

# Tropical cyclogenesis simulated by LM: real and idealized cases

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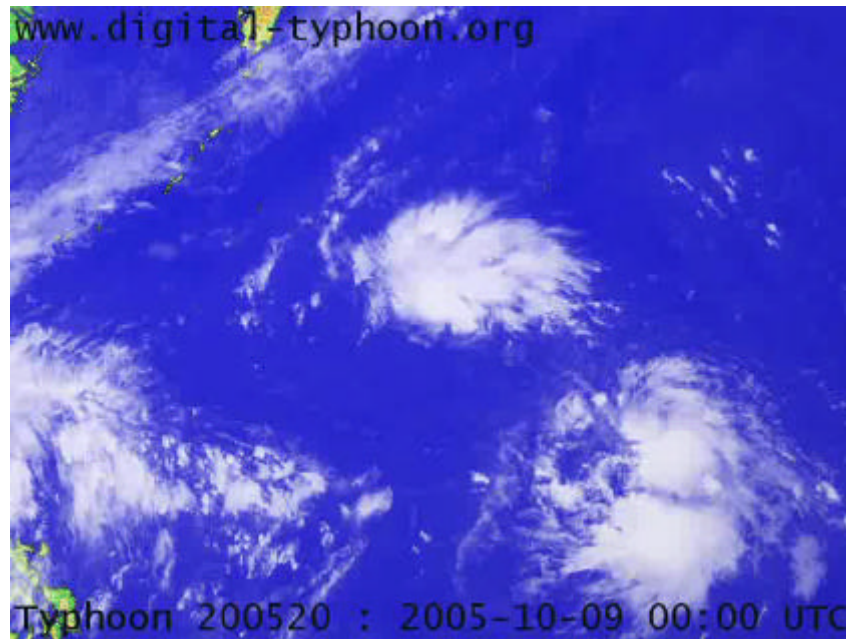
- **Real-case study**

**Simulation of typhoon Kirogi**

(\* North-West Pacific 137,9° E, 22° N 10.10.2005,

† near Japan 143,2° E, 31,7° N 19.10.2005)

- maximum horizontal velocity 110 kn (Saffir-Simpson Cat III)
- minimum central pressure 930 hPa



## **Configuration for the LM** (Version 3.15):

- 401 x 241 x 35 gridpoints with  $\Delta x = \Delta y = 6.95$  km  
(covering the area 120-145° E long., 16-31° N lat.)
- Simulation time span 144 h,  $\Delta t = 20$  sec
- Neglect of radiative effects
- Horizontal diffusion
- Cloud microphysics with prognostic treatment of precipitation

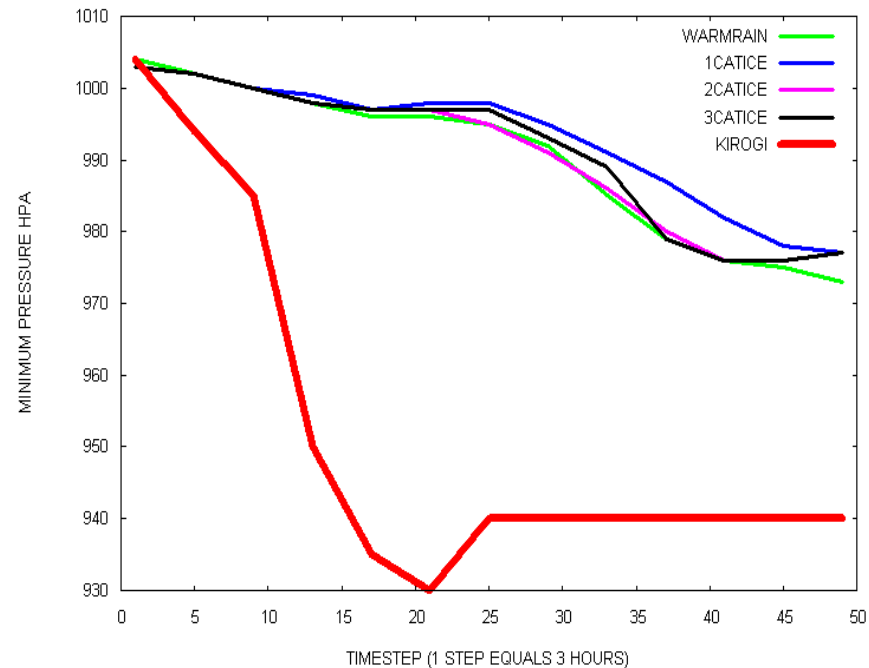
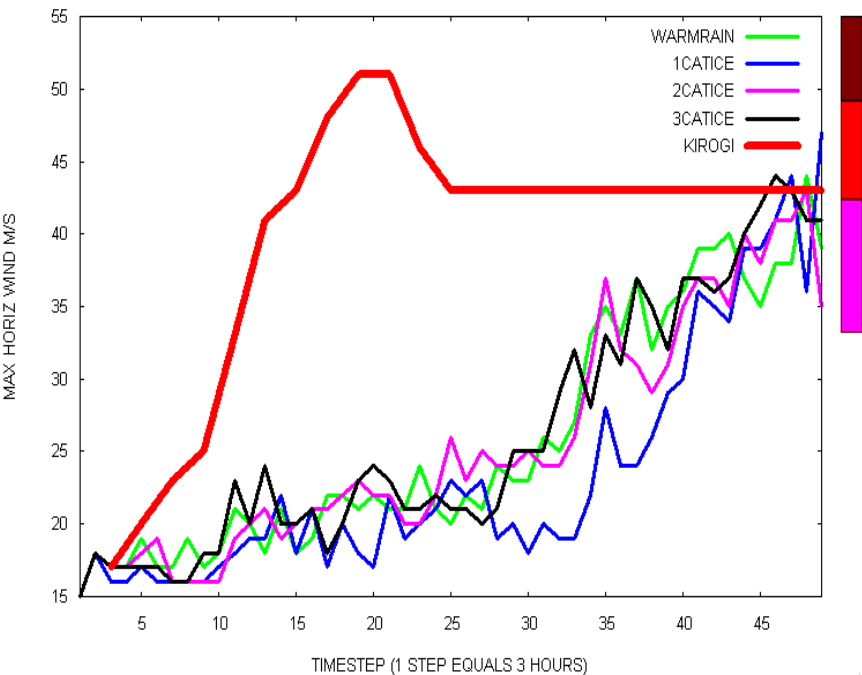
- Initial and boundary data are taken from the corresponding GME forecast
- Simulated time: 10.10.2005, 0 h UTC - 16.10.2005, 0 h UTC

#### **4 different experiments:**

- WARMRAIN : Only warm rain physics
- 1CATICE : Cloud scheme with one category of ice (snow)
- 2CATICE : Cloud scheme with two categories of ice (additional cloud ice)
- 3CATICE : Cloud scheme with three categories of ice (additional graupel)

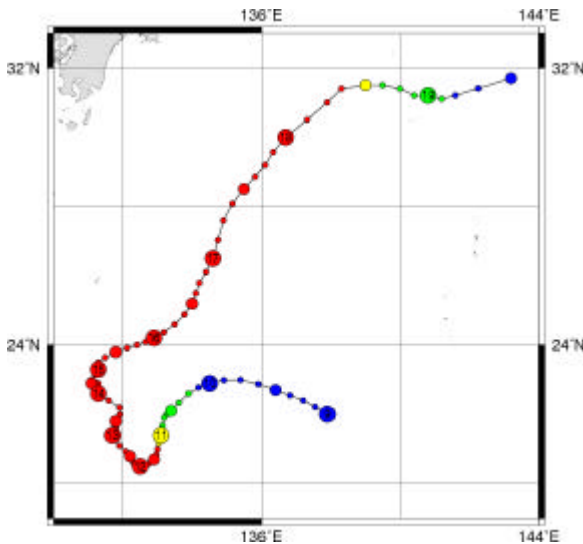
# Results

- In all four cases, a tropical cyclone of Saffir-Simpson Cat. I – II developed.
- Most of the development took place on day 5 of the simulation.
- At the end of the simulation period, the simulated and real wind velocities are similar in magnitude.
- The simulated minimum pressure is much higher than observed.

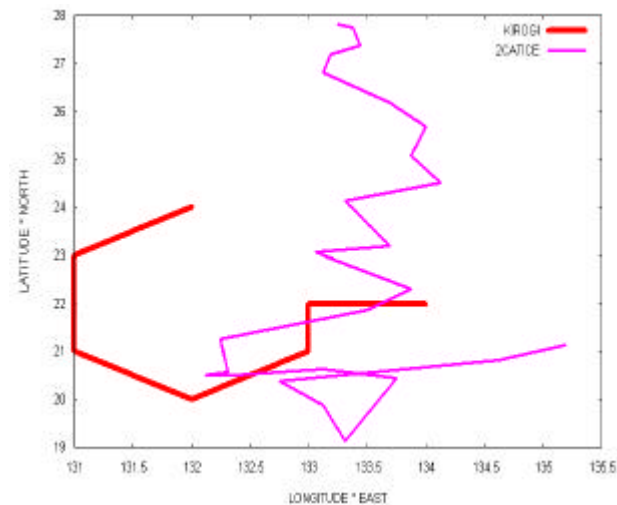


# The simulated storm track heavily deviates from the actual

- Simulated low pressure system advected by the steering flow
- Intrusion of cold air at the northern boundary

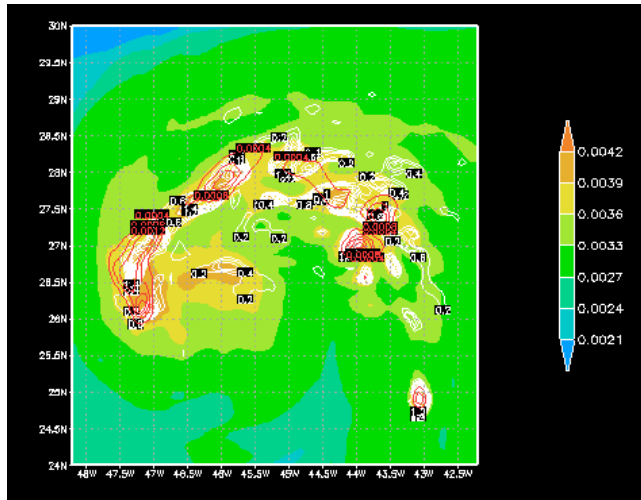


Storm Track Kirogi 9.10.-19.10.2005

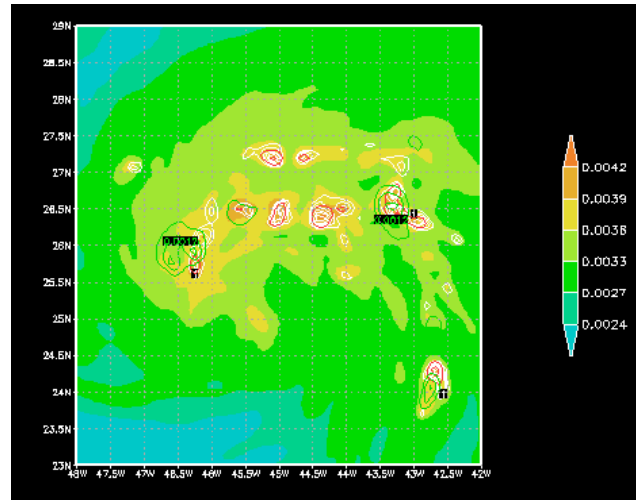


Comparison Kirogi-Simulation  
10.10. 0h UTC -16.10. 0h UTC

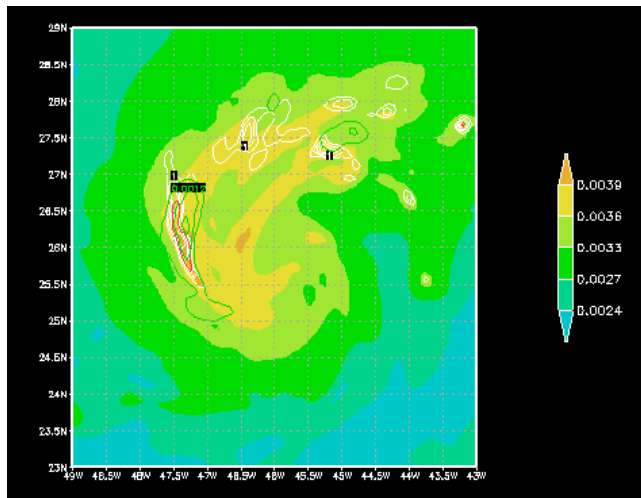
# Different precipitation categories, vertical motion in the developing cyclone (t = 108 h)



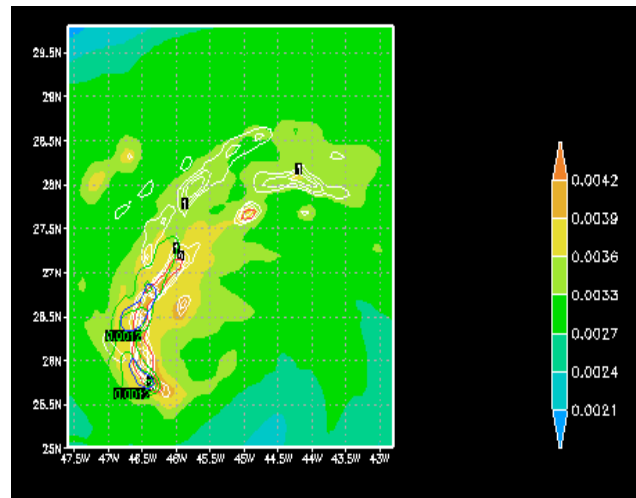
**WARMRAIN**



**1CATICE**



**2CATICE**



**3CATICE**

vertically averaged  
precipitation  
categories

rain (red)

snow (green)

graupel (blue)

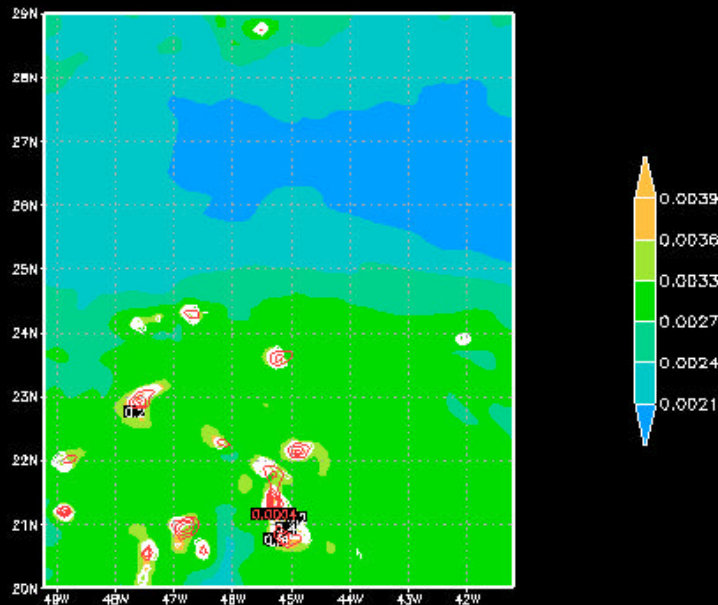
shaded:  
water vapor

white contours:  
updraft velocity  
(z = 5040 m)

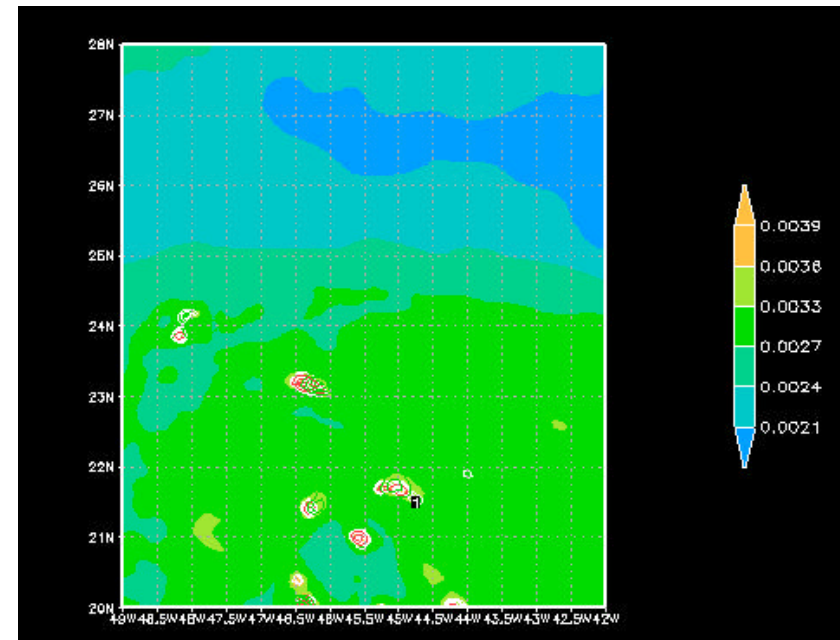
The animated view shows the development of coherent precipitation-updraft structures in the simulated cyclogenesis

Timesteps  $t = 21 - 37$  (12.10.2005 0h UTC – 14.10.2005 0h UTC)

Vertically averaged precipitation categories: rain (red), snow (green), graupel (blue)  
updraft in 5040 m (white), water vapour content (shaded)



WARMRAIN



1CATICE

## Conclusions

- Even with coarse initial data, a tropical cyclogenesis can be modelled by the LM.
- Without the application of e.g. bogus vortex techniques or additional information from radar data, the vortex evolution is rather slow.
- The intensity of simulated tropical cyclones is not sensitive to the ice phase and the number of ice categories.
- Coherent updraft structures together with the different precipitation categories seem to form an essential part in our modelled tropical cyclogenesis.

## Future plans

- Analysis of the convective energy budget in the different simulations for a deeper understanding of the impact of precipitation through convective processes.
- Detailed examination of the cyclone's nuclei structures (,Vortical Hot Towers', VHTs), their merger and the necessary conditions for them to attain coherent structure.

## 2. Idealized Experiments

### Questions

- What is the effect of the ice phase on the initiation of tropical cyclogenesis in the LM ?
- Is there a minimum threshold value in the LM for the initial vortex strength for tropical cyclogenesis?

## Configuration for the LM (Version 3.15):

- Neglection of spherical geometry (f-plane,  $f_0(30^\circ\text{N})=0.729 \times 10^{-4} \text{1/s}$ )
- 200x200x39 gridpoints with  $\Delta x = \Delta y = 6.95 \text{ km}$
- Neglection of radiation
- Lower boundary: Ocean surface with temperature  $T_S = 28^\circ\text{C}$
- No parameterization of convection
- Cloud microphysics with prognostic treatment of precipitation

## Experiments

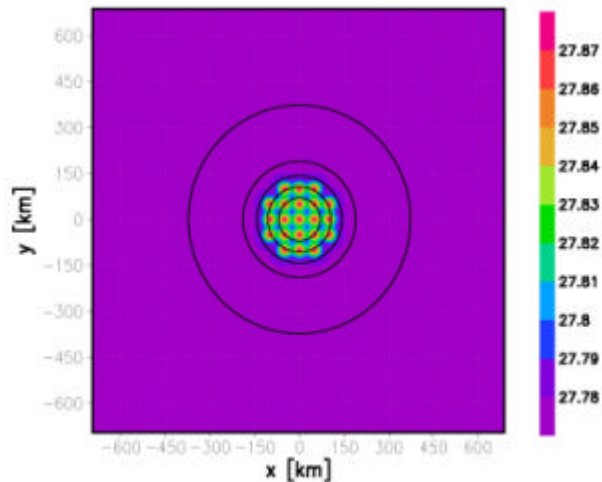
**WARMRAIN:** Only warm rain physics

**2CATICE:** Cloud scheme with 2 categories ice (snow and cloud ice)

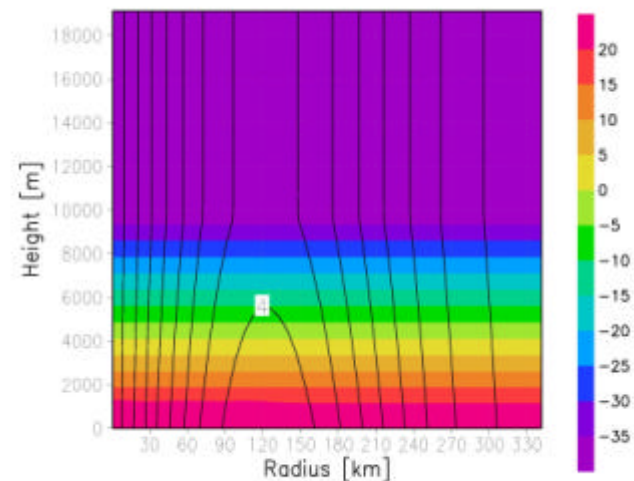
## Initial state

- Circular symmetric low having a central pressure deficit  $\Delta p = p - p_c$  and a characteristic radius  $r_0 = 150\text{km}$
- 21 buoyancy elements with increased moisture and temperature
- Temperature  $T = T_s - Gz$  with  $G = 6.5\text{K/km}$  for  $z < 10\text{km}$  (troposphere) and  $G = 0\text{K/km}$  for  $z > 10\text{km}$  (stratosphere)
- Horizontal wind is in gradient wind balance
- Uniform relative humidity  $RH = 70\%$

Temperature and pressure  
at the lowest model level

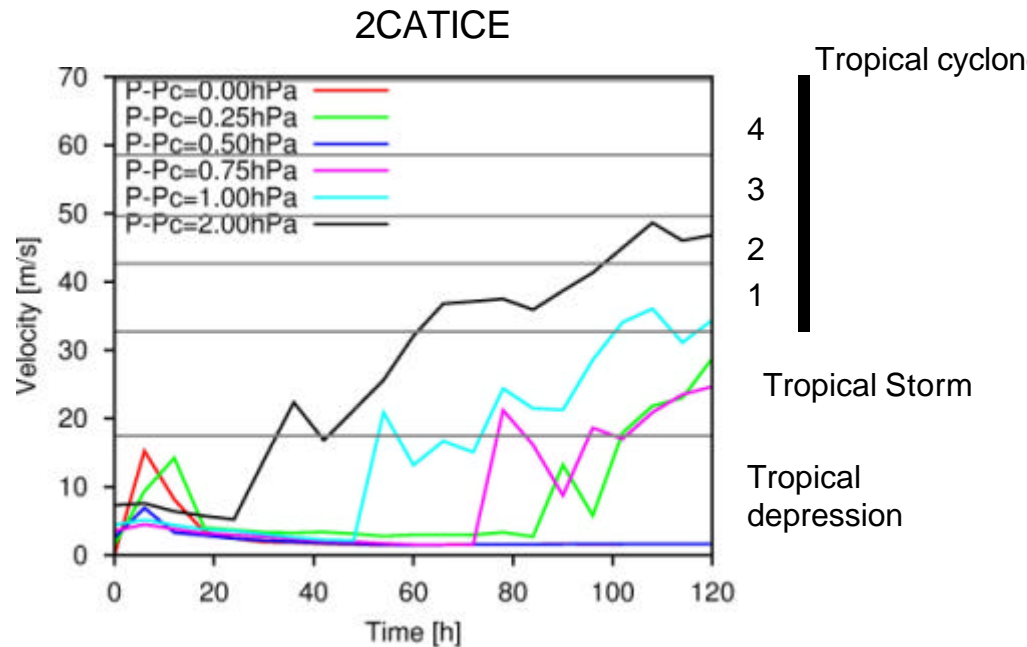
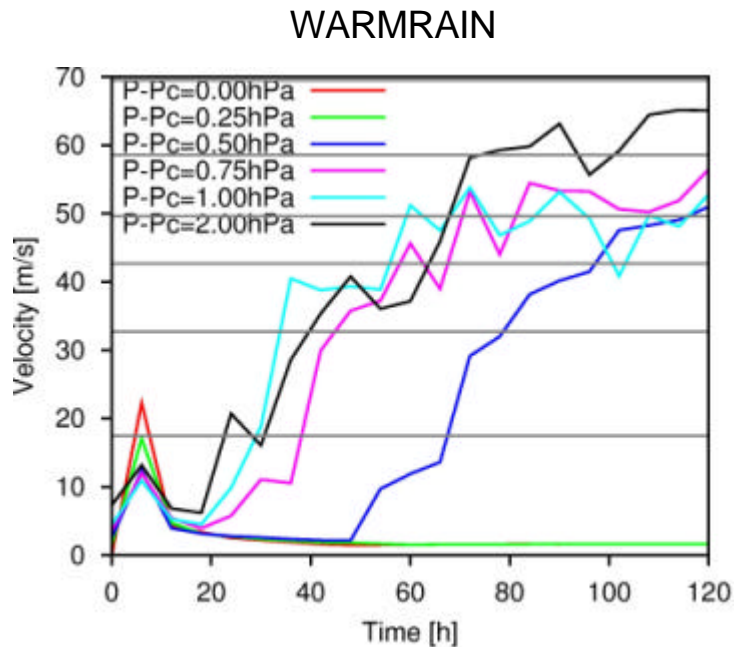


Radius-height cross section of  
Temperature and tangential wind



### 3. Results

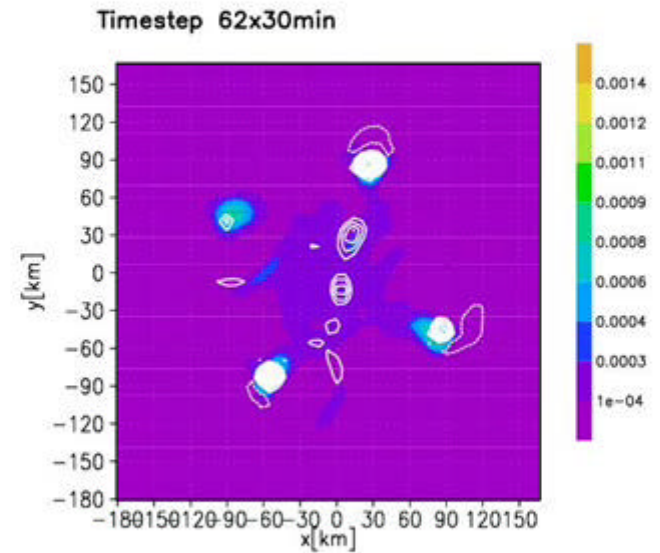
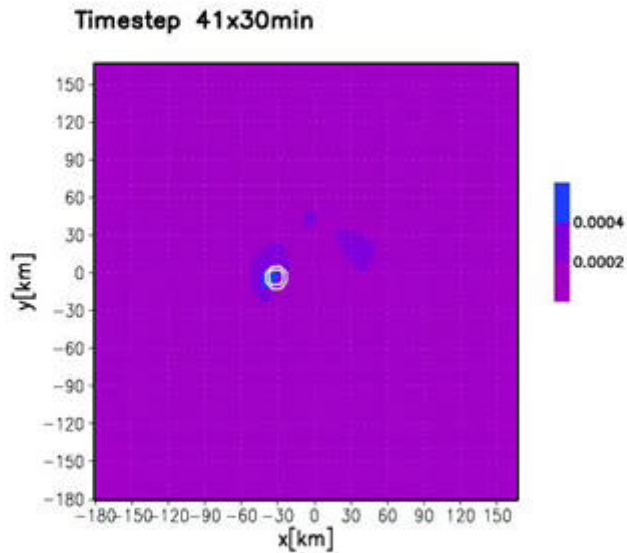
#### Maximum wind velocity near the surface



Vorticity  $z=200\text{m}$  (shadings) and vertical wind  $z=5400\text{m}$  (isolines,  $Cl=1\text{m/s}$ )

WARMRAIN ( $p-p_c = 1\text{ hPa}$ )

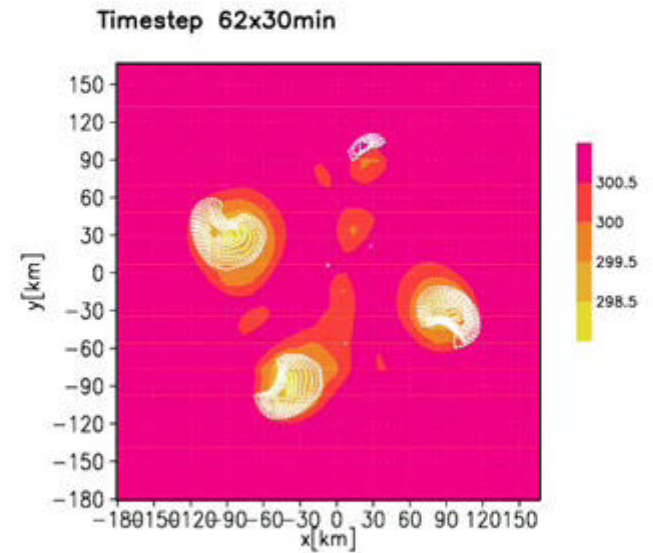
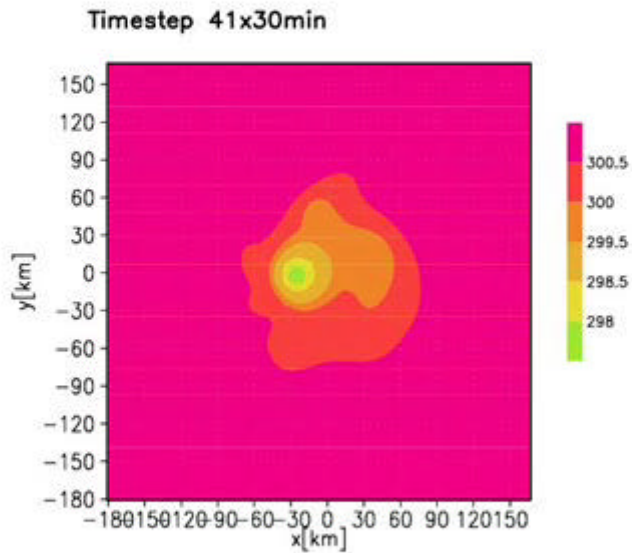
2CATICE ( $p-p_c = 2\text{ hPa}$ )



temperature  $z=34\text{m}$  (shadings) and downdraft  $z=1012\text{m}$  (isolines,  $Cl=0.1\text{m/s}$ )

WARMRAIN ( $p-p_c = 1\text{ hPa}$ )

2CATICE ( $p-p_c = 2\text{ hPa}$ )



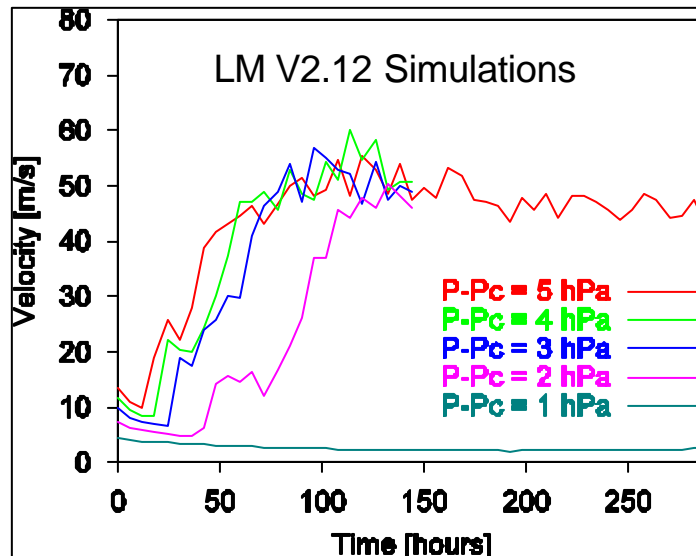
## 4. Conclusions

- The initialization of the LM with buoyancy elements together with a finite amplitude vortex can reveal tropical cyclogenesis.
- A finite amplitude vortex must be initially present for cyclogenesis.
- The threshold initial vortex strength for cyclogenesis depends on the consideration of the ice phase in the microphysical cloud scheme.
- The cooling of the boundary layer by downdrafts due to melting of snow hinders the development in the 2CATICE simulations.
- A more realistic representation of cyclogenesis behaviour can be expected when the ice-phase is simulated within the cloud microphysical scheme.

## Old Experiments

Initialization of the LM with a finite amplitude vortex having the pressure deficit  $p-p_c$ .

### Maximum wind velocity near the surface



No convection is released in the case  $p-p_c = 1 \text{ hPa}$

# Acknowledgments

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