The role of convection in the momentum budget of ICON-LEM hindcasts over the North Atlantic

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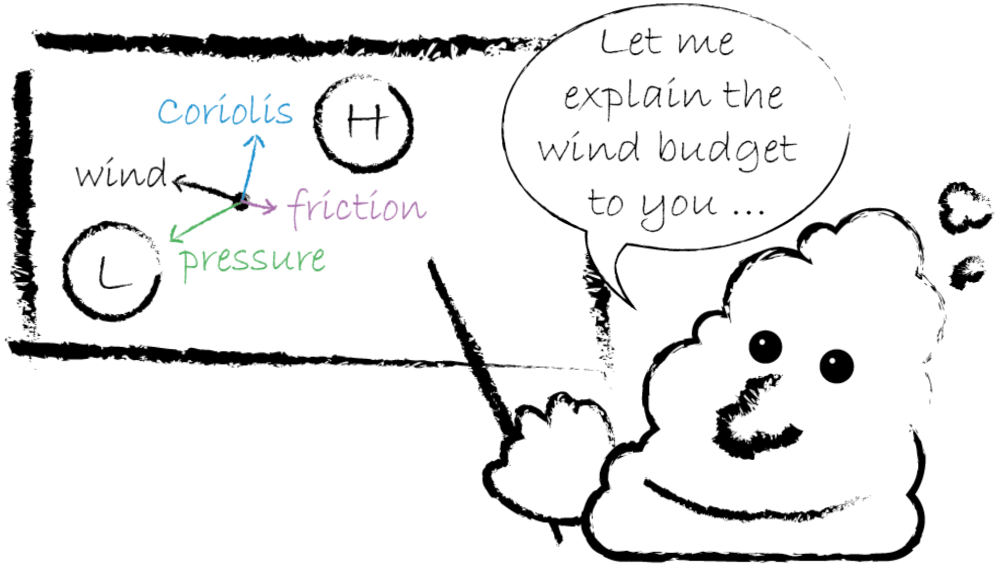
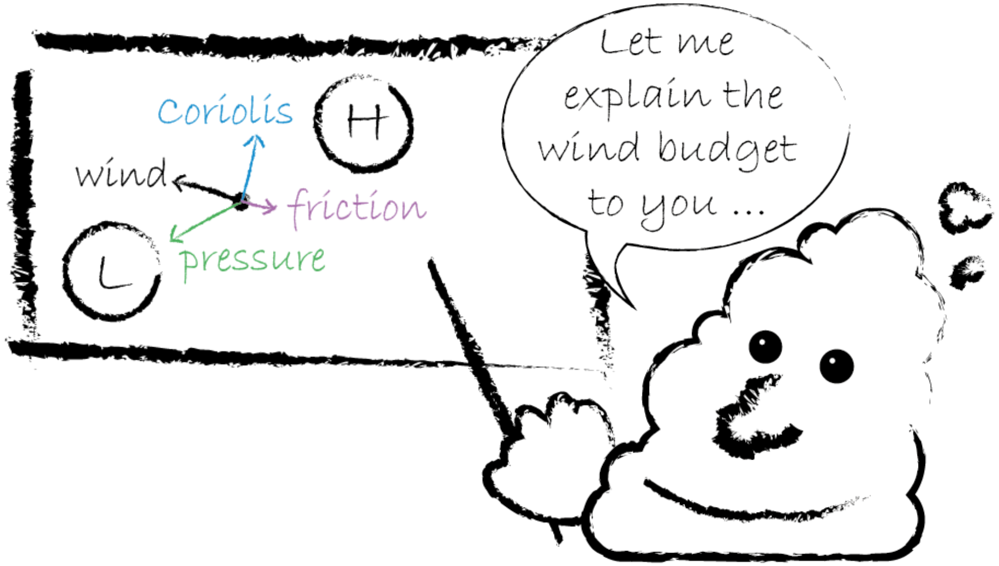


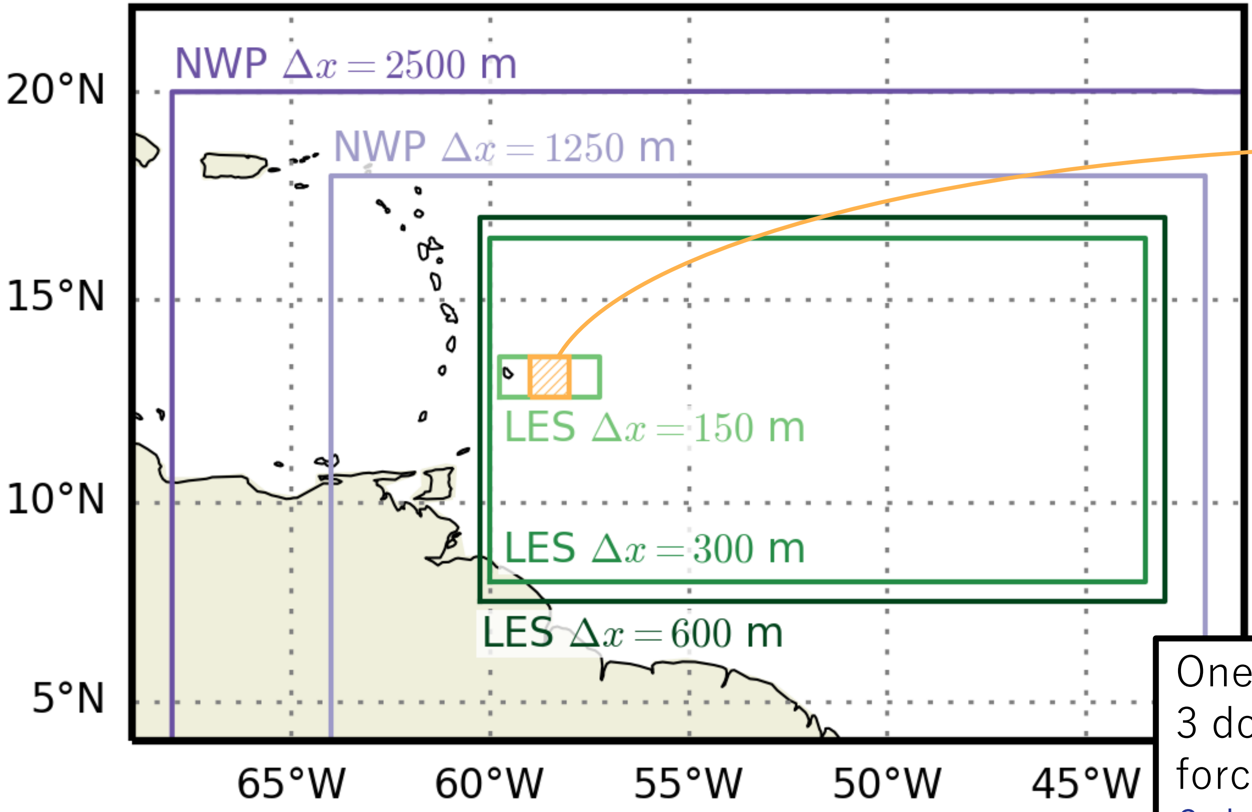
We analyse the Navier-Stokes equation
(from LES output, i.e. LES-filtered)

- What is the role of convection in the momentum budget?
  ↳ It slows down the wind, but how exactly depends on the season and altitude
  ➡ *Slide 4*
- What sets the shape of the momentum flux profile?
  ↳ Two factors: the surface wind speed and the convection depth
  ➡ *Slide 5*
- What about counter-gradient momentum transport?
  ↳ We find a layer of counter-gradient flux (even without organisation) that may help to maintain the jet at cloud base
  ➡ *Slide 6*

$$\frac{\partial u_i}{\partial t} = f \varepsilon_{ij3} u_j - \frac{1}{\rho}\frac{\partial p}{\partial x_i} - u_j \frac{\partial u_i}{\partial x_j} + \nu \frac{\partial^2 u_i}{\partial x_j^2}$$



We analyse ICON-LEM hindcasts over the North Atlantic



We focus on a 1×1-degree box east of Barbados

which coincides with the main area of operations of the EUREC^{4}A field campaign

One-way nesting,
3 domains with LES physics,
forcing from ECMWF analysis,
6 days in Dec. '13, 6 days in Aug. '16

These simulations were run by M. Brueck & D. Klocke at MPI-Met Hamburg and are documented in [Stevens et al. (2019)](#).

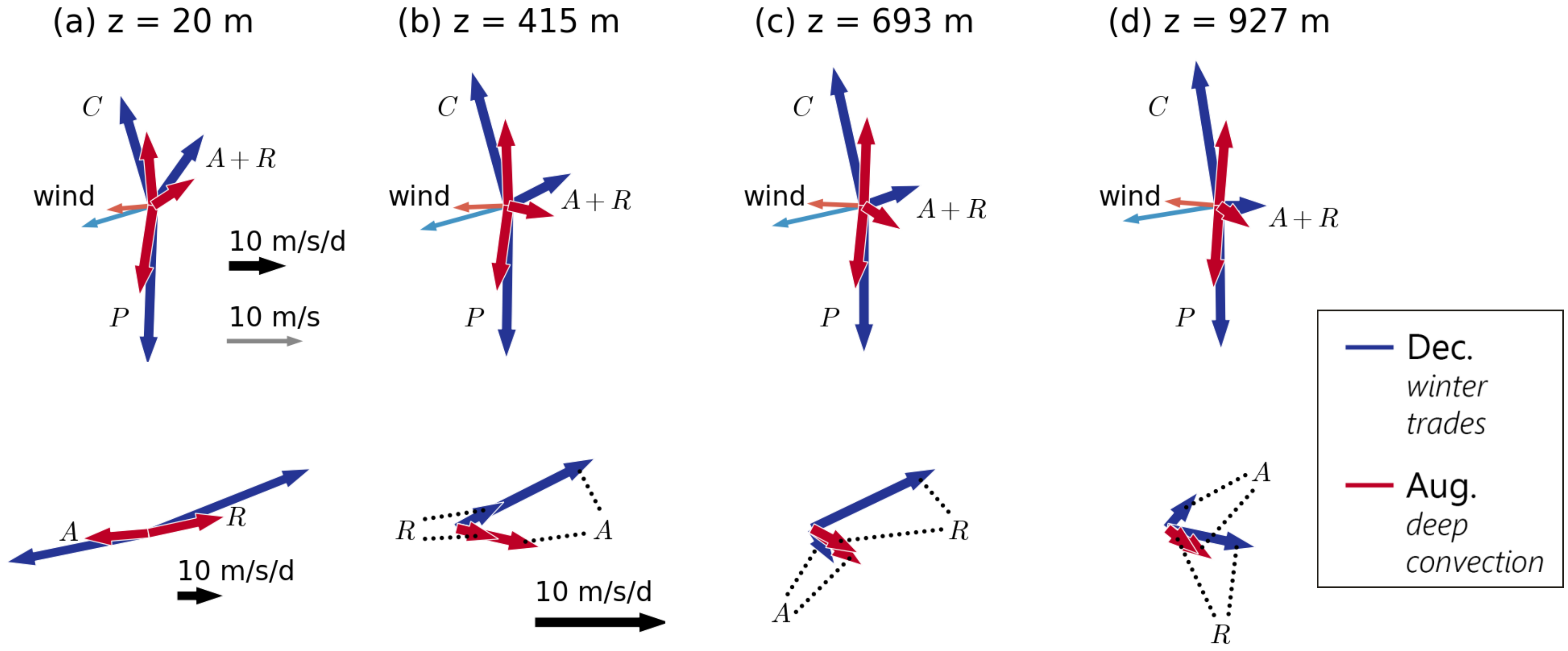
Remember, we consider the full Navier-Stokes equation with LES filter:
(not the Reynolds-averaged equation)

$$\frac{\partial u_i}{\partial t} = \underbrace{f\varepsilon_{ij3}u_j}_{C}$$

$$\underbrace{-\frac{1}{\rho}\frac{\partial p}{\partial x_i}}_{P}$$

$$\underbrace{-u_j\frac{\partial u_i}{\partial x_j}}_{A}$$

$$\underbrace{+\nu\frac{\partial^2 u_i}{\partial x_j^2}}_{R}$$

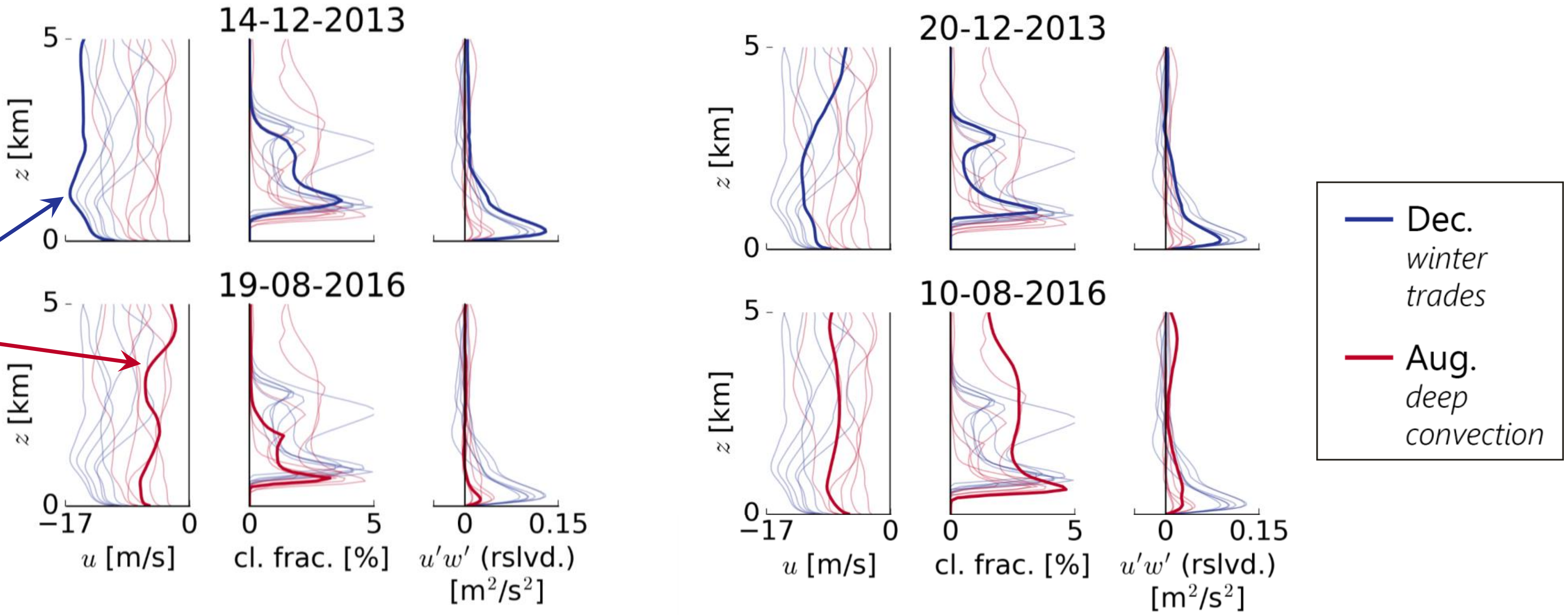


Surface layer	Mixed layer	Cloud base	Cloud layer
Weaker wind in summer due to weaker N–S pressure gradient (ITCZ wander)			
Resolved advection and subgrid stress together $(A + R)$ act as a friction force, providing a westerly component to the wind			
$A + R$ is not exactly opposite to the wind because A acts to accelerate	A and R act in the same direction in each season	In summer, A and R still act in the same direction	
		In winter, they act in different directions	

Both geostrophic wind and convection depth explain momentum flux divergence

$$\frac{\partial \overline{u_i}}{\partial t} \sim -\frac{\partial \overline{u_i' w'}}{\partial z}$$

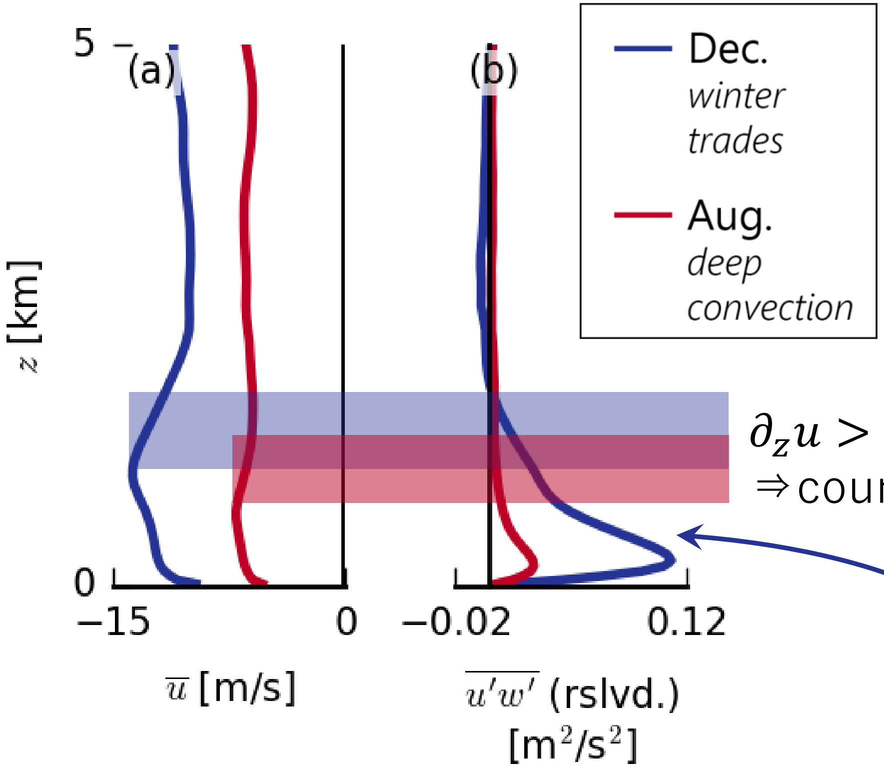
Focus on the thick lines, which are daily averages
(the thin ones are daily averages of the other simulation days)



These two days have similar cloud fraction profiles, but in December the surface wind blows stronger, leading to a more pronounced maximum of $u'w'$

These two days have similar wind speeds, but in August convection is much deeper, leading to a weaker momentum flux divergence

Counter-gradient transport may help to maintain the cloud-base wind maximum
(without organisation)



$\partial_z u > 0$ and $u'w' > 0$
⇒ counter-gradient momentum transport

More deceleration in the mixed layer than in the lower cloud layer

Such a counter-gradient layer commonly occurs in idealised LES cases of marine shallow convection if a jet is present in the wind profile (Larson et al, 2019).