PLANETARY BOUNDARY LAYER & CLOUD PHYSICS GROUP

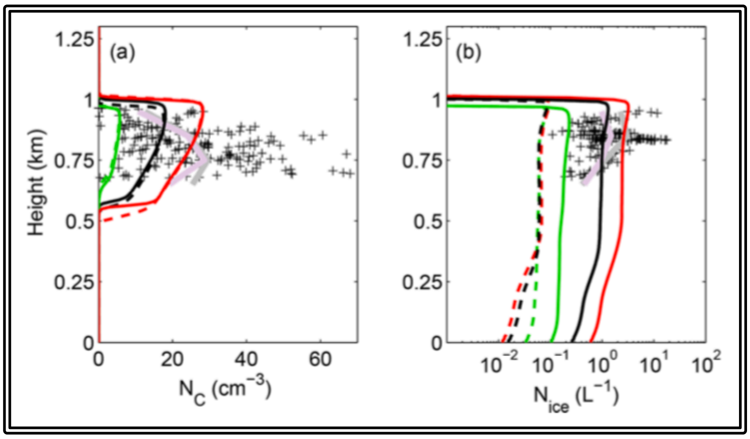
We use atmospheric models of various scales in combination with in-situ and remote-sensing observations to study the planetary boundary layer (PBL) and the complex interactions of clouds with turbulence, aerosols, radiation and precipitation. The Arctic boundary layer consists a main research focus, as the Arctic is the most climatically sensitive region of the planet, warming ~4 times faster than the rest of the globe. From all cloud types, our main interest is on mixed-phase clouds, which are the dominant cloud type at mid- and high-latitudes. These clouds occur at subzero temperatures and consist of an intriguing mixture of liquid and ice. Despite being thermodynamically unstable, mixed-phase clouds are ubiquitous in the atmosphere and can persist for relatively long timescales, playing a critical role in the Earth's radiative balance. Clouds consist a notorious source of uncertainty in future climate projections (IPCC 2021), with mixed-phase clouds being at the heart of this uncertainty.

GROUP MEMBERS:

Georgia Sotiropoulou *(Assistant Professor)*
Foteini Floka *(PhD student, Thesis title: 'The Role of Aerosol-Cloud Interactions in the Development of Precipitation Extremes')*
Faidon Mavroudis *(M.Sc. student, Thesis title: 'Evaluating climate model representation of dust episodes in Eastern Meditteranean')*
Thodoris Stamatopoulos *(M.Sc. student, Thesis title: 'The role of cloud-aeorosol interactions in NorESM2 climate simulations of North Atlantic hurrricanes')*

➢ RESEARCH TOPICS:

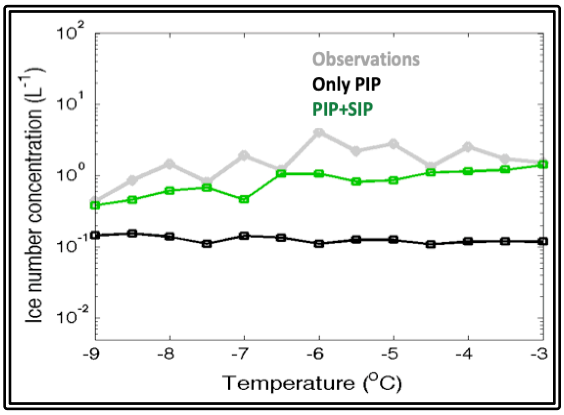
Cloud-aerosol interactions:



Aerosols act as Cloud Condensation Nuclei (CCN) and Ice Nucleating Particles (INPs), which assist in cloud droplet and ice crystal formation. Understanding how changes in aerosol concentrations shape cloud phase and cloud life-cycle under different atmospheric conditions is a main research focus of the group.

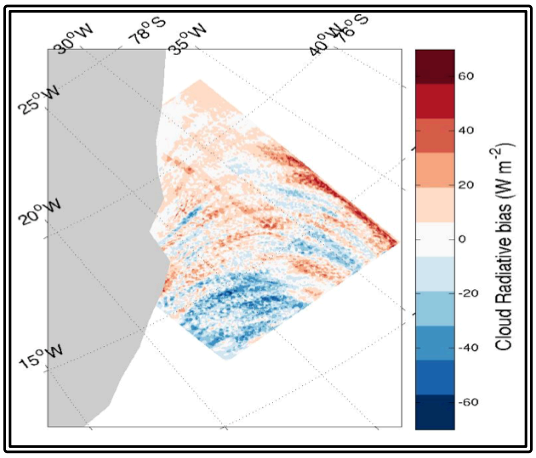
Cloud ice formation:

Among all microphysical processes, ice formation is the most complex and least understood one. This can be divided in two main categories: (a) primary ice production (PIP) with cloud ice crystals forming from INPs, and (b) secondary ice production (SIP) which refers to ice multiplication processes. While significant progress has been made in understanding PIP, the relative importance of several INP species remains poorly constrained. SIP mechanisms remain poorly investigated and thus poorly understood. As a result, the numerical description of these processes in atmospheric models remains incomplete or even non-existent.



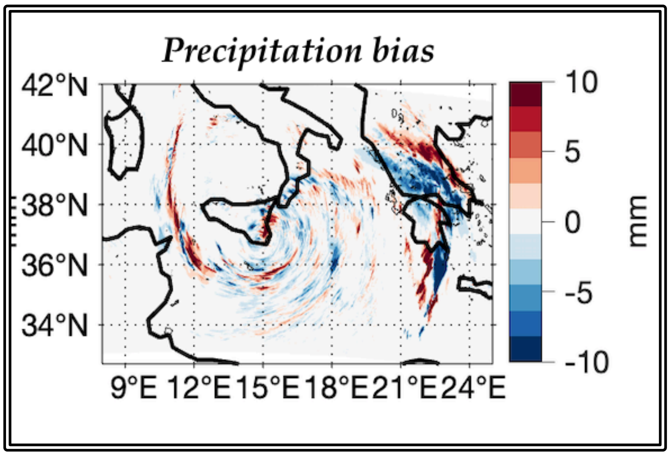
Cloud-radiation interactions:

Quantifying the sensitivity of the cloud radiative effect to cloud-aerosol interactions and different microphysical processes is important for understanding the cloud and climate feedbacks, and improving the representation of the Earth radiative budget in numerical models. Our studies so far have mainly focus on cloud-radiation interactions at high latitudes (in the Artic region and over the Southern Ocean)

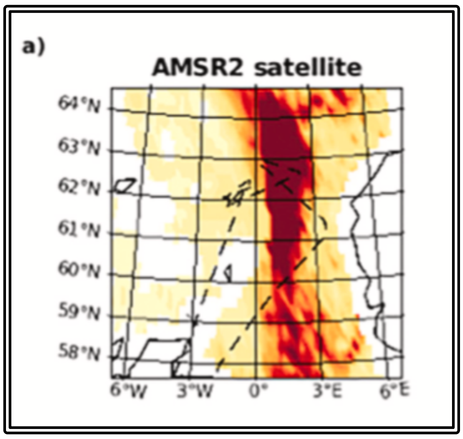


Cloud-precipitation interactions:

Our research aims to understand the role of aerosols in precipitation development and quantify the sensitivity of precipitation forecasts to the representation of various micro-physical processes. We are particularly interested in investigating these interactions during extreme conditions, like tropical-like cyclones in the Mediterranean region and hurricanes in the North Atlantic sector.



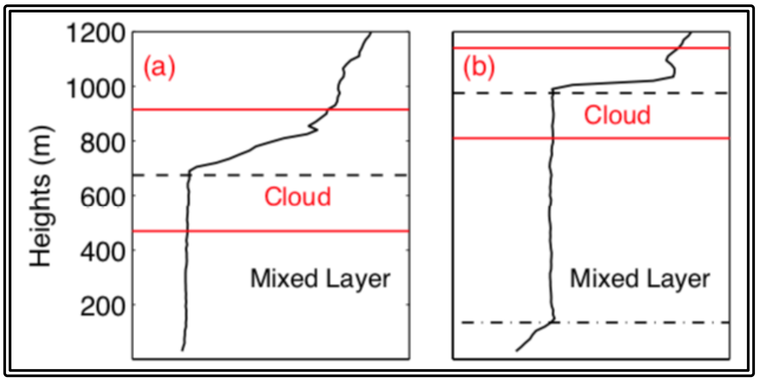
Stratocumulus to cumulus transitions:



Transition from overcast stratocumulus to a cumulus-topped boundary layer with a much lower cloud fraction, is an important phenomenon that results in abrupt changes in the surface radiation budget and precipitation. These transitions are often poorly captured by the models. Some of our knowledge gaps regarding these phenomena concern the underlying microphysical processes and their relative importance compared to the dynamical processes that drive these transitions.

Cloud-Surface interactions:

Subtropical cloudy boundary layers typically consist of a mixed-layer that extends from the surface all the way up to the cloud top, allowing for the surface processes to directly impact clouds. However, decoupled PBLs are often observed e.g. during stratocumulus to cumulus transitions or over the cold ice-covered surfaces in polar regions, where the surface-turbulence is weak. Understanding the drivers of the decoupling and how it affects cloud macrophysical properties is critical for the correct representation of the cloud life-cycle in atmospheric models.



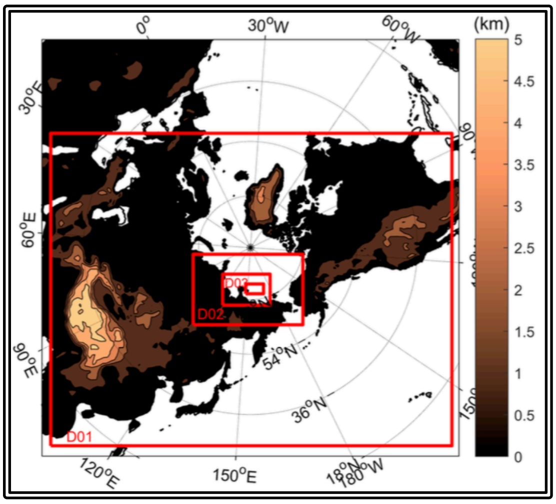
➢ MODELING TOOLS:

Large Eddy Simulation (LES):

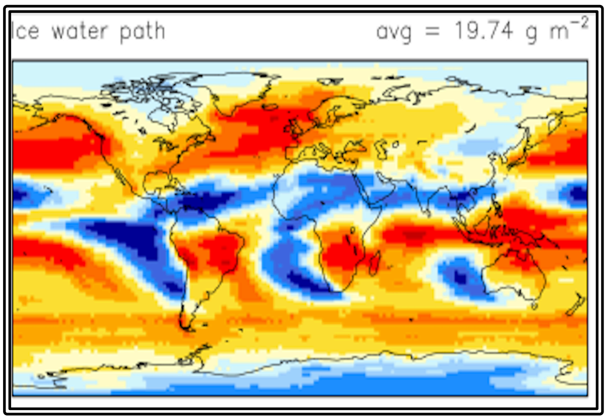
We study cloud-turbulence interactions using a Large Eddy Simulation (LES), which is a high resolution model that can explicitly resolve turbulence at very fine scales, with only the very small eddies (<~ 5 m) being parameterized. This model is ideal for studying cloud-aerosol interactions in the PBL and microphysical processes in low-level clouds, as the uncertainty induced by turbulence parameterizations is minimized. For our investigations we use the MIT/MISU Cloud-Aerosol (MIMICA) LES, developed at Stockholm University by the group of Professor Annica Ekman.

Weather and Research Forecasting (WRF) model:

The WRF model is a numerical weather prediction system, suitable for both atmospheric research and operational forecasting. WRF serves a wide range of research applications across scales from tens of meters to thousands of kilometers, thus is suitable for process-level, mesoscale and regional climate model studies. Our work with WRF mainly focuses on the improvement of the microphysical parameterizations through the implementation of missing ice formation processes.



The Norwegian Earth System Model version 2 (NorESM2):



The Norwegian Earth System Model version 2 (NorESM2) is the second generation of the coupled Earth System Model developed by the Norwegian Climate Center and has been used in the 6th phase of the Coupled Model Intercomparison Project (CMIP6). NorESM2 is used to study cloud-aerosol interactions, cloud microphysical processes and dust aerosol impacts at climate scales.

➢ PUBLICATIONS:

http://scholar.uoa.gr/georgiasot/publications