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Analyses of Physical Processes Driving Continental Fog and Low Stratus Life Cycle Based on Large-Eddy Simulations and Detailed Remote Sensing Measurements

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Context/purpose. Continental fog and low stratus (FLS) clouds can have high impact on human transport planning and safety, yet forecasting the location and timing of such events remains a challenge to current day numerical weather prediction models. Predictions suffer from imprecise initial and boundary conditions, parametrized representations of processes, poorly understood processes, and limitations in spatial resolution. To make progress in this field, radiative, dynamical and microphysical processes driving the FLS life cycle must be better-understood and key variables and their variability must be better quantified. Our study brings new quantified insights on the processes that affect FLS liquid water content, FLS top and bottom boundaries, and FLS dissipation time (i.e. when the FLS no longer touches the surface).

Method. To do so, we rely on information from analyses of high-resolution Large-Eddy Simulations (LES) and detailed in-situ and remote sensing measurements of FLS occurring in the Paris continental basin (France). Using the LES, we conduct sensitivity studies to quantify how radiative and dynamical processes contribute to accelerating or delaying FLS dissipation. Using 45 observed fog events, we study how the observed variability in key variables may affect the time of dissipation.

Results. Our research confirms that longwave radiative cooling is the dominant process to maintain FLS liquid water, and allows us to quantify this for both thin and opaque FLS, and to quantify the role of overlying cloud layers. We also find that during daytime solar radiation is responsible for several processes that are the main drivers, among local processes, reducing FLS liquid water and increasing FLS top height, such as in-cloud absorption, surface turbulent heat fluxes, and entrainment due to buoyancy. Differences in dissipation time up to 90 min are found by varying surface conditions, or humidity and thermal stability of the air just above the FLS.

Interpretation. Our results show that the dissipation time of continental well-mixed FLS can be defined as the time when the (vertically integrated) liquid water path drops below a critical value so that it is no longer sufficient to fill the layer between surface and FLS top. Tracking FLS top height and FLS liquid water path can be done most accurately with a profiling cloud radar and microwave radiometer. These measurements show that the observed variability in radiation, entrainment at FLS top and surface heat fluxes can explain part of the variability in FLS dissipation time.

Conclusions. Our findings show that real-time analysis of Doppler cloud radar, microwave radiometer and ceilometer measurements can support detailed diagnosis of processes responsible for FLS evolution, and could potentially find applications in FLS nowcasting.