GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
RAJYA SABHA
UNSTARRED QUESTION NO. 3246
ANSWERED ON 21/08/2025

BHARAT FORECAST SYSTEM

3246. SHRI HARIS BEERAN:

Will the Minister of **EARTH SCIENCES** be pleased to state:

(a) whether Government will provide a complete list and description of all core components of the Bharat Forecast System (BFS) model;
(b) whether the Triangular Cubic Octahedral (TCO) Grid used in BFS was originally developed in India, if so, the details thereof;
(c) if not, the name of foreign country or institution from which it has been adopted;
(d) whether the algorithms for the TCO Grid were entirely developed by Indian scientists & institutions;
(e) whether the forecast algorithm used in BFS is fully indigenous, or adapted from a foreign model;
(f) if so, the detail thereof; and
(g) whether BFS is fully indigenous as stated, if not, the component-wise breakup of indigenous & non-indigenous contributions?

ANSWER
THE MINISTER OF STATE (INDEPENDENT CHARGE) FOR
MINISTRY OF SCIENCE AND TECHNOLOGY
AND EARTH SCIENCES
(DR. JITENDRA SINGH)

(a) Yes. Numerical weather prediction models have two major components—the dynamics and the physics of the model. The dynamics component handles the resolved scales of atmospheric motion, while the physics component represents sub-grid scale processes. In BharatFS, the dynamics have been modified using a new grid structure called Triangular Cubic Octahedral (TCO). The physics components remain similar to those in its predecessor. All details related to the model development and results have been published in a peer-reviewed research journal.

More details about the BharatFS are readily available in the below referred research paper published recently.

Phani, M.K.R., Kumar, S., Prajeesh, A.G., Bechtold, P., Wedi, N., Roy, K., Ganai, M., Reddy, B.R., Tirkey, S., Goswami, T., Kanase, R., Sarkar, S., Deshpande, M., & Mukhopadhyay, P. (2025). Indian Institute of Tropical Meteorology (IITM) High-Resolution Global Forecast Model version 1: An attempt to resolve the monsoon prediction deadlock. Geoscientific Model Development, 18, 1879–1894. https://doi.org/10.5194/gmd-18-1879-2025.

(b) The Triangular Cubic Octahedral grid at this specific truncation in the BharatFS model was developed in India, although the concept is well established in the scientific literature. It applies the Collignon projection of a sphere onto an octahedron. Unlike the linear reduced Gaussian grid, the TCO grid's resolution varies smoothly from pole to equator, with the highest resolution near the equator. This design offers several advantages over the conventional reduced Gaussian grid, including reduced computational cost, improved orographic representation, enhanced filtering, and superior conservation properties of mass, momentum, energy, and tracers.

Further details are provided in the reference mentioned in the reply of part (a) of the Question.

(c) Not applicable.

(d) Yes. The TCO grid structure and its development in the BharatFS model were carried out by scientists at the Indian Institute of Tropical Meteorology, Pune.

(e) The development of BharatFS is based on its predecessor, operational numerical weather prediction model (~12 KM resolution), which was operational for short- to medium-range weather prediction. The TCO (Triangular Cubic Octahedral) grid was inspired by work from the European Centre for Medium-Range Weather Forecasts (ECMWF). Scientists at IITM Pune maintained informal collaborations with some ECMWF scientists; however, no components were borrowed from any external sources during the model's development phase.

(f) Numerical Weather Prediction (NWP) models solve the nonlinear partial differential equations governing fluid motion using numerical techniques on a specified grid structure. Processes occurring at scales smaller than the model's grid spacing are parameterized as functions of the resolved-scale variables. In the context of climate change, small-scale heavy rainfall events are becoming more frequent, making it necessary to employ finer model resolutions to capture these phenomena. However, increasing the model resolution demands substantial computational resources and due to the nature of the problem, can introduce numerical instabilities and noise. To address these challenges, the Triangular Cubic Octahedral (TCO) grid was adopted.

Further details are provided in the reference mentioned in the reply of part (a) of the Question.

(g) The BharatFS model (~ 6 km resolution) was developed as an evolution of the operational IMD-GFS (~ 12 km resolution). Its dynamical core was built from scratch, drawing on published literature for reference. The physics component of the model remains similar to that of its predecessor, the IMD-GFS.

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