Determining Atmospheric Boundary Layer Behavior over Mountainous Terrain Using Aircraft Vertical Profiles from 2009-2018 NASA Student Airborne Research Program Data

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SARP
NATIONAL SUBORBITAL RESEARCH CENTER

Finding Boundary Layer Heights over Mountains Is Important

Pollution

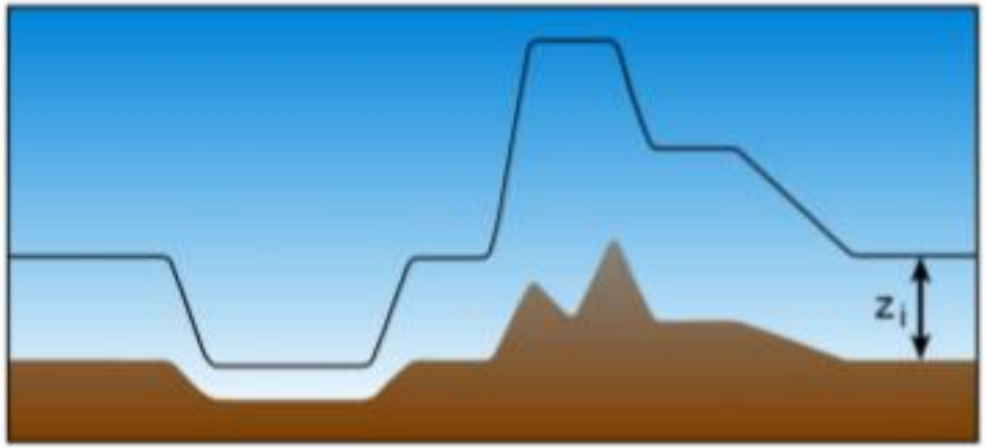
Weather Models

Greenhouse Gas Monitoring

Four Boundary Layer Behaviors over Mountains

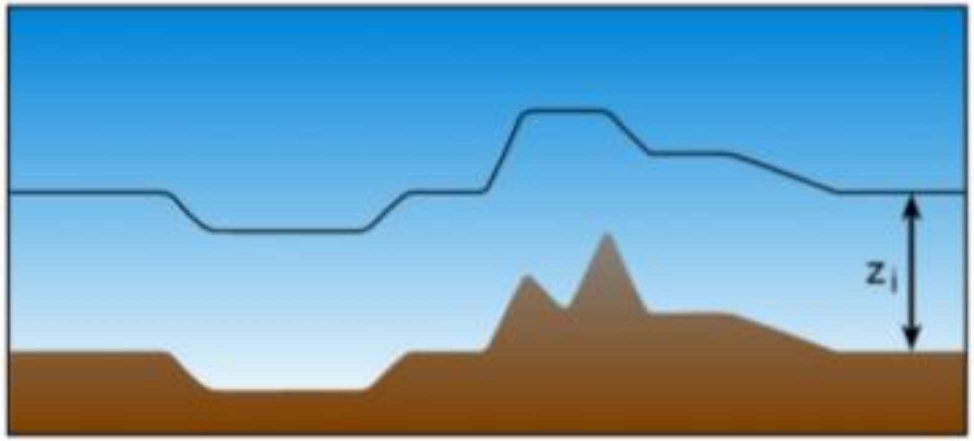
Hyper Terrain Following (HT)

A



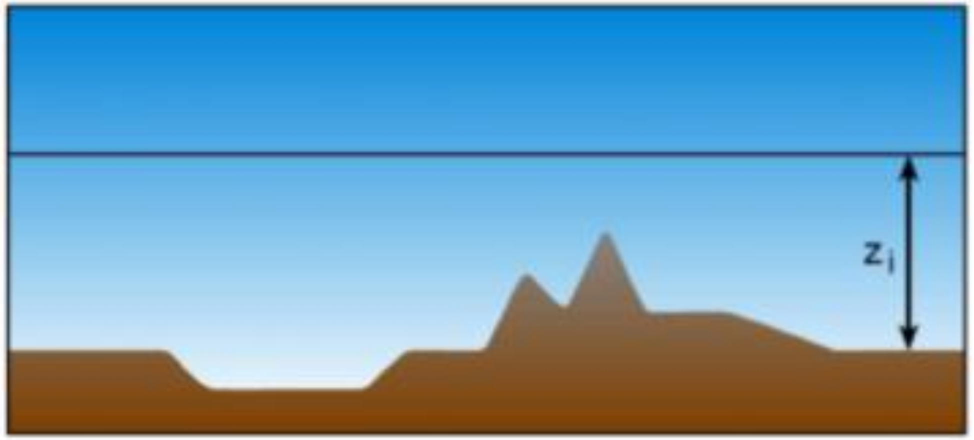
Terrain Following (TF)

B



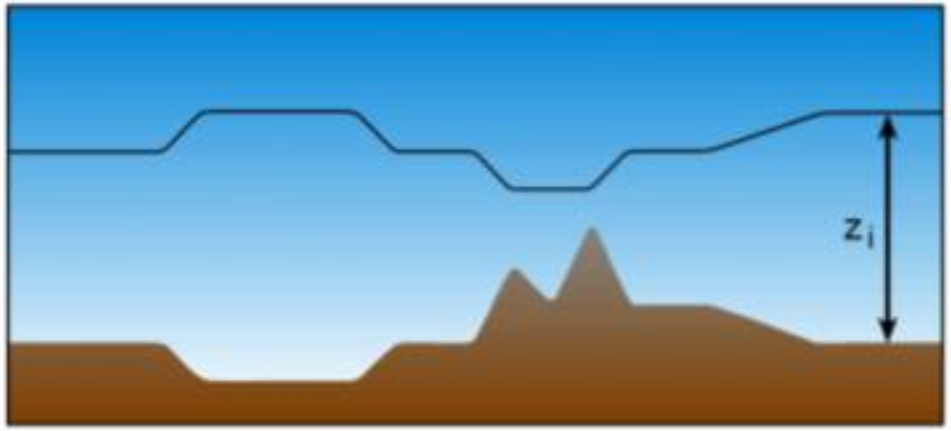
Flat (FL)

C



Contra Terrain Following (CT)

D



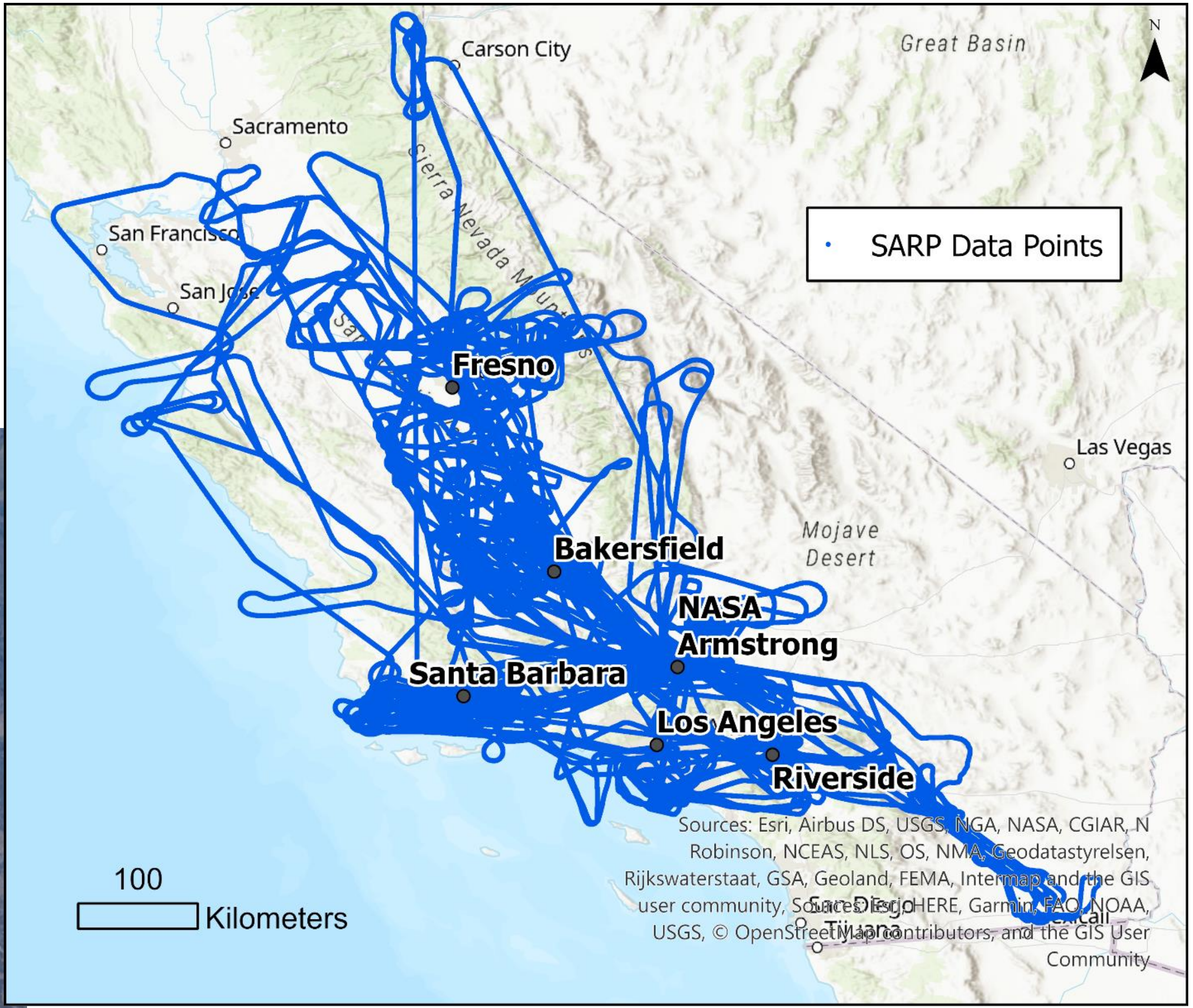
De Wekker et al 2015, *Front. Earth Sci.*

Are the atmospheric boundary layers (ABL) over three mountainous regions in California hyper terrain following (HT), terrain following (TF), contra terrain following (CT), or flat (FL) during 2009-2018 SARP’s?

How is boundary layer behavior related to synoptic conditions?

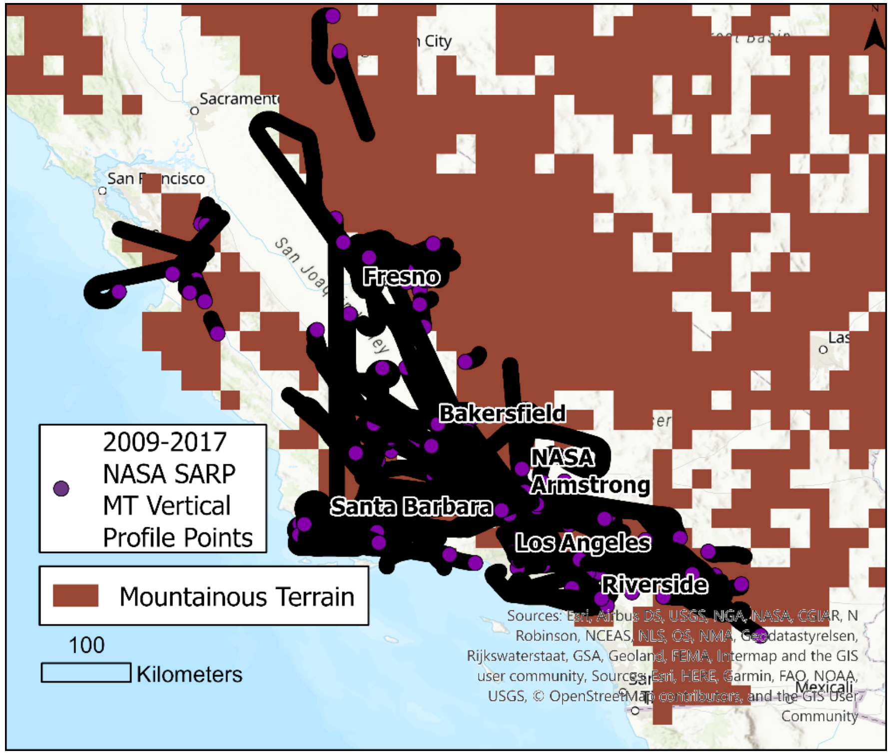
Data

- 43 Research Flights
- Always in June or July
- Over CA



Methods

What is mountainous terrain?

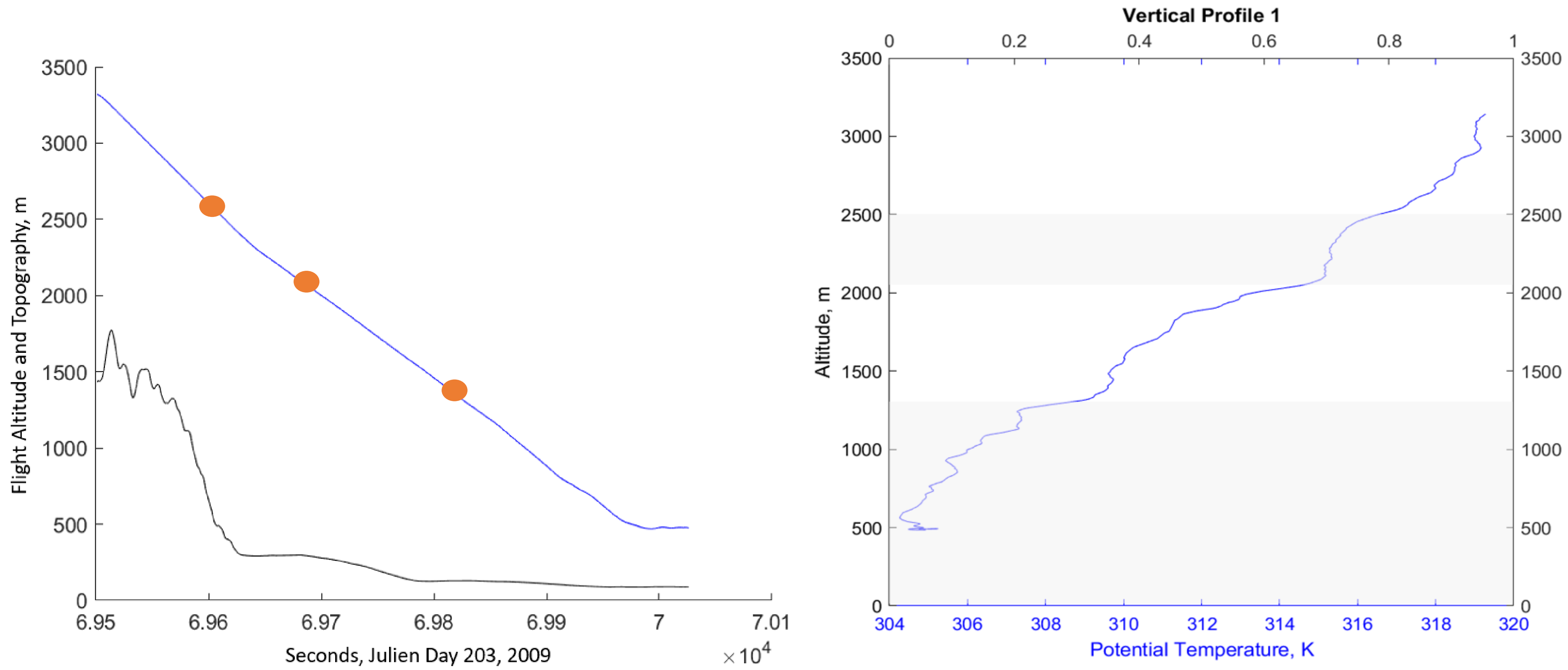


- Maybeck et al. 2001 defines mountainous terrain by roughness coefficient at 0.5^{o} X 0.5^{o} resolution
- *RR = (max – min elevation)/horizontal resolution*
- RR >= 40 m/km is mountainous terrain

Potential Temperature: Temperature Air Could Be If It Were 1000 mb of Pressure

- $Potential\ Temperature = Temperature(\frac{1000\ mb}{pressure})^{\frac{2}{7}}$
- Due to combined gas law
- Changes can define boundary layer height

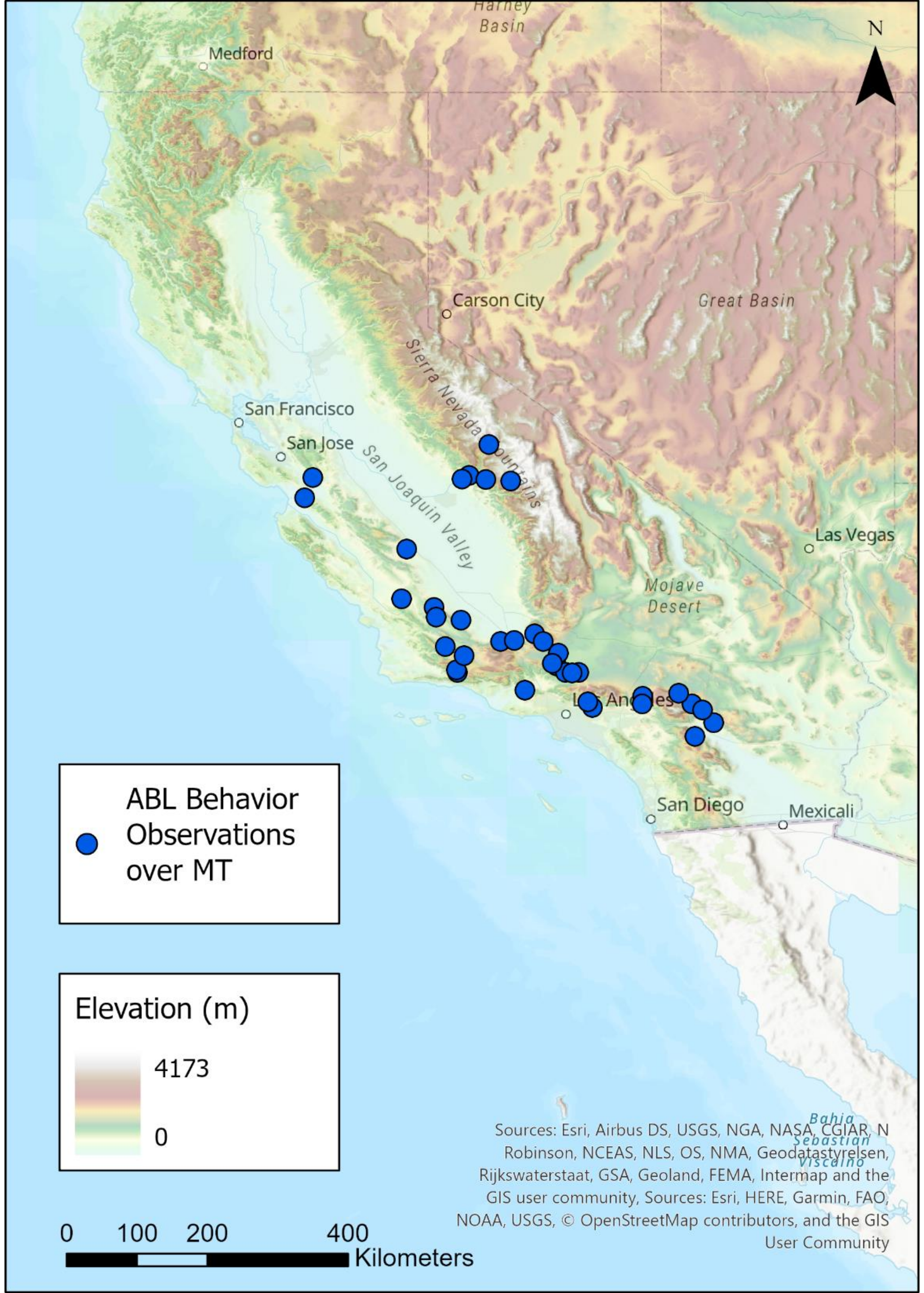
Pitot-Static Tube

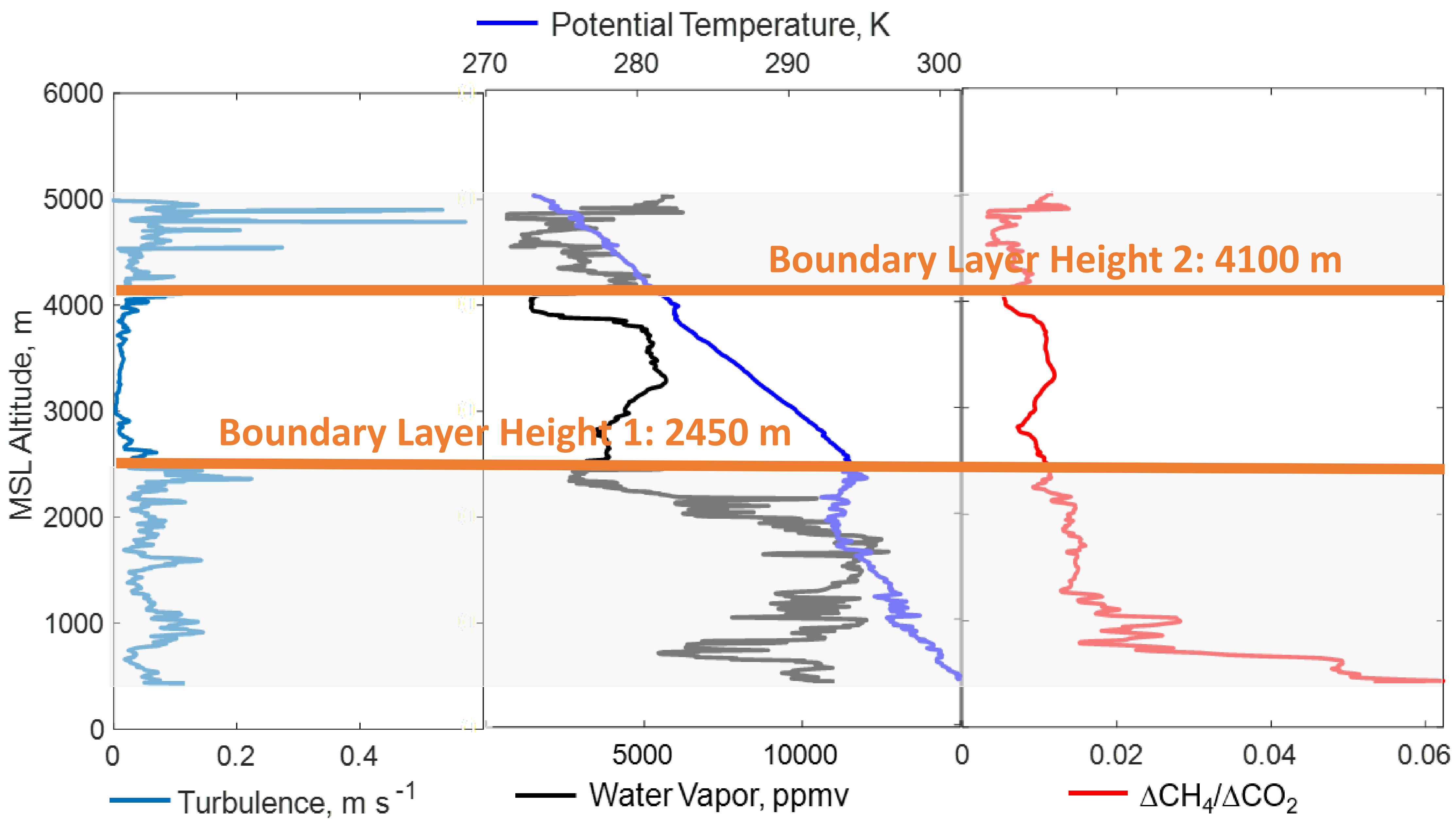


More than one ABL height observation in a vertical profile allows for the ABL behavior to be determined

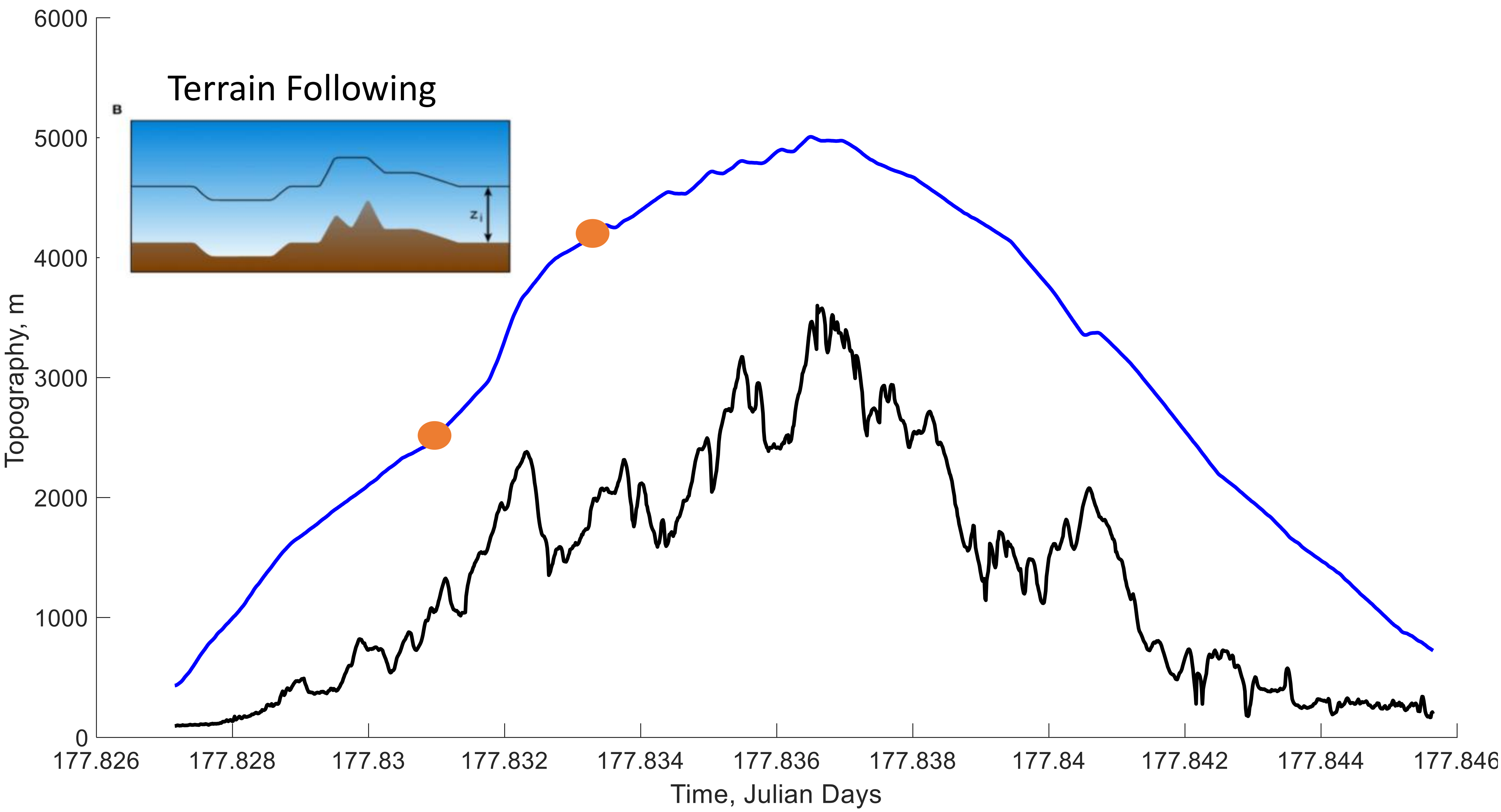
Results

- Analyzed 197 MT vertical profiles
- Identified ABL behavior over MT for 36 vertical profiles
- Determined that GHG enhancements were poor indicators of ABL



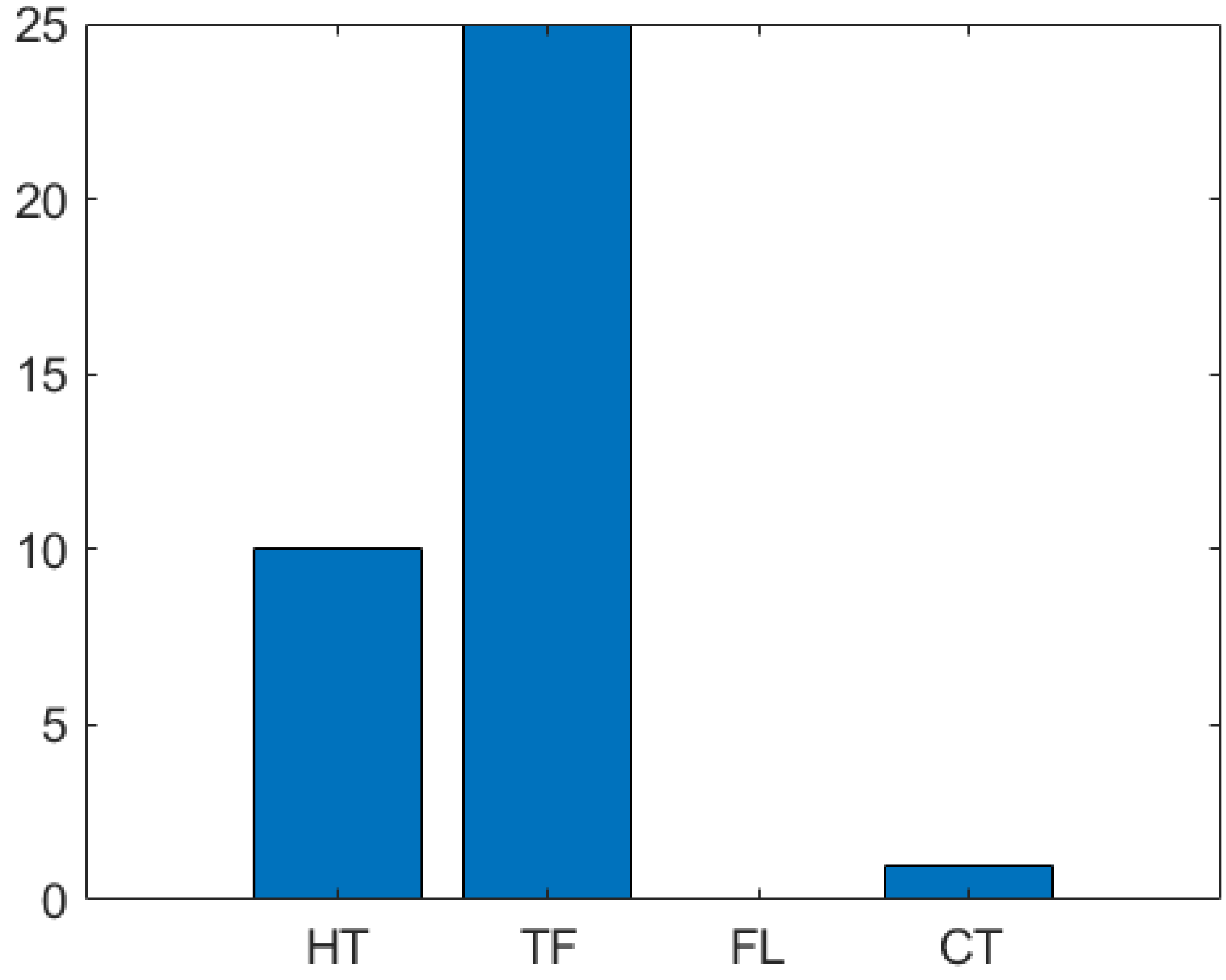


Potential Temperature, K
270
280
290
300
6000
5000
4000
3000
2000
1000
0
MSL Altitude, m
Boundary Layer Height 2: 4100 m
Boundary Layer Height 1: 2450 m
0
0.2
0.4
5000
10000
0
0.02
0.04
0.06
Turbulence, m s -1
Water Vapor, ppmv
ΔCH4/ΔCO2

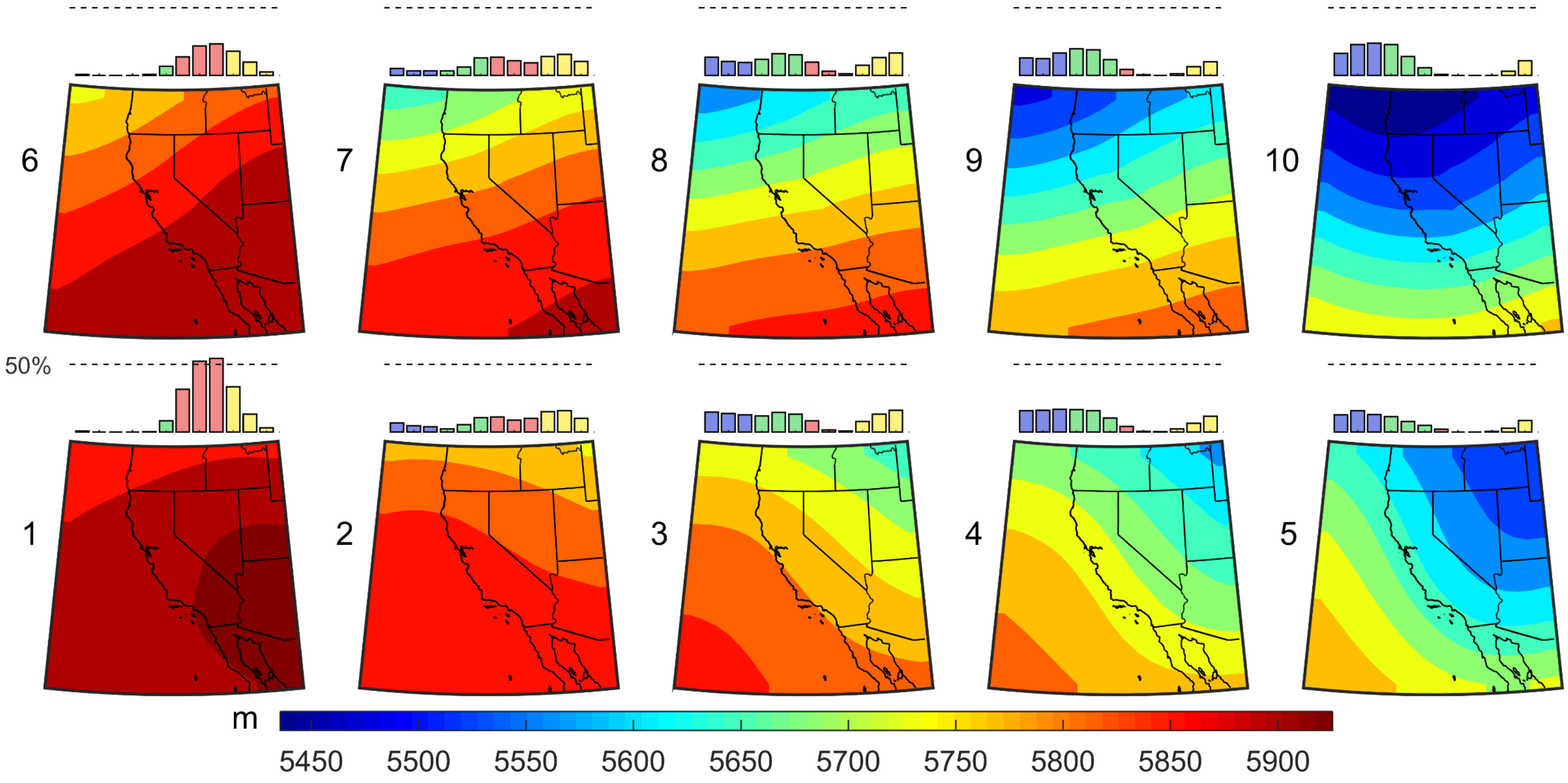


Terrain Following
B
z_i
Topography, m
6000
5000
4000
3000
2000
1000
0
177.826
177.828
177.83
177.832
177.834
177.836
177.838
177.84
177.842
177.844
177.846
Time, Julian Days

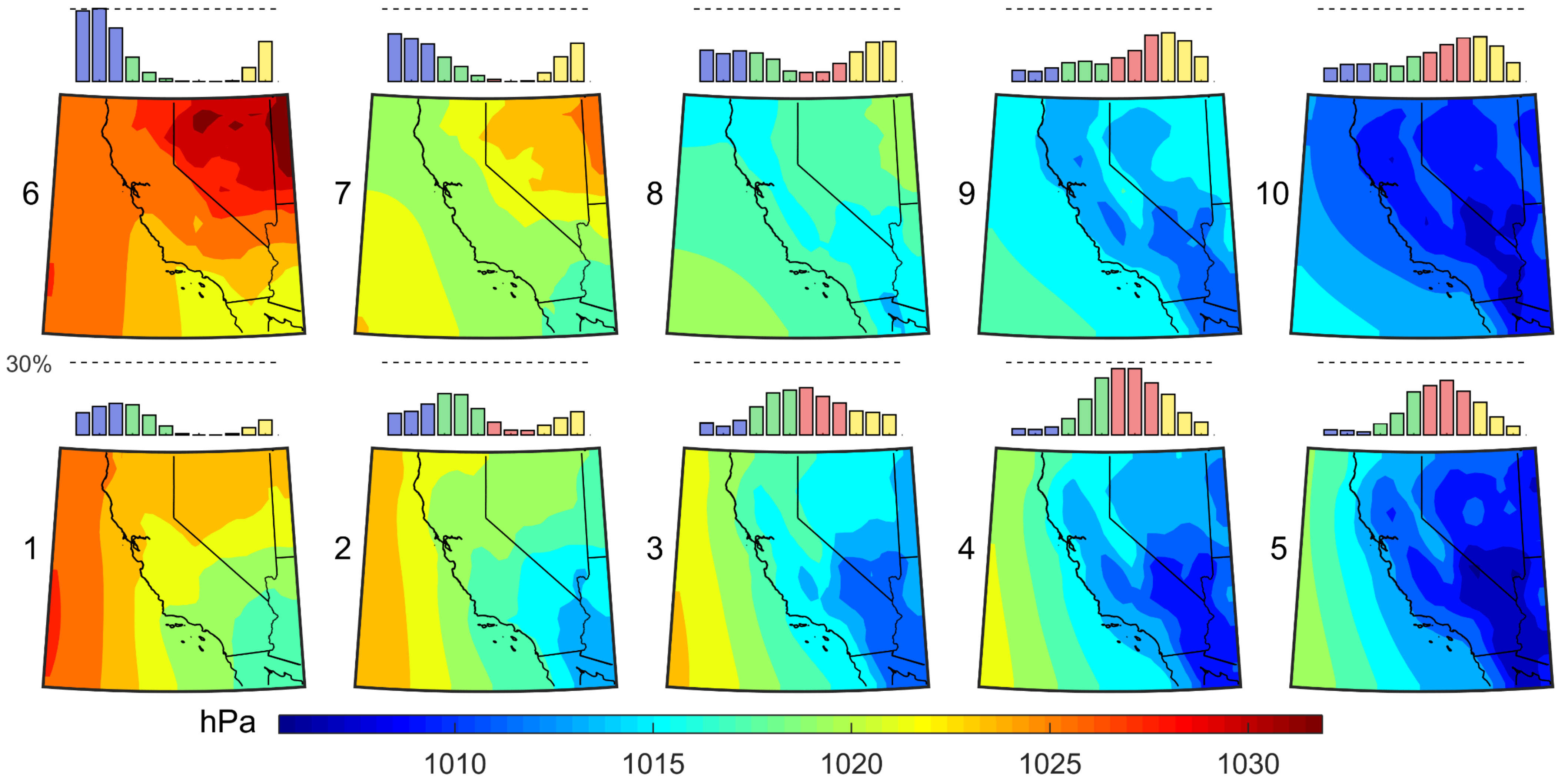
ABL Behavior over MT

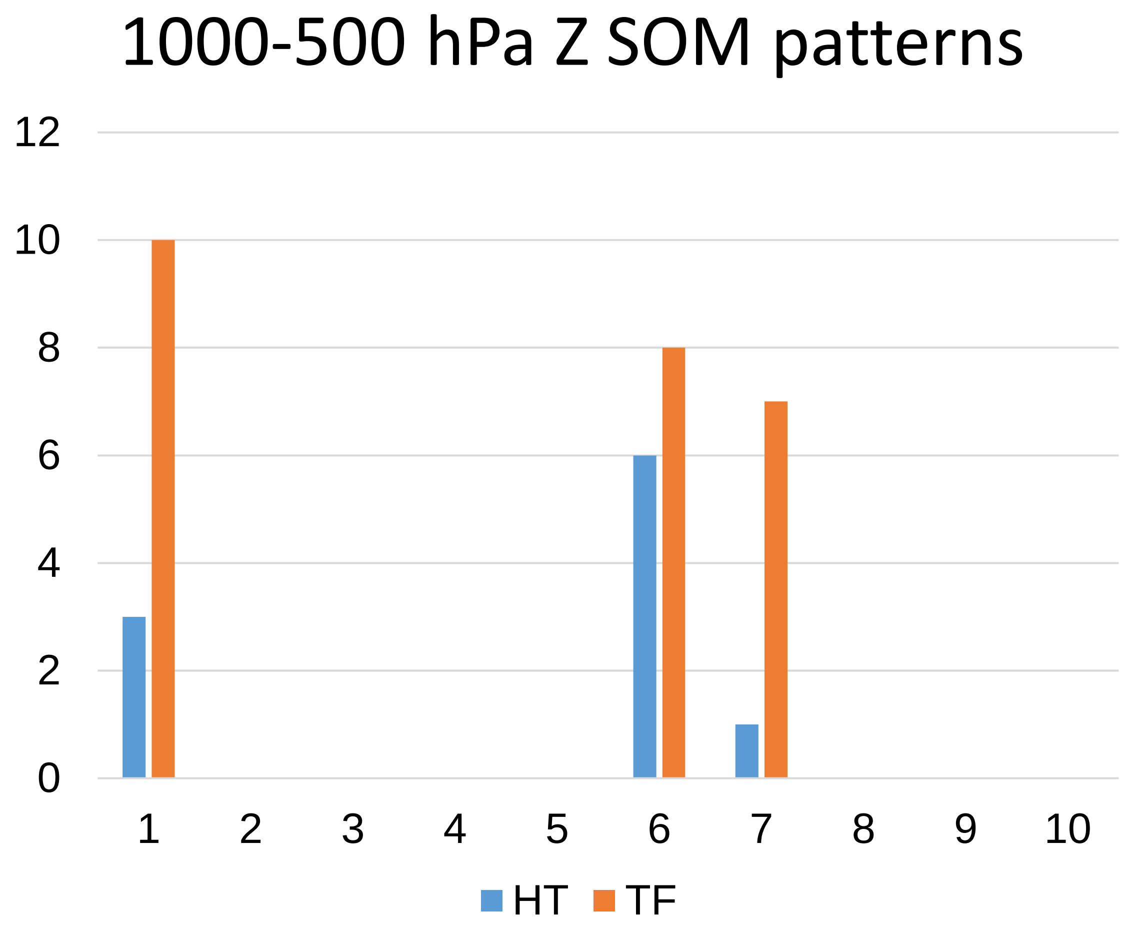


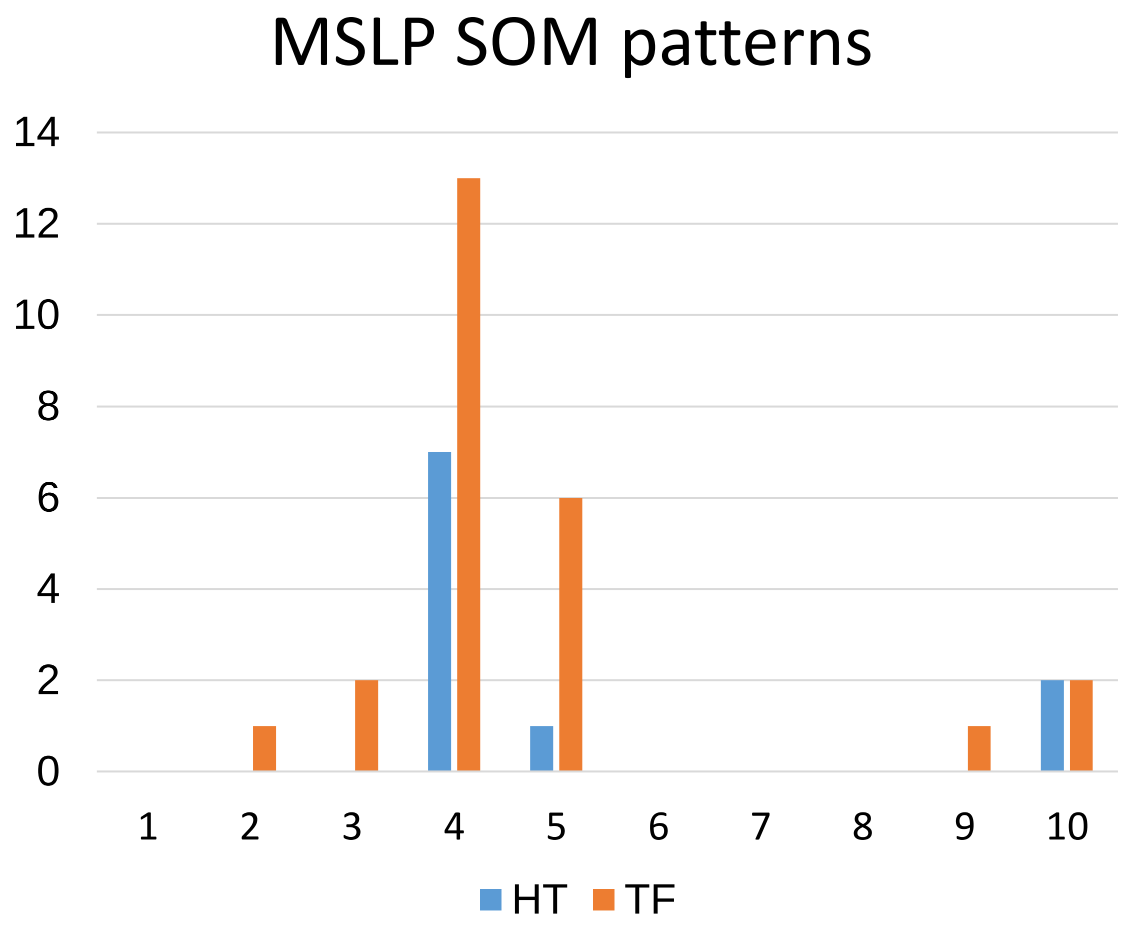
1000-500 hPa Z SOM patterns



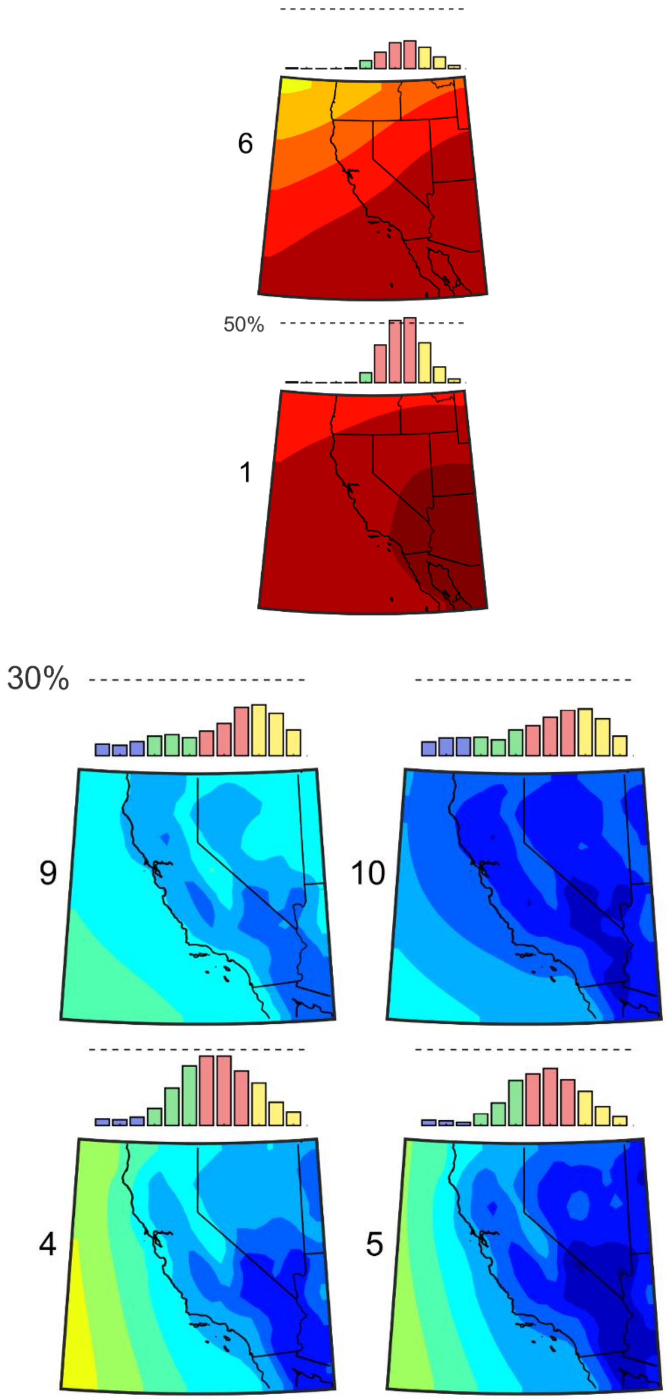
MSLP SOM patterns




1000-500 hPa Z SOM patterns
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
HT
TF

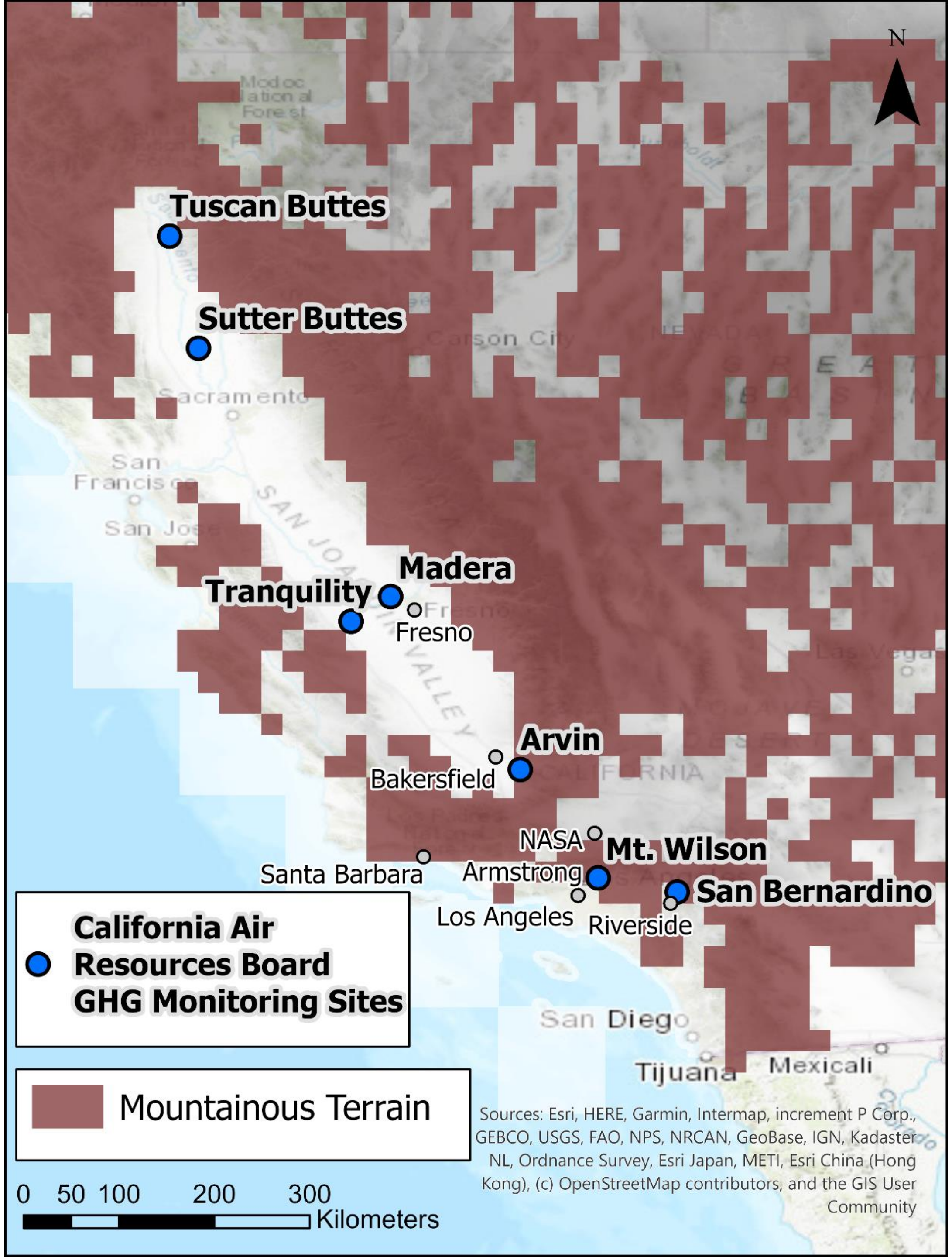

MSLP SOM patterns
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
HT
TF

- HT and FT ABL behaviors occurred over MT when synoptic ridging was present
- TF was more associated with upper level pattern 1
- HT was more associated with upper level pattern 6 with upper level pattern 1 having a slightly stronger trough over southern California
- Both FT and HT were most associated with the MSLP pattern 4 where the thermal low is developing, but not as strong as in pattern 5 or 10



Conclusions

- Synoptic ridging occurred during each of the 2009-2018 NASA SARP research flights
- Both HT and TF ABL behavior were favored when a strong MSLP, thermal low formed in the Central and Imperial Valleys and an upper level ridge was centered over CA
- GHG monitoring sites are often located in or near MT >>
- This study of ABL behavior could provide insights on when these stations are making observations in the free troposphere or the ABL



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References

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