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IFDA2019-3 abstracts

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Numerical simulations of fog extent in the Miyoshi basin, Japan.

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Context/Purpose
In the Miyoshi basin (in Hiroshima Prefecture, Japan), large fog extents were often found in autumn and winter. Although their fogs are considered as a radiation fog type by the past researches, how mechanism of the formation has ever been unknown well because one routine observation site of temperature exists in the center of basin. A typical fog scale in Miyoshi is about 30 km-square. Hence, in our study, using a high-resolved gridded atmospheric model, numerical simulations of the fog formation in the Miyoshi basin were executed to clarify an occurrence, movement, and development on complex topographies in the Miyoshi basin.

Methods
The weather research and forecasting model (WRF ver. 3.7.1) was used to simulate Miyoshi fogs. The horizontal spatial resolutions were assigned by three cases of 300 m, 500 m, and 1500 m. Then, these results were analyzed and compared with each other during the period of November 1-5, 2007 when special in-situ observations were multi-directionally conducted. Initial and boundary conditions of the model were assigned by the NCEP final analysis, JMA meso-analysis, and NCEP RTG_SST data. The land use (100-m resolution) and topographic data (50-m resolution) of the Geospatial Information Authority of Japan (GIAJ) were used in the model.

Results
We judged a radiation fog formation by using the existence of cloud water contents outputted in model calculations. The model simulated radiation fogs on the Miyoshi basin. In particular, large extents of the fog were found from the night to morning of November 2 and 3, which was broadly similar to results of in-situ top-down views with a thermo-camera and surface observations. A simulated fog density (cloud water contents) was the highest at heights of 200-300m above ground level, and the top height was found at about 400 m. These features also agreed with the result of vertical meteorological observations. On the other hand, at some sites with high altitude, surface air temperature during the night when the fog appeared was calculated higher than that of observation because the radiative cooling of ground surface was suppressed by the fog. Therefore, it was considered that excess fog extents were simulated for actually non-fog regions.

Interpretation
Simulated fogs were probably generated by not only radiative cooling effect on the Miyoshi basin but also in surrounding mountain regions. In addition, the mountain fogs were advected through above the Miyoshi basin. Fogs advected from outside regions of the basin can be actually observed with the thermo-camera viewing. Meanwhile, higher resolved model well simulated radiation fog within the basin.

Conclusion
Simulated fogs by the WRF were similar to observed those in the Miyoshi basin, Japan. Our model simulations suggested co-existence and development of the radiation fog generated within the basin and the fog advected from outside basin.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-8

An Observational and Modeling Analysis of a Sea Fog Event over the Yellow Sea During Spring

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An Observational and Modeling Analysis of a Sea Fog Event over the Yellow Sea During Spring
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Abstract
A sea fog event in the Yellow Sea from April 13 to 15, 2016 is observed and simulated using WRFv3.5 model. The GOES-9 visible satellite imagery is used to observe the evolution process of the sea fog event. The atmospheric circulation, temperature field, wind field, air-sea temperature difference and atmospheric stability were analyzed. It is concluded that this sea fog event was mainly due to the warm air blowing to the cold sea surface. This fog event can thus be classified into an advection sea fog. In northern part of the Yellow Sea, The prevailing Northerly winds result in the rapid dissipation of sea fog in the northern part of the Yellow Sea, whereas in the southern region, sea fog maintained longer. In addition, this present study suggests that when the air-sea temperature difference is between 1 and 3 [U+2103], it is the most favorable condition for sea fog formation over the Yellow Sea. Based on the analysis of the station data, the results suggest that the inversion layer has an important influence on the formation and development of sea fog. Finally, this sea fog event is simulated by using WRF model (v3.5). The simulation results are in good agreement with the satellite cloud image. The horizontal and vertical distributions of cloud-water mixing ratio were analyzed. The results show that sea fog are denser in the southern part of the Yellow Sea. The height of the fog layer is about 950 hPa, right under the top of the inversion layer. There also exist some problems in terms of this simulation. In the simulation, sea fog dissipated earlier than that in the observation. In the eastern part of Yellow Sea, the WRF model cannot reproduce the distribution of sea fog as in the satellite imagery. Three sensitivity tests were conducted with WRF model: SST+2K, SST-2K and no surface flux. In the warmer sea surface, the fog patch tends to be smaller. The cooler the sea surface, the larger the fog patch. The results suggested that with cooler sea surface, it is more favorable for advection sea fogs to form. Without surface flux, when southerly winds prevail, the fog tends to be stronger, whereas the northerly winds prevail, the fog tends to be weakened.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-17

Assessment of fog predictability in the Mexico Basin

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The numerical weather prediction of fog is challenging, as many models typically show large biases for the timing of the onset and dispersal of the phenomenon, as well as for its depth and low liquid water content. With the purpose to understand the role of the various physical processes involved – such as radiation, land-surface coupling, and microphysics – the fog skill prediction of the Weather Research and Forecasting (WRF) model was evaluated for the period between 1999 and 2018 in the Mexico Basin, where Mexico City's International Airport (AICM) is located.

First, a climatology for the study period was realized using Météorologique Aviation Régulière (METAR) reports issued for the AICM. Individual events were characterized in terms of their most common formation mechanisms in the region: radiation, advection and frontal fog types. The WRF model results suggest that the boundary-layer formulation is critical for forecasting fog onset. For fog type, the choice of the microphysical scheme is a key element: for radiation fogs, a double-moment scheme outperforms any of the single-moment schemes, whereas the opposite occurs for advection and frontal fogs. Also, the WRF model results appear to be relatively sensitive to the initial time condition, since a 24-hour lead time has a much better skill than the 12-hour lead time forecasting.

Finally, statistical dichotomous analyses – using a simple 2 X 2 contingency table – showed that the WRF model, with the configurations and settings used, has good forecasting skills for each of the different fog types occurring in the Mexico Basin.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-37

Comparison of fog forecast results by PAFOG model and fog identification by satellite data in Brazil.

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Adverse phenomena are great danger for society, they can cause economic and social losses, including human lives. This work study fog events in Brazilian Northeast and Porto Alegre (Southern Brazil) to compare satellite fog identification results and fog forecast by PAFOG model. A bibliographical review was carried out to present theoretical point of view. The next data and methodology from different sources were used: a) surface data obtained by the Department of Air Space Control for the airports of Maceio, Campina Grande and Porto Alegre; b) images of the final product of the GOES, METEOSAT and EUMETSAT satellites in the visible, water vapor and infrared channels; c) radiosonde data from the Center of the Weather Forecast and Climate Studies (CPTEC) and the University of Wyoming; d) reanalysis products of the numerical model of the ERA-Interim (ECMWF). GrADS software were used for the composition of the meteorological fields and simulated vertical profiles. Period of study in the Campina Grande and Maceio was from 2008 to 2016, and in Porto Alegre from 2008 to 2009. From 20 fog events identified In the Maceio only 1 was the intense case. Also, one event was identified by the satellite data with the duration superior than observed by METAR code. From 105 events identified in Campina Grande, 18 were intense. Likewise, 4 events were identified by the satellite data with the duration of two events different than observed. Twenty-three events were recorded in Porto Alegre of which 4 were intense. Fifteen events from 23 were identified by the satellite data where start time of 11 events were different than by METAR. Moreover all 15 events presented a different duration, thn by METAR. The PAFOG model predicted fog in Maceio (June 11th, 2010) 12 hours in advance and in Porto Alegre (July 5th, 2008) 15 hours in advance. Then this forecast was interrupted for 4 hours. PAFOG model did not forecast the visibility decrease in Campina Grande (August 21st, 2009) 6 hours in advance. For example, 24 hours forecast was not completed because of fog reached the upper layer above 400m. The results can be used in the elaboration of a fog forecasting method for the Brazilian Northeast and improvement of the method for Porto Alegre.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-38

Fog and mist forecast by the PAFOG model at the Northeast Brazilian airports.

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Adverse weather phenomena cause economic and social losses. Its formation is associated with atmospheric conditions and synoptic scale systems. Therefore, forecast methods of adverse phenomena have to be created worldwide for each specific region. Different studies were performed previously in the Synoptic Meteorology and Physics Laboratory of the Institute of Atmospheric Sciences (ICAT UFAL). Some of these results were published in papers and books. The objective of this paper is to study fog in the tropical region, where there is information lack about its formation process. The next methodologies and data from different sources were used: a) surface data of the Meteorology Network of the Aeronautics Command and the National Institute of Meteorology; b) radiosonde data of the Center for Weather Forecasting and Climate Studies (CPTEC); c) images of the GOES and METEOSAT satellites available by CPTEC in visible, water vapor and infrared channels; d) reanalysis products of the NCEP/NOAA Reanalysis 2, ERA-Interim (ECMWF) and CFSv2 (NCEP/CFSR-NCAR) numerical model were used for synoptic analysis. GrADS and NCL softwares were used to plot the meteorological fields and simulated vertical profiles. There were 125 fog events in the airports of Maceio and Campina Grande from 2008 to 2016. The processes of fog formation in the two cities were different. Influence of a trough at the low levels was detected in most cases in Maceio. Different fog mechanisms were observed in Campina Grande: a) influence of a ridge; b) convective cloud formation during the fog (atypical); c) rained (one case). However, both cities had similar conditions. All events occurred by dawn and early in the morning. The PAFOG model presented satisfactory results in Campina Grande predicting fog for 12 and 6 hours. In Maceio it was not satisfactory. It is important to note that for the most fog events PAFOG model predicted reduced horizontal visibility. The study results can be used to elaborate the adverse phenomena forecasting methods for the Brazilian Northeast.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-41

Using Recurrent Neural Network to Improve Forecasting of Fog and Visibility

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Low-visibility conditions heavily influence aviation, navigation and urban road traffic. Accurate visibility forecasting is difficult due to its highly non-linear features. Artificial Neural Network (ANN) such as Back Propagation Neural Network (BPNN) were used to try to solve this problem and some effect was obtained. With the rapid development of mathematics and computer technology, some novel neural networks are proposed, developed and known as deep learning. Deep learning, which can extract a high-level representation of raw data, has been widely used to deal with non-linear problems in various fields. Recurrent Neural Network (RNN) is one of the deep learning architectures where connections between nodes form a directed graph along a sequence. This allows it to exhibit temporal dynamic behavior for a time sequence and use their internal state to process sequences of inputs. The present study builds statistical models for nowcasting of fog and visibility, which is based on the Long Short-Term Memory Recurrent Neural Network (LSTM-RNN) and the surface observational data at Fuzhou weather station (119.3E°,36.1N°). The observational data is sampled every 5 minutes and is from January 2016 to August 2018. The predictor variables include wind speed, wind direction, surface pressure, temperature, dew point temperature, precipitation and visibility. All the predictor variables were reframed as a 12-hour time series with 5-minute intervals for the input data. The dataset was composed of 200000 samples, randomly divided into a training set (160000) and a testing set (40000) for model building and validation. The forecasting results were evaluated using mean absolute error (MAE), root mean square error (RMSE) and equitable threat score (ETS), and were compared with results from the BPNN. The experimental results show that the prediction errors are significantly reduced using the LSTM-RNN compared with the BPNN, especially in the forecasting of low visibility events such as fog. The variation tendency of visibility predicted by our model is basically in conformity with the measured data, indicating that LSTM-RNN is effective for accurate visibility nowcasting. The present study provides a new solution for the forecast of meteorological elements that are highly non-linear.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-67

Towards an improved representation of fog and low stratus in high-resolution numerical weather prediction models

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Context
Predicting the extent of fog and low stratus (FLS) is increasingly important. For example, airport authorities require accurate forecasts of visibility to optimise operations and in the energy sector knowledge about future low cloud cover is required to estimate the short-term solar energy yield. Despite the many improvements in recent years high-resolution numerical weather prediction (NWP) models still show unsatisfactory performance regarding FLS forecasts.

Aim
Our goal is to improve FLS forecasts with COSMO-1, a deterministic 1-km resolution NWP-model employed operationally at MeteoSwiss, the Swiss national weather service.

Methods
To enable an objective intercomparison of different model versions and configurations, we developed a verification method for FLS forecasts based on infrared satellite imagery. In order to identify the key processes that are responsible for the insufficient representation of FLS in NWP models we conducted sensitivity experiments addressing the microphysics parameterisation, subgrid-scale turbulence parameterisation, model resolution and model topography for a series of case studies. In this presentation, we focus on a case in December 2017 where the modelled FLS clouds had dissipated after only a few hours, whereas in reality they had persisted throughout the entire day.

Results
A novel algorithm based on three infrared channels allowed us to objectively quantify the quality of the modelled spatial extent of FLS. We could show that COSMO-1 underpredicts FLS already at the beginning of the model forecast, indicating deficiencies in the data assimilation scheme. Furthermore, the modelled FLS generally dissipates too fast with increasing leadtime. Changes in the model parameterisations have shown limited improvements only: Adopting a two-moment microphysics scheme for cloud water does not significantly affect the FLS extent. Reducing the minimum turbulent diffusion coefficients for momentum and heat slightly reduces the warm temperature bias close to the ground but the FLS dissipation remains too early. The model showed improved performance when decreasing the horizontal grid spacing from 2km to 1km to 500m. However, even at 500m resolution, the modelled life cycle remains unsatisfactory.

Conclusions
A novel validation procedure based on satellite imagery confirms that the NWP-model COSMO-1 generally underestimates the extent of FLS clouds and dissipates them too fast. Adaptations to the model resolution show the most promising results so far. We will conclude the presentation with an overview of future directions in order to improve FLS forecasts.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-88

Boundary Layer Parameterizations to Simulate Fog over Atlantic Canada Waters

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Dense fog occurs frequently and lasts for days over Northwest Atlantic Waters, which significantly affects marine transport, offshore oil and gas activates and other marine operations. However, accurate numeral simulations and forecasts of marine fog are a big challenge. We present numeral simulations and forecasts of a series of fog events that occurred near Halifax, Canada, during June 20 to July 31 2016. The Weather Research and Forecasting Model version 3.8.1 (WRF) is used to study the sensitivity to fog simulation with five local and nonlocal Planetary Boundary Layer (PBL) schemes. In situ and satellite remotely sensed observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) are used to validate fog simulation, and give a new exponent for the Kunkel visibility equation to predict visibility. Results show that these five PBL schemes in WRF lead to overestimates in liquid water content (LWC), especially the nonlocal schemes, and that they are biased earlier than observations, while local schemes are more consistent with observations. Results show that the local schemes work better than the nonlocal schemes, except for MYJ, which missed a fog event on July 5 2016. Thus, we recommend MYNN2.5 as providing the best PBL for fog simulation over the Northwest Atlantic as a result of this study, because it succeeds in capturing every fog event in this study, with high correlation coefficient and low RMSE. In this methodology, the Kunkel equation is used to calculate visibility based on WRF modelling of LWC. Comparisons with observed visibility show that the original Kunkel formulation sometimes fails to predict fog dissipation. Thus we present a modification of this formulation with the new exponent (1.271) for visibility that shows improved agreement with observations and more accurate fog dissipation.

In summary, in comparison with the other PBL formulations considered, our study provides a best PBL scheme (MYNN2.5) to simulate fog over Atlantic Canada Waters, and gives a new exponent (1.271) in the Kunkel formulation to predict visibility. Thus, our study helps to improve our ability to predict fog over Atlantic Canada Waters. However, fog prediction is still a big challenge, and continued improvements in the PBL scheme and visibility parameterization are needed for more accurate fog prediction.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-92

Advection-radiation fog over the northeast Pacific in summer: long-term ship observations and LES simulations

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The fog over the northwest Pacific is predominantly advection fog, which forms due to the cooling of moist air by relatively cold sea surface. Using 40-year ship observations, we find that the fog air temperature (FAT) frequently ($\sim$30 % of the total fog observations) falls below sea surface temperature (SST) over the northwest Pacific, and the fog with positive SST-FAT mostly occurs during night when longwave radiative cooling is not canceled out by solar radiative heating at fog top. We subsequently perform large-eddy simulations (LESs) to study the physical processes within boundary layer producing the positive SST-FAT. The LESs follow the trajectory of an air parcel from the warm to cold ocean surface and are initialized with typical summertime boundary-layer soundings. The control run is forced by realistic solar incidence with diurnal variation. Results show that FAT falls below SST 3 hours after fog occurrence. Heat budget analysis of the fog/cloud-resident boundary layer suggests that the longwave radiative cooling at fog top overcomes the sea surface cooling 2 hours after fog formation. After that, the positive buoyancy flux produced by the longwave radiative cooling at fog top takes over the turbulent production from surface wind shear, and further thickens the fog layer. The turbulence intensified by the air-sea instability kills fog droplets and leads to the transition of fog to stratus. The FAT in the sensitive run with diurnal mean solar radiation keeps above SST, indicative of the important role of radiative budget within fog layer for the fog development, maintenance, and dissipation. This study advances our knowledge of advection fog by clarifying the important role of fog-top radiative cooling, and helps improve the skills in fog prediction over the northwest Pacific where marine traffic is heavy.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-95

Winter Fog Experiment (WiFEX) at Delhi International Airport, India: Results from 2015-2019 winter campaign

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Abstract
Context By considering the national interests and key research issues it is important to consider how future research on fog modeling and forecasting will be organized so that it will most effectively address the issues that are important for public services in India. Therefore, Ministry of Earth Sciences (MoES), Government of India (GoI) has taken a multi-institutional lead in understanding broad aspects of winter-time haze and fog formation over northern regions of India, and for developing a suitable fog forecasting system that has relevance to all sectors and policy issues.
Methods The WIFEX project was designed to study the characteristics and variability of fog events and improve understanding some of the key questions on fog formation and dispersion.
Results From a numerical modeling point of view the project was designed to improve understanding of the key parameters needed for physical parameterization of fog to improve it’s prediction. This study provides results on fog thermo dynamical, microphysical and chemical analysis. We found that the fog particles grew larger and number concentration increased uniformly with time along entire diameter ranges when condition changes from the non-foggy to the foggy condition. Hence it is most likely that the particles grew larger by vapor deposition/collection processes.
Interpretation This paper will present the brief overview of microphysical, chemical and thermo dynamical properties of fog from the measurements carried out in Delhi under the WiFEX campaign followed by evaluation of fog forecast demonstrated using the IITM-WRF product.
Conclusion It is challenges in visibility forecasting for airport will be discussed in this research.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-100

Modeling the life cycle of fog in the Namib desert with COSMO-PAFOG

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Fog and low stratus clouds are a typical feature in coastal deserts. In the hyper-arid Namib Desert at the southwestern African coast, fog is an important source of water for ecosystems. The knowledge of the spatial and temporal patterns of fog in the Namib-region contributes to a deeper understanding of fog processes and fog-related ecosystems and thus is of great ecological and socio-economic interest.
The central aim of our study is to understand processes controlling the spatial and temporal development of coastal desert fog in the Namib by means of numerical simulations. Low stratus clouds form at the top of the marine boundary layer over the cold Benguela Current. These low clouds are advected overland by meso-scale circulations. The interaction of turbulent mixing with microphysical and advection processes in the formation, maintenance and dissipation of fog and low clouds in the Namib Desert imposes high requirements on the corresponding parametrizations.
Numerical simulations are performed with an extension of the regional weather prediction model COSMO (Consortium for Small-scale Modeling) which is adapted for the application in the Namib region. To account for microphysical processes involved in fog formation, the microphysical parametrization of the one-dimensional fog forecast model PAFOG (PArameterized FOG) has been implemented into COSMO. The resulting fog forecast model COSMO-PAFOG is run with kilometer-scale horizontal resolution.
In our study, individual case studies are analyzed with respect to their spatial extent as well as the dynamic, thermodynamic and microphysical processes yielding fog formation and dissipation. The model results are evaluated by satellite and ground observations obtained during the field campaign in September 2017 within the framework of the NaFoLiCA (Namib Fog Life Cycle Analysis) project.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-107

Visibility in the ACCESS NWP model

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Low visibility associated with fog at the aerodrome remains one of the major forecast challenges for aviation. Despite major improvements in Numerical Weather Prediction (NWP) models over the past decades, the local nature and complex interactions of fog continue to make it a challenging phenomenon to predict. The Bureau of Meteorology uses the Australian Community Climate and Earth-System Simulator (ACCESS) model to provide operational numerical weather prediction (NWP) guidance for fog forecasting. Visibility is a standard diagnostic output from the model, but the performance in Australia has been quite poor and the guidance has had limited value for forecast operations. The shortcomings in the predicted visibility are due to both the functioning of the diagnostic visibility scheme and to inaccuracies in the meteorological fields predicted by the NWP model. In this work, we isolate the visibility scheme from the model and perform a variety of sensitivity, tuning and trial experiments to better understand it's performance. Based on results from the experiments, values of configuration parameters that yield improved diagnoses of visibility within the scheme are suggested for implementation in Australia. Case studies are used to test the effects of these changes in the ACCESS NWP model, and to investigate other factors affecting the model performance such as the land surface scheme. Even though the ACCESS model generally simulates meteorological variables such as temperature, dewpoint temperature and wind quite well, high urban fractions in the land surface ancillaries can lead to an over forecast of afternoon and evening screen temperatures and the method used to estimate visibility is very sensitive to small variations in the temperature and moisture fields. Trial experiments of the visibility scheme have shown that it is difficult to produce consistently accurate predictions of visibility even when observations are used in place of NWP data. With the improvements, the performance of the visibility scheme can be maximised in terms of the equitable threat score for a specific threshold visibility distance and should provide useful forecast guidance for fog even with the noted limitations.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-109-1

Adaptation of computational model for prediction of dew formation in semi-arid conditions of Iran

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Artificially induced Dew formation could be an important secondary source of water, especially in semi-arid regions such as Iran. To characterize the amount of dew that could be collected in semi-arid region, we use a computationally efficient dew formation model. In this model, dew condenses on a condenser made with a horizontally aligned sheet; thermally insulated from the ground at a height of 2 m. The model valuate the powers involved in the heat exchange processes between the atmosphere and the condenser, for water or ice condensation. By doing iteration, The model algorithm integrates the prognostic equations for the mass and heat balance, describing in each step, the temperature of the condenser and the resulting condensation rate onto it. We run the model simulations for an urban (Tehran,1190 m asl) and coastal (Bandarabas, 10 m asl) area in Iran, using 10 years of meteorological reanalysis data as input. The model result shows a daily yield of dew of 0.07 mm and 0.13 mm, respectively for Tehran and Bandarabas. The highest daily yield rate is 0.55 mm in Tehran and 0.67 mm in Bandarabas. Dew fall is predicted during December–April in Tehran with an annual harvesting ∼26.44 mm. In contrast, the coastal region would experience dew formation during December–April and October–November with an annual harvesting ∼49 mm. This model is further used by combining data from 30 measurements stations (equipped with GAW stations) covering the whole domain of Iran during the last 38 years. The results of the model will be shown as well as potential place for dew collection panel installation.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
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An Improved Method for Assimilating MTSAT-Derived Humidity in Nowcasting Sea Fog over the Yellow Sea

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In our previous study, an extended three-dimensional variational data assimilation (3DVAR) method based on the Weather Research and Forecasting Model (WRF) was developed to assimilate satellite-derived humidity from sea fog at its initial stage over the Yellow Sea. The sea fog properties, including its horizontal distribution and thickness, are retrieved empirically from the infrared and visible cloud imageries of the Multifunctional Transport Satellite (MTSAT). Assuming a relative humidity of 100% in fog, the MTSAT-derived humidity is firstly converted to absolute humidity (e.g., water vapor), and then assimilated by the extended 3DVAR assimilation method. Assimilation of the MTSAT-derived humidity can greatly improve the sea fog forecast area, and the improvement is attributed to a more realistic representation of the marine boundary layer (MBL) and better descriptions of moisture profiles. However, the MBL moisture is often overestimated due to lack of the limitation of temperature information within and outside fog, resulting in overpredicted fog area. In this study, in order to decrease the bias of moisture overestimation, the assimilation method is improved by putting extra temperature profiles that are statistically determined for sea fog area. For a typical advection sea fog case in April 2008, the new method makes improvement on the ETS (Equitable Threat Score) of forecasted fog area by 35%, owing to larger hit area and smaller false area. Additional data assimilation experiments of 10 sea fog cases show that the new method gets the average bias and ETS improved by 16.2% and 16.9% relative to the previous method.

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-120

Sub-kilometre numerical weather prediction of fog events and the sensitivity to soil thermal conductivity.

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Despite its impact on human activity fog still remains a challenge for numerical weather prediction models to simulate accurately. To help overcome this challenge sub-kilometre scale models have been developed. Here, the performance of the Met Office Unified Model (MetUM) at three resolutions, 1.5km, 333m and 100m, is compared against observations from the recent Local and Non-Local Fog experiment (LANFEX). The LANFEX data provide the opportunity to assess the models' ability to form dew and deposit fog water, the vertical extent of the fog and the spatial variation of fog over the different valleys in two contrasting orographic regions, one a complex valley system and the other a more homogenous area. The results show that increasing the horizontal resolution reduces the depth of fogs but this does not necessarily compare well with the observations. The horizontal variation of the fog at the shallow and wide valley site is not improved by the increased resolution but the sub-kilometre scale models are more accurate in terms of the spatial variation of fog in the complex valley region. A comparison of soil temperature indicates the model transfers heat too readily to the surface erroneously preventing fog from forming. Sensitivity tests show the specification of soil thermal conductivity can lead to as much as a 5 hour delay in the formation of fog. These results highlight the potential sub-kilometre models have to forecast fog but continued work on the development and implementation of parametrizations such as soil conductivity and dew deposition at these resolutions is needed.

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An operational forecasting system of radiation fog in an arid region using the WRF model

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We run an operational setup of the WRF model as part of a research project in order to forecast next day fog events over the United Arab Emirates. Fog is a winter time phenomenon in the region that causes a decrease in visibility and has major adverse effects on road transport networks and aviation operations. We use a threshold method with modifications to create a fog probability field from model results. Here, we describe our system and how the thresholds are calculated from observations. We include a probability function which indicates proximity of forecast to the threshold values. The final “fog” product is then verified against a satellite product to assess its performance on fog days. Bias in the model is identified and shown to be linked to the land surface parametrisation schemes and the characterisation of the desert land surface.

Results show that the fog probability performs well on fog days with a POD of 0.7 to 1. However it also highlights some deficiencies within the model that include the following. 1.) Sensitivity to cooling rate, which is an important factor to consider when simulating radiation fog. A sensitivity test to the cooling rate is assessed and presented. This is achieved by modifying the land surface parametrization within WRF. 2.) The treatment of the desert as a uniform land use land cover type. The desert surface is diverse and oversimplified within WRF. Sensitivity to surface characteristics such as soil texture and surface roughness are explored and presented. Lastly we present some ongoing and future investigations.

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WRF model performance & challenges to predict fog events during the WIFEX field campaign at IGI Airport, New Delhi, India

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Abstract:
Context-Every winter, from November to February, the extended periods of dense fog affect lives of people living in the New Delhi metro area in India. The winter fog frequently reduces the visibility to a few meters, which causes fatalities from road accidents and significant economic losses via cancellation/delay of road, rail and air transport. WInter Fog Experiment (WIFEX) was conducted during 2015-2018 winter seasons (November to February) at Indira Gandhi International Airport (IGIA) India. Meteorological data were collected with a 20m micrometeorological tower, Radiometer, sodar, and radio-sondings.
Methods-To support WIFEX field campaign during 2016-17 and 2017-18 seasons, Weather Research and Forecasting (WRF) model was used to predict fog. The collected data set from the 20m mass tower, Radiometer and Radio-sonde were used to evaluate the model results during different visibility (Vis) conditions (moderate Vis <500m, Dense fog Vis <200m) in which airport operations can't hamper.
Results- This paper provides the model performance and its challenges for different visibility conditions during the WIFEX 2016-17 & 2017-18 seasons. Even though the model predicted most of the fog events, it shows difficulty in predicting accurate fog onset (in terms of liquid water content). Out of 40 moderate fog episodes model predicted 16 fog events and out of 44 dense fog events it captured 33. The model forecast also captured the deepest part of fog layer (when the Vis < 50m), low-level temperature inversion and moisture nicely during the most of the fog events. For the failed fog events it was found model has a dry bias for moisture which is coming from the initial condition.
Interpretation- Validation results with the WRF model and WIFEX observational site data suggesting that the WRF model shown 04 hours early onset and this bias may be due to the misrepresentation of different processes in which conditions fog forms. It is also noted that fog forecasting is very challenging to the present NWP models (in terms of horizontal and vertical spread).
Conclusion- Overall WRF model forecast for the national capital region (NCR) New Delhi, India, especially for airport operations, it was found reasonable results which can improve in future by using the observational data into the model.

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Status of Sea Fog Research in Fujian Province and Taiwan Strait

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The sea fog disaster in Taiwan Strait, which is a foggy traffic artery, often leads to personnel and property losses. There's many mountains and long coastline in Fujian Providence, and fog is one of the natural disasters. This review covers the main achievements of sea fog in the western side of Taiwan Strait and makes a comparison with sea fog research progress in other sea areas, mainly including sea fog synoptic and climatic characteristics, monitoring means, the microphysics and numerical prediction research. The results show that some achievements have been made in terms of sea fog synoptic climatology in the western side of Taiwan Strait. With the development of science and technology, the monitoring method is constantly improving, but the inversion of satellite remote sensing monitoring results still needs further study. The study on micro-physical characteristics of sea fog helps to improve the sea fog model and the retrieval technology of satellite remote sensing sea fog, so it will be the next research focus in the western side of Taiwan Strait. Fujian province meteorological observatory has developed visibility prediction rely on high resolution model and fog probability forecast products rely on ensemble forecast, now they have been used in daily business. But the numerical simulation of sea fog in Taiwan Strait is less, the sea fog formation mechanism is unknown. With the continuous improvement of observation technology and dynamic statistical method, the sea fog forecast ability in Taiwan Strait can be improved by combining the numerical prediction products with traditional synoptic method.

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Taipei, Taiwan, 14–19 July 2019
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Assimilation of wind from AMDAR into the one dimensional fog forecasting model COBEL

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As poor visibility conditions have a considerable influence on airport traffic, a need exists for accurate and updated fog and low cloud forecasts. COBEL-ISBA, a boundary layer 1D numerical model, has been developed for the very short term forecast of fog and low clouds. This forecast system assimilates (using 1D-Var method) the information from a local observation system designed to provide details on the state of the surface boundary layer, as well as that of the fog and low-cloud layers, to produce initial profiles of temperature and specific humidity. The initial conditions have a great impact on the skill of the forecast. The impact of assimilation of high temporal resolution of wind observation from aircraft measurements, on short-range numerical weather forecasting (up to 12 hours) using the one dimensional fog forecasting model COBEL is studied in the present work. The wind observations are extracted at Nouasseur airport, Casablanca, Morocco, over a winter period from the national meteorological database. It is the first time that wind profiles (up to 1300 m) are assimilated in the framework of single column model. When assimilated into COBEL with an hourly update cycle, the wind field is better for now-casting purposes. The assimilation system estimates the flow-dependent background covariances for each run of the model and takes the cross-correlations between temperature, humidity and wind into account. It is found a positive impact of wind assimilation in the first hours of the forecast and then its impact gradually turns into a neutral impact. Thus, assimilation of high resolution wind observations from AMDAR is beneficial for now-casting and short-range fog forecasts up to three hours.

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Valleys fog events: relative importance of local and non-local processes during radiative/advective fog formation

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In regions of complex terrain, during nightime stable conditions, important heterogeneities on temperature and dynamics could be found between valleys and surrounding elevated areas. Furthermore, thermally driven circulations, such as drainage flows, can lead to modifications on valley thermodynamical conditions, highly variable in time and space and depending on valley geometry. This study proposes to investigate the effect of such circulations on valley fog formation according to different valley configurations during the LANFEX campaign (Price et al., 2018).

In this way, observations from the LANFEX campaign were used in addition with the numerical approach using the Meso-NH research model (Lac et al., 2018). Sites situated in valleys with different geometries have been widely instrumented in order to understand why a same airmass could lead to different fog behaviours, or the absence of fog, from a valley to another one. The present study focuses on the IOP 12 of LANFEX, where a stratocumulus passage during the night gives the opportunity to study two formation stages. The numerical modelling consists in a 100-m resolution simulation with a nested downscaling approach from the AROME operational model, and uses a 2 moment microphysics with a prognostic representation of a multimodal aerosol population (Vié et al., 2016). It aims to analyze local and non-local contributions to fog formations in the different valleys.

The model succeeds to reproduce the occurrence of fog before and after the cloudy interlude and the differences between sites. Important features, such as drainage flow in narrow valleys and associated thermodynamical characteristics, are well represented. It appears that the fog forms through local processes (i.e. condensation) across narrow valleys floor, and is partially balanced by non-local processes (i.e. advection) within drainage flow. Such balance is variable depending on the valley geometry : basins are likely to experiment denser fog through a prevalence of local formation and reduced non-local destruction, while lateral contraction induces a balance between advection and local contribution. Advective fog events occur at basin apertures when basin fog overflows downstream in the valley, associated with a strenghtening of valley circulation because of the valley narrowing. The largest valleys, opened to tributary valleys and surrounding plains, are subjected to numerous circulations with different impacts on fog conditions, more complex than in narrow valleys. Even if both local and non-local processes in the largest valleys are favorable to the fastest fog growth, subtle interactions between different flows with different origins lead to modulate the fog behaviour which is highly variable from an event to another one.

Lastly, a sensitivity test is conducted between 2-moment and 1-moment microphysical schemes and shows a positive impact of the 2-moment approach when the radiative impact of the droplet concentration is taken into account.

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Taipei, Taiwan, 14–19 July 2019
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Large eddy simulation of radiation fog: impact of microphysics on the fog life cycle

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Large eddy simulations (LESs) of a radiation fog event occurring during the ParisFog experiment at the SIRTA (Site Instrumental de Recherche par Télédétection Atmosphérique) observatory are studied with a view to analyse the impact of the microphysics on the fog life cycle.

A first LES of this case, presented in Mazoyer et al. (2017), performed with the Meso-NH model (Lac et al., 2018) at a resolution of 5 m horizontally and 1 m vertically with a 2-moment microphysical scheme, includes the drag effect of a tree barrier and the deposition of droplets on vegetation. The model showed good agreement with measurements of near-surface dynamic and thermodynamic parameters and liquid water path. The blocking effect of the trees induced elevated fog formation, as actually observed, and horizontal heterogeneities during the formation. Deposition was found to exert the most significant impact on fog prediction as it not only erodes the fog near the surface but also modifies the fog life cycle and induces vertical heterogeneities. A comparison with the 2m horizontal resolution simulation reveals small differences, meaning that grid convergence is achieved. But the simulation overestimated significantly cloud droplet concentration and mixing ratio near the ground compared to the observation as is often the case in the models.

Therefore new tests have been conducted with the updated LIMA (Liquid Ice Multiple Aerosols) 2-moment microphysical scheme (Vié et al., 2016). Additionally, considering that the diagnostic maximum supersaturation may be partly responsible for the overestimation of droplet concentration, the pseudo-prognostic supersaturation scheme proposed by Thouron et al. (2012) is tested in order to mitigate cloud condensation nuclei activation. An aerosol sensitivity study on the fog life cycle is finally conducted.

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Taipei, Taiwan, 14–19 July 2019
IFDA2019-160

The recent improvement and progress in operational visibility forecast at NCEP

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Fog/low visibility is a high impact weather to aviation, ocean and ground transportation but more difficult to predict than other types of weather due to its complexity in model physical parameterizations. Tremendous efforts in fog prediction have been made in the past decades, but most of them are focused on fog simulation instead of fog's operational forecast. An obvious hurdle for fog operational prediction is that the micro-physical scheme in the current operation models is not specific for fog but for high level clouds and precipitation. Fog is still not an official forecast guidance at National Centers for Environmental Prediction (NCEP) of NOAA. As a result, forecasters are just using low visibility as an agent to predict fog which is diagnosed from model post processor. The performance of low visibility forecast from various operational models at NCEP is still low, much lower than other predictions such as precipitation from the same models a decade ago (Zhou, et al 2011). Since then a lot of efforts have been dedicated to improving the visibility operational forecast at NCEP, including continuous increase in model resolution, tuning of visibility algorithm in the post processor, and improvement in analysis and observational data for visibility verification. This paper will present a brief summary of the these efforts and how much the skill improvement has been achieved after these efforts: (1) the overall Equitable Threat Score (ETC) of low visibility (<1000m) forecast from various models at NCEP has been raised from 5% 10 years ago to currently 10% (2) NCEP's high resolution rapid refresh model HRRR (5km) is more skillful than its lower resolution rapid refresh model RAP (13km), (3) the ETS of low visibility forecast from HRRR already reach 30% which is at same level as precipitation forecast at NCEP, (4) the modified visibility algorithm is also credited for the improvement of visibility prediction.
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Spring Fog over Taiwan Strait: Formation and Model Prediction Capability

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Fog is a low-level stratus cloud with dense water or ice droplets which can reduce visibility and affect the air, marine, and land transportations and cause huge economic losses. The prediction of fog in global and regional models is still a challenge since its formation and dispersion depend on the complex interactions among thermodynamics, dynamics, and microphysical processes. The East China Sea accommodates intense human activities, but the air and marine transportations are frequently influenced by fog events especially in late winter and spring. Although some studies have addressed the modeling capability of fog simulation over the Yellow Sea, scare studies focus on the Taiwan Strait, which hosts busy marine and airborne transportations. In this study, a two-moment mixed-phase bulkwater cloud microphysical parameterization (NTU1) incorporated into the NCAR Weather Research and Forecasting (WRF) model was used to understand the fog formation processes and tested for fog prediction. Fog events during the spring of 2010-2012 were simulated, and the results were evaluated with visibility observation from the coastal meteorological stations. Simulations of fog events using different microphysical schemes showed that the NTU1 scheme obtained higher TS and POD scores, however, it also showed slightly over-forecast. All microphysical schemes that tested performed relatively well at Kinmen, but failed to simulate fog formation at Matsu and Pengjiayu in some cases. A notable difference among different microphysical schemes can be found in cloud number concentration and the particle size. Compared with the MODIS effective radius, the RMSD predicted by MYJ and NTU1 schemes are smaller than predicted by WDM6 and Morrison schemes. The correlation between simulated and MODIS cloud optical thicknesses were about 0.5 for MYJ, WDM6 and Morrison schemes, but over 0.8 when using the NTU1 scheme. The POD of all schemes is lower than 0.3.

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IFDA2019-178

Atmospheric Model Evaluation with Observation Data for Persistent Fog Prediction in the Lower Region of the Himalayas

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Persistent fog is the issue that affect the life of people in Southern Nepal in winter these recent years, and the Atmospheric Modelling System, set up at International Centre for Integrated Mountain Development (ICIMOD) Headquarters in Kathmandu, Nepal, is used for making the assessment with an attempt to forecast the event during December. The Weather Research and Forecasting with Chemistry (WRF-Chem) model has been implemented over a regional domain stretching across 5000 x 4500 km centred at Kathmandu. Meteorological data from routine observation from 4 stations in the Terai are compared with meteorological output of the WRF simulation for the December time period at high horizontal resolution (1 km $\times$ 1 km), which is achieved by nesting the domain of interest, e.g. Kathmandu Valley, inside three coarser domains. Model evaluation is performed against these field data with the challenge of capturing the necessary atmospheric processes relating to persistent fog events in December 2013 and 2014. In 2014, the persistent fog events in December were likely happening on3 consecutive days at Biratnagar; 3 consecutive days and a week during December 23 – 30 at Bhairahawa; 5 intervals of the foggy day at Simara, and 5 intervals of two consecutive foggy days at Nepalgunj. It is clearly shown that, at Biratnagar, the dew-point temperatures were well predicted only on the 1st of December, while those were with much discrepancy between the observed and modeled ones, particularly on the foggy days. The dew-point temperatures were also poorly predicted at Bhairahawa except during December 13-15, 2014, when the Domain 2 output made a closer prediction to the observation. Note that observation, particularly for dew-point temperatures are very sparse with not only made 3-hourly during the day-time (0 – 12 UT, i.e. 05:45 – 17:45 LT), same like the ambient air temperatures, but also missing for one or two hours on some day. Therefore, it is quite challenging to actually observe the foggy hours by the standard meteorological method, during the most critical time.
Overall, the WRF meteorological model has a tendency to underestimate the temperatures in the Terai region.
Improved meteorological prediction will allow us to provide crucial information needed for mitigation and adaptation strategies. Better simulation of the atmospheric processes in the WRF modelling that when coupling chemical transport models will be able to provide more accurate prediction that may give warning that lead to mitigation actions that will reduce impact of the air pollution to the events and thus far the public across the affected area of the Himalaya region.