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Analysis of Meteorological Conditions for a Sea Fog Process in 2016

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Abstract

The visibility characteristics and meteorological conditions of a sea fog process on 27th February, 2016 are analyzed and the heavy fog process is simulated by the Weather Research and Forecasting (WRF) model in this paper. The forecast results show that the visibility in Qingdao coastal area is light fog on the night of the 26th. In the WRF simulation, it can be observed from the sea-level pressure that the wind direction of Qingdao and the coastal area turned southerly with the eastward movement of the low pressure system on surface from 1200 UTC to 1800 UTC on the 26th. A large amount of water vapor brought by easterly and southerly wind provides sufficient water vapor conditions for the formation and development of the sea fog. At 975 hPa, there is a strong warm tongue over Shandong Peninsula at 0600 UTC on the 26th, while the offshore is affected by the cold tongue, where the horizontal temperature gradient is large and there is a strong baroclinicity. At 850 hPa, there is a weak warm ridge over Qingdao at 1200 UTC on the 26th, which means that it is an inversion layer, which is conducive to the maintenance of fog.

Keywords

Qingdao Offshore, Heavy Fog, WRF, Satellite Remote Sensing, Dual-Channel

1. Introduction

Sea fog is a weather phenomenon that occurs in the near land or water surface layer. After the occurrence of sea fog, the horizontal visibility of the sea surface is less than 1000 m, sometimes even less than 50 m, which brings great danger to the safety of ships sailing and is called "silent killer", so sea fog is known as the "silent killer" on the sea. According to the incomplete statistics of Qingdao Maritime Safety Administration, nearly 50% of ship collisions or grounding accidents are related to sea fog.

The systematic research on sea fog in China can be traced back to the 1960s, professor Wang Binhua accumulated more than 40 years of research results and published the world's first monograph on sea fog, called "sea fog".

There are five relatively foggy areas along the coast of China from south to North: the Leizhou Peninsula and the Qiongzhou Strait, Fujian coast area, Zhoushan Archipelago, sea area near Qingdao-ChaoLian Island and sea area near Chengshantou, the Yellow Sea includes two of them. In recent years, the research on the distribution characteristics and formation conditions of sea fog over the Yellow Sea has been paid attention by scholars.

The maximum frequency of sea fog is from 4 am to 10 am every day, followed by 20 pm to 3 am the next day. Gao *et al.* used a mesoscale model to simulate a sea fog case [1]. With the enrichment of satellite data and the development of remote sensing technology, many scholars began to use remote sensing technology to identify and forecast fog over recent years. Hunt found that the emissivity of opaque clouds (such as fog, low cloud and ice cloud) is significantly different in the mid-infrared band and long wave infrared band [2]. On this basis, Eyer *et al.* used AVHRR/NOAA brightness temperature difference between mid-infrared band and long wave infrared band to identify fog/low cloud at night [3]. After that, Turner *et al.*, Bendix *et al.*, Reudenbach and Bendix continuously tried and applied, and formed a method called "dual-channel" which is widely used in meteorological operation to identify fog/low cloud at night [4] [5] [6]. Then, Zhang and Yi, Yi *et al.* used Dynamic Threshold to distinguish sea fog and low clouds [7] [8] [9].

With the rapid development of numerical forecast technology, by adding fog diagnosis algorithm in the post-processing module of numerical model, China has initially established the Sea Fog Numerical Prediction System for the Yellow Sea, Bohai Sea and coastal region in the East China, which provides technical support for sea fog forecast in coastal areas. This paper will analyze the meteorological conditions of the sea fog process which occurred on February 27th, 2016 through the analysis and numerical simulation. The purpose of this paper is to enrich the research cases of sea fog along the coast of Qingdao and improve the operational forecasting ability of sea fog

2. Data and Methods

The Weather Research and Forecasting (WRF) model is used to examine the physical processes involved in the fog event. The center of domains is at (116˚E, 39˚N). The entire grid system has 46 vertical layers in η coordinates. The main physical options of the models are shown in **Table 1**. The time step is 120 s. The reanalysis data from FNL and SST product from EAR-GOOS are used as the initial and boundary conditions.

Routine weather data (eight times daily) and GPS soundings (two times daily) are provided by Qingdao Meteorological Administration. The visibility is obtained from an automatic weather station (ATWS) in Qingdao with the sampling interval in 10 minutes.

3. Observations

Figure 1 shows the visibility from 2000 LST 26th to 0800 LST 27th, as shown in this Figure, The visibility dropped significantly form 2000 LST to 2200 LST 26th February. Especially, the visibility reduced most at the Daqiao4 station and dropped below 1000 m at other stations successively, which means a heavy fog occurred. In some periods, the visibility dropped below 100 m.

4. Weather Situation Analysis

From the sea level pressure field (Figure 2), it can be seen that from 1200 UTC on the 25th to 0000 UTC on the 26th, the Qingdao area was mainly affected by the inverted trough on the ground, and the wind direction changed from southerly to easterly. At 0600 UTC on the 26th, Qingdao was located in the northwest of the low pressure. The wind direction of the land on the west side of Qingdao is westerly, and the wind direction of the ocean on the east side of Qingdao is easterly.

Table 1. Specification of WRF modeling.

	Domain 1	Domain 2
Grid spacing (km)	30	10
Timesteps (s)	120	60
IC/BC	FNL and EAR-GOOS	Domain 1
Convection	Betts-Miller-Janjic	
Longwave Radiation	RRTMG	
Shortwave Radiation	RRTMG	
PBL	MYNN2	
Microphysics	Eta(Ferrier)	
Surface	Noah	

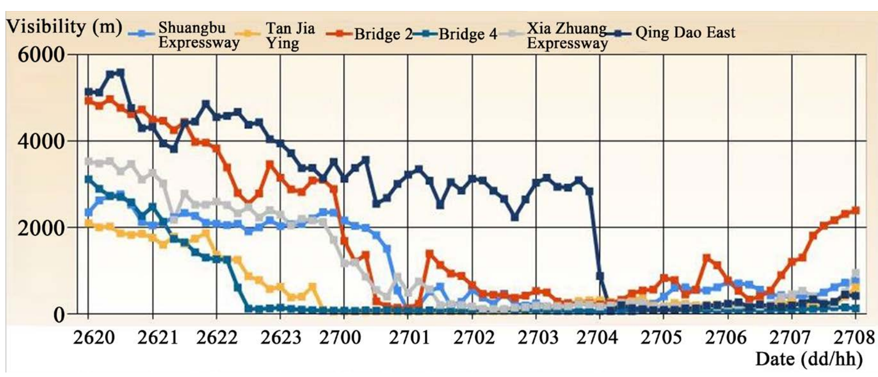

Figure 1. The time series of visibility from 2000 LST 26th to 0800 LST 27th FEB 2016.

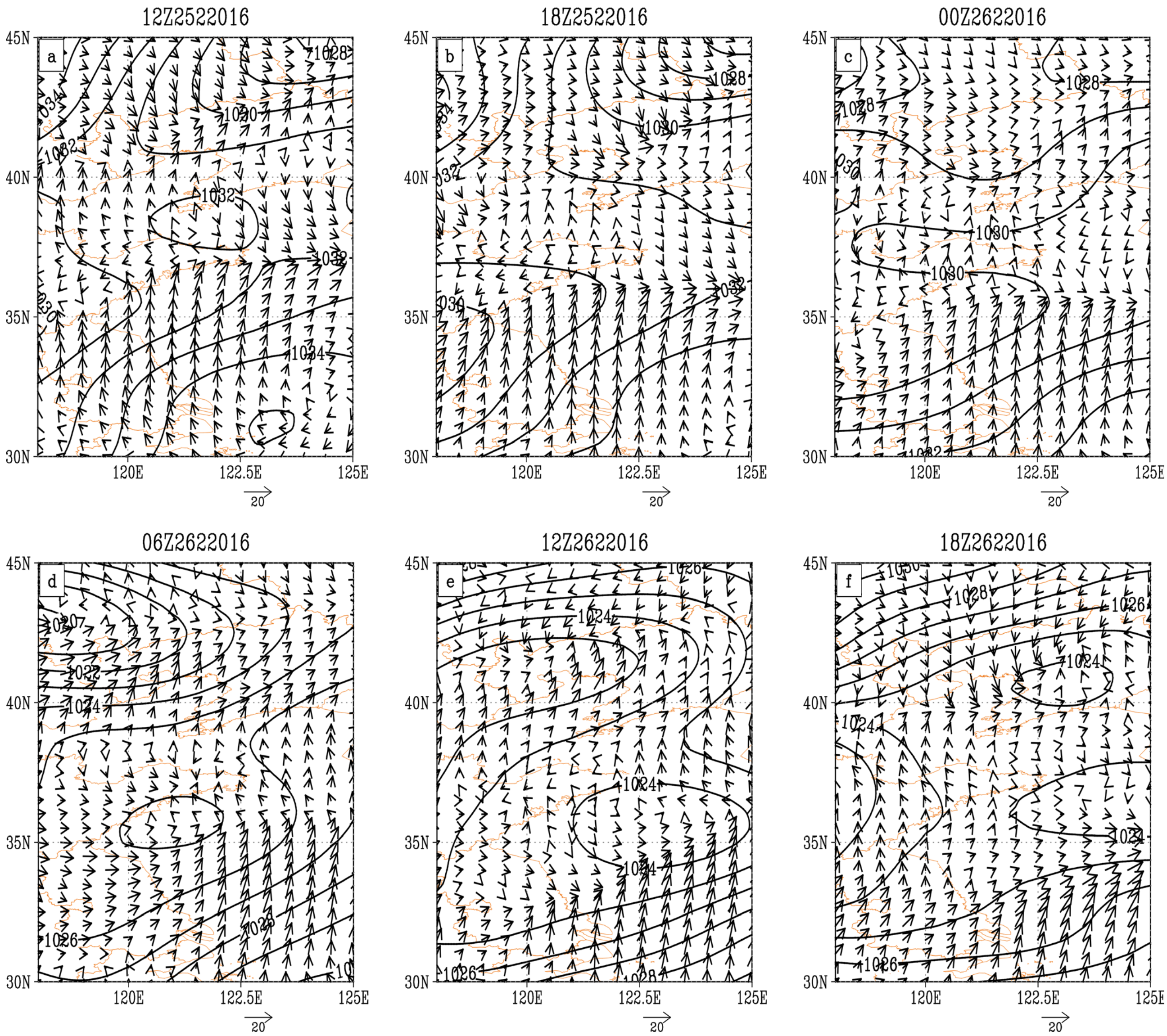

Figure 2. Sea level pressure field (solid line, 1 hPa interval) and 1000 hPa horizontal wind field (vector) (The red lines represent the land topography).

From 1200 UTC to 1800 UTC on the 26th, as the ground low pressure system moved eastward, the wind direction in Qingdao and adjacent sea areas turned to south. The easterly wind and the southerly wind carry a large amount of water vapor, and the water vapor conditions for the formation and development of sea fog are sufficient.

It can be seen from **Figure 3** that, except for 0000 UTC on the 26th, the isotherms of Qingdao and adjacent sea areas are relatively dense. From 1200 UTC on the 25th to 1800 UTC on the 26th, the area has been affected by warm advection and the warm advection is strong except for 1200 UTC on the 26th. At 1200 and 1800 UTC on the 25th, 1200 UTC on the 26th, there was a weak warm tongue in Qingdao offshore. At 0600 UTC on the 26th, there was a strong warm tongue over the Shandong Peninsula, while the coastal waters were affected by the cold

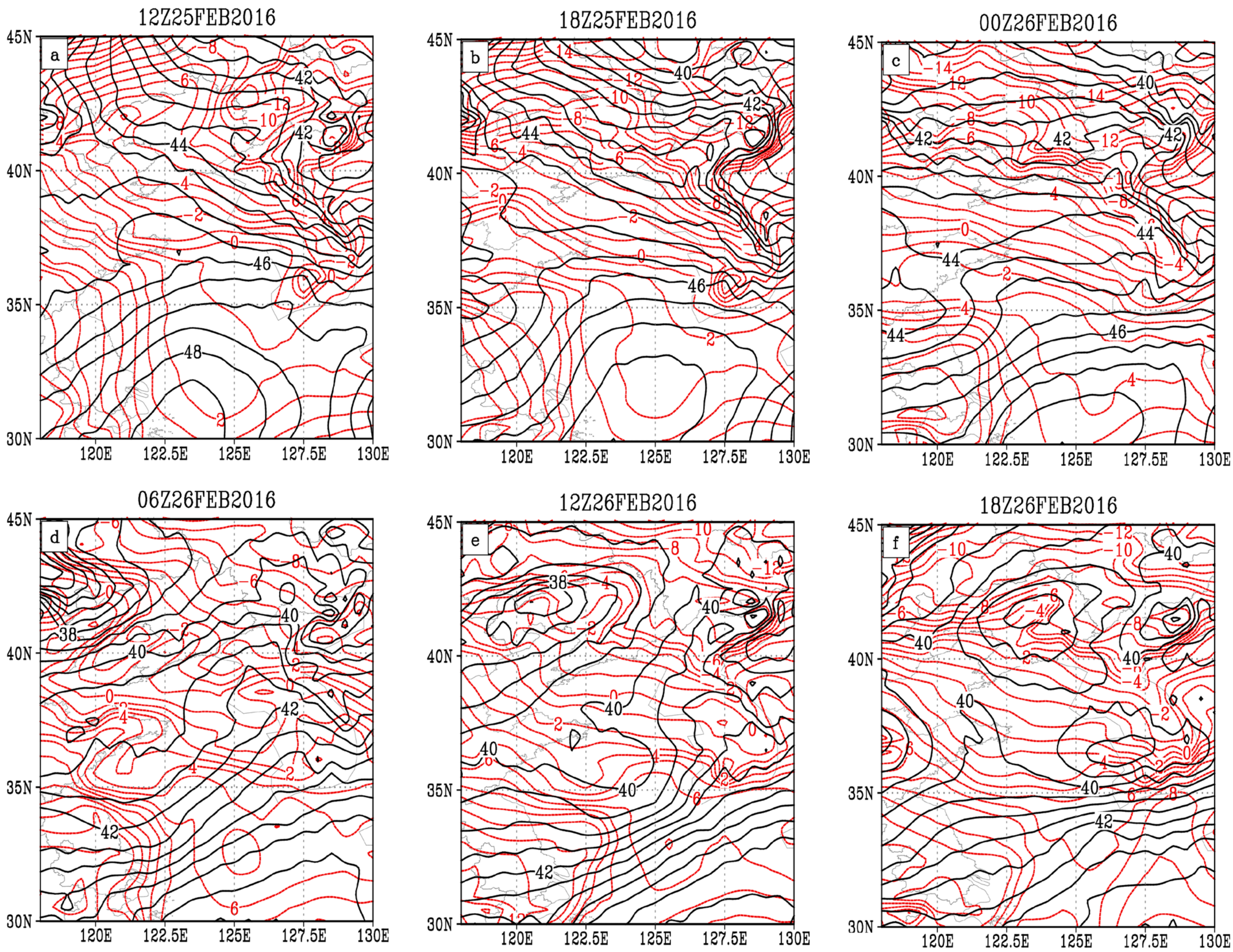

Figure 3. 975 hPa weather chart. The black line is the geopotential height (interval 5 gpm), the red line is the temperature (interval 1˚C).

tongue, where the horizontal temperature gradient was large, and there was strong baroclinicity.

Except for 0600 UTC on the 26th, there has been warm advection over Qingdao (picture omitted). From 1200 UTC on the 25th to 0000 UTC on the 26th, the warm tongue is located in the Yellow Sea and is constantly moving eastward. A warm tongue was formed on the land west of Qingdao at 0000 UTC on the 26th, and a strong warm tongue was present over the Shandong Peninsula at 0600 UTC on the 26th, while a cold tongue was seen offshore. The formation of this inversion layer was a favorable condition for the development of fog.

It can be seen that the isotherms of Qingdao and adjacent sea areas are relatively dense. There has always been a warm advection over Qingdao. This provides favorable conditions for the development of sea fog to form an inversion layer. There are weak warm ridges over Qingdao from 12 UTC on the 25th to 00 UTC on the 26th and 12 UTC on the 26th, which means that there is still a weak temperature inversion here, which is conducive to the maintenance of fog. This feature still exists at levels below 850 hPa and the warm ridge is more pronounced

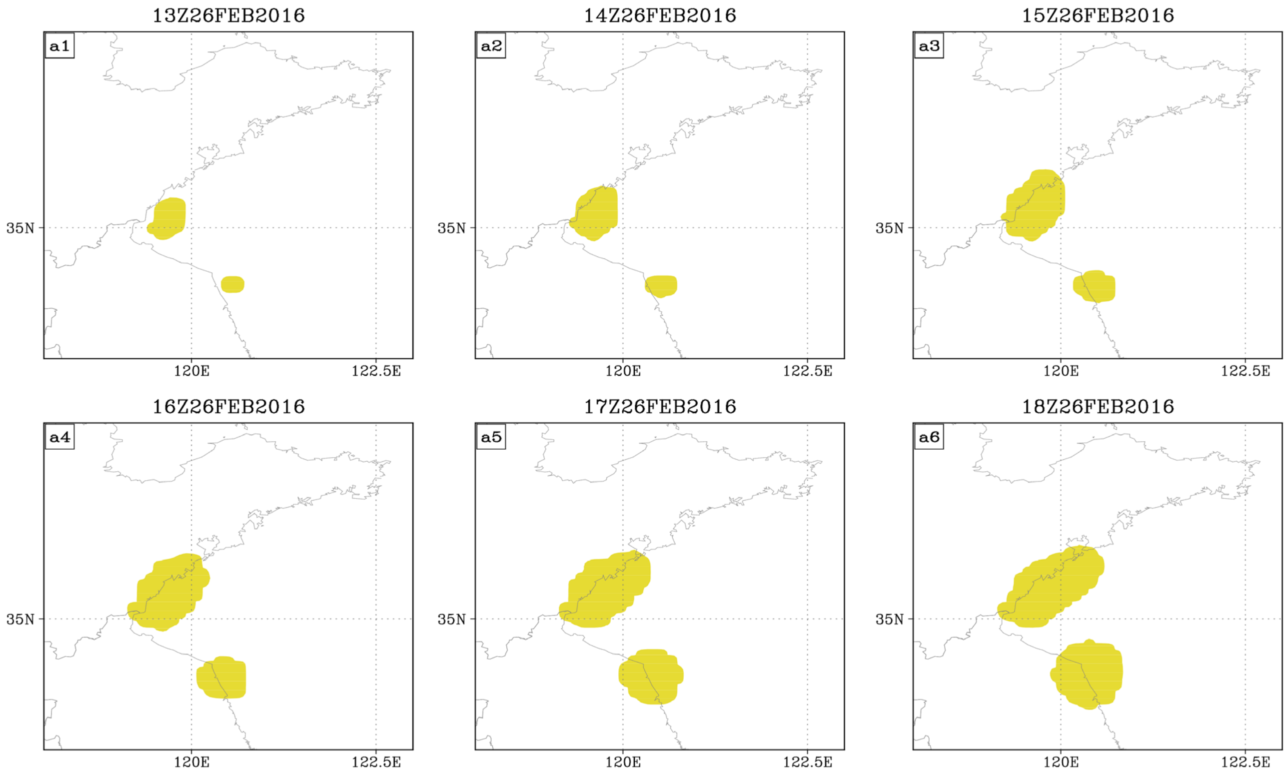

Figure 4. Cloud-water mixing ratio distribution map. The filling is greater than 0.016 g/kg.

than 850 hPa. The schematic diagram of cloud-water mixing ratio (**Figure 4**) shows that the foggy area extends from southwest to northeast.

5. Summary

It can be seen from the sea level pressure field that from 1200 UTC to 1800 UTC on the 26th, with the eastward movement of the surface low pressure system, the wind direction of Qingdao and its adjacent coastal areas turned southerly. The easterly and southerly winds bring a lot of water vapor, which provides sufficient water vapor conditions for the formation and development of sea fog.

6. Discussion

At 975 hPa, there is a strong warm tongue over Shandong Peninsula at 0600 UTC on the 26th, while the offshore is affected by the cold tongue, where the horizontal temperature gradient is large and there is a strong baroclinicity. At 850 hPa, there is a weak warm ridge over Qingdao at 1200 UTC on the 26th, which means that it is an inversion layer, which is conducive to the maintenance of fog.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Gao, S.H., Wu, W., Zhu, L., *et al.* (2009) Detection of Nighttime Sea Fog/Stratus over the Huanghai Sea Using MTSAT-1Rdata. *Acta Oceanol Sincia,* **28**, 23-35.

[2] Hunt, G.E. (1973) Radiative Properties of Terrestrial Clouds at Visible and Infra-Red Thermal Window Wavelengths. *Quarterly Journal of the Royal Meteorological Society*, **99**, 346-369. https://doi.org/10.1002/qj.49709942013

[3] Eyre, J.R., Brownscombe, J.L. and Allam, R.J. (1984) Detection of Fog at Night Using Advanced Very High Resolution Radiometer (AVHRR) Imagery. *Meteorology Magazine,* **113**, 266-271.

[4] Turner, J., Allama, R.J. and Maine, D.R. (1986) A Case Study of the Detection of Fog at Night Using Channels 3 and 4 on the Advanced Very High Resolution Radiometer (AVHRR). *Meteorology Magazine*, **115**, 285-297.

[5] Bendix, J. (2002) A Satellite-Based Climatology of Fog and Low-Level Stratus in Germany and Adjacent Areas. *Atmosphere Research,* **64**, 3-18. https://doi.org/10.1016/S0169-8095(02)00075-3

[6] Reudenbach, C.H. and Bendix, J. (1998) Experiments with a Straightforward Model for the Spatial Forecast of Fog/Low Stratus Clearance Based on Multi-Source Data. *Meteorological Applications*, **5**, 205-216. https://doi.org/10.1017/S1350482798000814

[7] Zhang, S.P. and Yi, L. (2013) A Comprehensive Dynamic Threshold Algorithm for Daytime Sea Fog Retrieval over the Chinese Adjacent Seas. *Pure and Applied Geophysics,* **170**, 1931-1944. https://doi.org/10.1007/s00024-013-0641-6

[8] Yi, L., Zhang, S.P., Thies, B., Shi, X.M., Trachte, K. and Bendix, J. (2015) Spatio-Temporal Detection of Fog and Low Stratus Top Heights over the Yellow Sea with Geostationary Satellite Data as a Precondition for Ground Fog Detection: A feasibility Study. *Atmospheric Research,* **151**, 212-223. https://doi.org/10.1016/j.atmosres.2014.03.020

[9] Yi, L., Thies, B., Zhang, S.P., Shi, X.M. and Bendix, J. (2016) Optical Thickness and Effective Radius Retrievals of Low Stratus and Fog from MTSAT Daytime Data as a Prerequisite for Yellow Sea fog Detection. *Remote Sensing,* **8**, 8. https://doi.org/10.3390/rs8010008