Shallow circulations rooted in shallow convection across the trade-wind mesoscales

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Photo by Anna Lea Albright during EUREC^{4}A

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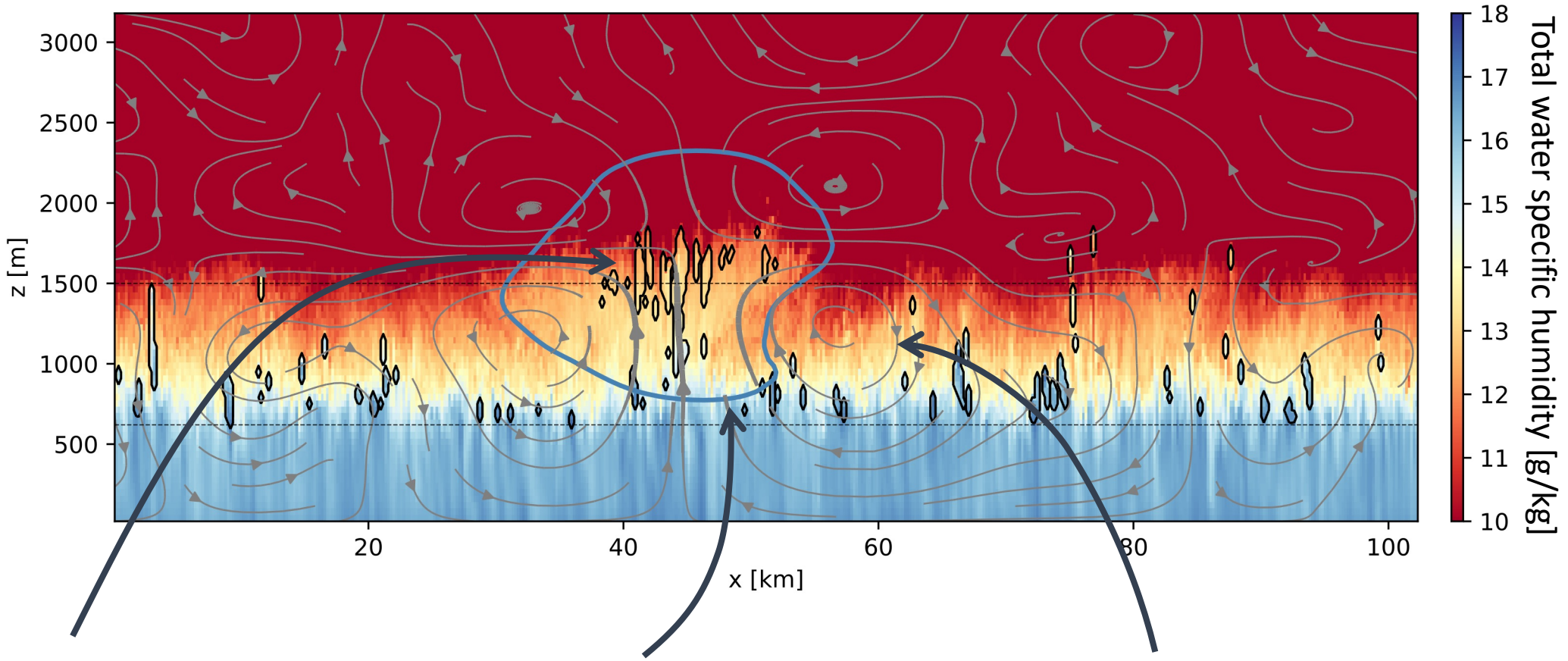
Idealised
large-eddy simulation of
trade cumuli
(Cloud Botany)
Jansson et al., (in revision), JAMES

Bretherton & Blossey (2017), JAMES
Janssens et al. (2022), JAS

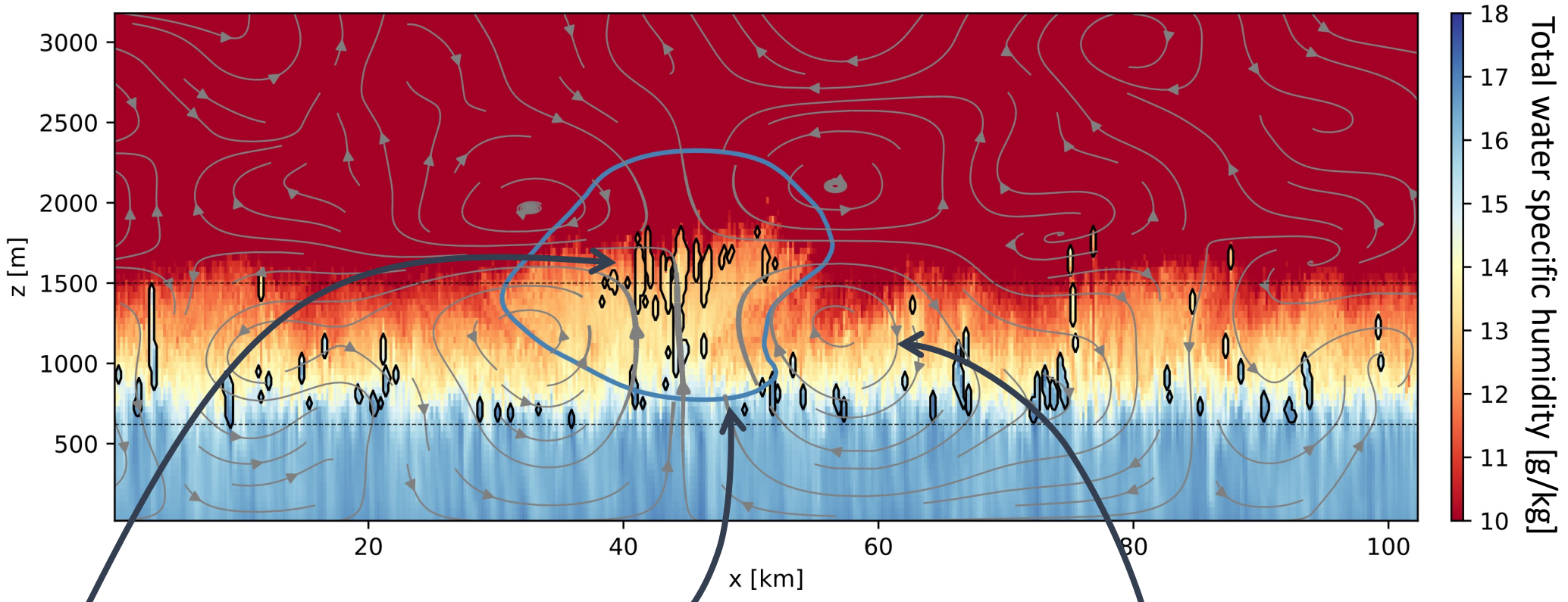


Mesoscale cloud clusters ← Mesoscale moisture fluctuations ← SMOC* ← Convective heating

***Shallow Mesoscale Overturning Circulation**

Is any of this real?

Bretherton & Blossey (2017), JAMES
Janssens et al. (2022), JAS



Mesoscale cloud clusters ← Mesoscale moisture fluctuations ← SMOC ← Convective heating

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Widespread shallow mesoscale circulations observed in the trades

Geet George ✉, Bjorn Stevens, Sandrine Bony, Raphaela Vogel & Ann Kristin Naumann

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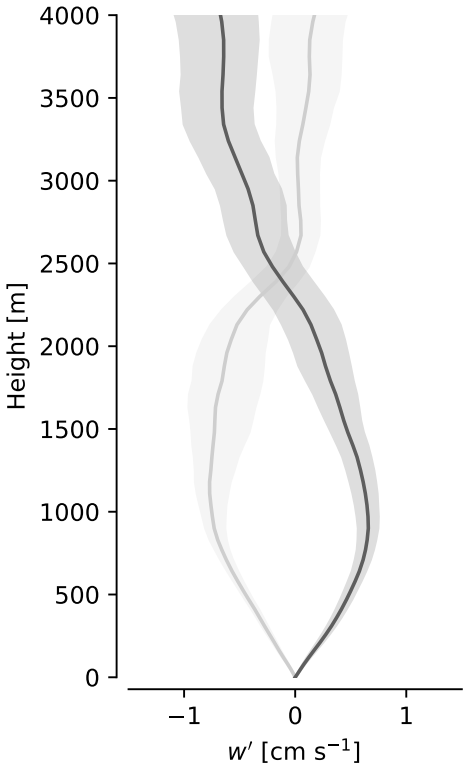
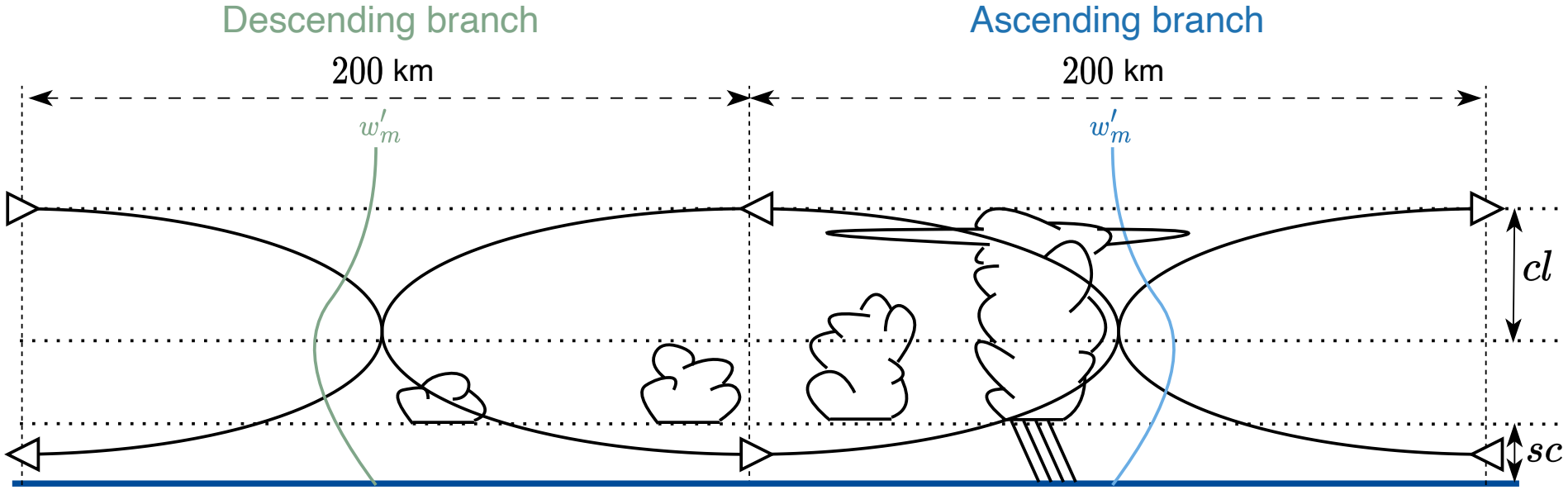
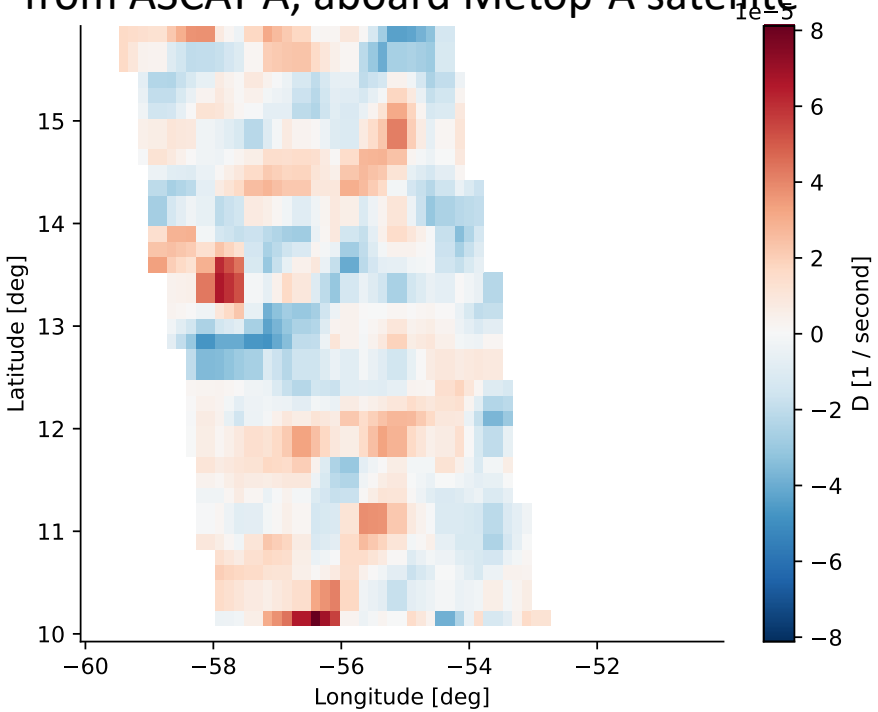


EUREC⁴A dropsondes
(JOANNE, George et al., 2021, ESSD)
Descending
Ascending



Near-surface divergence $\mathcal{D}_{srf}$
from ASCAT-A, aboard Metop-A satellite



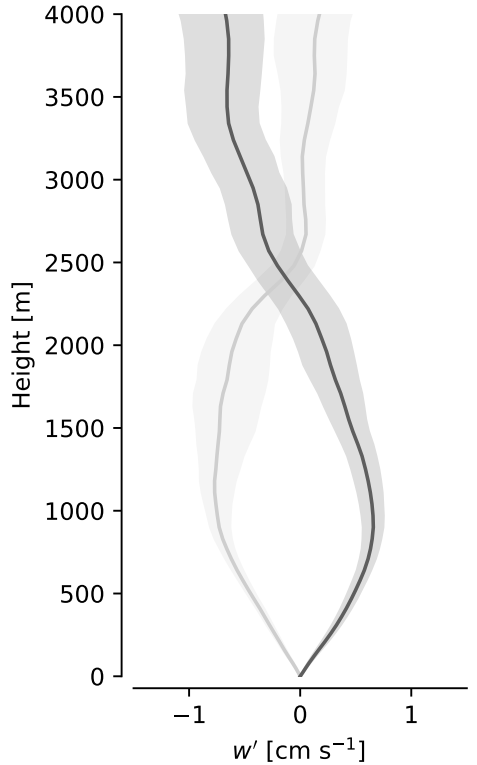
$$\mathcal{D}_{srf} \approx \mathcal{D}_{sc}$$

$$w_{cb} \approx \mathcal{D}_{srf} z_{cb}$$

EUREC^{4}A dropsondes
(JOANNE, George et al., 2021, ESSD)

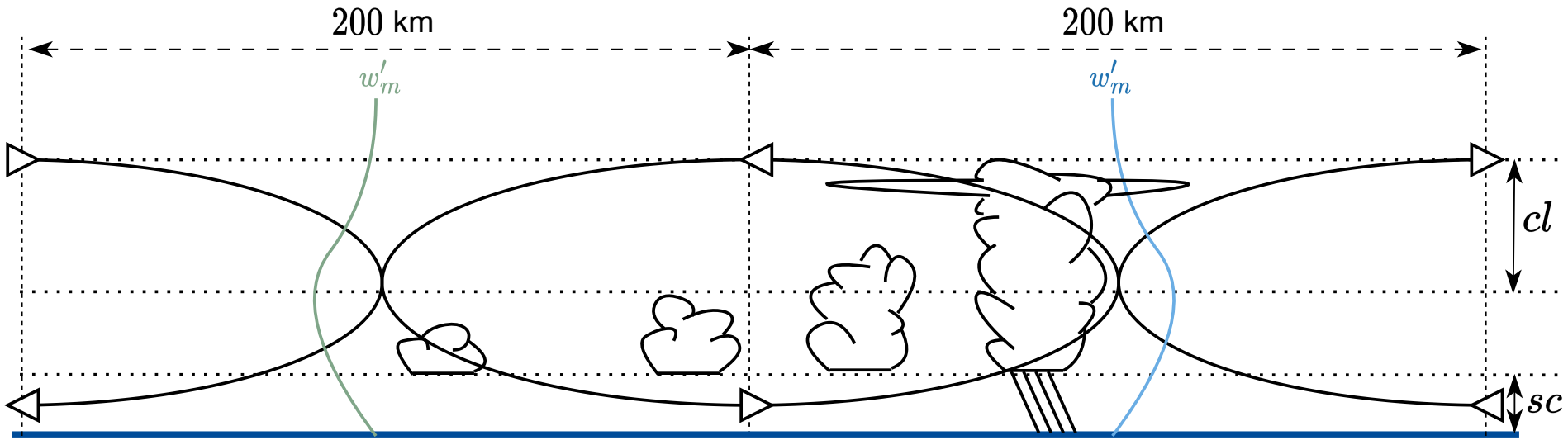
Descending

Ascending



Descending branch

Ascending branch



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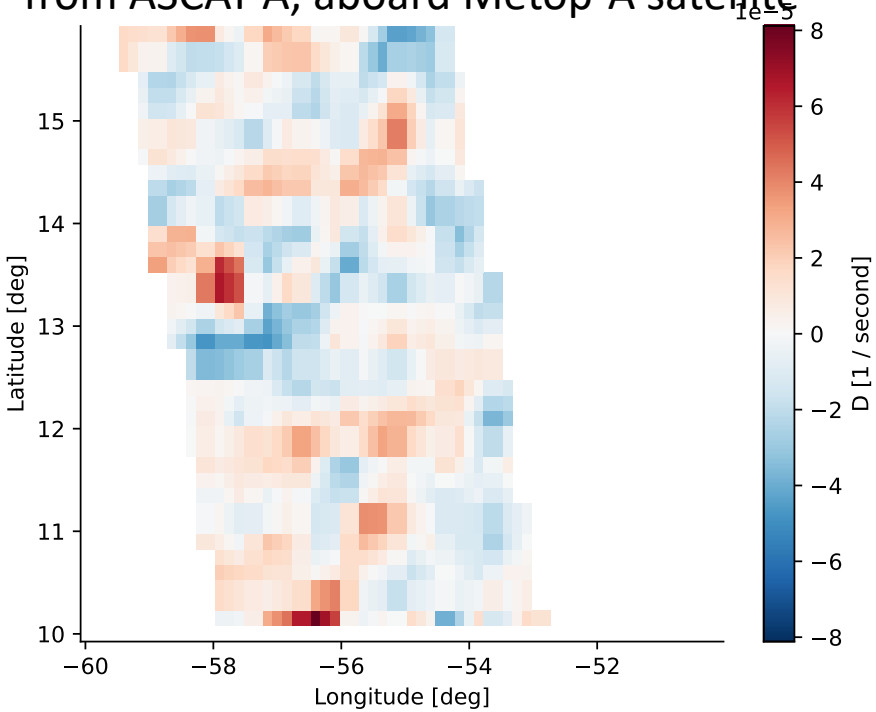
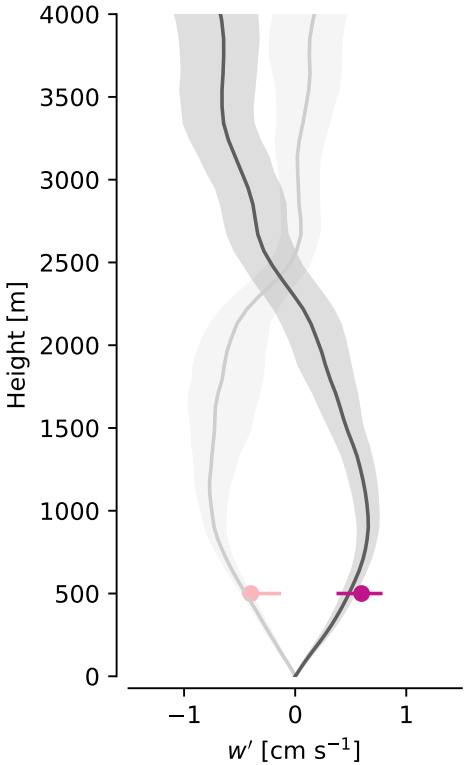


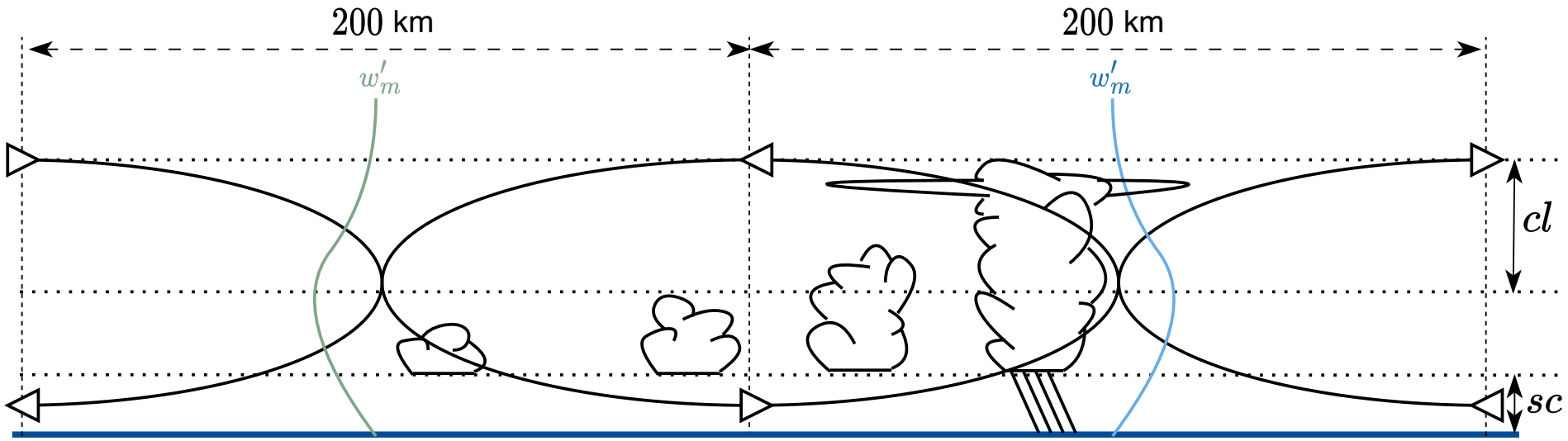
ASCAT, $w' \approx \mathcal{D}'_{sc} z_{cb}$
(George et al., in preparation)
- Descending
- Ascending

EUREC^{4}A dropsondes
(JOANNE, George et al., 2021, ESSD)
- Descending
- Ascending



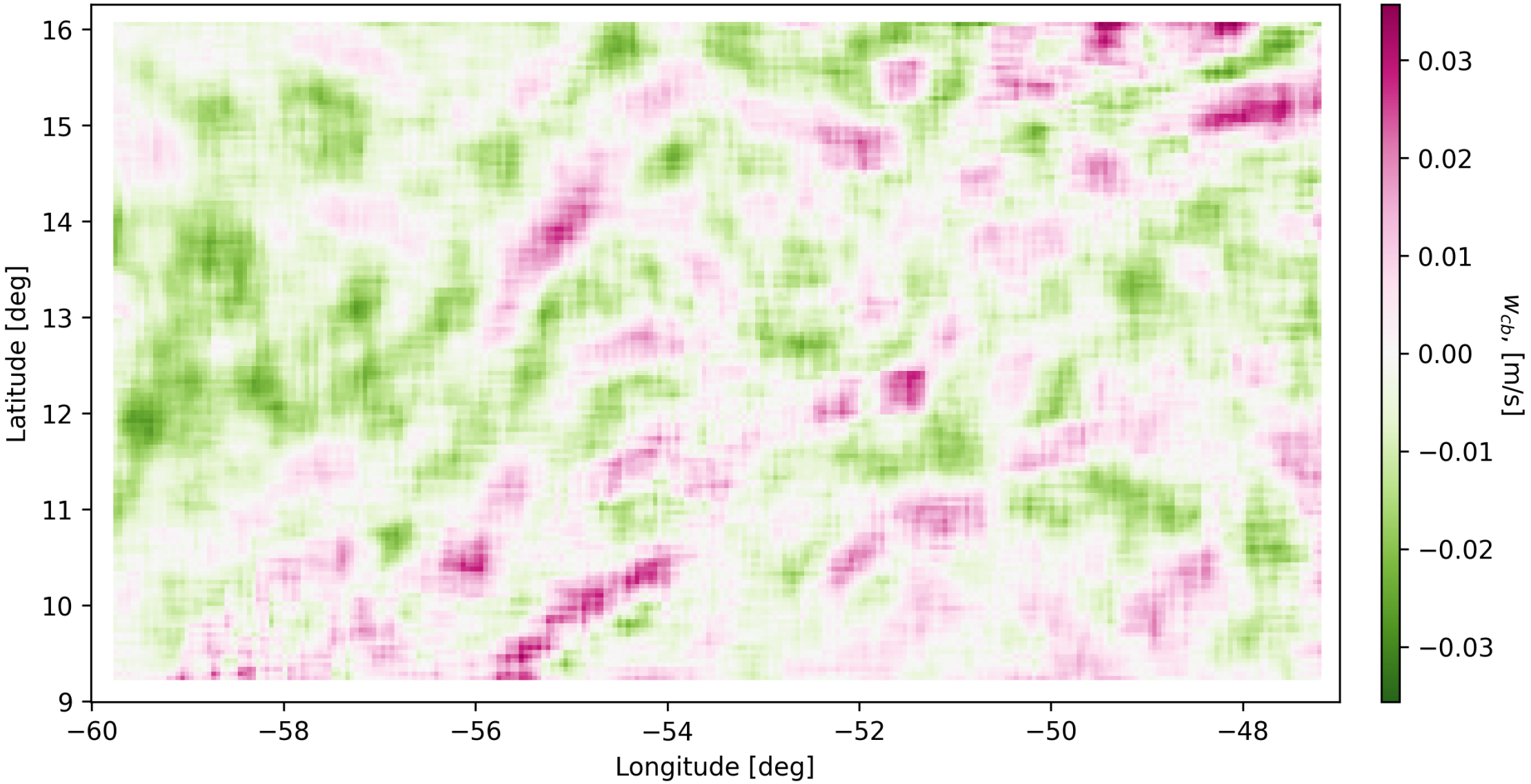
Descending branch

Ascending branch

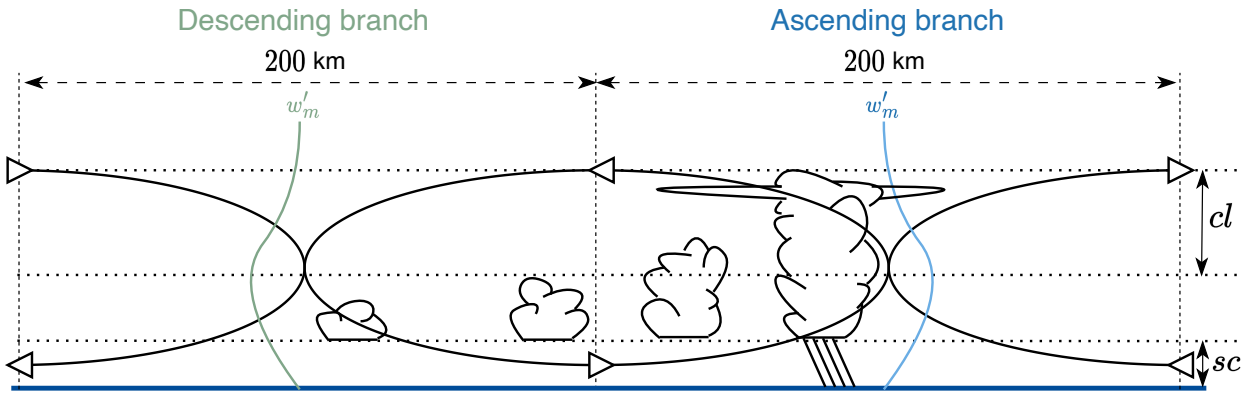


Okay, if SMOCs are real,
can we simulate them?

ICON LES ($\Delta x = 312$ m) of the entire North-Atlantic downstream trades, for two months



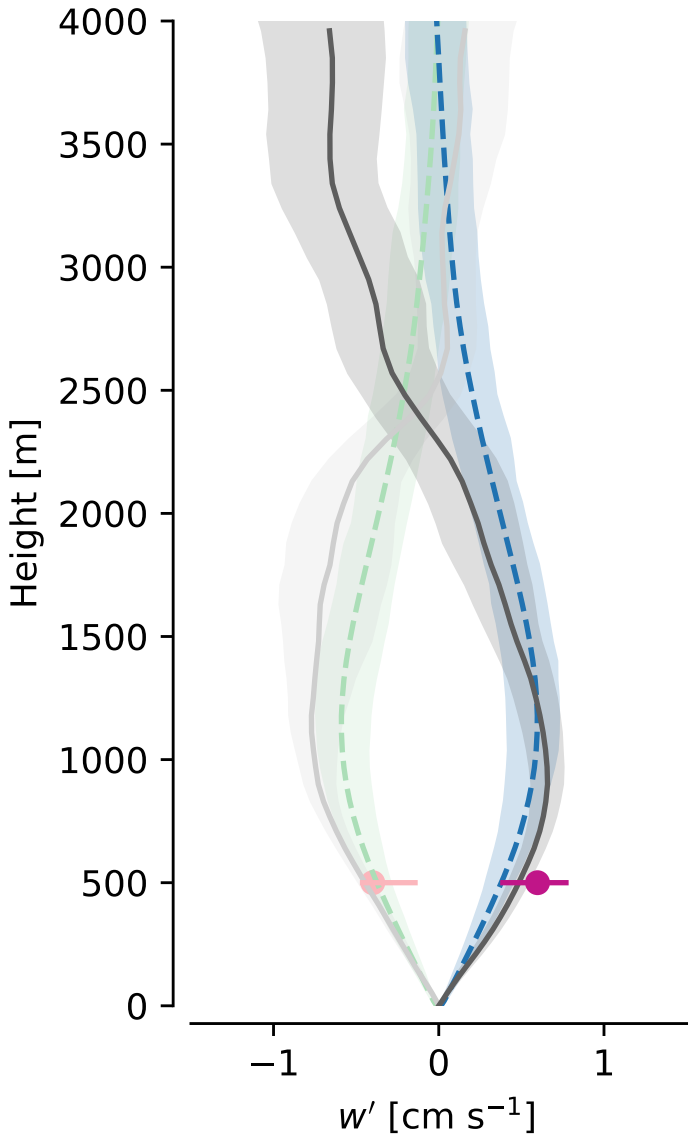
Schulz & Stevens (in revision), JAMES



LES
(Schulz & Stevens, 2023, JAMES)
Descending
Ascending

ASCAT, $w' \approx \mathcal{D}'_{sc} z_{cb}$
(George et al., in preparation)
Descending
Ascending

EUREC^{4}A dropsondes
(JOANNE, George et al., 2021, ESSD)
Descending
Ascending



Can we simulate SMOCs?

Yes!

What causes the simulated SMOCs?

Hypothesis from idealised LES

SMOCs are formed by convective heating, under WTG

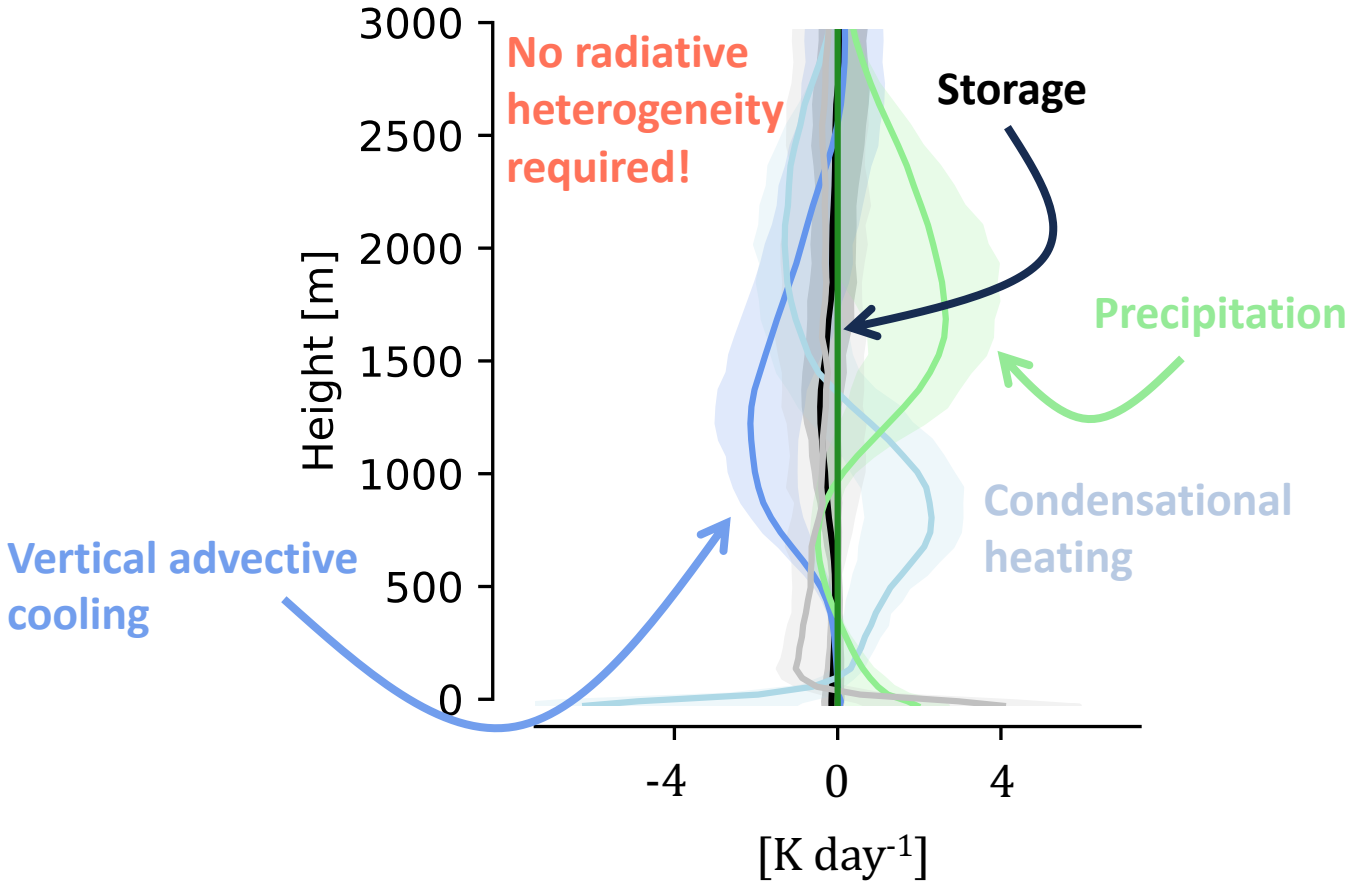
Approach

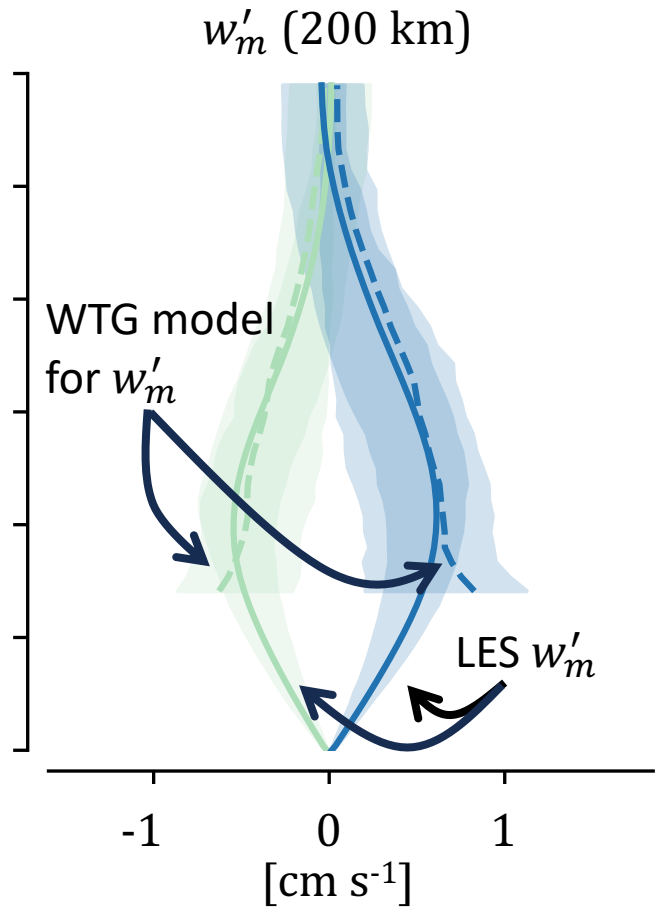
Study budgets for mesoscale fluctuations in

$$s_{lv} = c_p T + gz - L_v q_l + 0.608 c_p T_0 q_t,$$

$$s'_{lv_m}$$

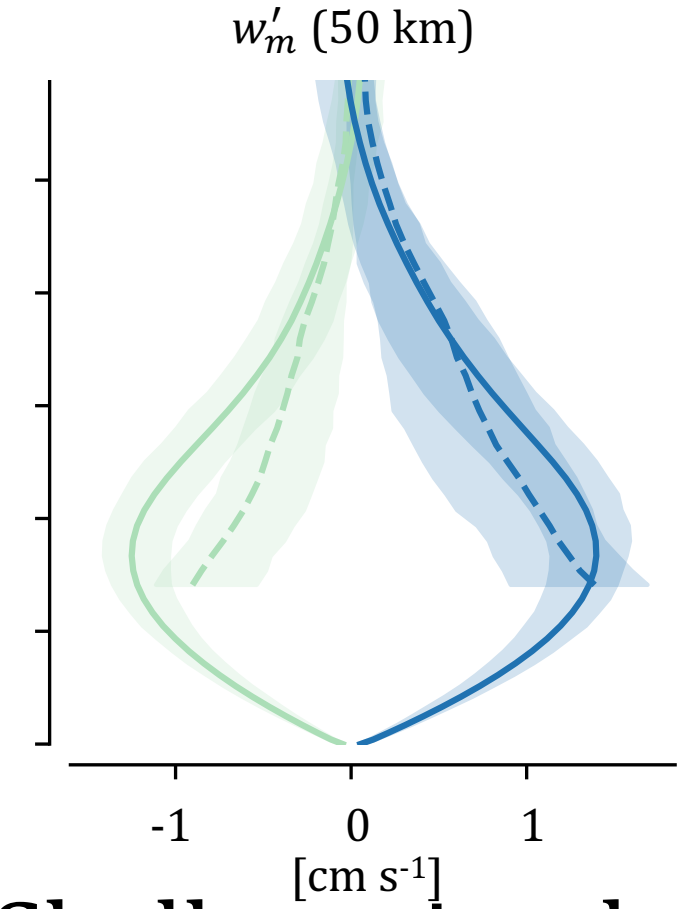
Contribution to s'_{lv_m} budget
in ascending regions of **200 km**

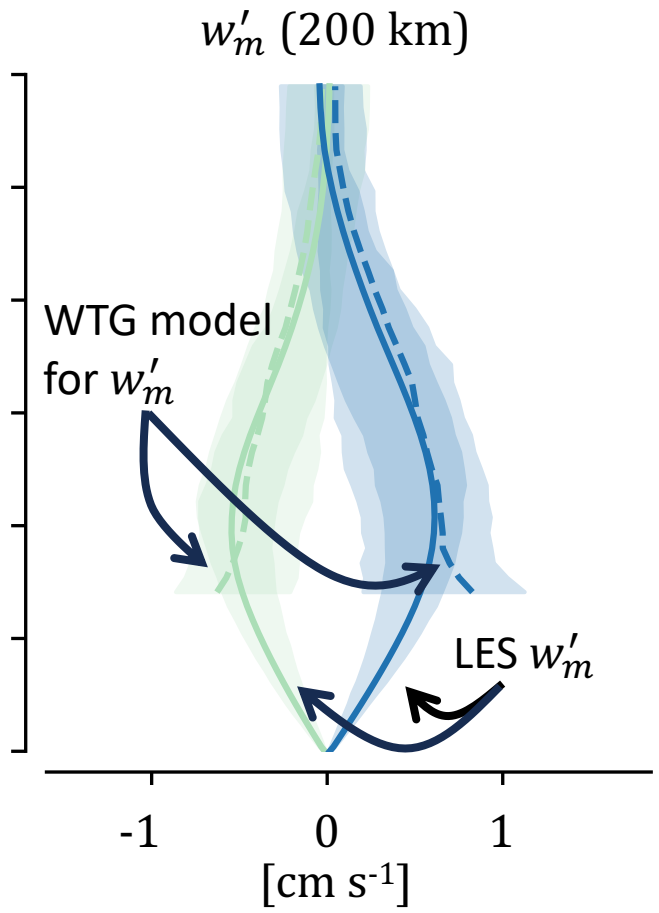




$$\partial_t s'_{lv_m} \approx 0 \approx -\partial_z F_{s'_{lv_m}} + S_{prec} + S_{rad} - w'_m \partial_z \overline{s_{lv}}$$

$$w'_m \approx \left(-\partial_z F_{s'_{lv_m}} + S_{prec} + S_{rad}\right) / \partial_z \overline{s_{lv}}$$



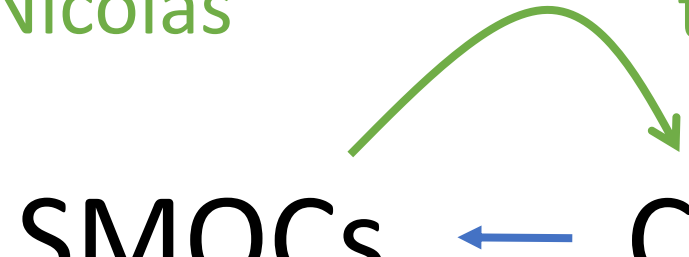


Shallow circulations rooted in (precipitating) shallow convection across the trade-wind mesoscales

SMOCs ← Convective heating, clouds

Sandrine, Nicolas

Denser, larger, stronger thermals near cloud base?



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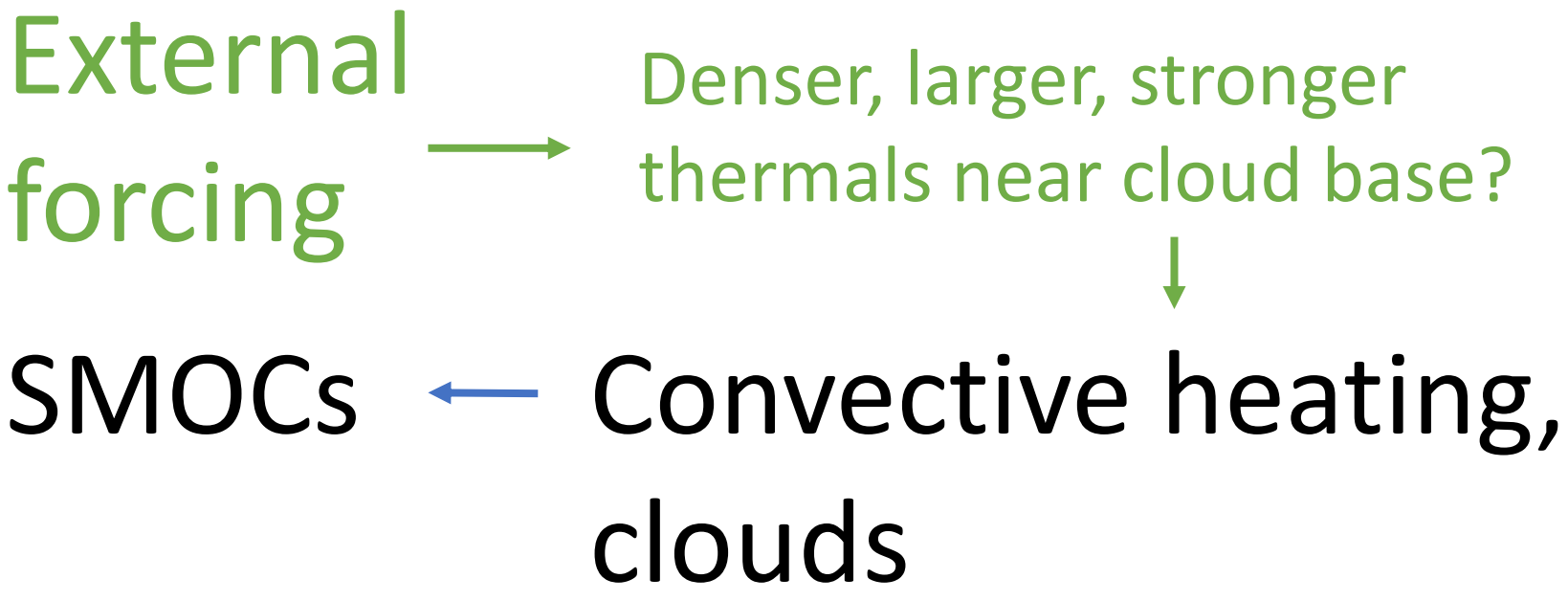
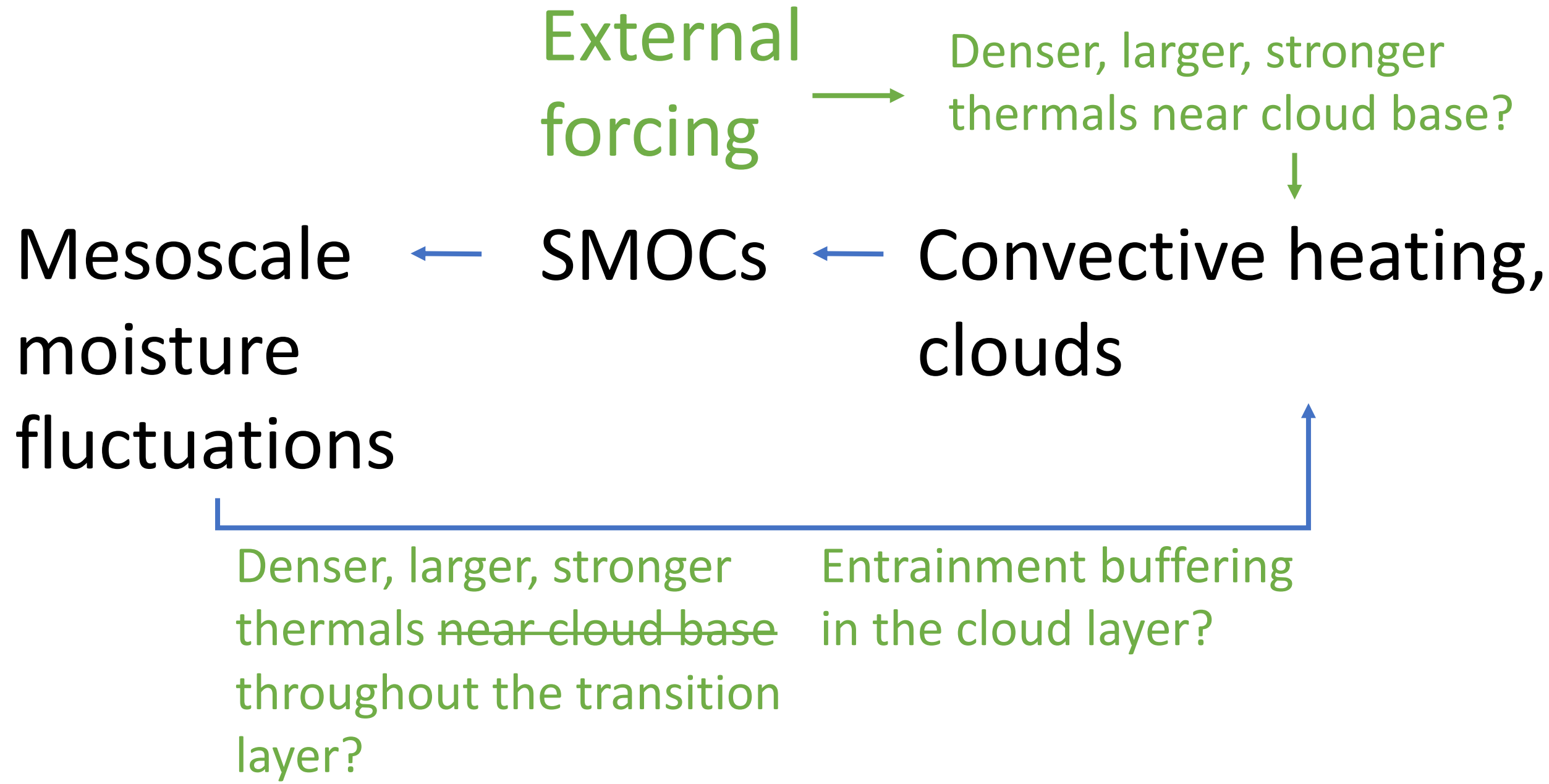

External forcing
Denser, larger, stronger thermals near cloud base?
SMOCs
Convective heating, clouds


External forcing
Denser, larger, stronger thermals near cloud base?
Mesoscale moisture fluctuations
SMOCs
Convective heating, clouds
Denser, larger, stronger thermals ~~near cloud base~~ throughout the transition layer?
Entrainment buffering in the cloud layer?

Shallow circulations (are real and simulatable) rooted in shallow convection (in convective heating) across the trade-wind mesoscales (in WTG)

What controls convective heating patterns?
How do SMOCs and water vapour interact?
What roles are played by radiation and rain evaporation?

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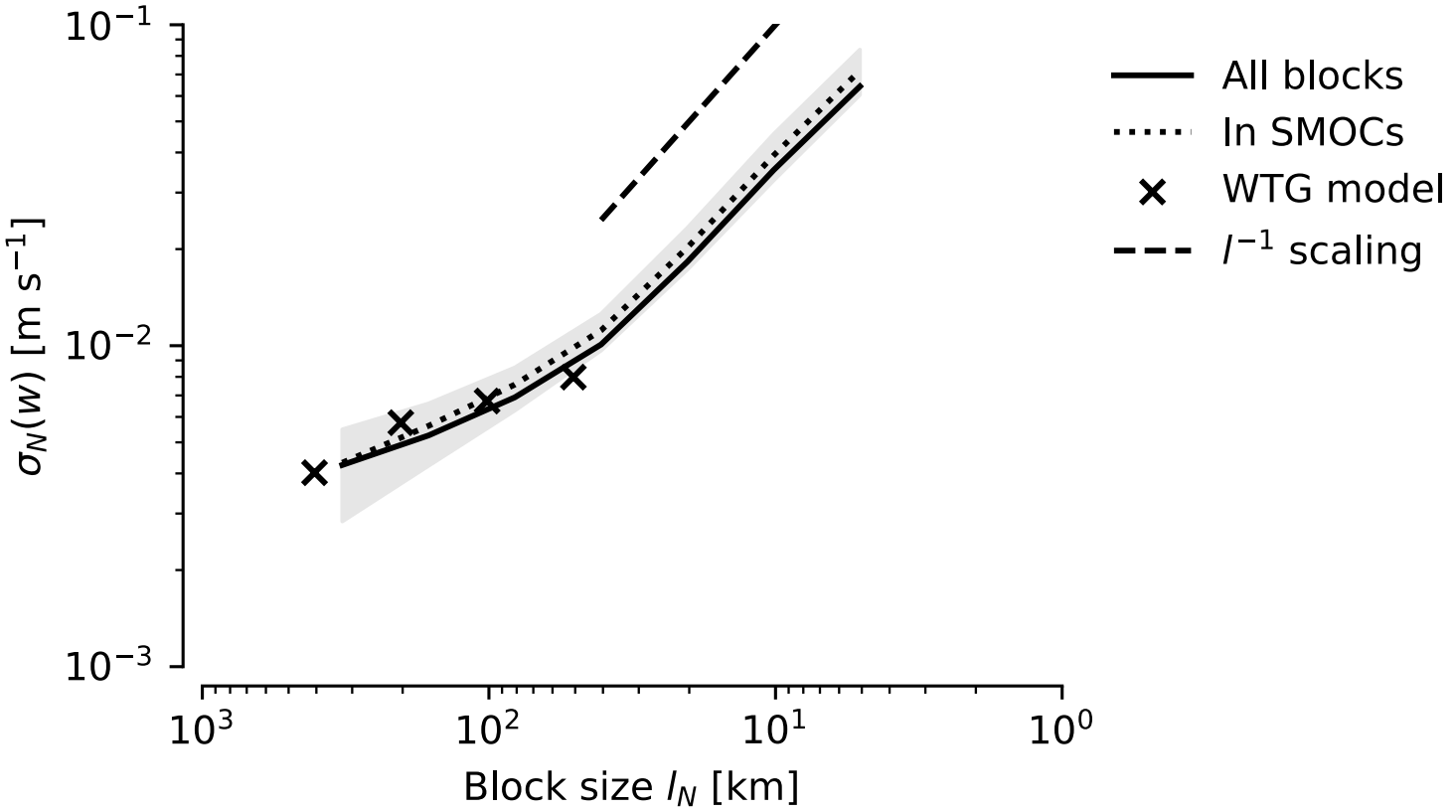
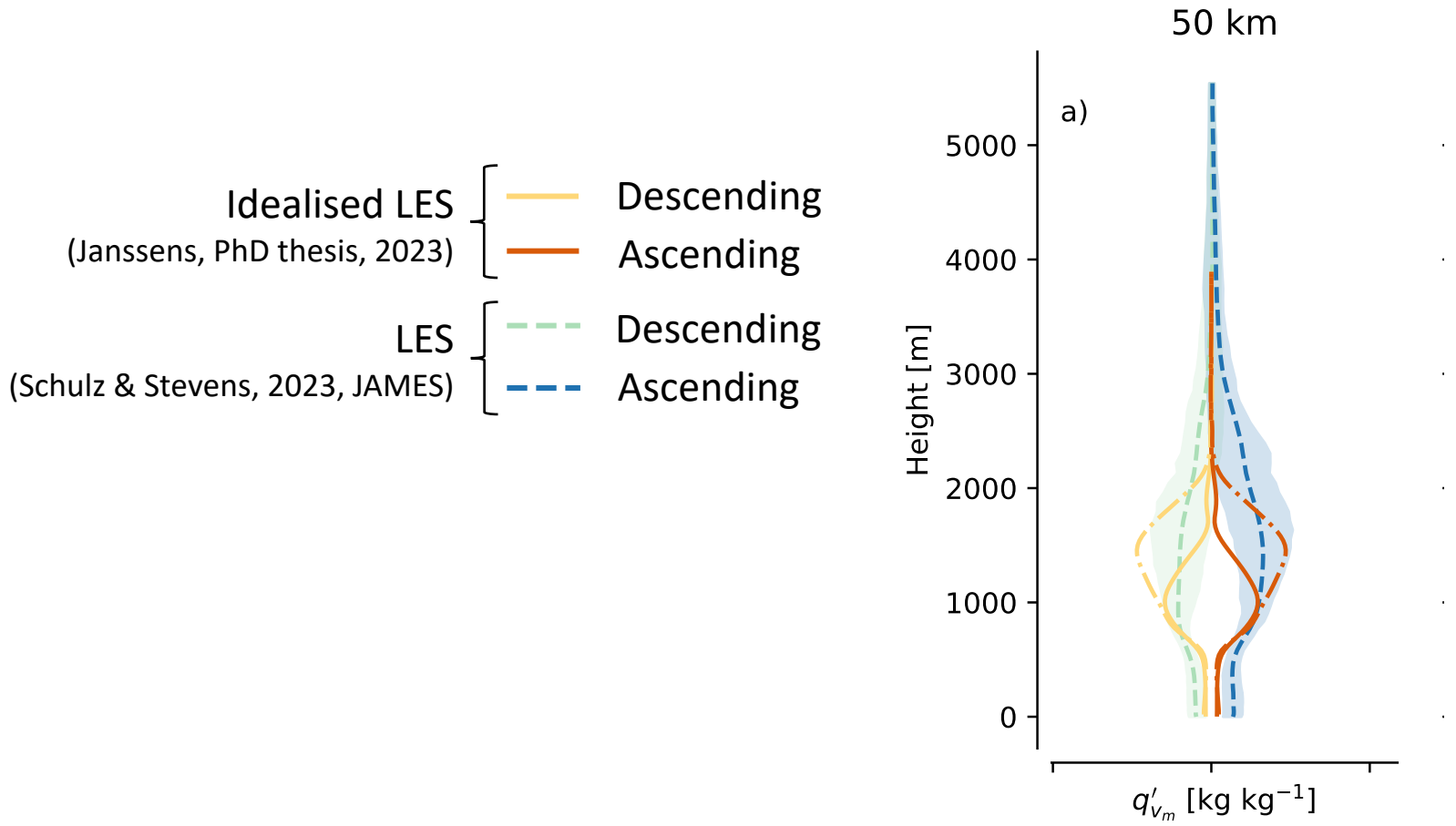
Photo by Anna Lea Albright during EUREC^{4}A


10^{-1}
10^{-2}
10^{-3}
$\sigma_N(w)$ [m s^{-1}]
10^3
10^2
10^1
10^0
Block size l_N [km]
All blocks
In SMOCs
WTG model
l^{-1} scaling


Idealised LES
(Janssens, PhD thesis, 2023)
Descending
Ascending
LES
(Schulz & Stevens, 2023, JAMES)
Descending
Ascending
50 km
a)
5000
4000
3000
2000
1000
0
Height [m]
q'_{v_m} [kg kg^{-1}]

LES
(Schulz & Stevens, 2023, JAMES)
Descending
Ascending

IASI-ASCAT, $w' \approx \mathcal{D}'_{sc} z_{cb}$
(George et al., in preparation)
Descending
Ascending

EUREC⁴A dropsondes
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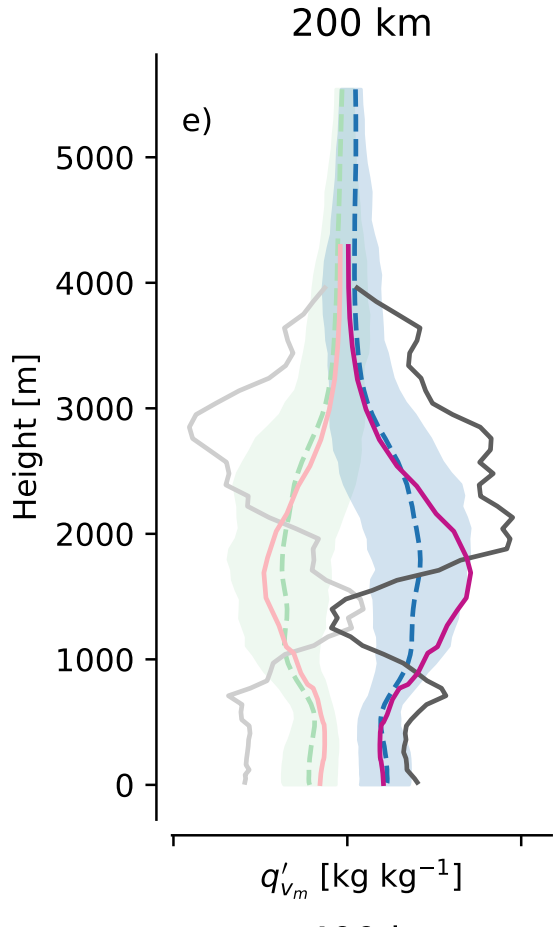
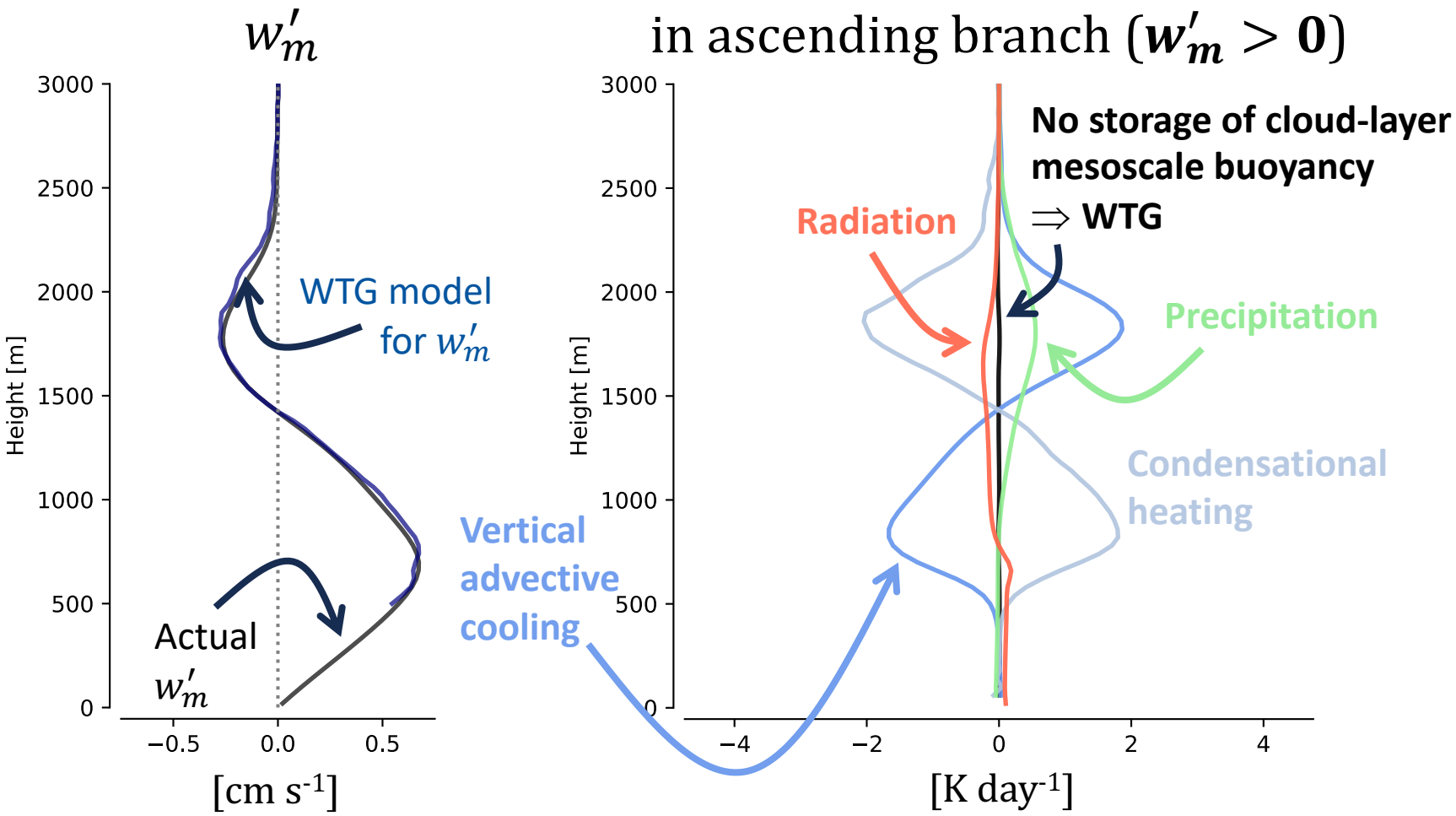
Descending
Ascending



Contribution to s'_{lv_m} budget in ascending branch ($w'_m > 0$)



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$$w'_m \approx \left(-\partial_z F_{s'_{lv_m}} + S_{prec} + S_{rad}\right) / \partial_z \overline{s_{lv}}$$