



## **Monitoring climate-driven interannual variability of European Larch phenology in an alpine environment: results of the REPHLEX project**

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In this contribute we present the results of the REPHLEX experiment (REmote sensing of PHenology Larix Experiment), conducted by the Environmental Dynamics Remote Sensing Laboratory of the University of Milano-Bicocca, by the Regional Protection Agency of the Aosta Valley and by Vegetation Biology Department of the University of Torino. The project was aimed at developing appropriate techniques for monitoring the interannual variability of European Larch (*Larix decidua* Mill.) phenological cycle in the Alpine region of Valle d'Aosta (Northern Italy), and to evaluate its relationships with environmental and climatic drivers. This was achieved by combining field observations, phenological models and satellite remote sensing.

Phenological field observations were weekly conducted in 8 test sites during 2005, 2006 and 2007 in order to determine the dates of completion of different phenological phases of the analyzed Larch stands. MODIS 250 16-days composite NDVI data (Product MOD13Q1 – v005) acquired from TERRA platform for the 2000-2007 time period were used to estimate budburst and senescence dates, as well as the length of the growing season. With this aim, NDVI time series were fitted with a double logistic curve, and the dates corresponding to different characteristic points of the curve (maximum of the first derivative and zeroes of the third and fourth derivative) were determined. The comparison between MODIS estimated dates and field data showed that the points of the fitted NDVI curve that allow to better estimate larch phenological dates are the zeroes of its third derivative, which allowed to estimate the start and the end of the growing season with Mean Absolute Errors (MAE) of about 6 and 4 days, respectively. This result is particularly significant since to our knowledge these inflection points have never been used for the estimation of phenological dates in previous studies.

Start and end of season were also estimated by applying the Spring Warming and the GSI phenological models. Models' optimization was performed through numerical inversion against field data collected in 2005, and their accuracy was assessed comparing modeling results with 2006 and 2007 field observations. The comparison of MODIS estimated start and end of season dates with that obtained by the phenological models shows a general agreement between the two methodologies. Phenological models were found however to provide erroneous results when applied in areas characterized by conditions different from that of the sites considered for their optimization, or in years characterized by anomalous meteorological conditions. This suggests that, at regional or continental level, the accuracy in the estimation of the spatial and interannual variations of the main phenological dates achievable by satellite monitoring can be expected to be more stable than that of phenological models driven by climatological variables.

The relationships between interannual variability of Larch phenological cycle and regional climate were investigated comparing the mean start and end of season yearly anomalies computed from MODIS data with air temperature anomalies relative to different periods of the year. Results of this analysis showed the existence of a linear relationship ( $R^2 = 0.82$ ) between mean spring temperatures (March, April and May) and the mean start of the season date. An increase of  $1^\circ\text{C}$  in mean spring temperature was found to lead to an advance of about 7 days in the mean budburst date of larch at regional level. For example, mean start of season in 2007 showed an advance of about 7 days as a consequence of the very high late winter and early spring temperatures. Mean leaf discoloring dates were instead found to be best related with mean September temperature ( $R^2 = 0.78$ ), with an increase of  $1^\circ\text{C}$  in September temperature leading to a posticipation of the end of the season of only 1 day.