# Clouds blowing (in) the wind

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TU Delft

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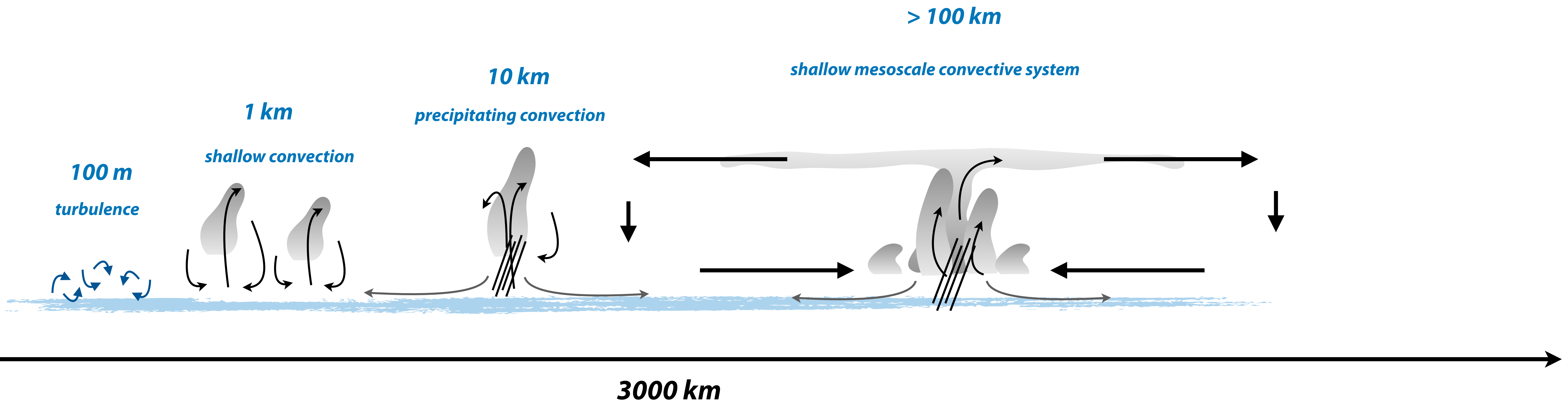

# (Where) do shallow clouds decelerate or accelerate the wind?

1. Analysis of the momentum budget using EUREC$^4$A observations

2. The near-surface wind vector balance

3. Wind balance throughout the lower troposphere (in observations and IFS forecast)

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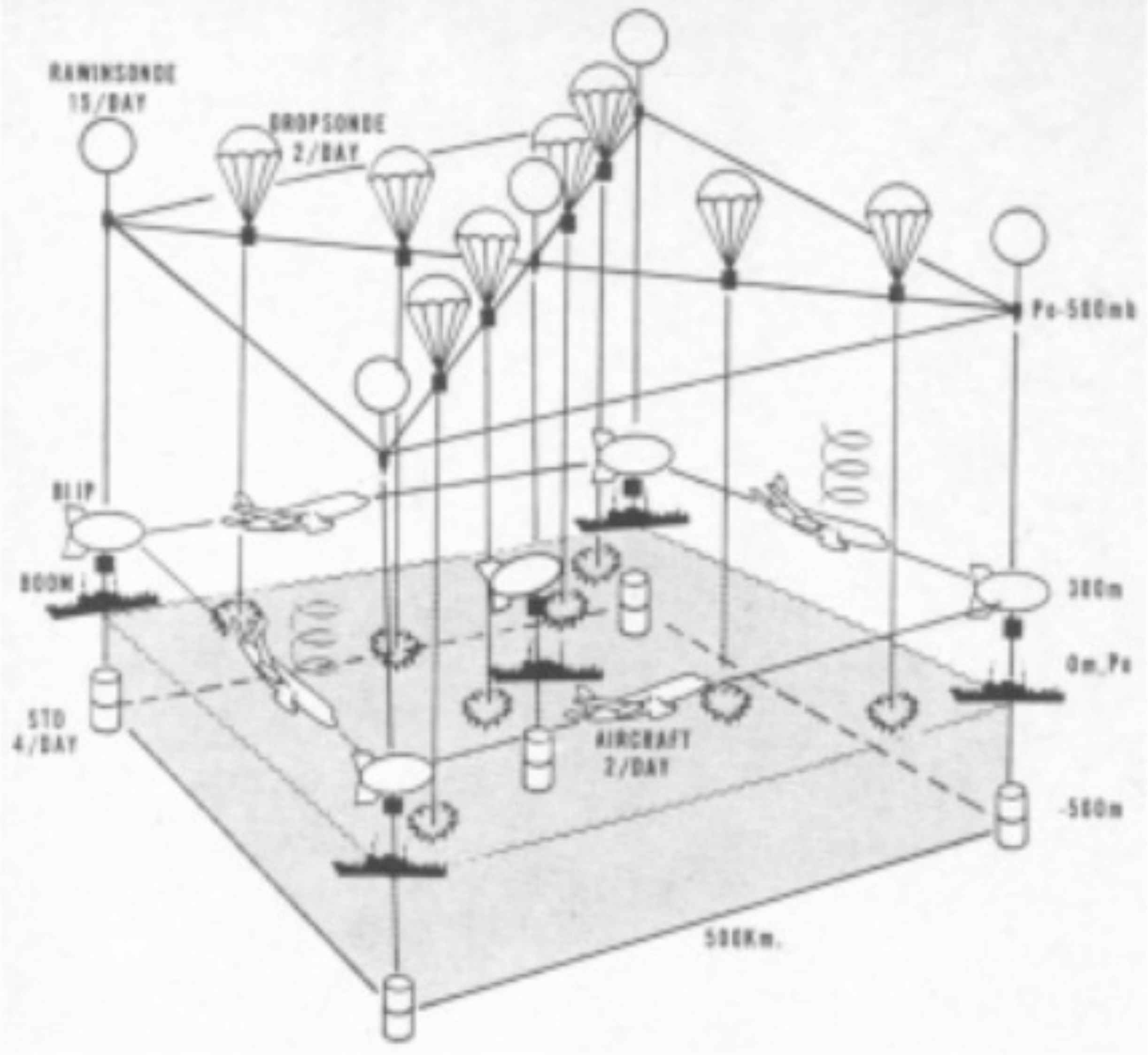
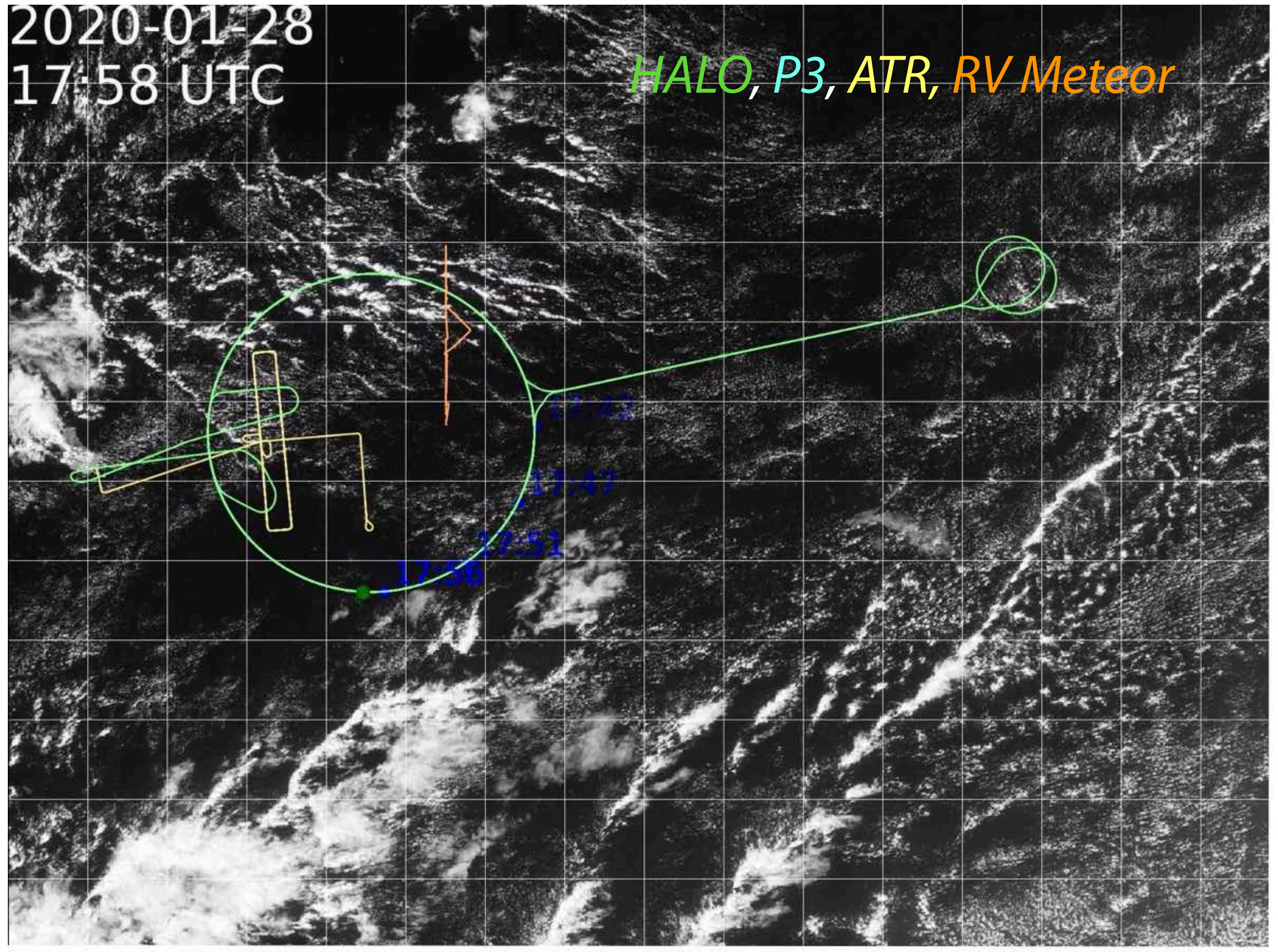
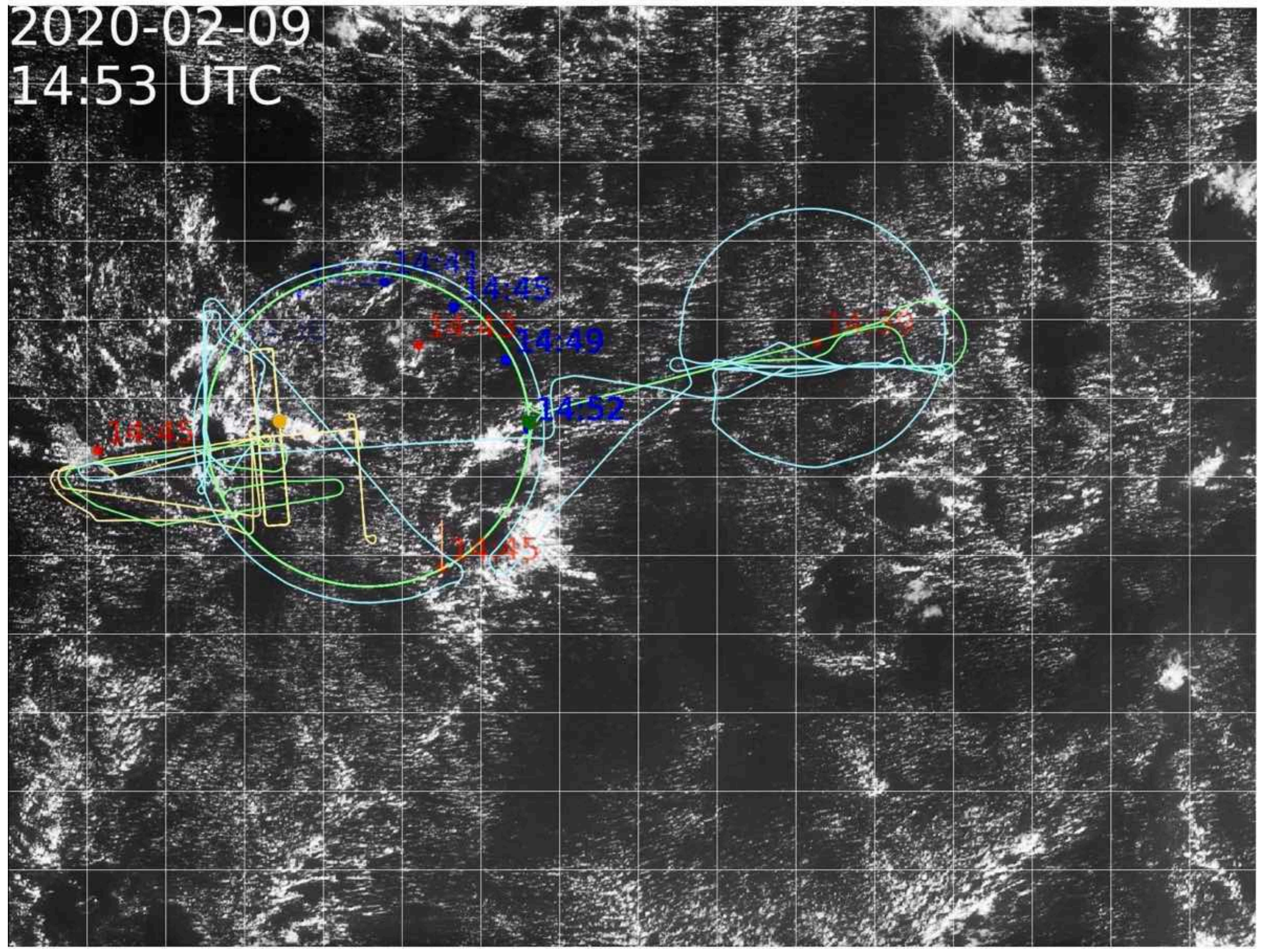
**Stronger trade-winds - in response to stronger pressure gradients - drive deeper, larger clouds, which may reduce cross-isobaric wind turning and large-scale wind convergence in the ITCZ**

# Central to EUREC4A were circular sounding arrays that allow us to revive early budget studies




***Holland & Rasmusson (1973):***
***Ship array during BOMEX " where the air meets the ocean"***

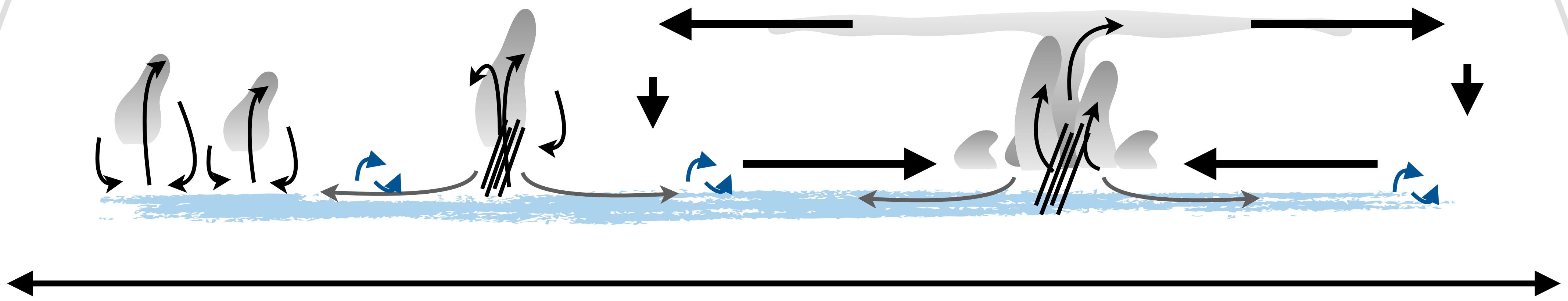
***Bony et al (2017), Stevens et al (2021):***
***Elucidate the Couplings between Clouds, Convection and Circulation***

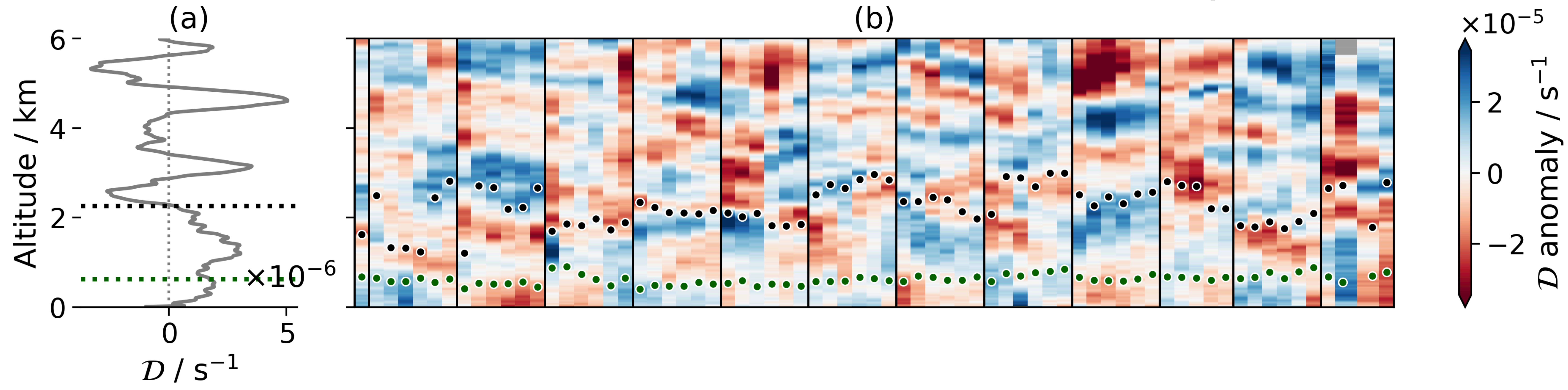
# The residual in the momentum budget is interpreted as eddy momentum flux divergence (a friction)

* **JOANNE: circular dropsonde arrays** (85 circles, 13 flight days): meso-scale divergence, pressure gradients and winds are used to construct the momentum budget

* **In-situ turbulence measurements**:
  - profiles: the French ATR Safire aircraft legs within the circle
  - profiles: the Unmanned Airborne Vehicle CU RAAVEN
  - near-surface: the NOAA Saildrone in the trade-wind alley

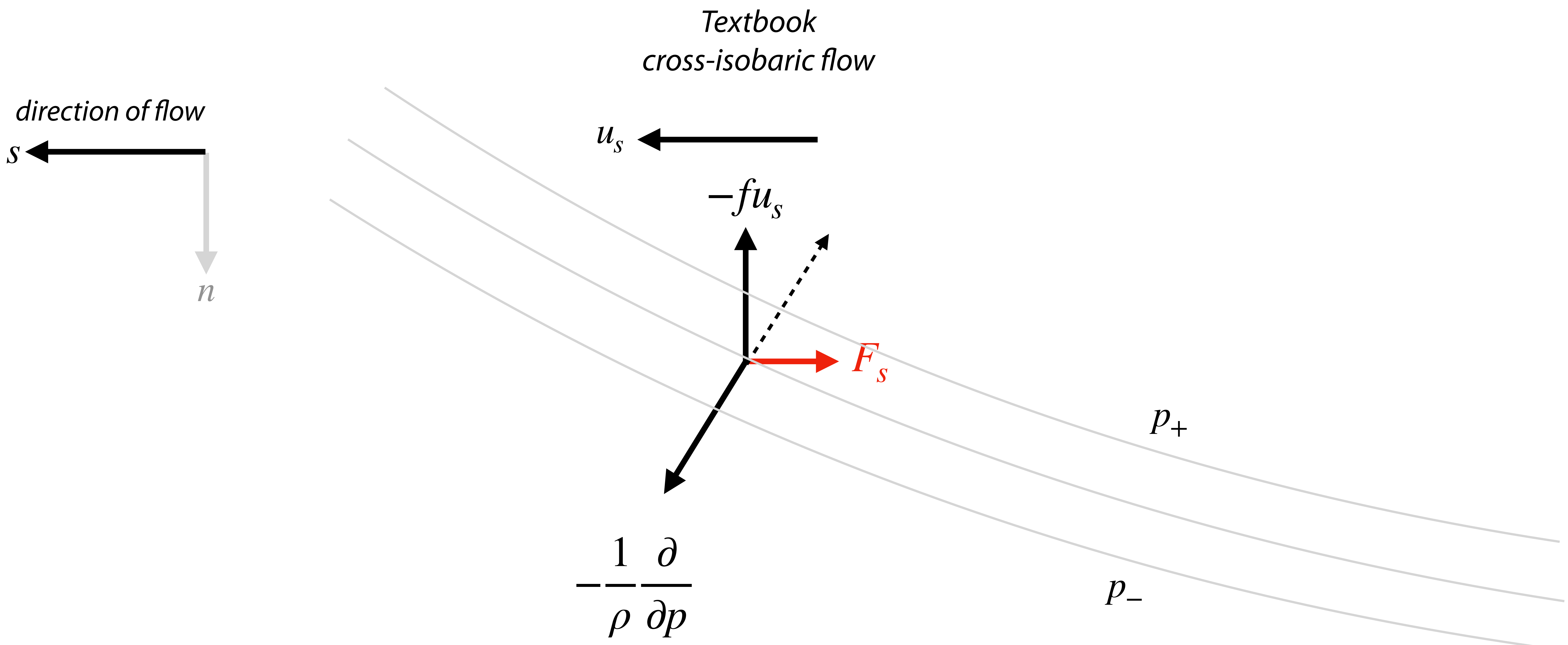
* **Flights sample mesoscale variability in divergence**




*George et al (2021), Nuijens et al (2022, in review)*

# Near the surface, what is the wind vector balance?

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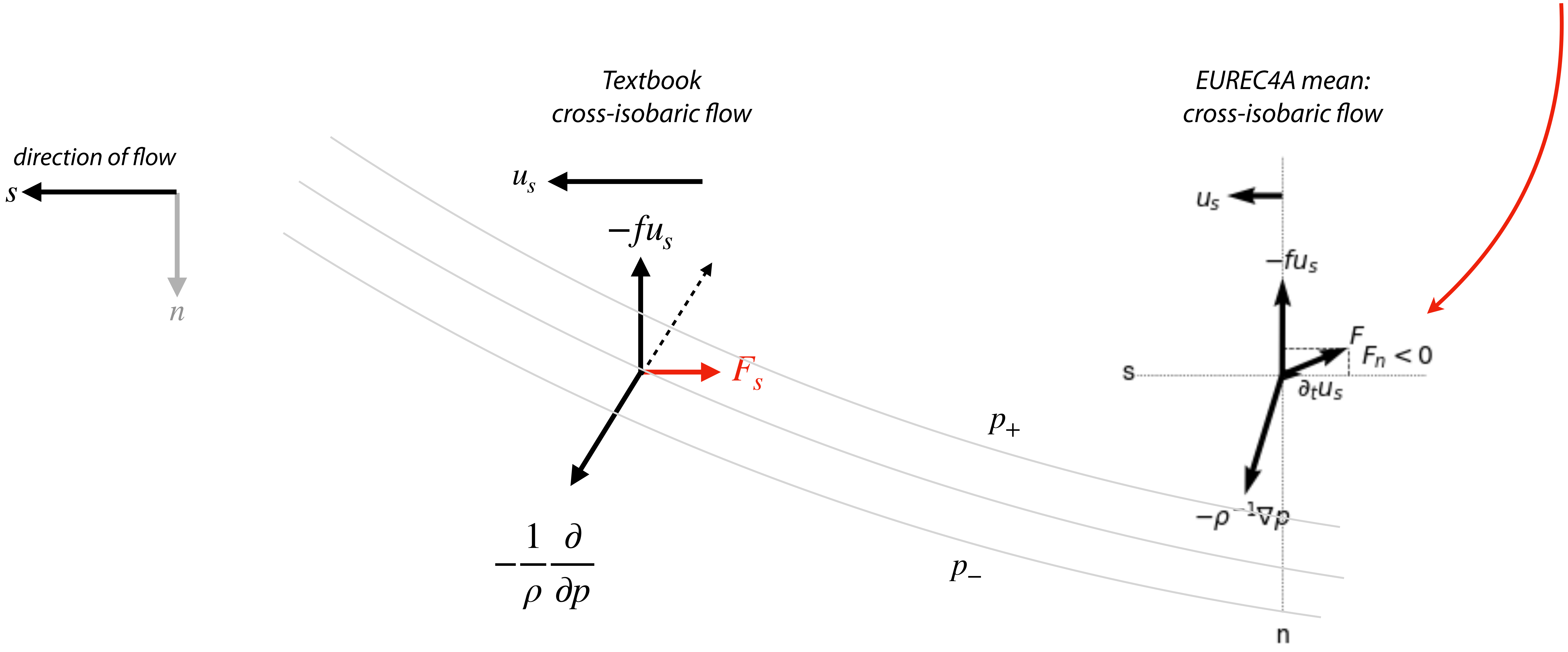


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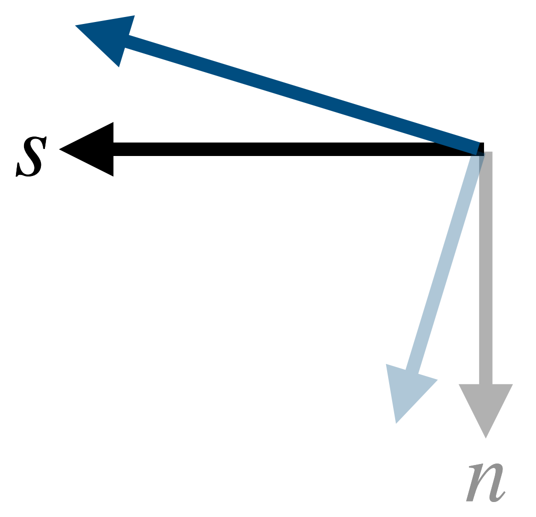
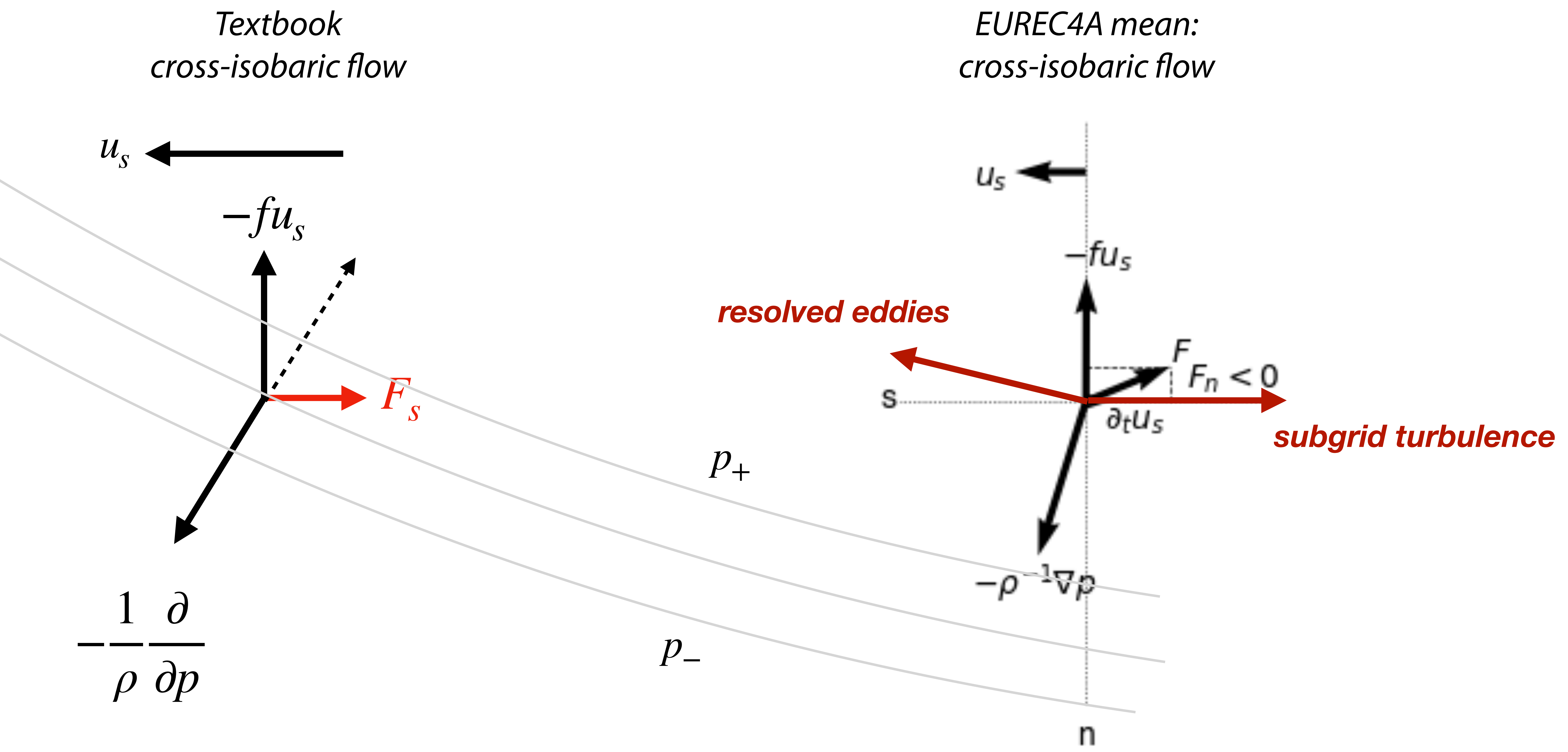


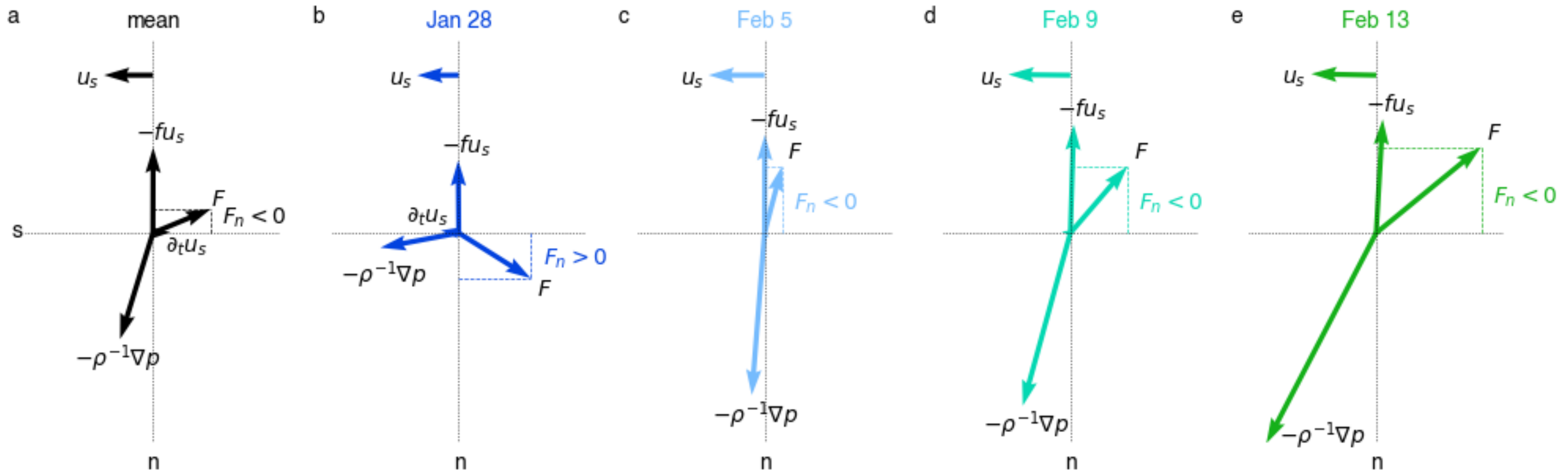

***wind veering with height, vertical transport introduces momentum with positive v-component***

***wind veering is small (2.7° up to cloud base) vertical transport efficient!***

***Helfer et al (2020), Nuijens et al (2022, in review)***

# A component of friction that veers the wind - opposing cross-isobaric wind turning - is most pronounced during a period of stronger trade-winds and convection

*strengthening trade-winds during EUREC4A*

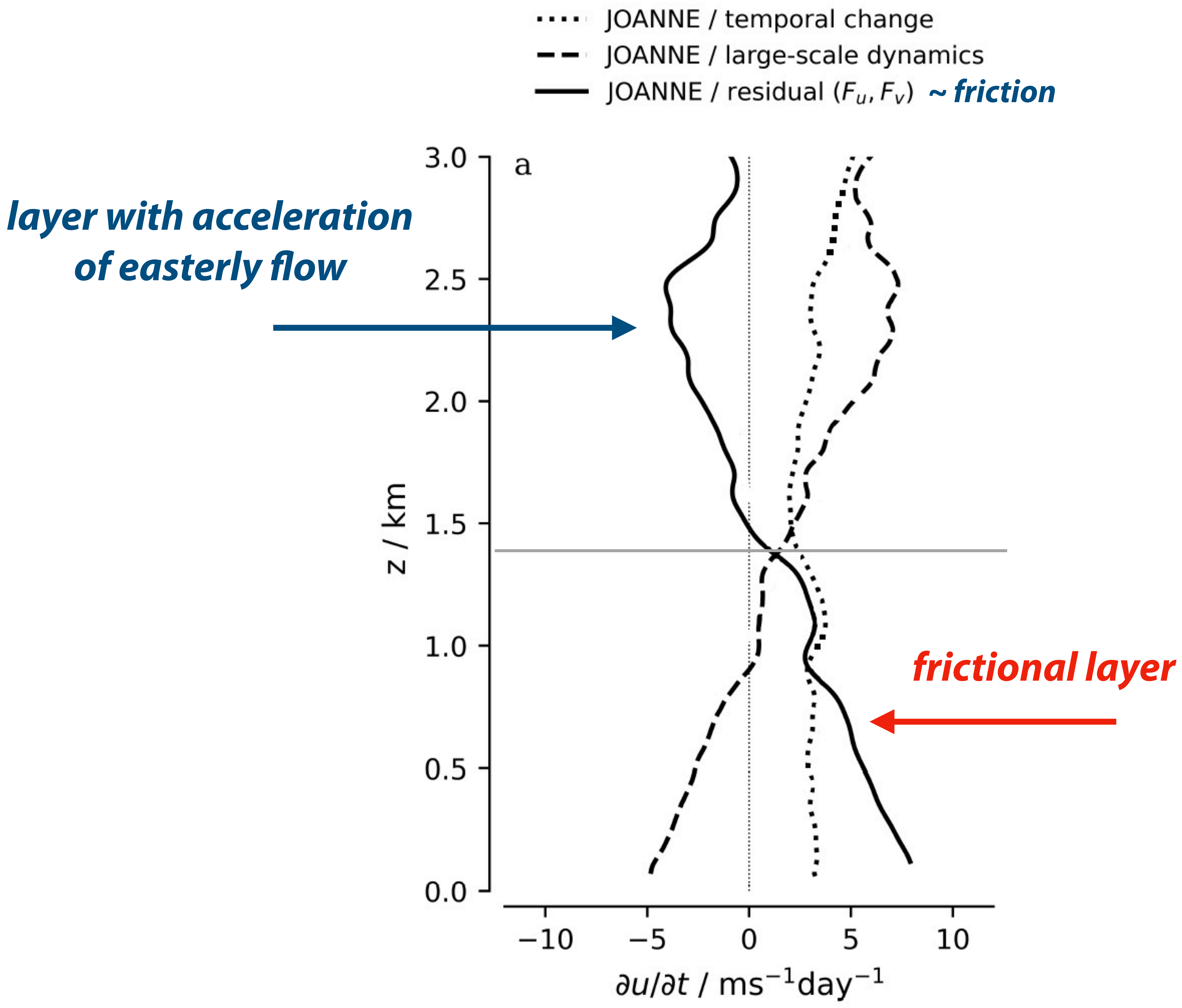


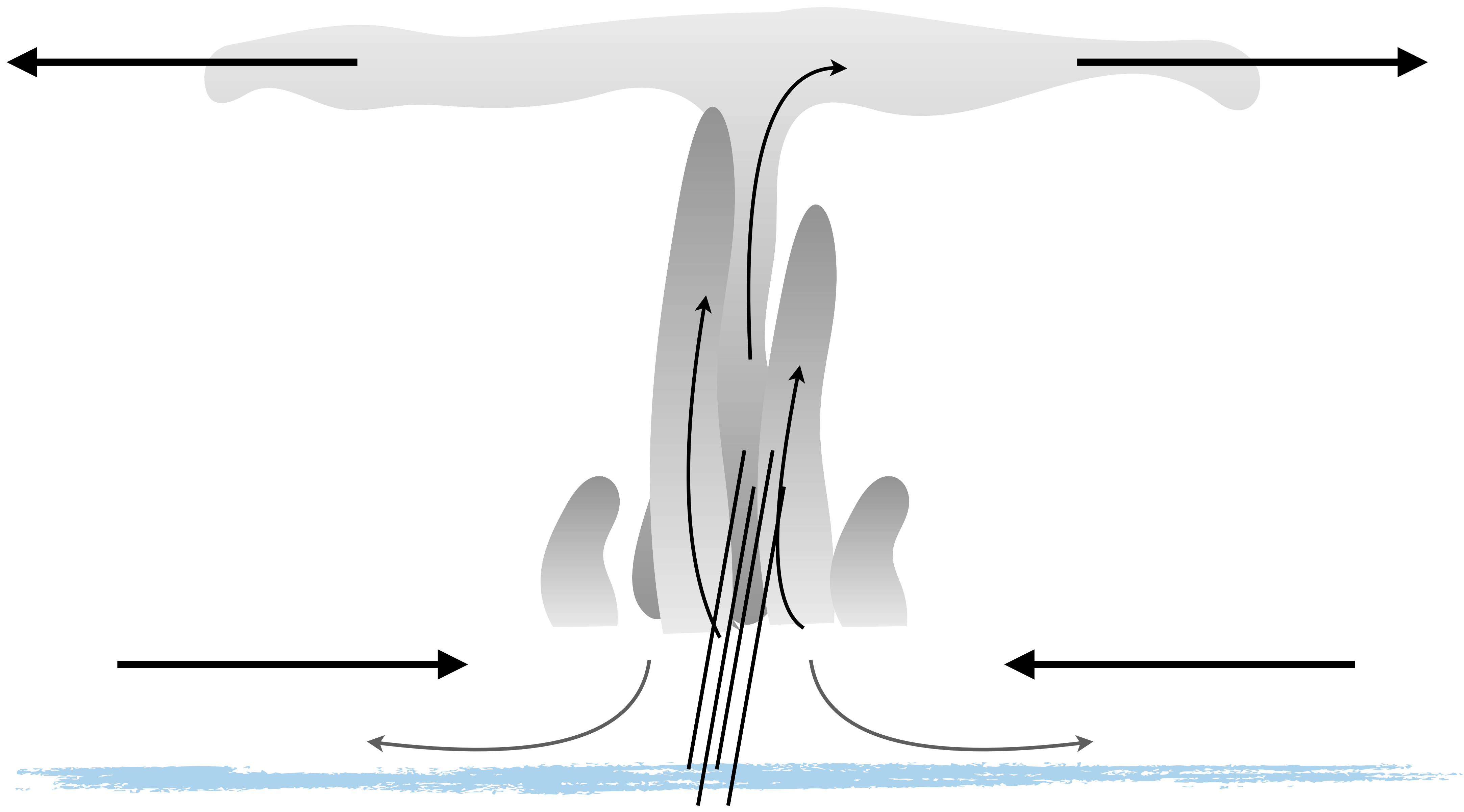

*flow across isobars*

*flow almost parallel to isobars*

***Nuijens et al (2022, in review)***

# Convective, mesoscale flows create a deeper layer of easterly flow



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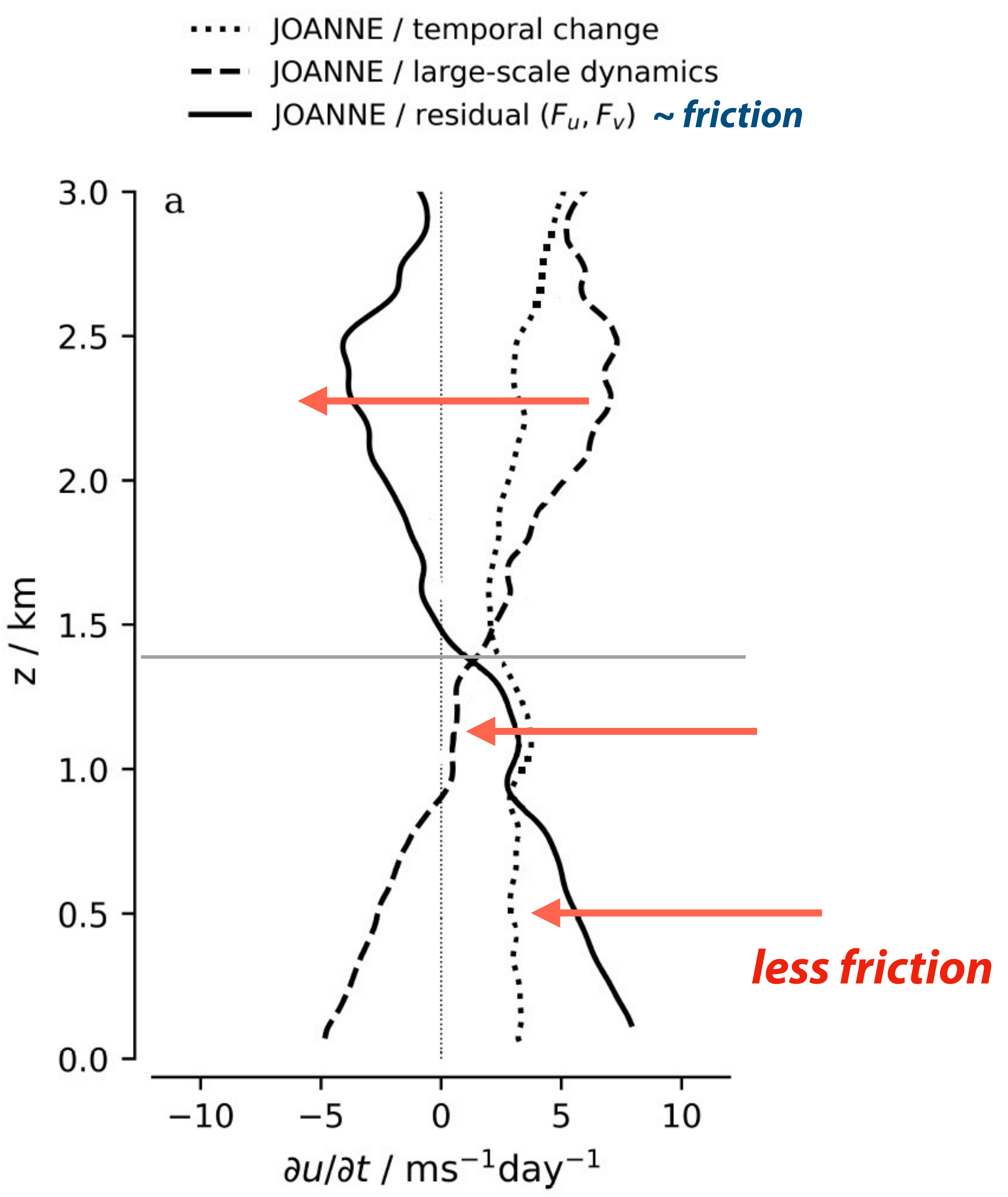
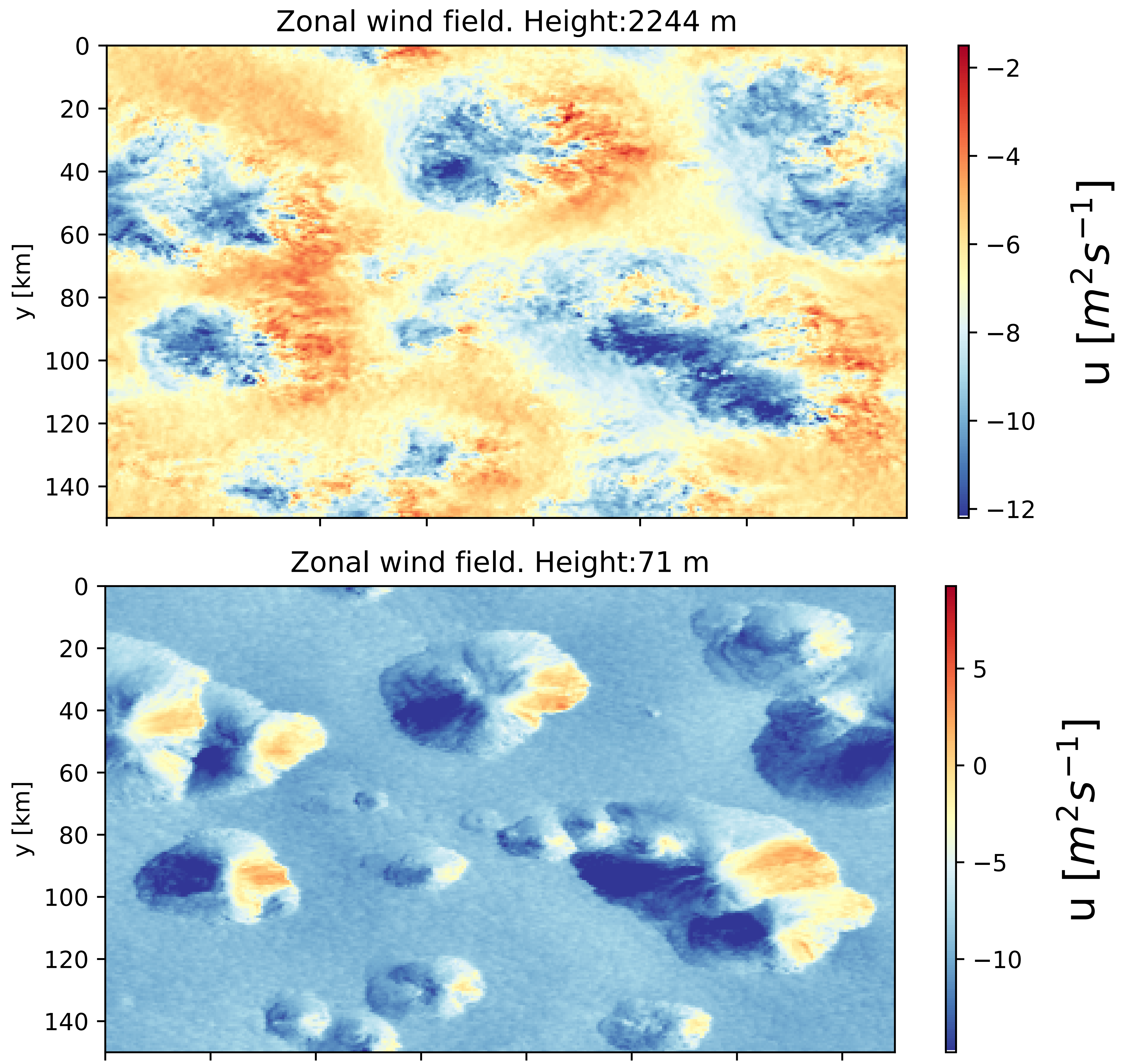
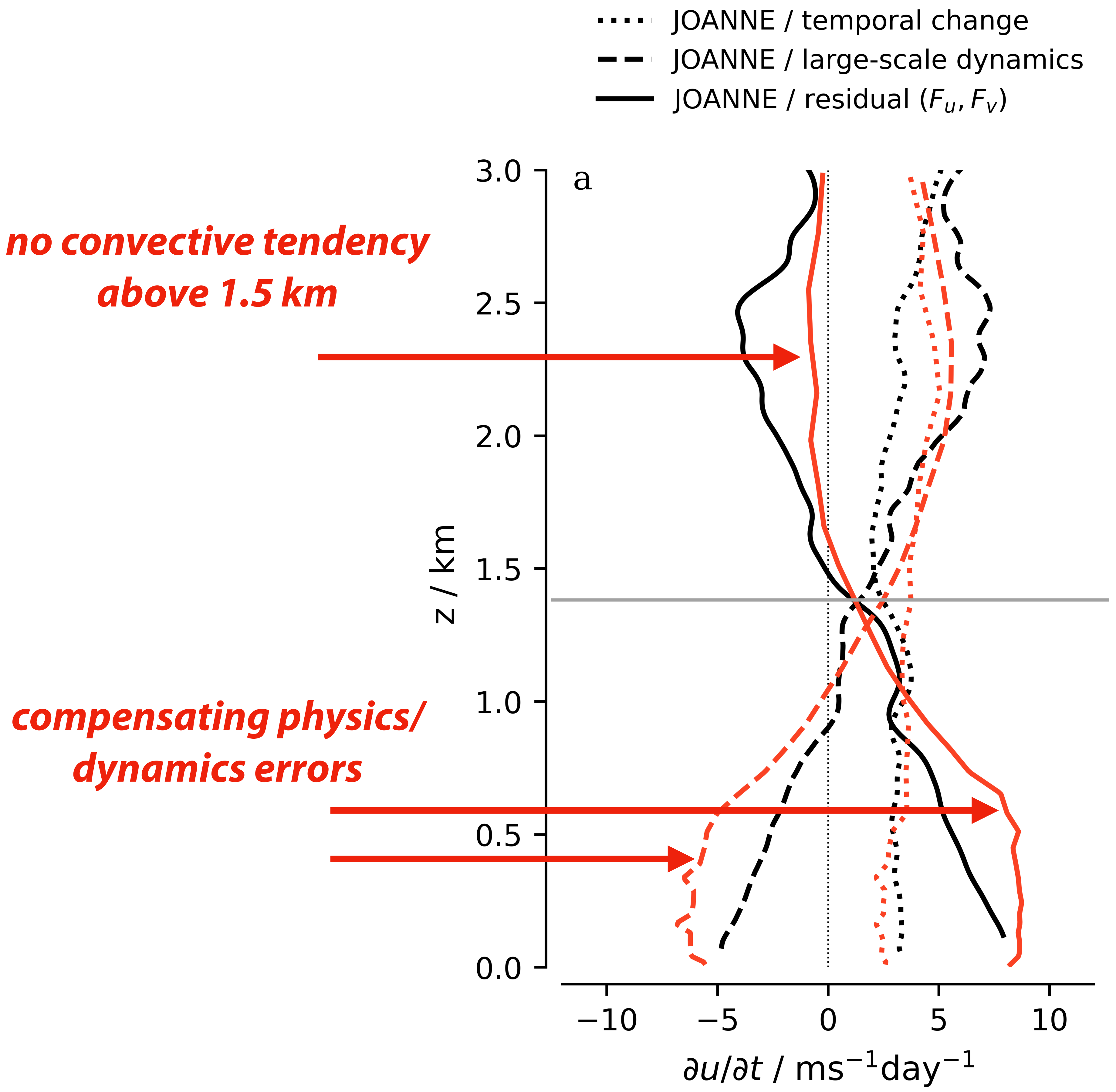
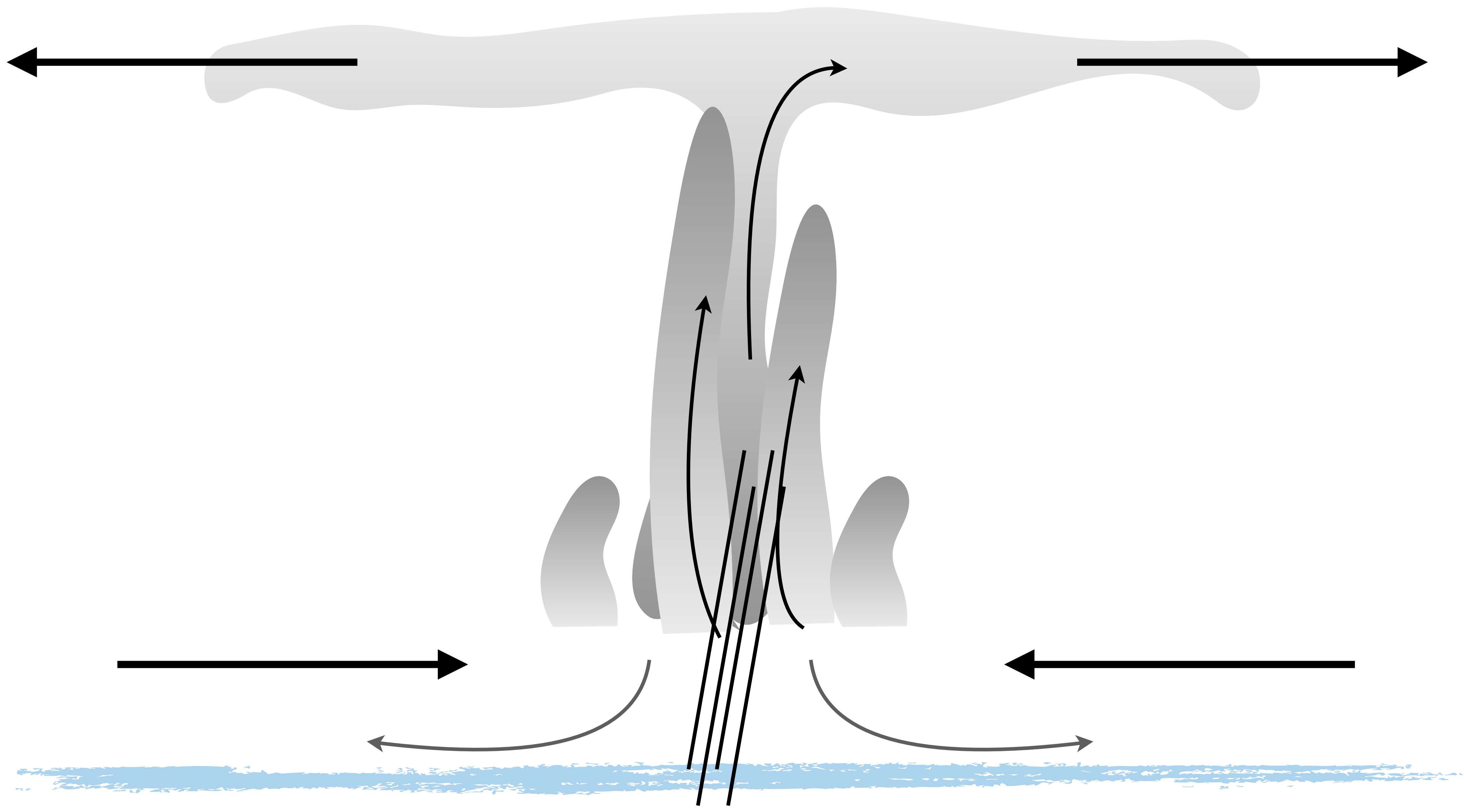



*See Poster Alessandro Savazzi:*
*CO63 – Convective Momentum Transport in Organised Shallow Cumulus Fields*

# Differences in wind tendencies linked to weak zonal wind bias in IFS

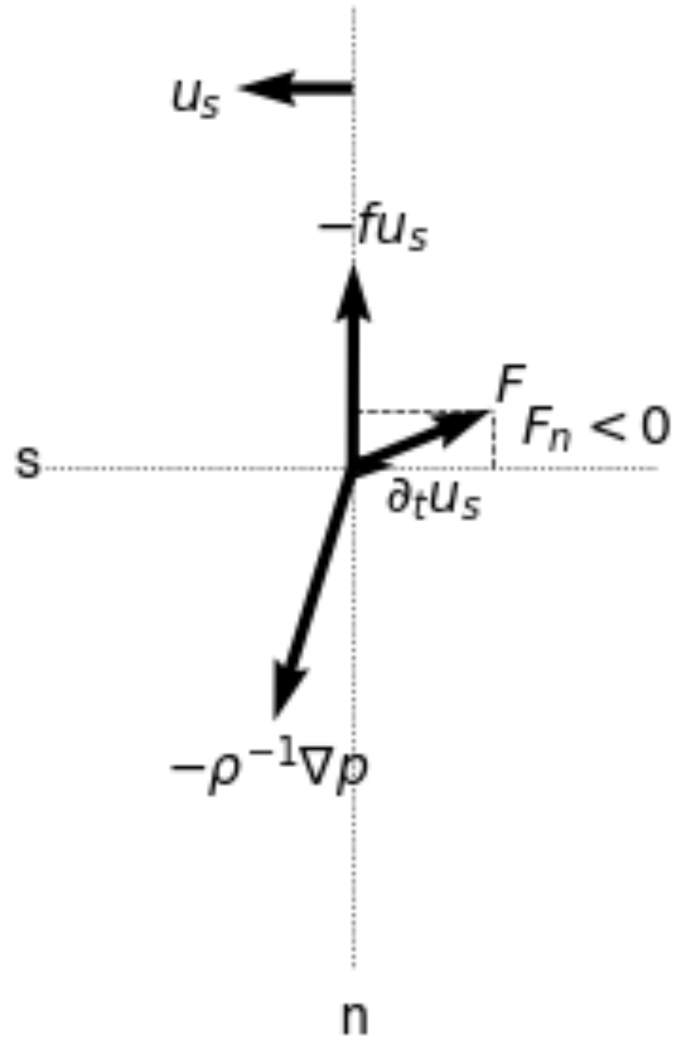


*Savazzi, Nuijens, Sandu, George and Bechtold (in review)*

# Highlights and implications

- **Trade winds convection accelerates flow near surface and cloud tops:** Frictional layer is ~ 1,5 km deep, convection contributes to friction in the upper mixed-layer and lower cloud layer. Weak wind turning!



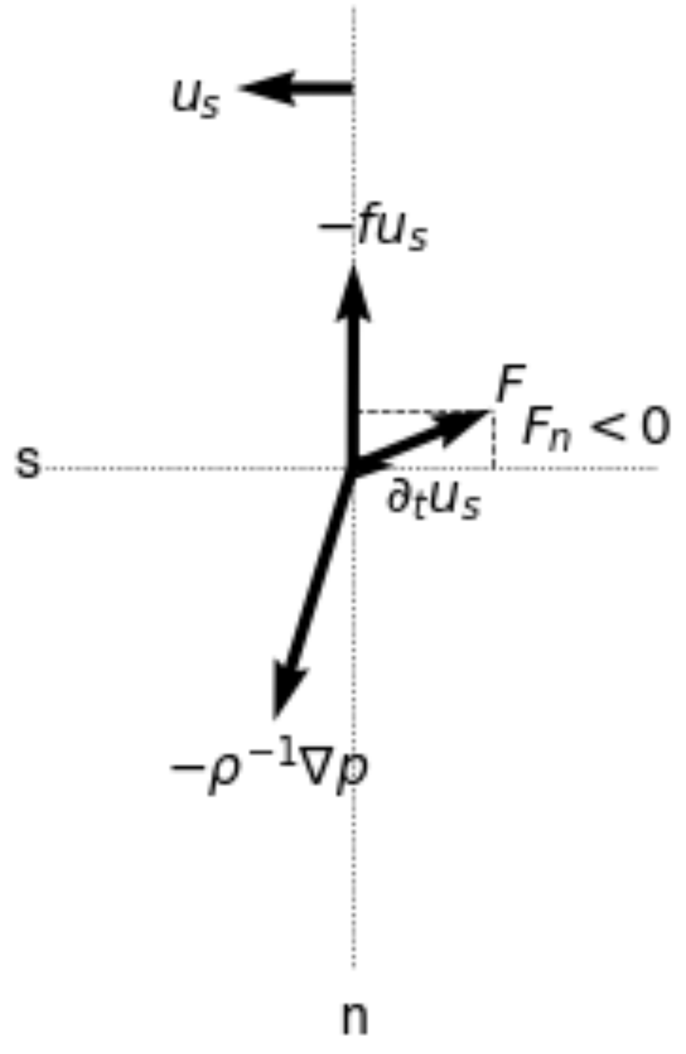



***Larsson et al (2019), Helfer et al (2020), Dixit et al (2020)***

# Highlights and implications

- **Trade winds convection accelerates flow near surface and cloud tops:** Frictional layer is ~ 1,5 km deep, convection contributes to friction in the upper mixed-layer and lower cloud layer. Weak wind turning!

- **A brake on the circulation?**
  Convection plays a role in veering the wind, opposing friction-induced cross-isobaric flow (Ekman pumping), which may impact the structure of the ITCZ




➡ *EUREC4A Large Eddy Simulations show an increase in the role of physics to veer the wind as winds strengthen*

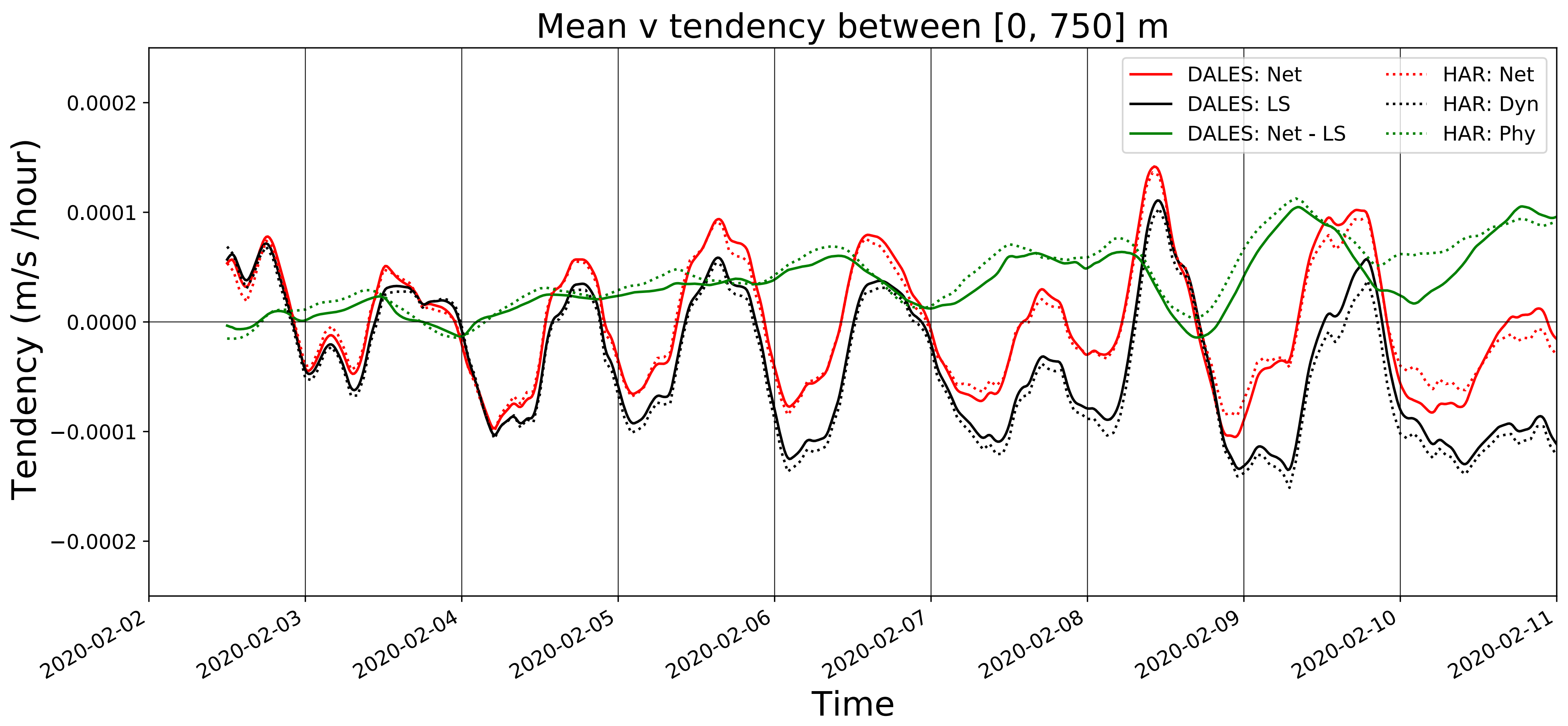



***Figure courtesy: Alessandro Savazzi***

# Highlights and implications

- **Acceleration near surface and cloud tops:** Frictional layer is about 1,5 km deep, convection contributes to that friction in the upper mixed-layer and lower cloud layer

- **A brake on the circulation?** Convection plays a role in veering the wind, opposing friction-induced cross-isobaric flow (Ekman pumping), which may impact the structure of the ITCZ

- **Break-out group discussion tomorrow:** Shallow convective momentum transport, impact on the large-scale circulation and persistent wind biases in GCMs