Initialization of layer models for numerical weather prediction

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October 2008

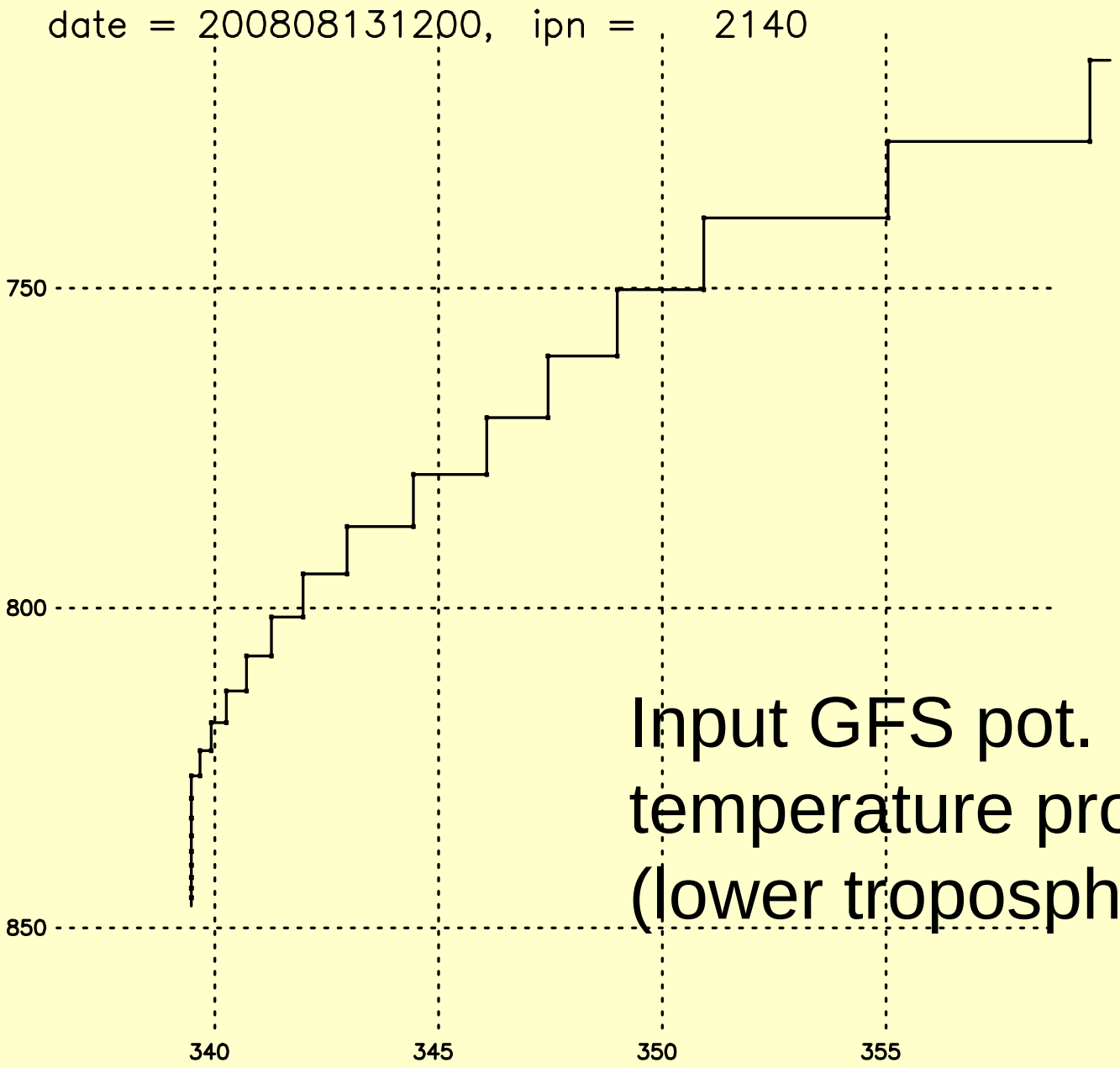
Why and when is this important?

Suppose …

- A new model (“model B”) comes online.
- There is a desire to show that Model B is equal to or better than Model A.
- An inter-comparison project is launched. Initial conditions? Must come from “reference” Model A (i.e., don’t burden A team with extra work).
- This immediately puts Model B at a disadvantage (unless the 2 models run on the same 3-D grid).

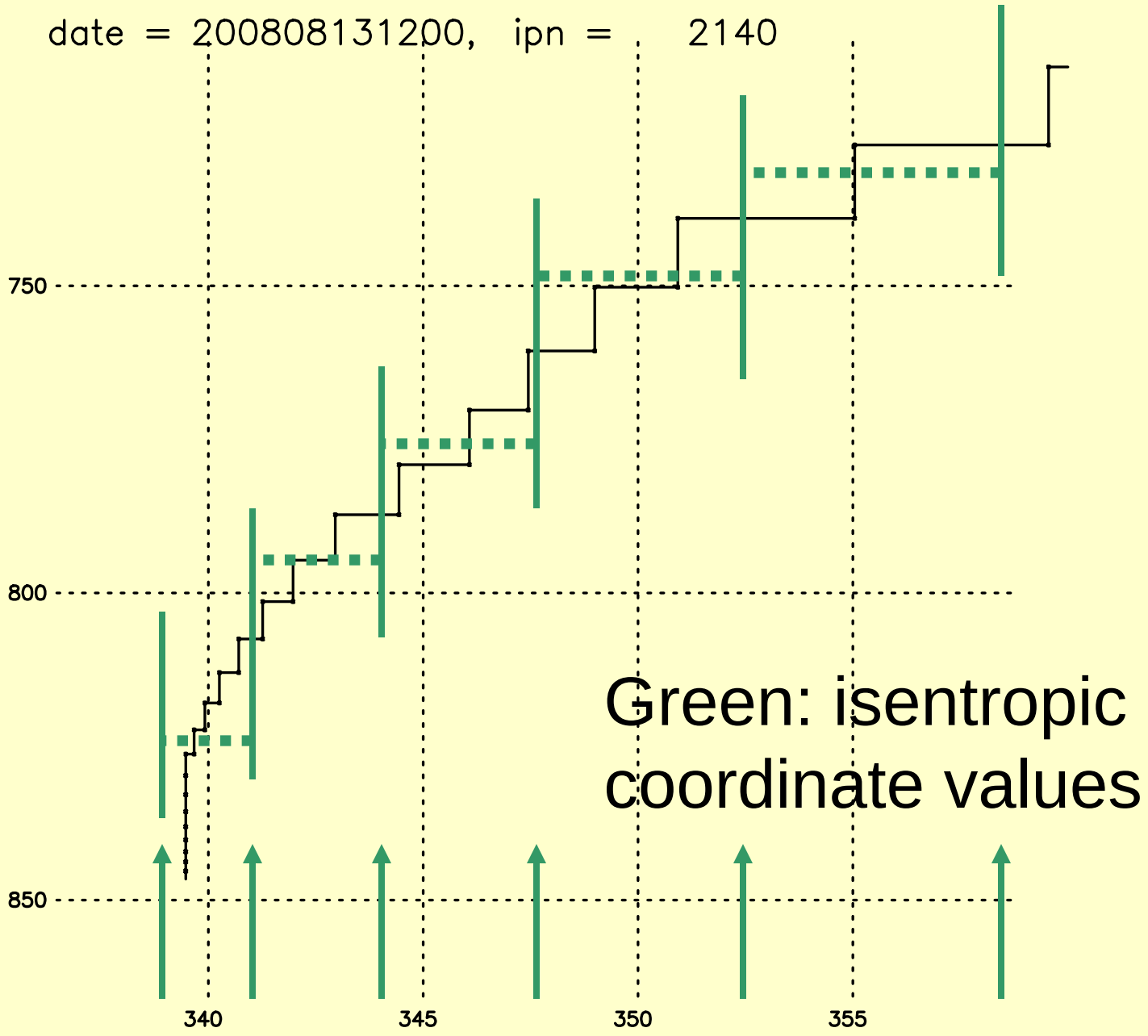
Variables typically are staggered vertically.

- Pressure and height are carried on one set of surfaces. Mass field “tracers” (temperature, moisture, greenhouse gases) are carried on surfaces in-between.
- Column integrals of tracers (example: hydrostatic eqn) are usually evaluated by interpreting tracer “point” values as layer averages.
- Hence, for all intents and purposes, vertical tracer profiles are stairstep curves.



Input GFS pot. temperature profile (lower troposphere)

Step 1: interpolate to purely isentropic coordinates


date = 200808131200, ipn = 2140
750
800
850
340
345
350
355
Green: isentropic coordinate values

Desirable attributes of sigma/pressure-to hybrid/isentropic grid transformation:

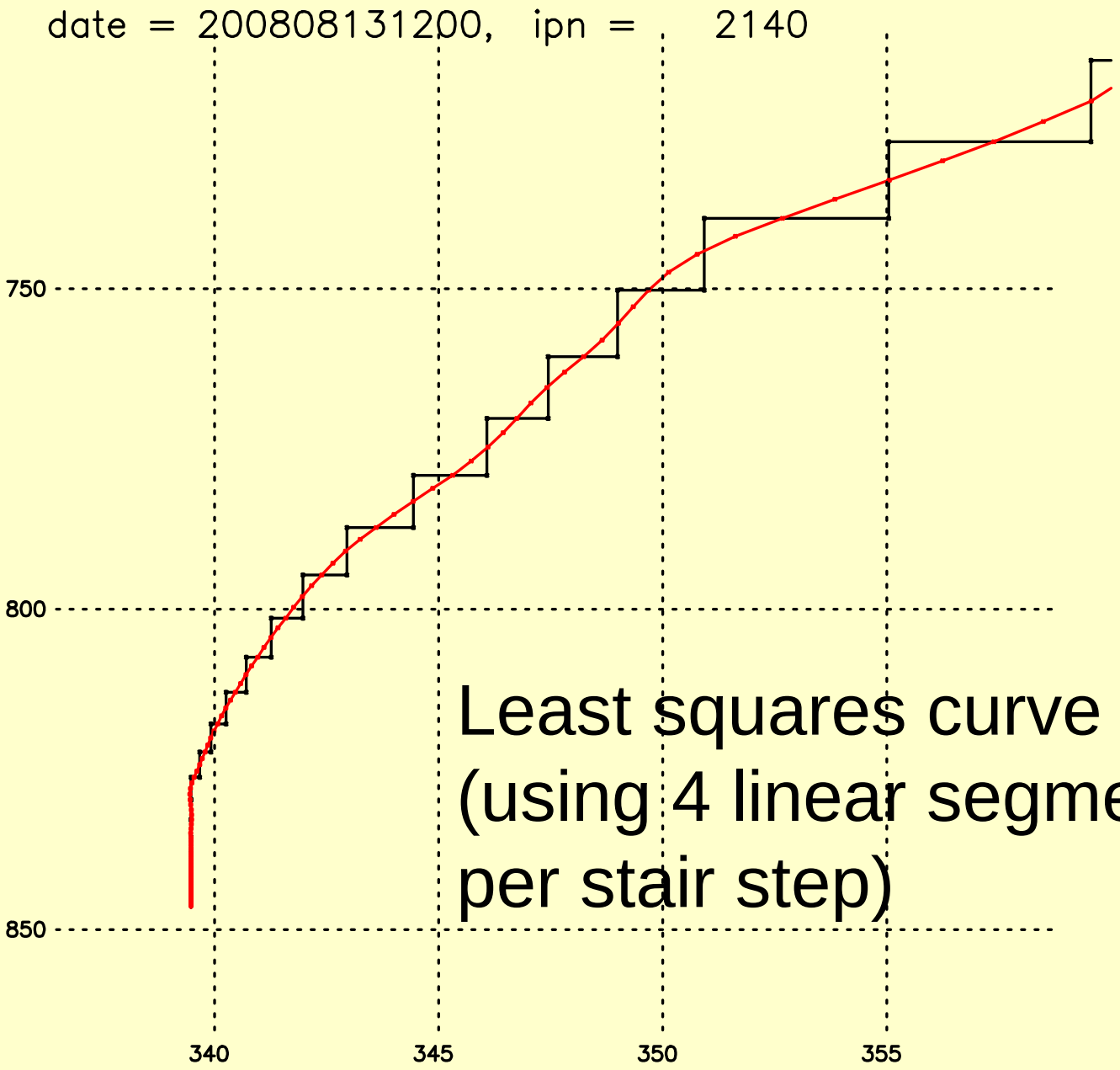
- Faithful replication of temperature/ moisture profiles in planetary boundary layer
- No alternation of thin/thick layers (2-Δk computational mode) in isentropic sub-domain
- Preservation of column integrals

To improve accuracy, first convert input stair-step profile into continuously varying profile.

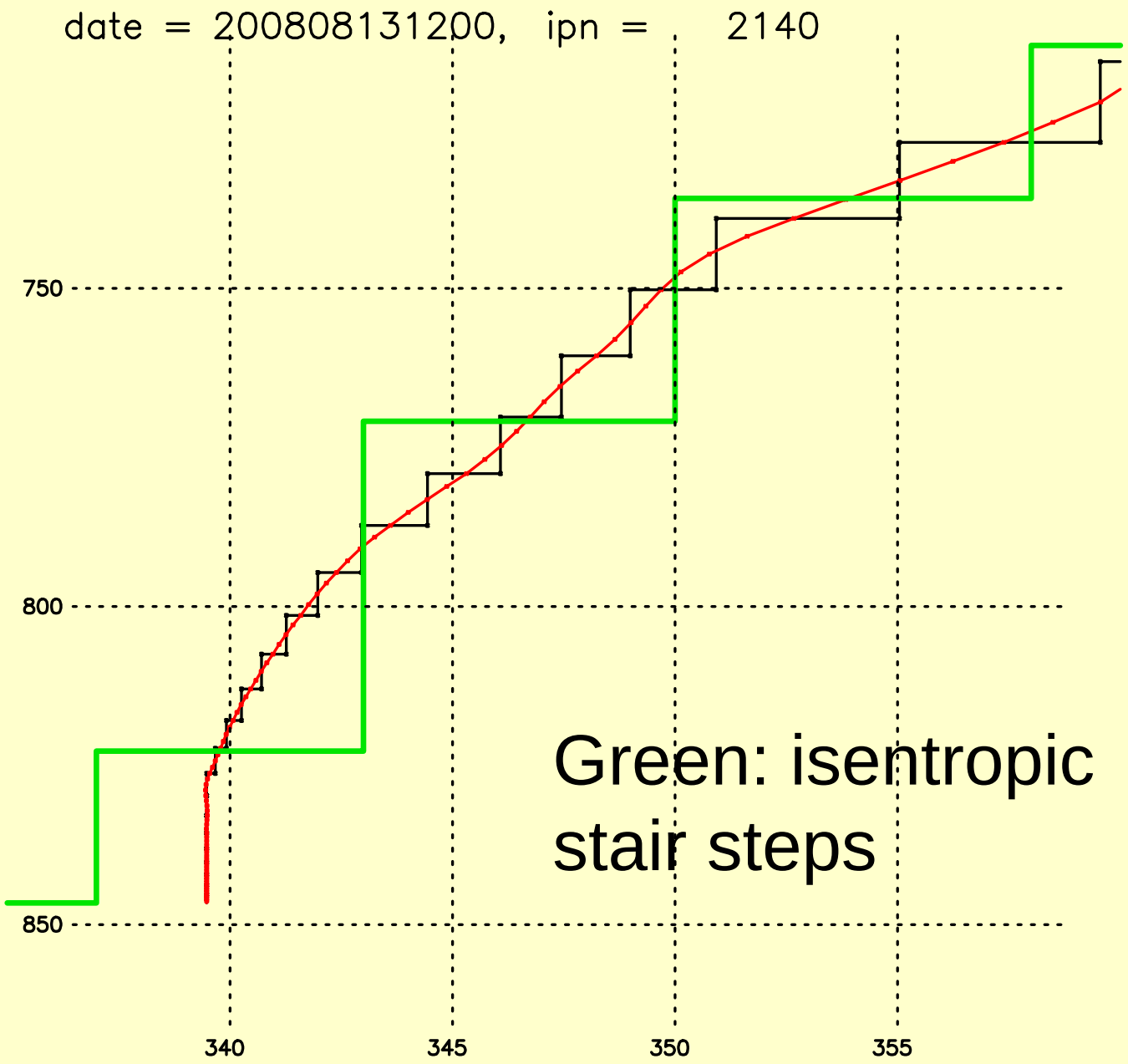
Approach: construct a sequence of linear segments under the following 2 constraints:

- Preservation of column integral
- Minimal “kinks” between neighboring segments

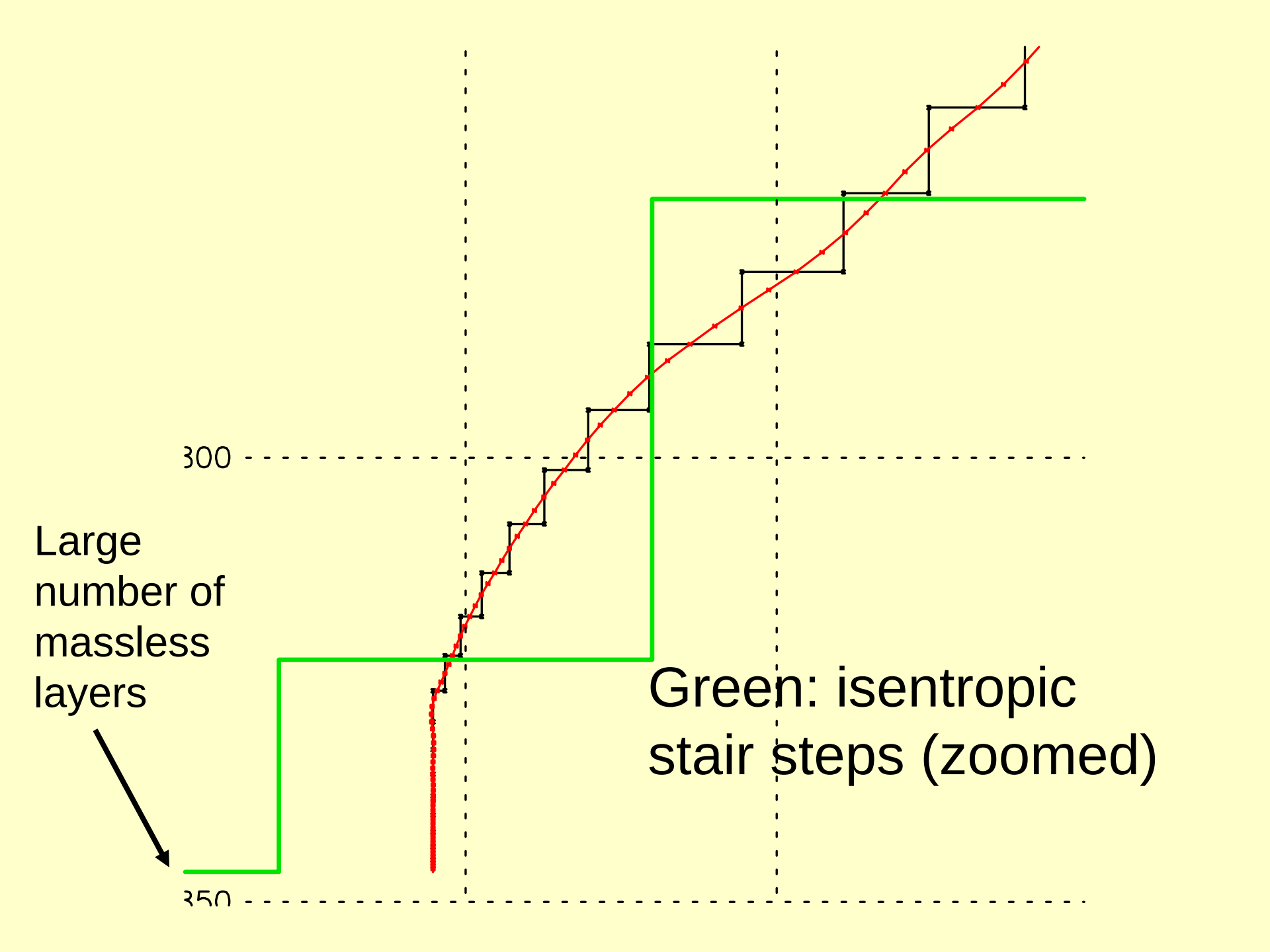
This leads to a constrained least-squares problem solved by means of Lagrangian multipliers

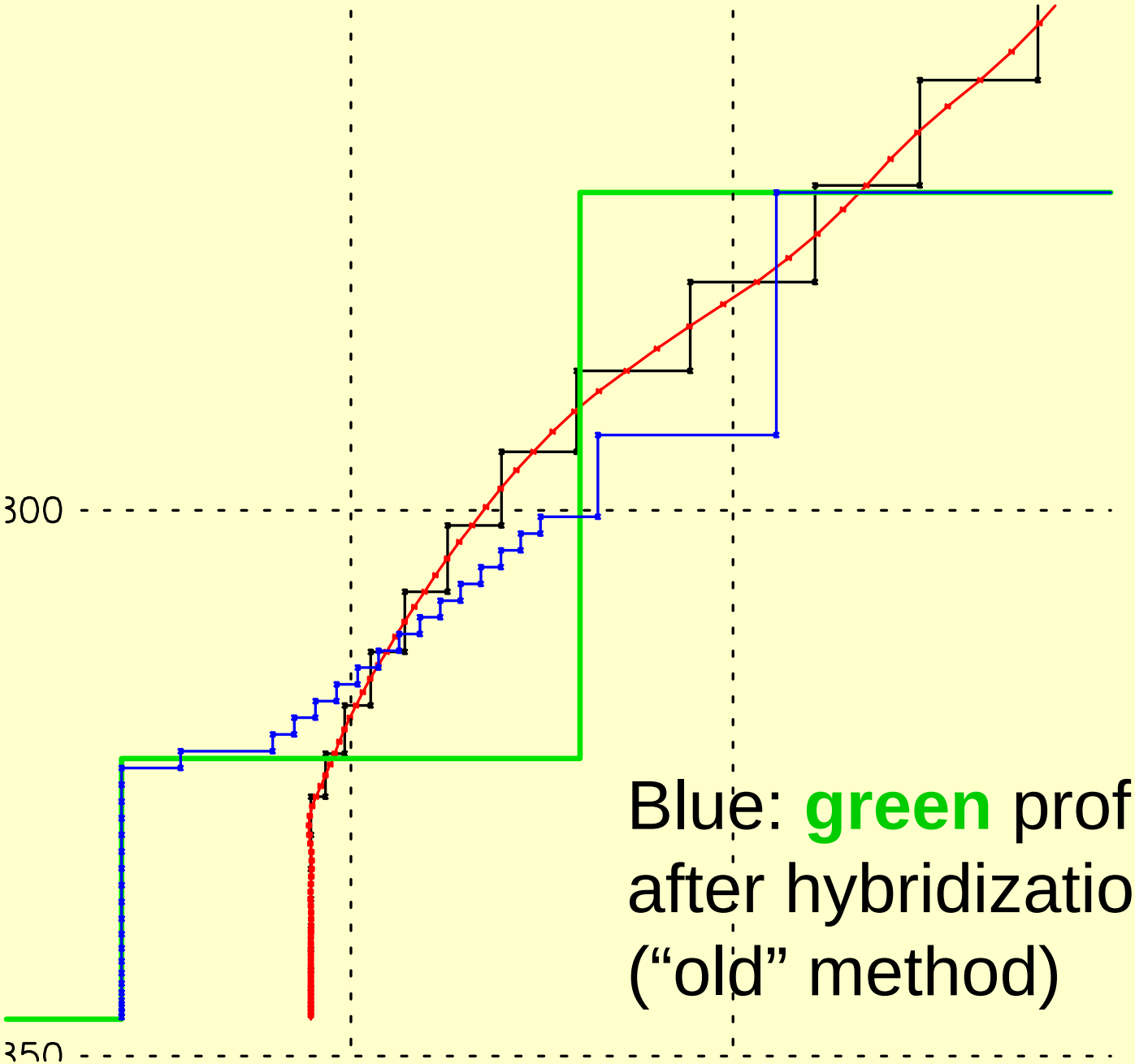


Least squares curve fit (using 4 linear segments per stair step)

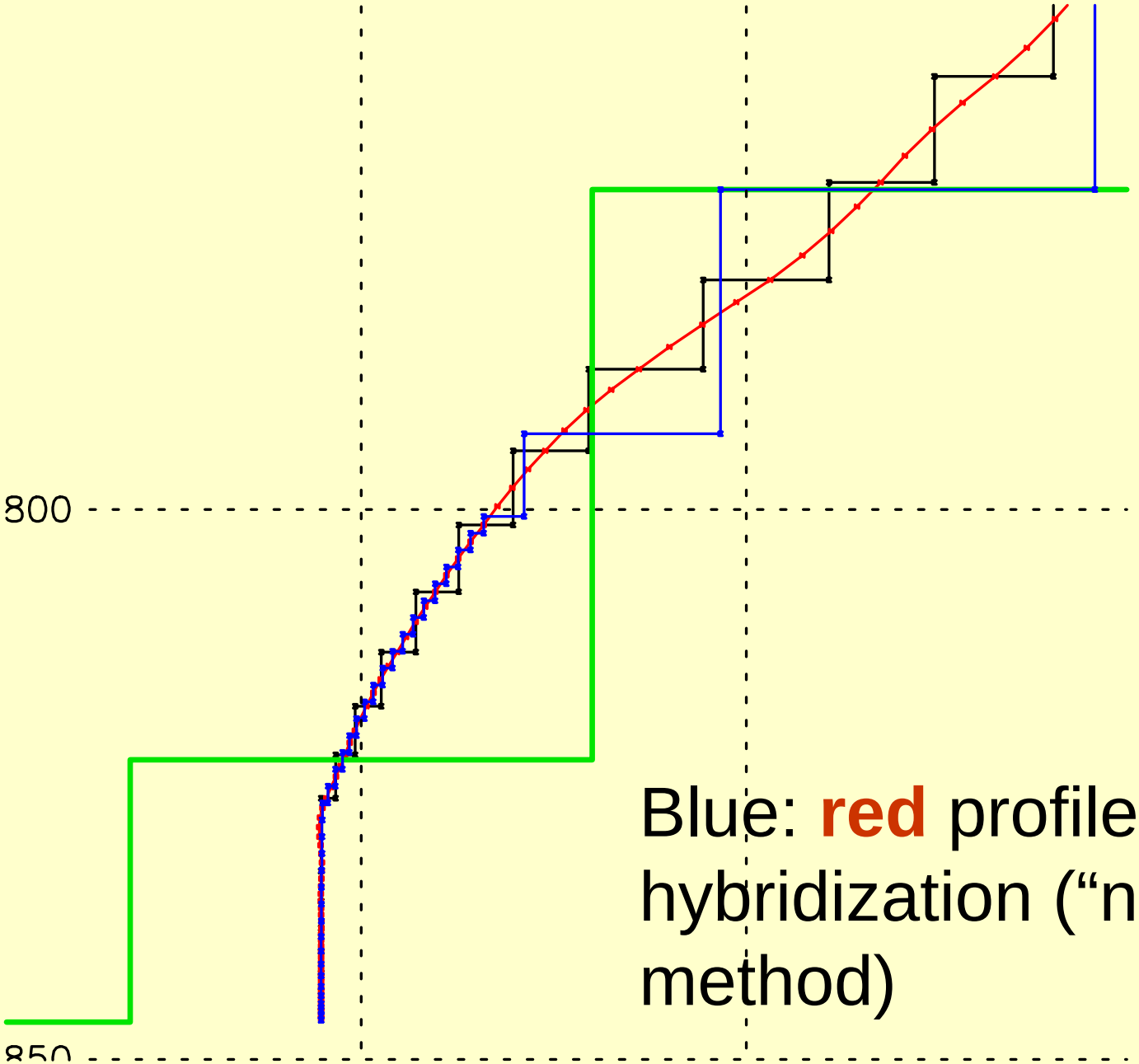

date = 200808131200, ipn = 2140
750
800
850
340
345
350
355
Green: isentropic
stair steps

Step 2: modify stair steps to eliminate massless layers at bottom

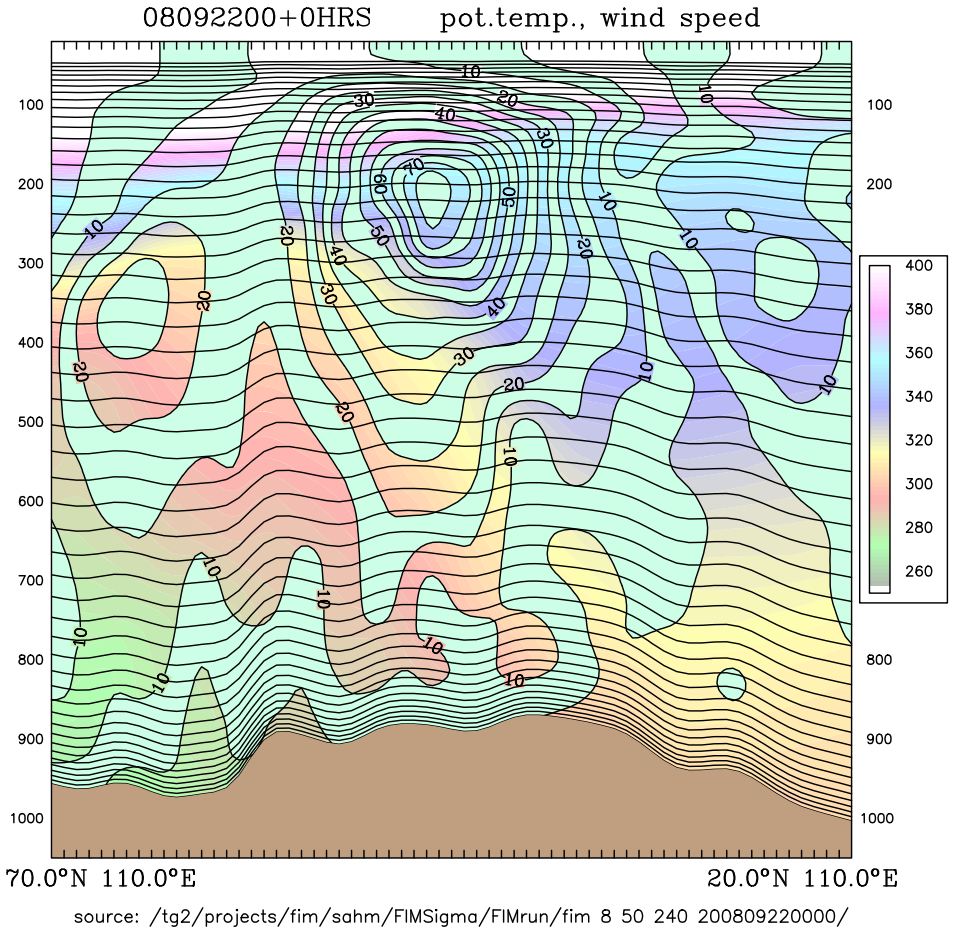

300
350
Large number of massless layers
Green: isentropic stair steps (zoomed)



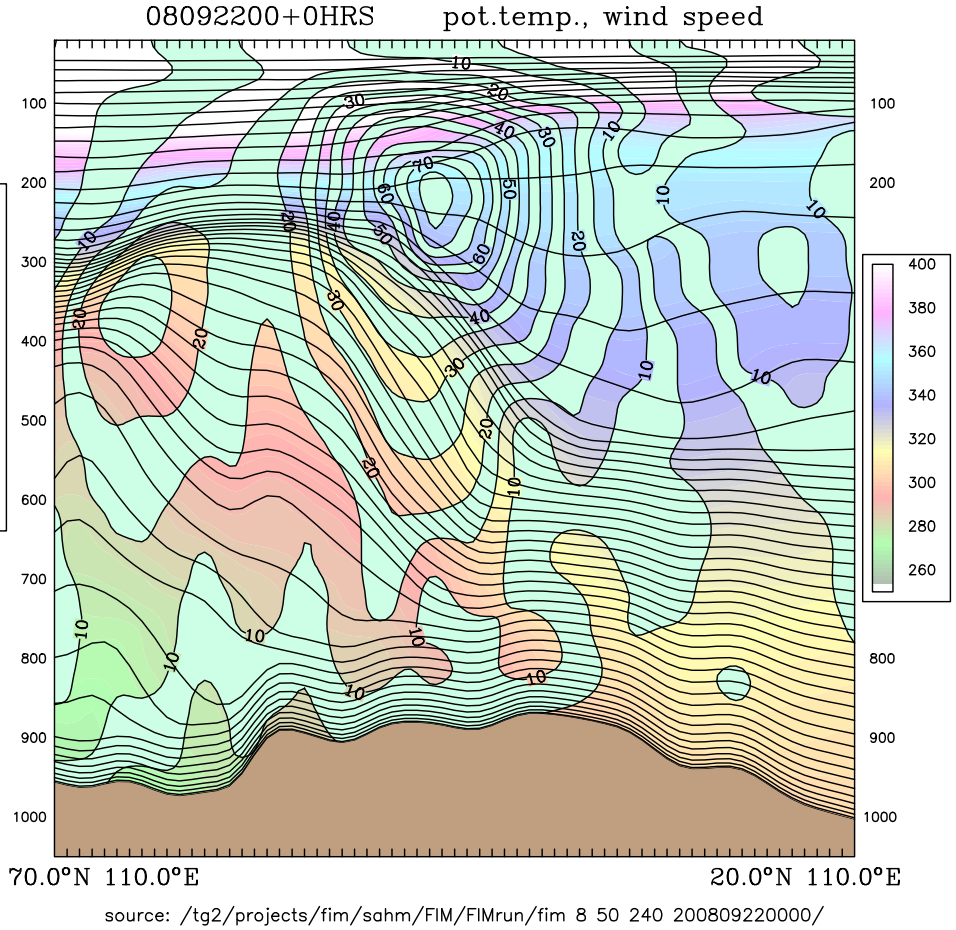
Blue: **green** profile after hybridization (“old” method)



Blue: **red** profile after hybridization (“new” method)



Sigma coordinate



Hybrid-isentropic coordinate

As mentioned earlier …

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- Faithful replication of temperature/ moisture profiles in planetary boundary layer
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- Preservation of column integrals

"Summary": A scheme has been cobbled together that does a reasonable job satisfying the above.