Fields, entities, ecosystems?

Conceptual grounds for appreciating convective organization

Brian Mapes, ITCP July 2019

Book, Aug 15: *Atmospheric convection: the short course (World Scientific)*

Five-fingered brains, complex world

- **Reductionism**: carve nature (at its joints, preferably)
  - isolate, interrogate & characterize parts
    - refine, refine, refine
- Reconstruction of serious ***fundamentals***
  - →**software**; temporal prediction (our bread and butter)
    - refine, refine, refine
- Re-syntheses of simplified ***essentials***
  - →**appreciation** ("understanding", "explanation" type predictions)
    - useful? ...ideas for serious parts?

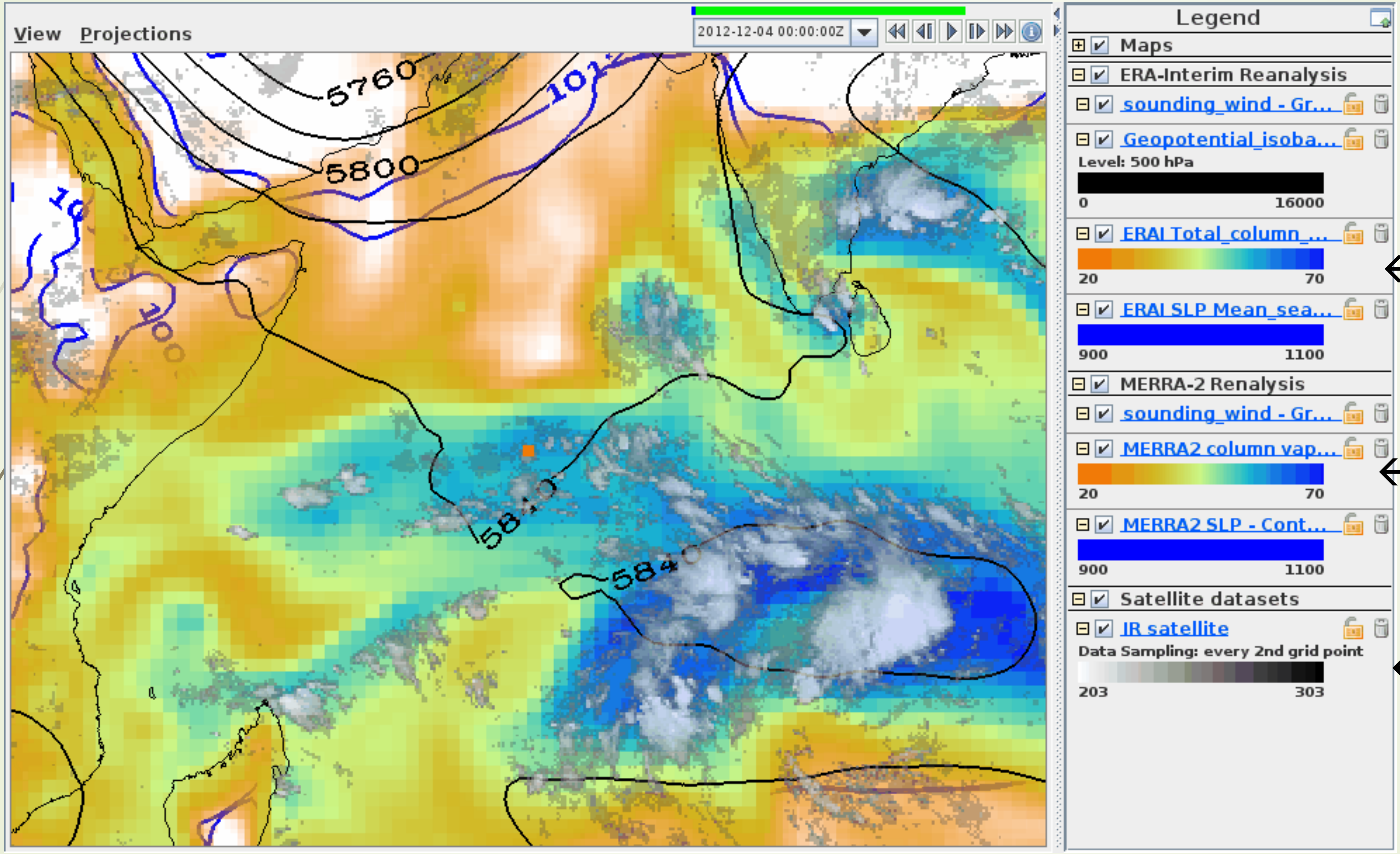
Outline

- **Observations**

- **Textbook**: 3 Parts, 3 chapters each
  - Part I: Fields (the PDEs, and scale bookkeeping)
  - Part II: Entities (observed; and as crude ‘solutions’)
  - Part III: Ecosystems of entities (fulfilling field *telos?*)

- **Are there Principles? Telos (purpose), Games (interactions)**

Rain for the Horn: a CWV "storm"
CWV & IR w/ Z500,SLP Dec. 2012



←CWV ERAI

←CWV MERRA-2

← IR cloud top

Upper level variance grows faster

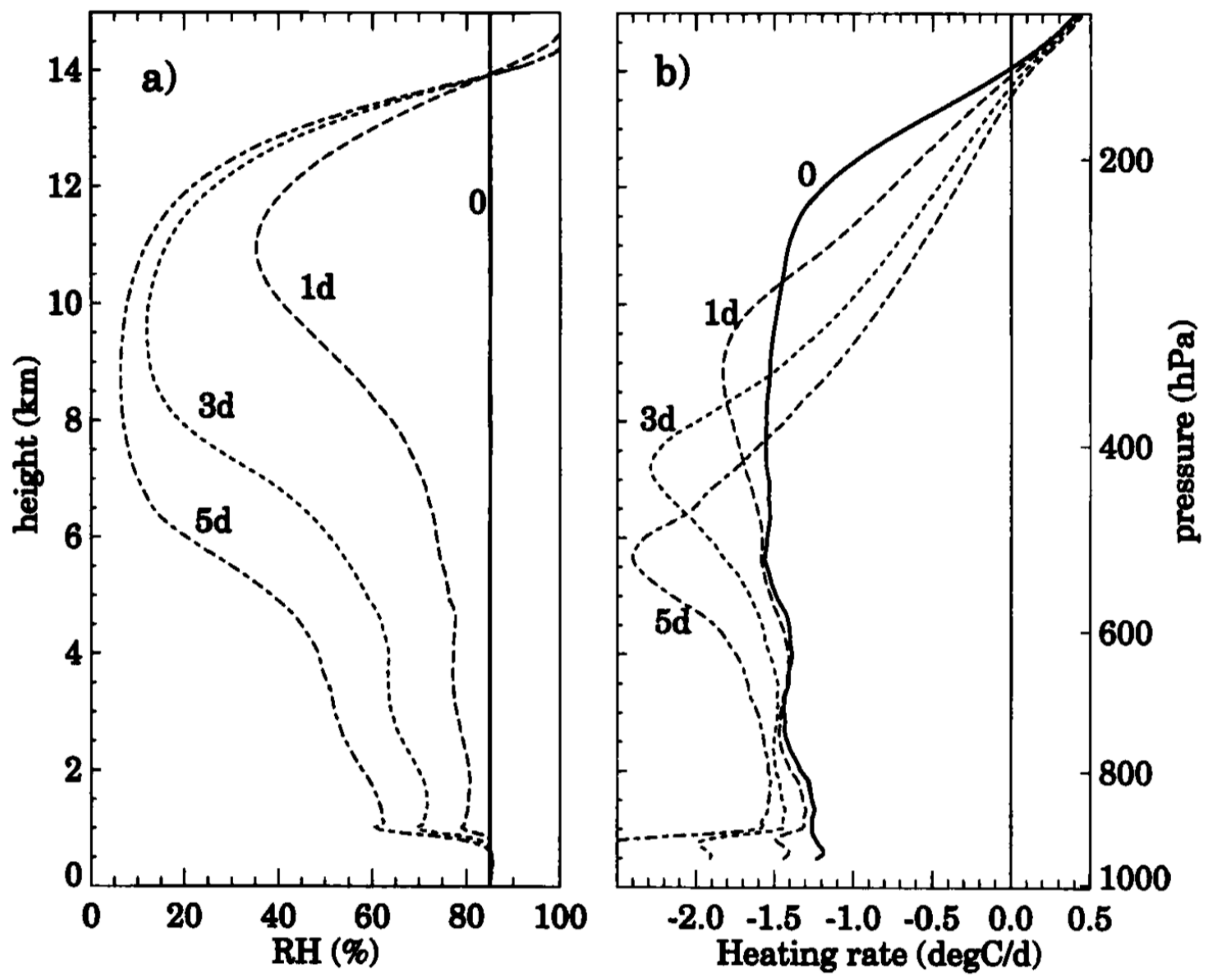


Figure 2. (a) Relative humidity (RH) with respect to ice, and (b) computed net radiative heating rate, plotted

Top-down vs. bottom-up: meaningful?

Statements and questions

- Cloudy convection (IR) fine-grained
- Highly confined to big-enough CWV (~50)

- Vapor field has long-lived filaments
  - of dry in "normal" wetness?
  - of wet in "normal" dryness?
  - **is it convection, or just advection?**

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Part I: Fields **I: *Teleology of p***

mass continuity : flux divergence vanishes

- continuity

$$\nabla_4 \cdot (\rho \vec{V}_4) = S_{mass} = 0$$
$$\vec{V}_4 = [u, v, w, 1]$$

Part I: Fields **I: *Teleology of p***

mass continuity; then *specific momentum*

- continuity

$$\nabla_4 \cdot (\rho \vec{V}_4) = S_{mass} = 0$$
$$\vec{V}_4 = [u, v, w, 1]$$

- specific (per unit mass) momentum in x:

$$\nabla_4 \cdot (u \rho \vec{V}_4) = S_{mom} = -p_x + fv$$

Part I: Fields **I: *Teleology of p***

mass continuity; then *specific momentum*

- continuity

$$\nabla_4 \cdot (\rho \vec{V}_4) = S_{mass} = 0$$

$$\vec{V}_4 = [u, v, w, 1]$$

- specific (per unit mass) momentum in z:

$$\nabla_4 \cdot (w \rho \vec{V}_4) = S_{mom} = -p_z - g$$

Part I: Fields **I: *Teleology of p***

4 equations in 5 unknowns – inconvenient ρ!

- Assume $\rho = \rho_0$=const (incompressible)

$$0 = u_x + v_y + w_z$$

$$u_t = -(uu)_x - (uv)_y - (uw)_z \quad -\pi_x + fv$$

$$v_t = -(vu)_x - (vv)_y - (vw)_z \quad -\pi_y - fu$$

$$w_t = -(wu)_x - (wv)_y - (ww)_z \quad -\pi_z - g$$

where $\pi = p/\rho_0$.

Part I: Fields

for incompressible flow

I: ***Teleology of p***

- → a *teleological* appreciation of pressure:

$$\pi = \nabla^{-2} [\nabla \cdot \boldsymbol{F}]$$

- *Mass continuity is the Law*
- *Pressure is the Cop*
- ***F****=m****a*** *is the Enforcement*

Teleology

- *Telos*: know it by *the function it performs*
- Can *convective organization* be appreciated in terms of some *job it performs*?
- Philosophically disrespected in biology as *vitalism: invoking* life's "purpose" is woolly
- Convection has a purpose : *lower the center of gravity*. Relentless as gravity.

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Part I: Fields **II: *KE comes from [wb]***

Allow ρ to vary, so there is buoyancy b,

$$0 = -\nabla\cdot(\rho \boldsymbol{V})$$

$$du/dt = -\pi_x + fv \qquad *u$$

$$dv/dt = -\pi_y - fu \qquad *v$$

$$dw/dt = -\pi_z + b \qquad *w$$

$$db/dt = -wN^2 + Q_b \qquad (2.10)$$

Part I: Fields **II: *KE comes from [wb]***

Let [] denote an integral over the whole fluid. Subscript for time derivative:

$$[KE]\downarrow t = [wb] - [\boldsymbol{F}.\boldsymbol{V}]$$

$$[PE]\downarrow t = [Jb] - [wb]$$

sum:

$$[PE + KE]\downarrow t = [Jb] - [\boldsymbol{F}.\boldsymbol{V}]$$

$J = Q_b/N^2$, Q_b = buoyancy source from thermo (density)

Part I: Fields **II: *KE comes from [wb]***

$[KE]\downarrow t = [wb] - \text{friction}$

- Yes ***all*** of the kinetic energy
- Can be decomposed into any orthogonal basis set
  - by zonal Fourier wavenumber
  - by orthogonal vertical modes
  - but NOT by plume radius or depth!

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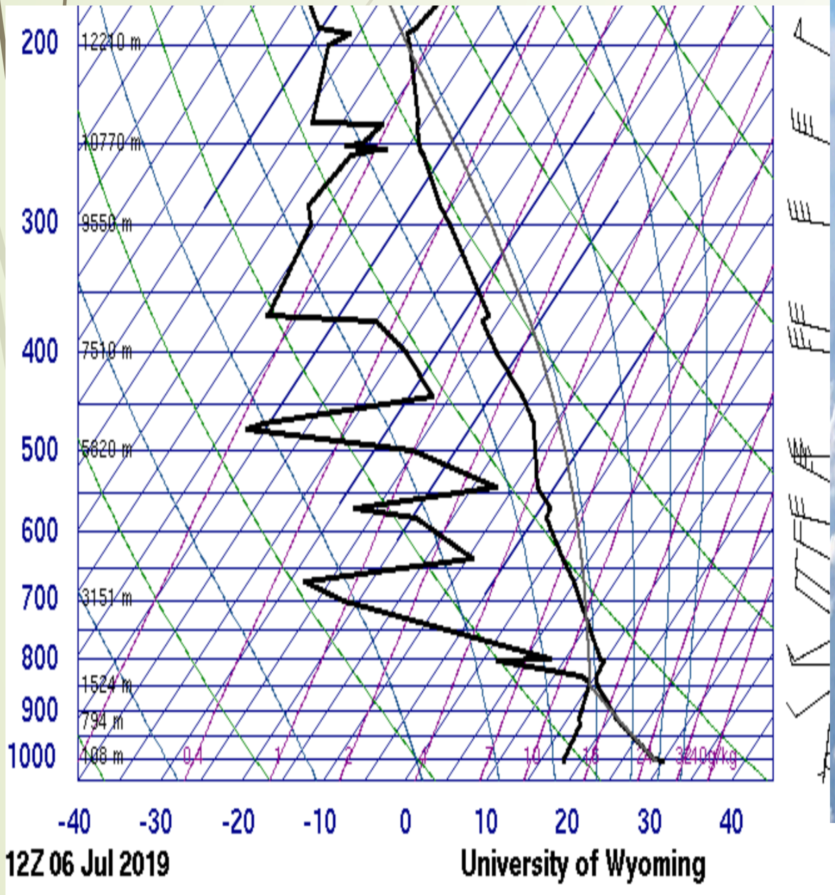
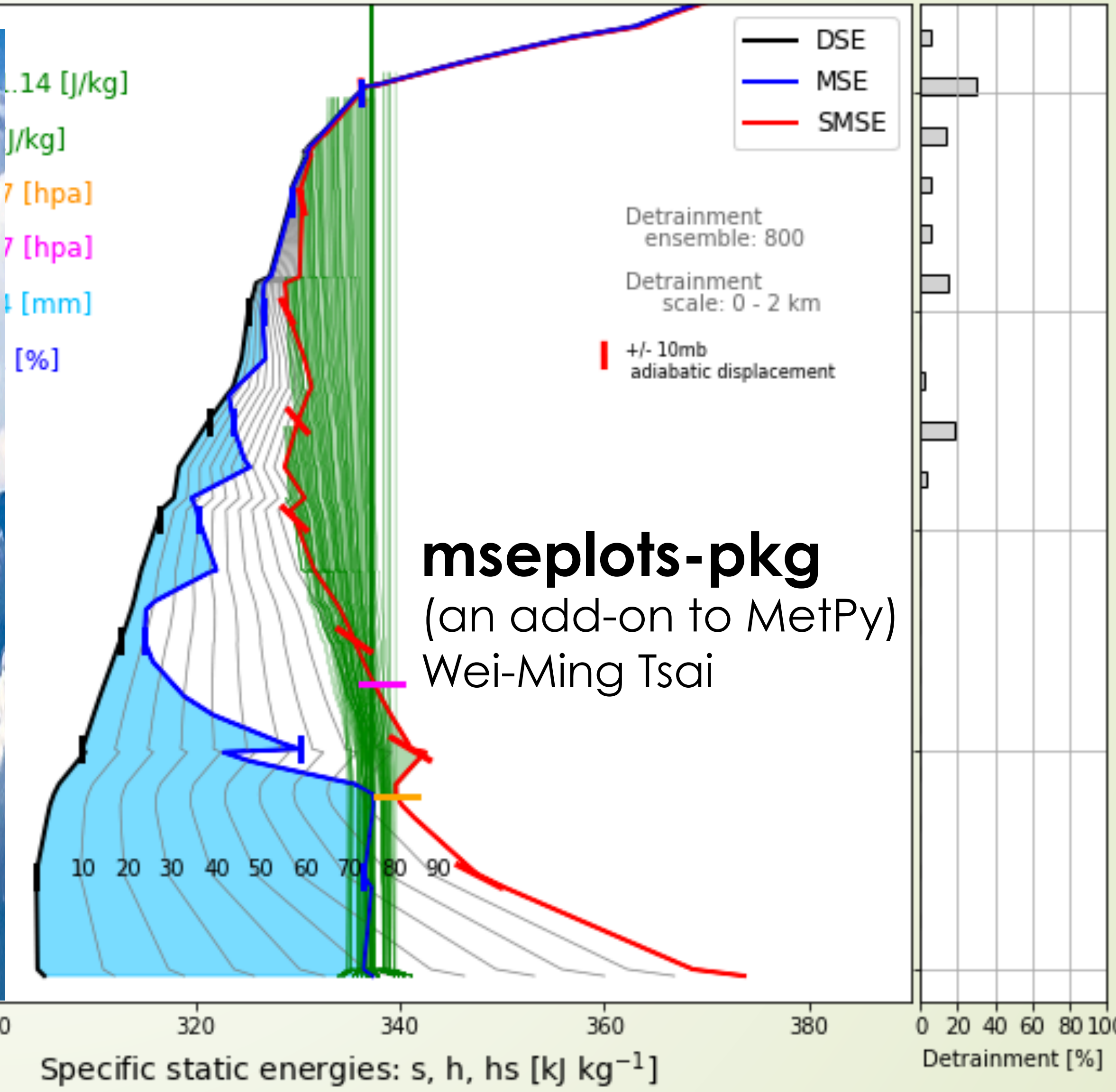
Part II: Entities   I: *parcels*

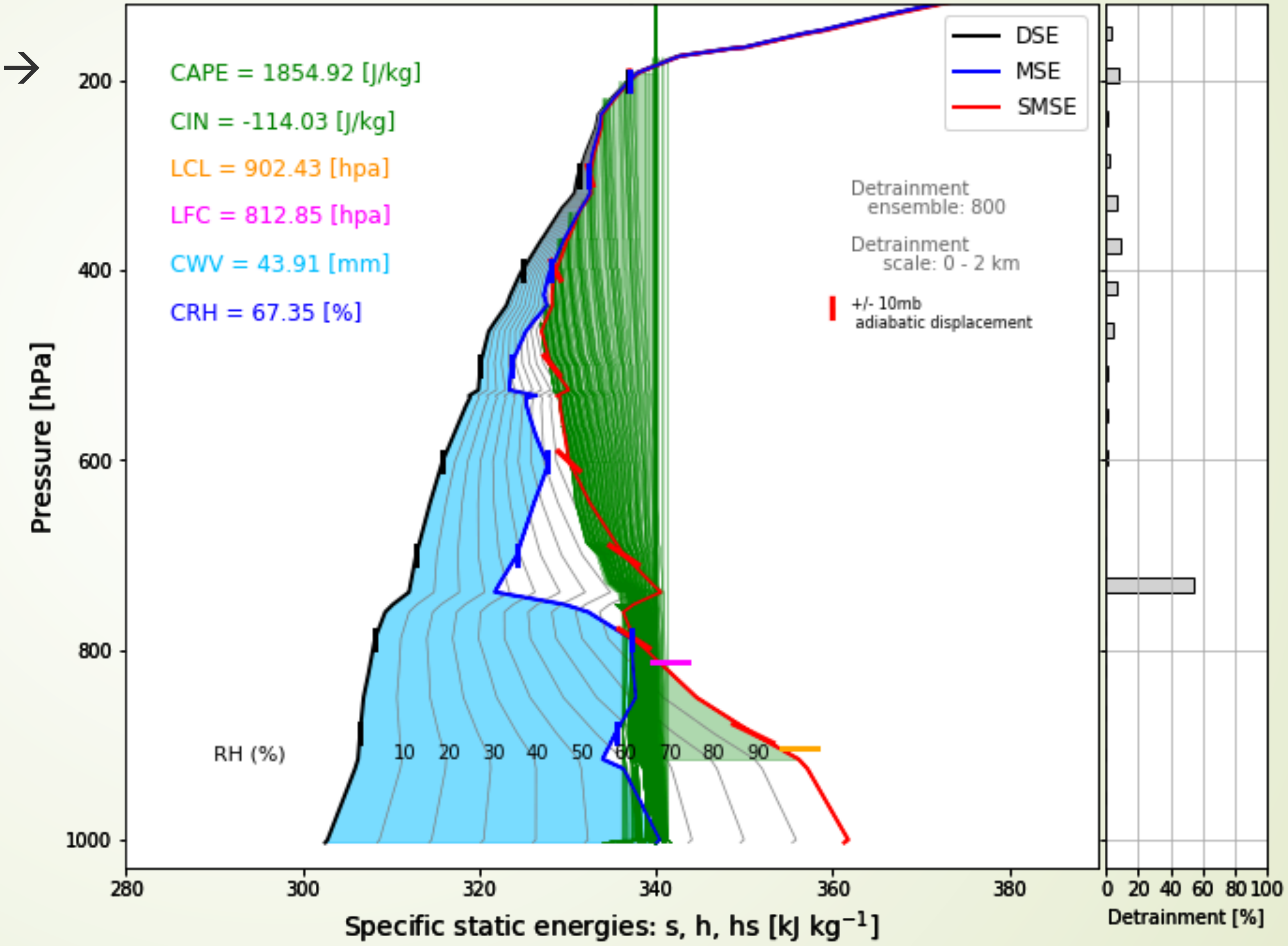
- Saturda
- 12Z:





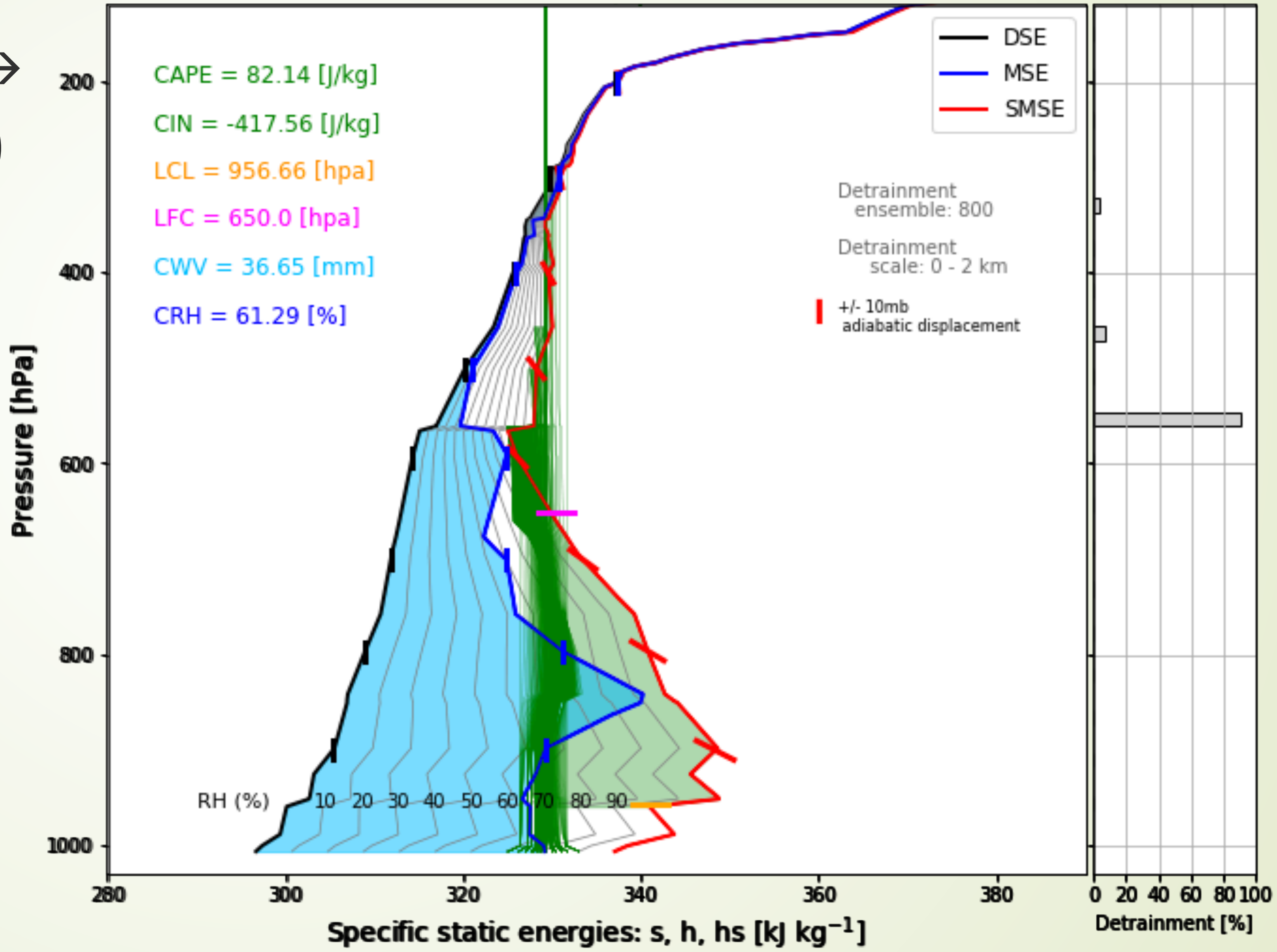
Part II: Entities I: *parcels*

- Saturday→
- 18Z:



Part II: Entities I: *parcels*

- Saturday→
- 00Z (Sunday)



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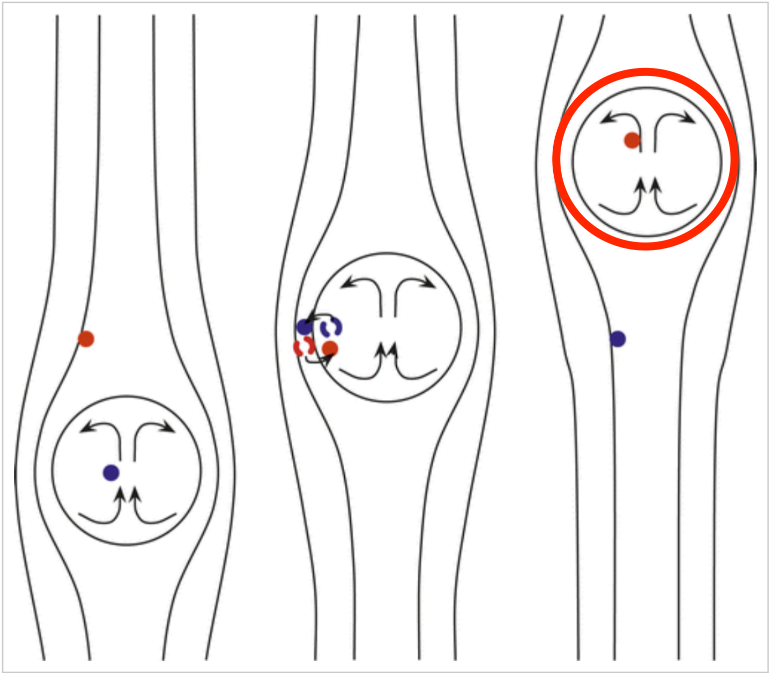
Part II: Entities **II: *bubbles***

- "**thermals**": from obs w/ soaring birds and gliders
- ***vortex ring: realizable solution to field equations***

see also recents: Peters, Morrison, Hannah 2017-2019



Conceptual illustration of how a thermal vortex can exchange mass with the surrounding airstream without losing momentum.

←Sherwood, S. C., D. Hernandez-Deckers, M. Colin, and F. Robinson, 2013: Slippery thermals and the cumulus entrainment paradox. J. Atmos. Sci., 70, 2426–2442,

Romps, D. M., and A. B. Charn, 2015: Sticky thermals: Evidence for a dominant balance between buoyancy and drag in cloud updrafts, JAS 72, 2890-2901.

Part II: Entities II: ***bubbles***

Part II: Entities **II: *bubbles***

- studies are mostly centered on the w equation
  - pbuoy= $\nabla^{-2}\,[\partial b/\partial z]$
  - BPGF = $-\partial pbuoy/\partial z$
  - total buoyancy-related force **dw/dt = b+BPGF** + …
    - BPGF favors Narrow drafts→
    - mixing favors Wider
      - compromise: a Game

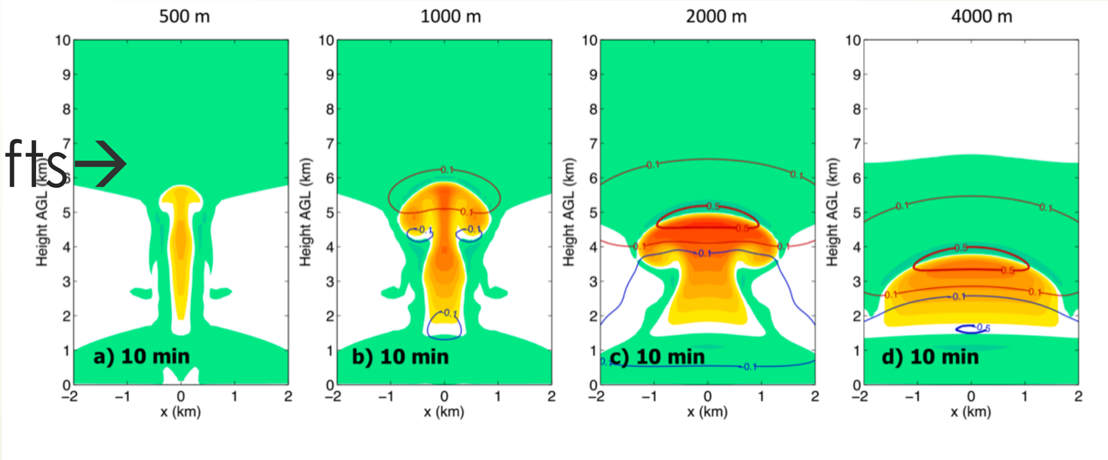


Fig. 5.1. Buoyancy (warm colors for positive values) and π_{buoy} from Eq. (5.1), ten minutes after releasing a bubbles in quiescent air. Narrower drafts feel less opposition from the BPGF, and have ascended further. Fig. 5 of Morrison and Peters (2018).

- compromise: a Game

Part II: Entities **II: *bulk mass entities***

- **ch. 6: steady-state plume** mass flux $M = \rho A w$
  - $dM/dz = M(e-d)$
- based on ***scale similarity property*** of field eqs
  - not a ***solution*** per se…

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- Are there Principles? Telos (purpose), Games (interactions)

Ooyama (1971) “dispatcher function”

- **However one defines discrete entities, a counting scheme can be set up to keep track of them.**
  - … the properties of a bubble with any set of initial conditions [**s**] can be calculated by the [bubble] model …At a given time-step and at a given horizontal grid-point of the large-scale model, … N(**s**) d**s** is defined as the number of bubbles, per unit time and per unit area, starting from initial states between **s** and **s**+d**s**, that is, between [starting altitude] p* and p*+dp*, [mass] m* and m*+dm*, etc. It seems appropriate to call N(s) a "dispatcher" function.

Part III: Envelopes and ecosystems

- **chapter 7: multi-cellular systems (MCSs)**
  - each cell being multi-bubble, as we saw
- Runaway "dispatcher function" in small area
  - triggered by convected mass in PBL (cold pool)
  - aided by convected mass at higher levels

Part III: Envelopes and ecosystems

- **chapter 7: multi-cellular systems (MCSs)**
  - each cell being multi-bubble, as we saw

- Runaway "dispatcher function" in small area
  - triggered by convected mass in PBL (cold pool)
  - aided by convected mass at higher levels
  - conditionality of instability reduced by waves

Part III: Envelopes and ecosystems

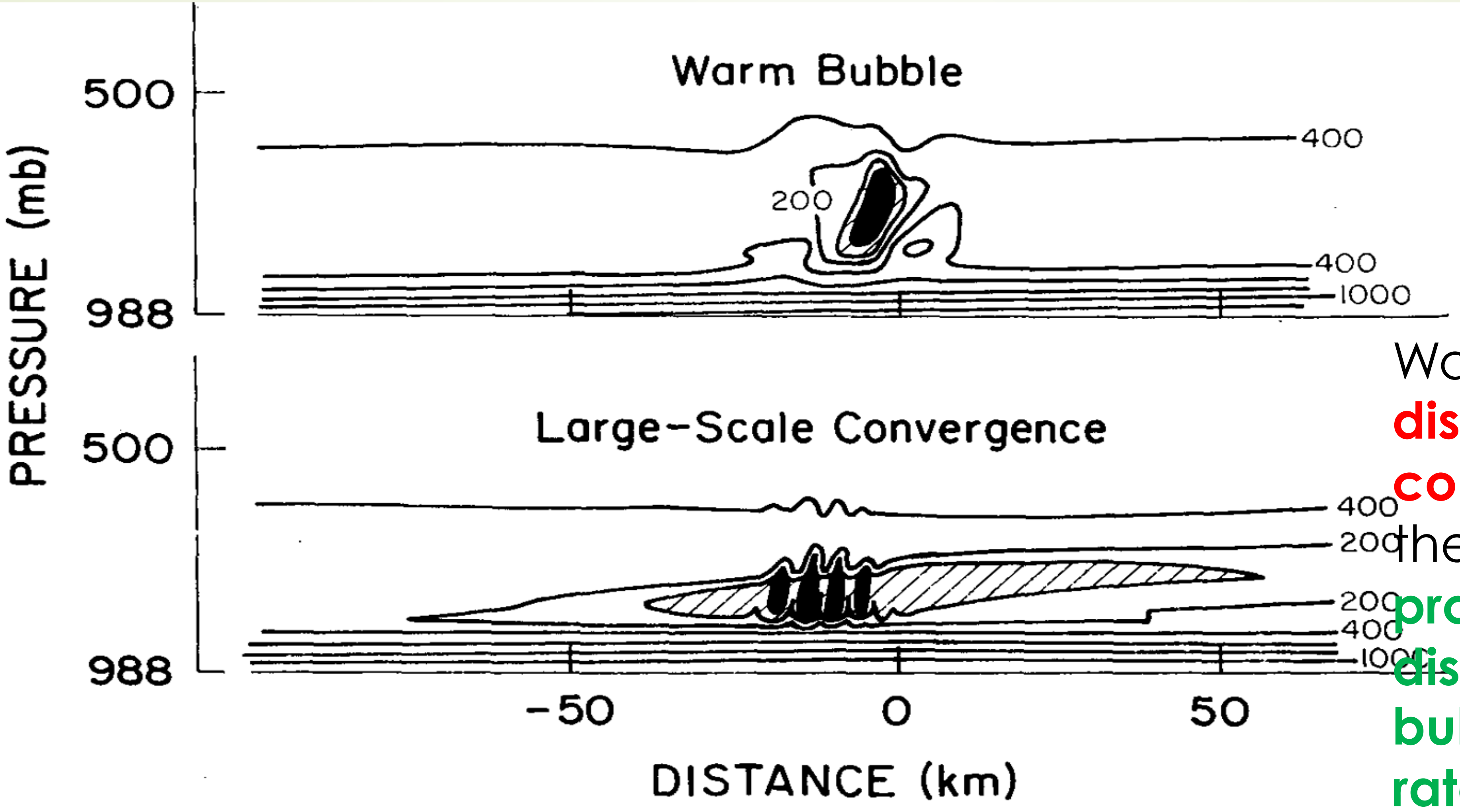

FIG. 7. The vertical distance (in meters) that air needs to be lifted to its level of condensation for the two different methods of initiation, warm bubble and large-scale convergence. The solid regions are regions of cloud, the hatched regions indicate air that has to be lifted less that 100 m.

Waves don't **dispatch convective cells**, they **alter the probability of the dispatcher or bubble success rate.**

Crook and Moncrieff 1988

Particle Fountain model of observable aspects of runaway dispatcher

“MCS”
extremely broad catch-all term

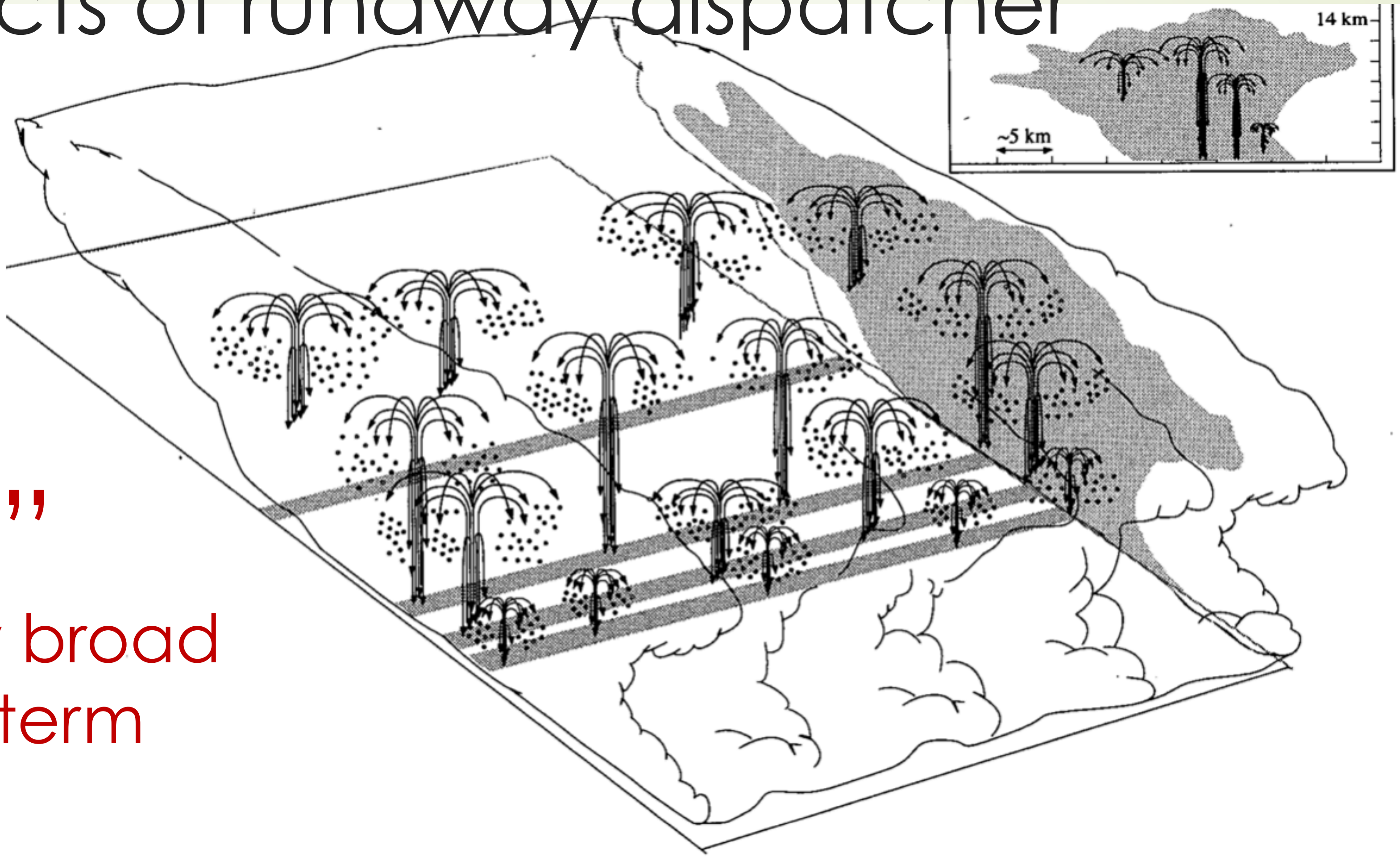

Fig. 5.4. Particle fountain model of the observed phenomenon of MCSs. Convective cells that are abundantly dispatched within a region, *for whatever reason,* expel ice crystals at high altitudes which merge into a contiguous area of cloud and falling hydrometeors. Yuter and Houze (1995) call this “an extension of bubble-based conceptual models”.

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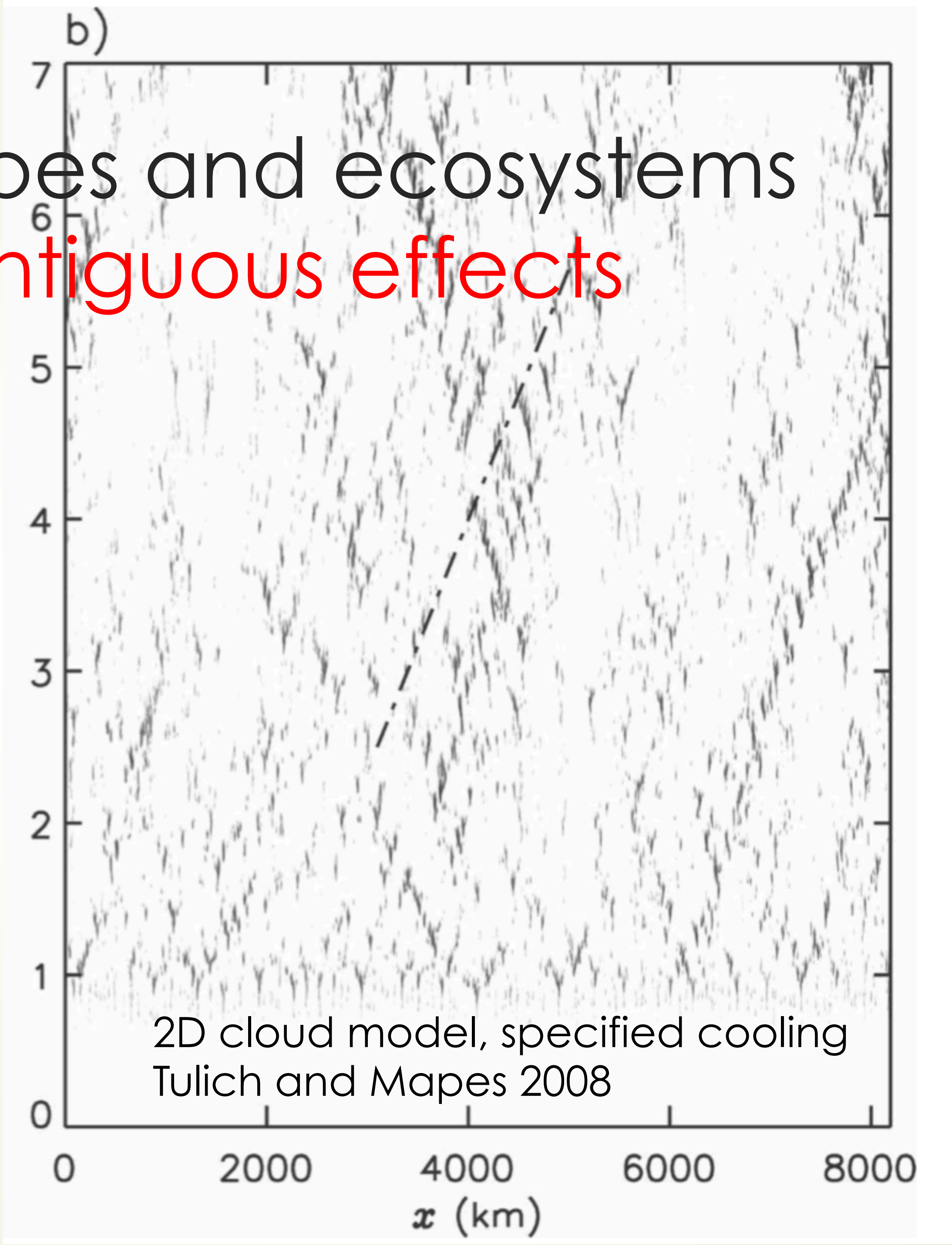
Part III: Envelopes and ecosystems
Ch. 8: Non-contiguous effects

multiple MCSs
each multicellular;
each cell
multi-bubble



Obs:

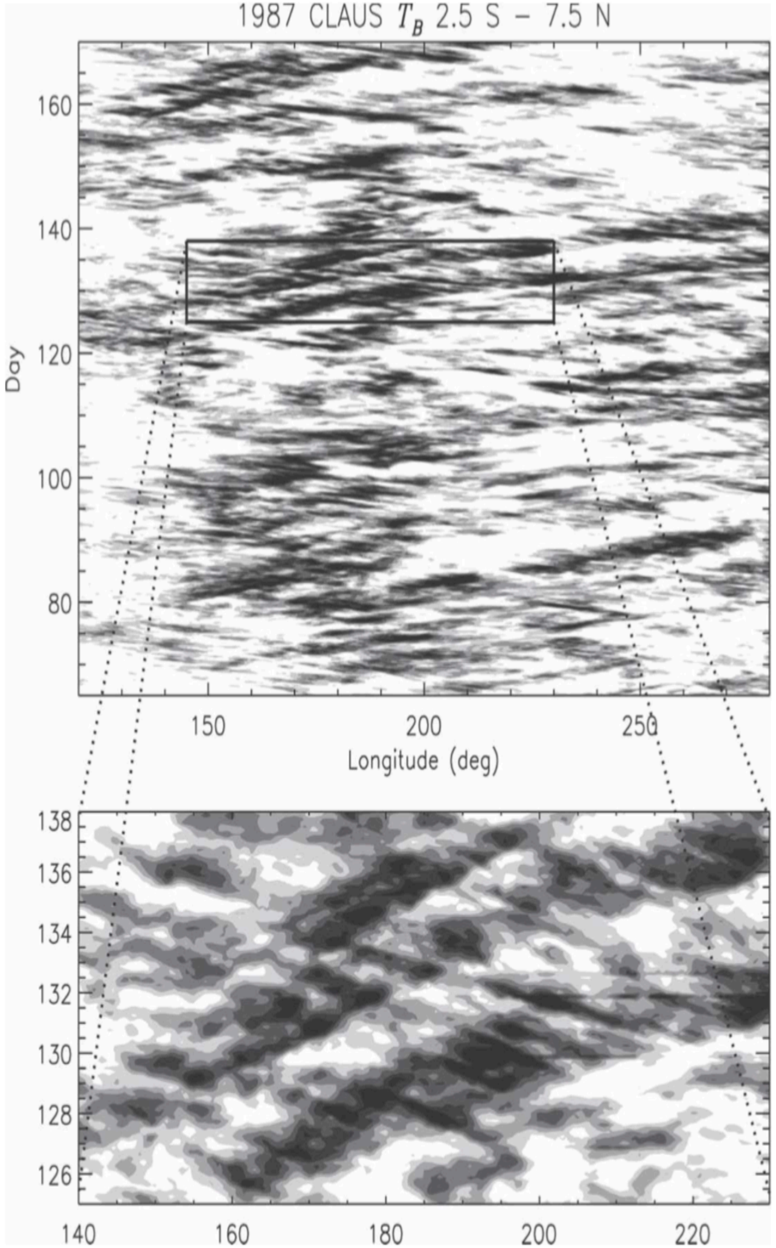
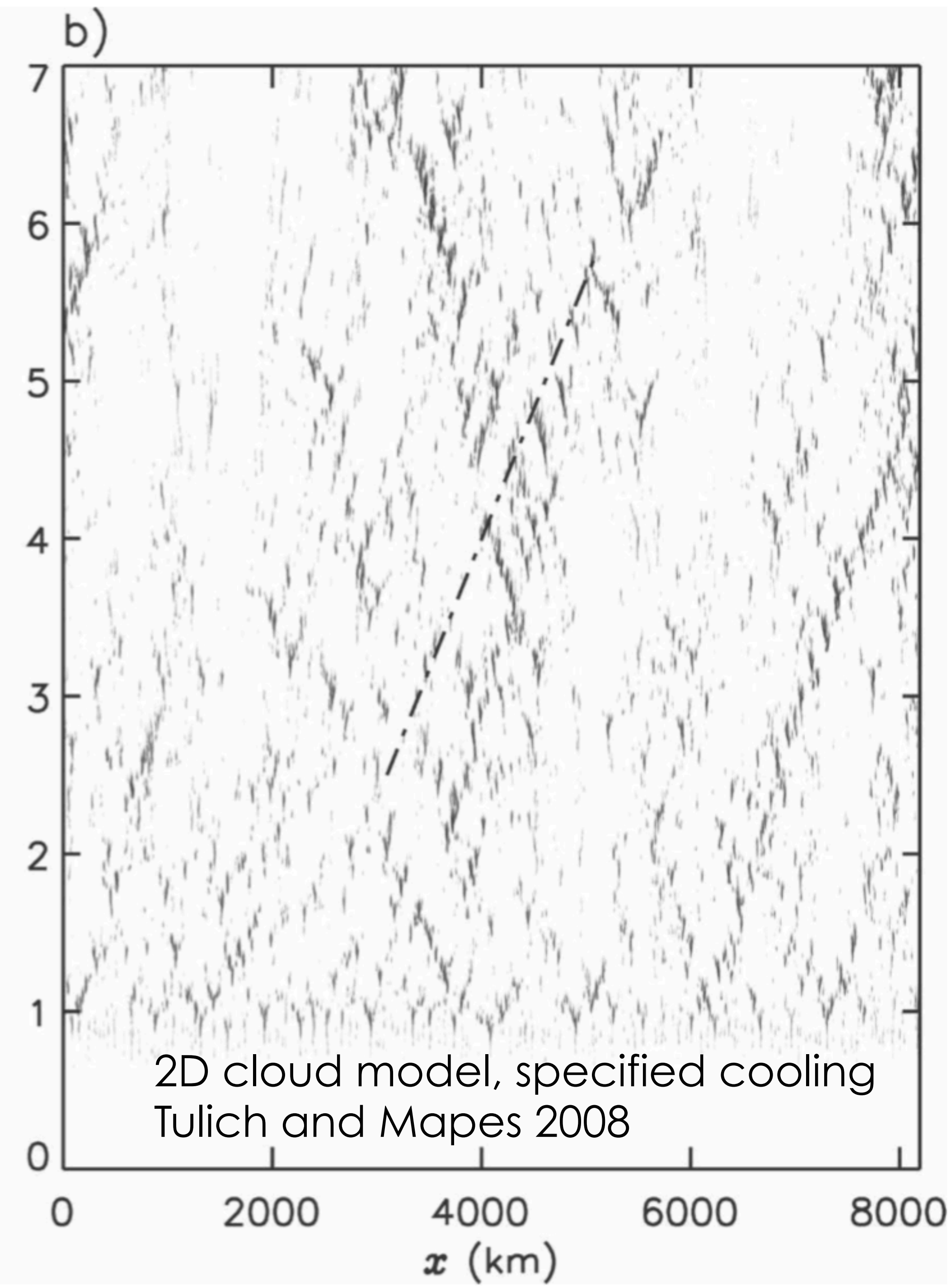
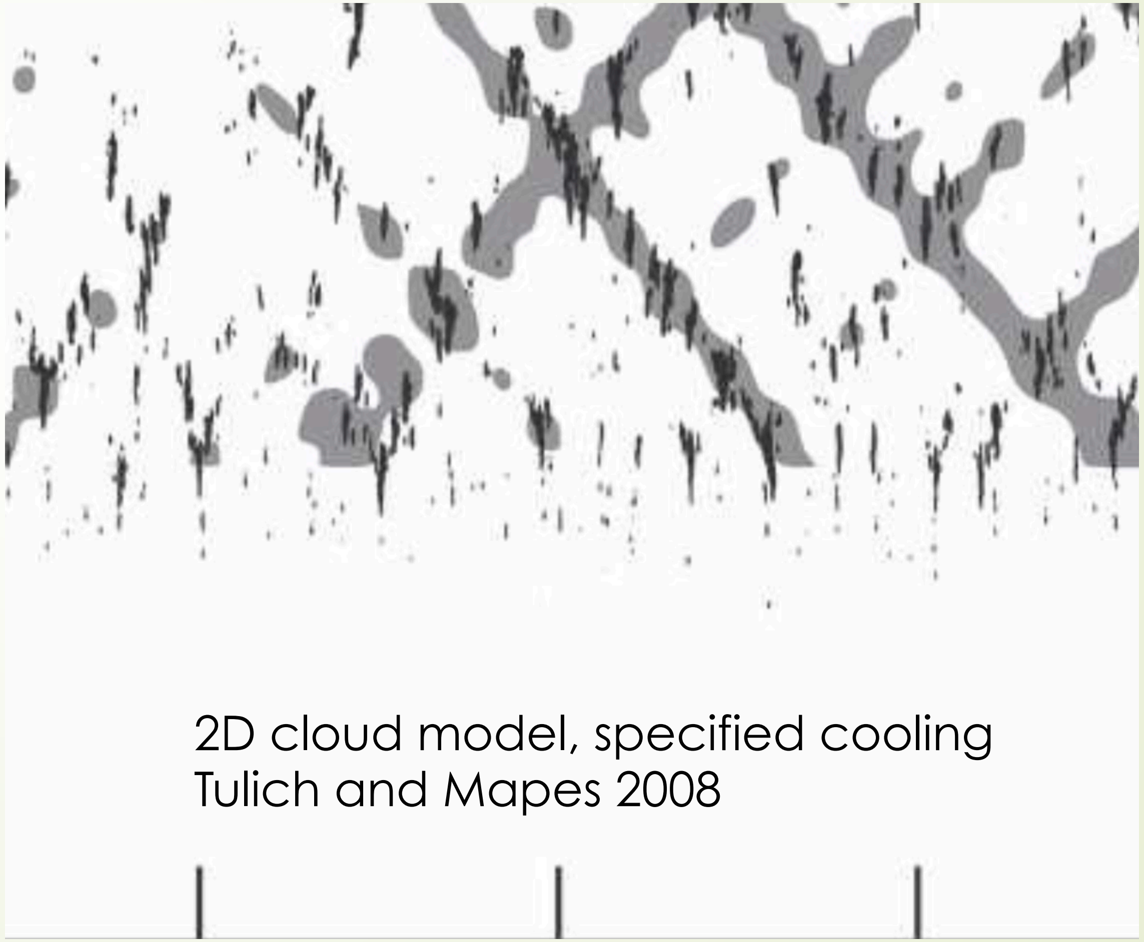


FIG. 1. Time–longitude diagram of satellite-derived brightness temperature T_B (produced by the CLAUS Project) averaged between 2.5°S and 7.5°N for days 140–230 (20 May to 18 Aug) of



2D cloud model, specified cooling
Tulich and Mapes 2008

Part III: Envelopes and ecosystems
Ch. 8: Non-contiguous effects



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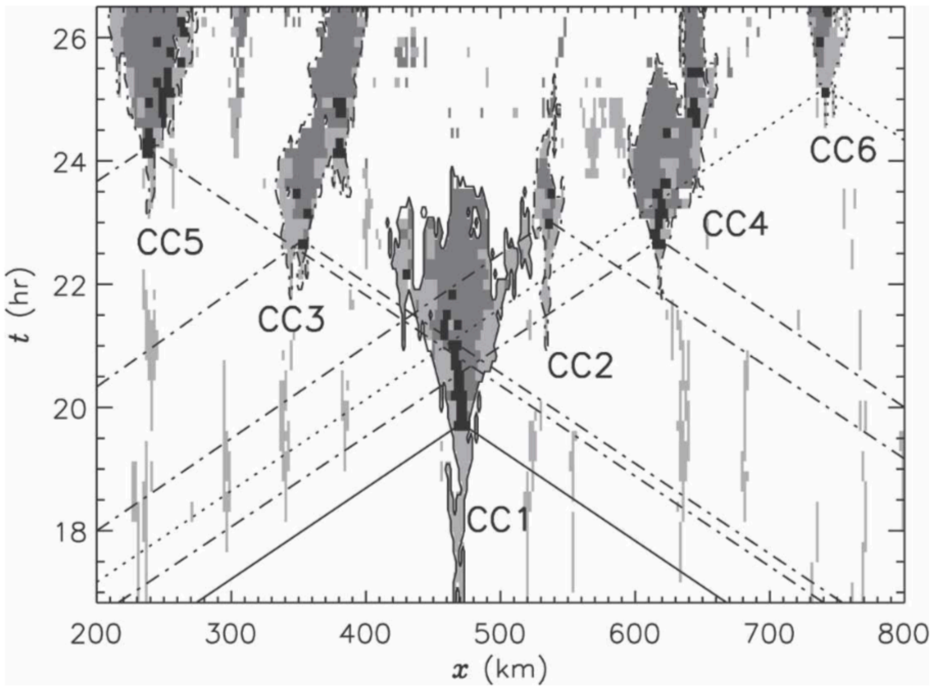


FIG. 4. Illustration of a scheme for classifying cloud clusters on the basis of when they develop relative to other clusters. Light, dark, and medium shadings denote columns masked as shallow convective, deep convective, and stratiform, respectively. Sloping lines denote the boundaries of space–time cones (corresponding to phase speeds of ± 19 m s^{-1}) extending backward in time from the earliest set of deep convective columns within each cluster.

→ **probability** (frequency) of D.C.

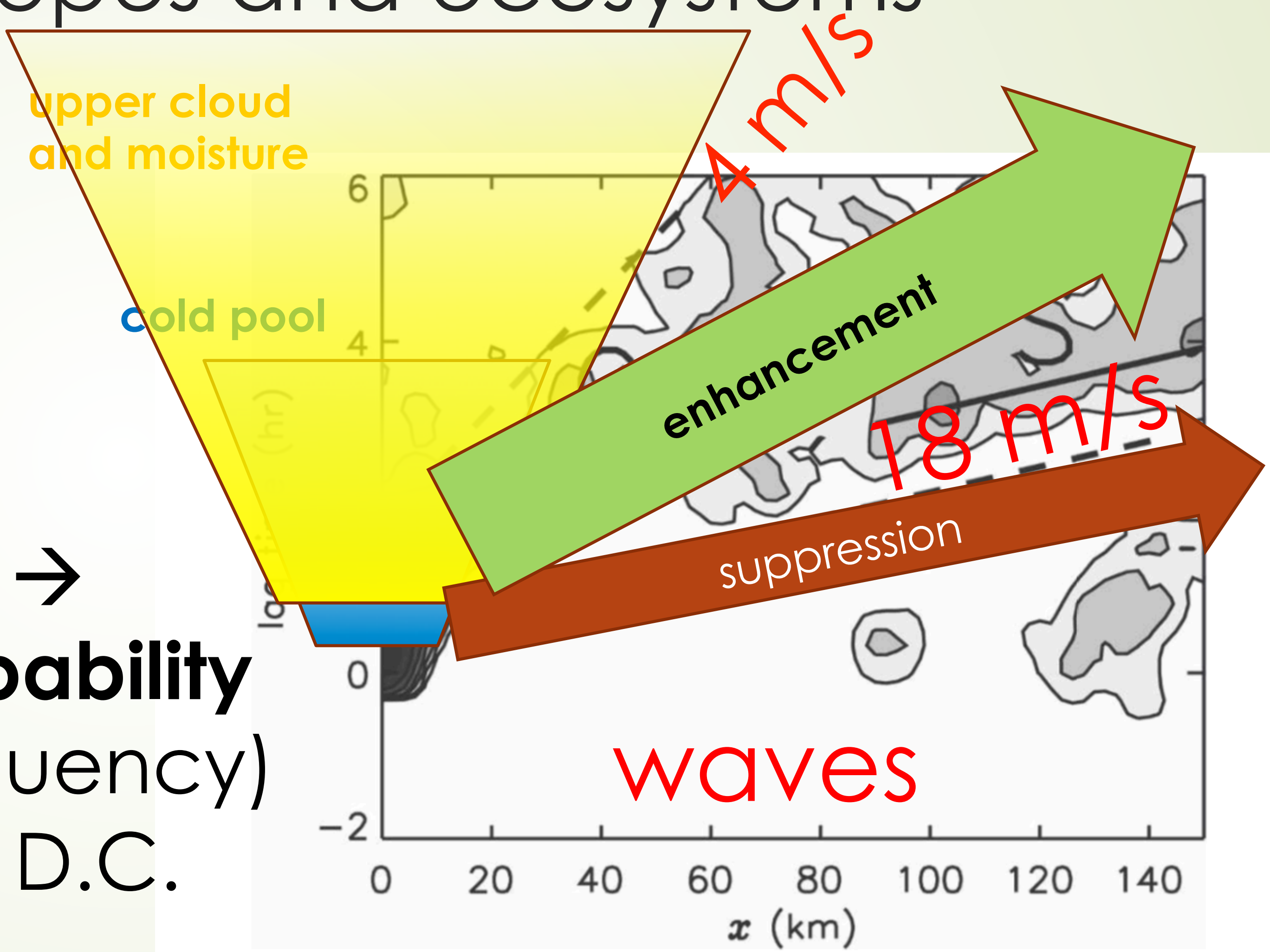


FIG. 10. Space–time evolution of the symmetric component of deep convection occurrence probability P_{dc} associated with the composite GEN1 cluster for $x \geq 0$. Contour levels are 0.75%,

Part III: Envelopes and ecosystems
Ch 8: far-field effects, non-contiguous

- What happens to all those far-field waves?
  - of suppression, by vertical displacement
    - (subsidence)

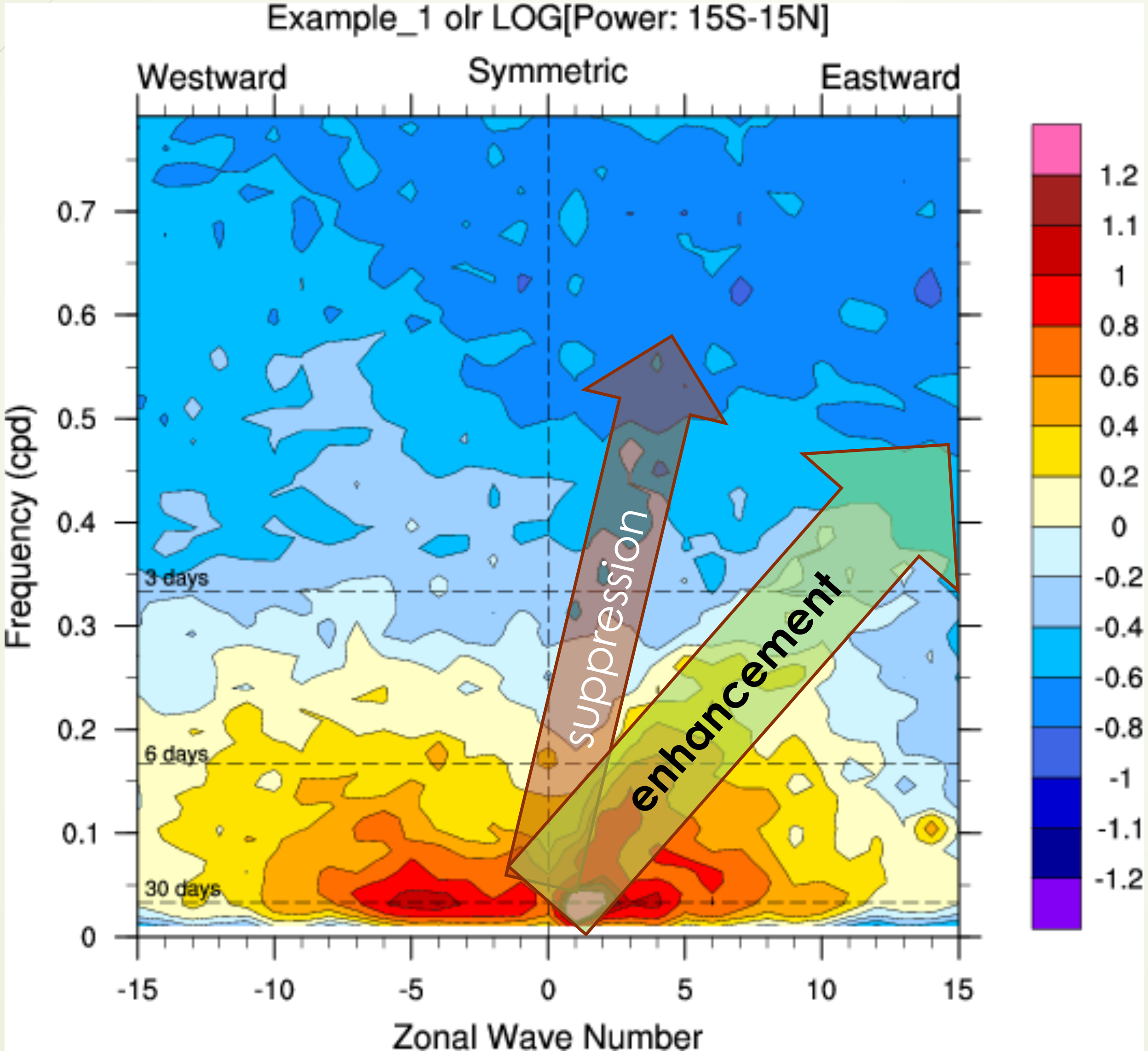
Part III: Envelopes and ecosystems
Ch 8: far-field effects, non-contiguous

- deep waves from large areas add up
- Coriolis force gets involved

- → ***wind fields of troposphere depth from net Q***
  - *advection of momentum* (new “entities”: jets, etc.)
  - *advection of moisture* (elsewhere; good and bad)
  - *surface winds, engage fluxes* (elsewhere; TCs even)
  - *momentum instability of jets* → *synoptics* (elsewhere)

- [bw] drives **all KE**, but is this really “convection”?

Part III: Envelopes and ecosystems



suppression is part of Kelvin wave signal (observed)

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Part III: Envelopes and ecosystems
Ch. 9: The Great Game

- Population ecology paradigm: the Lotka-Volterra equation

$$\frac{d}{dt}(n_i) = F_i n_i + \sum_{j=1}^{N} K_{ij} n_i n_j$$

- If "food" F_i is positive, population i grows exponentially.
- If $K_{ii} < 0$, $(F_i + K_{ii} n_i) < 0$, population asymptotes to $n_i = -F_i/K_{ii}$.

- Interactions
  - mutualism ($K_{ij} > 0$), competition ($K_{ij} < 0$)
  - predator-prey ($K_{ij}K_{ji} \leq 0$) moves entities among categories

Part III: Envelopes and ecosystems
Ch. 9: The Great Game

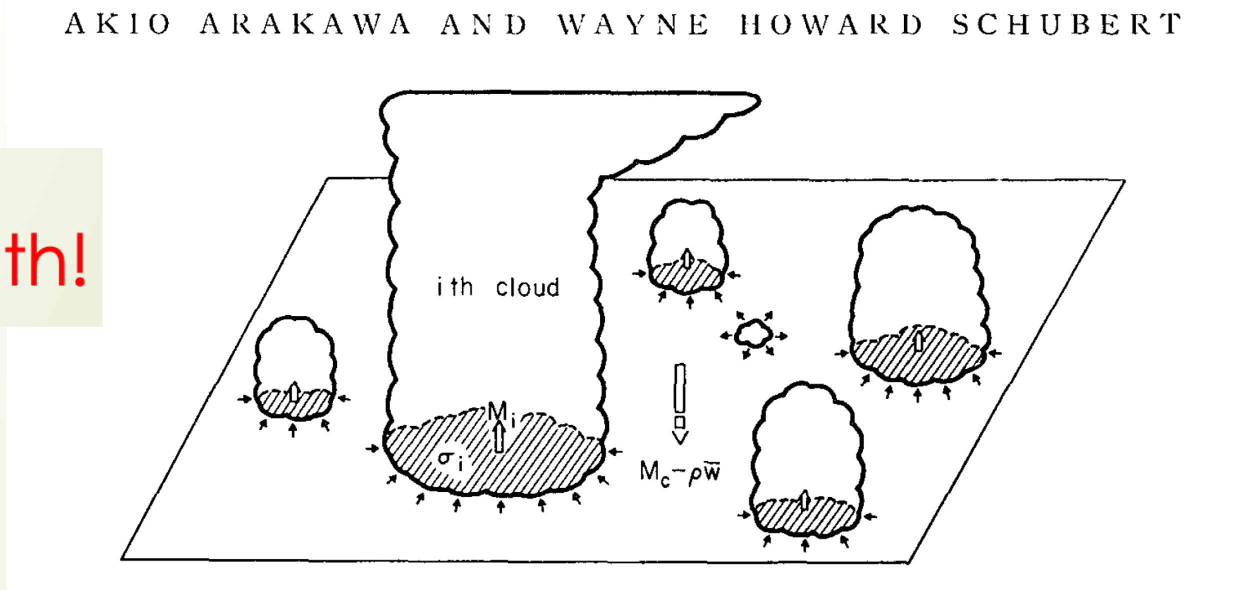
- Nober+Graf (2005)
  - see also comment/reply by Plant+Yano

"The analogy to convective clouds is straightforward. The reason for convective clouds to form is convective instability ('food supply')....each cloud type acts on its environment and tends to reduce instability. Therefore each cloud tends to reduce somehow the 'food-supply' for all other cloud types including itself."

Nober, F. J., and H-F. Graf, 2005: A new convective cloud field model based on principles of self-organisation. *Atmos. Chem. Phys.*, **5,** 2749–2759.

Part III: Envelopes and ecosystems
Ch. 9: The Game

- But Nober and Graf (2005) drew on A&S 1974
  - truncated (*large-scale w interaction forbidden*)
  - energy production rate [bw] (treated as *plume vigor source*), decomposed by plume size
  - by orthogonal vertical modes
  - but NOT by plume radius or depth!



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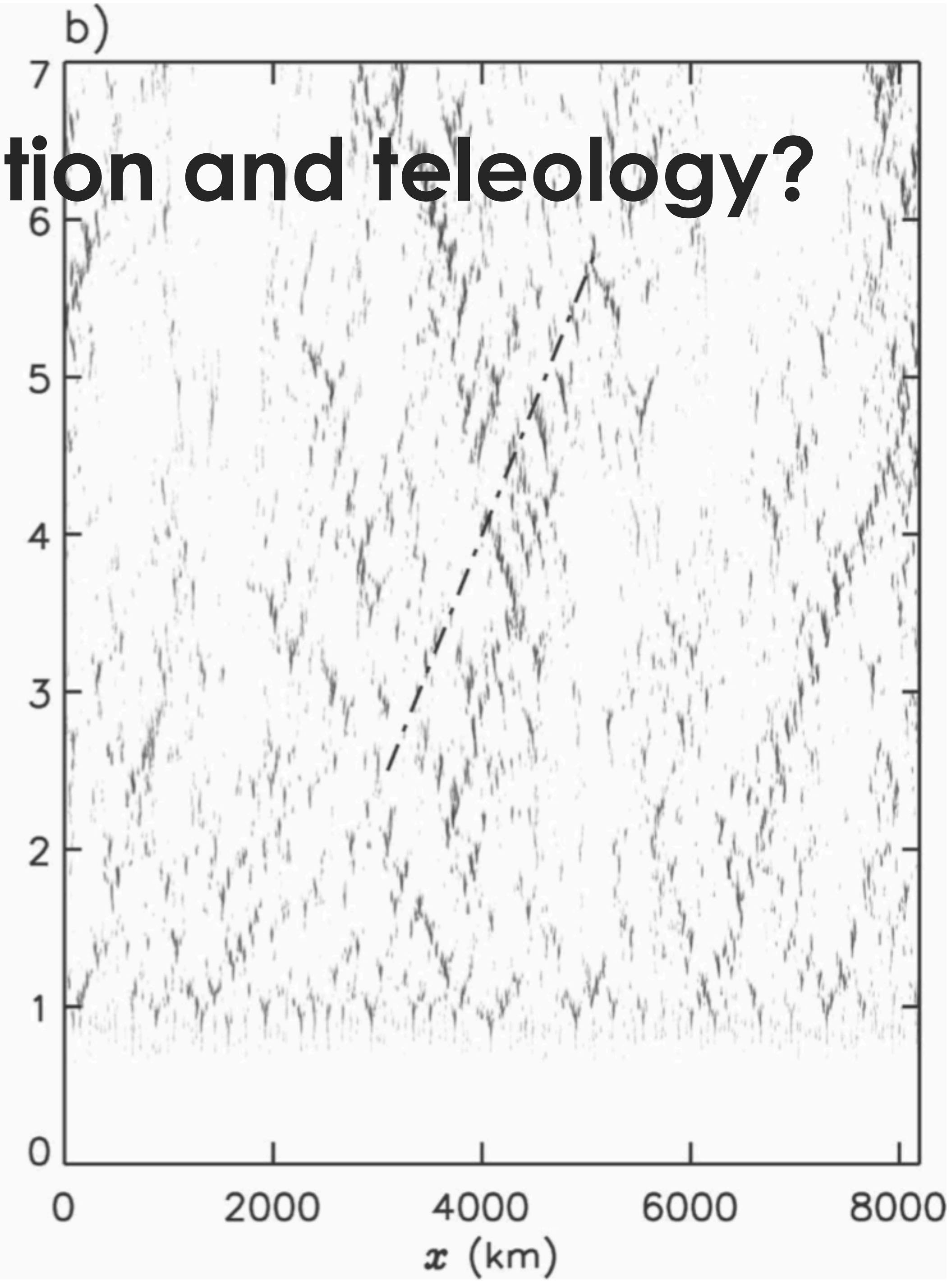
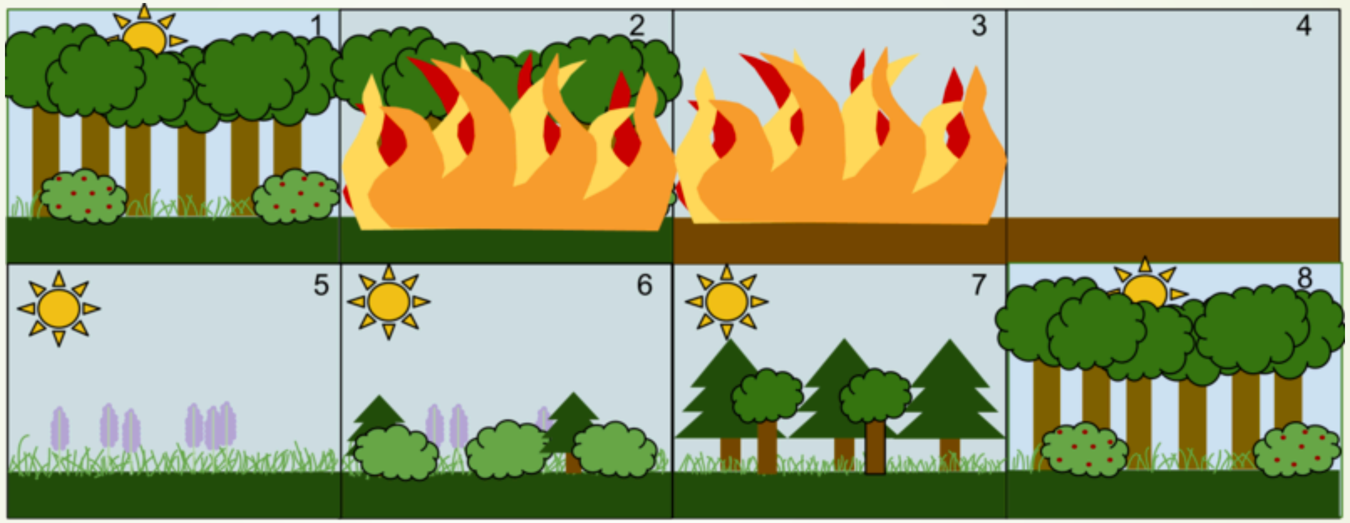
Principles of interaction and teleology?

- are we sure the right interacting entities are **contiguous *drafts*** *(clouds)*?
- or are the real entities ***superposed drafts of different scales***?



Back to the well of ecology?

- **succession**



- entities of interaction are **populations of species**
  - Interactions may be contingent, sequential

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- **Would some job go undone** if convection didn't organize or compete or whatever the heck it is doing? **SP says no…?**

Can models help **by being wrong?**

- Popcorn vs. Typhoons in early NICAM
- depending entirely on PBL scheme
  - not in publications Satoh links me to…
  - “pers. comm.” = annals of tuning
    - as remembered by bystander

Parameterized popcorn vs. typhoons

Some Counterintuitive Dependencies of Tropical Cyclone Frequency on Parameters in a GCM

Ming Zhao
GFDL/UCAR, Princeton, New Jersey

Isaac M. Held *and* Shian-Jiann Lin
NOAA/GFDL, Princeton, New Jersey

https://doi.org/10.1175/JAS-D-11-0238.1
Received: 16 September 2011
Final Form: 26 February 2012
Published Online: 2 July 2012

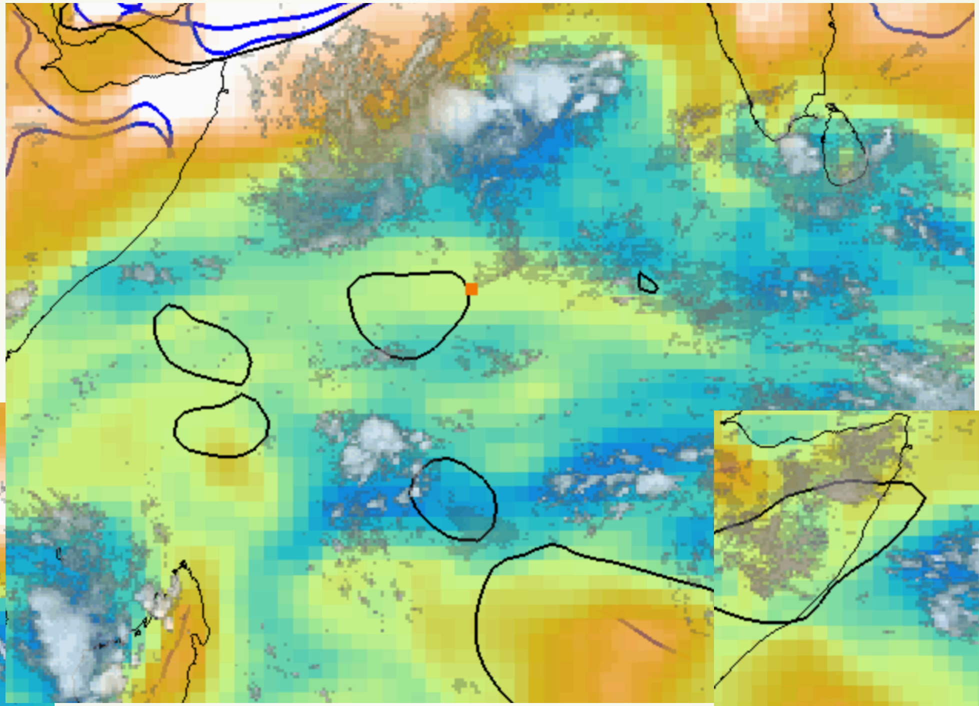
- "…enhanced cumulus entrainment reduces in-cloud buoyancy, resulting in **decline of parameterized deep** convective mass flux.
- This generally cools and dries much of the upper troposphere and moistens the boundary layer and lower troposphere, **leading to growth of resolved-scale convection**.
- Compared to the parameterized convection, the resolved-scale convection provide **more intense latent heat release and w**.
- All other things being equal, this shift in the strength of convection would lead to an **increase of global TC frequency with e_0**, which is what the model simulated as e_0 increases up to 10.
- However, the flattening and unexpected drop of the global TC count as e_0 advances from 10 to 12 and 14 suggests that other processes may set in to prevent TC genesis in this model… (another competition effect…)

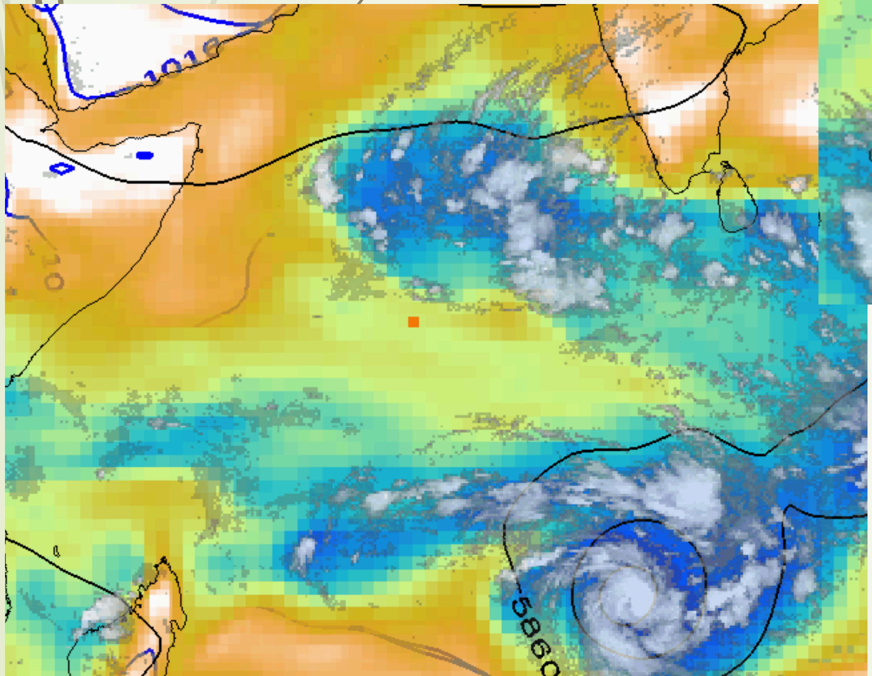
Closures: teleology vs. mechanistic vs. meta-principles

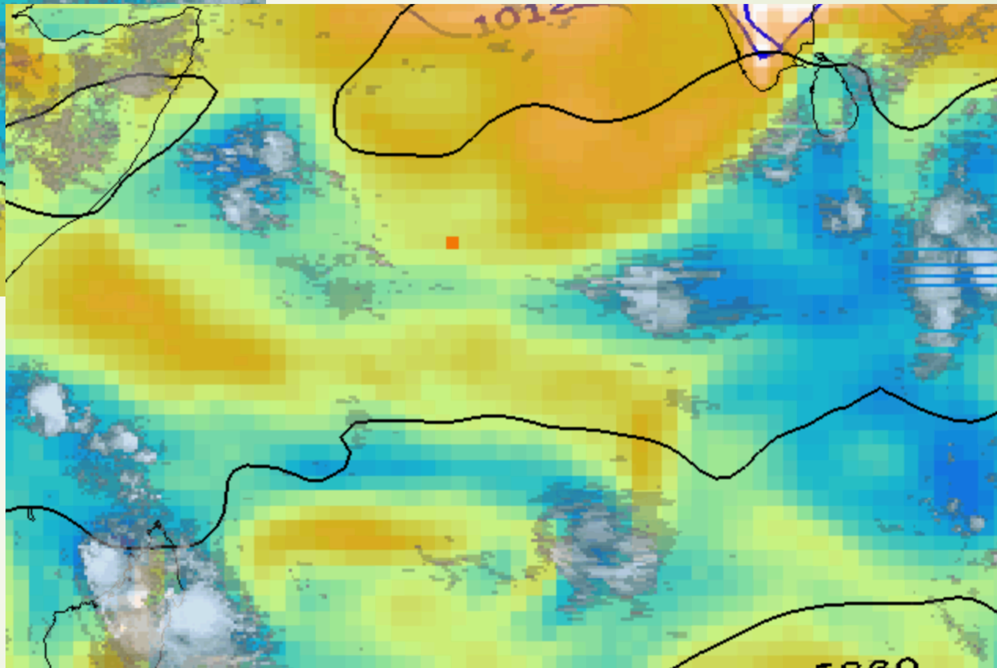
- adjustment or QE is a teleological closure
- dispatcher and bubble dynamics is mechanistic
- is there something better to be done? (org)?

Which scale(s) are driving what we see?

cloud-cond? vapor-rad?







Conclusions

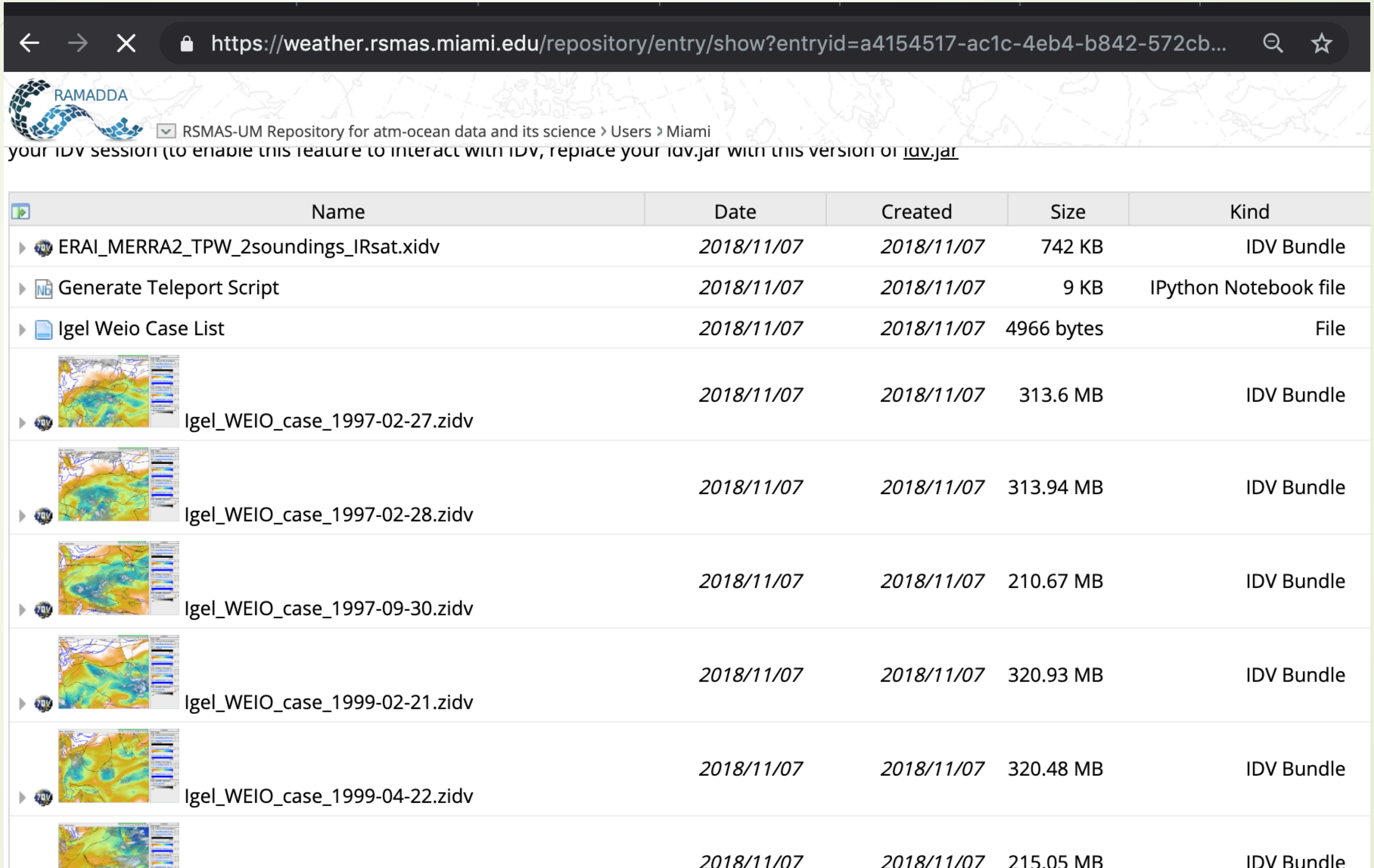
- We have only a few tools for thinking about this.
  - **Fluid field equations** embody integral constraints & local relationships. And → software → data fields.
  - **Contiguous entity models**, either descriptive (bubbles, cells, MCSs) or theoretical (vortex ring, self-similar plume w/ contrived top+bottom); *all are caricatures*.
  - **Interactions of entities:** a forefront of appreciation? Only if the interactions of caricatures have new regularities and patterns to learn..

- To discover emergent laws, we need to seek ***failures of bad models to fail as badly as they should***…

a repository of those WEIO CWV-island cases

300 MB or so data cubes w/ vis (IDV)

and Jupyter notebooks with xarray_open() method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RAMADDA

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your IDV session (to enable this feature to interact with IDV, replace your idv.jar with this version of idv.jar

Name	Date	Created	Size	Kind
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Generate Teleport Script	2018/11/07	2018/11/07	9 KB	IPython Notebook file
Igel Weio Case List	2018/11/07	2018/11/07	4966 bytes	File
Igel_WEIO_case_1997-02-27.zidv	2018/11/07	2018/11/07	313.6 MB	IDV Bundle
Igel_WEIO_case_1997-02-28.zidv	2018/11/07	2018/11/07	313.94 MB	IDV Bundle
Igel_WEIO_case_1997-09-30.zidv	2018/11/07	2018/11/07	210.67 MB	IDV Bundle
Igel_WEIO_case_1999-02-21.zidv	2018/11/07	2018/11/07	320.93 MB	IDV Bundle
Igel_WEIO_case_1999-04-22.zidv	2018/11/07	2018/11/07	320.48 MB	IDV Bundle
	2018/11/07	2018/11/07	215.05 MB	IDV Bundle