N000142112296 : Fatima: Fog and turbulence interactions in the marine atmosphere

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Major Goals

In the long term, Fatima [MURI] project seeks transformative leaps in fundamental knowledge as well as prediction and detection capabilities of fog. The project particularly focuses on marine fog, on which significant knowledge gaps and data paucity exist and current and emerging applications abound. In particular, the emphasis is on Marine Sea Fog that forms over shallow seas and shelves. Coastal Ice Fog is also of interest. The approach is multi-faceted, and includes theoretical analysis, process studies via novel high-resolution numerical and laboratory simulations, extensive field measurements, and numerical weather prediction (NWP) modeling. Fatima draws expertise from a multidisciplinary group of researchers covering a scale continuum from large weather systems (synoptic) to fog droplets of micrometer scales that grow on aerosols of nanoscales (microphysical).

The overall goals are to: (i) deploy leading-edge instrumentation and novel measurements techniques in field campaigns to probe from synoptic to microphysical scales, including the capture of (smallest) scales of atmospheric turbulence where momentum, temperature and moisture fluctuations dissipate and, together with physicochemical properties of aerosols, control the droplet growth; (ii) conduct theoretical and numerical analyses that push the frontiers of multi-phase turbulence, especially nonlinear interactions between fog droplets and turbulence; (iii) elicit earth-surface processes that dictate fog genesis and cause vivid differences between fog and low-level clouds; (iv) identify deficiencies of fog microphysical parameterizations in NWP models and implement improvements; and (v) understand and model fog and turbulence impacts on optical propagation. Different participants focus on specific aspects that form the building blocks of understanding and prediction of fog life cycle in the overall framework of multiscale-flow (synoptic to turbulence cascade), microphysical (dissipating turbulence, drops), physicochemical (aerosol transformations) and thermodynamical (radiation, heat exchange) processes.

The project included two one-month field campaigns at Grand Banks (Fatima-GB, 2022) and Yellow Sea (Fatima-YS, 2023), which have been identified as two non-polar global fog maxima having different fog formation mechanisms. Both campaigns were successfully completed, with deployment of research vessels and capitalizing on fixed operational platforms of Fatima international partners. They included: (i) Sable Island in the outer Canadian Atlantic Shelf, in collaboration with MEOPAR (Marine Environmental Observation, Prediction and Response), a Canadian National Network of Strategic Science; and (ii) Korea Ocean Research Stations (KORS) in the Yellow Sea, in the EEZ of the Republic of Korea (ROK), in collaboration with the Korea Institute of Ocean Science and Technology (KIOST). Multitude of point, profiling and remote sensors pooled from Fatima participants conducted measurements across fog-relevant space-time scales.

University of Notre Dame (UND) with H.J.S. Fernando as the PI (and senior personnel D. Richter and I. Gultepe) leads the project by organizing field campaigns and facilitating the research conducted by co-PIs and partners. The Co-PIs are from the Naval Postgraduate School (NPS, PI: Qing Wang), University of California, San Diego and Scripps Institution of Oceanography (UCSD, PI: Clive Dorman); University of Utah (UU, PI: Eric Pardyjak) and University of Minnesota (UM, PI: Lian Shen). A large number of US and international collaborators funded through other sources are participating in and immensely contributing to the program. They are listed in the project website (https://efmlab.nd.edu/research/Fatima/).

UND PI deployed extensive instrumentation in Fatima-GB and FY-YS, probing from synoptic to Kolmogorov and Obukhov-Corrsin scales. The goal was to capture the nonlinear cascading of properties from synoptic to dissipative scales, develop a general framework for fog-turbulence interactions and construct physics-based parameterizations. They are also delving into special cases of fog lifecycle that have not been studied hitherto. UND also utilizes high-resolution simulations to investigate interactions between aerosol and droplet microphysics with atmospheric boundary layer turbulence. The main numerical tool is a Lagrangian Cloud Model (LCM), coupled with Large Eddy Simulations (LES-LCM). Some examples are the role of droplet collision-coalescence during the activation, role of vertical gradients of mean aerosol composition, droplet settling tendencies and the transition to drizzle, and the effects of heterogeneous mixtures of CCN size and composition. During the 2024 FY, UND conducted field data analysis, simulations and preparations for the 2026 ice fog experiment.

The goals of NPS co-PI are two-fold: (i) to understand physical and terrestrial processes affecting fog evolution, and (ii) to identify microphysical and turbulence parameters affecting optical attenuation to develop more effective parameterizations of attenuation and scintillation of optical signals through fog. The first goal seeks innovative and extensive field deployments and in-depth analyses of observational data in synergy with complementary observations obtained by other Fatima collaborators. The second goal addresses the impacts of fog on important applications such as high-energy lasers and free-space optical communications due to beam attenuation and scatter. Existing parameterizations for Meteorological Optical Range (MOR) or Visibility are examined using data from both campaigns. During the past FY, the NPS Group continued to conduct quality control and field data analysis from both field campaigns.

The UM group addresses how ocean surface processes such as wave-breaking, Sea Surface Temperature (SST), momentum, sensible and latent heat fluxes, along with coastal and island land topography, collectively affect marine fog. UM addresses this question by using LES and direct numerical simulations (DNS). They also use an LCM to simulate fog, with evaporation and condensation of sea spray included and fog droplets modeled via Kohler theory. A radiation model accounts for long-wave and short-wave radiation effects on marine fog. The UM Group also has accounted for the effects of large-scale dynamics (LSD) by adding several terms to the LES governing equations. This integrated approach provides a tool for comprehensive understanding of the fog lifecycle. Furthermore, in the LES, the effects of coastal and land topographies have been added by using an advanced implementation of the immersed boundary method (IBM) that captures complex land geometry in the simulations and study its effect on the velocity, temperature, and humidity fields. The UM group plans to combine this fog model with simulations of moist air, while resolving wave breaking and sea-spray generation.

The UU group continues to analyze Fatima-GB campaign data, for which they play a major role in instrumenting the Sable Island. In the Fatima-YS campaign, they deployed in-house developed liquid water content (LWC) measuring instruments. The UU group emphasizes understanding of the roles of radiative heating and cooling, droplet thermodynamics, vertical profiles of microphysical parameters, dissipative processes, and infrared beam propagation through the fog.

The PI from the UCSD leads the climatological analysis component, in particular, conduct studies on how synoptic scales drive fog formation through cascading of momentum, temperature and water vapor inhomogeneities. Together with Naval Research Laboratory (NRL), UCSD played a leading role in providing forecasting support for field studies and providing climatological perspectives during data analyses by different groups. During the past year, UCSD group investigated how collusion of different synoptic systems provides a strong trigger for fog formation.

Accomplishments Under Goals

Detailed accomplishments were presented in the “Third In-Person Fatima Review” held in Jeju Island, Korea, hosted by the National Institute of Meteorological Sciences (ROK), KIOST, GeoSystem Research Corporation and UND. A Photo of attendees is in Figure 1 of the attachment, and for presentations see: https://efmlab.nd.edu/research/fatima/workshops-meetings/. Vignettes of [PIs] accomplishments are listed below: (1) In the newly developed LSD-LES-LCM (L3) framework, advective and subsidence tendencies of large scales are incorporated into the LES equations, while simulations are ‘nudged’ towards the LSD mean state. The LES is coupled with the LCM, enabling a more realistic representation of fog microphysics. Field observations, ERA5 Reanalysis, and COAMPS simulations derive initial conditions for LES and LSD. A L3 simulation for the fog event on13 July 2022 on SI during FATIMA-GB (Fig. 2) agreed well with field observations (UM). (2) An unstructured triangular mesh of IBM and Lidar elevation data generated a highly detailed topographic map for LES simulations. The use of periodic boundary conditions is unrealistic with inclusion of topography, and hence inlet-outlet boundary conditions were used. Simulating well-developed marine fog upstream of SI using the inlet-outlet approach demands an extensive domain and high computational costs, which was allayed by coupling the periodic and topographic simulations. The combined approach improved air-temperature simulations over the ocean and land, showing good agreement with experimental data (Figs. 3 and 4) (UM). (3) The LES-LCM model under refinement at UND was configured to capture microphysics of local sea salt generation vis-à-vis background aerosols. Sea salt aerosols are often quite large with large critical radii, and thus rapidly produce fog. Sea-salt aerosols were introduced to LES-LCM via a realistic source function, and a numerical experiment is afoot (UND). (4) An auxiliary field study was conducted in Monterey, CA from 16 January – 1 March 2024, to study

the impacts of hydrometeors on EM wave propagation based on two scintillometers. It was a collaboration between UU, NRL, Air Space Integration Inc., Monterey Bay Academy, and NCAR EOL, and brought to bear some instruments that were dysfunctional during Fatima-GB. The objectives were to study: (1) transmission of infrared (IR) and microwave (MW) radiation in fog, and (2) the relationships between droplet size distribution (DSD) and IR and MW attenuation along the beam path for different hydrometeor types. To this end, DSD, turbulence, and precipitation along the propagation path were measured and correlated with attenuation. [UU] (5) A hypothesis of the Fatima Project -- that fog dissipation can be tied to the exponent of structure function of temperature and velocity fluctuations with respect to distance -- was tested using turbulence measurements. Turbulence was represented using a variant of the codimension (H - 1/3), H being the observed exponential slope of structure function; for isotropic turbulence, H=1/3. H < 1/3 suggests that the rate of diffusion is less than expected. Results suggest that the codimension is relatively constant during clear skies, inversely proportional to visibility during fog, a larger rate of diffusivity as fog clears and visibility improves, and a smaller rate of diffusivity during thick fog (Fig. 5). (UU) (6) Hot-wire-LWC (a new technology development) data of both campaigns were compared with those of the instrument FM120. A good agreement was noted during weak fog events (i.e., low dN)) but not for high LWC periods. To investigate the reason, a lab experiment was designed to investigate heat transfer from the wire, which included a laser camera system (for DSD and dN), a hot-wire probe, a calibrated portable [constant speed] wind tunnel, a thermal camera [for temperature profile of the sensor wire], and a water droplet spray system. Note that the convective heat transfer coefficient decreases with increasing diameter of the sensor wire. During dense fog, the sensor is fully covered with water droplets that effectively increase wire diameter. By calibrating the convective heat transfer coefficient when the wire is fully covered by droplets, the LWC measurements were improved. (UU) (7) During both campaigns, fog microphysics was measured as part of the Deck-based Cloud and Aerosol Measurement System (D-CAMS). The visibility as a function of measured LWC is shown in Fig. 6. Also, Fig. 6b show measurements from coastal sites in central CA and Newfoundland for comparisons; here, the C-CAMS (Crane-Based Aerosol Measurement System) data from Fatima-GB is also included. The trend of fast visibility attenuation with LWC is very similar in fog conditions (vis < 1 km) for two marine fog cases (Fig. 6a). However, more mist cases (1 km < vis

Plans Next Period

The Fatima group will continue to analyze field data from Fatima-YS and Fatima-GB, conduct LES-LCM as well as high resolution mesoscale (COAMPS, WRF and WRF-LES) simulations, carry out process studies, create new knowledge on Fog and Turbulence Interactions and disseminate data via journal and conference papers, conference and workshop presentations, and train graduate students, post-doctoral fellows and early career scientists. Some undergraduate research participation is also expected. A major emphasis will be placed on STEM education. The LES-LCM (UND) has been equipped and configured to understand the role of localized aerosol generation on marine fog, with particular emphasis on the effects of aerosol size and composition. A systematic series of numerical experiments will be conducted during the next reporting period using FATIMA-GB field data. The simulations will be initialized using observed data, and LES-LCM group will work with aerosol scientists to better understand variety of aerosol activation pathways in heterogeneous mixtures of aerosol types. Following the development of the L3 methodology and its application to simulating Fatima-GB fog, UM attention is shifting toward applying L3 to Fatima-YS observations. The sensitivity of fog lifecycle to physical processes will be investigated, including turbulent mixing, heat and moisture exchanges, droplet size distribution, and number concentration. Additionally, efforts are underway to implement the L3 methodology along with the immersed boundary method to model the effects of the large-scale dynamics in simulations domains with coastal topography. A comprehensive analysis on the effect of physical and microphysical parameters on the marine fog lifecycle is planned, including eliciting the behavior of fog over Fatima observational sites subjected to large-scale effects.

To understand the characteristics of fog attenuation on optical signals, visibility as a function of LWC was extensively measured/studied in Fatima field studies, and continuing analysis of these data will be priority in the next year. During on-going analysis, it was found that in coastal fog there is a faster enhancement of visibility with decreasing LWC when compared with sea fog, the reason for which is unclear. Continuing data analysis is expected to provide clues for this disparity, while identifying the underlying physical processes.

As mentioned elsewhere in this report, the UU Group conducted a short-term field experiment in Monterey, CA to better understand the transmission of infrared and microwave radiation in fog and to use the attenuation of infrared and microwave radiation to infer microphysical properties along the path of a scintillometer. The analysis of data from this study will continue into the next reporting period, with emphasis on developing relationships between the DSD and attenuation for different hydrometeor types.

Studies on marine atmospheric boundary layer (MABL) will continue to the next reporting period, especially to understand how different cloudy boundary layer types in consonance with synoptic forcing types promote fog genesis. To this end, the Fatima-YS data are of great importance, as they come from multiple platforms including K-ORS. Several MABL types have already being identified using Fatima-YS data by UND, and the nexus between large scale meteorological forcing and small-scale dynamics is expected to elicit some important new mechanisms of cloud-related fog genesis.

The UCSD PI will continue to work on several collaborative research papers involving multiscale interactions during fog formation, especially the role of turbulence and other sub mesoscale processes. Darko Koracin (University of Split, Croatia) will be visiting UND during January/February 2025 to collaborate with UCSD and UND PIs on this topic.

Results Dissemination

Dissemination of research results were accomplished via multiple approaches, as follows: (1) A special issue of the Quarterly Journal of the Royal Meteorological Society (Journal Impact Factor 3; 5-year Impact Factor 7.2) on the Fatima project is in progress, with ~ 10 papers already submitted or accepted and another 10 have been committed. The editors of this special volume are Ismail Gultepe and Eric Pardyjak. The deadline for the submittal has been set for December 20, 2024. (2) The results were disseminated by conference presentations as well as submittal of peer reviewed publications. The PI made several invited presentations at conferences and universities: Keynote Speaker 10th International Conference on Environmental Hydraulics (University of Aberdeen, 25-27 June 2024); Invited Presentation at the 2023 AGU Fall Meeting, San Francisco (December 11-15, 2023); and invited seminar at the University of California, San Diego (April, 2024). (3) The Third Fatima Review was an open, but invitation-only, meeting (March 25-26, 2024) hosted by the National Institute of Meteorological Sciences (ROK), KIOST, GeoSystem Research Corporation and UND, for which about 40 scientists attended. The Office of Naval Research (Global, Japan), University of Notre Dame and Geosystems Research Corporation provided financial support for the meeting: https://efmlab.nd.edu/research/fatima/workshops-meetings/ (4) PI Clive Dorman and collaborators Ismail Gultepe, Darko Kora?in, Reneta Dimitrova and Adriana Formby-Fernandez organized a special session on “Marine Fog and Multi-Phase Turbulence” at the AGU Fall Meeting in San Francisco, December 11- 15 September, 2023. (5) PI Lian Shen and collaborators are organizing a special session: “Life Cycle of Fog: Observations, Experiments, and Modeling” at the AGU24 Meeting in Washington DC. (6) Senior Personnel Ismail Gultepe and collaborators H.J.S. Fernando, A.J. Heymsfield, and Seong-Soo Yum are organizing a special session on “Fog and Visibility” at the American Meteorological Society’s Second Symposium on Cloud Physics to be held on January 12 - 16, 2025 in New Orleans, LA. (7) The PI contributed to the following popular press articles: “Journeying Through the Fog (New York Times Kids Section, October 29, 2023, by Emily Reily); “Uncovering layers of marine fog” by Vaisala https://www.vaisala.com/en/case/uncovering-layers-marine-fog, Published January 22, 2024; “Cold Fog Is Capricious, but Not for Long” https://eos.org/articles/cold-fog-is-capricious-but-not-for-long, Published by Grace van Deelen, EOS, Transactions American Geophysical Union, 13 February 2024. Presentations made during the 2023-2024 reporting period are included in the Appendix 1 of the attached file, following the figures.

Honors and Awards

A senior researcher from UND, Ismail Gultepe, was listed by ScholarGPS as #88 in the list of top scholars in the world in the area of “Aviation” (https://scholargps.com/top-scholars?year=2022&p=5&ranking_duration=LAST_5_YEARS&e_ref=ea4d97d5186f0c7ebcb1&specialty=Aviation#8)

PI Fernando shared the 2024 Annual Alan Berman Research Publication Award with a collaborator group at the Naval Research Laboratory, Stennis.

Training Opportunities

The project offered extensive training opportunities for early career scientists, post-docs, graduate and undergraduate students, and technical staff. The graduate students were directly trained under the PIs, and all had opportunities to participate in 2022 and 2023 Fatima Cruises and obtain experience in instrument deployment and data analyses. Since Both Fatima cruises were international, all trainees had opportunities to travel to international destinations and interact with

host-country scientists. Student were given opportunity to seek out international internships with partners. A particular highlight in 2023-24 was the participation in "Third In-Person Fatima Review" held in Jeju Island, Korea, hosted by the National Institute of Meteorological Sciences (NIMS, ROK), KIOST, GeoSystem Research Corporation and UND. Many of the trainees involved participated in national and international workshops and conferences. PhD Student Anne Dowling (UND) was a Research Intern at KIOST for three months (April to June, 2024), where she worked with the Fatima-YS ROK Chief Scientist Dr. Seok Lee and prepared two journal papers, which will be a part of her PhD thesis. A KIOST staff member and a PhD student, Mr. Hojin Kim, spent four months (August – November, 2024) at UND, analyzing Fatima-YS meteorological data. Collaboration was maintained with DoD personnel on identifying science needs and transitioning project outcomes to applications. The trainees had an opportunity to interact with DOD laboratories.

Early Career Scientists (5): Jesus Ruiz-Plancarte (NPS), David Ortiz-Suslow (NPS), Ryan Yamaguchi (NPS), Francesco Barbano (UU, University of Bologna), Dhiraj Singh (UU),

Post-Doctoral Fellows (6): Camilo F. Rodriguez-Geno (UND), Han Liu (UM), Alexei Perelet (UU), Karli Rees (UU), Baban Nagare (UND), Sen Wang (UND)

Graduate Students (11): Stef Bardoel (UND, Graduated 03/24), Anne Dowling (UND), Sen Wang (UND, Graduated 03/24), Edgar Gonzales (UND, Graduated 03/24), Matthew Huckins (UU), Anup Barve (UM), Leyla Salehpoor (York University), Gianina Massa (Dalhousie University), Shubham Mittal (UM), Sai Chaitanya Gembali (UM), Kee Horng (Rolf) Seh (UND)

Undergraduate Students (7): Jacob Ropp (UND), Eilliott Kirwan (UND), Karolek Suchocki (UND, REU), 2nd Capstone Senior Design Team (UU), Anna Leuer (UND, Benedictine University), Ben Roper (UND), Own Diamond (UND)

Technical Staff (2): Scott Coppersmith (UND), Orson Hyde (UND)

Technology Transfer

A highlight of the project is the close collaboration with DOD Laboratories, which included:

Naval Research Laboratory, Monterey (Sasa Gabersek, who was the lead forecaster of the Fatima-YS and Fatima-GB campaigns. NRL used couple atmosphere-ocean COAMPS model at 1 km resolution and different initialization times to guide IOP predictions; Model-data intercomparisons are being used to identify model deficiencies and remedy them by developing new parameterizations). In addition, COAMPS is being used in certain process studies.

Army Research Laboratory, White Sands Missile Range, New Mexico (Ed Creegan, Andrey Grachev, Chris Hocut). Ed Creegan was the Chief Scientists of both Fatima cruises. Grachev and Hocut are conducting research on optical turbulence in fog environments, based on turbulence measurements in Fatima field campaigns.

Airforce Institute of Technology AFIT (Steve Fiorino and Kevin Keefer deployed novel instruments in Fatima-GB to capture fine aerosols, in particular, the presence of P Syringae in marine aerosols).

Lt. William Griffin and a crew of 4 from the Naval Forces in Korea participated in the mobilization of Onnuri at the Jangmok Port in Busan during Fatima-YS.

In addition, NPS closely works with the Naval Air Warfare Center Weapon Division (NAWCWD), Physics Division, to use the measurement techniques used/developed in FATIMA to support US Navy high energy laser (HEL) weapon testing.

Participants

Name	Role	Person Months
Dorman, Clive	Co PD/PI	2
Pardyjak, Eric	Co PD/PI	2
Shen, Lian	Co PD/PI	1
Wang, Qing	Co PD/PI	2
Gultepe, Ismail	Co-Investigator	3
Hoch, Sebastian	Co-Investigator	3
Koracin, Darko	Co-Investigator	2
Richter, David	Co-Investigator	2
Barbano, Francisco	Faculty	1
Ortiz-Suslow, David	Faculty	3
Ruiz-Plancarte, Jesus	Faculty	3
Singh, Dhiraj	Faculty	3
Yamaguchi, Ryan	Faculty	3
Bardoel, Stef	Graduate Student (research assistant)	9
Barve, Anup	Graduate Student (research assistant)	9
Dowling, Anne	Graduate Student (research assistant)	12
Gonzales, Edgar	Graduate Student (research assistant)	9
Huckins, Matthew	Graduate Student (research assistant)	2
Kim, Hojin	Graduate Student (research assistant)	3
Massa, Gianina	Graduate Student (research assistant)	1
Mittal, Shubham	Graduate Student (research assistant)	6
Salehpoor, Leyla	Graduate Student (research assistant)	1
Seh, Kee	Graduate Student (research assistant)	5
Wang, Sen	Graduate Student (research assistant)	6
Coppersmith, Scott	Other Professional	4
Fernando, Harindra	PD/PI	2
Liu, Han	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Nagare, Baban	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Perelet, Alexei	Postdoctoral (scholar, fellow or other postdoctoral position)	3

Rees, Karli	Postdoctoral (scholar, fellow or other postdoctoral position)	6
Rodriguez-Geno, Camio	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Wang, Sen	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Suchocki, Karolek	Research Experience for Undergraduates (REU) Participant	3
Hyde, Orson	Technician	4
Kirwan, Elliot	Undergraduate Student	3
Lauer, Anna	Undergraduate Student	3
Roper, Ben	Undergraduate Student	3
Ropp, Jacob	Undergraduate Student	3
University of Utah, Senior Design Team	Undergraduate Student	2

Figures and Publications Document

Figure 1: Attendees at the Fatima Year-3 Review, held at the National Institute of Meteorological Sciences (NIMS), Jeju, Republic of Korea (ROK) during March 25-26, 2024.

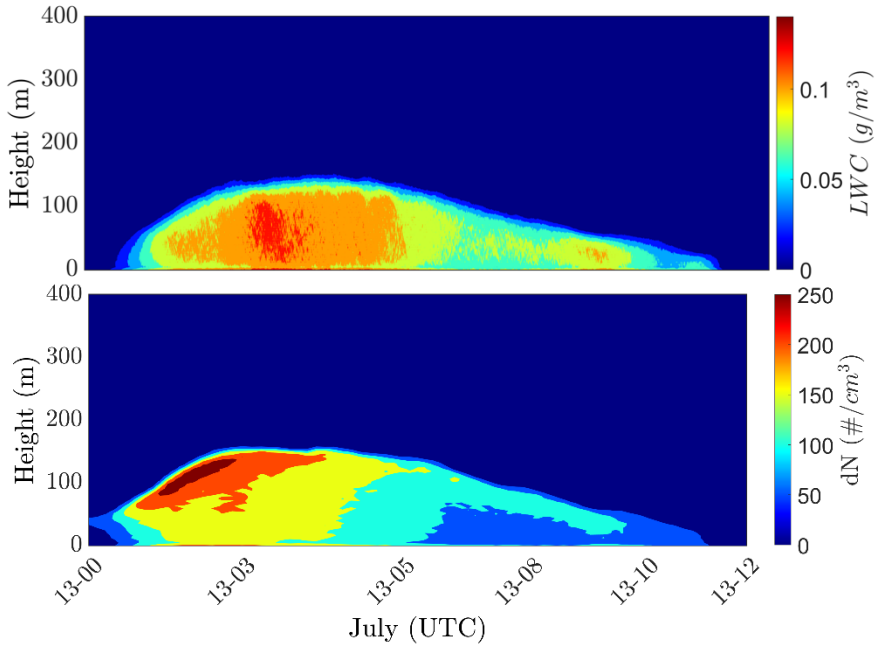


Figure 2: LES of fog event performed using L3 coupling. Plotted is horizontally averaged time-height history of various microphysical parameters for the 13 July case of Fatima-GB. a) LWC, b) Droplet number concentration (dN) for droplet sizes above 2 μm. The fog is characterized by an LWC exceeding a threshold of 0.01 g m^{-3}. On the basis of this threshold, Figure 1a shows the temporal and spatial dimensions of the fog event.

The computation started at 2100 UTC on July 11 with the initial meteorological conditions derived from the ERA5 data. Initial aerosol distribution was approximated as bimodal, the sum of two lognormal distributions with an aerosol number concentration of 800 per cm^3. The simulation continued till 1500 UTC on July 13.

Fog initiation occurred at 0100 UTC and persisted till 1100 UTC on the same day. Initially, the fog was shallow, deepening significantly by 0300 UTC to a maximum vertical extent of ~ 150 meters. At this peak, the LWC also reached its maximum of 0.15 g m^{-3}. Thereafter, both the depth and density of fog began to diminish, leading to its eventual dissipation. For dN, there was an increase in the droplet number concentration during the fog period, peaking at ~ 250 cm^{-3} before it began to decrease. This pattern matches the behavior in Figure 1a, suggesting that the larger particles settled, leading to reduction in both the LWC and the number concentration in the later stages of the fog event.

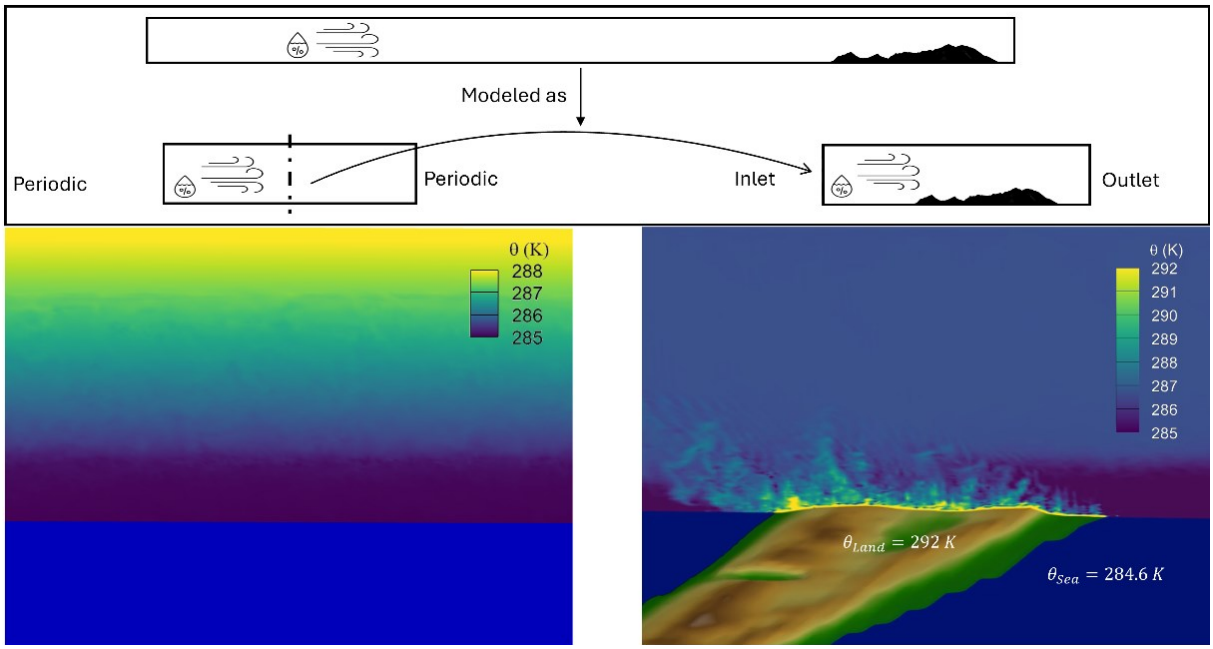


Figure 3: LES set-up consisting of a precursor periodic-domain simulation with one of its planes copied to the inlet plane of an inlet-outlet simulation to study the behavior of fog as wind blows over the land topography from open-ocean upstream. The plots show the instantaneous temperature profiles for the wind over the open ocean and over SI.

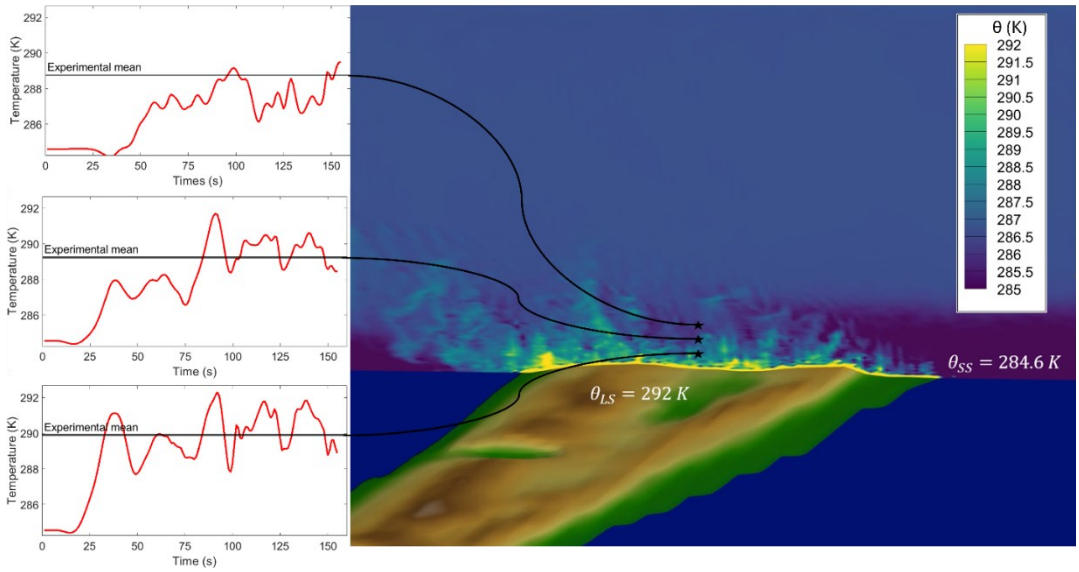


Figure 4: An instantaneous snapshot of temperature profiles simulated over SI during Fatima-GB as the flow moves from the sea surface at a temperature of 284.6 K to the hotter land surface with a temperature of 292 K. Temperature profiles at different heights show good agreement with mean experimental data from the south tower on SI at three different heights (horizontal lines), indicating the model's capability to capture the thermal structure of the atmospheric boundary layer over complex terrain. (Data source: South Tower RH/T data; courtesy: Kelly Huang, Thomas Hintz, Andrey Grachev).

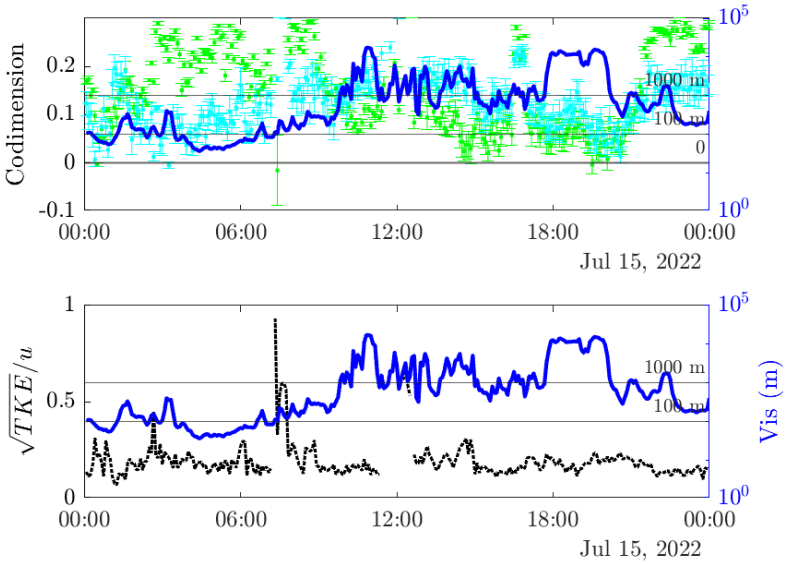
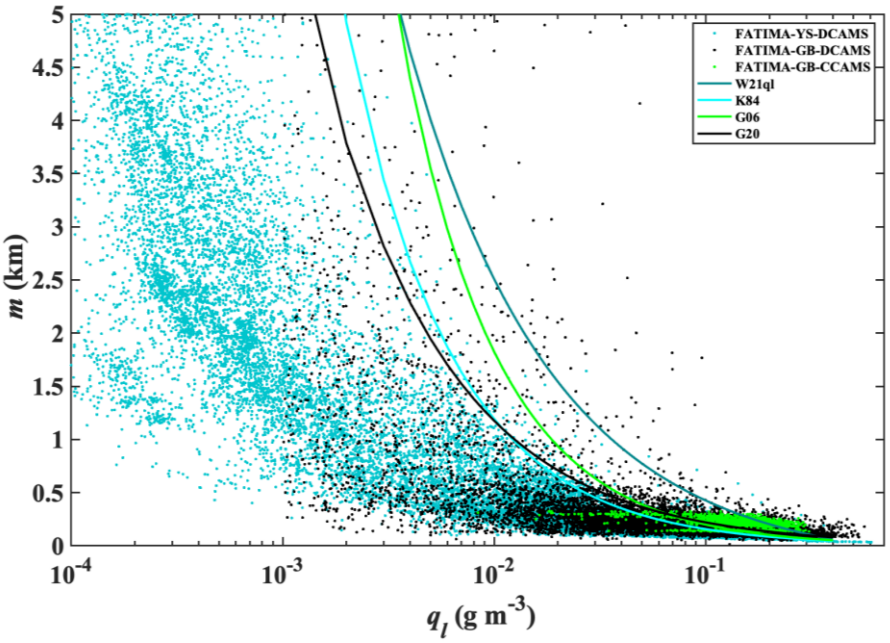


Figure 5: Measurement of visibility at the center tower on SI during Fatima-GB and comparison with corresponding structure function exponents. The upper figure shows the codimension of measured temperature (green), vertical velocity (cyan) and visibility (dark blue line) during the Monterey field study. The lower figure shows a characteristic turbulent velocity, normalized by the mean value as well as the visibility.

(a)



(b)

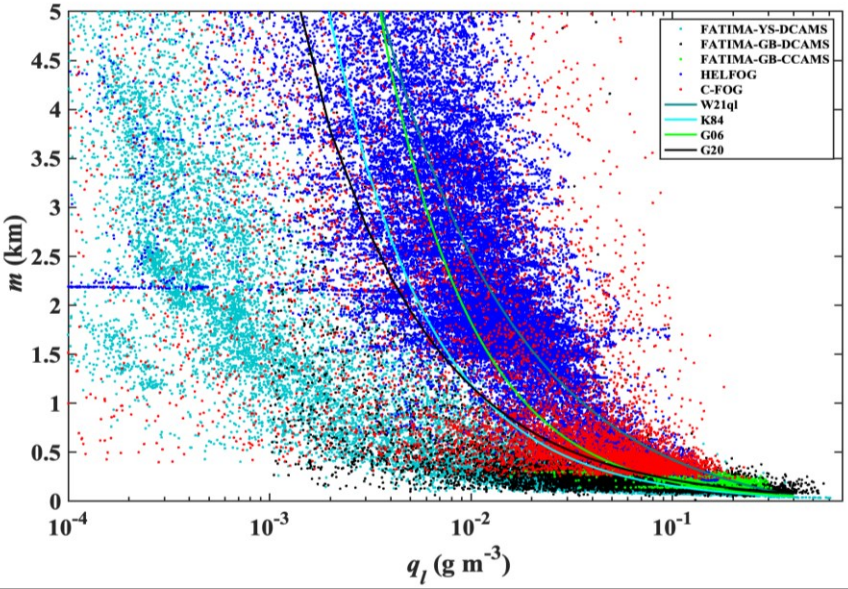
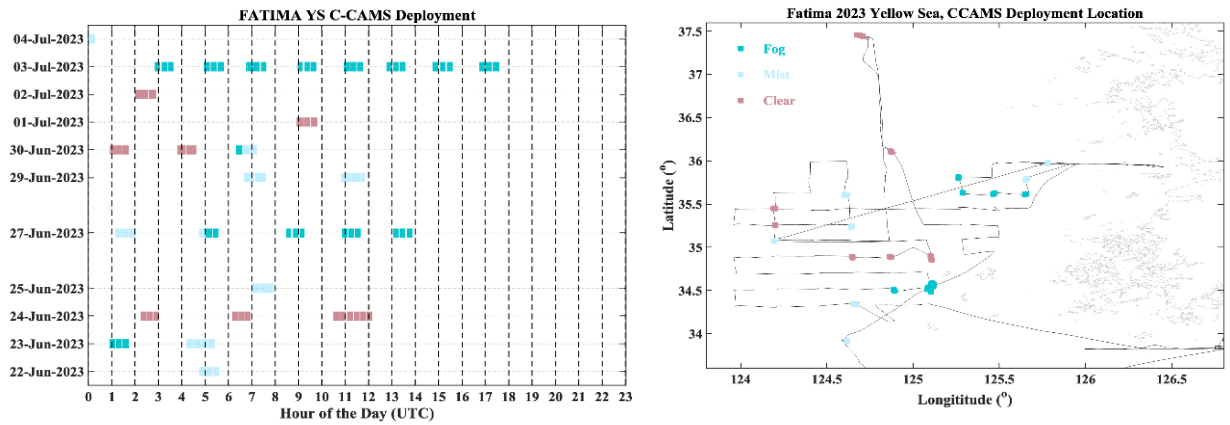


Figure 6: Observed variability of visibility as a function of fog LWC. (a) measurements from the two Fatima field campaigns; (b) same as in (a) except added coastal fog events from two previous field campaigns, HELFOG and C-FOG. The solid lines represent various relationships in the literature, mostly for coastal fog events. The D-CAMS was mounted at ~25.4 m and ~15 m, respectively, above the waterline during Fatima-GB and Fatima-YS.



(a) (b)

Figure 7. The timeline (a) and location (b) of each C-CAMS flight during Fatima YS. For each flight, the C-CAMS normally covered 3 altitudes, nominally at 3, 5, and 9 m above the waterline, spending ~ 15 minutes at each altitude to collect sufficient data for computing turbulent statistics. A total of 34 C-CAMS flights with > 60% in fog or mist conditions. The continuous grey line in (b) indicates the R/V Onnuri track and the light grey dots shows the coastline. Fog, mist and clear conditions are indited in the legend.

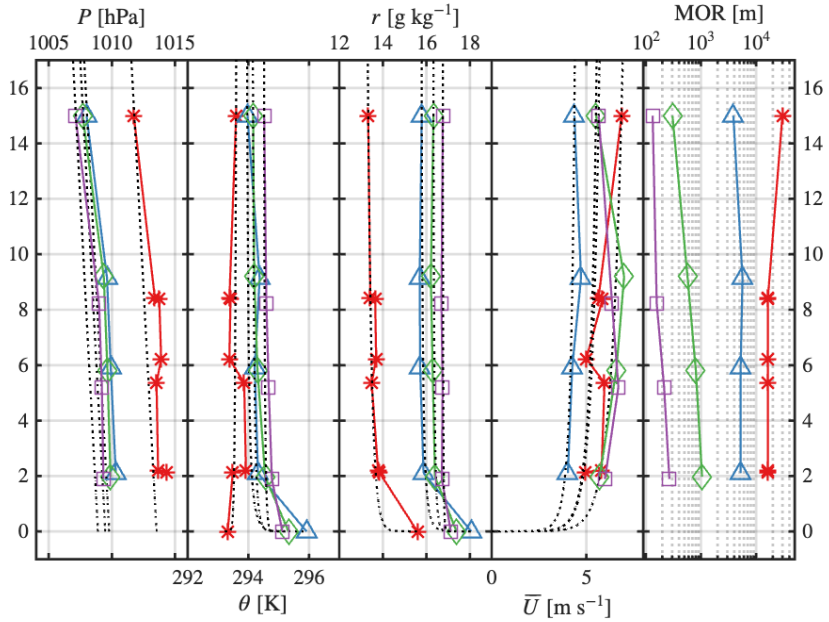


Figure 8: Vertical variations of mean pressure, potential temperature, mixing ratio, wind speed, and visibility based on three C-CAMS flights in fog/mist on 27 June 2023 and one clear flights from June 24 from the R/V Onnuri during Fatima-YS. Of the four flights, two were in fog (purple and green), one in mist (blue) and one in clear (red) conditions. The concurrent D-CAMS data extend the profiling to ~15 m altitude. Visibility in both foggy conditions indicates a decrease with height. Similar results were noted during Fatima-GB. The potential temperature profiles in all flights with fog/mist indicate unstable stratification while in the clear case show slightly stable stratification. The clear flight on a separate day shows an average of 4 mb pressure difference between June 24 and 27, likely a difference in the synoptic environment.

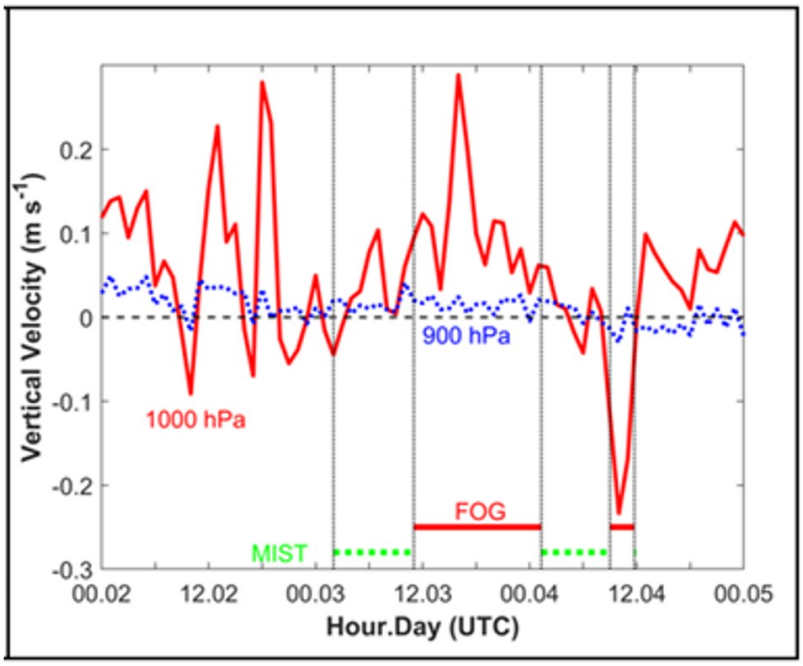


Figure 9: ERA5 1000 and 900 hPa level vertical velocity over SI on 03 – 04 July 2022. The 1000 hPa vertical velocity was a maximum during the main fog period between 1100.03 and 0118.04 July and was dominantly positive during the mist periods before and after. During this time, there was a cyclonic system over SI. A ridge encroached on the west side of the cyclonic system, replacing the short fog period at the end with anticyclonic conditions in the boundary layer. At 900 hPa, the vertical was weakly positive until the ridge encroached with weakly anticyclonic vertical velocity.

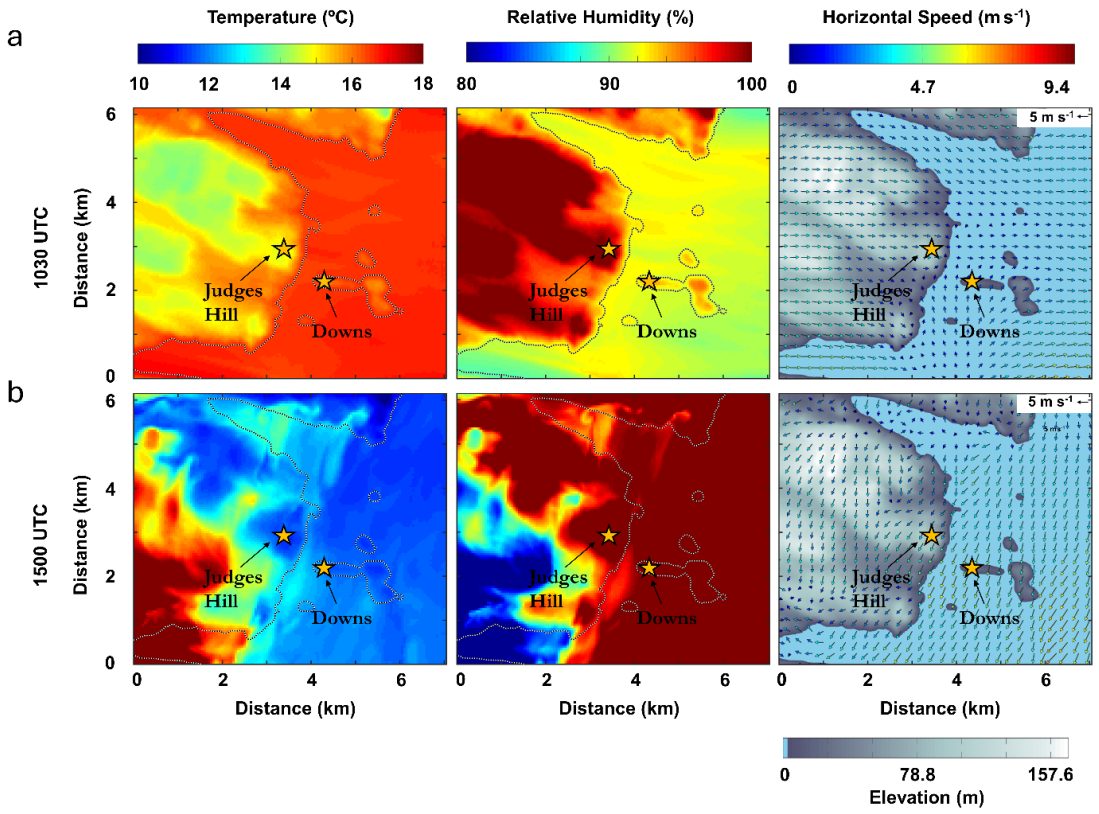


Figure 10: Horizontal plots at approximately 50 m above ground level for temperature, relative humidity and horizontal wind speed from WRF-LES for different times: (a) fog free conditions at 1030 UTC and (b) initial fog formation stage at 1500 UTC on 16 September 2018 during the C-FOG campaign (Bull Am. Meteor. Soc., 102(2), E244-E272, 2021), an antecedent to the Fatima campaigns. The topography is shown along with the wind vectors, which are colored by wind speed. Results are for a WRF-LES domain with 50 m horizontal resolution, downscaled from a WRF domain of 12 km resolution.

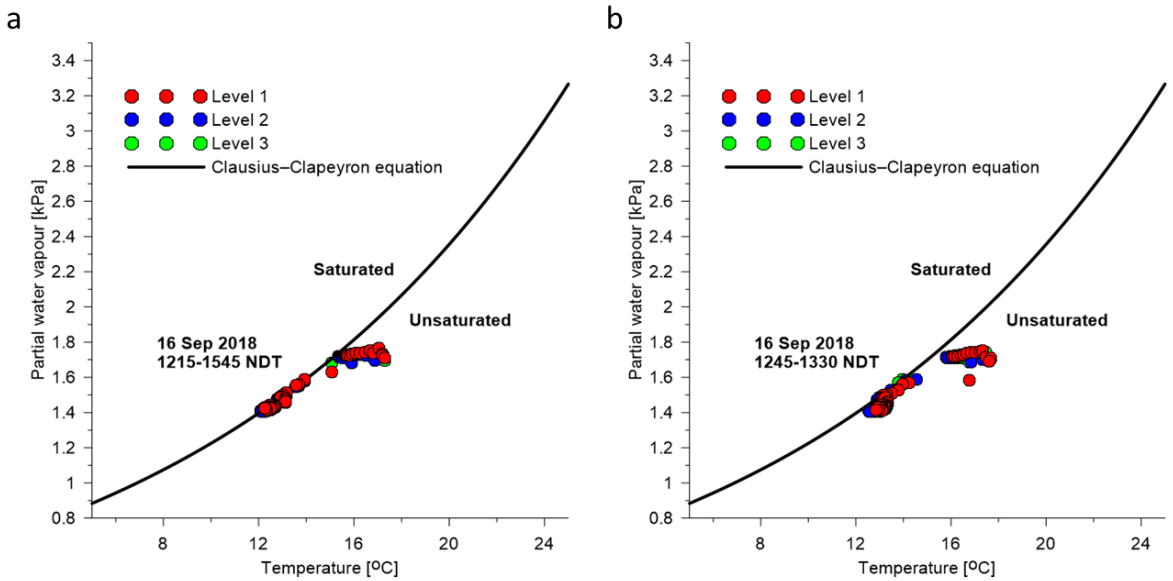


Figure 11: A diagram of partial water vapor pressure as a function of temperature at nearest-to-the-ground (three) levels simulated by WRF-LES (note the three different colors in the legend) at (a) Downs and (b) Judges Hill sites. The curve represents the Clausius–Clapeyron equation for a perfect gas. The processes described start from the circles in the right (warmer unsaturated air), cross marginally to the saturated regime and then again gradually move to the unsaturated regime.

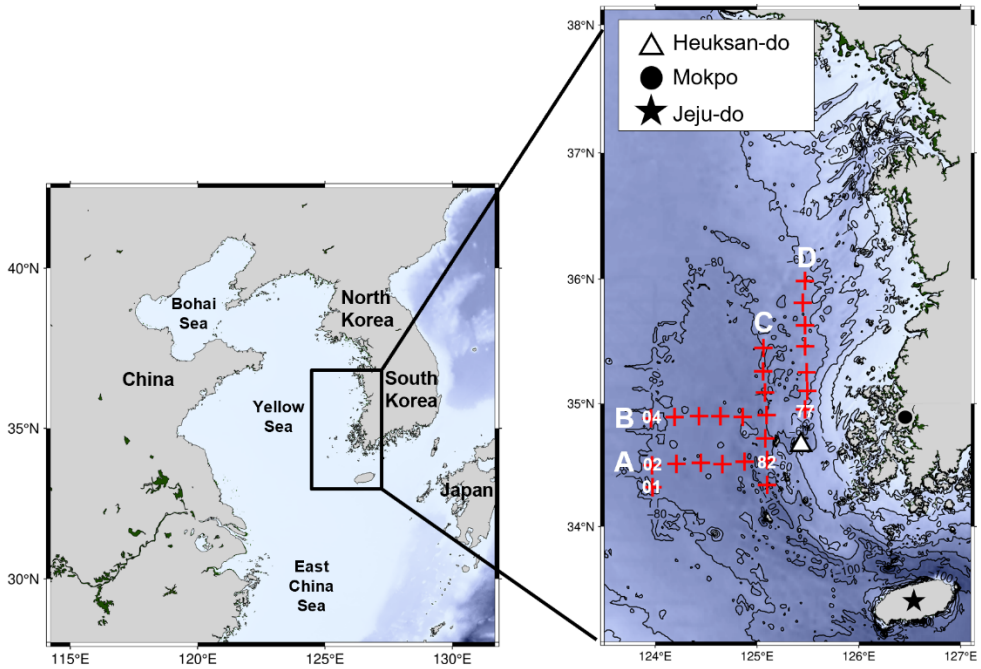


Figure 12: The observation site for the boundary-mixing study with bathymetry contours. Station 82 is the primary source of data for this study while Lines A, B, C and D provided data for cross-section observations. Locations of significance are depicted with shapes: Heuksan-do (triangle), Mokpo (circle) and Jeju-do (star).

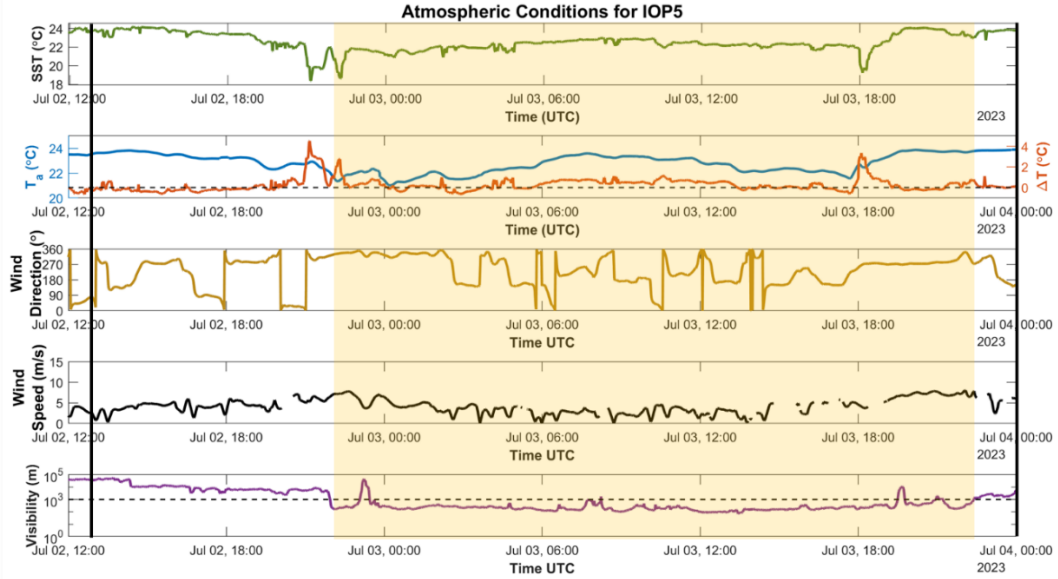


Figure 13: Atmospheric conditions during Fatima-YS IOP5 with (a) SST from the Sea Snake, (b) Air Temperature and ΔT, (c) wind direction, (d) wind speed, and (e) visibility. The black lines indicate the start and end of IOP5. A significant drop in visibility from 8.7 km at 21:21 UTC, 2 July to 164 m at 22:06 UTC 2 July occurred. The fog event (shaded region) lasted from 21:56 UTC, 2 July to 22:22 UTC, 3 July. At the end, fog dissipated and visibility increased to 3.1 km at 23:04 UTC, 03 July.

Appendix 1:

Journal Papers *in 2023-24:*

Published or Accepted: 19

Acharja, P., Ghude, S.D., Sinha, B, Barth, M., Govardhan, G., Kulkarni, R., Sinha, V., Kumar, K. Ali, R., Gultepe, I., Petit, J.E., and Rajeevan, M. N., 2023: Thermodynamical framework for effective mitigation of high aerosol loading in the Indo-Gangetic plain during winter. *Scientific Reports,* 13(1), 13667. https://doi.org/10.1038/s41598-023-40657-w

Barbano, F. and Pardyjak, E.R., 2024: Potential-temperature variance budget in a saturated coastal-fog environment, *Q. Jour. Roy. Met. Soc.*, https://doi.org/10.1002/qj.4827.

Bardoel, S., Hoch, S., Ruiz-Placarte, J., Lenain, L., Gultepe, I., Grachev, A., Gaberšek, S., Wang, Q., and Fernando, H.J.S., 2024: Study of fog dissipation in an internal boundary layer on Sable Island. *Q. Jour. Roy. Met. Soc.*, In Press

Bhowmik, M., Anupam H., Ghude, S.D., Wagh, S., Chowdhury, R., Parde, A.R., Govardhan, G., Gultepe, I., and Rajeevan, M. 2024: Is a more physical representation of aerosol

chemistry needed for fog forecasting? *Q. Jour. Roy. Met. Soc*, 150, 762, 2690-2711. https://doi.org/10.1002/qj.4729.

Carvalho, M., Moradi, S., Hosseinnouri, F., Keshavan, K., Villeneuve, E., Gultepe, I., Komar, J., Agelin-Chaab, M., and Hangan, H., 2024: Towards a Model of Snow Accretion for Autonomous Vehicles. *Atmosphere*, 15 (5), 548. https://doi.org/10.3390/atmos15050548

Ghude, S., Kulkarni, R., Wagh, S., Dhangar, N.G., Avinash, Parde, N., Acharja, P., Gultepe, I., Biswas, M., Karipot, A., Prabhakaran, T., Nanjundiah, R.S., and Rajeevan, M., 2023. WiFEX: Walk into the warm fog over Indo Gangetic Plain region. *Bull. Amer. Meteor. Soc.* (BAMS), 104, V5, E980-E1005. https://doi.org/10.1175/BAMS-D-21-0197.1

Gultepe, E., Wang, S., Blomquist, B.W., Fernando, H.J.S., Kreidl, O.P., Delene, D.J., and Gultepe, I., 2024. Machine Learning Analysis and Nowcasting of Marine Fog Visibility Using FATIMA Grand-Banks Campaign Measurements, *Front. Earth Sci.*, 11:1321422, doi: 10.3389/feart.2023.1321422.

Gultepe, I., 2023. A review on weather impact on aviation operations: Visibility, Wind, Precipitation, Icing. *J Airline Oper. Aviat. Management*. 2 (1), 1-44. https://doi.org/10.56801/jaoam.v2i1.1

Hangan, H., Agelin-Chaab, M., Gultepe, I., Elfstrom, G., and Komar, J., 2023: Weather Aerodynamic Adaptation for Autonomous Vehicles: A Tentative Framework. Transactions of the Canadian Society for Mechanical Engineering, *CSME Trans*. 47, 1, 175-184. https://doi.org/10.1139/tcsme-2021-0198

Hintz, T., Huang, K., Hoch, S., Bardoel, S., Gaberšek, S., Gultepe, I., Ruiz-Plancarte, J., Pardyjak, E., Wang, Q., and Fernando, H.J.S., 2024: A Mechanism for Coastal Fog Genesis at Evening Transition, *Q. Jour. Roy. Met. Soc*, In Press. https://doi.org/10.1002/qj.4732

Koracin, D., Dorman, C.E., and Fernando, H.J.S., 2024: Frontal effects on the rapid formation of a deep layer of marine fog and cloud in the NW Atlantic. *Q. Jour. Roy. Met. Soc*, 1–18. Available from: https://doi.org/10.1002/qj.4843

Lozovatsky, I., Escauriaza, C., Suarez, L., Fernando, H.J.S., Coppersmith, R.S., Williams, M., Mayorga, N., "A Snapshot of Marine Turbulence in the Northeastern Strait of Magellan" *Ocean Dynamics.* https://doi.org/10.1007/s10236-024-01613-y

Pao, W.Y, Carvalho, M., Hosseinnouri, F., Li, L., Rouaix, C., Agelin-Chaab, M., Hangan, H., Gultepe, I., and Komar, J., 2024: Evaluating weather impact on vehicles: a systematic review of perceived precipitation dynamics and testing methodologies. *Eng. Res. Exp.,* 6 (1), DOI 10.1088/2631-8695/ad2033.

Pu, Z., Pardyjak, E.R., Hoch, S.W., Gultepe, I., Hallar, A.G., Perelet, A., Beal1, R., Carrillo-Cardenas, G., Li, X., Garcia, M., Oncley, S., Brown, W., Anderson, J., and Vakhtin, A., 2023: Cold Fog Amongst Complex Terrain. *Bull. Amer. Met. Soc*., 10411, E2030-E2052. https://doi.org/10.1175/BAMS-D-22-0030.1.

Rodriguez-Geno, C., and Richter, D.H., 2024: The role of collision and coalescence on the microphysics of marine fog, *Q. Jour. Roy. Met. Soc*, In Press, doi:10.1002/qj.4831

Singh, D.K., Hoch, S.W., Gultepe, I., and Pardyjak, E.R., 2023: A case study of the life cycle of a stratus-lowering coastal-fog event in Newfoundland, Canada. *Q. Jour. Roy. Met. Soc,* 150, 759, 641-662. https://doi.org/10.1002/qj.4615.

Suarez, L., Guerra, M., Williams, M.E., Escauriaza, C., Lozovatsky, I., Coppersmith, R.S., and Fernando, H.J.S., 2024: Flow Characterization and Turbulence in the Eastern Section of the Strait of Magellan, Southern Chile, *Cont. Shelf Res*, In Press.

Todorov, P., Ivanov, O., Gultepe, I., Agelin-Chaab, M., Pérez-Díaz, J.L., Dreischuh, T., and Kostadinov, K., 2024: Optimization of the Air Cleaning Properties of *Fog. Aerosol Sci. and Eng.,* 9 pp https://doi.org/10.1007/s41810-024-00220-0. 9.

Wagh, S., Kulkarni, R., Lonkar, P., Parde, A.N., Dhangar, N.G., Govardhan, G., Sajjan, V., Debnath, S., Gultepe, I., and Rajeevan, M, 2023: Development of visibility equation based on fog microphysical observations and its verification using the WRF model. Model. *Earth Syst. Environ*., 9(1), 195-211. https://doi.org/10.1007/s40808-022-01492-6.

In Revision: 9

Bardoel, S.L., Cheng, S., Chamorrow, L., and Fernando, H.J.S., Gravity Currents past Thin Two-Dimensional Obstacles, *J. Fluid Mech.*, In Revision.

Dimitrova, R.N., Fernando, H.J.S., Silver, S., Bardoel, S.L., Dorman, C.E., Koračin, D., Vladimirov, E., and Giani, P., Study of a Mixing Fog Event using WRF-LES Numerical Simulations, . *Q. Jour. Roy. Met. Soc*, In Revision.

Dorman, C., Koracin, D., Gultepe, I., Hoch, S., Ruis-Plancarte, J., Wang, Q. and Fernando, H.J.S., The role of the synoptic scale conditions in driving fog and mist during the FATIMA July 2022 Sable Island Field Program, *Q. Jour. Roy. Met. Soc*, In Revision.

Dorman, C., Kim, J-H., Koracin, D., Dimitrova, R., and Fernando, and H.J.S., Interaction of Land and Sea Processes Conductive to Fog over Nova Scotia under a Ridge on 8 September 2021, Q. *Jour. Roy. Met. Soc*, In Revision.

Fernando, H.J.S., Dorman, C.E., Pardyjak, E., Shen, L., Wang, Q., Creegan, E., Gaberšek, S., Gultepe, I., Hoch, S.W., Lenain, L., Richter, D.H., Chang, R., VandenBoer, T., Bardoel, S., Barve, A., Blomquist, B., Bullock, T., Chen, Z., Colosi, L., Coppersmith, R.S., Crawford, I., Crilley, L.R., Dimitrova, R., Dowling, A., Eleuterio, D., Fiorino, S., Gallagher, M., Gapp, N., Giacosa, G., Grachev, A., Grare, L., Hintz, T., Hocut, C., Huang, K.Y., Hyde, O., Keefer, K., Ortiz-Suslow, D., Perelet, A., Perrie, W., Ruiz-Plancarte, J., Salehpoor, L., Singh, D., Statom, N., Taylor, P., Wang, S., and Yamaguchi, R. 2024. Fatima-GB: Searching Clarity within Marine Fog. *Bulletin of the American Meteorological Society*, In Revision.

Formby-Fernandez, A., Lenain, L., Pizzo, N., Dorman, C.E., and Xie, S-P. "Spatial and temporal structure of the fog life cycle over Atlantic Canada and the Grand Banks", *Q. Jour. Roy. Met. Soc*, In Revision.

Liu, D., Jing, T., Yan, M., Gultepe, I., Bao, Y., Wang, H., and Zu, F.: A New Method for Calculating Highway Blocking due to High Impact Weather Conditions, *Nat. Hazards Earth Syst. Sci.* Discuss. [preprint], in review, 2024. https://doi.org/10.5194/nhess-2023-230.

Ortiz-Suslow, D.G., Ruiz-Plancarte, J., Yamaguchi, R., Kalogiros, J., Fernando, H.J., Creegan, E., Pardyjak, E., Gaberšek, S., Gultepe, I., and Wang, Q., A case study of boundary layer development downstream of a small, remote island, *Quart. J. Roy. Meteor. Soc*., In Revision.

Ortiz-Suslow, D., Ruiz-Plancarte, J., Kalogiros, J., Yamaguchi, R., Fernando, H.J.S., Creegan, E., Pardyjak, E., Gaberšek, S., Wang, Q., A Case Study of Boundary Layer Development Downstream of a Small, Remote Island, *Q. Jour. Roy. Met. Soc*. In Revision.

Submitted: 4

Barve, A, Gultepe, I., Fernando, H.J.S., Wang, Q., and Shen, L., 2024: Large-Eddy Simulation with Lagrangian Cloud Modeling and Large Scale Dynamics (L^3) for Studying the Marine Fog Lifecycle, *Q. Jour. Roy. Met. Soc.,* Submitted.

Gaberšek, S., Gapp, N., Bardoel, S., Fernando, H.J.S., Ruiz-Plancarte, J., Ortiz-Suslow, D., Wang, Q., Pardyjak, E., Hoch, S., Gultepe, I., Dorman, C., Creegan, E., and Taylor, P., Fog clearing in the lee of an isolated, flat island: A fog shadow, *Q. Jour. Roy. Met. Soc*., Submitted.

Rowe, K., Ruiz-Plancarte, J., Yamaguchi, R.T., Ortiz-Suslow, D.G., Pardyjak, E., Gultepe, I. Fernando, H.J.S., and Wang, Q., 2024: Characteristics of summertime marine fog observed from a small remote island, to be submitted to Fatima special Issue, *Q. Jour. Roy. Met. Soc.,* Submitted.

Seok, Lee, Gultepe, I., Fernando, H.J.S., Gaberšek, S.[3], Lenain, L., Wang, Q., Chang, R.Y.-W., Dorman, C., Lozovatsky, I., Pardyjak, E., Ortiz-Suslow, D.G., Ruiz-Plancarte, J., Yamaguchi, R., Creegan, E.D., Hoch, S., Perelet, A., Singh, D., Cha, J.W., Shen, L., Barve, A.V., Dowling, A., Wang, S., Gultepe, E., Giacosa, G., Garare, L., Gapp, N., Taylor, P., Chen, Z., Teeloku, P., Lee, S.-W., Jeong, J.-M., Kim, H., Jeong, J.-Y., Heo, K.-Y., Kim, M., Park, M.-S., Oh, K.-H., Park, J.-S., Jeon, D.-C., Song, K.-M., Kim, J.-Y., Jung, D., Chang, K.-I., Lee, J.H., Kim, K.M., Yu, D., Yum, S.S., Heymsfield, A.J., Agelin-Chaab, M., Goo, T.-Y., and Ryu, D.-G., 2024: FATIMA 2023 Yellow Sea Marine Fog Campaign. Submitted to ACP, EGU, (Submitted.

Book Chapters (1)

Gultepe, I., Fernando, H.J.S., and Dorman, C., 2024: Fog Observations and Forecasting. *Encyclopedia of Atmospheric Sciences*, Third Edition, Chapter 1013. Elsevier Publishing, In Press.

Thesis Dissertations (2)

Sen Wang, Field and Numerical Investigation of Moist Thermodynamical Structure of Marine Fog, PhD Thesis, March 18, 2024 (97 pages)

Stef Bardoel, The Lifecycle of Marine Fog in the Coastal Zone, PhD Thesis, March 20, 2024 (134 pages)

Conference Papers (1)

Gultepe, E., Wang, S., Blomquist, B., Fernando H.J.S., Kreidl, O.P., Delene, D., et al. Generative Nowcasting of Marine Fog Visibility in the Grand Banks area and Sable Island in Canada. In: NeurIPS 2023 Workshop on Tackling Climate Change with Machine Learning. 2023. Available from: https://www.climatechange.ai/papers?.

Conference Presentations: ***42***

Bardoel, S., Hoch, S., Ruiz-Plancarte, J., Lenain, L., Gultepe, I., Grachev, A., Gabersek, S., and Fernando, H.J.S., The Formation of Internal Boundary Layers over Sable Island and the Fog Lifecycle during FATIMA, Paper #A51S-2236, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Barve, A., Singh, J., Ortiz-Suslow, D.G., Yamaguchi, R., Wang, Q., Fernando, H.J.S., Gultepe, I., and Shen, L., Effect of Radiative Fluxes on the Life Cycle of Marine Fog: a Large-Eddy Simulation Study Anup Barve, Paper # A51S-2232, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Chang, R., Dionne, J., Nagare, B., Giacosa, G., Robinson, L., Merrick, F., Gauvin-Bourdon, P., Power, C., Wiacek, A., Young, C., Gong, W., Salehpoor, L., Crilley, L., VandenBoer, T. C., Creegan, E.D., and Fernando, H.J.S., Relating Fog Droplets, Sources, and Aerosols in the Atlantic and the Central Arctic , Paper #8.1, *104th AMS Annual Meeting* 28 Jan to 1 February, Baltimore, MD, 2024.

Creegan, E.D., Lee, H-S., Chang, K-I., Jeong, D-C., Cha, J.W., Pardyjak, E., Wang, Q., and Fernando, H.J.S., Notable Observations of the Fatima 2023 Field Campaign Edward D Creegan, Paper # A51S-2234, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Dorman, C.E., and Koračin, D.R., "A Duo Synoptic System Event Causing Fog At Sable Island In July 2022" was presented at the Fall, 11-15 Dec 2023 American Geophysical Meeting at Denver, CO.

Dorman, C.E. and Koračin, D.R., "Fog Structure and Stability at Sable Island on 3-4 July 2022" FATIMA conference on Mar 25 – 26, 2024 on Jeju Island, South Korea.

Dorman, C.E., Koračin, D.R., and Gašparac, G., Fog Structure and Stability at Sable Island in July 2022" was presented at the Winter, Jan 28 – Feb 1 2024 American Meteorology Meeting in Baltimore, MD.

Dorman, C.E., Koracin, D., Gultepe, I., Dimitrova, R., and Formby-Fernandez, A., 2023: Marine Fog and Multiphase Turbulence. AGU 2023 Fall Meeting, San Fransisco, Presentation.

Dowling, A., Fernando, H.J.S., Gonzalez, E., Creegan, E.D., Lee, H-S., Chang, K-I., Gultepe, I., Oh, K., Wang, Q., Ortiz-Suslow, D.G., Ruiz-Plancarte, J., and Gabersek S., Occurrence of Fog over Surface Cold Patches in the Yellow Sea. Paper #A51S-2235, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Fernando, H.J.S., Dorman, C., Wang, Q., Pardyjak, E., Shen, L., Creegan E., and Gultepe, I., Aspects of Multiphase Turbulence Dynamics in Marine Fog, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Giacosa, G., Robinson, L., Gauvin-Bourdon, P., Salehpoor, L., Crilley, L., VandenBoer, T.C., Ortiz-Suslow, D.G., Yamaguchi, R., Wang, Q., Creegan, E., Fernando, H.J.S., and Chang, R., Aerosol contribution to fog life cycle during the FATIMA fog study in the Northwest Atlantic Ocean, *Canadian Meteorological and Oceanography Society 58th Congress*, June 3–6, 2024 (Virtual)

Gonzalez, E., Dowling, A., Fernando, H.J.S., Creegan, E.D., Lee, H-S., Chang, K-I., Gultepe, I., Wang, Q., Ortiz-Suslow, D.G., and Ruiz-Plancarte, J., Marine Fog Observations During the 2023 FATIMA Yellow Sea Field Campaign Edgar Gonzalez, Paper #A51S-2233, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023

Gultepe, E., Wang, S., Fernando, H.J.S., Gultepe, I., and Blomquist, B., 2023: Artificial Intelligence Analysis of Marine Fog Visibility Using Atlantic Condor Ship Measurements from FATIMA. IFDA 9th International Conference on fog, fog collection, and dew. 23-28 July 2023, Fort Collins, Colorado, USA

Gultepe, I., Fernando, H.J., Dorman, C.E., Gabersek, S., Pardyjak, E.R., Creegan, E.D., Hoch, S.W., Wang, Q., Gallagher, M.W., Crawford, I., Komar, J., Agelin-Chaab, M., and Villeneuve, E., 2023: Synoptic Scale to Microphysical Scale of Marine Fog

Characteristics during Fatima Field Campaign. AMS 103th Annual Meeting, Denver, CO. Poster #223.

Gultepe, I., Fernando, H.J.S., Pardyjak, E., Wang, Q., Hoch, S., Perelet, A., Jesus, R.-P., and Dorman, C., 2023: Profiling of Shallow Marine Fog using a UAV and Remote Sensing Observations over the Sable Island during FATIMA, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-10484, https://doi.org/10.5194/egusphere-egu23-10484.

Gultepe, I., Fernando, H.J.S., Wang, Q., Pardyjak, E., Hoch, S.W., Perelet, A.O., Ruiz-Plancarte, J., Wang, S., Komar, J., Villeneuve, E., and Agelin-Chaab, M., 2023: Comparisons of Marine Fog Microphysics during FATIMA: Turbulence Impact on Fog Microphysics. IFDA 9th International Conference on fog, fog collection, and dew. 23-28 July 2023, Fort Collins, Colorado, USA

Gultepe, I., Fernando, H.J.S., Wang, Q., Pardyjak, E., Hoch. S.W., Perelet, A.O., Ruiz-Plancarte, J., Wang, S., Komar, J., Villeneuve, E., Agelin-Chaab, M., Lee, H-S., Chang, K-I., Lee, J.H., and Cha, J.W., A Comparative Study of the Marine Fog Microphysics during FATIMA-I and II: Turbulence Impact on Fog Microphysics, Paper # A51S-222, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Gultepe, I., Fernando, H.J.S., Wang, Q., Pardyjak, E. R., Hoch, S. W., Perelet, A., Ruiz-Plancarte, J., Wang, S., Dorman, C.E., Komar, J., Villeneuve, E., Agelin-Chaab, M., Seok, J.H., Chang, K.I., Lee, H., Joo Wan, C., and Kim, H., The Marine Fog Microphysics Based on the Ship Data during FATIMA-I and II , Paper #8.1, *104th AMS Annual Meeting* 28 Jan to 1 February, Baltimore, MD, 2024.

Huang, K.Y., Hintz, T., Hoch. S.W., Bardoel, S., Gabersek, S., Ruiz-Plancarte, J., Gultepe, I., Pardyjak, E., Wang, Q., Fernando, H.J.S., A Mechanism for Coastal Fog Genesis at Evening Transition Kelly Y Huang, Paper # A51S-2231, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Kim, H., Korea Institute of Ocean Science and Technology, Busan, Busan, Korea, Republic of (South); and K.Y. Heo, I. Gultepe, J.Y. Jeong, and H.J. Fernando. 2024: A Yellow Sea Fog Observations and Modeling using the Korea Ocean Research Stations: FATIMA-YS Case. AMS 2024 Annual Meeting, Baltimore, USA, Presentation#8.2.

Kim, H., Heo, K.Y., Gultepe, I., Jeong, Y.J., and Fernando, H.J.S., Yellow Sea Fog Observations and Modeling using the Korea Ocean Research Stations: FATIMA-YS Case, Paper #8.2, *104th AMS Annual Meeting* 28 Jan to 1 February, Baltimore, MD, 2024

Lata, N.N., Gultepe, I., Fernando, H.J.S., Dexheimer, D., C. Zezhen, Mei, F., and China, S., Arctic Ice Fog: Unveiling the Role of Aerosol Chemistry, AAAR 42nd Annual Conference, October 21-25, Albuquerque, New Mexico, 2024.

Lee, J-H., Chang, K.-I, Cha, J.W., Fernando, H.J.S., Highlights of FATIMA Yellow Sea 2023 Campaign, Paper # A44F-02, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Lee, J-H., Chang, K.-I, Lee, S., Cha, J.W., and Fernando, H.J.S., FATIMA Yellow Sea 2023 Experiment: A sea fog study, *2nd UN Ocean Decade Regional Conference & 11th WESTPAC International Marine Science Conference,* April 22-25, 2024, Bangkok, Thailand.

Ortiz-Suslow, D., Kalogiros, J., Ruiz-Plancarte, J., Yamaguchi, R., and Wang, Q., 2024: A report on fog-air-surface interactions: preliminary fingings from the Yellow Sea and Grand

Banks, Marine Fog and its Prediction and Contributions of the FATIMA Project, 25-26, March 2024, Jeju Island, Republic of Korea.

Ortiz-Suslow, D.G., Ruiz-Plancarte, J., Yamaguchi, R., Kalogiros, J., Fernando, H.J.S., Creegan, E.D., Pardyjak, R., Blomquist, B.W., Gabersek, S., Gultepe, I., and Wang, Q., Observations of Boundary Layer Evolution Downwind of a Remote, Small Island during the FATIMA 2022 Campaign, Paper #8.5, *104th AMS Annual Meeting* 28 Jan to 1 February, Baltimore, MD, 2024.

Ortiz-Suslow, D.G., Ruiz-Plancarte, J., Yamaguchi, R., Kalogiros, J., Fernando, H.J.S., Creegan, E., Pardyjak, E., Gabersek, S., Gultepe, I., and Wang, I., A case study of boundary layer development downstream of a small, remote island. 6th California Geophysical Fluid Dynamics Conference, Stanford, Palo Alto, CA, Sep 4, 2024.

Pardyjak, E.R., Gultepe, I., Hoch, S.W., and Perelet, A.O., 2024:b Linking heat and moisture budgets during fog events to droplet spectra behavior. AMS. 21st Conference on Mountain Meteorology. 22 - 26 July 2024 Boise, Idaho. Oral Presentation.

Perelet, A.O., Gultepe, I., Hoch, S.W, Pu, Z., and Pardyjak, E., University of Utah, Department of Mechanical Engineering, Salt Lake City, United States, The importance of nuances in the droplet size distribution on measurements of infrared and microwave extinction to derive fog microphysical properties, A44F-07, AGU23 Meeting in San Francisco, December 11-15, 2023.

Richter, D.H., Rodriguez, C., Chang, R., VandenBoer, T., Giacosa, G., and Salehpoor, L., "Aerosol-turbulence-fog interactions in marine fog: Insights from Lagrangian cloud model simulations", presentation at the International Conference on Clouds and Precipitation, Jeju Island, South Korea, July 15, 2024

Rodriguez Geno, C., Richter, D.H., Chang, R., VandenBoer, T., Giacosa, G., and Salehpoor, L., "Investigating aerosol activation and microphysics in marine fog using a Lagrangian cloud modelling framework", presentation at the American Meteorological Society Annual Meeting, Baltimore, MD, January 29, 2024

Ruiz-Plancarte, J., Yamaguchi, R.T., Kalogiros, J.A., Ortiz-Suslow, D.G., and Wang, Q. (2023), "Turbulent Fog Processes in the Lower Boundary Layer of Sable Island", AGU Fall meeting, 10-15 December, San Francisco, CA

Ruiz Plancarte, J., Ortiz-Suslow, D., Kalogiros, J., Yamaguchi, R., and Wang, Q., 2024: Exploring turbulence and fog characteristics in FATIMA, Marine Fog and its Prediction and Contributions of the FATIMA Project, 25-26, March 2024, Jeju Island, Republic of Korea.

Salehpoor, L., Crilley, L.R., Young, C.J., Giacosa, G., Robinson, L., Gauvin-Bourdon, P., Chang, R., Tao, Y., Creegan, E., Fernando, H.J.S., and VandenBoer, T., Characterization of chemical composition in size-resolved marine aerosol during fog formation events over the Northwest Atlantic Ocean during FATIMA 2022, *107th Canadian Chemistry Conference Exhibition (CSC 2024)*, June 2-6, 2024, RBC Convention Centre, Winnipeg, Canada.

Singh, M.D., Huckins, K., Gare, L., Lenain, L., Perelet, A.O., Hoch, S.W., Gultepe, I., and Pardyjak, E., Validation of Liquid water content measurements from a low-cost hot wire probe during fog campaigns, A51S-2239, AGU23 Meeting in San Francisco, December 11-15, 2023.

VandenBoer, T.C., Salehpoor, L., Crilley, L., Young, C., Giacosa, G., Gauvin-Bourdon, P., Chang, R., Creegan, E.D., and Fernando, H.J.S., Characterization of Chemical

Composition in Size-resolved Marine Aerosol during Fog Formation events over the Northwest Atlantic Ocean during FATIMA 2022, Paper #8.4, *104th AMS Annual Meeting* 28 Jan to 1 February, Baltimore, MD, 2024

VandenBoer, T., Salehpoor, L., Crilley, L., Young, C., Giacosa, G., Gauvin-Bourdon, Chang, R., Creegan, E., and Fernando, H.J.S., -Fog Interactions and Chemical Processing: Insights from the Grand Banks and Sable Island regions during Fatima 2022, AAAR 42nd Annual Conference, October 21-25, Albuquerque, New Mexico, 2024.

Wang, Q., Ortiz-Suslow, D., Ruiz Plancarte, J., Yamaguchi, R., Kalogiros, J., and Rowe, K., 2024: An overview of NPS measurements on R/V Onnuri during Fatima Yellow Sea, Marine Fog and its Prediction and Contributions of the FATIMA Project, 25-26, March 2024, Jeju Island, Republic of Korea.

Wang, Q., Ruiz-Plancarte, J., Ortiz-Suslow, D.G., Yamaguchi, R., Kalogiros, J.A., Rowe, K.M., Creegan, E.D., Pardyjak, E., and Fernando, H.J.S., Turbulence and Fog Microphysics and Their Impact on Optical Propagation from FATIMA, Paper # A44F-04, Paper # 44F-01, AGU23 Meeting in San Francisco, December 11-15, 2023.

Yamaguchi, R., NPS, Monterey, CA; and Ruiz-Plancarte, J., Ortiz-Suslow, D.G., Chang, R., Creegan, E.D., Fernando, H.J.S., Kalogiros, J., and Wang, Q., 24SMOI A Shipboard Atmospheric Surface Layer Profiling System for Air-Sea Interaction and Fog Studies, Poster 385, *104th AMS Annual Meeting* 28 Jan to 1 February, Baltimore, MD, 2024

Yamaguchi, R., J. Kalogiros, Q. D. Ortiz-Suslow, J. Ruiz Plancarte, R. Chang, E. Creegan, J. Fernando, and Q. Wang, 2024: Shipboard profiling platform for air-sea interaction and fog measurement deployed during FATIMA, Marine Fog and its Prediction and Contributions of the FATIMA Project, 25-26, March 2024, Jeju Island, Republic of Korea.

Yamaguchi, R.T., Ruiz-Plancarte, J., Ortiz-Suslow, D.G., Chang, R., Creegan, E.D., Fernando, H.J., Kalogiros, J., and Wang, Q., 2024, A Shipboard Atmospheric Surface Layer Profiling System for Air-Sea Interaction and Fog Studies. Presentation at the 24th Symposium on Meteorological Observation and Instrumentation, American Meteorological Society 104th Annual Meeting, 28 January – 1 February 2024, Baltimore, MD.