University of Utah LES Results

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Objectives

- Compare conditionally sampled LES cloud properties to similarly sampled aircraft measurements (this talk)
- Infer entrainment characteristics from measured in-cloud mean and variance profiles (future)
- Examine LES representation of entrainment (future)

Cloud properties

- For given cloud base and environmental conditions, cloud property profiles depend primarily on:
  - vertical velocity: w
  - fractional entrainment rate: λ
  - characteristic entrained blob size: d
  - TKE dissipation rate: ε

- For a given λ, the quantities w, d, and ε determine the degree of mixing or internal structure.

- The parameters w, d, and ε determine the mixing height scale, $w(d^2/\varepsilon)^{1/3}$.

- For larger values of this scale, a parcel will be relatively less mixed at a given height and thus have more internal variability.

- Of the three mixing parameters, two are reasonably well measured quantities (w and ε), while the remaining parameter (d) is not.

Some factors that affect large droplet production

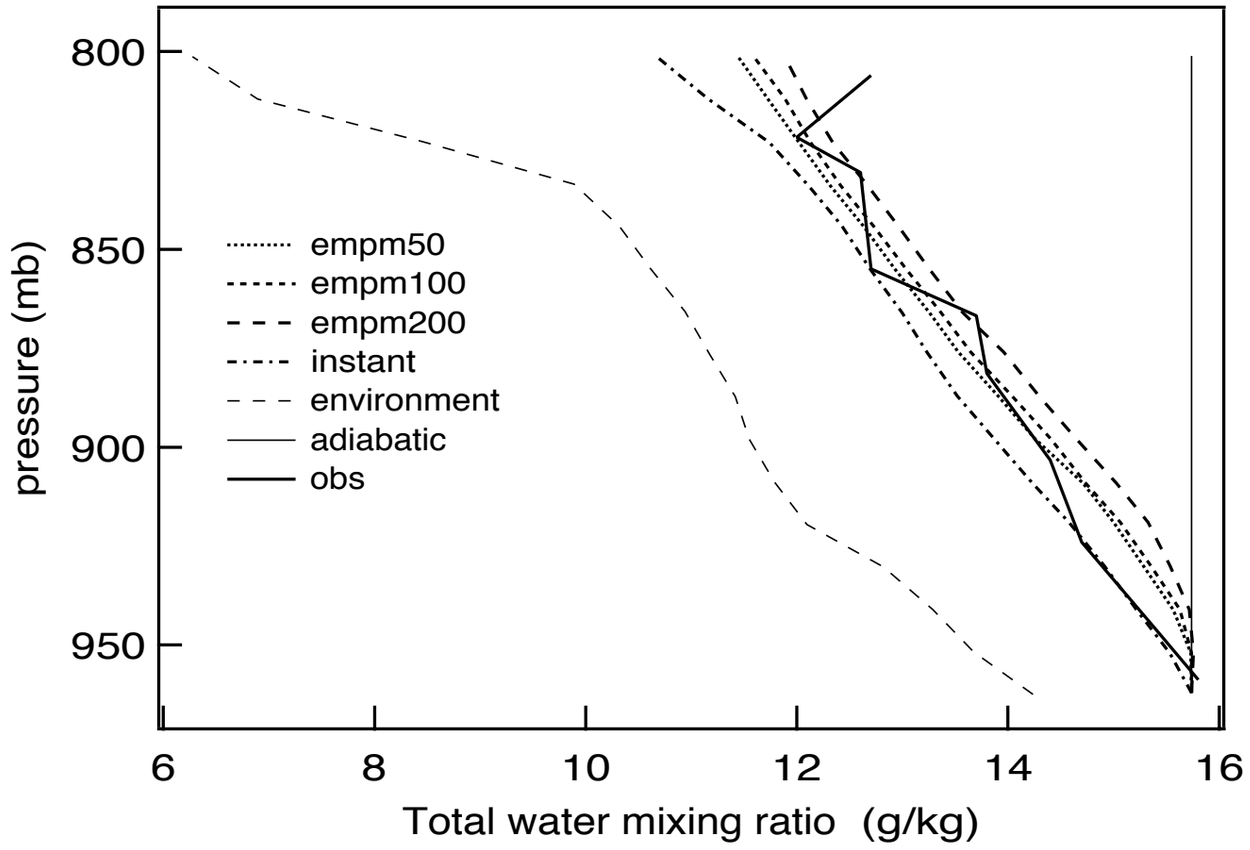
- Turbulence intensity (dissipation rate)

- Entrained blob size

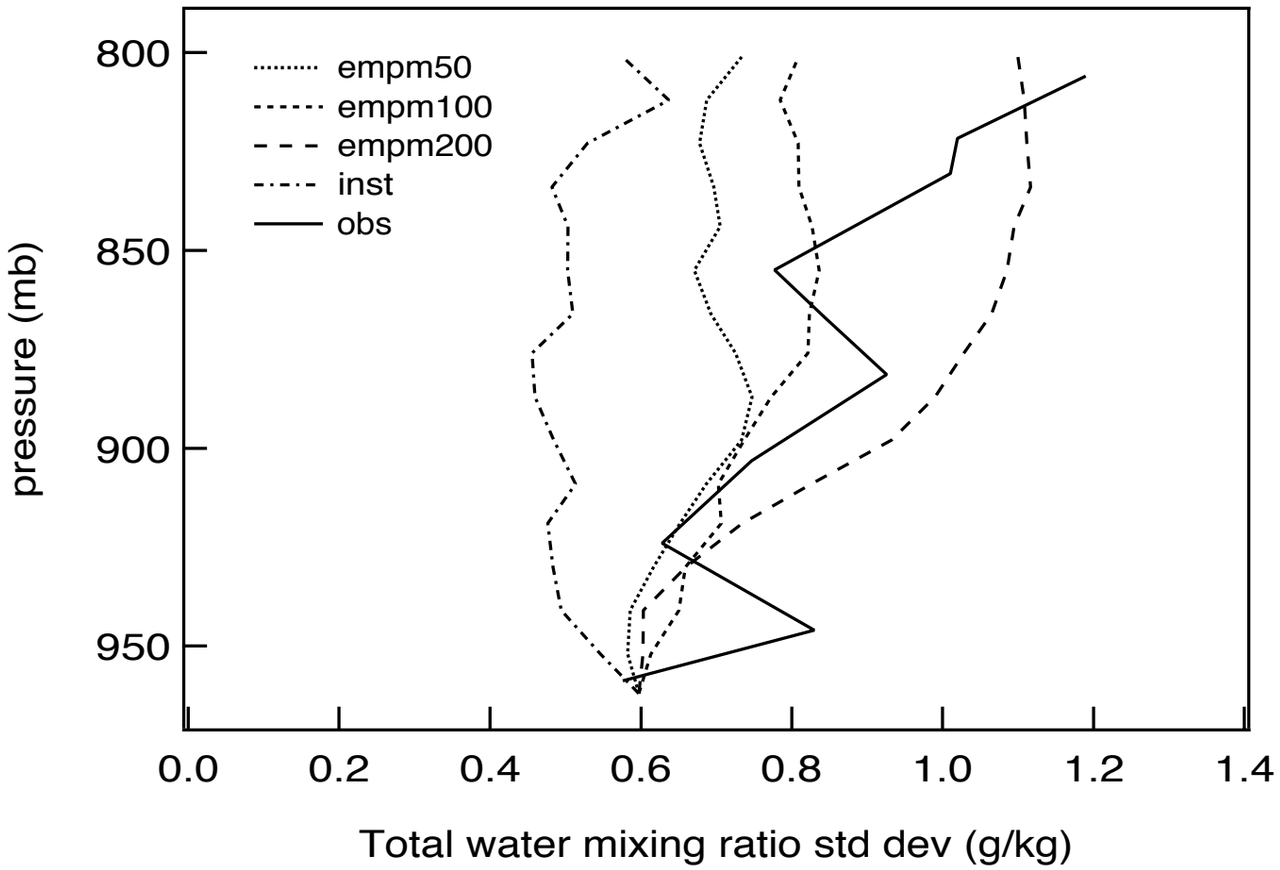
- Entrainment rate

- Relative humidity of entrained air

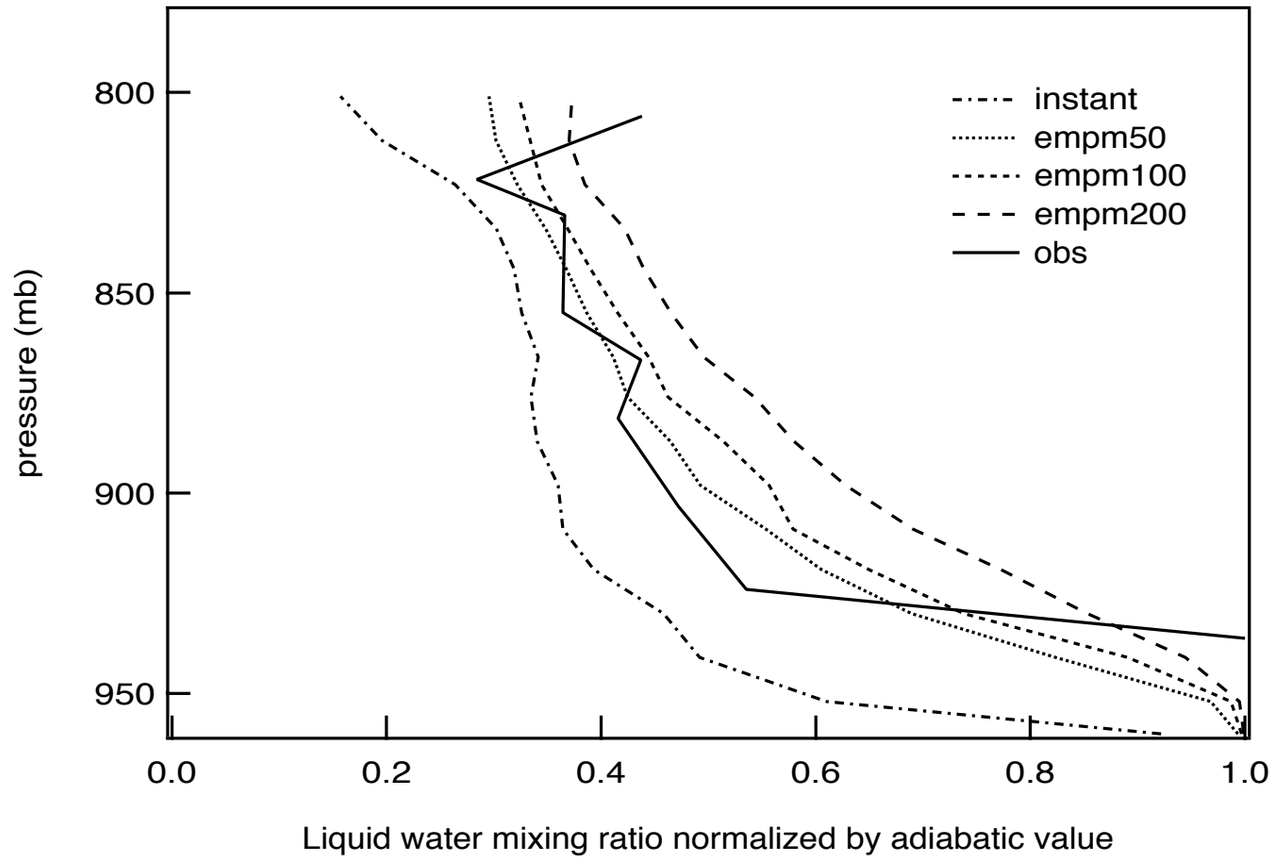
EMPM (Explicit Mixing Parcel Model, Krueger et al. 1997)

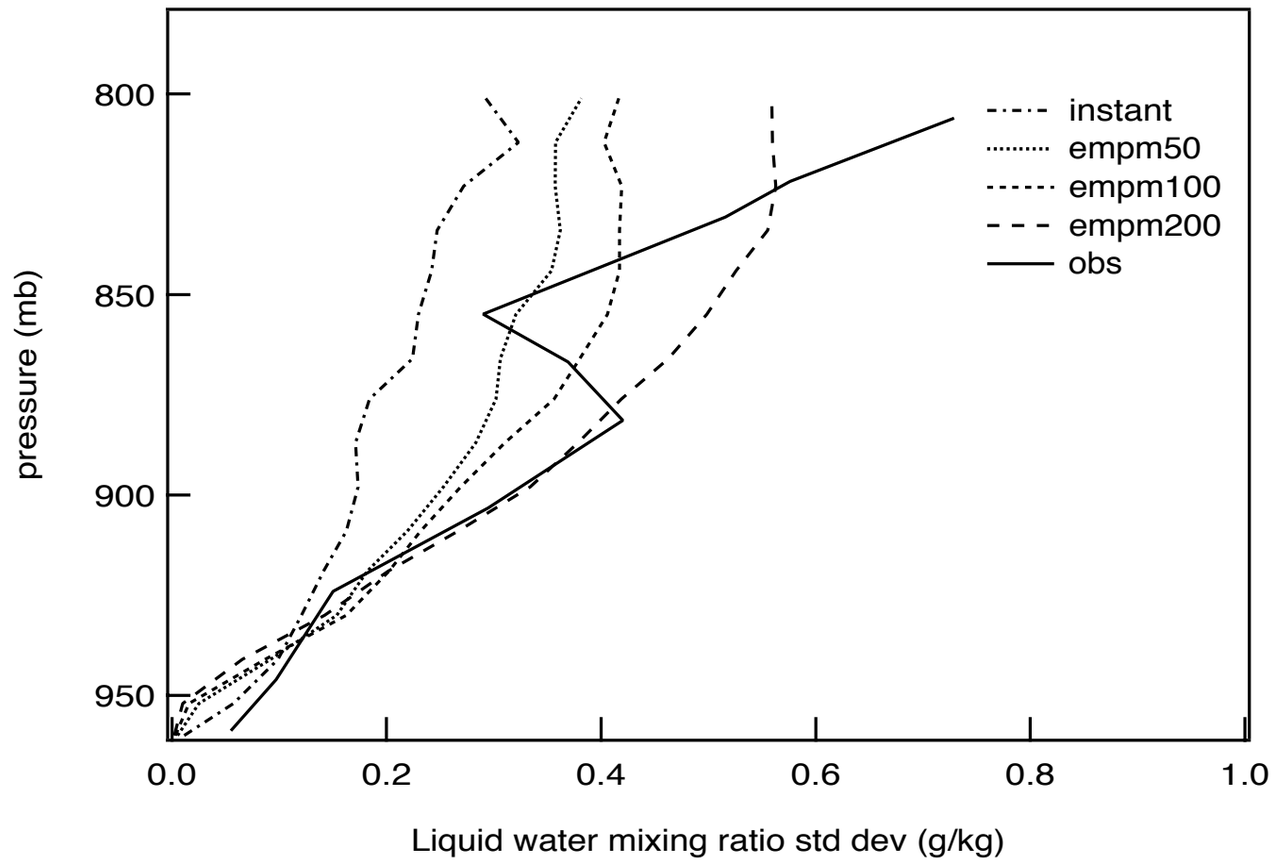


Total water mixing ratio variance depends on entrained blob size



Cloud water mixing ratio mean and variance depend on entrained blob size



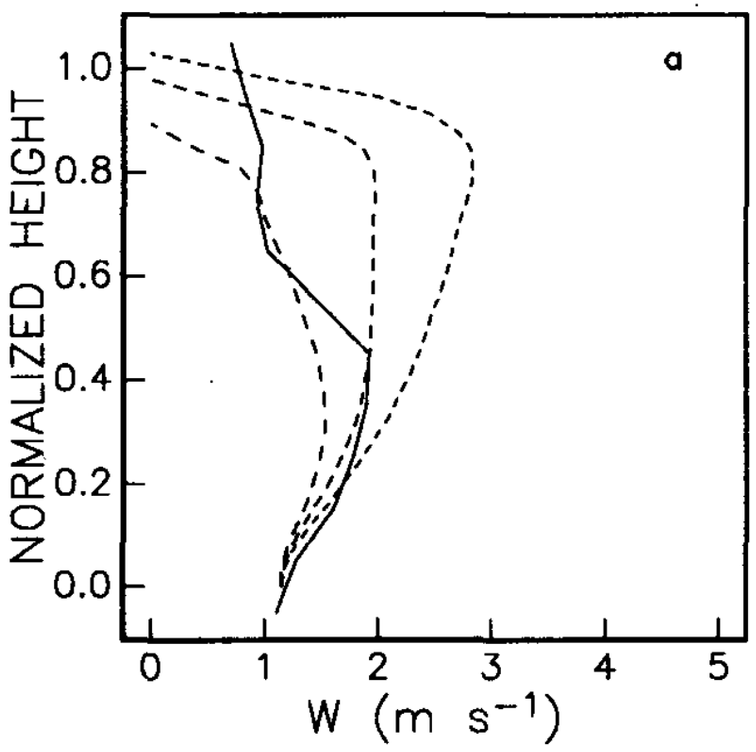


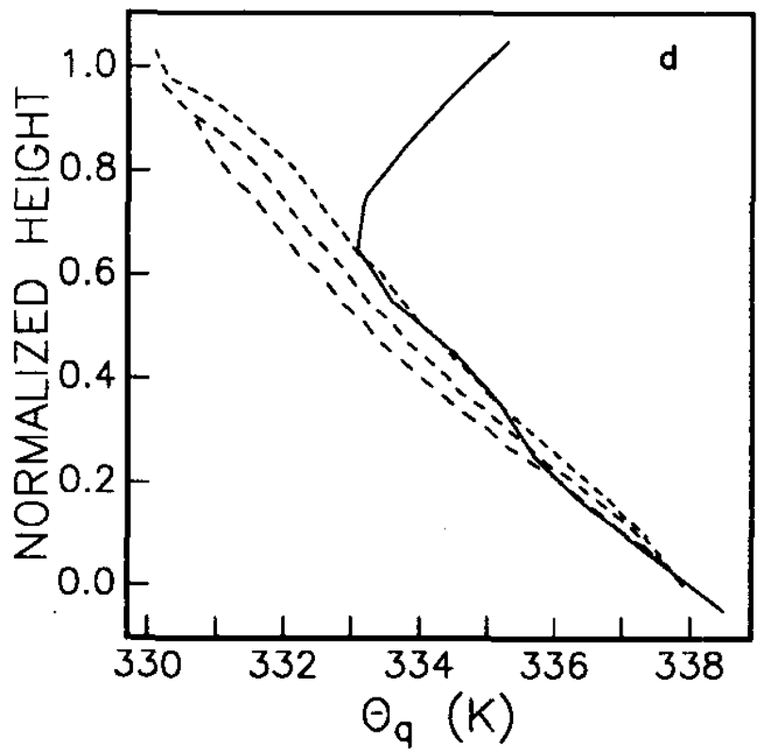
- Aircraft data sets for RICO RF 12 based on conditional sampling
  - *Hermann Gerber*
  - *Brad Baker*

Gerber's Cu turrets

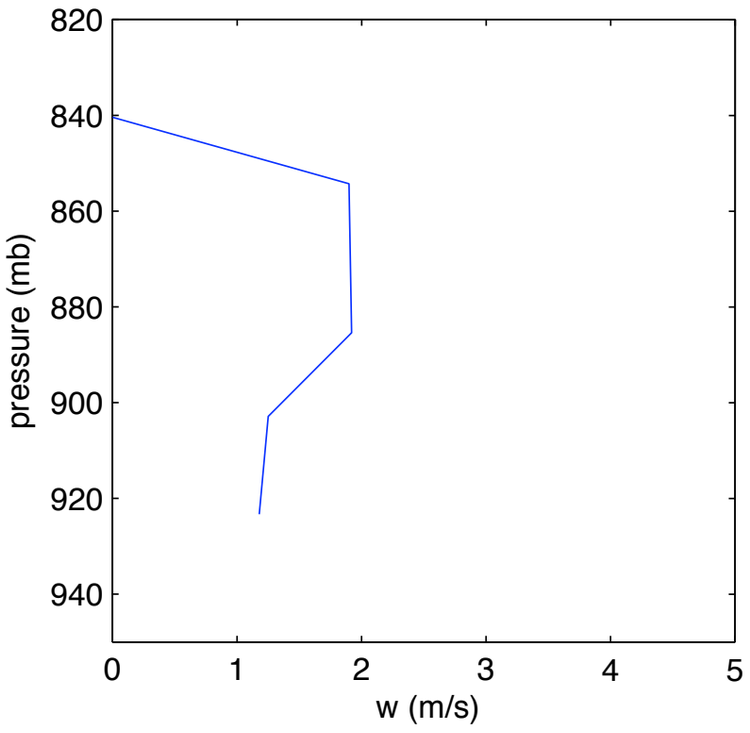
- More than 80 percent cloudy updraft
- Sampled about 200 m below cloud tops
- A 35-cloud subset of 200 cloud penetrations during RF 12
- Raga, Jensen, and Baker (1990) used a similar sampling strategy for Hawaiian Cu

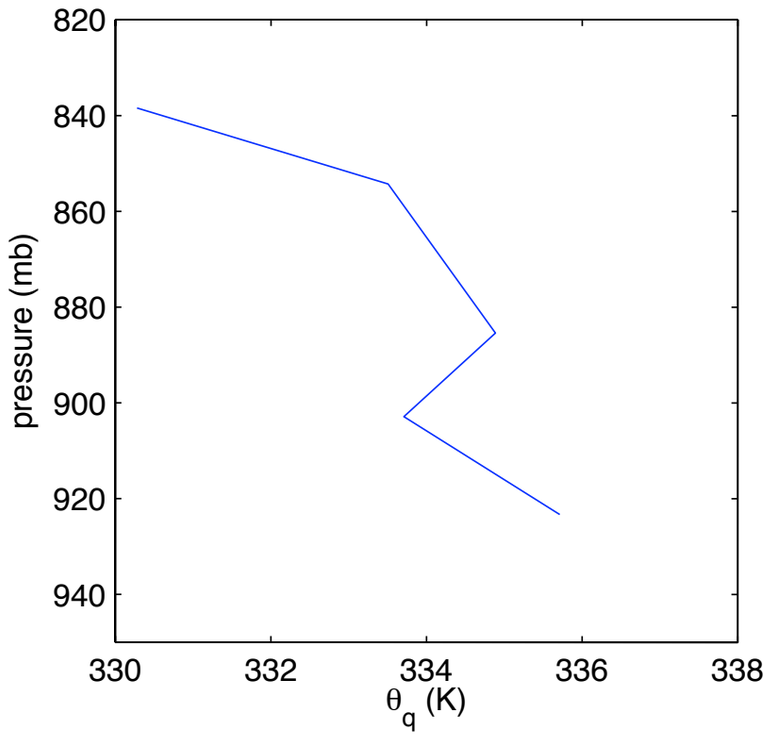
Hawaiian Cu turrets (Raga Jensen Baker 1990)



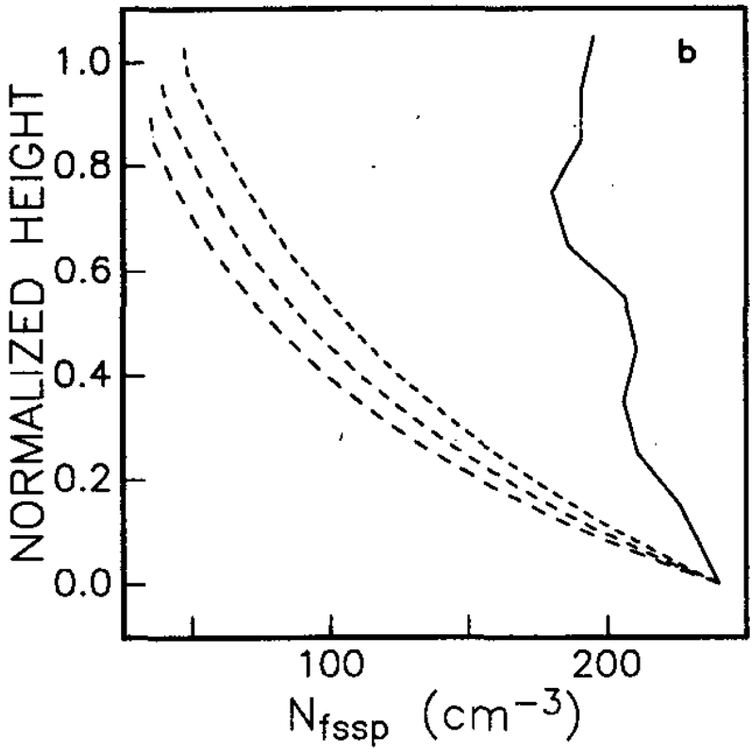


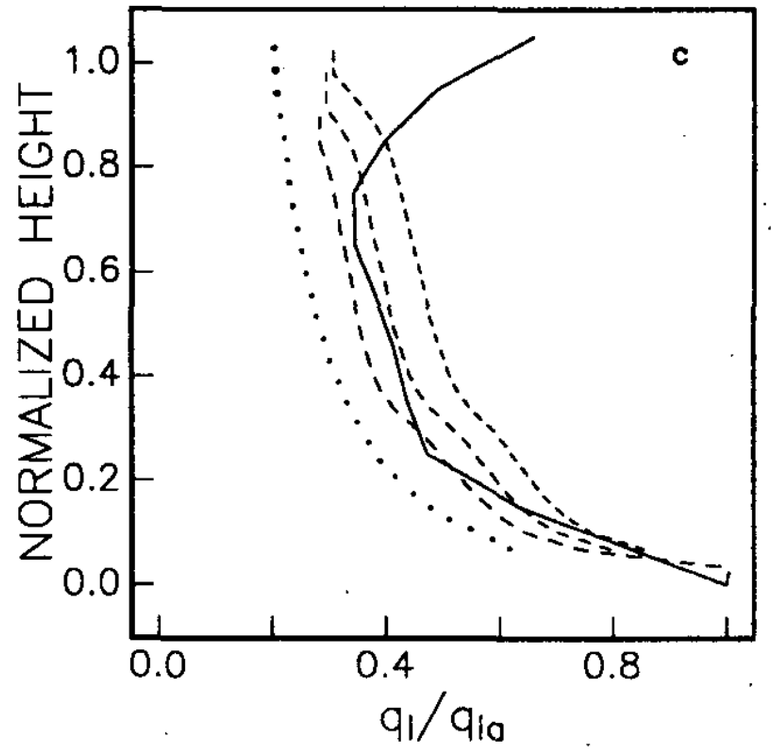
RICO RF 12 Cu turrets (Gerber)



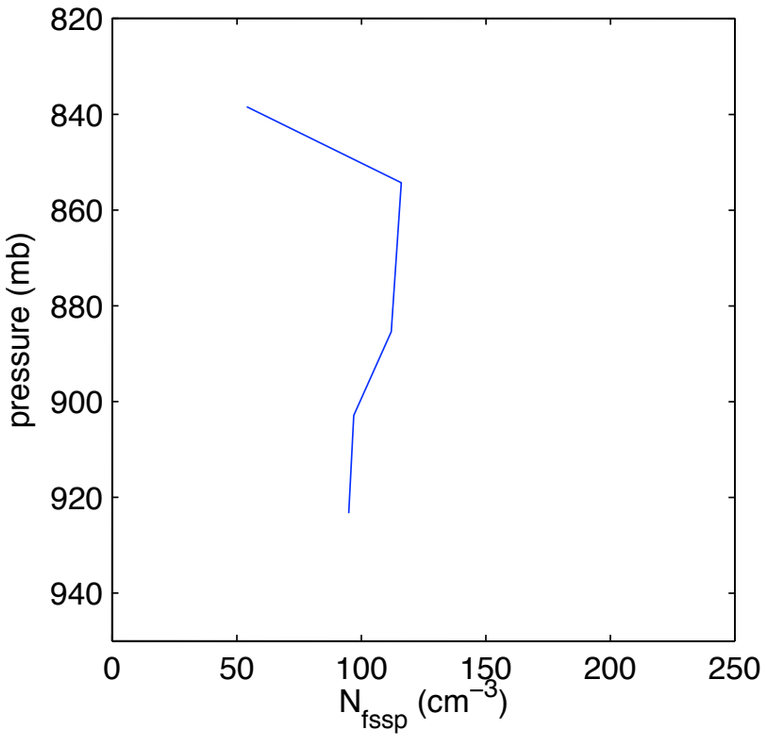


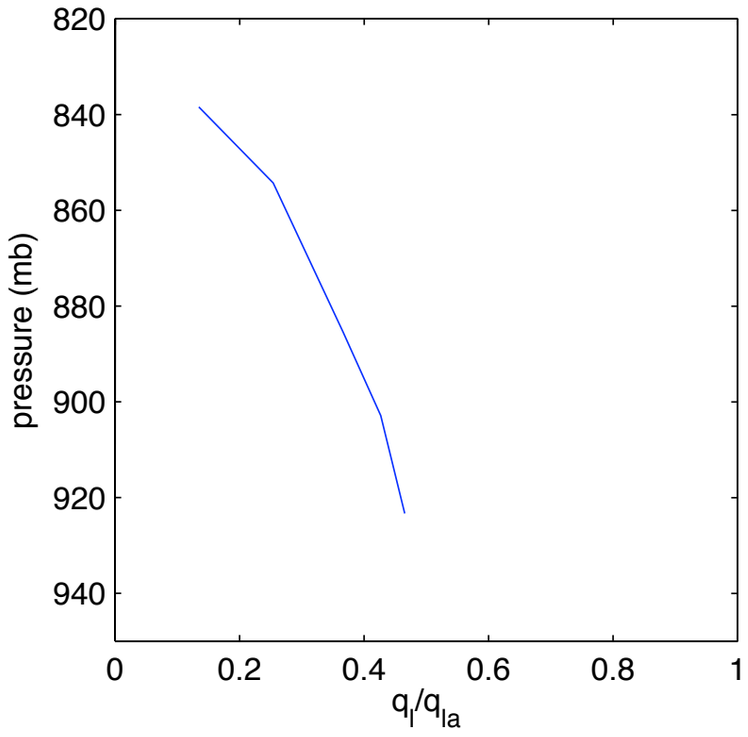
Hawaiian Cu turrets (Raga Jensen Baker 1990)





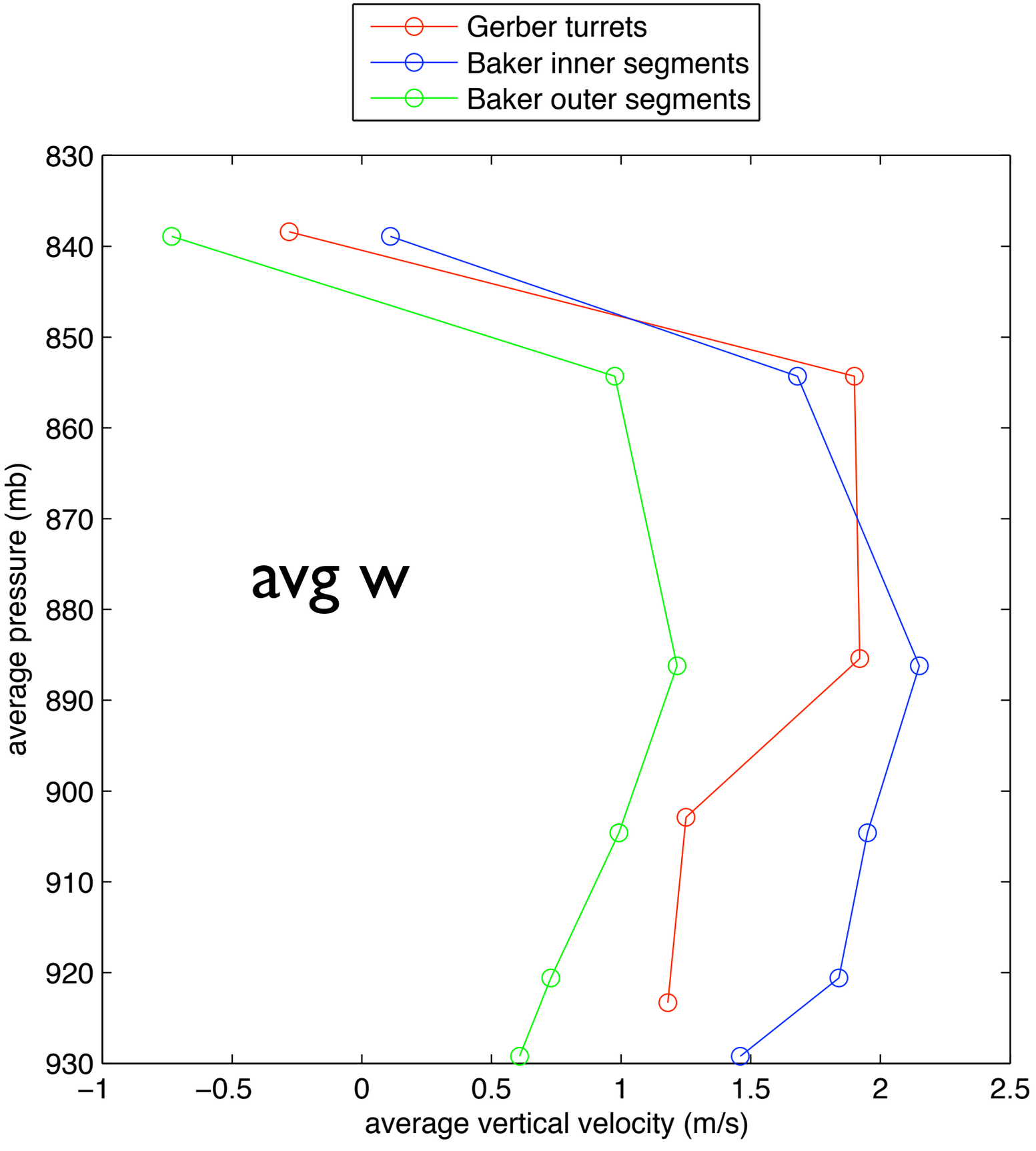
RICO RF 12 Cu turrets (Gerber)

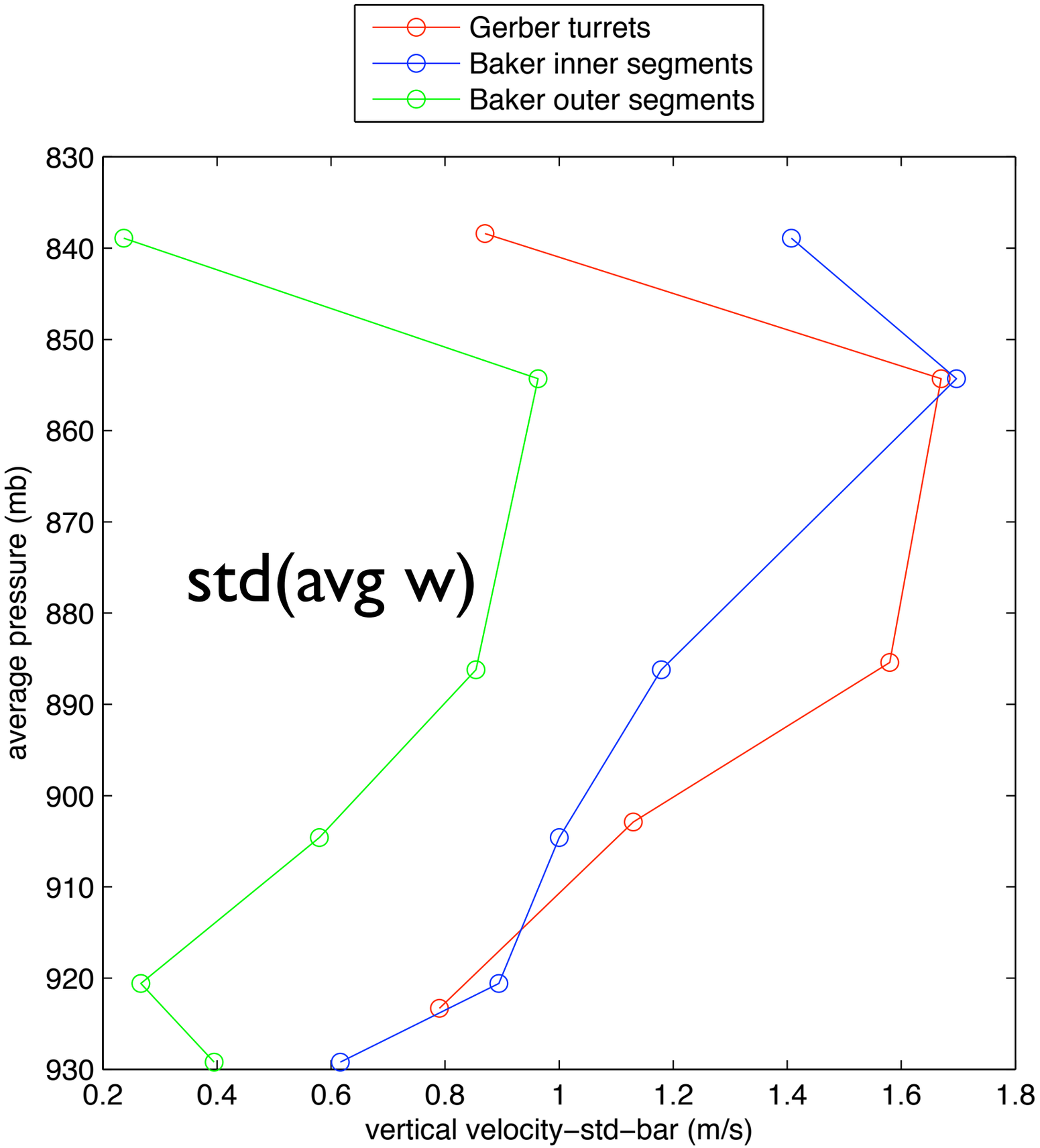


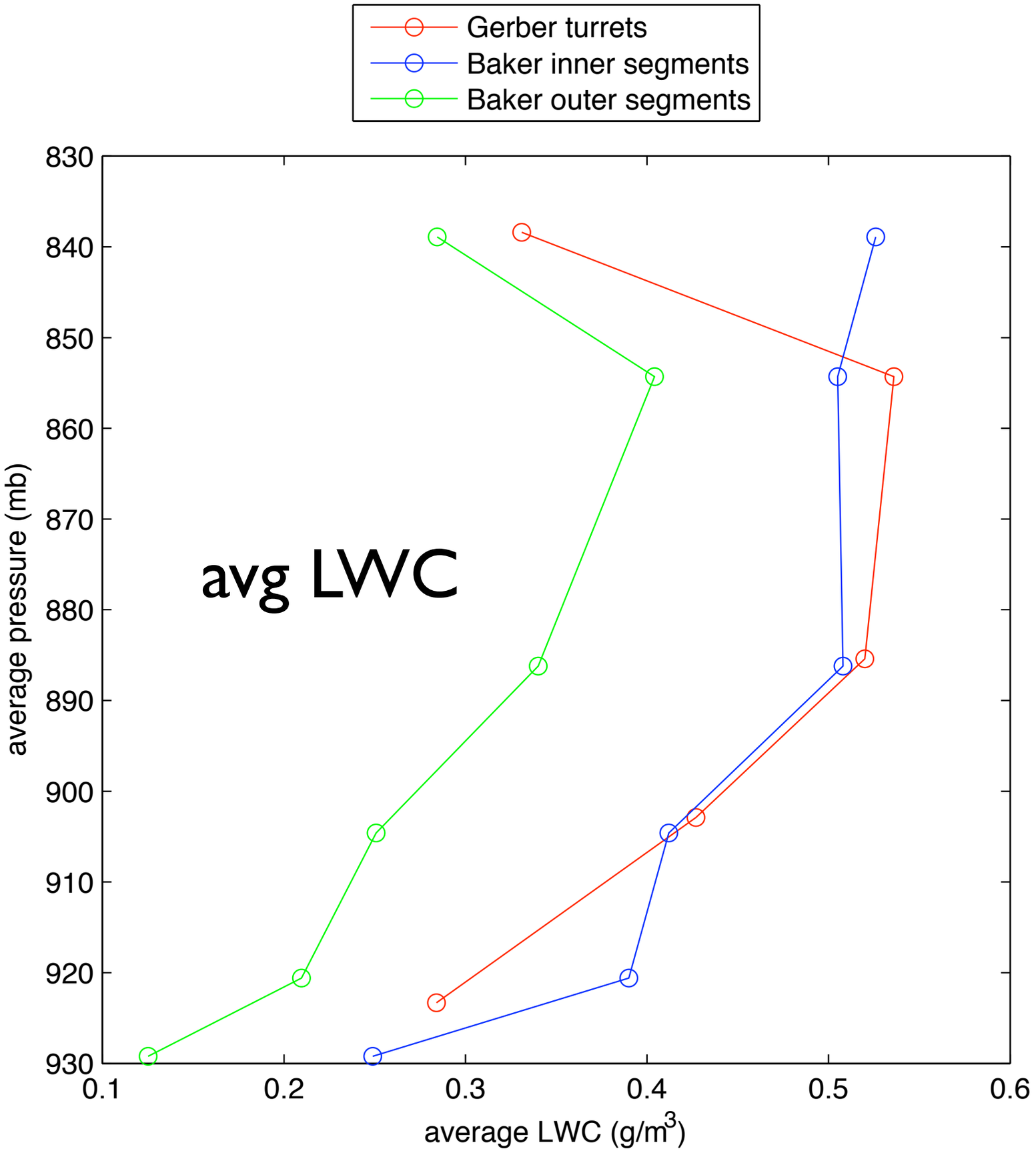


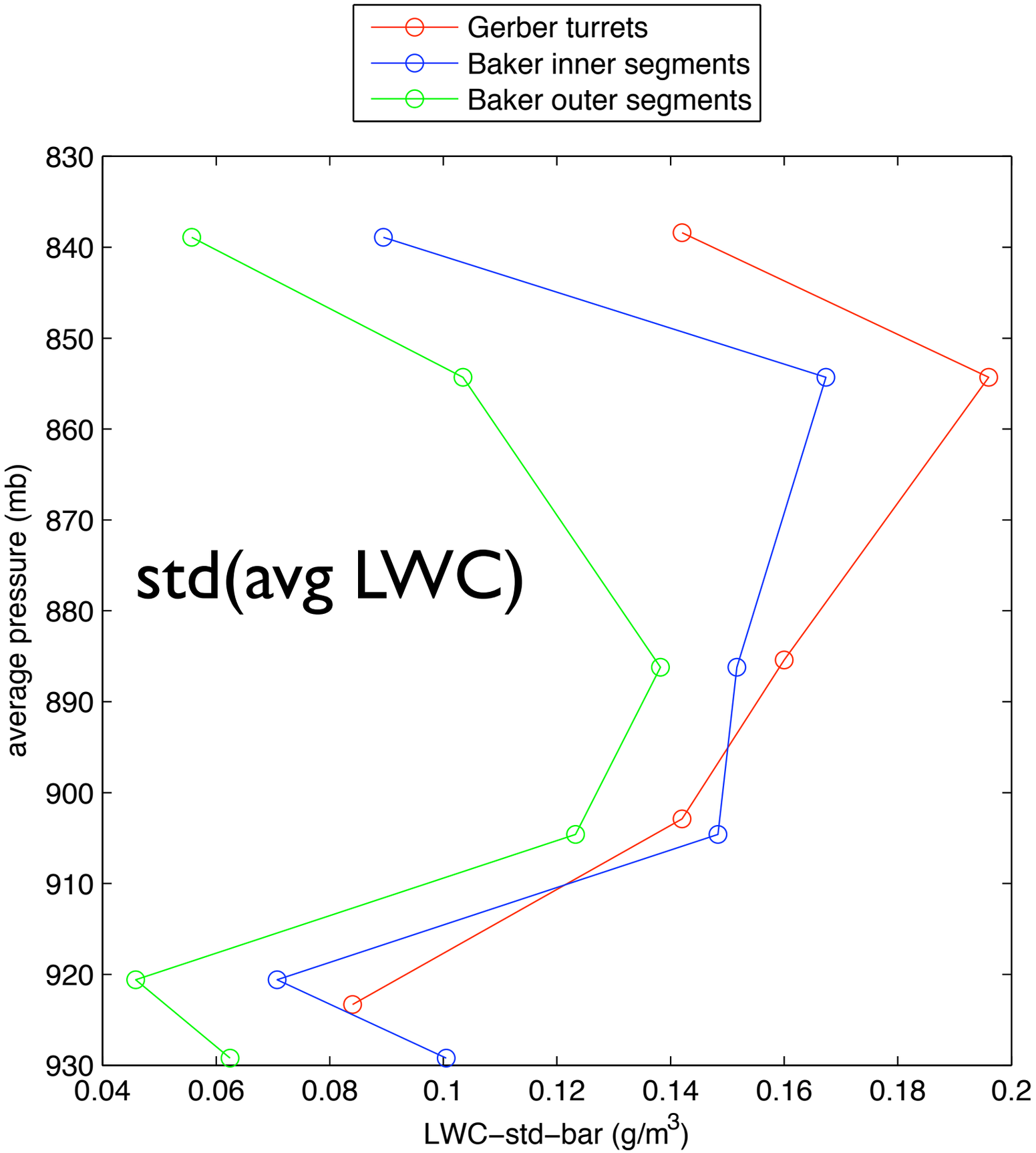
Brad Baker's cloud segments

- *Outer cloud segments:*
  - N_{FSSP} > 10 cm^{-3} bounded by N_{FSSP} < 0.1 cm^{-3} for 0.2 s (20 m) or more.
- *Inner cloud segments:*
  - Occur within outer segments when min(N_{FSSP}) > 0.8 avg(N_{FSSP}) and max(N_{FSSP}) < 1.2 avg(N_{FSSP}) for 1.2 s (120 m) or more.
  - About 130 identified for RF 12


Gerber turrets
Baker inner segments
Baker outer segments
avg w
average pressure (mb)
830
840
850
860
870
880
890
900
910
920
930
−1
−0.5
0
0.5
1
1.5
2
2.5
average vertical velocity (m/s)


Gerber turrets
Baker inner segments
Baker outer segments
std(avg w)
average pressure (mb)
830
840
850
860
870
880
890
900
910
920
930
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
vertical velocity–std–bar (m/s)

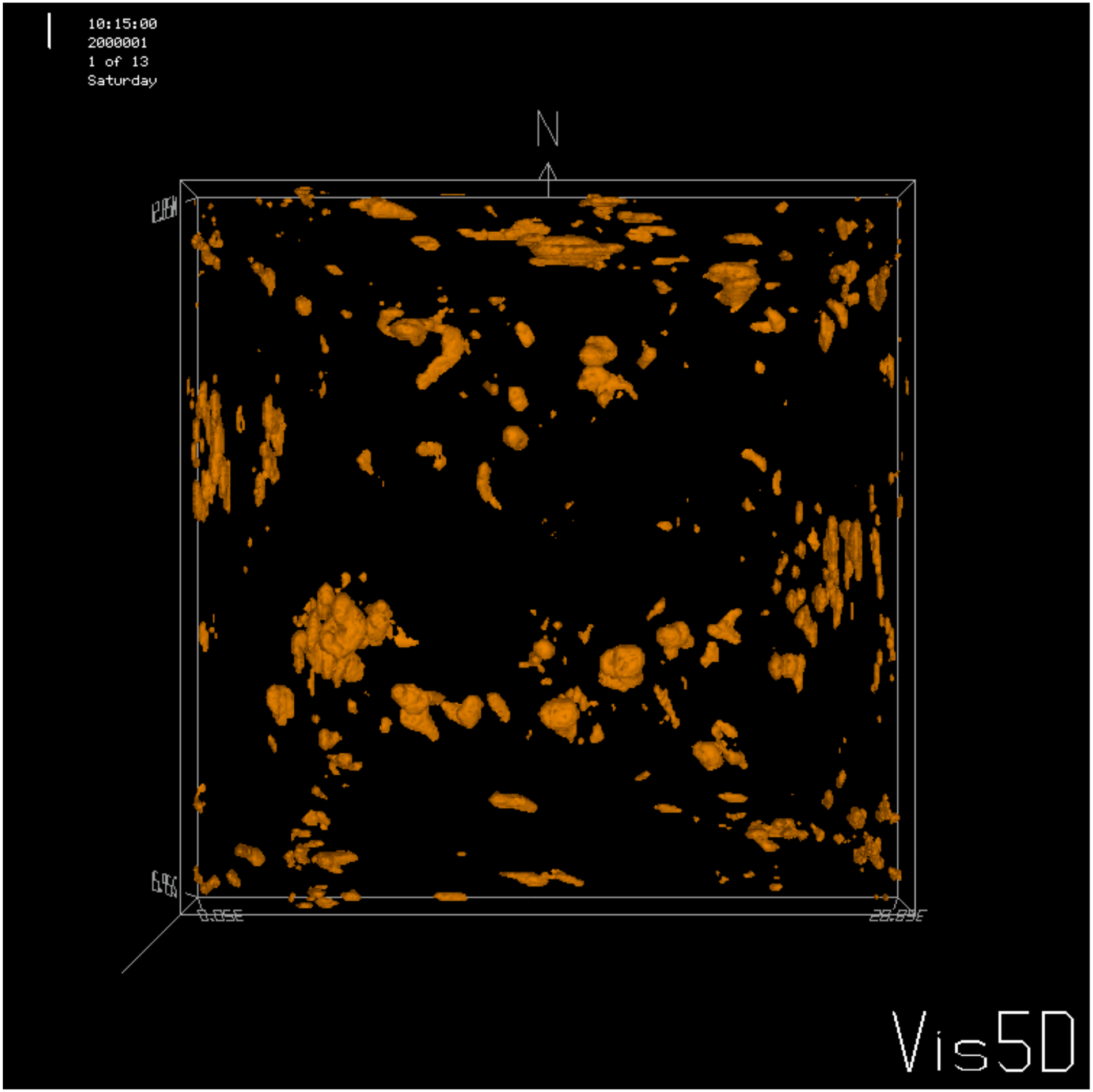

Gerber turrets
Baker inner segments
Baker outer segments
avg LWC
average pressure (mb)
830
840
850
860
870
880
890
900
910
920
930
0.1
0.2
0.3
0.4
0.5
0.6
average LWC (g/m3)


Gerber turrets
Baker inner segments
Baker outer segments
std(avg LWC)
average pressure (mb)
830
840
850
860
870
880
890
900
910
920
930
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
LWC−std−bar (g/m3)

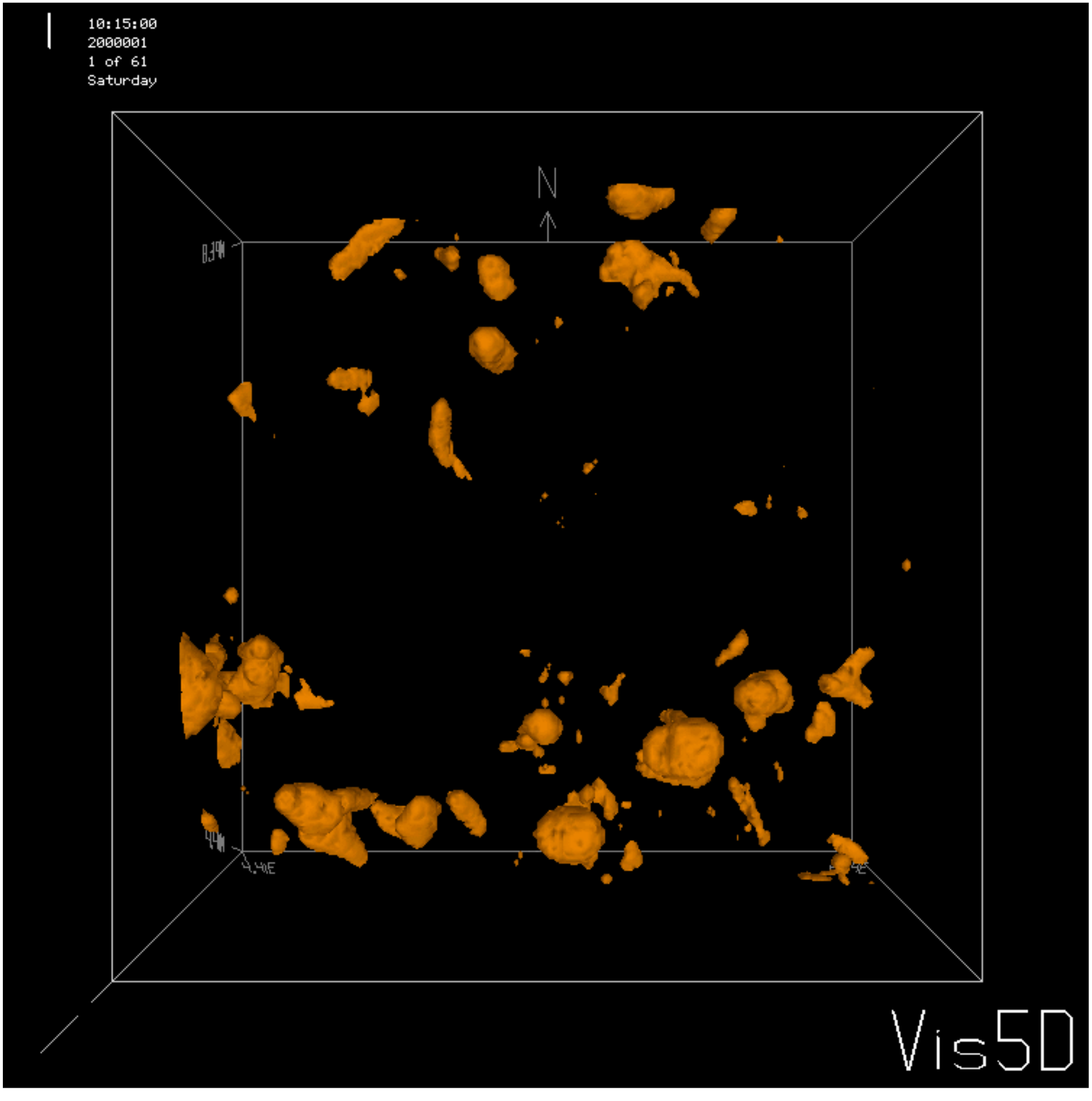
UU (Univ of Utah) LES of GCSS RICO case

- *To simulate Cu at high resolution over a limited area for a limited time:*
  - Use a horizontally variable grid size in *x* and *y*.
  - Select a domain translation that keeps clouds stationary relative to the grid.
  - Spin up successively higher resolution runs.

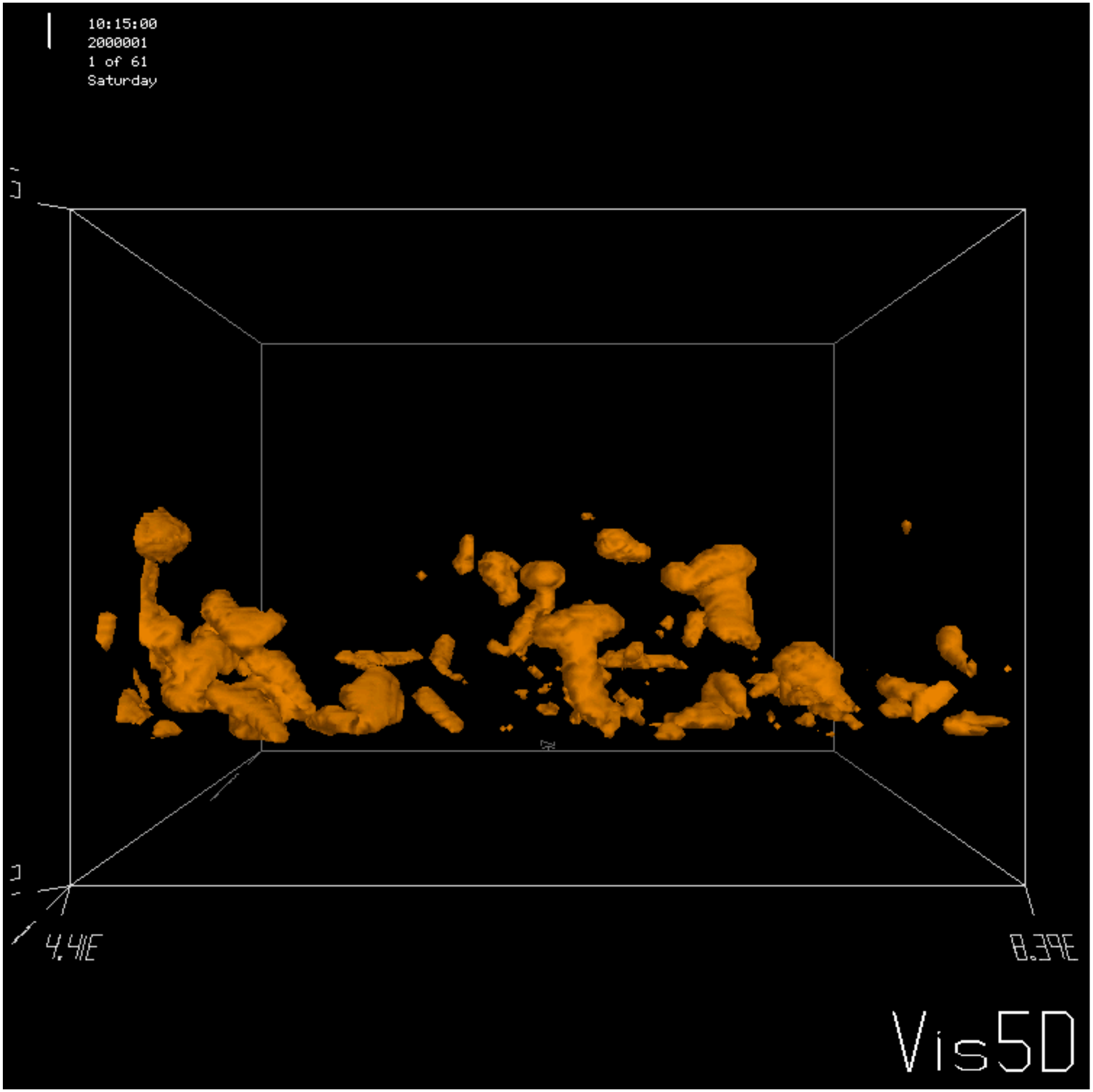
entire domain from above (25-m grid size, 1 hr @ 5 min)



hi-res region from above (25-m grid size, 1 hr @ 1 min)



hi-res region from side (25-m grid size, 1 hr @ 1 min)



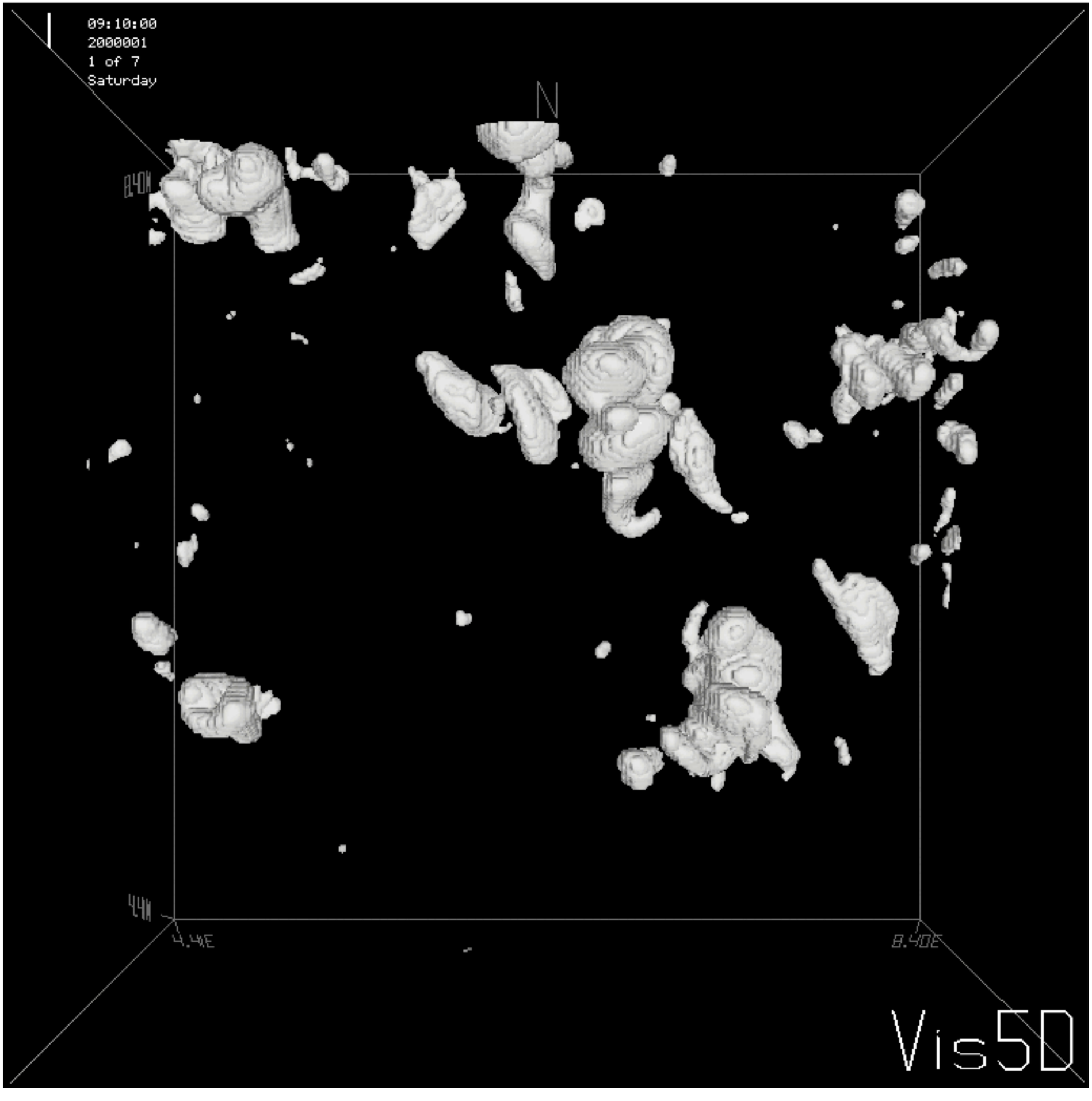
Our Procedure

1. Perform a simulation using standard grid for 12 h.
2. Select a period of interest.
3. Restart some time before to spin-up to desired higher resolution.
4. Spin-up time is $\sim 3\ \Delta x/u'$

Spin-up to 10-m grid size

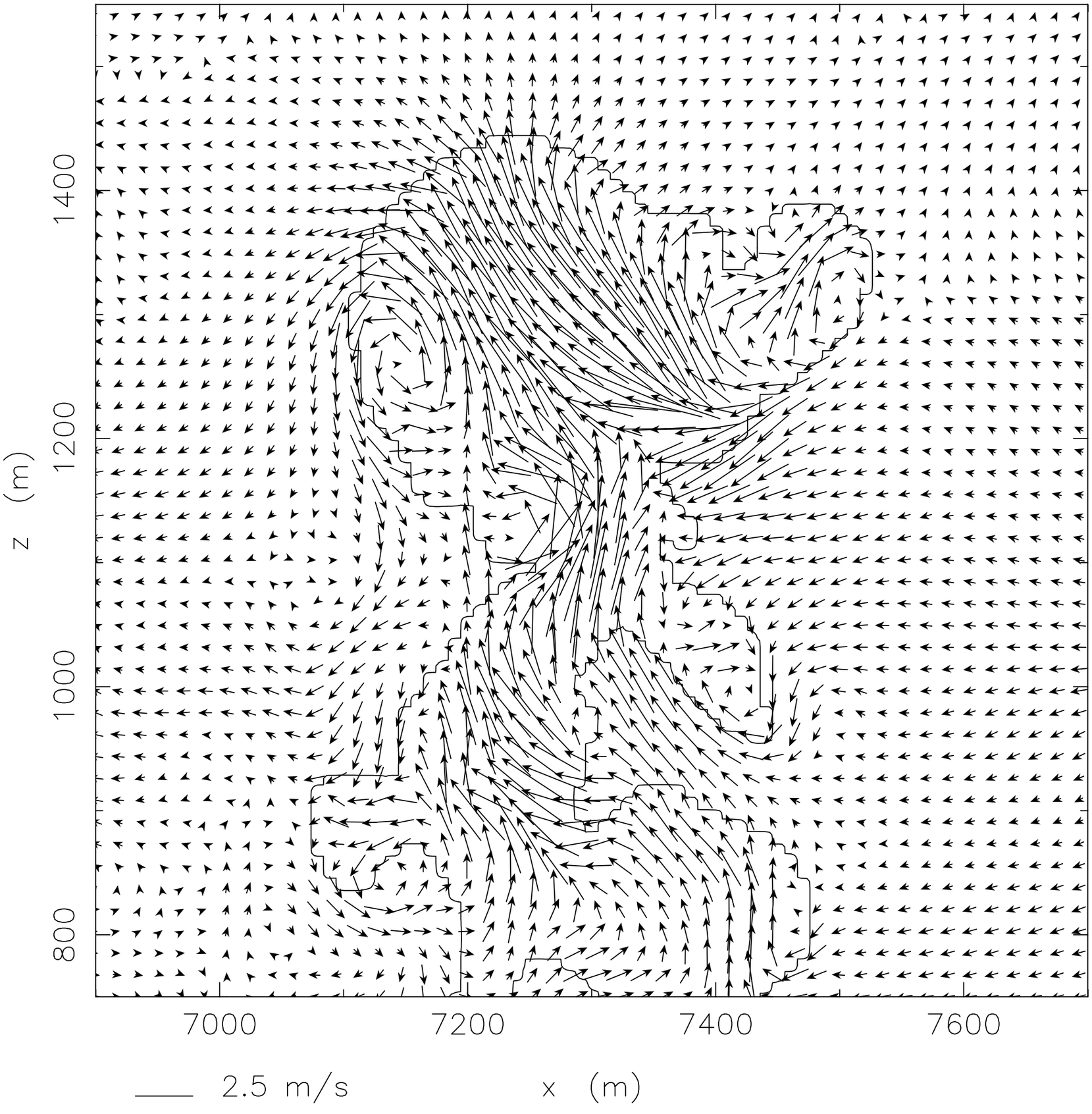
- Total domain size is 12.8 km x 12.8 km x 4 km.
- The hi-res region is 4 km x 4 km.
- The outermost regions have 50 m horizontal resolution.
- There is a variable-grid-size region between the outer region and the central hi-res region.
- Central region has 200 x 200 points for the 20 m run, and 400 x 400 for the 10 m.
- The vertical grids are slightly stretched: over the depth of active convection the vertical resolution is roughly the same as the horizontal resolution (in the hi-res regions).
- To spin up from 20 m to 10 m, for a simulated 180s, with a 0.5-s time step, took 158 minutes wall time on 64 CPUs (Opterons, jacquard at NERSC).

hi-res region from above (spin-up period for 10-m grid size)



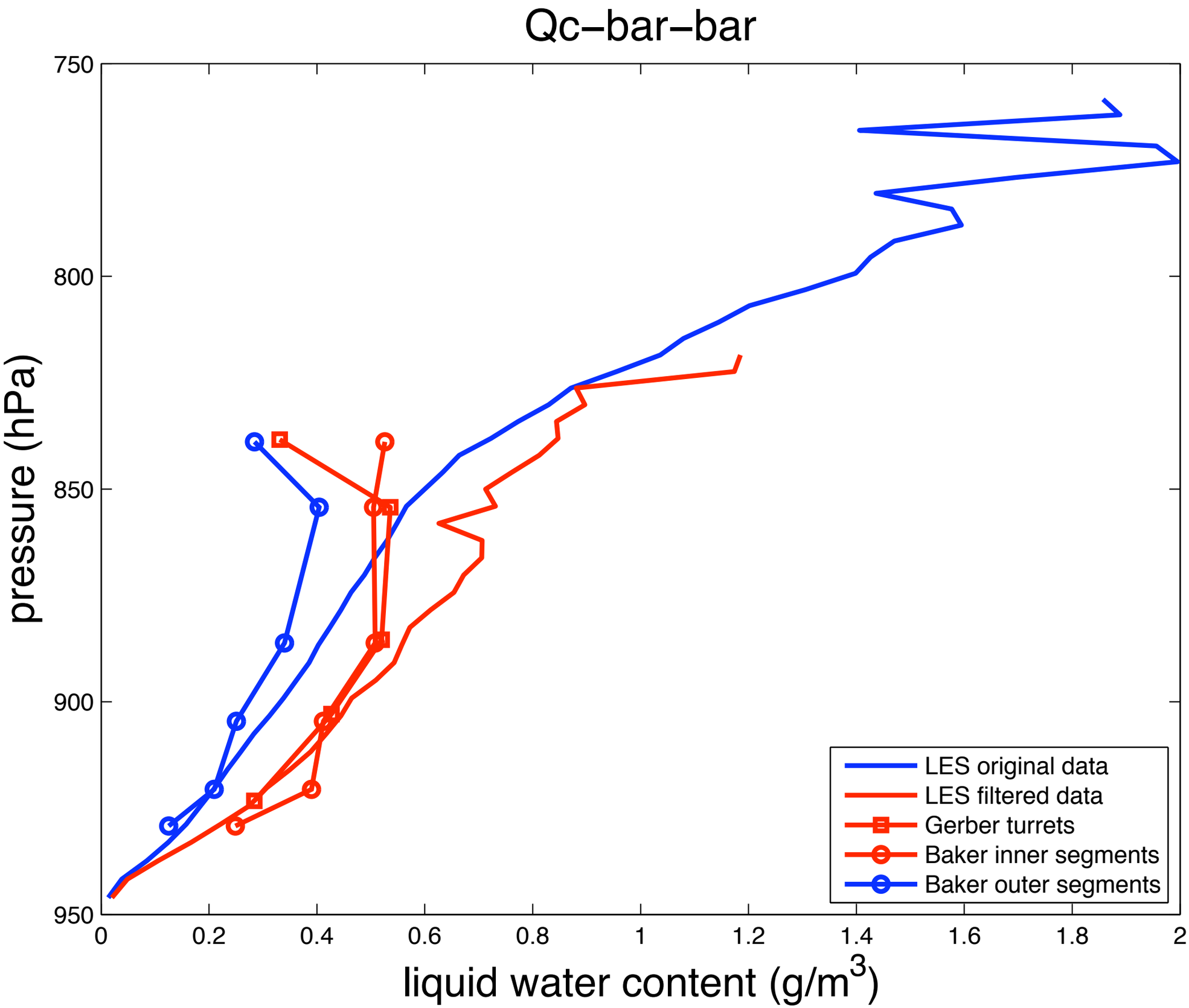
hi-res region from side (spin-up period for 10-m grid size)

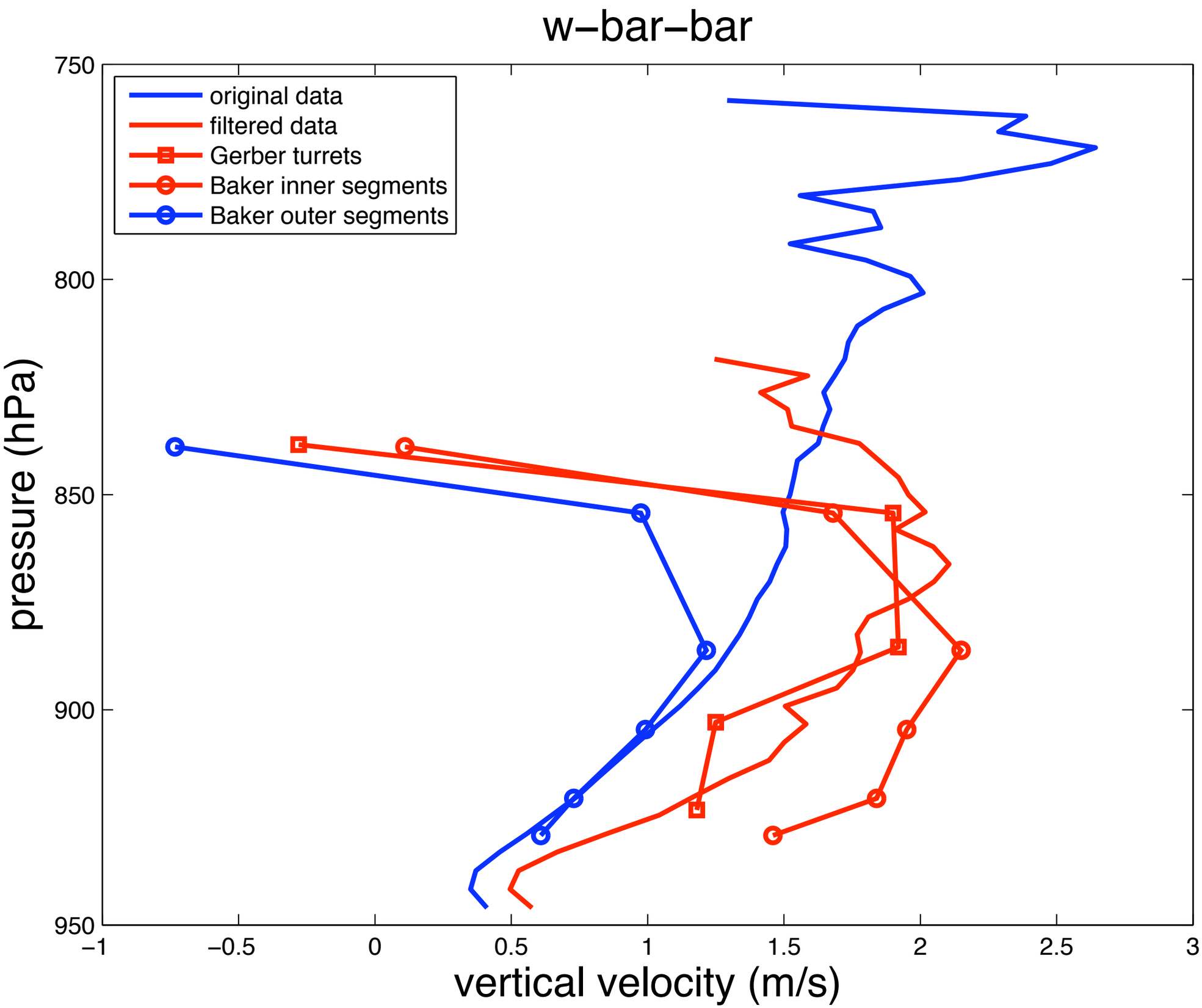
x-z zoom (20-m grid size)



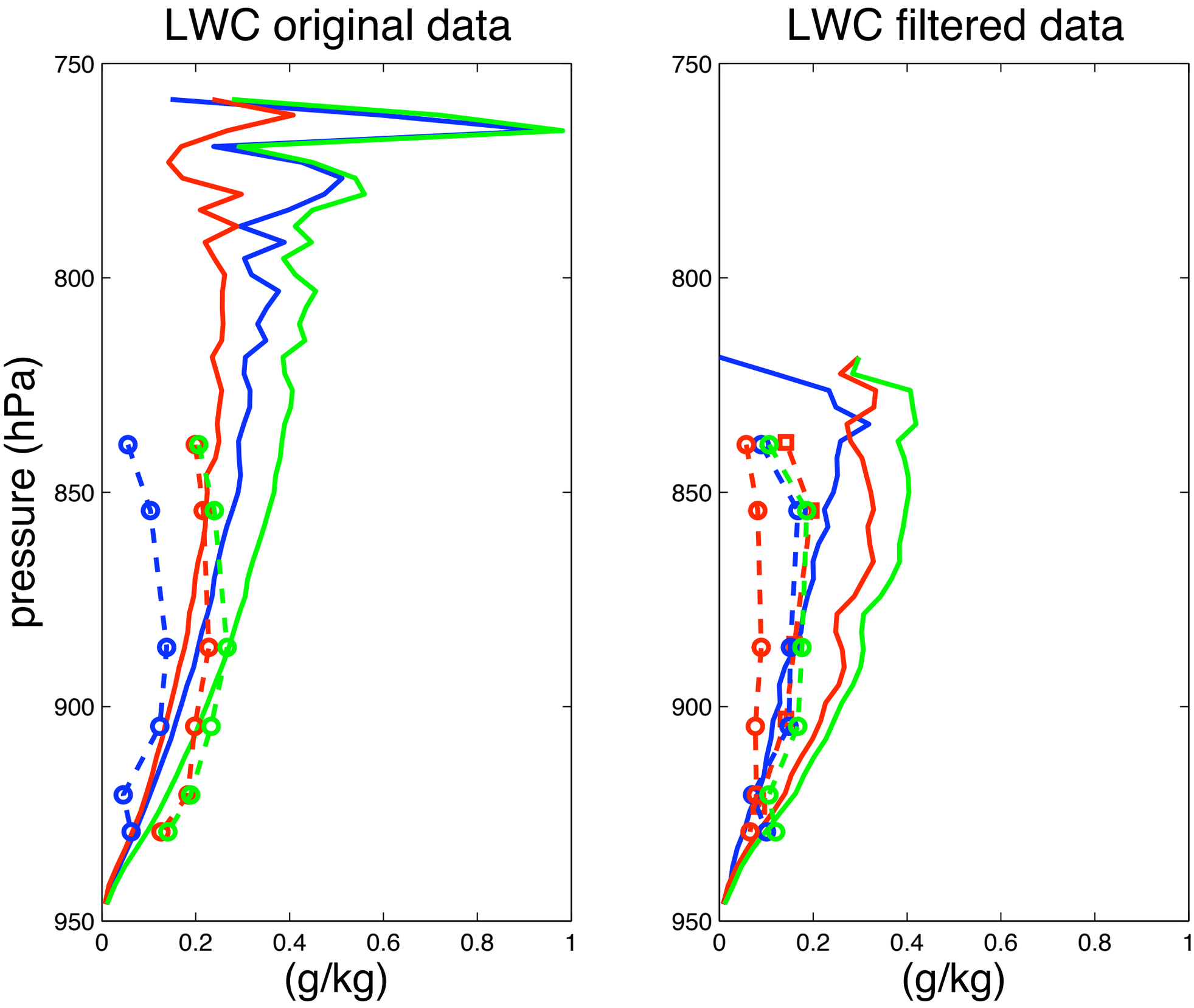
UU LES cloud segments

- *Cloud segments:*
  - LWC > 0 for 40 m bounded by LWC = 0 for 40 m.
- *Long cloud segments:*
  - Cloud segment length > 99 m

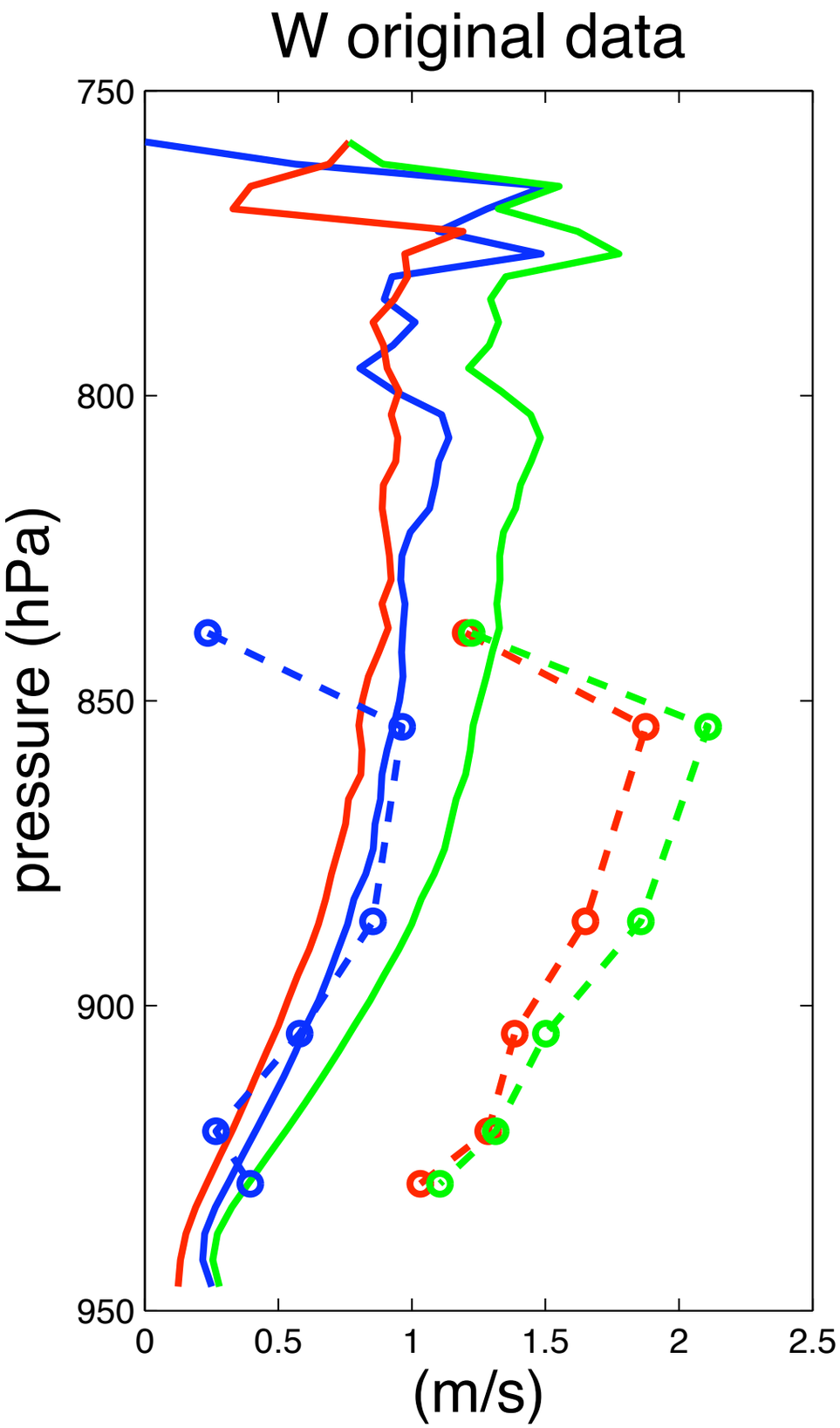

Qc–bar–bar
750
800
850
900
950
pressure (hPa)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
liquid water content (g/m3)
LES original data
LES filtered data
Gerber turrets
Baker inner segments
Baker outer segments

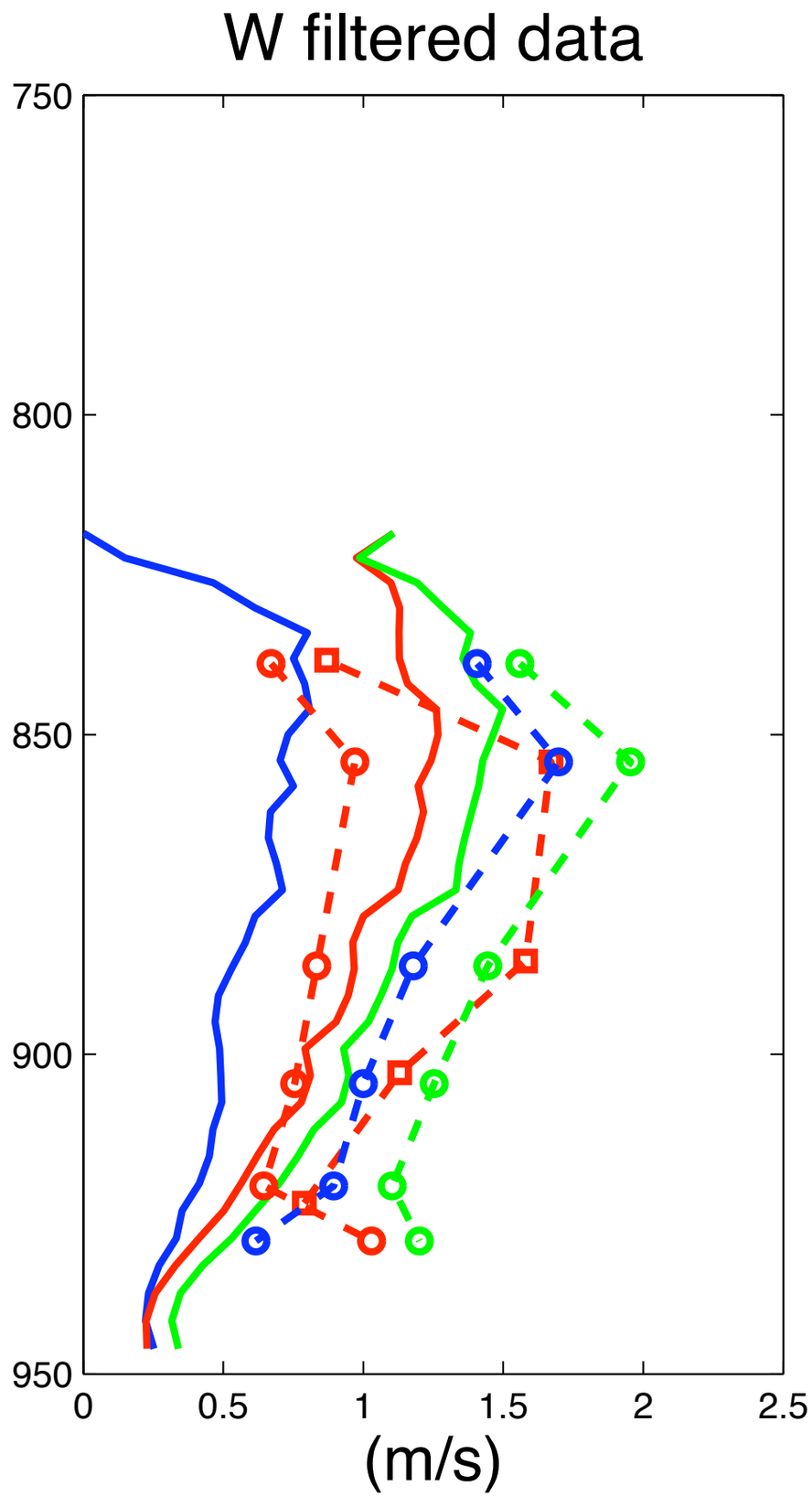

w–bar–bar
original data
filtered data
Gerber turrets
Baker inner segments
Baker outer segments
750
800
850
900
950
pressure (hPa)
−1
−0.5
0
0.5
1
1.5
2
2.5
3
vertical velocity (m/s)

std dev of averages: red, in-cloud: blue, total: green



std dev of averages: red, in-cloud: blue, total: green





Issues

- Are we comparing apples to apples?
  - LES case versus RF 12
  - Conditional sampling methods
  - Spatial scales resolved

Plans

- Analyze 10-m grid simulation.
- Attempt to implement Gerber's turret sampling method.
- Study sensitivity of LES conditional sampling results to sampling criteria, spatial resolution, and case specifications.
- Study sensitivity of aircraft conditional sampling results to sampled variables, sampling criteria, and flight.