STAGE DE RECHERCHE de MASTER 2ème ANNEE

Master SOAC / WAPE
Année Universitaire 2025-2026

Subject: Directional dependence and spatio-temporal variability of aerodynamic roughness length over the East Antarctic Ice Sheet

Short description: Using multi-year in situ wind profile measurements in East Antarctica, this project aims to estimate the aerodynamic roughness length at multiple locations, assess its directional and methodological sensitivities, and investigate its spatial and temporal variability in relation to local microreliefs, and prevailing wind and accumulation regimes.

Host laboratory: Institut des Géosciences de l'Environnement (Grenoble)

Supervisers: Charles Amory and Vincent Favier

Duration: 5 months (February–June 2026)

Level and prerequisite: Master 2 in climate science, oceanography, hydrology, or a related field

Key words: aerodynamic roughness length - surface turbulent fluxes - Antarctic ice sheet - in situ observations

Context: Over the East Antarctic Ice Sheet (EAIS), strong and persistent near-surface winds continuously reshape the snow surface, forming wind-carved microreliefs such as sastrugi and snow dunes (e.g., Poizat et al., 2024). These surface roughness elements develop according to the prevailing wind direction at the time of their formation (Fig. 1). The combination of their geometry, spatial arrangement and orientation relative to the wind - that is, their morphological parameters - determine, to first order, the aerodynamic roughness length (z_0). Because these microreliefs are inherently anisotropic, z_0 exhibits a pronounced directional dependence, varying with the angle between the wind and the dominant alignment of microreliefs (e.g., Vignon et al., 2017). z_0 plays a central role in the parameterization of turbulent fluxes and the surface energy balance of glaciers and ice sheets (e.g., Favier et al., 2011), thereby influencing surface melt and ice mass loss. However, due to the scarcity of direct observations, z_0 remains poorly constrained in climate and surface mass/energy balance models, where it is often assumed constant or empirically tuned (Van Tiggelen et al., 2023).

Snow microreliefs undergo continuous transformation under the combined effects of accumulation, erosion, and snow metamorphism. As a result, z_0 varies substantially in both space and time across the Antarctic continent. Its spatial variability reflects differences in the type and morphology of microreliefs, which are primarily controlled by local wind and accumulation regimes and the redistribution of snow by wind (Amory et al., 2015). For instance, in high-wind areas, erosional features such as sastrugi can lead to z_0 values several orders of magnitude higher than those observed over smooth blue-ice surfaces. Over time, the morphology of these microreliefs evolves in response to changing meteorological conditions through processes such as aerodynamic adjustment (Amory et al., 2016), burial by accumulation, or even surface deflation following rain or melt events, while enhanced snow cohesion due to sintering and wind hardening can inhibit erosion and hinder the aerodynamic streamlining of the surface (Amory et al., 2017).

Leveraging a unique, multi-year meteorological dataset collected across five sites (e.g., Fig. 2), spanning from the interior plateau to the windy coastal margins, this internship aims to investigate the physical mechanisms controlling the spatial and temporal variability of z_0 across a latitudinal sector of the EAIS.

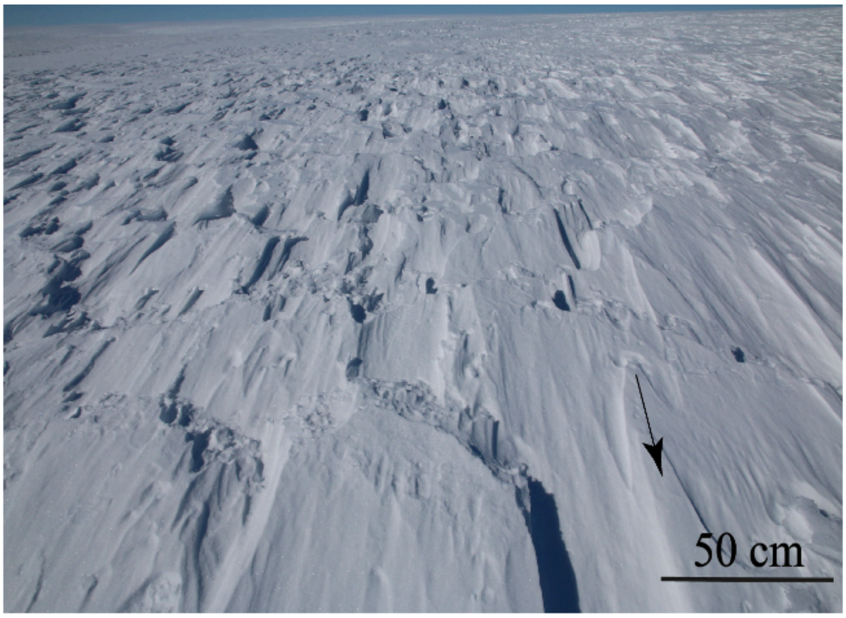

Fig. 1 - Photograph of the snow surface in coastal East Antarctica. The arrow indicates the mean direction of the wind episode that led to the formation of the sastrugi. From Amory et al. (2016).

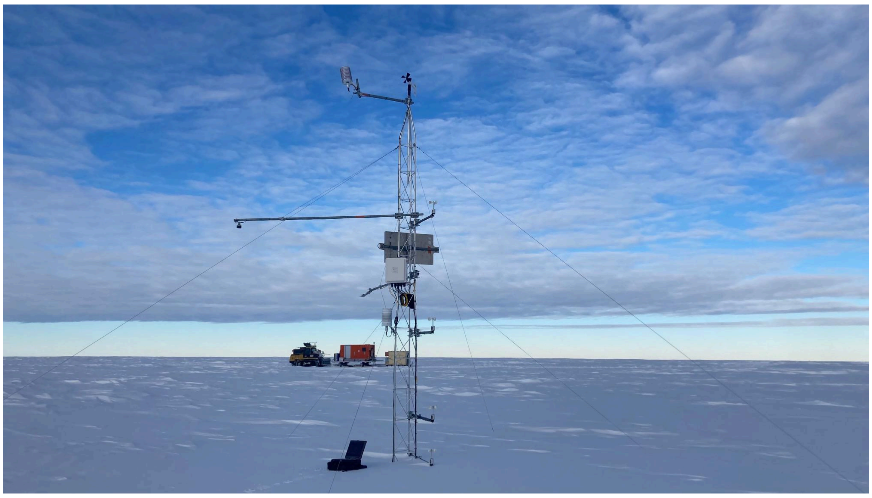

Fig. 2 - Photograph of the ICORDA-KATABATIC automatic weather station at site D47, East Antarctica.

Objectives:

i) Estimation of z_0 **:** Derive z_0 from in situ wind speed profiles at multiple sites and over different periods.

ii) Methodological sensitivity **:** Assess how z_0 estimates depend on data processing parameters such as minimum fitting height, measurement height, number of sensors, and atmospheric stability corrections.

iii) Directional dependency **:** Quantify the dependence of z_0 on wind direction and relate it to the presence, preferential orientation and morphology of snow microreliefs.

iv) Spatio-temporal variability **:** Characterize how z_0 varies across sites and through time, and link these variations to changes in local wind and accumulation regimes.

v) Implications for modeling **:** Discuss how the observed variability in z_0 could be used to improve the representation of surface turbulent fluxes in climate and surface mass/energy balance models.

Required skills: Background in climate science and/or numerical modeling, experience in handling meteorological datasets (preferably NetCDF format), proficiency in programming and data analysis, ideally in Python.

Nature of the internship: The internship primarily involves data analysis based on in situ meteorological observations, with a strong component of numerical processing and methodological evaluation. It includes a moderate degree of theoretical interpretation, but no experimental, modelling or instrumental work.

Possibility of continuation: This internship is not intended to lead to a PhD project**.**

How to apply: Please send a CV and a short motivation letter (≤ 1 page) to vincent.favier@univ-grenoble-alpes.fr and charles.amory@univ-grenoble-alpes.fr

References:

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