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Components of the Caribbean Low-Level Jet as a Predictor for Precipitation in Guatemala and Belize

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Abstract: Current operational Seasonal to Sub-seasonal (S2S) forecast systems in Central America are mostly based on direct (precipitation model outputs) sources of predictability, usually constrained by the availability of North American Multimodel Ensemble (NMME) outputs. The predictive skill of available models is significantly lower than those that were available a decade ago. The decommission of NMME models has had a negative impact on the perception of S2S systems by users in the region. Here we present a novel source of predictability based on the Caribbean Low-Level Jet and demonstrate its potential use to not only gain predictive skill in the region, but to reinstate trust in the forecasting systems by end-users, including international organizations promoting Anticipatory Actions in the region to fight hunger.

Key words: S2S Forecasting, Central America, Sources of Predictability, NMME.

Introduction: In recent years, there has been great effort to promote the use of seasonal climate forecast systems in Central America. Some of these systems have been successfully implemented together with the local meteorological services (Munoz et al., 2019) However, the predictive skill and perceived value of the model ensembles used in these domains have been restricted by the decommissioning of models from the North American Multimodel Ensemble (NMME; Kirtman et al., 2014) and by the favored use of dynamic model outputs in the same geographical domain. In turn, meteorological services in this climate-vulnerable region have been using *what is left and not what is best* when it comes to model availability (see Table 1). Considerations on the perceived and real disadvantages of the decommissioning of models and the consequences on the ground (including maladaptation) have been rarely addressed in the literature. Additionally, alternatives to dynamic forecasting, aside from the use of Sea Surface Temperatures (SST) have not been explored in depth (with the exception of Martinez et al.2019, and Martinez et al.,2022) and therefore have yet to be operationalized.

Table 1. List of contemporary models used by the meteorological service in Guatemala to generate a model ensemble. Notice the inconsistencies throughout the initialization months.

Model	Initialization month of reference							
	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24
CCSM4	•	•	•	•	•	•	•	•
CanSIPS-IC3	•	•			•	•	•	
GEM5NEMO	•	•	•				•	
SPEAR		•	•	•	•	•	•	
CFSv2					•	•	•	•
CanCM4i					•	•	•	
GEOSS2S							•	•
GEN5NEMO							•	
SEAS51	•			•			•	•
METEOFRANCE8				•		•	•	•
SPSv3p5							•	•

One regional-scale feature that has the potential to be a predictor for precipitation in Central America is the Caribbean Low-Level Jet (CLLJ) (Amador et al. 1999). The Caribbean Low-Level Jet (CLLJ) is a key atmospheric feature that influences precipitation patterns in Central America. Positioned between northern South America and the Greater Antilles, extending across the western Caribbean, the CLLJ acts as a major conveyor of moisture into the region. This jet stream plays a crucial role in the seasonal climate, particularly in connection with the mid-summer drought (MSD), a period characterized by a brief reduction in rainfall between two wetter intervals. The formation of the CLLJ is linked to the strengthening of easterly winds by the North Atlantic Subtropical High (NASH), while its intensity and direction are shaped by the Atlantic Warm Pool (AWP), NASH, and regional topography. These interactions make the CLLJ a significant factor in the weather and climate dynamics of the Caribbean and Central America.

Methods: Following Martinez et al., 2022 and Kowal et al., 2023, we compare forecast skill for Guatemala and Belize based on direct (GCMs estimates like rainfall) and hybrid sources including zonal winds (U component at 925 hPa) of wind in the Caribbean region. Since some of the NMME models do not produce zonal winds at 925, we restricted our assessment to the Copernicus models (C3S). We used the following predictor and predictand spatial domains in our calculations for hybrid assessments (Figure 1). For the dynamic (direct) evaluation, the predictor and predictand domains are the same following current protocols by the Guatemalan National Meteorological Service (INSIVUMEH).

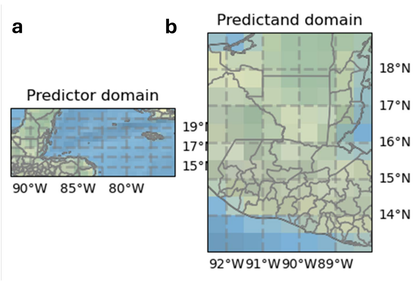

Figure 1. Predictor and predictand spatial domains for hybrid forecast used to assess the predictive skill of the U component (zonal winds) as predictors for precipitation in Guatemala and Belize (a and b, subsequently) and dynamic forecast (both predictor and predictand domain use the *b domain*).

Results: We found similar results in our study to those of Kowal et al., 2023. Here, both the North American Model Ensemble (NMME) and the Copernicus European (C3S) models perform well as direct (dynamic) predictors of precipitation in most of Central America (not shown). However, once consideration was given to the leading times of the forecast, the zonal winds at 925 hPa outperformed the direct forecasts (Figure 2).

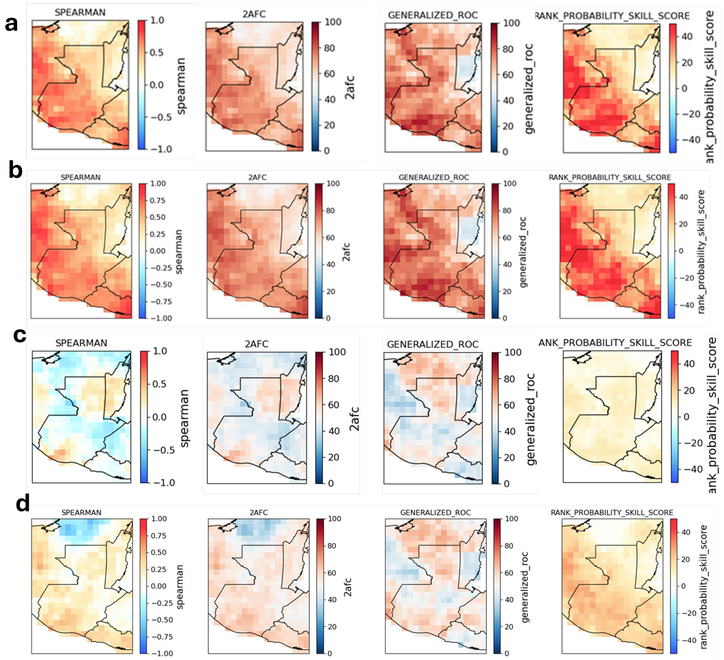

Figure 2. Evaluation of predictive skill (Spearman correlation, 2AFC, Generalized Roc and Rank Probability Skill Score) for the June-July-August (JJA) season for precipitation as predictand using dynamic (a) and hybrid (b) forecast for JJA initialized in May. Same metrics using dynamic (c) and hybrid (d) forecast for JJA initialized in January. Note the substantial skill on most scores for the hybrid approach.

Conclusions: Our results suggest that zonal winds at 925 hPa are good candidate predictors for precipitation in Guatemala and Belize (not shown) and should be considered for distant lead times that outperform the skill of dynamic forecasts at those scales using NMME models of a combination of NMME and C3S models. Higher predictive skill at these lead times is an operational advantage since anticipatory action plans could begin the activities informed by the forecasts sooner. We also recommend using C3S models for consistency on the hindcast time and availability of zonal winds at 925 hPa.

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