# Using the moisture flux divergence over the Alps as an indicator for heavy rain cases

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## Introduction

Heavy rain over a sizeable region must be connected with the convergence of the vertically integrated transport of moisture into the heavy rain region. The local moisture input due to evaporation is comparatively small (except, perhaps in Summer). Thus heavy rain events should be visible as strong peaks not only in time series of precipitation but also in those of the moisture flux divergence (MFD). Here we calculate the mean MFD on a

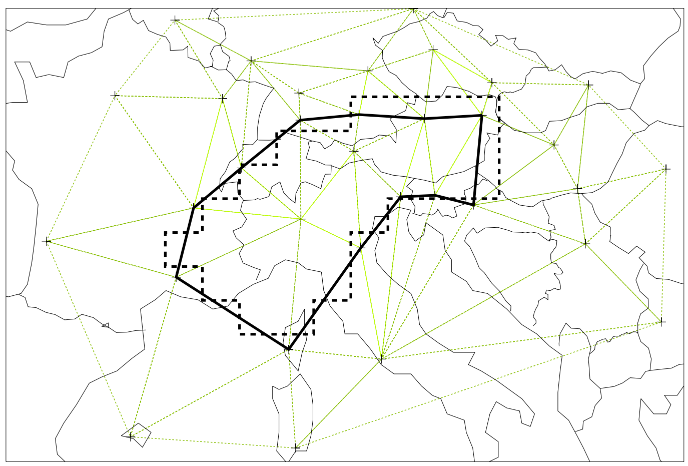

Figure 1:
Whole domain and subdomain for which the vertically integrated MFD has been calculated. Solid: subdomain used with FEM, dashed: subdomain used with ECMWF analysis data and with SYNOP-Precipitation.

relatively large scale, i.e. for the whole Alpine region (see Fig. 1). Input data available are (i) radiosonde data (every 12 hours) at nodes of the FEM-mesh as indicated in Fig. 1, (ii) operational ECMWF analyses (every 6 hours), (iii) 12-hourly SYNOP-precipitation objectively analyzed with OI method.

Concerning (i) we use the Finite Element Method (FEM) where the radiosonde stations are the nodes of the FEM-grid in the horizontal. The vertical dimension is discretized using standard pressure levels. Only moisture and wind measurements from the radiosondes are used for calculating the MFD over the subdomain. The advantage of this method is that the moisture data are independent from an assimilating forecast model. The main disadvantage is the low resolution both in space and time and the fact that the radiosonde data are not internally consistent.

Since the radiosonde wind field does not fulfil the discretized continuity equation the wind field is modified such that the spurious mass flux divergence is removed under the constraint that the energy of the modifying wind field is minimized. This has been done using the FEM following Göber (1997), see also Matulla et al. (2000). The effect of the wind field modification on the time series of the mean MFD over the subdomain is shown in Fig. 2-a): the variance of the MFD in time is reduced by 40%.

## Results

The calculation of MFD from ECMWF analyses is more straightforward since this dataset is consistent provided that data on model levels are used and that the MFD is discretized exactly in the same manner as in the assimilating model. Fig. 2-b) compares time series of the MFD from radiosonde data with those from ECMWF analyses. The statistical properties of the series are quite similar but the correlation between them is 0.64 - relatively low considering the size of the subdomain.

When comparing both datasets with objectively analyzed SYNOP precipitation one finds that there is much better correlation between the MFD derived from ECMWF analyses and precipitation than between the MFD from radiosonde data and precipitation. This can be to a small extent explained by the fact that the overlap

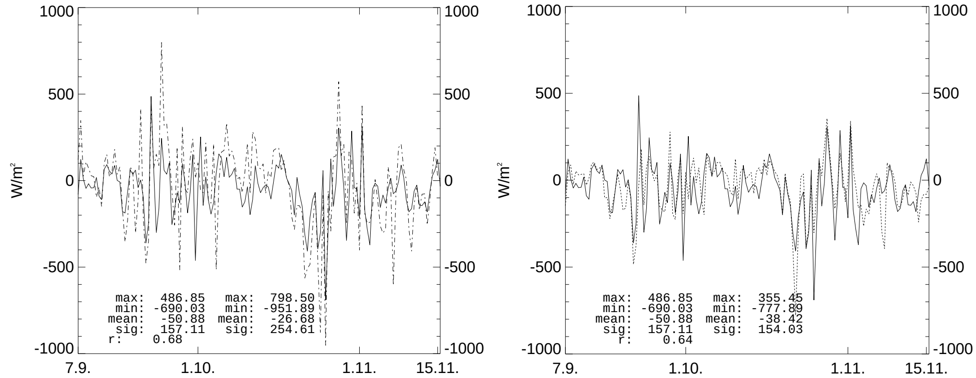


Figure 2:
Time series of mean vertically integrated MFD over the subdomain in W/m$^2$ for the MAP IOP. a) Comparison between time series calculated from radiosondes with FEM with wind field modification (solid) and time series calculated without wind field modification (dash-dotted). b) Comparison between time series calculated with FEM (solid) and time series calculated from ECMWF analyses on model levels (dotted). Left figures correspond to solid curves, right figures to dotted curves. $r$ is correlation coefficient between time series.

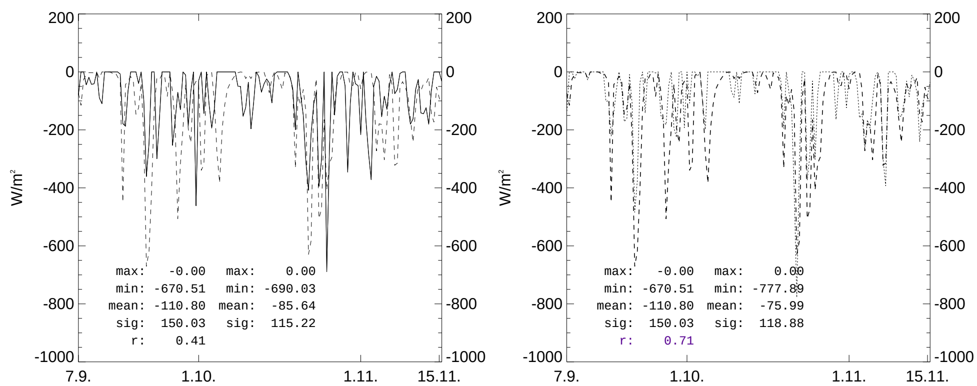


Figure 3:
Time series of mean vertically integrated MFD and mean precipitation over the subdomain in W/m$^2$ for the MAP SOP. a) Comparison between time series calculated from FEM data (solid, right figures) and precipitation (dashed, left figures), b) corresponding comparison between MFD from ECMWF analyses (dotted, right figures) and precipitation (negative downward, dashed, left figures). Values of positive MFD have been padded to zero since precipitation also does not change sign.

between FEM-subdomain and ECMWF subdomain is only 90%. The main error source is, however, the coarse resolution in space and time that introduces large errors. In order to show this we transformed the spectral ECMWF analysis data onto the locations of radiosonde stations and then calculated MFD using the FEM method. The resulting MFD time series correlated well (94%) with that from radiosonde data.

Comparing the MFD from ECMWF analyses with that from precipitation one can notice a small phase lag of 6-12 hours. The MFD typically peaks in the early stage of the strong rain events that occured.

## Conclusions

The idea of calculating MFD directly from radiosonde data seems attractive since the result is truly independent from errors in the parameterization schemes of the assimilating model. Practice has shown, however, that the inconsistencies in the radiosonde data are not sufficiently filtered out by the proposed mass flux modification scheme. This error source, together with the coarse time and space resolution and the lack of information of the past (which is available in assimilated data) outweighs the benefit due to the independence from the assimilating model. This is true on the time and space scale considered here but also on the monthly time scale (not shown).

## References


Göber, M., 1997: *Regionale Klimadiagnostik großskaliger Wirbel*. Ph. D. thesis, Universität Bonn.

Matulla, C., L. Haimberger and M. Dorninger, 2000: Calculation of moisture budgets from radiosonde data using finite elements. *MAP Newsletter*, **13**, pp. 26-27.