32nd Conference on Hurricanes and Tropical Meteorology. San Juan, Puerto Rico

Decoupling of Convectively Coupled Kelvin Waves (CCKWs)

Super Cloud Clusters (SCCs) versus Moist Kelvin Waves (MKWs)

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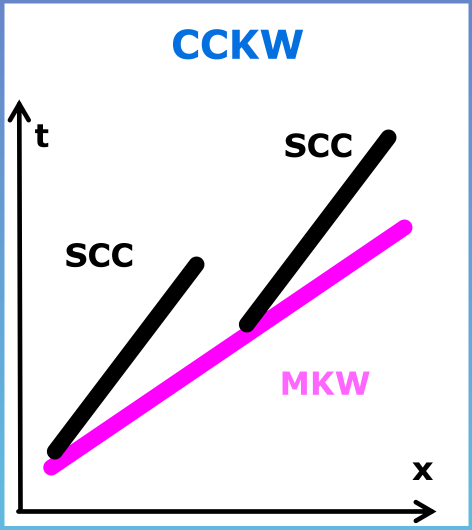
CCKW, SCC, MKW

WORKING QUESTIONS:

- Can a SCC be considered as a CCKW or vice versa?
- How does the structure and phase speed of SCC/CCKW change along its life cycle?

OVERALL FINDINGS:

- A SCC propagates slower than its associated **MKW**. When the separation is sufficiently large, the SCC decays.
- Simultaneously, a new SCC forms ahead, nearly collocated with the MKW.
- The SCC-MKW separation is "continuous" in the vertical, when considering *mse*.



MODEL CONFIGURATION AND EXPERIMENTS

WRF model V3.4.1

Aquachannel

60ºS to 60ºN (L_y~13300km)
free-slip walls N-S
periodic boundary E-W
no map factors (β-plane)

SST PROFILE (forcing)

A) CONTROL
B) OBSERVED

from
Aquaplanet Intercomparison Project (AIP)
Aquaplanet Experiment (APE)

PHYSICS SCHEMES

Boundary Layer:	YSU
Radiation LW&SH:	Goddard
Microphysics:	Goddard GCE
Cumulus:	**Tiedtke**

L_x~40000km

Δ=139km

288x96 points

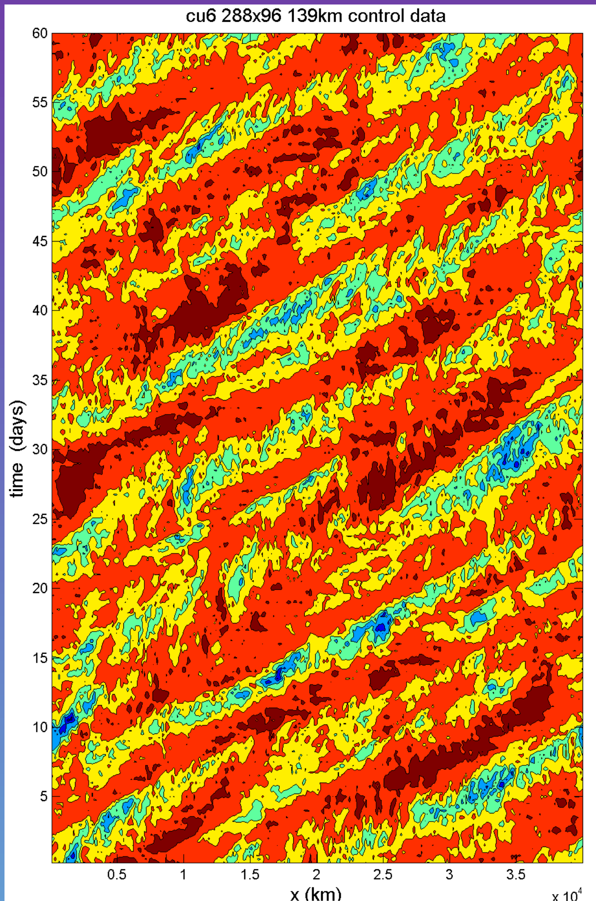
L_y

No seasonality (permanent equinox)

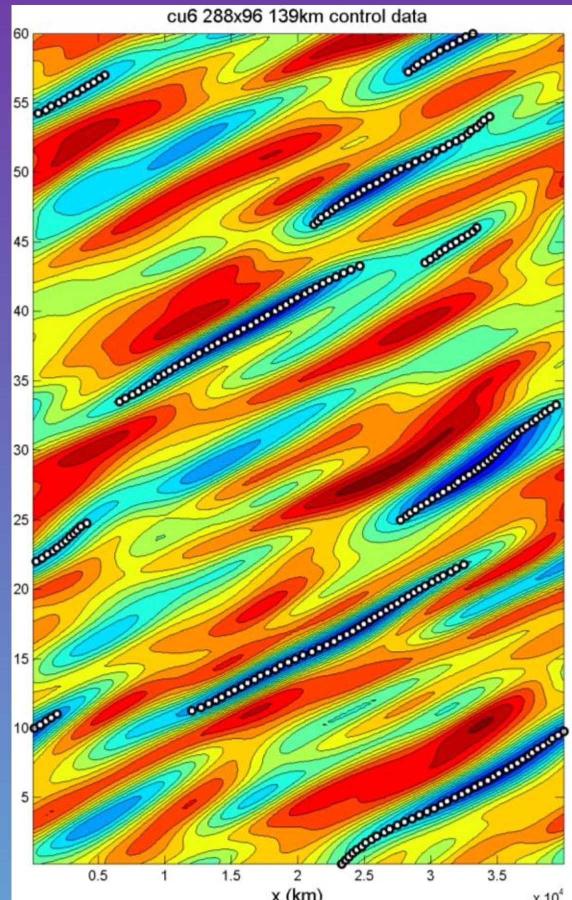
Initial conditions: Rest + thermodynamic sounding

Model spin-up: 1 year
Integration time: 1 year

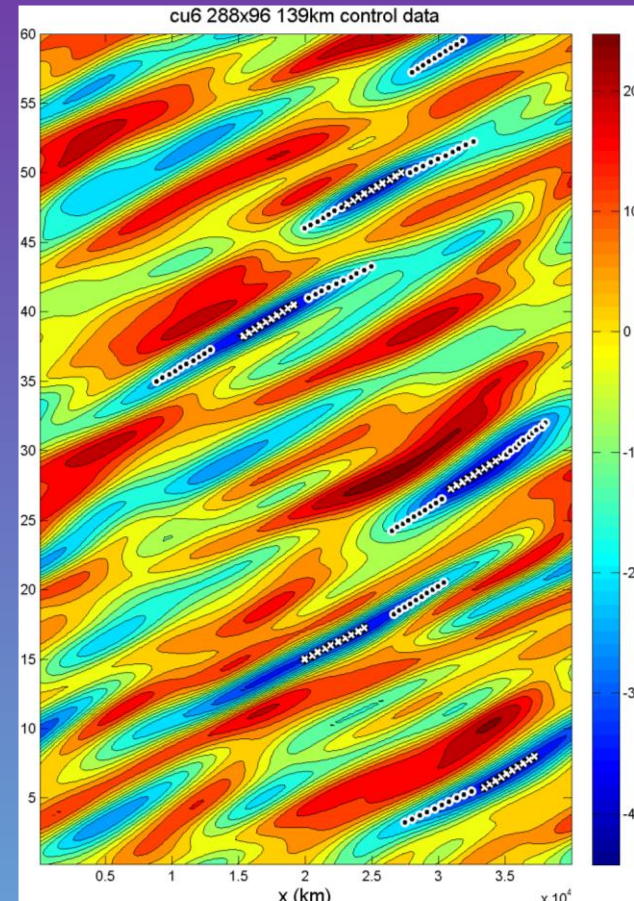
RAW OLR-S

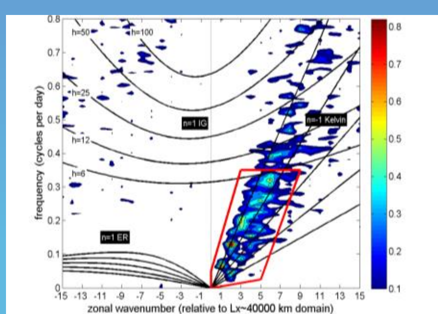


CCKW-FILTERED + AUTOMATIC DETECTION

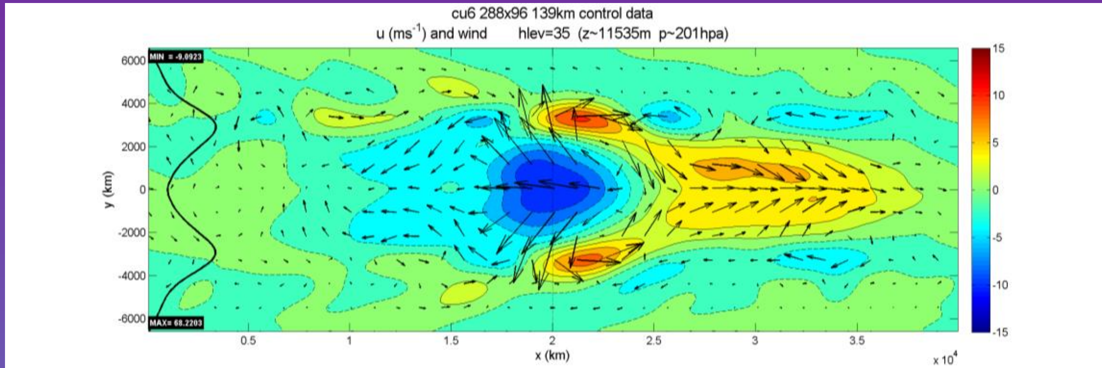


CCKW-FILTERED + IDEAL STAGES



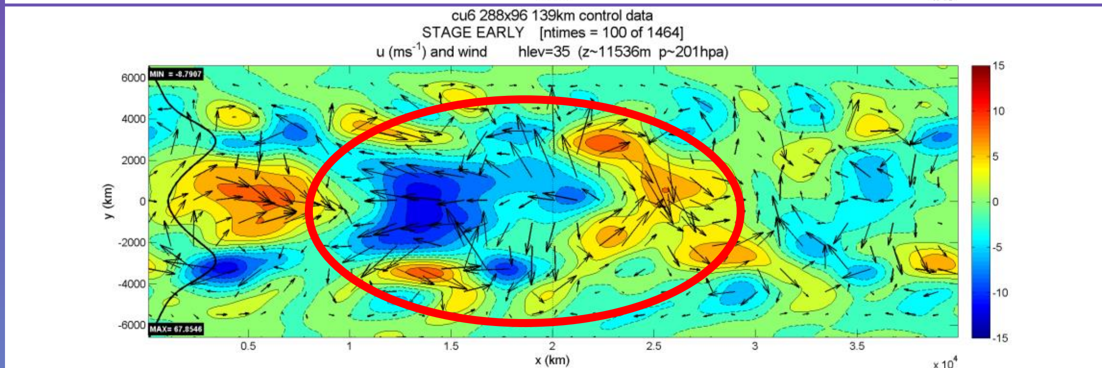


STAGES COMBINED REPRESENT ~25% OF THE SIMULATION PERIOD



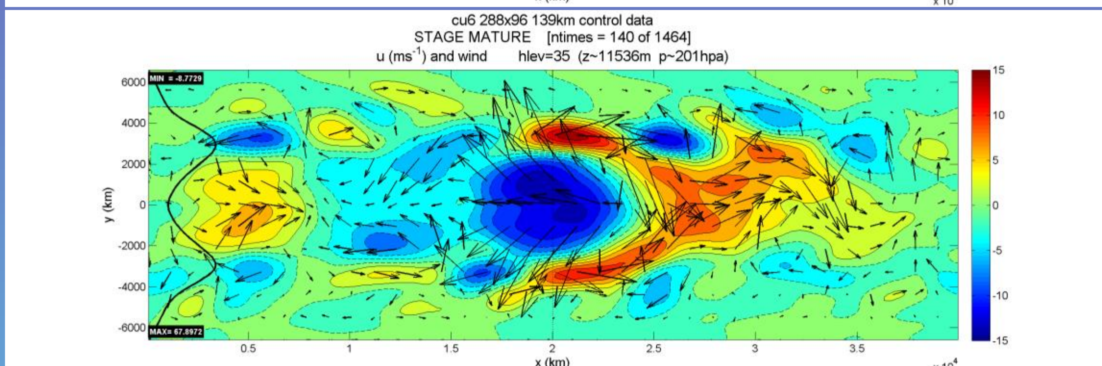
ALL-TIMES COMPOSITE

U*(x,y) at 200 mb

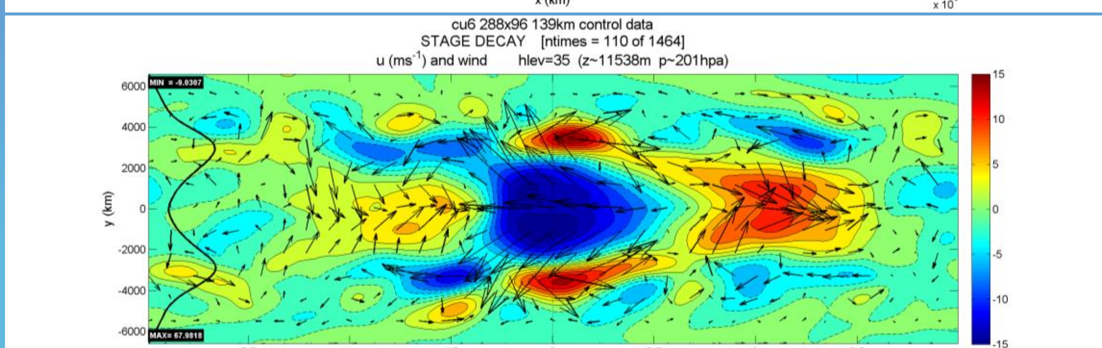


EARLY

U200 delay
Structure of upper level wind takes longer to adjust to CCKW dynamics



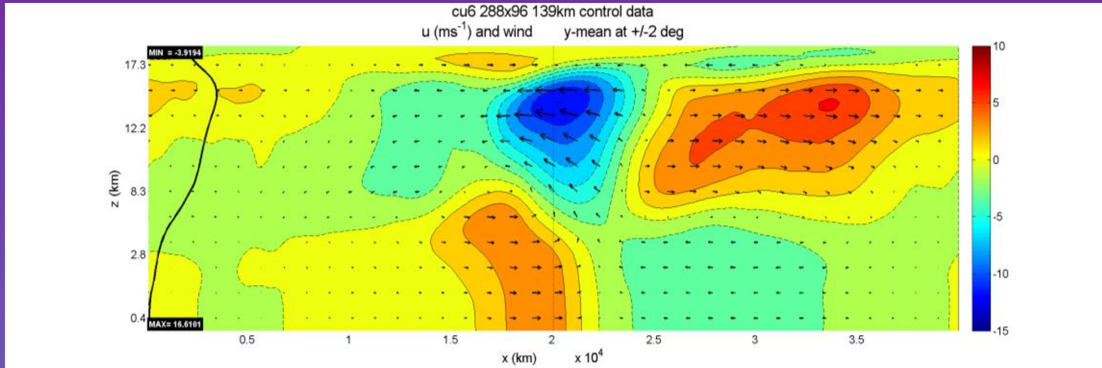
MATURE



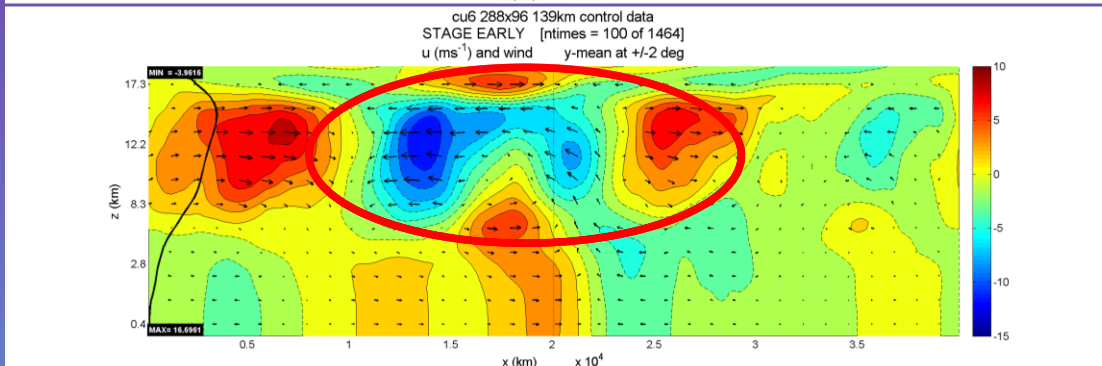
DECAY

ALL-TIMES COMPOSITE

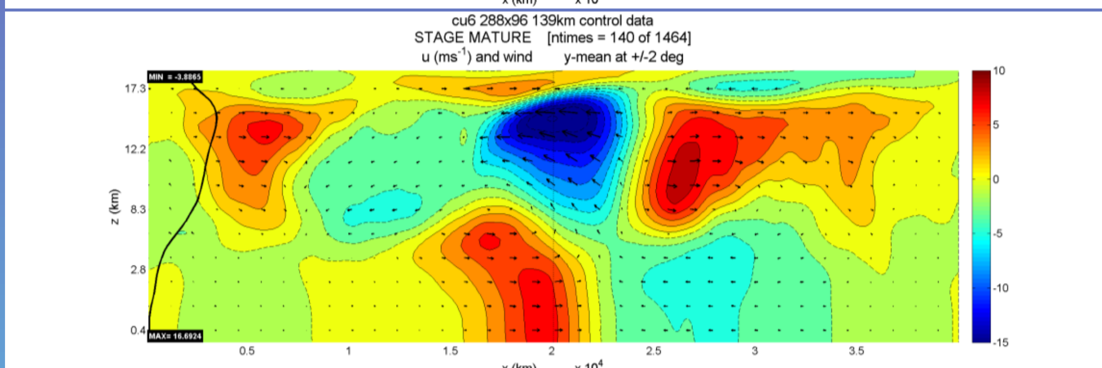
U*(x,z) AT THE EQ



EARLY



MATURE



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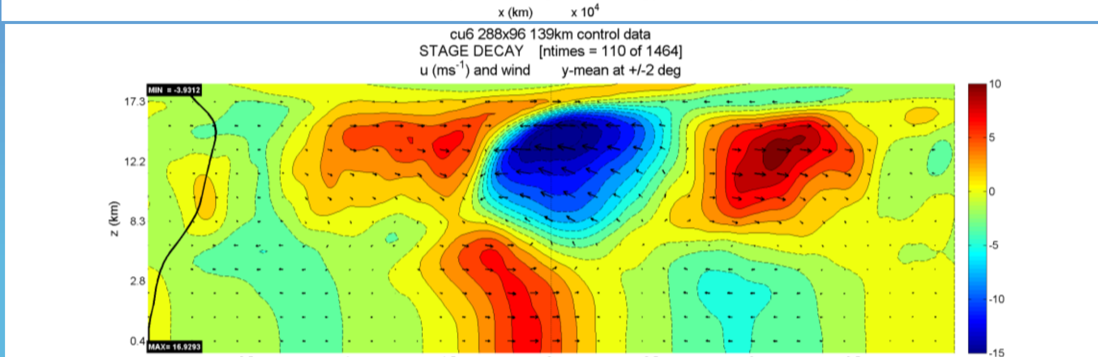
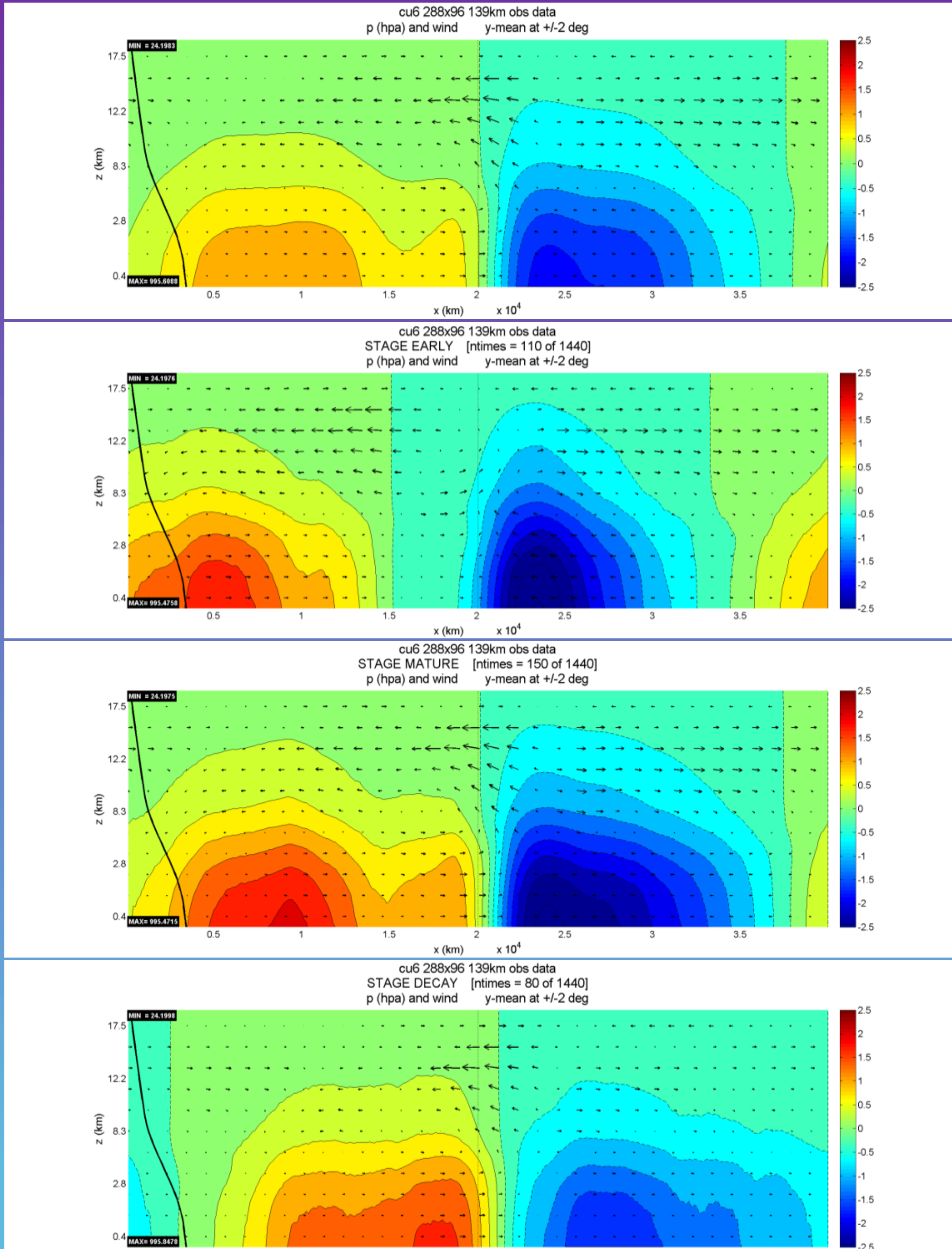




ALL-TIMES COMPOSITE

P*(x,z)
AT THE EQ.

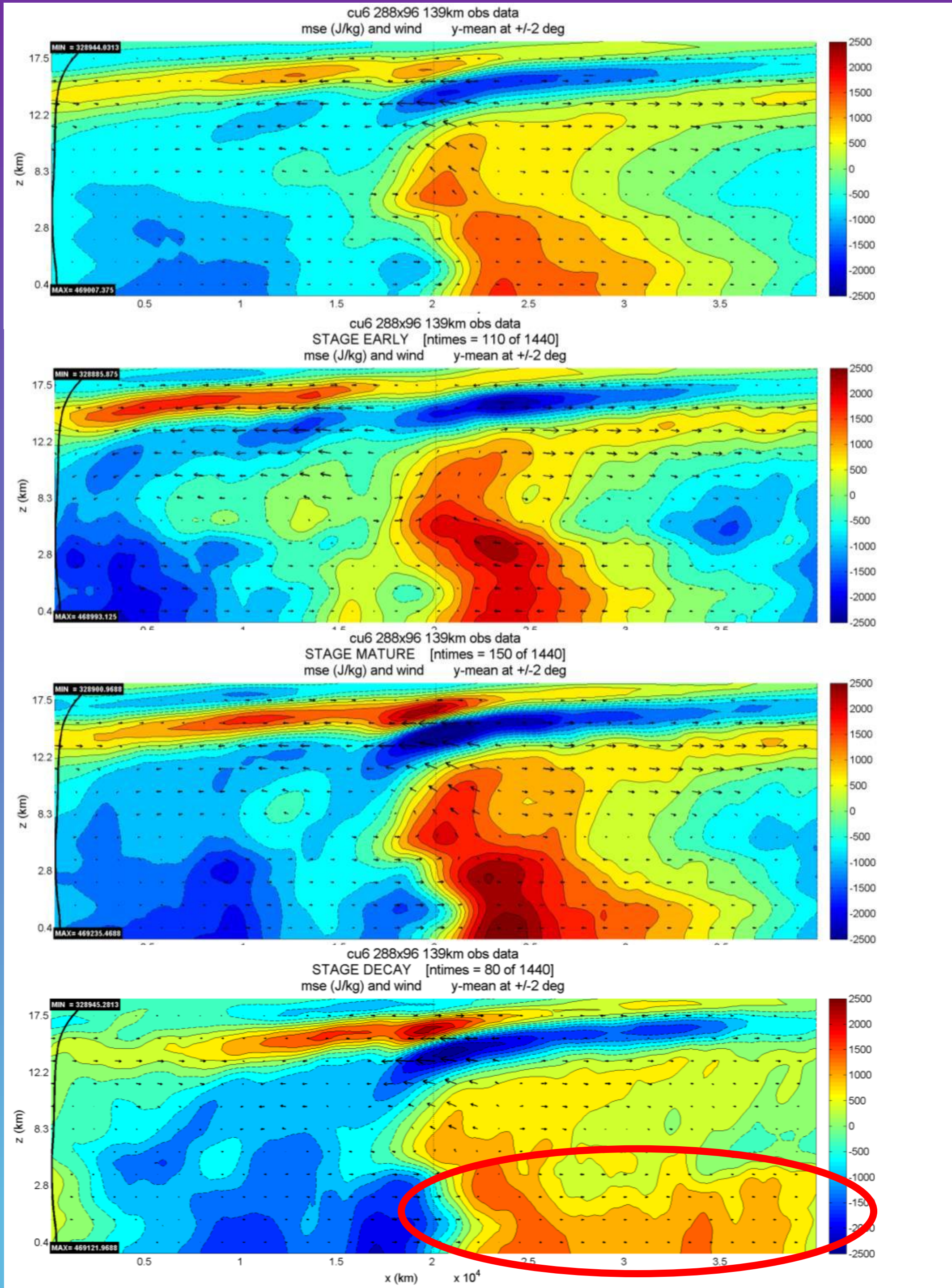
EARLY

DIFFERENCES IN:

- MAGNITUDE
- SPREAD
- LOCATION
- SECONDARY PEAKS

MATURE

DECAY



ALL-TIMES COMPOSITE

MSE*(x,z)
AT THE EQ.

EARLY

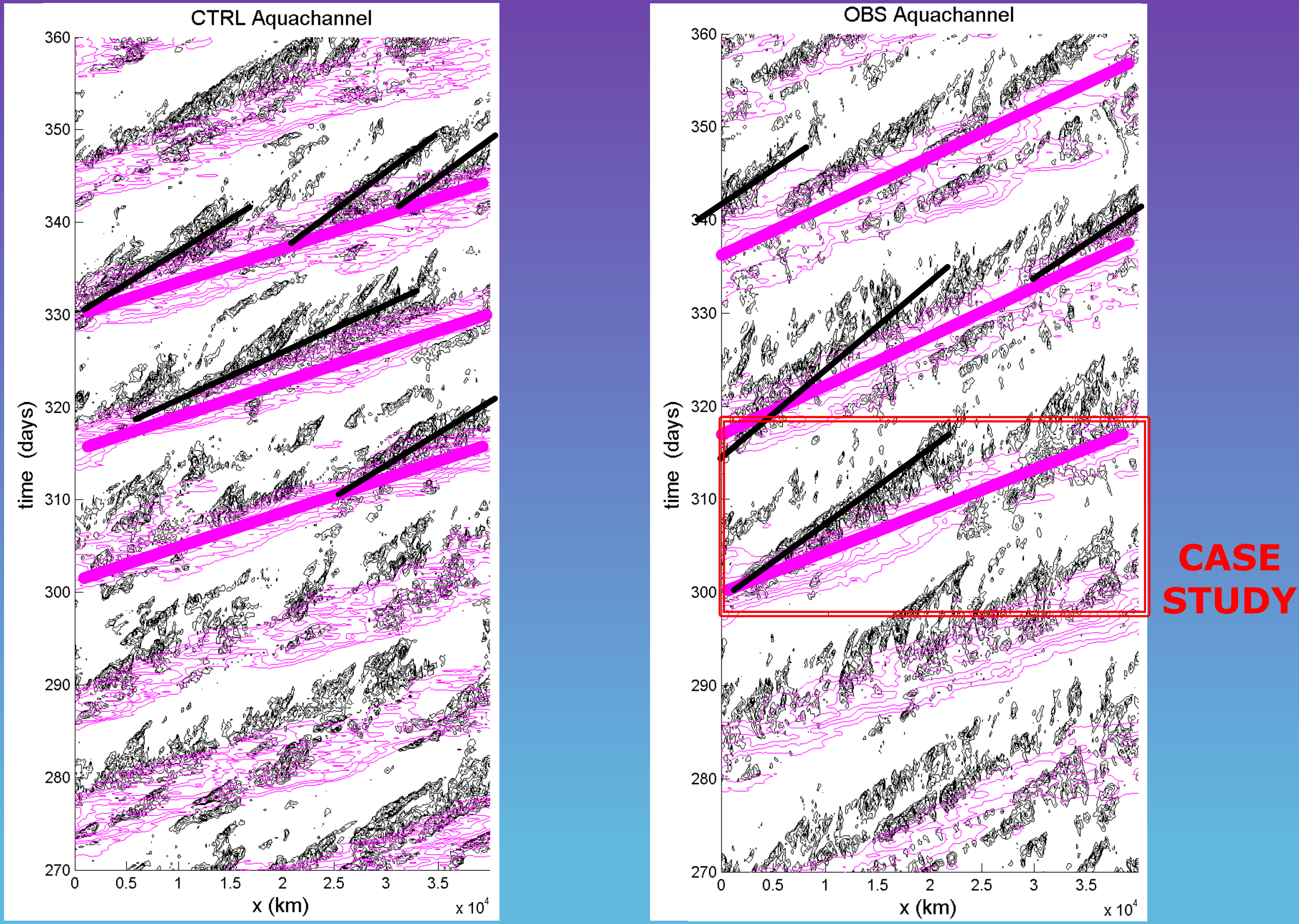
MATURE

Boundary layer MSE
Broad signal

DECAY

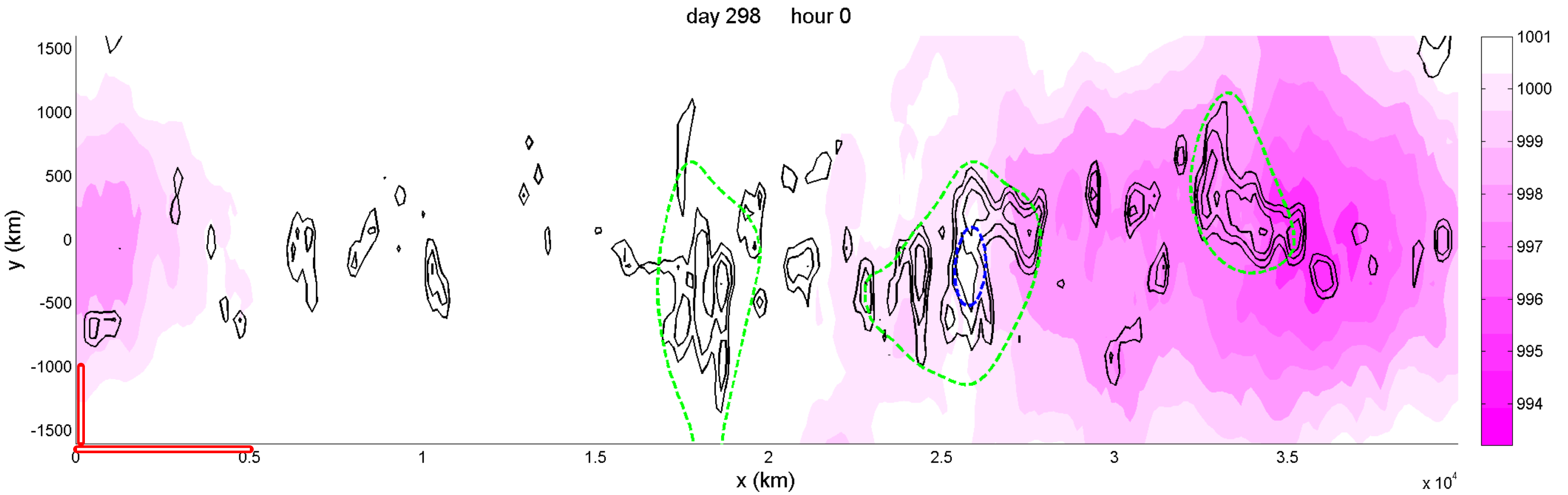
OLR AND PSFC: ZONAL TIME DIAGRAMS

NEGATIVE ANOMALIES; MEAN IN [-15°:15°]



OLR AND PSFC: HORIZONTAL STRUCTURE

CASE STUDY: DAYS 298-321 (OBS SST simulation)

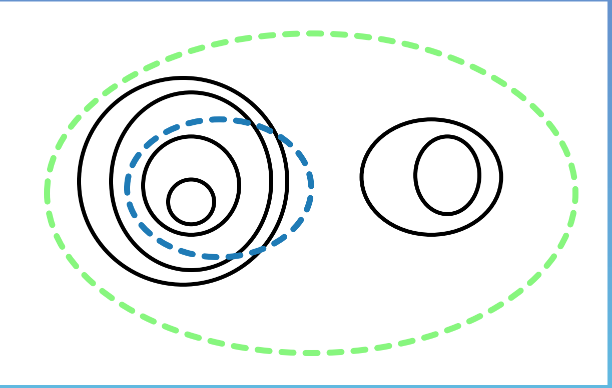


ASPECT RATIO
x/y = 2.3

OLR CONTOURS

Cloud Clusters (CCs) and Stratiform region
4 curves: 120, 150, 180 and 210 W/m2
(1 time smoothing)

Super Cloud Clusters (SCCs)
OLR was smoothed another 50 times
Green 240 W/m2
Blue 210 W/m2
Red 180 W/m2



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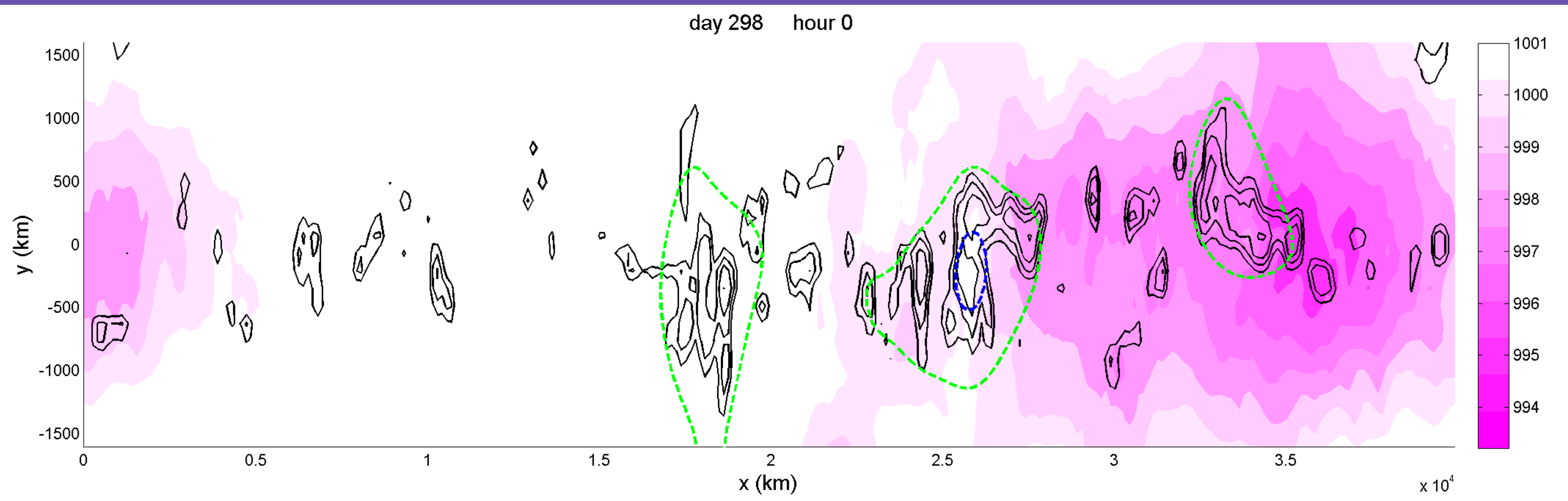

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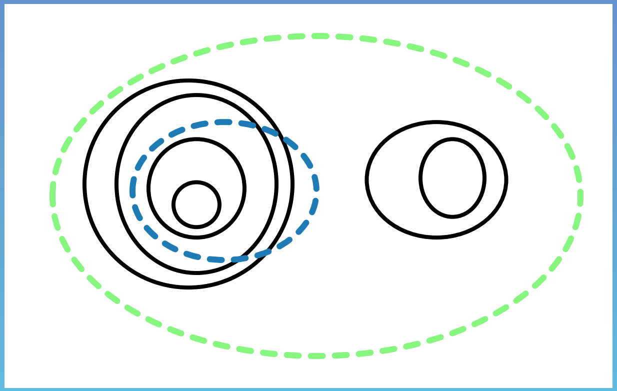
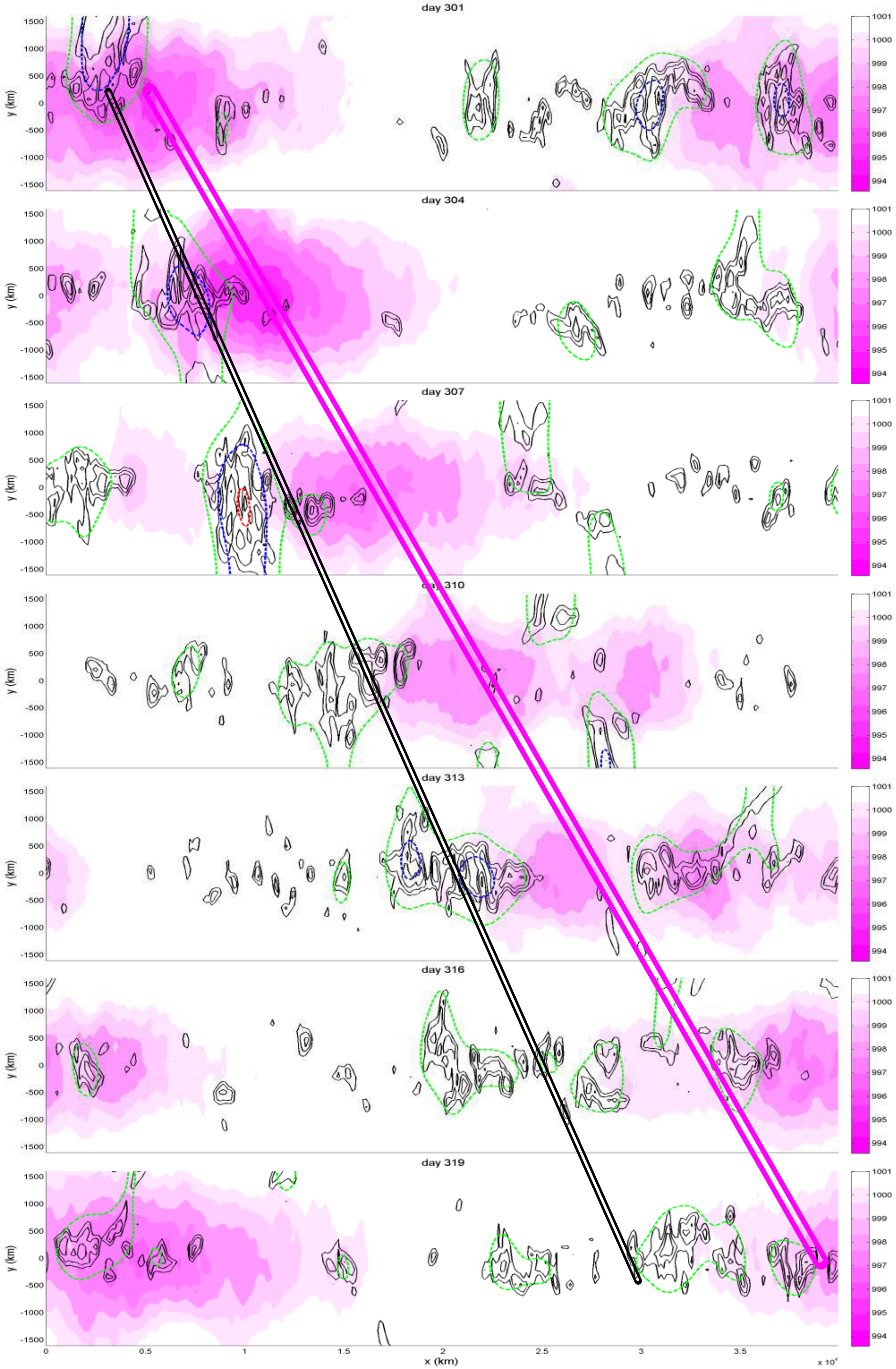




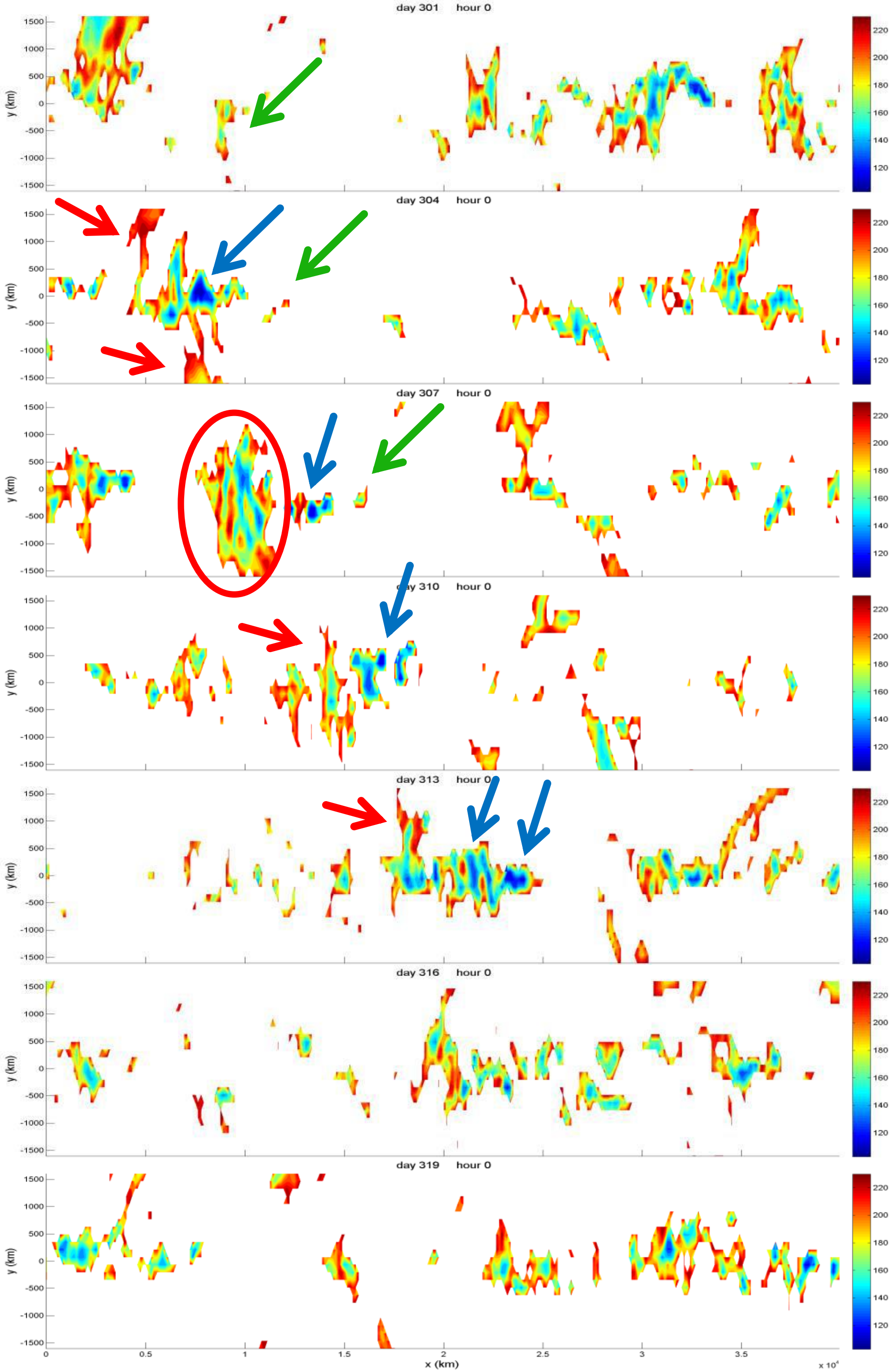
DAYS 301-319

Pressure

$C_x \sim 21.2$ m/s

SCC

$C_x \sim 17.4$ m/s



Precipitation organization within SCCs

1) Shallow convection

ahead

2) Deep convection

center

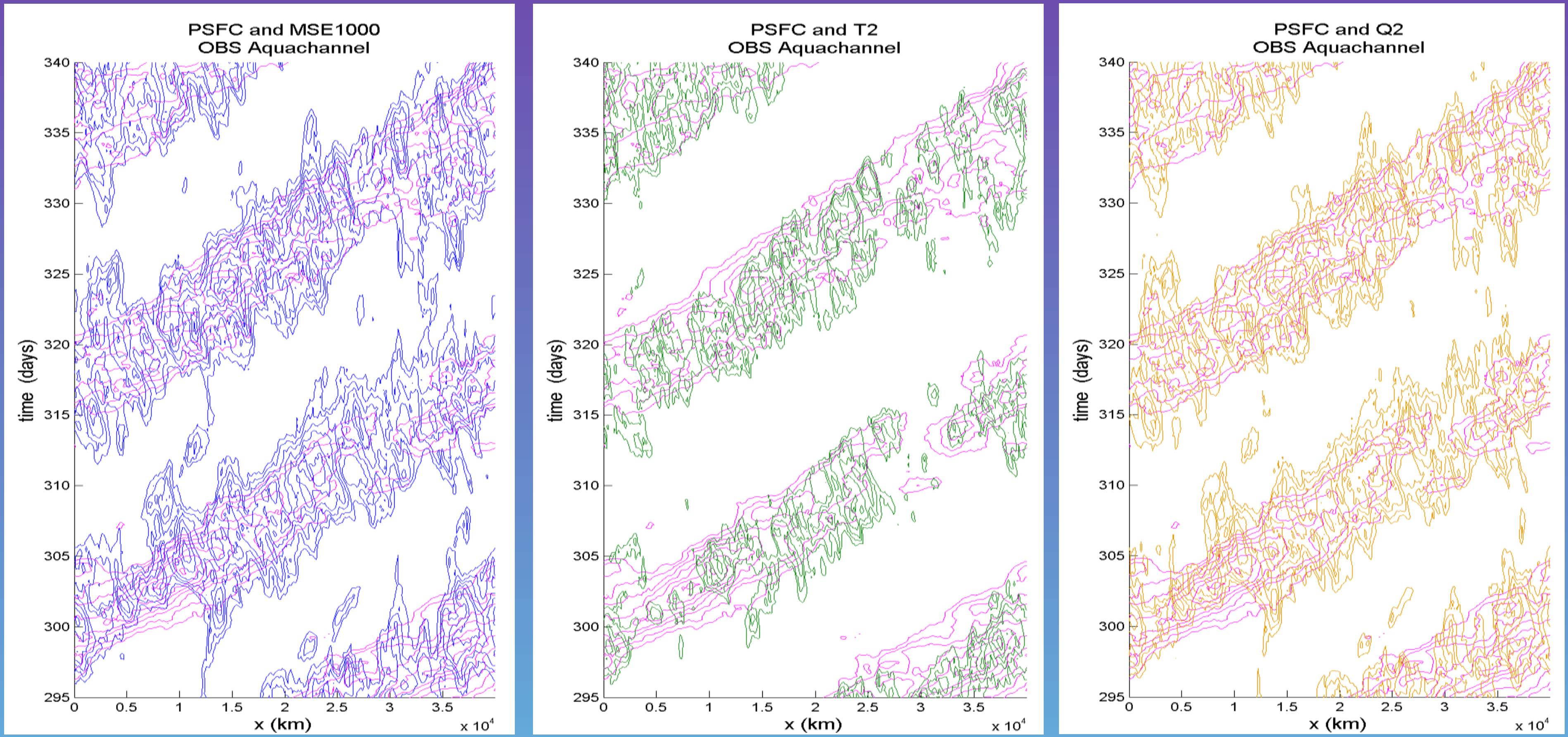
Cloud Clusters (CCs)

3) Stratiform precipitation

behind

Super Convective Systems (SCSs) or Mesoscale Convective Systems (MCSs)

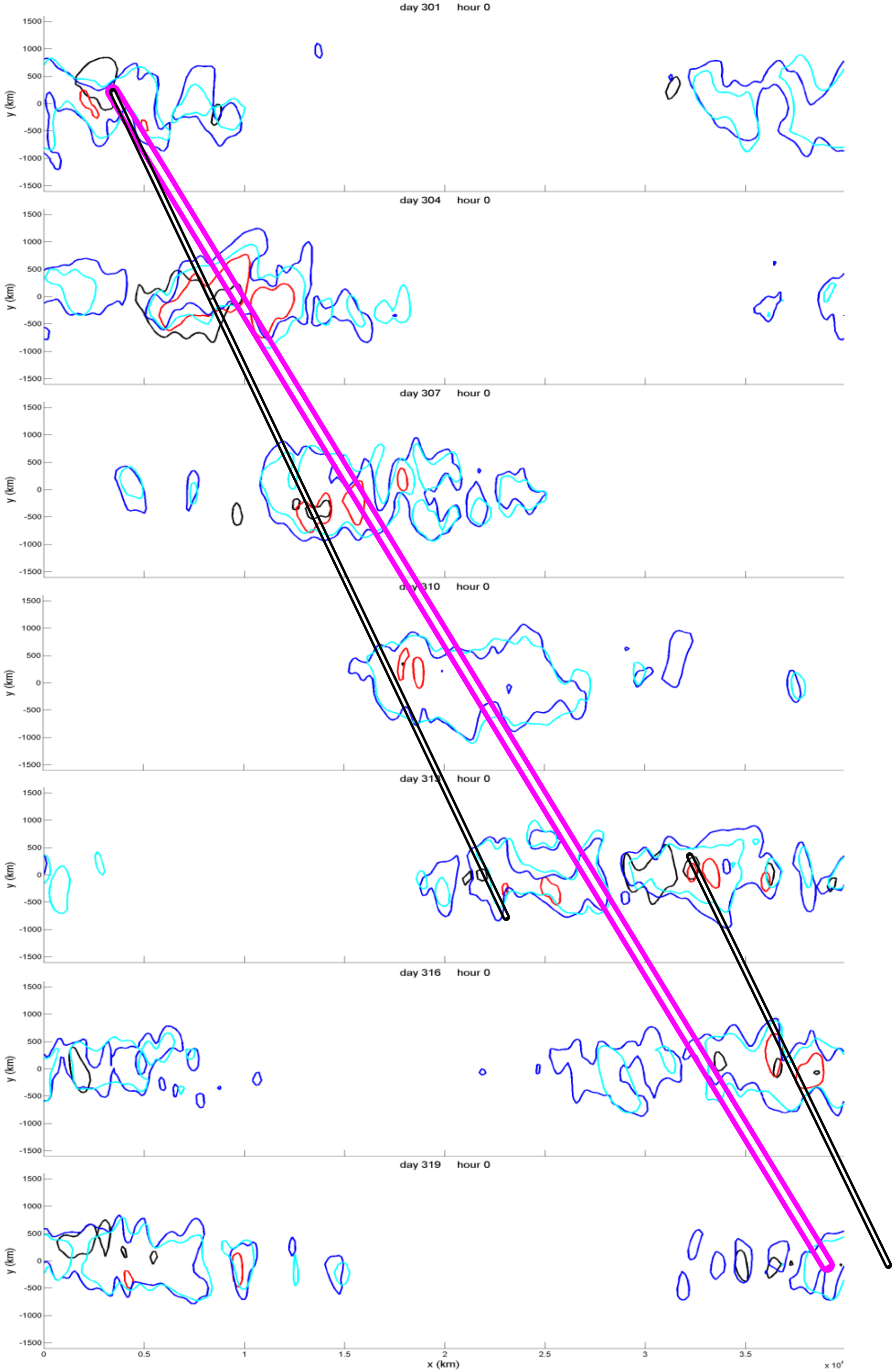
What other variables are coupled to the "dry Kelvin mode" (PSFC)?



$$mse = g\,z + c_p\,T + L\,q$$

define a **Moist Kelvin Wave**

not dry, not saturated



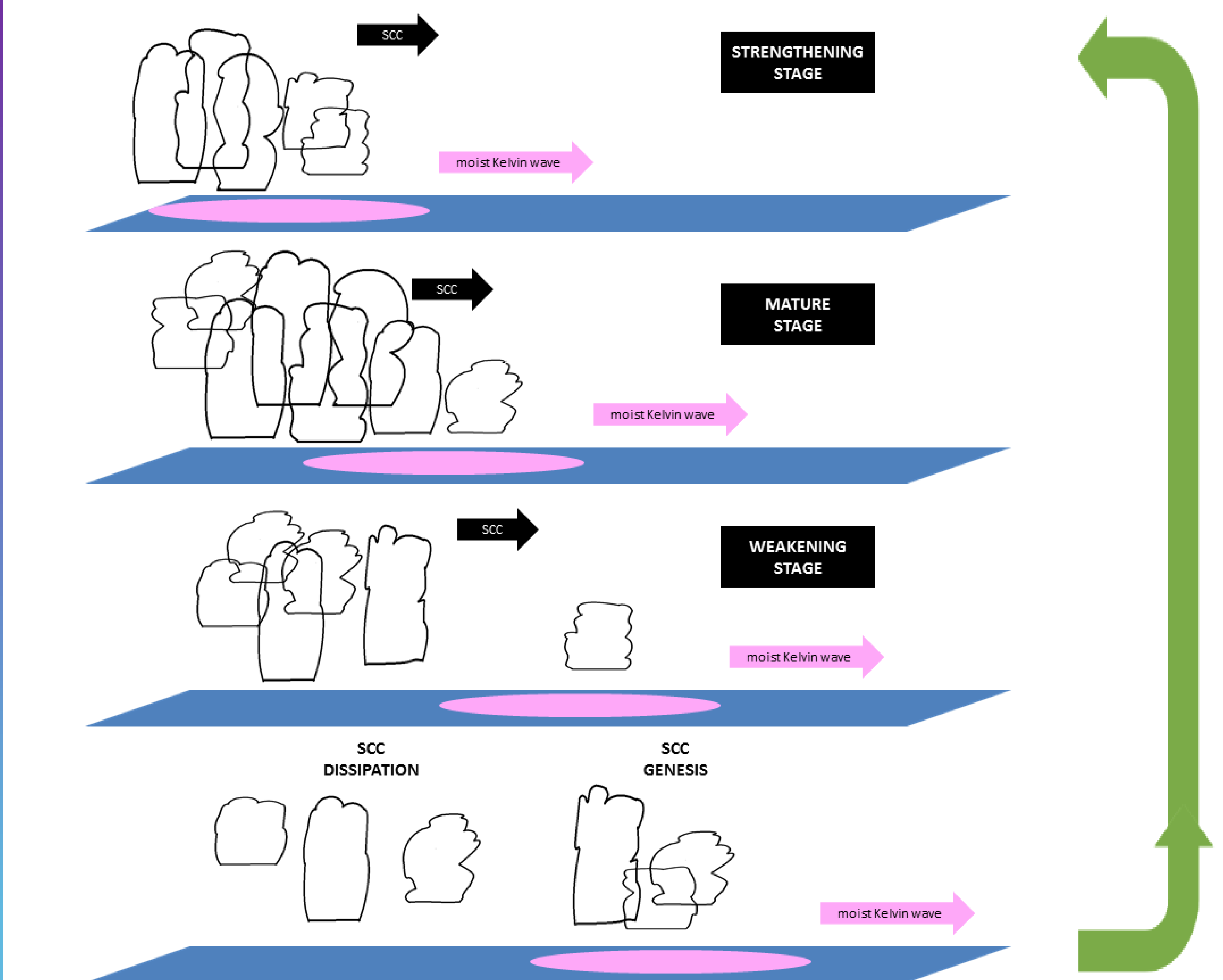
A single contour of smoothed *mse* is plotted for 4 vertical levels.

The corresponding high *mse* values were computed as MAX−(MAX−MIN)/10, for each level

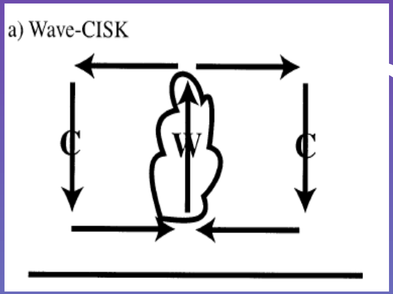
mse 1000 mb
mse 850 mb } **MKW**

mse 685 mb
mse 500 mb } **SCC**

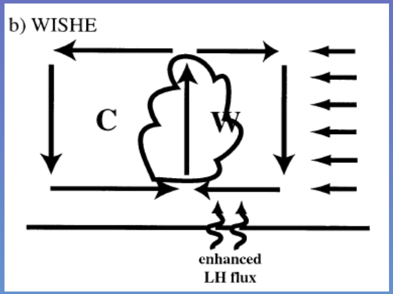
Increasing westward tilt with height of *mse*>0,*
until the slow-moving upper section weakens as the SCC dissipates.


SCC
STRENGTHENING STAGE
moist Kelvin wave
SCC
MATURE STAGE
moist Kelvin wave
SCC
WEAKENING STAGE
moist Kelvin wave
SCC DISSIPATION
SCC GENESIS
moist Kelvin wave

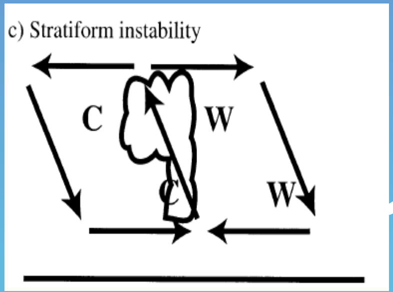
The dynamics of developing CCKWs has been explained by several theories



Lindzen (1974)

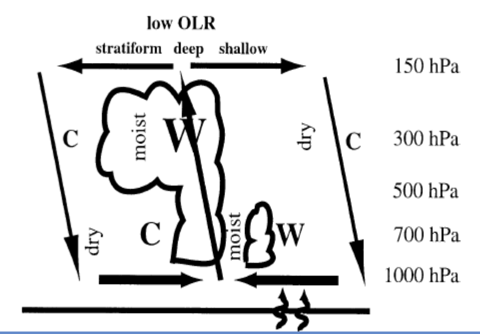


Neelin et al (1987)
Emanuel (1987)



Mapes (2000)

Several aspects from our results can be explained by (and provide additional evidence to)
the proposed CCKW dynamics in SK03:



Straub and Kiladis (2003)

- **preexistent MKW** -> Enhanced surface winds -> evaporation -> moistened BL
- The positive temperature anomalies are provided by **shallow convection**.

  Deep convection is initially inhibited. (large CIN).
- The convection wave lags behind the MKW: **deep convection** is triggered.

  Organized convection - large-scale circulation feedbacks (WISHE, wave-CISK mechanisms).
- **SCC and MKW separation**: pronounced westward tilt of height of *mse*.

  Shallow (ahead)-deep-stratiform (behind) structure (stratiform instability theory)

Previously: "Coupled Phase" of the CCKW

genesis strengthening mature stage → perpetual ?

This study

genesis strengthening mature stage **weakening** **dissipation**

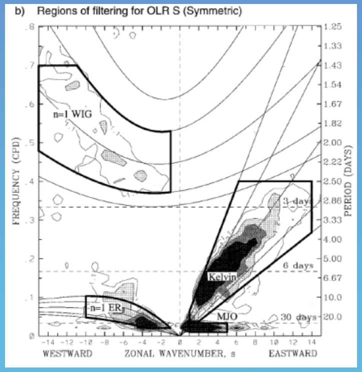
- No more positive feedbacks for the SCC
- SCC-MKW Decoupling

Revisiting the concept of Convectively Coupled Kelvin Waves

Terms SCC, CCKWs, Kelvin wave are usually interchangeably used

***Power spectra**: Coupling between Matsuno (1966) SW modes and observations (WK99)*

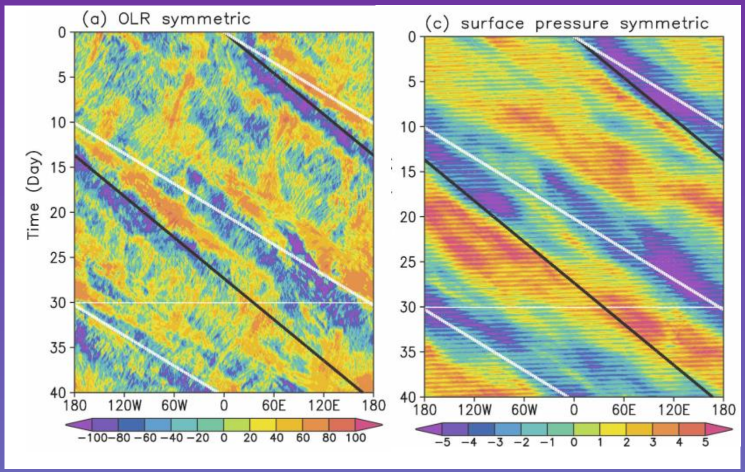
***CCKW composite Structure**: Coupling between convection and dynamics (OLR, pp, div, U, mse, T, etc)*



Nasuno et al (2008)

NICAM MODEL: AQUAPLANET WITH EXPLICIT CONVECTION (dx= 7km)

-Found and analyzed the Pressure (k=1) and SCC (k=2-3) waves separately
BUT
-Their interaction was not addressed
-Simulation was a "case study" (run for 40 days)



RESULTS OF OUR ANALYSIS MORE ROBUST:
2 SIMULATIONS, run for 1 year

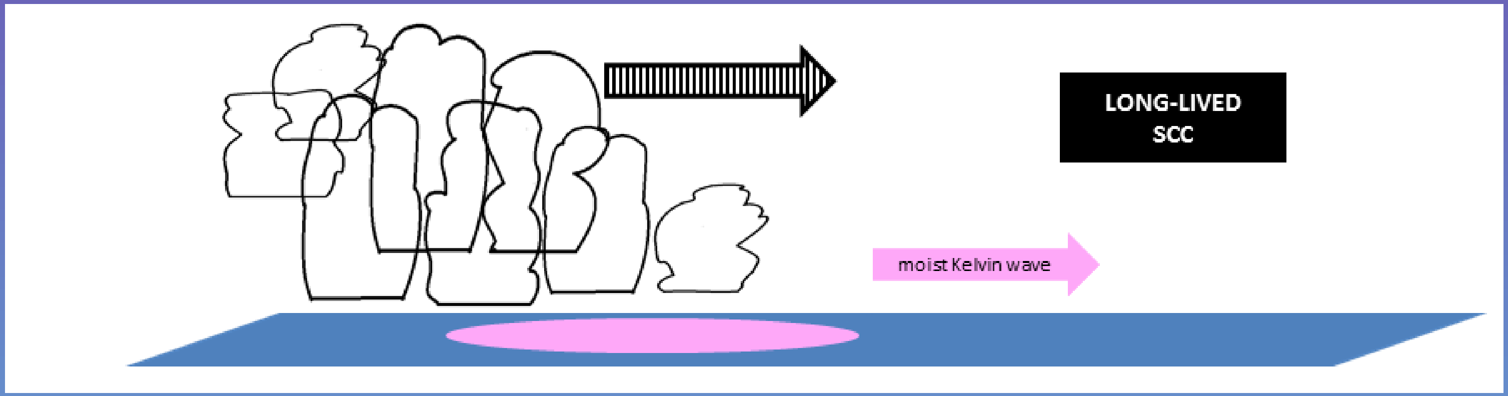
REMAINING QUESTIONS

The modulation of the SCC by the MKW is strong… Is the MKW modulated by the SCC?

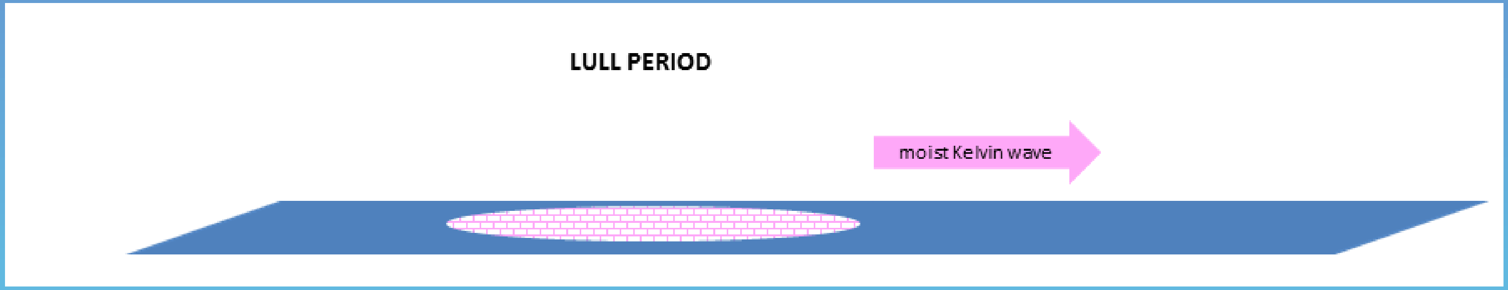
Why sometimes CCKWs as a whole (SCCs & MKW) decay?

The conceptual model for the CCKW life cycle, in terms of the MKW-SCC interaction, is representative of the ITCZ variability for the aquachannel simulations.

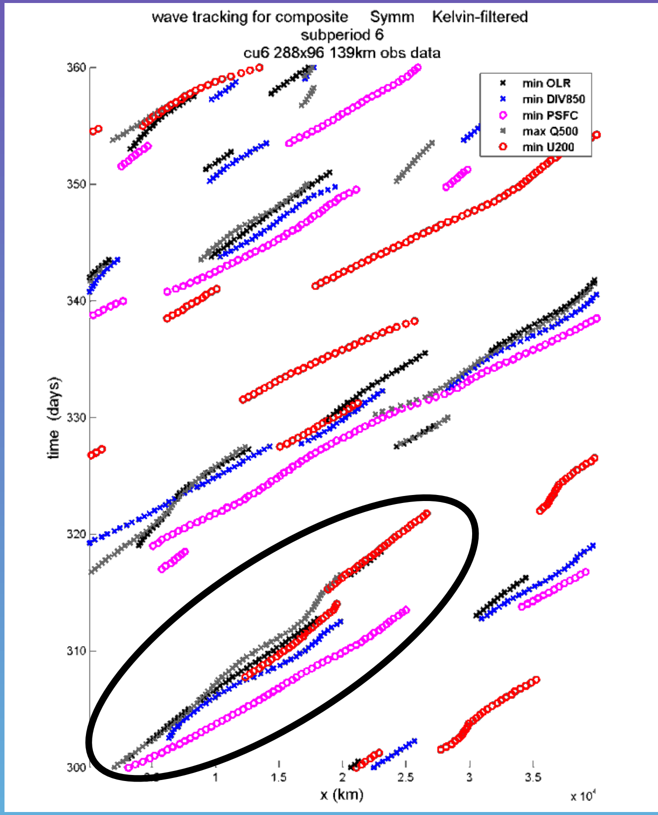
But occasionally, some other features can be present too:



or ...



TRACKING ALGORITHM



CCKW PROPAGATION SPEEDS (m/s)

	CTRL SST	OBS SST
OLR	**19.11**	**16.58**
Qtotal 500mb	14.93	13.74
Div 850mb	19.83	17.33
U 200mb	21.03	17.14
PSFC	**22.91**	**19.68**

MKW (PSFC)
travels ~3 m/s faster than
SCC (OLR)

CASE STUDY:
DAYS 301-319 (OBS SST)