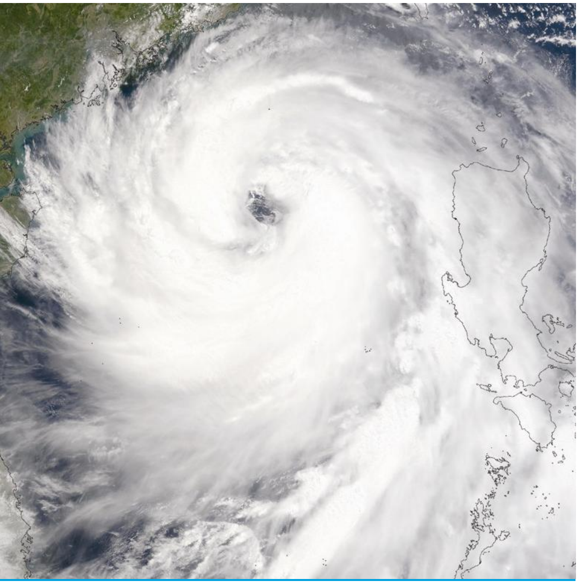


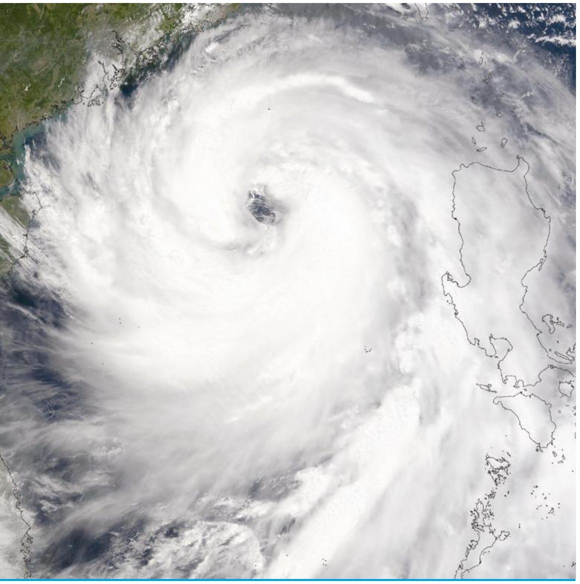
Changes in Track and Structure Associated With Tropical Cyclone Landfall

Johnny Chan

Guy Carpenter Asia-Pacific Climate Impact Centre
School of Energy and Environment
City University of Hong Kong

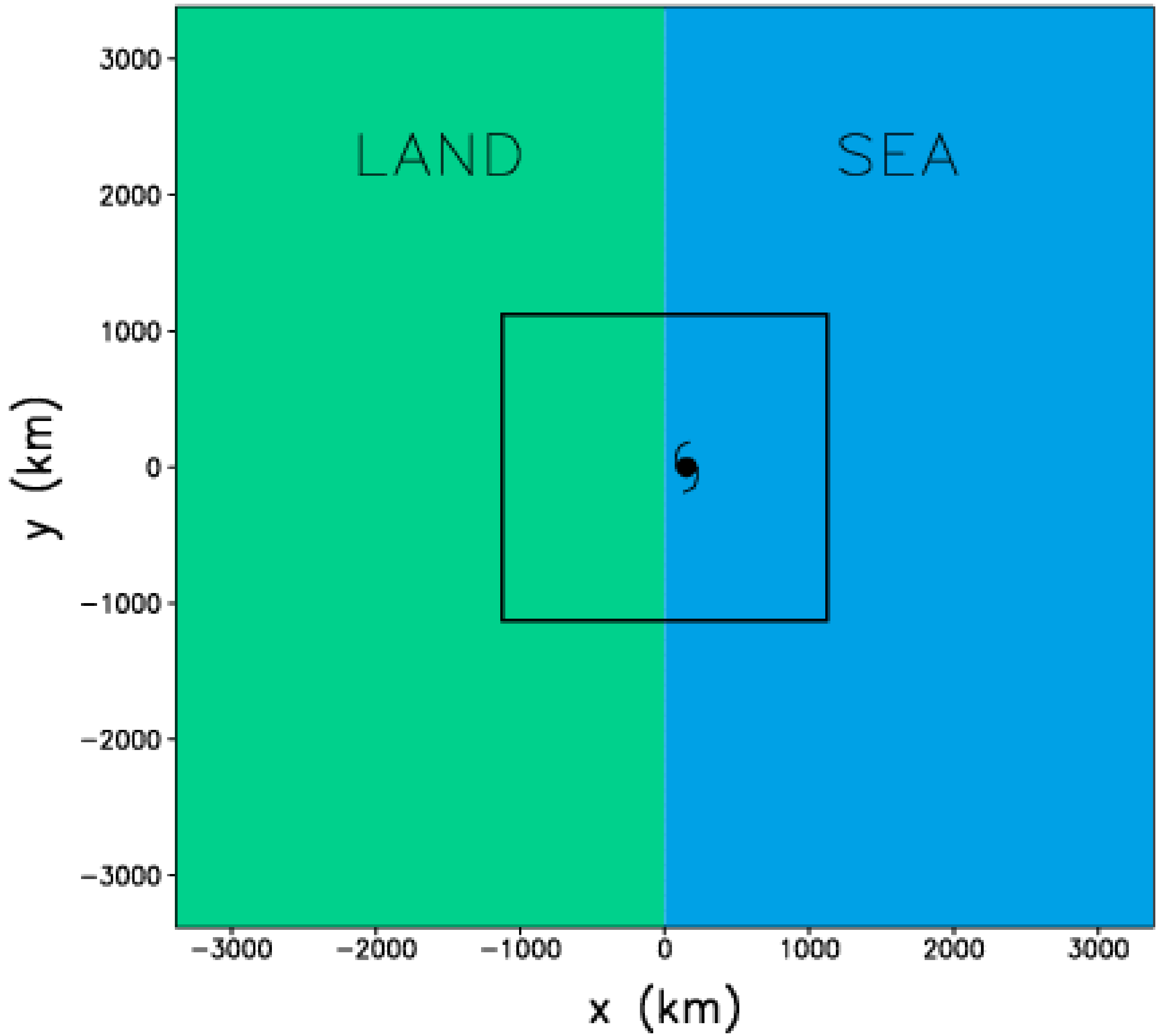
Outline

- Changes in track
- Convection distribution
- Summary

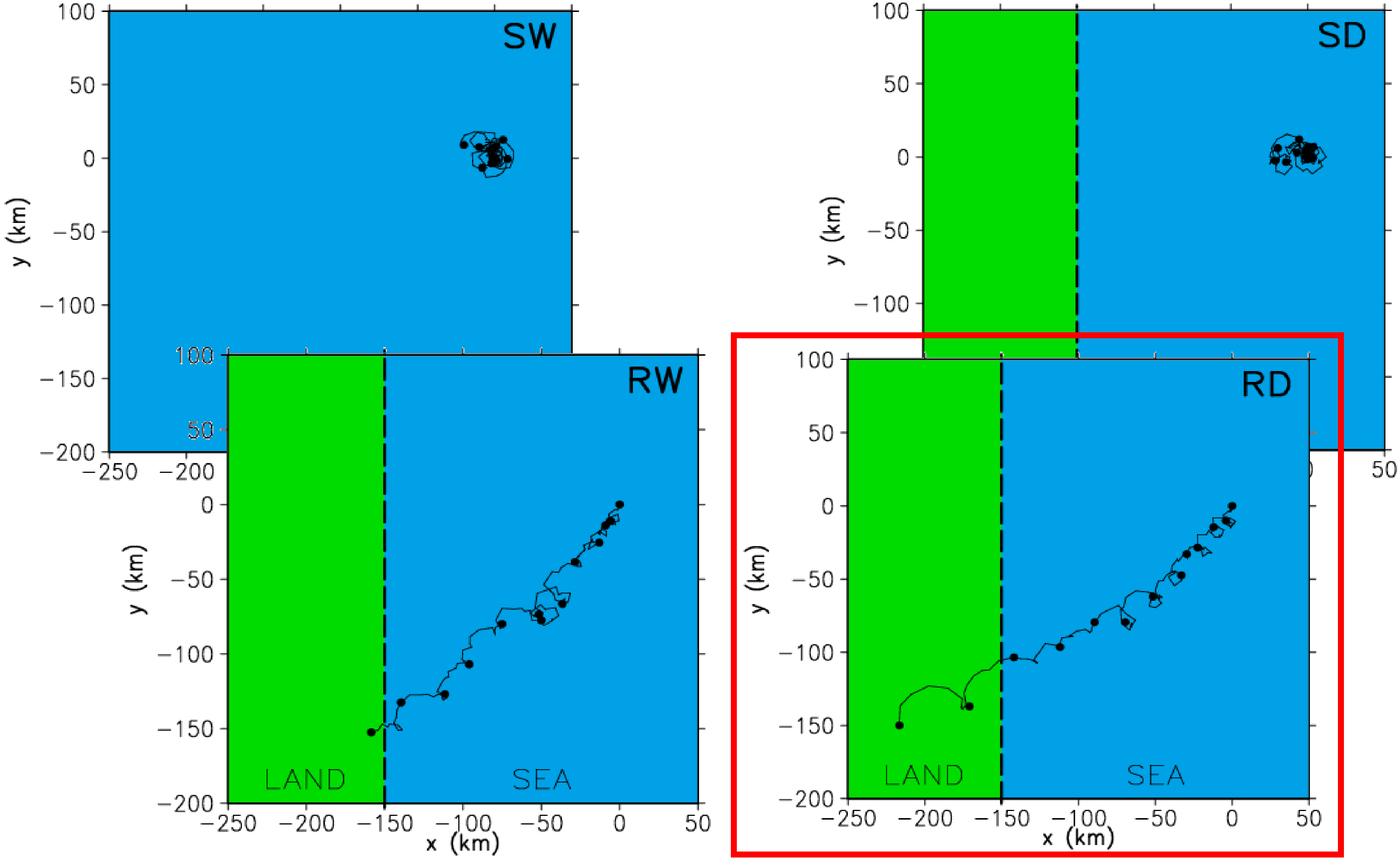


Changes in Track

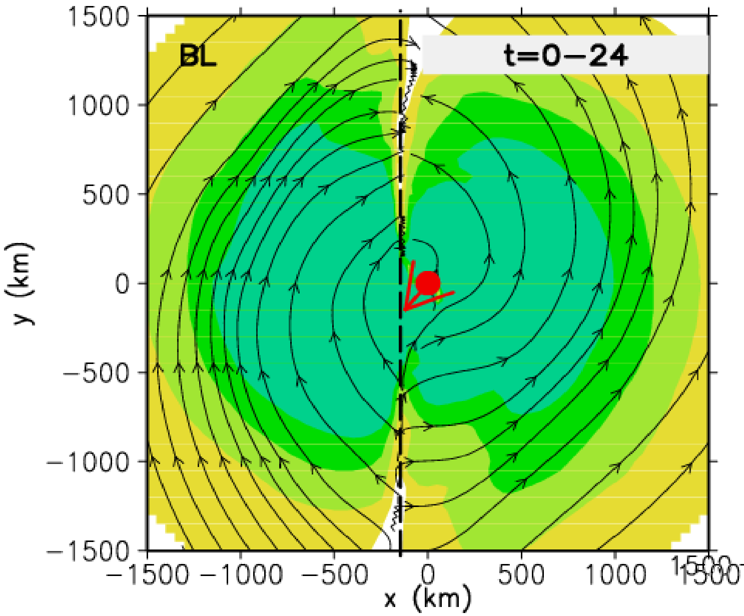
Track – *f* plane experiments



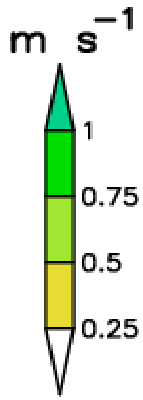
Track – *f* plane experiments



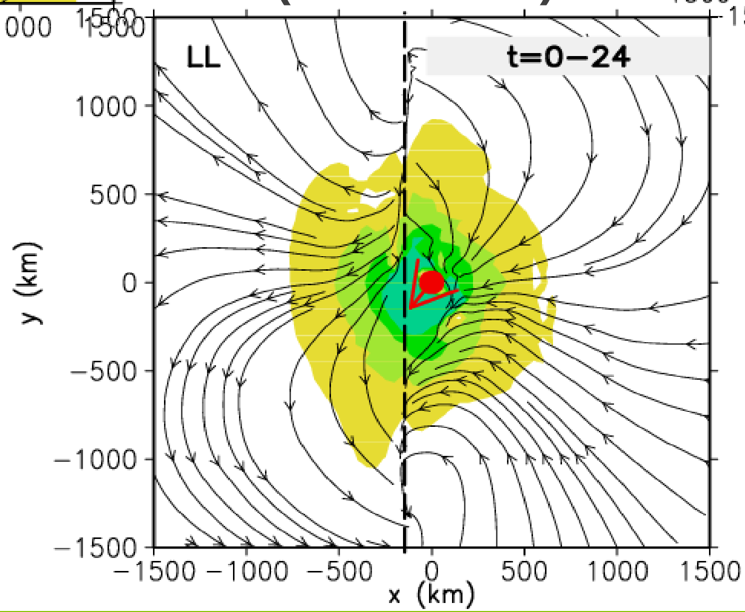
Asymmetric flow RD experiment Day 1

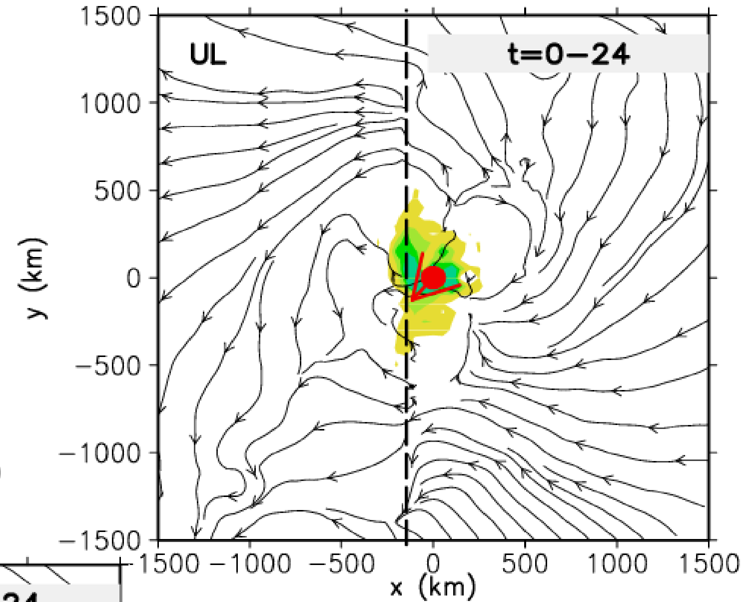


boundary layer
(0.9<σ<1.0)



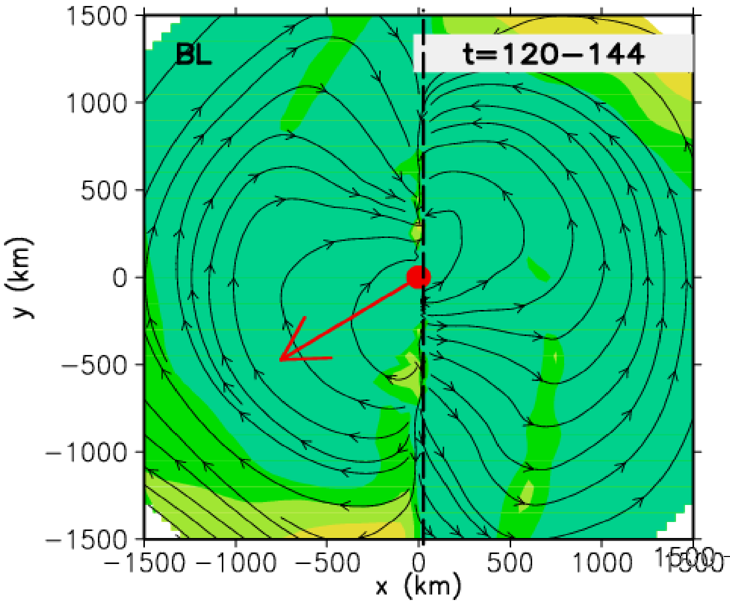
lower layer (LL)
(0.55<σ<0.9)





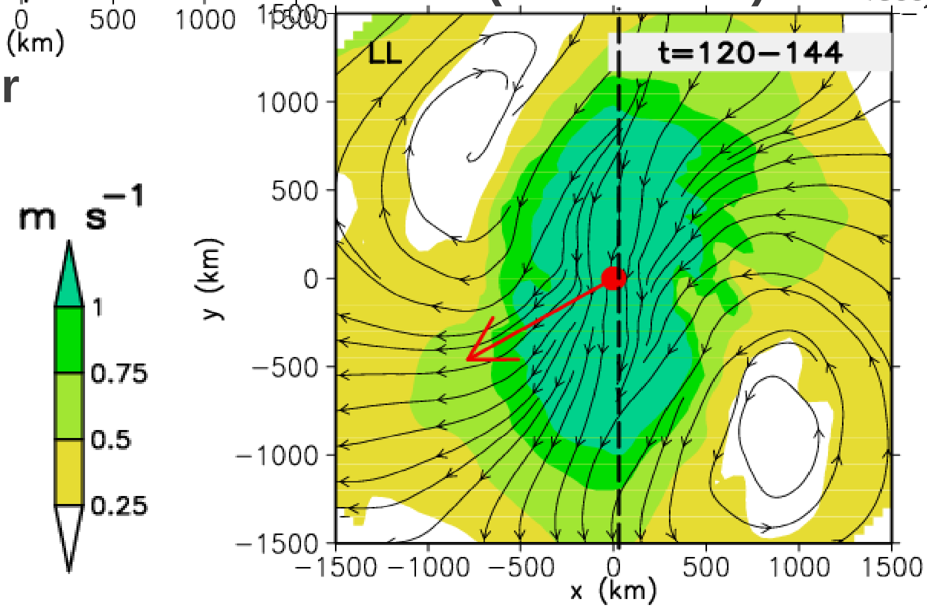
upper layer (UL)
(0.25<σ<0.55)

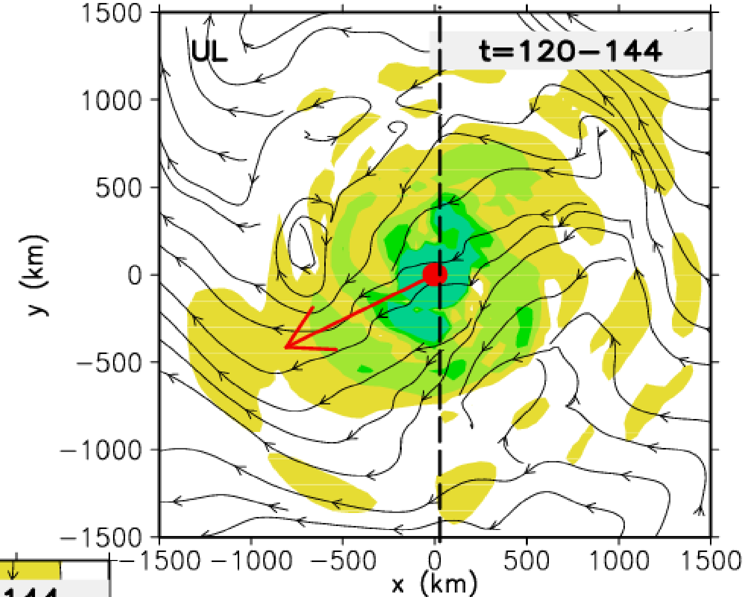
Asymmetric flow RD experiment Day 6



boundary layer
(0.9<σ<1.0)

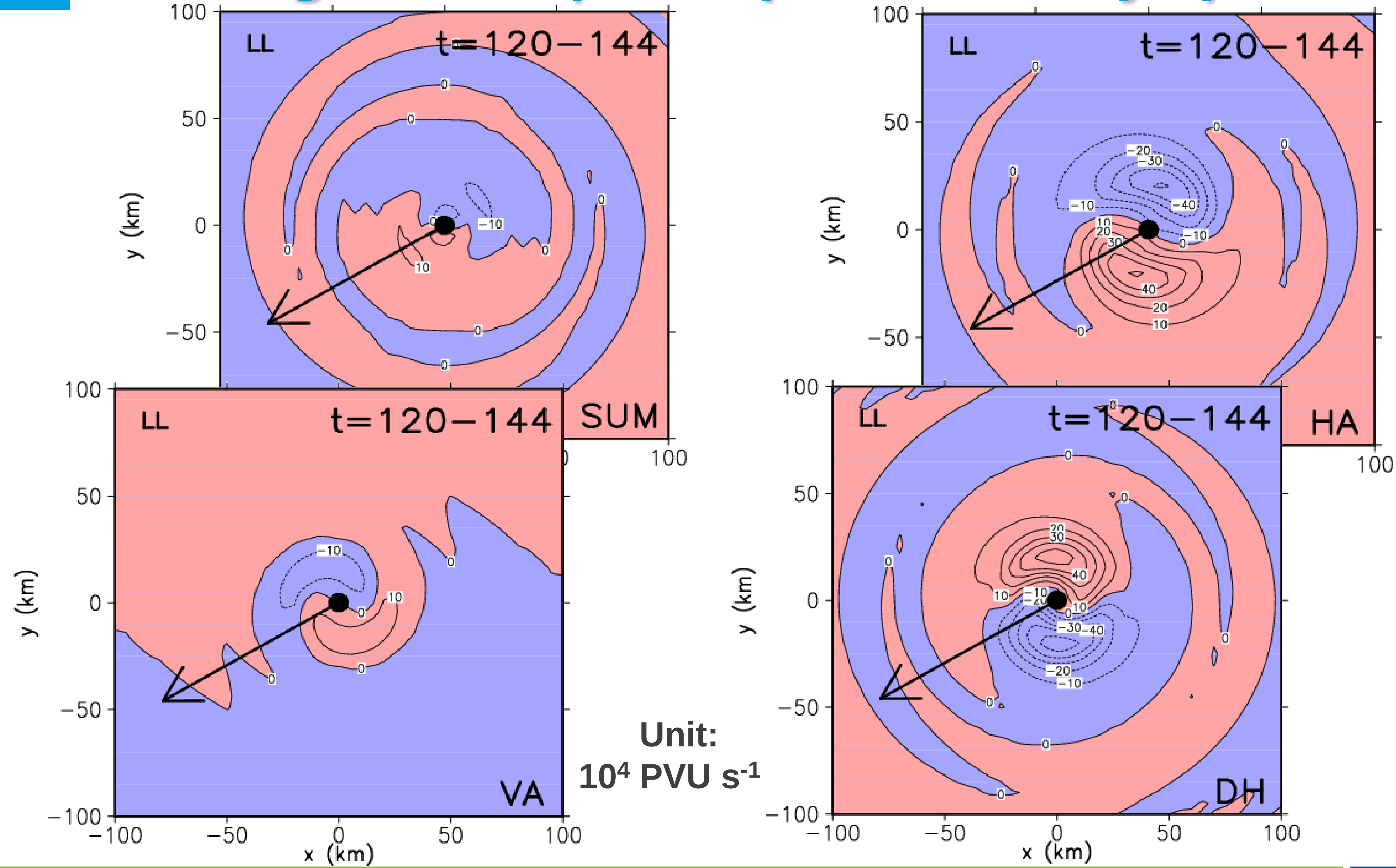
lower layer
(0.55<σ<0.9)





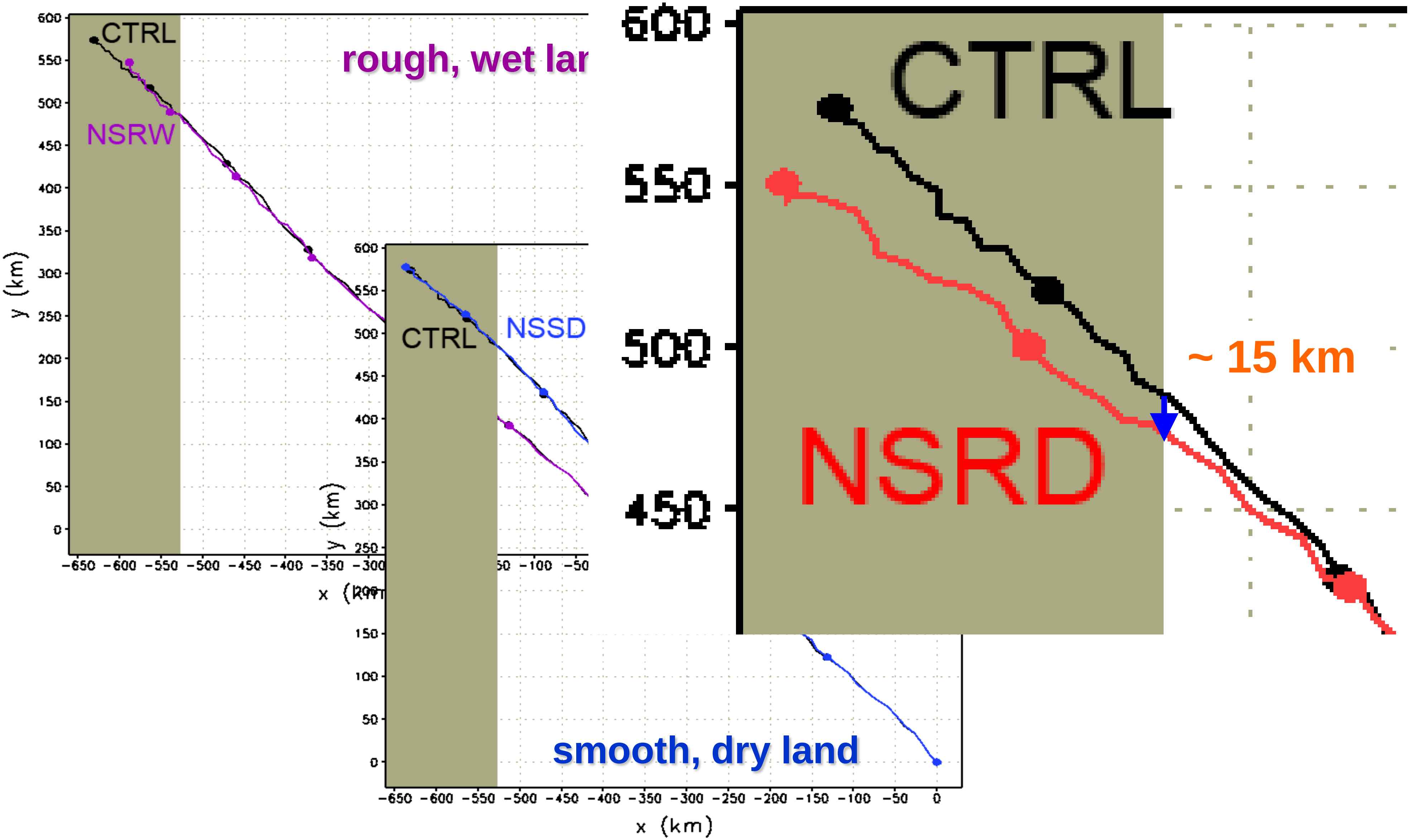
upper layer
(0.25<σ<0.55)

PV budget at LL (RD experiment Day 6)

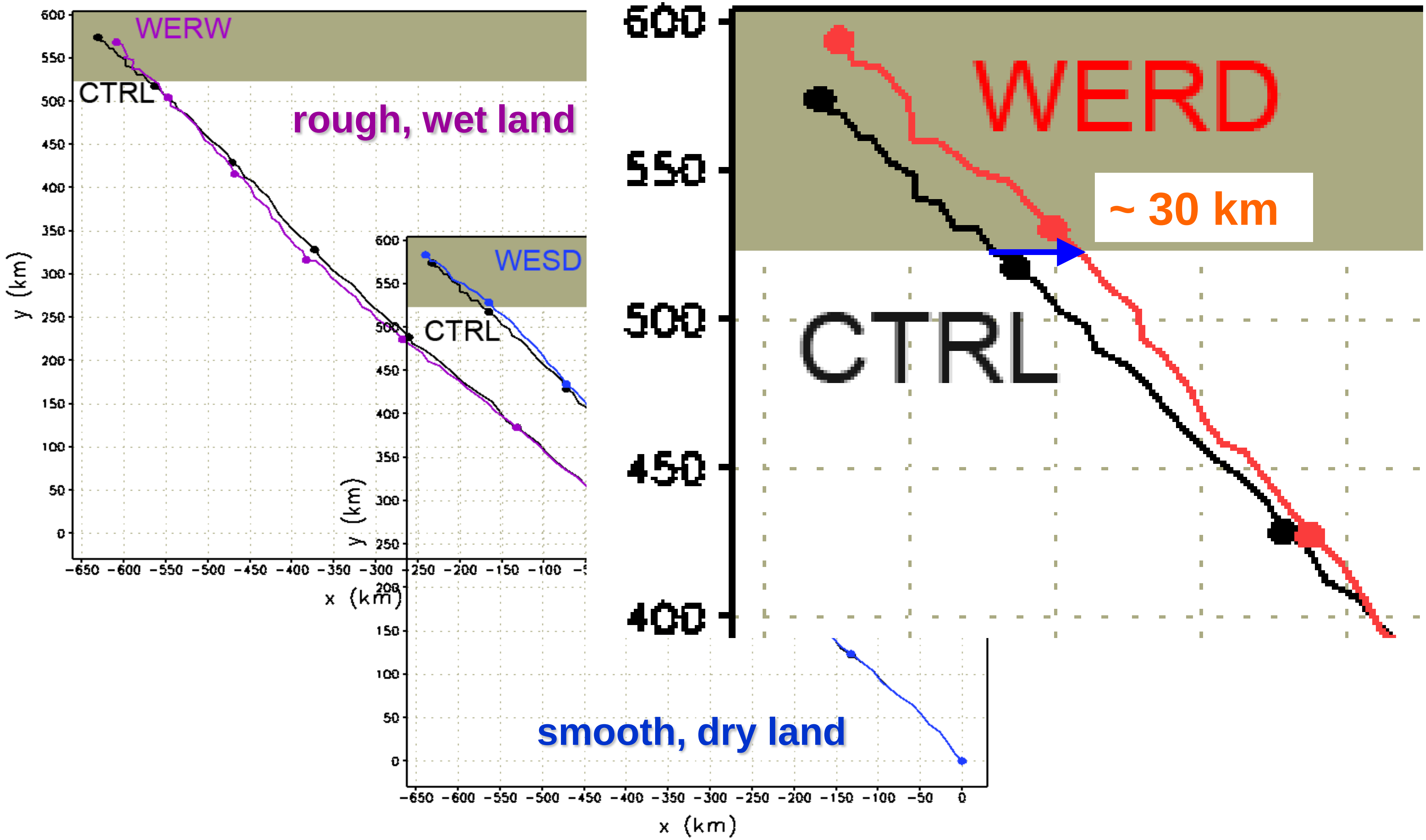


Unit:
10^4 PVU s^{-1}

Track – β plane experiments NS-oriented coastline



Track – β plane experiments EW-oriented coastline



Land-induced flow

Hypothesis :

TC circulation = Symmetric flow + Asymmetric flow

Asymmetric flow = Beta gyres + Land-Induced Flow

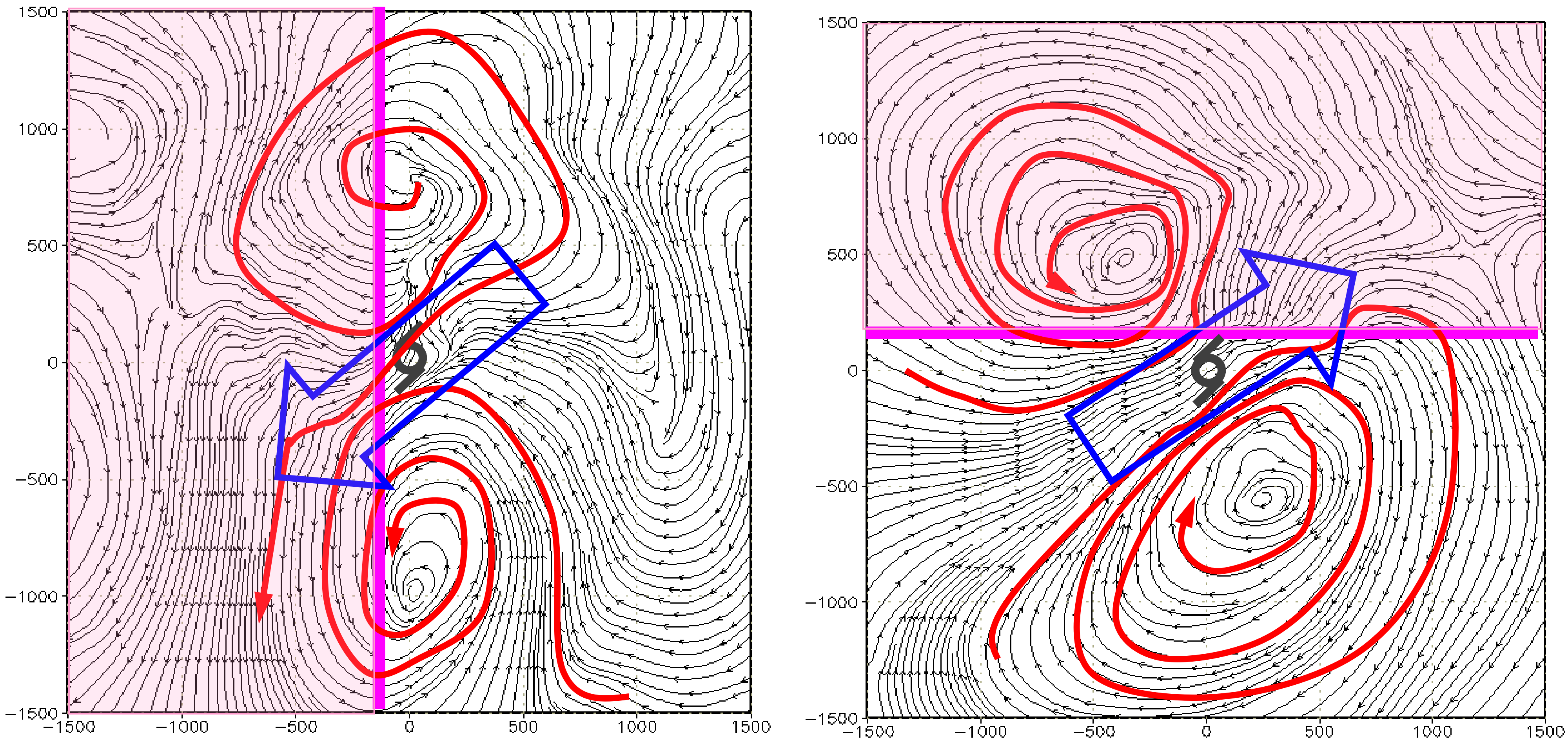
Not present in the CTRL

Land-induced Flow = Asymmetric flow – Beta gyres

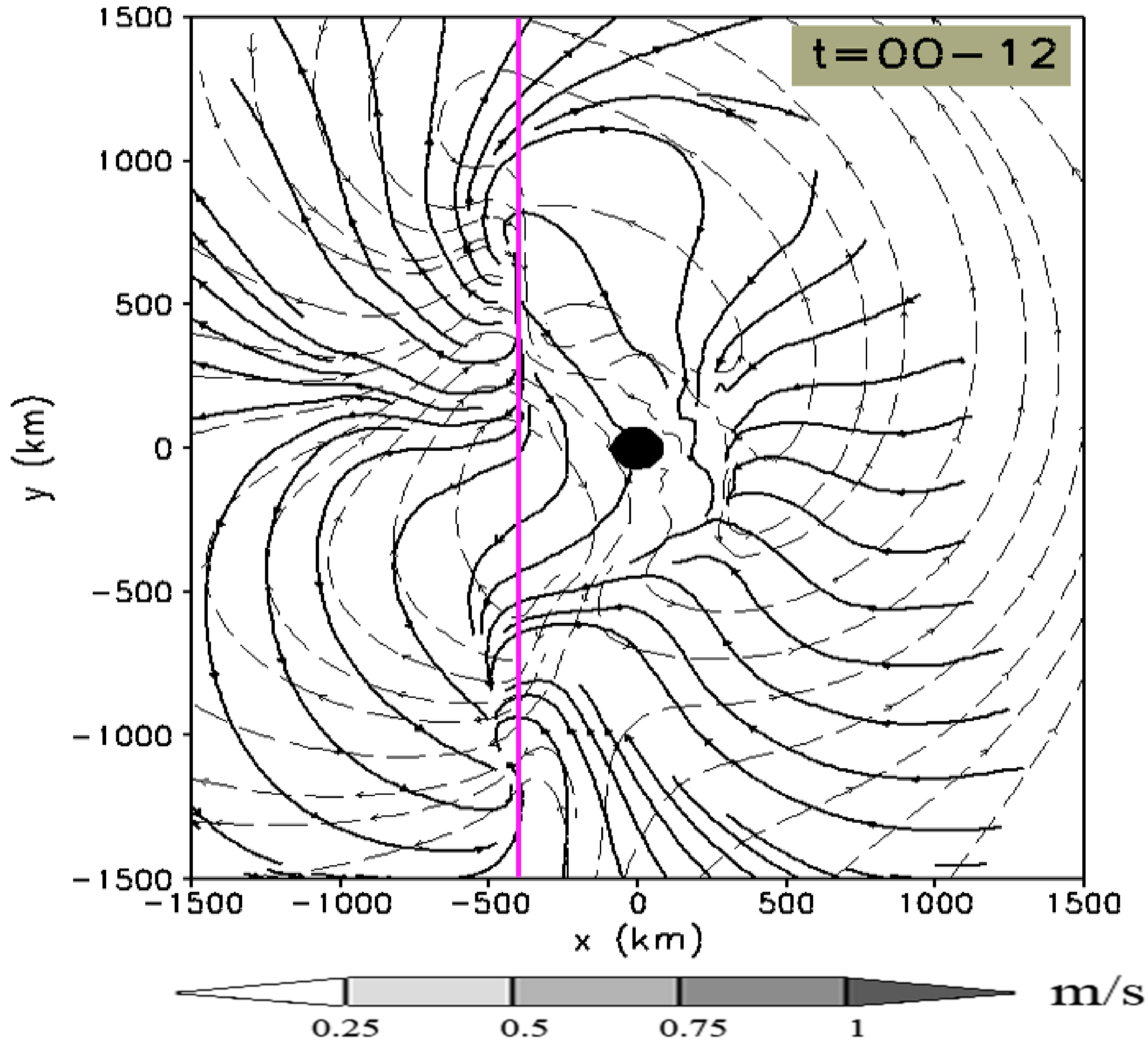
= (Asymmetric flow)$_{Landfall}$ – (Asymmetric flow)$_{CTRL}$

LL Asymmetric flow (0.9 ≥ η ≥ 0.55) *t* = 36 – 48 h

Rough and dry land



Evolution of asymmetric flow NSRD experiment

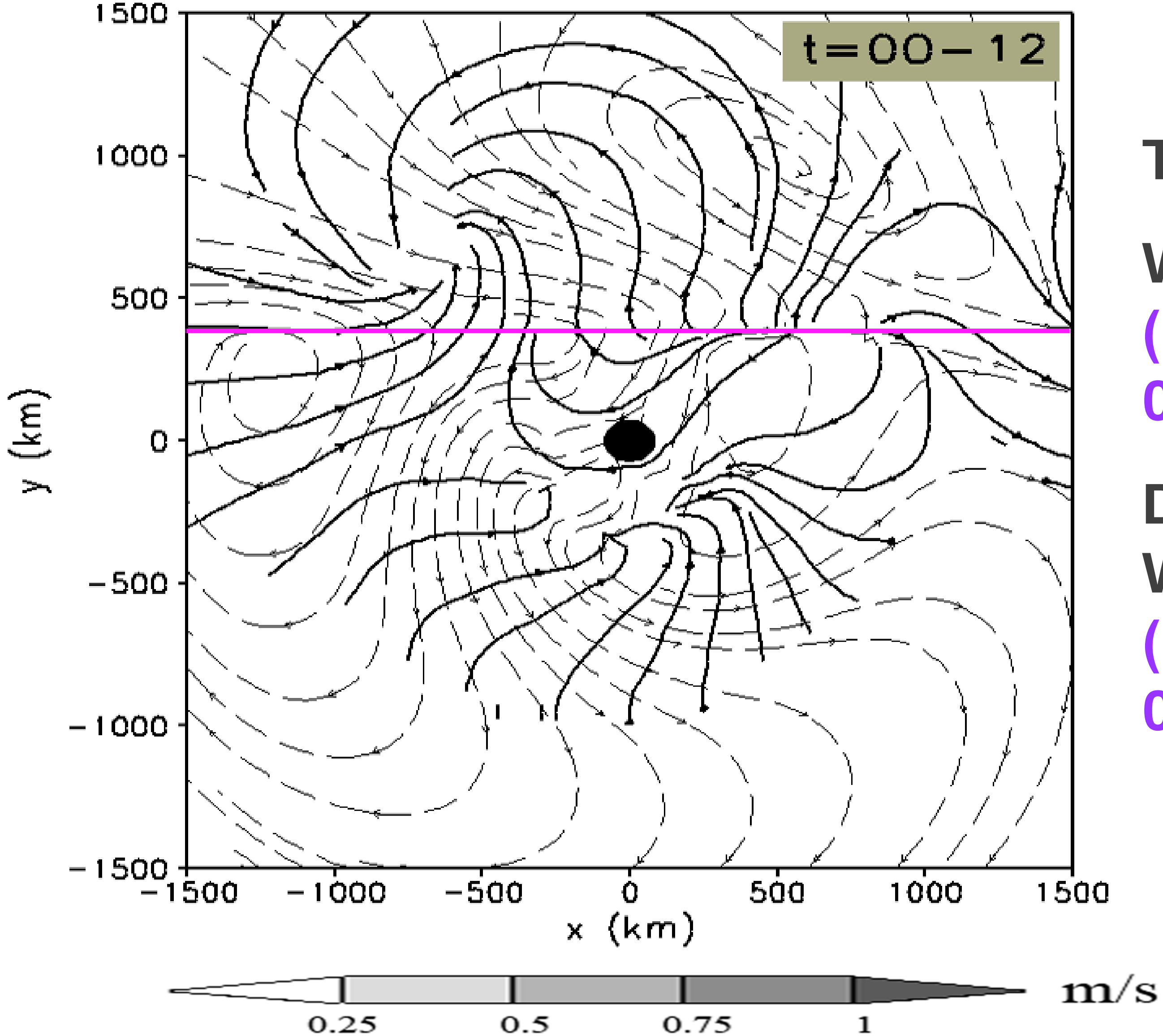


Thick:

Within LL
(0.9 ≥ η ≥ 0.55)

Dashed: Within BL
(1.0 ≥ η ≥ 0.9)

Evolution of asymmetric flow EWRD experiment



Thick:

Within LL

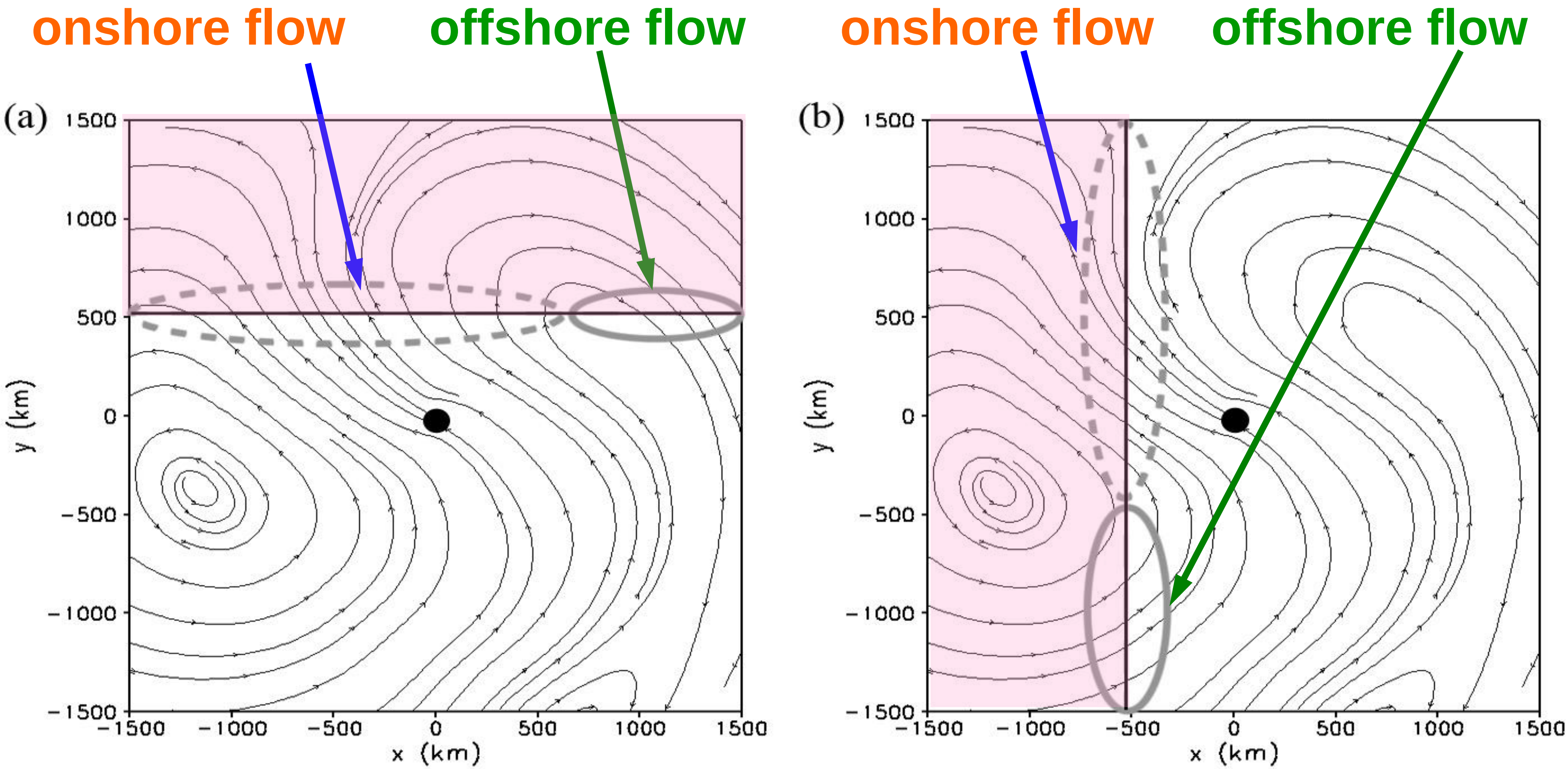
(0.9 ≥ η ≥ 0.55)

Dashed:

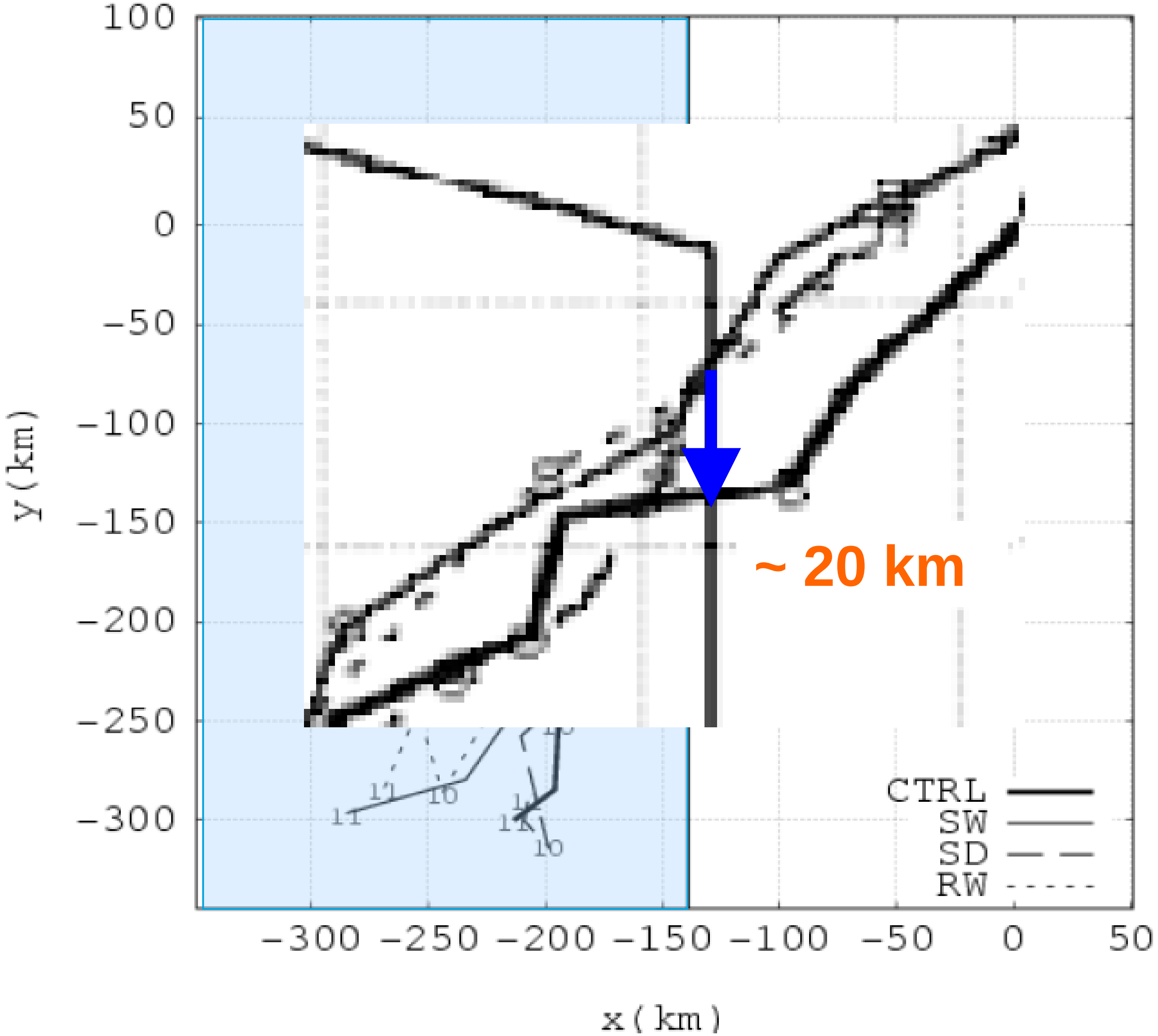
Within BL

(1.0 ≥ η ≥ 0.9)

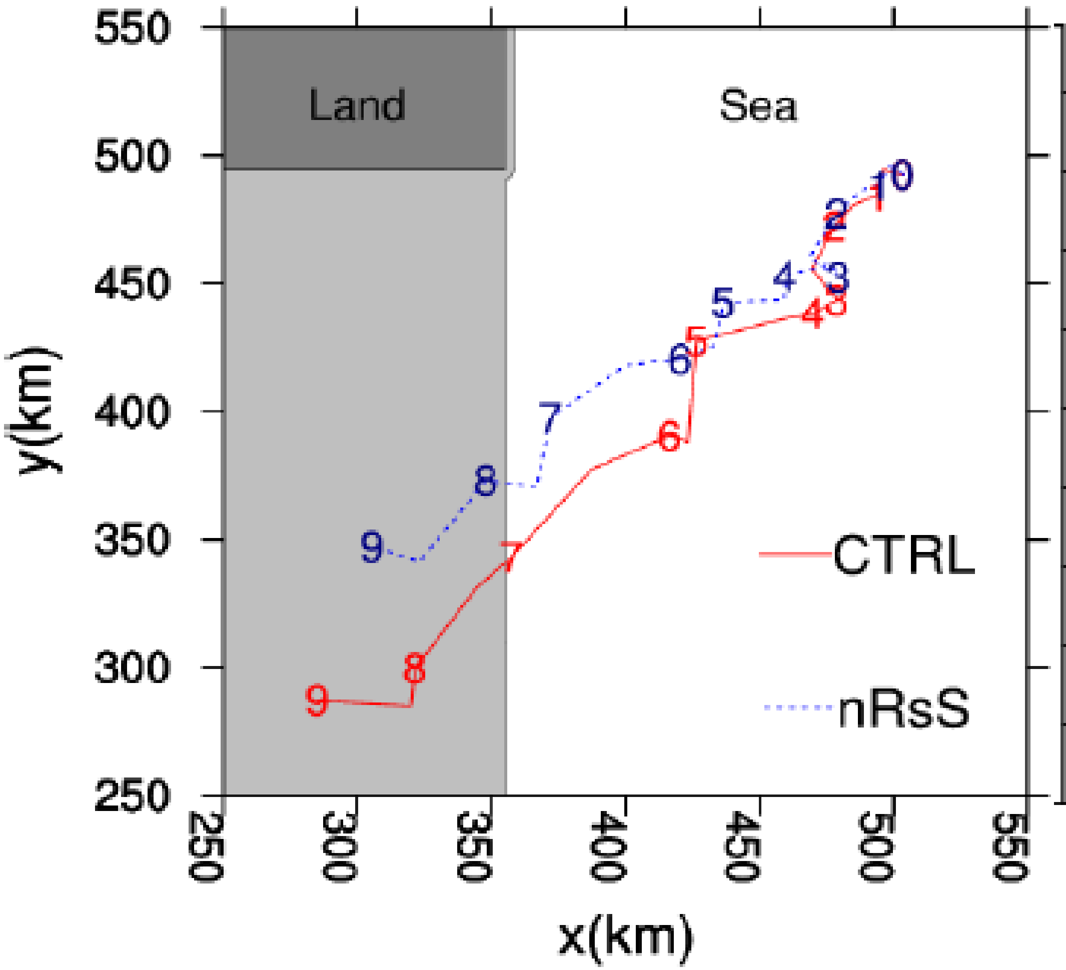
Changes in the location of onshore vs. offshore flow



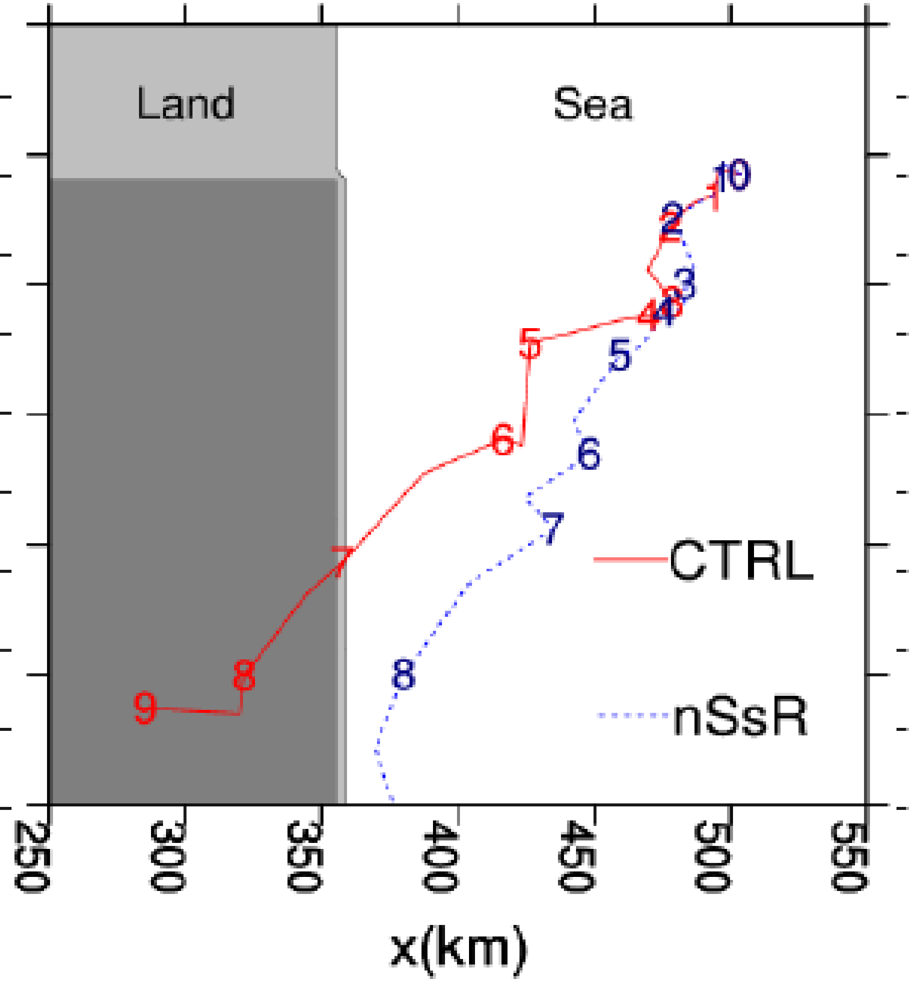
Track – *f* plane experiments River Delta



Track – *f* plane experiments Differential roughness



north Rough south Smooth



north Smooth south Rough

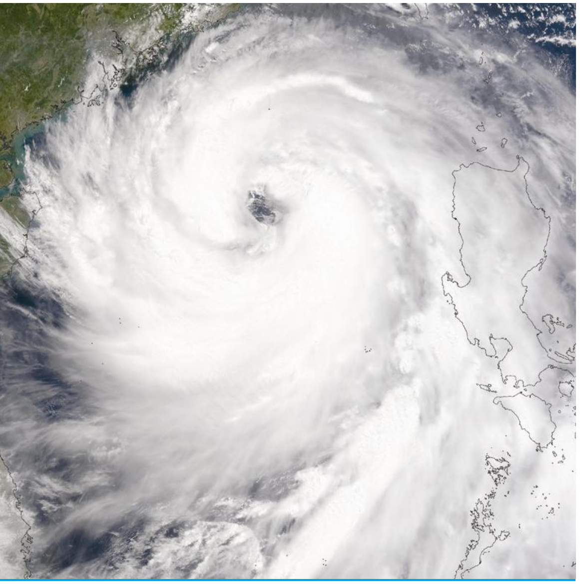
Summary on track changes

- An inherent vortex motion in the presence of a discontinuity in surface friction.
- Such motion is caused by two main processes:
  - the development of a “ventilation flow” associated with a vortex pair through the generation of relative vorticity from the divergent term in the vorticity equation
  - diabatic heating due to differential convergence

Summary on track changes

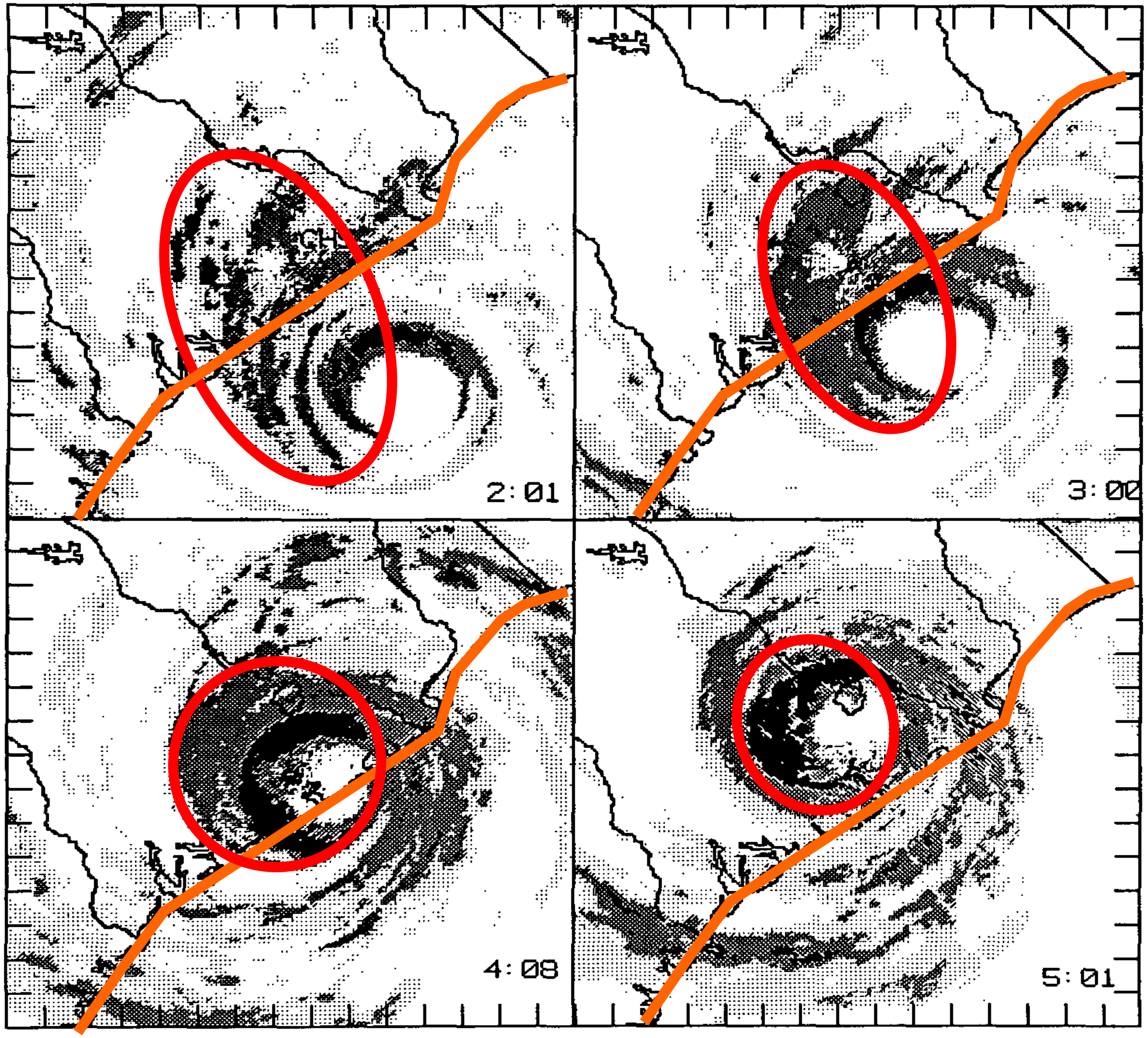
- Such an inherent motion modifies the beta effect so that different coastline orientation will cause the TC track to deviate differently.

- Differential friction over land will also cause track deviations towards rougher land

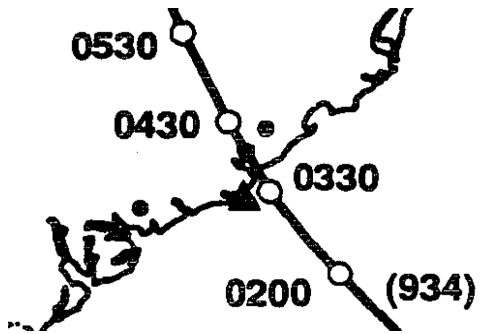


Convection Distribution

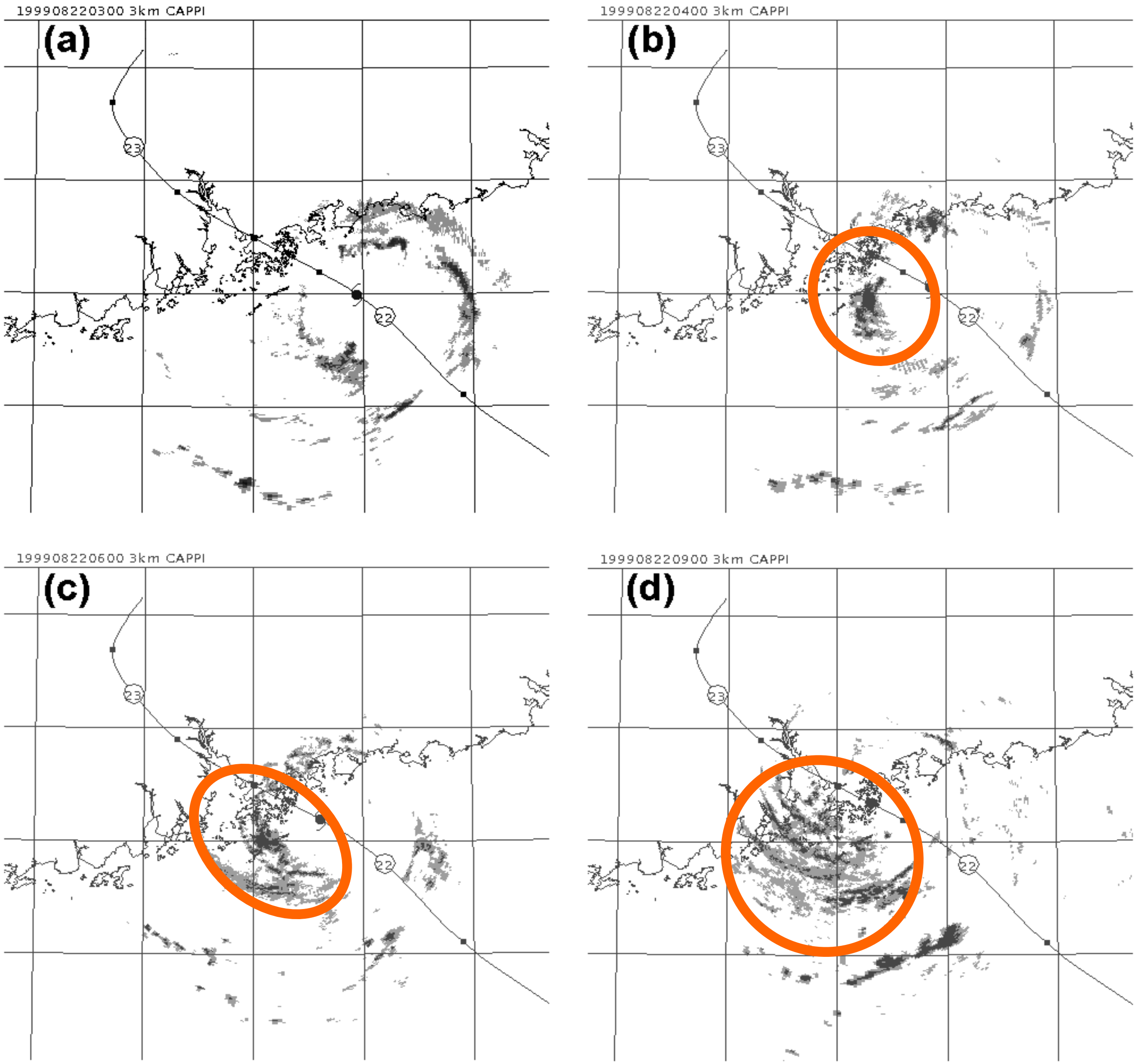
Convection associated with Hurricane Hugo (1989) at landfall



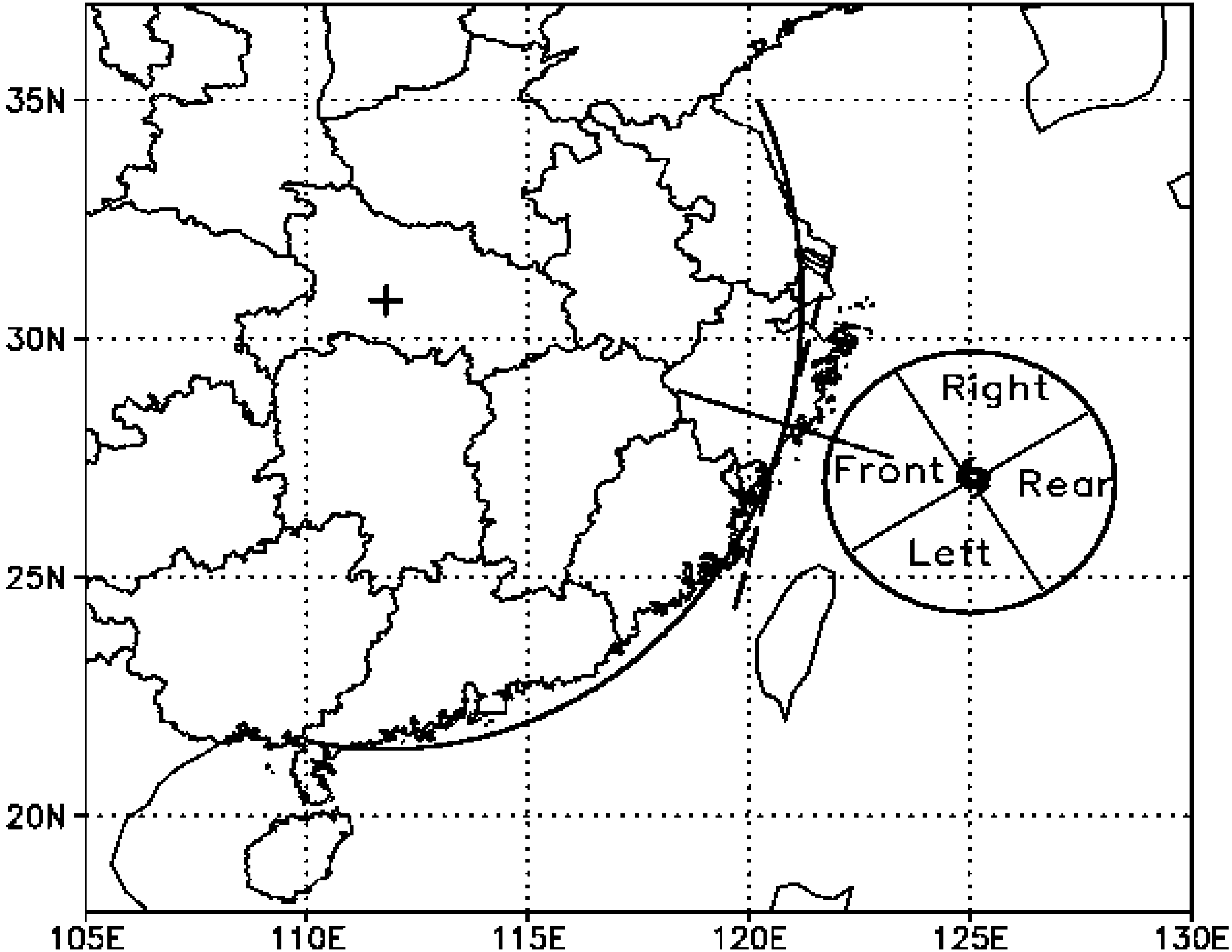
(from Powell 1991 WF)



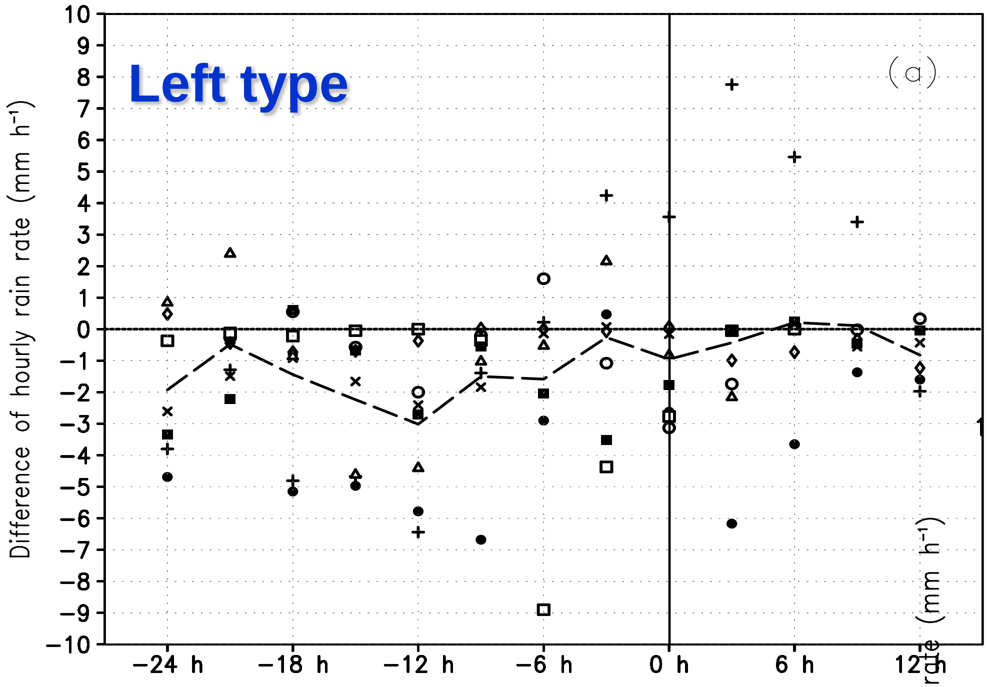
Convection associated with Typhoon Sam (1999) at landfall

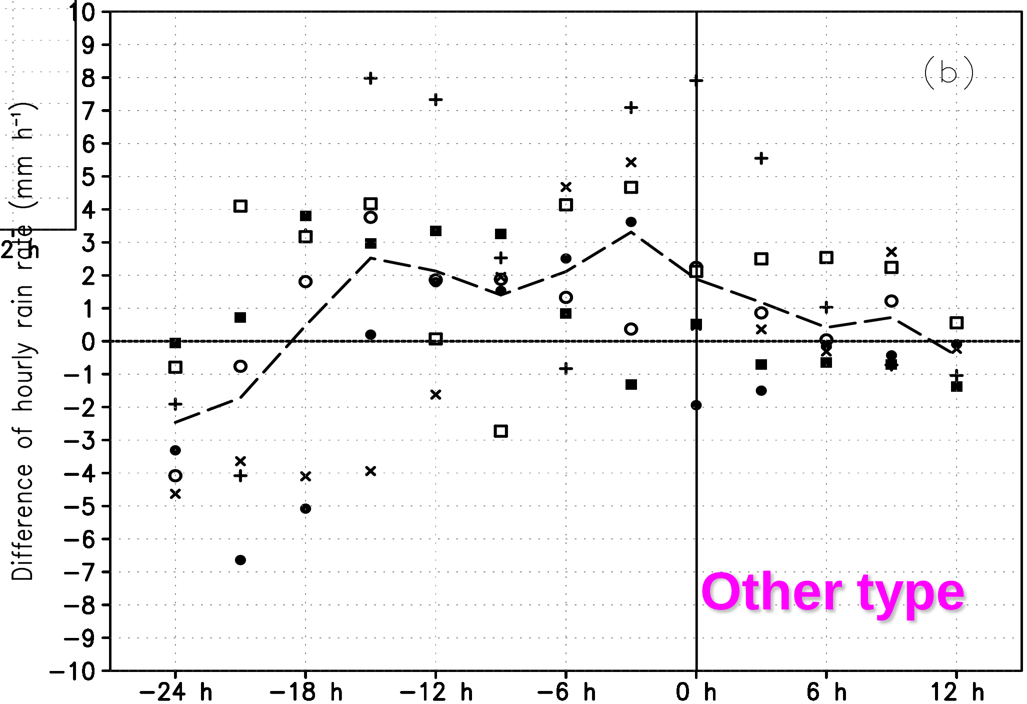


Landfall Along the China Coast

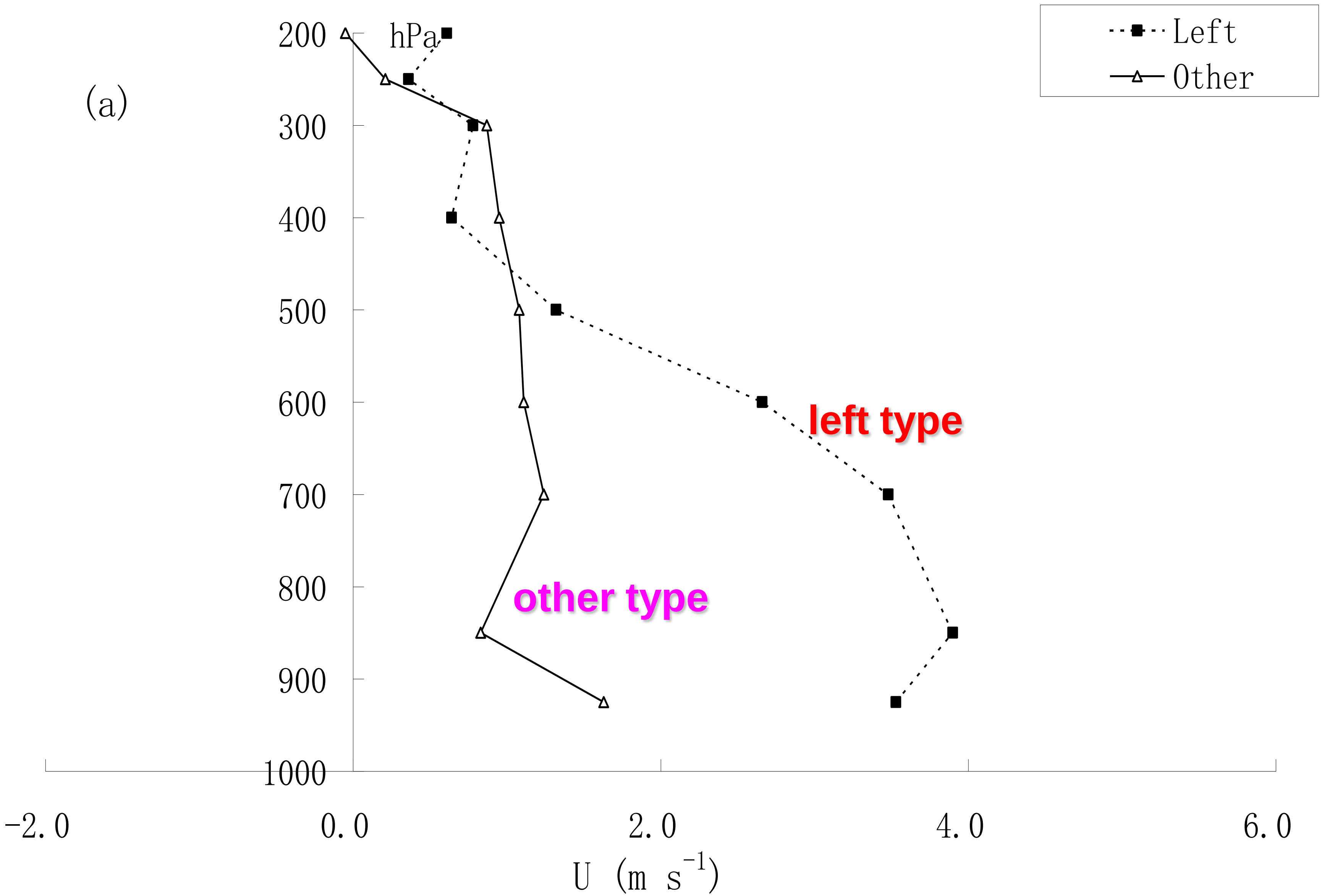


Hourly Rain Rate within 200 km of TC centre (right minus left)

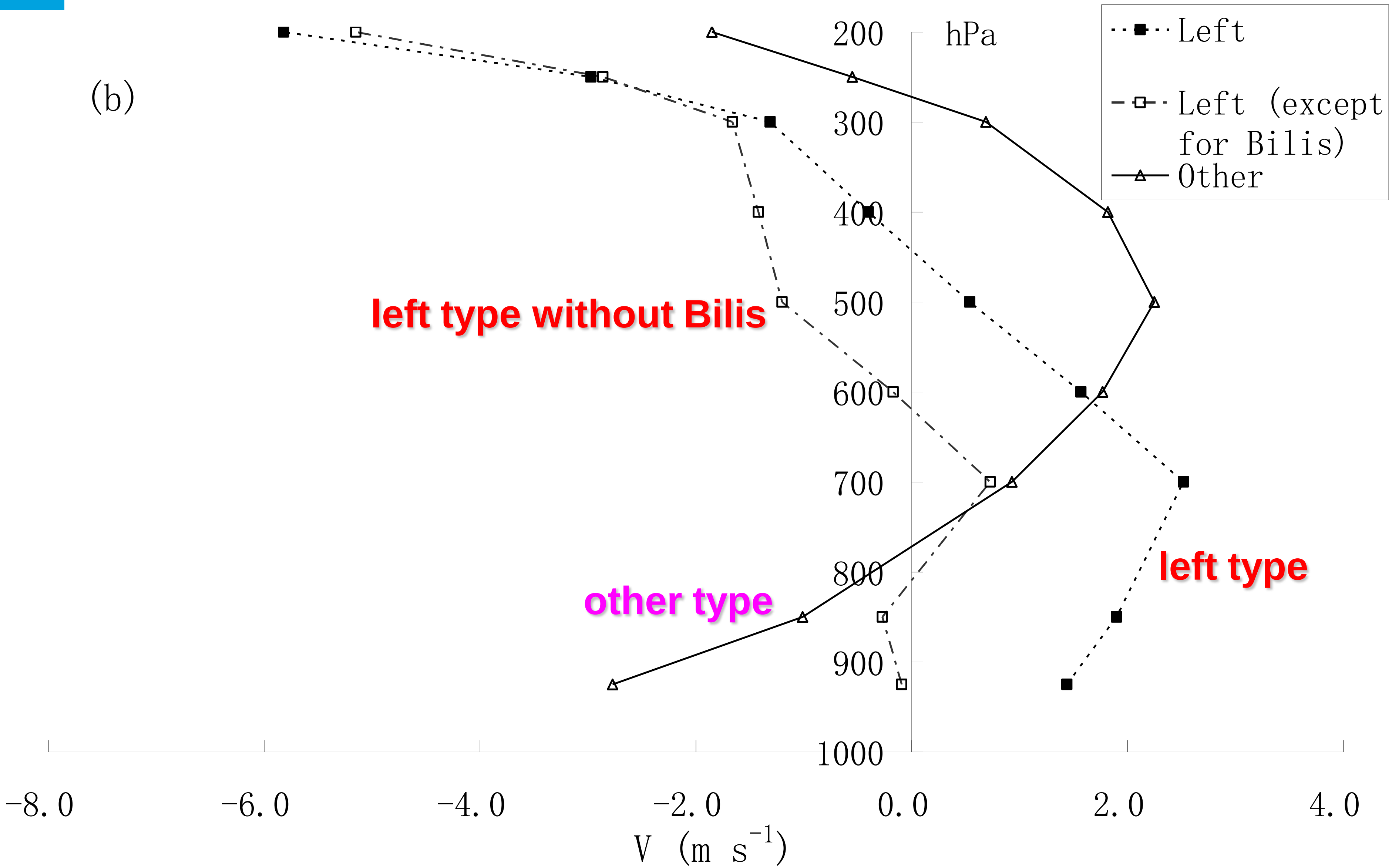




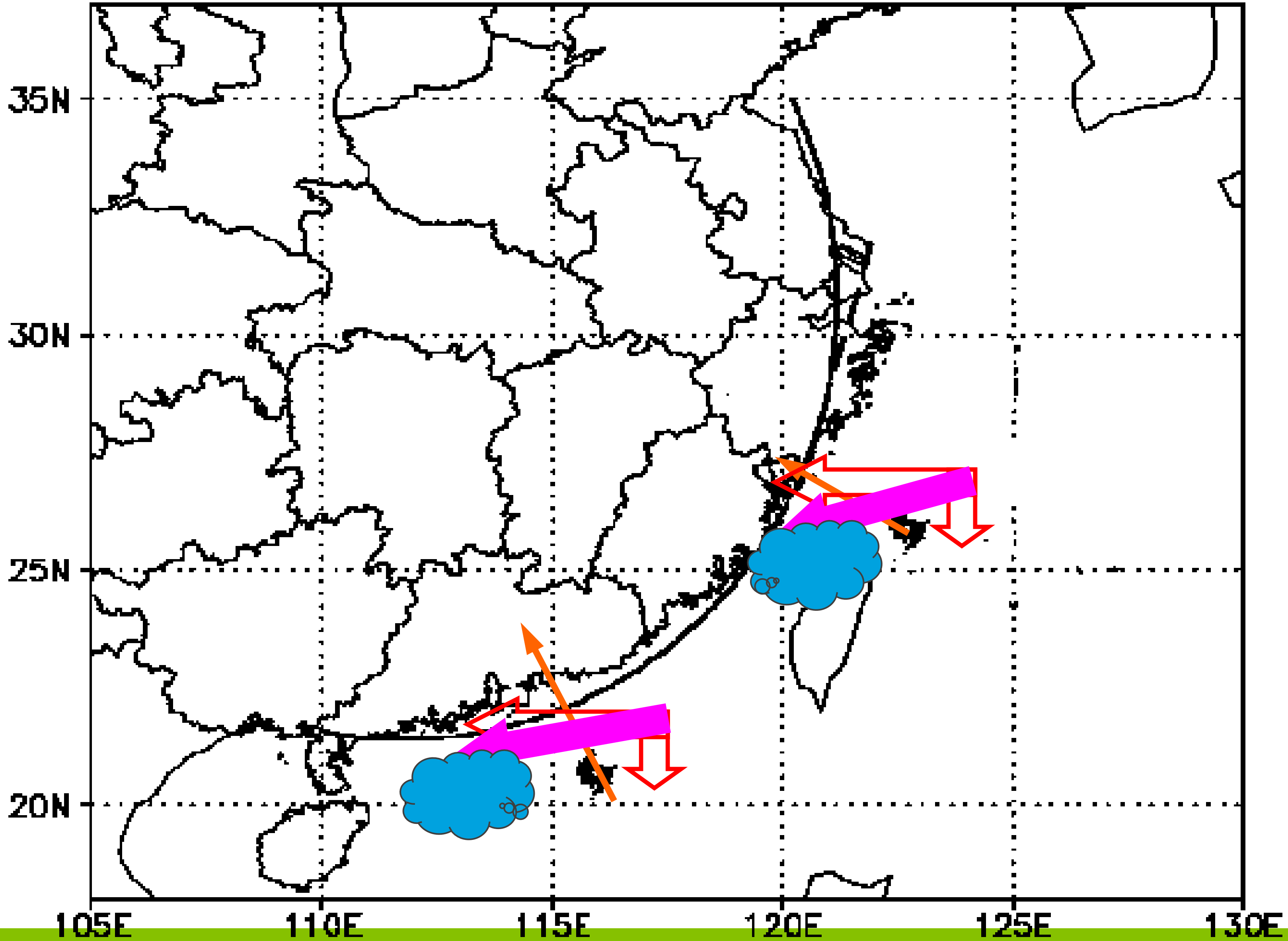
Mean Zonal Wind



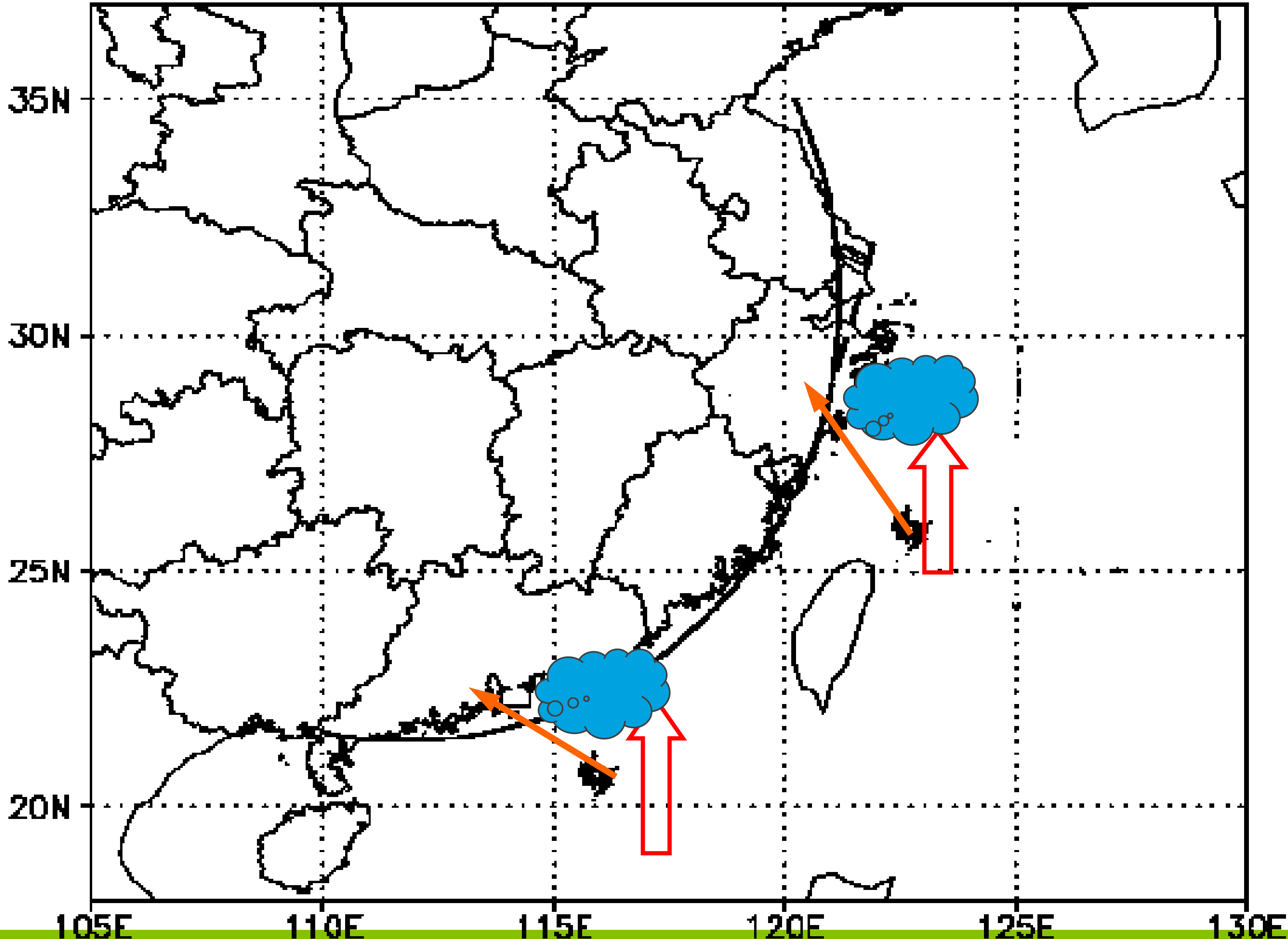
Mean Meridional Wind



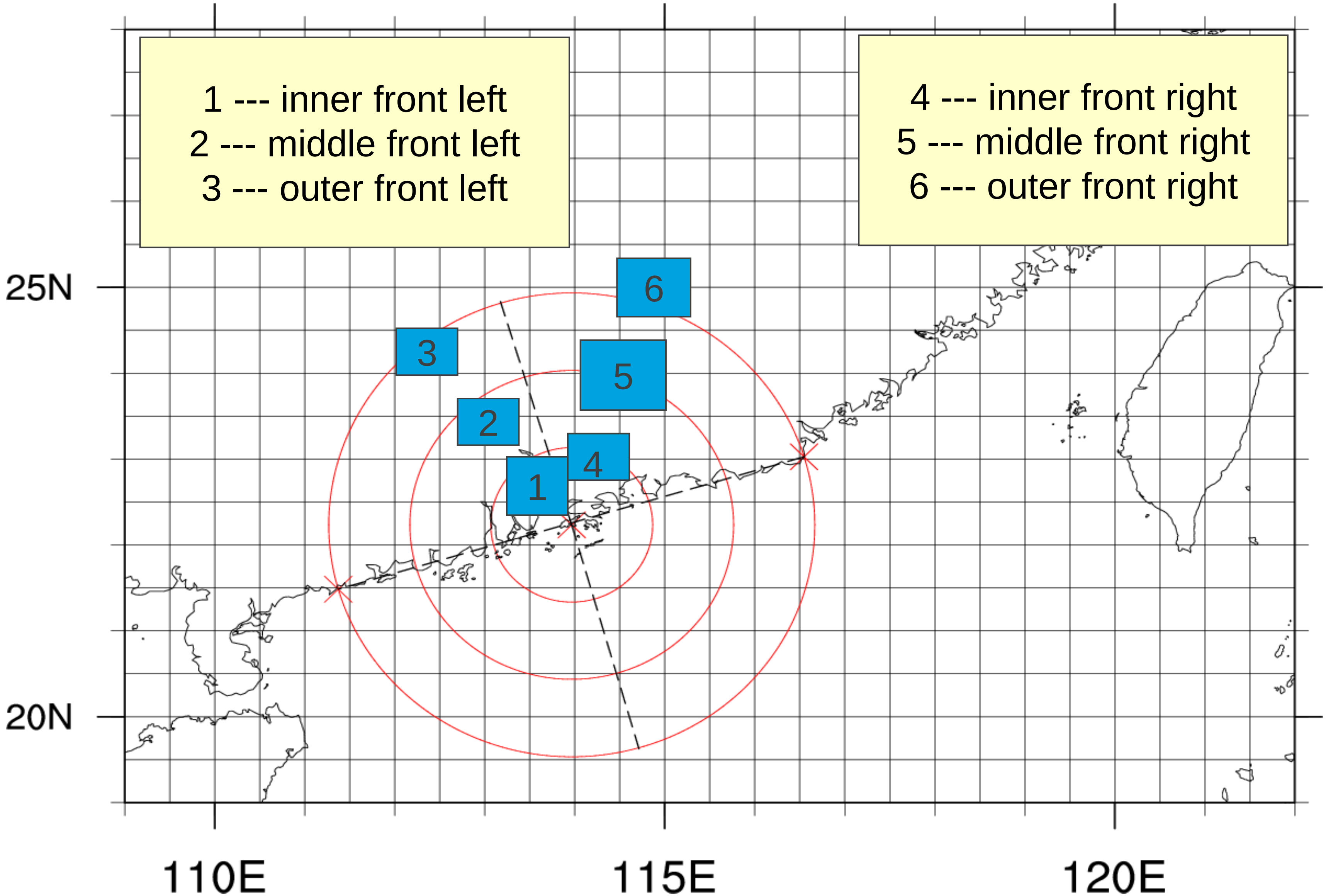
Shear-induced convective asymmetry – left type



Shear-induced convective asymmetry – other type



Rainfall distribution over land at landfall

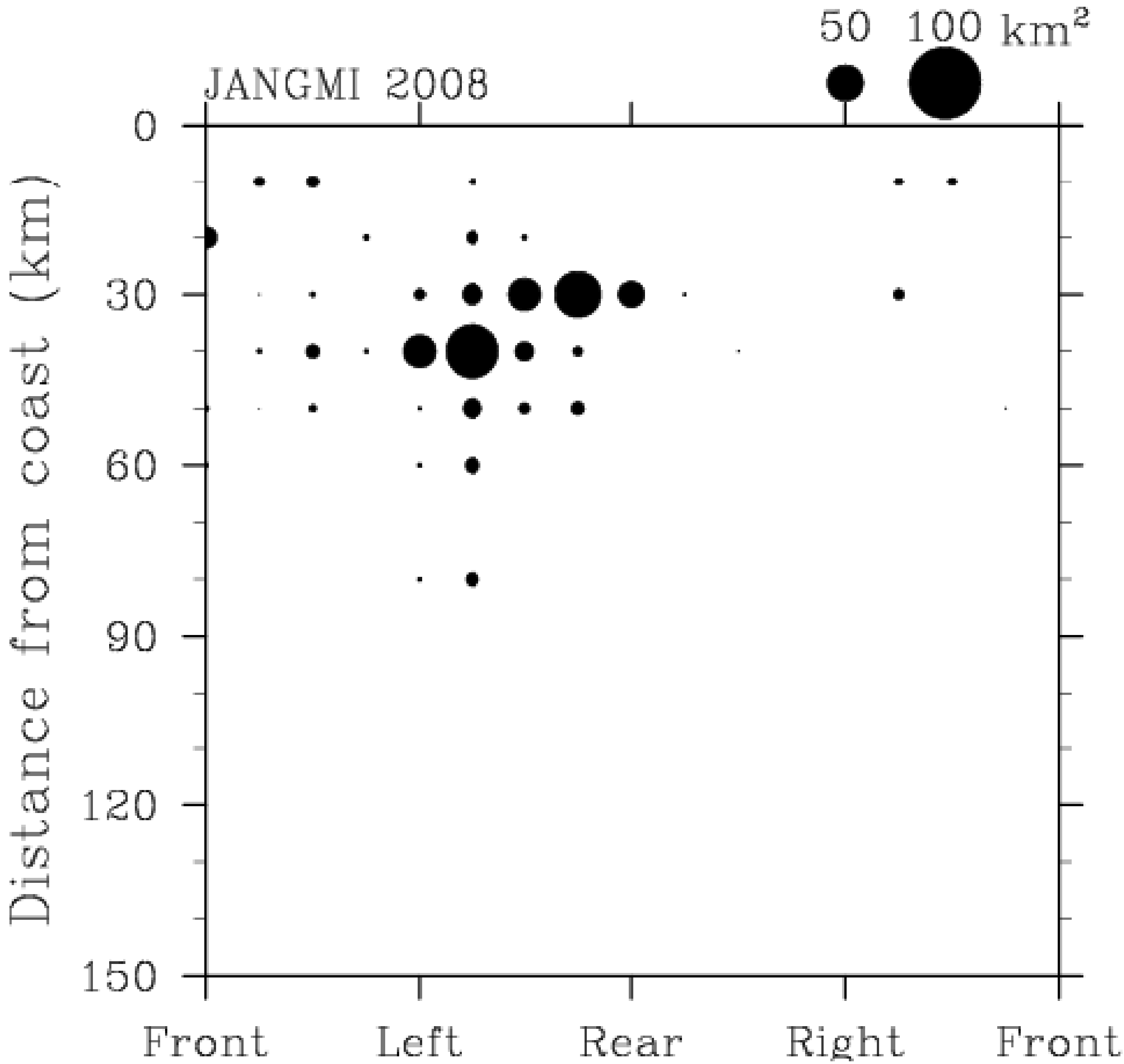


Rainfall distribution over land (within 300 km radius)

At landfall	**Mean (mm/h)**	**Standard Deviation**
Left Front Quadrant	**16.31**	**15.16**
Right Front Quadrant	**31.05**	**21.93**

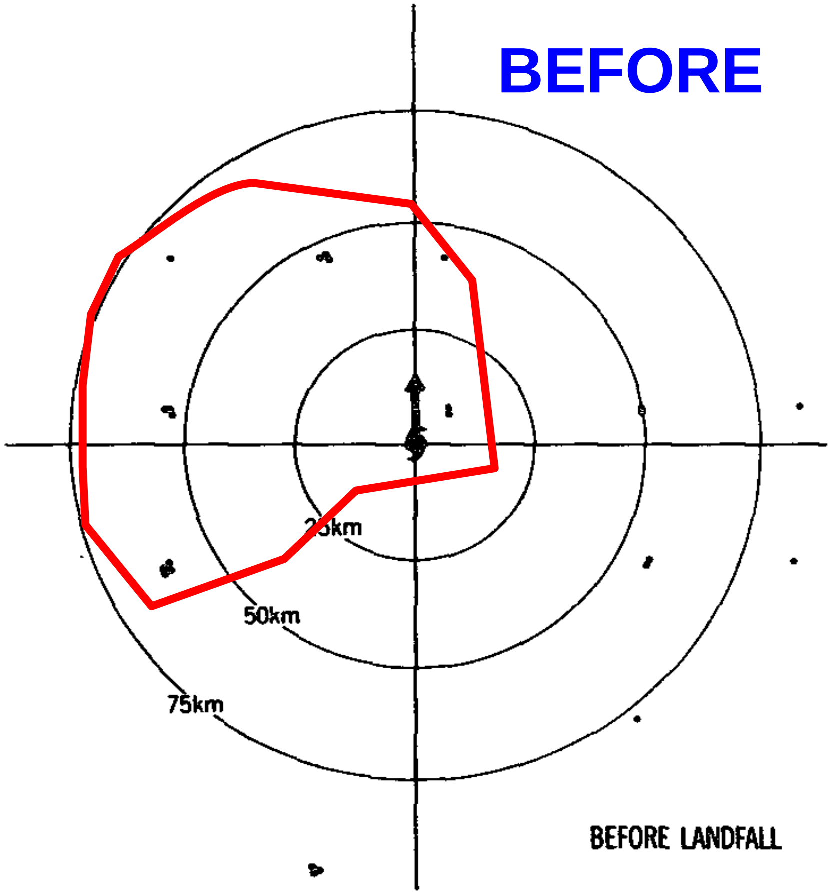
50 km from coastline	**Mean (mm/h)**	**Standard Deviation**
Left Front Quadrant	**15.04**	**16.38**
Right Front Quadrant	**34.80**	**21.09**

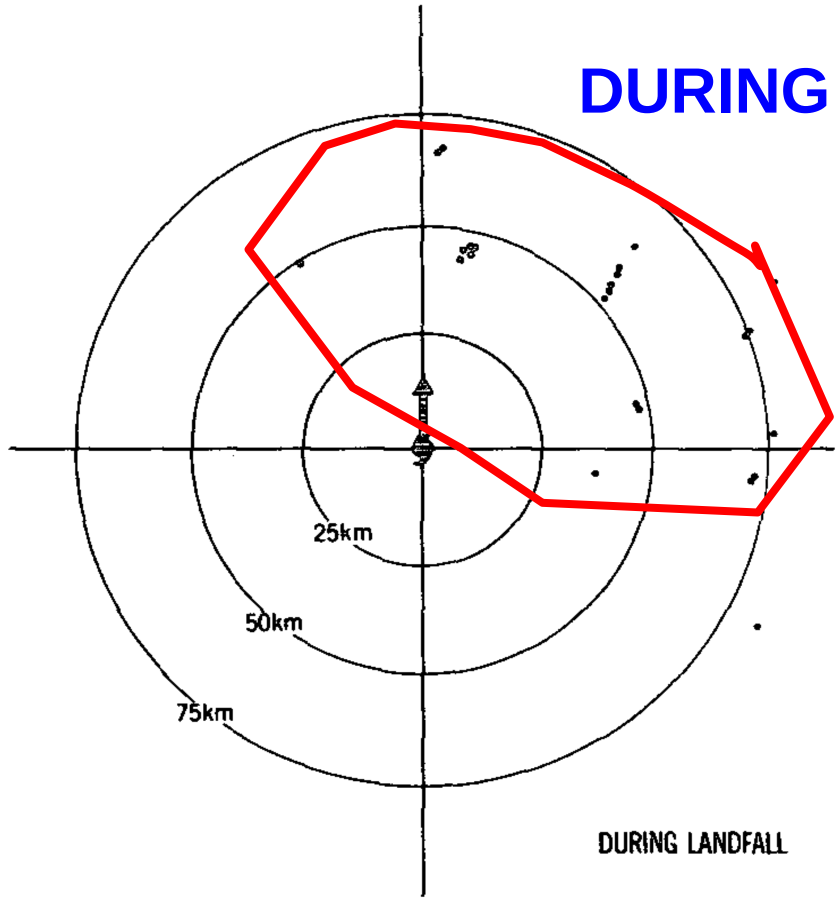
Areas of composite reflectivity >= 55 dBZ within 75 km from TC centre



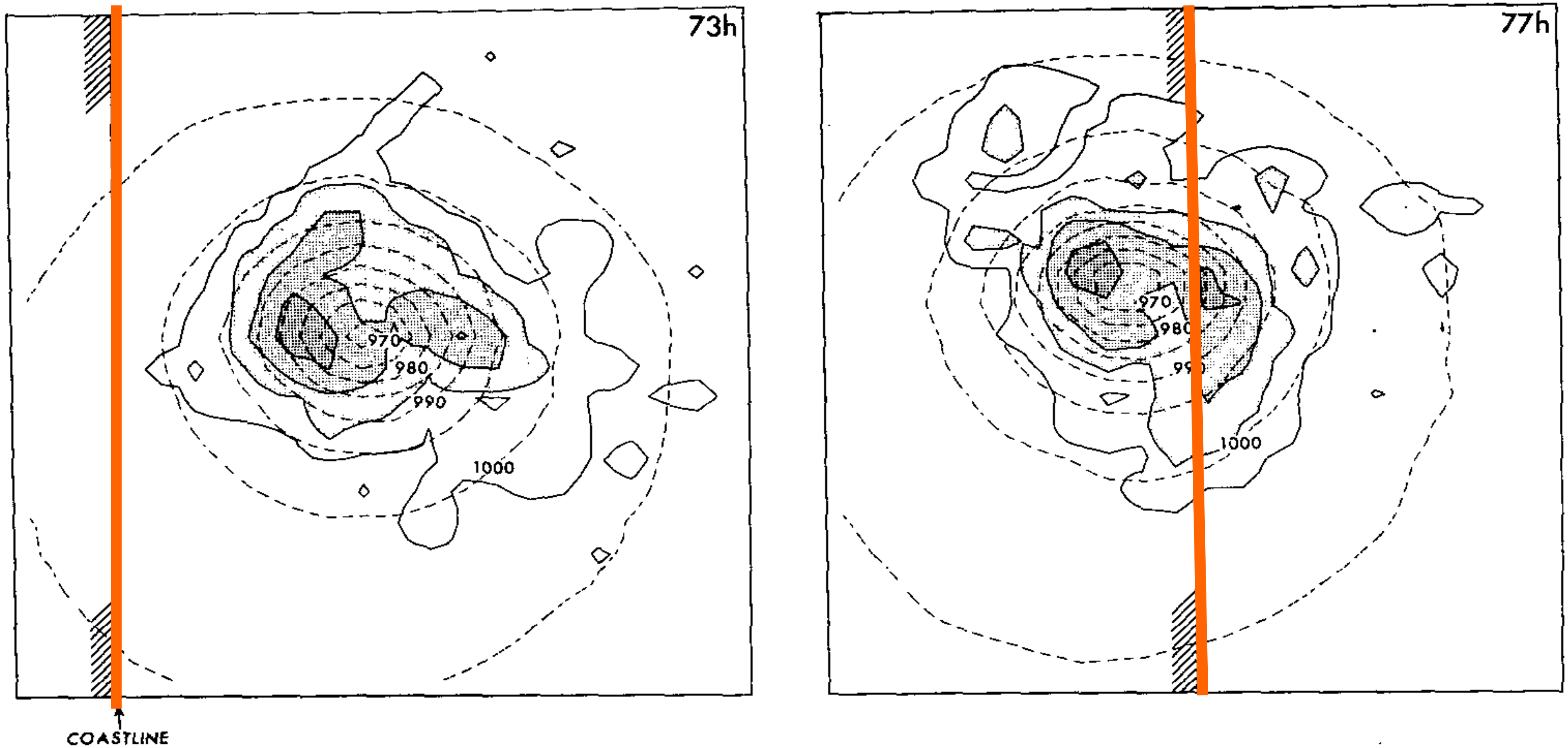
Points of Max Rainfall (land moving towards TC)

(from Tuleya and Kurihara 1978 JAS)

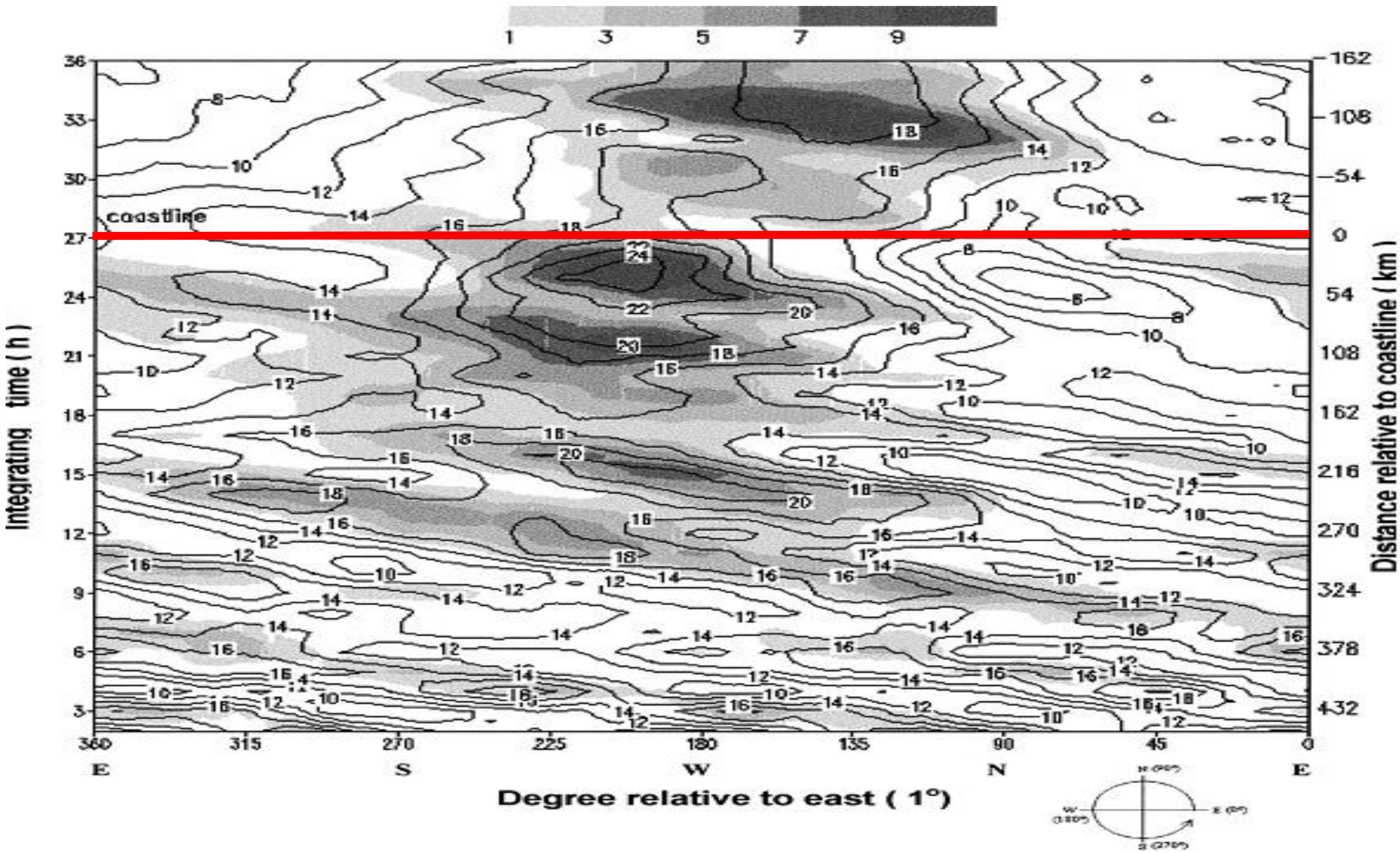




Points of Max Rainfall (U = -10 m s^{-1})

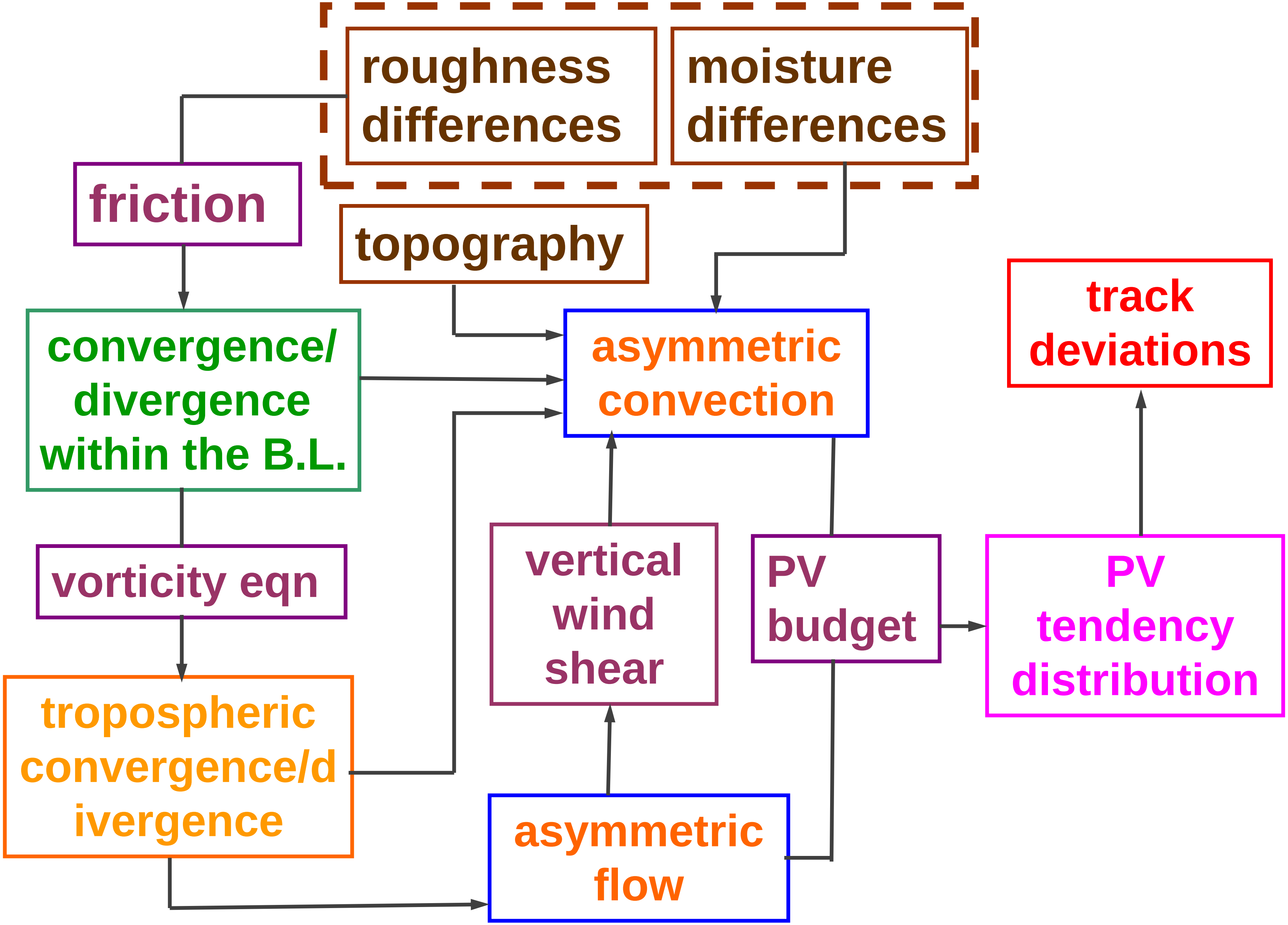


Rainfall (0-300 km) with increased friction over land and no moisture flux



Summary

- Convection asymmetries appear to be prevalent around landfall.
- Such asymmetries are not only related to friction and moisture differences, but also to vertical wind shear, and topography.


roughness differences
moisture differences
friction
topography
convergence/ divergence within the B.L.
asymmetric convection
track deviations
vorticity eqn
vertical wind shear
PV budget
PV tendency distribution
tropospheric convergence/d ivergence
asymmetric flow