WCRP-WGSIP Climate Prediction Across Timescales | (SMR 4188)

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P01

Verification of weekly precipitation and mean temperature forecasts generated with the analogs regression technique

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The National Meteorological Service (NMS) of Argentina provides operational accumulated precipitation and mean temperature forecasts and their anomalies for week 1 (days 1 to 7) and week 2 (days 8 to 14) since February 2019. The analogs regression technique was used given the documented advantages of using this technique over using the non-calibrated model outputs. The technique was applied to surface stations data from the NMS observation network and to GEFS retrospective forecasts database, both within the 2000-2019 period. This work [1] aims to assess the generation of these weekly forecasts, and to analyse and document their performance. To achieve this, a verification was made for 5 mm and 30 mm thresholds of weekly accumulated precipitation, using some scores associated to the contingency table: Bias in Frequency, Probability of Detection and Equitable Threat Score. In the case of weekly mean temperature, the scores used were Correlation of Anomalies and Root Mean Squared Error, in 2021-2023 period. Also, the performance of the forecasts generated using the analogs regression technique was compared with the performance of the non-calibrated forecasts. The results show that, for both accumulated precipitation and –to a greater extent-- mean temperature, calibration using analogs regression reduces the error of the non-calibrated forecasts in both weeks. Consequently, better quality forecasts are obtained compared to using the model outputs without any post-processing.

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P02

The North Atlantic Oscillation (NAO) exerts a strong influence on European surface climate on seasonal-to-decadal timescales. Studies have highlighted weak signal-to-noise ratios in winter NAO predictions on seasonal-to-decadal timescales, though the causes of this remain unclear. Two recent studies showed a lagged relationship between autumn North Atlantic sea surface temperature (SST) anomalies and the winter NAO suggesting a potential source of predictability. However, it has been suggested the lagged SST-NAO relationship is weaker in climate models than in reanalysis data, exposing apparent limitations in the representation of air-sea coupling. This study investigates whether coupled climate models from CMIP6 simulate a lagged SST-NAO relationship and the associated representation of air-sea coupling processes. We use multi-model large ensemble historical simulations to account for the role of internal variability in evaluating model performance against ERA5 reanalysis. Our results show that the relationship between autumn SST anomalies and the winter NAO is weaker in models than in reanalysis data on interannual timescales, and that North Atlantic SST anomalies associated with the winter NAO in models exhibit a different pattern. In contrast, models can realistically simulate the relationship between winter SSTs and the winter NAO, which is thought to be atmospheric-driven. We also show that models simulate a component of autumn SST variability that is consistent with the ERA5 relationship of autumn SST and the winter NAO. Several models reproduce relationships between air temperature, 10-m wind and mean sea level pressure and the autumn SST anomalies that lead to the winter NAO in ERA5, but are limited in their representation of turbulent heat fluxes. Our results provide insights into the role of air-sea coupling in driving the weak signal-to-noise ratios found in NAO predictions.

P03

Skill Assessment of Subseasonal-to-Seasonal (S2S) Precipitation Forecasts for East Nusa Tenggara

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East Nusa Tenggara (NTT) is recognized as one of the driest regions in Indonesia, where rainfall variability is strongly influenced by large-scale climate drivers such as the Indian Ocean Dipole (IOD) and the El Niño–Southern Oscillation (ENSO) [1][2]. For local communities, particularly farmers, timely and reliable rainfall information is crucial for anticipating extreme weather or drought conditions, optimizing water resource management, and supporting agricultural planning. In this context, reliable Subseasonal-to-Seasonal (S2S) forecasts are essential for bridging the gap between short-term weather forecasts and long-term climate projections [3]. We propose the study aiming to evaluate the performance of the ECMWF S2S rainfall forecasts over NTT by comparing them against ERA5 reanalysis data, which is widely used as a reference or "ground truth" for climate verification studies [4]. The analysis covers forecasts from 2014 to 2024 with lead times ranging from one week up to four weeks, allowing us to assess forecast skill across different timescales. To comprehensively assess forecast accuracy, several statistical metrics are applied, including the Pearson correlation coefficient [5], the Root Mean Square Error (RMSE) [6], and the Brier Score [7]. The Pearson correlation coefficient measures the degree of association between forecasted and observed rainfall patterns, reflecting temporal consistency. The RMSE quantifies the magnitude of forecast errors, highlighting systematic biases or random deviations. Meanwhile, the Brier Score evaluates the probabilistic accuracy of rainfall predictions, particularly in distinguishing between below normal, normal or above normal rainfall condition [8]. By conducting this assessment, we hope to establish a baseline understanding of forecast skill in the region. Such knowledge is important not only for improving scientific understanding of rainfall predictability in NTT but also for guiding the translation of forecast information into actionable insights for stakeholders. Ultimately, enhancing the usability and credibility of S2S rainfall forecasts can contribute to building resilience against climate risks and supporting sustainable livelihoods in drought-prone areas such as NTT.

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P04

To improve subseasonal forecasts of extreme events, it is essential to evaluate how well past events were predicted. This study investigates the sources of predictability for the 2017 and 2023 extreme precipitation events that caused widespread flooding and landslides in Peru, both associated with the two most recent extreme Coastal El Niño episodes. Using reanalysis data and observations, we examine key characteristics, drivers, and mechanisms behind these events. Forecast skill from the National Center for Atmospheric Research (NCAR) Community Earth System Model Version 2 (CESM2) subseasonal reforecast is assessed to determine how far in advance useful information could have been provided to the affected region.

We also leverage a novel set of initialized CESM2 prediction experiments with climatological initial conditions in different Earth system components (e.g., land, atmosphere, and ocean) to identify which components most influenced the occurrence and prediction of these events. This comparative analysis provides insights into the predictability of Coastal El Niño – related precipitation. Our results show that the Coastal El Niño was the dominant driver of extreme precipitation in both years, with oceanic initial conditions contributing most to prediction skill. Notably, model performance improved in 2023 compared to 2017, with useful precipitation forecasts available up to 3 – 4 weeks in advance.

P05

Hindcast quality assessment of calibrated South America seasonal precipitation predictions for the austral summer

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Seasonal predictions are produced by several global climate modeling centers. This study presents a hindcast quality assessment of calibrated South America seasonal precipitation predictions for the austral summer (DJF) produced in the previous November. The assessment is performed over the 1991 to 2020 period using 7 global models of the North America Multi-Model Ensemble (NMME [1]) project (CanESM5, GEM5.2-NEMO, NCAR-CSSM4, NASA-GEOS5v2, NCAR-CESM1, GFDL-SPEAR, CFSv2) and one global model (BAM-1.2[2, 3]) from the Centre for Weather Forecast and Climate Studies (CPTEC) of the National Institute for Space Research (INPE), Brazil. Each model is calibrated using a local linear regression procedure [4] (applied at each grid point) of the predicted ensemble mean anomalies on the corresponding observations (GPCP). This procedure is conducted in cross-validation (leave one year out) mode. The assessment is performed in terms of the linear association attribute (measured through the correlation between the predicted and observed anomalies), the discrimination attribute (measured through the area under the area under ROC curves), and the reliability and resolution attributes (assessed with the aid of reliability diagrams), the later three attributes evaluated for probabilistic prediction for the event occurrence of positive precipitation anomaly. The assessment revealed comparable performance among all investigated models, with tropical and southeastern South America presenting the largest linear association and discrimination abilities (due to the ability of all models to reproduce ENSO atmospheric teleconnections), in consistency with previous studies. All models calibrated predictions also presented similar levels of reliability and resolution.

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P06

A Regional Earth System Model for the Southeast Pacific and Peru: From retrospective simulations to forecasting

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Abstract
Reliable climate prediction across timescales is essential for regions strongly affected by ENSO variability, such as the Southeast Pacific. The northern coast of Peru is among the most vulnerable areas, experiencing intense rainfall and flooding during El Niño events. To address this challenge, the Instituto Geofísico del Perú (IGP) has implemented a regional Earth system model in both retrospective and forecast mode, called IGP RESM-COW (CROCO v2, OASIS3-MCT5 ,WRF v4); where the forecast mode is initialized from the retrospective simulation. The model's performance under climatological conditions for the period 2001-2024 shows that the known aspects of the regional dynamics (e.g., mean ocean and atmospheric circulation, seasonal cycle, among others) are adequately reproduced by the IGP RESM-COW. In the forecast mode, fifteen seasonal forecasts with lead times ranging from 1 to 7 months were evaluated for the period 2024-2025 to assess forecast skill, particularly for sea surface temperature in the Niño 1+2 region, given its relevance for ENSO monitoring. Correlations between the time-averaged modeled data and observed AVHRR data ranged from 0.70 to 0.97, while the root mean square error (RMSE), averaged across all leads, ranges from 0.72 to 1.8°C, with the largest errors occurring between the third and fifth months of prediction. These results highlight recent progress in regional forecasting in Peru, but also underscore the challenges of reaching an operational system.

P07

Summer drought predictability in the Euro-Mediterranean region in seasonal forecasts

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ABSTRACT

Seasonal drought forecasts are essential for risk management in climate-sensitive sectors, yet their performance across Europe remains uncertain. This study evaluates the ability of state-of-the-art seasonal forecast systems from the Copernicus Climate Change Service (C3S) to predict summer drought conditions in Europe using the June-August Standardized Precipitation Evapotranspiration Index (SPEI-3), which shows more spatially coherent and higher forecast skill across the region than the Standardized Precipitation Index (SPI). Leveraging this superior performance, we adopt SPEI-3 as the reference drought indicator. We then implement a systematic multi-metric evaluation framework to benchmark individual systems, their multi-model ensemble (MME) and to identify patterns of predictive skill across regions and lead times. Our findings reveal that when SPEI forecasts are initialized at the onset of the summer season, all models exhibit on average good quality in terms of correlation, accuracy, reliability, and discrimination skills, though with local variability. The performance is better for all models in Southern Europe, indicating higher predictability of SPEI in that region compared to Northern Europe, where summer drought variability is mainly driven by precipitation, which is inherently less predictable than temperature. Results show that, when a general analysis is needed, the MME offers the most robust solution, demonstrating more widespread significant skill compared to single models up to a 1-month lead time. These findings highlight the value of SPEI-based ensemble forecasts for early summer drought detection and provide actionable insights into where and when seasonal predictions offer the greatest utility across Europe.

P08

Deep Learning for Improved Forecasting of DCV Modes in CMIP6 DCPP Hindcasts: An LSTM-Based Approach

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Abstract:

Having reliable climate forecasts that look years into the future is a game-changer for policymakers and communities building resilience— it lets us get ahead of the curve, planning smartly to tackle the ups and downs of climate change and variability.

Decadal climate variability (DCV) modes shape weather across the globe over spans of several years to a decade. If we can improve predictions for these modes and their teleconnections, it would enable us to do proactive, long-term planning. Pacific Decadal Oscillation (PDO) in the Pacific Ocean or the Tropical Atlantic SST Gradient (TAG) in the tropical Atlantic— they're key drivers behind extended periods of drought or heavy rainfall, with real-world impacts on economies and societies everywhere. The Decadal Climate Prediction Project (DCPP), part of the Coupled Model Intercomparison Project phase-6 (CMIP6), has rolled out valuable hindcast and forecast experiments to help with this.

Conventional statistical methods often fail to capture the nonlinear, and ever-shifting nature of these DCV modes. This presents an opportunity to apply deep learning (DL) to refine DCPP predictions, leveraging its capacity to learn the complex, non-linear interactions between large-scale trends, short-term shifts, and inherent patterns of natural variability..

In our work, we set out to sharpen the forecasting edge of the CMIP6 multi-model ensemble (MME) DCV index, targeting trends and phase changes for lead times of 1 to 10 years, using the DL approach. We built an LSTM-based model to improve the accuracy of that CMIP6 MME PDO/TAG index. What we found is exciting: there's real potential here for ML and DL to take CMIP6 predictions to the next level. In the context of post-processing, machine learning is a valuable tool for calibrating real-time forecasts, which ultimately can improve the robustness and skill of operational systems as well.

P09

Evaluating Indo-Pacific Water Mass Exchange in Met Office Models

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The Indonesian Throughflow (ITF) is the only low latitude connection between major oceans, specifically the Pacific and Indian. It is a key part of the global thermohaline circulation, redistributing heat from the Indo-Pacific warm pool into the Indian Ocean and beyond [1]. The strength of the ITF is influenced by climate modes such as the El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) [2]. In turn, the ITF influences regional climates, including the monsoons. Understanding the transport pathways and fate of Pacific waters entering the Indian Ocean via the ITF is therefore essential for quantifying heat transport and improving the accuracy of model predictions.

This study applies a Lagrangian particle tracking analysis of near-surface ocean currents using the OceanParcels framework [3] to the Met Office Global Coupled Model (GC5) and the reanalysis-forced Global Ocean Model (GOSI9) [4]. There are known biases in the Indian Ocean in GC5 that appear in short-range weather predictions to seasonal forecasts and persist to climate timescales; however, the origins of these biases are not fully understood. Therefore, we first aim to quantify the routes of Pacific water through the ITF and evaluate the progression of the waters across the Indian Ocean, highlighting key pathways and residence times. The comparison of GC5 and GOSI9 will help to identify mechanisms contributing to biases. We then assess the seasonal variability of transport associated with monsoon dynamics, ENSO, and the IOD. The analysis of the particle trajectories will combine traditional statistical methods (e.g., transit times, particle flux fractions) with advanced techniques such as trajectory clustering. Complementary Eulerian diagnostics, including cross-sectional analysis of volume and heat transport in the models and reanalysis data, will provide physical context to the Lagrangian approach.

This work has broad scientific relevance, providing insights into Indo-Pacific water mass exchange and its representation in Met Office models. By identifying the drivers and impacts of ocean circulation biases, this study will inform future model development, highlight areas to improve, and enhance seasonal and climate forecasting efforts.

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P10

Abstract template for WCRP School on Climate Prediction Across Timescales

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In this work, the CONFESS experiments [1] by the European Centre for Medium-Range Weather Forecasts are used to examine the effect of inter-annually varying vegetation on seasonal forecasts for the African continent. Using seasonal-reliant empirically orthogonal function analysis [2], we identify a mode of variation responsible for 20% of the variation in the inter-annually varying Leaf Area Index (LAI) dataset that is spatially concentrated in East Africa (covering chiefly Tanzania, Kenya, Mozambique). The temporal variation of the mode is shown to be strongest in the December-January-February season, and its time series is correlated with the Indian Ocean Dipole (IOD) index for the September-October-November season with a correlation coefficient of 0.75; we view the mode of variation as the vegetation response to the IOD. Results show a spatially consistent 2 meter temperature response in the forecasts: temperature increases in East Africa for low LAI years and decreases for high LAI years, consistent with changes in the surface sensible and latent heat fluxes. The temperature response to the IOD is shown to be improved (closer to ERA5 temperatures) when interannually varying vegetation is included in the forecasts.

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P11

Calibrated South America subseasonal predictions for the austral spring produced with CPTEC/INPE global model

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This study presents a system developed for producing calibrated precipitation and near surface (2 metre) temperature subseasonal predictions (i.e., predictions for the expected conditions in the forthcoming weeks, fortnights or slightly longer periods). The system is based on the version 1.2 of the Brazilian Global Atmospheric Model (BAM-1.2, [1,2]), of Center for Weather Forecast and Climate Studies of the National Institute for Space Research (CPTEC/INPE). Although the system was developed for producing global predictions though all weeks of the calendar year, in this study calibrated predictions for South America produced during the austral spring weeks of September, October and November are presented. Calibrated predictions for the next 7 days (weeks 1 to 4), 14 days (fortnights 1 and 2), 21 days, and 30 days are produced for each model grid point using a linear regression procedure [3] of the predicted ensemble mean anomalies on the corresponding observations (GPCP and ERA-Interim). As the model predictions are produced every Wednesday, calibrated predictions are constructed using retrospective predictions which are also produced every Wednesday over the 20-year (1999–2018) period by aggregating retrospective predictions of three weeks (the target prediction week and the two neighbour weeks, the one ahead and the one before the target week) to increase the sample size and improve the robustness of the regression parameters estimation. The calibration procedure is conducted in cross-validation (leave one year out) mode. Hindcast quality assessment (verification) of calibrated predictions is performed separately for each month considering four initialization dates (i.e. four weeks) per month, leading to a sample verification size of 80 retrospective predictions per month. Verification results for deterministic predictions are assessed in terms linear association (correlation between predicted and observed anomalies), and for probabilistic predictions of the event occurrence of positive anomalies are assessed in terms of discrimination (area under the ROC curve), reliability and resolution, the latter two evaluated using reliability diagrams.

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P12

Extreme rainfall over South America and their association with IOD events

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The Intergovernmental Panel on Climate Change reports that extreme events are accentuated with climate change, contributing to the risk and vulnerability of social and environmental systems. Extreme climate events can cause significant social, economic and environmental impacts. These extreme events are characterized by spatial and temporal variabilities and are conditioned by different local and remote forcings. The sea surface temperature (SST) anomalies in Indian Ocean can have substantial remote effects on climate in South America (SA). One of the most important forcings is Indian Ocean Dipole (IOD). In this study, extreme climate precipitation and IOD influence are assessed based ERA5 and on the Global Climate Models (GCM) from the Coupled Model Intercomparison Project Phase 6 (CMIP6).

This study analyzed three extreme climate indices: total accumulated precipitation (PRCPTOT) and maximum number of consecutive wet and dry days (CWD and CDD, respectively). These indices were used to understand the climate impacts and the regional adaptation. In addition, this study analyzed the relationship between IOD events with the extreme climate indices. The analysis is carried out in the period 1981-2010, in the trimester October–December (OND), over SA.
To identify IOD influences over the continent, the composites were constructed for PRCPTOT, CDD and CWD under warm and cold phases. PRCPTOT during positive phase of IOD shows a strong signal with positive anomalies in SESA and this is reflected in the wet extreme index (CWD).

This work allows a better understanding of regional characteristics of rainfall extreme events in response to IOD forcing. In addition, they will provide useful information to climate services focused on seasonal forecasting for the planning of agriculture and tourism sectors and adopting mitigation and adaptation measures in the framework of climate change.

P13

Identification of Atmospheric Circulation Patterns in Bolivia Using Machine Learning for Improved Climate Forecasting

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Atmospheric circulation patterns are configurations of air movement that directly influence the climate of each region. Studying them allows us to understand how some important climate variables, such as humidity and temperature, are distributed, which is key for applications like improving weather forecasts and anticipating phenomena such as heavy rains or droughts.

In Bolivia, the reliability of some forecast prediction systems remains limited. Some causes include the lack of accessible computational tools and the scarcity of nationally applied studies. One consequence is the limitation in anticipating adverse climatic events, which affects decision-making in sectors such as agriculture, water management, and disaster prevention.

This project proposes to identify atmospheric circulation patterns using machine learning techniques in Python, applied to upper-level atmospheric pressure data. The idea is to adapt existing codes, integrate them with global and local data, and focus on regions of interest in Bolivia. This has the potential to improve sub-seasonal to seasonal forecasting.

The objectives are to adapt models for identifying climate variable patterns over Bolivian territory, identify the relationship between atmospheric patterns and precipitation regimes, and explore possible forecasting applications through pilot studies.

The expected impact is a possible improvement in the quality of precipitation-related forecasts, which can help reduce risks and negative impacts in vulnerable sectors.

P14

Subseasonal prediction presents significant challenges for numerical models because it lies at the transition between weather and climate timescales, where forecast errors typically increase substantially beyond 10 days. This study uses the North American Multimodel Ensemble (NMME) to assess subseasonal predictability in CCSM4, CFSv2, and GEOS-5. Following the methodologies of Becker et al. (2014), we evaluate homogeneous predictability—verification of a model's ensemble mean against a single member of the same model—and heterogeneous predictability—verification of a model's ensemble mean against a single member of another model. In the heterogeneous analysis, one model's individual ensemble members are designated as "truth," and the ensemble mean of another model is compared to them. Predictability is quantified using root mean squared error (RMSE) and anomaly correlation (AC) metrics, and both homogeneous and heterogeneous results are compared to ERA5 reanalysis to evaluate forecast skill. By relating heterogeneous predictability to reanalysis-based skill, we aim to assess the potential for predicting forecast skill itself, with implications for improving model performance and reducing biases in subseasonal simulations.

P15

The Interdecadal Weakening of the Relationship Between Northwest Pacific Ocean Sea Surface Temperature and Spring drought in East Africa

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Spring East African Drought (SEAD) holds significant implications for local agriculture and ecosystems, with its variability mainly modulated by Sea Surface Temperature Anomalies (SSTA) over Northwest Pacific Ocean (NWP). The NWP-SEAD relationship has experienced pronounced interdecadal shifts, though mechanisms remain elusive. The relationship has weakened since the 1970s and varies with the Atlantic Meridional Mode (AMM) phase transition. During the warm phase of the AMM (1950-1974), drought in East Africa was significantly positively correlated with the NWP. Conversely, during the cold phase of the AMM (1975-2022), this correlation became insignificant. The decrease in the interannual variation in the NWP resulted in the weakening of the westerlies from Congo basin and cyclone variation over the Madagascar. Along with the weak westerlies, the NWP exhibited only a weak positive correlation with precipitation and SEAD in East Africa after the 1970s. This remarkable contrast in the impact of NWP during different phases of the AMM offers intriguing possibilities for improving climate prediction in East Africa.

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P16

Investigating Mixed Rossby–Gravity Waves and Extratropical PV Intrusions in an Idealized Aquaplanet

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Mixed Rossby–Gravity (MRG) waves are westward-propagating, synoptic-scale modes of tropical variability and are known to contribute significantly to intraseasonal precipitation in the tropics. Yet climate models often underestimate their variance and simulate them with unrealistically fast phase speeds. While the local convective coupling of MRG waves has received considerable attention, recent observational works have highlighted the major role played by extratropical Potential Vorticity (PV) intrusions in modulating MRG wave activity. Using the widely adopted idealized aquaplanet model, we isolate the roles of convective coupling, wave–mean flow interactions, and extratropical forcing in shaping MRG wave variability. We find that while spectral power in MRG wave scales is weak in the lower-tropospheric wind and precipitation variables, the meridional wind field exhibits strong and coherent peaks particularly near zonal wavenumber 5, consistent with observed upper-tropospheric signatures linked primarily to extratropical wave activity. This demonstrates that MRG waves can be dynamically robust even when their convective signatures are weak, reflecting distinct triggering mechanisms for internal versus external forcing. Additionally, the strength and structure of MRG wave peaks are found to be sensitive to the background upper-tropospheric westerlies. The choice of convective parameterization also influences the MRG wave variability, with simulations using no convection and the Arakawa–Schubert scheme producing stronger and more distinct MRG wave peaks in both the lower and upper troposphere compared to the simple Betts–Miller scheme. We will further discuss the results from simulations in which other key model properties, including ocean mixed-layer depth, radiative transfer scheme, and vertical resolution, are varied using an event-based diagnostic framework to analyze MRG waves.

P17

WCRP School on Climate Prediction Across Timescales

Evaluating Seasonal Prediction Skill of the Indian Summer Monsoon Rainfall: A Comparative Analysis of C3S, NMME, and Multi-Model Ensembles

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The Indian Summer Monsoon Rainfall (ISMR) constitutes a critical component of the South Asian climate system, exerting a profound influence on agricultural productivity, water resource availability, and socio-economic stability across India) (Acharya et al. 2013). Despite significant advances in dynamical modelling, skillful seasonal prediction of ISMR remains a major scientific challenge owing to the complex, nonlinear interactions among atmospheric circulation, land–ocean coupling processes, and large-scale climate modes. However, climate models often have biases in replicating ISMR due to complex atmospheric dynamics, interactions with land and oceans, and the influence of multiple climate factors such as ENSO, IOD, and regional topography, leading to significant errors in predictions (Sperber et al. 2013).

This study undertakes a systematic assessment of the seasonal prediction skill of individual dynamical models from the Copernicus Climate Change Service (C3S) and the North American Multi-Model Ensemble (NMME), along with their respective Multi-Model Ensemble (MME) configurations. The analysis utilizes high-resolution gridded rainfall observations from the India Meteorological Department (IMD) for the period 1993–2016, regridded to a common spatial resolution to ensure consistent inter-model comparison.

The evaluation is conducted in two stages: first, model-specific skill is assessed by comparing JJAS climatologies with observations and generating spatial bias maps to identify systematic errors; second, MMEs are constructed for C3S and NMME to examine the added skill of multi-model averaging. Forecast performance is quantified using metrics such as Correlation Coefficient (CC), Standard Deviation Ratio, and Index of Agreement (IOA). Additionally, models are analyzed for their ability to capture major teleconnections, particularly ENSO and IOD, which strongly influence ISMR variability.

This multi-metric, two-tiered evaluation framework enables an in-depth characterization of the strengths and limitations of the C3S and NMME systems, as well as the added value of MME approaches in improving ISMR prediction skill. The results further examine model-specific biases, the representation of large-scale teleconnections, and the comparative skill of individual models versus their ensemble configurations.

Keywords: Indian Summer Monsoon Rainfall (ISMR), Seasonal prediction skill, Multi-model ensemble, Teleconnections, ENSO, IOD.

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P18

A process-based approach towards improving near-surface wind and precipitation seasonal forecasts over Northeast Brazil

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The climate of Northeast Brazil (NEB) is characterised by hot and semi-arid conditions, with precipitation being concentrated in a short rainy season during March-April-May, when the Intertropical Convergence Zone (ITCZ) typically reaches its southernmost position [1]. NEB is often affected by severe droughts [2], which occur partly due to anomalous displacements of the ITCZ, leading to severe socio-economic impacts in the region, including widespread crop failures [3]. NEB is also a key region for wind energy generation, concentrating 90% of Brazil's total wind power capacity. Near-surface wind and precipitation in NEB display strong anti-correlation, a relationship that could be exploited to improve the usability of wind and precipitation forecasts in the region [4]. Nonetheless, the timely anticipation of harmful climate impacts often remains limited by forecasting systems with a predictive skill that decays at low lead times. This decay is partially explained by an inadequate model representation of key physical processes, limiting the use of forecasts for decision-making in climate-dependent sectors.
In this study, we conduct a process-based evaluation of seasonal forecasting systems (e.g., ECMWF's SEAS5.1, NCEP's CFSv2, etc.) to determine whether the representation of dynamic processes in the Tropical Atlantic (TA) influences the predictive skill of precipitation and surface wind in NEB. We focus on the TA and Southern Atlantic dipoles (TAD/SAD), while considering cross-scale interactions with other modes of variability. During drought years, a positive (negative) interhemispheric SST gradient (i.e., TAD), if co-occurring with the positive (negative) phase of the El Niño-Southern Oscillation (ENSO), prevents the ITCZ from moving southwards (northwards), leading to a deficit (excess) in NEB precipitation [1]. To add a layer of complexity, the climate response to TA variability in NEB is modulated by constructive/destructive interference with ENSO [5] and the Madden-Julian Oscillation [6], resulting in a constellation of climate impacts. These interactions can reinforce/suppress the expected climate response in the region, leading to periods of increased predictive skill known as windows of opportunity, potentially rendering improved seasonal forecasts and serving to boost user confidence in climate predictions.

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P19

Seasonality, climate teleconnections and projections of water availability in South America

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Water availability (precipitation minus potential evapotranspiration — hereafter CWA) was assessed using SNIPE (Standardized Non-parametric Index of Precipitation and Evaporation), a non-parametric index originally proposed by Onyutha (2017; 2021), which had not previously been employed comprehensively to characterize water availability in South America. The objective is to assess multiple space–time aggregation windows (1, 3, 6 and 12 months) and to compare observations (CRU TS v4.0, ERA5-Land) with CMIP6 model outputs (historical and SSP scenarios). Methodologically, drought incidence was evaluated for varying thresholds (-1, -5, -25, -50 mm), model biases, RMSE, and correlations and multiple regressions between SNIPE and SST/variability indices (ONI/ENSO, TNA/TSA, AMO, TPI–IPO, PDO, SAM). Results show that, at short windows (1-3 months), very marked seasonal contrasts emerge. Pronounced surpluses occur in the northern/central-northern Amazon in DJF (monthly accumulations that can exceed 300 mm) and along wet corridors from the west to the south of Brazil, while marked deficits appear over the Andes, southern Chile and Patagonia. When the scale is increased (6-12 months) patterns smooth out, revealing that drought detection strongly depends on the chosen aggregation window. Historical incidence maps indicate persistent drought hotspots in the core of the Atacama, the semi-arid Sertão of northeastern Brazil, and portions of Patagonia, with pronounced sensitivity to the adopted threshold. Low thresholds highlight high-frequency events in semiarid regions, whereas high thresholds concentrate extremely dry areas. CMIP6 models qualitatively reproduce the patterns but exhibit systematic regional biases: there is a tendency to underestimate CWA over parts of the Amazon and to overestimate it over the Andes and the extreme south, with RMSE decreasing as temporal aggregation increases. In future projections there is a widespread drying signal, more intense and spatially extensive under the high-emission greenhouse gas scenario (SSP5-8.5). Teleconnection analyses show that the dominant indices vary regionally. The TPI-IPO appears as the dominant contributor across much of the domain, while ONI, TNA and AMO emerge as dominant in localized areas, indicating strong local heterogeneity in the indices contributions.

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P20

Application of the Constructed Analogue Method to Improve Subseasonal-to-Seasonal (S2S) Rainfall Prediction Skill in Indonesia

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Abstract

Subseasonal-to-seasonal (S2S) rainfall prediction constitutes an essential component in supporting agriculture, water resource management, and disaster risk reduction. However, its predictive skill in Indonesia remains limited, primarily due to systematic biases and the coarse spatial resolution of global forecast models. To address these limitations, this study employs the Constructed Analogue (CA) method as a statistical downscaling technique to enhance the skill of S2S rainfall forecasts. Prior to the application of CA, potential sources of S2S predictability, particularly large-scale circulation patterns, will be examined to identify the most relevant predictors for rainfall variability in Indonesia.

The analysis will utilize Climate Forecast System Version 2 (CFSv2) outputs as predictors and evaluate forecast performance through deterministic and probabilistic metrics. The expected outcomes include an improved spatial representation of S2S rainfall predictability across Indonesia, the identification of regions with higher predictive potential, and a refined understanding of the effective lead times for operational applications. This research is anticipated to contribute to the advancement of climate services and to inform risk-based decision-making in Indonesia.

Keyword: Subseasonal-to-seasonal (S2S) prediction, statistical downscaling, constructed analogue (CA).

P21

Evaluating causal relationships in deep learning models for eastern Pacific El Niño prediction

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Currently, Peru has an operational AI model based on CNN [1]. The model successfully hindcasted the extreme events of 1998 and 2016 in the independent testing dataset and performed well for the subsequent 2024 El Niño. However, since the observational record contains few extreme events, whether the model will perform well in the future will depend on its adequate representation of the relevant physical causal relationships. However, experiments with this CNN model showed very low sensitivity of extreme El Niño forecasts even to the reversal of the easterly wind anomalies in the central equatorial Pacific (U') in its input, rather than the expected neutralisation of the prediction of El Niño [2]. Instead, application of the PCMCI method for causal discovery [3], which is based on conditional independence tests, revealed that for the CNN model, the sea surface temperature anomaly (SST') in August has a stronger causal effect than U' on the occurrence of El Nino in the following January, counter to what is obtained with observations. This warns us that good performance of deep learning models is not a guarantee that they are fully trustworthy for rare events such extreme El Niño, specially given the diversity among the events. In this talk we also present preliminary results of tests using other model architectures to assess whether they might learn causal relationships more effectively, for which we implemented and tested a transformers model [4] and CNN with absolute location [5].

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P22

Calibration of Seasonal Wind Speed Predictions for Argentina, 1993-2016

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Seasonal wind prediction is crucial for sectors such as wind energy, although it remains underdeveloped in Argentina. This study evaluates and calibrates seasonal 10-m wind speed forecasts from seven models of the Copernicus Climate Change Service (C3S) for the period 1993–2016. We apply post-processing methods to correct the forecasts, including quantile mapping, mean/variance adjustment, and a neural-network–based approach, using homogenized monthly series from 86 stations of the National Meteorological Service of Argentina as the reference. Verification is performed with deterministic and probabilistic metrics under cross-validation. Overall, post-processing improves forecasts for bias-sensitive metrics, although decreases can be observed in some probabilistic verification indicators.

P23

Poster: Data Assimilation Methods for the upcoming German Climate Forecast System 3.0 for Seasonal Prediction

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Here we present some of the progress and challenges of setting up the next generation of the German Climate Forecast System, which is based on an entirely new model setup with respect to the previous generations. The new setup consists of the coupled seamless earth system model ICON-XPP, which is extended with data assimilation to obtain the best possible model state ensemble for starting seasonal forecasts.
The data assimilation consists of a Localised Singular Evolutive Interpolated Kalman Filter (LSEIK) for multivariate data assimilation of temperature and salinity in the ocean, and ERA5-based nudging in the atmosphere above the planetary boundary layer. Additionally, we are experimenting on the usage of sea ice and land data assimilation.
On this poster, we analyse the performance of different configurations and settings of the nudging and LSEIK filter, and present diagnostics to showcase the way we decide from this data which settings we use to gain optimal starting conditions.

P24

Explained predictions of strong eastern Pacific El Niño events using deep learning

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Global and regional impacts of El Niño-Southern Oscillation (ENSO) are sensitive to the details of the pattern of anomalous ocean warming and cooling, such as the contrasts between the eastern and central Pacific. However, skillful prediction of such ENSO diversity remains a challenge even a few months in advance. Here, we present an experimental forecast with a deep learning model (IGP-UHM AI model v1.0) for the E (eastern Pacific) and C (central Pacific) ENSO diversity indices [1], specialized on the onset of strong eastern Pacific El Niño events by including a classification output. Testing with historical and observational data shows the model can match the skill of leading climate models for eastern Pacific predictions, where it performs particularly well in forecasting the onset and evolution of events like the extreme 1997–1998 El Niño. We find that higher ENSO nonlinearity is associated with better skill, with potential implications for ENSO predictability in a warming climate. Explainable AI (XAI) techniques provide insights into the physical drivers of these forecasts, improving their interpretability and operational relevance. By focusing on operational simplicity and observable inputs, this approach makes ENSO predictions more accessible.

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P25

Abstract template for Poster/Talk

Activity Title: Seasonal Forecasts of Precipitation in the Eastern Mediterranean

Gayathridevi Salila[1] , **Chaim Garfinkel**[1] , **DoritaRostkier-Edelstein**[1] **and Yoni Isaacs**[2]

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Seasonal forecasts of precipitation and evaporation form a bedrock for planning water allocation and evaluating the need of desalination. It is therefore imperative to better understand the factors that lead to wetter or drier conditions on seasonal timescales, and to assess whether operational seasonal forecast models capture the observed connections. In this study we analyze seasonal predictions from eight models in the Copernicus C3S database, focusing on the Eastern Mediterranean.

Our initial findings indicate that seasonal forecasts initialized on January 1st for January through March show strong predictive skill for precipitation, Z500, and T2m (temperature at 2m) over the Eastern Mediterranean—comparable to skill levels observed in well-understood regions like Western North America.

Furthermore, the analysis using the September 1st initialized models for January and February shows notable skill for Z500 and T2m. Also, the individual models such as UKMO, ECMWF, Meteo-France, and NCEP retain significant skill for January-February precipitation and Z500 when initialized on September 1st. Ongoing work is aimed at understanding mechanistically the source of this skill, and also the implications for specific hydroclimate basins, using both classical and machine learning techniques.

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P26

Calibrating C3S Seasonal Rainfall Forecasts in Colombia's Coffee Region: Initial Findings

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The National Colombian Coffee Research Centre (Cenicafé) seeks to offer better climate services that enable coffee growers to take informed decisions, particularly around critical phenological periods such as flowering and harvest windows. A core, ongoing objective is the validation and calibration of seasonal prediction models suited to the coffee sector. We evaluated Copernicus Climate Change Service (C3S) seasonal forecasts of station-scale total precipitation and quantified the added value of post-processing by Empirical Quantile Mapping (EQM) and Model Output Statistics conditioned on the Oceanic Niño Index (MOS-ONI), together with a multi-model ensemble (MME) constructed from the best-performing correction. We analysed four C3S systems (ECMWF, CMCC, DWD, NCEP) retrieved via *cdsapi* as seasonal-monthly-single-levels and merged them with observations from 106 Cenicafé stations. Forecasts and observations were aggregated into 3-month moving totals with lead = 2, indexed by the trimester's ending month; calibration was performed per station and ending month. Quarterly verification used complementary metrics—RMSE, MAE, bias, Willmott's d, and Skill_RMSE relative to a station-wise climatology.

Raw systems showed negative relative skill and large errors (Skill_RMSE: CMCC −4.03, DWD −0.91, ECMWF −2.00, NCEP −1.39). EQM reduced error magnitude (RMSE ≈ 171.9–222.3 mm) and increased d (≈ 0.66–0.80), yet did not surpass climatology (Skill_RMSE ≤ 0). In contrast, MOS-ONI achieved positive Skill_RMSE across all four systems—CMCC +0.089, DWD +0.051, ECMWF +0.095, NCEP +0.059—with lower errors (RMSE ≈ 149.2–159.0 mm; MAE ≈ 116.7–123.0 mm) and higher d (≈ 0.78–0.81). Consequently, the MME was built only from MOS-ONI–corrected members, leveraging their superior and consistent skill. By quarter, the MOS-ONI MME showed peak skill in the first quarter (JFM; ≈ 0.27) and remained clearly positive in JJA–ASO (≈ 0.17–0.19); skill was positive but moderate in DJF (~ 0.18), FMA/SON (~ 0.11–0.13), and NDJ (~ 0.14), and was weak or near zero in AMJ (~ −0.01; some members ~ −0.04 to −0.06) and marginally in MAM (~ 0.04–0.05).

These findings were consistent with regional literature indicating that seasonal precipitation predictability tends to be lower and more variable—owing to intermittency and strong local controls—than for other variables [2], while C3S systems can exhibit meaningful, region- and season-dependent skill when appropriately assessed [1]. The gains from station-scale MOS-ONI and the resulting MME were particularly relevant as a starting point for exploring pathways to translate forecasts into actionable coffee climate services. For the Colombian coffee region, MOS-ONI followed by an MME offered the most reliable improvement over raw C3S forecasts and clearly outperformed EQM in relative skill. Ongoing work included: (i) machine-learning MOS to capture non-linear correction behaviour, (ii) transition to probabilistic verification and skill metrics (e.g., CRPS, Brier score, ROC/AUC), and (iii) additional steps to enhance discrimination and reliability and to operationalize these products within coffee climate services.

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P27

Seasonal Inflow Forecasts for Hydropower

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Reliable seasonal inflow forecasts are essential for hydropower management and energy planning in Uruguay. This work focuses on developing three-month forecasts for the Salto Grande reservoir, a binational plant providing a significant share of electricity to Uruguay and Argentina. Our approach combines multiple sources of climate information, including ERA5 reanalysis, GFS forecasts, and dynamically downscaled RegCM simulations. To address systematic errors, bias correction techniques are applied.

Machine learning methods, particularly recurrent and convolutional neural networks, are employed to model the complex relationship between climate predictors and river inflows.

Preliminary results suggest that forecast performance is not uniform: in some years GFS-based predictors outperform RegCM, while in others the regional simulations provide more skill.

This research aims to provide robust tools for operational use within ADME’s energy planning framework, contributing to more resilient climate services for Uruguay’s power sector.

P28

Intensity and Distribution of Brazilian Intraseasonal Precipitation

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This study aims to evaluate the presence and intensity of intraseasonal variability over Brazilian territory, using data from CHIRPS v2/v3, IMERG, MERGE v6/v7, BR-DWGD, and CMORPH for the period 2001–2023. The analyses are conducted by comparing the ability of each dataset to capture phenomena at this scale, applying indices and statistical methods that allow quantitative and spatial distinction of differences among the products. Initially, a high-pass filter was applied to confirm the existence of differences in the representation of the intraseasonal band across datasets. In addition, an evaluation was performed to measure the skill of each product against BR-DWGD as the reference. The study is expected to contribute to the identification of the most suitable precipitation products for monitoring intraseasonal events in Brazil and to highlight the importance of intraseasonal variability in climate studies.