Update on CAPE closure

C. Daleu, B. Plant , A. Stirling, M. Whitall, and S. Lavender

Sensitivity to the closure method within CoMorph

Standard closure

- Mass-flux launched from any height just depends on the local vertical instability $-N^2$:

$$M_{init} = \frac{1}{4} f \sqrt{-N^2} \rho \Delta z$$

- Cloud-base mass-flux is an emergent property of the entraining-detraining plume-model, not a closure variable!

CAPE closure

The cloud base mass flux is calculated based on the reduction to zero of CAPE by convection over a given timescale τ_{CAPE}

From the rate of changes in CAPE between t and $t + \Delta t$

$$\frac{CAPE(t)}{\tau_{CAPE}} = \alpha \frac{CAPE(t) - CAPE(t + \Delta t)}{\Delta t}$$

The mass flux at the base of the plume is multiplied by the scaling actor (α) to give convective mass flux that dissipates CAPE at the prescribed rate

$$M_1^{new} = \alpha \, M_1$$

Sensitivity to the closure method within CoMorph

Specification of a single value of τ_{CAPE} throughout the simulation (1 and 3 hours)

W1: simulations of tropical cyclones

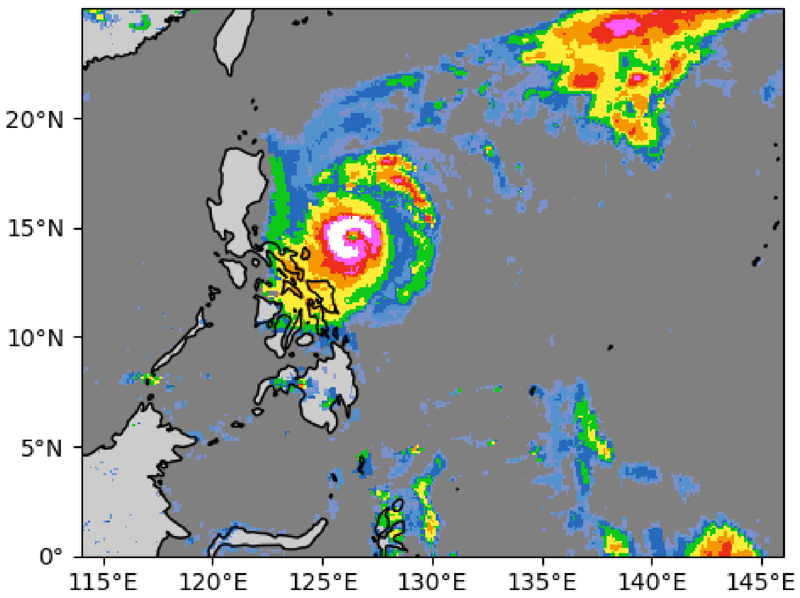
W2: convective responses to moisture tendency perturbations (Daleu et al., submitted)

W3: Diurnal cycle of shallow convection over land (*Brown et al., 2002*)

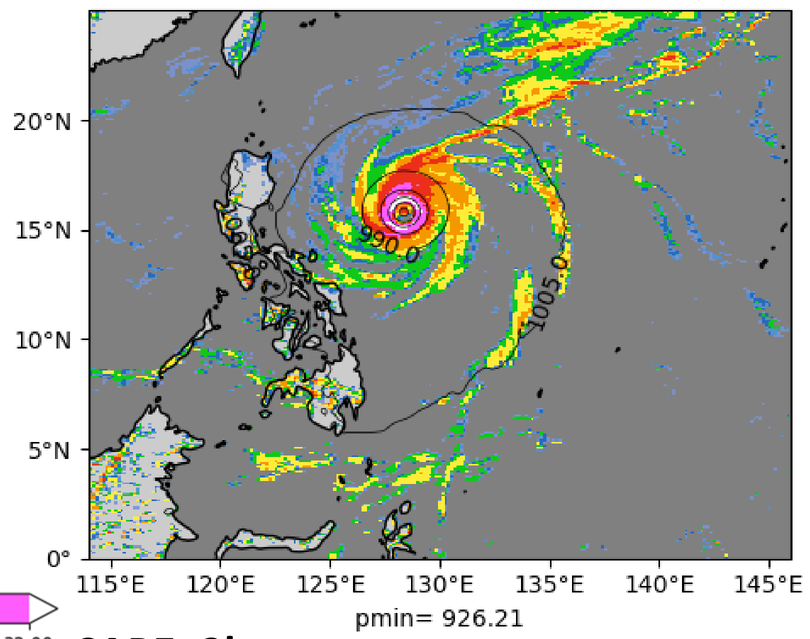
W4: Idealization of the EUROCS diurnal cycle deep convection case (Guichard et al., 2004)

W1: simulations of tropical cyclones: **Atm-only N1280 (~10km resolution)**

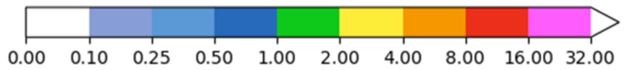
GPM



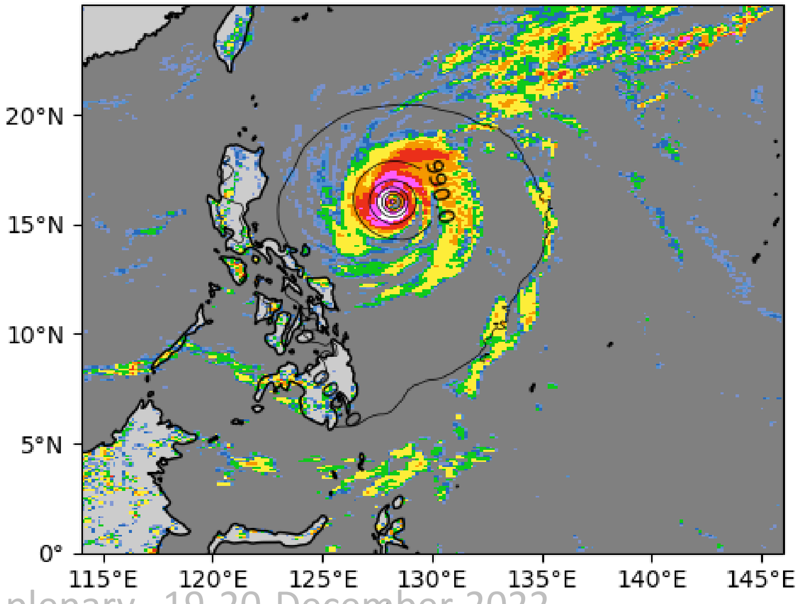
CoMorphA



The CAPE closure reduces the occurrence of excessively linear features in comorph A

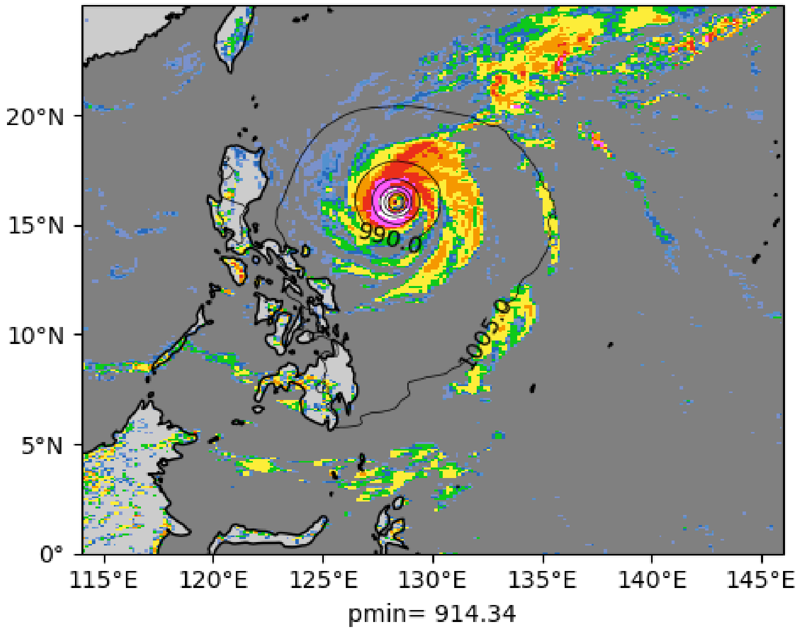


CAPE_1hr



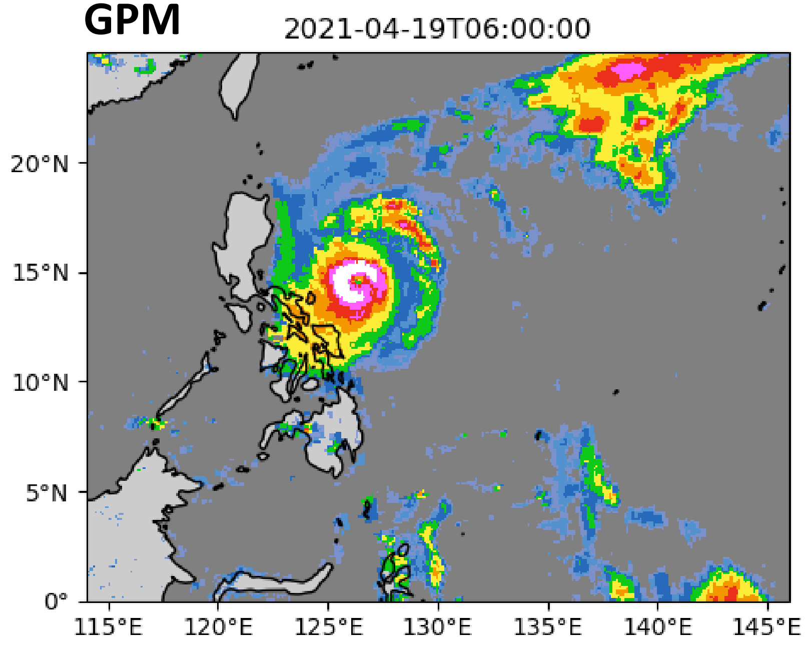
A possible theory is that the CAPE closure is allowing the large scale to do more but in CoMorphA the convection scheme has more control resulting in the linear features

CAPE_3hr



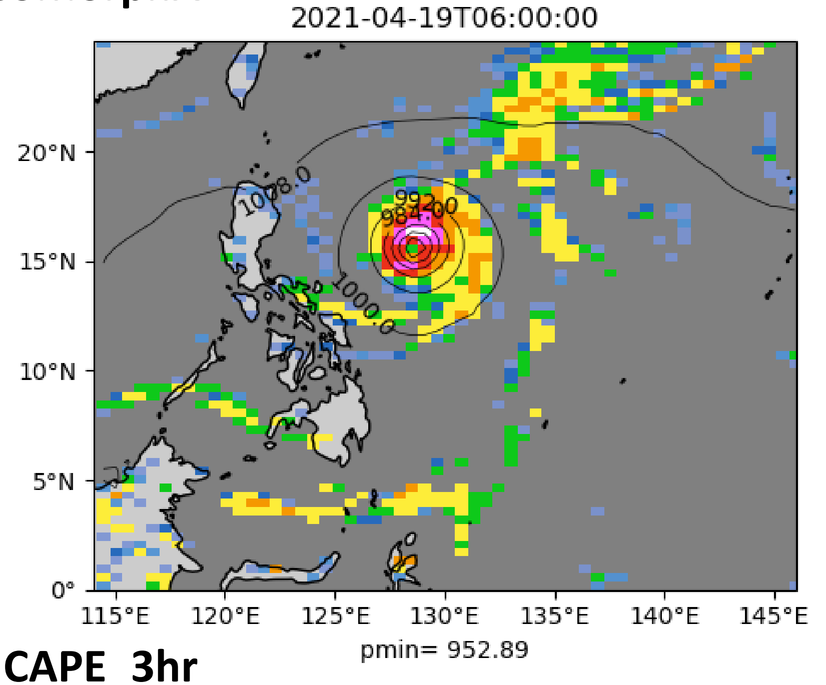
W1: simulations of tropical cyclones: Atm-only N320

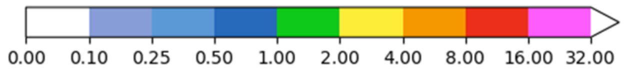
GPM



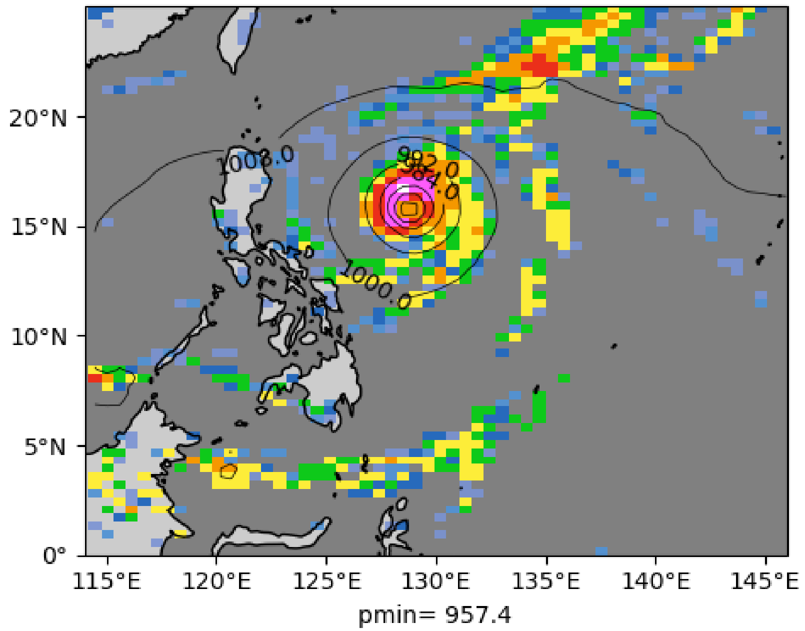
At coarser resolution the linear features in comorph A is reduced

CoMorphA



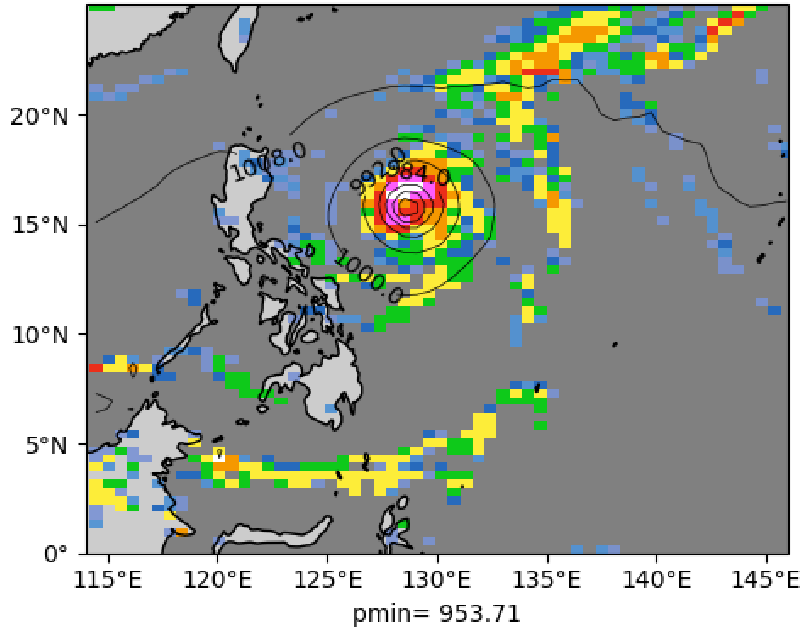


CAPE_1hr



the CAPE closure reduces the occurrence of excessively linear features in comorph A

CAPE_3hr



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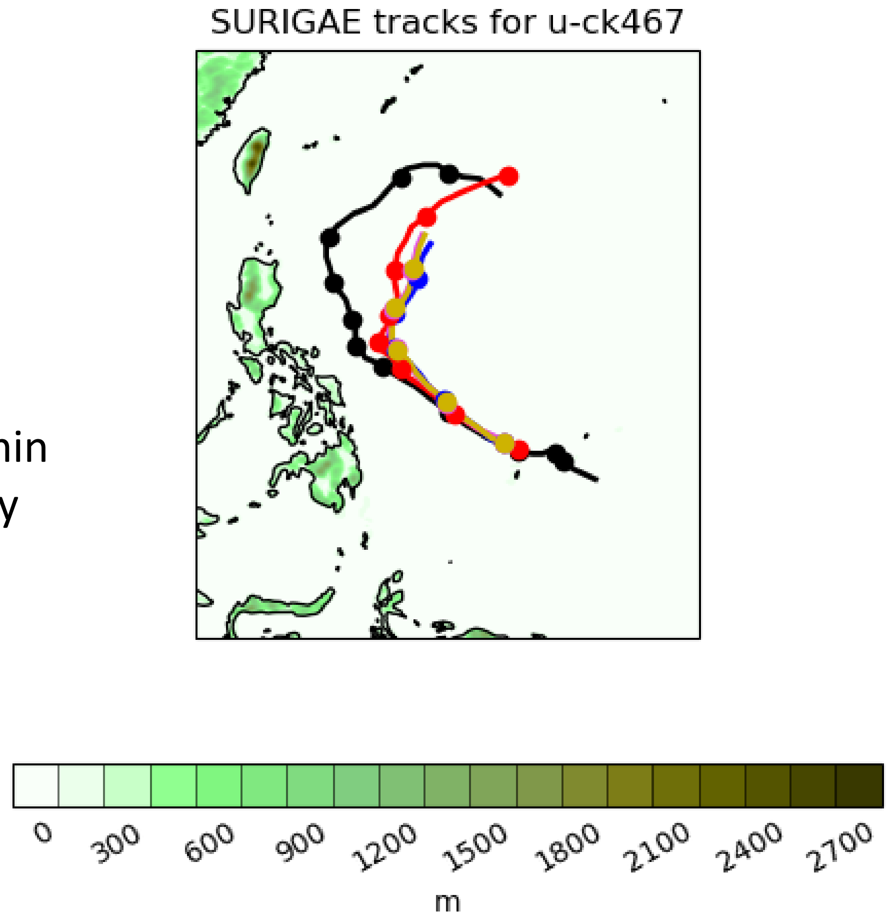
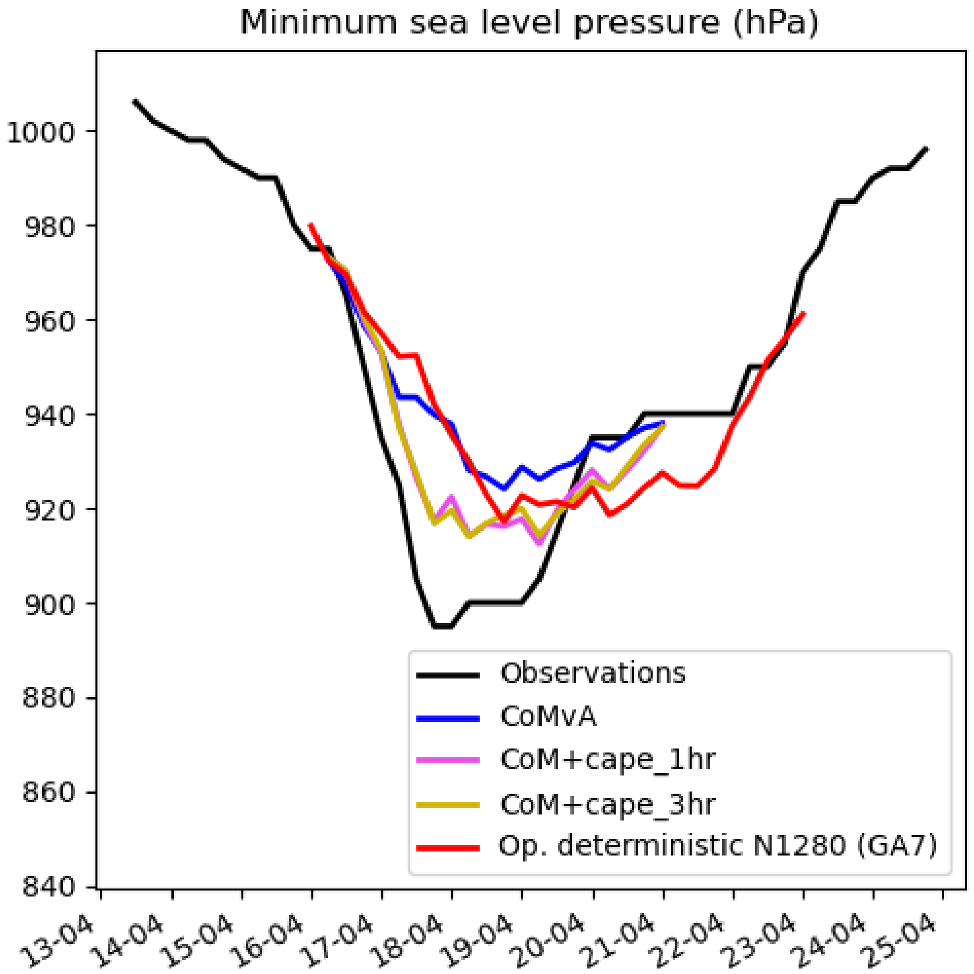
Atm-only Typhoon Surigae

Tracked by min pressure only





Slight increase in intensity with CAPE closure
with little difference between the 2 timescales tested

Sensitivity to the closure method within CoMorph

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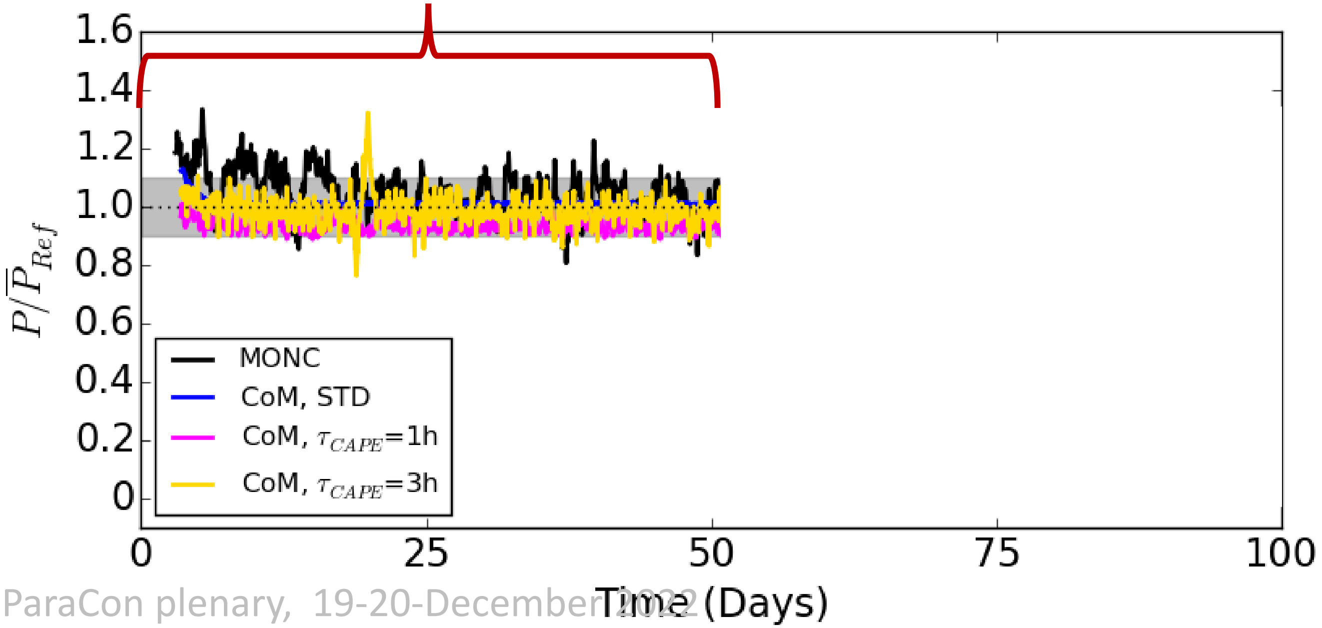
W2: Simulations of convection coupled to parameterized large-scale circulation (Daleu et al., submitted)

large-scale circulation parameterized using the

damped-gravity wave approach $$\frac{\partial}{\partial p}\left(\varepsilon\frac{\partial\overline{\omega}}{\partial p}\right)=\frac{\kappa^2 R_d}{\overline{p}^{Ref}}\left(\overline{T}_v-\overline{T}_v^{Ref}\right)$$

$$\frac{\partial\theta}{\partial p}=\cdots-\overline{\omega}\frac{\partial\overline{\theta}}{\partial p}\quad\text{and}\quad\frac{\partial q}{\partial p}=\cdots+\overline{\omega}\frac{\partial\overline{q}}{\partial p}+\max\left(\overline{\omega}\frac{\partial\overline{\omega}}{\partial p},0\right)\left(\overline{q}^{Ref}-\overline{q}\right)$$

Days 0-50: unperturbed temperature and moisture tendency profiles



- Days 0-50: the reference state is a stable equilibrium state under the DGW method

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W2: Simulations of convection coupled to parameterized large-scale circulation (Daleu et al., submitted)

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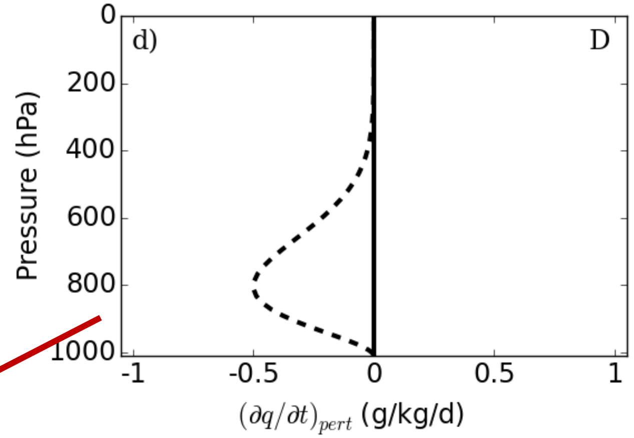
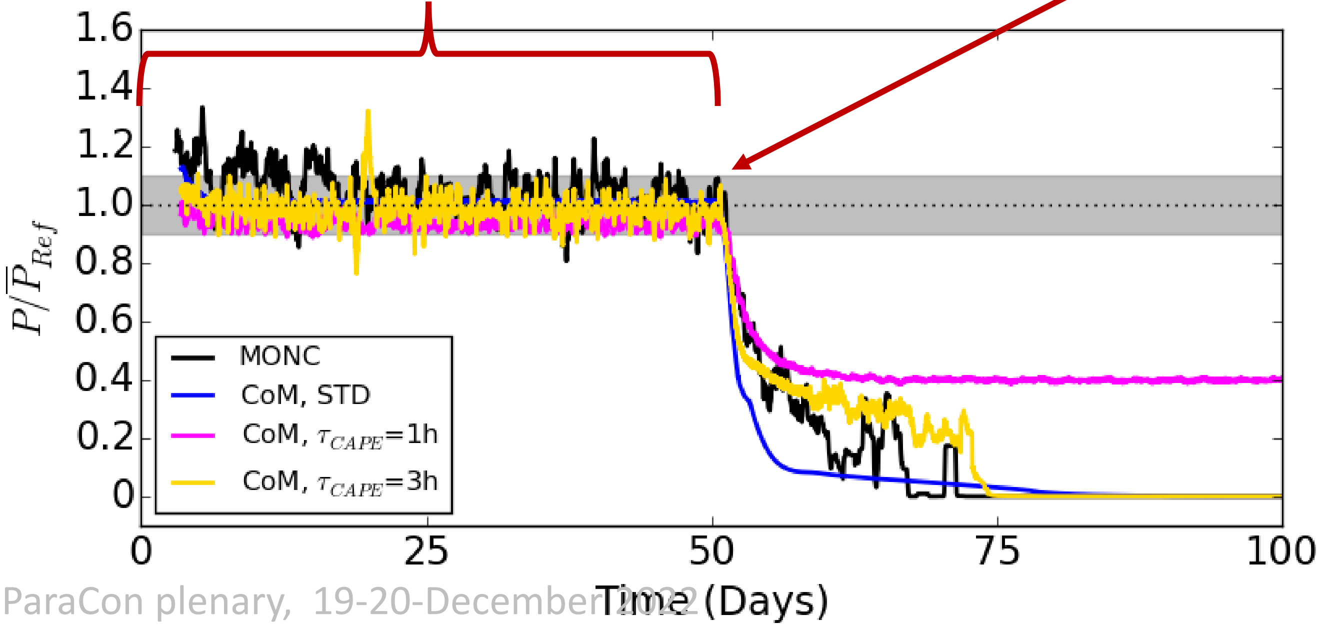


Days 0-50: unperturbed temperature and moisture tendency profiles

From day 50: Dry tendency perturbations applied



- Days 0-50: the reference state is a stable equilibrium state under the DGW method
- From day 50: adhustment to dry equilibria
  - CoMorph with its standard closure:
    - The adjustment is **much quicker**
    - Achieves **zero precip** as in MONC
  - CoMorph with CAPE closure:
    - the adjustment is slower
    - τ_{CAPE}=3h achieves **zero precipitation** as in MONC and standard CoMorph closure
    - τ_{CAPE}=1h **achieves 60%** reduction in precip

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Specification of a single value of $\boldsymbol{\tau_{CAPE}}$ throughout the simulation (1 and 3 hours)

Simulations of TCs→ little difference between the 2 timescales tested

Convective responses to dry tendency perturbations → precipitating or non-precipitating equilibria depending on the value of $\boldsymbol{\tau_{CAPE}}$.

Let's performed simulations with other variations on the CAPE closure.

$\boldsymbol{\tau_{CAPE}}$ varies vary throughout the simulations depending on the level of convective activity

Case3: w based CAPE closure: (the user supplies w_{crit}, depending on model resolution)

If $w_{max} > w_{crit}$, then τ_{CAPE} is reduced as follows:

$$\tau'_{CAPE} = \tau_{CAPE} \frac{w_{crit}}{[w_{crit} + f_{wcape}(w_{max} - w_{crit})]}$$

with $\boldsymbol{\tau'_{CAPE}}$ > convection model time step

Case 7: large-scale vertical velocity based CAPE timescale

$$\tau_{CAPE}(h) = \begin{cases} \dfrac{a}{w_{LS}^{b}} & \text{for } w_{LS} > 0 \\ 4 & \text{for } w_{LS} \leq 0 \end{cases}$$

with convection model time step < $\boldsymbol{\tau_{CAPE}} < 4$h

where $a = 0.069$ and $b = 0.7$

*(Analysis of the **high resolution convection permitting simulations over West Africa and the Indian Ocean done for the CASCADE**).*

W3 Diurnal cycle of shallow convection over land (*Brown et al., 2002*)

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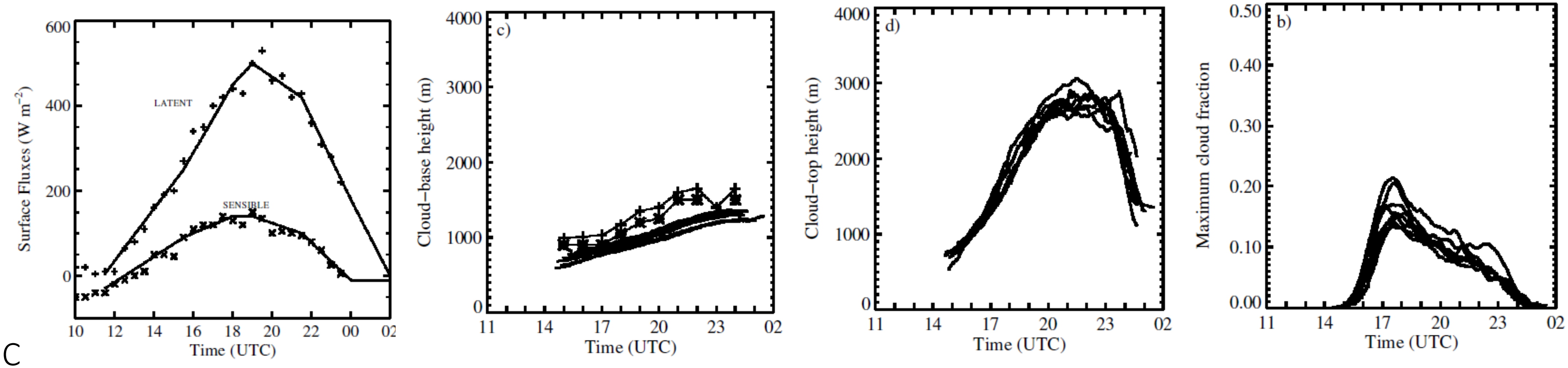
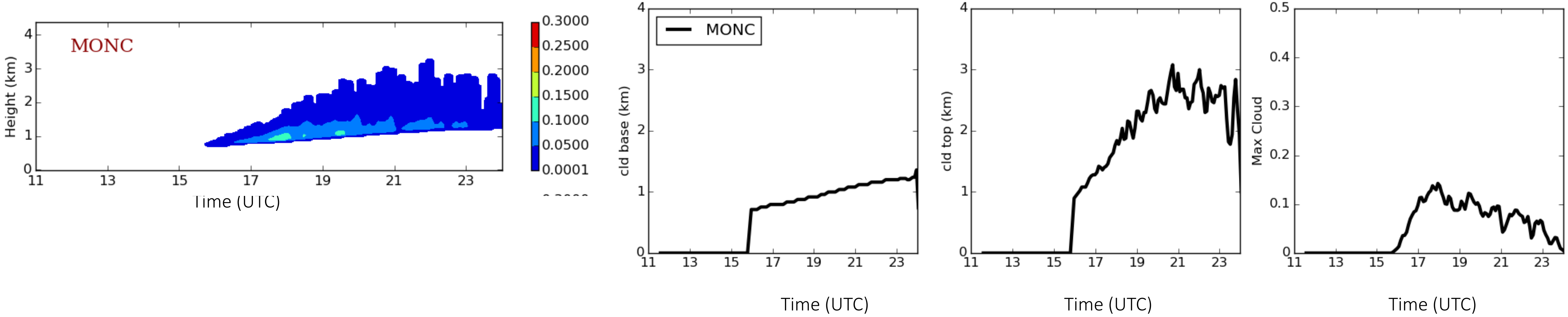
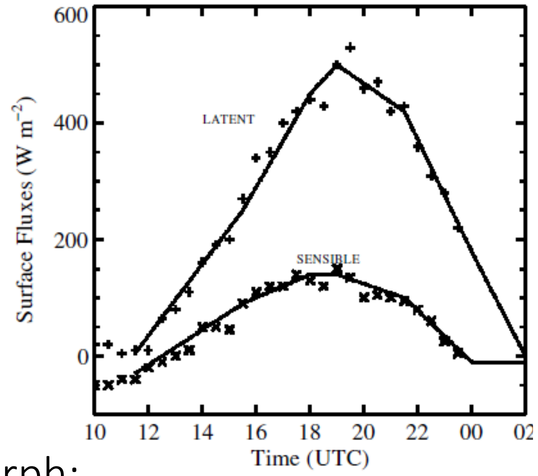


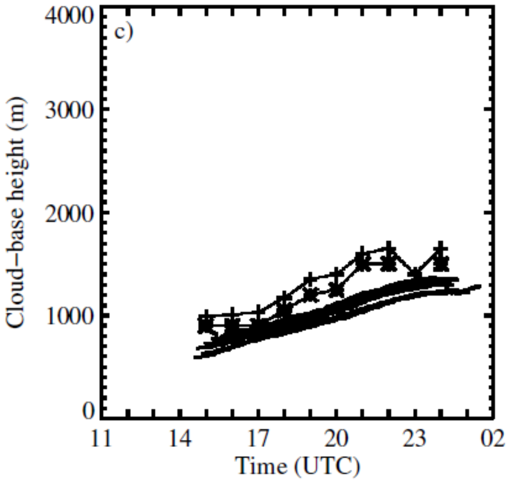
Results from MONC

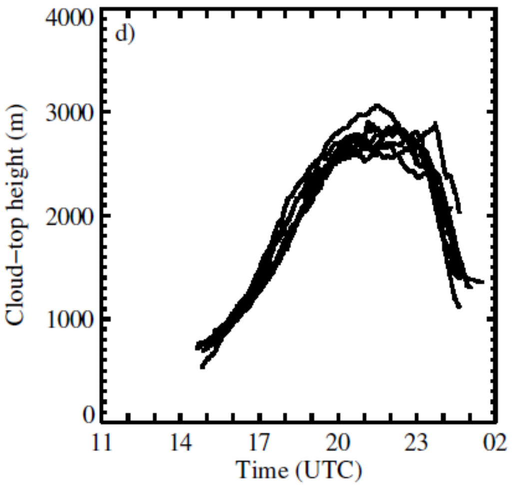


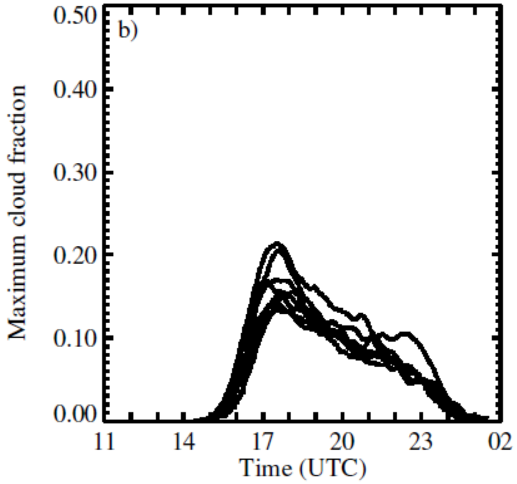
Similar to those obtained in simulation using eight independent models *(brown et al., 2002)*

W1: Diurnal cycle of shallow convection over land (*Brown et al., 2002*)

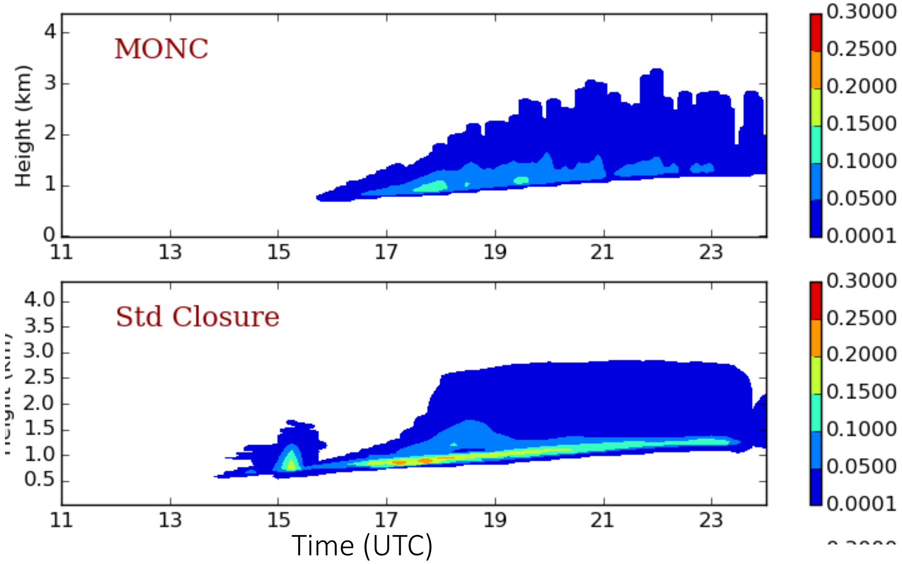


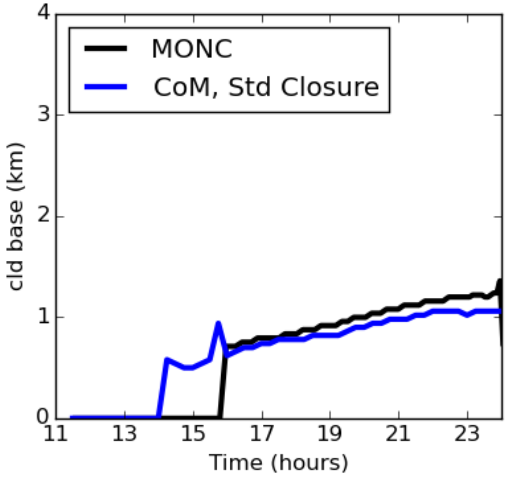


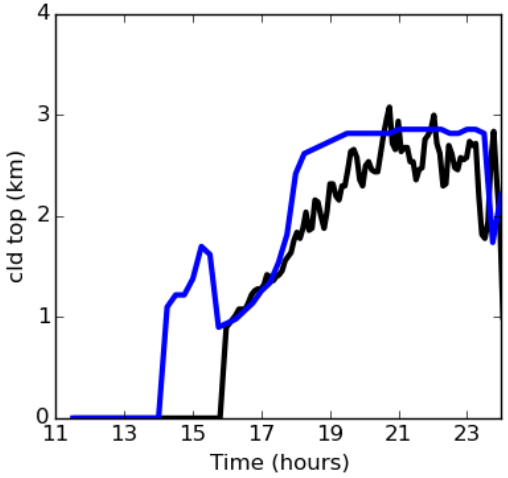


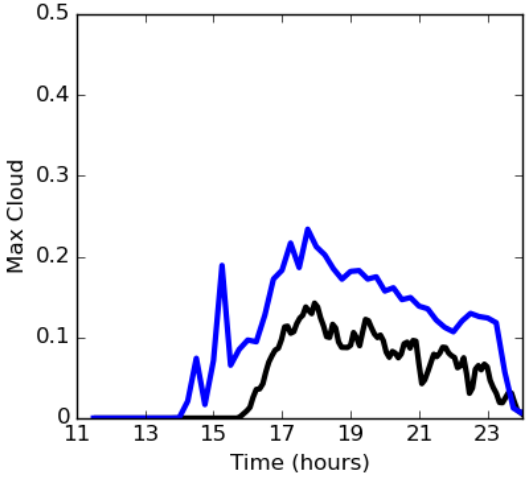


Results from CoMorph:







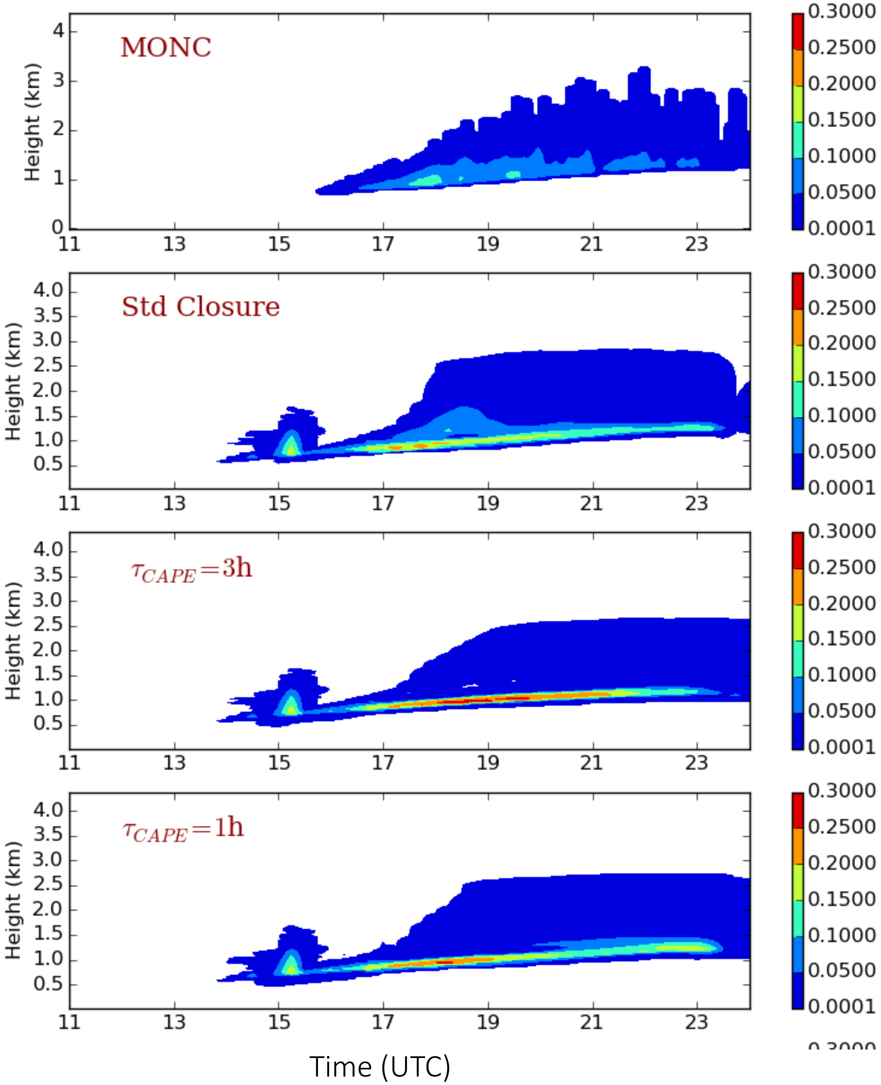


Time (UTC) Time (UTC) Time (UTC)

CoMorph vs **MONC** results and those from *Brown et al 2002*:

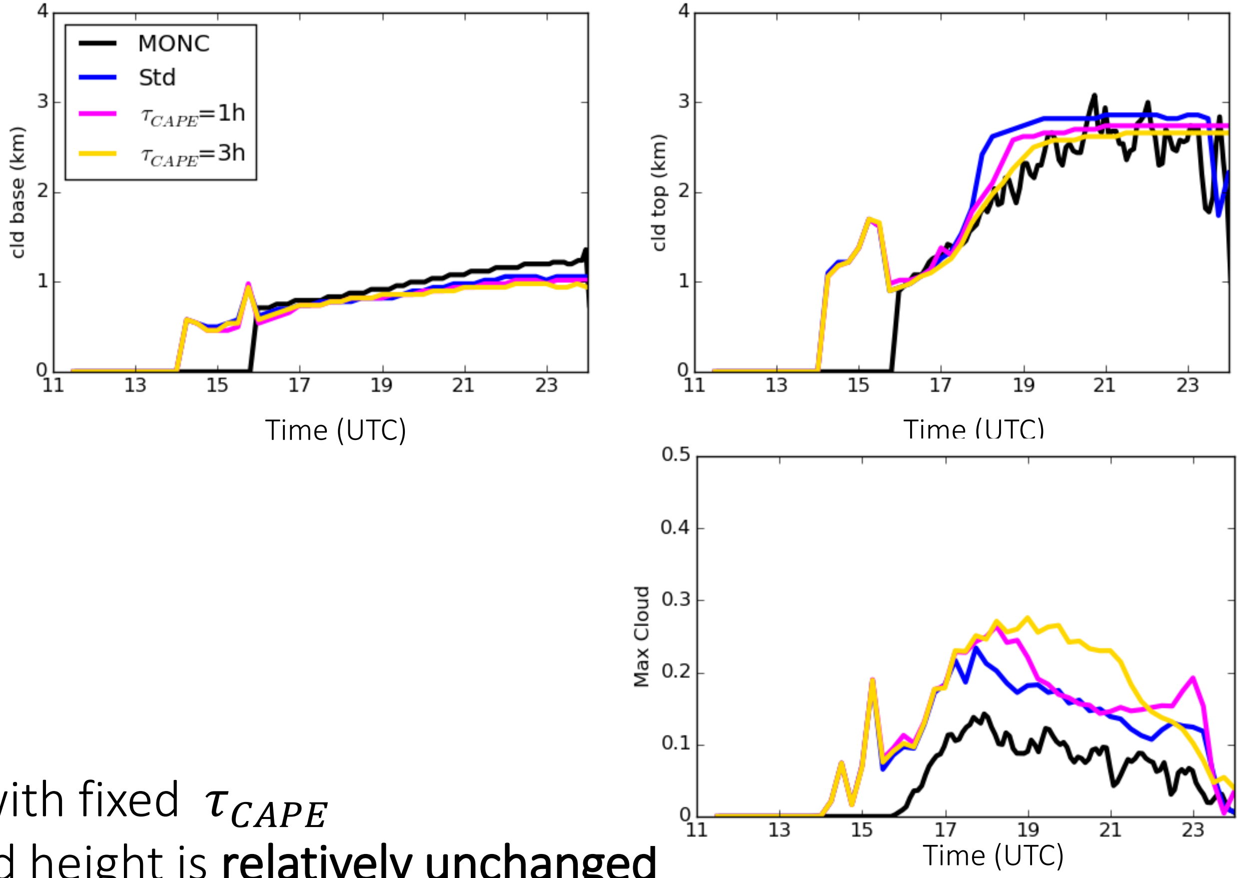
- Convection is triggered a **couple of hours earlier**
- Cloud base height doesn't go as deep as in MONC
- Cloud **emerges rapidly** and reaches its maximum height earlier
- **Larger cloud fraction** throughout the simulation

W1: Diurnal cycle of shallow convection over land (*Brown et al., 2002*)



Sensitivity to the closure method within CoMorph:

fixed CAPE time scale τ_{CAPE} =3, 1 or 0.5 hours



CAPE closure with fixed τ_{CAPE}

- Cloud based height is **relatively unchanged**
- The max cloud **is increased with CAPE closure**
- Cloud **emerges less rapidly with CAPE closure**
  - $\boldsymbol{\tau_{CAPE} = 3h}$ → Evolution of cloud to height **comparable to that obtained in MONC**

W1: Diurnal cycle of shallow convection over land (*Brown et al., 2002*)

Case3: w based CAPE closure:

If $w_{max} > w_{crit}$, then τ_{CAPE} is reduced as follows:

$$\tau'_{CAPE} = \tau_{CAPE} \frac{w_{crit}}{[w_{crit} + f_{wcape}(w_{max} - w_{crit})]}$$

with

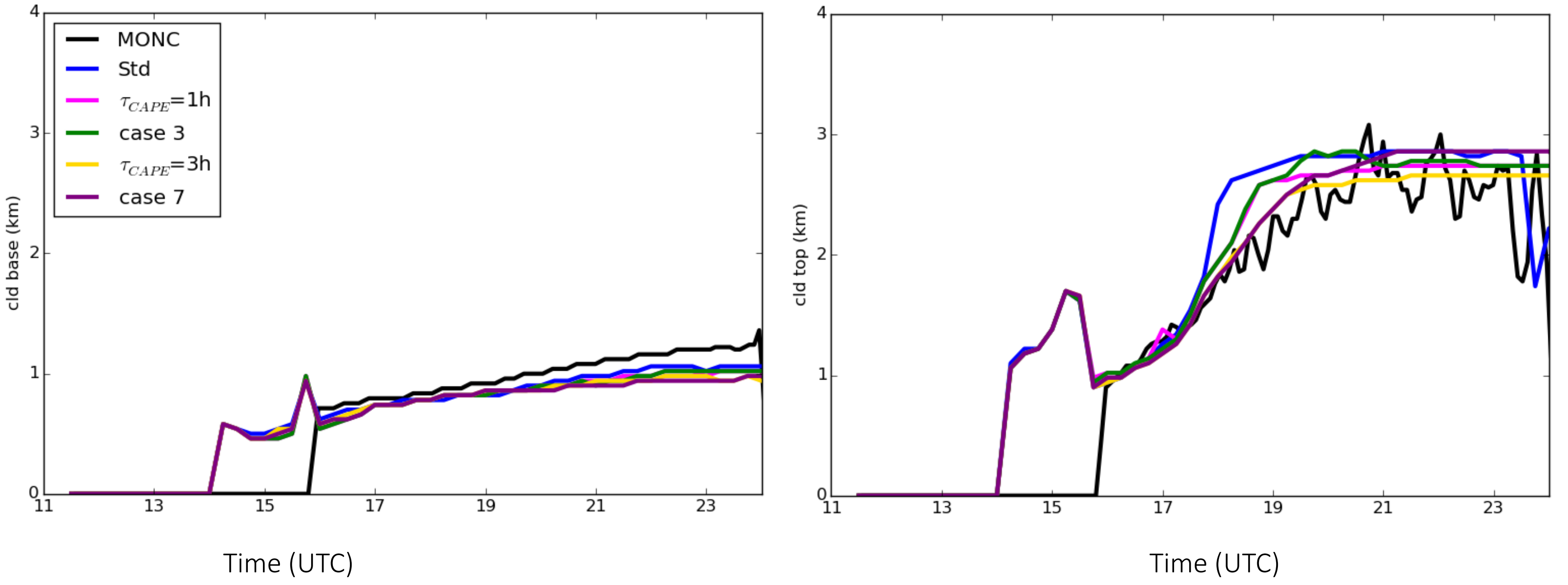
$\tau'_{CAPE} >$ convection model time step

Case 7: large-scale vertical velocity based CAPE timescale

$$\tau_{CAPE}(h) = \begin{cases} \frac{a}{w_{LS}^{b}} \\ 4 \end{cases}$$

Sensitivity to the closure method within CoMorph:

Other variations on the CAPE closure: Case3: (w based CAPE closure) and Case 7 (large-scale vertical velocity based CAPE timescale)



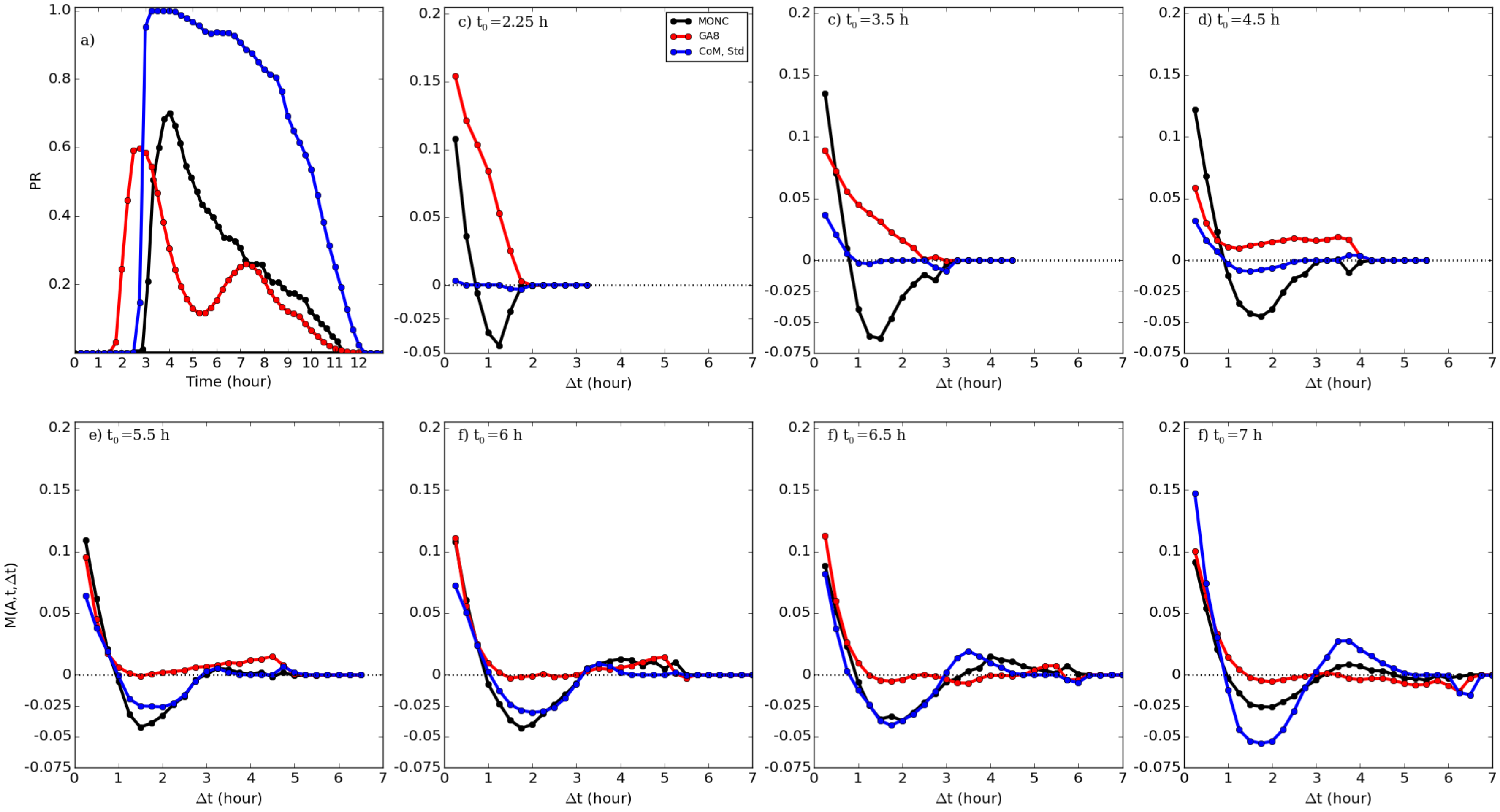
Case 3 vs **CAPE closure with fixed τ_{CAPE}=1h** and case 7 vs CAPE closure with fixed τ_{CAPE}

- Cloud based height is **relatively unchanged**
- From hours 19
  - cloud **emerges further**
  - Cloud top height **is slightly increased** with CAPE closure with variable timescale.

W2: Idealization of the EUROCS diurnal cycle deep convection case (Guichard et al., 2004)

Memory function: $M(A,t_0,\Delta t) = P[R(A,t_0) \cap R(A,t_0-\Delta t)] - P^2[R(A,t_0,\Delta t)]$

- 1st phase: persistence of newly developing convection
- 2nd phase: suppression of convection
- 3rd phase: secondary enhancement of convection



Results from GA8 vs **MONC**

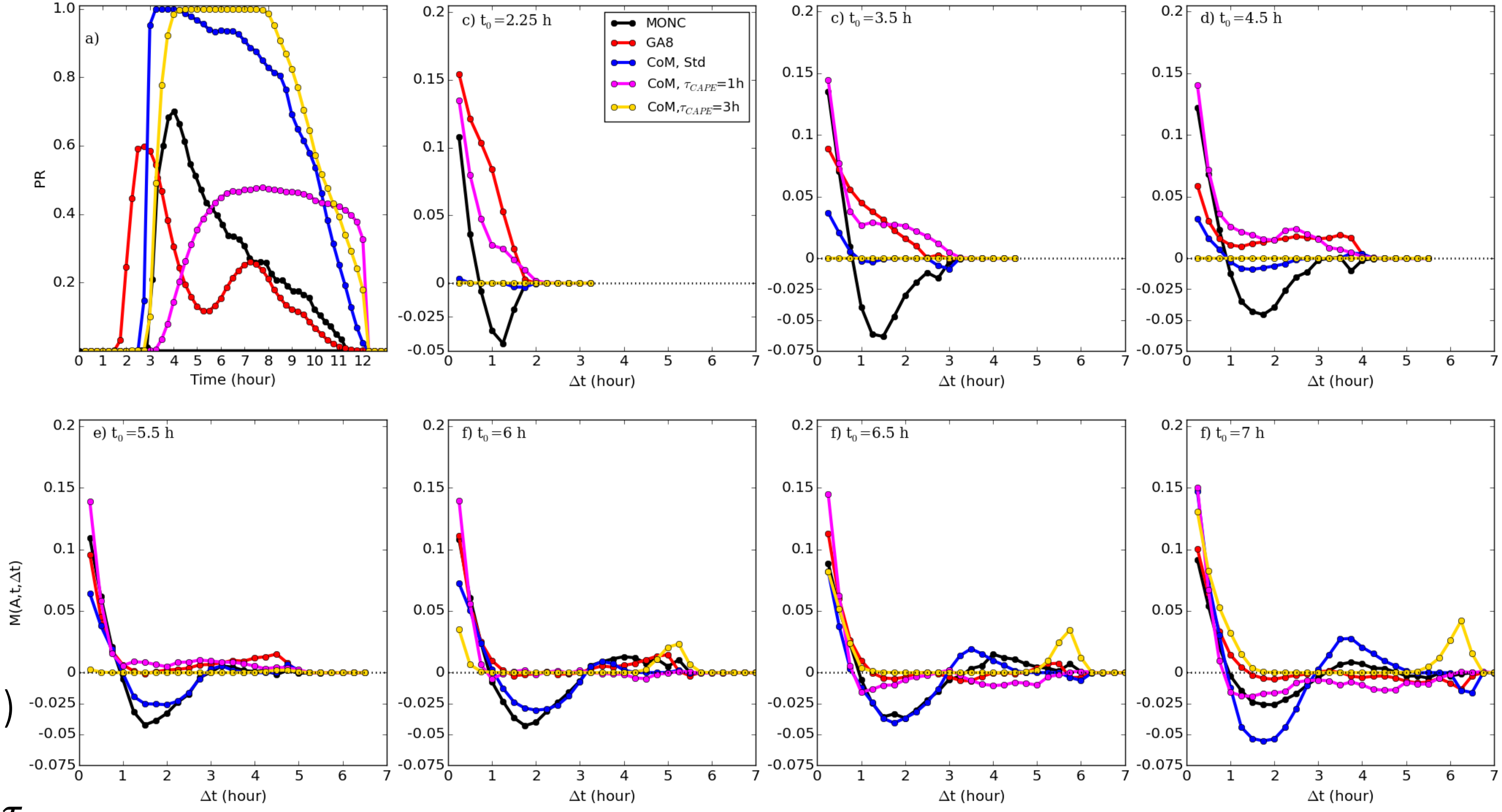
- The triggering of convection (t_0) about 1.5 h earlier

Results from CoMorph vs **MONC**

- The triggering of convection (t_0) is slightly earlier
- $P(t_0 < 1h) \sim 1$: convection triggers in almost all grid points
- $M(A, t_0 < 3h, \Delta t) \approx 0$: **random distribution of convection**
- The 1st and 2nd phases occur from $t_0 \geq 3.5$h
- There is **a 3rd phase** as in MONC
- $M(A, t_0 > 7h, \Delta t)$ is stronger than in MONC

W2: Idealization of the EUROCS diurnal cycle deep convection case (Guichard et al., 2004)

Memory function: $M(A,t_0,\Delta t) = P[R(A,t_0) \cap R(A,t_0-\Delta t)] - P^2[R(A,t_0,\Delta t)]$

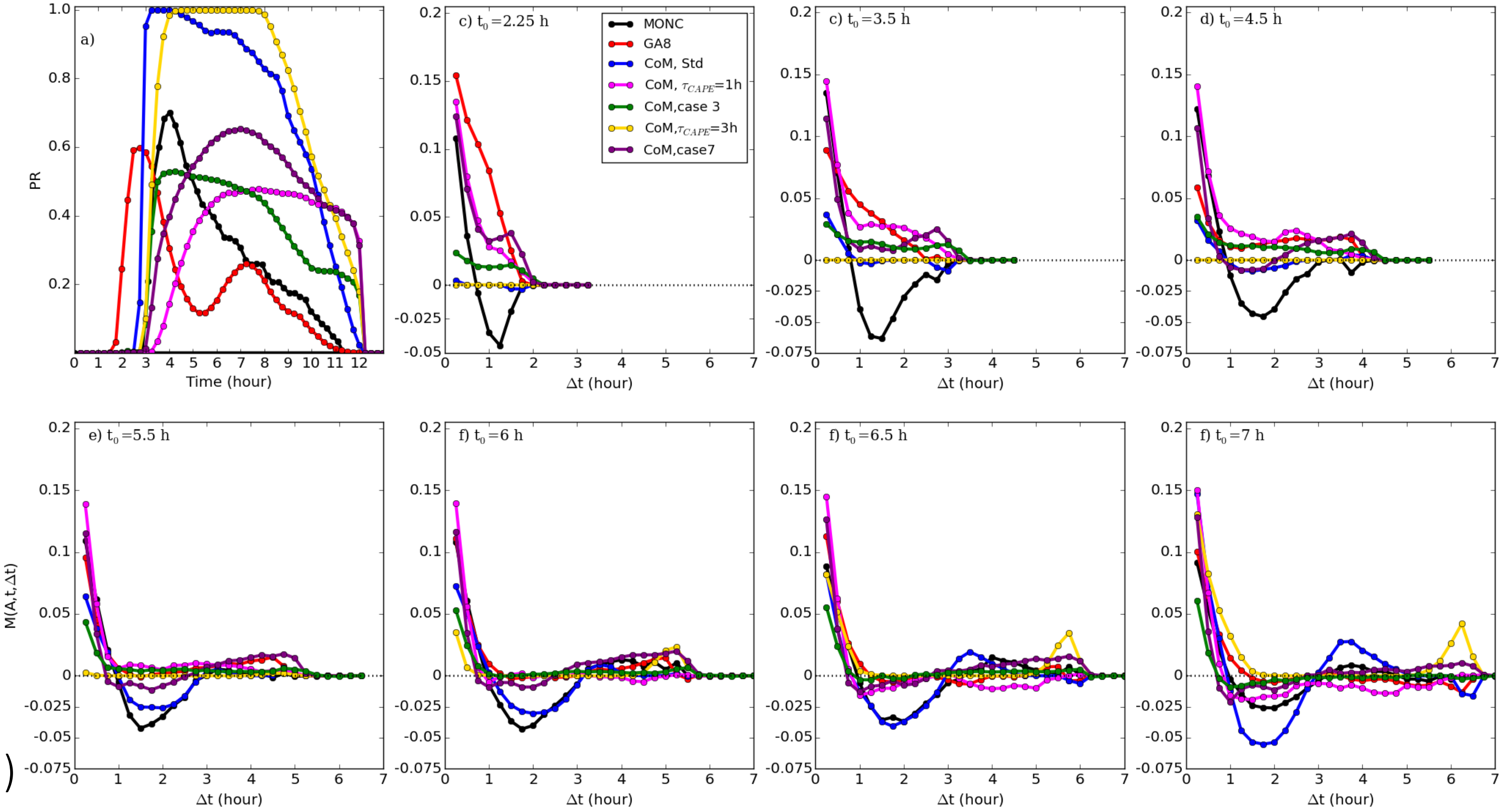


CAPE closure with fixed τ_{CAPE}

- The triggering of convection (t_0) depends on τ_{CAPE}
- $M(A, t_0 < 6h, \Delta t)$ depends on τ_{CAPE}
- τ_{CAPE}=3h: the 2nd and 3rd phases do not occur
- τ_{CAPE}=1h: the 2nd occurs for t_0>6.5 h but is weaker
- In general, $M(A,t_0,\Delta t)$ for CAPE closure and fixed τ_{CAPE} similar to that obtained in GA8

W2: Idealization of the EUROCS diurnal cycle deep convection case (Guichard et al., 2004)

Memory function: $M(A,t_0,\Delta t) = P[R(A,t_0) \cap R(A,t_0-\Delta t)] - P^2[R(A,t_0,\Delta t)]$



CAPE closure

Fixed vs variable τ_{CAPE}

- The triggering of convection (t_0) is sensitive
- $M(A,t_0,\Delta t)$ is also sensitive
- However, $M(A,t_0,\Delta t)$ for CAPE closure and fixed or variable τ_{CAPE} is similar to that obtained in GA8

Summaries

We **e**xplored the sensitivity to the closure method within CoMorph

1. <u>simulations of TCs</u>
* Slight increase in intensity of TCs with CAPE closure with little difference between the 2 timescales tested

2. <u>Convective responses to moisture tendency perturbations (Daleu et al., submitted).</u>
* The adjustment to the dry equilibrium is much quicker in the simulation using CoMorph and standard closure.
* The adjustment to the dry equilibrium is slower with CAPE closure.
    *with precipitating or non-precipitating equilibrium depending on the value of the fixed CAPE timescale.

3. <u>Diurnal cycle of shallow convection over land (*Brown et al., 2002*)</u>
* MONC results are quantitatively similar to those obtained in Brown et al., 2002
* CoMorph with standard closure or CAPE closure triggers convection a couple of hours earlier
* Convection emerges rapidly with standard closure and less rapidly with CAPE closure
    *slightly increase of cloud top height with CAPE closure with variable timescale

4- <u>Idealization of the EUROCS diurnal cycle deep convection case (Guichard et al., 2004)</u>
* CoMorph with standard closure: the three phases of the memory function (found in MONC) occur, but at different time after triggering of convection
* The 2nd and 3rd phases do not occur with the CAPE closure
    * The memory function is similar to that obtained in GA8

What is Next?

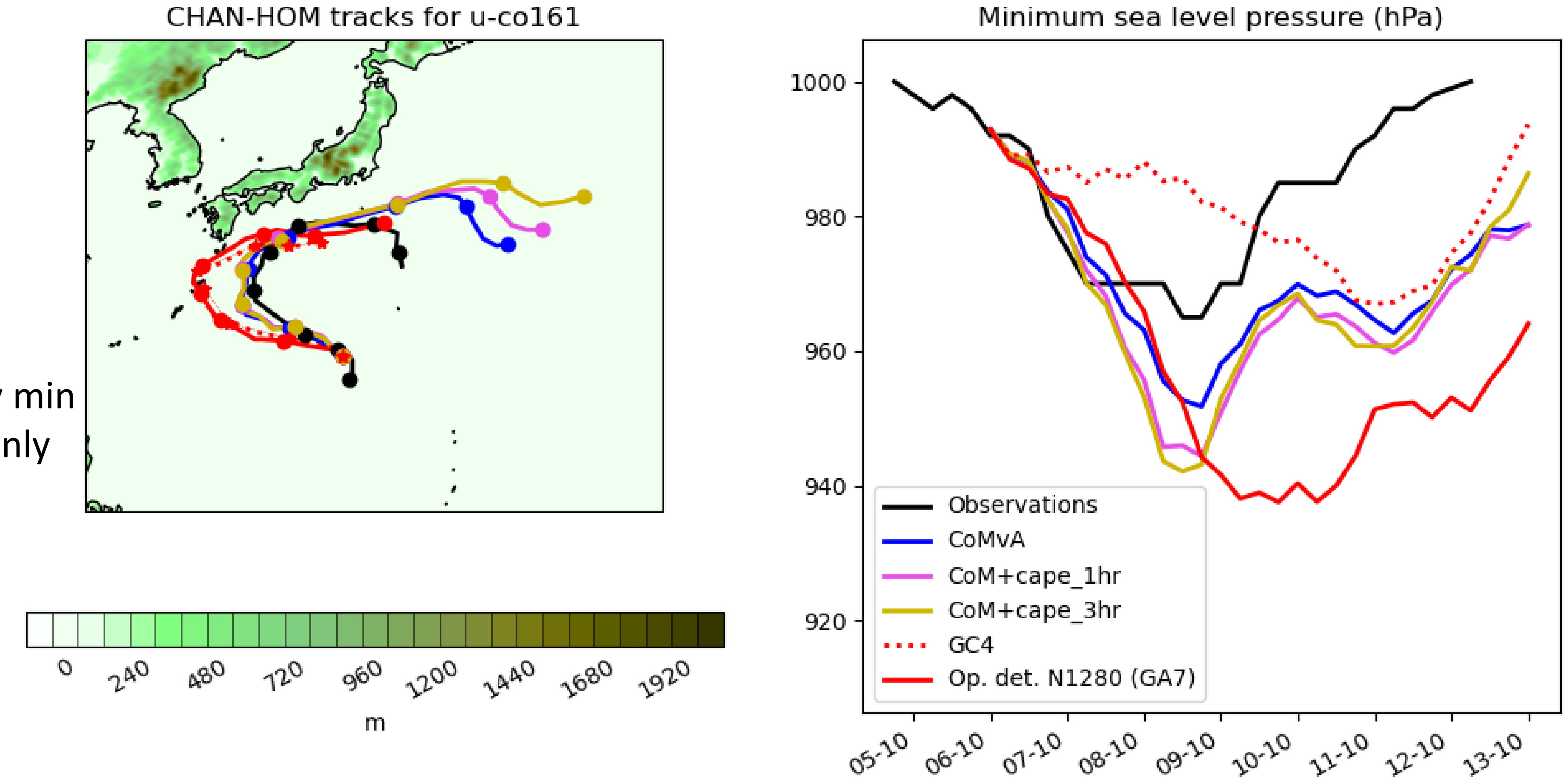
Continue with the analysis

performed diurnal cycle of deep convection using CoMorph A with CAPE closure and default or lowest entrainment rate.

W1: simulations of tropical cyclones

(coupled)

Tracked by min pressure only



Slight increase in intensity with CAPE closure
with little difference between the 2 timescales tested

Thanks!

Any Questions?