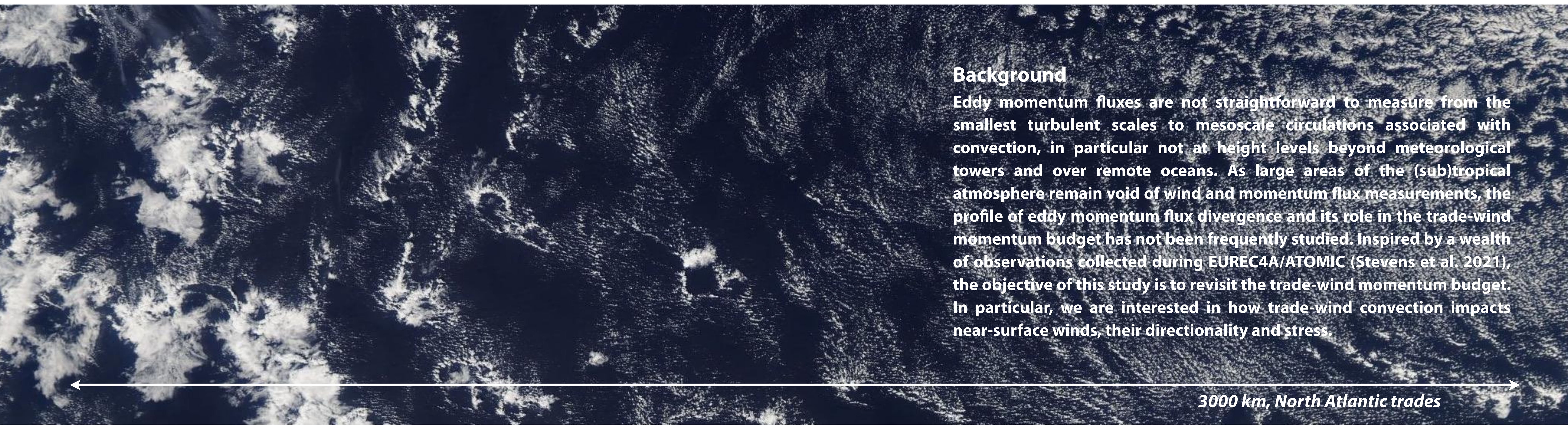
Influence of shallow precipitating convection on near-surface wind speed, directionality and stress

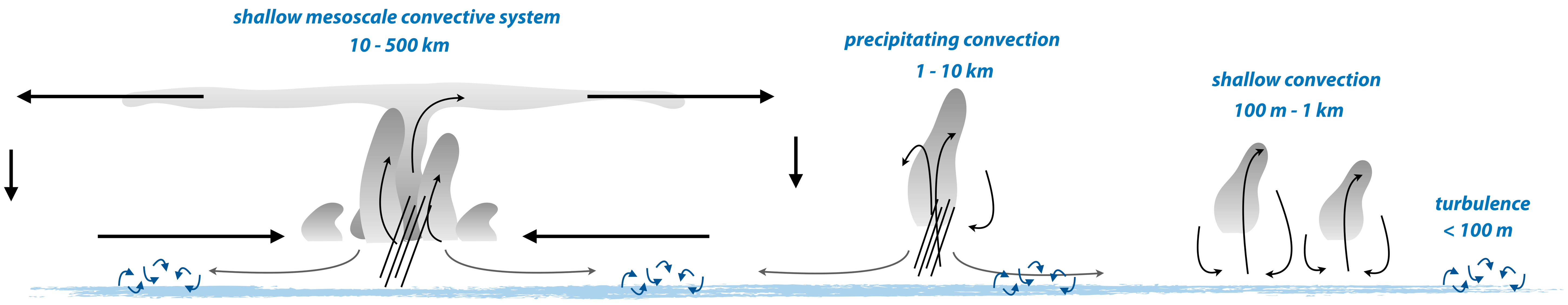
TU Delft

Louise Nuijens, Alessandro Savazzi, Gijs de Boer, Pierre-Etienne Brilouet, Geet George, Marie-Lothon and Dongxiao Zhang



Background

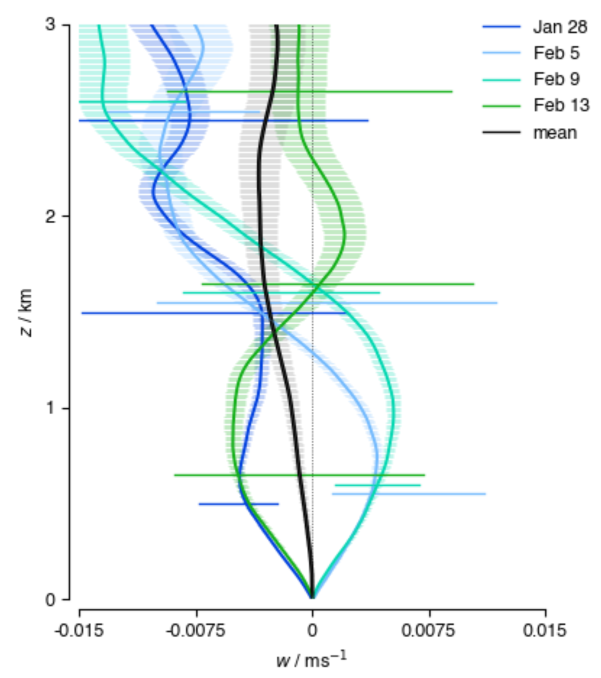
Eddy momentum fluxes are not straightforward to measure from the smallest turbulent scales to mesoscale circulations associated with convection, in particular not at height levels beyond meteorological towers and over remote oceans. As large areas of the (sub)tropical atmosphere remain void of wind and momentum flux measurements, the profile of eddy momentum flux divergence and its role in the trade-wind momentum budget has not been frequently studied. Inspired by a wealth of observations collected during EUREC4A/ATOMIC (Stevens et al. 2021), the objective of this study is to revisit the trade-wind momentum budget. In particular, we are interested in how trade-wind convection impacts near-surface winds, their directionality and stress.



Multi-scale flows in the presence of various shallow cloud fields

EUREC4A field measurements allow to revive early budget studies

- **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 ~ 200 km (Figure to the right)**

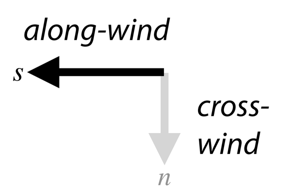


What we find:

- In the direction of the flow, a mean flux divergence (friction) exists over a 1.5 km deep Ekman layer
- From the frictional profile, an average near-surface momentum flux of ~ 0.1 Nm–2 is derived, in line with the Saildrone, but with significant deviations from day to day that reflect the presence of (presumably convectively-driven) mesoscale flows
- Shallow convection accelerates and acts to veer the surface wind, opposing the friction-induced cross-isobaric wind turning
- in-situ measurements show large spatial variability of momentum fluxes, with a non-negligible contribution of mesoscales

The momentum budget

- Momentum budget is constructed in natural coordinate frame



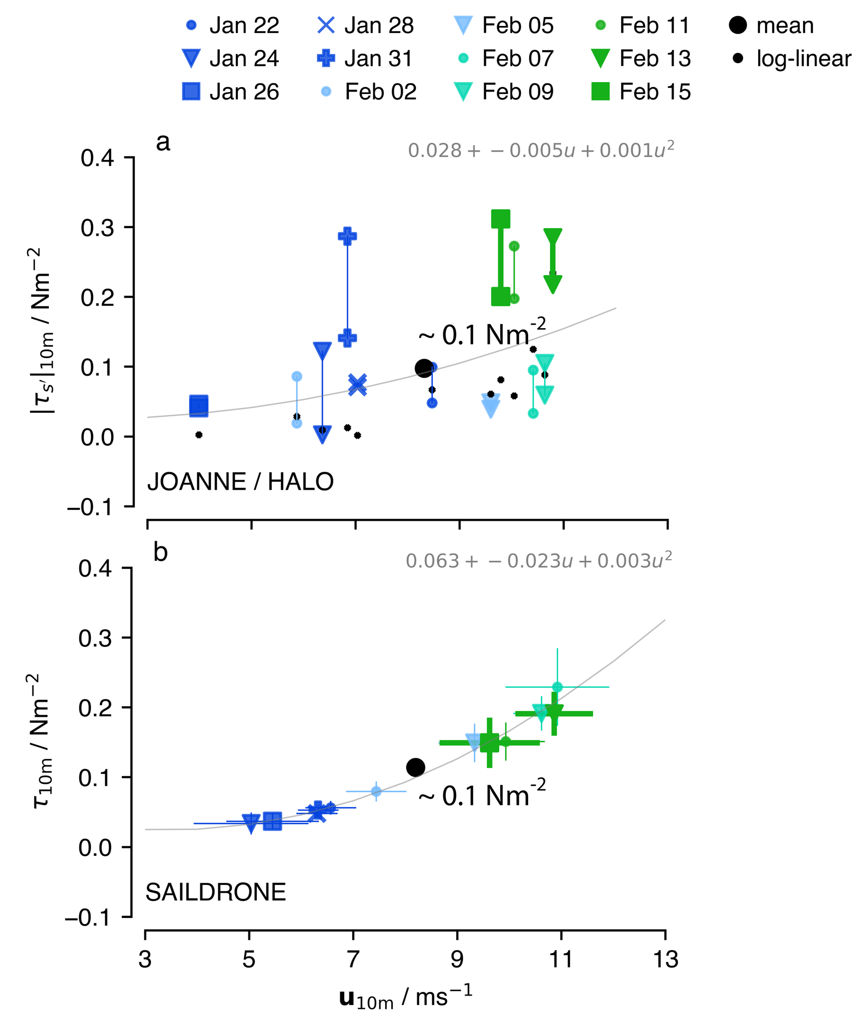
$$D\bar{u}_s/Dt = -\bar{\rho}^{-1}\partial_s p + \mathcal{F}_s$$

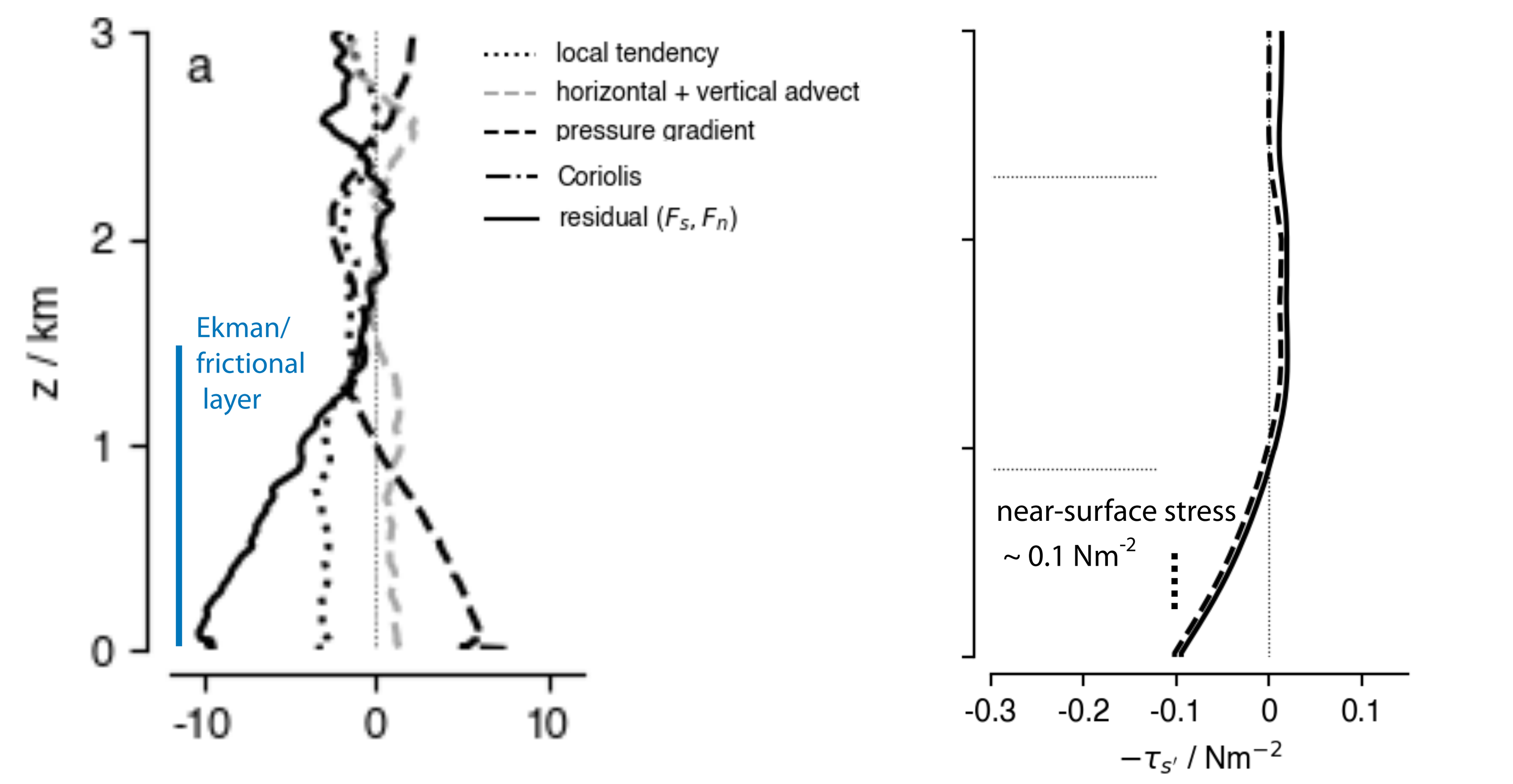
$$0 \approx -\bar{\rho}^{-1}\partial_n p - f\bar{u}_s + \mathcal{F}_n$$

residual

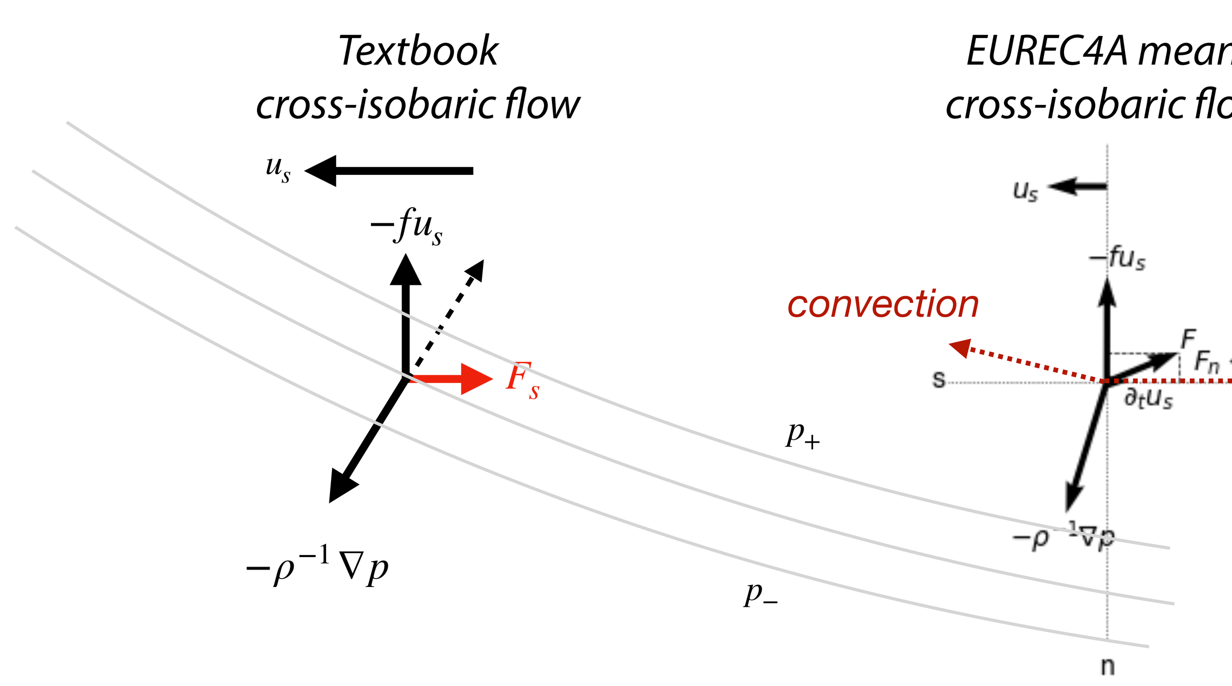
- The residual in the momentum budget is interpreted as eddy momentum flux divergence:

$$\mathcal{F}_{s'} \approx -\frac{\partial \overline{u'_{s'}w'}}{\partial z} \equiv \frac{1}{\rho}\frac{\partial \tau_{s'}}{\partial z}$$

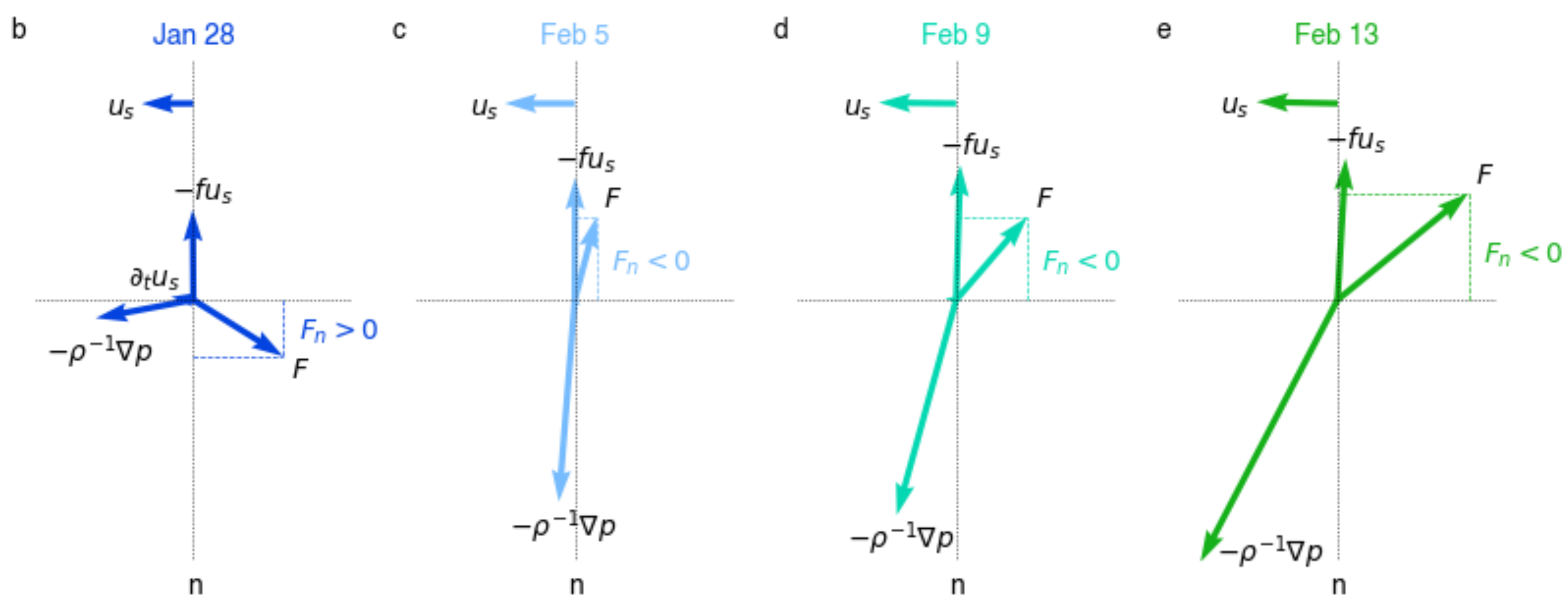




Wind vector balance near the surface



with strengthening trade-winds, and the presence of deeper convection, we find weaker along-wind stress divergence, stronger cross-wind flux divergence, on ~ 200 km scales



Nuijens, L., A. Savazzi, G. de Boer, P.-E. Brilouet, G. George, M. Lothon, and D. Zhang, 2022: The frictional layer in the observed momentum budget of the trades. Quarterly Journal of the Royal Meteorological Society, 148 (748), 3343–3365, https://doi.org/10.1002/qj.4364