TRAM: EL NUEVO MODELO NUMÉRICO DE METEO-UIB ADECUADO PARA TODO TIPO DE PREDICCIONES ATMOSFÉRICAS REGIONALES

TRAM: THE NEW NUMERICAL MODEL OF METEO-UIB SUITED FOR ALL KINDS OF REGIONAL ATMOSPHERIC PREDICTIONS

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SUMMARY

A new limited-area numerical model, TRAM (Triangle-based Regional Atmospheric Model), has recently been developed at Meteo-UIB. The model utilizes a nonhydrostatic and fully compressible (NHFC) version of the Navier-Stokes equations and incorporates numerous original characteristics. In this work, it is presented and validated through numerous 2D and 3D tests. TRAM performs as well as state-of-the-art models and is suitable for simulating circulations ranging from small-scale thermal bubbles to synoptic-scale baroclinic cyclones, including orographic circulations, thermally driven flows, squall lines, supercells, all kinds of precipitation systems, and medicanes. Besides opening a myriad of academic and research applications, TRAM regional forecasts at different resolutions are available at https://meteo.uib.es/tram

At the project's inception several years ago, our goal was to develop a novel atmospheric numerical model from scratch, encompassing a wide range of time-space scales. Encouraged by the consistently positive results achieved at every stage of model-building — steps precisely outlined and discussed in this talk — we successfully created a state-of-the-art numerical model, significantly enhancing the modeling capabilities of Meteo-UIB.

The incorporation of the NHFC dynamical set with minimal simplifications, advanced numerical integration methods, and intermediate-complexity physical parameterizations resulted in a versatile modeling system. TRAM is well-suited to simulate processes spanning from thermal bubbles to extratropical baroclinic cyclones — circulations differing in size and life cycle by several orders of magnitude.

The model accurately represents a full spectrum of atmospheric waves, flow perturbations, and instability types, linked to both internal dynamics and external factors such as orography. TRAM can effectively simulate circulations associated with differential heating, including phenomena like sea/land breezes and slope/valley winds, as well as cyclonic disturbances, encompassing tropical-like cyclones. Moreover, the model captures the diverse facets resulting from atmospheric moisture, highlighting its crucial role in the genesis of high-impact convective and mesoscale weather systems (e.g. Fig. 1).

Key Technical Characteristics of TRAM are:

1. Dynamical Core: The model employs a classical NHFC version of Euler's equations for the atmosphere, predicting three velocity components and perturbations of Exner pressure and potential temperature. Although not in flux-form, this formulation is suitable for short- to medium-range weather predictions. No explicit filters are required to control numerical instabilities.
2. Spatial Representation: TRAM uses a mesh of equilateral triangles in the horizontal (3D version of the model), with no staggering of variables. Horizontal advection avoids dimensional splitting and employs the Reconstruct-Evolve-Average (REA) strategy with the MC slope limiter.
3. Vertical Coordinate: The classical height coordinate is used in the vertical with arbitrary stretching of computational levels, allowing higher resolution in the Planetary Boundary Layer (PBL). The fields are not staggered vertically, and a one-dimensional REA method is used for advection. A proper treatment of terrain slopes and bottom BCs allows to correctly incorporate the effects of the complex orography.
4. Time Integration: Time splitting is applied, with a short timestep for fast terms (e.g., gravity waves ad acoustic modes) and a longer timestep for slow terms (e.g., advection). Second-order Runge-Kutta (RK2) is used for fast terms, and semi-implicit solving in the vertical relaxes the CFL stability condition.
5. Physical Parameterizations: TRAM is fully coupled with up to six water species, incorporating realistic parameterizations for cloud microphysics, cumulus convection, radiation, PBL processes, and surface fluxes. Moist effects on pressure and thermodynamics are retained.

6. Earth Representation: Applications on the real Earth use the Lambert map projection, retaining all Coriolis and curvature terms in the equations.

While TRAM has achieved crucial milestones, there are areas for further development. Enhancing the complexity and options of physical schemes, implementing data assimilation methods, and allowing nested domains with varying resolutions are ongoing considerations. Despite its continuous evolution, TRAM is already being utilized for educational and research activities at Meteo-UIB, demonstrating its effectiveness in investigating synoptic and mesoscale mechanisms. Real-time applications, available to the public and stakeholders at https://meteo.uib.es/tram, serve as a valuable testbed for assessing the model's performance across different scales and weather situations. Continuous improvements, testing, and debugging are anticipated, with the ultimate goal of releasing an open-source version for external use.

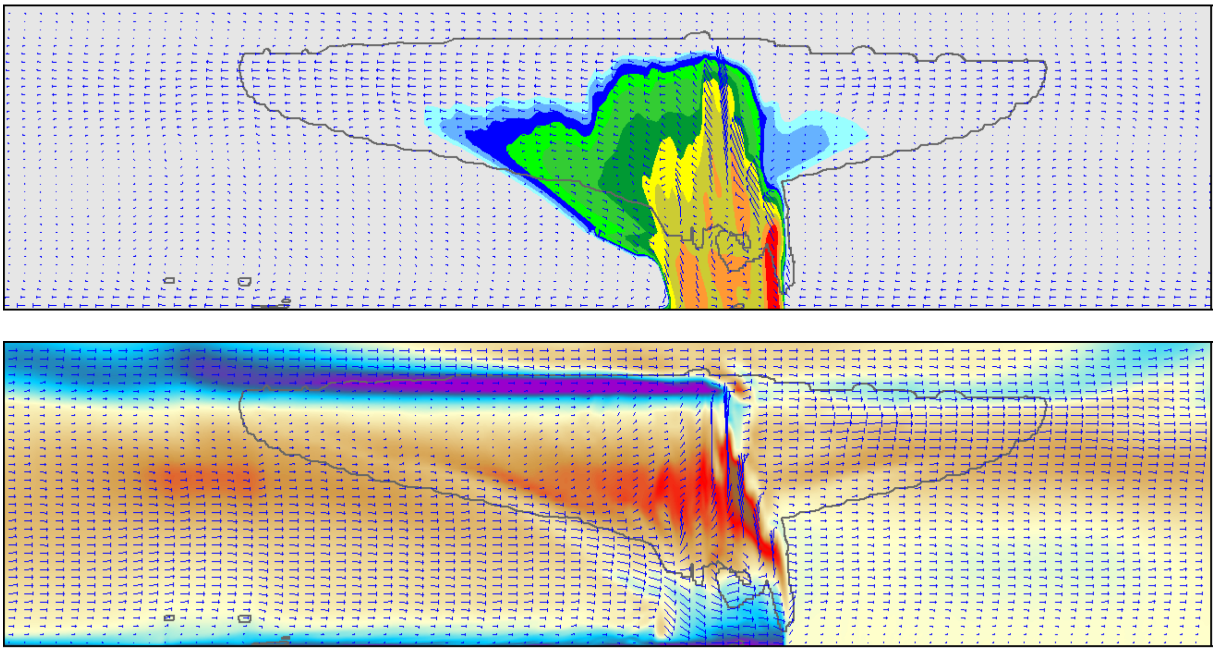

Figure 1 - Numerical simulation with TRAM of a squall line, corresponding to the case with moderate vertical wind shear: (a) Reflectivity (color field, with an interval of 5 dbZ starting at 5 dbZ) and storm relative wind (vector field); (b) Potential temperature perturbation (colors, ranging from -10 K to +10 K from magenta to brown, with yellow indicating zero perturbation) and absolute wind (vector field). In both panels the cloud envelope of the storm is also displayed by means of the grey contour.

REFERENCES

Romero, R. (2023): *TRAM: A new nonhydrostatic fully compressible numerical model suited for all kinds of regional atmospheric predictions.* Q. J. R. Meteorol. Soc., DOI 10.1002/QJ.4639.