Initialization of layer models for numerical weather prediction

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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.
date = 200808131200, ipn = 2140

Input GFS pot. temperature profile (lower troposphere)
Step 1: interpolate to purely isentropic coordinates
Green: isentropic coordinate values

date = 20080813 1200, ipn = 2140
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
Green: isentropic stair steps
Step 2: modify stair steps to eliminate massless layers at bottom
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
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“Summary”: A scheme has been cobbled together that does a reasonable job satisfying the above.