Analysis of Multiple Stable Layers in Cold-Air Pools

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Outline

- Developing a baseline of the 4D PBL structure during PCAPS through integration of prior and field campaign observations
- Recasting Convective Inhibition, CIN, as “Rising Motion Inhibition” to objectively define stable and mixed layers
- Next talk- interactions between Valley and larger Great Salt Lake Basin

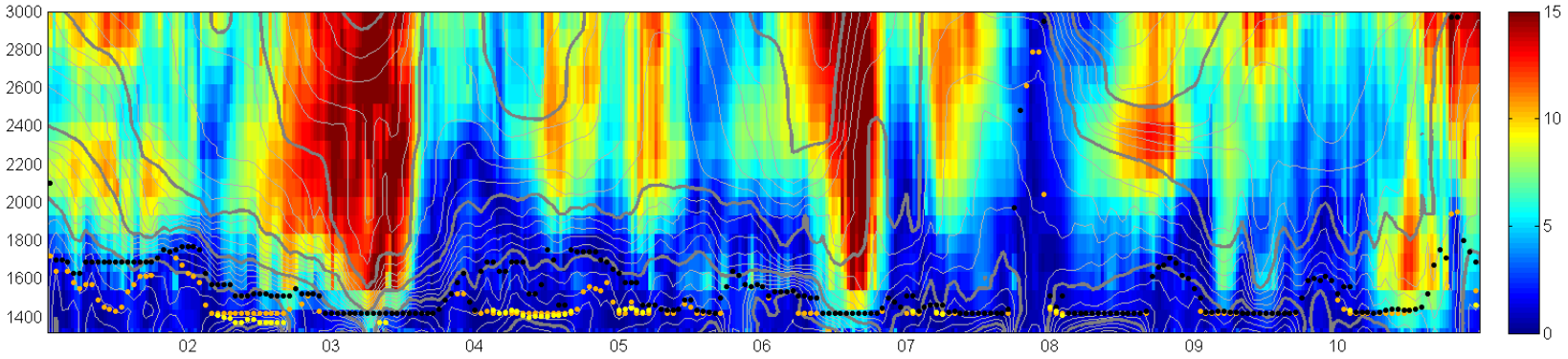
Developing a Baseline of the 4D PBL Structure During PCAPS

- High resolution (10 m) vertical structure in core of Salt Lake Valley (NCAR ISS site) at hourly intervals
  - Integrate 102 soundings with subhourly profiler winds and temperatures constrained by surface conditions
- High resolution (~ 100 m) horizontal surface structure of temperature, wind, and moisture at hourly intervals
  - 2D variational assimilation system (Tyndall and Horel 2012, *WAF* In Press)
  - Background defined by hourly vertical profiles
  - Adjust background by ~100 surface observations
  - Assume observational errors small relative to background
  - Diurnal evolving bias correction incorporated in the surface analyses (Dee 2006)

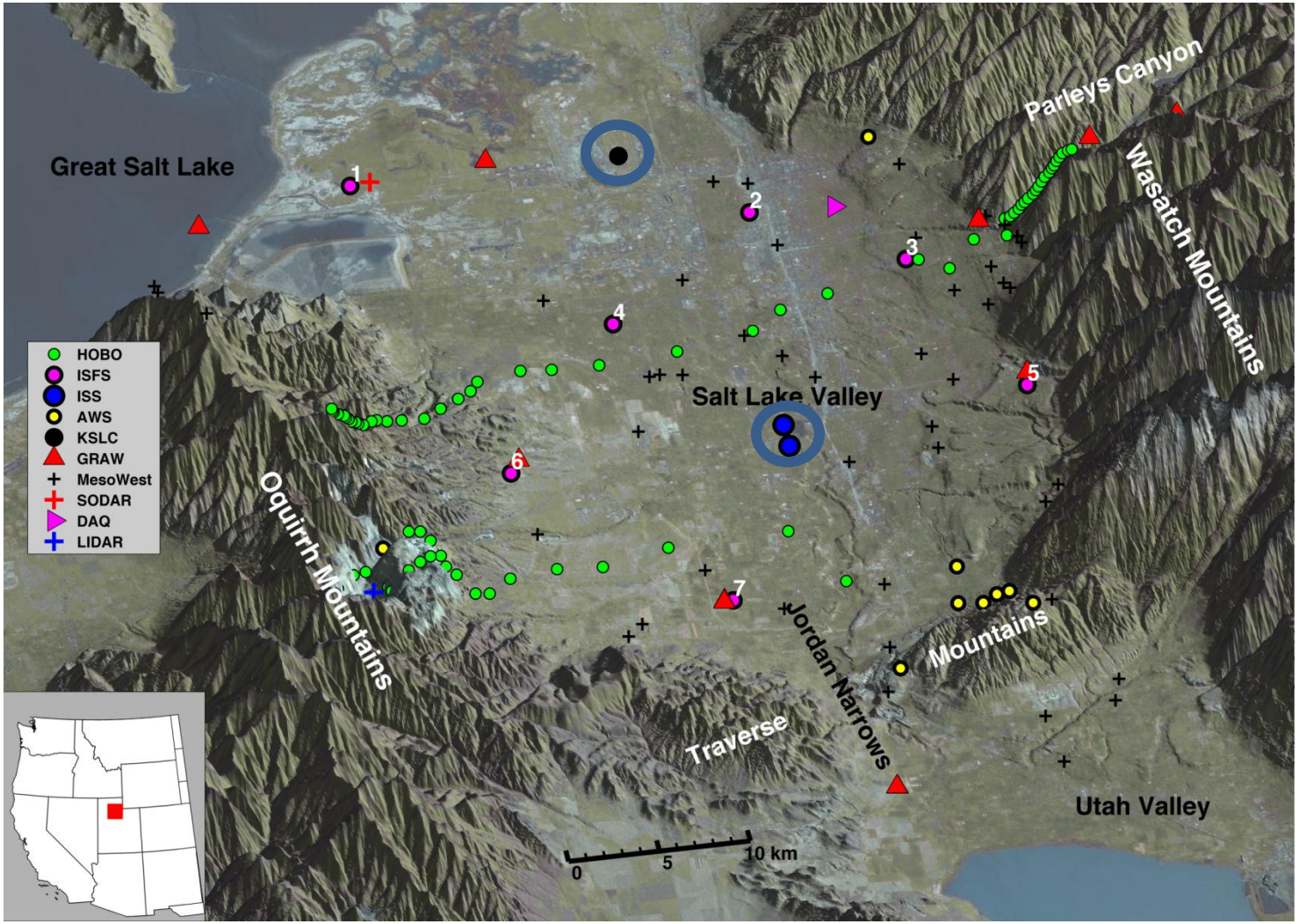
IOPs-1&2
1-11 December 2010

PCAPS
Persistent Cold-Air Pool Study

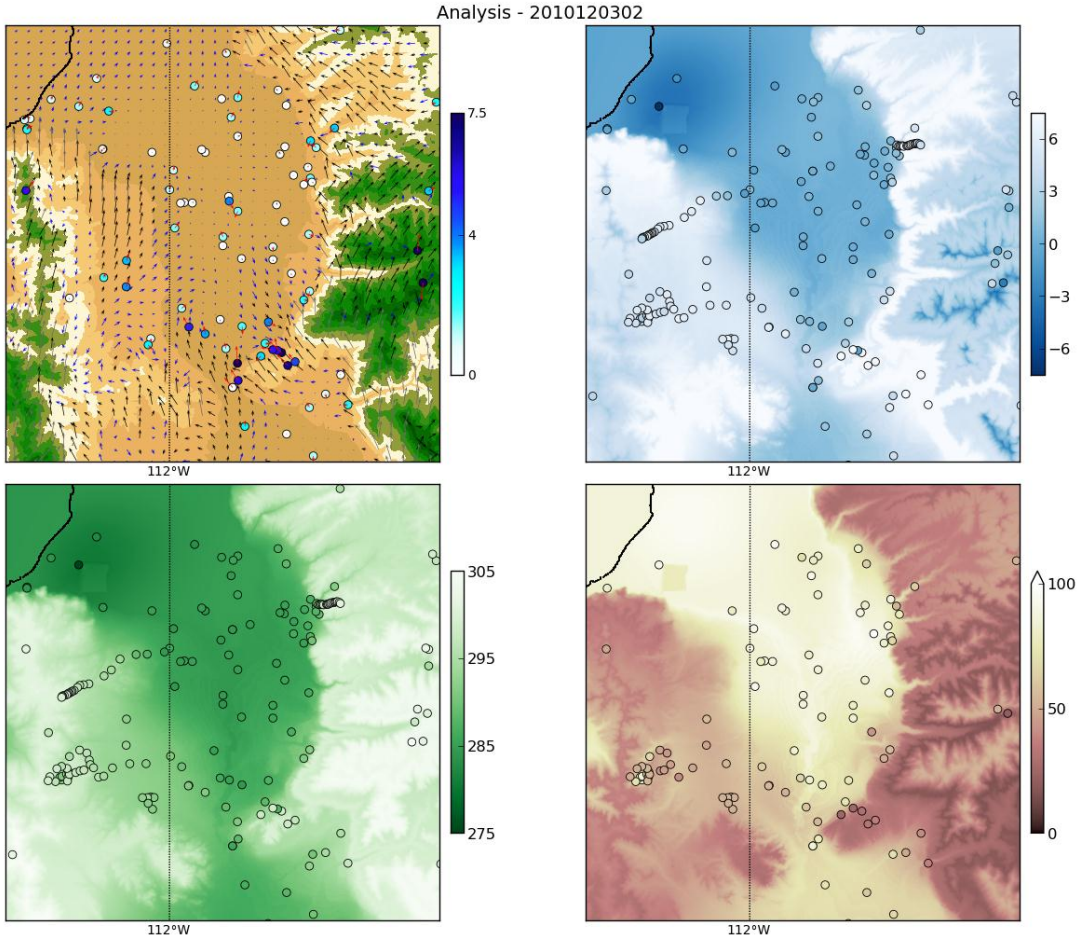
- Sondes and Neil processing
- Potential temperature and wind speed



PCAPS field campaign instrumentation



Maps During 3 December



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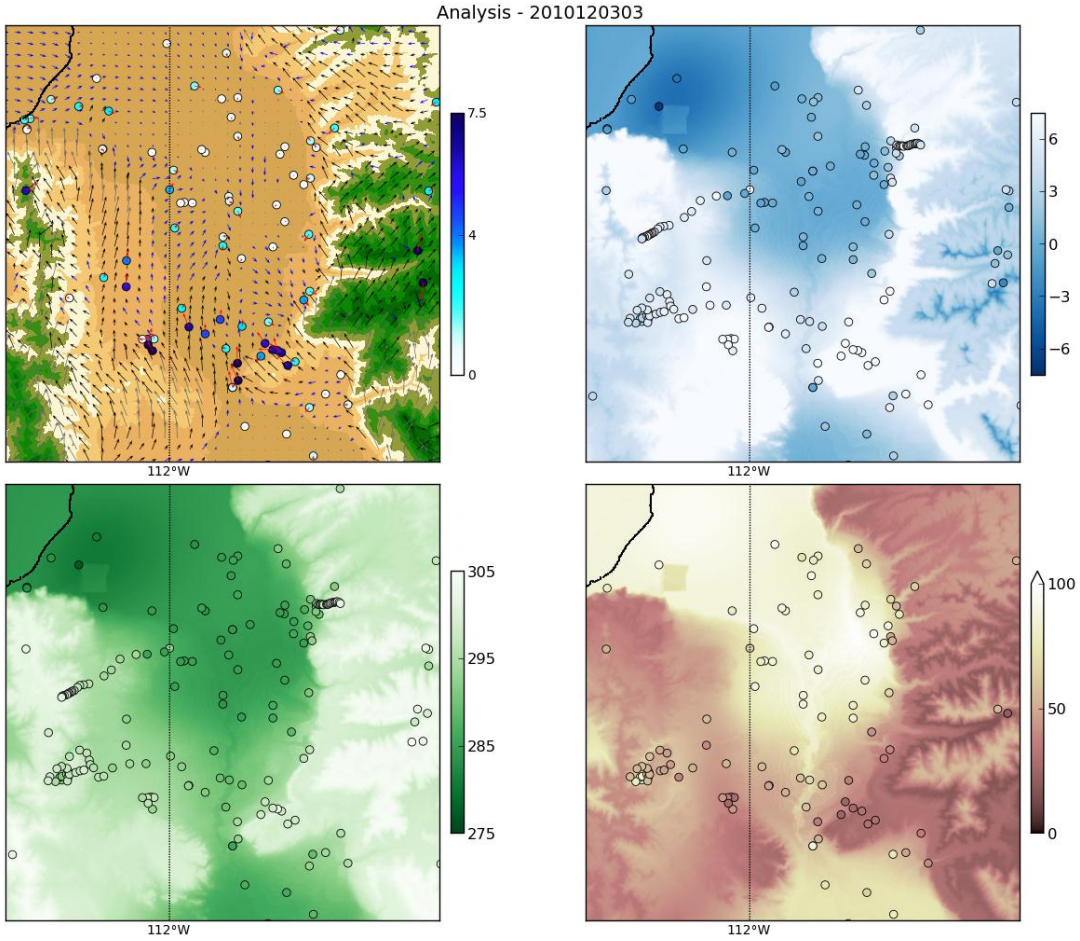

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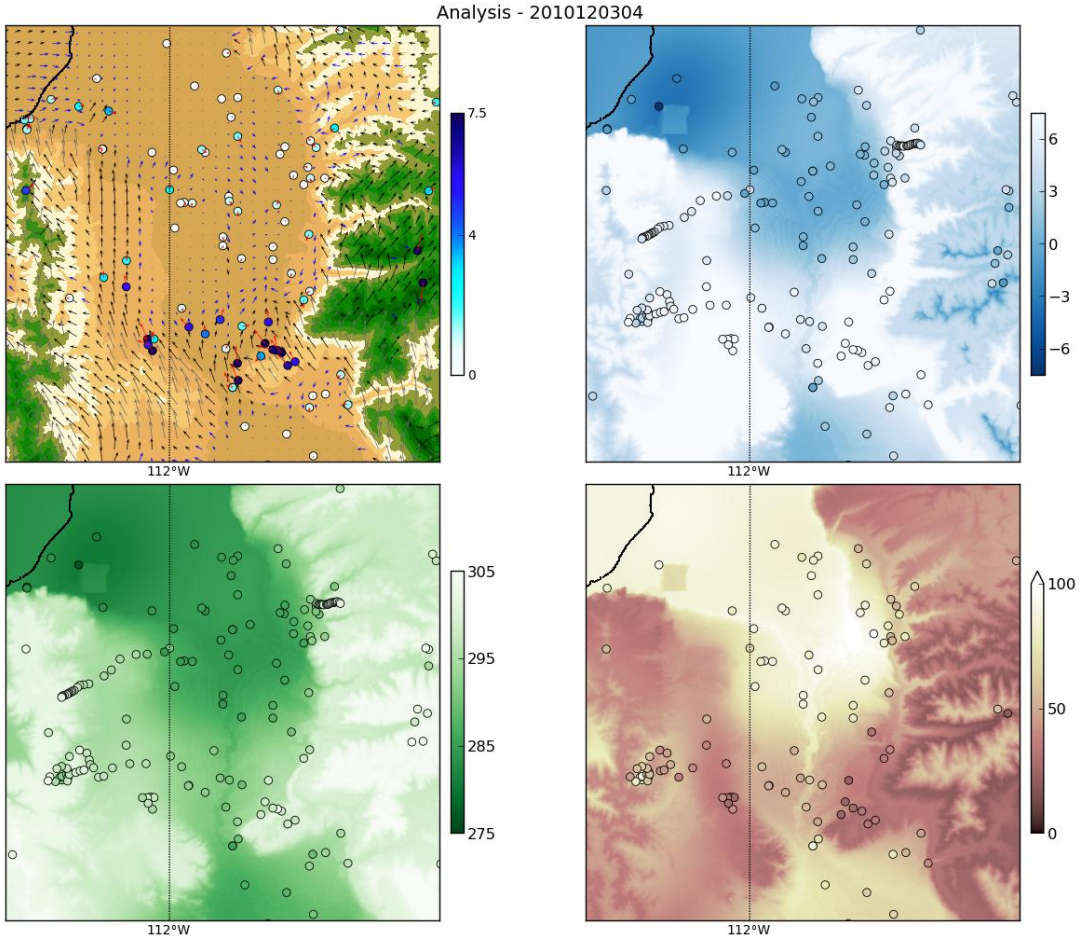

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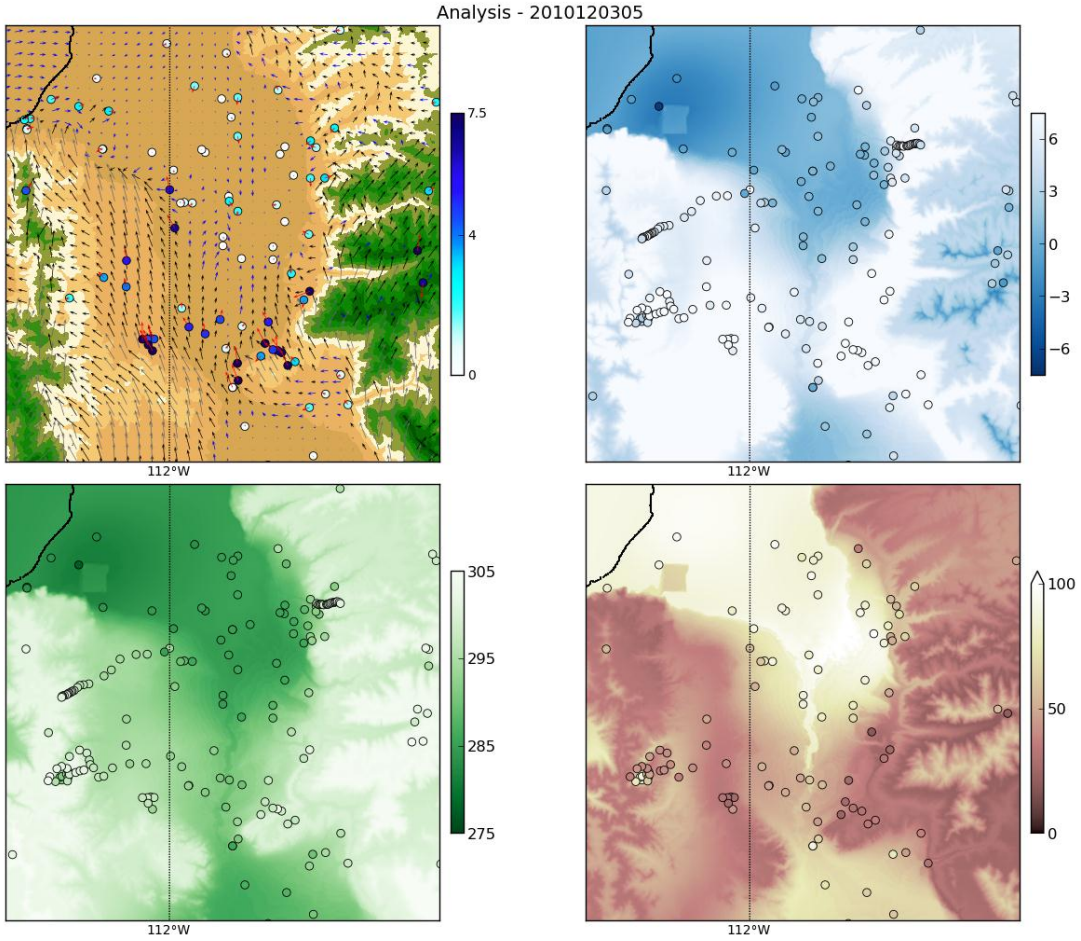

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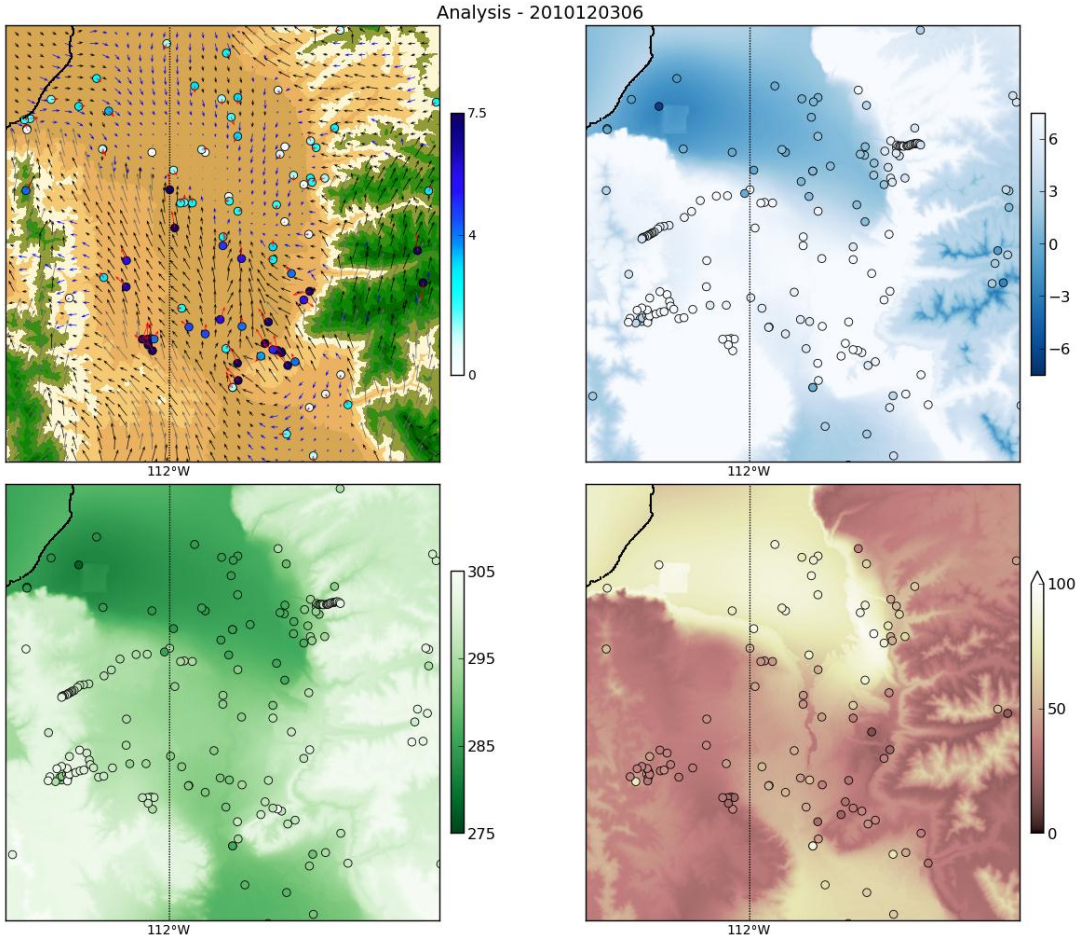

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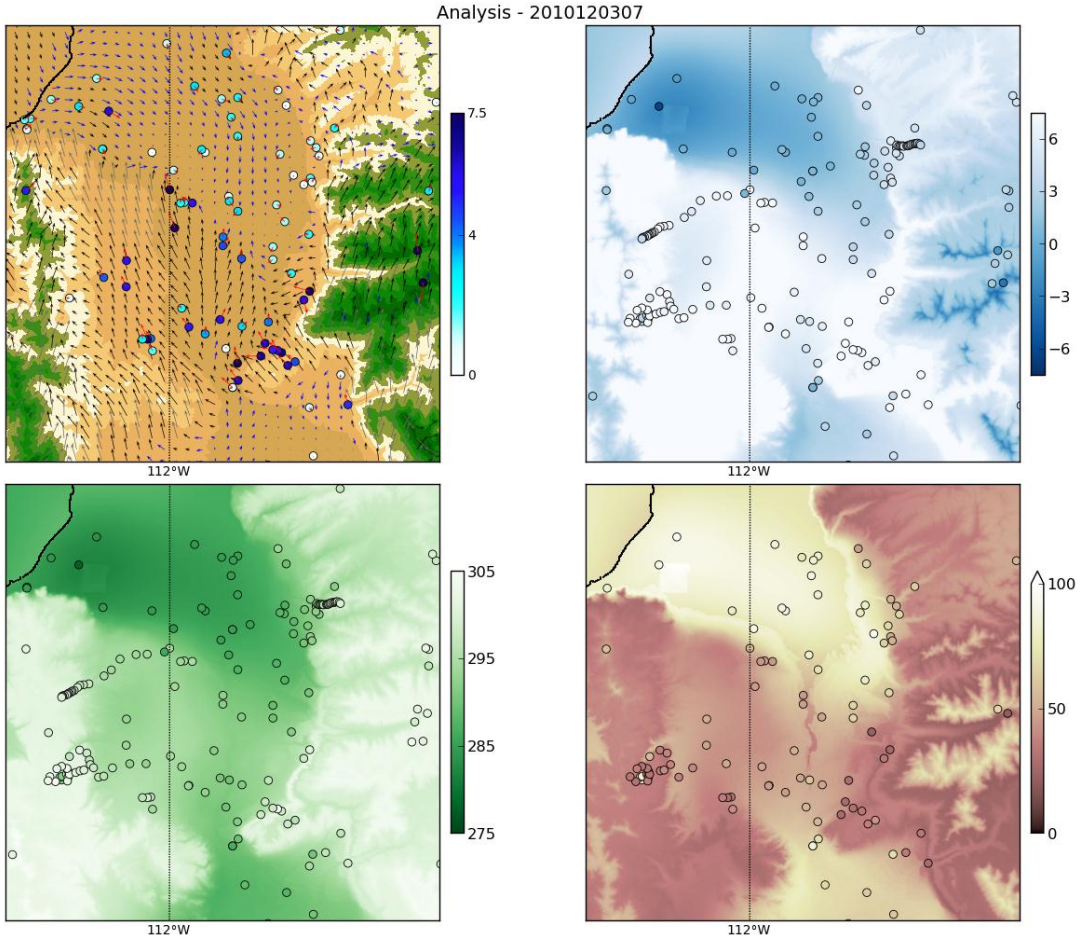

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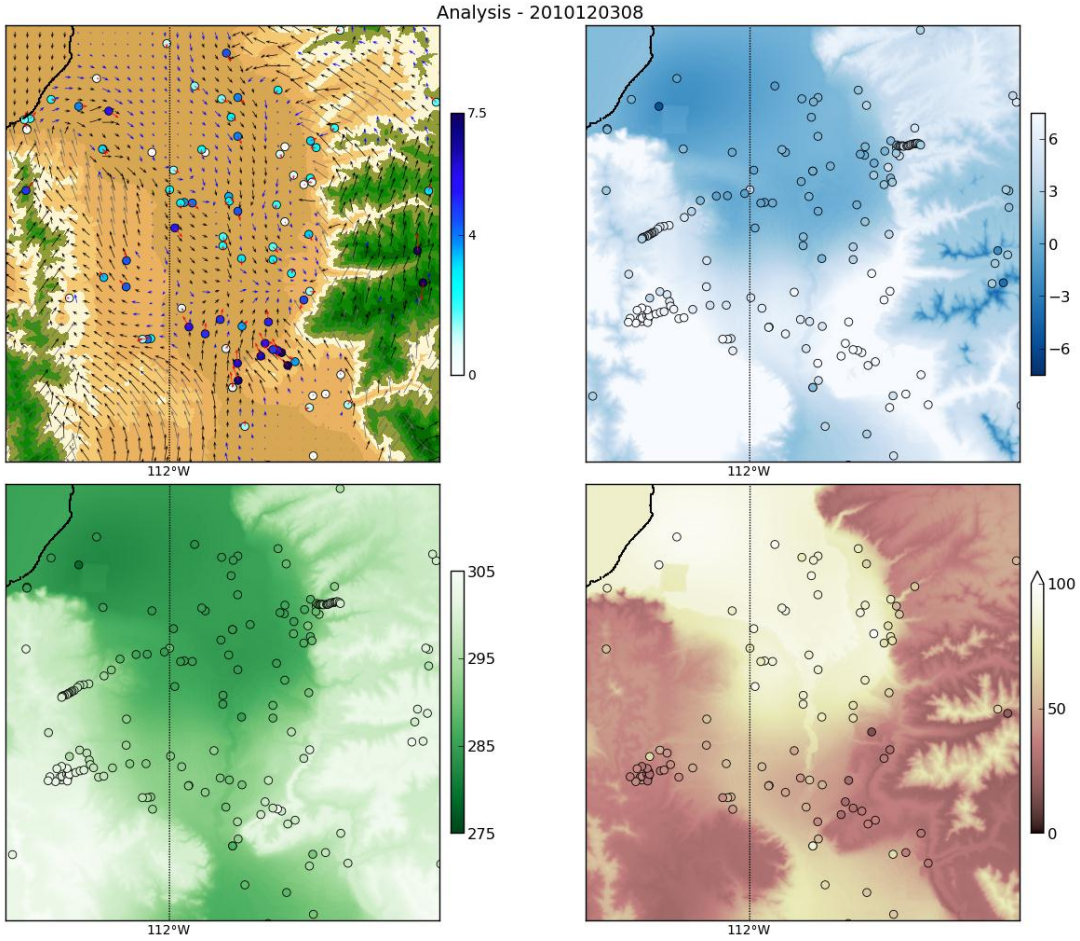

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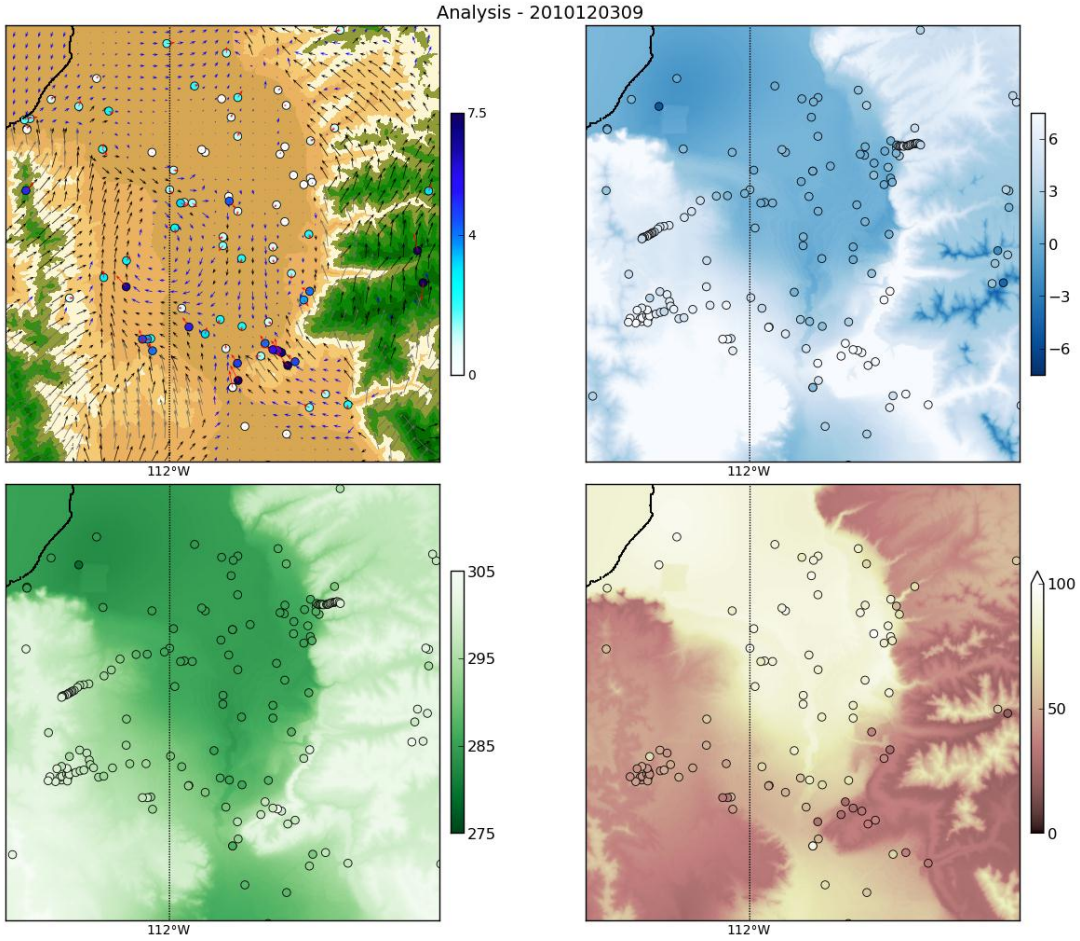

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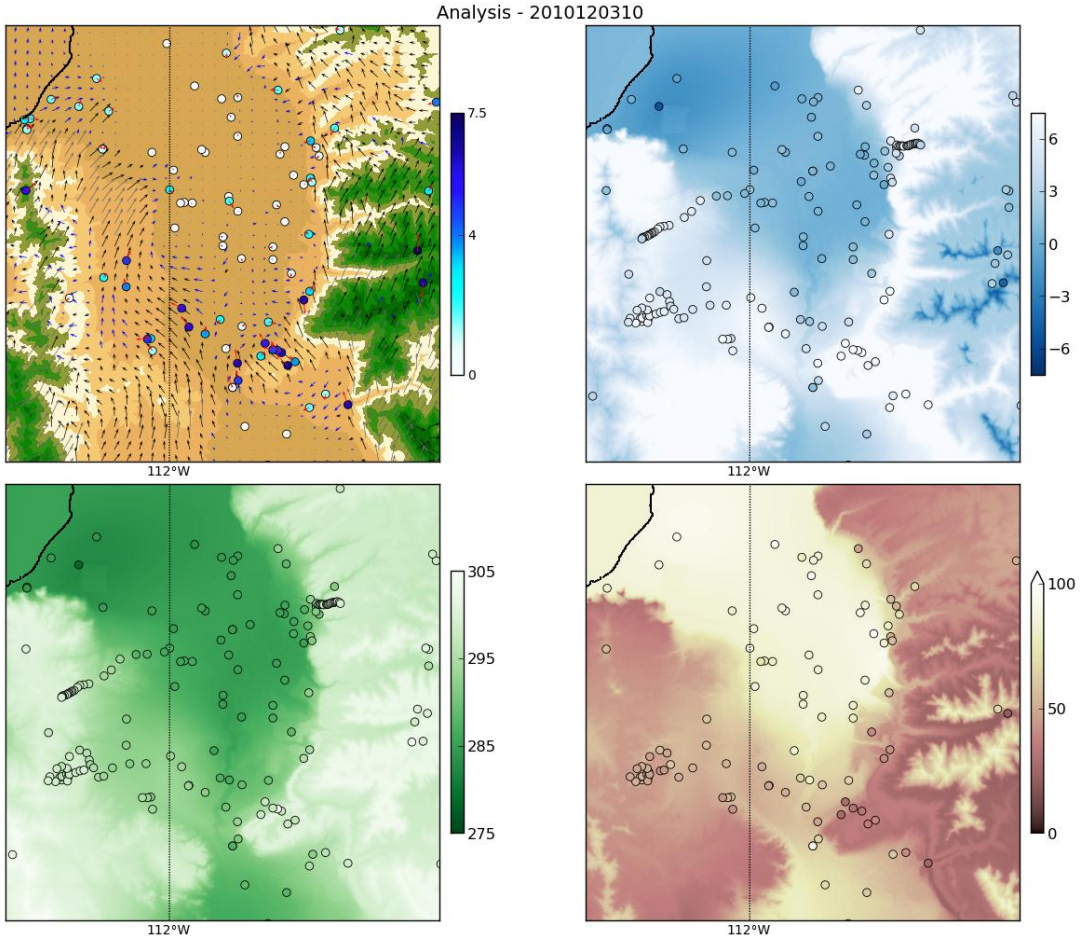

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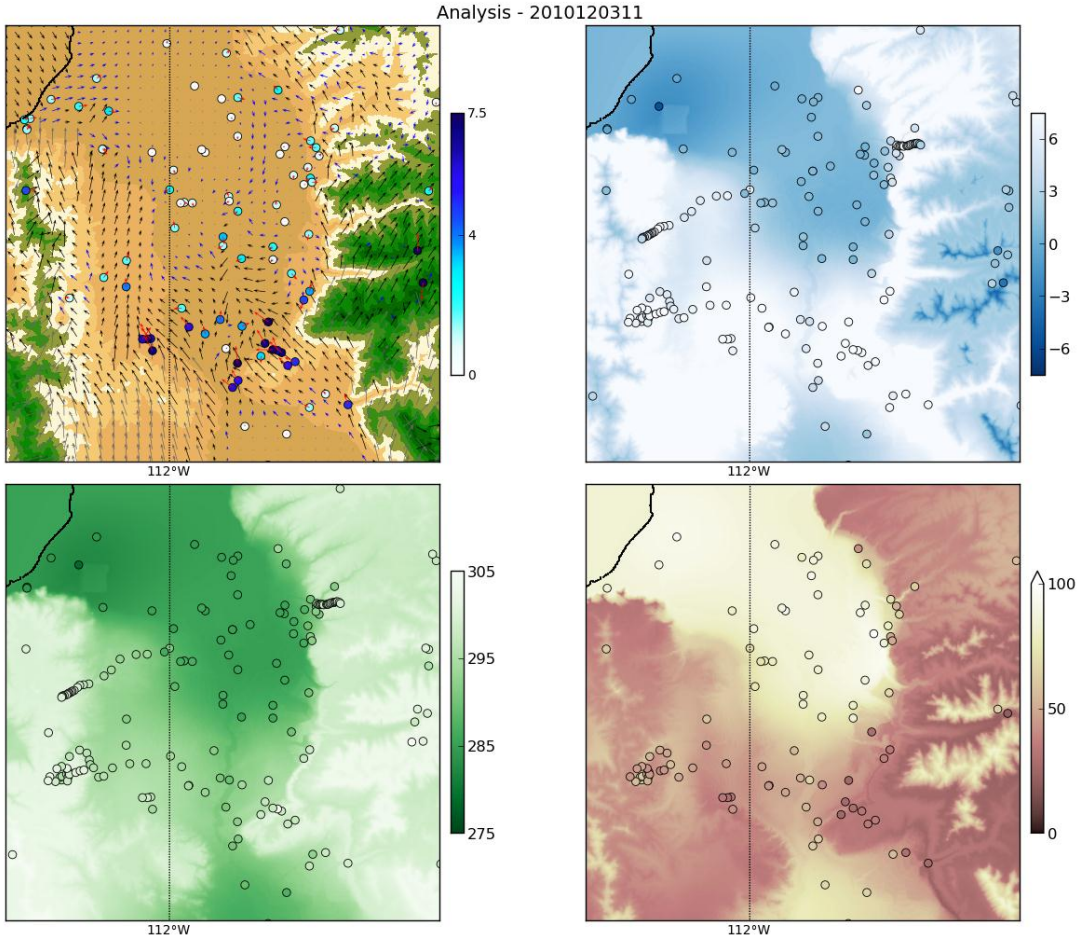
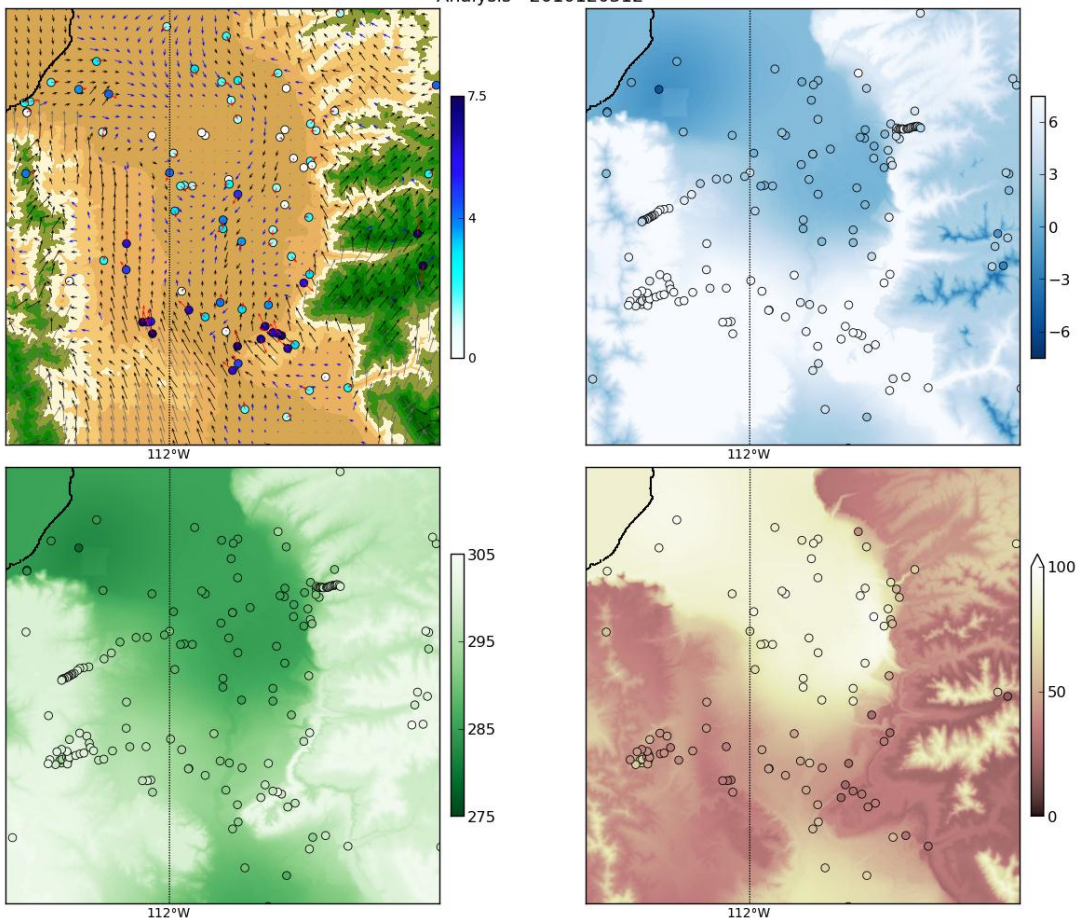


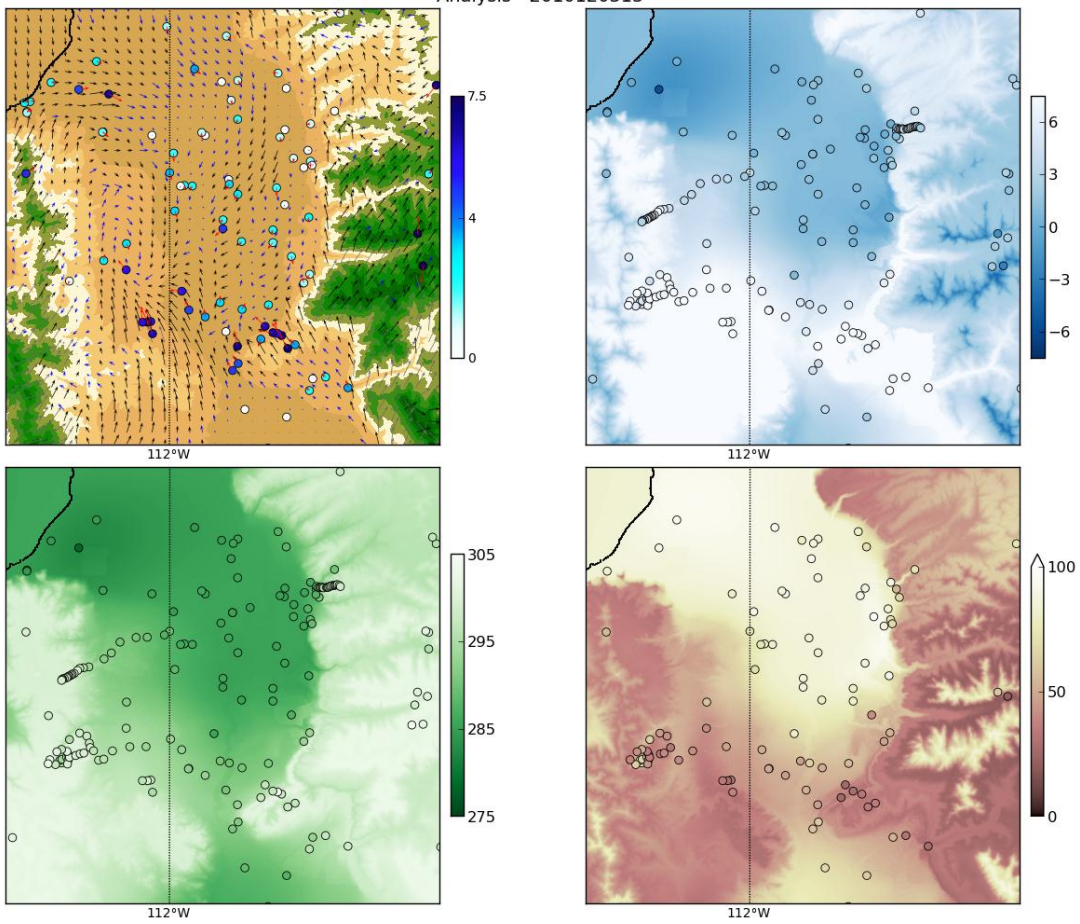
PCAPS
Persistent Cold-Air Pool Study

Analysis - 2010120312



PCAPS
Persistent Cold-Air Pool Study

Analysis - 2010120313



PCAPS
Persistent Cold-Air Pool Study

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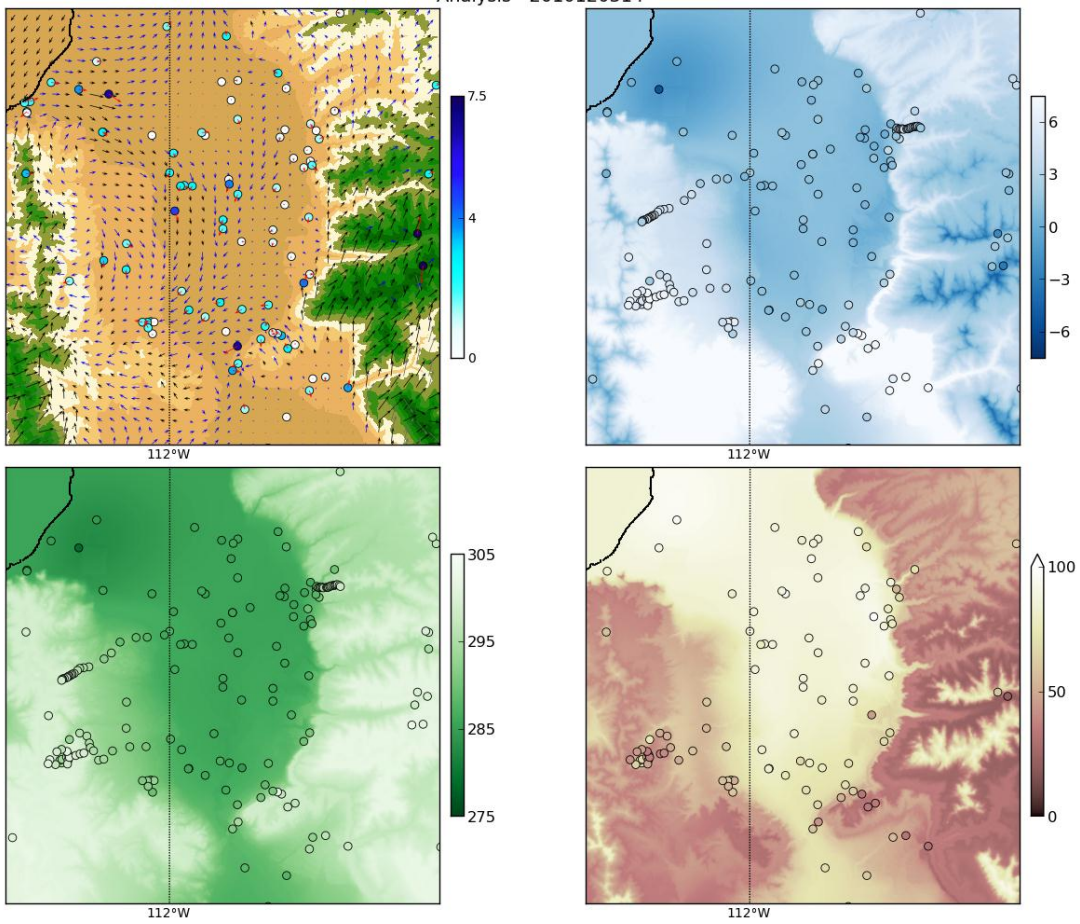
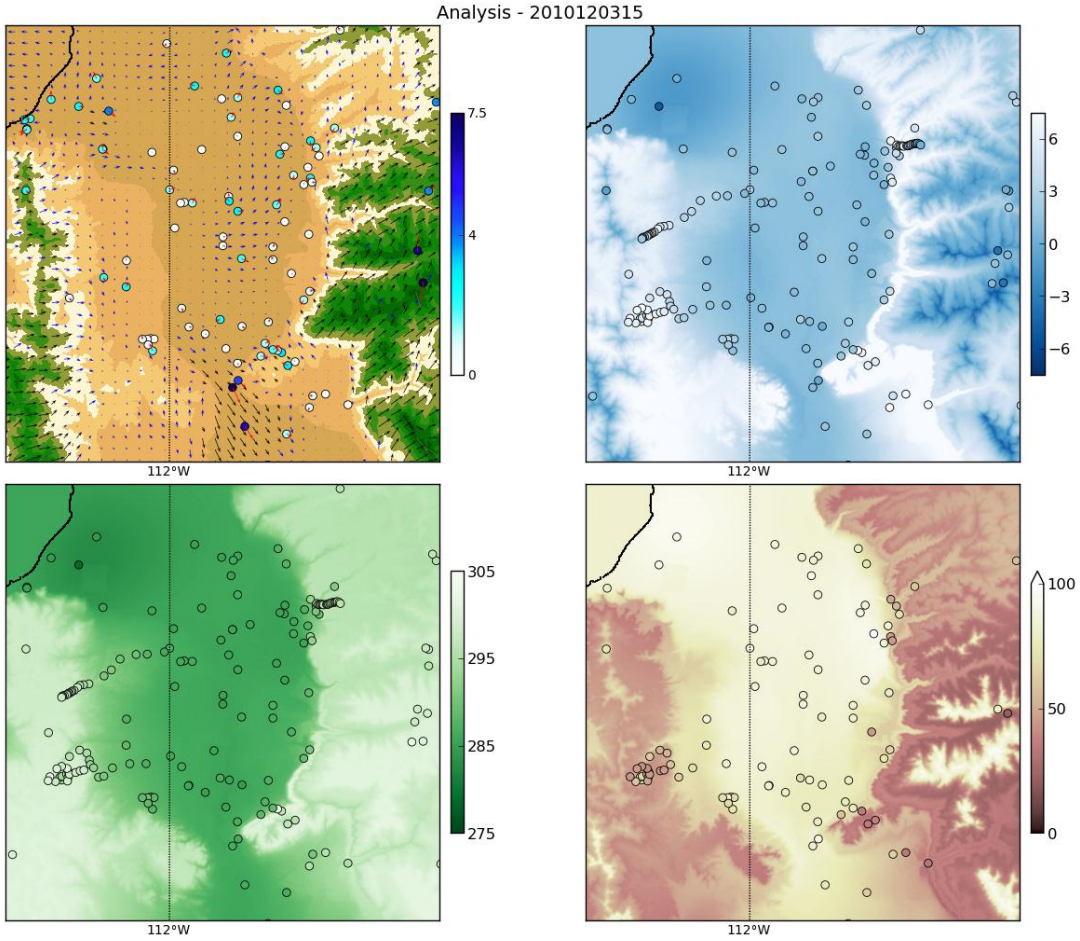


PCAPS
Persistent Cold-Air Pool Study



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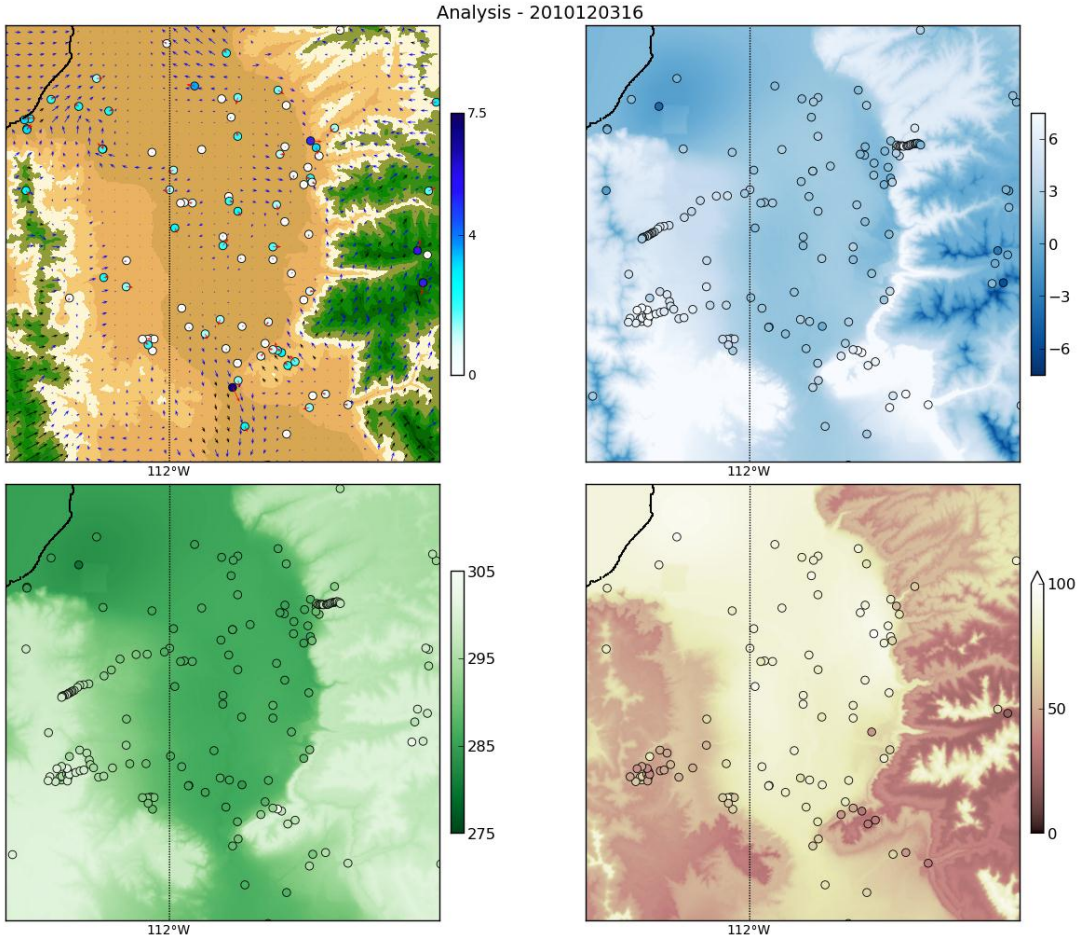
Persistent Cold-Air Pool Study



Presence vs. Structure of Persistent Cold-Air Pools

PCAPS
Persistent Cold-Air Pool Study

- You know one when you see one…
- Objectively identifying occurrence can be accomplished by many metrics but estimating intensity and structure is more difficult
- The criteria for stable boundary layer classification need to be sharpened with simultaneous measurement of vertical profiles and turbulence through the stable boundary layer (Fernando and Wier, 2010 BAMS)

Common Metrics

- Wolyn and McKee (1989; MWR): lapse rate < 2.5°C/km below 1.5 km AGL
- Reeves and Stensrud (2009; WAF); Reeves et al. (2011; WAF): Inversion below crest with wind speed < 5 m/s
- Liu and Liang (2010, JCLIM): PBL height derived from ~50,000 fine-resolution research soundings with stable BL defined by potential temperature gradients

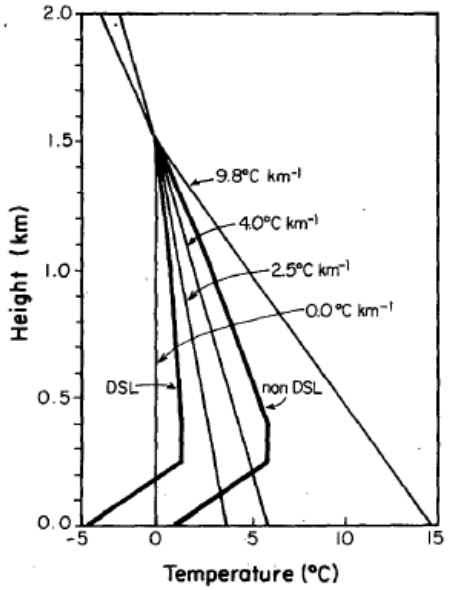
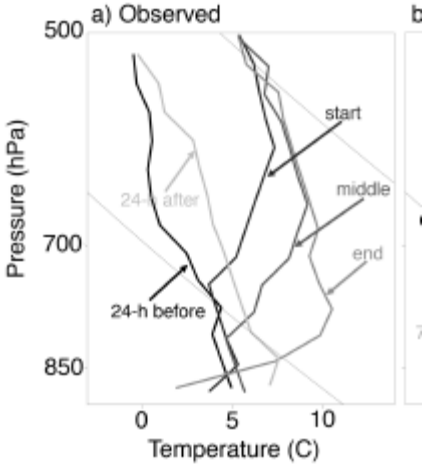


FIG. 2. A temperature versus height plot of a sounding which meets the DSL criteria and one which does not. The lighter lines are lapse rates of 9.8, 4.0, 2.5°C km^{-1}, and isothermal.



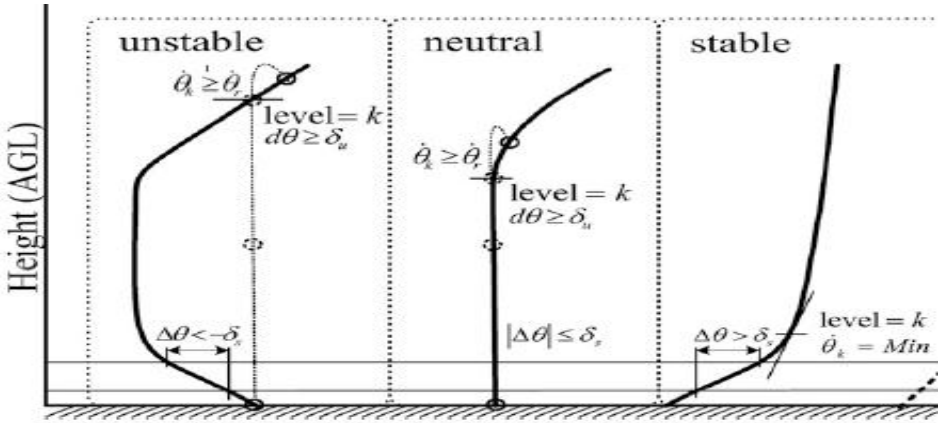
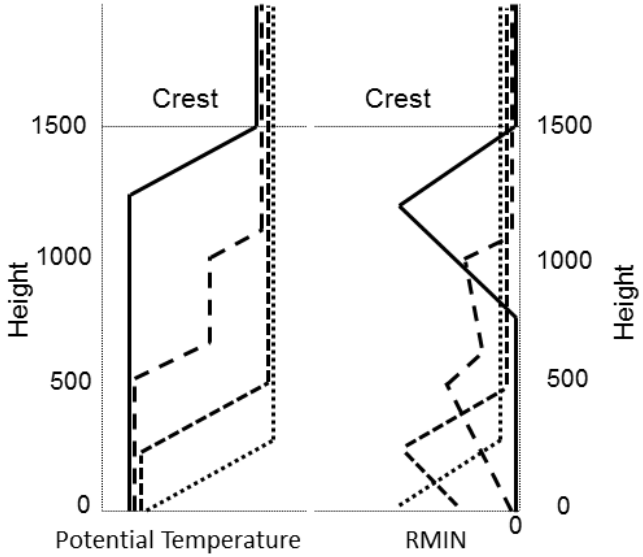


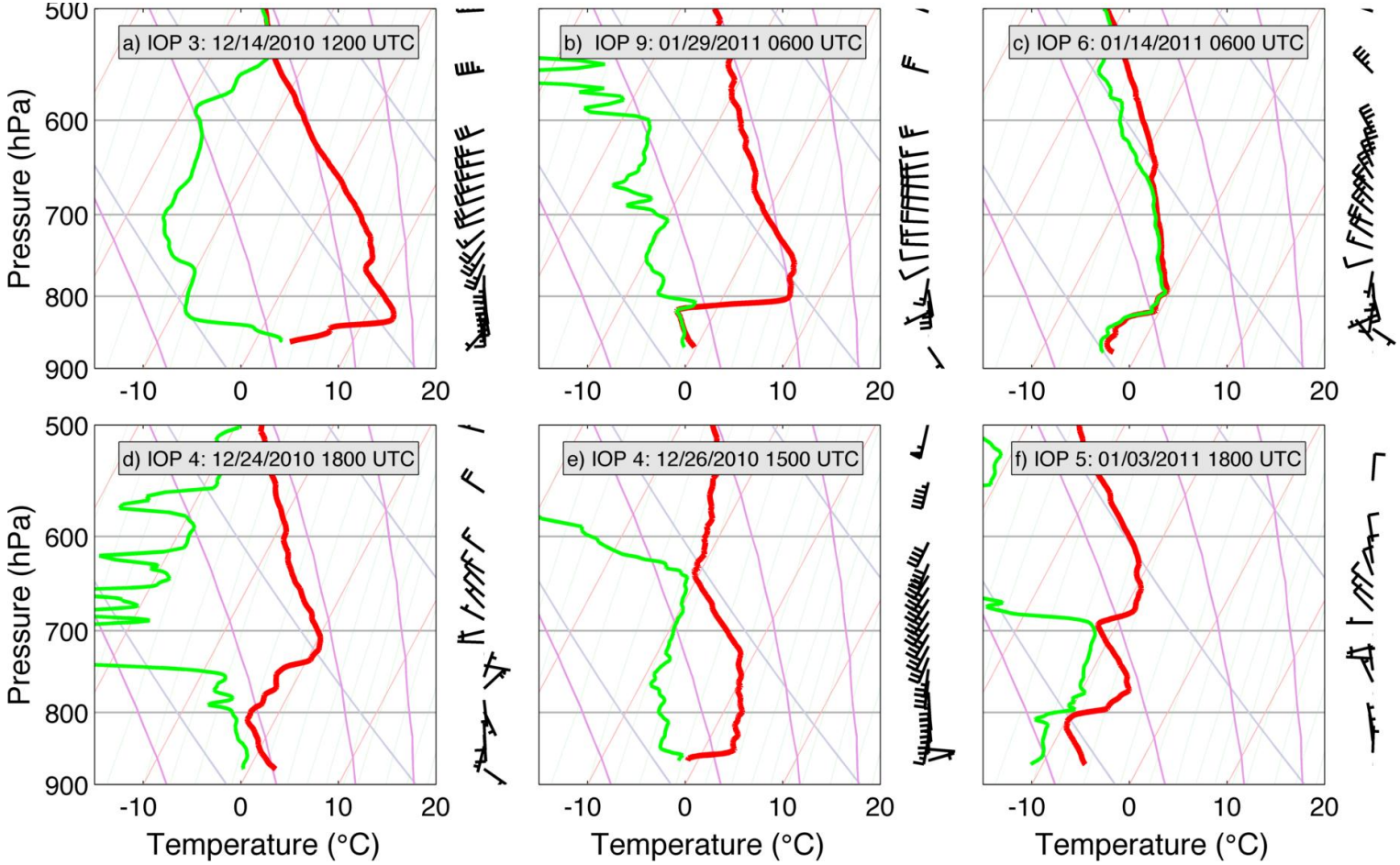
FIG. 3. Illustration of idealized PBL regimes (CBL, NRL, SBL) and PBLH

Approach

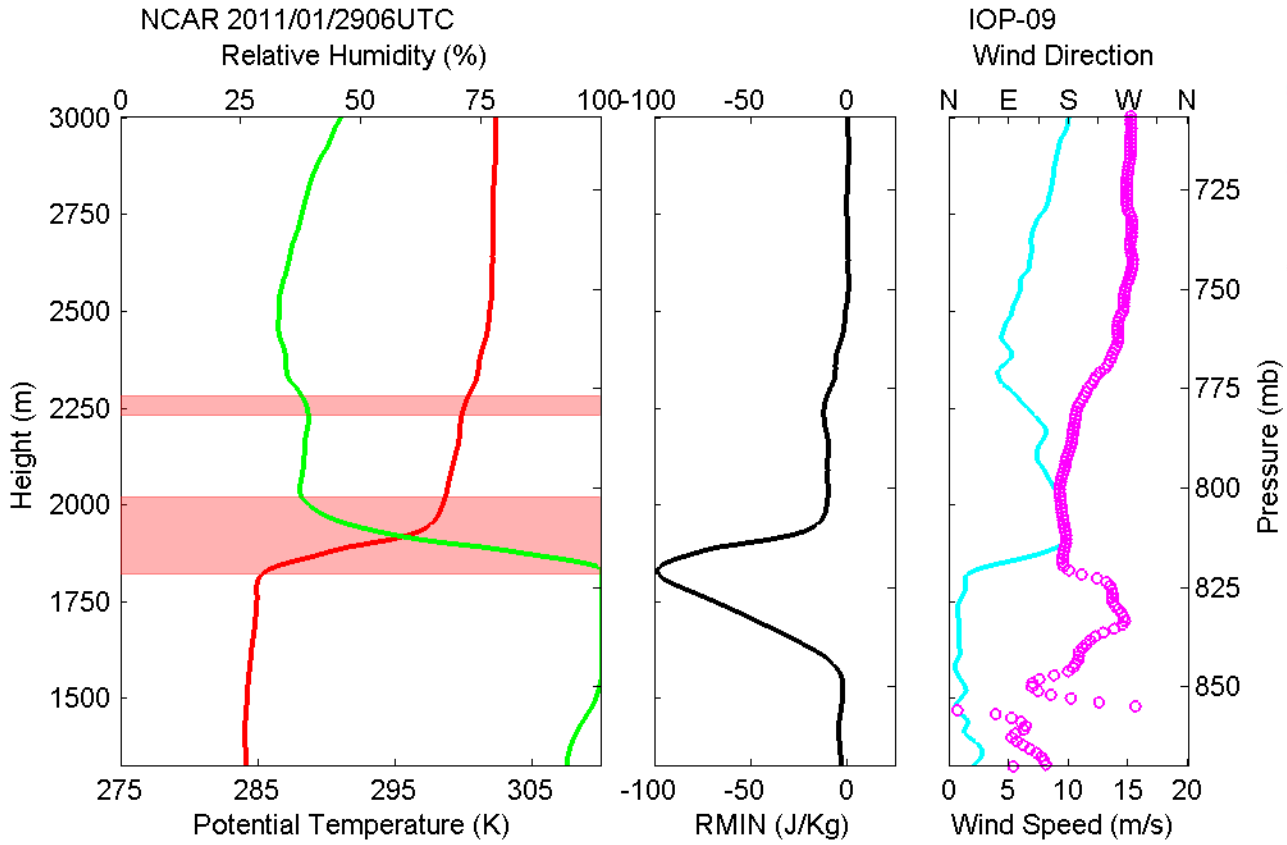
- Recast “Convective Inhibition” as “Rising Motion Inhibition (RMIN)”- work (J kg^{-1}) required to lift parcels adiabatically 300 m
- Maximum work required at base of stable layer base; least amount of work required at base of mixed layer
- If RMIN = -10 J kg^{-1}
  - then 4.5 m s^{-1} vertical velocity required to lift parcel 300 m

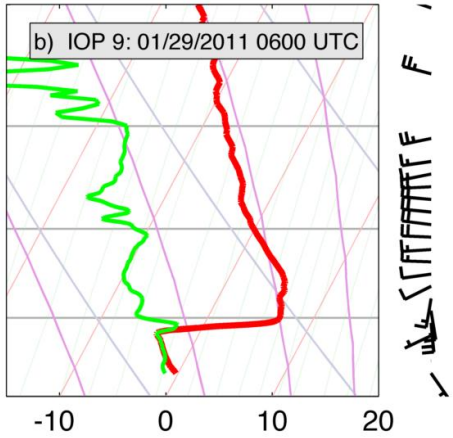


Representative Vertical Structures During PCAPS Cold Air Pools (Lareau et al. 2012)

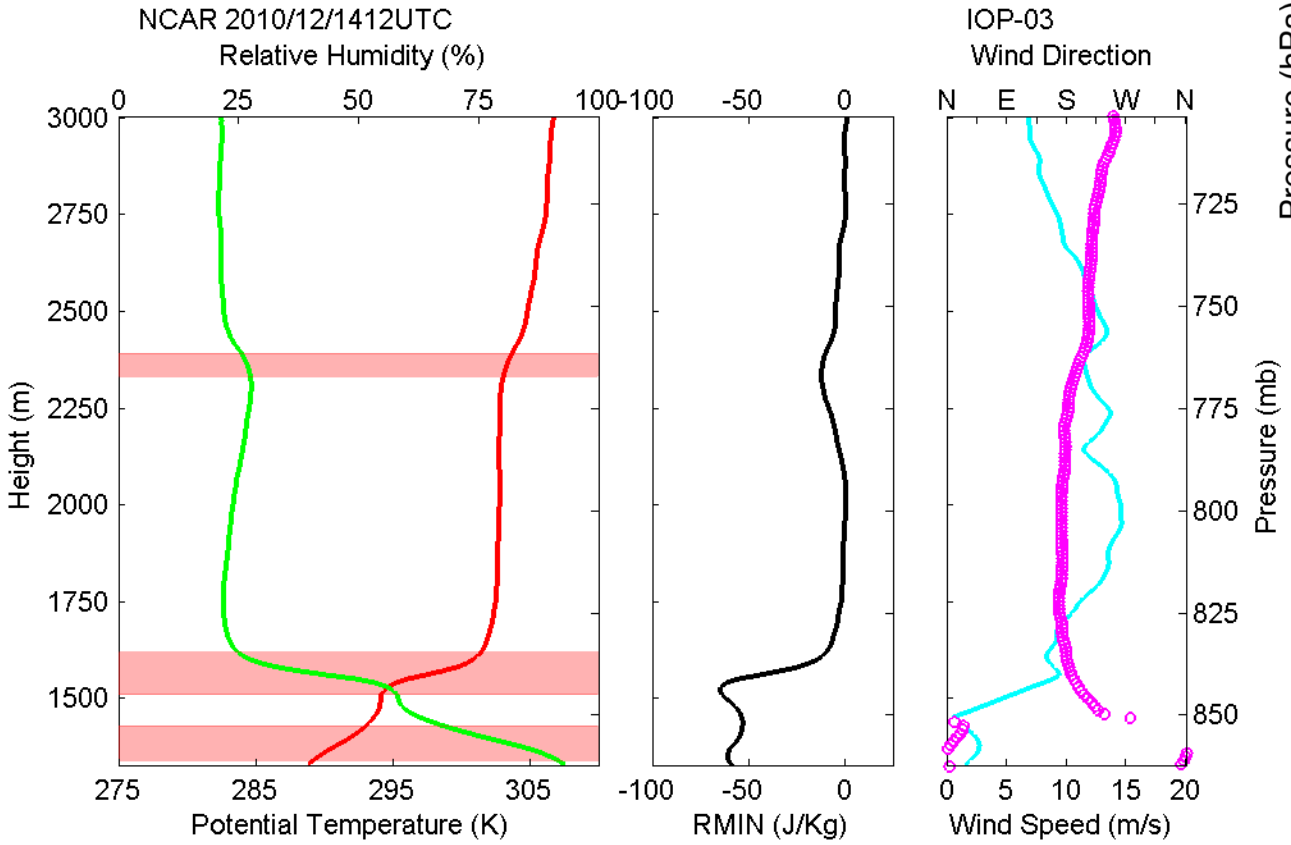


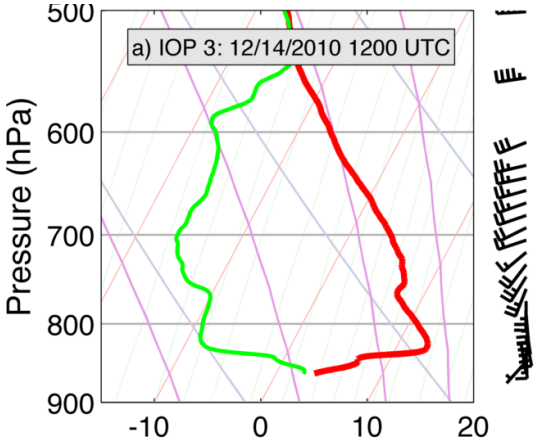
Representative Vertical Structures During PCAPS Cold Air Pools : ~500 m surface mixed layer



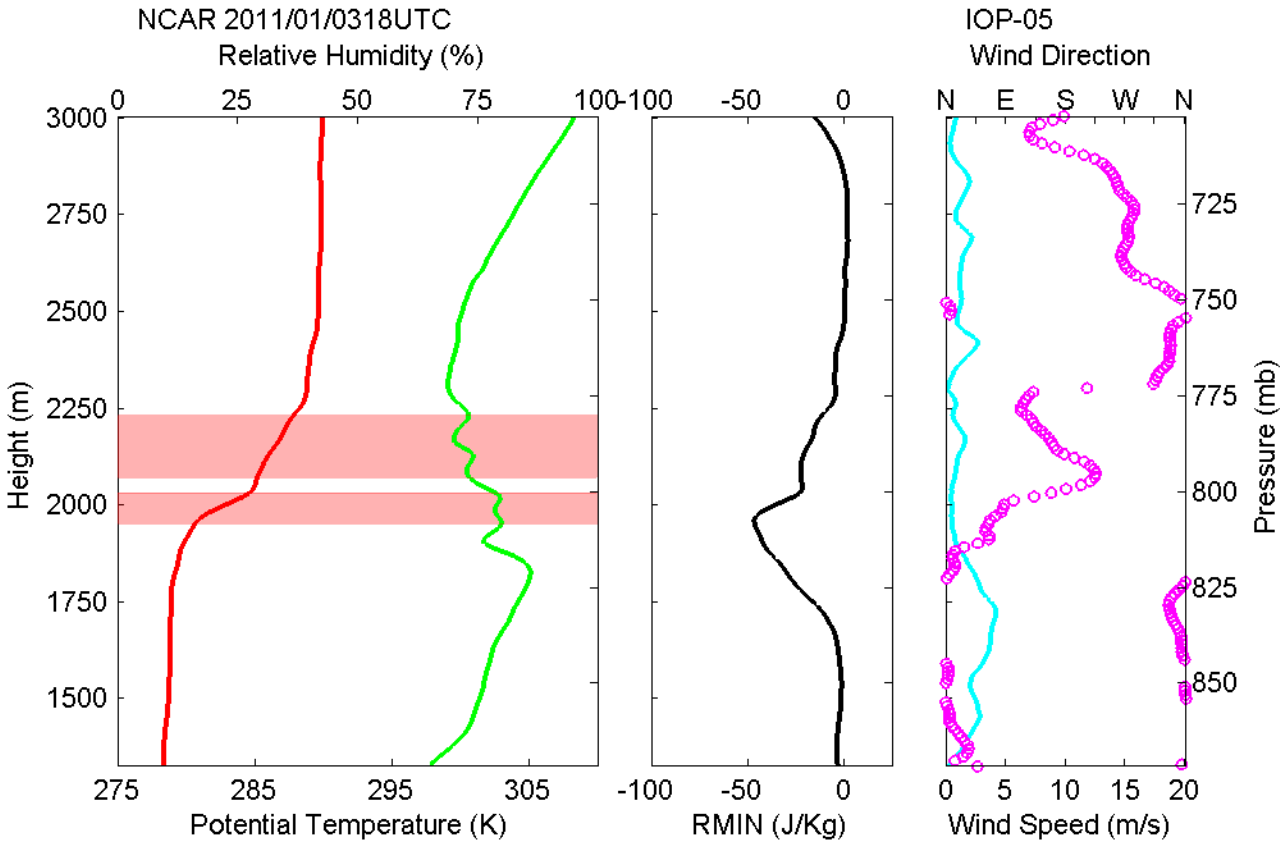


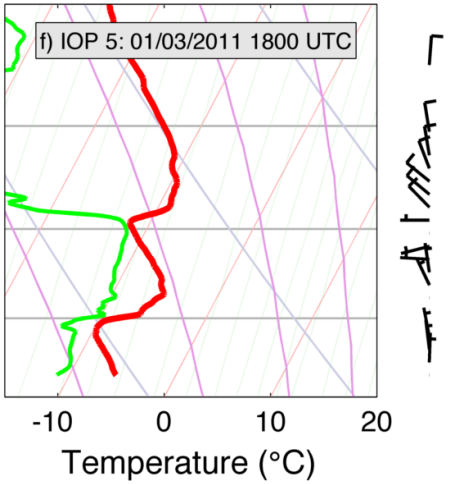
Representative Vertical Structures During PCAPS Cold Air Pools: ~100 m deep mixed layer between surface and elevated stable layers





IOP-5


NCAR 2011/01/0318UTC
Relative Humidity (%)
0
25
50
75
100
3000
2750
2500
2250
2000
1750
1500
Height (m)
275
285
295
305
Potential Temperature (K)
-100
-50
0
RMIN (J/Kg)
IOP-05
Wind Direction
N
E
S
W
N
725
750
775
800
825
850
Pressure (mb)
0
5
10
15
20
Wind Speed (m/s)

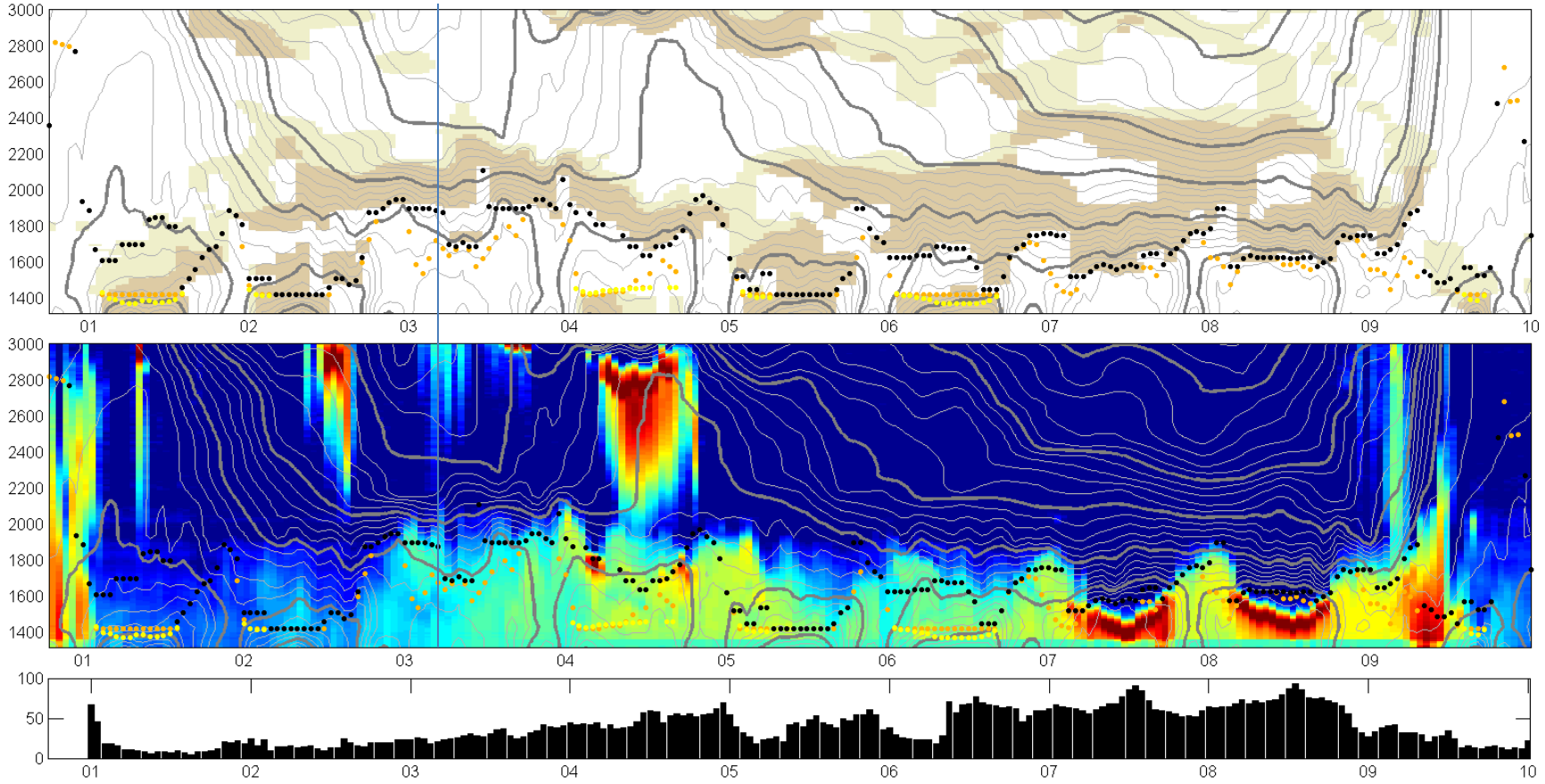

f) IOP 5: 01/03/2011 1800 UTC
-10
0
10
20
Temperature (°C)

Objectively defining mixed layer depth

- For surface based mixed layers, max elevation of:
  - Standard definition of mixed layer height based on lifting surface parcel with sfc temp +1K …or…
  - base of stable layer with RMIN ≤ -5 J kg^{-1}
- For surface based stable layers, max elevation of:
  - Base height of 100 m AGL adjusted as function of surface RMIN within 50-200 m AGL
  - Top of residual layer if prior mixed layer extending above top of existing surface stable layer

Time Evolution During IOP-5
1-10 January 2011

PCAPS
Persistent Cold-Air Pool Study



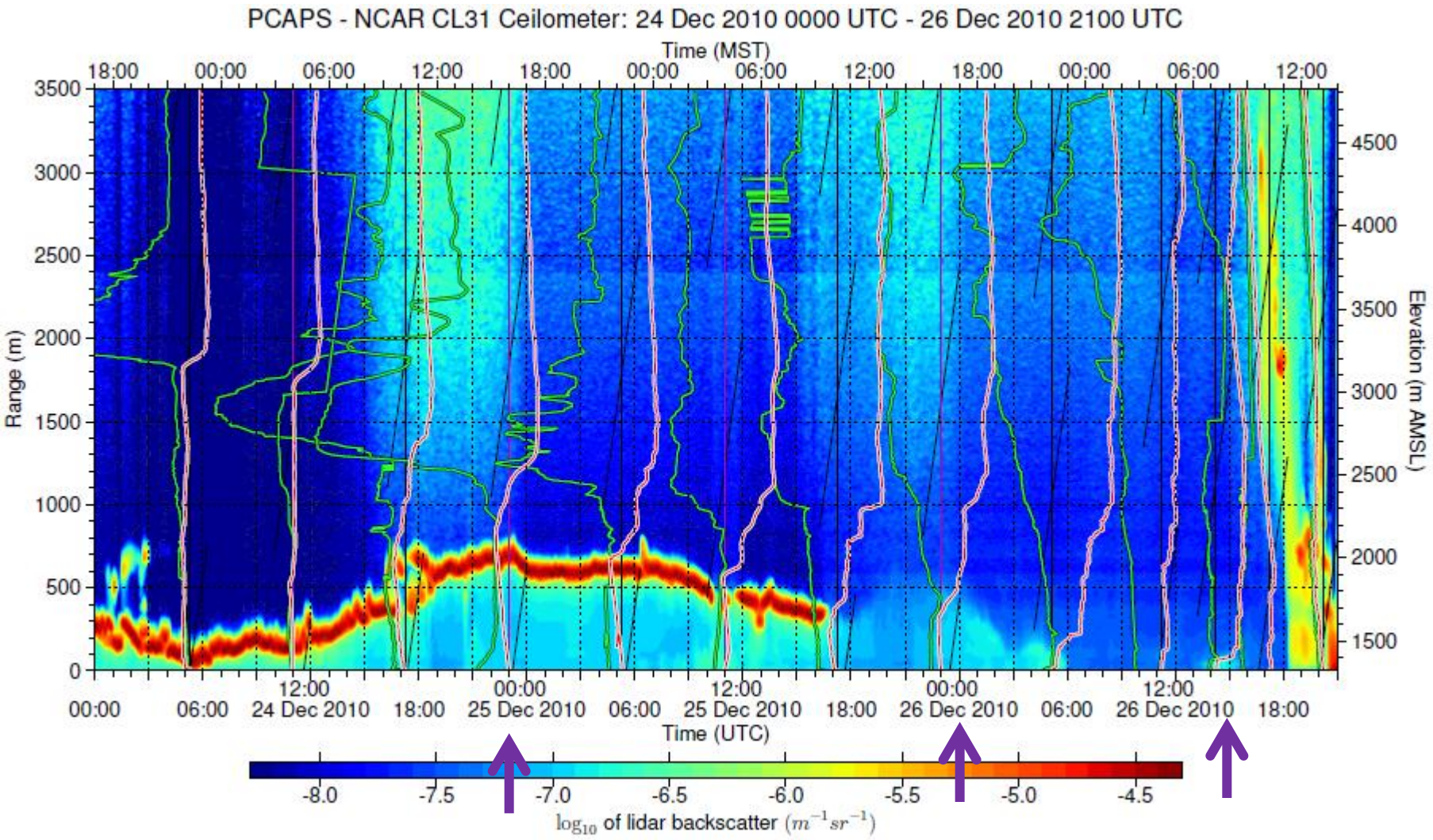
Summary

- PCAPS provides diverse cases to examine persistent cold-air pools
- Hourly surface analyses and vertical profiles available to characterize key aspects of PBL evolution during PCAPS
- RMIN serves as a metric of cold-air pool structure to help identify multiple stable layers and provide estimate of surface mixed layer depth
- See http://pcaps.utah.edu for more information

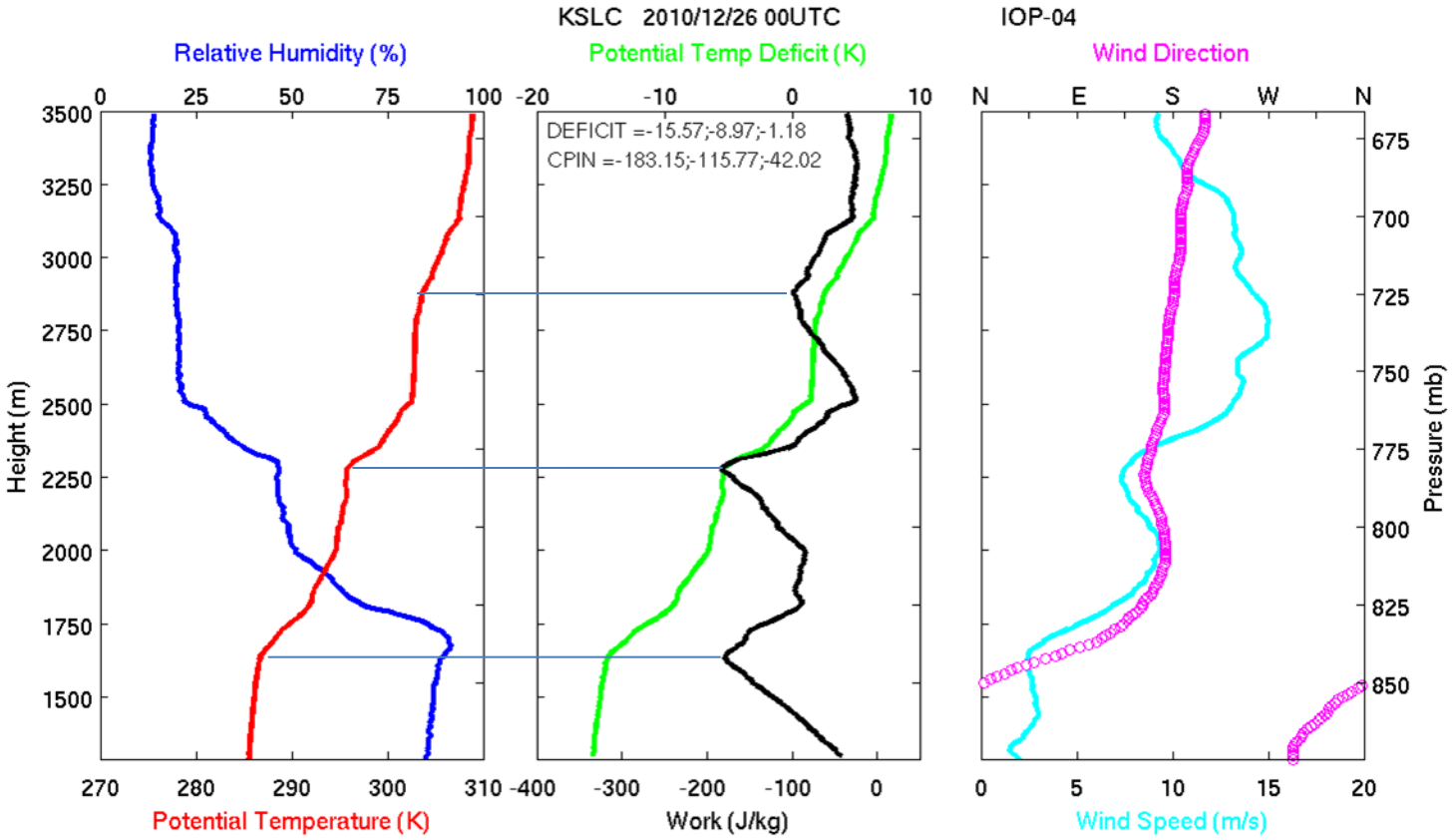
And thanks to all of our participants

IOP4: 12/24-12/26 2010

PCAPS
Persistent Cold-Air Pool Study

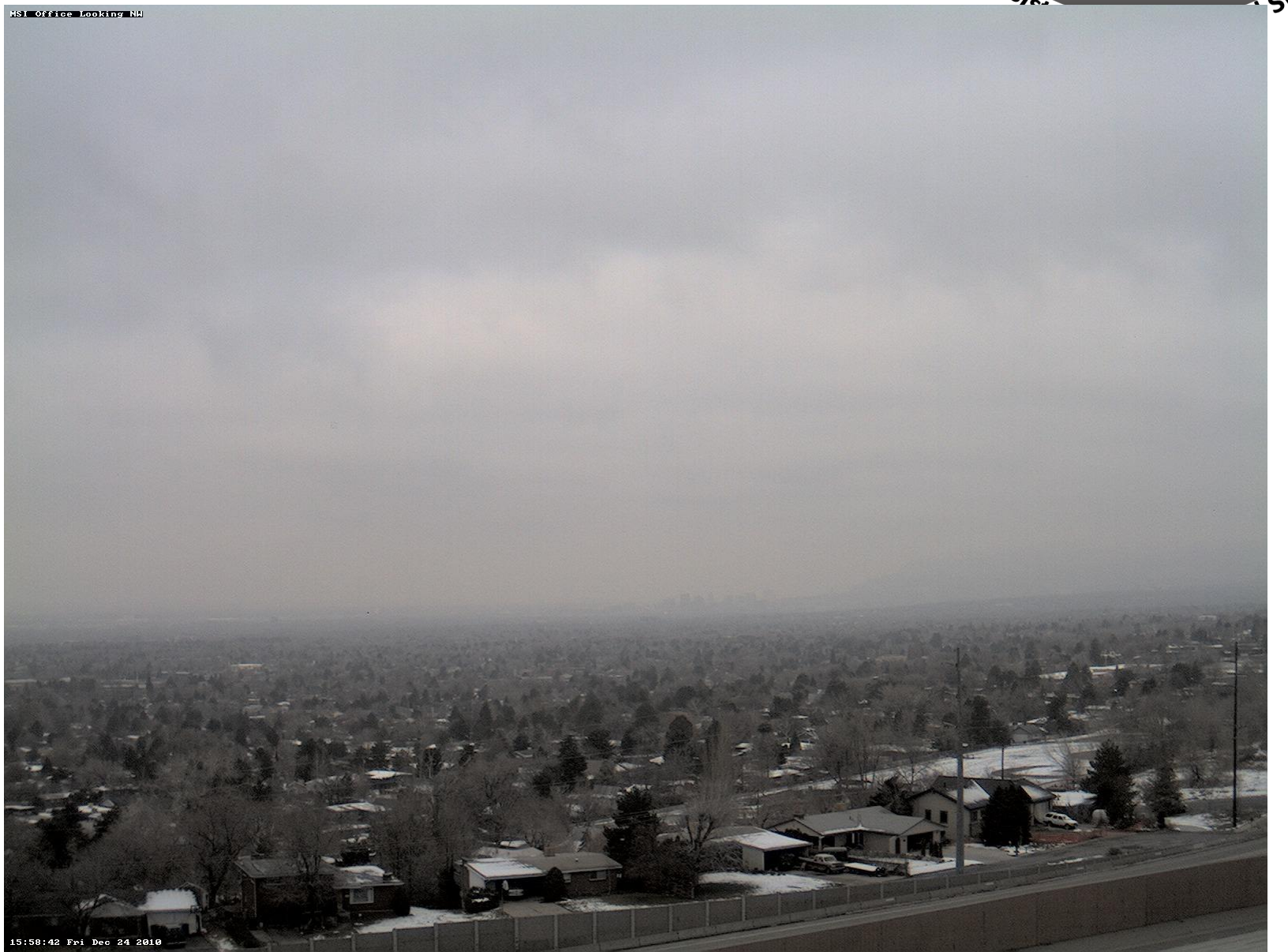


00 UTC 12/26


KSLC 2010/12/26 00UTC
IOP-04
Relative Humidity (%)
Potential Temp Deficit (K)
Wind Direction
DEFICIT =-15.57;-8.97;-1.18
CPIN =-183.15;-115.77;-42.02
Height (m)
Pressure (mb)
Potential Temperature (K)
Work (J/kg)
Wind Speed (m/s)
N E S W N

A Good Day: MSI Camera

“00 UTC 12/25”



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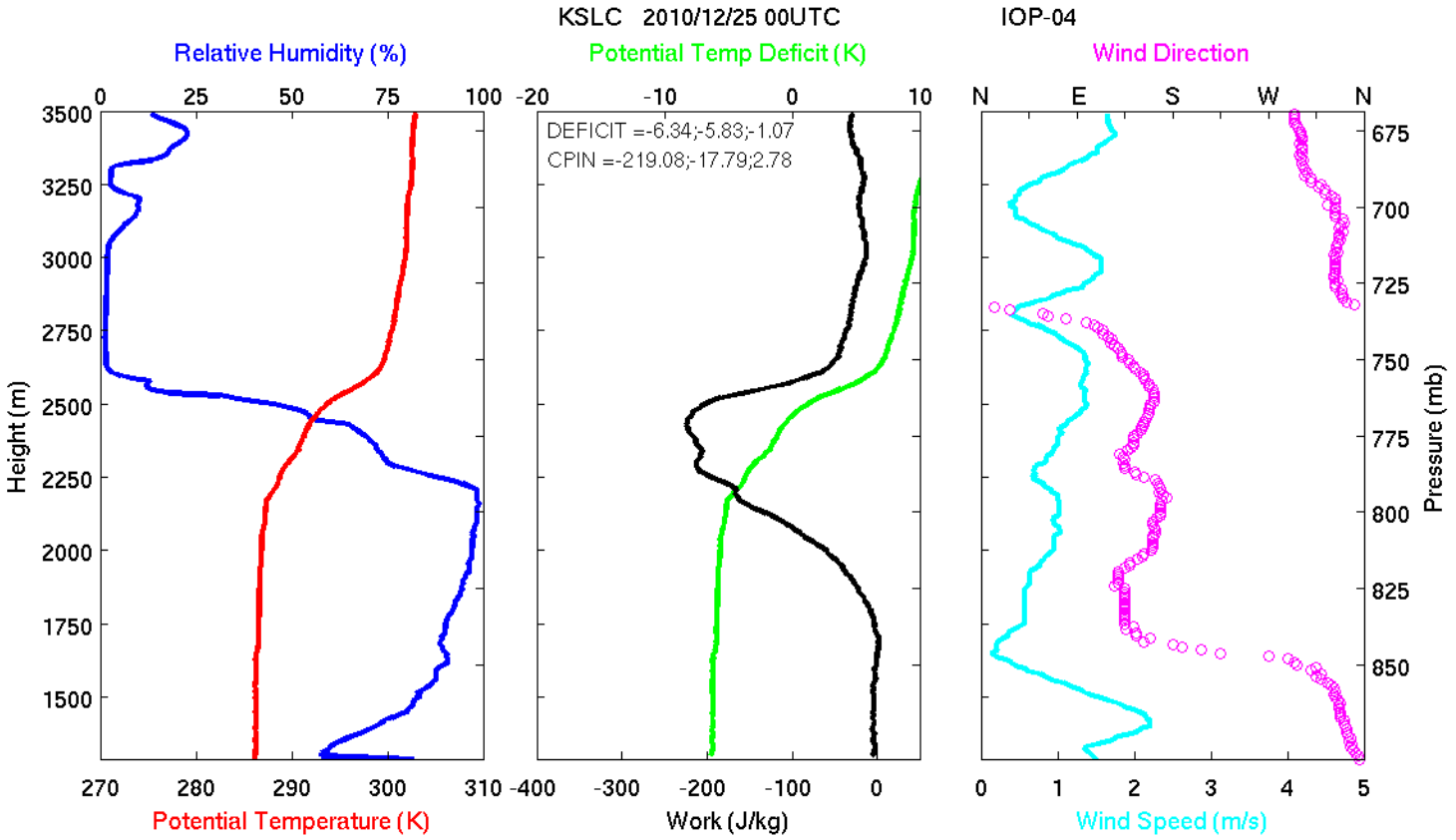
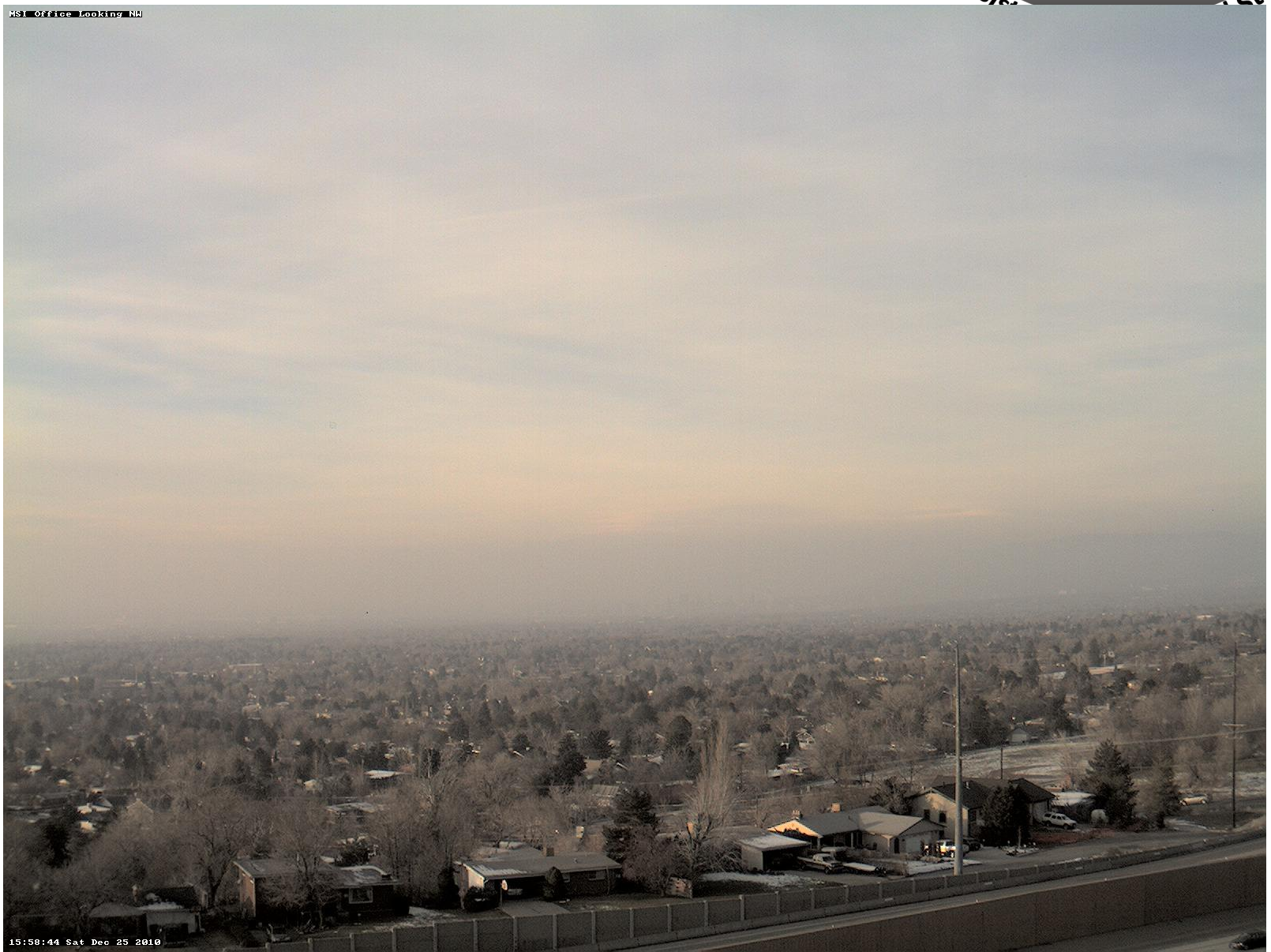
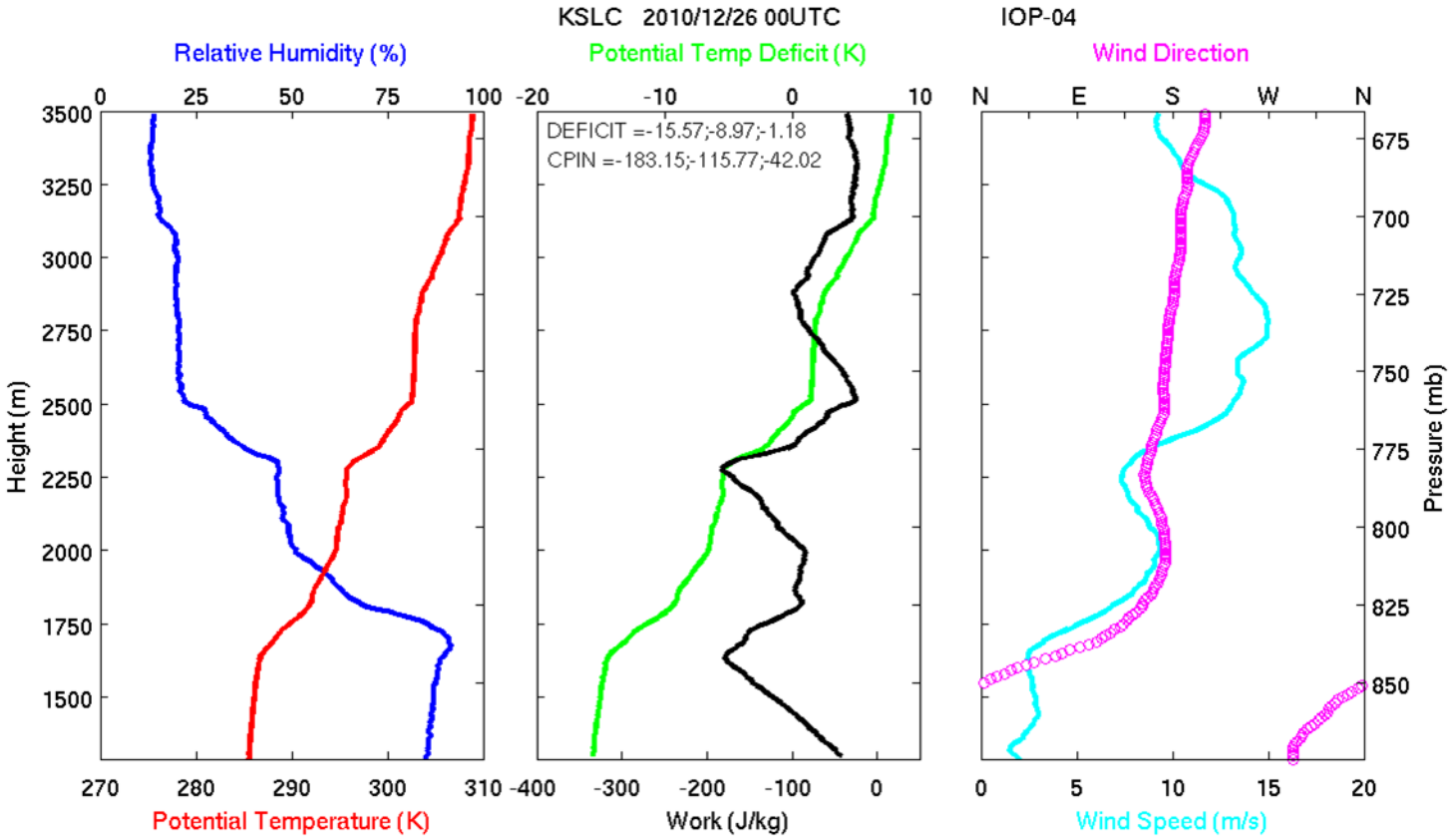

KSLC 2010/12/25 00UTC
IOP-04
Relative Humidity (%)
Potential Temp Deficit (K)
Wind Direction
DEFICIT =-6.34;-5.83;-1.07
CPIN =-219.08;-17.79;2.78
Height (m)
Pressure (mb)
Potential Temperature (K)
Work (J/kg)
Wind Speed (m/s)
N E S W N

“00 UTC 12/26”

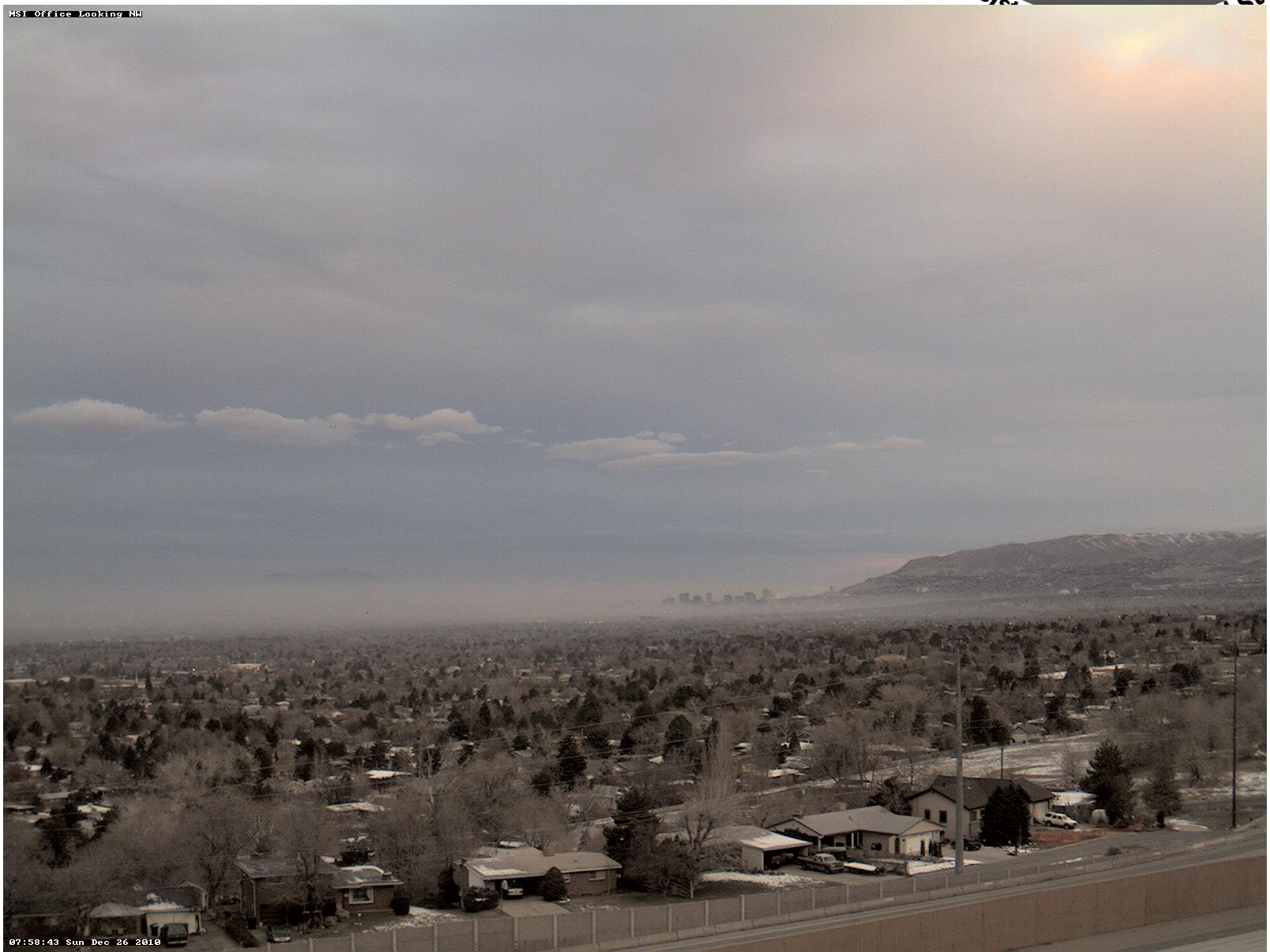


00 UTC 12/26

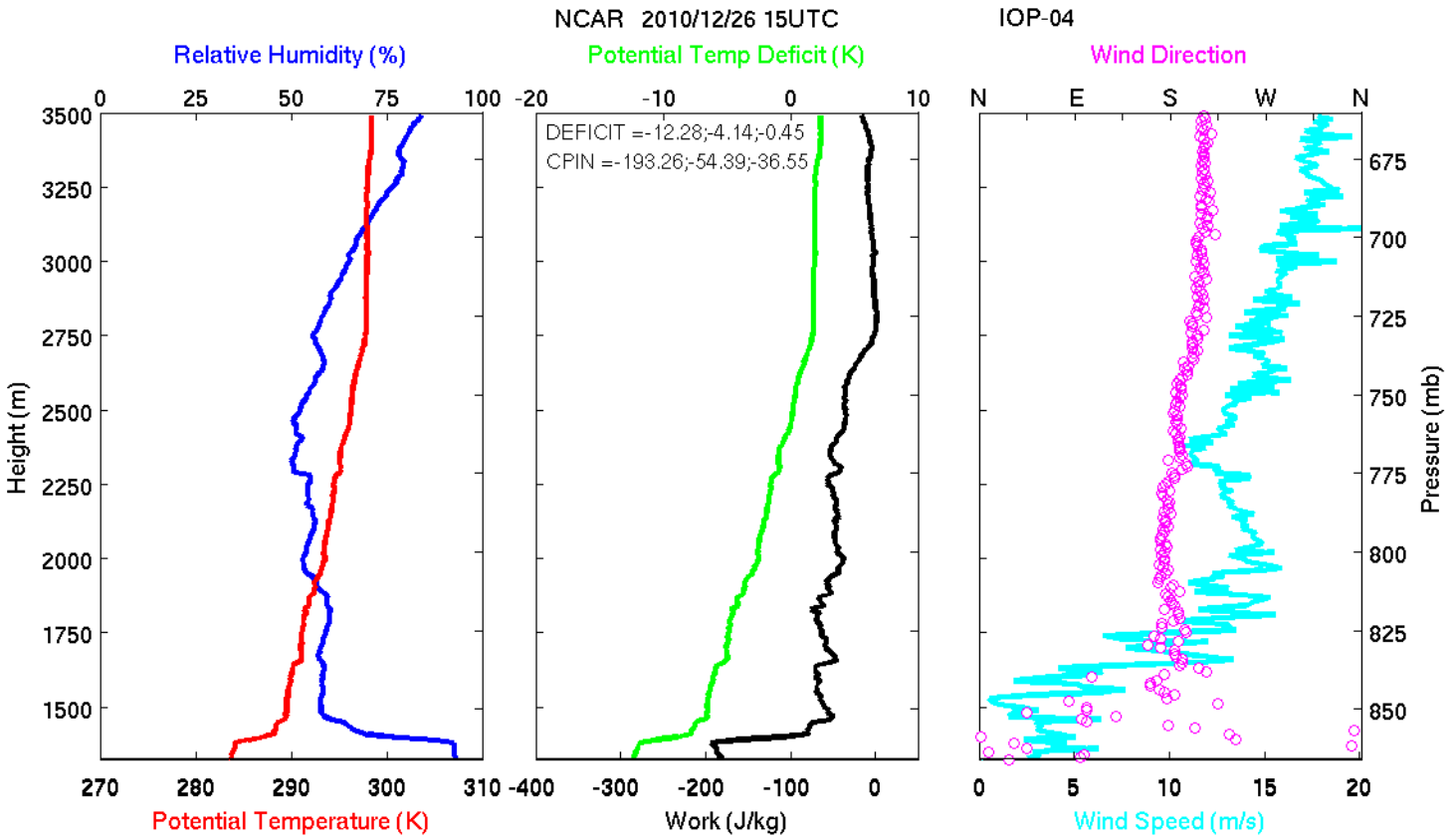
PCAPS
Persistent Cold-Air Pool Study



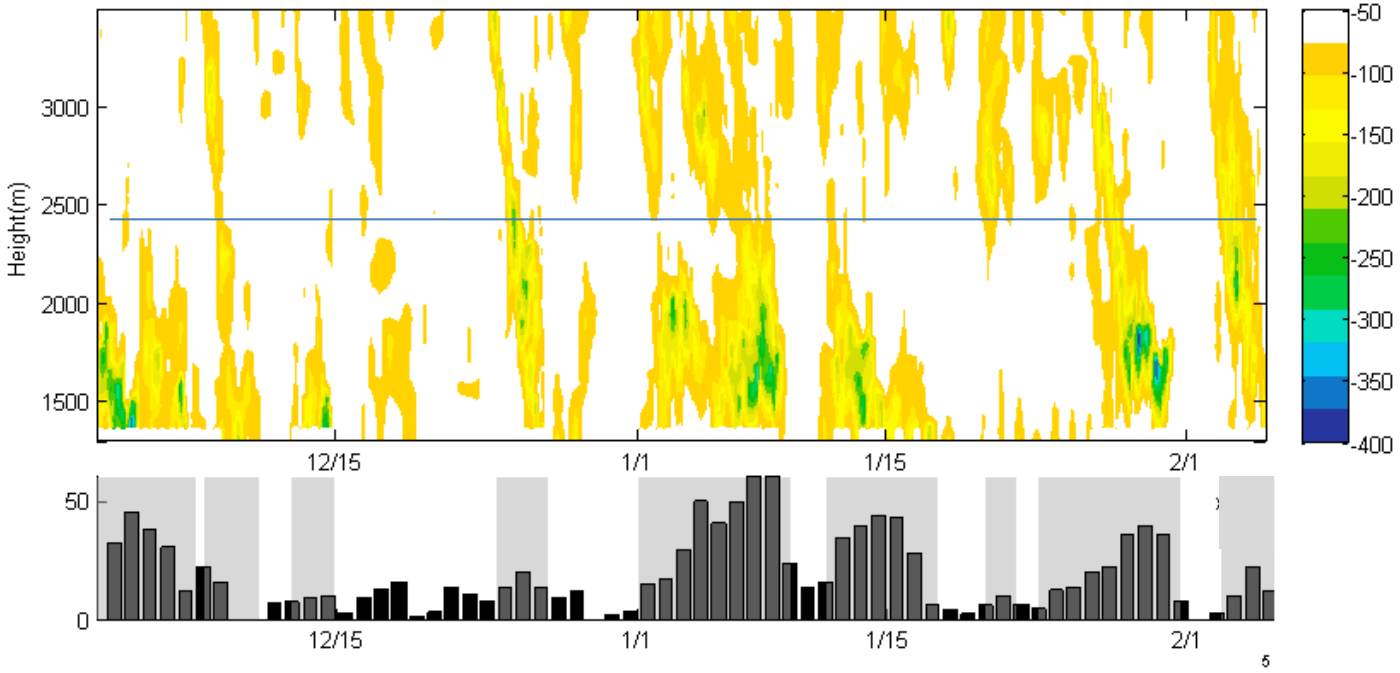
“15 UTC 12/26”



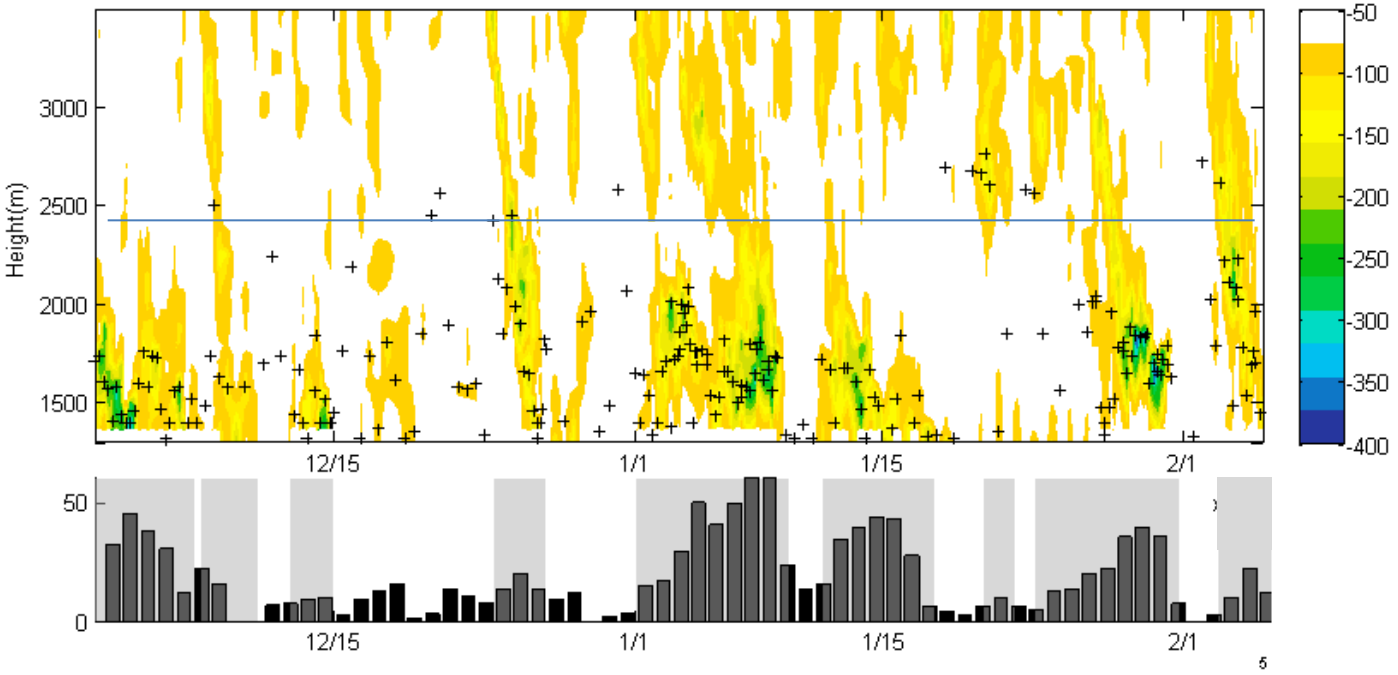
15 UTC 12/26


NCAR 2010/12/26 15UTC
IOP-04
Relative Humidity (%)
Potential Temp Deficit (K)
Wind Direction
DEFICIT =-12.28;-4.14;-0.45
CPIN =-193.26;-54.39;-36.55
Height (m)
Pressure (mb)
Potential Temperature (K)
Work (J/kg)
Wind Speed (m/s)
0 25 50 75 100
-20 -10 0 10
N E S W N
3500 3250 3000 2750 2500 2250 2000 1750 1500
675 700 725 750 775 800 825 850
270 280 290 300 310
-400 -300 -200 -100 0
0 5 10 15 20

PCAPS: CPIN(J/kg)

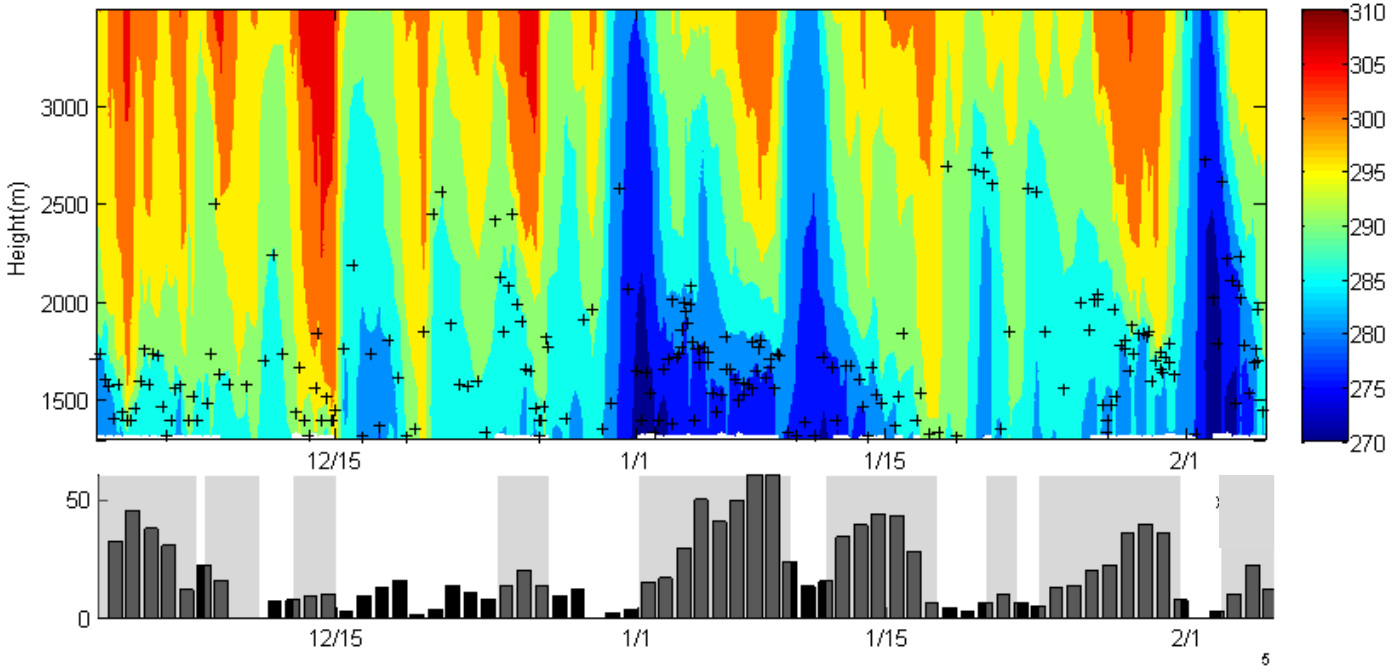


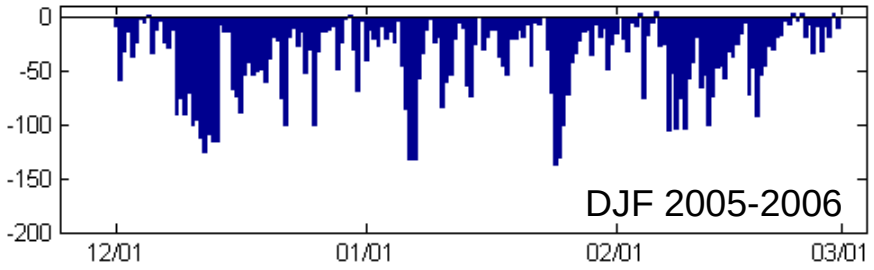
PCAPS: CPIN(J/kg)

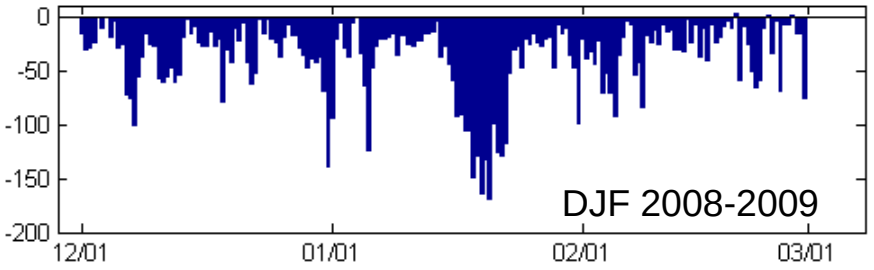


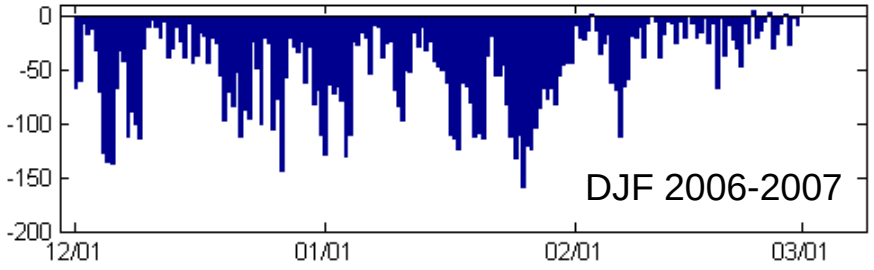
+ estimate of top of mixed layer defined by lowest minimum in CPIN above surface

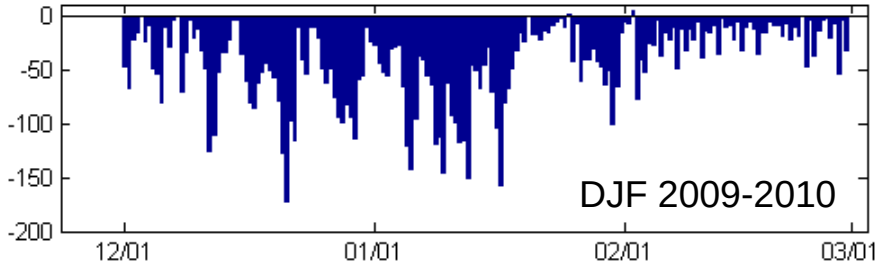
PCAPS: θ(K)
with estimate of mixed layer height

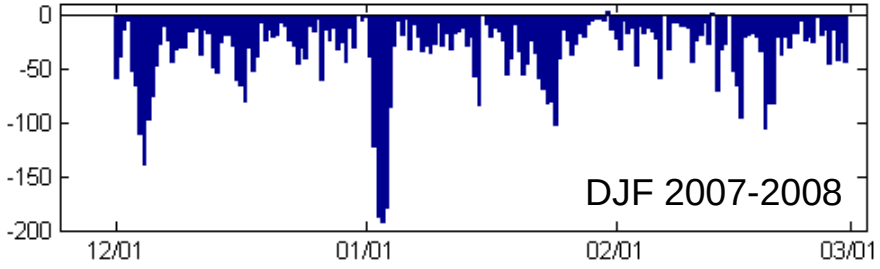


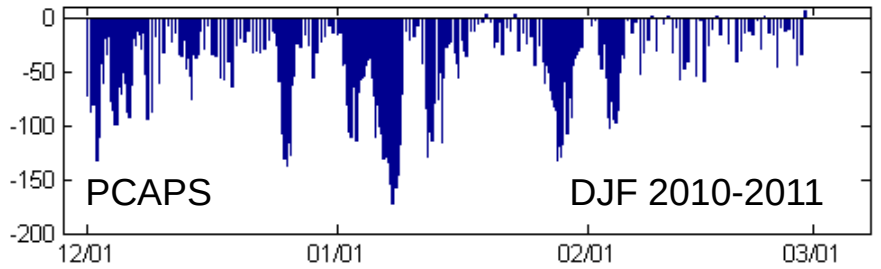






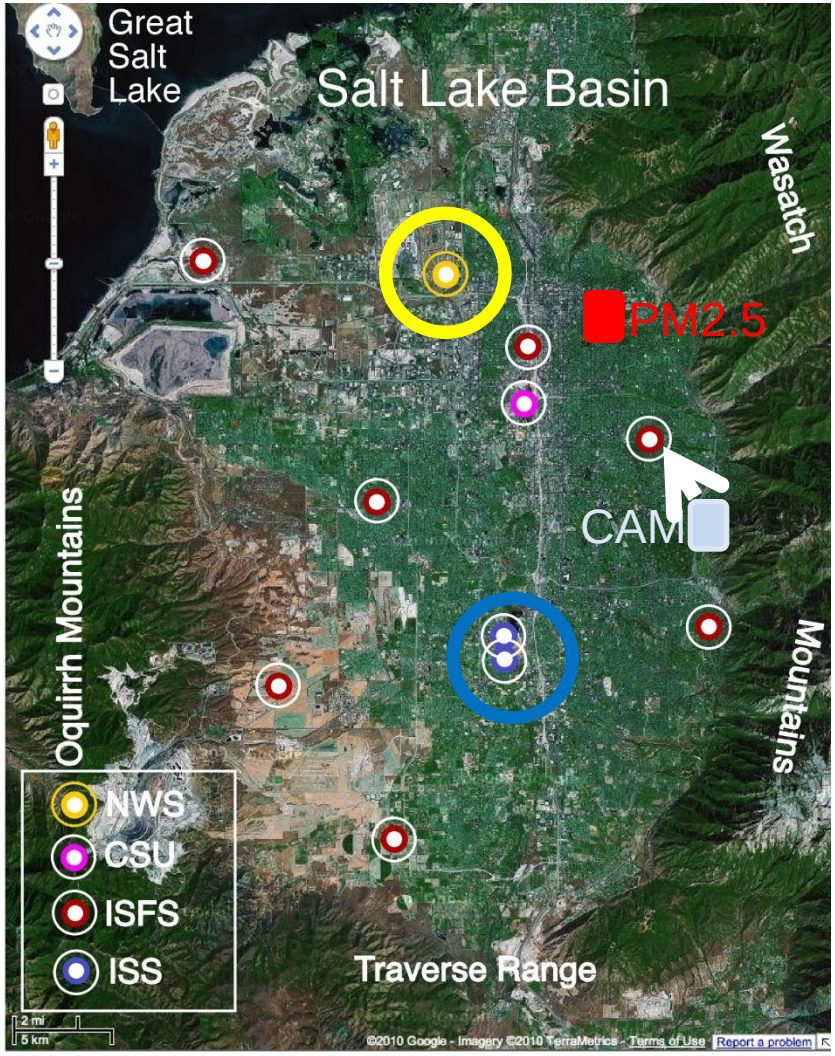




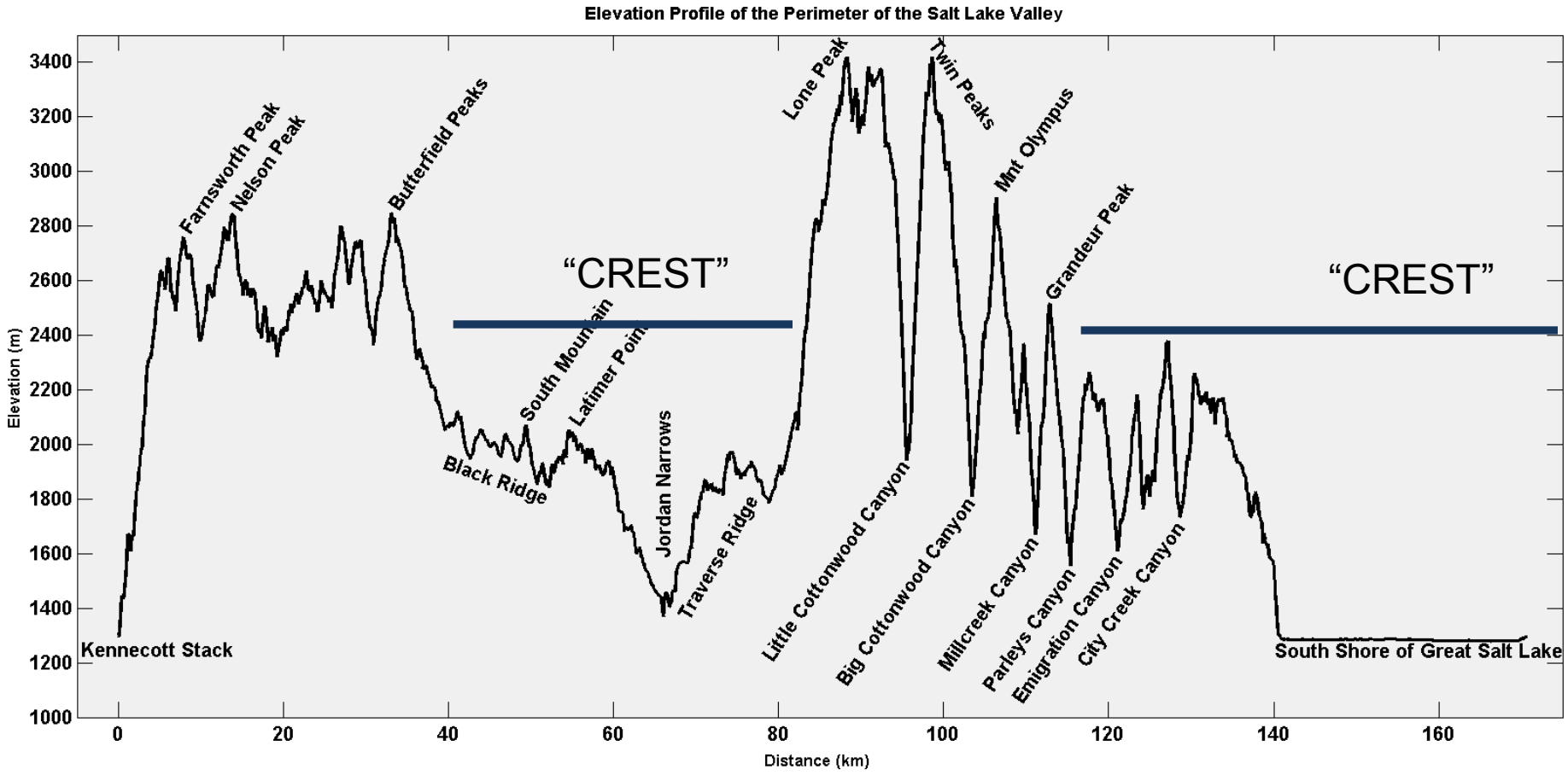


Salt Lake Valley CPIN (J/kg): 2006-2011 Winters
Averaged within layer from surface to crest (2400 m)
NWS GPS High Resolution Sondes

PCAPS: Salt Lake Valley



Terrain Surrounding Salt Lake Valley



WEST SOUTH EAST NORTH