Variational Assimilation of Atmospheric Observations into an Earth System Model

Simon Blessing
FastOpt GmbH
Thomas Kaminski
FastOpt GmbH
Frank Lunkeit
University of Hamburg, KlimaCampus Hamburg
Ion Matei
University of Hamburg, KlimaCampus Hamburg
Ralf Giering
FastOpt GmbH
Armin Köhl
University of Hamburg, KlimaCampus Hamburg
Marko Scholze
University of Bristol, Department of Earth Sciences,
University of Hamburg, KlimaCampus Hamburg
Detlef Stammer
University of Hamburg, KlimaCampus Hamburg

We present the Planet Data Assimilation System (PLADAS), a variational assimilation system that is built around the Planet Simulator (PLASIM) and its adjoint. PLASIM is an Earth System Model that comprises a spectral atmospheric component (PUMA), a slab ocean component with thermodynamic sea ice, and a terrestrial biosphere component (SIMBA). The adjoint is generated by the automatic differentiation tool TAF from the PLASIM Fortran 90 source code. We describe the generation of the adjoint and its verification as well as modifications that enhance the model's linearisability and, thus, the PLADAS performance. We present two sets of calibration experiments that use PLADAS for estimation of a set of ten process parameters controlling the atmospheric model's schemes for radiation, dynamics, and boundary layer fluxes. First, a set of identical twin experiments are used to explore the length of the feasible assimilation window. In this type of experiment pseudo-observations (long term means of temperature and vorticity in every grid cell and of surface pressure in every surface grid cell) are generated by a model run with default values of the control parameters. Our setup is such that each assimilation experiment consists of three optimisations that independently minimise the model-data mismatch by variation of the control parameters, where each optimisation is starting from a different set of perturbed control parameter values. In a reduced model configuration the default parameter values can be reliably recovered for assimilation windows of up to eight weeks in about 50-70 iterations. More precisely, all three optimisations reduce the misfit function by more than nine orders of magnitude, the norm of its gradient by more than five orders of magnitude, and the norm of the control parameter vector to its default value by more than five orders of magnitude. A second set of experiments assimilates ECMWF reanalysis data and, so far, achieves feasible assimilation windows of up to three days. In both sets of experiments the improvement in the simulated state persists beyond the assimilation window, i.e. the assimilation has improved the forecast quality.

Corrersponding Author:

Name: Simon Blessing
Organisation: FastOpt GmbH
Address: Lerchenstraße 28a
D-22767 Hamburg
Germany
Email Address: simon.blessing@FastOpt.com