Supplementary material for "Atmospheric Brown Clouds in the Himalayas: first two years of continuous observations at the Nepal-Climate Observatory at Pyramid (5079 m)"

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SI-1: Mesoscale modelling using WRF

As shown in the Section 3.4, LAGRANTO back trajectories allow the assessment of the large-scale circulation of air masses arriving at NCO-P. To simulate the meteorology at a scale that captures individual peaks and valleys, nested runs were set up of the Advanced Research (ARW) Version 3 of the Weather Research and Forecast (WRF) model. This is a limited area non-hydrostatic model designed for a range of tasks, from weather forecasting to air pollution transport simulation (Skamarack et al 2008). The WRF ARW was set up with four levels of nested domains, all centred on Mt. Everest (27.99° N, 86.93° E). The coarsest-resolution (27 km) outermost domain covers much of South Asia and the Tibetan Plateau, while the innermost domain (3 km resolution) covers the Khumbu and adjoining regions.

The model is driven at the boundary of the outermost domains by NCEP Final Analysis (FNL) analyzed meteorology, available at six hourly intervals at 1° x 1° horizontal resolution on 27 vertical levels. The nested domains have two-way interactions with each other. Model physics are parameterized using a simple ice scheme, and a Goddard scheme for shortwave radiation (Chou and Suarez, 1994). Cumulus clouds are parameterized in the outer two domains using a Kain-Fritsch scheme (Kain, 2004), where they are recalculated every 5 minutes. They are calculated explicitly in the inner two domains. The bottom boundary has a 4 layer Noah land surface model. Surface land use and topography data is ingested at 30 arc-second resolution, and interpolated to the model grid by the WRF pre-processor. In the region around Mt. Everest, the default USGS 30 arc-second digital topography database normally used by WRF contains excess smoothing, which results in a loss of the actual shape of the topography. For example, the Mt. Everest, Lhotse, and Nuptse reliefs are merged into one large dome shaped mountain, while deep tributary valleys are merged together into one large basin. Thus, an accurate simulation of the Khumbu valley meteorology for the analysis of air-mass transport to NCO-P involved correcting the elevation of the bottom boundary. Use was made of a gap-filled version of the NASA Shuttle Radar Topography Mission (SRTM) 3 arc-second database obtained from http://www.viewfinderpanoramas.org, averaged to 30 arc-seconds, to correct the elevation data employed by WRF from 26° to 28° north, and 86° to 88° east. The domain of the third nest level of the present WRF simulation, covering a 300 km by 300 km area centred on Mt. Everest, is shown in Figure S1, where the NCO-P location is marked by a red dot, located at grid points (46.3, 49.7).

With this set-up WRF has been applied to describe the diurnal evolution wind fields around NCO-P was for selected days during pre-monsoon (30 March 2006) and monsoon (14 July 2007), as reported in Figures S2 and S3 where surface wind vectors are reported for night-time (02:45NST) and day-time (14:45 NST).

References

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Skamarock, W. C., Klemp, J. B., Dudhia, J., Gill, D.O., Barker, D.M., Duda, G. M., Huang, X.-Y., Wang, W., and Powers, J.G.: A description of the Advanced Research WRF Version 3, Boulder, CO, NCAR: 113 pp., 2008.

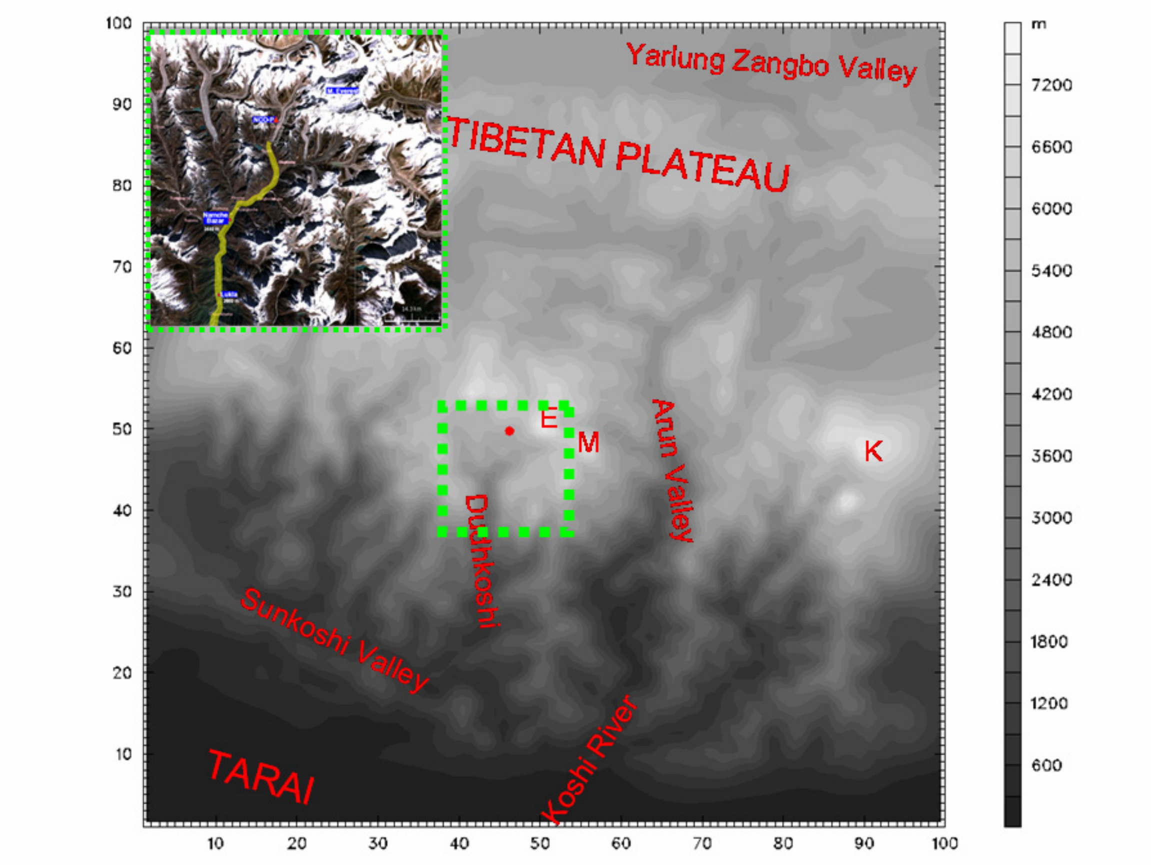

Figure S1. Map of the domain of the third nest level in WRF simulations (surface elevation expressed in meters a.s.l., see coloured scale). NCO-P is marked by the red dot. Mountain peaks are denoted by single letters as follows: S = Shishapangma, E = Everest, M = Makalu, K = Kanchanjunga. For reference, the map of the valley region is also reported in the green box.

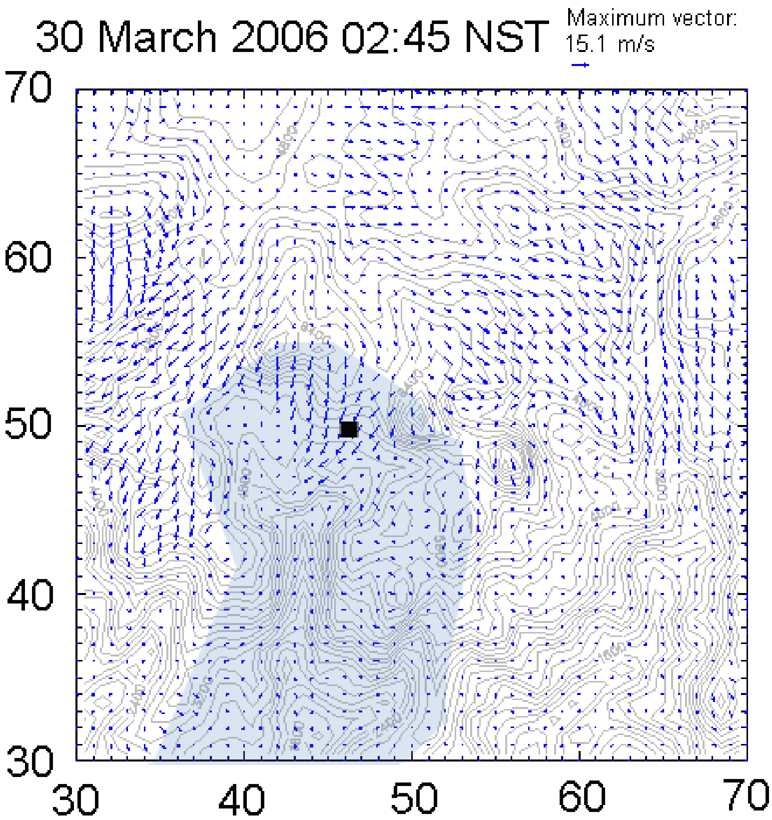

Figure S2a. 3 km resolution WRF model simulations in the region surrounding Mt. Everest at 02:45 NST for a specific pre-monsoon day (30 March 2006). Surface wind vectors are plotted in blue arrows. Terrain height is shown with a contour interval of 200 meters. The black square represents NCO-P location, while the shaded contour denoted the Khumbu valley extension.

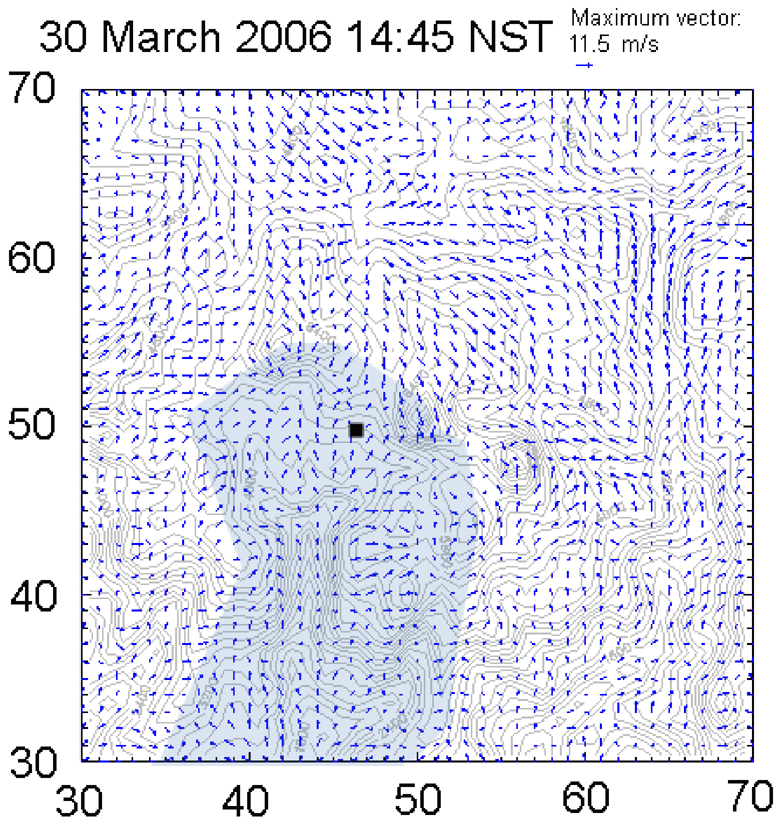

Figure S2b. As for figure S2a but at 14:45 NST.

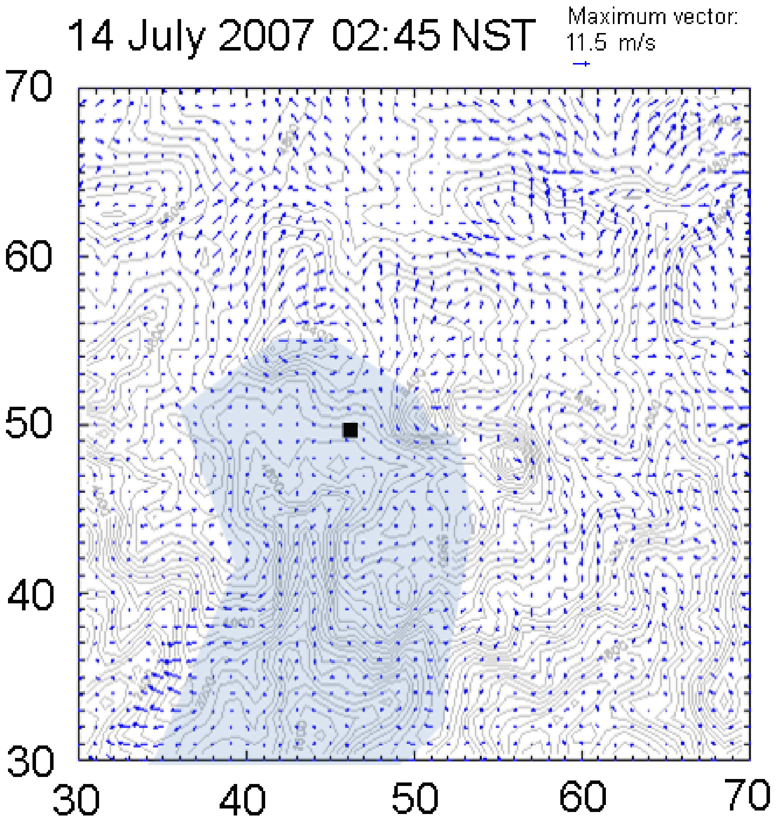

Figure S3a. 3 km resolution WRF model simulations in the region surrounding Mt. Everest at 02:45 NST for a specific monsoon day (14 July 2007). Surface wind vectors are plotted in blue arrows. Terrain height is shown with a contour interval of 200 meters. The black square represents NCO-P location, while the shaded contour denoted the Khumbu valley extension.

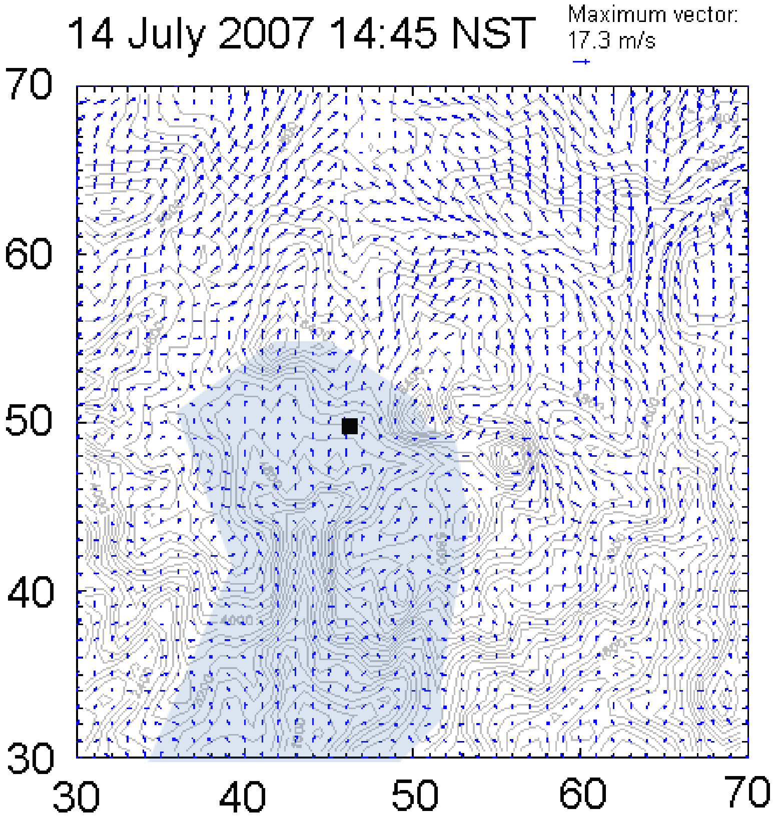

Figure S3b. As for figure S3a but at 14:45 NST.