



Influence of Cyclonic Activity on Atmospheric Radiative Forcing and Energetics

Nishi Srivastava¹

¹Dept. of Physics, Birla Institute of Technology, Mesra, Ranchi, 835215, India

Goal: Aerosols indirectly contribute to the modulation of strength of cyclones. However, the role of cyclones in the redistribution and generation of aerosol, and their radiative effects are less explored. In the present work, we explored the redistribution and generation of aerosols and the resulting moderation of radiative forcing resulting from these changes during the development of severe cyclone Mocha (9 - 15 May 23) and its landfall in May 2023.

Data Used:

- ❑ MERRA-2 reanalysis daily data of dust, sea salt, black carbon (BC), and Aerosol Optical Depth (AOD) has been used
- ❑ MODIS AOD daily data at 550 nm from Terra and Aqua satellites retrieved using the dark target algorithm
- ❑ CERES SYN1deg Daily data Edition 4.2

Study Period:

- ❑ Study Period: Mocha cyclone started to form on 9 May 23 and dissipated by 15 May 23. We have taken an extended study period from 4 May 23 to 19 May 23. We selected five days before and after the cyclone time duration to monitor the background conditions before and after the cyclone development.

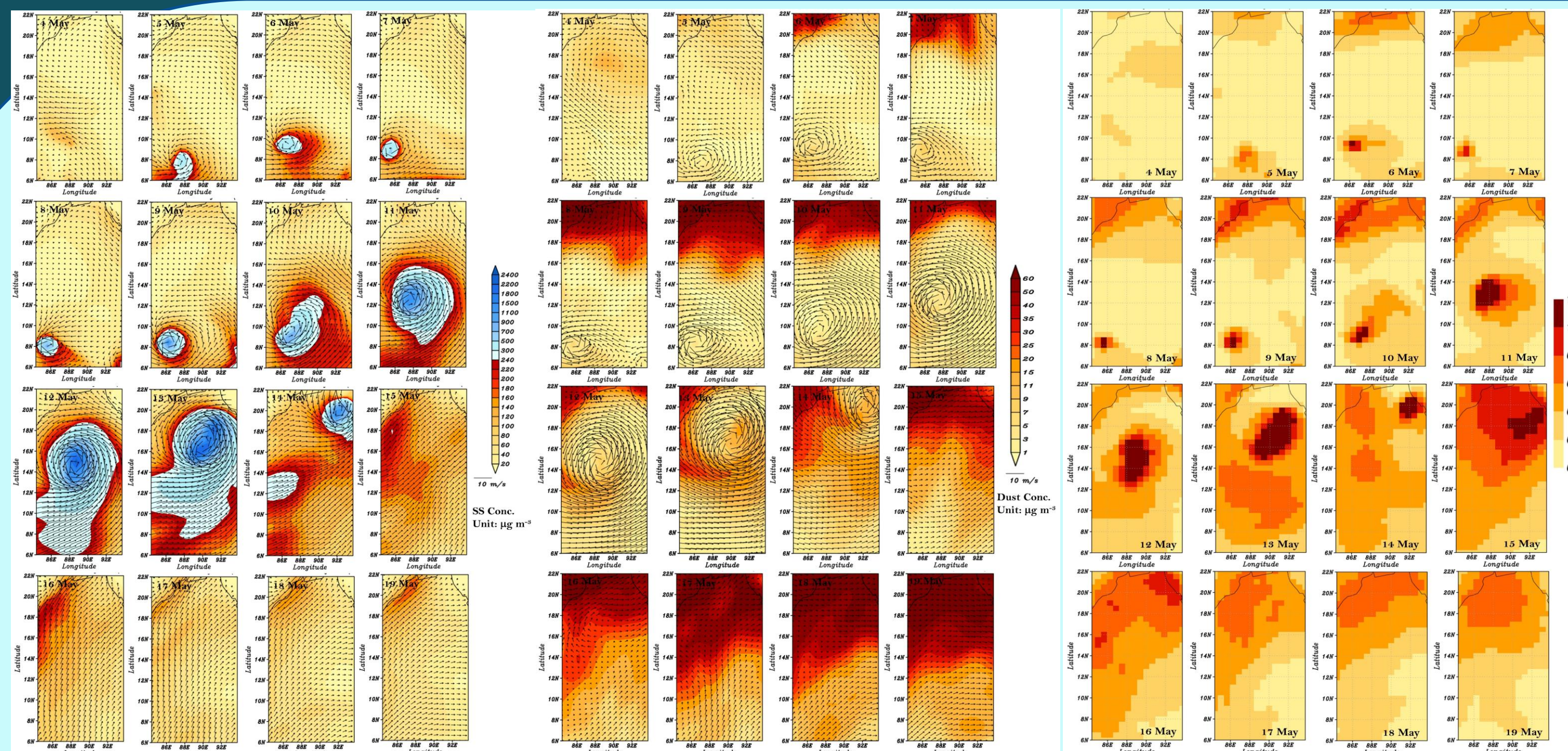


Fig1: Spatial variation of sea salt aerosols over the Bay of Bengal during the development and dissipation of Cyclone (Units: $\mu\text{g m}^{-3}$)

Fig2: Spatial variation of Dust aerosols over the Bay of Bengal during the development and dissipation of Cyclone (Units: $\mu\text{g m}^{-3}$)

Fig3: Spatial variation of AOD over the Bay of Bengal during the development and dissipation of Cyclone

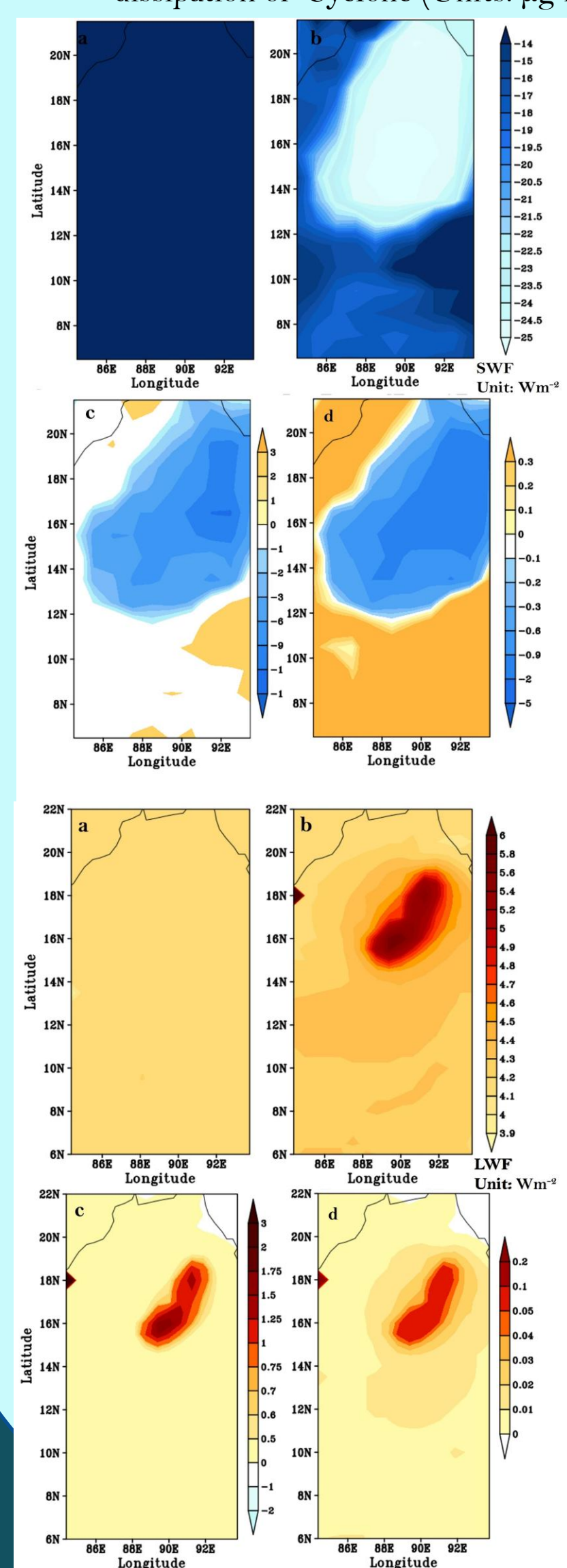


Fig4: Spatial variation of SW forcing from SBDART at the top of the atmosphere (TOA) over the Bay of Bengal during the development and dissipation of Cyclone (a) 4 May 23, (b) 13 May 23 (c) Difference between SWF (Effect of Cloud + Aerosol) on 13 May 23 to that on 4 May 23 (d) Difference between SWF (Effect of Aerosol only) on 13 May 23 to that on 4 May 23

Fig6: Spatial variation of LW forcing from SBDART at the top of the atmosphere (TOA) over the Bay of Bengal during the development and dissipation of Cyclone (a) 4 May 23, (b) 13 May 23, (c) Difference between LWF (Effect of Cloud + Aerosol) on 13 May 23 to that on 4 May 23 (d) Difference between LWF (Effect of Aerosol only) on 13 May 23 to that on 4 May 23.

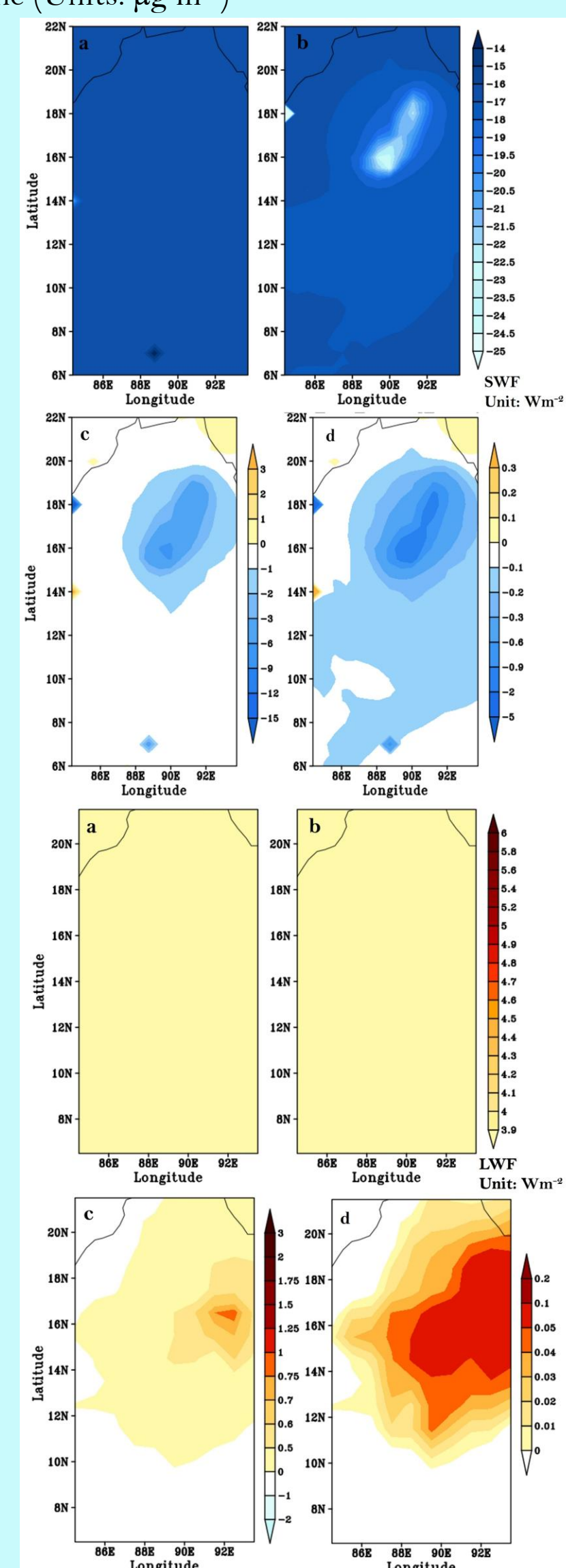


Fig5: Spatial variation of SW forcing from CERES at the top of the atmosphere (TOA) over the Bay of Bengal during the development and dissipation of Cyclone (a) 4 May 23, (b) 13 May 23 (c) Difference between SWF (Effect of Cloud + Aerosol) on 13 May 23 to that on 4 May 23 (d) Difference between SWF (Effect of Aerosol only) on 13 May 23 to that on 4 May 23.

Fig7: Spatial variation of LW forcing from CERES at the top of the atmosphere (TOA) over the Bay of Bengal during the development and dissipation of Cyclone (a) 4 May 23, (b) 13 May 23, (c) Difference between LWF (Effect of Cloud + Aerosol) on 13 May 23 to that on 4 May 23 (d) Difference between LWF (Effect of Aerosol only) on 13 May 23 to that on 4 May 23.

Results

The concentration of dust and sea salt aerosols increased significantly during cyclonic activity. These aerosols have been observed to grow in duration multiple times during the cyclone's formation and dissipation. The concentration of sea salt aerosols was seen to be increasing along the trajectory of the cyclone, while the concentration of dust aerosols over the surrounding land region (i.e., Bangladesh and Myanmar, as well as in the vicinity of West Bengal, India) was increasing after landfall of the cyclone. The concentration of BC aerosol did not exhibit a significant shift. Since AOD levels are a good indicator of atmospheric aerosol loading, they changed noticeably as cyclones formed. Notable changes are observed in the radiative forcing and its distribution during cyclonic activity. The TOA and surface observed greater cooling than heating due to the cyclone. As the cyclone intensifies, the generation of fine-mode particles is greater than that of coarse-mode particles, as evidenced by the fact that the magnitude of SWF is greater than that of LWF over the cyclonic region.

Conclusions

In the present work, we have investigated the change in the different aerosol components along with AOD during a cyclonic activity.

- Both of natural aerosols (Dust and Sea Salt) are wind-generated, and during the cyclone formation and dissipation, wind stress increases significantly at the land and ocean surfaces. The concentration of BC aerosol did not exhibit a significant shift.
- The changes in SWF and LWF caused by variations in aerosol loading during the cyclone period are about one order of magnitude less than the changes caused by cloud variations during the same period. The signs of the area-averaged SWF and LWF forcings from the SBDART calculations are consistent with those from the CERES observations for the cyclone-impacted area, but there is about one order of magnitude difference between them.

References

- Cotton W. R., Krall G. M., Carrió G. G. (2012), Potential Indirect Effects of Aerosol on Tropical Cyclone Intensity: Convective Fluxes and Cold-Pool Activity, *Tropical Cyclone Research and Review*, 1, no. 3, 293-306, <https://doi.org/10.6057/2012TCRR03.05>
- Carrió, G.G., Cotton, W.R. (2011), Urban growth and aerosol effects on convection over Houston. Part II: Dependence of aerosol effects on instability, *Atmospheric Research*, 102(1-2), 167-174, doi:10.1016/j.atmosres.2011.06.022
- Monahan, E. C., Muircheartaigh, I. O. (1980), Optimal power-law description of oceanic whitecap coverage dependence on wind-speed, *J. Phys. Oceanogr.*, 10, 2094-2099, [https://doi.org/10.1175/1520-0485\(1980\)010<2094:Opldao>2.0.Co;2](https://doi.org/10.1175/1520-0485(1980)010<2094:Opldao>2.0.Co;2)
- Rosenfeld, D., Khain A., B. Lynn B., Woodley W. L. (2007), Simulation of hurricane response to suppression of warm rain by sub-micron aerosols. *Atmos. Chem. Phys.*, 7, 3411-3424.
- Stokes M. D., Deane G. B., Prather K., Bertram T. H., Ruppel M. J., Ryder O. S., Brady J. M., and Zhao, D. (2013), A marine aerosol reference tank system as a breaking wave analogue for the production of foam and sea-spray aerosols, *Atmos. Meas. Tech.*, 6, 1085-1094, <https://doi.org/10.5194/amt-6-1085-2013>.
- Wahiduzzaman Md., Arfan Ali A. Md., Kevin C. B., Jing-Jia L. C., Tang S. A., Prasad K. B. A., Yuan C.D., Bilal A. M., Qiu B. Z.B. and Mansour A. (2022), Impacts of Aerosols and Climate Modes on Tropical Cyclone Frequency over the North Indian Ocean: A Statistical Link Approach, *Journal of Climate*, 35, 2549-2564, DOI: 10.1175/JCLI-D-21-0228.1

Acknowledgement

- We acknowledge GES DISC for MERRA, Version 2 data download. Aerosol and cloud properties were obtained from the MODIS 434 (<https://search.earthdata.nasa.gov/>) and CERES (<https://ceres.larc.nasa.gov/data/>).
- Science and Engineering Research Board (SERB) for funding MATRICS project (MTR/2022/000095)