Atmospheric boundary layer response to oceanic sub-mesoscale SST fronts

Hugo Jacquet[1], Alex Ayet[2] and Fleur Couvreux[3]

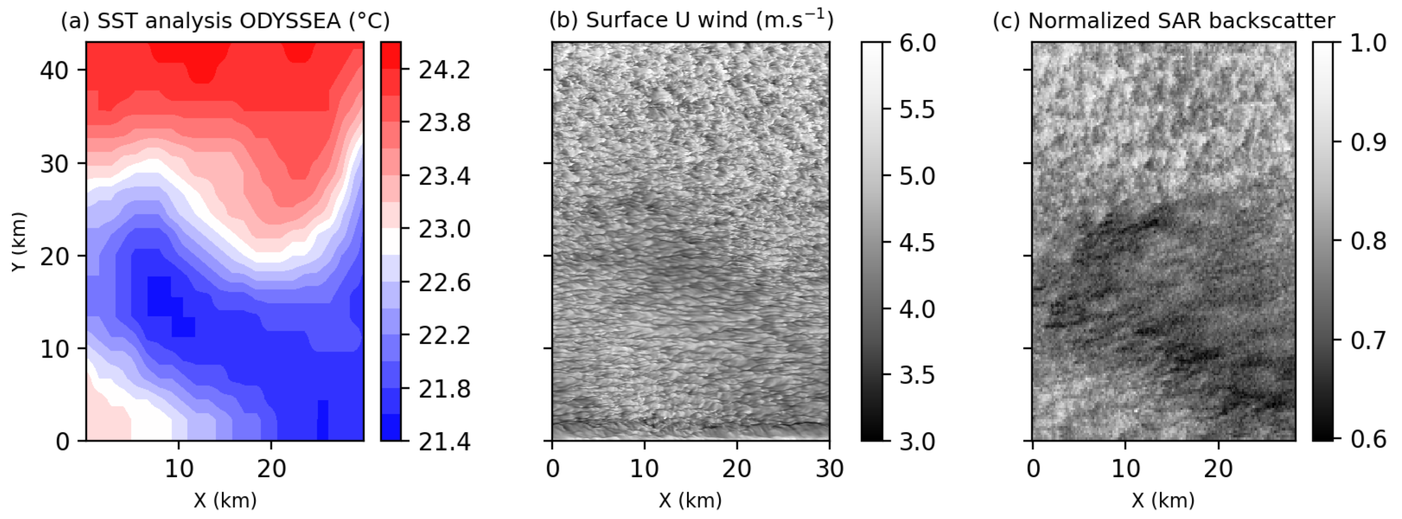
[1] IGE, CNRS, Grenoble [2] GIPSA, CNRS, Grenoble [3] CNRM, Météo-France, Toulouse

Motivation

Surface heterogeneities can greatly affect the atmospheric boundary layer (ABL), through changes in surface roughness, humidity, or heat fluxes. Recent improvements of satellite imagery allow observing the response of the ABL to such heterogeneities at small scales (see the "Case Study" pannel). Those images suggest that the ABL response could be scale-dependent (e.g. advection could play a non negligible role). While this type of air-sea interactions has been largely studied at larger scales [1], atmosphere response to SST front of width of 1-10km is not well understood [2][3].

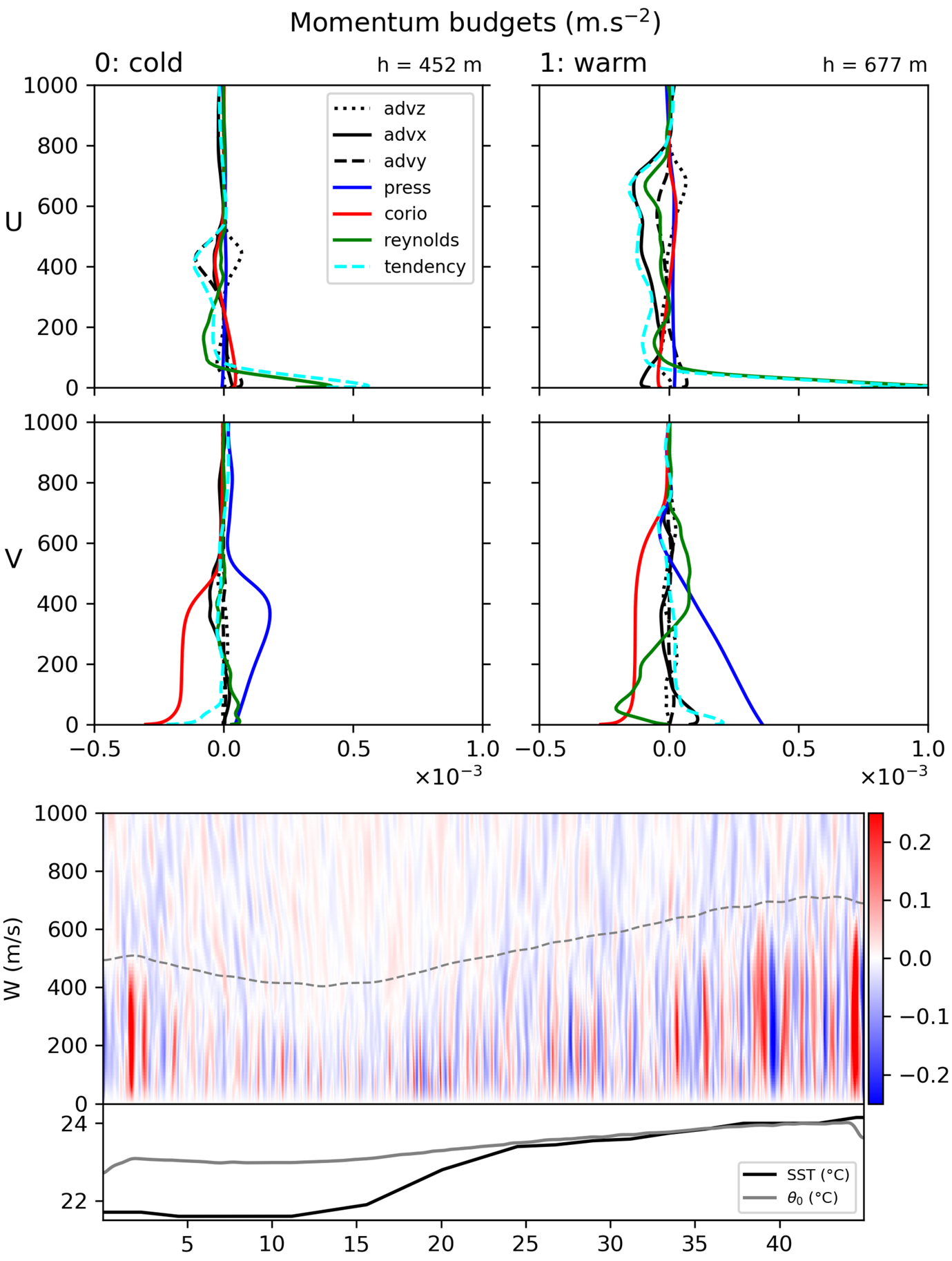
The goal of this study is to provide an understanding of the processes at stake in the atmosphere response to sub-mesoscale sea surface temperature (SST) fronts.

Case study: Agulhas current



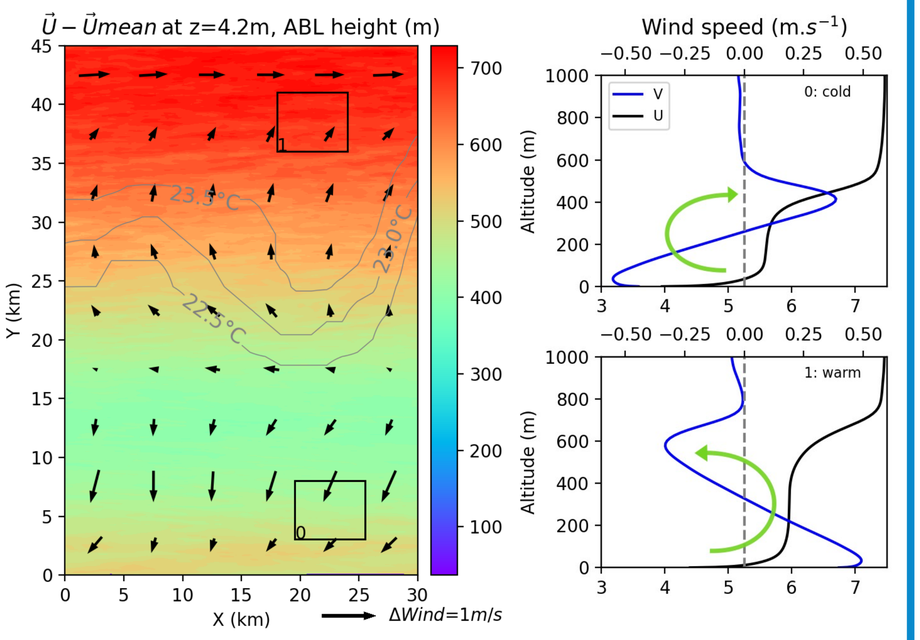
The simulation is in the Agulhas current region, over a strong SST gradient (2° over 10km). The mean wind is mostly along the x direction, as is the general direction of iso-SST. This is referred as a 'along-front' configuration.

Processes



- On warm SST, the turbulent (buoyant) production is enhanced: faster wind from aloft is mixed towards the surface, accelerating the surface winds and slowing upper layers.
- Two V secondary circulations have formed ('LES overview' panel, right), with well marked upward motion but more diffuse subsidence, maintained by a north/south pressure gradient and Coriolis forces.
- The ABL height is increased from cold to warm SST, suggesting that SST heterogeneities can modify the whole ABL. Surface large scale winds show a divergence aligned with the mean wind but no fully bi-dimension heterogeneity ('LES overview' panel, left).

LES overview



- LES on a 30km x 45km x 2000m domain, Δx=Δy=50 m Δz in [2,20] m,(86.4x10^6 grid cells)
- Boundaries: N/S open, E/W cyclic. initial wind (U,V) = (7.5,0) $m.s^{-1}$, $N^2 = 10^{-4}$ s^{-2}
- MesoNH model, 20h run. No moisture, clouds or radiation. Date = 10/12/2015

Conclusion

Winds are directly modified by the bidimensional SST heterogeneity, while bulk properties such as the boundary layer height is only influenced by a global north/south SST gradient.

Other simulations will be conducted, with 1D SST front in a canal geometry. Taking into account moist and clouds could change the dynamics of the processes and should be investigated.

References

[1] Kilpatrick, T., N. Schneider, and B. Qiu, 2016: Atmospheric Response to a Midlatitude SST Front: Alongfront Winds. J. Atmos. Sci., 73, 3489–3509, https://doi.org/10.1175/JAS-D-15-0312.1.

[2] Wenegrat, J. O., & Arthur, R. S. (2018). Response of the atmospheric boundary layer to submesoscale sea surface temperature fronts. Geophysical Research Letters, 45, 13,505– 13,512. https://doi.org/10.1029/2018GL081034

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