CONSORTIUM FOR SMALL SCALE MODELING

COSMO

Priority Project T^2RC^2:

Coupling between the schemes of shallow-convection and radiation

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[1]IMS, [2]DWD

COSMO General Meeting, S. Petersburg, September 2018

Outline

1. How it is done in COSMO-operational?
2. How it is done in COSMO-”cloudrad”?
3. Next improvement
4. The fate of LWC from Shallow-Convection scheme
5. Summary

Cloud cover + Liquid Water Content + Effective Radius → Radiation scheme

How it is done in COSMO-operational ?

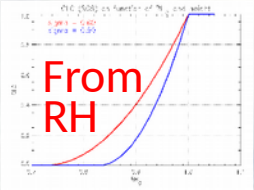
If RH=100%

Cloud cover + Liquid Water Content + Effective Radius → Radiation scheme

=1 | Computed | $a_1+a_2q_c$ for "typical clouds"

If RH<100% , SGS stratus

Cloud cover + Liquid Water Content + Effective Radius → Radiation scheme



f(T) $0.005*QV_{sat,g}*(1-f_{ice})$ | $a_1+a_2q_c$

If RH<100% , SGS cumulus

Cloud cover + Liquid Water Content + Effective Radius → Radiation scheme

Using cloud depth from Shallow Conv. scheme | f(T) $0.005*QV_{sat,g}*(1-f_{ice})$ | $a_1+a_2q_c$

CLC_CON TOP_CON BAS_CON

How it is done in COSMO-"cloudrad" ?

If RH=100%

Cloud cover + Liquid Water Content + Effective Radius

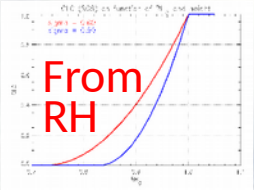
=1 Computed $\overline{R_e} = c_1 \left(\frac{\overline{q_C}}{\overline{n_C}}\right)^{c_2}$

const or Segal-Khain using W_{eff} and Tegen/CAMS!

→ Radiation scheme

If RH<100% , SGS stratus

Cloud cover + Liquid Water Content + Effective Radius



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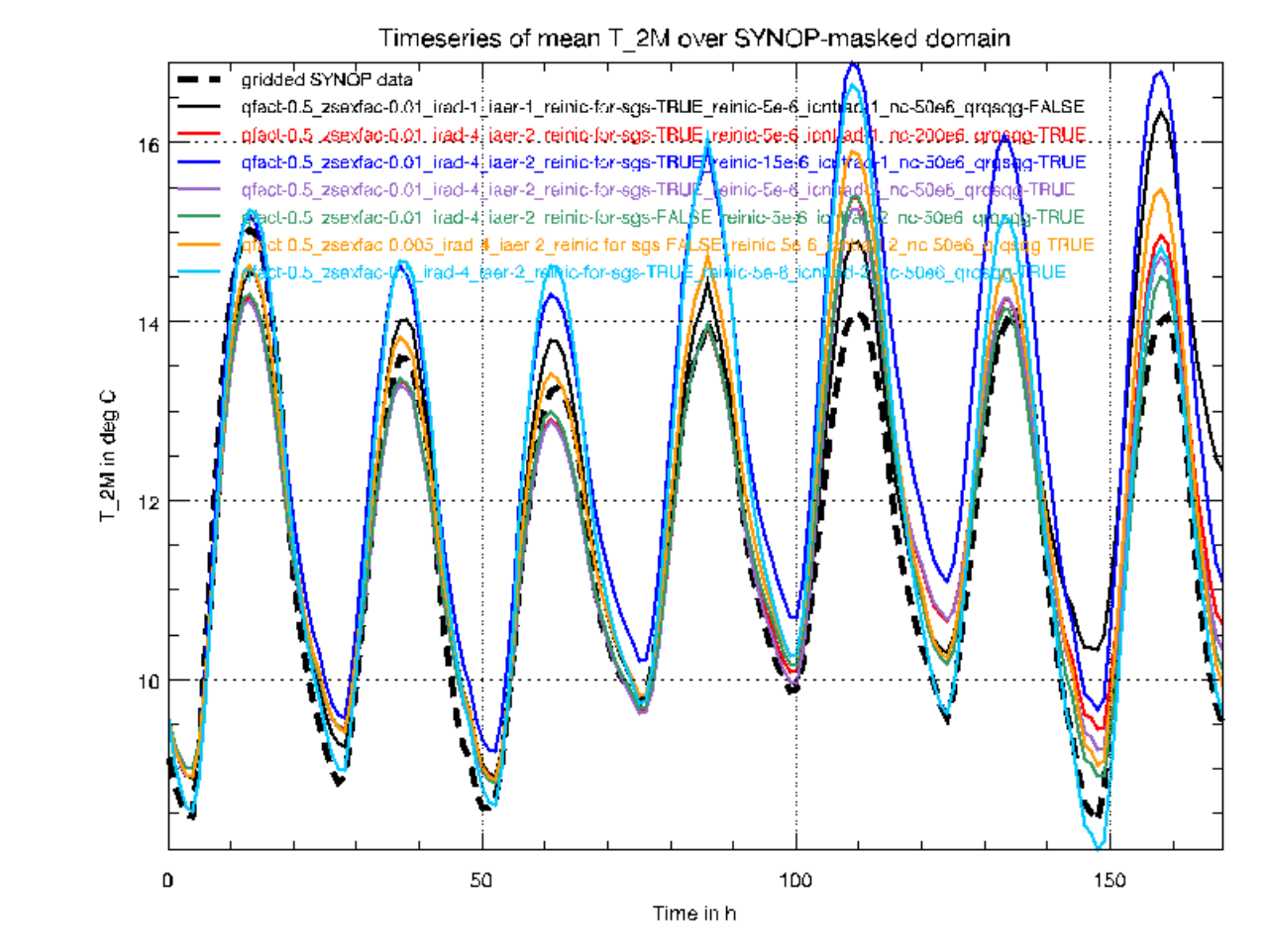
CLC_CON TOP_CON BAS_CON

Is this effective radius important?

Sensitivity of T_{2M} in 7-day experiment with COSMO-DE



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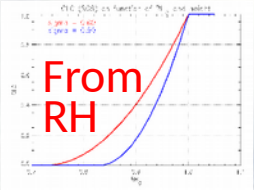

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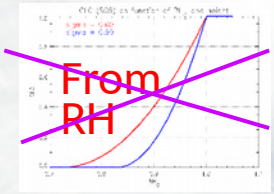

From RH

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Next improvement

If RH=100%

Cloud cover + **Liquid Water Content** **+** **Effective Radius** → Radiation scheme

=1 | Computed | Not from q_c! **New parametrization** with Segal-Khain using CAMS or ART ?

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Mean effective radius

q_c and N_d are highly dispersive but R_e is not! Better get q_c from R_e

$$\overline{R_e} = c_1 \left(\frac{\overline{q_C}}{\overline{n_C}} \right)^{c_2}$$

Better calculation

In cloud core below rain formation level and before significant mixing occurs:

$$r_{e\_ad}(z) = 1.15 \cdot r_v = 1.15 \cdot \left(\frac{LWC_{ad}(z)}{\frac{4}{3}\pi \rho_w N_{d\_ad}} \right)^{1/3}$$

From Segal-Khain using CAMS/ART !

Due to rain formation:

$$r_{e_{max}} = \min(22\mu m, r_{e\_ad})$$

The mean eff. radius is slightly smaller:
and deviates with height from the core value due to mixing:

$$\overline{r_e}(z) = \alpha(z) r_{e\max}(z)$$

$$\alpha(z) = 0.95 - 1.2 \cdot 10^{-4}(z - z_{cb})$$

In case of rain …

$$r_{e_{max}} = \min(22\mu m, r_{e\_ad})$$

Formation of raindrops is seen by termination of the r_e growth with height. In case of rain drop formation, effective radius determined within the range of cloud droplet radii (<25 μm) does not exceed about 22 μm and remains height independent (Fig. 10, E500H). Such regime is known as rainout (Rosenfeld and Lensky, 1998). The reason of low dependence of r_e with height in case of raindrop formation is that raindrops collect cloud droplets of all sizes that leads to decrease in droplet concentration, but does not change effective radius of the cloud droplet mode.

Next improvement

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LWC for shallow convection (SGS)

In cloud core:

$$N_{d\_max}(z) = \begin{cases} N_{d\_ad}, & below\ the\ level\ z_{12}\ , where\ r_{e\_ad} = 12\mu m \\ N_{d\_ad}[1 - \gamma(z - z_{12})], & above\ the\ level\ z_{12} \end{cases}$$

Cloud mean:

$$\overline{N_d}(z) \approx \beta N_{d\_max}(z), \quad \beta = 0.38$$

$$\overline{LWC}(z) = \frac{4}{3}\pi\rho_w \overline{N_d(z) r_v{}^3(z)} = \frac{4}{3}\pi\rho_w \overline{N_d(z) \left(\frac{r_e(z)}{1.15}\right)^3}$$

However, since variability of effective radius is low, the last equality can be rewritten as:

$$\overline{LWC}(z) \approx \frac{4}{3}\pi\rho_w \overline{N_d}(z) \left(\frac{\overline{r_e}(z)}{1.15}\right)^3 ,$$

LWC for shallow convection (SGS)

Below rain formation level, due to mixing, the mean LWC deviates from LWC_{ad} (stronger with Z) :

$$LWC(z) \approx \frac{4}{3}\pi \rho_w \beta N_{ad} \left(\frac{\alpha(z) r_{e\,ad}(z)}{1.15} \right)^3 = \beta \left[0.95 - 1.2 \cdot 10^{-4} (z - z_{cb}) \right] LWC_{ad}(z) \qquad (*)$$

In COSMO Shallow-Convection scheme, an ascending parcel with entrainment rate “entr_sc” approximates an ensemble of shallow Cu in the grid-box.

During the ascend, the parcel saturates and produces **LWC_{sc}** which is not used further in the model

The parametrization (*) was obtained for a real ensemble of shallow cumulus with detailed description of mixing.

Do they agree ?

23/2/2018 06 UTC

COSMO LWC_{sc}

Parametrization for LWC

Adiabatic LWC

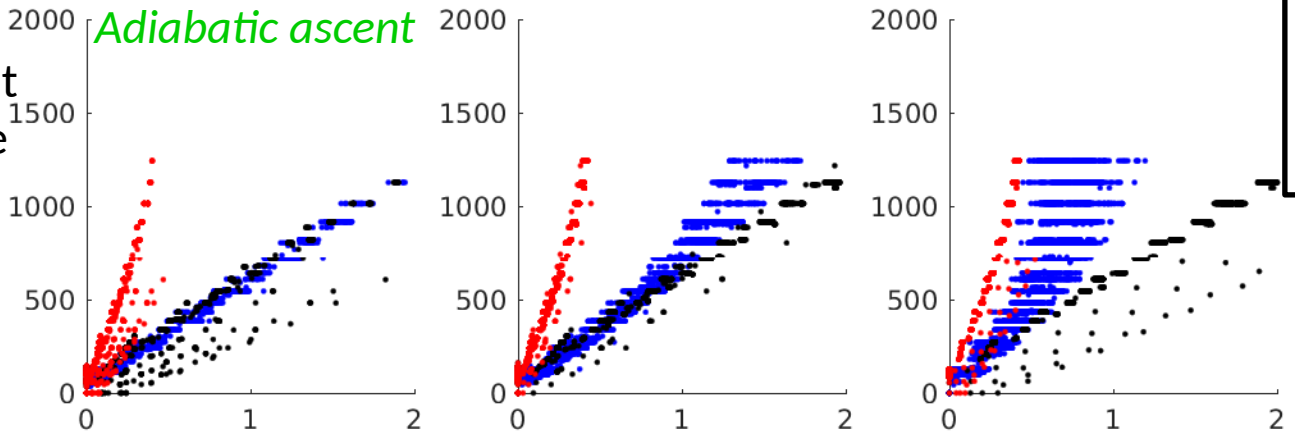
Oper. scheme
entr_sc=3e-06
Adiabatic ascent

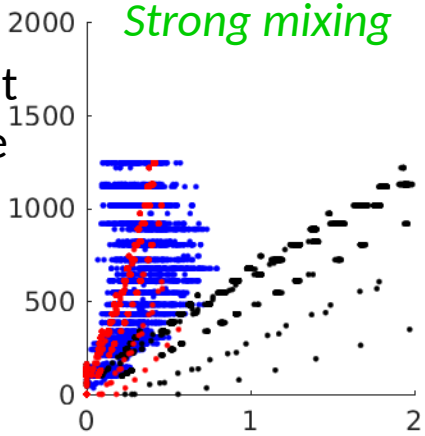
Oper. scheme
entr_sc=0.0003

Oper. scheme
entr_sc=0.001

Oper. scheme
entr_sc=0.003
Strong mixing

Height above cloud base (m)





LWC (g/kg)

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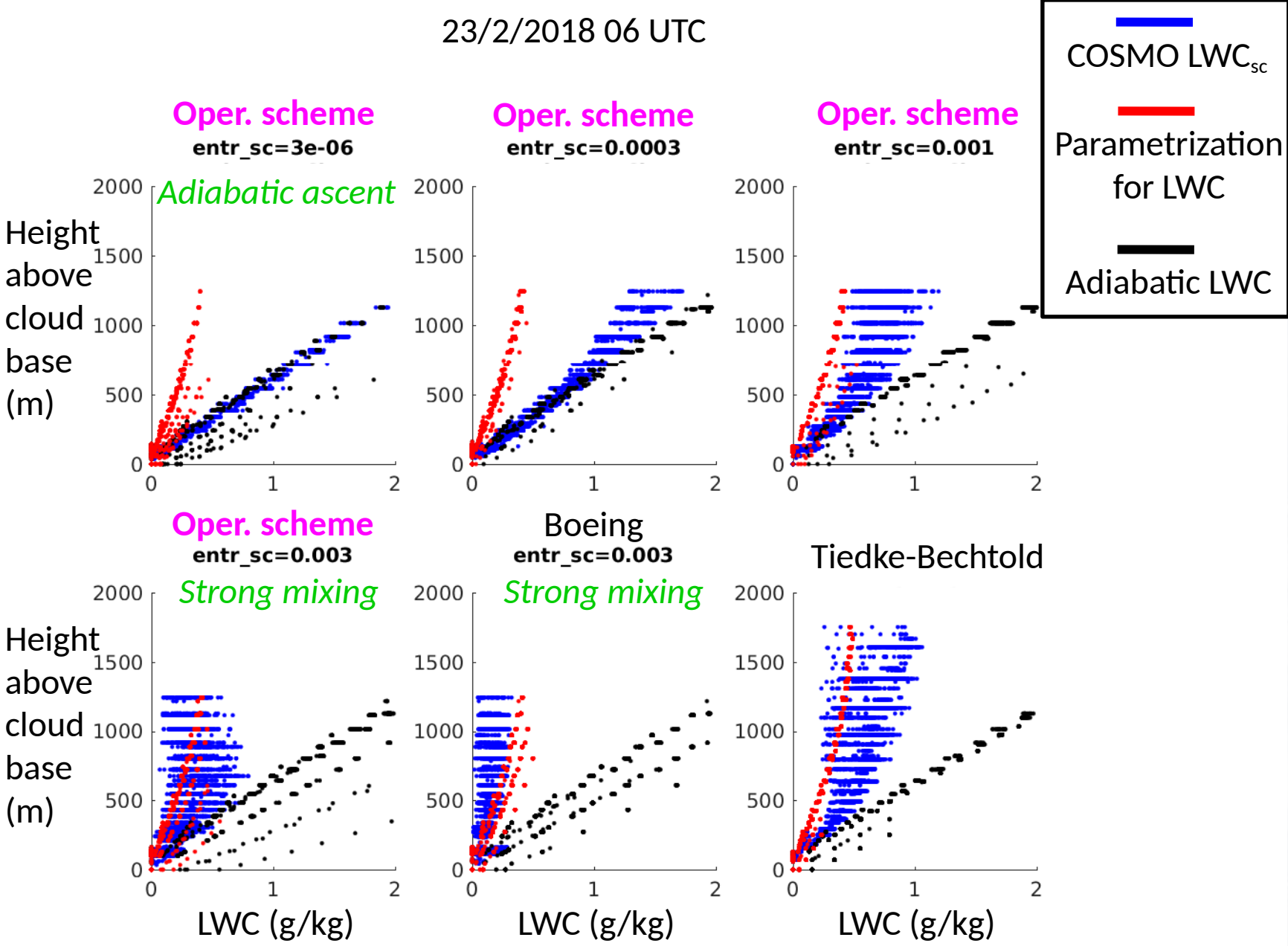

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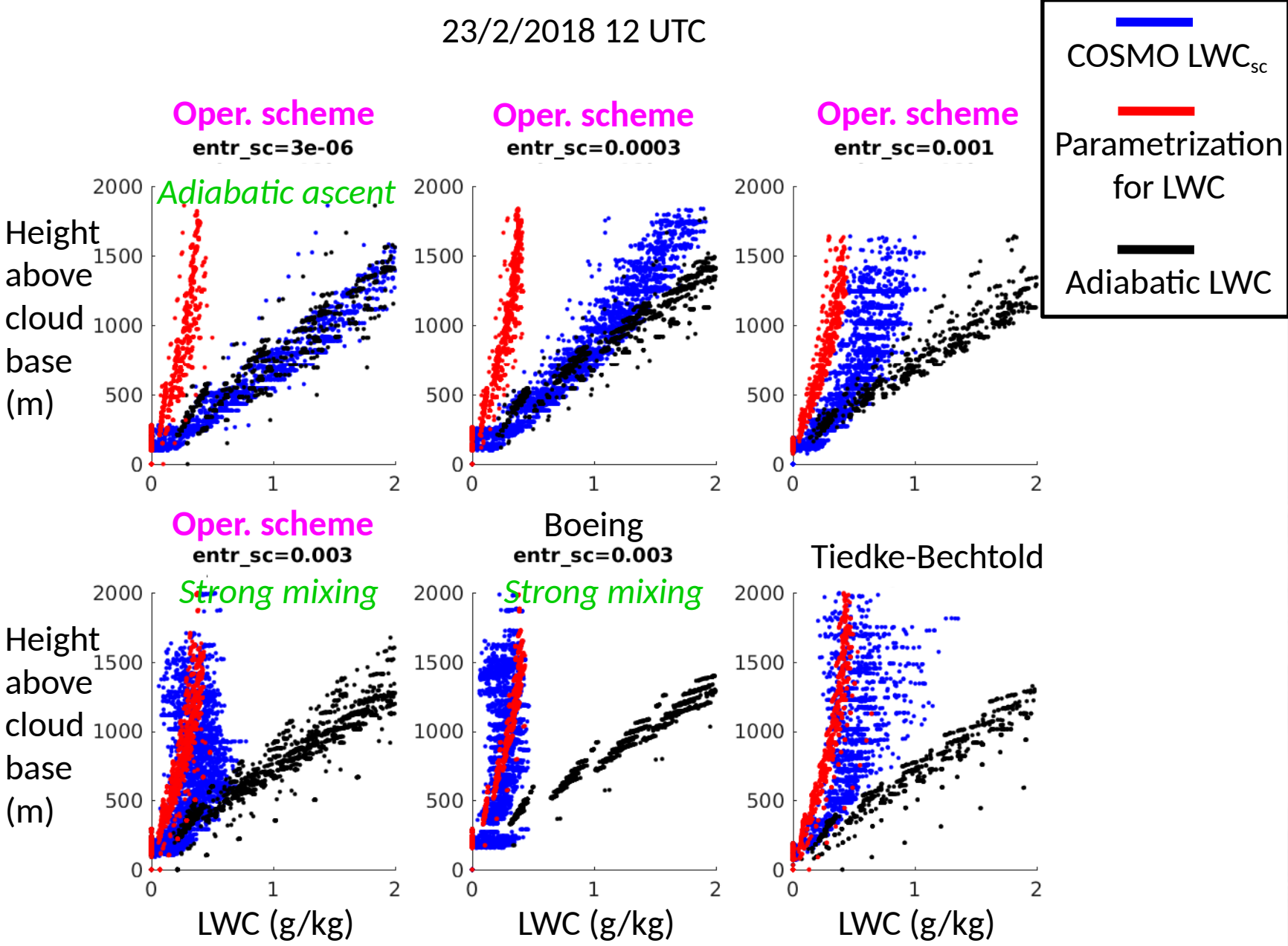

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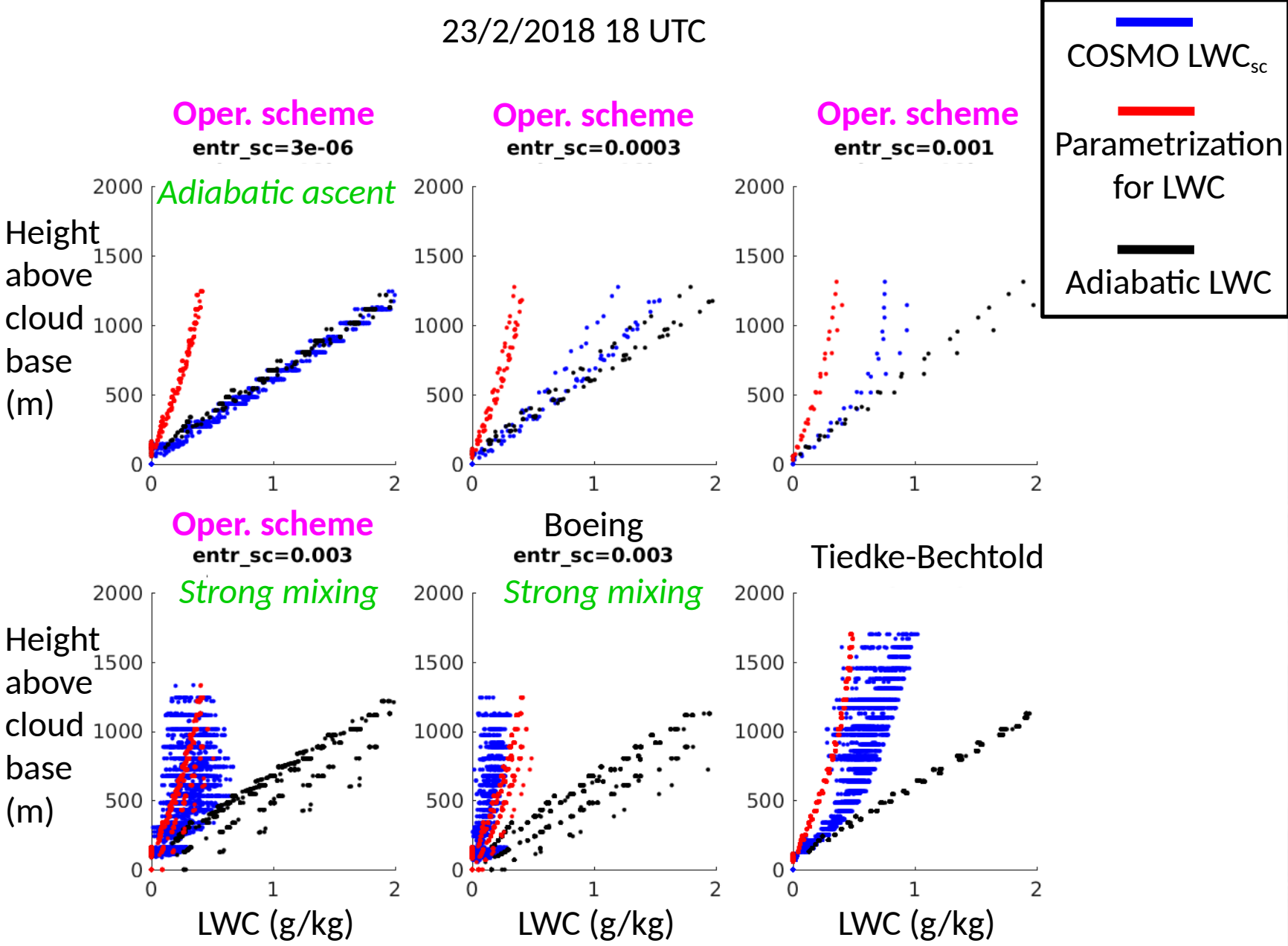

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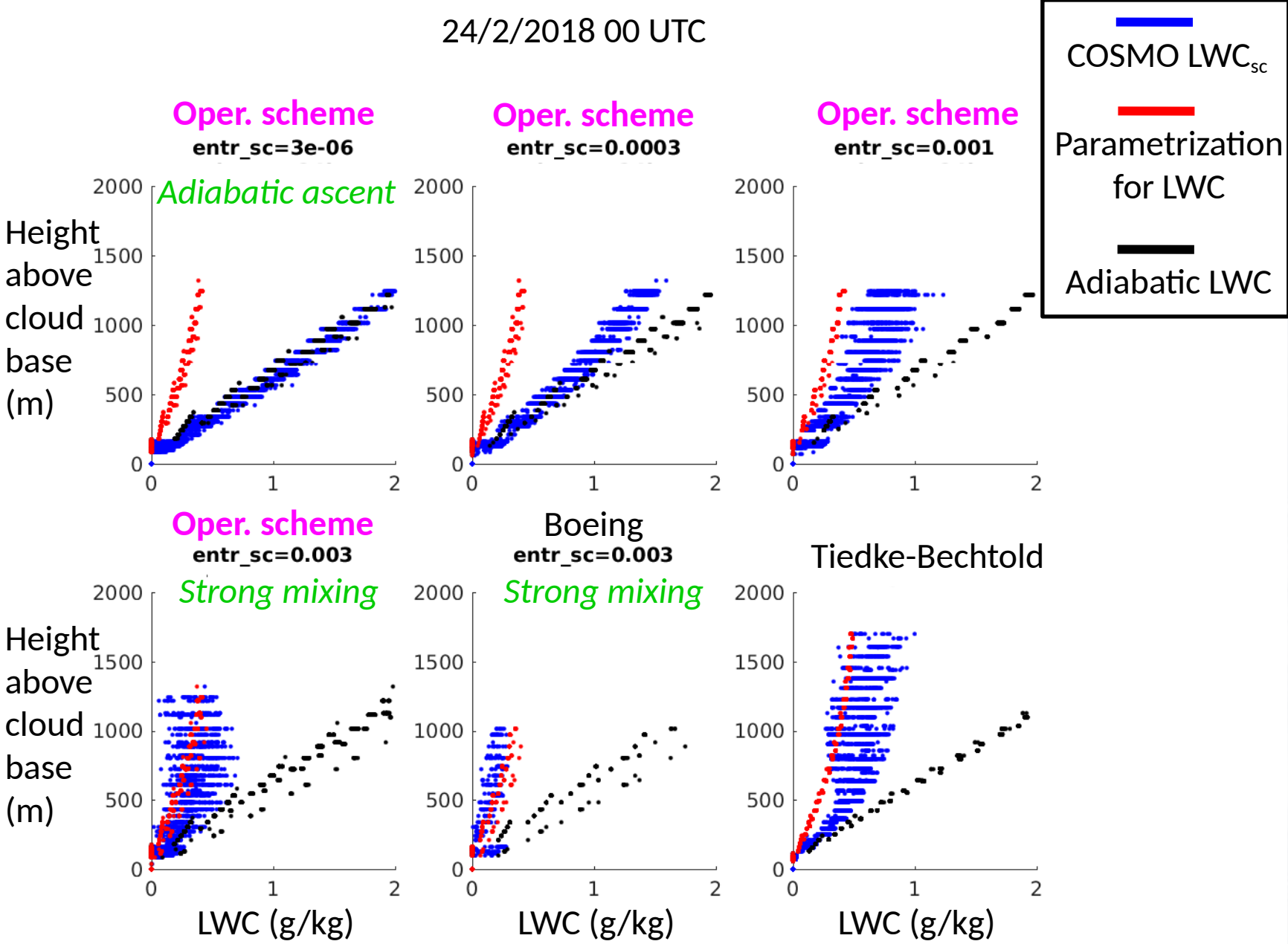

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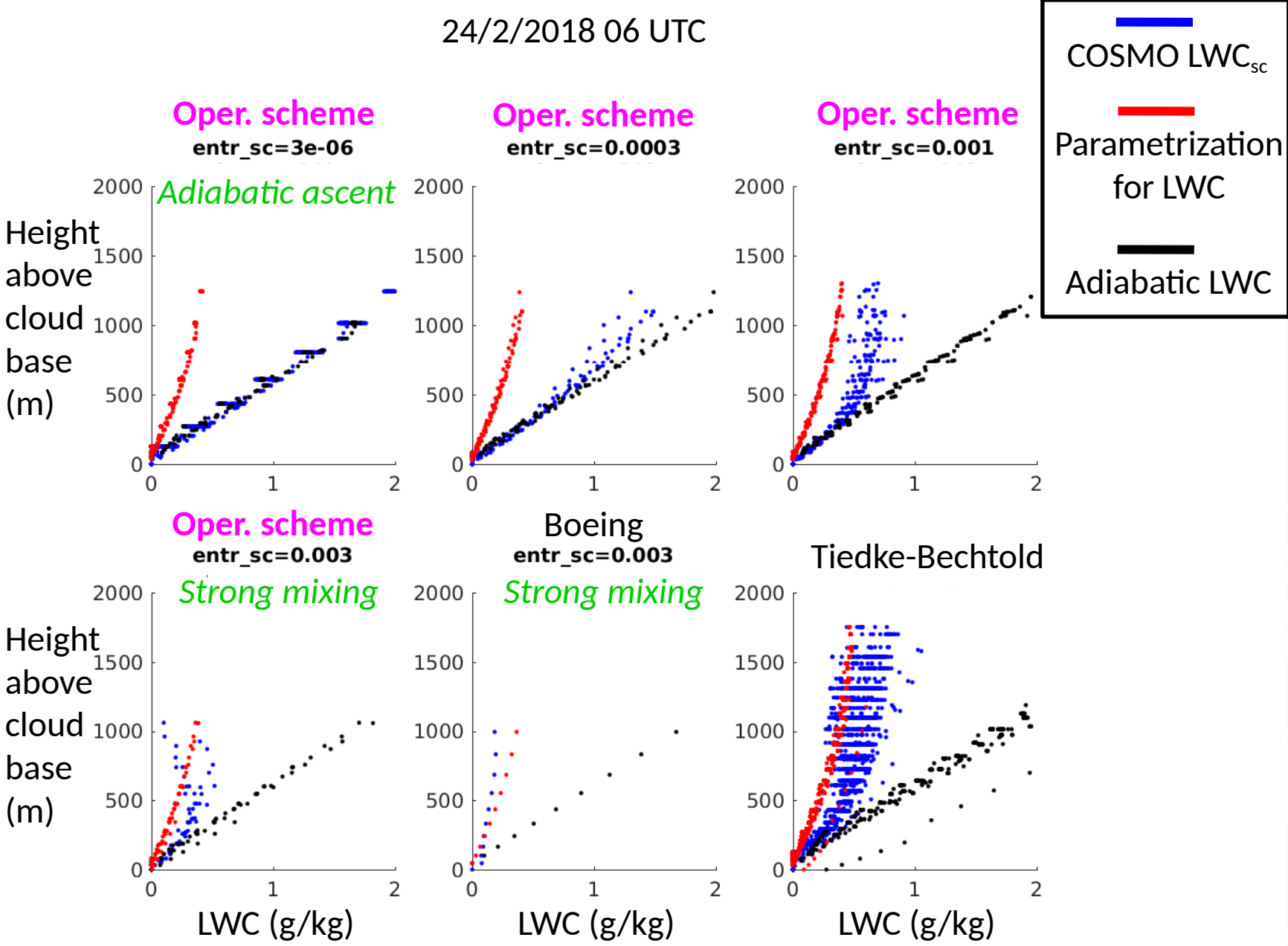

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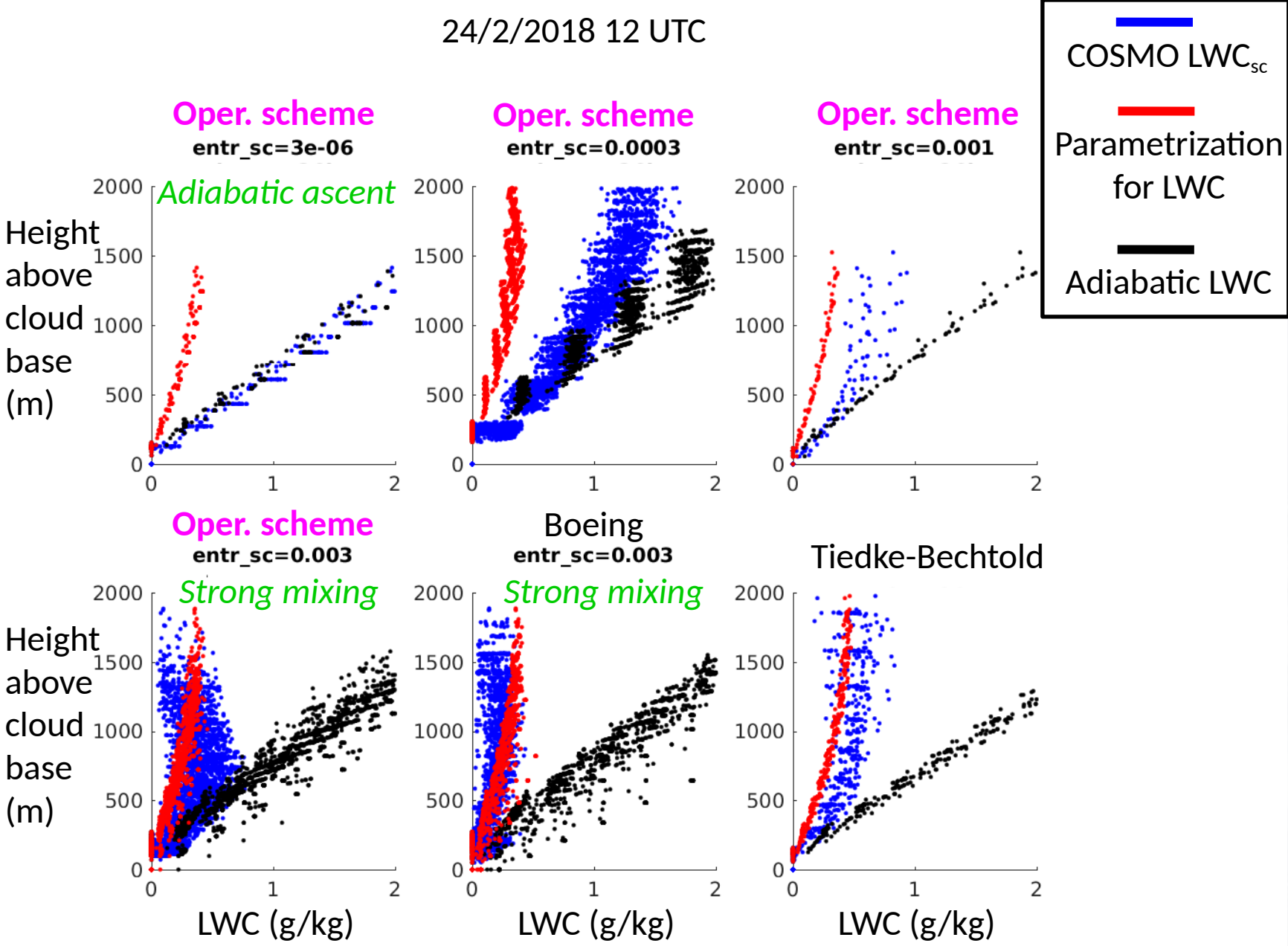

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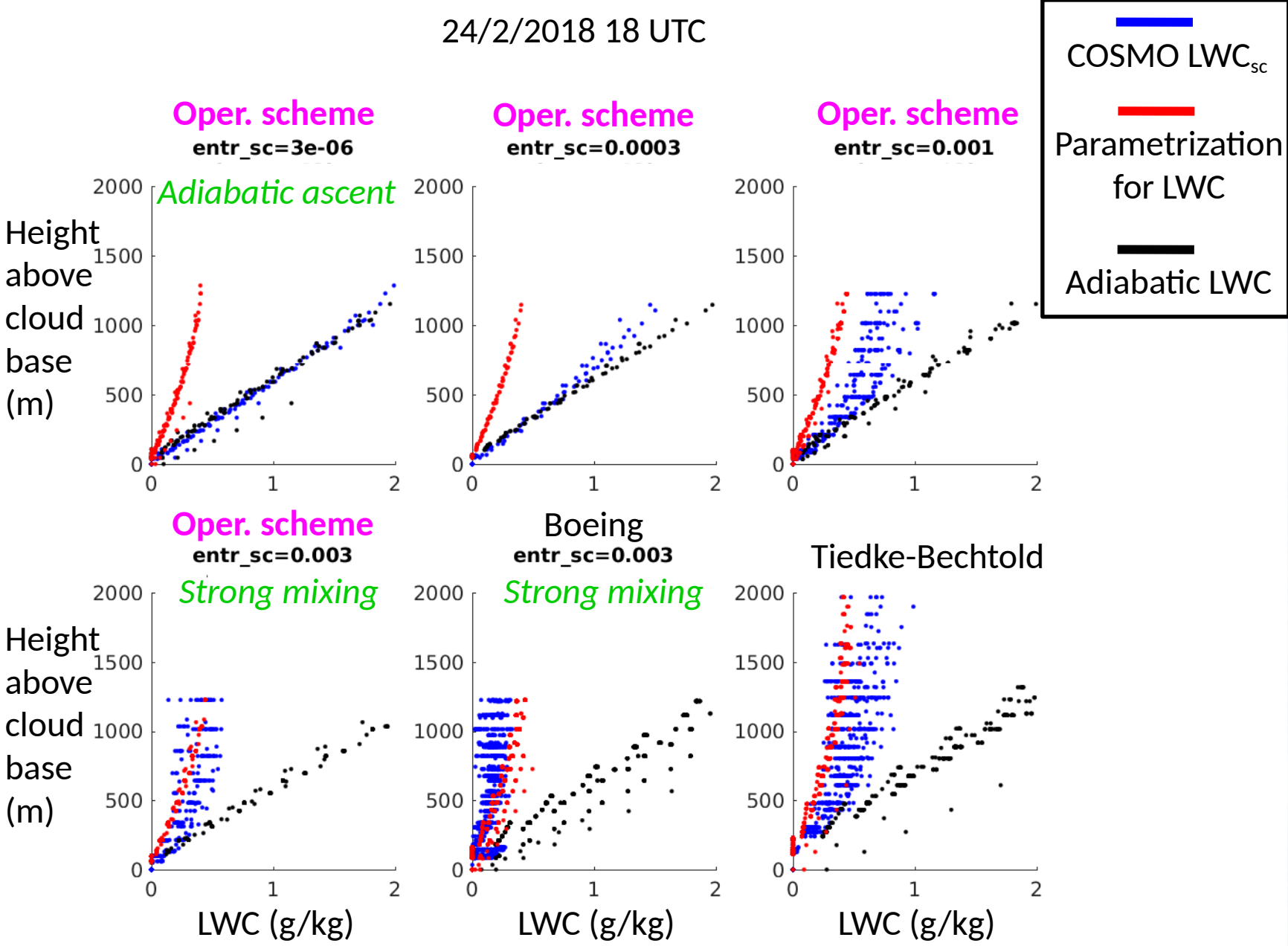

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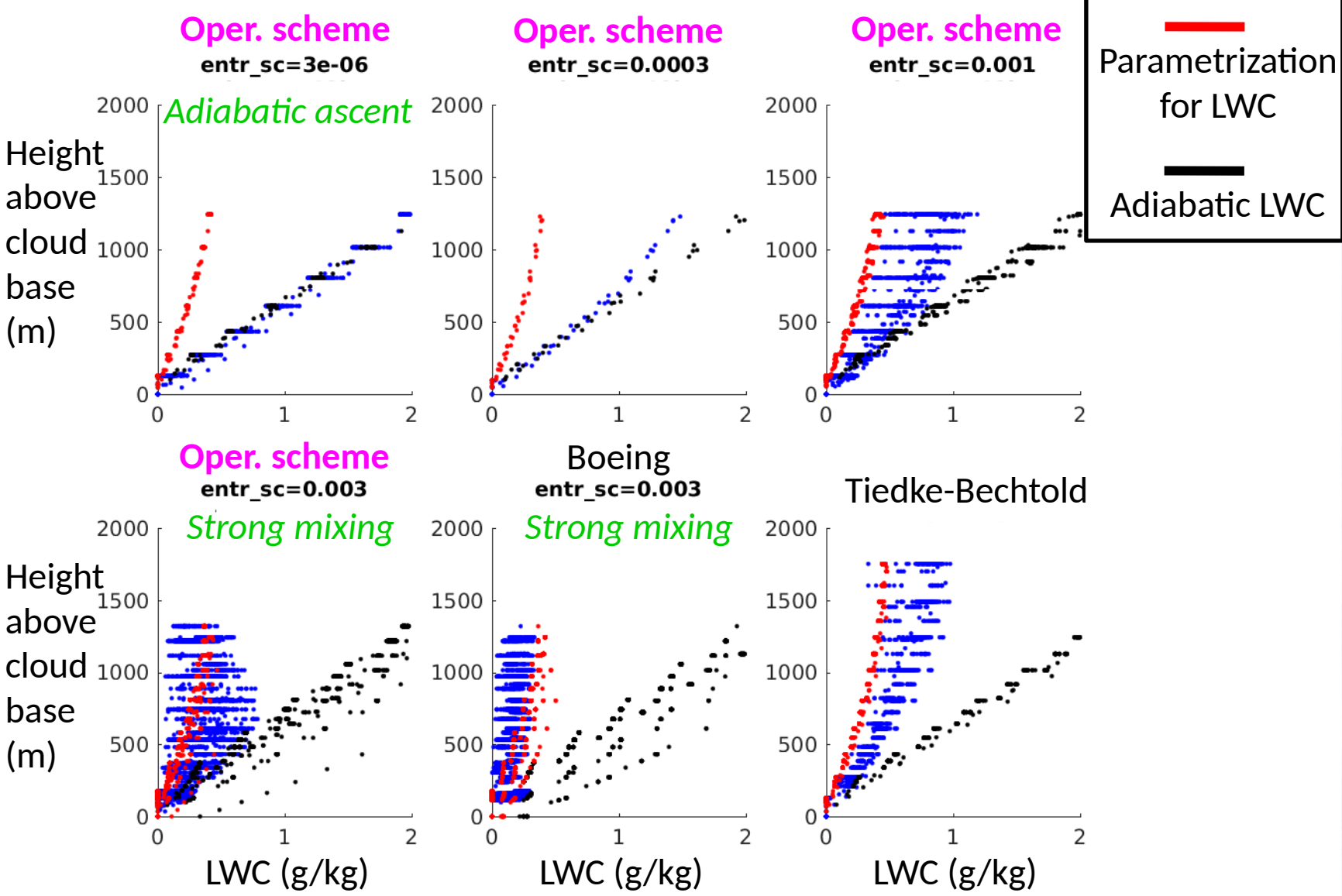

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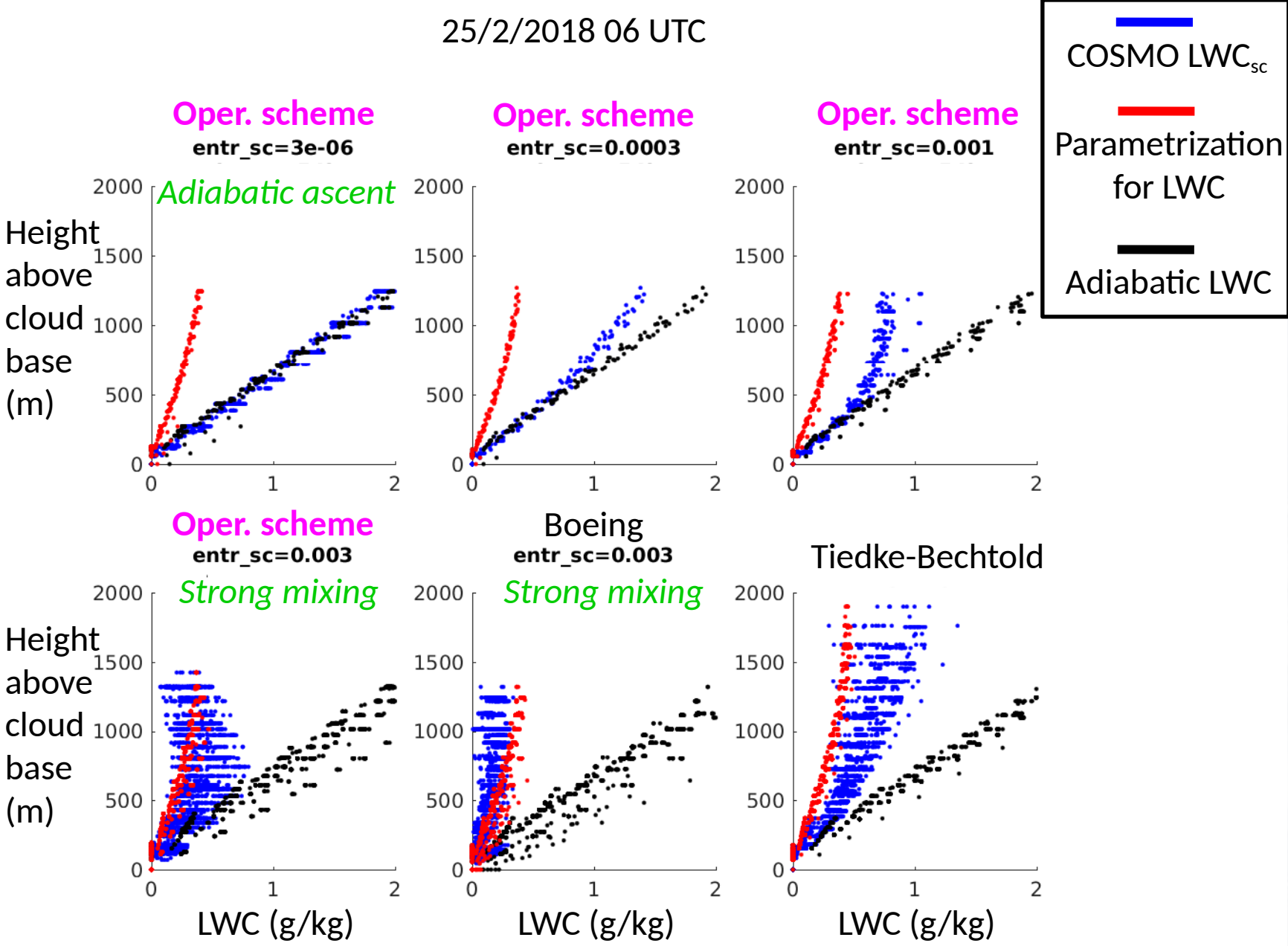

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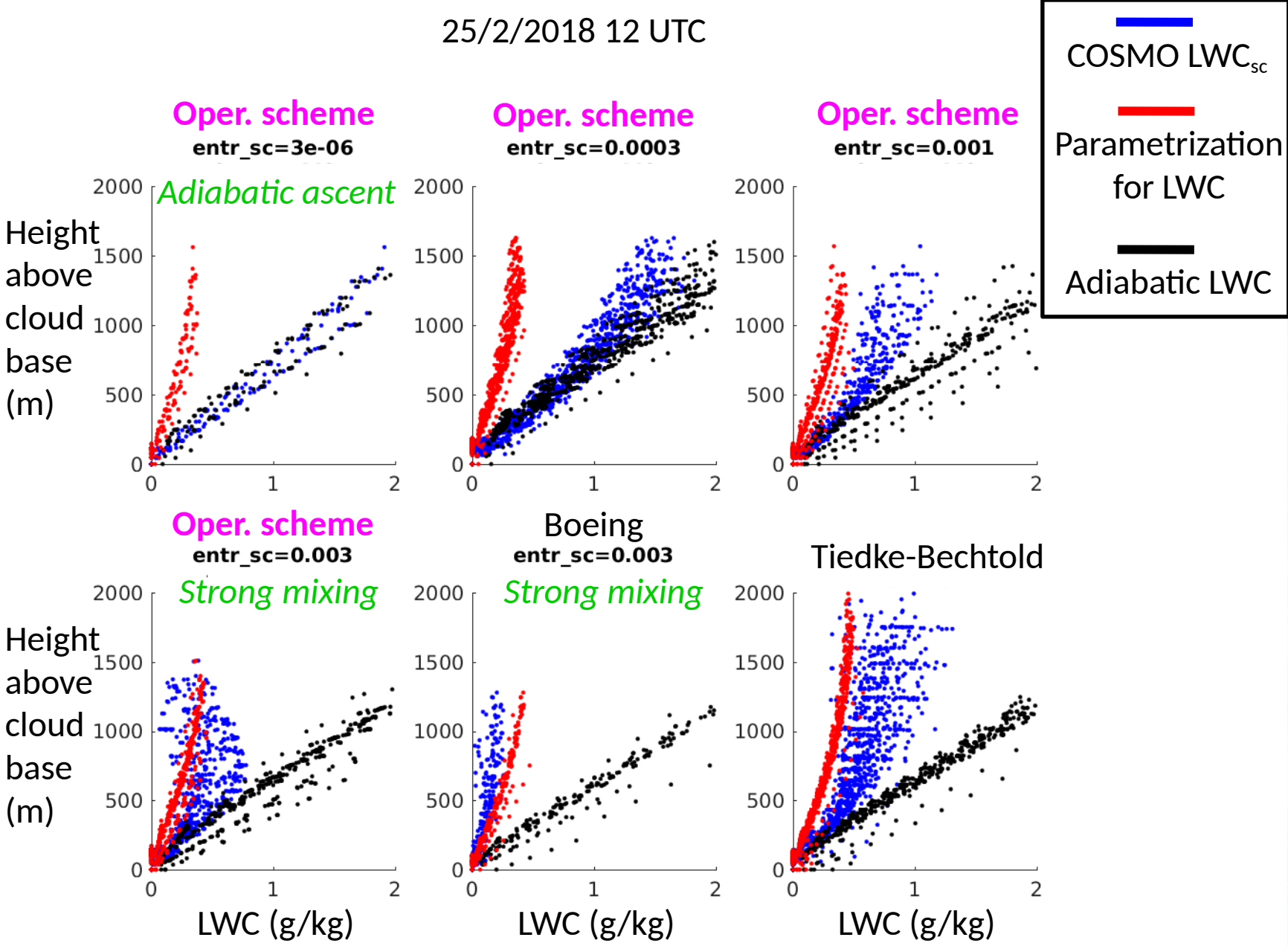

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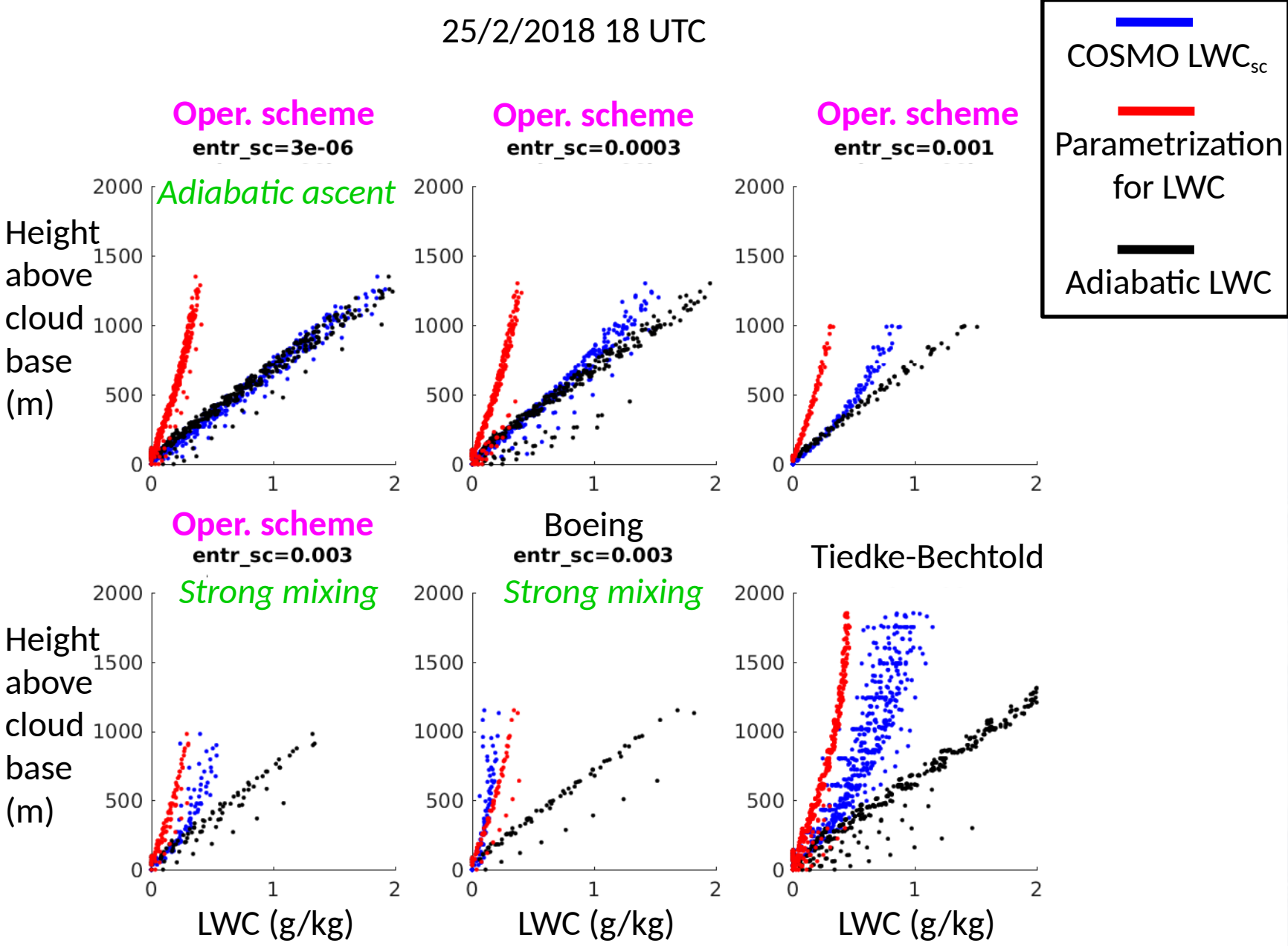

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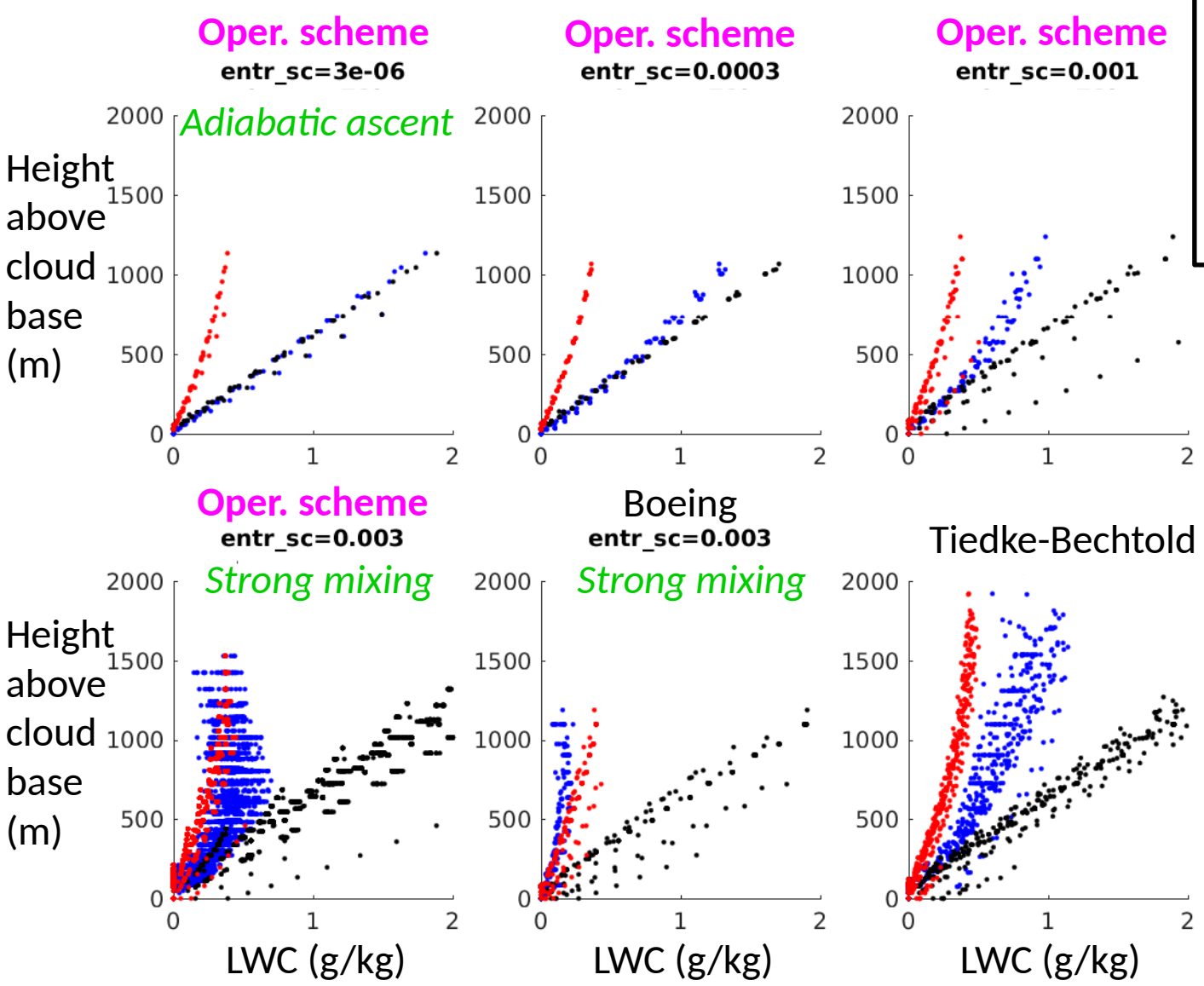

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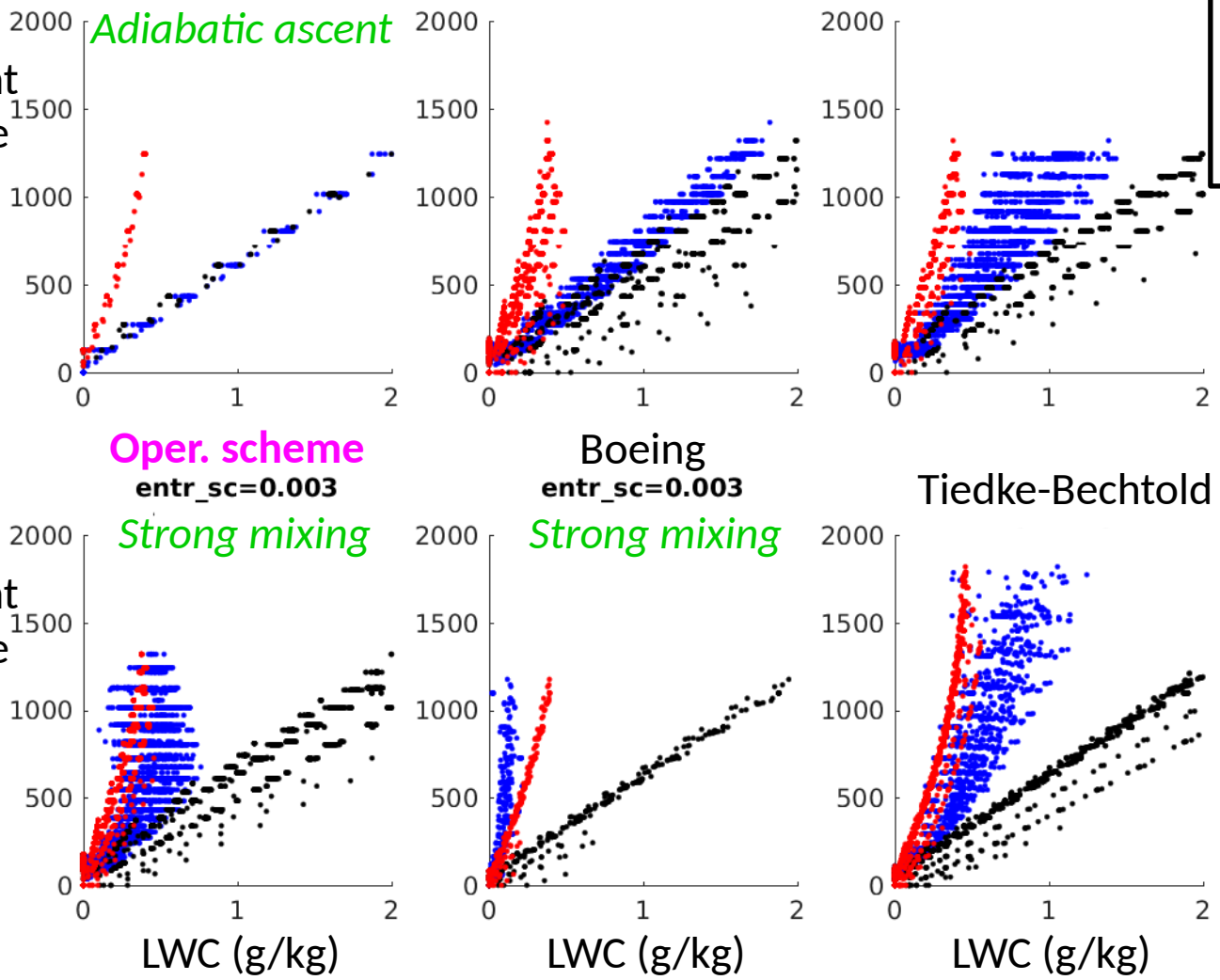
LWC (g/kg)



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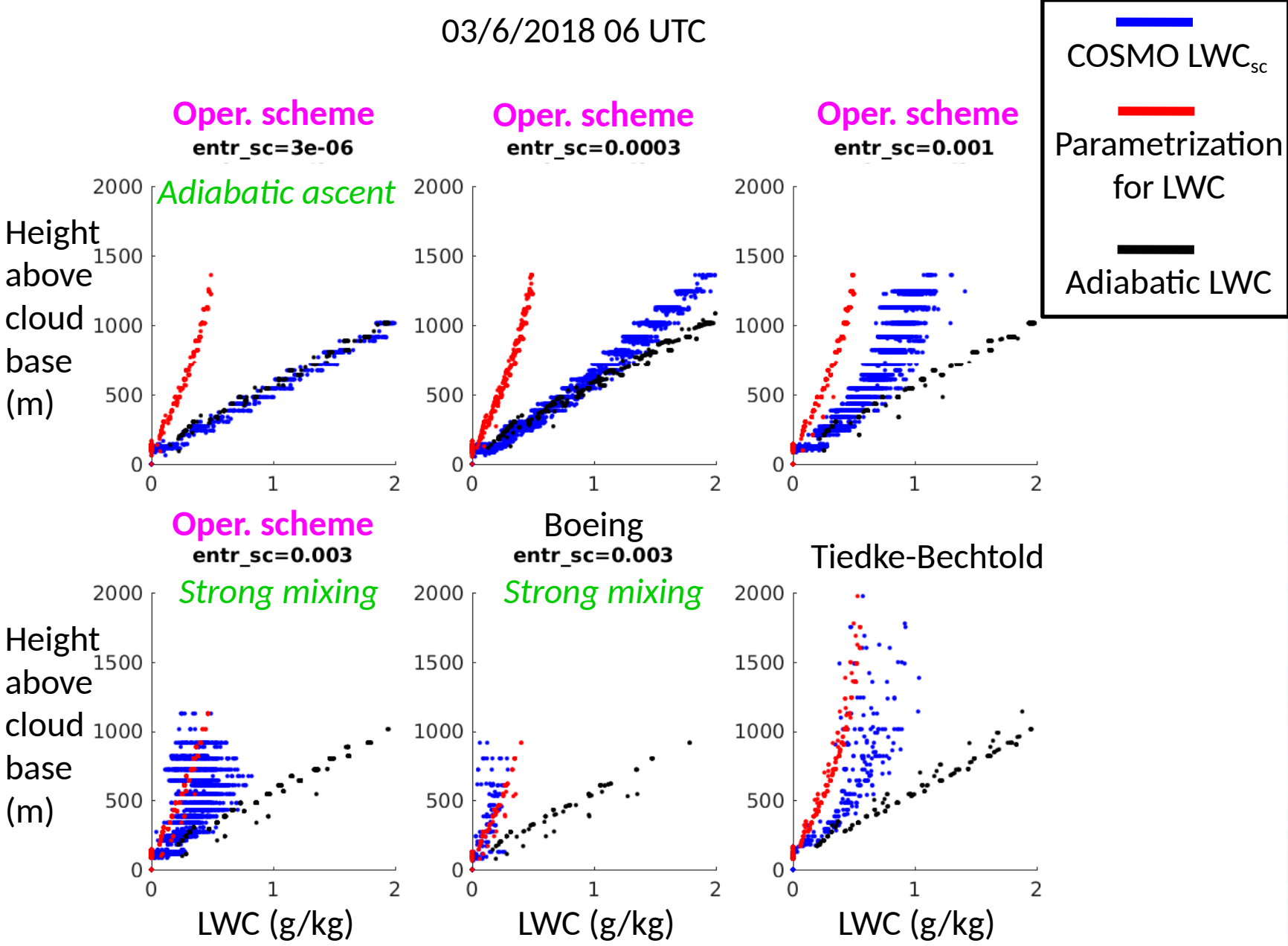

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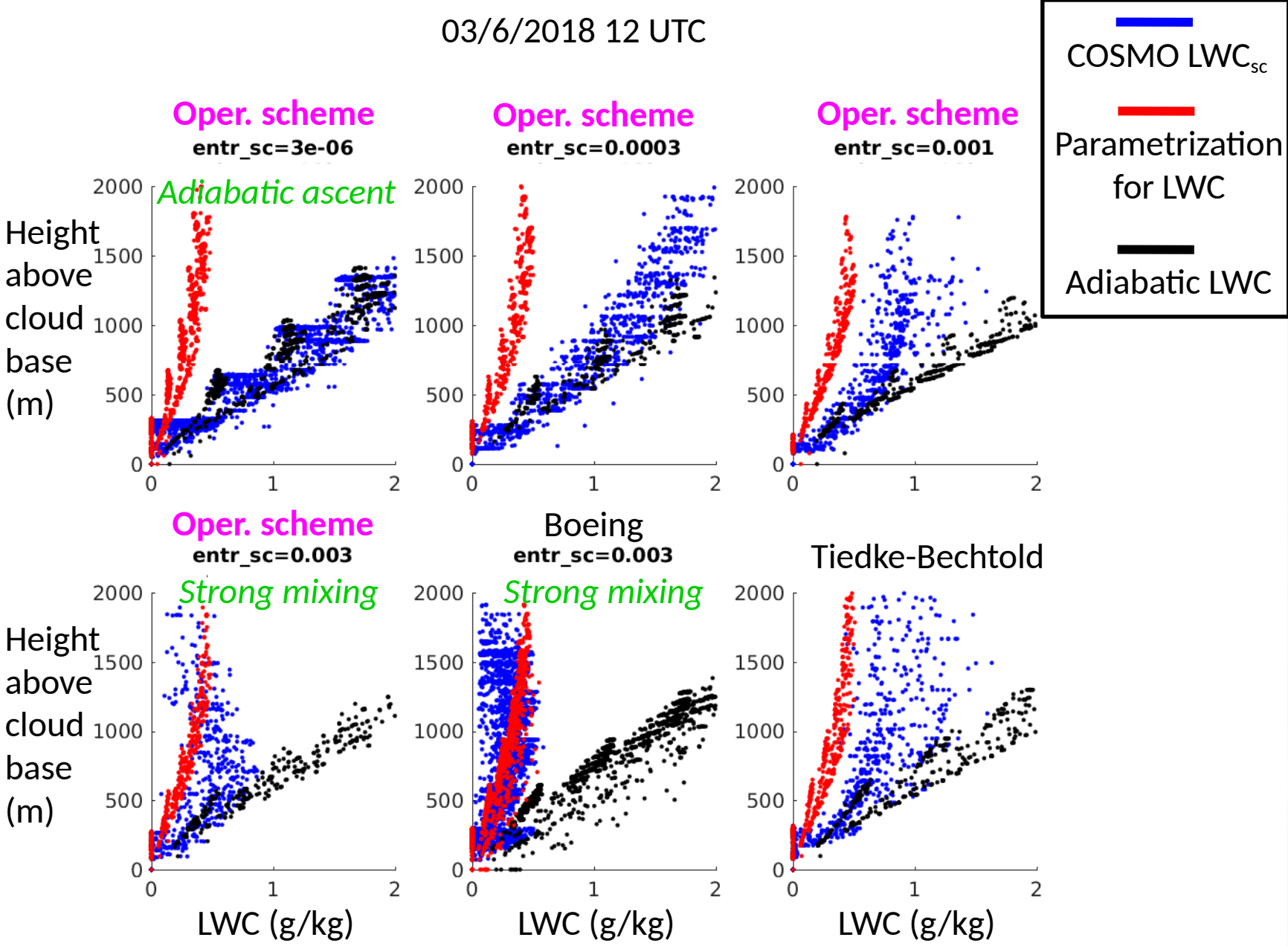

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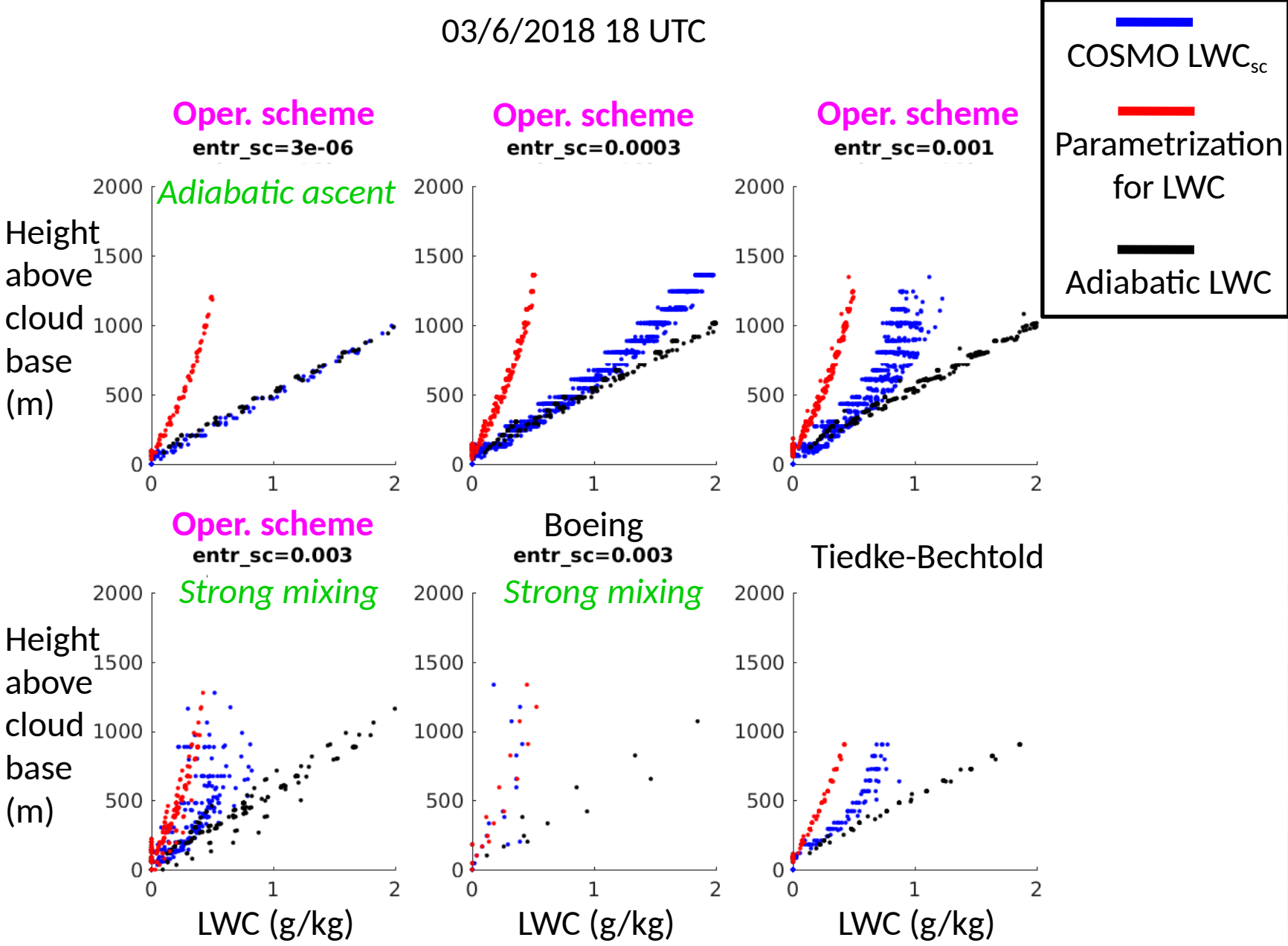

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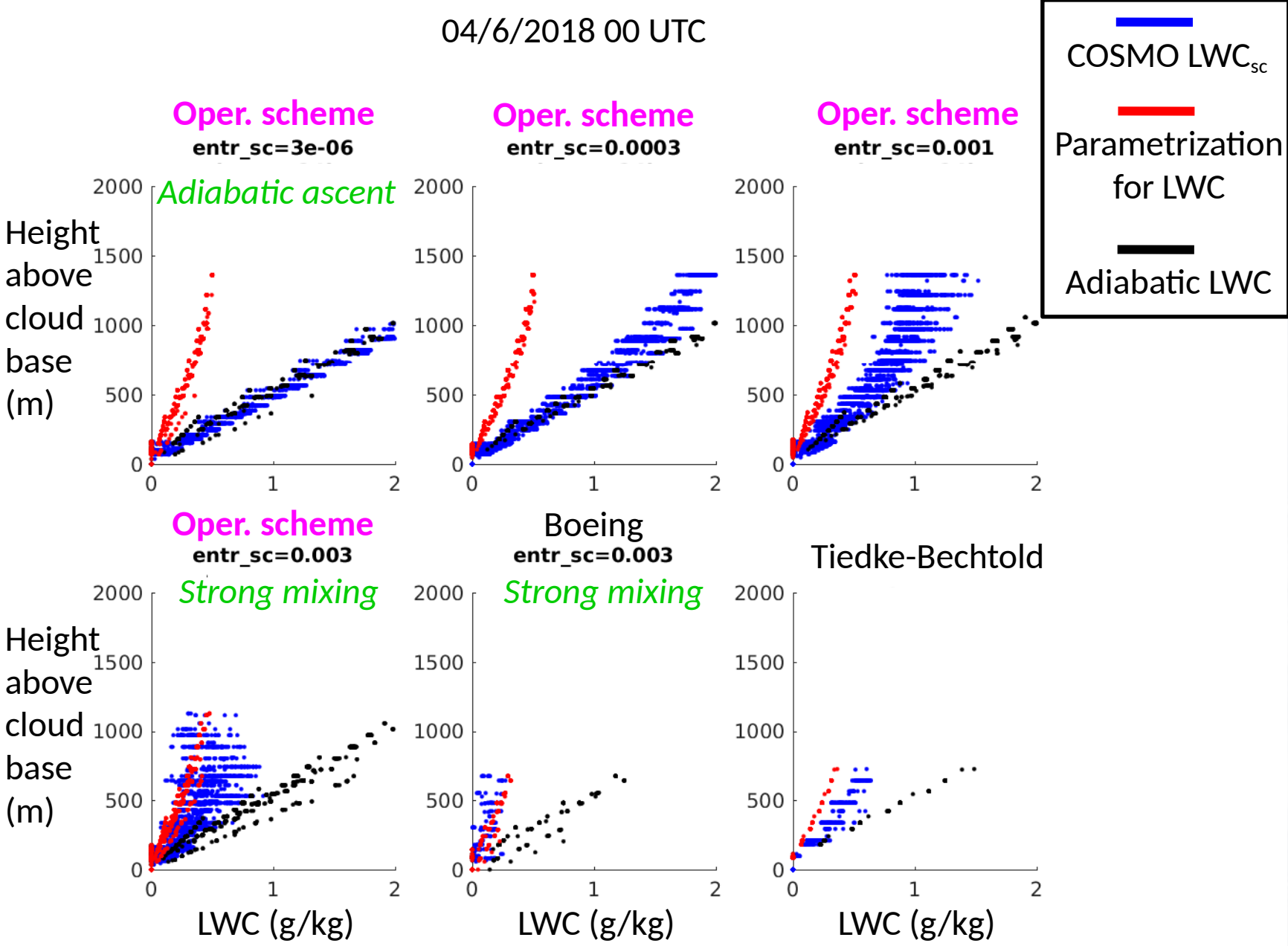

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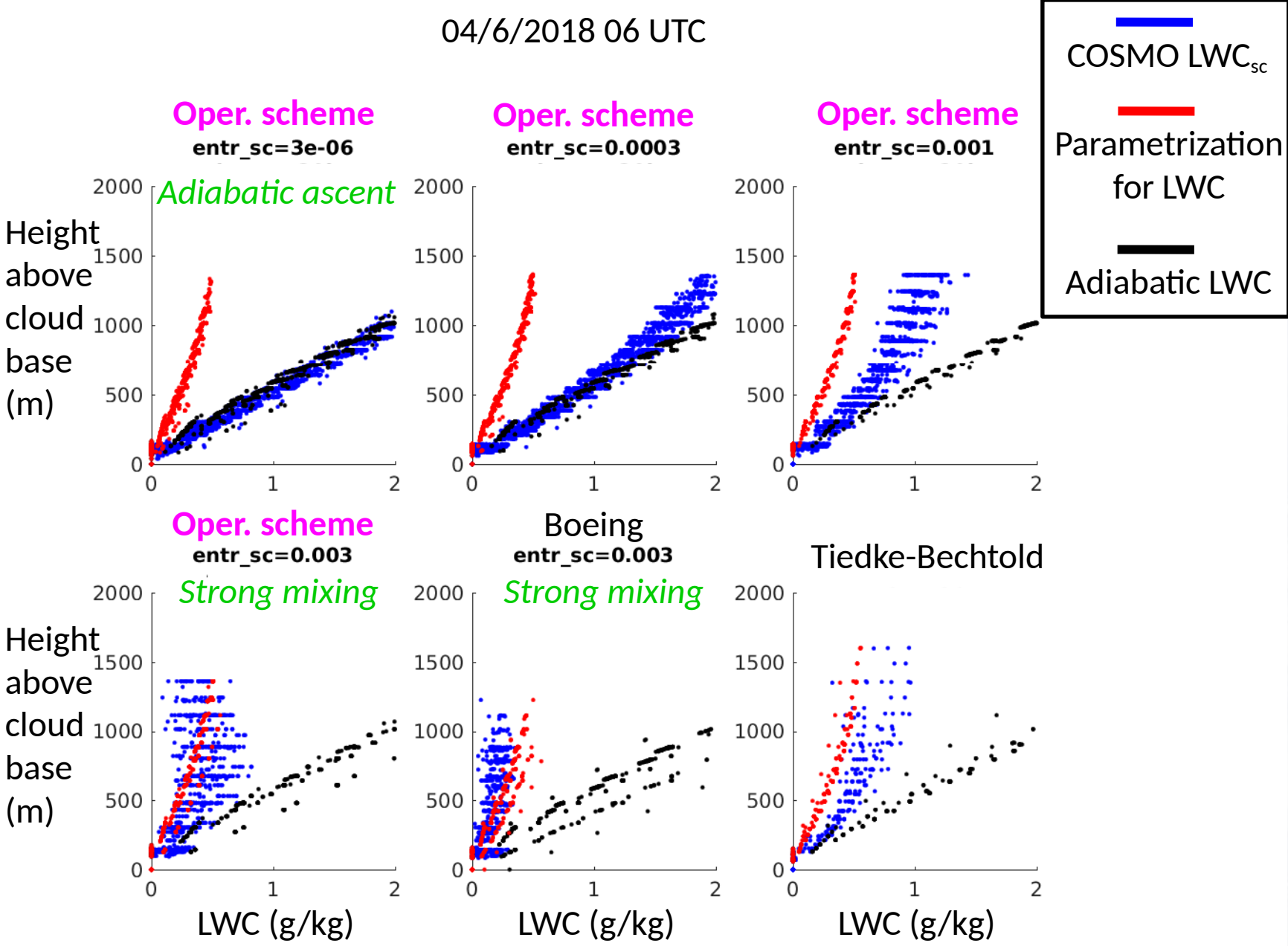

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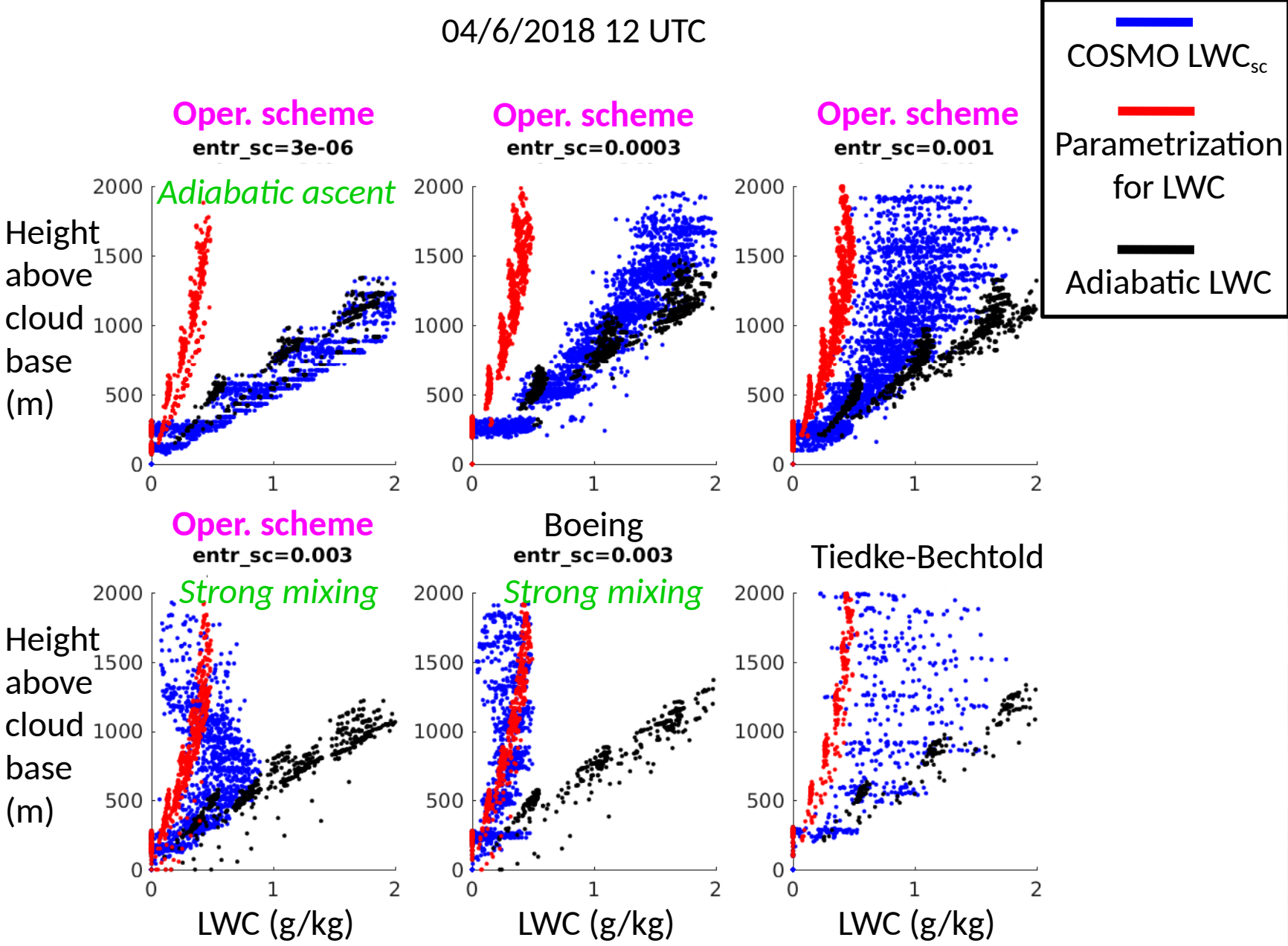

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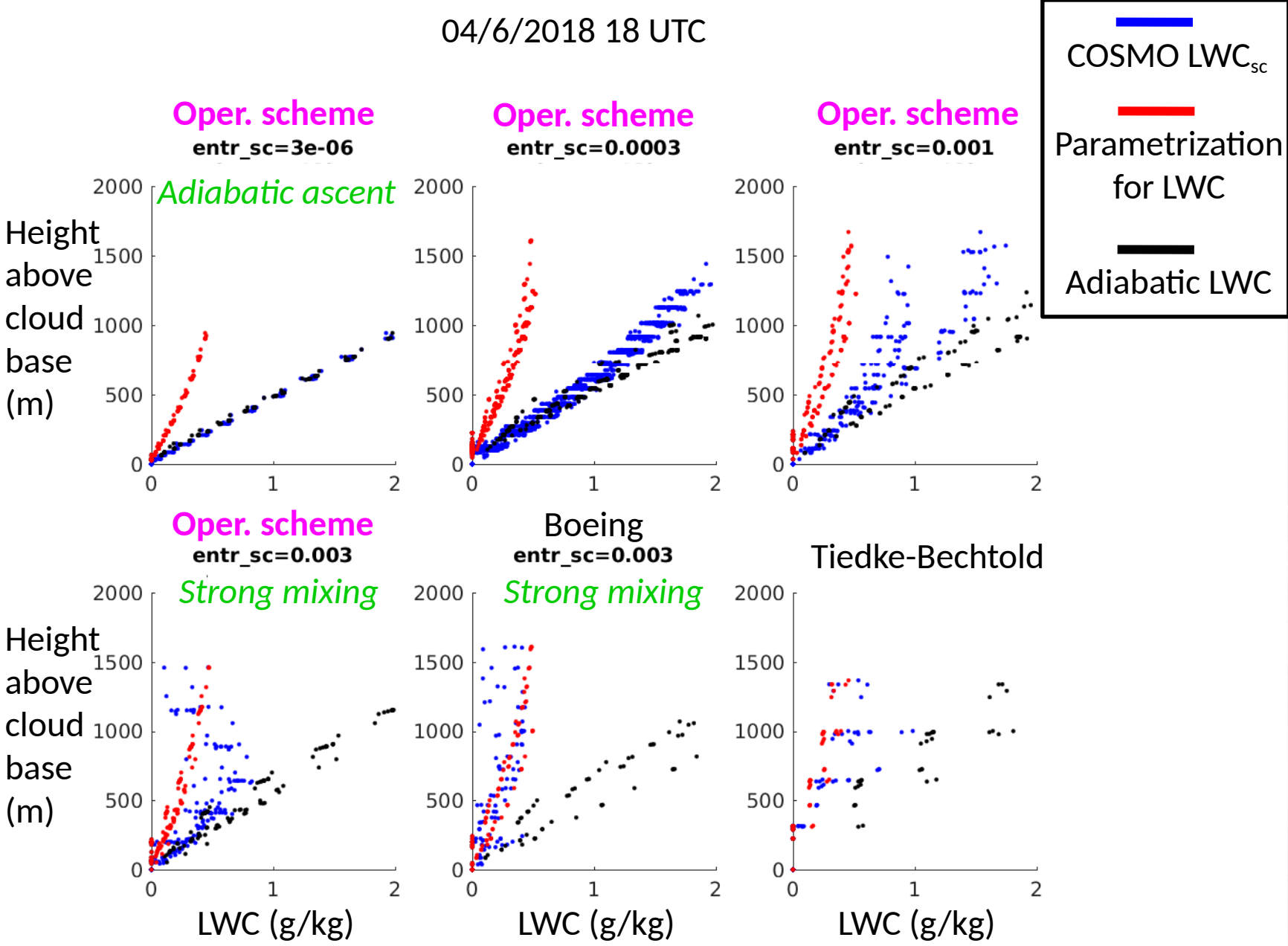

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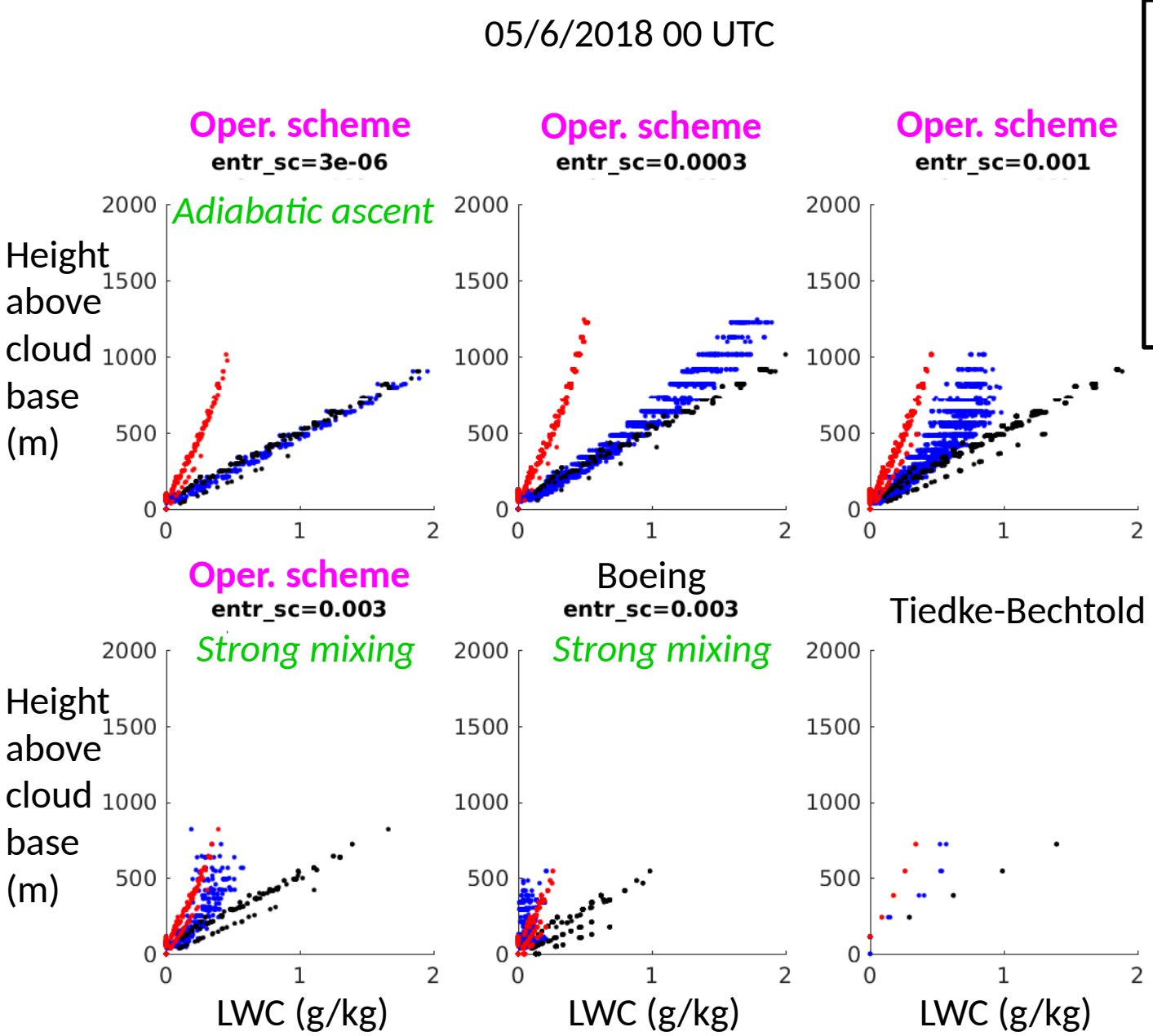

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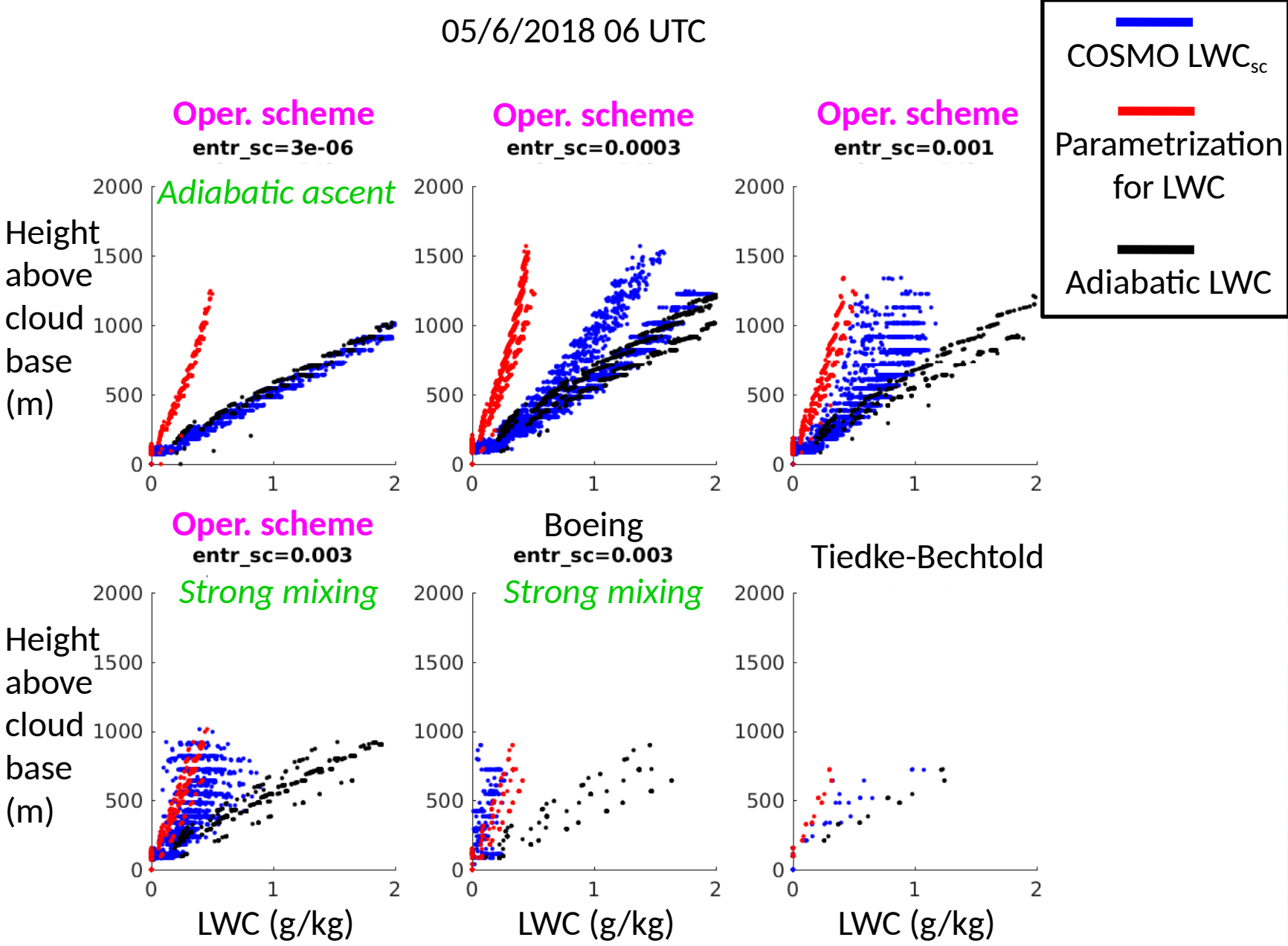

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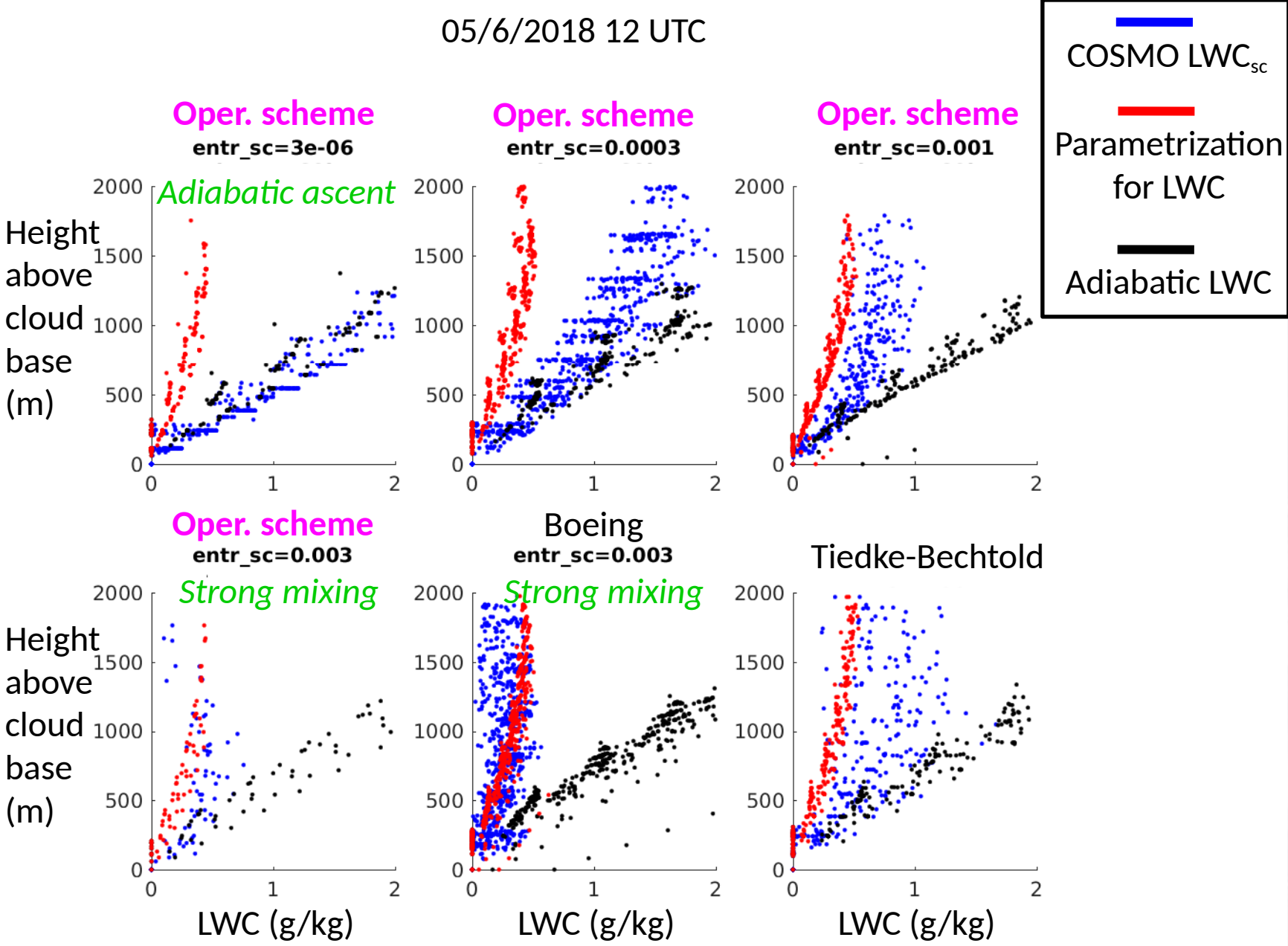

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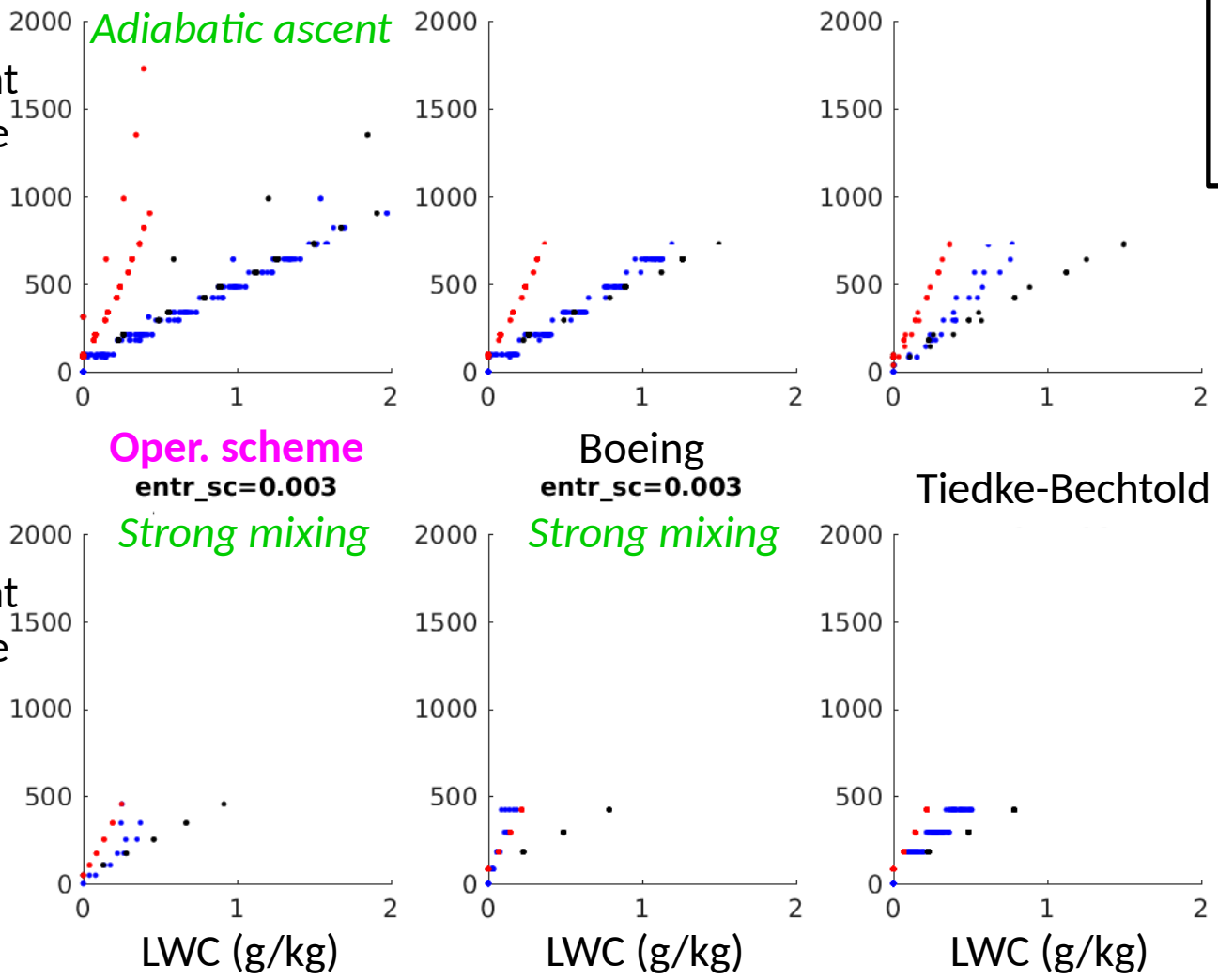

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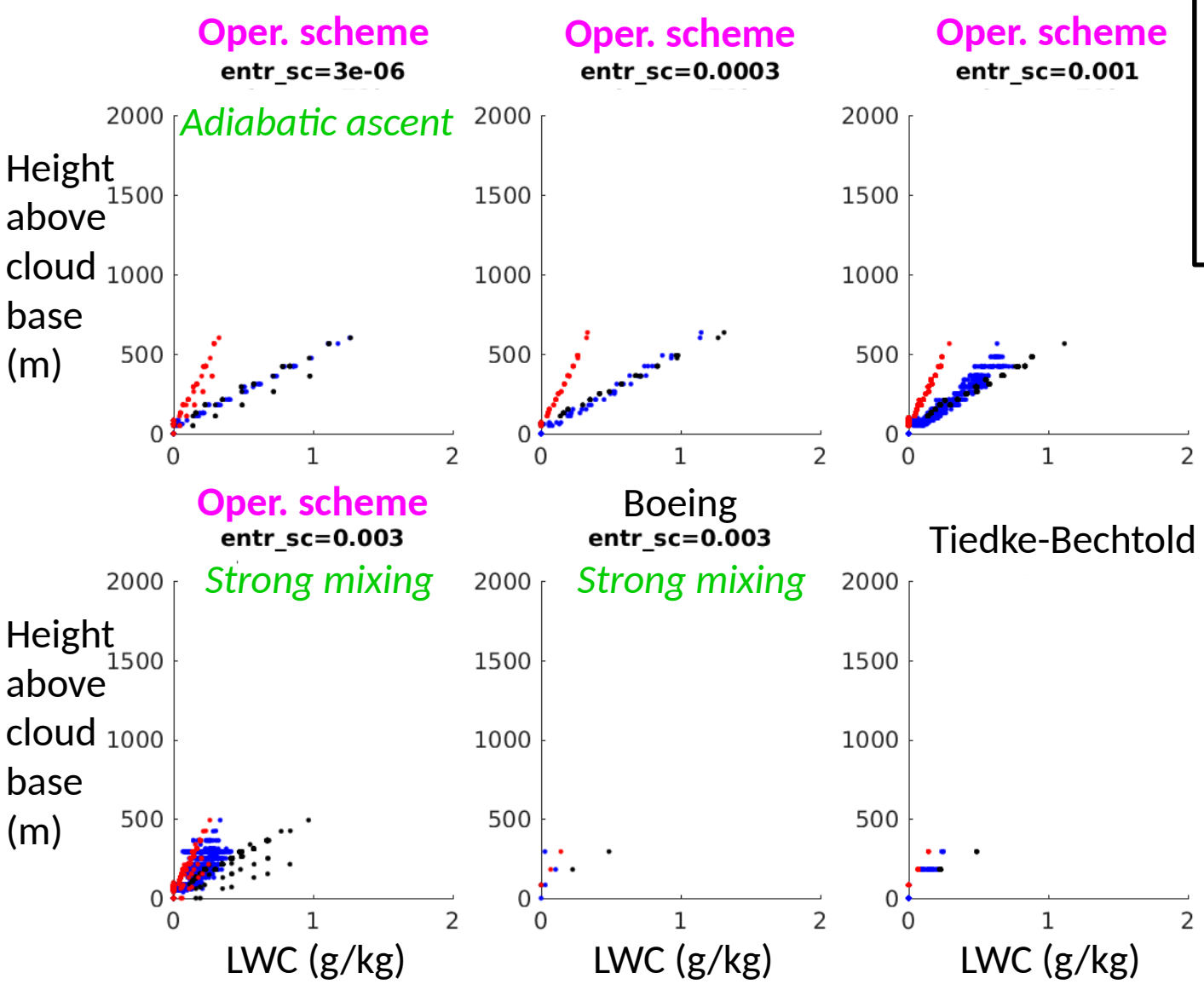

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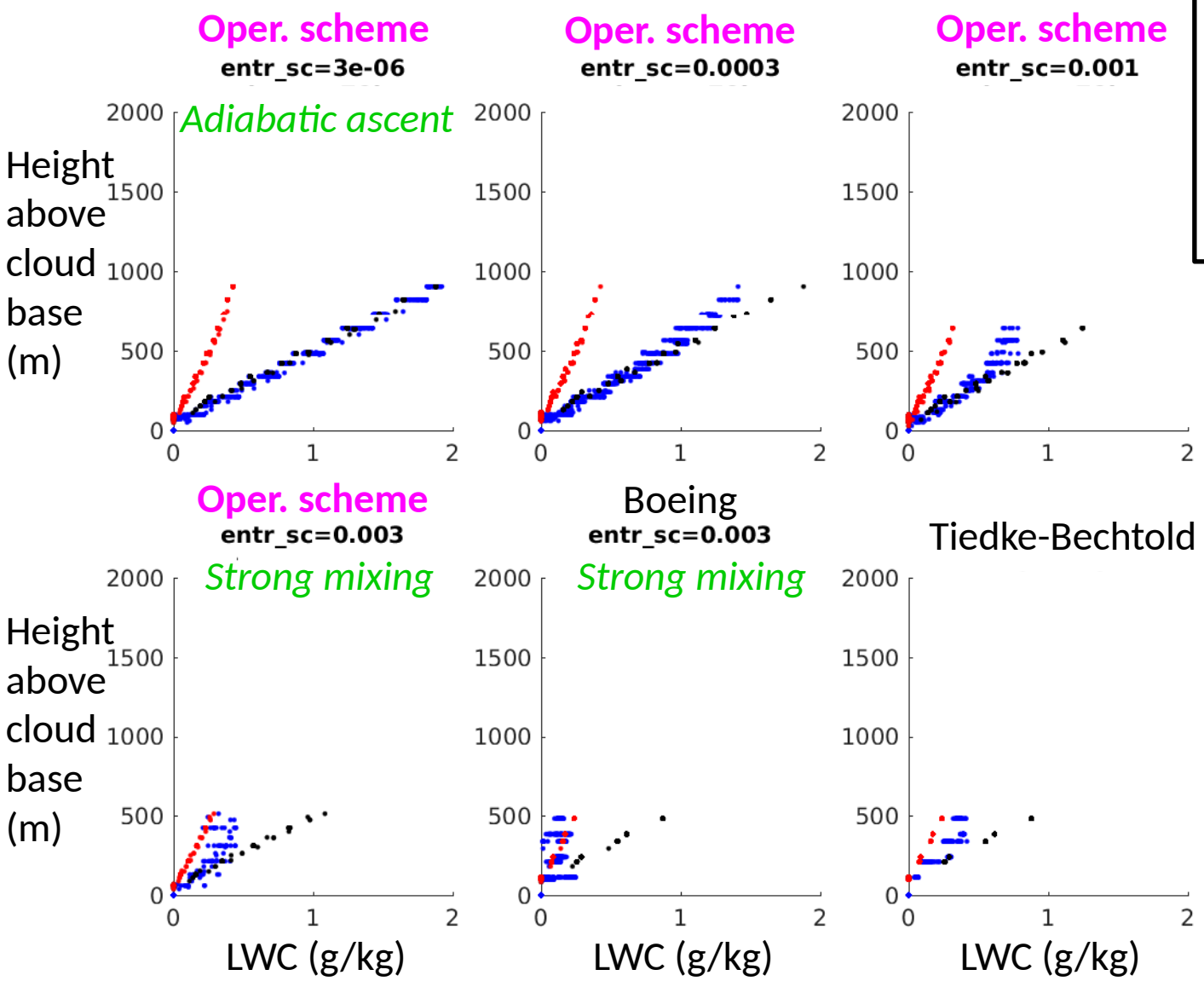

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