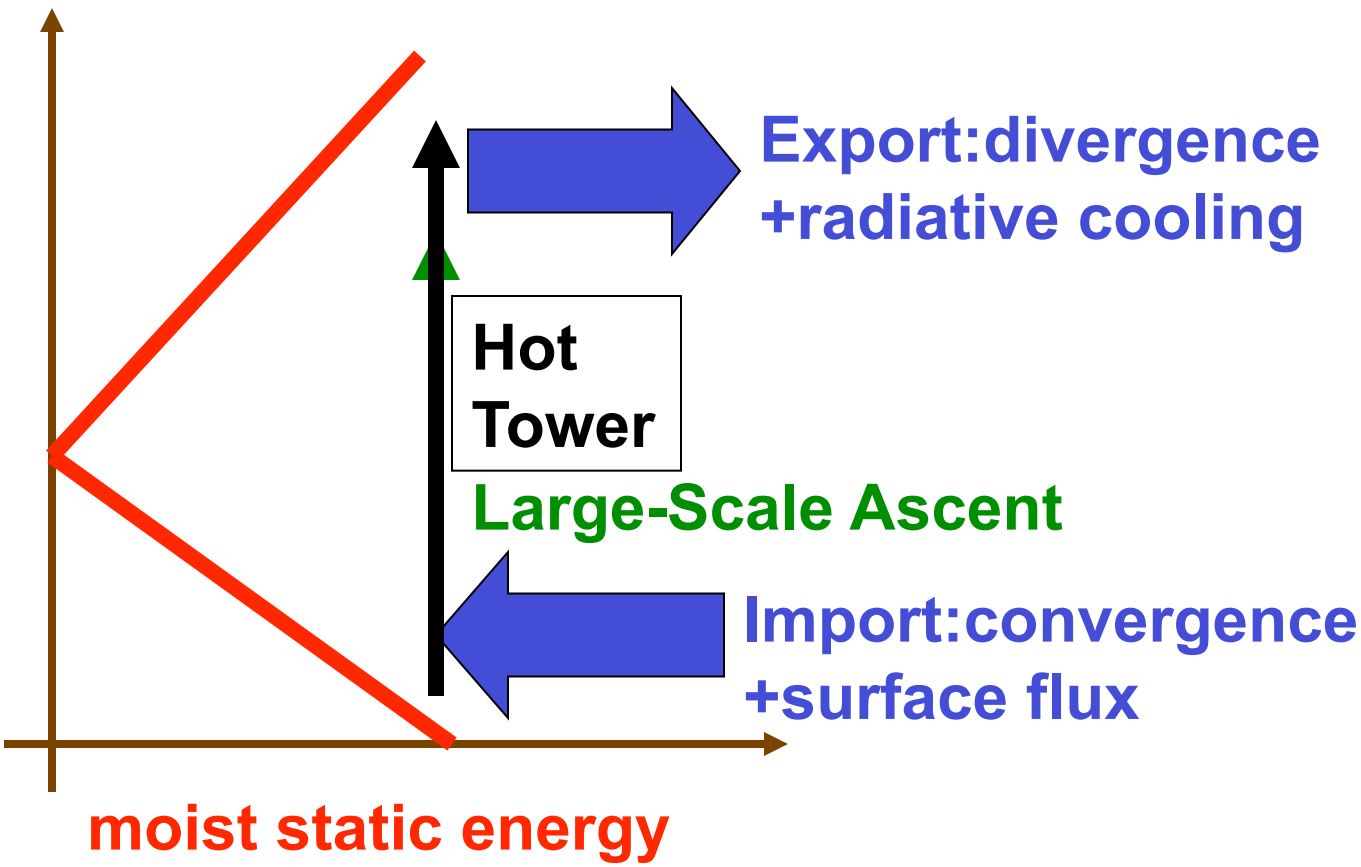
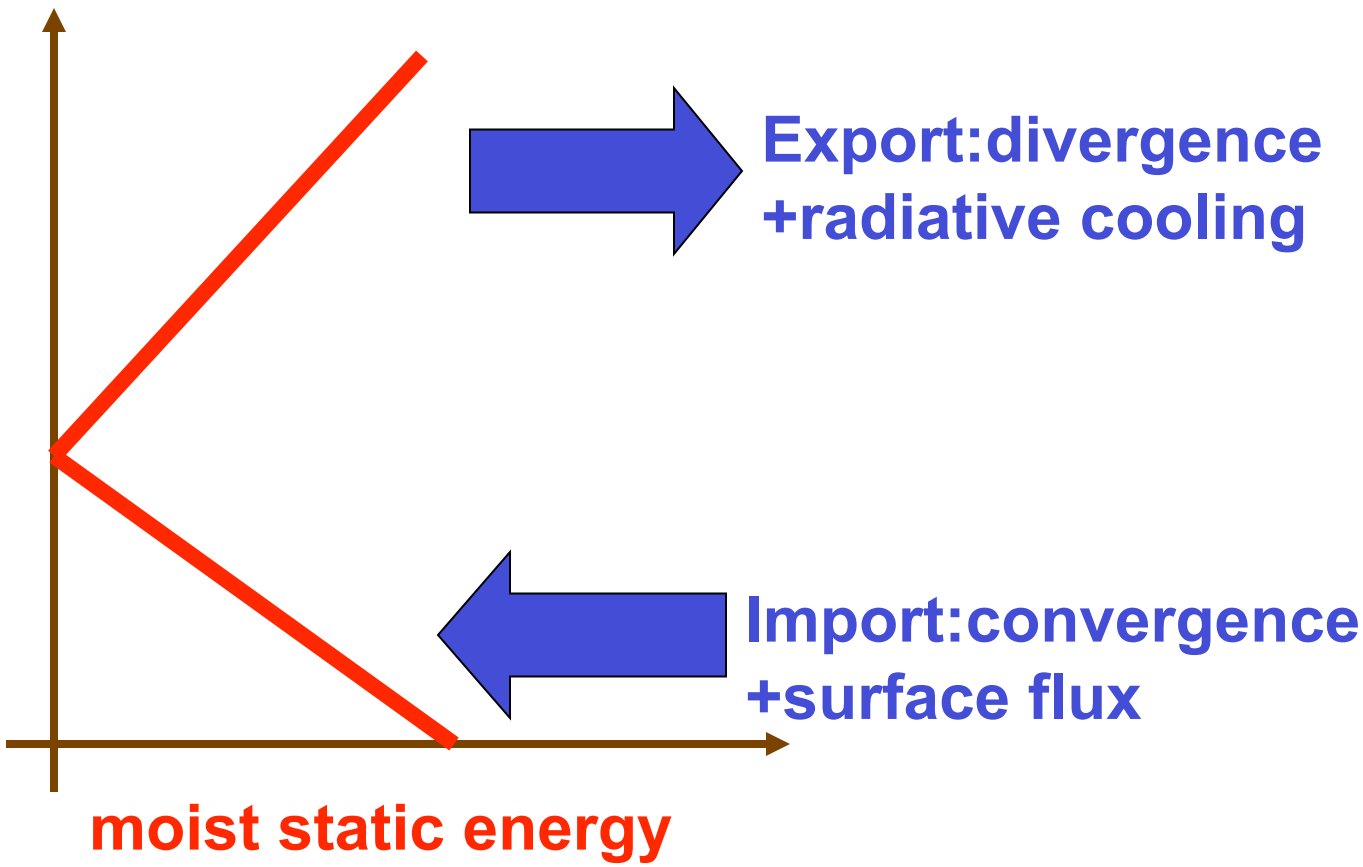
Revisit of Riehl and Malkus (1958): Hot-Tower Hypothesis:

Tropical Mean Heat Budget:

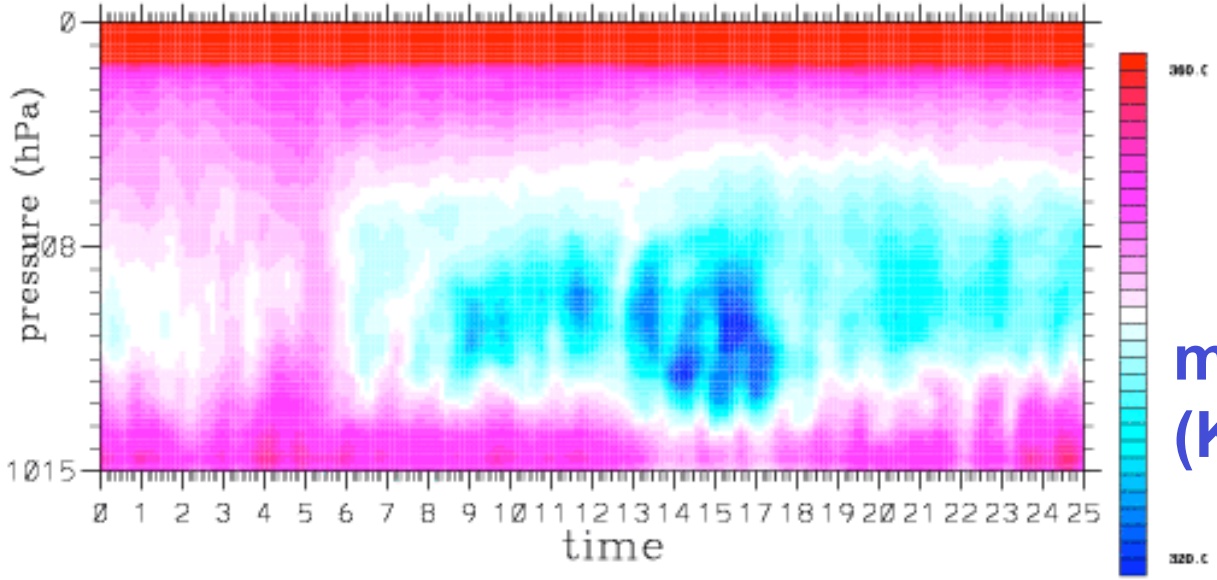


Revisit of Riehl and Malkus (1958): Hot-Tower Hypothesis:

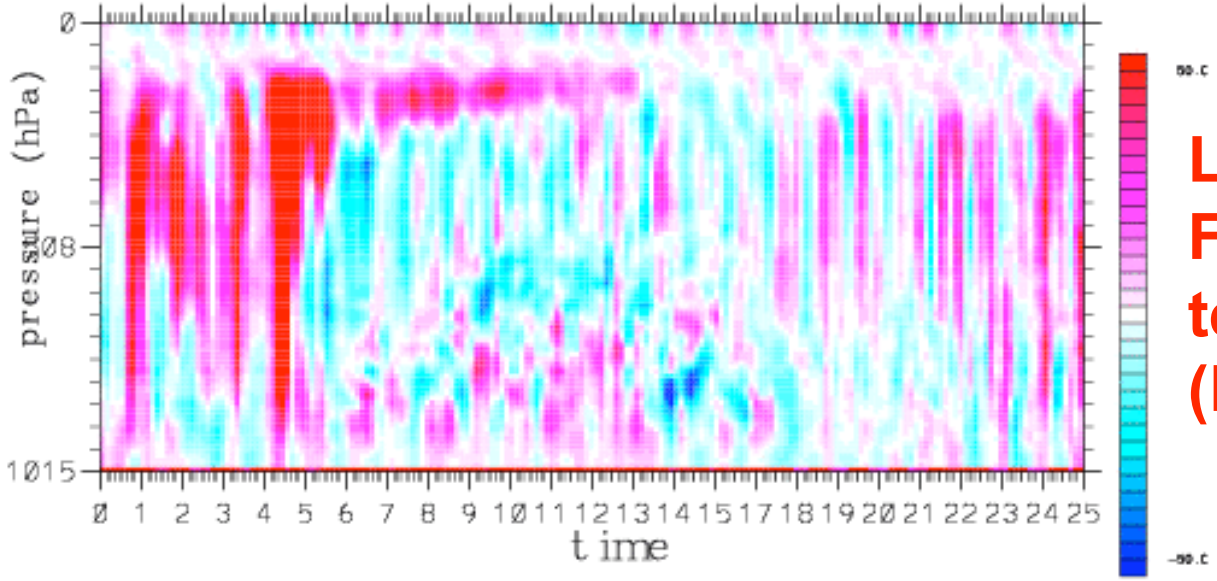
Is this mean picture consistent with TWP-ICE Period?:



Time-Evolution of TWP-ICE Period (SCM case)



moist static energy (K)

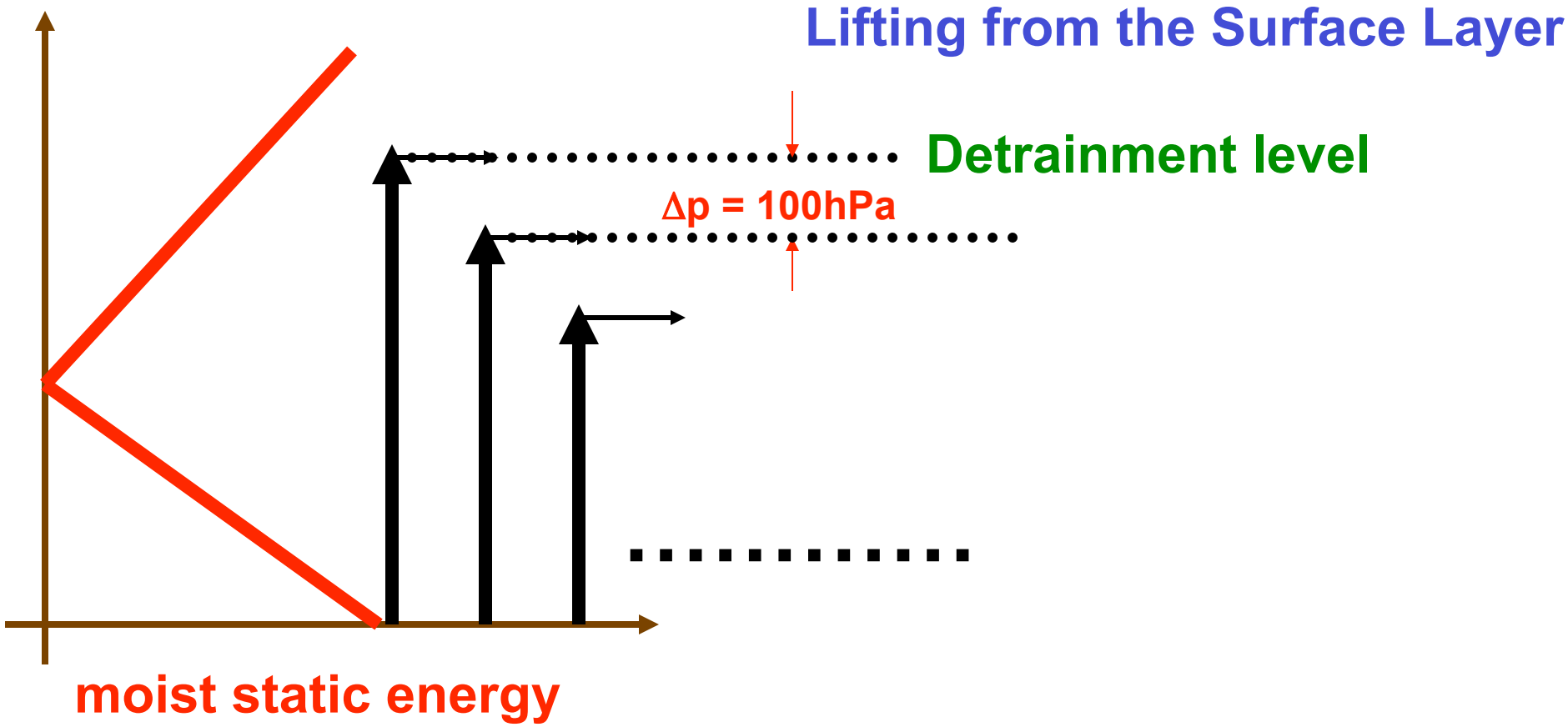


Large-Scale Forcing - temporal tendency (K/day)

Revisit of Riehl and Malkus (1958): Hot-Tower Hypothesis:

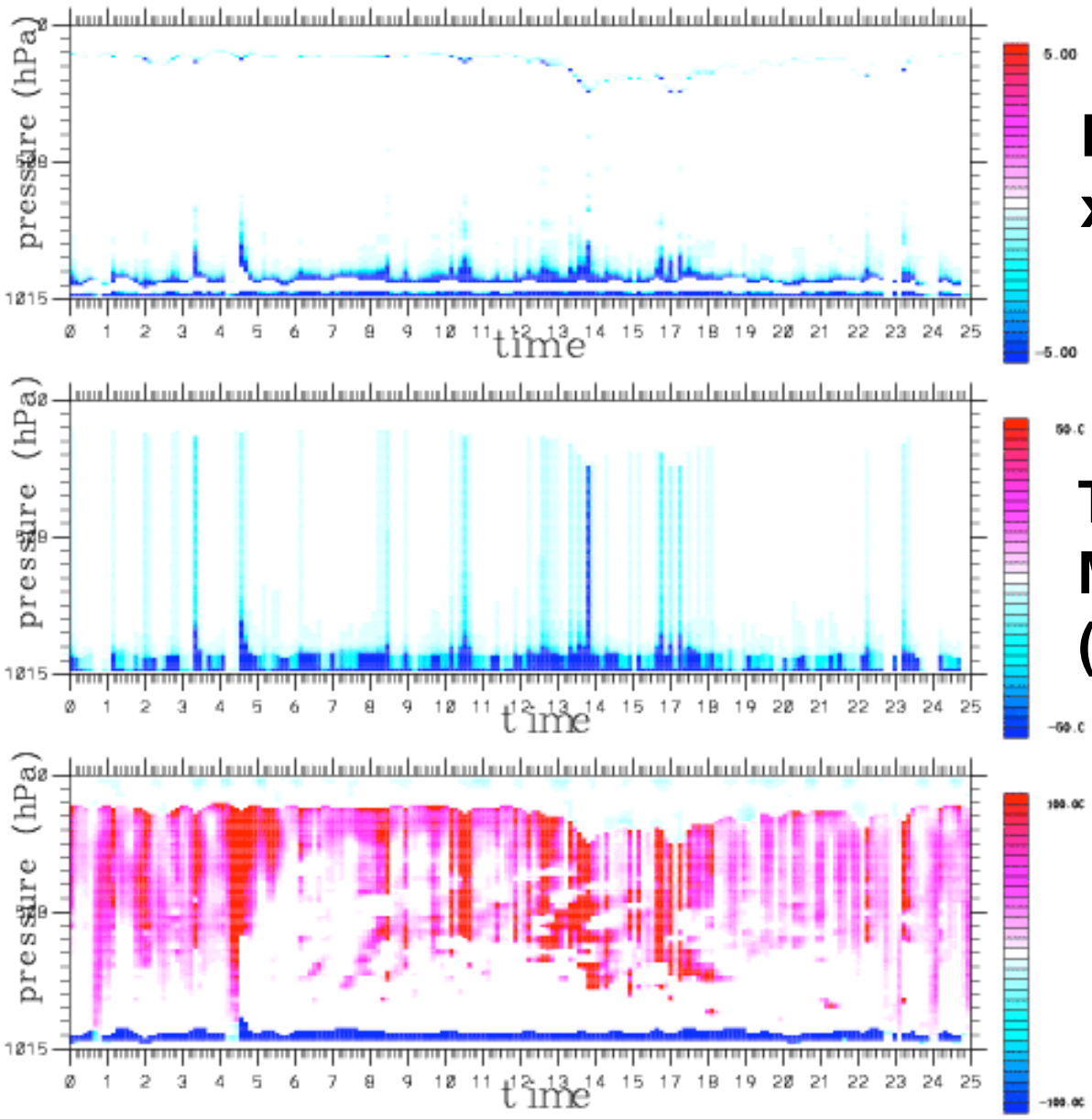
Diagnosis(1):

Ensemble of hot-towers consistent with heat budget:



NB: A detraining hot-tower solution does not exist at some vertical levels

Time-Evolution of TWP-ICE Period (SCM case)



Detrainment Rate x Δp (hPa/sec)

Total Convective Mass Flux (hPa/sec)

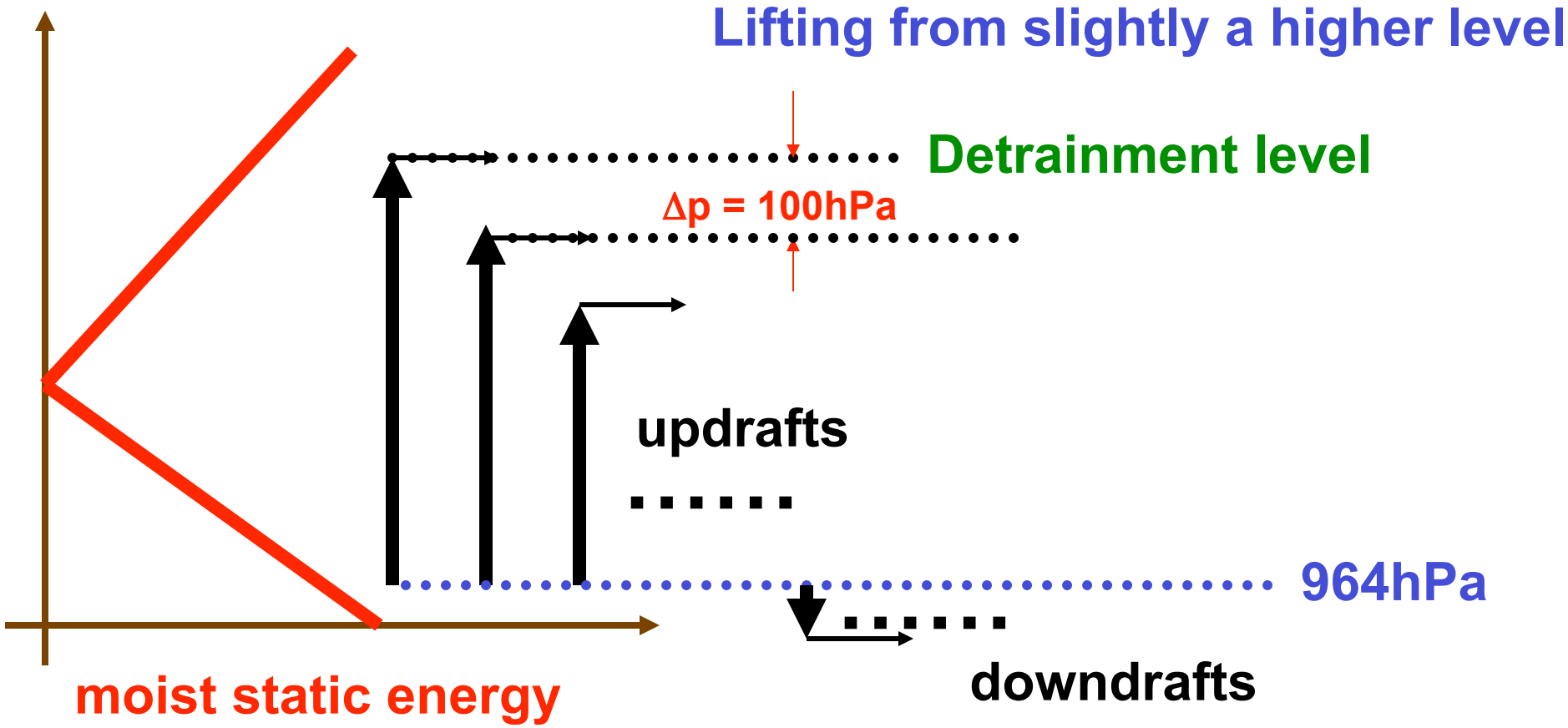
Analysis Error (K/day)

NB: Hot-Tower solution does not exist at some vertical levels

Revisit of Riehl and Malkus (1958): Hot-Tower Hypothesis:

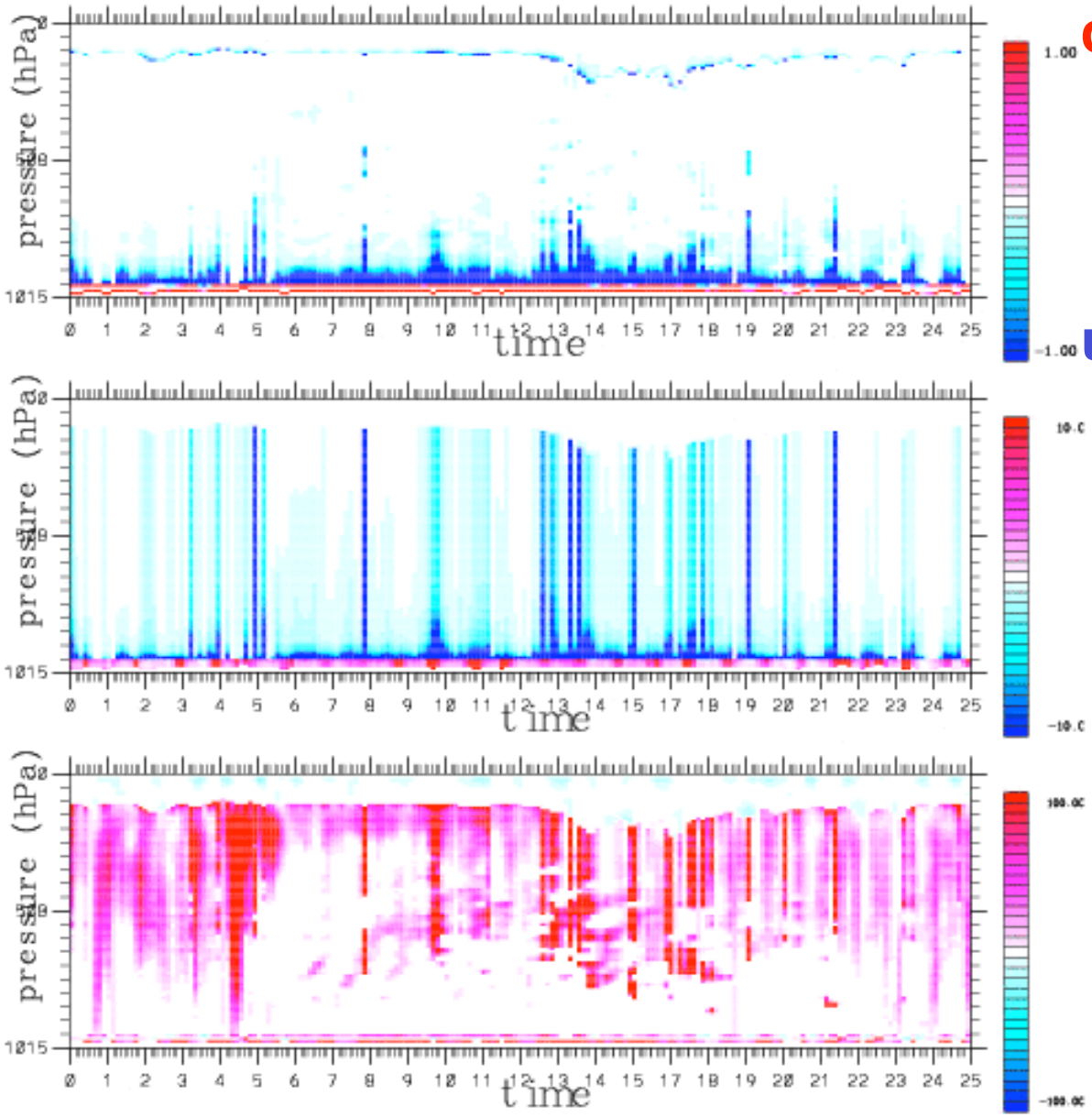
Diagnosis(2):

Ensemble of hot-towers consistent with heat budget:



NB: A detraining hot-tower solution does not exist at some vertical levels

Time-Evolution of TWP-ICE Period (SCM case)



downdrafts

Detrainment Rate x Δp (hPa/sec)

updrafts

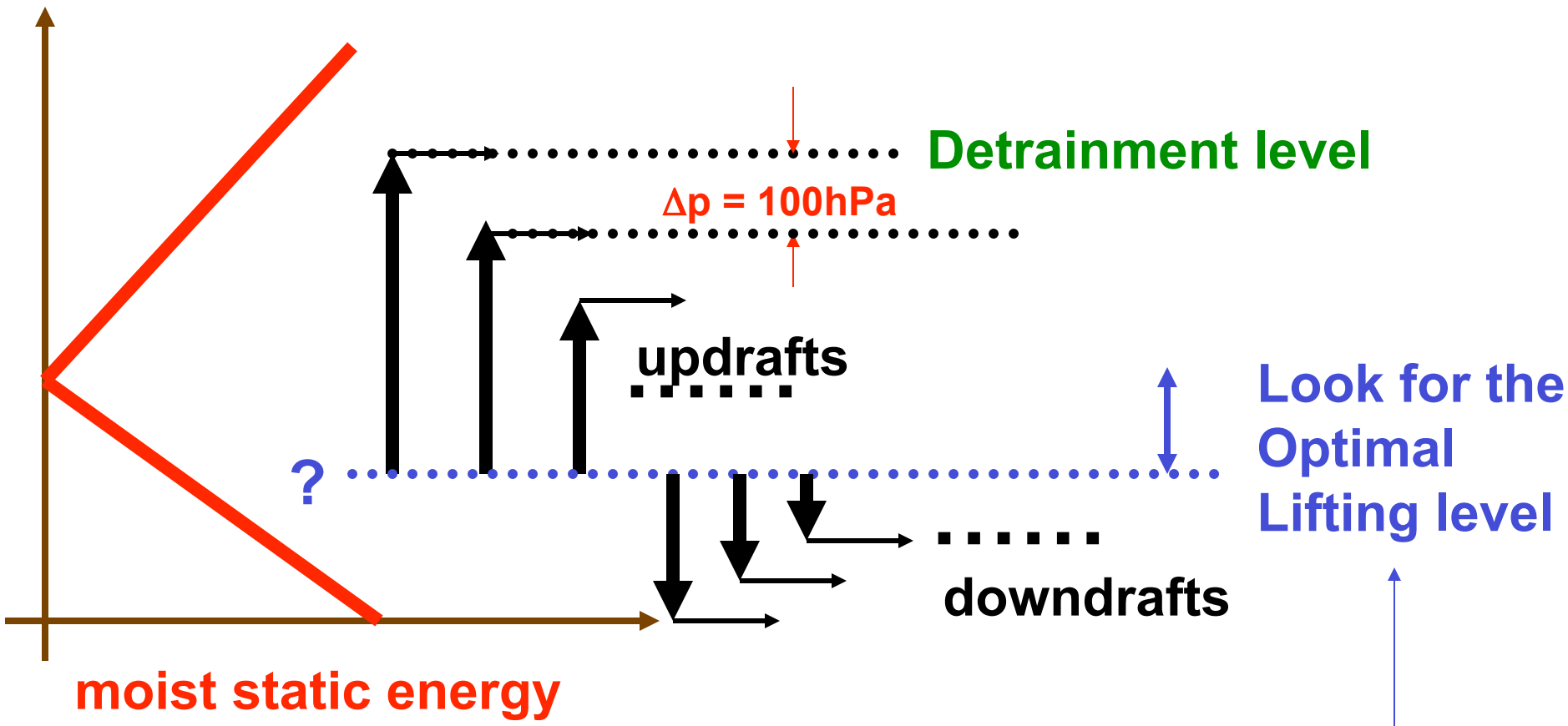
Total Convective Mass Flux (hPa/sec)

Analysis Error (K/day)

NB: Hot-Tower solution does not exist at some vertical levels

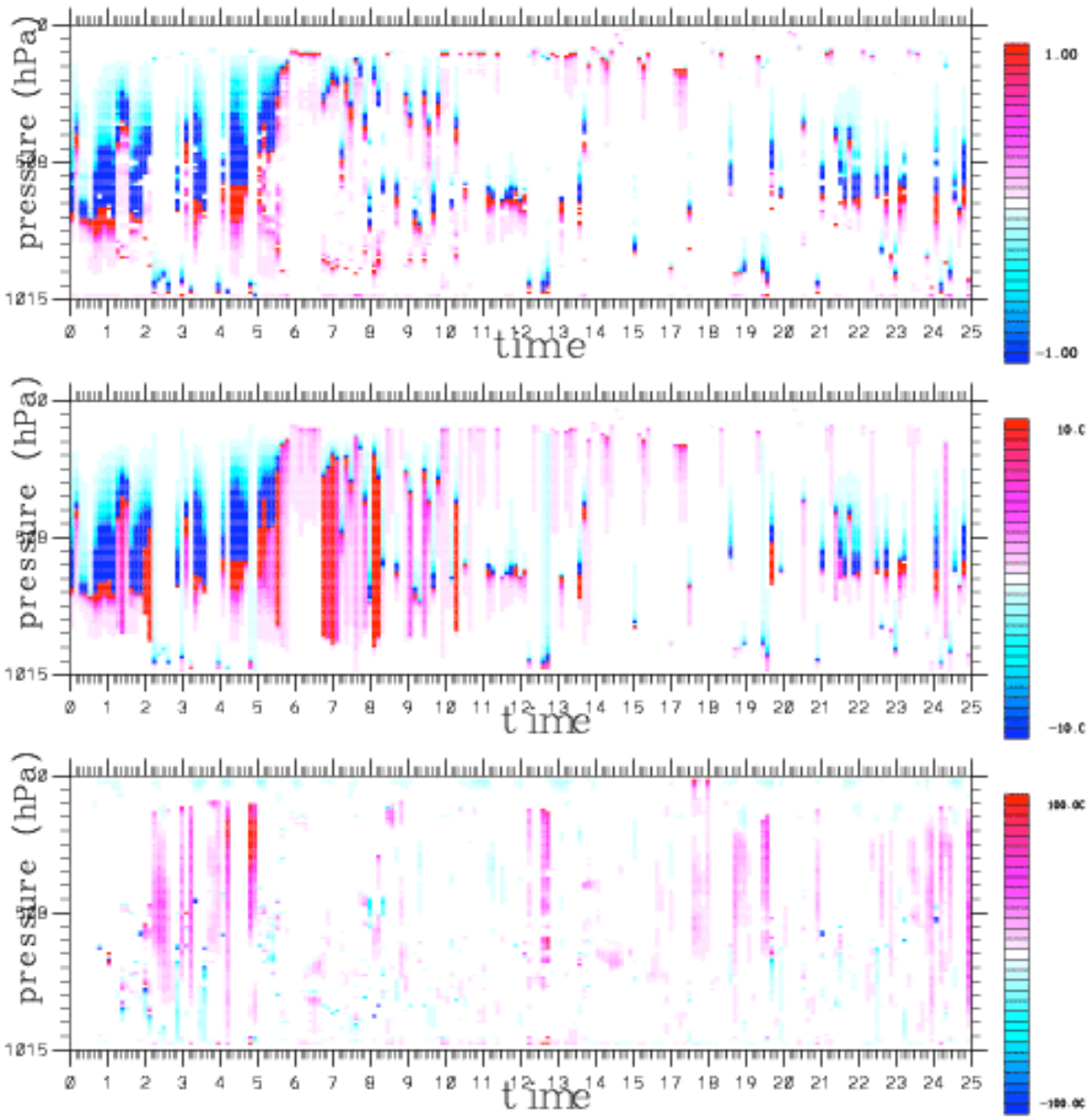
Revisit of Riehl and Malkus (1958): Hot-Tower Hypothesis:

Diagnosis(3):
Ensemble of hot-towers consistent with heat budget:



NB: A detraining hot-tower solution does not exist at some vertical levels

Time-Evolution of TWP-ICE Period (SCM case)



downdrafts

Detrainment Rate x Δp (hPa/sec)

updrafts

Total Convective Mass Flux (hPa/sec)

Analysis Error (K/day)

NB: Hot-Tower solution does not exist at some vertical levels

A Lesson from a Revisit of Riehl and Malkus (1958):

Convective Plumes (Hot Towers) are Not necessarily originating from a surface layer
But more than often
originating from a Middle level

↓

Needs to **Reconsider** a Basic Framework of
MassFlux Parameterizations?

Generalization and Link to MassFlux Parameterization

Entrainment-Detrainment Hypothesis:

Plume Profile (e.g., Hot Tower)

MassFlux Parameterization:

Closure Hypothesis

?

Observation :
Riehl-Malkus Diagnosis

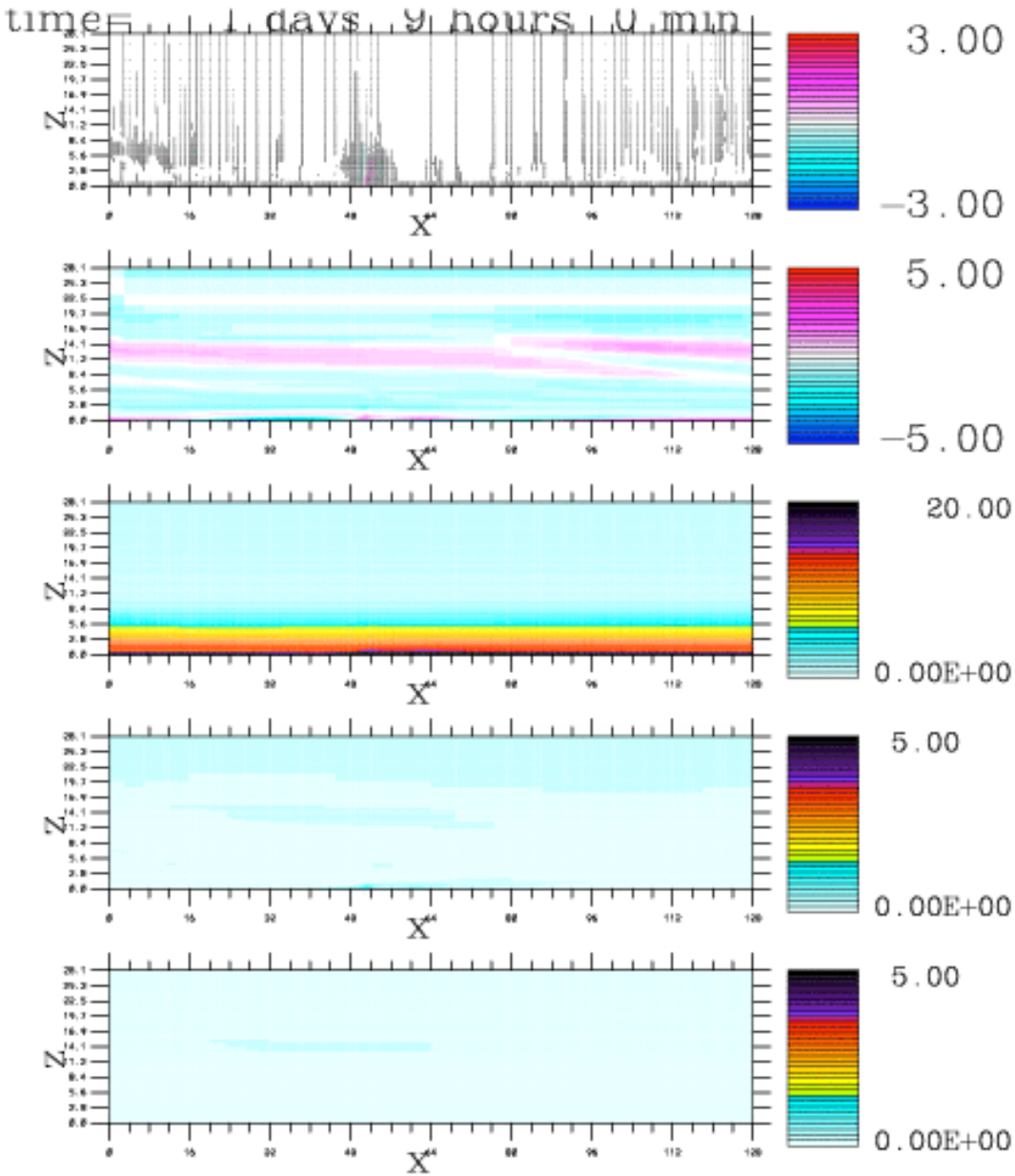
Convective Plume (Detrainment Level) Spectrum

Framework for testing Two Basic MassFlux Hypotheses Separately

A Possible Exercise under a Framework of SCM Case study?

Ensemble Plume (Hot-Tower) Dynamics can be studied even Prognostically [A Finite-Volume CRM]:

Convection+GravityWaves(TWP-ICE)



W (m/s)

θ' (K)

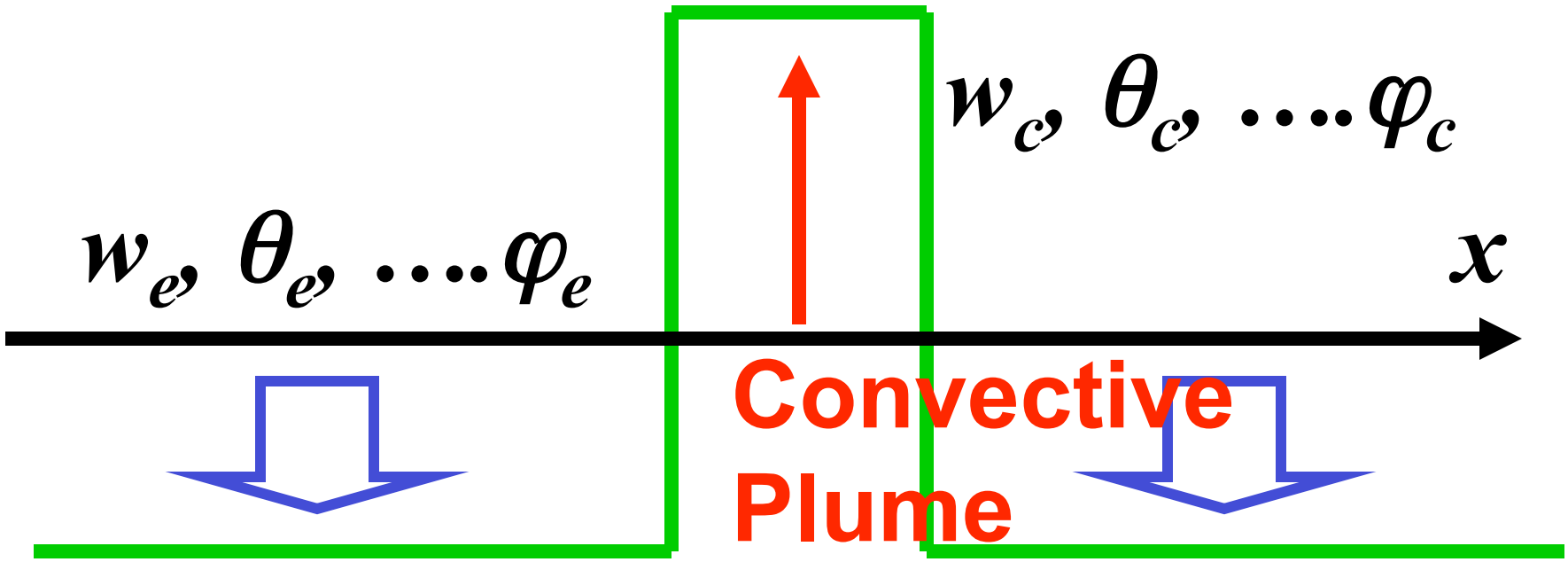
qv (g/kg)

qc (g/kg)

qp (g/kg)

Single Plume (MassFlux) Mode :

Segmentally-Constant Approximation (SCA)



Environment

NAM: Nonhydrostatic Anelastic Model

2D NAM-SCA Basic Formulation

The full system:

$$\frac{\partial}{\partial t}\varphi + \frac{\partial}{\partial x}u\varphi + \frac{1}{\rho}\frac{\partial}{\partial z}\rho w\varphi = F$$

Apply SCA over a segment $[x_{j,b}, x_{j+1,b}]$:

$$\int_{x_1}^{x_2}[\frac{\partial}{\partial t}\varphi + \frac{\partial}{\partial x}u\varphi + \frac{1}{\rho}\frac{\partial}{\partial z}\rho w\varphi]dx = \int_{x_1}^{x_2} F dx$$

or

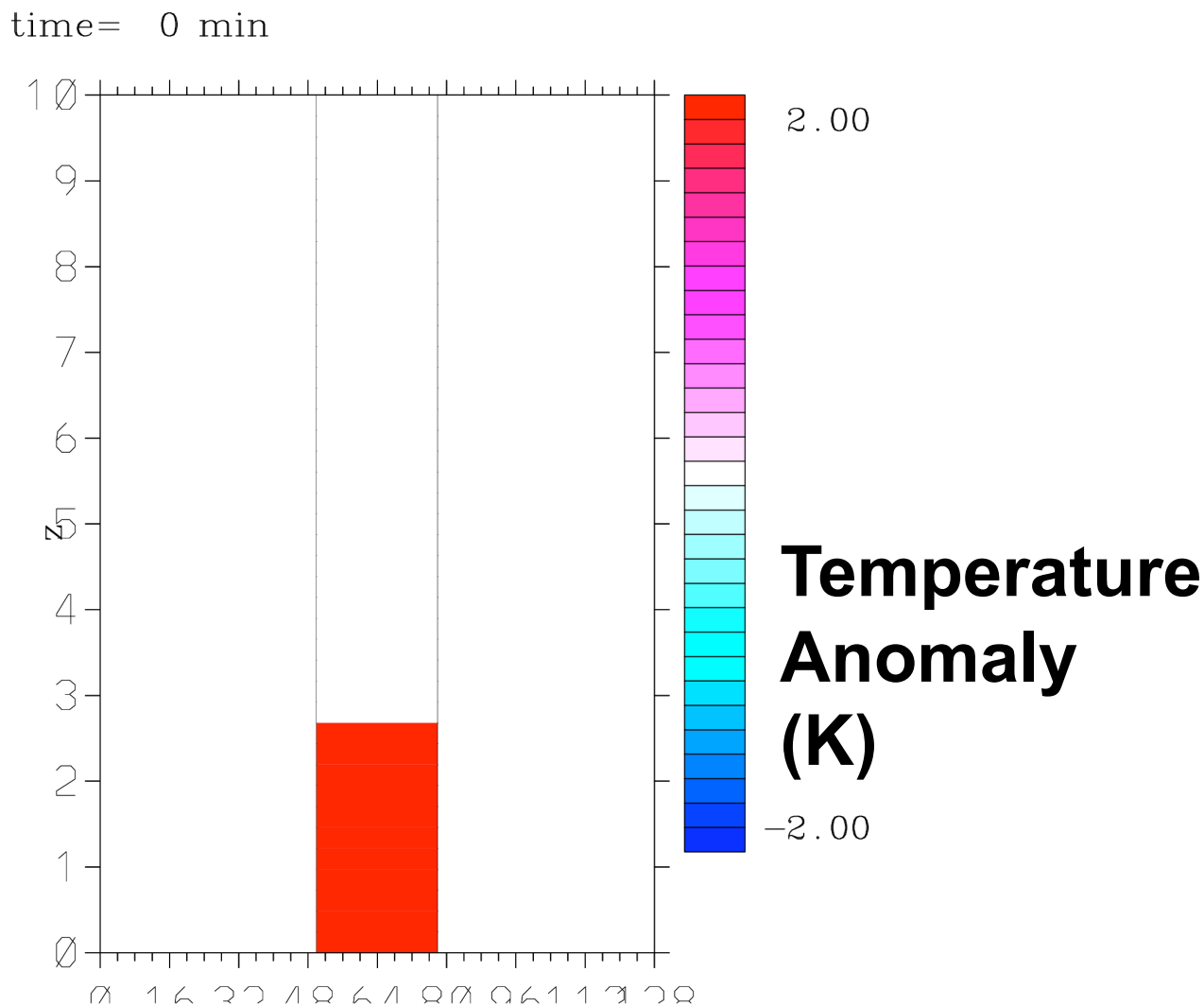
$$\frac{\partial}{\partial t}\sigma_j\varphi_j + \frac{1}{L}[(u_{j+1,b} - \dot{x}_{j+1,b})\varphi_{j+1,b} - (u_{j,b} - \dot{x}_{j,b})\varphi_{j,b}] + \frac{1}{\rho}\frac{\partial}{\partial z}\rho\sigma_j(w\varphi)_j = \sigma_j F_j$$

Mass continuity:

$$(u_{j+1,b} - u_{j,b}) + \frac{1}{\rho}\frac{\partial}{\partial z}\rho L_j w_j = 0$$

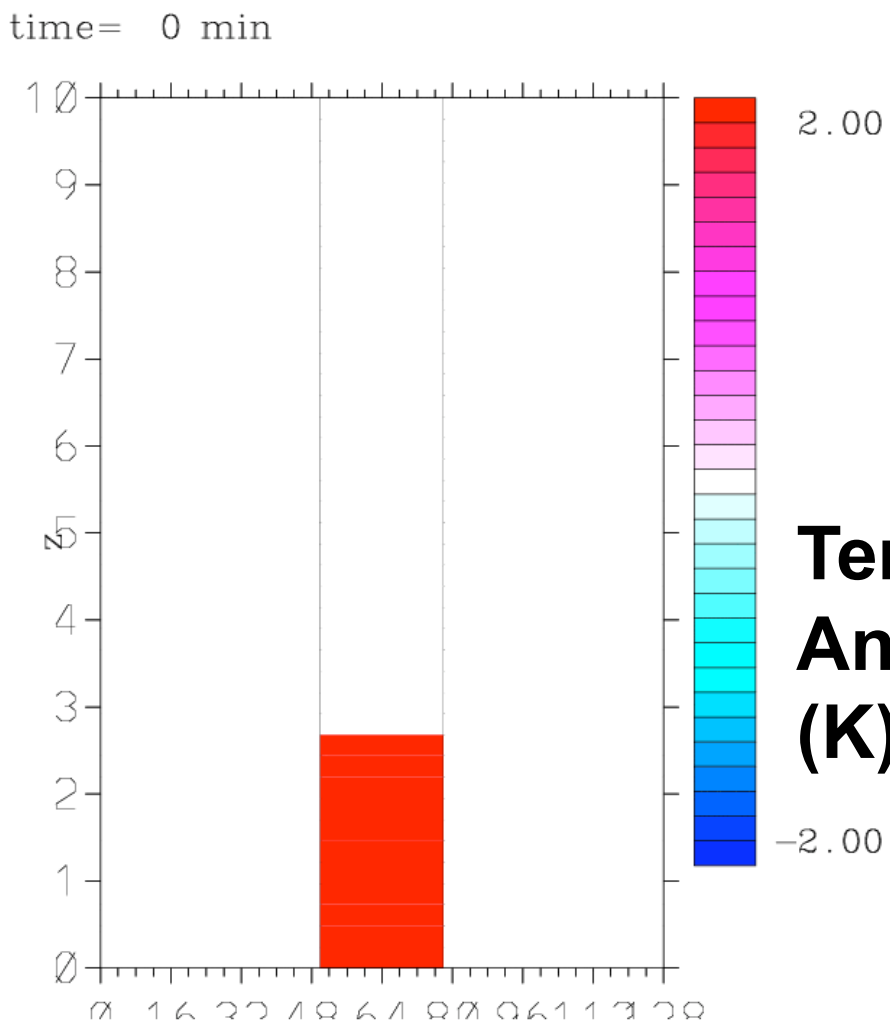
Plumes:

Segmentally-Constant Approximation (SCA)



Plumes:

Segmentally-Constant Approximation (SCA)



Temperature Anomaly (K)

Diagnosis Equation:

$$\sum_j D_j(\bar{h} - h_j) - M_c \frac{\partial \bar{h}}{\partial p} = \bar{F}^*$$

where

$\bar{h}$ **:moist static energy (for the large-scale)**

h_j **:moist static energy for the j-th hot-tower**

M_c **:(total) convective mass flux**

$$\bar{F}^* = \bar{F} - (\frac{\partial}{\partial t} + \mathbf{v}_H \cdot \nabla + \omega \frac{\partial}{\partial p})\bar{h}$$

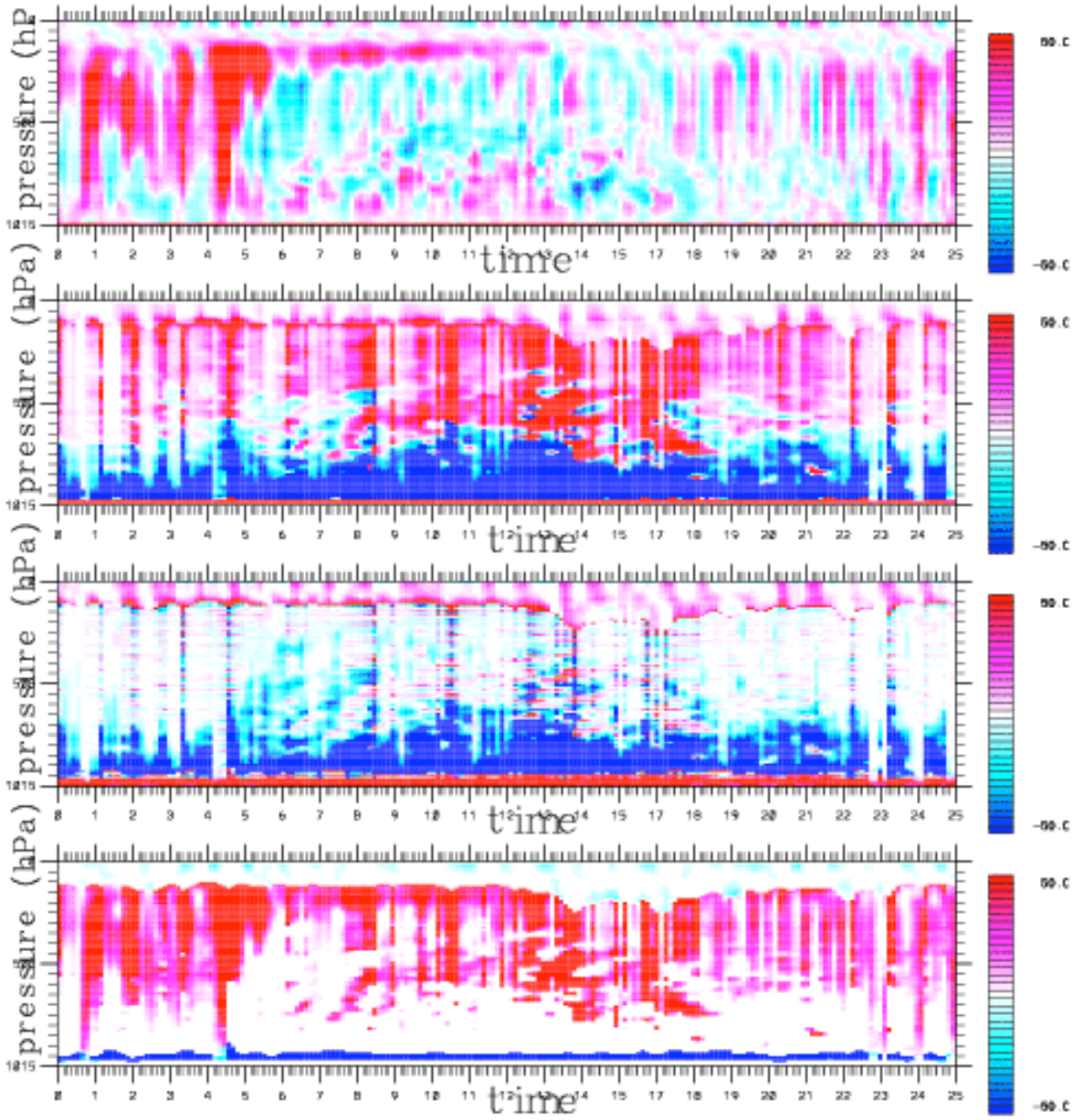
$\bar{F}$ **:large-scale diabatic forcing**

&

$$M_c = \sum_j M_j$$

$$\frac{\partial}{\partial p} M_j = E_j - D_j$$

Diagnosis Details (surface lifting)



Large-Scale Forcing* (K/day)

=

Compensating Subsidence (K/day)

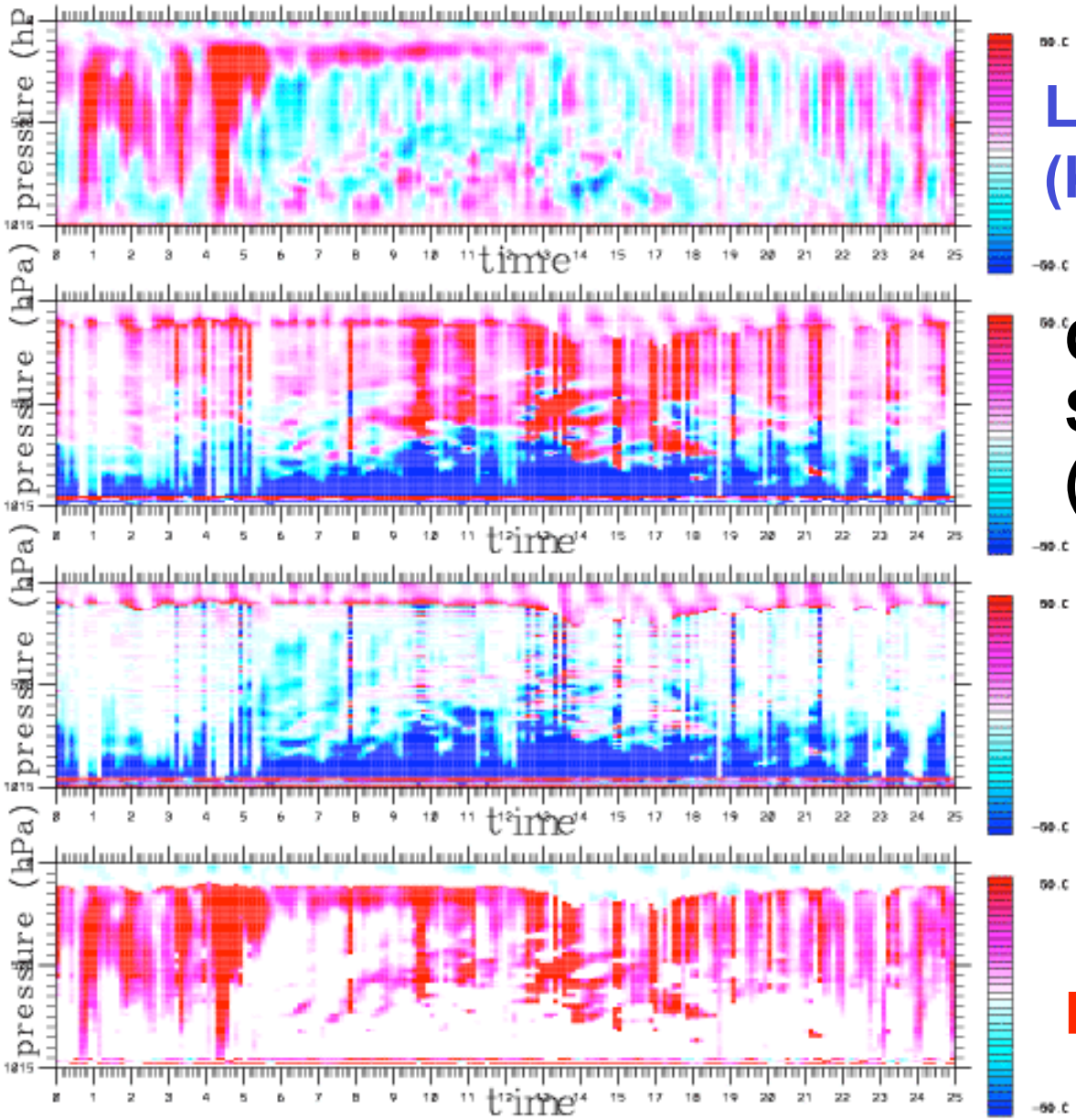
+

Detrainment (K/day)

+

Error (K/day)

Diagnosis Details (a higher lifting: 960hPa)



Large-Scale Forcing* (K/day)

=

Compensating Subsidence (K/day)

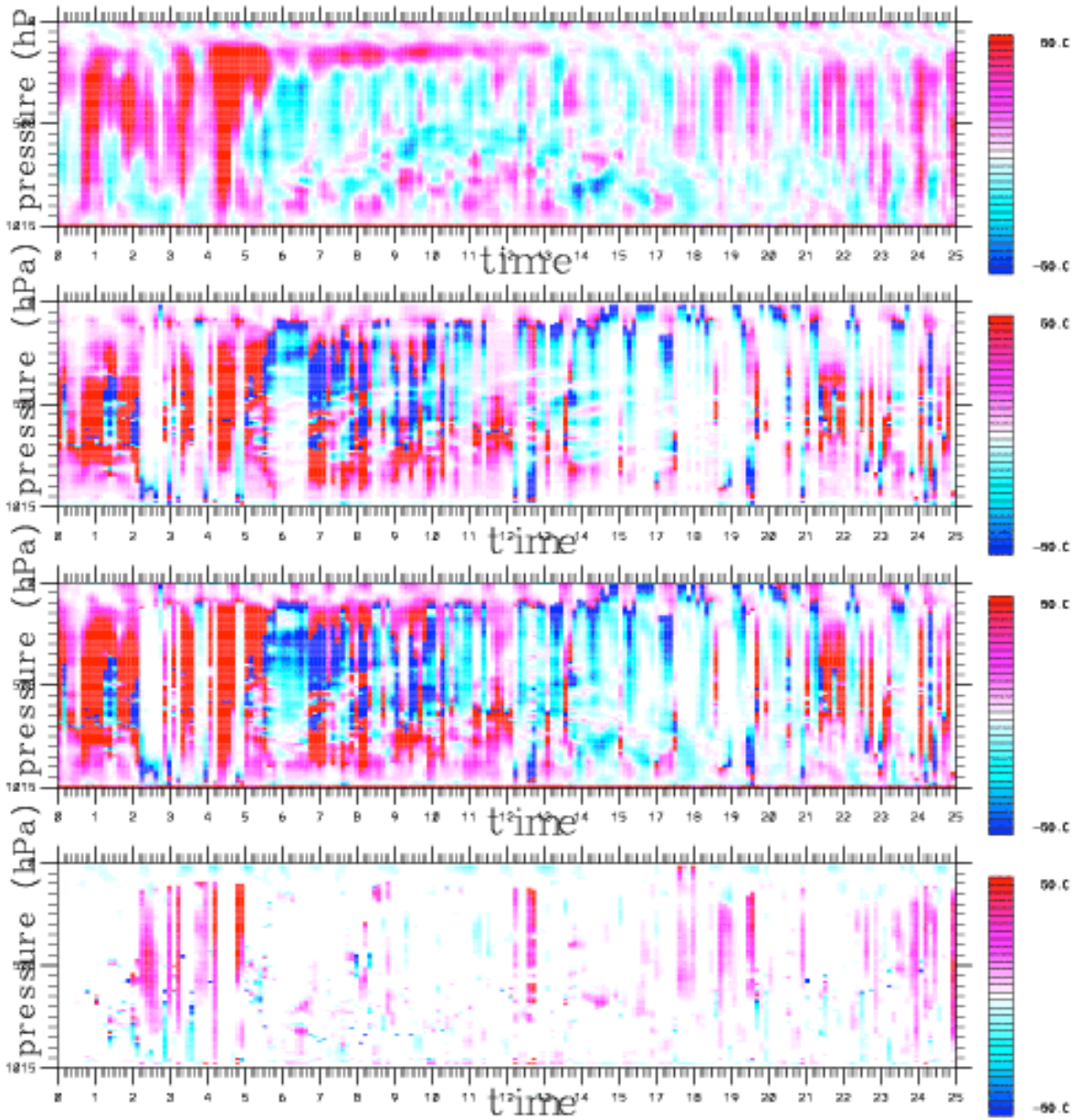
+

Detrainment (K/day)

+

Error (K/day)

Diagnosis Details (optimized lifting)



Large-Scale Forcing* (K/day)

=

Compensating Subsidence (K/day)

+

Detrainment (K/day)

+

Error (K/day)