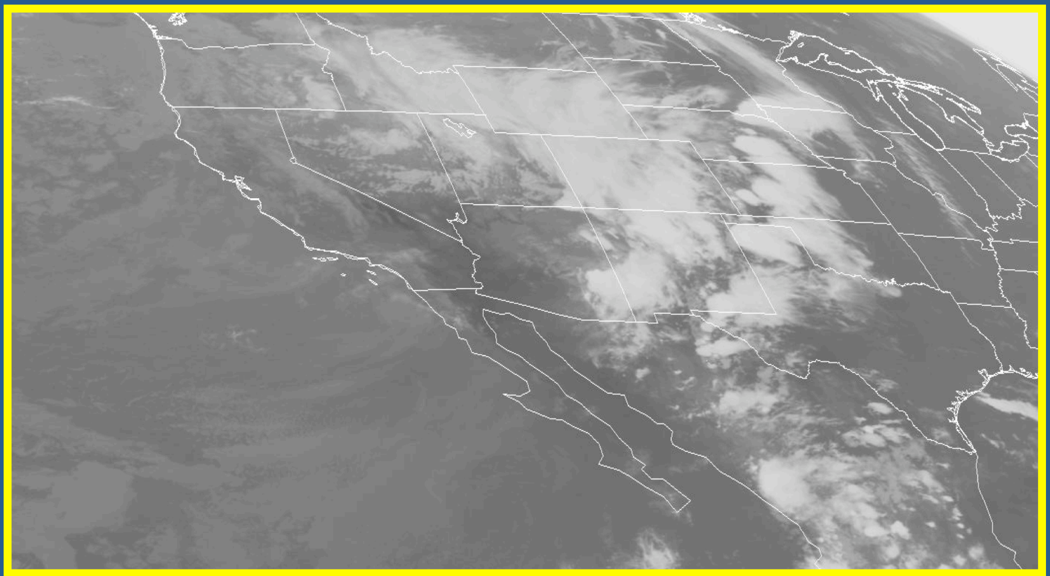
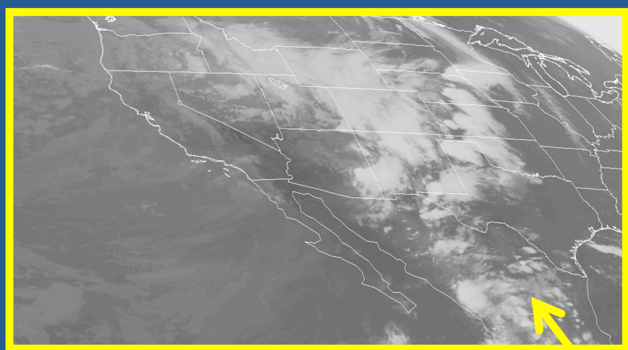
Orogenic Propagating Precipitation Systems over the Continental US

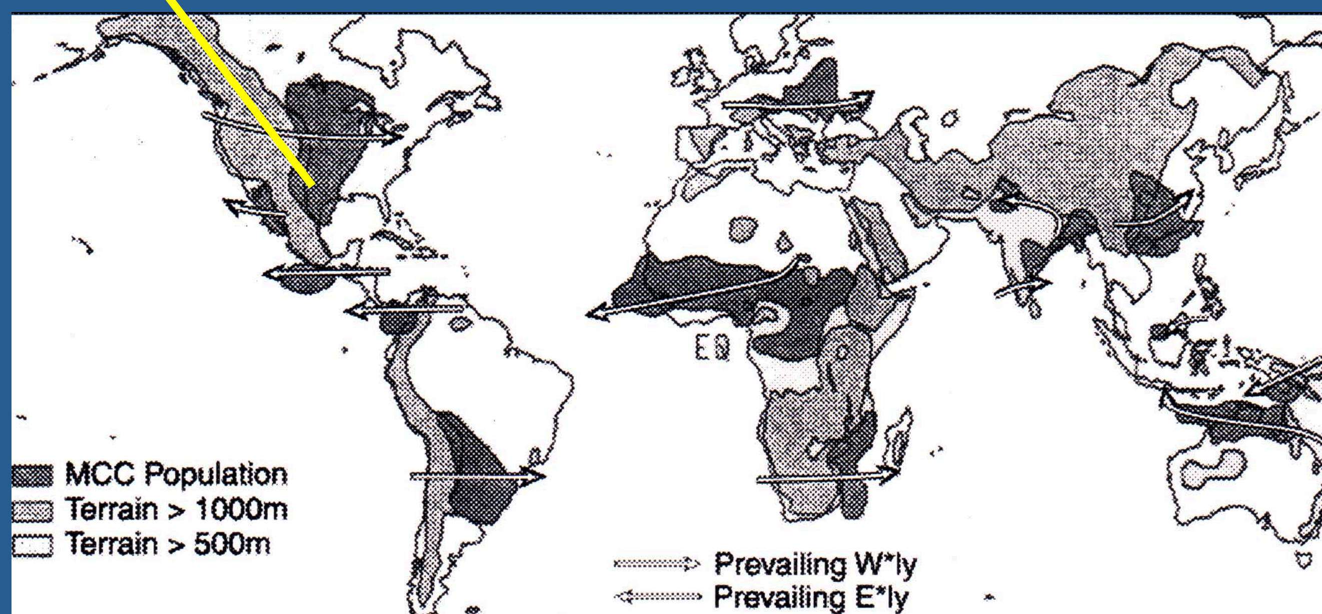


Mitch Moncrieff
NCAR

KT Breakout Group, CMMAP Workshop, Scripps, San Diego, Jan. 12-14, 2010

Orogenic MCS downstream of mountains





IPCC AR4: *Changes in precipitation* estimated from climate models for World's most populated regions have low confidence (< 66% of models agree on the sign of the change, white), especially in summer

Correlated with organized convective activity over continents

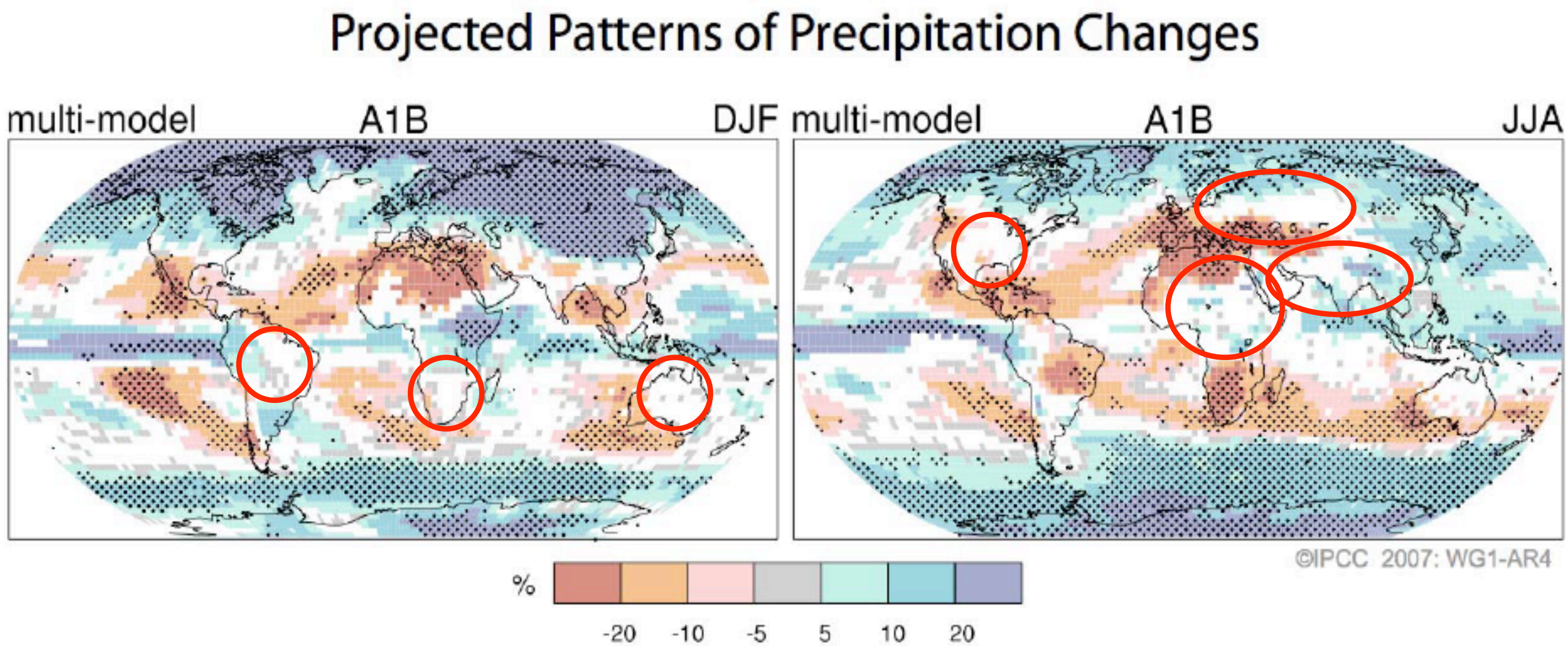
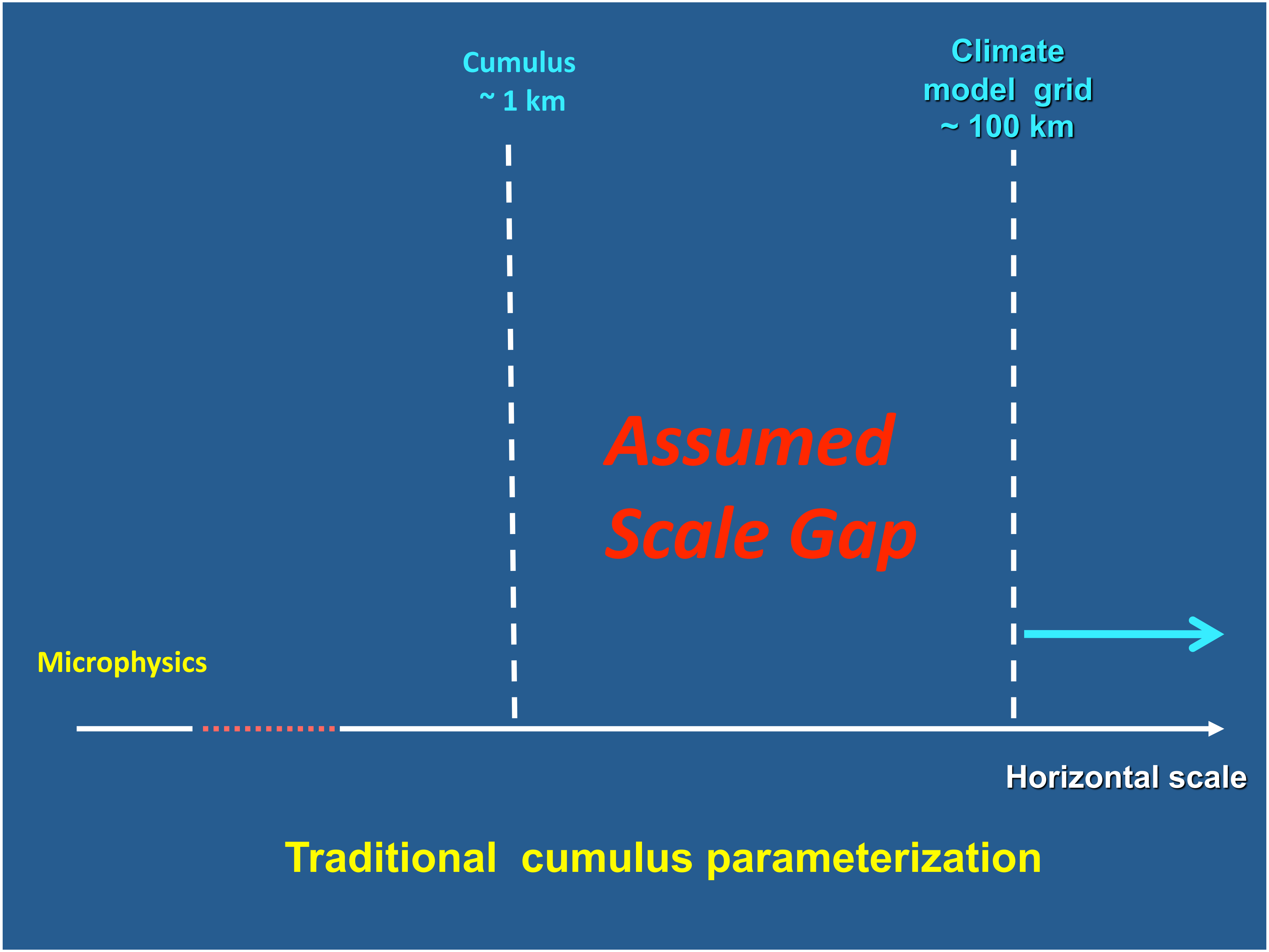
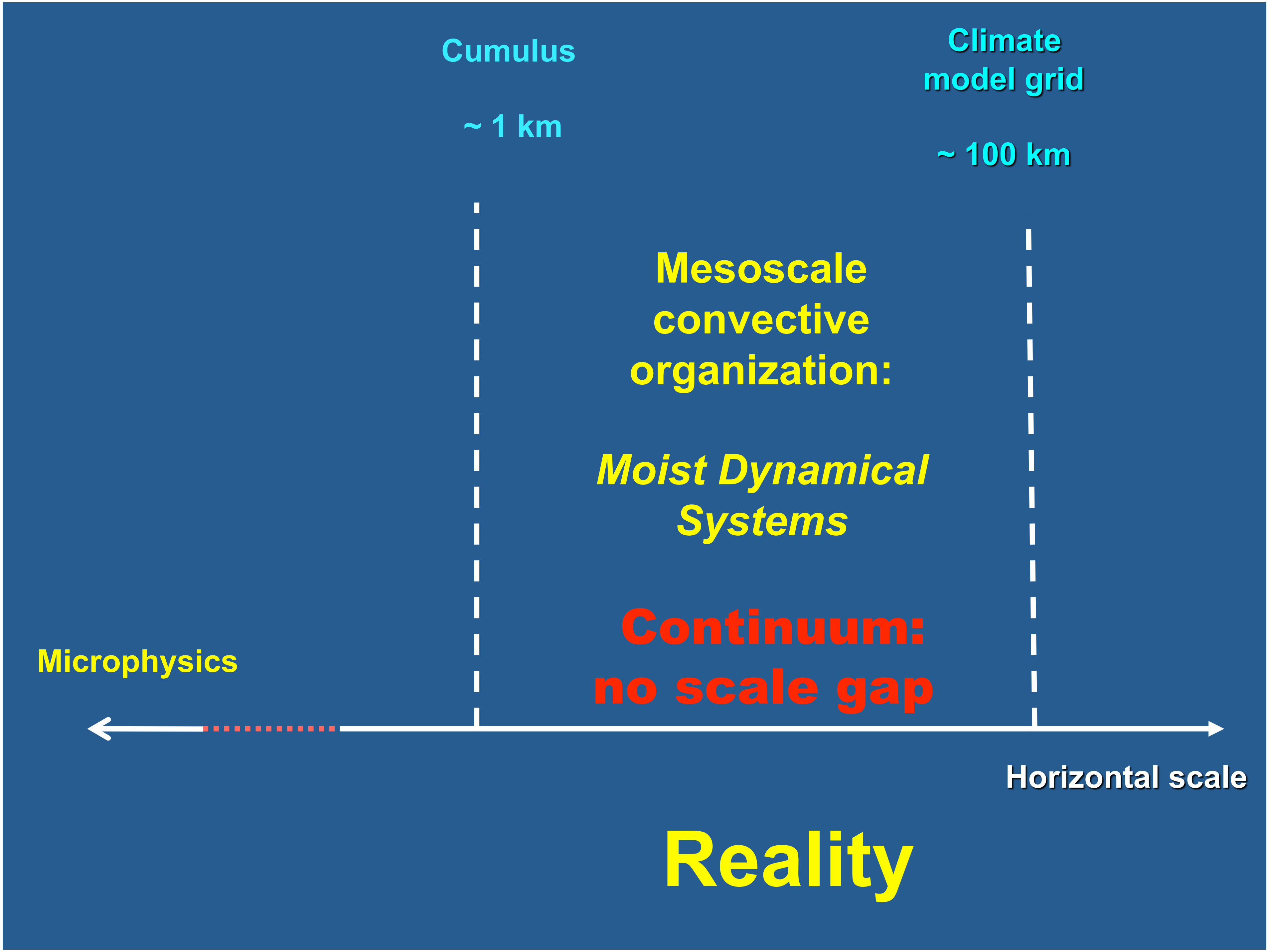


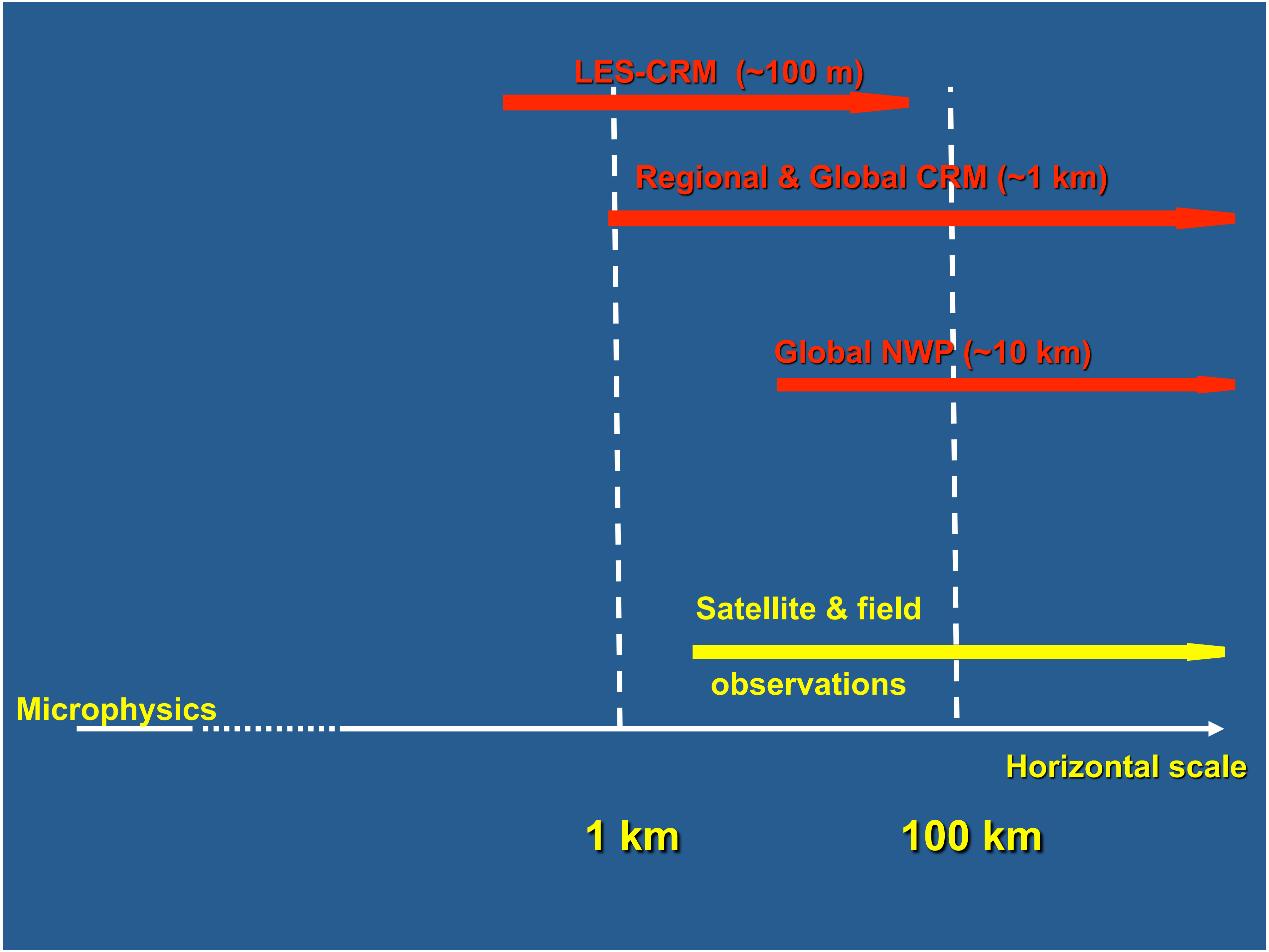
FIGURE SPM-7. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}

An objective of multiscale cloud-system modeling – to bridge the "parameterization scale gap"



Cumulus
~ 1 km
Climate
model grid
~ 100 km
Assumed
Scale Gap
Microphysics
Horizontal scale
Traditional cumulus parameterization


Cumulus
~ 1 km
Climate
model grid
~ 100 km
Mesoscale
convective
organization:
Moist Dynamical
Systems
Continuum:
no scale gap
Microphysics
Horizontal scale
Reality



LES-CRM (~100 m)
Regional & Global CRM (~1 km)
Global NWP (~10 km)
Satellite & field
observations
Microphysics
Horizontal scale
1 km
100 km

Dynamics

Approximate the nonlinear equations as total Lagrangians to facilitate integration

$$\frac{D}{Dt} F_i \quad = \quad 0$$

$$F_i(\underset{\sim}{x}, \psi) \; = \; C_i(\psi)$$

where F_i represents dynamics, energy, mass, vorticity variables

Momentum: Work-energy constraint

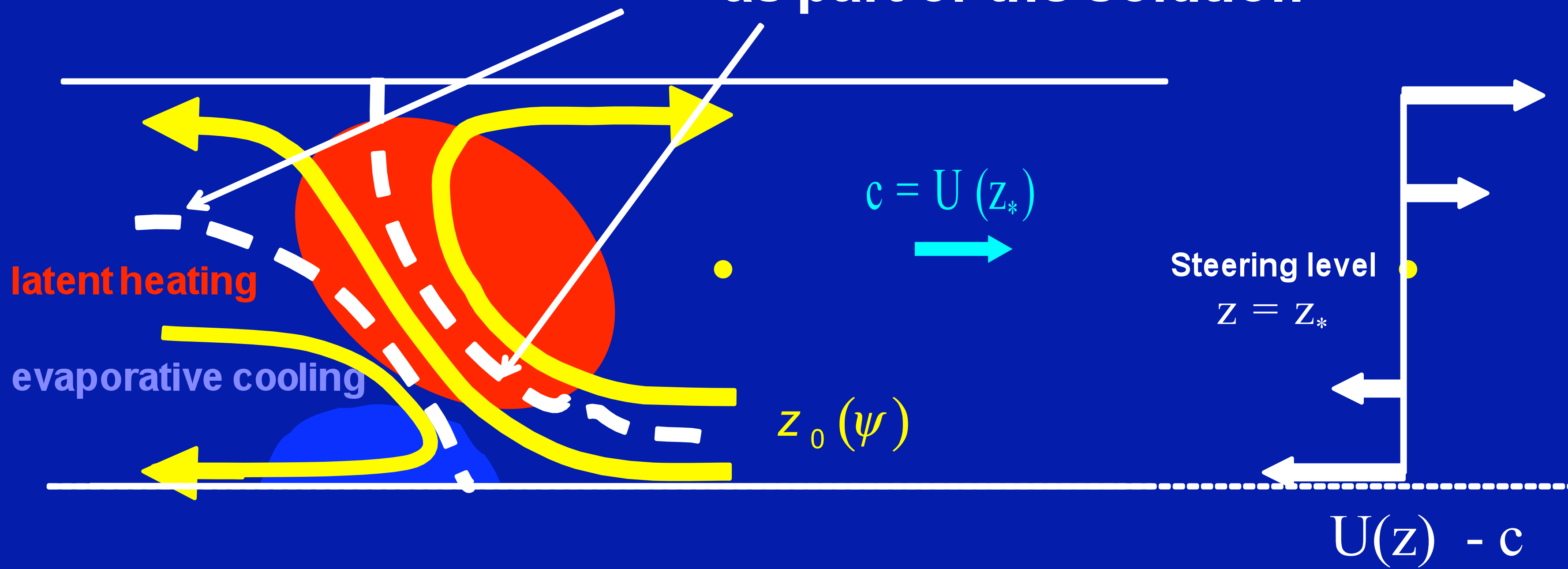
$$\frac{\partial \rho u}{\partial t} + \frac{\partial}{\partial x}(\rho u^2 + \delta p) + \frac{\partial}{\partial z}\rho u w = 0$$

$$\frac{\partial}{\partial t} = 0, \quad \text{rigid upper/lower boundaries z} = 0, \text{H}$$

integrate over model domain $\mathrm{A} \le x \le \mathrm{B},\ 0 \le \mathrm{z} \le H$

$$\left[u^2 + \frac{\delta p}{\rho} \right]_A^B = 0$$

Free boundaries, **shape determined as part of the solution**



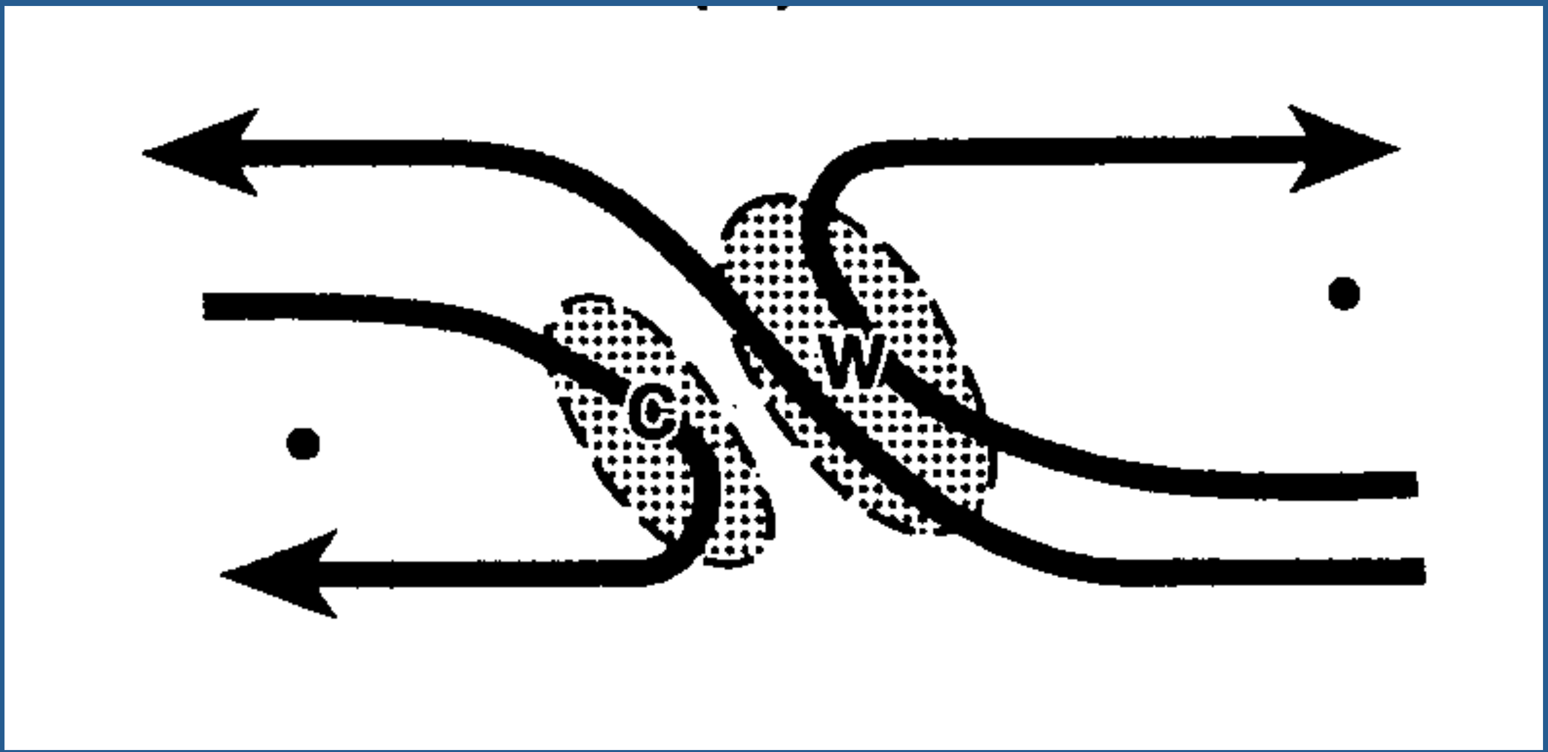
Slantwise layer overturning equation:

$$\nabla^2 \psi = G(\psi) + \int_{z_0}^{z} \left(\frac{\partial F}{\partial \psi} \right) dz$$

vorticity along trajectories	inflow vorticity	vorticity generated by latent heating

$F(\psi, z, c)$: **buoyancy**

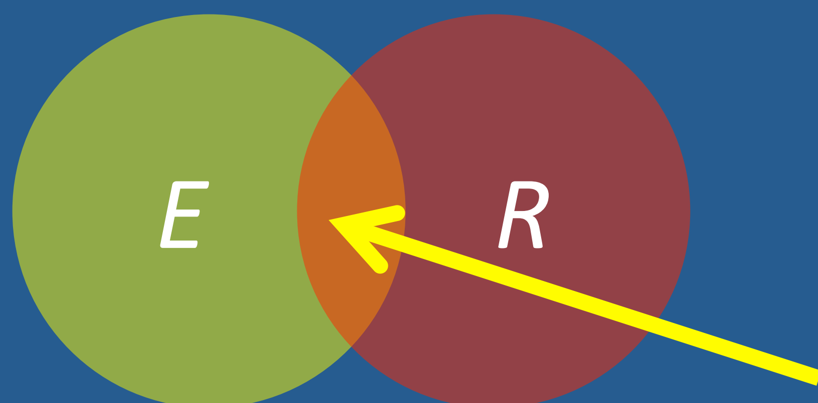
Maximally efficient regime of organization



3 forms of energy -- convective available potential energy (CAPE); kinetic energy of shear flow, work done by the pressure gradient -- 2 dimensionless quantities:

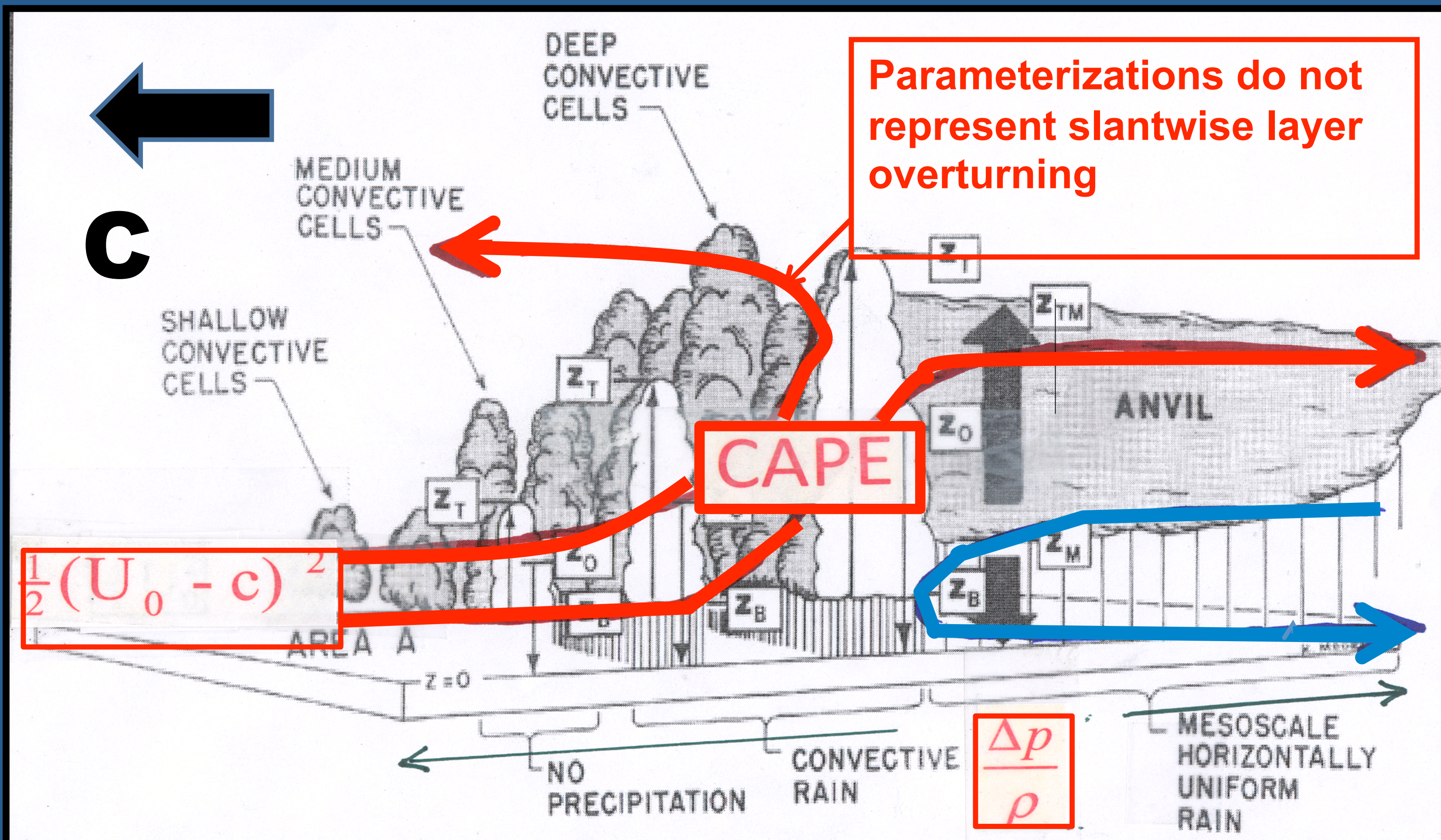
$$E = \frac{\Delta p}{\rho \frac{1}{2}(U_0 - c)^2}$$

$$R = \frac{CAPE}{\frac{1}{2}(U_0 - c)^2}$$



MCS- type organization

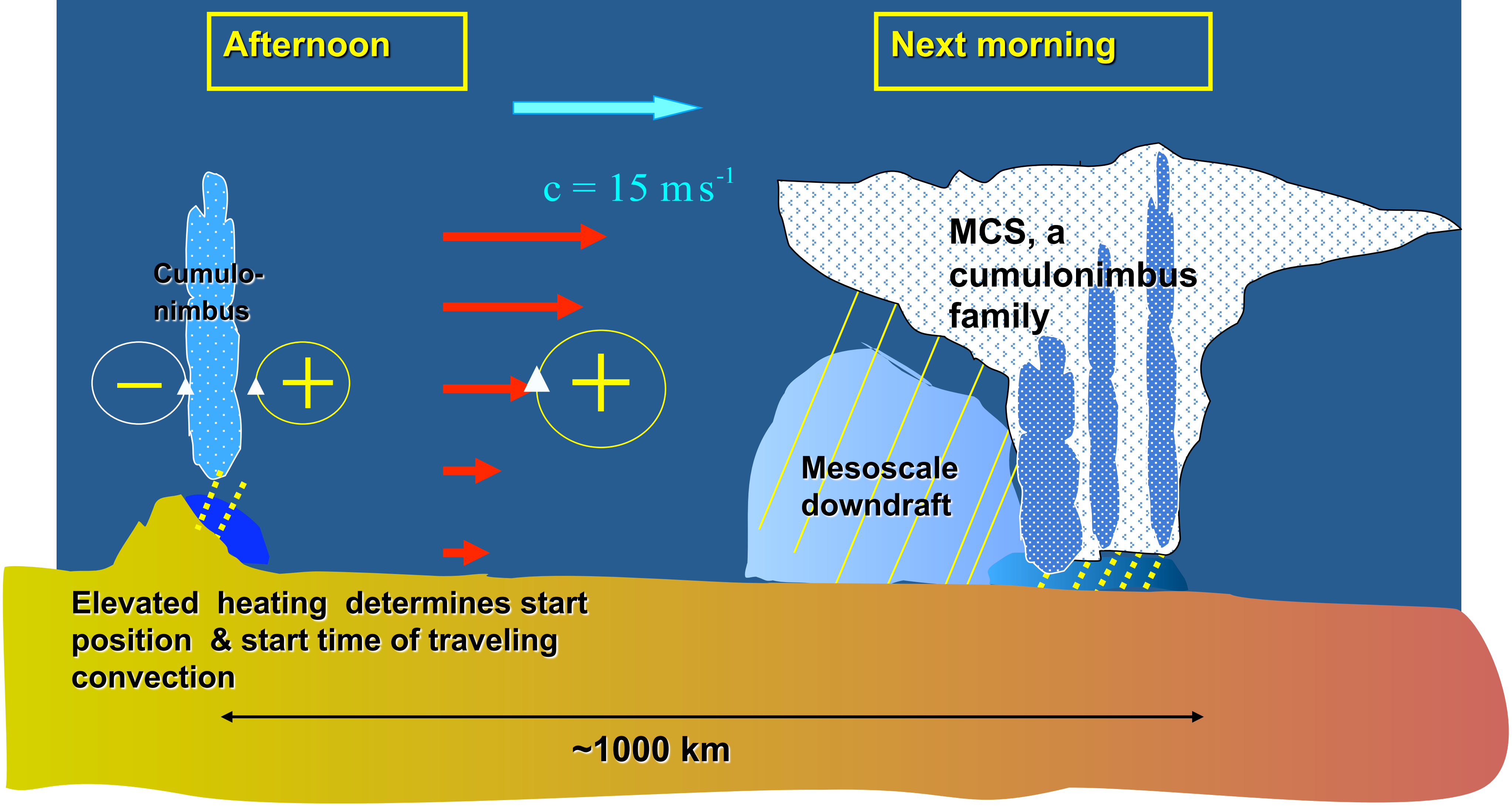
Anatomy of MCS-type organization



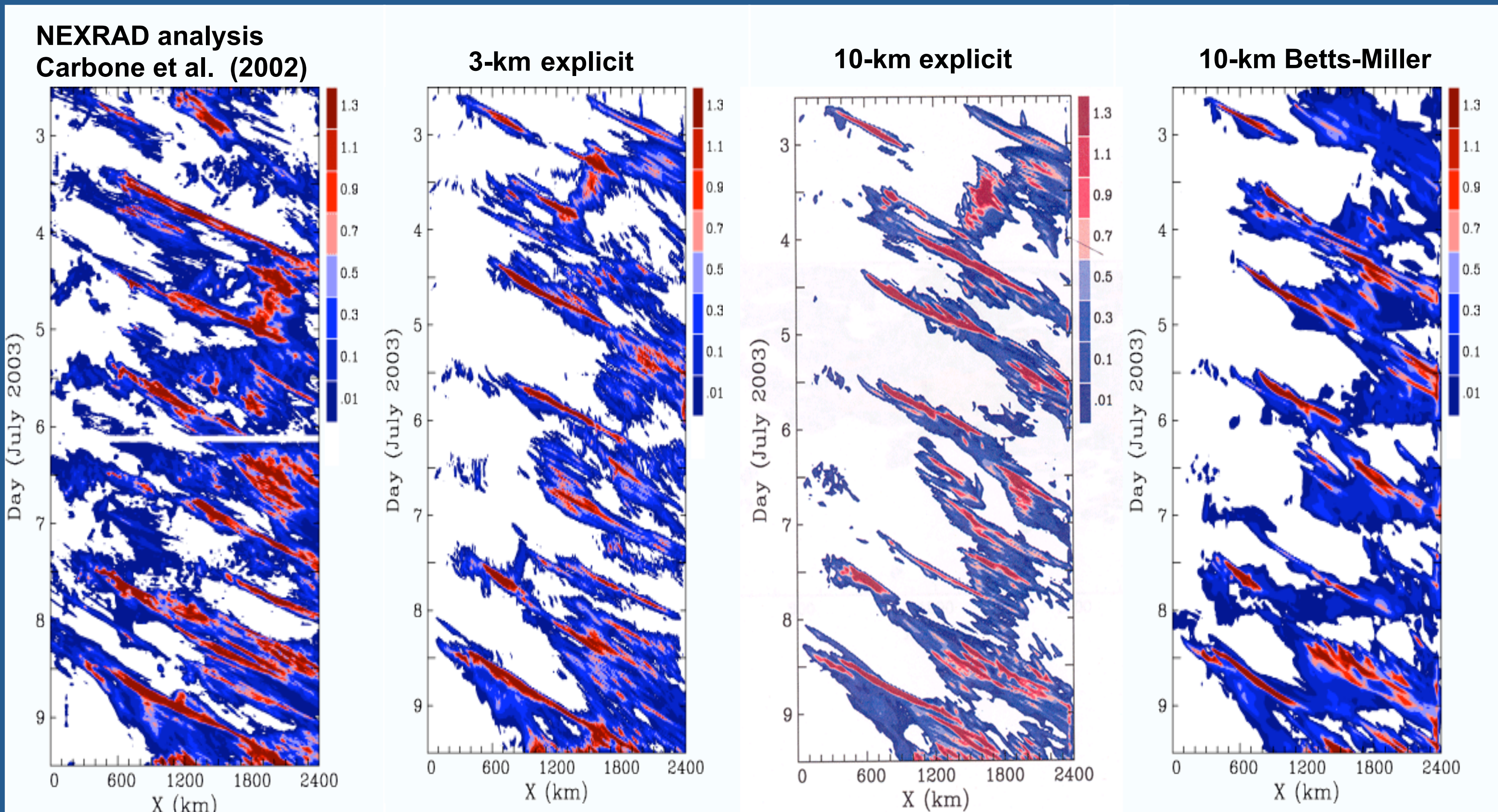
CAPE = Convective Available Potential Energy

CRM simulation

Propagating convection downstream of moutains

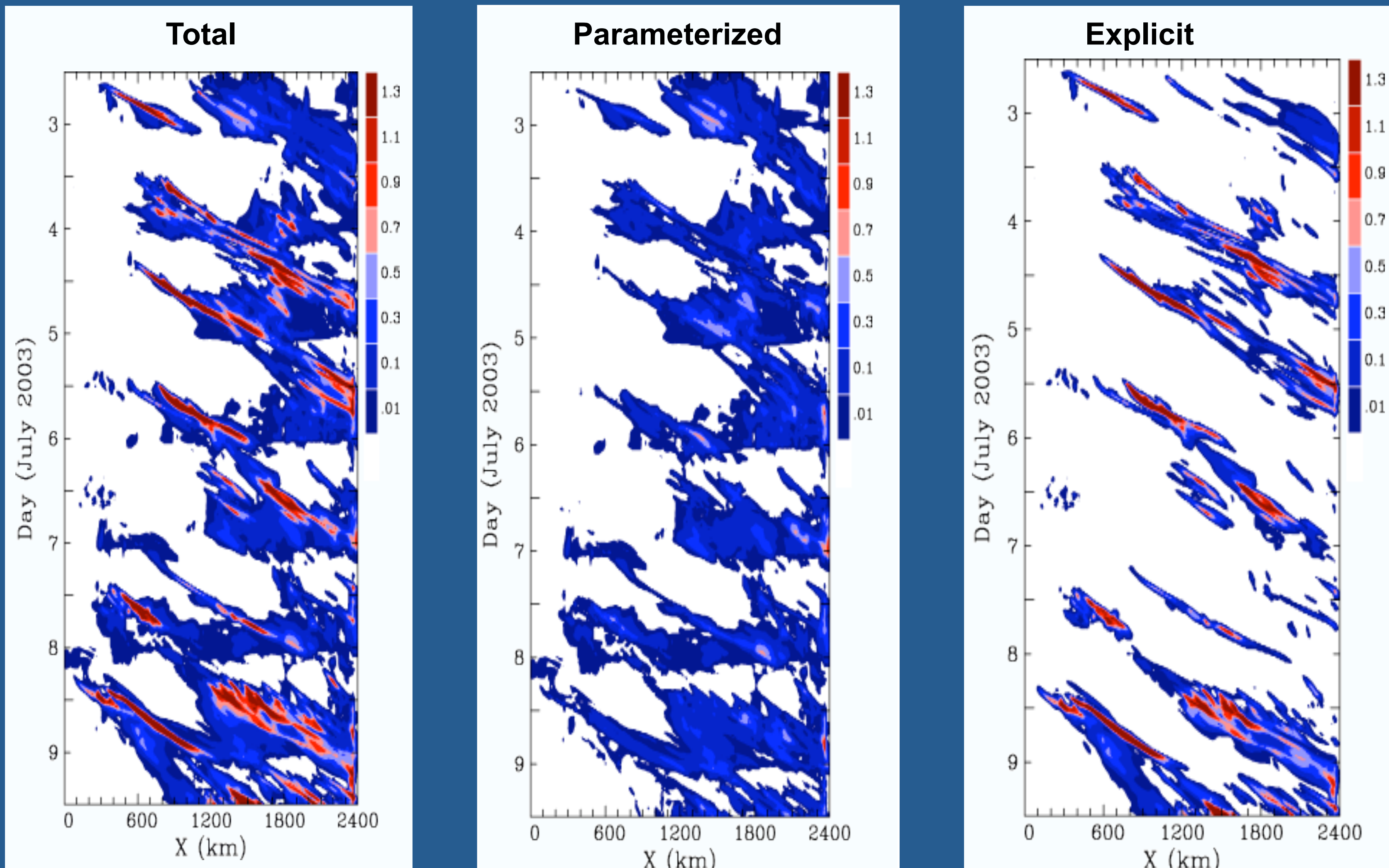


Meridionally averaged rain-rate

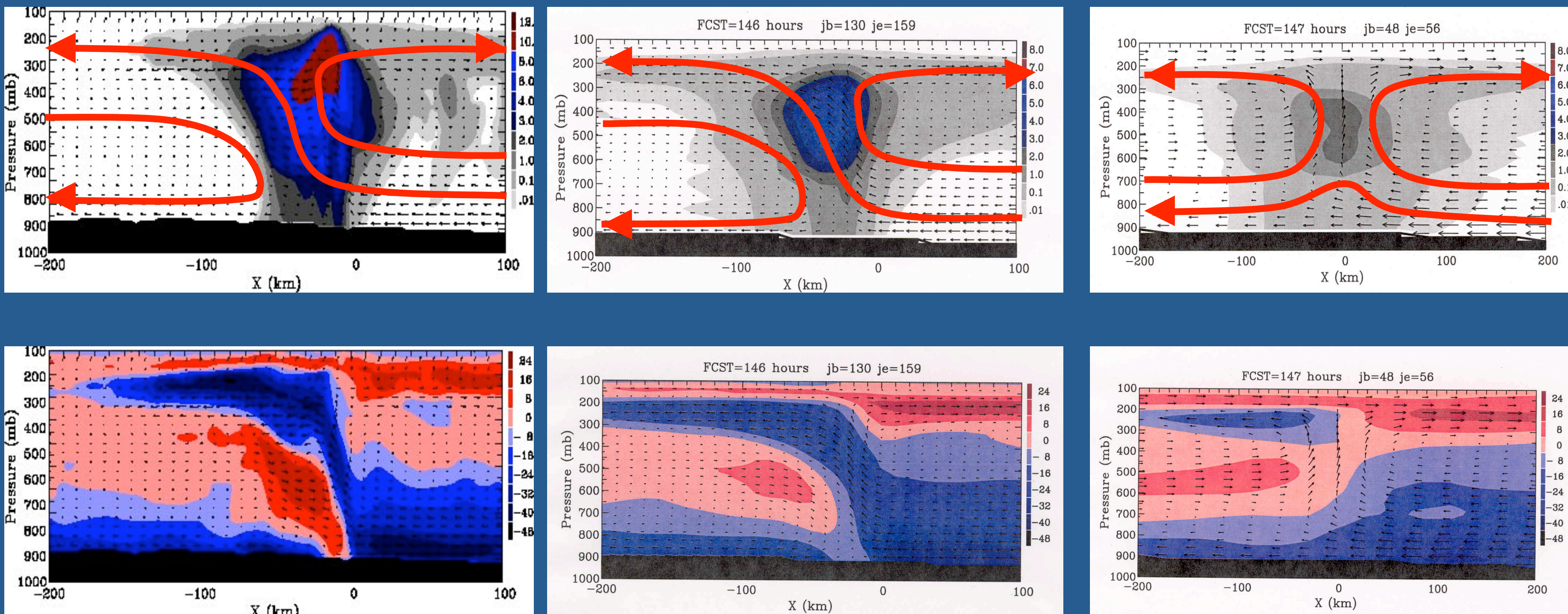


Moncrieff and Liu (2006)

‘Grid-scale’ circulations capture propagating precipitation



Resolution dependence

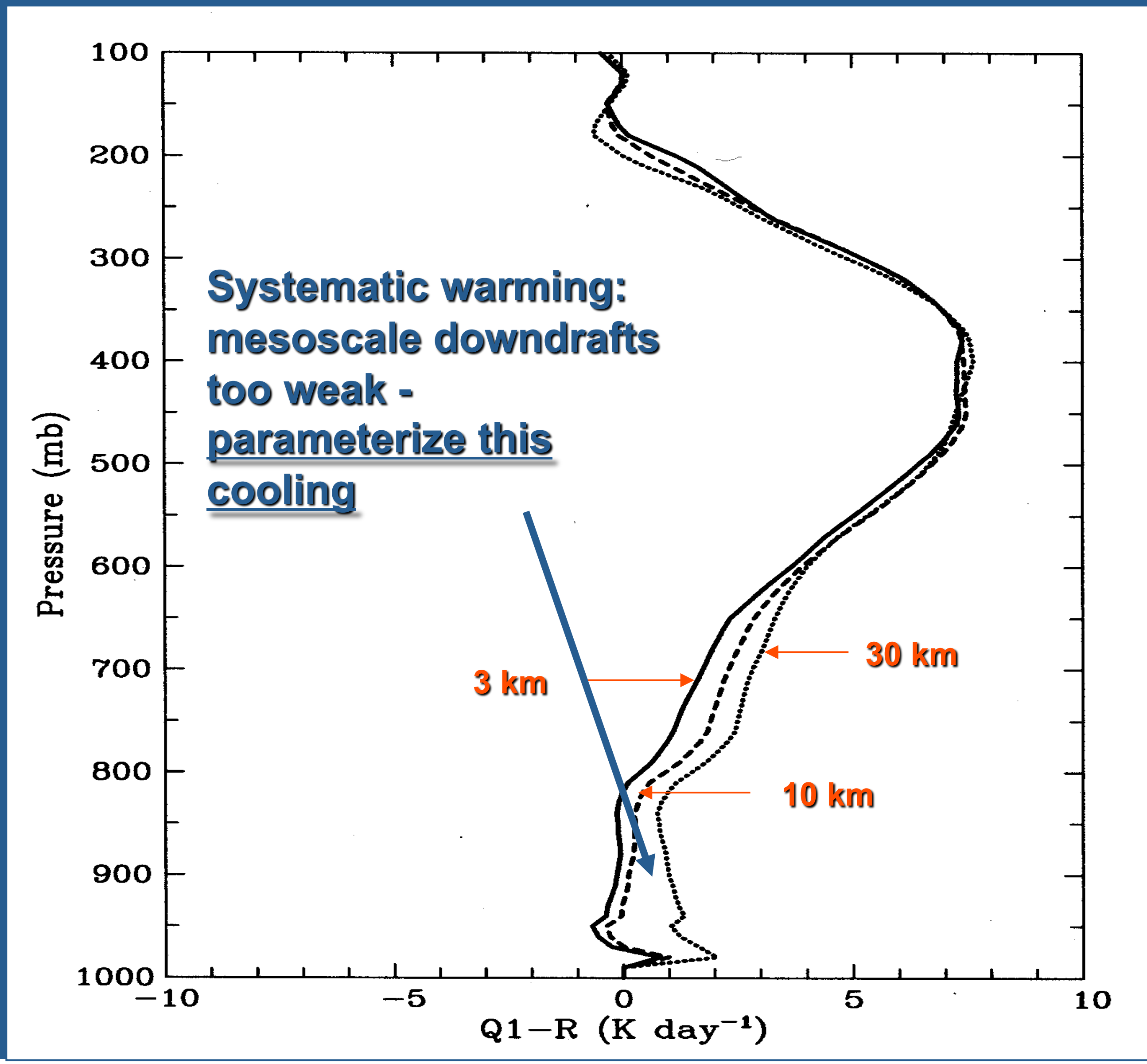


$\Delta = 3$ km $\Delta = 10$ km $\Delta = 30$ km

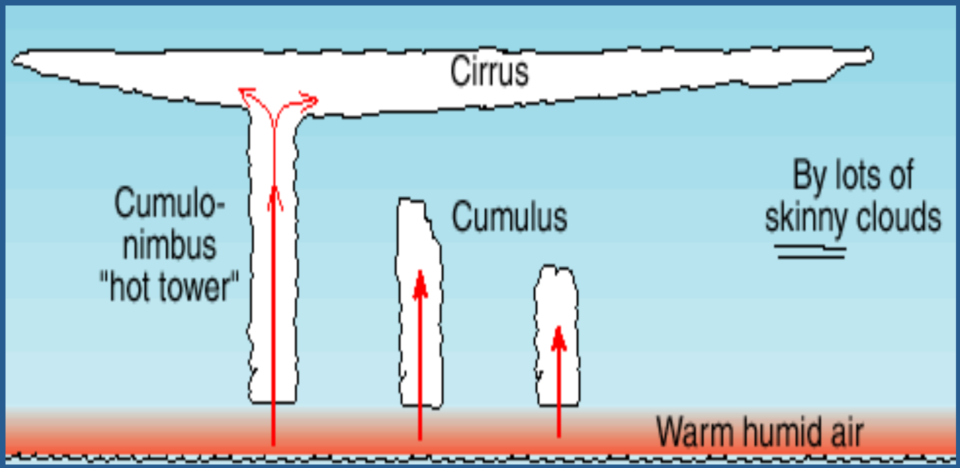
3-km & 10-km grids – similar morphology

30-km grid – unrealistic morphology

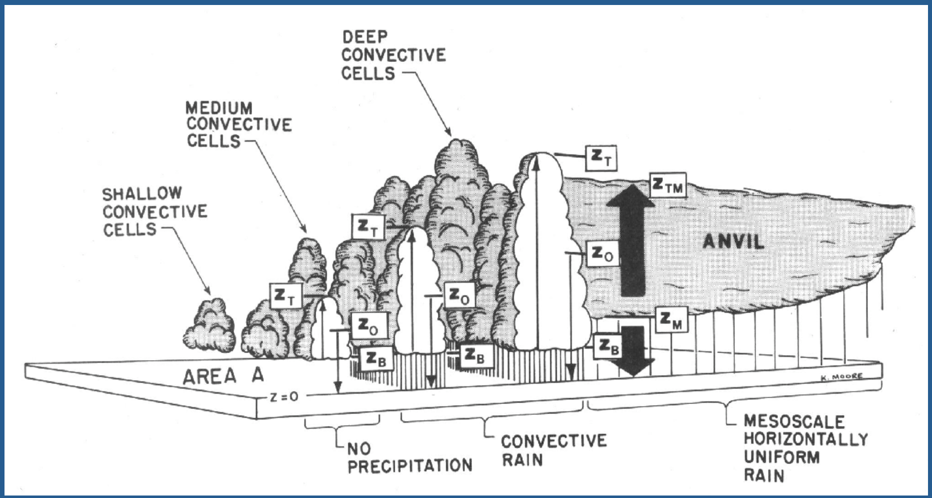
Systematic error in convective heating



EARLY VIEW OF OCEANIC TROPICAL CLOUD EXSEMBLE

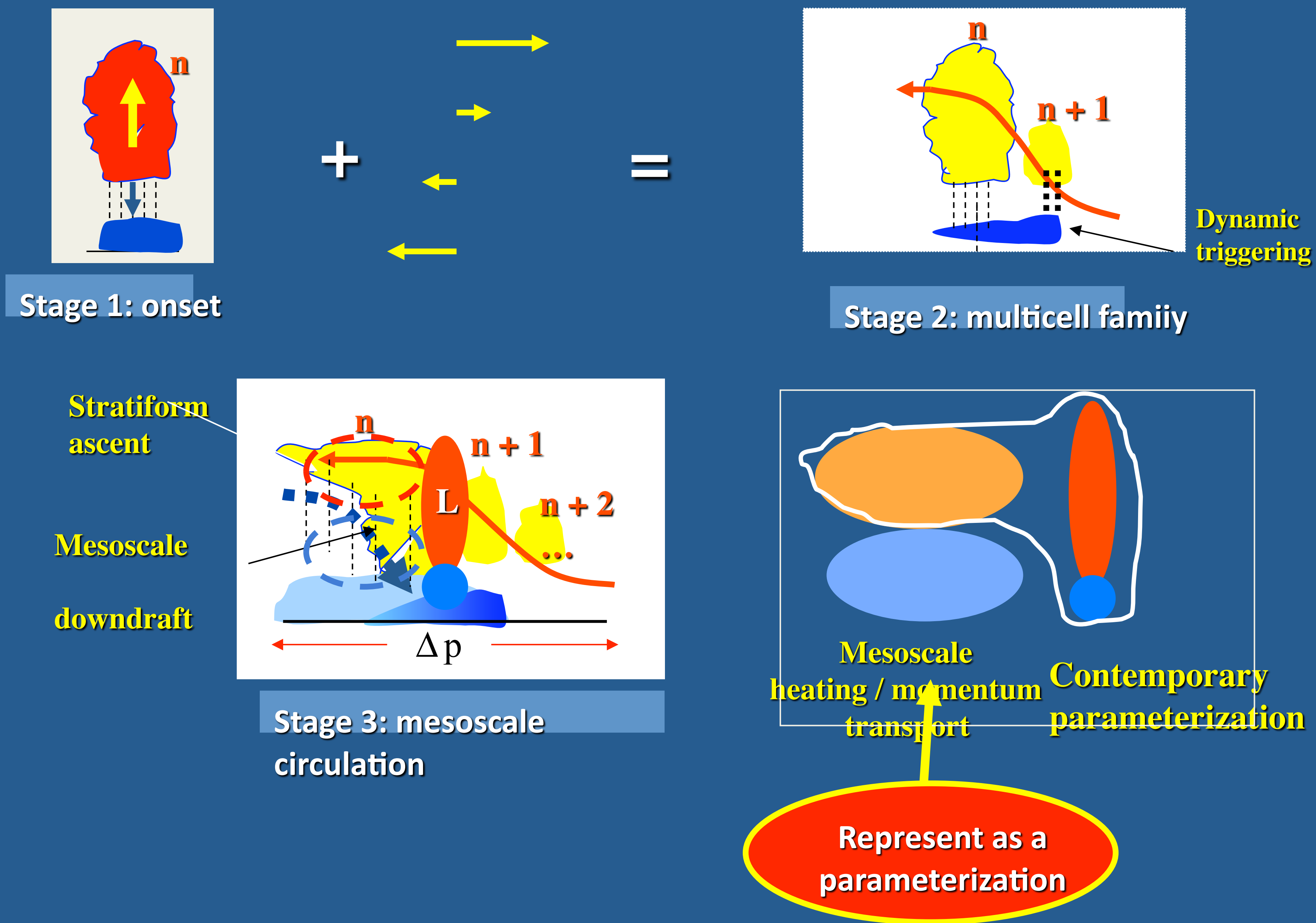


Arakawa & Schubert (1974)



PROPAGATING MCS: 3-D cloud structures (shallow vs. deep, convective vs. stratiform, warm vs. cold downdrafts, and associated mesoscale circulation patterns (Houze 1984)

Upscale evolution of MCS

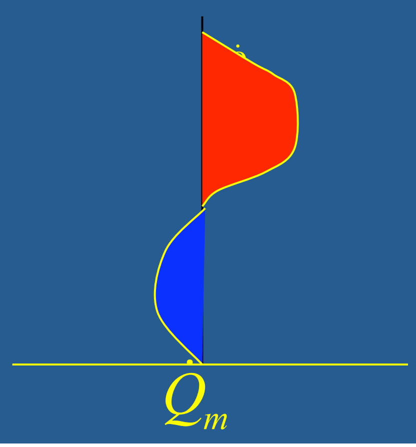


Stratiform heating/mesoscale downdraft parameterization

$$\dot{Q}_m(p,t) = \alpha_1 \dot{Q}_c(t) \sin \frac{p - p_s}{p_s - p_*} \qquad p_* \le p \le p_s$$

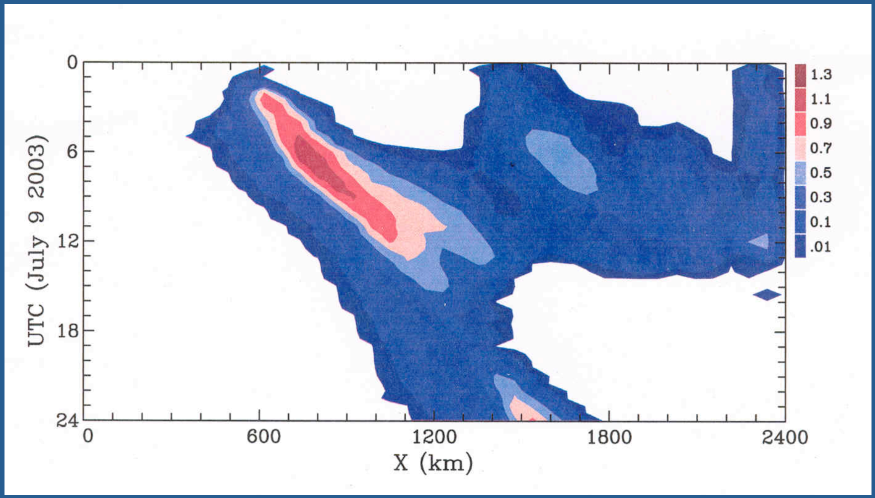
$$\dot{Q}_m(p,t) = \alpha_2 \dot{Q}_c(t) \sin \frac{p_s - p}{p_* - p_t} \qquad p_t \le p \le p_*$$

Q_c = parameterized *convective* heating

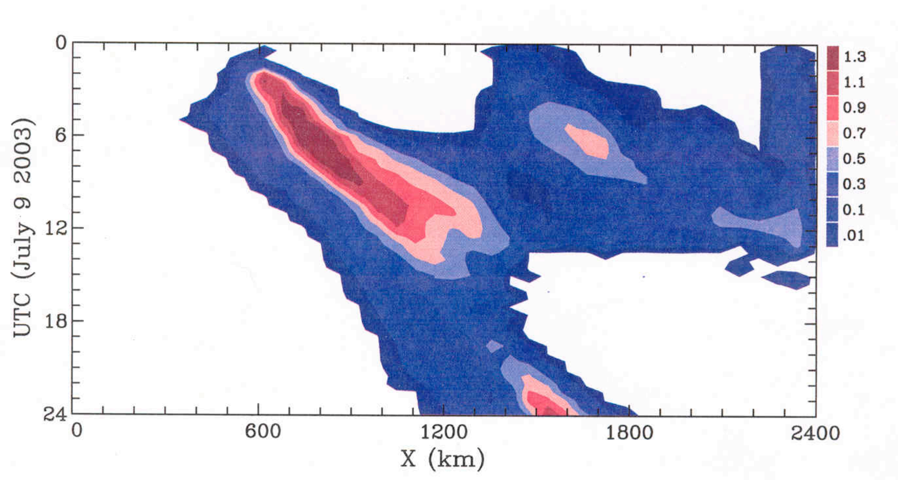


Moncrieff and Liu (2006)

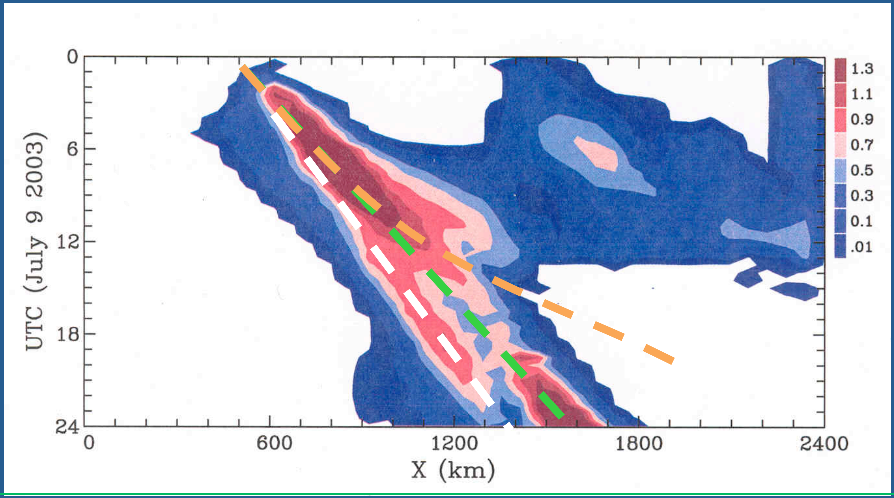
Δ = 60 km



Cumulus parameterization

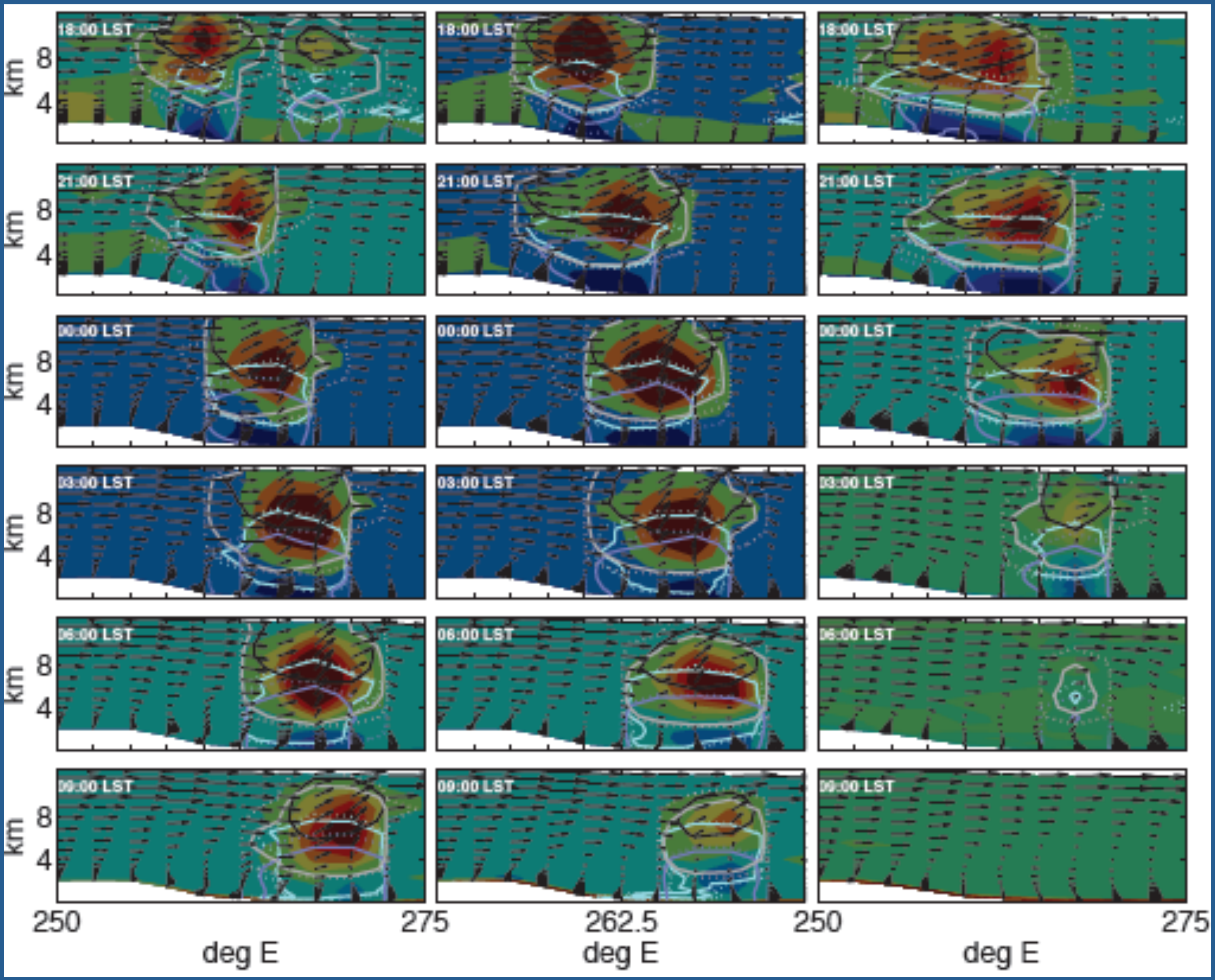


Cumulus + mesoscale param



Cumulus + mesoscale param + grid-scale

Propagating orogenic convective systems in SPCAM



Prichard, Moncrieff & Somerville, PP BOG

Conclusions

- **Orogenic propagating convection not represented in climate models**
- **Even highest resolution global NWP models do not well represent the stratiform heating, mesoscale downdraft, If at all**
- **Parameterization framework for straiform heating/ mesoscale downdrafts defined**
- **Explicit dynamical & numerical models a baseline for investigations of SP-CAM propagating convection over US**
- **… pathway to quantifying role of propagating mesoscale convection in the MJO**

Transpose-AMIP simulations of the MJO associated with Year of Tropical Convection (YOTC)

Mitch Moncrieff, NCAR

Year of Tropical Convection (YOTC)

Mitch Moncrieff, NCAR
Duane Waliser, JPL/Caltech

Co-chairs, YOTC Science Planning Group

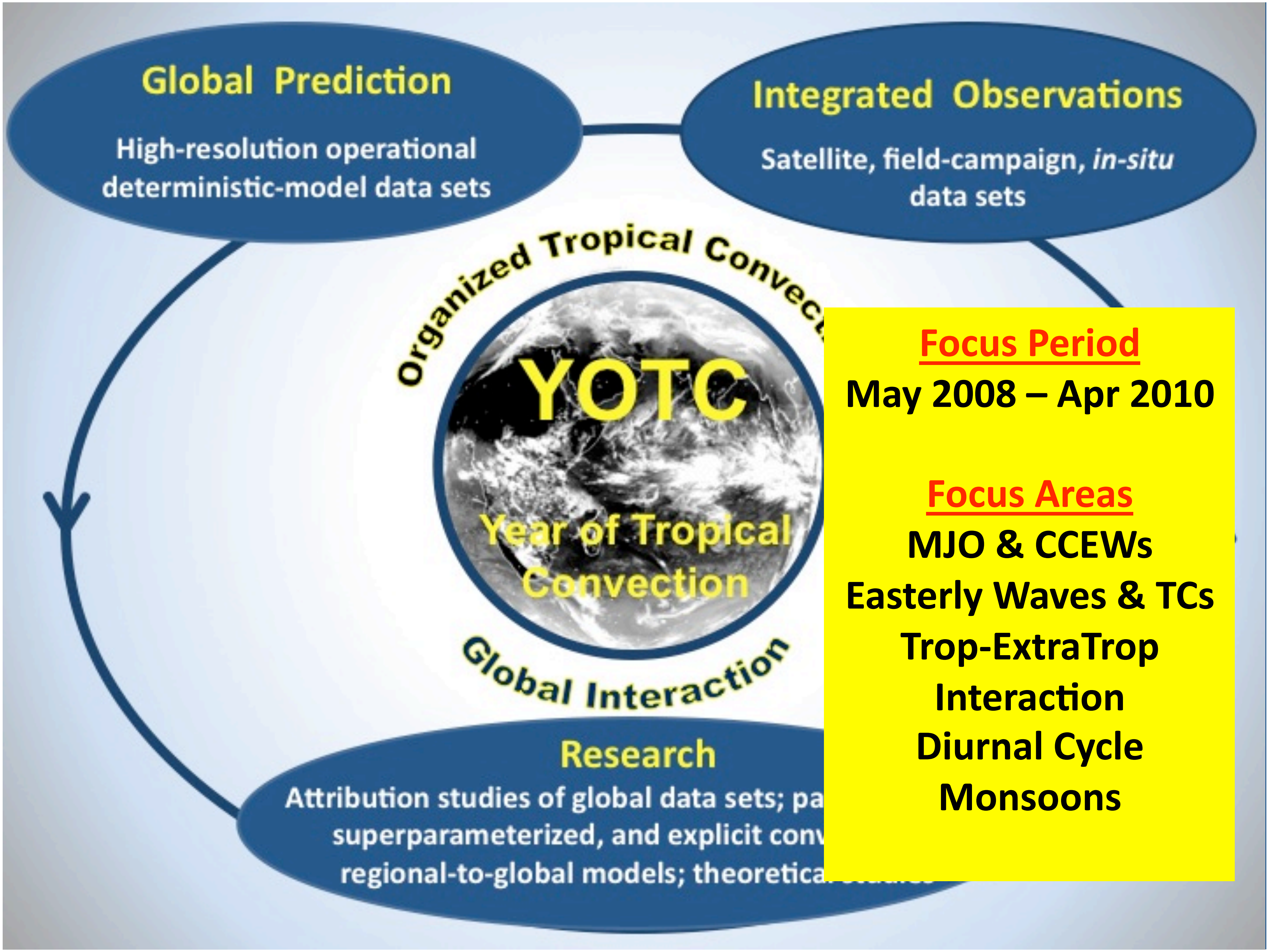
WWRP WORLD WEATHER RESEARCH PROGRAMME

THORPEX A World Weather Research Programme

WMO

WCRP

Contribution to Seamless Weather-Climate Prediction


Global Prediction
High-resolution operational deterministic-model data sets
Integrated Observations
Satellite, field-campaign, *in-situ* data sets
Organized Tropical Convec
YOTC
Year of Tropical Convection
Global Interaction
Research
Attribution studies of global data sets; pa
superparameterized, and explicit conv
regional-to-global models; theoretica
Focus Period
May 2008 – Apr 2010
Focus Areas
MJO & CCEWs
Easterly Waves & TCs
Trop-ExtraTrop Interaction
Diurnal Cycle
Monsoons

"Virtual Field Campaign" approach utilizing existing resources with model, parameterization & forecast improvement as the prime objective.

New/Improved Resources

- Satellite Observations (e.g., EOS)
- In-Situ Networks (e.g., ARM, CEOP)
- GOOS (e.g., TAO, RAMA, drifters)
- IOPs (e.g., VOCALS, T-PARC,

+

Conceptual Framework

FGGE,
GATE,
TOGA
COARE

=

YOTC

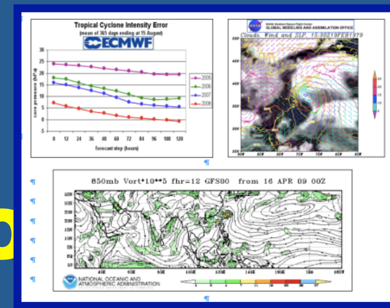
"Virtual Field Campaign"

Planning Phase completed

- Science Plan – Published
- Implementation Plan drafted
- YOTC Project Office at NCAR, funded by NSF, NOAA, NASA

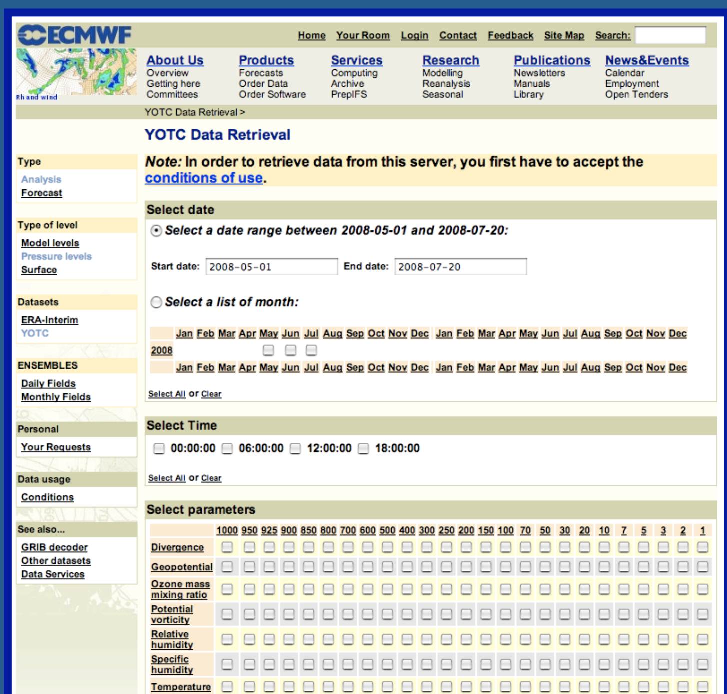
- [Website http://www.ucar.edu/yotc](http://www.ucar.edu/yotc)
- Successful YOTC Sessions – Fall AGU'08, AMS'09, Spring AGU'09, Fall AGU'09, AGU'10,

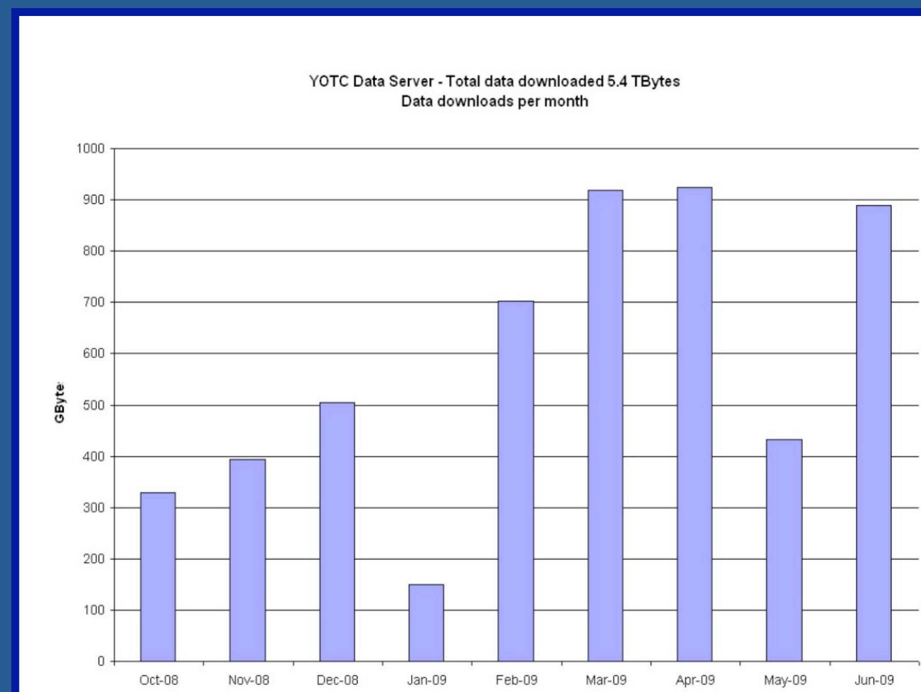
Analyses, Forecasts & Special Diagno



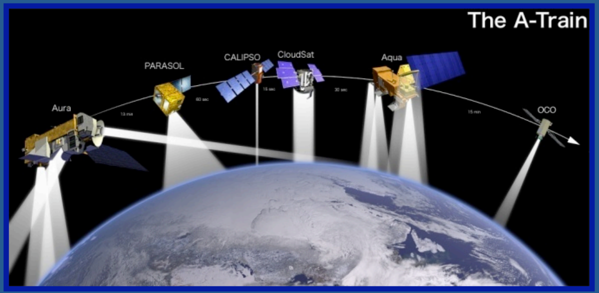
- **High-resolution, global analysis and forecast data sets available from ECMWF, NCEP and GMAO/NASA (e.g. T799 = 25km ECMWF) + diagnostic fields**

ECMWF Registered users ~ 166; Requests ~ 12600 (~2000/month), M. Miller as of July '09



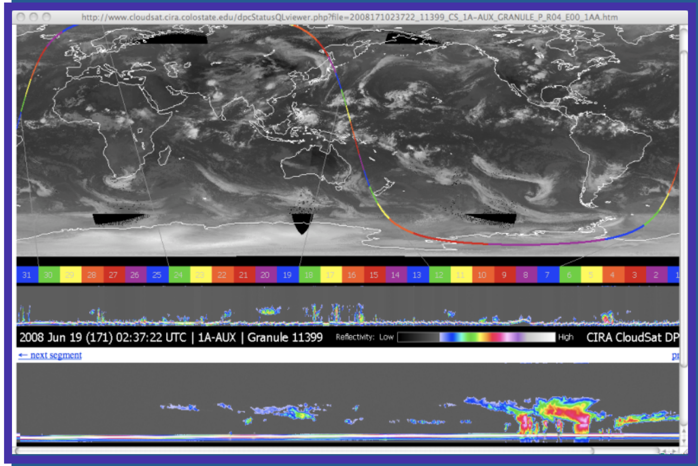


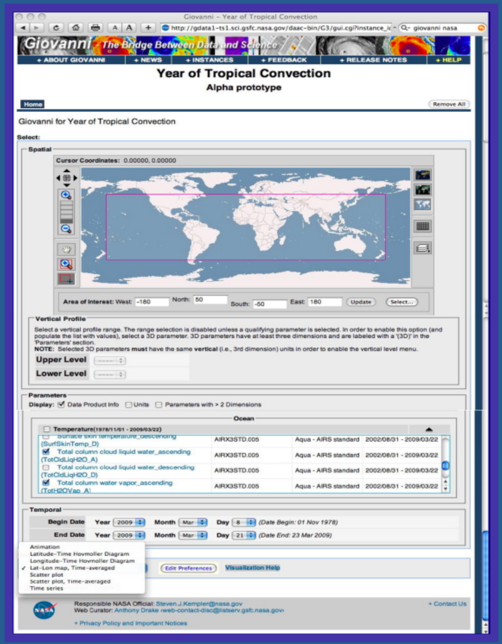
Satellite Data

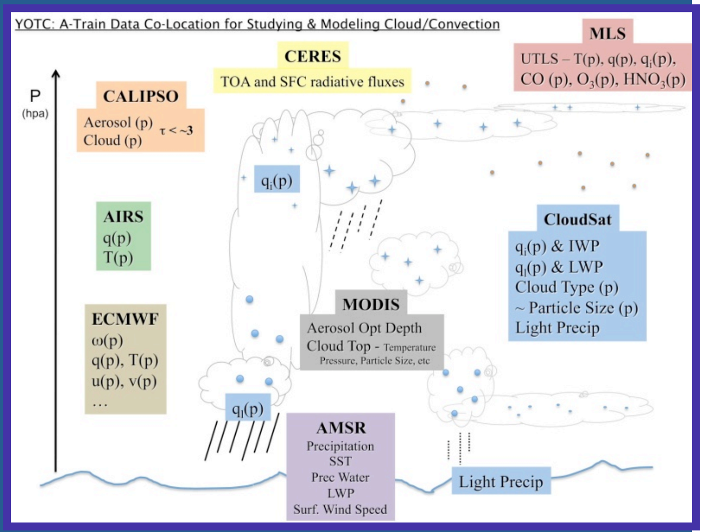


Key satellite data (e.g., A-Train, TRMM centric geostationary) identified, funding from NASA to develop for YOTC:

- **Giovanni-based dissemination framework - YOTC-GS.**



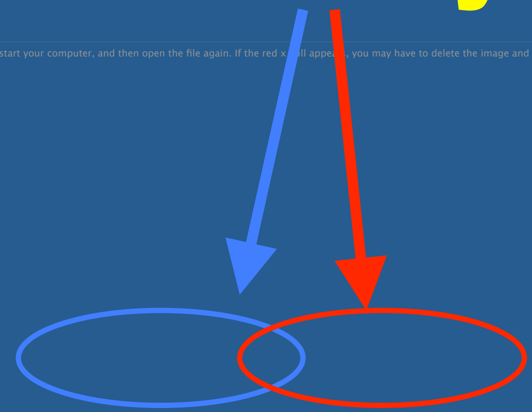




Field Programs & Synoptic Periods

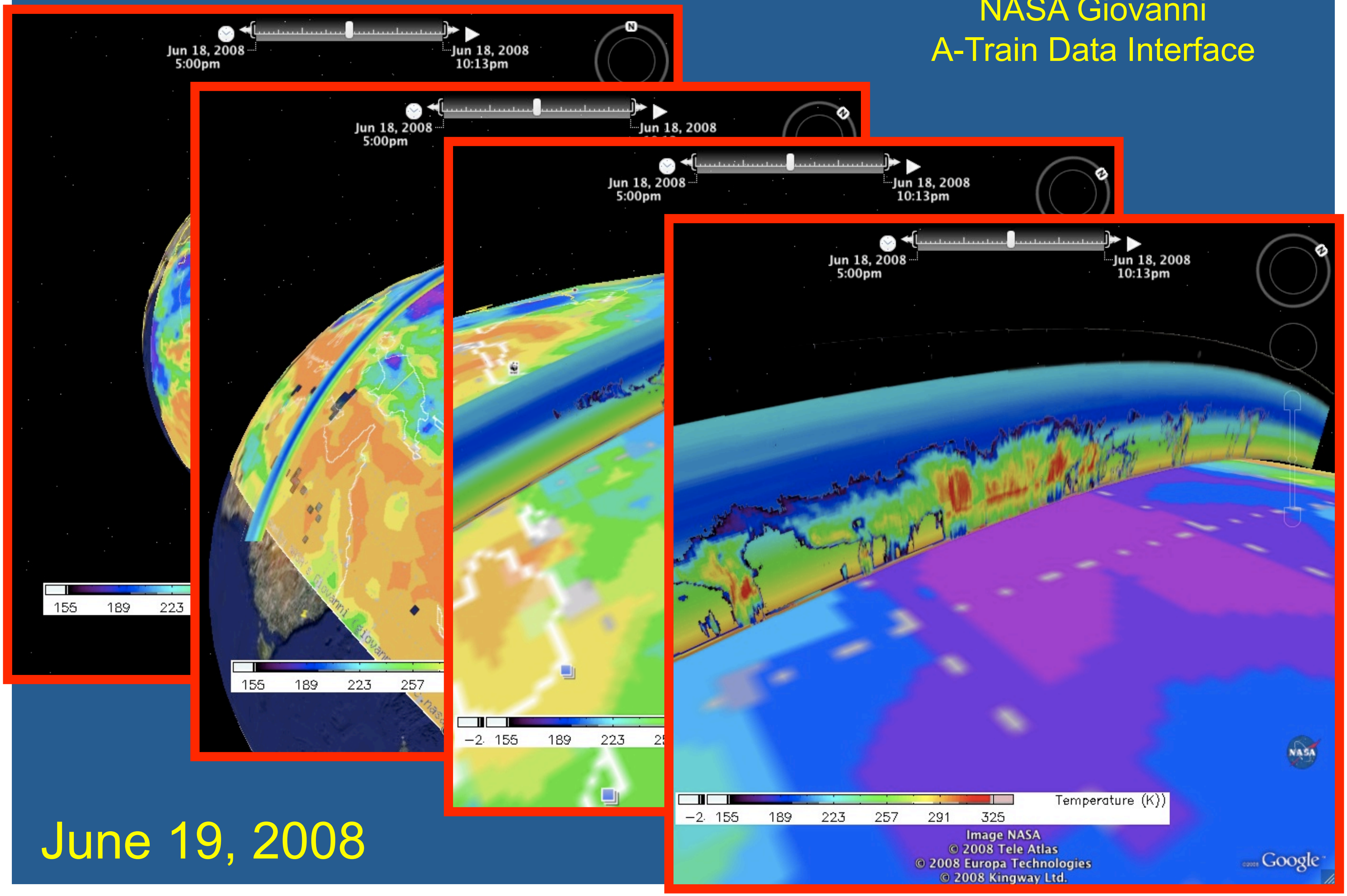
- Field programs during “Year” benefit from and contribute to YOTC.
- Synoptic periods of interest have been identified for research
- YOTC documents La Nina and El Nino episodes, and recent anomalous weather

Kelvin Wave Activity: June 19



Satellite Data Analysis & Dissemination

NASA Giovanni
A-Train Data Interface



June 19, 2008

YOTC's International Coordinated Research

Weather as an initial-value problem for climate (seamless prediction)

- **Transpose-AMIP 5-day hindcasts** :

i) WGNE CMIP5 Model studies.

ii) Multiple GCMs – European GEWEX/EUCLIPSE project.

iii) YOTC Transpose AMIP and other High-Res Experiments Multi-model (e.g., CMIP5, CAM, SPCAM), 5-day forecast every YOTC day; also NICAM, GEOS, NCM for selected events

MJO & Convectively-Coupled Equatorial Waves

- **High Resolution (~1 km -10 km) hindcasts: Cascade, NICAM, GMAO & NCAR.**
- **Multi-model 20-year hindcasts, CLIVAR Asian Australian Monsoon Panel (AAMP); Asian Monsoon Years (AMY)**
- **YOTC MJO Task Force**
- **Northward propagation of ITCZ, boreal summer**
- **Goddard Multiscale Modeling Framework (MMF)**