The Soil-Plant-Atmosphere System - A problem of scale.

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I'm very interested in plants and in how they interact with the climate system..

•Through much of Earth's history the continents were barren inhospitable places because very little of the rain that fell returned to the atmosphere.

•About 416 million years ago the first plant with a vascular system roots and conductive tissue appear in the fossil record. The key innovation was probably stomata.

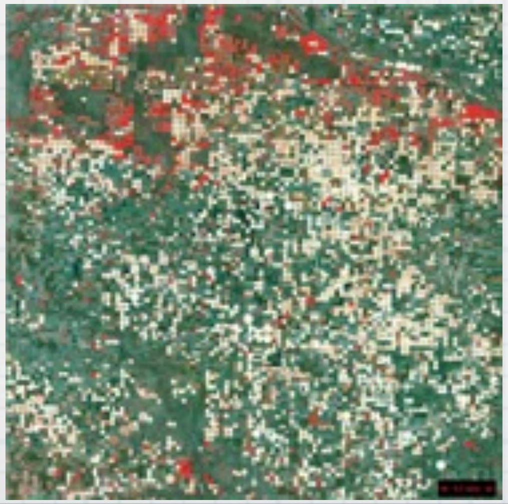
•We can be quite sure that these properties will influence the success and survival of plants and that evolutionary advances in these areas must have influenced the climate

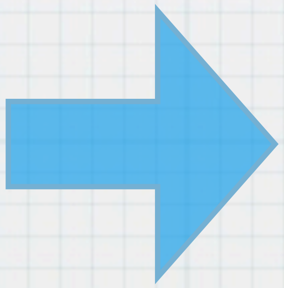
But, problems of **scale and heterogeneity** make it very difficult to quantify the impacts of evolutionary innovation on climate.

- Vegetation and land properties typically vary with a length scale of meters, while the length scale of a GCM grid box is hundreds of km.

- At this scale the atmosphere is presented as spatially averaged properties such as the albedo, slope, roughness and surface wetness.

- Averaging of these properties is very non-linear, hence it is difficult to make the link between detailed representation of plant processes and climate or climate change - much less evolution.

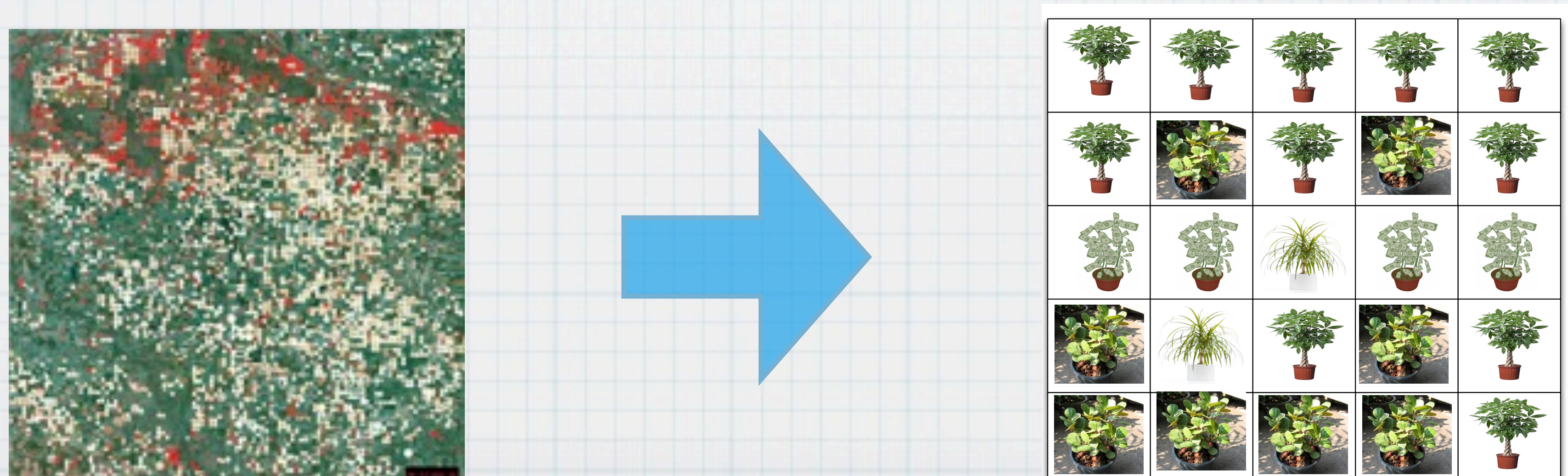


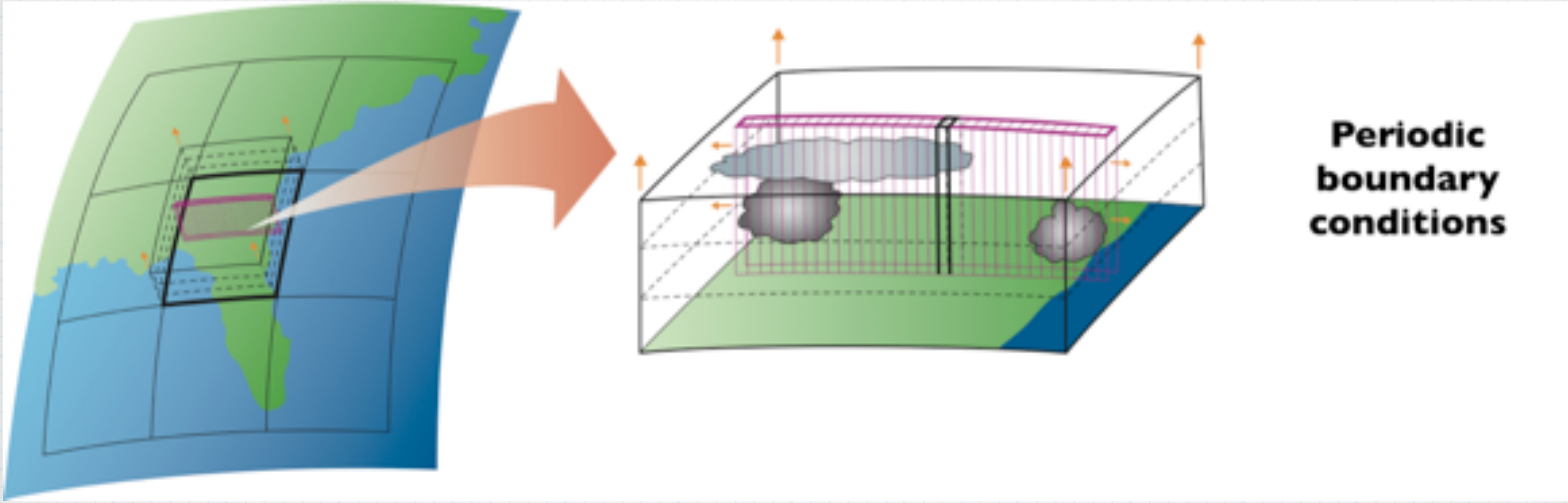


- Increased computer power and model resolution is unlikely to solve this problem.

- Finer scale representation is possible in mesoscale models, but the detail can be overwhelming and the boundary conditions we need to supply include the large scale atmospheric feedbacks - **the very things that we would like to evaluate**.

- The traditional approach has been to develop ways to parameterize these sub-grid-scale processes to the scale of the grid box.



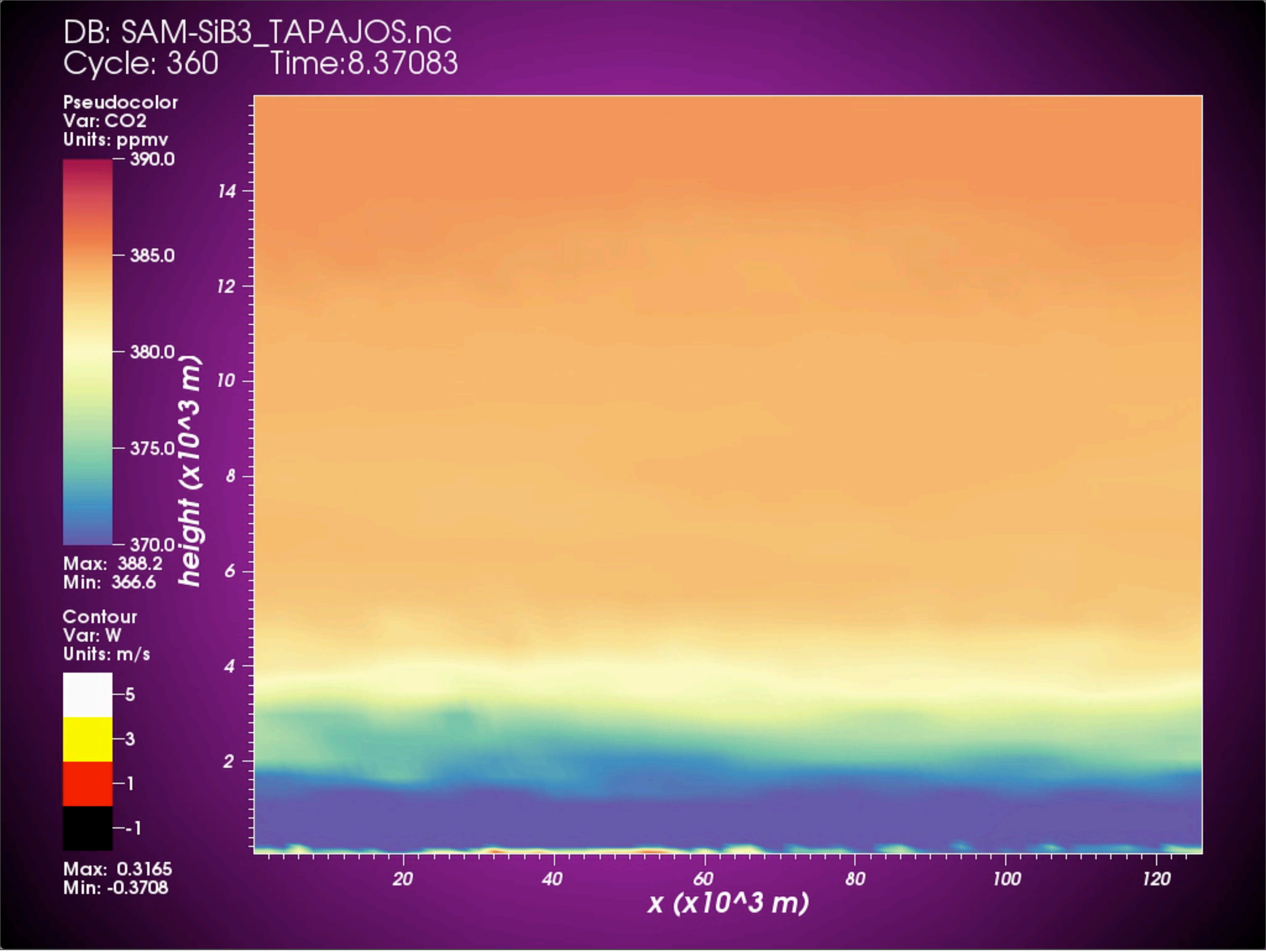


- The weather produced by a CRM is more like real weather. Land models can be run on a scale comparable the scale at which they are tested.

- We can introduce heterogeneity.

- A synchronous responses to forcing probably reduce feedbacks to the atmosphere.

- Land-atmosphere interactions get propagated to the climate system in a more realistic way.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Contour
Var: W
Units: m/s
5
3
1
-1
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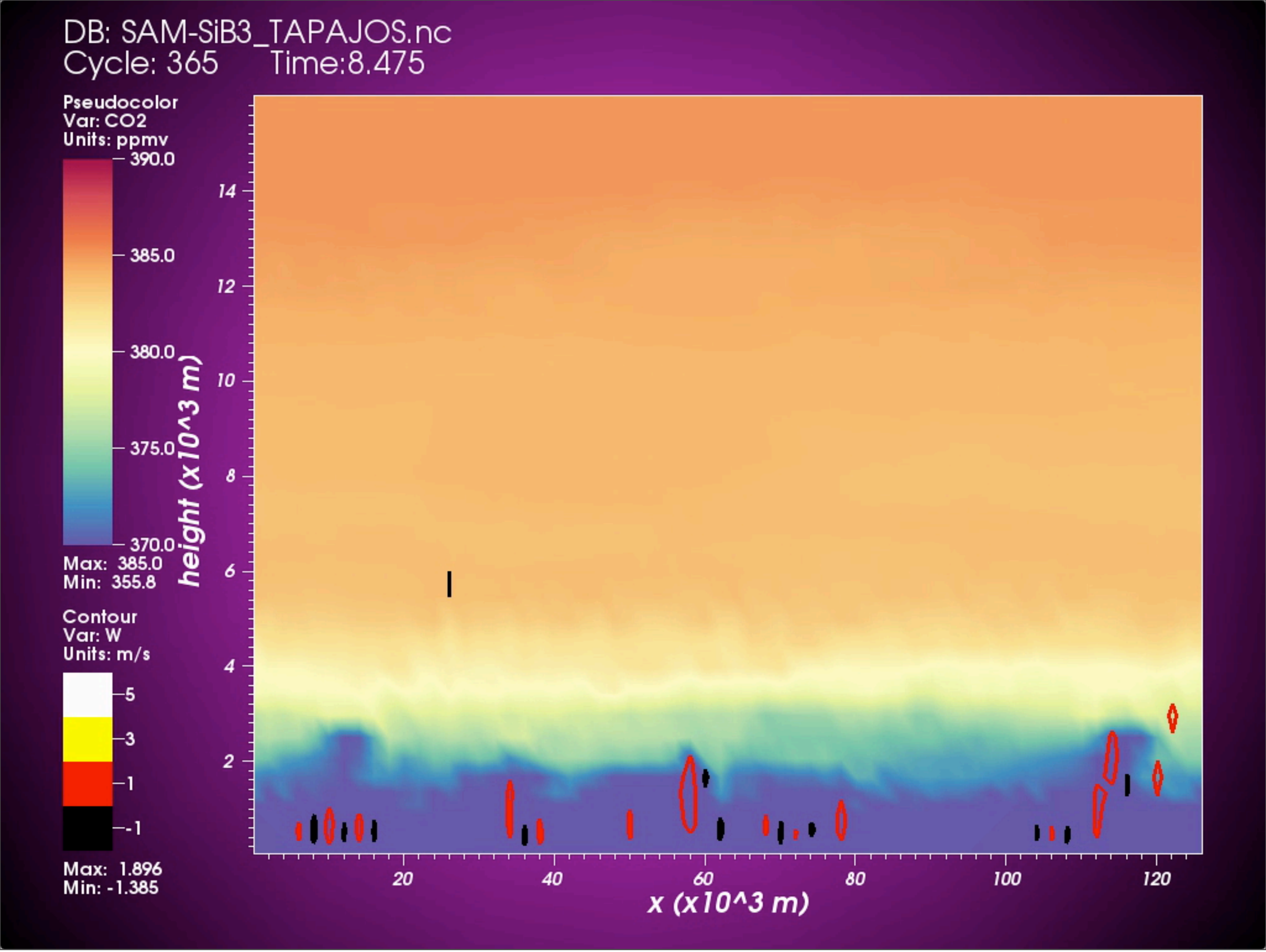
Min: -0.3708
height (x10^3 m)
14
12
10
8
6
4
2
20
40
60
80
100
120
x (x10^3 m)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3
1
-1
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height (x10^3 m)
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2
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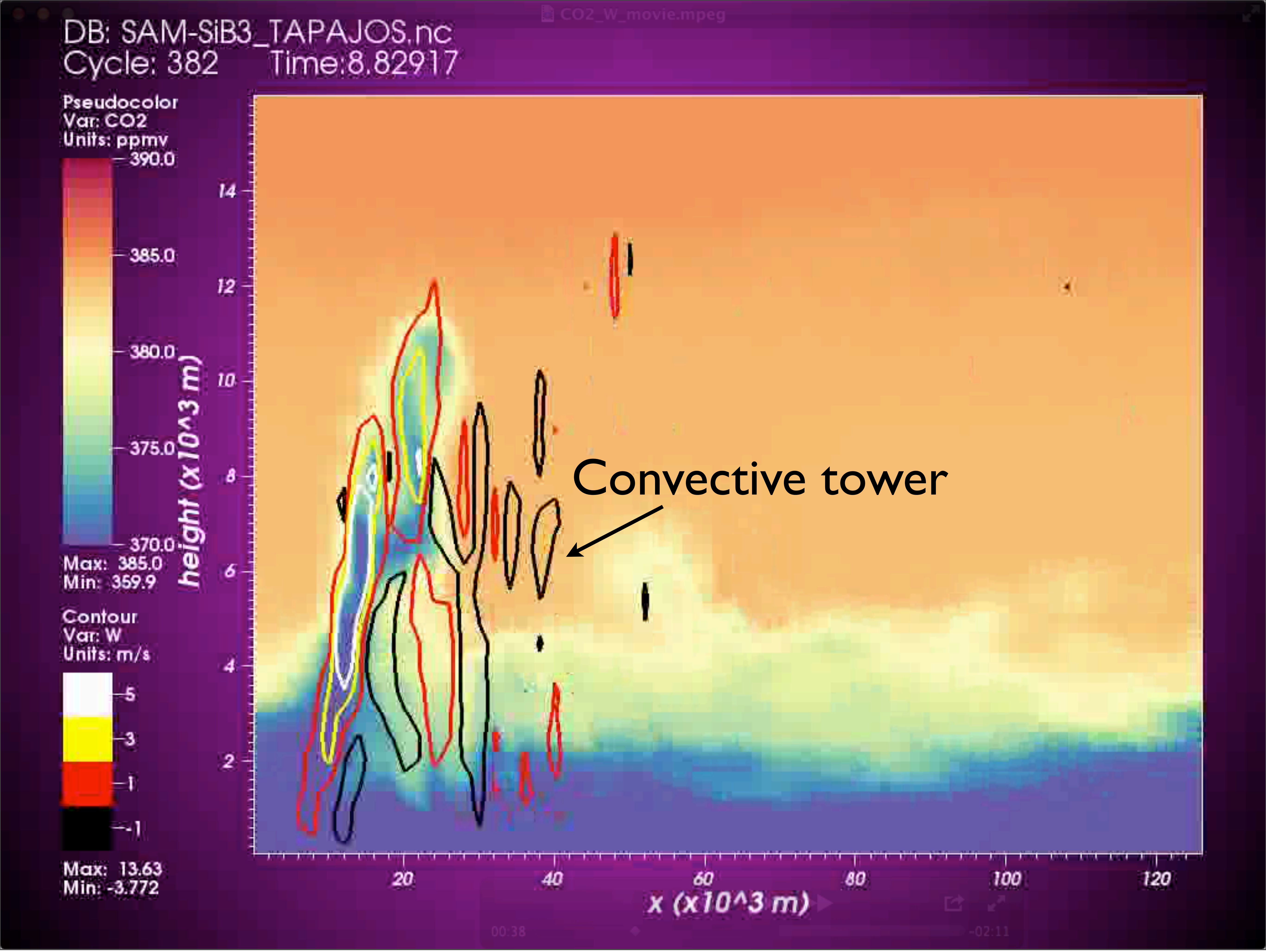
40
60
80
100
120
x (x10^3 m)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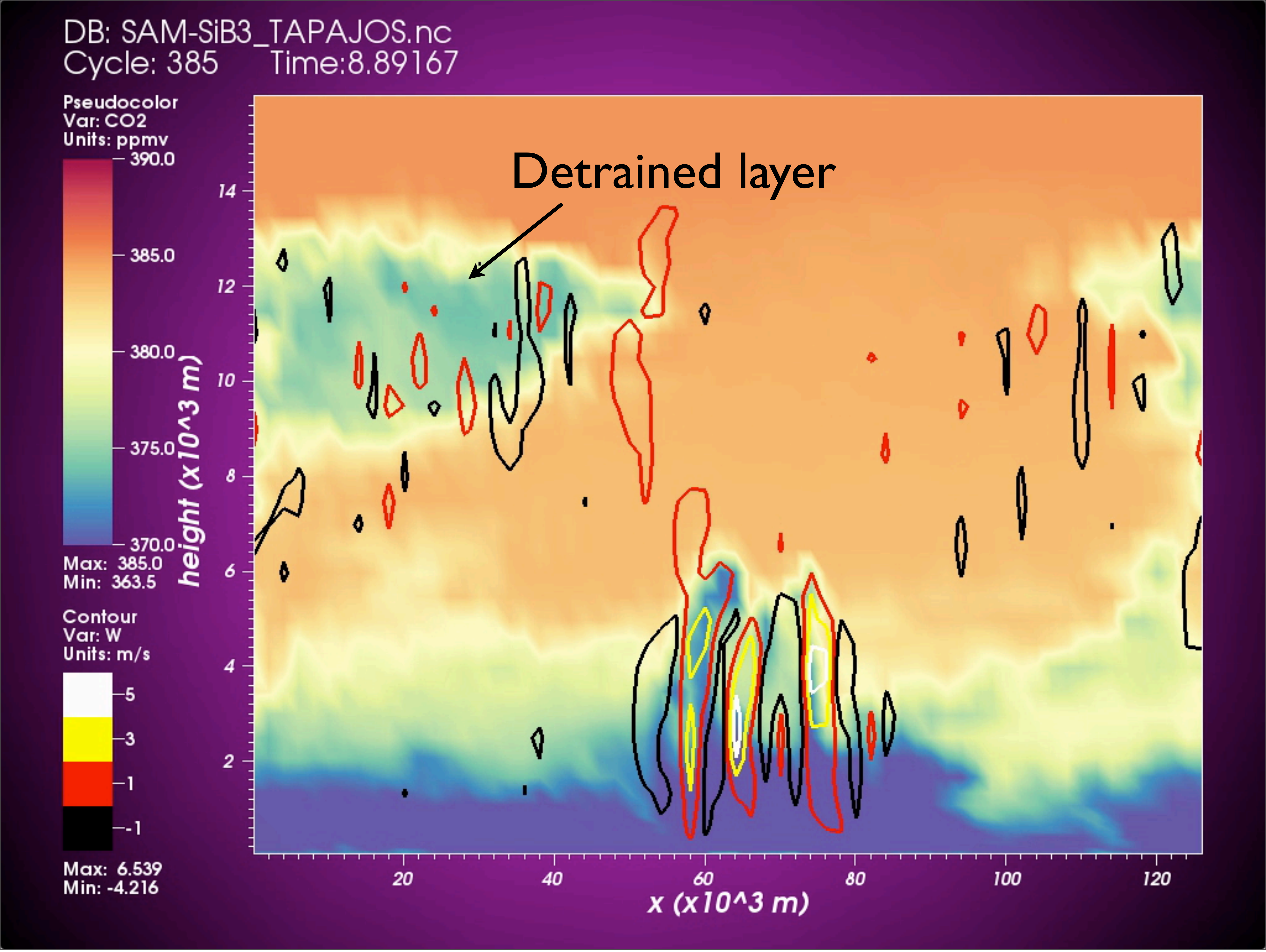
Contour
Var: W
Units: m/s
5
3
1
-1
Max: 13.63
Min: -3.772
height (x10^3 m)
14
12
10
8
6
4
2
20
40
60
80
100
120
x (x10^3 m)
Convective tower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Max: 385.0
Min: 363.5
Contour
Var: W
Units: m/s
5
3
1
-1
Max: 6.539
Min: -4.216
Detrained layer
height (x10^3 m)
x (x10^3 m)
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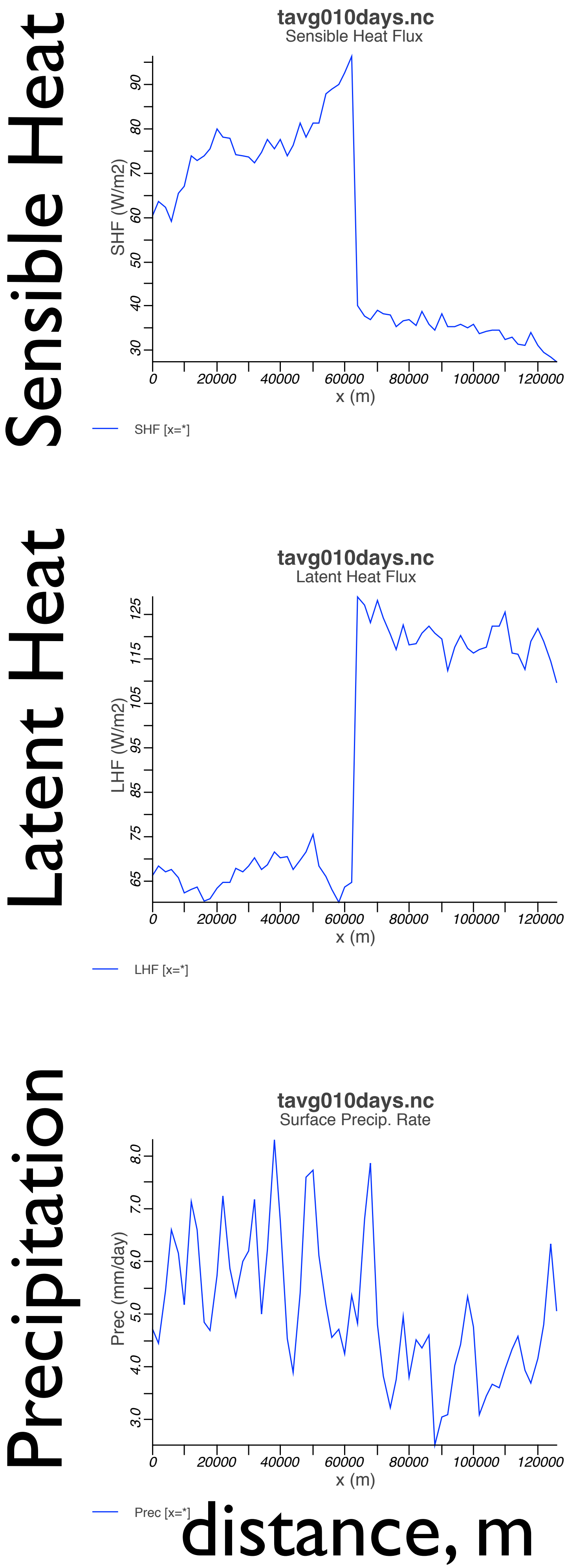
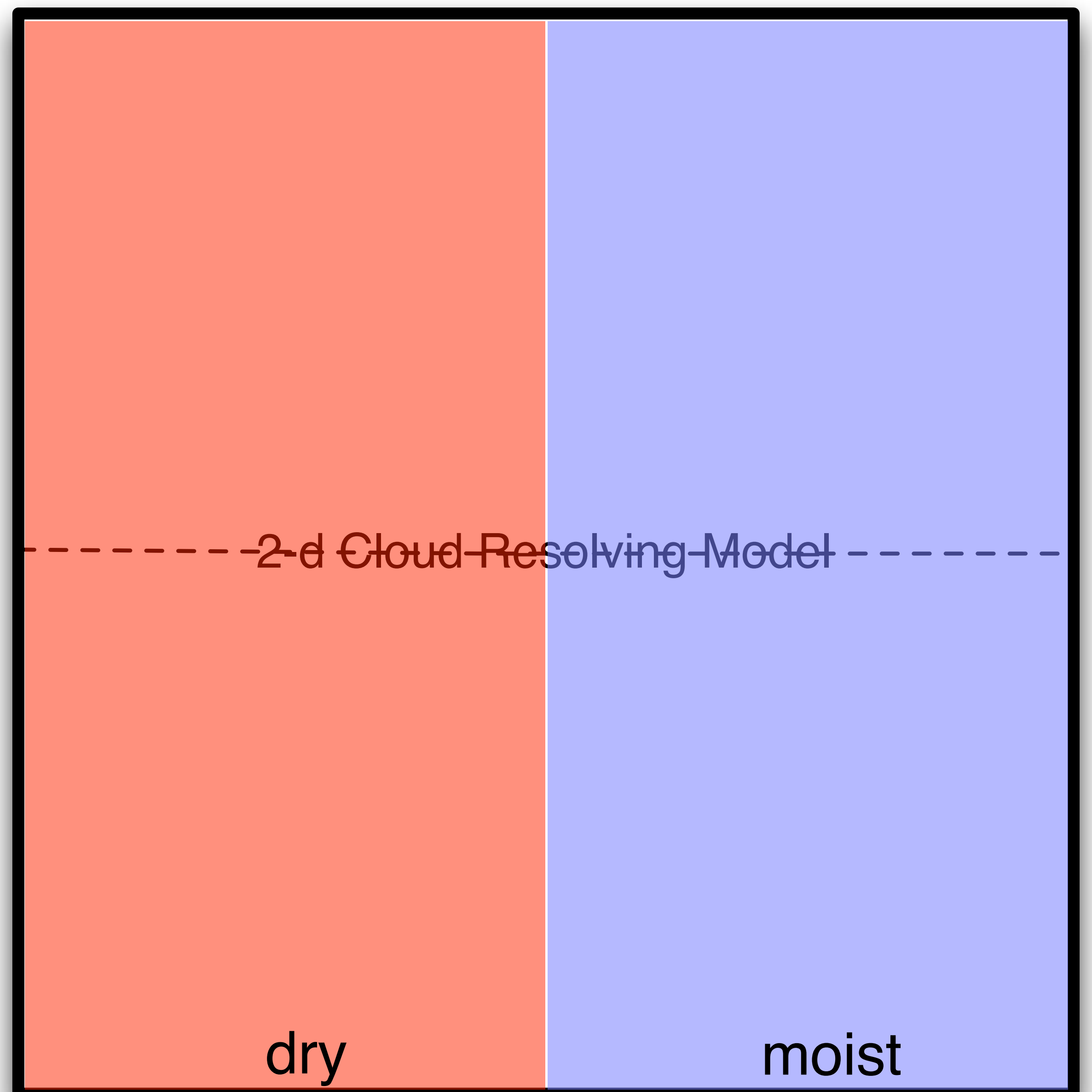
12
10
8
6
4
2
20
40
60
80
100
120

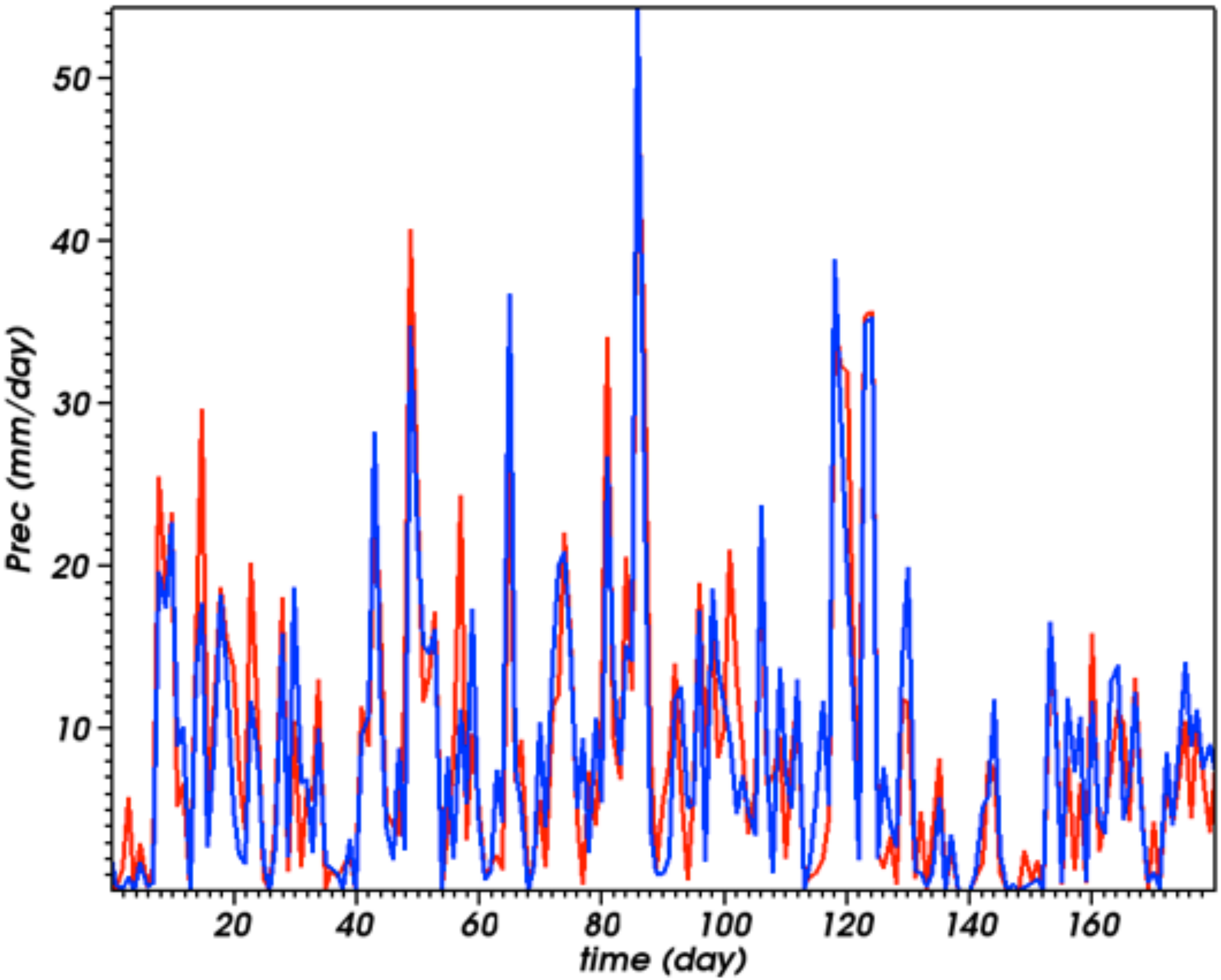


This study: Amazon grid cell, start of wet season, half wet/half dry.

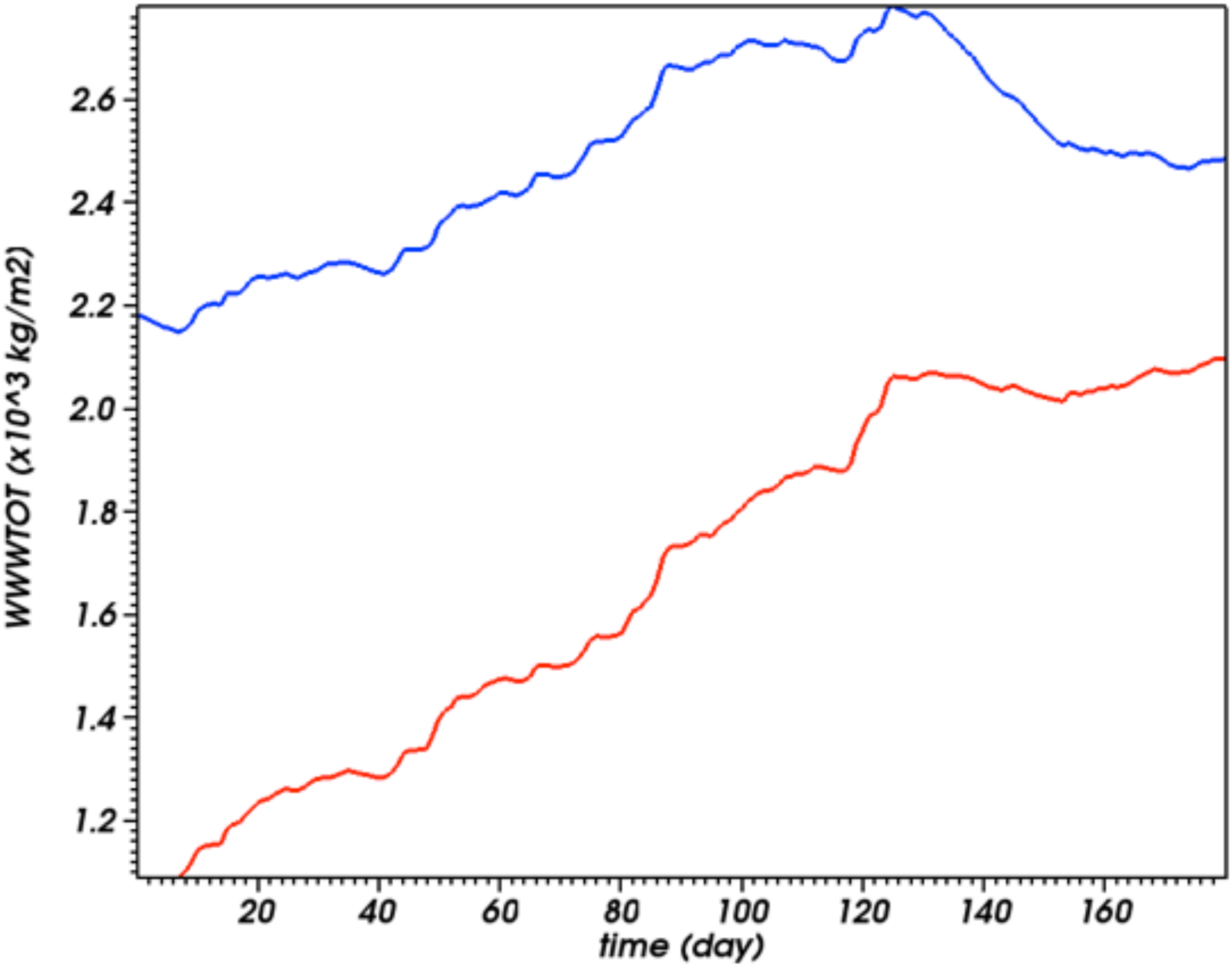
Model details: 2D Cloud resolving model 64 gridpoints by 64 layers. 2km horizontal resolution, periodic horizontal boundary conditions, lowest atmospheric layer thickness =75m, stretched vertical coordinate up to 28km, where model layers are 500m thick. The basic model timestep is 10s, SiB and interactive radiation are called every 150s, external forcing, NCEP, 6hr.



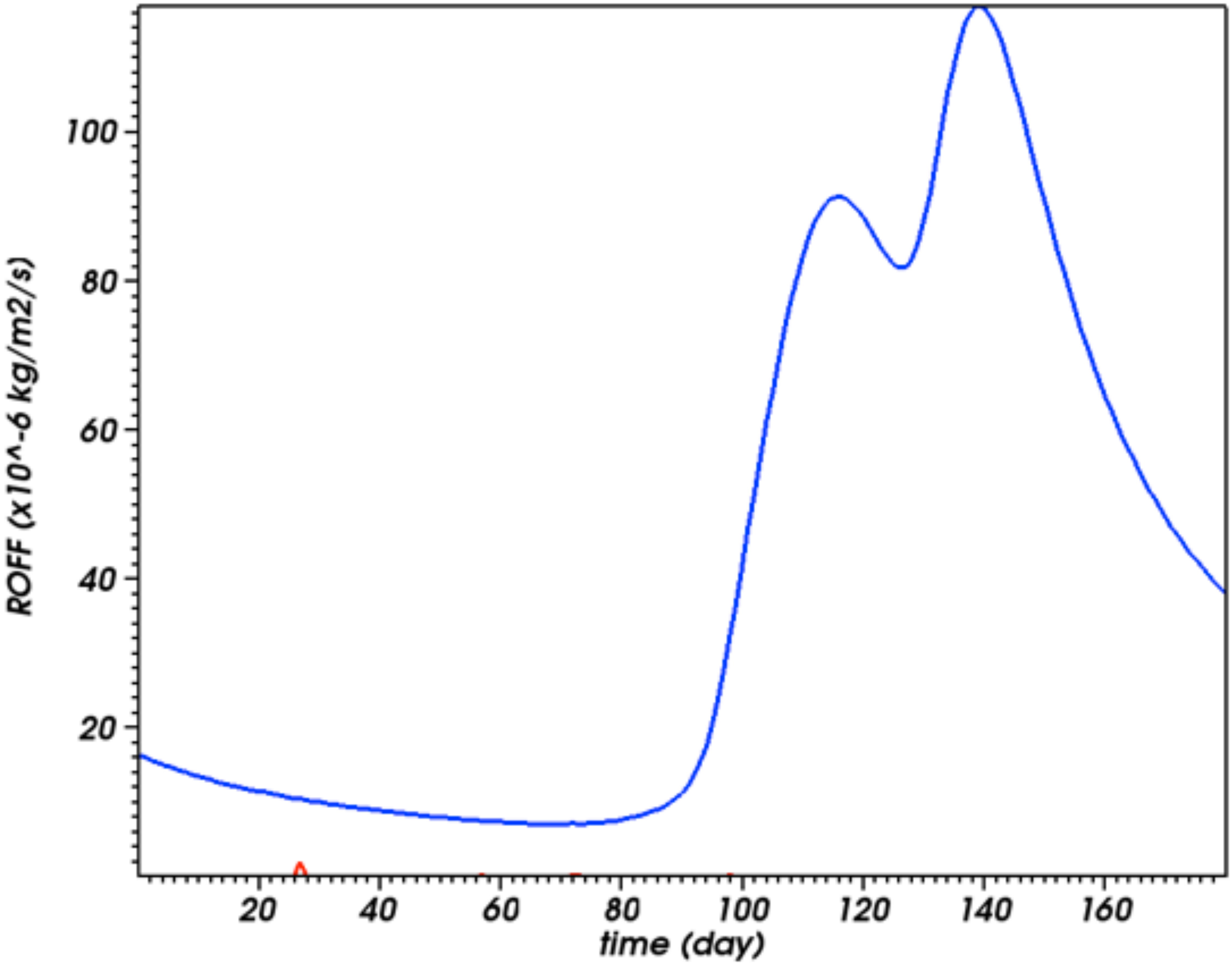
Precipitation



Total Soil Water

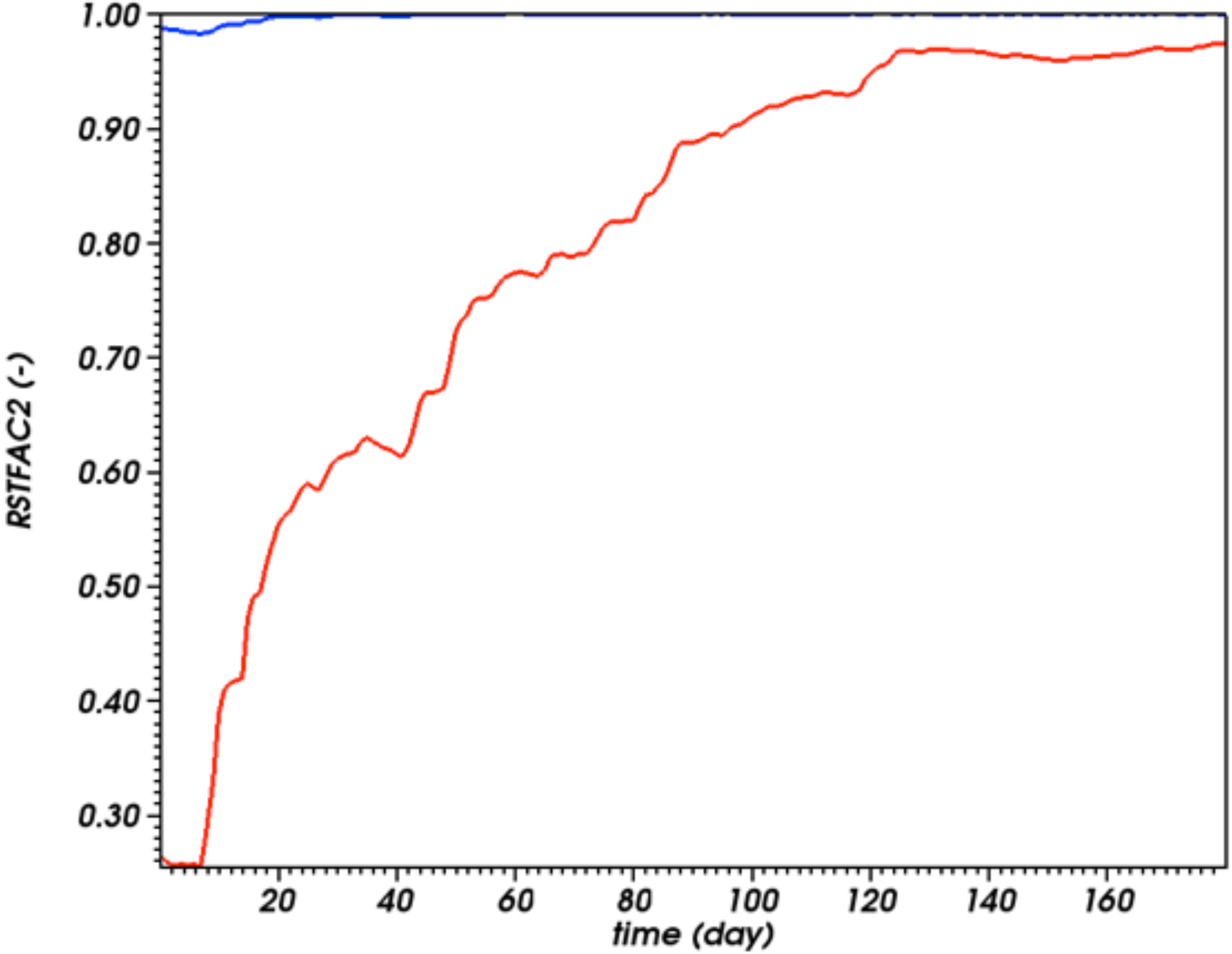


Runoff

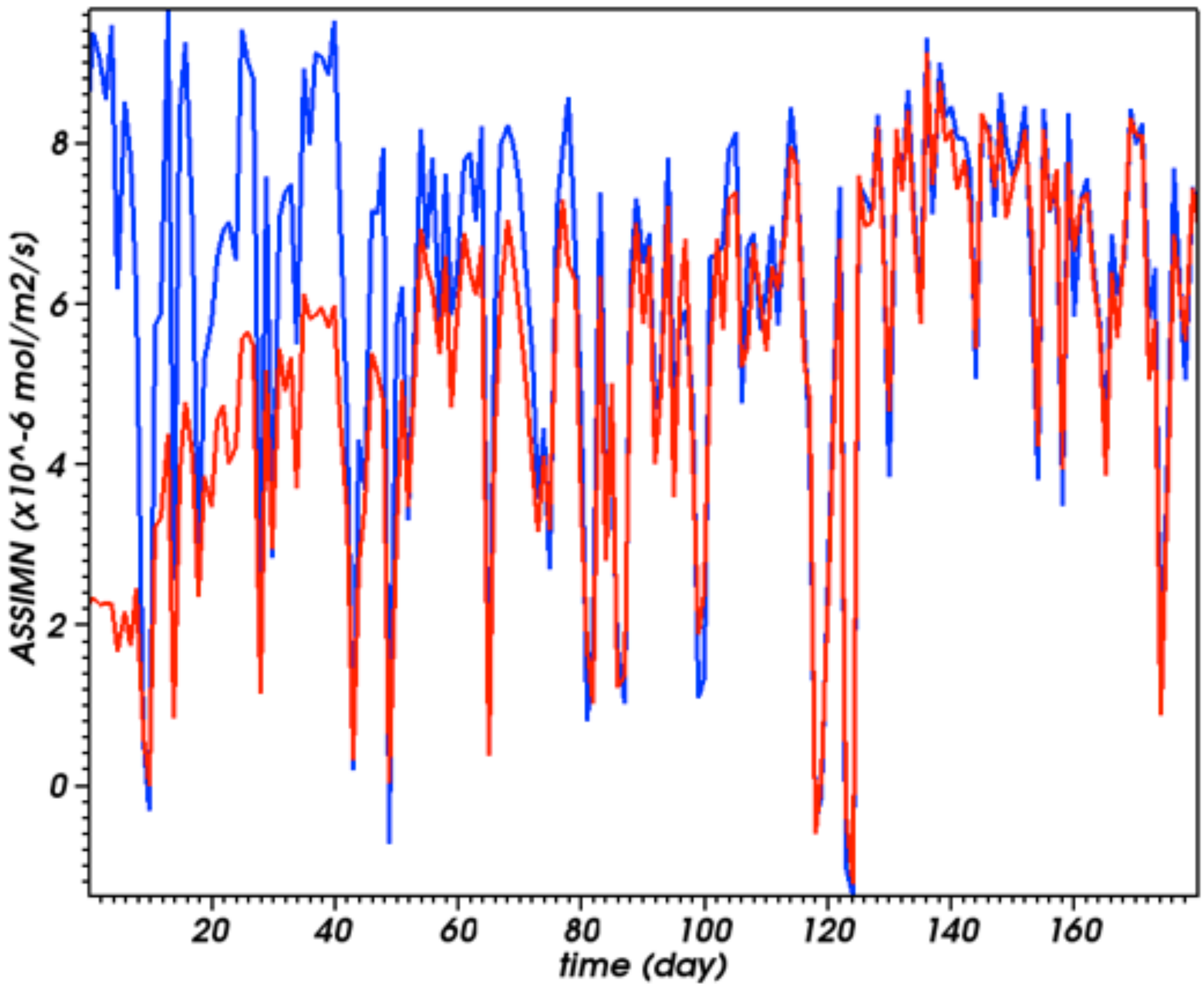


100
80
60
40
20
ROFF (x10^-6 kg/m2/s)
20
40
60
80
100
120
140
160
time (day)

Water Stress

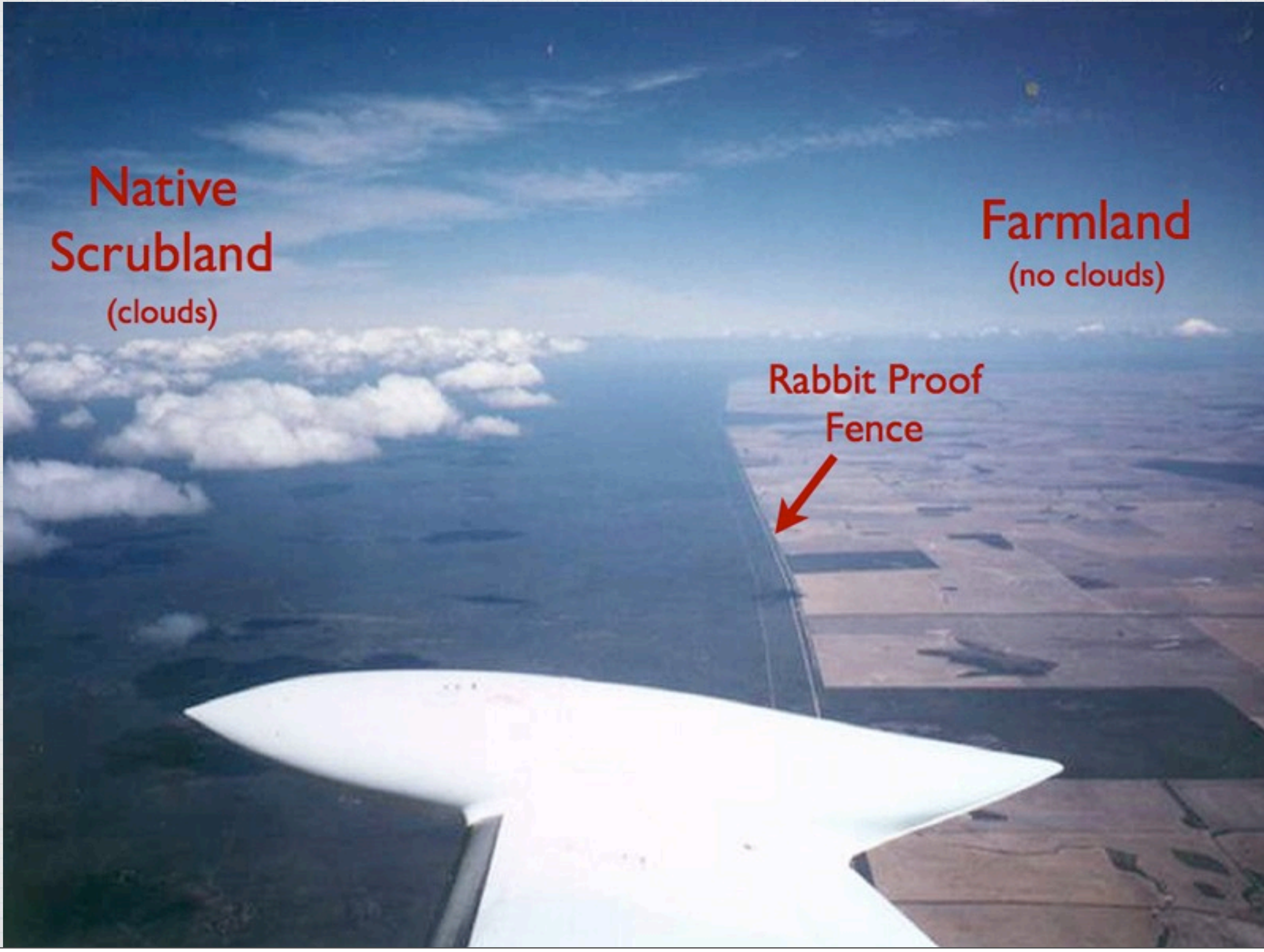


Photosynthesis, (24 hr average)



Conclusions

- Demonstrated simulation of the land surface at 2 km resolution, 2.5 min time-step in the context of a GCM cell.
- Initial conditions led to differential land-atmosphere coupling.
- Explicit tracer transport
- Possible extensions:
  - Add land and vegetation details: topography and over-land run off, different vegetation types, rivers and lakes.
  - Examine other climatic regions - especially areas already shown to have strong atmospheric feedbacks.
  - Use as a test-bed for scaling issues and emergent properties in land surface modeling.
  - Include high resolution land surface in full GCM simulations.


Native
Scrubland
(clouds)
Farmland
(no clouds)
Rabbit Proof
Fence