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Challenges in building a system for assimilating airborne thermal infrared data to predict wildland fire behavior

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The monitoring of wildfire behavior has recently emerged as a key public policy issue due to the occurrence of extreme events, in particular in the Euro-Mediterranean region, which is exposed to more frequent and more severe wildfires under climate change. Key to this monitoring is the development of an event-scale numerical simulation capability as a means of understanding and predicting the interactions between the atmosphere and the wildfire that drive its behavior. This capability combines through data assimilation, information coming from the Meso-NH/BLAZE coupled atmosphere/fire model (developed through a joint collaboration with the CNRM/Météo-France – Costes et al., 2021) and from airborne infrared images in order to best reconstruct the wildland fire progression. The coupled model simulates the fire front propagation at the land surface and the buoyant plume dynamics in the atmosphere. However, the biomass fuel and near-surface wind parameters required as inputs to the coupled model are only partially known. Our aim with the data assimilation approach is to solve an inverse problem and thereby reduce parameter uncertainties by taking advantage of available observations. There are four main issues in building this data assimilation capability.

1) The fire front propagation can be unsteady, with irregularities and changes in topology. Errors therefore correspond to position errors, which we address using a front shape similarity measure derived from image segmentation theory and based on the Chan-Vese contour fitting functional (Zhang et al., 2019).

2) To avoid equifinality issues, it is essential to spot the most influential input factors on the simulated fire front positions through global sensitivity analysis, which are good candidates for parameter estimation (Roubelat et al., 2022).

3) Simulating the envelope of plausible wildland fire behaviors requires designing and validating a reduced-cost ensemble modeling approach based on a metamodel to effectively mimic the relationship between the uncertain input parameters and the fire quantities of interest.

4) There is also an observational challenge, as extracting fire front positions from raw infrared images is not trivial and requires the development of advanced post-processing approaches based on deep learning.

The main objective of this talk is to present our progress on these fronts, and to discuss the prospects for extending data assimilation to the coupled atmosphere/fire model within the framework of the newly-launched ANR project FIREFLY.

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