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IceChrono1: a probabilistic model to compute a common and optimal chronology for several ice cores

Frédéric Parrenin (1,2), Lucie Bazin (3), Emilie Capron (4), Amaëlle Landais (3), Bénédicte Lemieux-Dudon (5), and Valérie Masson-Delmotte (3)

(1) CNRS/LGGE, St Martin d Heres, France (parrenin@ujf-grenoble.fr), (2) Univ. Grenoble Alpes, LGGE, 38041 Grenoble, France, (3) Institut Pierre-Simon Laplace/Laboratoire des Sciences du Climat et de l'Environnement, UMR 8212, CEA-CNRS-UVSQ, 91191 Gif-sur-Yvette, France, (4) British Antarctic Survey, Madingley Road, High Cross, Cambridge, CB3 0ET, UK, (5) Laboratoire Jean Kuntzmann, Grenoble, France

Polar ice cores provide exceptional archives of past environmental conditions. The dating of ice cores and the estimation of the age scale uncertainty are essential to interpret the climate and environmental records that they contain. It is however a complex problem which involves different methods. Here, we present IceChrono1, a new probabilistic model integrating various sources of chronological information to produce a common and optimized chronology for several ice cores, as well as its uncertainty. IceChrono1 is based on the inversion of three quantities: the surface accumulation rate, the Lock-In Depth (LID) of air bubbles and the thinning function. The chronological information integrated into the model are: models of the sedimentation process (accumulation of snow, densification of snow into ice and air trapping, ice flow), ice and air dated horizons, ice and air depth intervals with known durations, Δdepth observations (depth shift between synchronous events recorded in the ice and in the air) and finally air and ice stratigraphic links in between ice cores. The optimization is formulated as a least squares problem, implying that all densities of probabilities are assumed to be Gaussian. It is numerically solved using the Levenberg-Marquardt algorithm and a numerical evaluation of the model's Jacobian. IceChrono follows an approach similar to that of the Datice model which was recently used to produce the AICC2012 chronology for 4 Antarctic ice cores and 1 Greenland ice core. IceChrono1 provides improvements and simplifications with respect to Datice from the mathematical, numerical and programming point of views. The capabilities of IceChrono is demonstrated on a case study similar to the AICC2012 dating experiment. We find results similar to those of Datice, within a few centuries, which is a confirmation of both IceChrono and Datice codes. We also test new functionalities with respect to the original version of Datice: observations as ice intervals with known durations, correlated observations, observations as gas intervals with known durations and observations as mixed ice-air stratigraphic links. IceChrono1 is freely available under the GPL v3 open source license.