A Unified Modeling Approach to Improve the Atmospheric Predictability

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The meteorological conditions of any place are dependent on the surface characteristics of the nearby regions. The changes in any of its property gets reflected on the atmosphere above it, which will further influence the circulation pattern surrounding it. These conditions are often responsible for triggering or suppressing the different atmospheric phenomenon. These changes follow the basic primitive Partial Differential Equations (PDEs) governing the atmospheric motion and thermodynamics. These equations are framed together and are discritized using various numerical difference schemes and form a numerical model. Every model has its own way of discretion and setup of other physical processes including boundary layer friction, atmospheric convection and cloud microphysics. Each model requires certain initial or boundary condition to produce a solution. The model solutions are known to be highly sensitive to these conditions. Certain studies have even shown that a model setup with minor changes in initial condition will provide entirely divergent solutions. Thus the major focus of the scientific community has always remained to improve the initial conditions so as to provide accurate results. This is the reason that the operational forecasting community relies always on ensemble runs. They provide a set of possible solutions which they call ensembles corresponding to imperfect initial conditions and mathematical model formulations to study the tendencies of possible future state.

The initial conditions are already highlighted by the scientific community, one should also not ignore the importance of boundary conditions. The boundary conditions help derive the near

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surface heat fluxes balancing the radiation budget and controlling the heat and moisture content of the atmosphere. Their importance has been realized by many studies in literature, a study performed by Prof. J Shukla has even shown that two divergent solutions can be made convergent for a region, if the boundary conditions are similar. Therefore, for better understanding of the atmospheric processes, the present state of the art numerical models use different schemes for representation of surface boundary conditions. Since these models are meant to predict the weather and climate accurately, any discrepancy in their parameterization will lead to a large bias and their usefulness will be questioned. Their reliability becomes more important when a natural disaster or monsoon condition is to be forecasted. The scientists have put in a lot of efforts to capture the Indian monsoon realistically, but when it comes to storm related warnings, our country still lags behind others. It is still struggling with modeling the atmospheric state for the extended and seasonal range scale prediction. The reasons are apparent; we rely on models which are developed by foreign countries, so they are better representative of their region. One has to gain more expertise in tuning in the input parameters to improve our spatiotemporal model solutions. Secondly, we are trying to represent our weather and climatic conditions through these models but hardly intend to modify their inherent parameterizations or add the required factors of our concern. For largescale flows, the scientific community always relies on General Circulation Models (GCMs). But due to the nonlinear atmospheric perturbations and chaotic conditions, the model solutions appear to diverge from their true state and, thus, one has to depend upon the observations. The GCM outputs are trustworthy only when they are merged with observations and an assimilated output is obtained for the scientific usage. The bias generated in these models arises due to imperfect initial conditions, atmospheric uncertainty and the lack in our present understanding of the physical parameterization of boundary surface and its response to the surrounding atmosphere. The GCMs are designed to be run on coarser grids (>50 km), therefore, the land surface distributions are not always accurate in them. Moreover, these models use only few surface parameters, rest of the others are being neglected. For example, the contribution of ocean is very limited to the atmosphere in these models. We are only using SST to force a GCM, rest of the other variables are either ignored or considered to be passive.

One of such variables is Salinity. The present modeling generation still considers it as a passive tracer and very few studies are based on it. But, it has a great impact on general circulation and evaporation rate. Studies have come up with the fact that when saline water accumulates, there is less vapour pressure over it. While Arabian Sea (AS) is known to be saline, Bay of Bengal (BoB) has relatively low salinity because of the freshwater input from the Indo Gangetic plains. Thus, BoB and AS have very contrasting influences on the atmosphere. The region above Arabian Sea remains relatively drier because of its geographical conditions and influences from the African region. On the other hand, BoB remains moist and is known to have higher CAPE during pre- monsoonal and monsoonal seasons. The negative heat fluxes during this period around these regions are still an open question to the scientific community. A more puzzling paradigm is observed when the SST over the bay remains warmer in spite of the negative heat flux anomalies. The BoB depressions intensify to form severe cyclonic storms in the presence of low fluxes, nobody knows how are they fueled even when the surface fluxes are negative. The reasons can be synoptic or local, but are still unknown to the scientists. There are still uncertainties about flux tendencies and their relationship with subsurface parameters. Therefore, we need to perform more experiments with surface and subsurface parameters so that a reliable estimate of these variables and an acceptable parameterization is obtained.

Similarly, the representation of clouds in climate models has been a major issue till date. The lifespan of clouds is limited to a few hours and its spatial extent is also very low. Thus, the present day models are only capable of representing large -scale cloud and rainfall patterns in them. They are unable to capture the convection explicitly with or without using any cumulus parameterization scheme at the cloud resolving scale. Since the radiation budget and atmospheric heat fluxes are highly dependent on these clouds, we are getting their unclear profile with respect to the climate. The same issue is with land surface schemes in climate models. The low resolution climate models contain a blurred profile of vegetation and topography values, this limits our understanding of subgrid scale processes that have much contrasting influence on climate. These issues are resolved in weather prediction models, but they cannot be used for climate -based studies. They are run at a higher resolution and are computationally more expensive.

Thus, we need to adopt a unified approach that can be used for weather as well as climate -based studies at finer resolution. The aim can be accomplished by making little changes in the model design and numerical schemes used in it. The ultimate goal of the meteorological community is to get, "Accurate predictability with least dependence upon the observations". This can be achieved only if we become well equipped with theoretical as well as experimental physics.