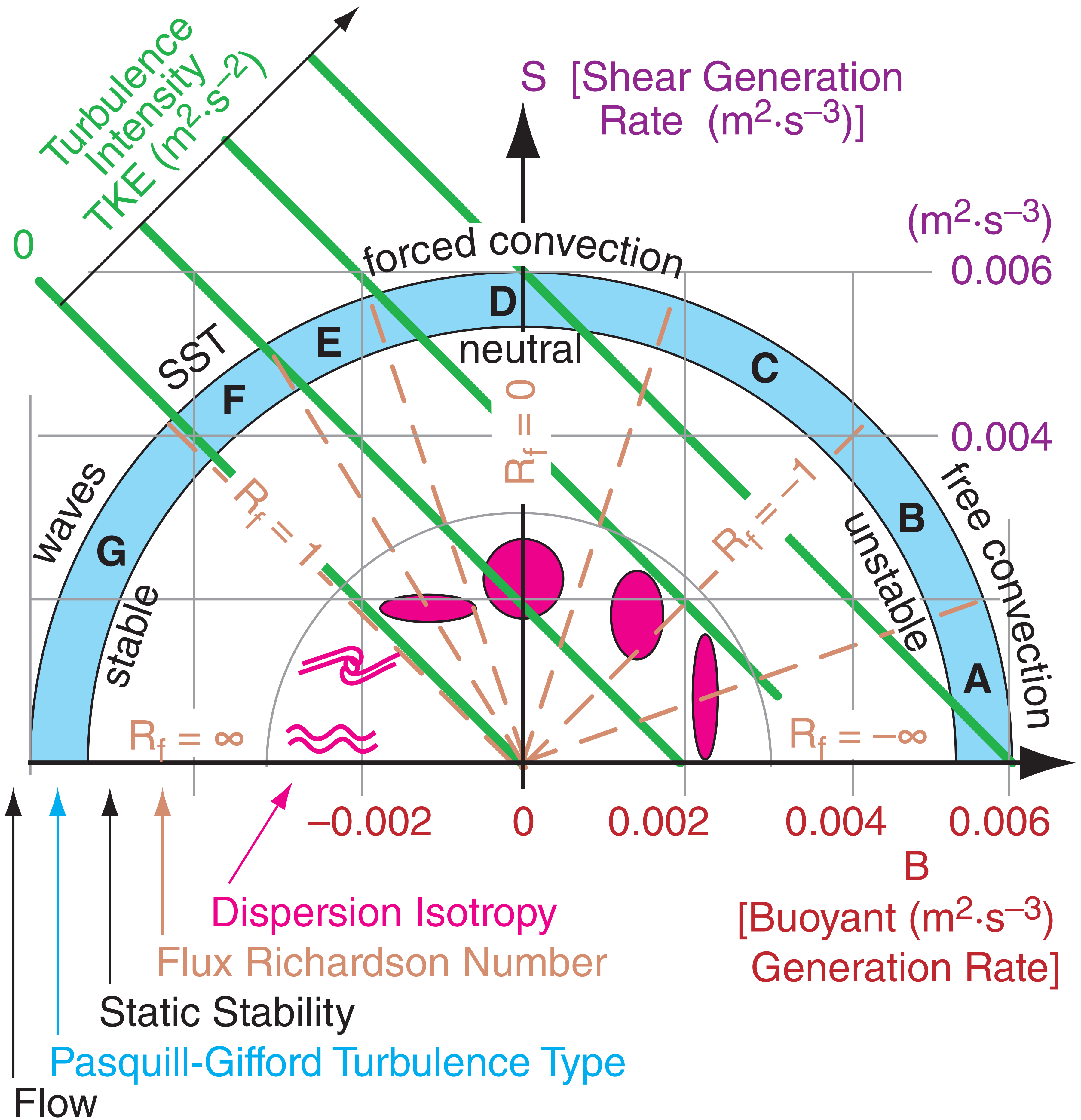
Atmos 5300

Review, Dec 7, 2022



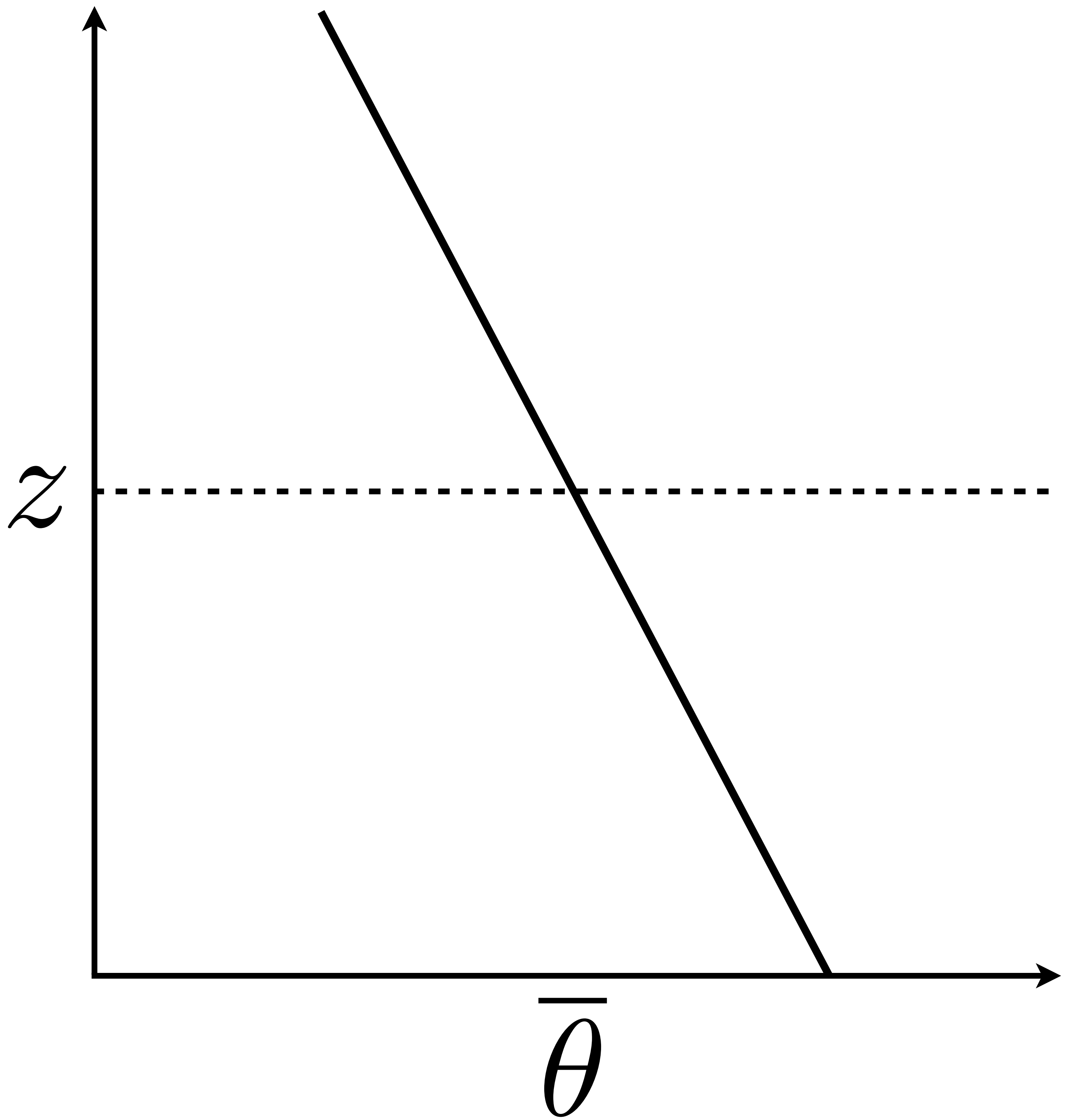
Turbulence Intensity TKE (m²·s⁻²)
0
S [Shear Generation Rate (m²·s⁻³)]
(m²·s⁻³)
0.006
0.004
forced convection
D
neutral
E
SST
F
C
waves
G
stable
B
unstable
free convection
A
Rf = 0
Rf = 1
Rf = –1
Rf = ∞
Rf = –∞
–0.002
0
0.002
0.004
0.006
B
[Buoyant (m²·s⁻³) Generation Rate]
Dispersion Isotropy
Flux Richardson Number
Static Stability
Pasquill-Gifford Turbulence Type
Flow

3. (8 points) (a) Turbulence can be created (produced) by two processes. What are they?

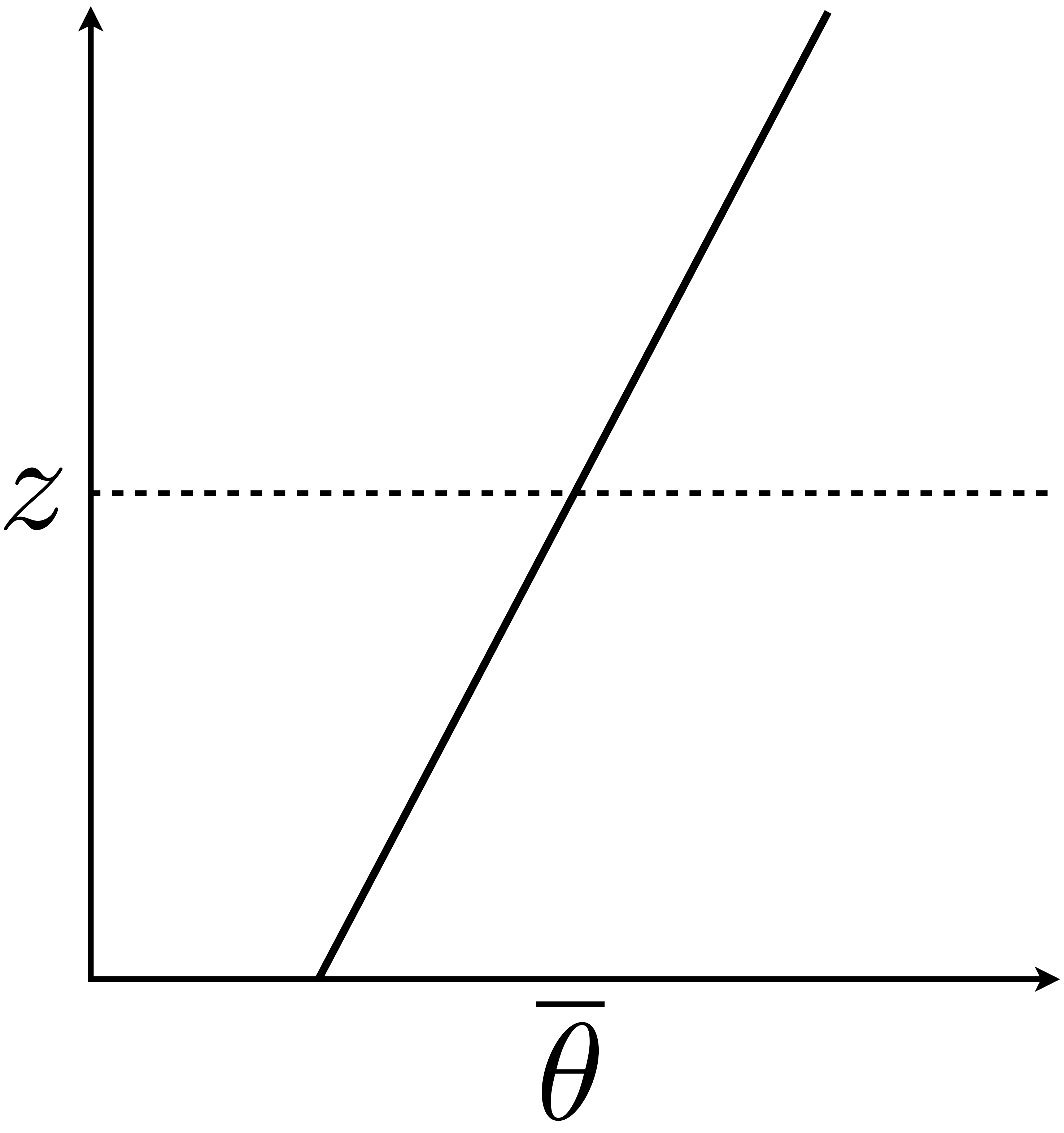
(b) Turbulence can be destroyed by two processes. What are they?

(c) Which of the turbulence creation (production) processes are most important during the summer fair-weather *daytime* boundary layer over land?

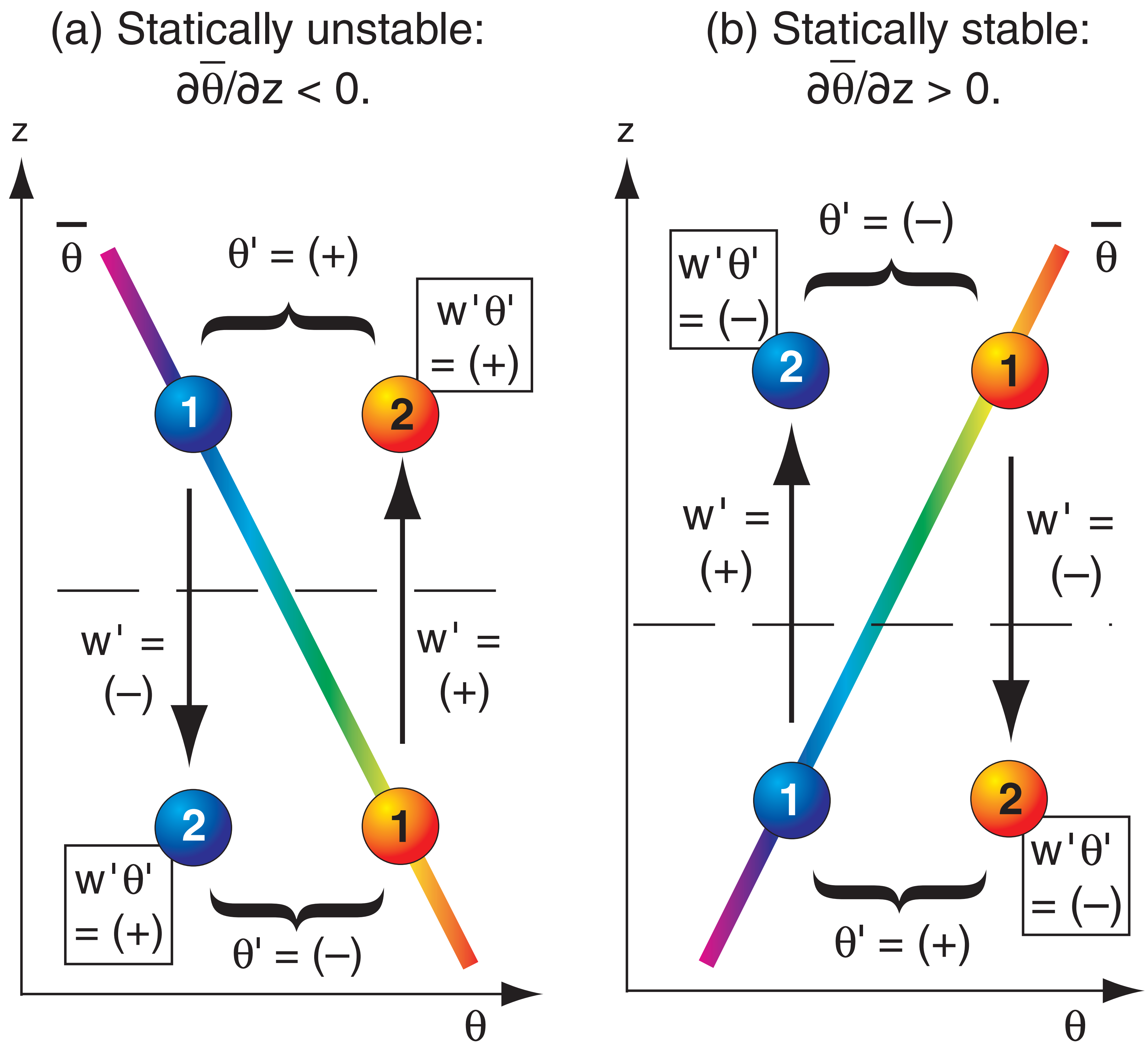
(c) Which of the turbulence creation (production) processes are most important during the summer fair-weather *nocturnal* boundary layer over land?



z
$\overline{\theta}$



z
$\overline{\theta}$



(a) Statically unstable:
∂θ̄/∂z < 0.
(b) Statically stable:
∂θ̄/∂z > 0.
z
θ̄
θ' = (+)
w'θ' = (+)
1
2
w' = (−)
w' = (+)
2
1
w'θ' = (+)
θ' = (−)
θ
z
w'θ' = (−)
θ' = (−)
θ̄
2
1
w' = (+)
w' = (−)
1
2
θ' = (+)
w'θ' = (−)
θ

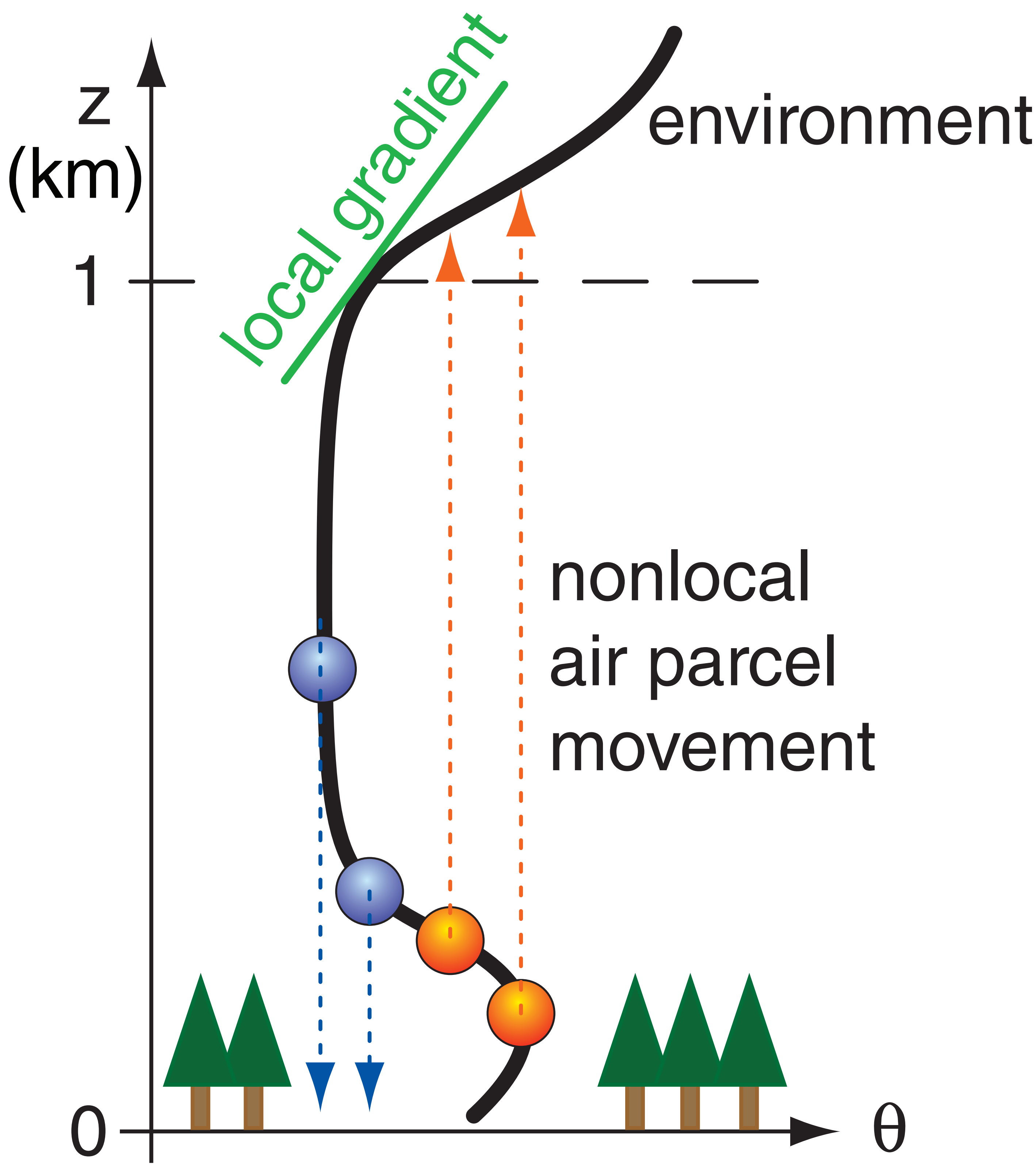
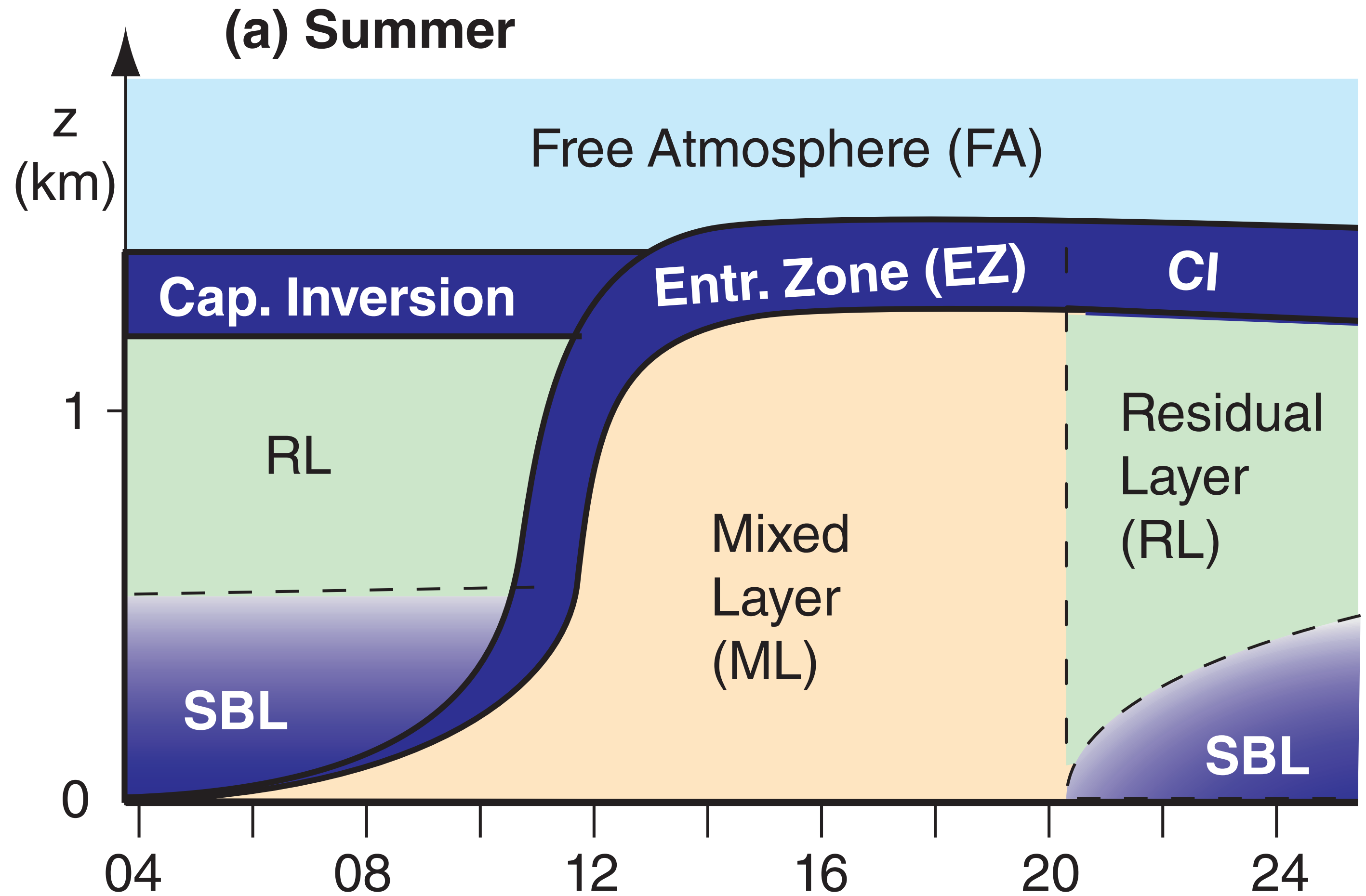
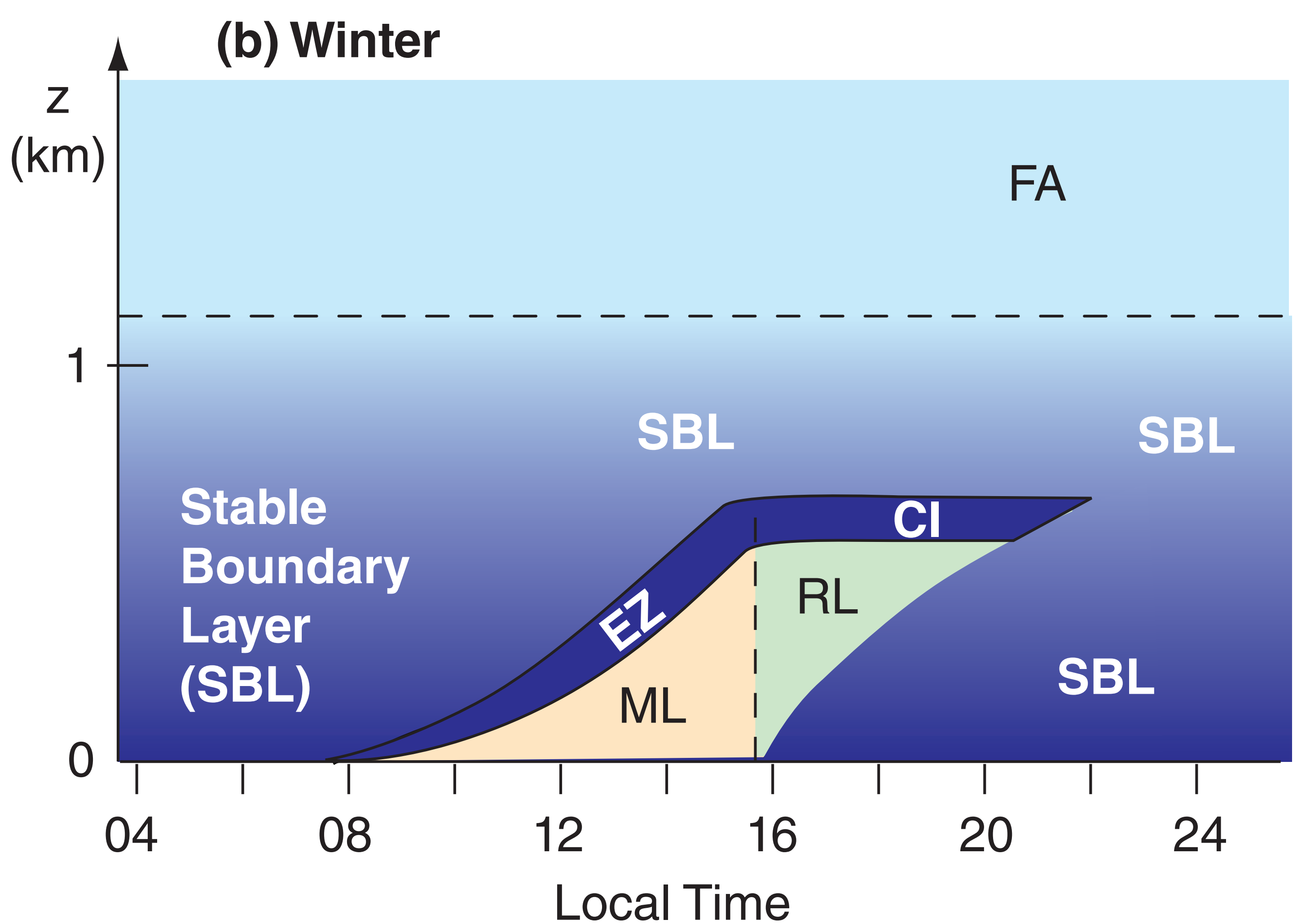


Figure 18.28
Typical environmental potential temperature (θ) profile in the ABL over a forest during daytime. During free convection, buoyancy drives many air parcels to move "nonlocally" across relatively large vertical distances, as illustrated with the dotted lines.

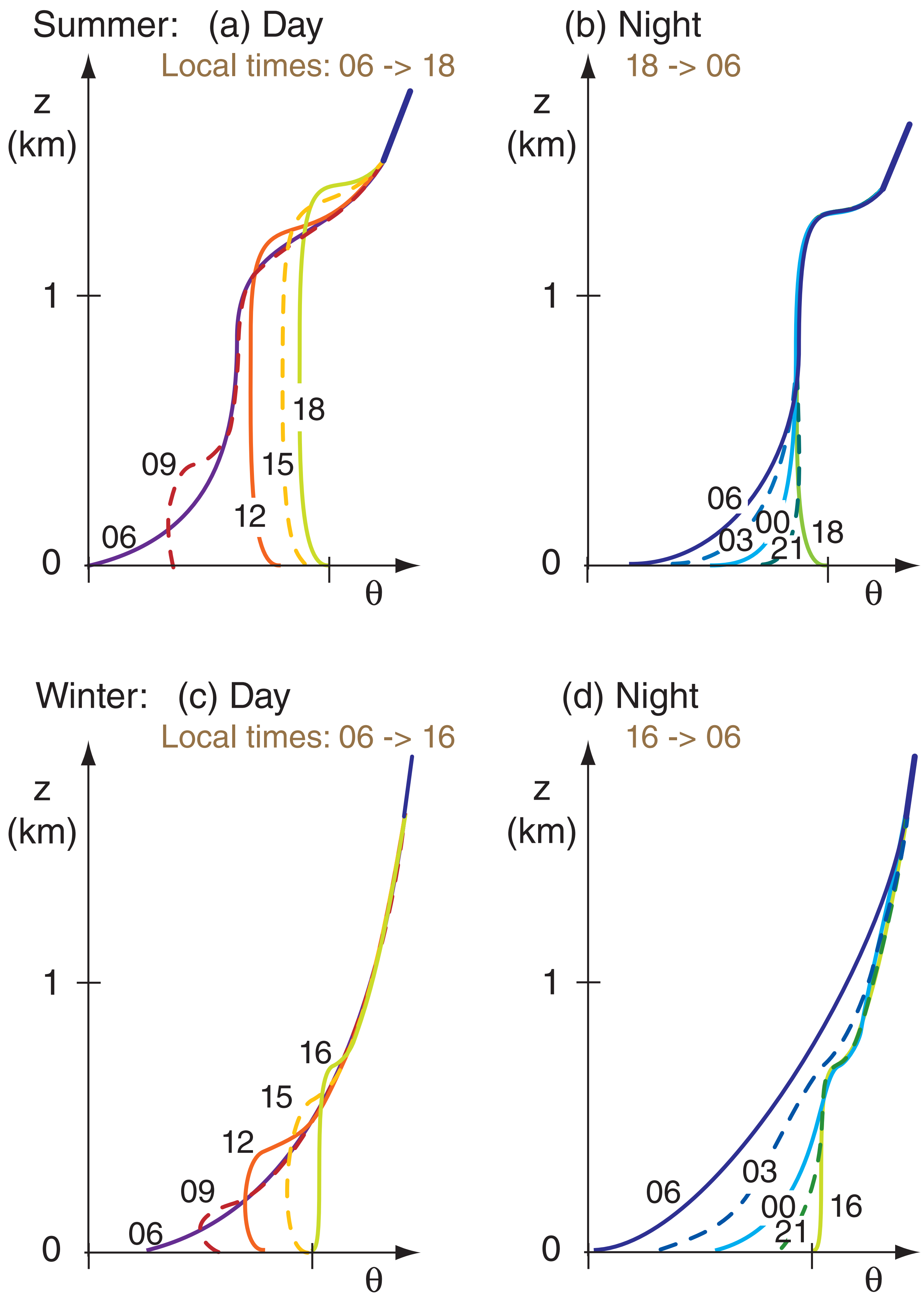
- **Winter time BL**
    - Compare soundings and diurnal cycle SLC now vs Sep.
    - What would happen with a snow covered valley?
    - What happens if BL becomes cloud-capped?
    - What does it take to ventilate the CAP?
- **Surface layer wind profiles**
    - How to determine z0? What if SL is not neutral?
    - How do variations in stability (and L) affect the profile?



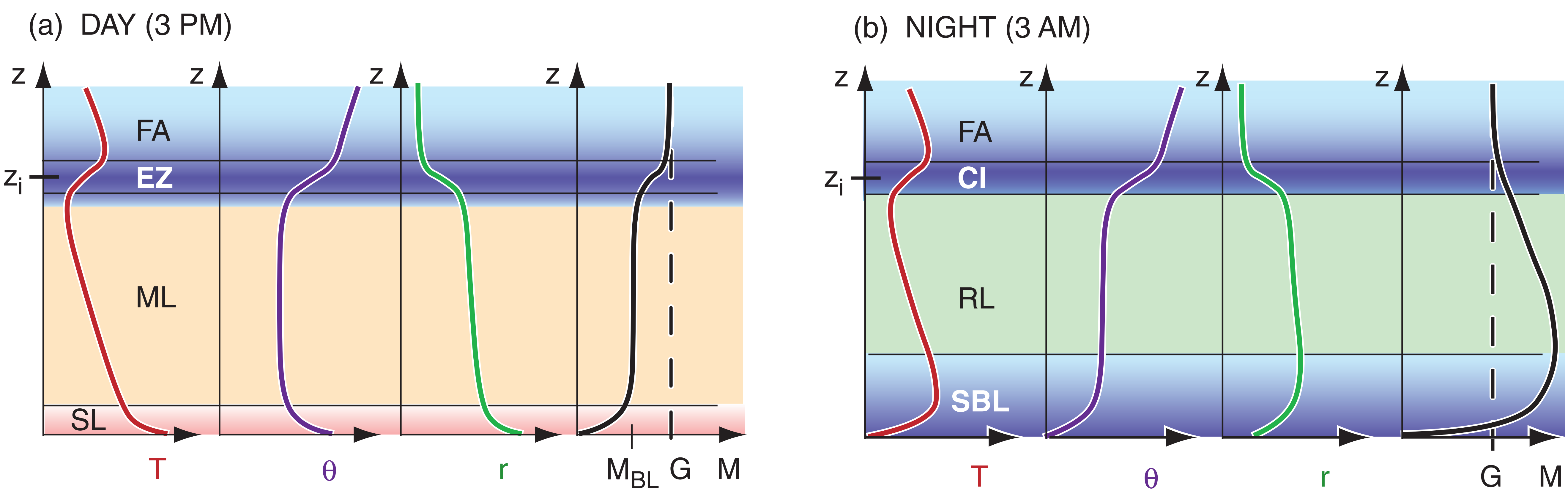
(a) Summer
z
(km)
Free Atmosphere (FA)
Cap. Inversion
Entr. Zone (EZ)
CI
1
RL
Mixed
Layer
(ML)
Residual
Layer
(RL)
SBL
SBL
0
04
08
12
16
20
24



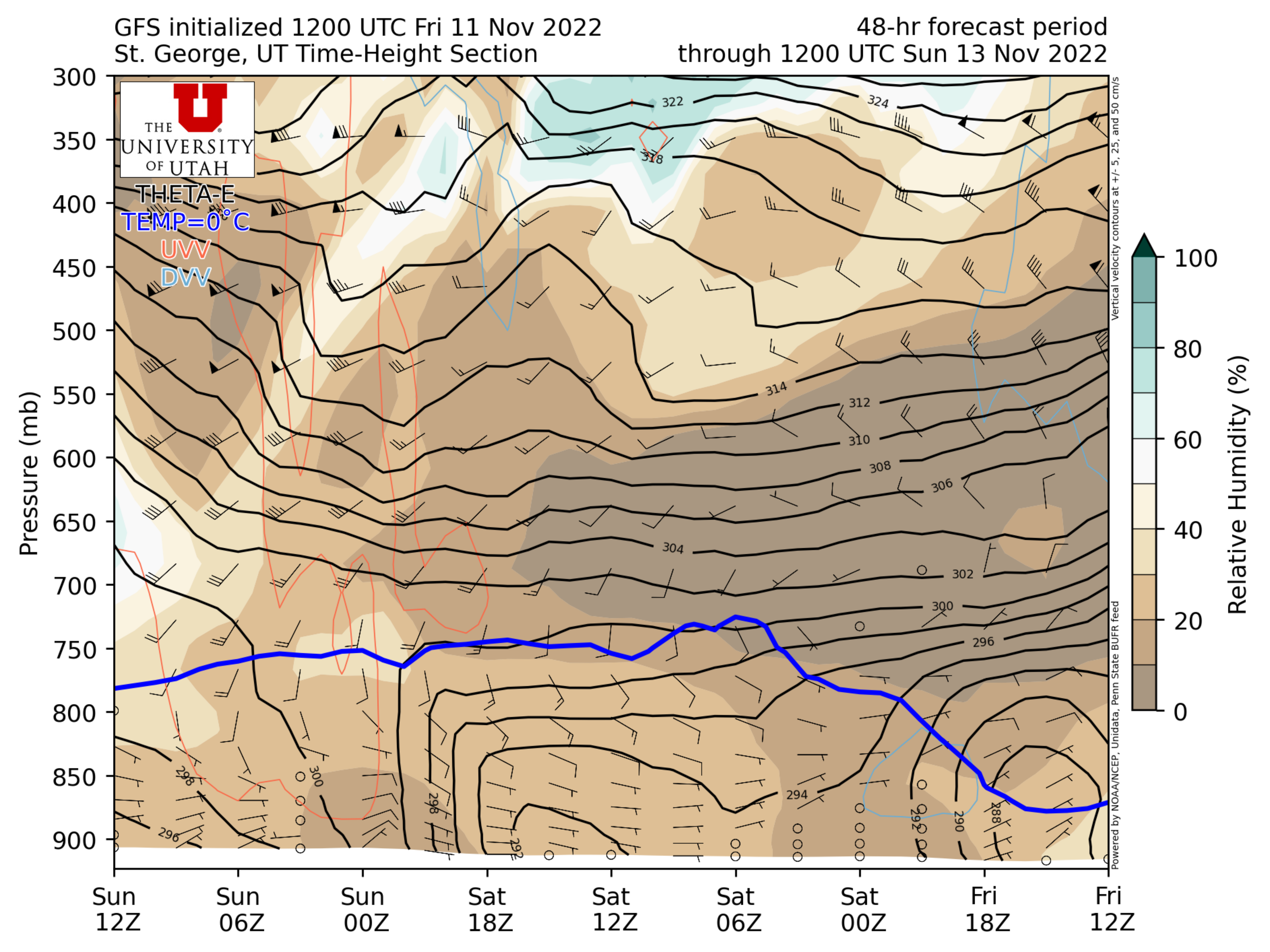
(b) Winter
z
(km)
FA
1
SBL
SBL
Stable
Boundary
Layer
(SBL)
CI
RL
EZ
ML
SBL
0
04
08
12
16
20
24
Local Time

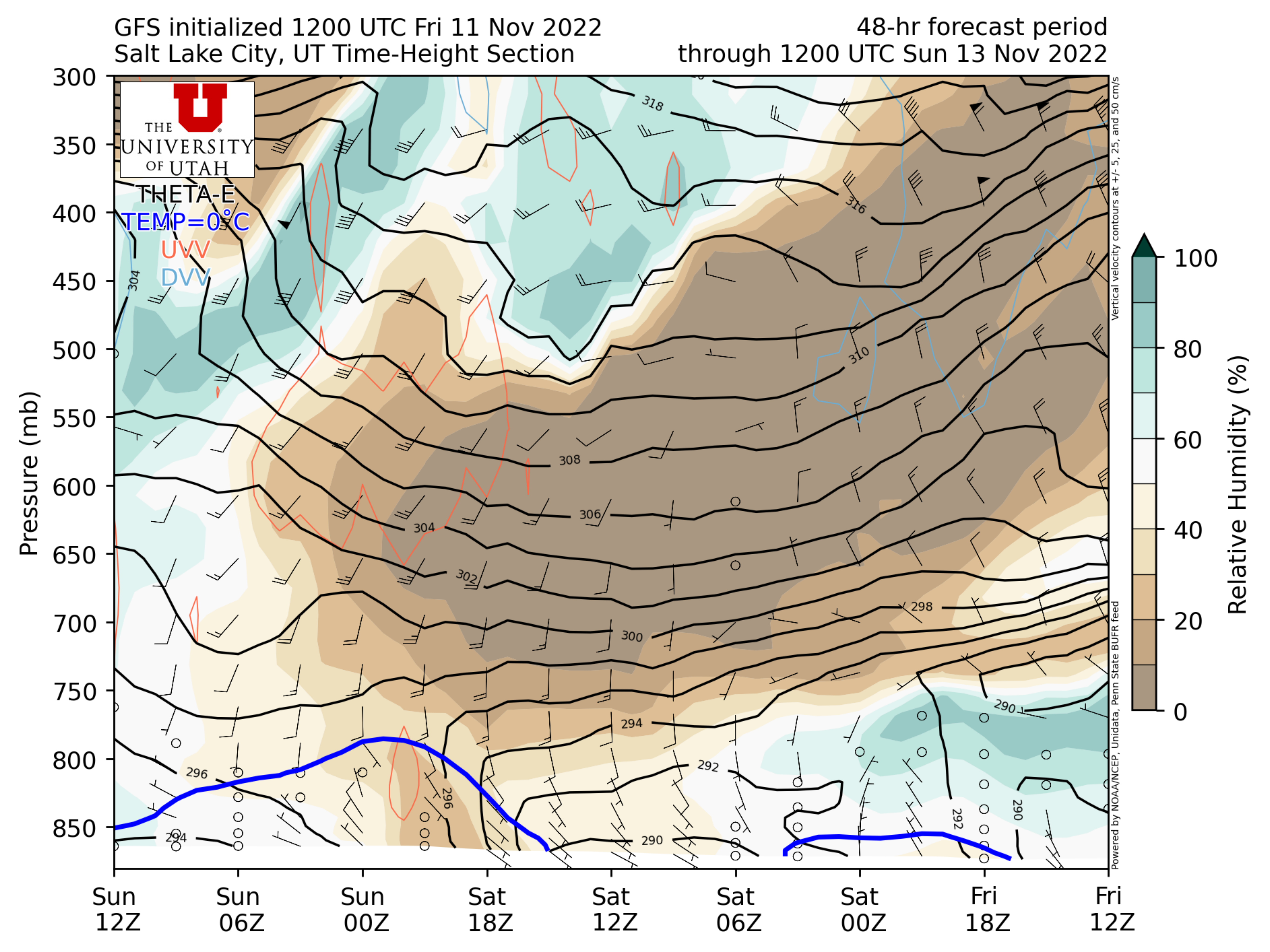


Summer: (a) Day
Local times: 06 -> 18
z
(km)
1
0
θ
06
09
12
15
18
(b) Night
18 -> 06
z
(km)
1
0
θ
06
03
00
21
18
Winter: (c) Day
Local times: 06 -> 16
z
(km)
1
0
θ
06
09
12
15
16
(d) Night
16 -> 06
z
(km)
1
0
θ
06
03
00
21
16

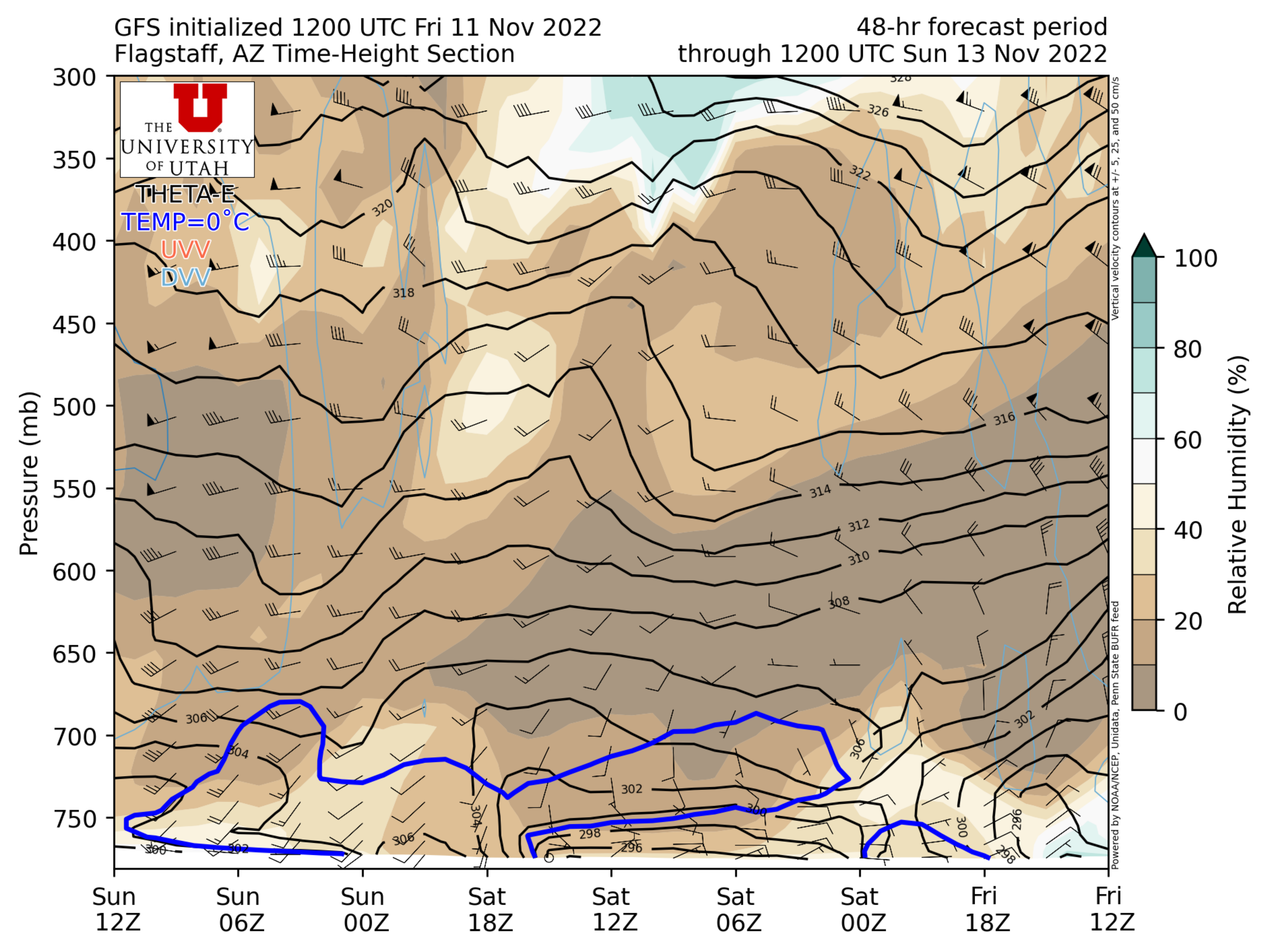


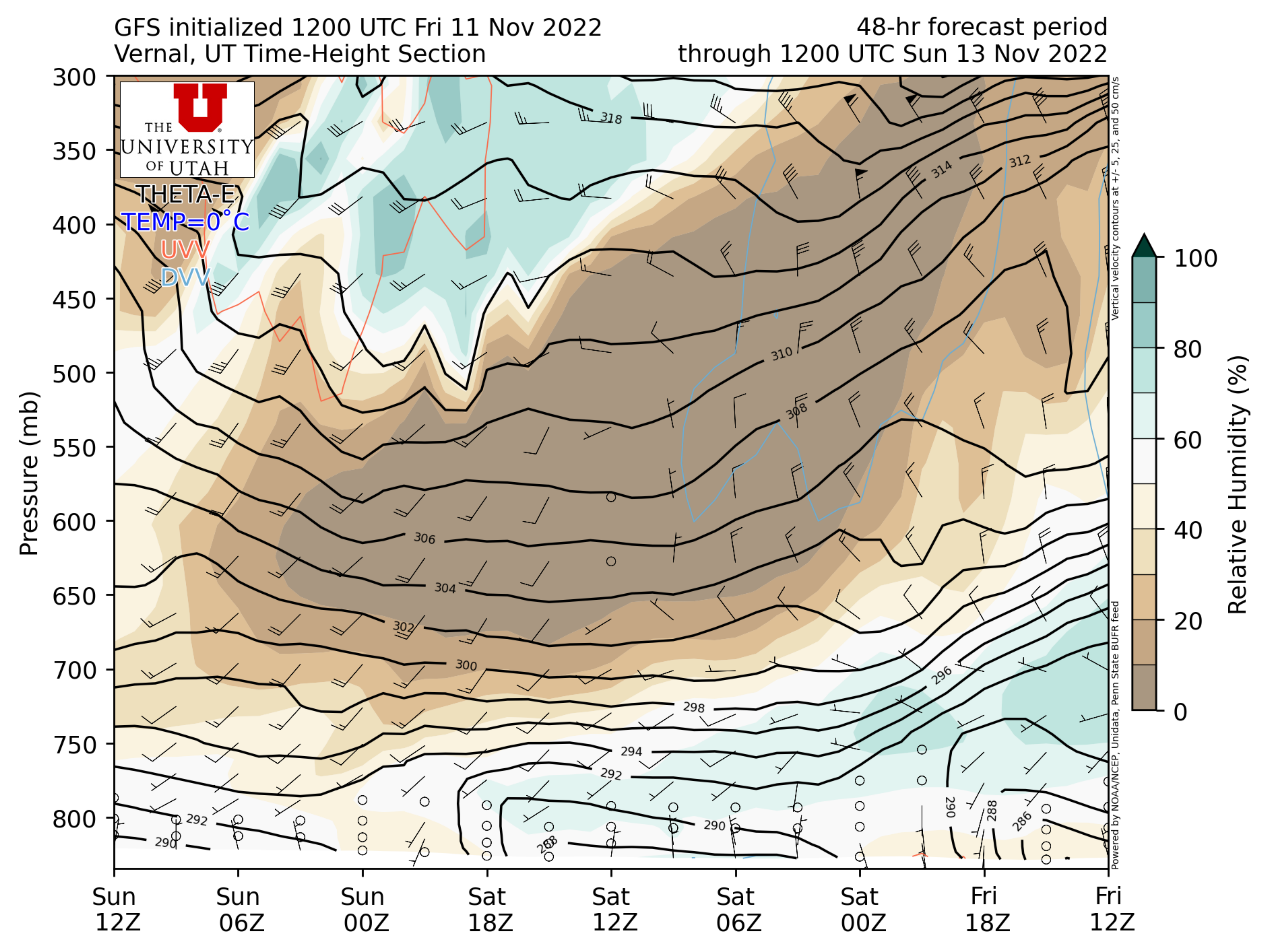
(a) DAY (3 PM)
(b) NIGHT (3 AM)
z
FA
EZ
ML
SL
z_i
CI
RL
SBL
T
θ
r
M_{BL}
G
M


GFS initialized 1200 UTC Fri 11 Nov 2022
St. George, UT Time-Height Section
48-hr forecast period
through 1200 UTC Sun 13 Nov 2022
THE UNIVERSITY OF UTAH
THETA-E
TEMP=0°C
UVV
DVV
Pressure (mb)
300
350
400
450
500
550
600
650
700
750
800
850
900
Sun 12Z
Sun 06Z
Sun 00Z
Sat 18Z
Sat 12Z
Sat 06Z
Sat 00Z
Fri 18Z
Fri 12Z
Relative Humidity (%)
100
80
60
40
20
0
Vertical velocity contours at +/- 5, 25, and 50 cm/s
Powered by NOAA/NCEP, Unidata, Penn State BUFR feed

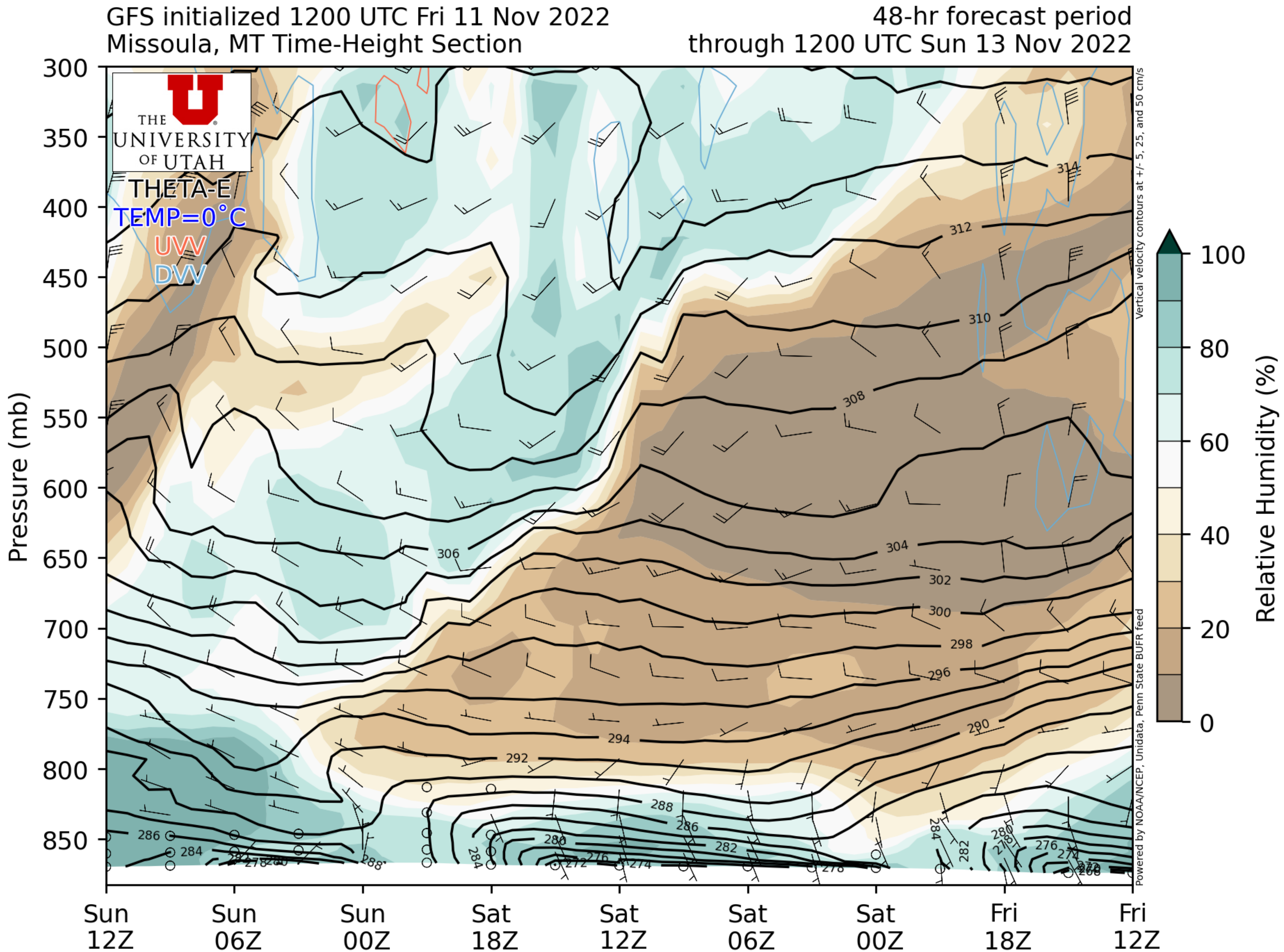


GFS initialized 1200 UTC Fri 11 Nov 2022
Salt Lake City, UT Time-Height Section
48-hr forecast period
through 1200 UTC Sun 13 Nov 2022
THE UNIVERSITY OF UTAH
THETA-E
TEMP=0°C
UVV
DVV
Pressure (mb)
300
350
400
450
500
550
600
650
700
750
800
850
Sun 12Z
Sun 06Z
Sun 00Z
Sat 18Z
Sat 12Z
Sat 06Z
Sat 00Z
Fri 18Z
Fri 12Z
Relative Humidity (%)
100
80
60
40
20
0
Vertical velocity contours at +/- 5, 25, and 50 cm/s
Powered by NOAA/NCEP, Unidata, Penn State BUFR feed


GFS initialized 1200 UTC Fri 11 Nov 2022
Flagstaff, AZ Time-Height Section
48-hr forecast period
through 1200 UTC Sun 13 Nov 2022
THE UNIVERSITY OF UTAH
THETA-E
TEMP=0˚C
UVV
DVV
Pressure (mb)
300
350
400
450
500
550
600
650
700
750
Sun 12Z
Sun 06Z
Sun 00Z
Sat 18Z
Sat 12Z
Sat 06Z
Sat 00Z
Fri 18Z
Fri 12Z
Relative Humidity (%)
0
20
40
60
80
100
Vertical velocity contours at +/- 5, 25, and 50 cm/s
Powered by NOAA/NCEP, Unidata, Penn State BUFR feed



GFS initialized 1200 UTC Fri 11 Nov 2022
Vernal, UT Time-Height Section
48-hr forecast period
through 1200 UTC Sun 13 Nov 2022
THE UNIVERSITY OF UTAH
THETA-E
TEMP=0°C
UVV
DVV
Pressure (mb)
300
350
400
450
500
550
600
650
700
750
800
Sun 12Z
Sun 06Z
Sun 00Z
Sat 18Z
Sat 12Z
Sat 06Z
Sat 00Z
Fri 18Z
Fri 12Z
Relative Humidity (%)
100
80
60
40
20
0
Vertical velocity contours at +/- 5, 25, and 50 cm/s
Powered by NOAA/NCEP, Unidata, Penn State BUFR feed
318
314
312
310
308
306
304
302
300
298
296
294
292
290
288
286


GFS initialized 1200 UTC Fri 11 Nov 2022
Missoula, MT Time-Height Section
48-hr forecast period
through 1200 UTC Sun 13 Nov 2022
THE UNIVERSITY OF UTAH
THETA-E
TEMP=0°C
UVV
DVV
Pressure (mb)
300
350
400
450
500
550
600
650
700
750
800
850
Sun 12Z
Sun 06Z
Sun 00Z
Sat 18Z
Sat 12Z
Sat 06Z
Sat 00Z
Fri 18Z
Fri 12Z
Relative Humidity (%)
0
20
40
60
80
100
Vertical velocity contours at +/- 5, 25, and 50 cm/s
Powered by NOAA/NCEP, Unidata, Penn State BUFR feed
314
312
310
308
306
304
302
300
298
296
294
292
290
288
286
284
282
280
278
276
274
272

9. (8 points) Explain the significance of the values of the:

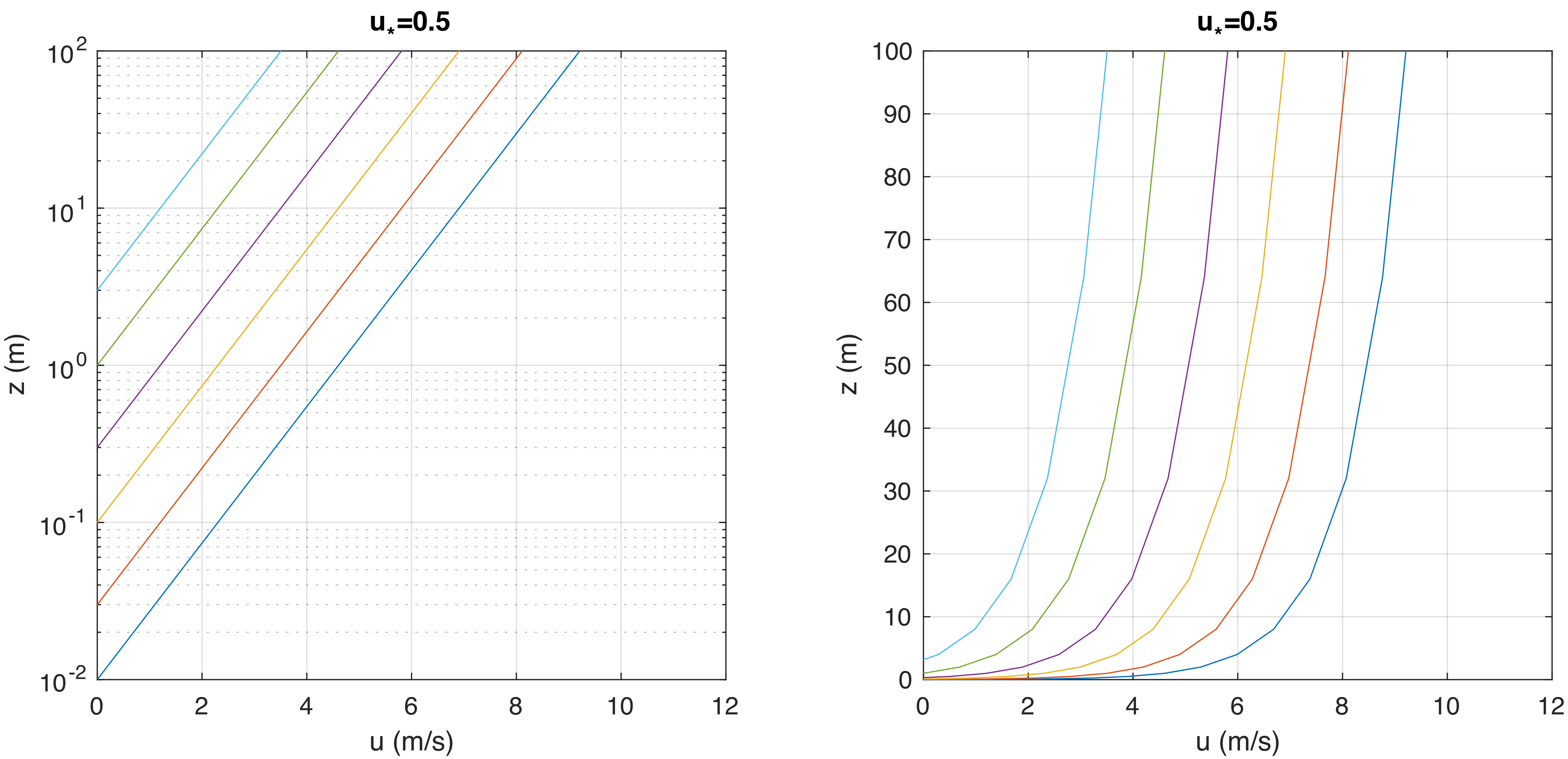
(a) convective velocity scale, w_*.

(b) Obukhov length, L.

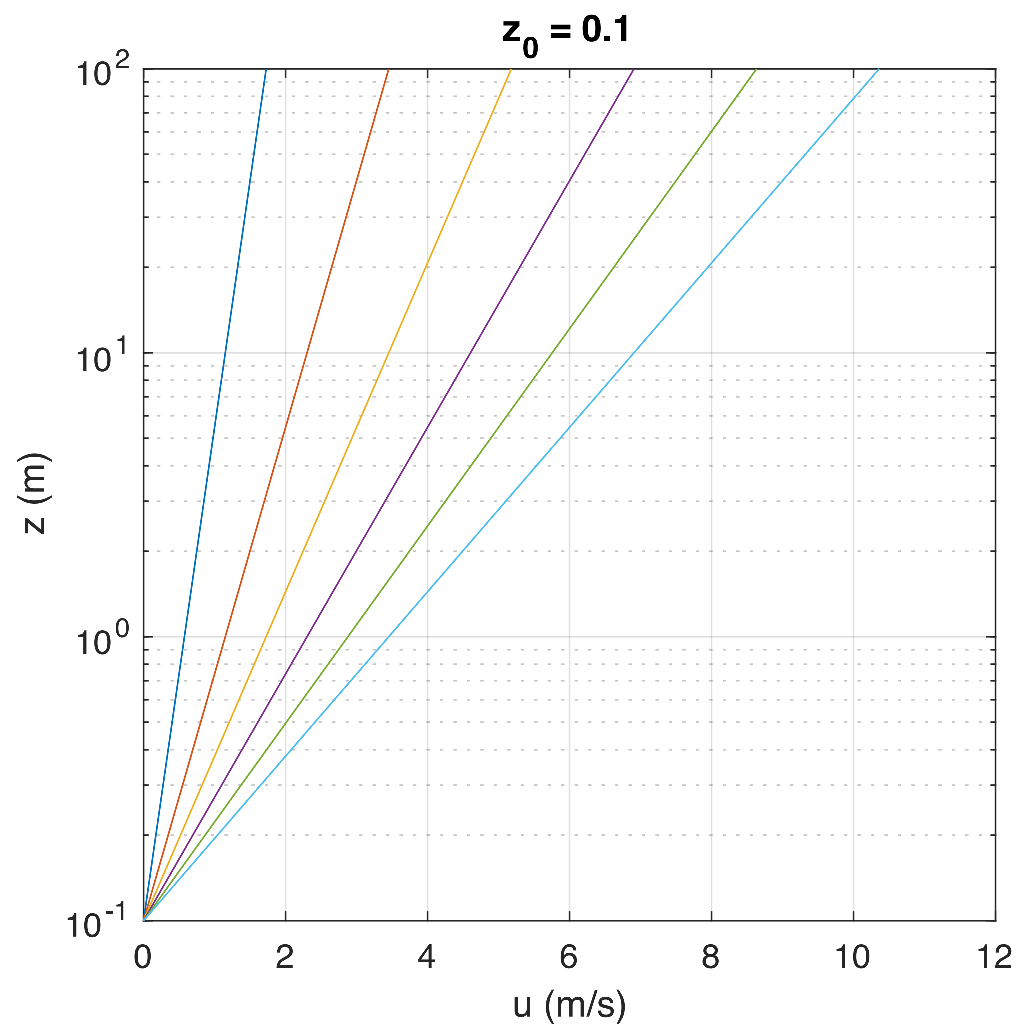
(c) friction velocity, u_*.

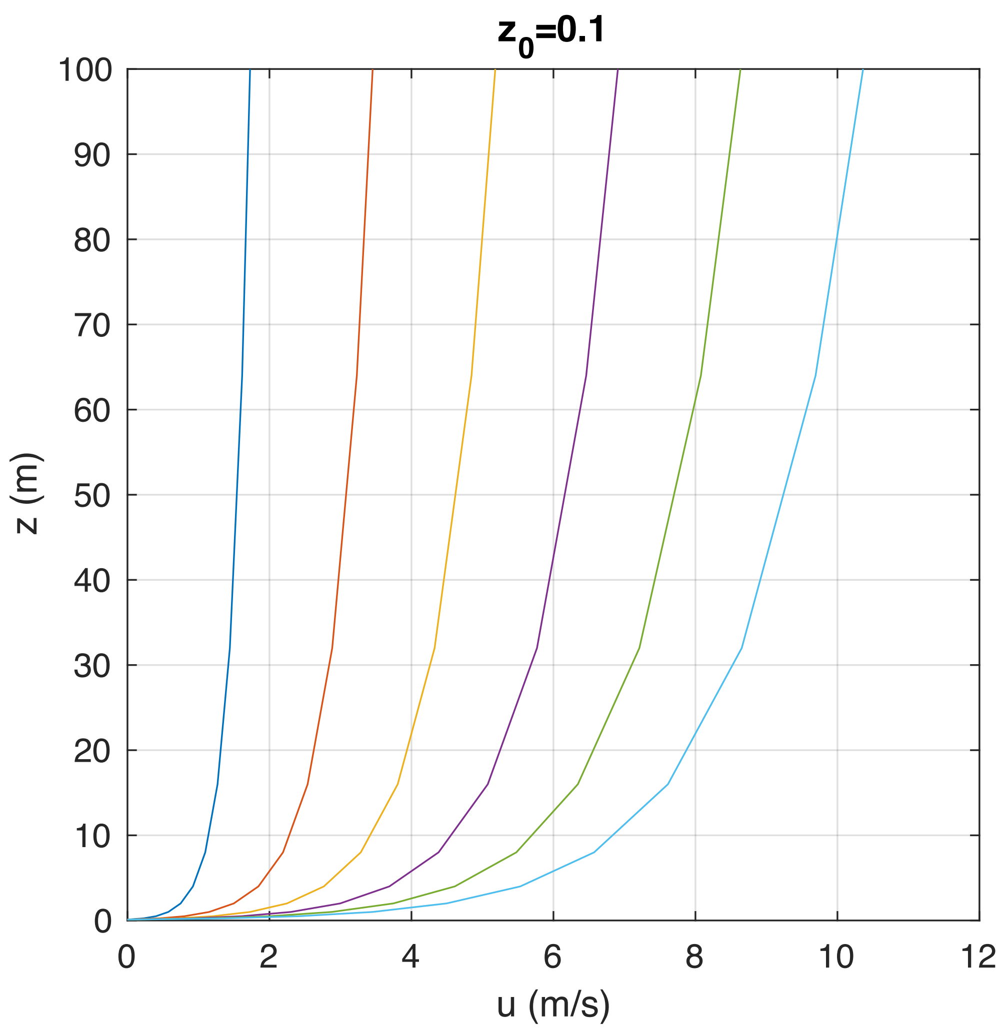
(d) roughness length, z_0

What parameter is different for each profile?

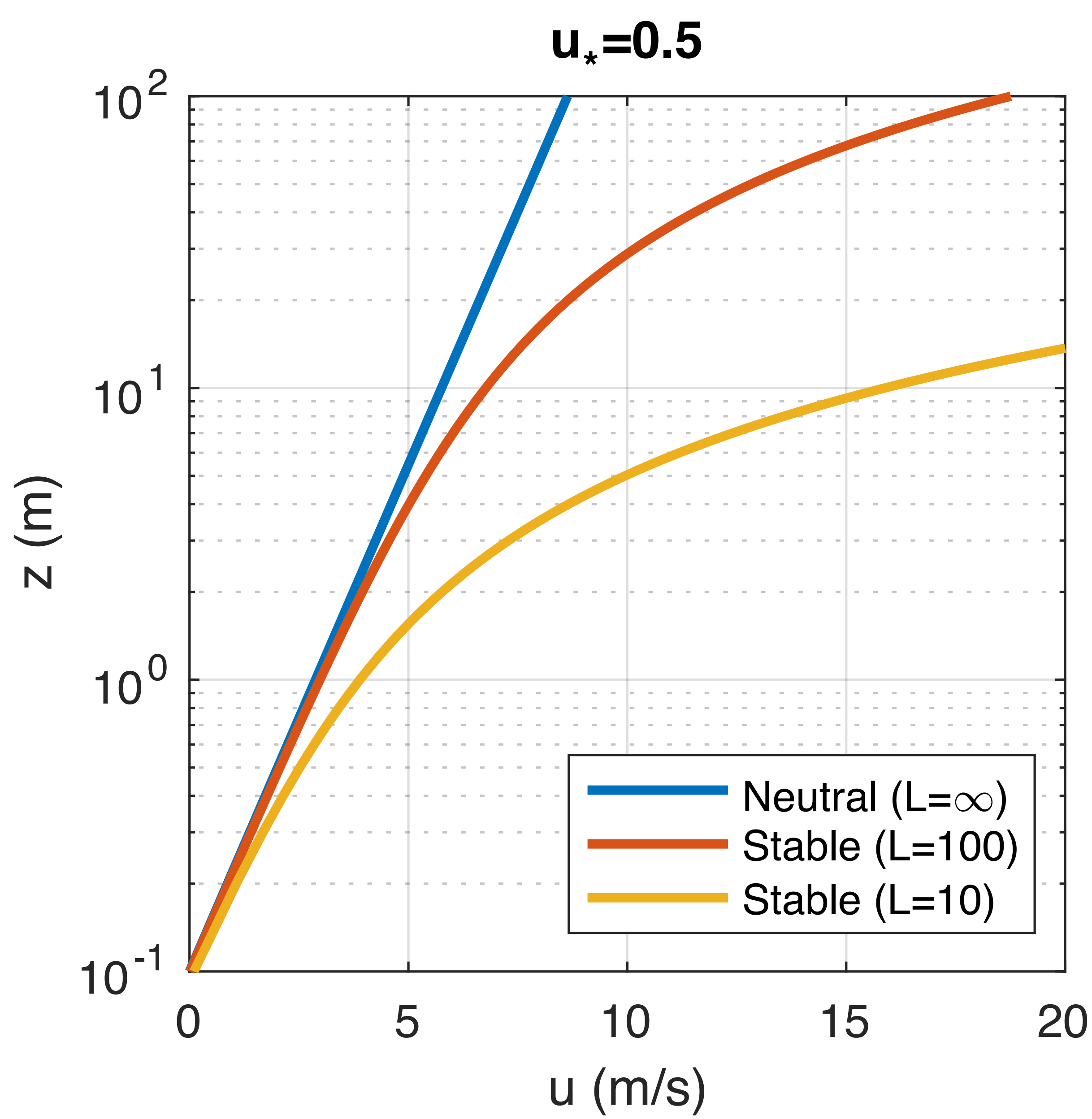


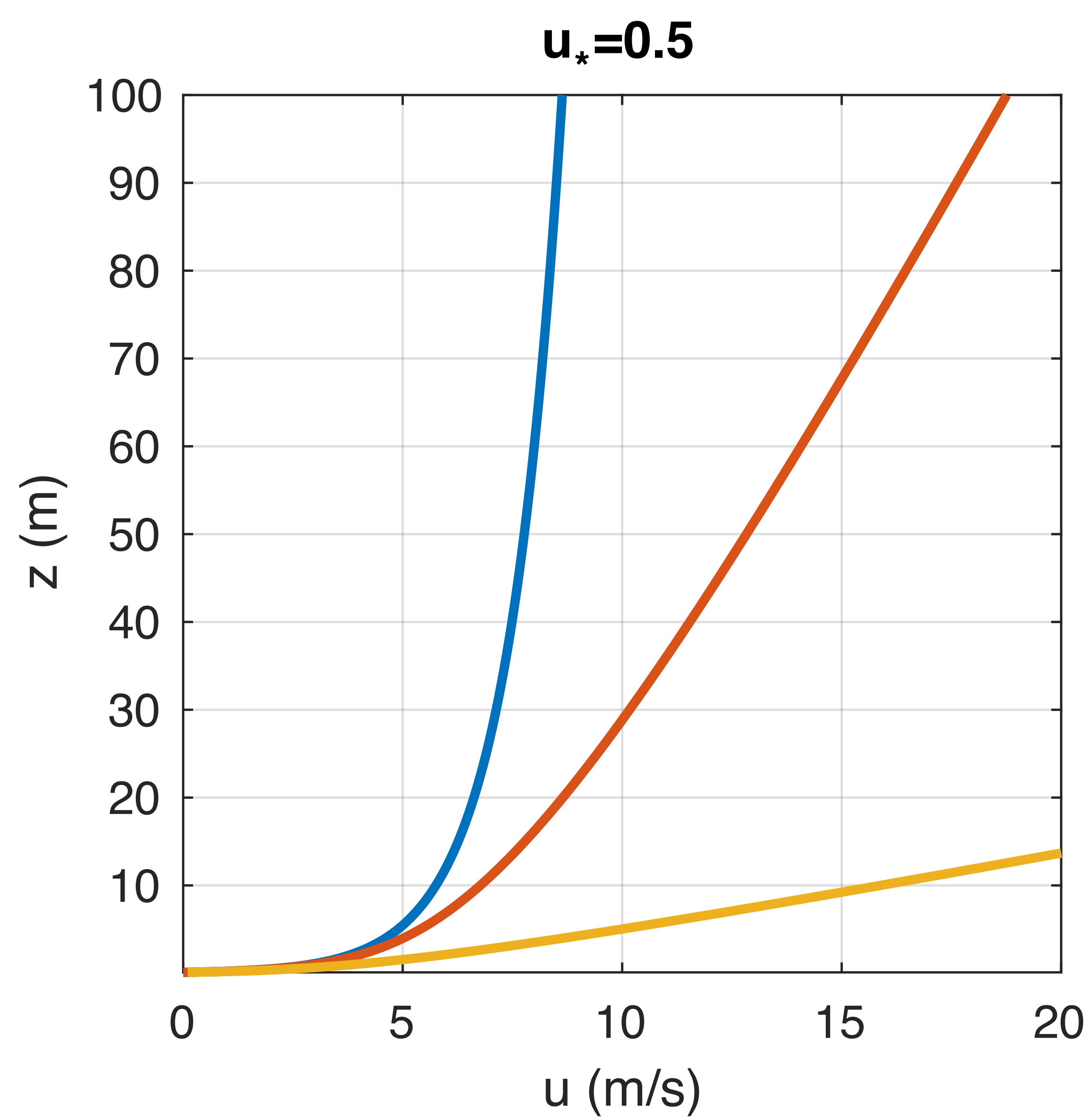
What parameter is different for each profile?



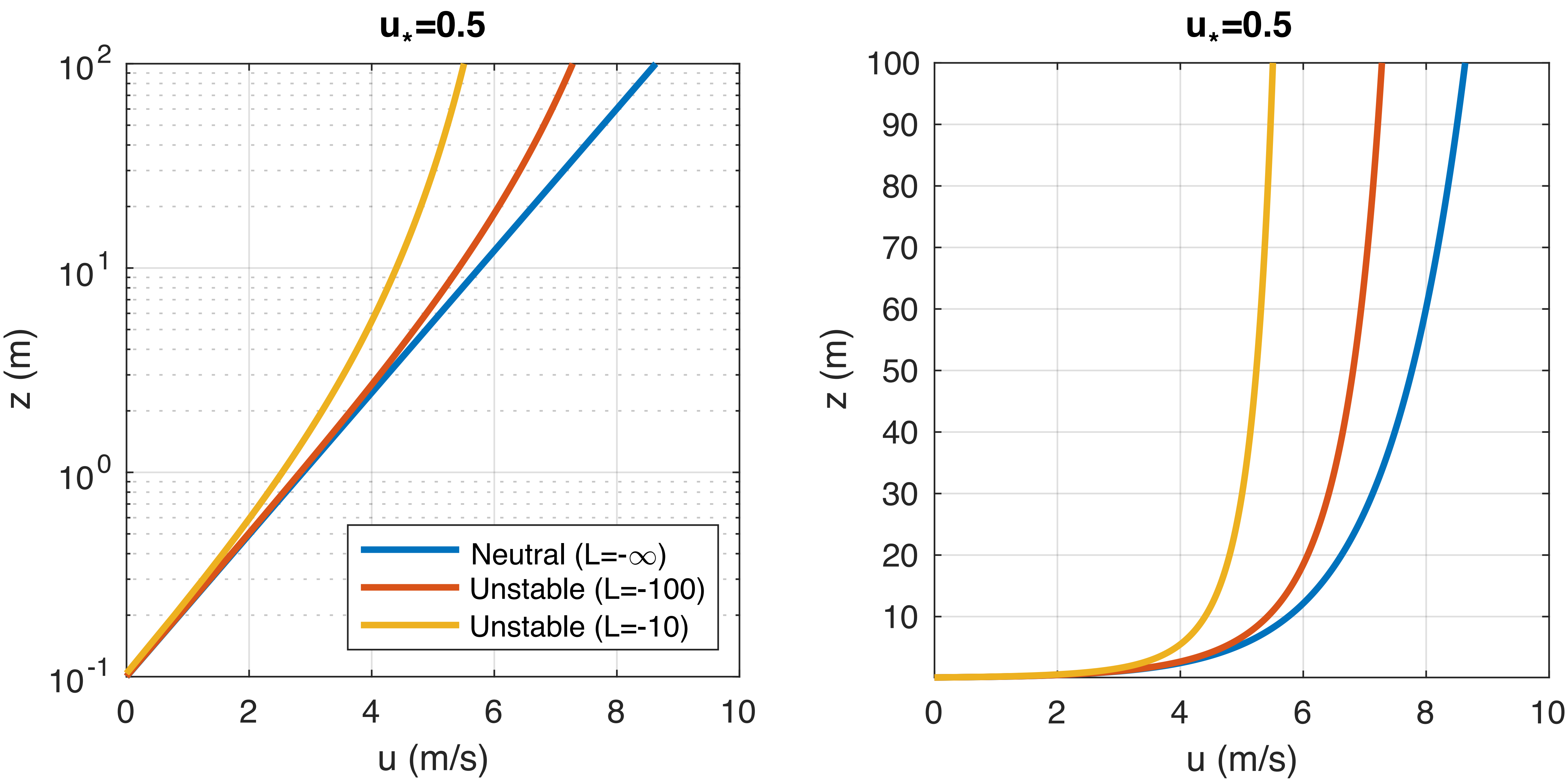


What parameter is different for each profile?





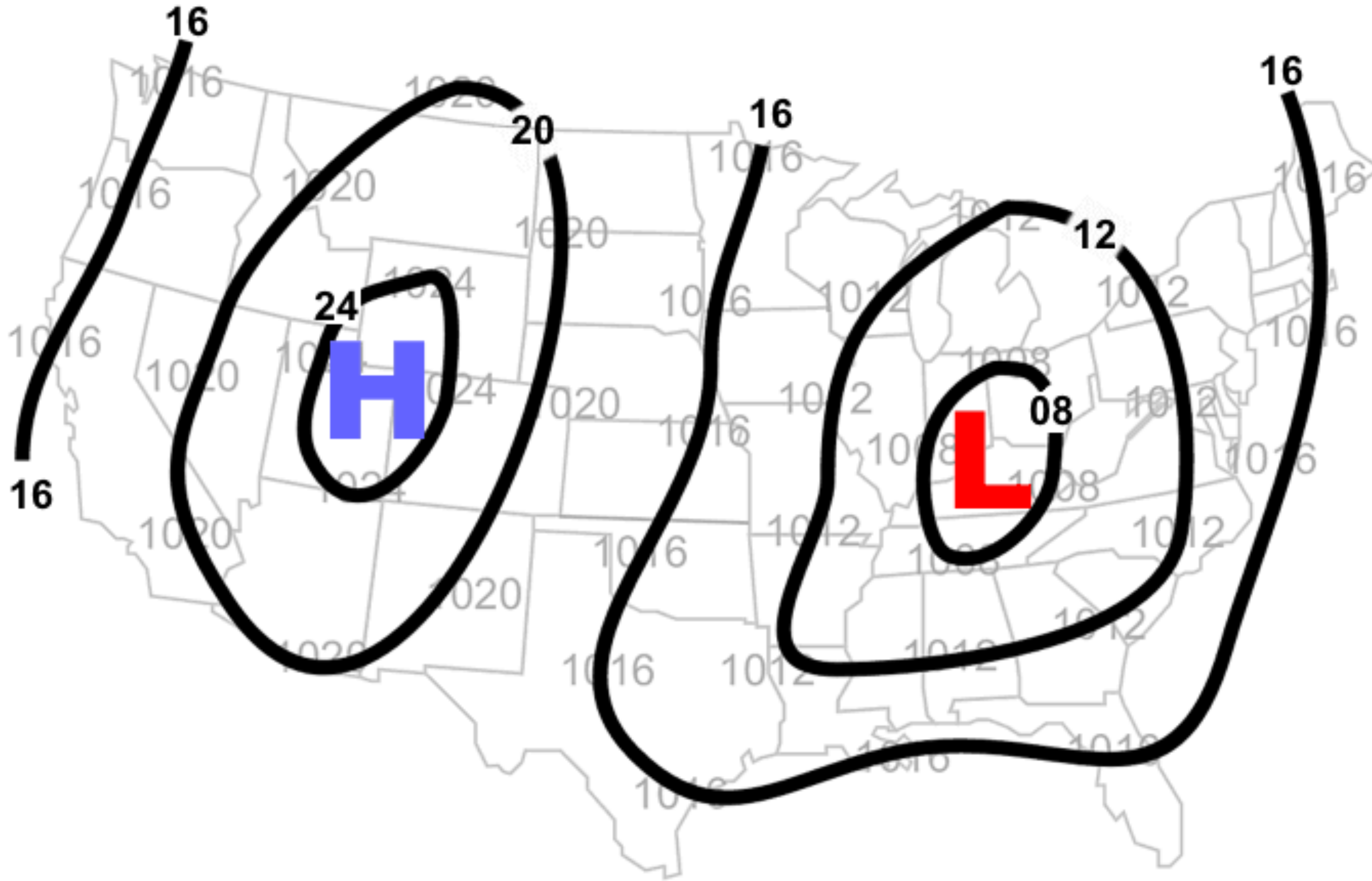
What parameter is different for each profile?



6. (4 points) (a) In the surface layer, how does the vertical gradient of wind speed change as the stability increases?

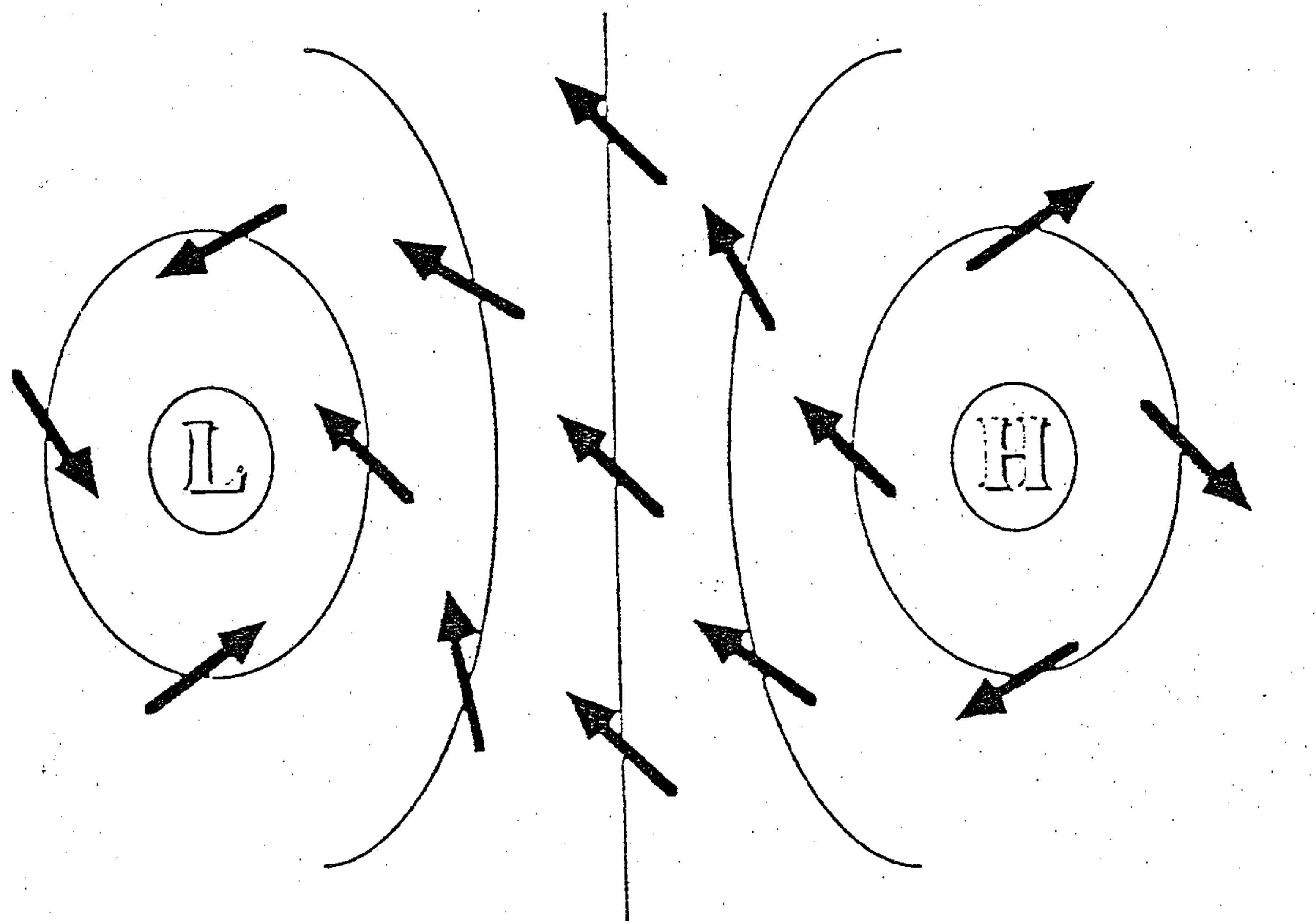
(b) In the stable surface layer, how does the ratio of the buoyancy consumption of TKE to the mechanical production of TKE change as the stability (as measured by the Richardson number) increases?

Surface Pressure (isobars)



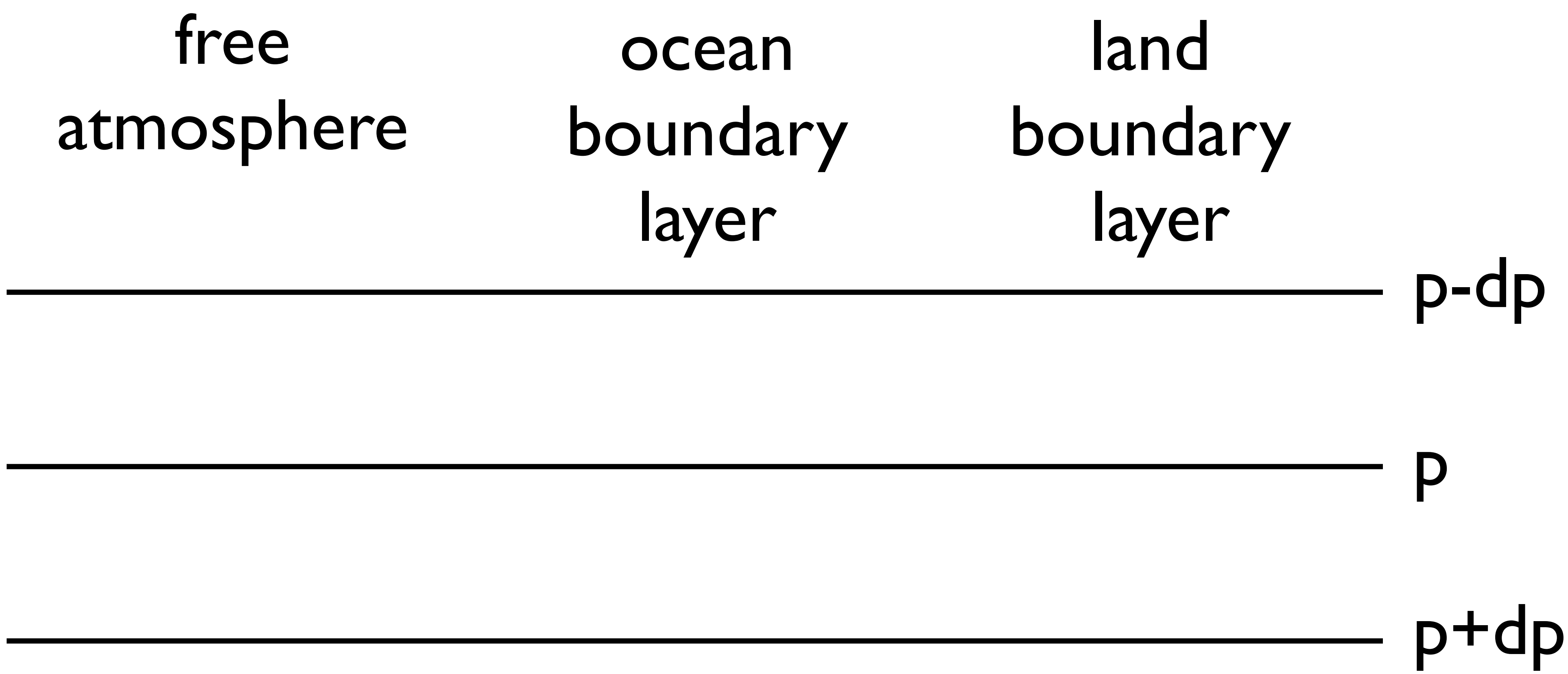
Draw the surface wind vectors

- Although not resolved by meteorological observing networks, turbulent eddies on the ABL are very important and their effects cannot be neglected.
- Due to their effects, *geostrophic balance* is not a good approximation to the large-scale wind field in the PBL. This diagram shows schematic surface isobars and wind vectors.



- The ABL is also the source of air that rises into *convective clouds*, and is affected by downdrafts and precipitation from such clouds.

7. (6 points) Draw arrows to schematically represent the horizontal wind vectors for the given *horizontal* pressure field and flow regimes in the northern hemisphere.



13. (6 points)

The plots below show how the boundary layer height (h), vertically averaged potential temperature (θ), sensible heat flux at the top of the boundary layer due to entrainment ($F_h \equiv (\overline{w'\theta'})_h$), and surface sensible heat flux ($F_s \equiv (\overline{w'\theta'})_s$) evolve in a cloud-free well-mixed boundary layer over an ocean surface with a fixed potential temperature of $\theta_s = 290$ K and a steady surface wind speed, V. This boundary layer undergoes no entrainment; this could occur when the boundary layer is capped by a very stable interface (a much warmer layer above).

(a) What is the bulk aerodynamic formula for calculating the surface sensible heat flux?

(b) Why does θ reach an equilibrium of 290 K?

(c) Why does F_s decrease to zero?