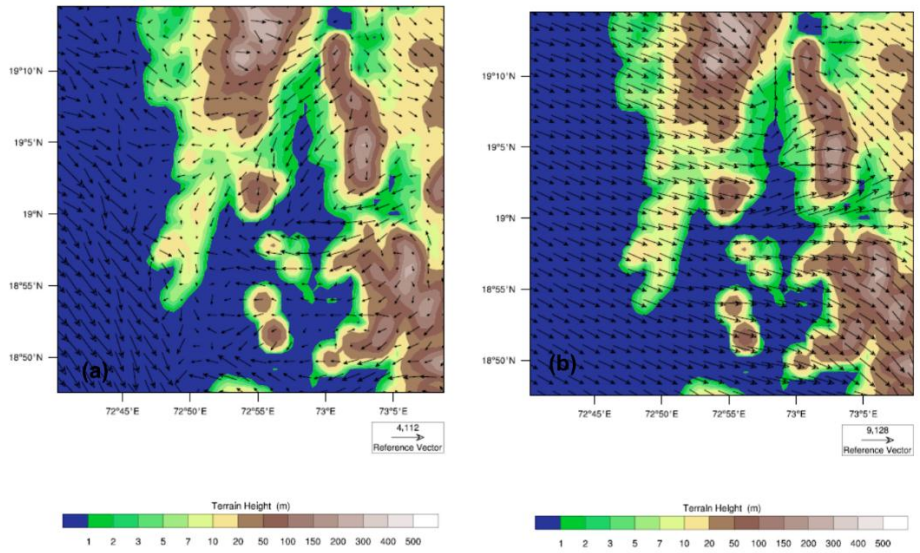
Application of Numerical Weather Prediction Models in Simulation of Atmospheric Flow Field

Numerical Weather Prediction (NWP) models can simulate the wind flow characteristics at horizontal resolution of several kilometers. They are used to forecast the spatial and temporal variation of the atmosphere by integration of a coupled set of non-linear differential equations. As an example, the Weather Research and Forecasting (WRF) is used for atmospheric flow field simulation for Trombay site. Initial and boundary conditions required for the model are from NCEP FNL (Final) global analysis data on 0.25-degree by 0.25-degree grid. The analyses are available on the surface, at 26 mandatory (and other pressure) levels from 1000 millibar to 10 millibar, in the surface boundary layer and at some sigma layers, the tropopause and a few others. Figures-1 (a) and (b) are snapshots of atmospheric flow field for Trombay site in stable (02nd May 2020 0 UTC) and unstable (02nd May 2020 6 UTC) atmospheric conditions respectively. Wind vectors are plotted at 10-m above topography in both the figures. Effect of topography on the flow field is seen from the figures. In stable atmospheric conditions, flow diverges around topographical barriers, whereas in unstable atmospheric conditions when the kinetic energy of the flow is higher, effect of topography on the flow is minimal. Variations in the flow field over land and water surfaces are also higher in stable atmospheric conditions as compared to unstable atmospheric conditions. Flow fields computed using NWP models can be used in atmospheric dispersion models, either to have a forecast of the impact of the released pollutant or to incorporate spatial in-homogeneities in atmospheric dispersion estimates.



Figures-1 (a), (b): Atmospheric flow field for Trombay site in stable (02nd May 2020 0 UTC) and unstable (02nd May 2020 6 UTC) atmospheric conditions respectively.

Application of Numerical Weather Prediction Models in Simulation of Tropical Cyclones

One of the application of NWP models is in the simulation of tropical cyclones. During natural calamities like tropical cyclones, NWP models integrated in forecast mode can be used to determine the future trajectory and intensity of the cyclone. These forecasts are utilized for disaster management and emergency preparedness. As an example, the Weather Research and Forecasting (WRF) is used for simulation of tropical cyclone Nisarga which made landfall in Raigad district on 3rd June, 2020. The extent of the domain used for simulation covers the Arabian Sea, Indian sub-continent and Bay of Bengal in the horizontal and few tens of kilometers in the vertical. Initial and boundary conditions required for the model are from NCEP FNL (Final) global analysis data on 0.25-degree by 0.25-degree grid. Figure-2 shows the atmospheric flow field at the time of landfall i.e. on 3rd June 2020 at 06 UTC. Wind vectors are plotted at 10-m above topography. On comparison with "Best Track Parameters" from India Meteorological Department, it is seen that the track and intensity of the cyclone are well reproduced in the simulation.

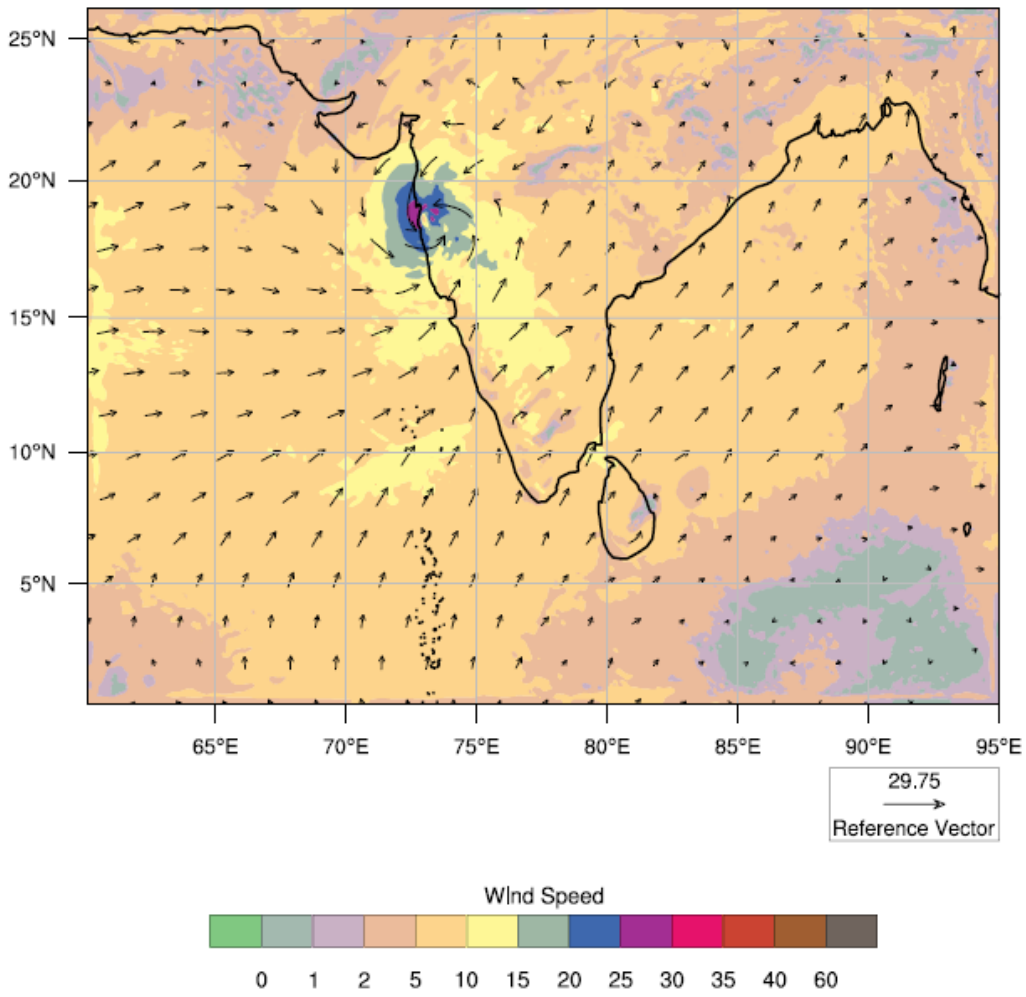


Figure-2: Atmospheric flow field for tropical cyclone Nisarga at the time of landfall i.e. on 3rd June 2020 at 06 UTC.

Estimation of Sea-Breeze – Land –Breeze Circulation around Trombay using the coupled WRF-CALMET model

Sea Breeze-Land Breeze Circulation (SLBC) is an innate characteristic of any coastal site. SLBC also affects the air quality of the site by re-circulating the pollutants released close to the surface. Thus it becomes imperative to understand the onset, duration and cessation of such circulation. The SLBC for Trombay site, within which BARC is located, was estimated using the coupled WRF-CALMET model. The predominant wind direction during the period of study was northeast for the domain. The wind field generated by WRF at a grid resolution of 1 km was used as input in CALMET model at a grid resolution of 90 m. Figure.1 shows the results of the model run at a height of 60 m agl for 0900 and 2200 UTC on 17th January 2012. Wind is coming mainly from north or northeast with slight variation at certain hours. The variation could be attributed to the presence of hill in the proximity of the instrument which reflects the wind in the lower heights and renders complex pattern. But after 1330 IST, the wind is predominantly from northwest at all heights indicating the onset of sea breeze and remains the same till 2230 IST when the wind slowly turns to northerly or northeasterly again. This indicates land breeze. Thus it can be concluded that the onset, duration and cessation of sea breeze for BARC site is at 13:30 IST, 9 hrs and 2200 IST respectively during the study period. The land/sea breeze shifts to sea/land breeze through north direction during the period of study. These conclusions are in agreement with the published results. Such studies are useful in studying pollutant dispersion at coastal sites.

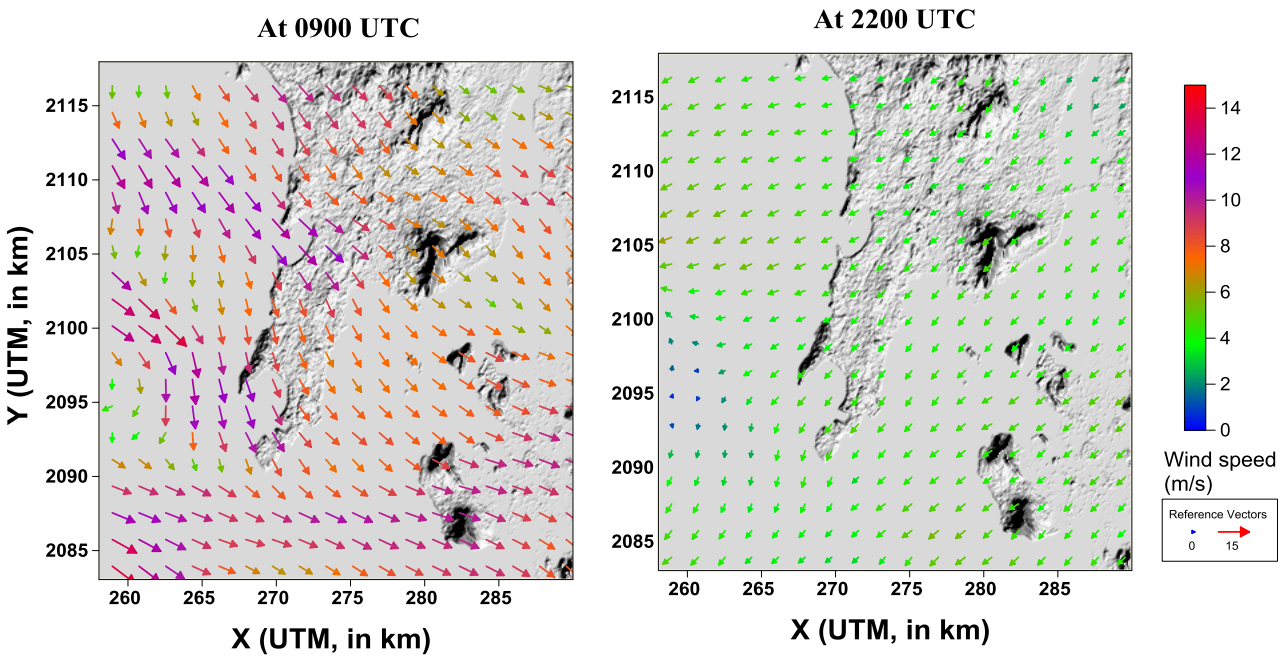


Figure-4: WRF-CALMET simulated wind field over Mumbai at 0900 UTC and 2200 UTC