

FOG – BOON OR BANE?

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With 1 figure

Fog is a specific form of a cloud touching the ground with complex spatio-temporal occurrence patterns. Its formation and genetic type depends on synoptic to local-scale circulation systems, the local radiation and energy budgets, and interactions of atmospheric processes with topography and land cover. A comprehensive overview on the nature of fog and related fields of research was recently given by BRUIJNZEEL et al. (2005) and EUGSTER (2008). A review on forecasting methods by using *in-situ* observations, remote sensing and numerical modelling was presented by GULTEPE et al. (2007). Several international collaborative field campaigns were conducted in the past decades to unveil fog dynamics with special regard to the underlying microphysics (e.g. FUZZI et al. 1992; CHOULARTON et al. 1997) and chemistry in fog water (e.g. FUZZI et al. 1998).

Because fog occurs near the ground, it affects people's life in many ways. Both positive and negative interrelations with the biotic and abiotic environment are obvious (Fig. 1). Consequently, the current special issue is devoted to an interdisciplinary view on the atmospheric phenomenon fog. These selected contributions, covering a broad topical range of fog research, were presented at the 5th International Conference on Fog, Fog Collection and Dew, held in Münster (Germany) from 25–30 July 2010.

Negative consequences are mainly related to fog as an obstacle for land, air and sea traffic, as well as the deposition of polluted fog water. WARD (1981) for instance emphasized the costs for the aviation industry that originate from delays and flight cancellations due to fog. Road traffic is most strongly affected by fog; where EDWARDS (1998) found out that accidents in fog result in the most severe injuries compared to other adverse weather conditions. The highest risk for ship-bridge collisions in rivers is related to fog occurrence (KUNZ 1998), and marine collisions and grounding frequencies also tend to increase with decreasing visibility (RØMER et al. 1995). If fog is accompanied by a temperature inversion, its clearance

by solar heating can be delayed or even inhibited and smog (SMOke in combination with fOG) formation might be fostered (refer e.g. to BENDIX 1998) in areas of high anthropogenic emissions and less-established emission control policies. In these areas, smog is well-known as a trigger of pulmonary diseases (SUNYER 2001) and reduced daylight length can lead to depression (BENEDETTI et al. 2001). With regard to ecosystems of different ecozones, fertilization (also remote) due to occult deposition of air pollutants dissolved in fog water (e.g. THALMANN et al. 2002; ROLLENBECK et al. 2010) can lead to eutrophication while direct contact with acid fog water might also harm the vegetation surface (e.g. CAPE 1993).

Two papers in this special issue explicitly deal with the chemical composition of fog and its origin. WATANABE et al. (2011) investigated the chemical composition of fog water at a site near the summit of Mt. Tateyama (western Japan). Based on observations at two sites and air trajectory modelling, they showed that strong acidic fogs occur during the summer and autumn if the westerly air stream predominates. They assume that the air pollutants as the cause for fog water acidification originate from regions of mainland Asia. In particular, HÜNOVÁ et al. (2011) analysed the sulphur deposition across the territory of the Czech Republic related to fog occurrence. They could show that the amount of occult deposition was twice as high as the sum of wet and dry deposition, affecting large forest areas.

Particularly in areas of low air pollution levels, fog occurrence and fog water deposition is essential for the establishment of specific vegetation types (Fig. 1). Fog, as a main water source and as a protection against heat and water stress particularly with respect to epiphytic vegetation in tropical mountain forests, is hitherto well documented (see e.g. FREIBERG and FREIBERG 2000). This could also be recently confirmed for a new type of a tropical lowland cloud forest (OBREGÓN et al. 2011; GEHRIG-DOWNIE et al. 2011). Fog water is essential in coastal

fog deserts for the survival of specific vegetation formations, as it is well-known e.g. for the Loma vegetation of the Atacama Desert (e.g. OKA and OGAWA 1984; WESTBELD et al. 2009). In the current issue, HAENSLER et al. (2011) investigate the fog frequency along the Namib Desert with satellite imagery and REMO model simulations. The validated REMO model is used to analyse the potential impacts of global climate change on the spatio-temporal fog distribution in the Namib Desert. The authors revealed for the IPCC SRES A1B climate change scenario that the number of fog days might slightly decrease for regions located further inland, which would mean an exacerbation of the existing water scarcity.

For more than two decades, fog water collection has been an emerging technology in arid environments, which has been used for different purposes, e.g. the production of potable water for rural and remote communities (SCHEMENAUER and CERECEDA 1991 and many more thereafter). In their short report, LUMMERICH and TIEDEMANN (2011) highlight technical improvements regarding the efficiency of fog water collectors and an economic investment model for profitable fog water harvesting in arid regions in the outskirts of Lima (Peru). In addition, two different applications of fog water harvesting are presented in this special issue. In the first paper, VALIENTE et al. (2011) underline the importance of fog water collection for the reforestation of a highland area in eastern Spain close to the Mediterranean coast where fog water is advected by the sea breeze, and additionally

channelled by a river valley. Radiation fog is mostly formed in the early morning and/or evening hours. The collected water amounts that were applied in small water pulses to planted tree saplings were shown to significantly increase the reforestation success, particularly for pine trees. The second paper by MARZOL et al. (2011) investigates meteorological circulation patterns suitable for fog water harvesting on the Canary Islands and in Morocco. They found comparable average quantities of collected water at both sites, but with an unexpected inverse seasonality (Morocco in winter, Canary Islands in summer). By establishing water storage containers, they conclude that fog water harvesting could significantly improve the water supply of rural communities.

References

- BENEDETTI, F.; COLOMBO, C.; BARBINI, B.; CAMPORI, E. and SMERALDI, E. (2001): Morning sunlight reduces length of hospitalization in bipolar depression. In: *Journal of Affective Disorders*, 62, 221–223. DOI: [10.1016/S0165-0327\(00\)00149-X](https://doi.org/10.1016/S0165-0327(00)00149-X)
- BENDIX, J. (1998): Ein neuer Methodenverbund zur Erfassung der klimatologisch-lufthygienischen Situation von Nordrhein-Westfalen. *Bonner Geogr. Abh.* 98. Bonn.
- BRUIJNZEEL, L. A.; EUGSTER, W. and BURKARD, R. (2005): Fog as a hydrologic input. In: ANDERSON, M. G. and McDONNELL, J. J. (eds.): *Encyclopedia of hydrological sciences* 1. Chichester, 559–582.

| Bane | Boon |
|---|--|
| <p>(1) Reduction of surface visibility = Obstacle for traffic == Accidents (land, sea) == Financial losses (all)</p> | <p>(4) Water harvesting = Financial benefit</p> |
| <p>(2) Reduced solar irradiance = Delayed clearance of temperature inversions == Might support smog formation === Pulmonary diseases === Mood</p> | <p>(5) Reduced solar irradiance = Reduction of heat and water stress for vegetation</p> |
| <p>(3) Dissolution of air pollutants = Occult deposition == Might harm vegetation</p> | <p>(6) Reduced IR-radiation losses = Lower risk of nocturnal ground frost == benefit for winter crops</p> |
| | <p>(7) Occult deposition = Water source of vegetation == in cloud forests == in fog deserts (e.g. Loma) == for epiphytes = Water source for desert animals == for fog harvesting beetles</p> |

Fig. 1: Main negative and positive consequences of fog occurrence

- CAPE, J. N. (1993): Direct damage to vegetation caused by acid rain and polluted cloud: definition of critical levels for forest trees. In: *Environmental Pollution* 82, 167–180. DOI: [10.1016/0269-7491\(93\)90114-4](https://doi.org/10.1016/0269-7491(93)90114-4)
- CHOUARTON T. W.; COLVILE, R. N.; BOWER, K. N.; GALLAGHER, M. W.; WELLS, M.; BESWICK, K. M.; ARENDS, B. G.; MÖLS, J. J.; KOS, G. P. A.; FUZZI, S.; LIND, J. A.; ORSI, G.; FACCHINI, M. C.; LAJ, P.; GIERAY, R.; WIESER, P.; ENGELHARDT, T.; BERNER, A.; KRUISZ, C.; MÖLLER, D.; ACKER, K.; WIEPRECHT, W.; LÜTTKE, J.; LEVSEN, K.; BIZJAK, M.; HANSSON, H.-C.; CEDERFELT, S.-I.; FRANK, G.; MENTES, B.; MARTINSSON, B.; ORSINI, D.; SVENNINGSSON, B.; SWIETLICKI, E.; WIEDENSOHLER, A.; NOONE, K. J.; PAHL, S.; WINKLER, P.; SEYFFER, E.; HELAS, G.; JAESCHKE, W.; GEORGH, H. W.; WOBROCK, W.; PREISS, M.; MASER, R.; SCHELL, D.; DOLLARD, G.; JONES, B.; DAVIES, T.; SEDLAK, D. L.; DAVID, M. M.; WENDISCH, M.; CAPE, J. N.; HARGREAVES, K. J.; SUTTON, M. A.; STORETON-WEST, R. L.; FOWLER, D.; HALLBERG, A.; HARRISON, R. M. and PEAK, J. D. (1997): The Great Dun Fell cloud experiment 1993: an overview. In: *Atmospheric Environment* 31, 2393–2405. DOI: [10.1016/S1352-2310\(96\)00316-0](https://doi.org/10.1016/S1352-2310(96)00316-0)
- EDWARDS, J. B. (1998): The relationship between road accident severity and recorded weather. In: *Journal of Safety Research* 29, 249–262. DOI: [10.1016/S0022-4375\(98\)00051-6](https://doi.org/10.1016/S0022-4375(98)00051-6)
- EUGSTER, W. (2008): Fog research. In: *Die Erde* 139, 1–10.
- FREIBERG, M. and FREIBERG, E. (2000). Epiphytic diversity and biomass in the canopy of lowland and montane rain forests in Ecuador. In: *J. Trop. Ecol.* 16, 673–688. DOI: [10.1017/S0266467400001644](https://doi.org/10.1017/S0266467400001644)
- FUZZI, S.; FACCHINI, M. C.; ORSI, G.; LIND, J. A.; WOBROCK, W.; KESSEL, M.; MASER, R.; JAESCHKE, W.; ENDERLE, K. H.; ARENDS, B. G.; BERNER, A.; SOLLY, I.; KRUISZ, C.; REISCHL, G.; PAHL, S.; KAMINSKI, U.; WINKLER, P.; OGREN, J. A.; NOONE, K. J.; HALLBERG, A.; FIERLINGER-OBERLINGNER, H. PUXBAUM, H.; MARZORATI, A.; HANSSON, H. C.; WIEDENSOHLER, A.; SVENNINGSSON, I. B.; MARTINSSON, B. G.; SCHELL, D. and GEORGH, H. W. (1992): The Po Valley Fog Experiment 1989: an overview. In: *Tellus*, 44B, 448–468. DOI: [10.1034/j.1600-0889.1992.t014-00002.x](https://doi.org/10.1034/j.1600-0889.1992.t014-00002.x)
- FUZZI, S.; LAJ, P.; RICCI, L.; ORSI, G.; HEINTZENBERG, J.; WENDISCH, M.; YUSKIEWICZ, B.; ORSINI, D.; SCHWANZ, M.; WIEDENSOHLER, A.; STRATMANN, F.; BERG, O. H.; SWIETLICKI, E.; FRANK, G.; MARTINSSON, B. G.; GÜNTHER, A.; DIERSSEN, J.; SCHELL, D.; JAESCHKE, W.; BERNER, A.; DUSEK, U.; GALAMBOS, Z.; KRUISZ, C.; MESFIN, S. N.; WOBROCK, W.; ARENDS, B. and TEN BRINK, H. (1998): Overview of the Po valley fog experiment 1994 (CHEMDROP). In: *Contr. Atmos. Phys.* 71, 3–19.
- GEHRIG-DOWNIE, C.; OBREGÓN, A.; BENDIX, J. and GRADSTEIN, S. R. (2011): Epiphyte biomass and canopy microclimate in the Tropical Lowland Cloud Forest of French Guiana. In: *Biotropica*. DOI: [10.1111/j.1744-7429.2010.00745.x](https://doi.org/10.1111/j.1744-7429.2010.00745.x)
- GULTEPE, I.; TARDIF, R.; MICHAELIDES, S. C.; CERMAK, J.; BOIT, A.; BENDIX, J.; MÜLLER, M. D.; PAGOWSKI, M.; HANSEN, B.; ELLROD, G.; JACOBS, W.; TOTH, G. and COBER, S. G. (2007): Fog research: a review of past achievements and future perspectives. In: *Pure and Applied Geophysics* 164, 1121–1159. DOI: [10.1007/s00024-007-0211-x](https://doi.org/10.1007/s00024-007-0211-x)
- HAENSLER, A.; CERMAK, J.; HAGEMANN, S. and JACOB, D. (2011): Will the southern African west coast fog be affected by future climate change? In: *Erdkunde* 65 (3), 261–275 (this issue). DOI: [10.3112/erdkunde.2011.03.04](https://doi.org/10.3112/erdkunde.2011.03.04)
- HÜNOVÁ, I.; KURFÜRST, P.; MAZNOVÁ, J. and COŇKOVÁ, M. (2011): The contribution of occult precipitation to sulphur deposition in the Czech Republic. In: *Erdkunde* 65 (3), 247–259 (this issue). DOI: [10.3112/erdkunde.2011.03.03](https://doi.org/10.3112/erdkunde.2011.03.03)
- KUNZ, C. U. (1998): Ship bridge collision in river traffic, analysis and design practise. In: GLUVER, H. and OLSON, D. (eds.): *Ship collision analysis*. Rotterdam, 13–20.
- LUMMERICH, A. and TIEDEMANN, K. J. (2011): Fog water harvesting on the verge of economic competitiveness. In: *Erdkunde* 65 (3), 305–306 (this issue) DOI: [10.3112/erdkunde.2011.03.07](https://doi.org/10.3112/erdkunde.2011.03.07)
- MARZOL, M. V.; SÁNCHEZ, J. L. and YANES, A. (2011): Meteorological patterns and fog water collection in Morocco and the Canary Islands. In: *Erdkunde* 65 (3), 291–303 (this issue). DOI: [10.3112/erdkunde.2011.03.06](https://doi.org/10.3112/erdkunde.2011.03.06)
- OBREGÓN, A.; GEHRIG-DOWNIE, C.; GRADSTEIN, S. R.; ROLLENBECK, R. and BENDIX, J. (2011): Canopy level fog occurrence in a tropical lowland forest of French Guiana as a prerequisite for high epiphyte diversity. In: *Agric. Forest Meteorol.* 151, 290–300. DOI: [10.1016/j.agrformet.2010.11.003](https://doi.org/10.1016/j.agrformet.2010.11.003)
- OKA, S. and OGAWA, H. (1984): The distribution of Lomas vegetation and its climatic environments along the Pacific coast of Peru. In: *Geographical Reports of Tokyo Metropolitan University* 19, 113–125.
- ROLLENBECK R.; BENDIX J. and FABIAN P. (2010): Spatial and temporal dynamics of atmospheric water- and nutrient inputs in tropical mountain forests of southern Ecuador. In: BRUIJNZEEL, L. A.; SCATENA, F. N. and HAMILTON; L. S. (eds.): *Tropical montane cloud forests: science for conservation and management*. Cambridge, 367–377.
- RÖMER, H.; STYHR PETERSEN, H. J. and HAASTRUP, P. (1995): Marine accident frequencies – review and recent empirical results. In: *Journal of Navigation* 48, 410–424. DOI: [10.1017/S037346330001290X](https://doi.org/10.1017/S037346330001290X)
- SCHEMENAUER, R. S. and CERECEDA, P. (1991): Fog water collection in arid coastal locations. In: *Ambio* 20, 303–308.
- SUNYER, J. (2001): Urban air pollution and chronic obstructive pulmonary disease: a review In: Euro-

- pean Respiratory Journal 17, 1024–1033. DOI: [10.1183/09031936.01.17510240](https://doi.org/10.1183/09031936.01.17510240)
- THALMANN, E.; BURKARD, R.; WRZESINSKY, T.; EUGSTER, W. and KLEMM, O. (2002): Ion fluxes from fog and rain to an agricultural and a forest ecosystem in Europe. In: Atmospheric Research 64, 147–158. DOI: [10.1016/S0169-8095\(02\)00087-X](https://doi.org/10.1016/S0169-8095(02)00087-X)
- VALIENTE, J. A.; ESTRELA, M. J.; CORELLI, D.; FUENTES, D.; VALDECANTOS, A. and BAEZA, M. J. (2011): Fog water collection and reforestation at a mountain location in a western Mediterranean basin region: air mass origins and synoptic analysis. In: Erdkunde 65 (3), 277–290 (this issue). DOI: [10.3112/erdkunde.2011.03.05](https://doi.org/10.3112/erdkunde.2011.03.05)
- WARD, M. W. (1981): The cost of fog at Canberra airport. PhD Thesis, Univ. British Columbia, Vancouver, Canada.
- WATANABE, K.; HONOKI, H.; IWAMA, S.; IWATAKE, K.; MORI, S.; NISHIMOTO, D.; KOMORI, S.; SAITO, Y.; YAMADA, H. and UEHARA, Y. (2011): Chemical composition of fog water at Mt. Tateyama near the coast of the Japan Sea in central Japan. In: Erdkunde 65 (3), 233–245 (this issue). DOI: [10.3112/erdkunde.2011.03.02](https://doi.org/10.3112/erdkunde.2011.03.02)
- WESTBELD, A.; KLEMM, O.; GRIESSBAUM, F.; STRÄTER, E.; LARRAIN, H.; OSSES, P. and CERECEDA, P. (2009) Fog deposition to a Tillandsia carpet in the Atacama Desert. In: Annales Geophysicae, 27, 3571–3576. DOI: [10.5194/angeo-27-3571-2009](https://doi.org/10.5194/angeo-27-3571-2009)

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