 500 m. MacDonald et al., 1999.

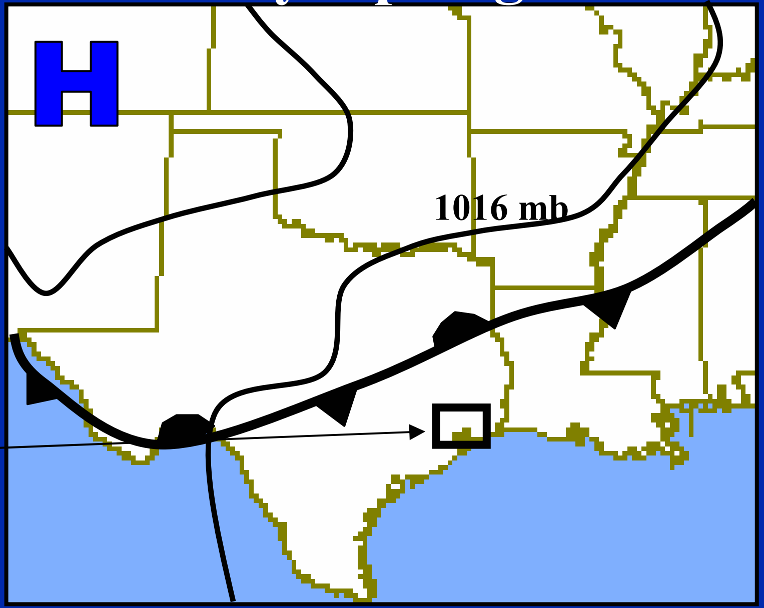
500-mb trough approaching the coast enhances the sea-breeze inflow into the central valley of California.

Winds - Recirculation Associated with Land/Sea Breeze Circulation



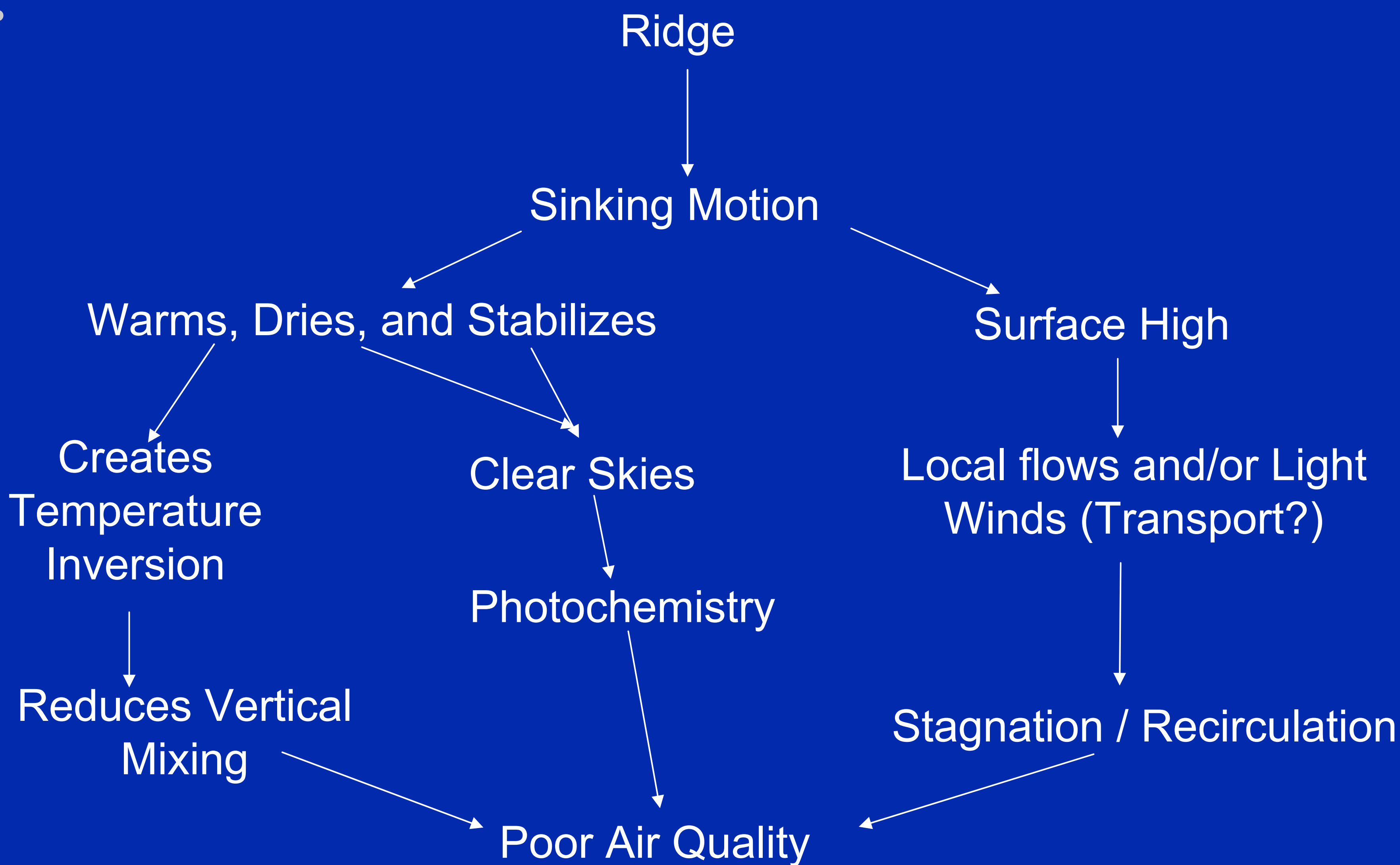
Forward 120-m agl and 505-m agl trajectories from downtown Houston (0600 to 1800 CST on August 29, 1998). Peak ozone concentrations and times of peak concentration (begin hour CST) at each monitoring site are shown (MacDonald et al, 2001).

Weak synoptic gradient

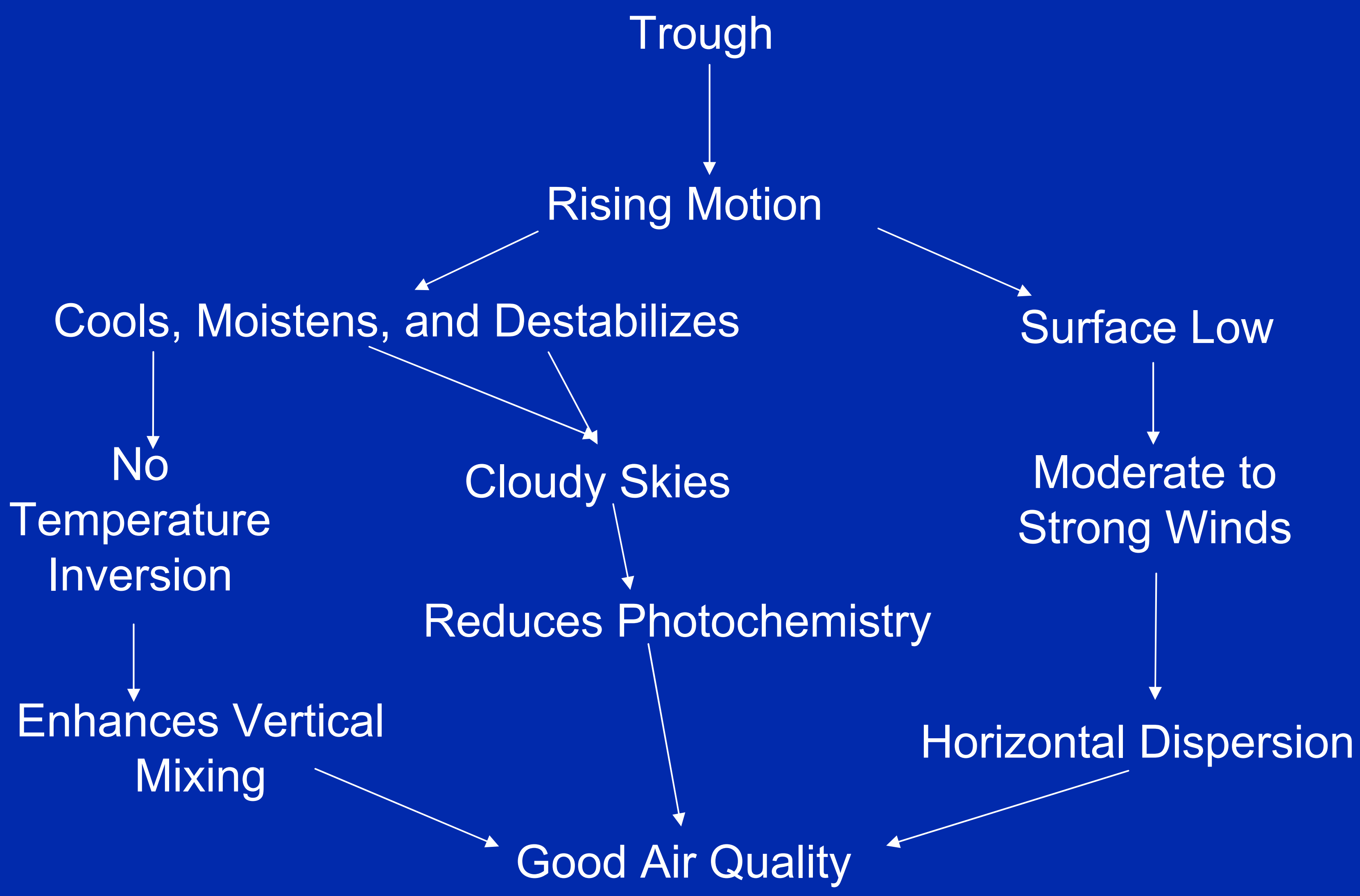


Surface pattern on August 29, 1998.

Summary - Meteorology Associated with Poor AQ



Summary - Meteorology Associated with Good AQ



Summary

Processes that influence air quality

- Large-scale weather pattern
- Surface highs and lows
- Vertical mixing
- Winds/Transport

- Next step
  - Obtaining and interpreting forecast information
- Questions