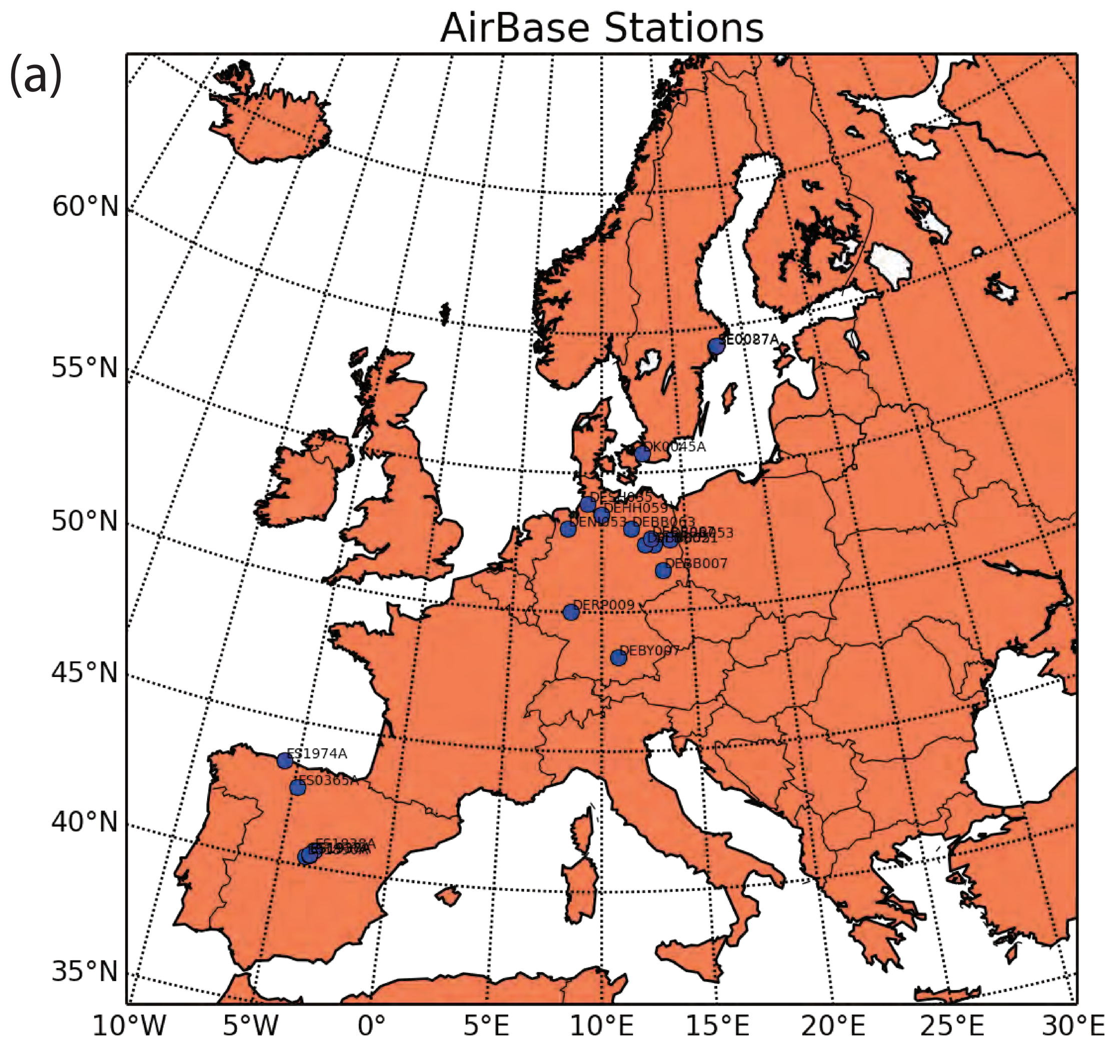
# Improvement of Enviro-HIRLAM weather forecasting through inclusion of cloud-aerosol interactions

R.B. Nuterman[1,2,*], U.S. Korsholm[3], K.P. Nielsen[3], B.H. Sass[3], A.A. Baklanov[4] and E. Kaas[1]

[1]University of Copenhagen, Niels Bohr Institute, Copenhagen, Denmark
[2]Tomsk State University, Mechanics and Mathematics Faculty, Tomsk, Russia
[3]Danish Meteorological Institute, Research Division, Copenhagen, Denmark
[4]World Meteorological Organization, Geneva, Switzerland
*Corresponding author: Roman Nuterman; E-mail: nuterman@nbi.ku.dk; Ph.: +45 5053 0275

(a)




(b)

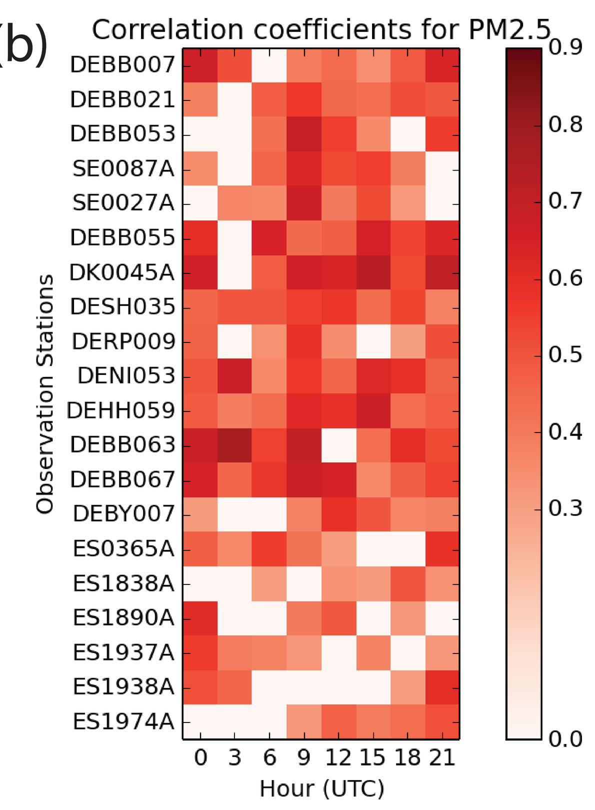



**Figure 1:** (a) Enviro-HIRLAM modelling domain and map of selected AirBase air-quality monitoring stations (http://acm.eionet.europa.eu/databases/airbase/) across Europe; (b) $PM_{2.5}$ correlation coefficient on diurnal cycle for selected AirBase observation stations.

## Enviro-HIRLAM model description

During the summer of 2010, there were a number of severe weather events, such as floods, heat waves and droughts across Middle East, most of Europe and European Russia. In particular, heat waves followed by wildfires in Europe and Russia led to substantial increase of atmospheric aerosols concentration.

In order to study aerosols indirect effects on meteorology, the online-coupled air-quality and meteorology model Enviro-HIRLAM (Environment – HIgh Resolution Limited Area Model) was used (*Unden et al., 2002*). The model includes aerosol microphysics HAM-M7 scheme (*Vignati et al., 2004*), tropospheric sulphur chemistry cycle (*Feichter et al., 1996*), wet scavenging and dry-deposition schemes (*Stier et al., 2005*) and aerosol activation scheme based on (*Abdul-Razzak, Ghan, 2000*). Several emission inventories were used, i.e. anthropogenic (*Kuenen et al., 2011*) and wildfires (http://is4fires.fmi.fi) as well as interactive sea-salt (*Zakey et al., 2008*), dust (*Zakey et al., 2006*) and DMS (*Nightingale et al., 2000*) emissions.

## Model setup

The Enviro-HIRLAM modeling domain with horizontal resolution of 0.15° x 0.15° and 40 vertical hybrid levels covers Europe, North of Sahara, and Central Russia (*Fig. 1a*). Boundary and initial conditions for meteorological fields and atmospheric tracers have been produced by ECMWF IFS (hor. res. 0.15° x 0.15°) and MOZART (hor. res. 1.125° x 1.125°) models, respectively. The model time step was 360 sec., surface data assimilation was applied every 6 hr. The aerosol-cloud interactions were quantified by means of difference (delta function) between outputs of Enviro-HIRLAM with aerosol-cloud interactions (ENV) and Reference-HIRLAM without interactions (REF).

## Results and Conclusions

The model predicts well $PM_{2.5}$ day-to-day variability, with fairly good correlation coefficient (more then 0.3, *Fig 1b*) on diurnal cycle;

The total cloud cover is mainly increased (with local maxima of 90%) except several inland areas, where cloud cover decreased by almost -90% (*Fig. 2, left*);

The delta function of cloud water content at average cloud base (*Fig. 2, right*) shows its increase comparing to the REF model with local maxima over North Atlantic, Iceland, North Sea, Sweden, Switzerland and Austria;

The REF model tends to over predict both frequency and amount of precipitation (*Fig. 4*) and the inclusion of aerosol-cloud interactions improves the model score (*Fig. 3*), i.e. the ENV model bias of precipitation with respect to its frequency and amount has been decreased comparing to the REF model results.

## Acknowledgments

The research leading to these results has received funding from EU FP7 PEGASOS and COST Action ES1004 (AQMEII-2) research and networking projects. The source code of aerosol microphysics was provided by ECHAM-HAM-MOZ consortium.

## References

Abdul-Razzak, H., and S. J. Ghan (2000): A parameterization of aerosol activation: 2. Multiple aerosol types, J. Geophys. Res., 105(D5), 6837–6844, doi:10.1029/1999JD901161.

Feichter, J. et al. (1996): Simulation of the tropospheric sulfur cycle in a global climate model, Atmos. Environ., 30, 1693-1707.

Kuenen, J. H. Denier van der Gon, A. Visschedijk, H. van der Brugh (2011): High resolution European emission inventory for the years 2003-2007, TNO report TNO-060-UT-2011-00588, Utrecht.

Nightingale, P. D., G. Malin, C. S. Law, A. J. Watson, P. S. Liss, M. I. Liddicoat, J. Boutin, and R. C. Upstill-Goddard (2000): In situ evaluation of air-sea gas exchange parameterizations using novel conservative and volatile tracers, Global Biogeochem. Cycles, 14(1), 373–387.

Saas, B.H. (2002): A research version of the STRACO cloud scheme, Danish Meteorological Institute, Tech. Rep. 02-10, 27 pp.

Savijärvi, Hannu (1990): Fast Radiation Parameterization Schemes for Mesoscale and Short-Range Forecast Models. J. Appl. Meteor., 29, 437–447.

Stier, P. et al. (2005): The aerosol-climate model ECHAM5-HAM, Atmos. Chem. Phys., 5, 1125-1156, doi:10.5194/acp-5-1125-2005.

Undén, P., et al. (2002): Hirlam-5 scientific documentation. Tech. rep., SMHI.

Vignati, E., Wilson, J. and Stier, P. (2004): M7: An efficient size-resolved aerosol microphysics module for large-scale aerosol transport models. Journal of Geophysical Research 109(D22): doi: 10.1029/2003JD004485. issn: 0148-0227.

Zakey, A. S., F. Giorgi, and X. Bi (2008): Modeling of sea salt in a regional climate model: Fluxes and radiative forcing, J. Geophys. Res., 113, D14221, doi:10.1029/2007JD009209.

Zakey, A. S., Solmon, F., and Giorgi, F. (2006): Development and testing of a desert dust module in a regional climate model, Atmos. Chem. Phys. Discuss., 6, 1749-1792, doi:10.5194/acpd-6-1749-2006.

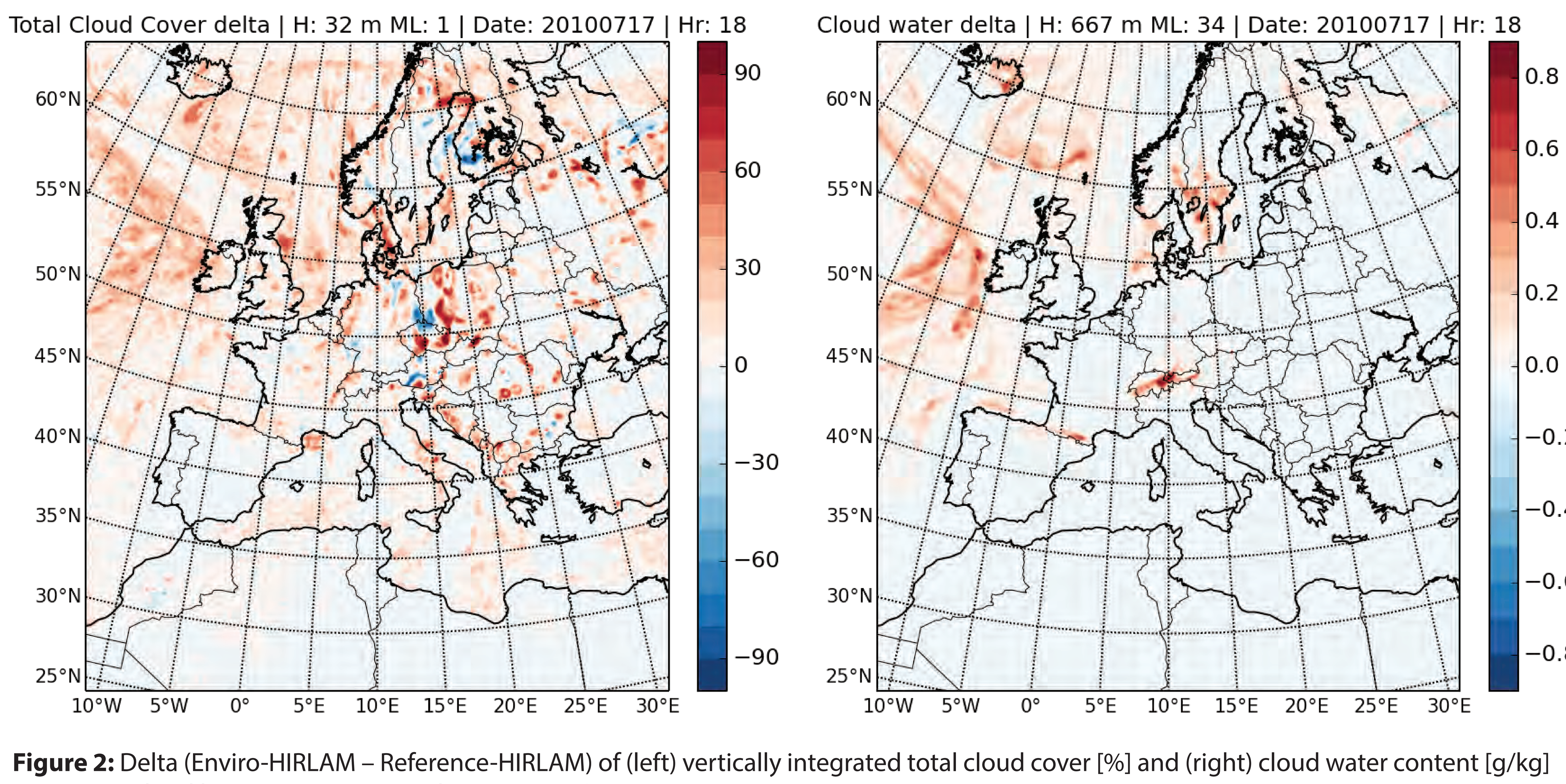



**Figure 2:** Delta (Enviro-HIRLAM – Reference-HIRLAM) of (left) vertically integrated total cloud cover [%] and (right) cloud water content [g/kg] at average cloud base (667 m) on 17 Jul 2010, 18 UTC.

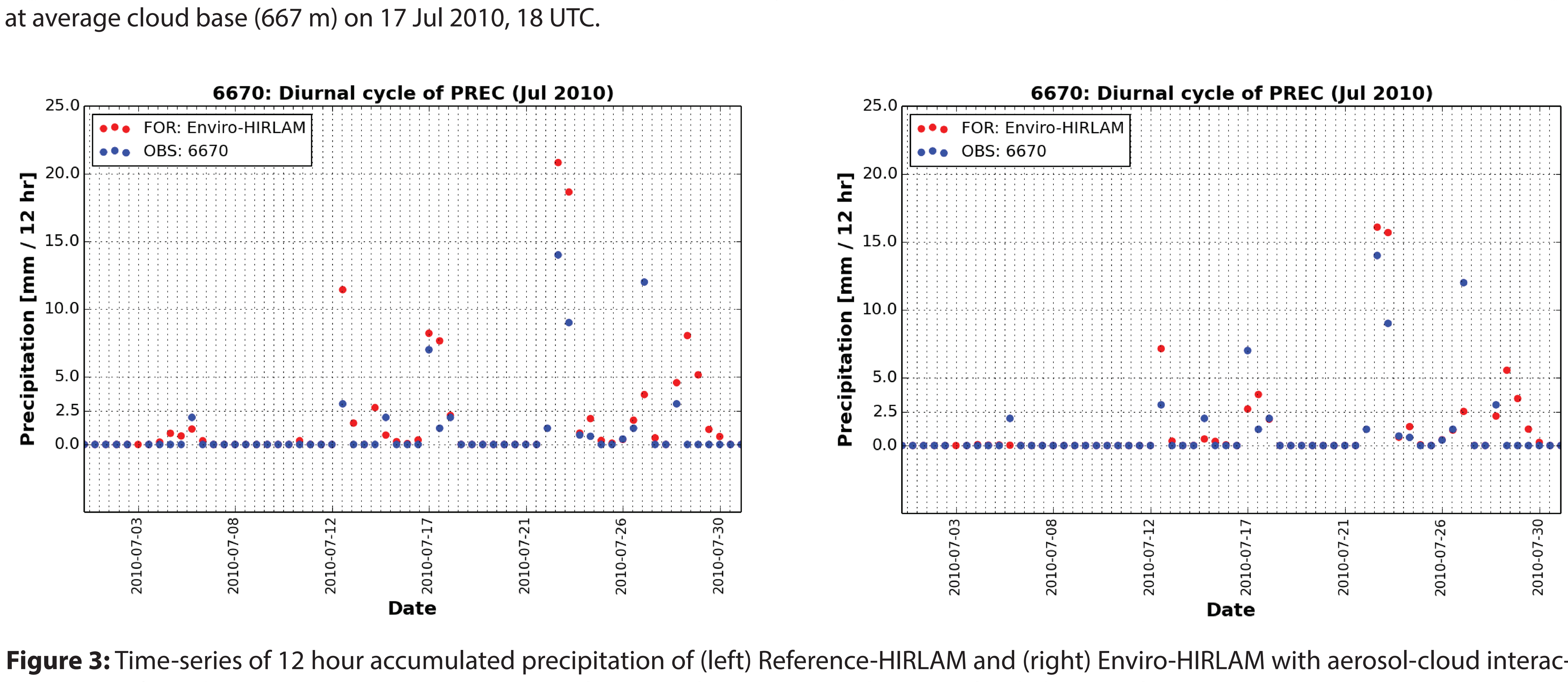



**Figure 3:** Time-series of 12 hour accumulated precipitation of (left) Reference-HIRLAM and (right) Enviro-HIRLAM with aerosol-cloud interactions vs. surface observations at WMO station 6670 (lat: 47.47; lon: 8.53), Zurich, Switzerland, during Jul 2010.

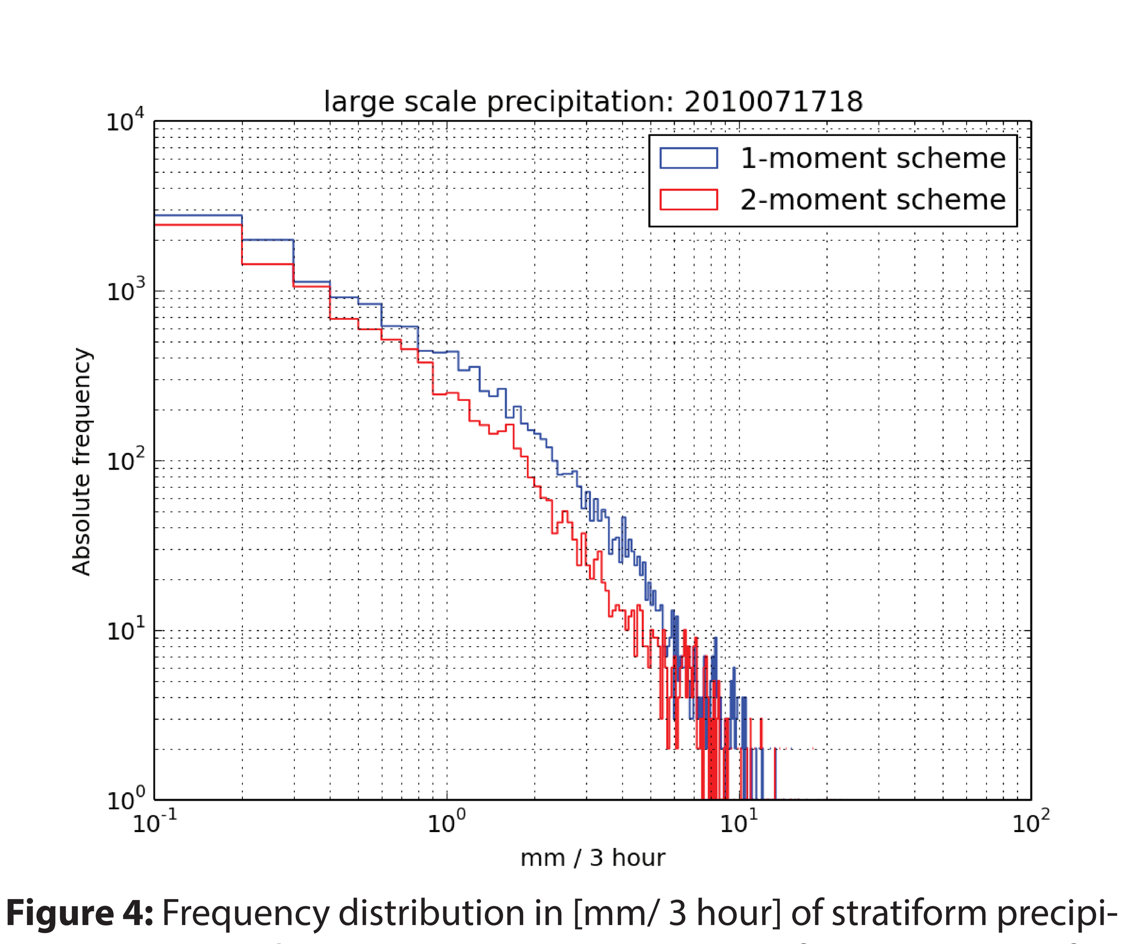



**Figure 4:** Frequency distribution in [mm/ 3 hour] of stratiform precipitation on 17 Jul 2010, 18 UTC. Comparison of 1-moment (Reference-HIRLAM) and 2-moment (Enviro-HIRLAM with aerosol-cloud interactions) cloud microphysics STRACO schemes (*Saas, 2002*).