

ICTM panel discussion on "Tropical Data Assimilation and Forecasting"

held on 29th April, 4-5 pm CET

Organizers: Prof. Nedjeljka Žagar and Prof. Sam Stechmann.

As a part of the International Union of Geodesy and Geophysics (IUGG)'s initiative to establish a commission on tropical meteorology under its Association of Meteorology and Atmospheric Sciences (IAMAS), a series of talks and panel discussions has been scheduled. The first panel discussion took place on the 29th of April 2025 between 4-5 pm CET on the topic "Tropical Data Assimilation and Forecasting". The panel was organised and the discussion moderated by Prof. Nedjeljka Žagar and Prof. Sam Stechmann. A short summary of the discussion is as follows,

The discussion started with a short welcome address by Prof. Nedjeljka Žagar, Professor of theoretical meteorology at the University of Hamburg.

The panel discussion started with invited talks from numerical weather prediction centers focusing on the perspectives of tropical meteorology initial value problem. The three presenters included

- 1) Dr. Daniel Holdaway, NOAA Environmental Modeling Center, USA.
- 2) Prof. Dale Barker, Centre for Climate Research, Singapore.
- 3) Dr. Elias Holm, European Centre for Medium Range Weather Forecasts, UK.

Dr. Daniel Holdaway, NOAA Environmental Modeling Center

The first speaker, Dr. Daniel Holdaway presented recent developments in data assimilation (DA) for NOAA GFS system including the JEDI system, unified DA framework under collaborative development between NOAA and its partners. His presentation included special forecasting setups for tropical hurricanes and atmospheric rivers. Dr. Holdaway brought out the growing use of commercial providers of observations such as ground-based and ground controlled long-duration flight balloons in observational system over the tropical oceans. He highlighted how these balloons are being used in areas where long flight travel and observations are quite challenging over open oceans that are far away from the coasts. Tropical cyclones and atmospheric river forecasting are examples where such observations are critical.

Prof. Dale Barker, Centre for Climate Research, Singapore

Prof. Baker began the presentation by highlighting the need and importance of very high resolution urban modelling in the tropical regions such as Singapore where the local weather has strong impact. He presented research carried out at the Centre for Climate Research, Singapore to bring in the use of Artificial Intelligence in nowcasting using Real time RADAR data observations based on the Graph Cast model. It was shown that these AI based models are able to provide predictability for 60-90 minutes in the nowcasting forecast window. Along with this, Prof. Baker also showcased the modelling efforts being done in the implementation of

SINGV, convective-scale numerical weather prediction system designed especially for local weather forecasting in the Singapore region, and its ensemble prediction system. It was shown that this regional model is constantly adding value on top of the global NWP (ECMWF model) in the region. There are also efforts being made in developing and testing a next-generation model, such as MPAS-NCAR (Model for Prediction Across Scales, a stretched grid model), which would involve km-scale modelling focused over the Singapore region and coarser resolution going outward radially. This model is shown to show good accuracy in predicting local convective scale features with data assimilation being incorporated with real time RADAR and all-sky radiances data. Prof. Baker also highlighted the efforts that are being made in the development of a regional Reanalysis dataset for South East Asia (MCARR- Maritime Continent Atmospheric Regional Reanalysis) for the past 30-60 years with the help of NWP and AI models.

Dr. Elias Holm, European Centre for Medium Range Weather Forecasts

Dr. Holm discussed properties of the ECMWF DA system in the tropics. He highlighted the differences in the nature of background errors between the tropics and the extratropics and explained how these are handled in the ECMWF DA. Starting with the global vertical temperature field, it was shown that the contribution of the unbalanced error component to the total error variance is larger in the tropics compared to the extratropics. He showed that he errors grow by a factor of 3 in the tropics, compared to a factor of 10 in the extratropics. The assimilation of large-scale fundamental field variables helps constrain these errors in the extra tropics, assimilation of radiance observations sensitive to humidity from satellites effectively constrains winds in the tropics in the ECMWF 4D-Var system. Recent work at ECMWF about re-centering DA was shown to produce more realistic tropical cyclones.

Discussions touched upon challenges in the tropical NWP initial value problem and modelling. Opportunities for academic research to include the role of reduced-complexity models in NWP developments were also discussed.

Recent progresses in tropical Numerical Weather Prediction and key gap areas:

- 1) There has been significant progress over the past few decades in refining DA methods and in improving models for tropical NWP. Notably, km-scale forecasting is seen as a key to advancing predictions, primarily at short spatio-temporal scales.
- 2) There are still significant observation gaps, e.g., missing wind profiles. The positive effects of the horizontal line-of-sight winds from ESA's Aeolus satellite have demonstrated the importance of wind data.
- 3) Only a portion of the observation information is utilized in DA. It is not clear how well do we understand the limitations of the usefulness of radiances in the tropical NWP.

- 4) Given the focus on global high-resolution modelling and the state of the Global Observing System, panel discussed what are the most important challenges and scientific questions that need to be addressed.

The moderators argued that reduced-complexity modelling of DA, predictability, and the tropical dynamics may be more important than ever necessity to filter and analyze large datasets from km-scale models. However, to be useful for this purpose, the reduced-complexity tropical models need to include multiple scales and wave interactions, incorporating tropical waves that are present across different scales.

Prof. Barker pointed out the challenge of getting the diurnal cycle right, including peak convection in km-scale models, and a useful seasonal outlook. Dr. Holm pointed to the need to work with AI outputs of NWP and predictability topics, whereas Dr. Holdaway highlighted the air-sea interaction topic and the use of GPUs. He also presented ucadre.org as an example of DA training at the USA universities in collaboration with NOAA, whereas Prof. Barker described university collaborations in DA research in Singapore.

The minutes of the meeting are prepared by Mr. Gokul Tamilselvam, IITM Pune
Reviewed by (Dr. Ramesh Vellore, Retired Scientist, IITM)