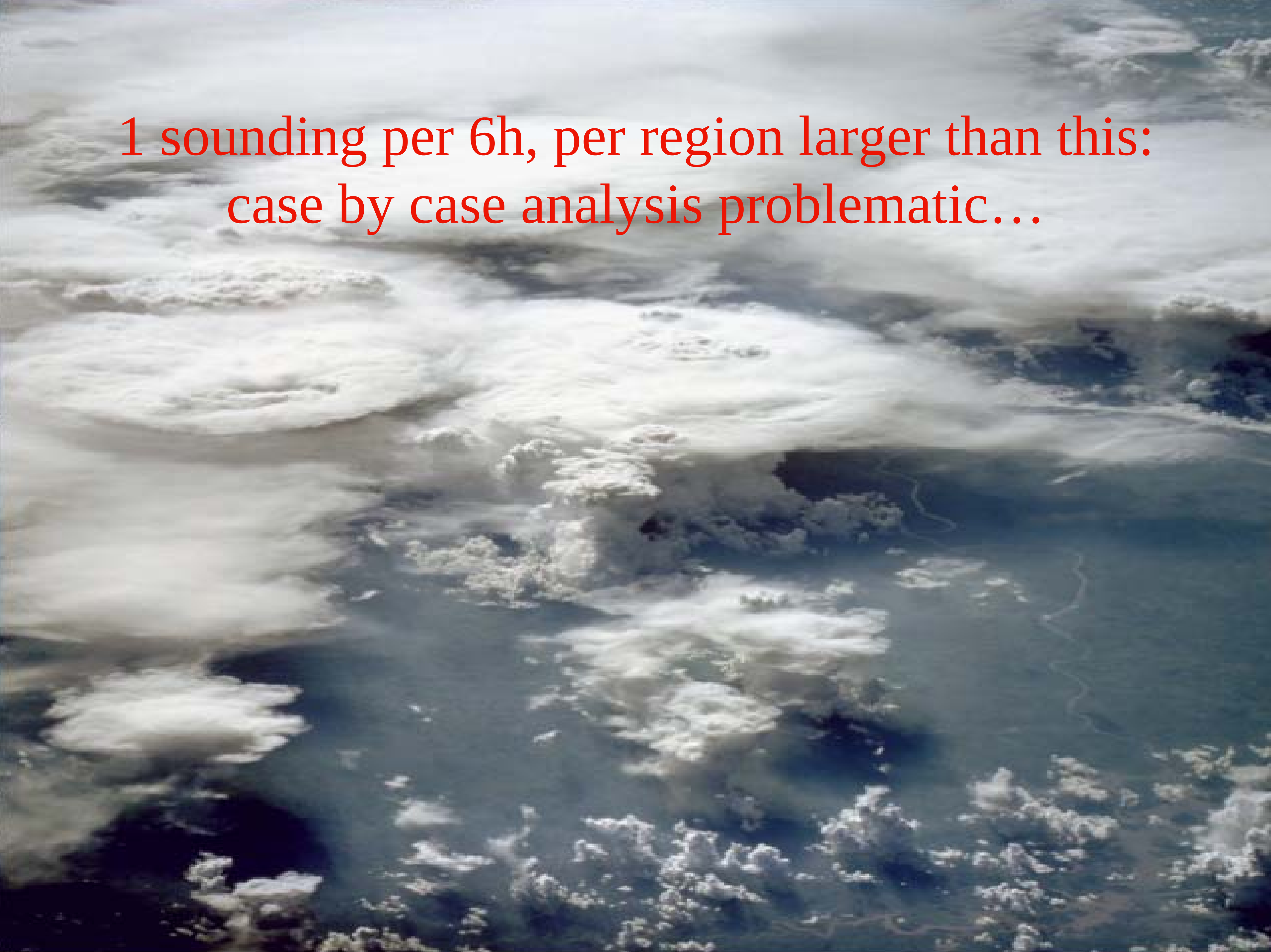
Cumulus parameterization in non-convection-resolving models

- Given a column profile of model variables*, what convective tendencies will* occur?
  - Hard questions:
    - *1 is mean thermo. sounding enough information?
      - » if not, what else should be included?
    - *2 should the answer be deterministic?
      - » if not, ensembles? perturbed/varied how?

A related data activity

- Given a set of soundings*, can we calculate an index that explains* the corresponding* set of convective outcomes*?
  - Hard questions:
    - *1 Measurements & sampling & averaging, Oh My!
    - *2 What comprises a satisfying or useful explanation?
    - *3 What region corresponds? (see *1)
    - *4 Measurements & definitions & details, Oh My!


1 sounding per 6h, per region larger than this:
case by case analysis problematic…

Illustrate with a strong signal

Diurnal cycle

Resistencia soundings

4-9 February

4x/day (8am, 2pm, 8pm, 2am)

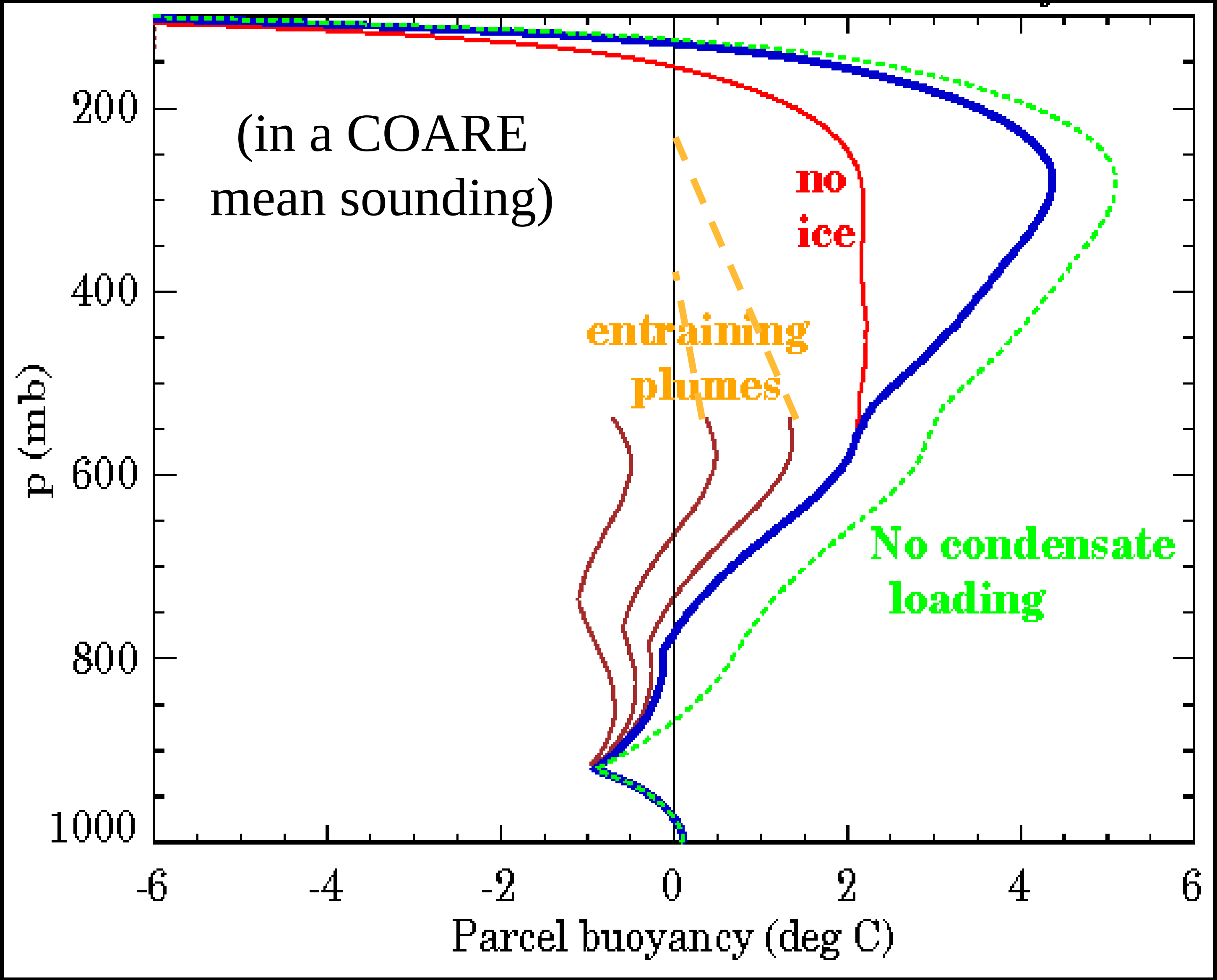
What index may explain convection, and/or form the basis for param'z'n?

- Physical key: buoyancy* of rising parcels*
  - Hard questions:

    *1 What aspect of buoyancy b(z)?
    - CAPE (integrated positive buoyancy) screens out impossibility of convection
    - CIN (negative buoyancy): important locally… details?

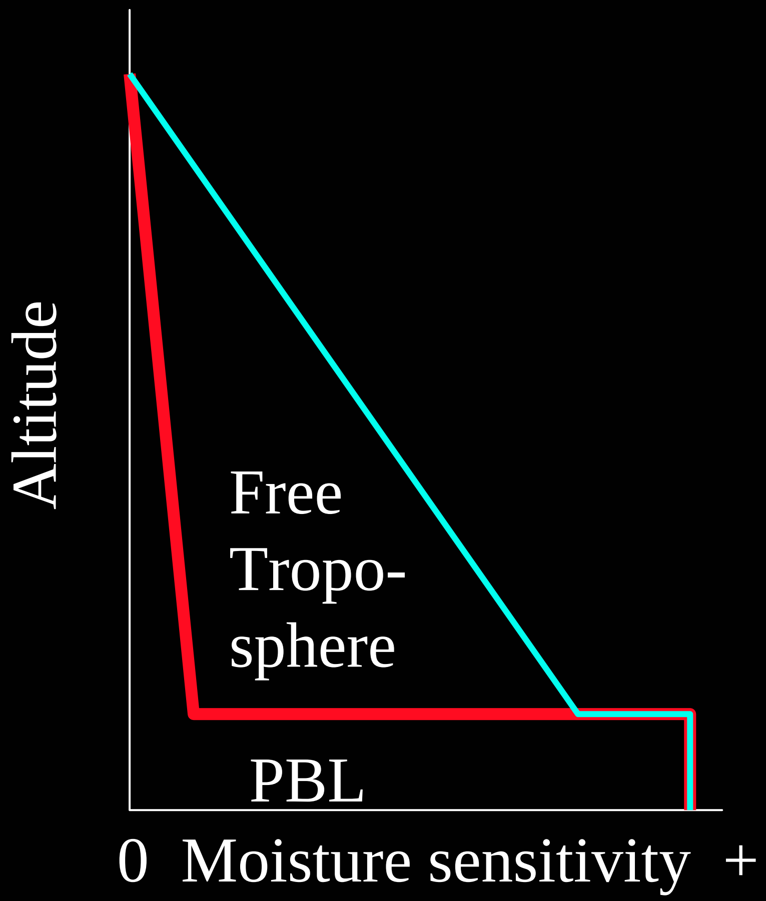
    *2 What parcel, what entrainment, what environment, what fallout of condensate, what freezing?

Defining the parcel & its ascent

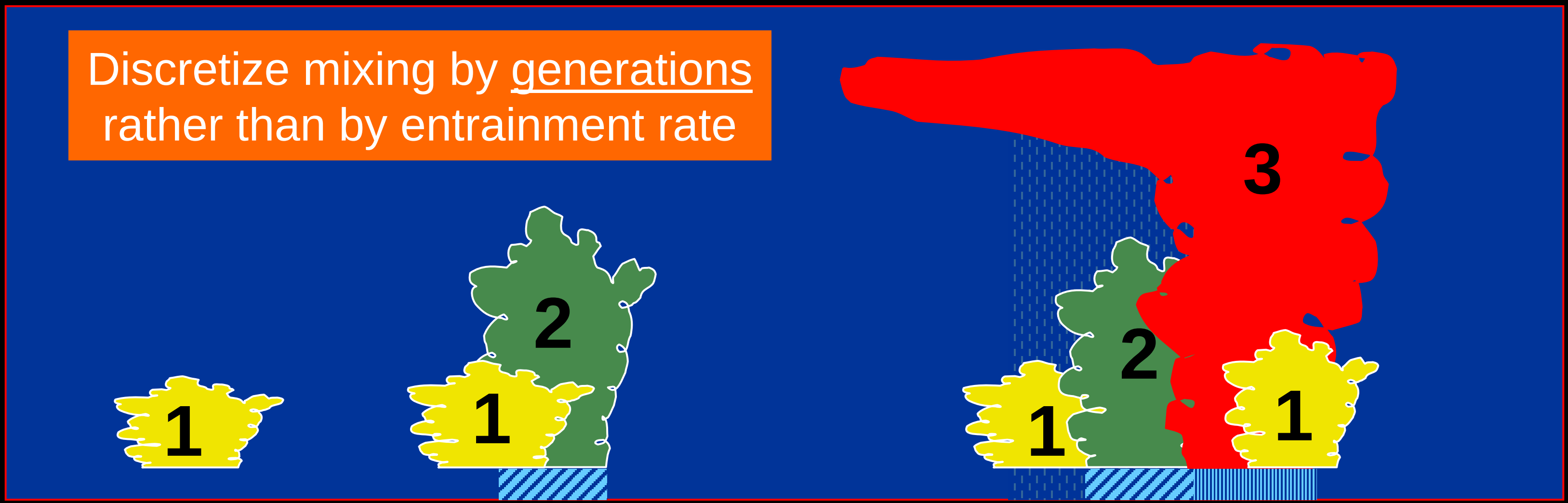


A problem with plumes

- For a plume to be buoyant to realistic altitudes, the entrainment rate must be small.
- This implies a humidity sensitivity of deep convection like this, whereas real deep convection feels free tropospheric moisture:

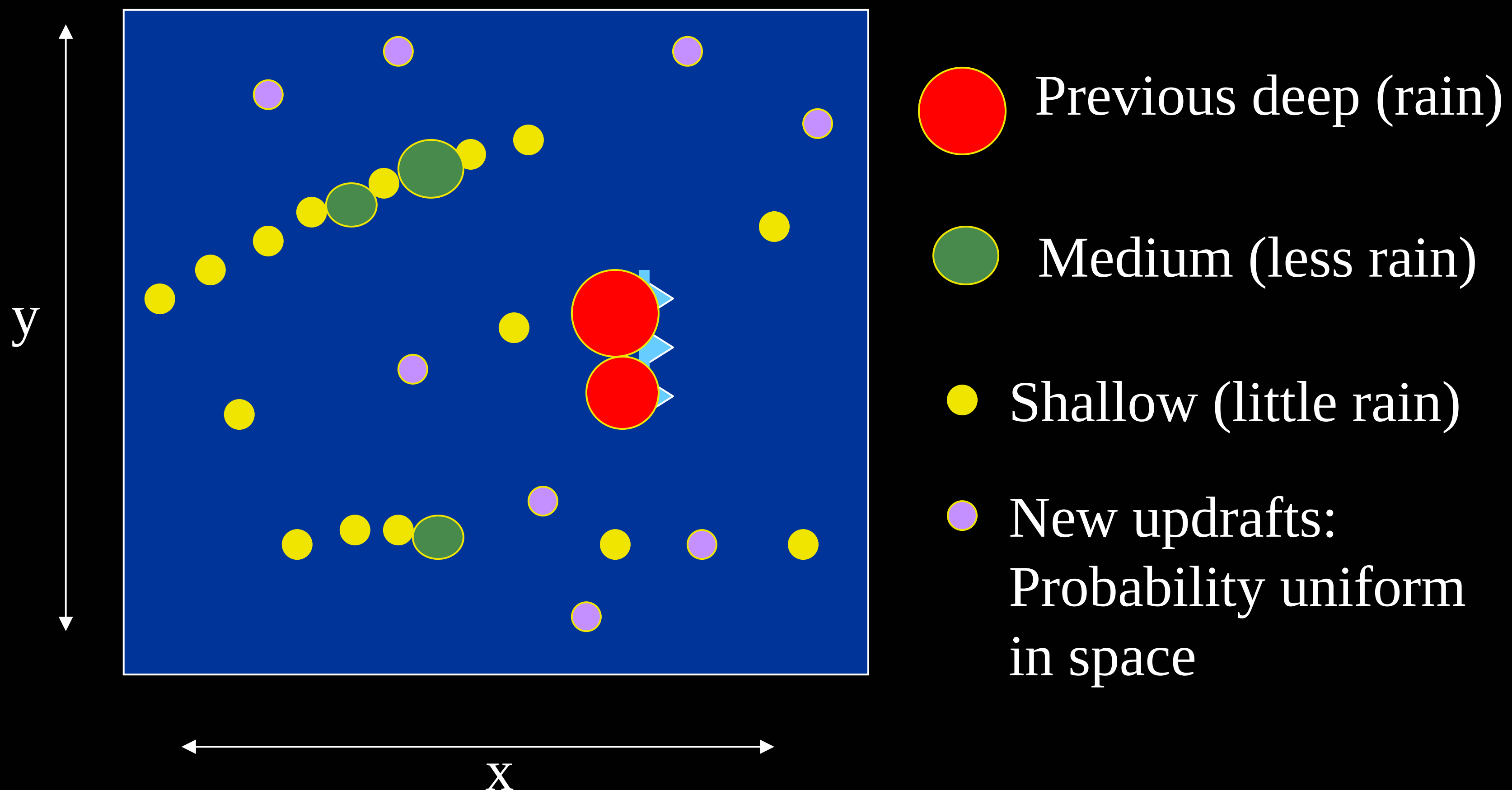


A solution to entrainment dilemma: successive entrainment

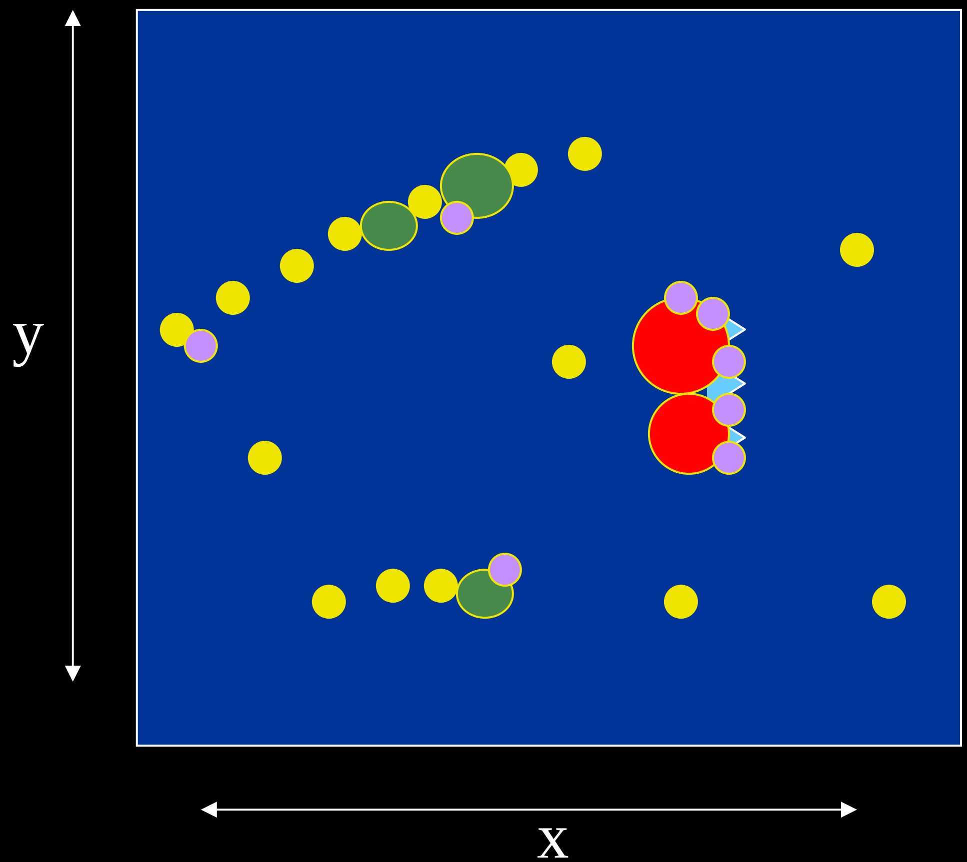


- All plumes entrain strongly.
- First clouds sensitive to free-troposphere q, usually shallow.
- Later convection may entrain prior clouds, becoming deeper.
- Deep clouds get an indirect q dependence, and a delay.
- Opens up questions of convective organization (weak sense)

Purely random new updrafts

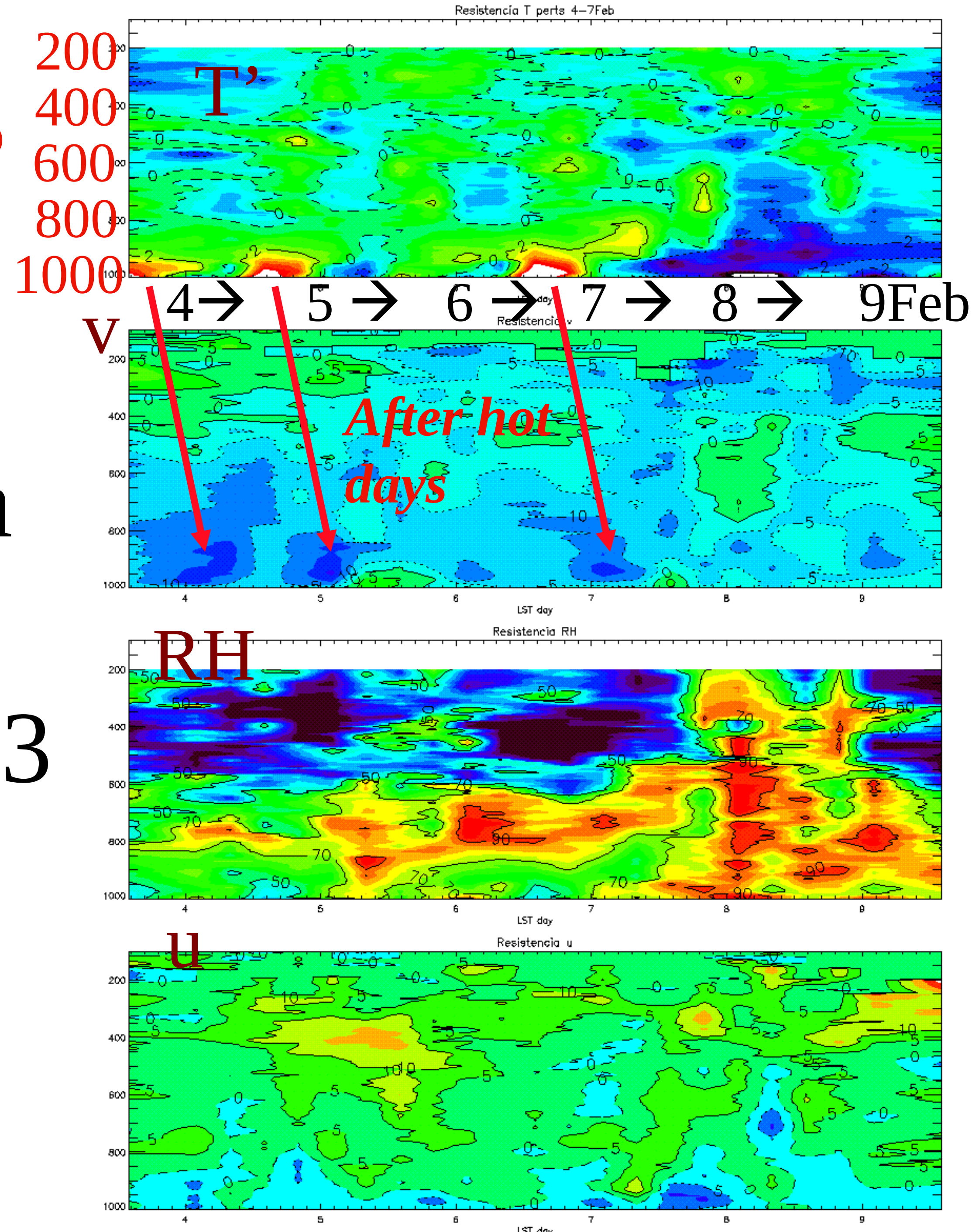


Purely rain-organized new updrafts

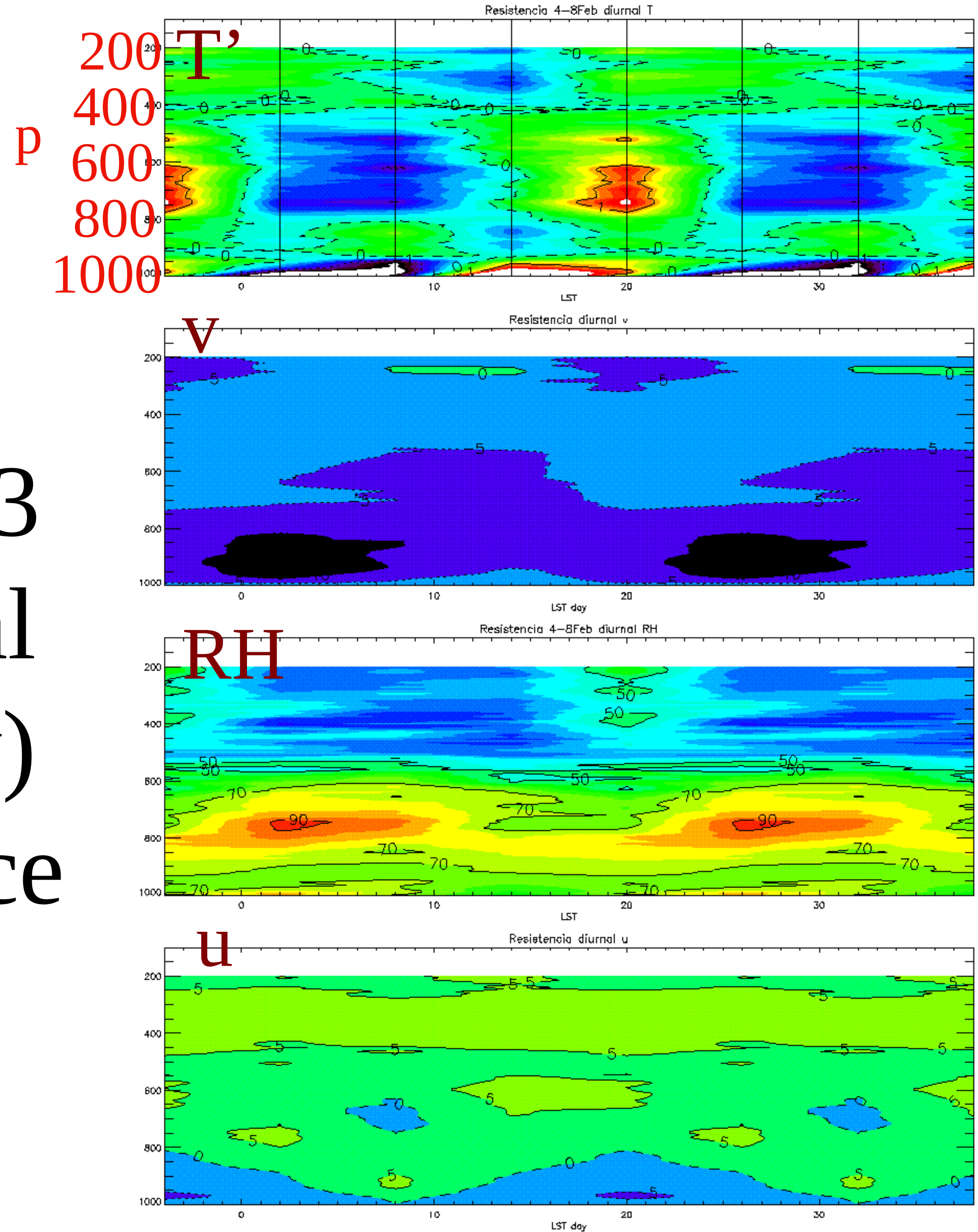


- Previous deep (5/8 rain)
- Medium (2/8 rain)
- Shallow (1/8 rain)
- New updrafts: Probability α *rain*, not area

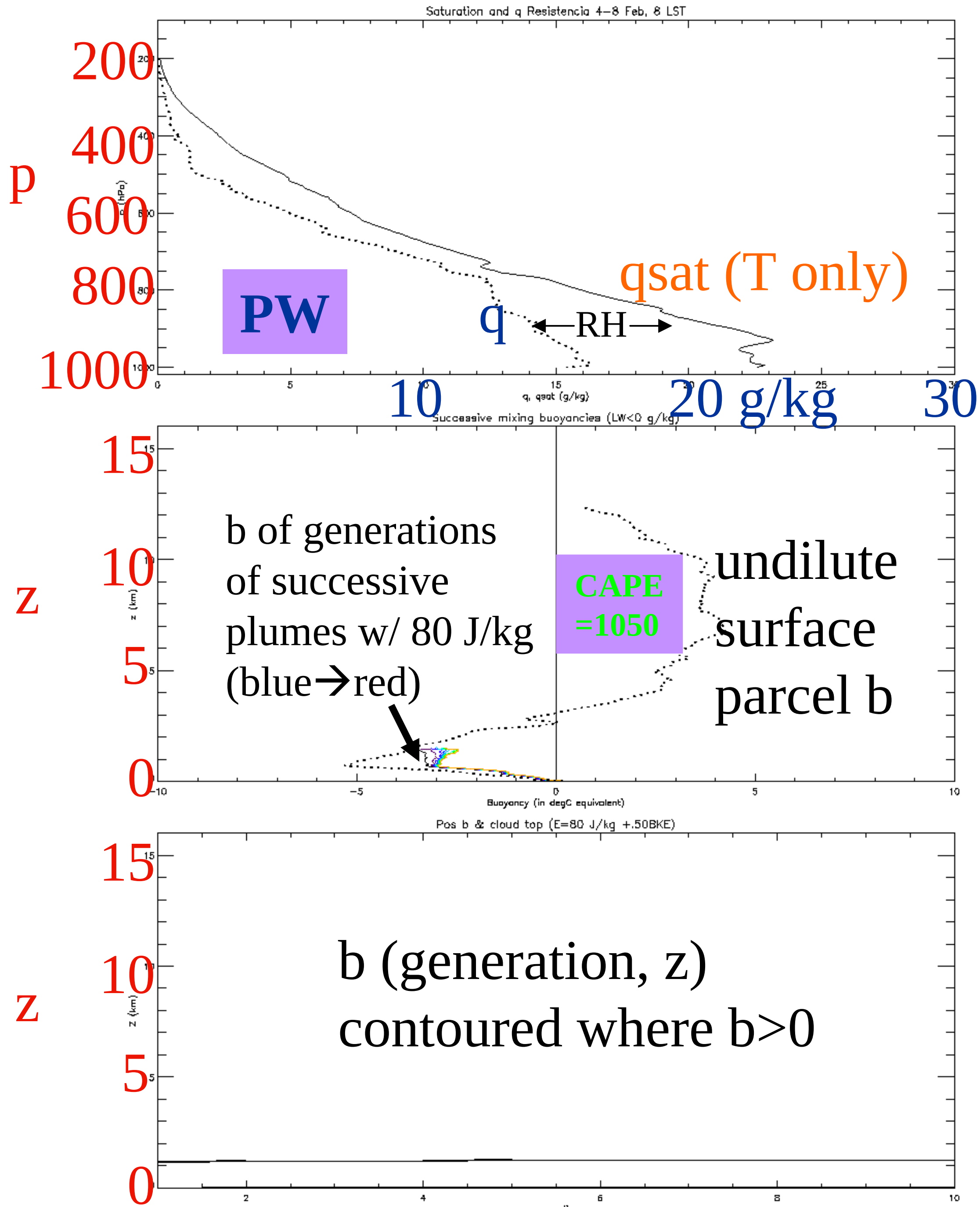
Resistencia soundings 4-9 Feb 2003



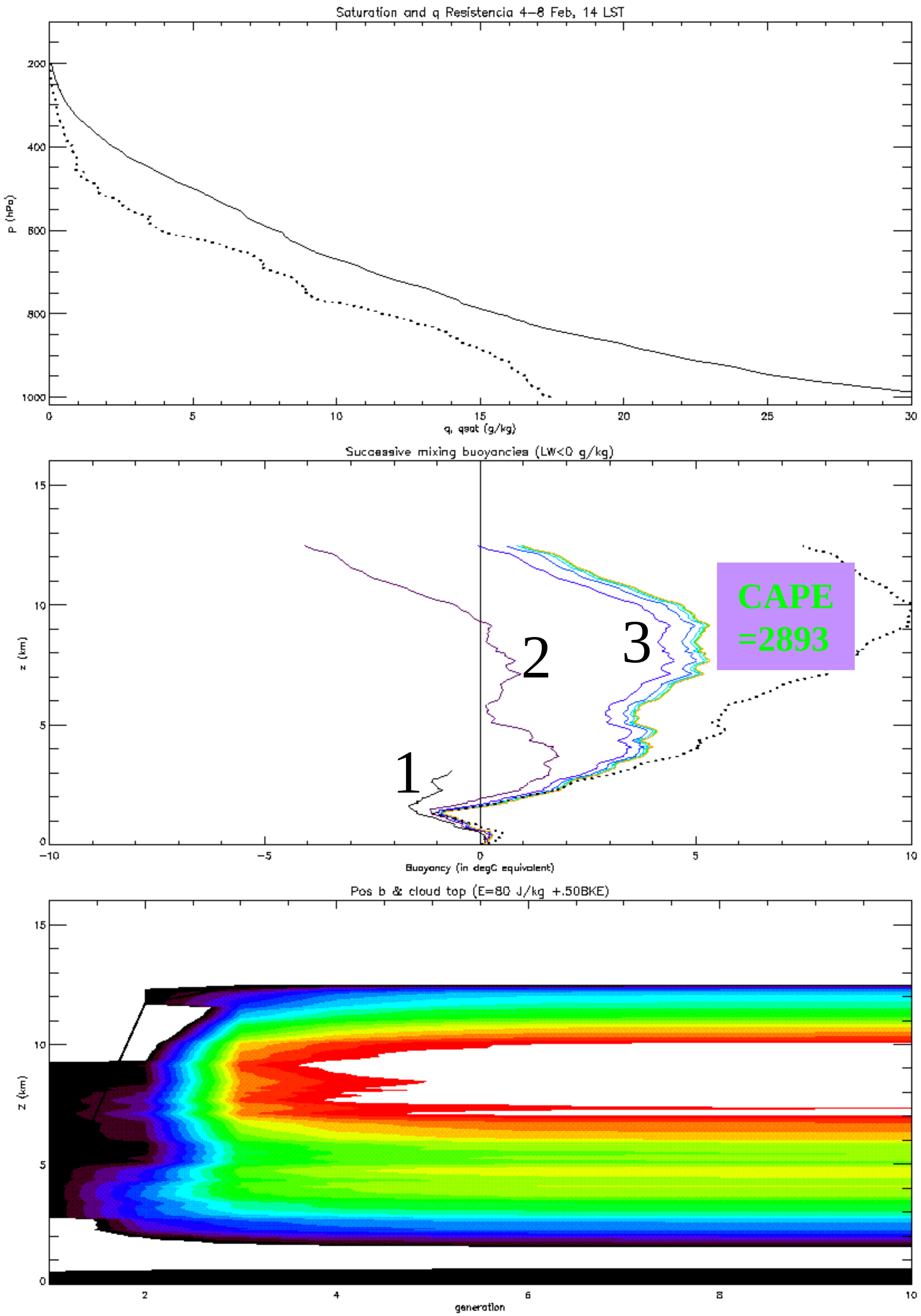
Resistencia 4-9 Feb 2003 mean diurnal cycle (4/day) repeated twice



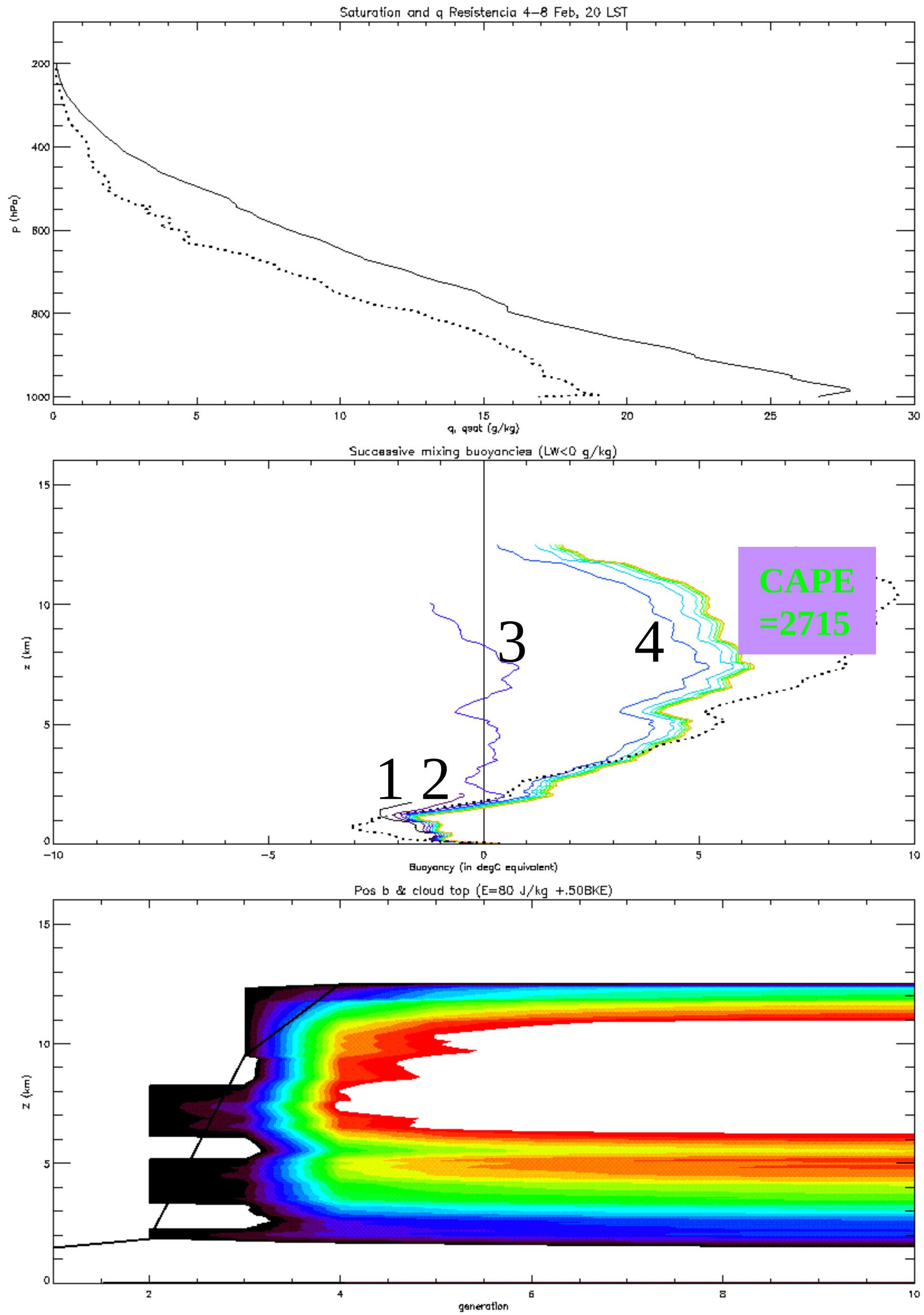
Resistencia 08 LST mean sounding and parcel buoyancies



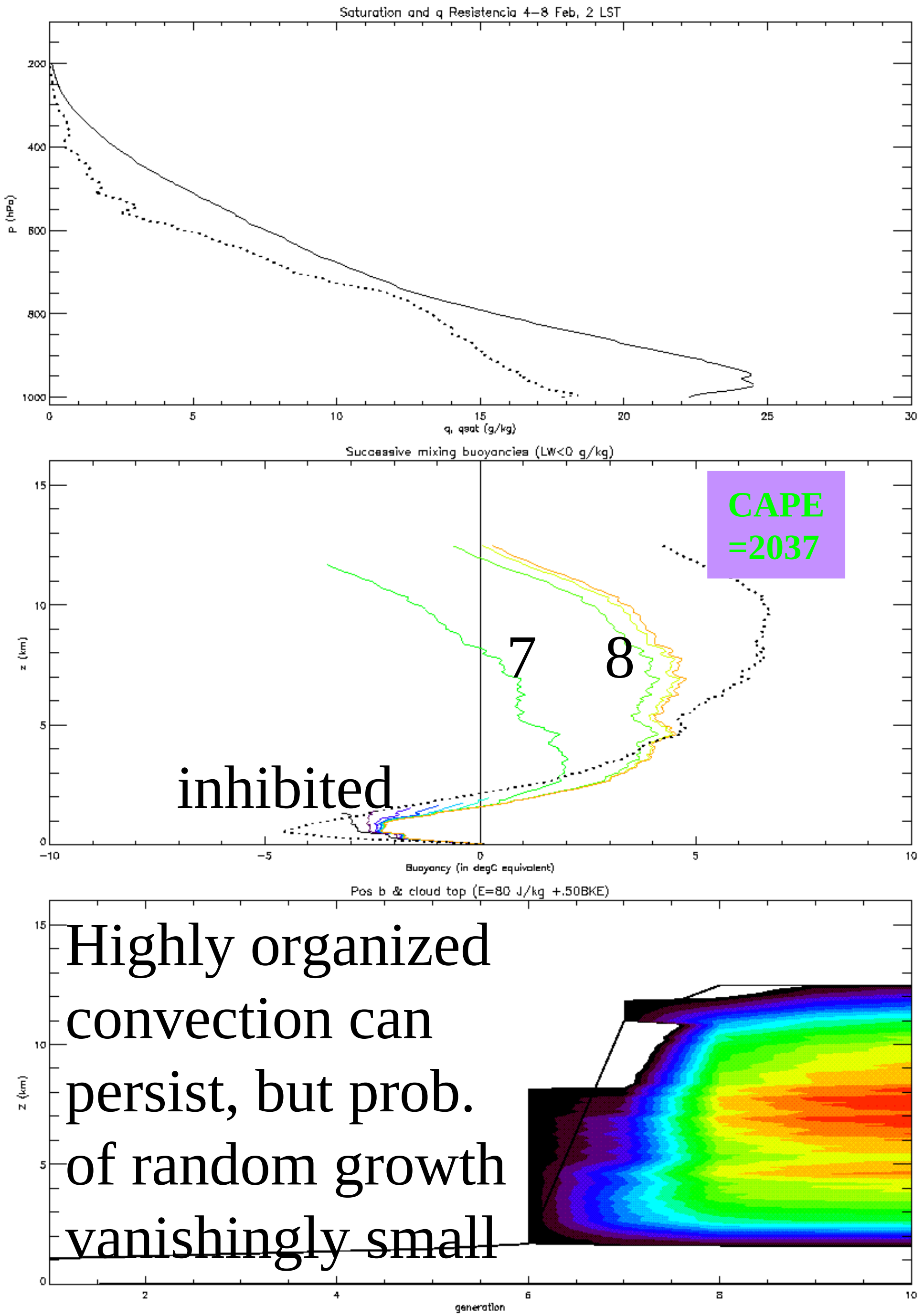
Resistencia 14 LST mean sounding and parcel buoyancies



Resistencia 20 LST mean sounding and parcel buoyancies



Resistencia 02 LST mean sounding and parcel buoyancies



Two ways to overcome 80 J/kg of mean-sounding CIN with subgrid fluctuations

- Convective: PBL updrafts overshoot into inhibition layer:

$$w = (2*80)^{1/2} = 13 m/s \text{ (!!)}$$

- Mesoscale: sub-grid T' fluctuation in inhibition layer has 80 J/kg of PE:

$$PE = g*\Delta T/T*\Delta z \text{ (just like b)}$$

$$= 2K \text{ over } 1200m \text{ layer}$$

then CIN → 0 in crest of wave

Two ways to overcome 80 J/kg of mean-sounding CIN with subgrid fluctuations

On a coarse grid (say 200km), most of the CIN-overcoming subgrid-scale energy may be in mesoscale fluctuations

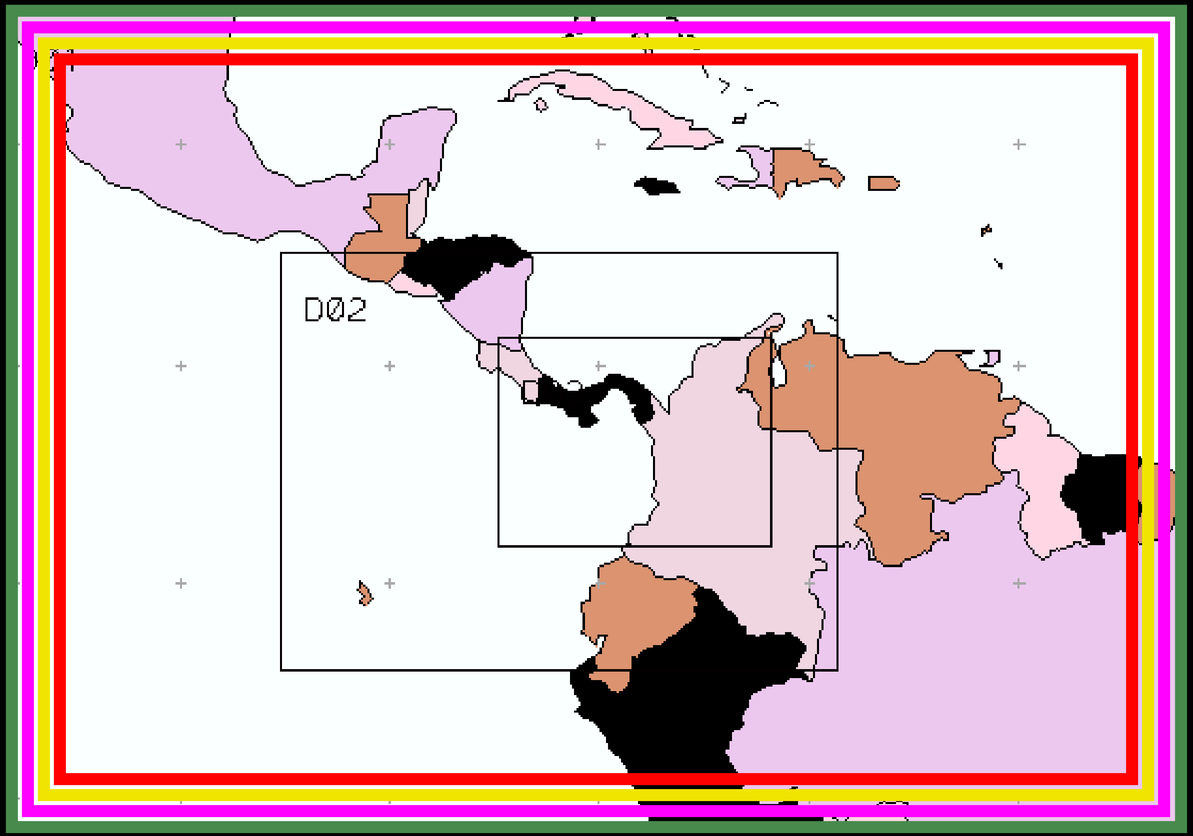
In a fine grid (say 10km), only convective fluctuations may be available, but mesoscale is now resolved, so some grid squares will have smaller CIN than the coarse-grid mean sounding

Power spectrum of subgrid energy can give a grid scale-dependent way to choose magic number needed for succession calculations

Summary

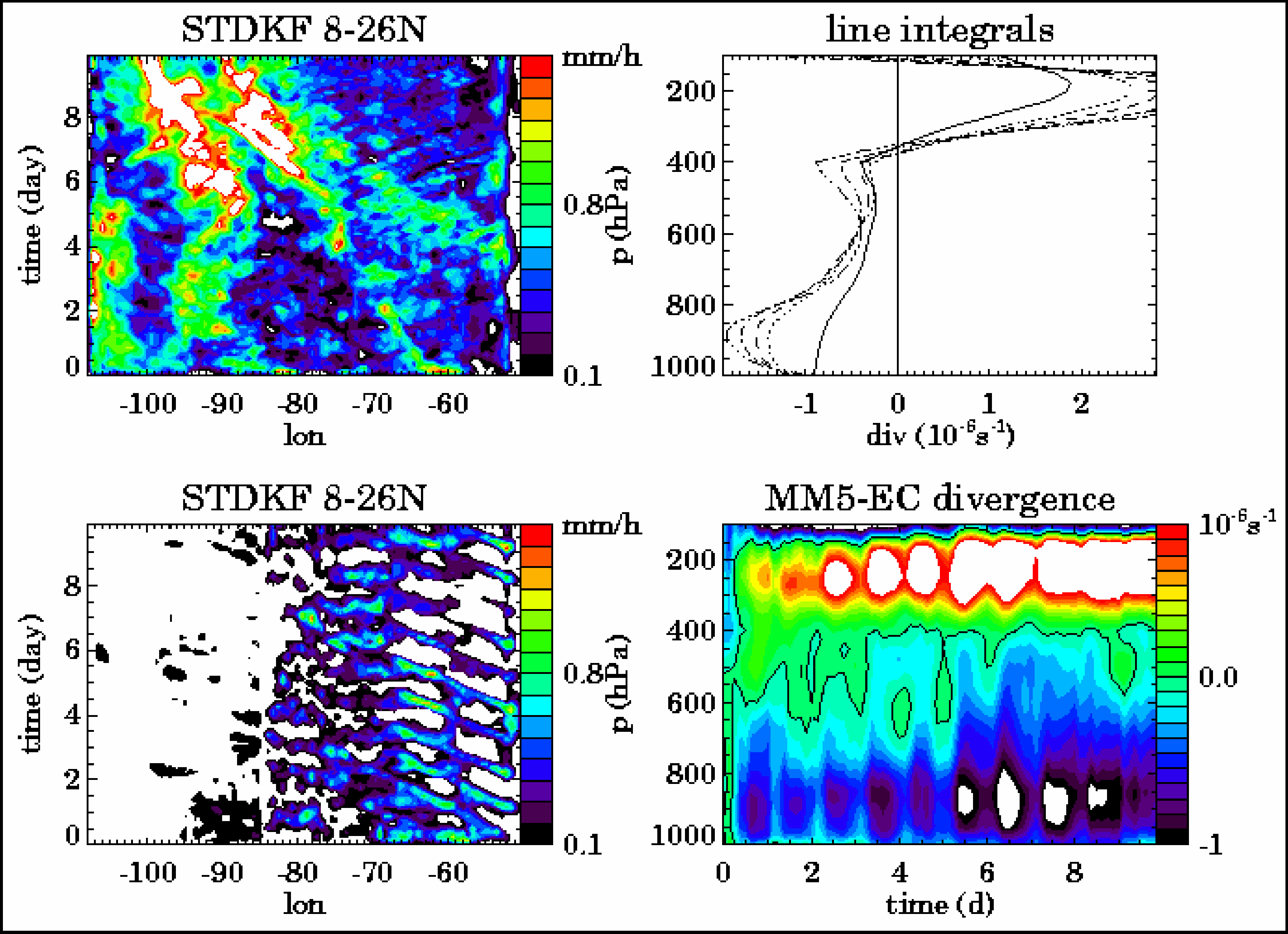
- Explaining convection from soundings is not unlike deciding convection in models
- Successive entrainment improves on low-entrainment CAPE closures
  - more sensitivity of deep convection to moisture
  - realistic development delays, e.g. in diurnal cycle
- Each requires top height of prior generations
  - necessarily involves inhibition/overshoot consideration
- Likelihood (coverage) of higher generations depends on organization (localization of updrafts in enhanced-humidity subgrid areas)

Regional divergence test of CPSs

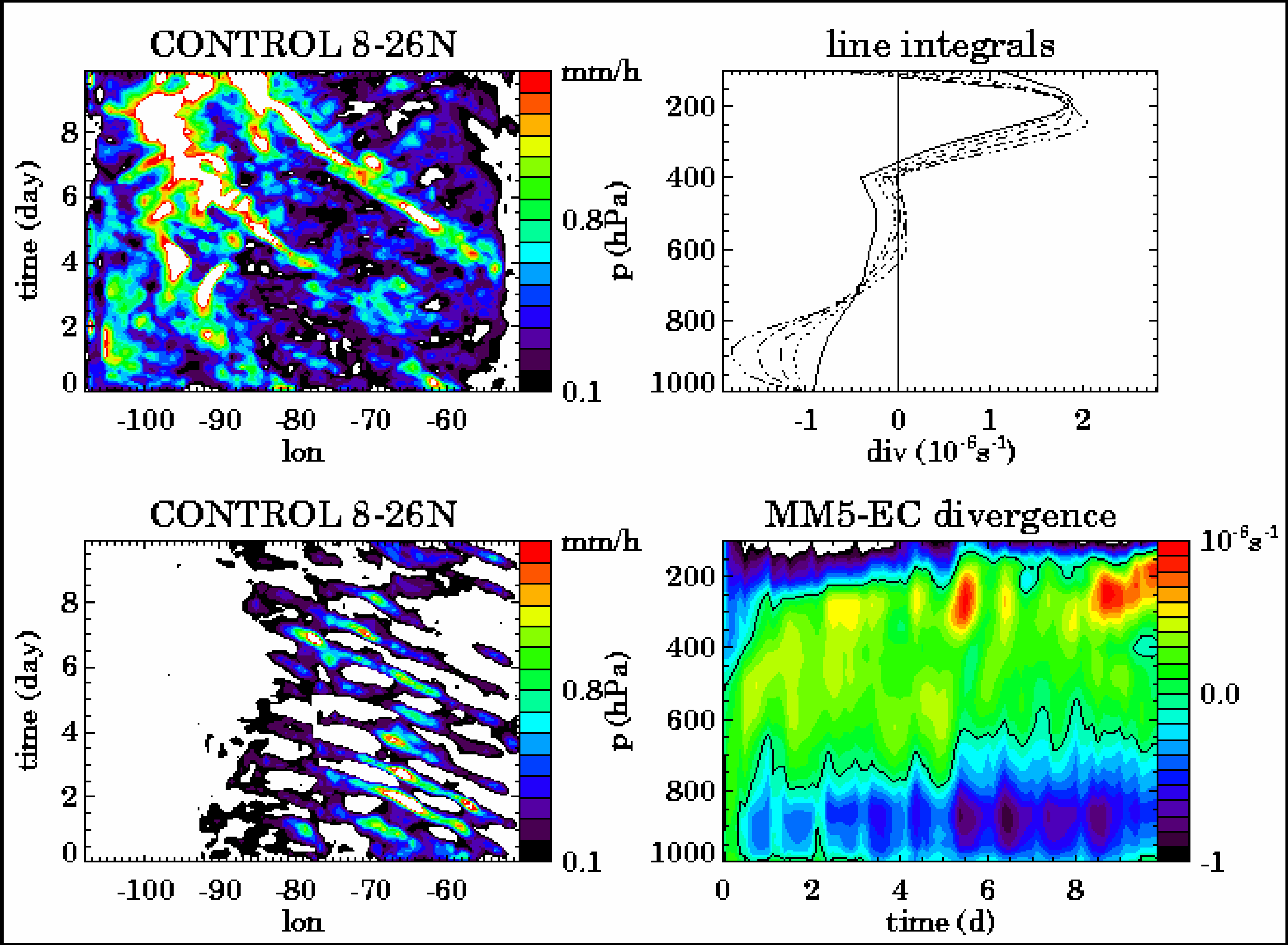


Perimeter line integral of normal wind =
area-averaged divergence over nearly identical areas
Green: ERA (BC); colors: MM5, less and less nudged

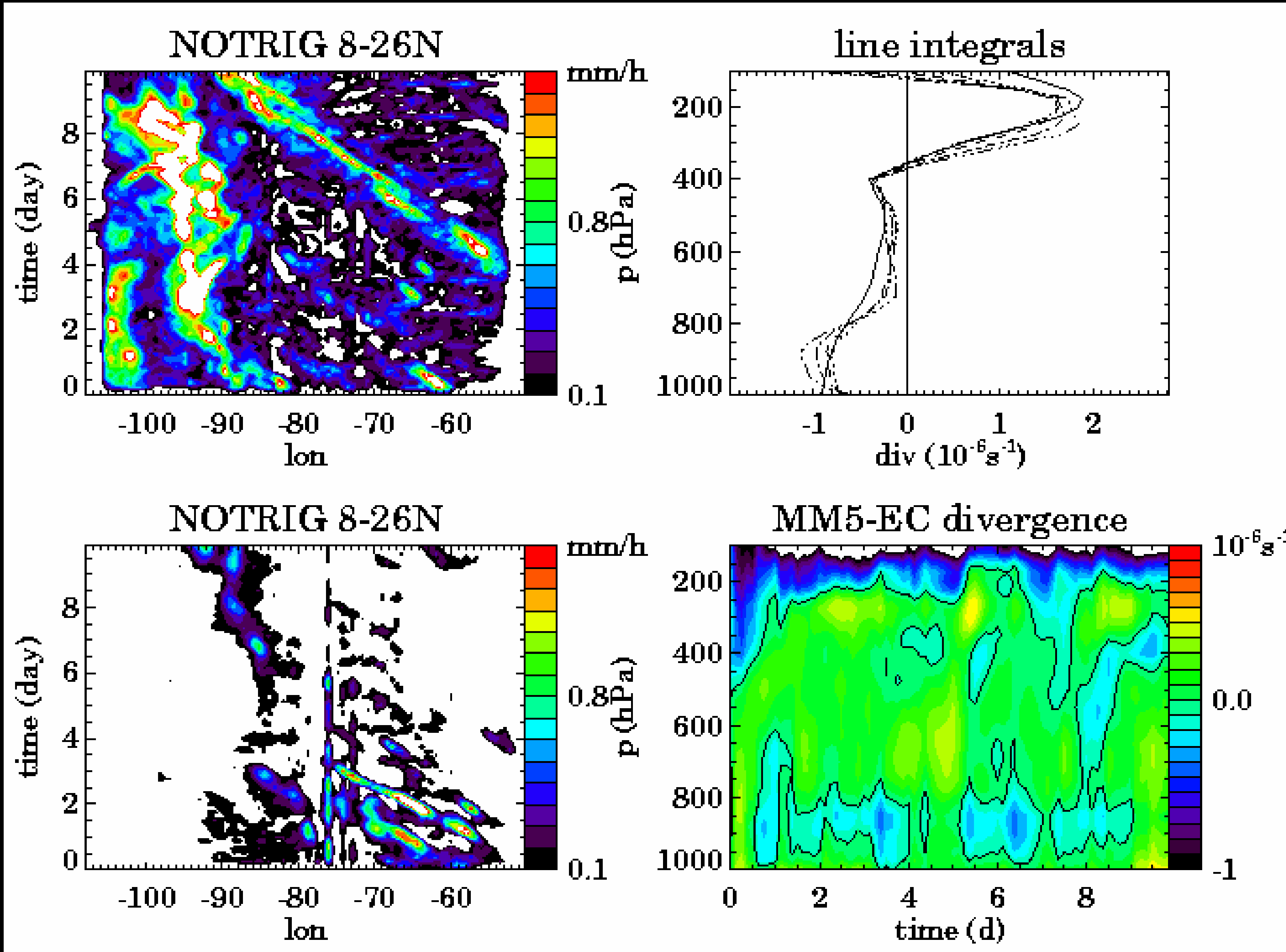
Standard entrainment value

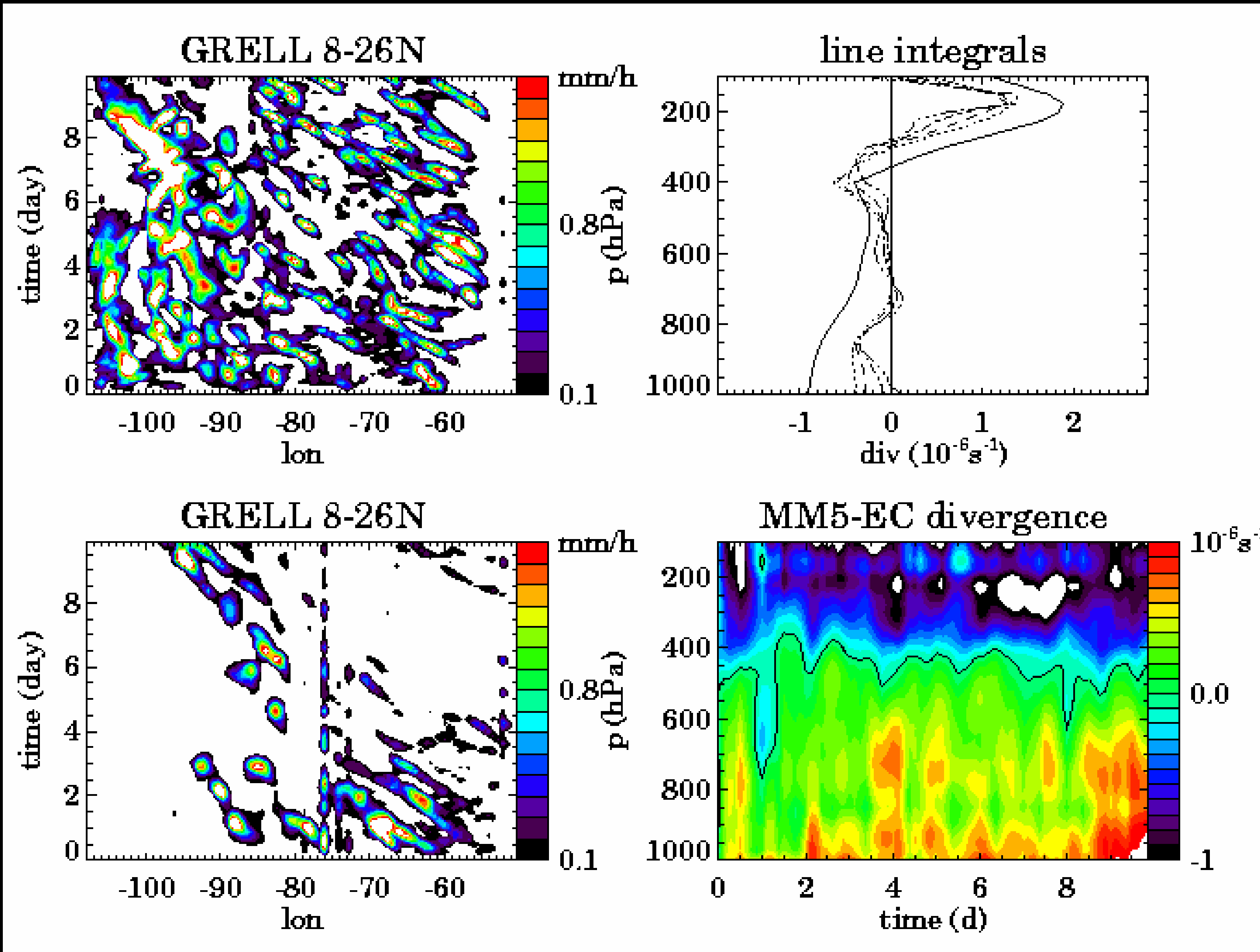


Doubled entrainment value

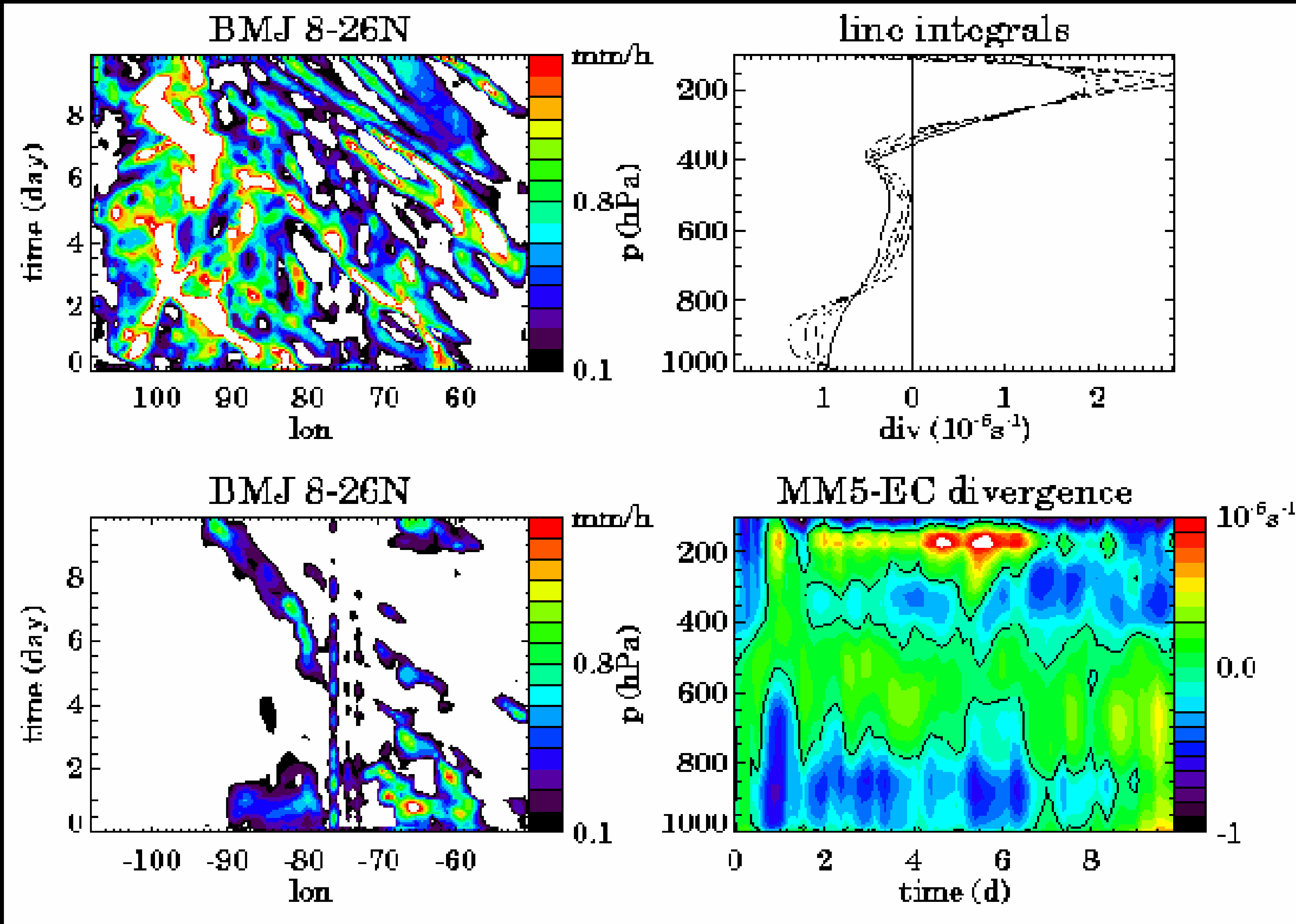


Double entrainment, disable trigger function

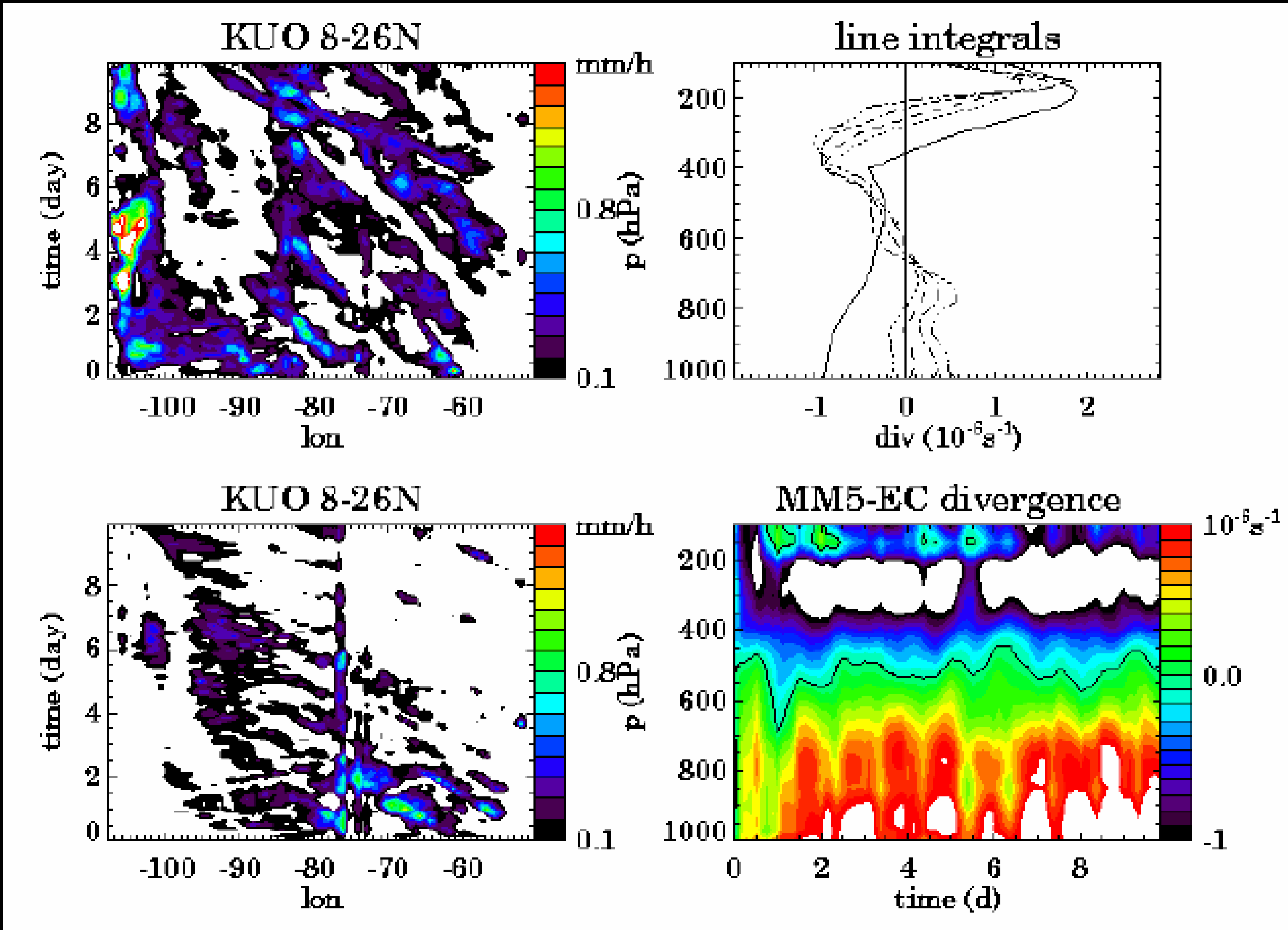




GRELL 8-26N
mm/h
0.8
0.1
time (day)
lon
-100
-90
-80
-70
-60
line integrals
p (hPa)
div ($10^{-6}s^{-1}$)
-1
0
1
2
200
400
600
800
1000
GRELL 8-26N
mm/h
0.8
0.1
time (day)
lon
MM5-EC divergence
$10^{-6}s^{-1}$
0.0
-1
p (hPa)
time (d)



BMJ 8-26N
mm/h
0.8
0.1
time (day)
0
2
4
6
8
100
90
80
70
60
lon
line integrals
p (hPa)
200
400
600
800
1000
1
0
1
2
div ($10^{-6}s^{-1}$)
BMJ 8-26N
mm/h
0.8
0.1
time (day)
-100
-90
-80
-70
-60
lon
MM5-EC divergence
$10^{-6}s^{-1}$
0.0
-1
p (hPa)
time (d)



KUO 8-26N
mm/h
0.8
0.1
time (day)
lon
-100
-90
-80
-70
-60
line integrals
p (hPa)
200
400
600
800
1000
div (10-6s-1)
-1
0
1
2
KUO 8-26N
mm/h
0.8
0.1
time (day)
lon
MM5-EC divergence
10-6s-1
0.0
-1
time (d)

Some parameterization-related activities using a little SALLJEX data

Brian Mapes

Dec 2003