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P01

Lagged relationships between the South Atlantic and ENSO: the mediating role of the South American Monsoon

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This study investigates the connections between Southwestern Tropical Atlantic (SWTA) and South American precursors during the South American Monsoon System (SAMS) onset period (SON, year -1) and subsequent ENSO development in the next year. Building upon existing research [1-5], we analyze ERA5 reanalysis (1950-2021) and a 1200-year CESM2 control run using partial linear regressions. We identify three significant ENSO variability precursors (as defined by [6]) with a 15-month lead time:

(1) SWTA SST anomalies (E-index),
(2) 250 hPa streamfunction anomalies over La Plata basin and SWTA (C-index), and
(3) equatorial Atlantic mean sea level pressure anomalies (C-index).

The associated regression patterns are:

(a) a cold tropical SWTA and a strengthened South Atlantic Subtropical High in SON (year -1),
(b) a persistent positive South Pacific Oscillation (SPO) pattern from DJF (year -1) to SON (year 0),
(c) rapid southeastern tropical Pacific (SETP) warming during MAM (year 0), and
(d) a clear El Niño signal for SON (year 0) and DJF (year 1).

We suggest that anomalous SAMS activity acts as a bridge in connecting the southern tropical Atlantic and Pacific basins (cf. [7]) during both its onset and retreat (MAM year 0), influencing SETP subsidence through anomalous upper-level divergence due to Rossby wave response to monsoon heating and interaction with the subtropical jet (cf. [8]). We argue that Ekman dynamics, wind-evaporation-SST feedback, and Bjerknes feedback (cf. [9]) amplify the initial atmospheric signals from SAMS and SPO.

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P02

Multi model evidence of future tropical Atlantic precipitation change modulated by AMOC decline

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Global climate models from the Coupled Model Intercomparison Project Phase 6 (CMIP6) archive show a large inter-model uncertainty in projections of the Atlantic Meridional Overturning Circulation (AMOC) decline, but the related impacts on simulations of future climate change are still unclear [1]. Previous research shows that the AMOC influences tropical rainfall, especially in the Atlantic sector [2]. However, to which extent the CMIP6 inter-model spread in AMOC decline contributes to uncertainties in projections of tropical Atlantic rainfall, remains unknown. Here, we address this question and we investigate the sensitivity of precipitation and the atmospheric meridional overturning circulation to inter-model differences in the amount of AMOC decline in projections of climate change into the 21st century using an ensemble of 30 climate model simulations from the CMIP6 ssp5-8.5 coordinated experiment. Through a moisture budget analysis, we find that changes in the mean meridional atmospheric circulation, namely a southward shift of the Hadley Cells, is linked to a displacement of the Intertropical Convergence Zone towards the Southern Hemisphere. However this only occurs in simulations where the AMOC reduction is sufficiently strong. In other simulations in which the AMOC decline is smaller, there tends to be an intensification of the hydrological cycle, but not significant meridional displacements. Our results have broader implications for understanding the mechanisms of tropical rainfall change in projections of future climate change.

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P03

Simulating AMOC collapses driven by internal climate variability with a rare event algorithm.

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The Atlantic Meridional Overturning Circulation (AMOC) is a key tipping element of the climate system. The possibility of transitions to collapsed AMOC states has been explored in the past by applying external forcings to climate models, i.e. altering the radiative forcing or the North Atlantic freshwater budget. However, the tipping of the AMOC may also spontaneously occur via internal variability as evidence from paleo climate experiments suggests[1]. Here, we address this hypothesis with an innovative approach by applying a rare event algorithm [2] to ensemble simulations with an intermediate complexity climate model (PlaSim-LSG) in pre-industrial conditions. We show that the algorithm successfully identifies trajectories leading to an abrupt AMOC slowdown, corresponding to extremely rare low values of the AMOC, which is unprecedented in a 2000 year control run. Part of these weakened states are collapsed states without evidence of AMOC recovery on multi-centennial time scales. The temperature and North Hemisphere jet stream responses to these internally-induced AMOC slowdowns shows strong similarities with those found in externally forced AMOC slowdowns in state-of-the-art climate models. The proposed approach enables us to isolate the processes driving the AMOC slowdown. The internal AMOC weakening seems to be initially driven by Ekman transport due to westerly wind stress anomalies in the North Atlantic ocean, and to be subsequently amplified by a collapse of the oceanic convection in the Labrador Sea. From a methodological point of view, these results show that rare event algorithms can be used to study tipping points in complex climate models since they introduce the possibility of collecting a large number of tipping events that cannot be sampled using traditional approaches. This opens the possibility of identifying the mechanisms driving tipping events in complex systems in which little a-priori knowledge is available. From a physical point of view, the results suggest that collapsed AMOC states can be reached in absence of imposed external forcing, solely due to the internal variability of air-ocean interactions.

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P04

Transient and Equilibrium Responses of the Atlantic Meridional Overturning Circulation to Radiative Forcing

In response to abruptly increasing atmospheric CO2 concentrations, GCMs typically evidence a rapid reduction or full collapse of the AMOC from its current, strongly overturning state. Far less understood is the evolution of the AMOC towards a new equilibrium state. Here, we perform multi-millennial CESM simulations, considering a pre-industrial control simulation, and abrupt 2x, 4x, 8x, and 16x, and 0.71x, 0.59x, 0.5x and 0.35x the pre-industrial control CO2 concentration. In all global warming scenarios, we observe a rapid collapse to the AMOC within the first 250 years, attributed mechanistically to the complex interplay between surface salinity and temperature which inhibits deep-water formation in the sub-polar North Atlantic [1]. In our abrupt doubling and quadrupling of atmospheric CO2 experiments we observe a recovery to the circulation after 1,000 years, and 3,500 years, respectively; however, our 8xCO2 experiment remains in this weakened state even after 10,000 years of model integration. This potentially indicates that a new equilibrium may have been met in this very warm climate, in which North Atlantic overturning is inhibited. In our abrupt 0.5xCO2 experiment, we observe a spontaneous collapse to the AMOC after 2,000 years, which precedes a recovery over the next 1,500 years, before a secondary, rapid collapse to the circulation at 3,500 years [2]. The behavior is strongly indicative of a Dansgaard-Oeschger Event. Overall, our results highlight the rich quasi-equilibrium dynamical behavior of the Global Meridional Overturning Circulation in past climates for which atmospheric CO2 concentrations were markedly different.

P05

Revisiting the tropical Atlantic western boundary circulation from a 25-year time series of satellite altimetry data

Geostrophic currents derived from altimetry are used to investigate the surface circulation in the western tropical Atlantic over the 1993–2017 period. Using six horizontal sections defined to capture the current branches of the study area, we investigate their respective variations at both seasonal and interannual timescales, as well as the spatial distribution of these variations, in order to highlight the characteristics of the currents on their route. Our results show two groups of currents branches with different variabilities depending on the location, and large cyclonic circulation observed between 0–6$\circ$ N and 35–45$\circ$ W during boreal spring. These variabilities follow the wind variability. We also observed a secondary North Brazil Current retroflection flow during the second half of the year, which leads to the two-core structure of the North Equatorial Countercurrent and might be related to the wind stress curl seasonal changes. To the east, the North Equatorial Countercurrent weakens and its two-core structure is underdeveloped due to the weakening of the wind stress. At interannual scales, depending on the side of the Equator examined, the North Brazil Current exhibits two opposite scenarios related to the phases of the tropical Atlantic Meridional Mode. At 32$\circ$ W, the interannual variability of the North Equatorial Countercurrent and of the northern branch of the South Equatorial Current (in terms of both strength and/or latitudinal shift) are associated with the Atlantic Meridional Mode, whereas the variability of the Equatorial Surface Current intensity is associated with both the Atlantic Meridional Mode and Atlantic Zonal Mode phases.

Two regimes of Atlantic multidecadal oscillation: cross-basin dependent or Atlantic-intrinsic

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The Atlantic Multidecadal Oscillation (AMO) is a prominent mode of sea surface temperature variability in the Atlantic and incurs significant global influence. Most coupled models failed to reproduce the observed 50–80-year period of AMO, but were overwhelmed by a 10–30-year period. Here we show that the 50–80-year AMO and 10–30-year AMO represent two different AMO regimes. The key differences are: (1) the 50–80-year AMO involves transport of warm and saline Atlantic water into the Greenland-Iceland-Norwegian (GIN) Seas prior to reaching its maximum positive phase, while such a transport is weak for the 10–30-year AMO; (2) the zonality of atmospheric variability associated with the 50–80 year AMO favors the transport of warm and saline water into the GIN Seas; (3) the disappearance of Pacific variability weakens the zonality of atmospheric variability and the transport of warm and saline water into the GIN Seas, leading to the weakening of the 50–80-year AMO. These results suggest that the 10–30-year AMO may be an Atlantic-intrinsic mode with no dependence on the variability in Pacific and in the GIN Seas while the 50–80-year AMO is strongly dependent on cross-basin connections, particularly the North Atlantic-GIN-Seas connection. Our results suggest that differentiating these AMO regimes and a better understanding of the cross-basin connections are essential to reconcile the current debate on the nature of AMO and hence to its reliable prediction, which is still lacking in most of coupled models.

Lin, P.; Yu, Z.; Lü, J.; Ding, M.; Hu, A.; Liu, H. Two Regimes of Atlantic Multidecadal Oscillation: Cross-Basin Dependent or Atlantic-Intrinsic. *Science Bulletin* **2019**, *64*, 198–204, doi:10.1016/j.scib.2018.12.027.

Investigating the Atlantic-Indian summer monsoon multidecadal teleconnections in the PMIP3/CMIP5 Last Millennium simulations

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Understanding the natural variability of Indian summer monsoon (ISM) is a crucial aspect relevant for decadal climate predictions and climate change studies. The multidecadal variability of ISM is known to have a close association with the Atlantic multidecadal oscillations (AMO). Several teleconnection pathways have been suggested to explain the co-variability of the AMO and ISM in multidecadal timescales. One hypothesis is that the AMO modulates the interannual North Atlantic Oscillation (NAO) mode and there by influences the monsoon via Eurasian temperature modulations [1]. Direct atmospheric teleconnection, across Eurasia, through upper-level circulation anomalies [2] has also been attributed to the observed AMO-ISM relationship. Another possibility is the AMO modulating the monsoon via the Pacific pathway through the atmospheric bridge mechanism and associated modulations of the Hadley-Walker circulations [3]. The Last millennium (LM) (851-1848) climate simulations part of the PMIP3/CMIP5 gives an opportunity to better understand the fidelity of climate models in capturing the AMO-ISM teleconnection mechanisms. In this study [4] we explore how well the proposed mechanisms are represented in eight global climate models (GCM) LM simulations. Such a study, assessing the validity of different AMO-monsoon teleconnection mechanisms in different model climates provides crucial information about how reliable the respective GCMs may be in making decadal climate predictions.

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P08

Tropical Indio-Atlantic temperature gradient modulates multi-decadal AMOC variability in models and observations

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A potential future slowdown of the Atlantic Meridional Overturning Circulation (AMOC) would have profound impacts on global and regional climate, but this slowdown is affected by many processes that may speed up or accelerate the changes. In particular, recent studies have shown that AMOC responds to changes in mean tropical Indian ocean (TIO) temperature [1,2]. In fact, a persistent warming of TIO relative to the rest of the tropical oceans, comparable to the one observed as part of anthropogenic global warming, can strengthen the AMOC via atmospheric teleconnections that modify the temperature and salinity fields in the North Atlantic on annual to multi-decadal timescales [2]. Such AMOC response to mean TIO warming is robust across different climate models. However, AMOC response to internal (unforced) TIO temperature variations has remained largely unexplored. Here, we use the three observational products for the period 1870-2014, as well as pre-industrial control (piControl) simulations with coupled climate models and show that internal changes in sea surface temperature gradients between the Indian and Atlantic Ocean (SSTgrad) can drive teleconnections that influence internal variations of North Atlantic climate and AMOC.

We separate the unforced observed component (i.e., internal signal) from the forced signal following the residuals method presented by Smith et al. (2019). In the absence of direct AMOC observation we estimate AMOC variability from an SST index ($\mathrm{AMOC}_{\mathrm{SST}}$) [4-5]. We find a robust observed relationship between the unforced tropical SSTgrad and $\mathrm{SST}_{\mathrm{AMOC}}$ when TIO leads by ~25 years. This time-lag is in line with a recently described mechanism of anomalous tropical Atlantic rainfall patterns that originate from TIO warming and cause anomalously saline tropical Atlantic surface water which slowly propagate northward into the subpolar North Atlantic, ultimately altering oceanic deep convection and AMOC [1,2]. Our study now suggests that it is the tropical SSTgrad that drives those AMOC changes, with a limited role for the western tropical Pacific. Pre-industrial control simulations with the IPSL-CM6A-LR model confirm this relationship, indicating a time lag of ~25 years between SSTgrad and $\mathrm{SST}_{\mathrm{AMOC}}$ variations.

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Recent warming of Greenland in the early summer and its link to atmospheric blocking trends in the Northern Atlantic sector.

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Recent studies [1][2] highlight an anomalous positive trend of the geopotential height field in the Greenland region in early summer. The observed trend constitutes an unexpected feature of Arctic amplification that can cause an accelerated melting of continental perennial ice, a rise of the seal level and a change in ocean salinity that impacts oceanic circulation.

Causality relations between Greenland temperature changes, Arctic Amplification, changes in ocean circulation - such as the AMOC decline - and changing weather regimes in the Northern Atlantic sector are hard to establish. A convenient framework is provided by the study of atmospheric blocking trends, a proxy for Northern Atlantic atmospheric variability. Indeed, the recent warming of Greenland can be interpreted as an increase in Greenland atmospheric blocking frequency. In this research we extend existing analyses making use of ERA5 reanalysis [3] and a geopotential meridional-gradient based index for instantaneous blocking detection [4]. Moreover, we apply a novel Lagrangian tracking algorithm that is able to compute the evolving features of atmospheric blocking over Greenland: the duration, area, displacement and center of mass of the blocking events are analyzed. The changing characteristics of atmospheric blocking can give useful insights into the dynamical causes of the frequency change.

Preliminary results show how the increased atmospheric blocking frequency over Greenland can be explained by an increased persistence of atmospheric blocking, rather than an increase in the number of events. These results suggest a change in the maintenance mechanisms rather than a more frequent triggering.

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P10

Mid-20th Century Atlantic Circulation informed by Modern Observations and Models

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Abstract Text The Atlantic Meridional Overturning Circulation (AMOC) is a driving force of the heat redistribution on our planet and has a particularly large impact on the climate of the northern hemisphere and Europe. It has been projected since the 1980s that the anthropogenic atmospheric CO2-concentration rise will weaken the AMOC. Such a change in AMOC intensity would lead to a change in European climate and extreme weather events. Therefore, it becomes crucial to understand how the AMOC responds to climate change. Faith in the reliability of coupled model projections has been questioned due to a growing body of evidence that the multi-model mean of climate models disagrees with observational proxies for the AMOC, in particular in the mid-20th century. In turn, the reliability of these observational proxies has been questioned as they are not direct observations of the AMOC. In this study, we present an AMOC reconstruction based on a simple layered model of the deep branch of the AMOC, trained with modern RAPID array measurements at 26N, in order to compute the AMOC from historic hydrographic data from the EN4 database. Our aim is to provide, in the light of modern direct observations, an answer on the reliability of AMOC reconstructions and historical climate simulations during the mid-20th century.

P11

Drivers and impact of the 2021 extreme warm event in the tropical Angolan upwelling system.

Between April and August 2021, high interannual sea surface temperature anomalies of more than 1.5◦C were recorded along the coasts of Angola and Namibia. This extreme coastal warm event has reached its peak amplitude in June 2021 in the Angola Benguela Area during the major upwelling season in tropical Angolan upwelling system. Analyses have revealed that the warm event was forced by a combination of local and remote forcing. In April 2020, a local warming was triggered around the Angola Benguela front (~15◦S -17◦S) by local positive anomalies of near coastal wind-stress curl leading to downwelling anomalies through Ekman dynamics and by anomalously weak winds. Moreover, between May and August 2021, downwelling coastal trapped waves (CTWs) were observed along the African coast. Those coastal trapped waves might have partly emanated from the downwelling equatorial Kelvin waves (EKW) triggered by the reflection of downwelling Rossby waves at the Brazilian coast. Additional forcing of downwelling EKW comes from the westerly wind anomalies observed in the western or central equatorial Atlantic in early May 2021. Along the southwest African coast, extra forcing for the downwelling CTWs likely resulted from an observed weakening of the prevailing coastal southerly winds along north of 10◦S between in early 2021. Moreover, a heat budget analysis reveals a contribution of meridional heat advection to the near-surface warming during the early stages of the warm event. A substantial reduction of net primary production in the Southern Angola and Angola Benguela front regions was observed during the extreme warm event.

P12

Triple-dip La Niña in 2020-23: North Pacific footprint drives the 2nd year La Niña

Triple-dip La Niña – triple-year persistence of events – occurred during 2020 to 2023 for the first time in the 20th century. It brings large social impacts, yet its persistence mechanisms remain unclear. Here, an atmosphere and ocean reanalysis and 100-member initialized forecasts using a state-of-the-art climate model were analyzed to identify factors contributing to the persistence of the first- to second-year La Niña in 2020-22. We found that North Pacific high pressure anomalies in the winter of 2020/21 forced a negative phase of the Pacific meridional mode through the following spring, forming the broader structure of La Niña. The resultant broader La Niña pattern slowed down the recharge-discharge process by Ekman transport, stimulating following La Niña. Hindcast experiments predicts the second-year La Niña although large spread exists across ensemble members. Ensemble forecast sensitivity analysis revealed that the Southwestward shifted North Pacific high and the resultant meridional extent of La Niña explains forecast spread, affirming the importance of La Niña spatial pattern. Thus, atmospheric variability in the North Pacific one year ago is responsible for the second-year La Niña in 2021/22.

P13

Low-frequency AMOC variability: mechanism and impacts

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We investigate the mechanisms driving the Atlantic meridional overturning circulation (AMOC) low-frequency variability and its climate impact using the atmosphere-ocean coupled general circulation model (AOGCM) IPSL-CM6A-LR. By analyzing the 2000-year pre-industrial control simulation, we found that low-frequency AMOC variability is driven by delayed freshwater accumulation and release in the Arctic. As the AMOC increases, a combination of reduced sea ice volume and anomalous currents reduces freshwater export from the Arctic and leads to a slow accumulation of freshwater in the central Arctic. Meanwhile, saltier Atlantic inflow through the Barents Sea results in a positive salinity anomaly in the Eastern Arctic subsurface. The mean transpolar drift across the Arctic towards the Lincoln Sea tends to transport the positive salinity in the Eastern Arctic subsurface to the central Arctic and the central freshwater anomaly to the Lincoln Sea north of Greenland. In parallel, a cyclonic circulation anomaly around Greenland competes with the tendency of the transpolar drift transporting freshwater southward towards Greenland. This competition leads to the relatively long retainment of a surface freshwater anomaly in the Arctic Ocean. When the accumulated central freshwater finally reaches the Lincoln Sea, oceanic currents around Greenland reorganize, leading to the export of the anomalous Arctic freshwater to the North Atlantic, enhancing stratification in deep convection sites. The AMOC then decreases and the variability switches to the opposite phase.

The climate responses to the AMOC low-frequency variations are investigated through experiments in which the baroclinic component of the North Atlantic Ocean currents is modified online in AOGCM to constrain the AMOC strength. The analogous experiment is also conducted using a slab ocean experiment. The responses to a strong AMOC include a widespread warming in the Northern Hemisphere and a northward shift of the intertropical convergence zone over the Atlantic Ocean. The driving mechanism of climate responses is then investigated with changes in the energy flows in the ocean and atmosphere. Large-scale atmospheric changes in the tropics are organized by an anomalous cross-equatorial Hadley circulation that transports energy southward and moisture and heat northward. Changes in the Indo-Pacific Ocean circulation and heat transport, driven by the wind stress associated with the abnormal Hadley cell, damp the atmospheric responses. The lack of Indo-Pacific transport and ocean heat storage leads to amplified atmospheric changes in the slab ocean experiments, which are further amplified by a positive feedback due to the inter-hemispheric antisymmetric changes in low cloud cover.

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P14

North Atlantic Oscillation impact on the Atlantic Meridional Overturning Circulation shaped by the mean state

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The North Atlantic Oscillation (NAO) can modulate the Atlantic Meridional Overturning Circulation (AMOC) intensity through surface buoyancy flux that in the deep convection region of the AMOC [1-3]. However, its efficiency significantly varies across climate models [4-5]. Using 42 models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6), our study found that the strength of the NAO–AMOC relationship is closely related to the mean stratification over the subpolar North Atlantic (SPNA). This is because the weaker the stratification in the SPNA, the more easily vertical penetration is allowed for a given NAO-induced buoyancy forcing, leading to more vigorous deep water formation. Conversely, models with the stronger stratification were characterized by advanced sea ice cover throughout the wintertime that hinders the air–sea interaction, resulting in weak or no significant relationship between NAO and AMOC. Compared to the mean stratification, the amplitude and spatial pattern of the NAO forcing turned out to be less significant in shaping the NAO–AMOC relationship. Previous studies have suggested that both mean MLD and NAO–AMOC relationship are relatively consistent in ocean-only models [4], indicating that air–sea feedback processes in coupled climate models drive the across-model diversity. Our results highlight that an accurate representation of the mean state is crucial to improve predictions of the atmospheric-driven AMOC variability.

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P15

Changes in the relationship between the North Atlantic and Tropical Pacific due to climate change in the CMIP model

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The warming (cooling) of the tropical Atlantic Ocean, called the North Atlantic (NTA), peaks during the FMA and is known to influence La Niña (El Niño) in the tropical Pacific through subtropical and tropical mechanisms with a lag of about 9 months[1]. Previous studies have shown that the connection between the tropical Atlantic and tropical Pacific is weakened in the CMIP5 climate change scenarios. This weakening is attributed to the relatively cooler mean sea surface temperatures in the NTA region compared to the overall tropical regions[2]. On the other hand, the interaction between the two oceans in CMIP6 climate change scenarios is limited, and no comparisons to CMIP5 have been made. Therefore, our study aimed to investigate the variations between CMIP5 and CMIP6 in terms of the NTA-ENSO relevance and explore the underlying reasons for these disparities.

By conducting a comparative analysis of the CMIP5 and CMIP6 models, we examined how the interaction between these two oceans is simulated in the context of climate change. Our findings indicate that in the CMIP5 model, the negative coupling, characterized by the cooling of NTA during spring followed by a subsequent winter El Niño, does not exhibit significant variations between the historical and RCP8.5 scenarios. However, in the CMIP6 model, this coupling is notably strengthened in the SSP585 scenario compared to the historical scenario.

In order to assess the varying impact of the CMIP5 and CMIP6 models on the relevance of the two oceans, we conducted an analysis of the mean fields. Our findings indicate a notable increase in mean precipitation within the tropical central to eastern Pacific due to climate change, specifically in CMIP6 as compared to CMIP5. Furthermore, we observed a strong correlation between these mean field distinctions and changes in NTA-ENSO during our correlation analysis. Within the CMIP6 model, exhibiting heightened mean precipitation as a result of climate change displayed a distinct pattern. Specifically, the precipitation response associated with NTA showed a tendency for greater intensity in the tropical western to central Pacific. This result could be attributed to the heightened sensitivity of precipitation to increased mean precipitation. Additionally, we noticed that the anomalies in the east-west wind field were more pronounced in the model where mean precipitation. These intensified east-west wind field anomalies exhibited a high correlation with the augmented relevance of NTA-ENSO in climate change. In simpler terms, models showcasing significant increases in mean precipitation exhibited a stronger NTA-induced response in the tropical Pacific. This outcome is favorable as it promotes the triggering of El Niño events and ultimately strengthens the connection between the two oceans.

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P16

Tropical subsurface dynamic adjustment and pattern formation responses to idealized subtropical low cloud forcing

Extratropical energy forcing exerts a strong influence on tropical patterns of sea surface temperature (SST) and precipitation via coupled ocean-atmosphere teleconnection pathways. Low clouds in subtropical subsidence regions have been especially studied for their ability to locally amplify extratropically-forced SST perturbations. While several studies have emphasized the important role of coupled surface ocean and atmospheric feedbacks in communicating subtropical temperature anomalies to the tropics, the subsurface adjustment remains understudied. In this work we force an ocean-only general circulation model (OGCM) with idealized low cloud forcing by relaxing SST to a specified anomaly in the marine stratocumulus regimes. We find that cooling in the Northeast Pacific low cloud deck dynamically adjusts the subtropical thermocline through baroclinic wave activity. This wave action communicates subtropical cloud deck forcing to the tropics such that a La Niña-like cooling develops in the Eastern Equatorial Pacific, then affecting the entire tropics through tropical basin interactions. Surprising differences in the equatorial temperature response to Northeast and Southeast Pacific low cloud deck cooling suggest this cloud forcing response is not necessarily hemispherically symmetric. By tracking the transient evolution of the subsurface ocean to subtropical low cloud-like forcing, these results clarify the subsurface extratropical-tropical teleconnection which communicates anomalies to the tropical Pacific via short-term dynamic adjustment and longer-term thermodynamic adjustment. These results have important implications for the climate sensitivity and tropical basin interactions by providing a clearer understanding of how the ocean may have adjusted to cloud forcing under observed historical forcing.

P17

Tropical waves, are known to modulate rainfall in tropical Africa on intraseasonal down to convective time scales. Data scarcity in central Africa, has long prevented a clearer picture on rainfall regional variability. In-situ and satellite rainfall dataset are used for a comparison of the role of waves on the variability of rainfall in Cameroon.

For the study period 2001-2019 in a selected domain over Cameroon, the outgoing longwave radiation (OLR) dataset of the National Oceanic and Atmospheric Administration (NOAA) are used to apply a wavenumber-frequency filtering in order to evaluate the co-occurrence of waves around rainfall events. These include the fast modes such as Kelvin waves and tropical disturbances (TD), as well as slow modes represented by equatorial Rossby waves and the Madden-Julian Oscillation (MJO). Due to regional differences in seasonal rainfall characteristics, the analysis is performed for a southern and northern sub-domain during the bi-modal (March–May/September–November) and unimodal (May–October) rainy seasons, respectively.

Results show that: 1) The passage of Kelvin waves and TDs have the strongest impact on daily rainfall rates, whereas the effect of the MJO is the weakest ; 2) the modulation by Kelvin waves is strongest in southern Cameroon whereas that of TDs is strongest in the north. Some CCEWs have been further isolated via a 2D spatial projection method based on parabolic cylinder functions (PCFs) using horizontal wind fields from ERA5 reanalysis data of the ECMWF. Here, first results suggest that the projection method yield less intense and slower Kelvin waves.

P18

Improved Extratropical North Atlantic Atmosphere–Ocean Variability with Increasing Model Resolution

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The representation of extratropical North Atlantic atmosphere–ocean variability is assessed in HighResMIP simulations that have low-resolution (LR) or high-resolution (HR) in their atmosphere and ocean model components. It is found that some of the LR simulations overestimate the low-frequency variability of subpolar sea surface temperature (SST) anomalies and underestimate its correlation with the NAO compared to ERA5 reanalysis. These deficiencies are substantially reduced in the respective HR simulations.

To understand the cause of the overestimated subpolar ocean variability in the LR simulations and the improvements in the HR simulations, a link is demonstrated between the amplitude of the subpolar ocean variability and the mean state of the Labrador–Irminger seas. Supporting previous studies, the Labrador–Irminger seas tend to be colder and fresher in the LR simulations compared to the HR simulations and oceanic observations from EN4. This promotes upper-ocean density anomalies in this region to be more salinity-controlled in the LR simulations versus more temperature-controlled in the HR simulations and EN4 observations. It is argued that this causes the excessive subpolar ocean variability in the LR simulations by favoring a positive feedback between subpolar upper-ocean salinity and Atlantic Meridional Overturning Circulation (AMOC) anomalies, rather than a negative feedback between subpolar SST and AMOC anomalies as in the HR simulations. The findings overall suggest that the simulated mean subpolar ocean state impacts the variability of the ocean circulation and SSTs, including their relationship with the atmospheric circulation, in the extratropical North Atlantic.

P19

An investigation on the relationship between North Atlantic climate variabilities and the dominant role of oceanic conditions

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The Atlantic meridional overturning circulation (AMOC), the Atlantic multidecadal oscillation (AMO), and the North Atlantic oscillation (NAO) are the dominant modes of climate variability over the North Atlantic. We use several climate model simulations using CESM2.1 to investigate the interrelationship between these climate modes on multi-year decadal timescales. The fully coupled CESM2.1 model used to assimilate the Ocean Data Assimilations with three different temperature and salinity profile data (ODA; [EN4.2, ORAS4, ProjDv7.3]), each having 10 ensemble members, is used in this study (for methods, see [1]). The AMOC transport at 26.5°N and 45°N simulated by the experiments based on ODA is compared with the output from the fully coupled CESM2-Large Ensemble (CESM2-LE; [2]). The observed decline in AMOC transport at 26N from the mid-1990s is successfully captured in CESM2-LE and all 10 members of the ORAS4-based assimilations. Interestingly, at 45°N, all the ODA-based simulations (EN4.2, ORAS4, and ProjDv7.3) and CESM2-LE reproduce the weakening of transport after the mid-1990s. The ODA shows predominant variability on interannual and decadal timescales but much weaker variability in the CESM2-LE. Our preliminary analysis shows that the NAO, estimated using EOF analysis of sea level pressure during the winter (DJF; December through February), is well simulated in all three ODA-based simulations and is able to capture the timing of the changes in phase during the historical period (1955–2020), highlighting the oceanic role in the atmospheric mode of variability over the North Atlantic Ocean. Further, extensive analysis needs to be carried out to understand the intrinsic properties of the above-mentioned linkages and to explore the role of oceans in earth system predictability.

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P20

South Atlantic Meridional Overturning Circulation in present and future climate from the Community Earth System Model, Version 2, Large Ensemble Project: Impacts on the Heat Balance

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For large-scale and long-term variations, the Atlantic Meridional Overturning Circulation (AMOC) may be an essential mechanism for ocean heat redistribution. Therefore, changes in this circulation may affect the role of the oceans as an attenuator of climate change. Our work focuses on the South Atlantic Ocean (0º-34ºS), a region that has been warming substantially in recent decades. More specifically, this work aims to understand changes in the AMOC affect the heat balance in the present and future climate. We rely on simulations performed as part of the Community Earth System Model, version 2, Large Ensemble Project, which used SSP3-7.0 following CMIP6 recommendations. We averaged the ensemble members since we wanted to focus on the forcing variability. The results indicate that the AMOC upper branch has a weakening trend in the SSP3-7.0 while the lower limb tends to increase. Also, while the upper branch tends to contract, the lower one expands. The intensification and expansion of the lower branch lead to the cooling of the ocean bottom layer, while the weakening and contraction of the upper branch lead to warming. Thus, the AMOC branches' future projection indicates that the vertical thermal stratification in the South Atlantic will increase by the end of the century. In addition, the AMOC anomaly is the main term capable of explaining the changes in the heat balance of the basin in the future climate.

P21

Determining dynamical drivers of intra-basin differences in spectral slope from the CESM Last Millennium Ensemble

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Paleoceanographic temperature proxy records in the North Atlantic Ocean provide estimates of multidecadal variability. Direct comparison of these records with numerical simulations is complicated by uncertainties in proxy calibration functions and record chronologies, measurement and representativeness error, and the fact that internal variability in free-running climate models is generally asynchronous with that in the real world. A complementary approach to direct comparisons is to compare the statistics (generally, length and time scales) of variability in models and proxies. Spectral slope, the exponent in a power-law fit to the power spectrum, is a single number characterizing the relative amount of low- and high-frequency variability and is insensitive to some sources of proxy error. Previous studies have debated the agreement of spectral slopes between models and surface temperature proxies.

Here, we examine spectral slopes of a 13-member ensemble of coupled climate simulations with realistic climate forcing. In the simulations, we identify a small number of modes of sea surface temperature variability that play a dominant role in setting spatial variations in spectral slopes. As slope is determined in logarithmic space, variability at high frequencies affects the overall shape of the spectrum more than that at low frequencies, allowing us to explain a large degree of spatial variance in the slope by isolating dominant patterns that maximize the relative amount of high frequency variance, following Wills et al. (2018) [1]. Consideration of ensemble statistics permits identification of regions where additional proxy data could be used to evaluate the fidelity of modeled internal variability.

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P22

Quasi-decadal to interdecadal ocean surface temperature variability in the Southern Benguela Upwelling System

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The Benguela Upwelling System is one of the four most productive fisheries areas in the world, and it is therefore important to understand the variability at different time and space scales before developing scenarios or forecasts for the future of the region. In this study, we investigate the decadal fluctuations in ocean surface temperature in the Benguela upwelling system focusing on the Southern Benguela and their relationship with the global ocean surface temperature. Two dominant decadal time scales of variability are identified over the twentieth century: the quasi-decadal (9-14 years) and the interdecadal (19-26 years). At the interdecadal scale, the tropical and subtropical ocean surface temperature, especially in the Pacific Ocean, is significantly correlated to the Southern Benguela ocean surface temperature fluctuations. There is also a significant correlation at the interdecadal scale with the Interdecadal Pacific Oscillation (IPO) and the Pacific Decadal Oscillation (PDO). At the quasi-decadal time scale, there is a link between Southern Benguela ocean surface temperature and the whole of the South Atlantic reminiscent of the Pan-Atlantic Decadal Oscillation (PADO) and its regional expressions in the South Atlantic, namely, the Subtropical Dipole mode (SASD) and the Atlantic Meridional Mode (AMM).

P23

Impacts of Atlantic Meridional Overturning Circulation decline on Euro-Atlantic circulation patterns

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The Atlantic Meridional Overturning Circulation (AMOC) is a vital component of the global climate system regulating heat, carbon, and freshwater distribution. Models agree on a future weakening of the AMOC, although there is significant uncertainty about its magnitude and the related regional climate impacts. In particular, the response of large-scale atmospheric circulation to the AMOC slowdown is still largely unknown, with implications for weather extremes and associated societal risks. The purpose of this study is to enhance our understanding of the impacts of an AMOC slowdown on atmospheric patterns with a focus on the Euro-Atlantic region, where the influence of AMOC is particularly relevant.

The atmospheric response to the AMOC slowdown is analysed from a weather regimes perspective. We analyse changes in weather regimes frequency and persistence in two ensemble of climate model simulations from the CMIP6 archive (SSP5-8.5 and idealised abrupt-4xCO2) compared to their control climates (historical and preindustrial). We split the models in two groups according to their AMOC response to greenhouse gas forcing. Through rigorous statistical testing, we attribute the differences in the simulated climate impacts across the two groups to the difference in the AMOC response.

We find that models that simulate a larger AMOC decline feature a net increase in the NAO+ regime frequency and a decrease in frequency and persistence of Scandinavian Blocking regime that is not detectable in models that simulate a smaller AMOC decline. We interpret our results as consistent with an enhanced mid-latitude jet-stream due to the increased baroclinicity induced by the AMOC decline.

We conclude that the AMOC is a key source of large inter-model uncertainty in the simulation of future climate change impacts. Further observational campaigns may thus help us alleviate model biases and provide constraints on a number of societally relevant climate change impacts.

OCEAN-ATMOSPHERE PROCESSES IN RESPONSE TO CLIMATE CHANGE IN THE TROPICAL SOUTH ATLANTIC

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The poleward heat transport in the ocean and atmosphere are important for the Earth's climate. In the Atlantic, the meridional heat transport from the southern to northern hemisphere is driven by the Atlantic meridional overturning circulation (AMOC) [1]. The AMOC upper branch in the South Atlantic has an east-to-west path characterized by southern branch of the South Equatorial Current (sSEC) [2], which acts as a primary pathway for cross-oceanic heat transport from the southeastern tropical Atlantic to the southwestern Atlantic warm pool (SAWP) [3]. The SAWP is responsible for the supply of water vapor, which is carried by the southeast trade winds [3,4] into the continent. Easterly wave disturbances [5] and also upper ocean heat anomalies transported by the sSEC[3] drive the precipitation in the East of Northeast Brazil (ENEB). ENEB is a coastal region affected by heavy rainfall, causing flash floods and landslides [6,7]. This study aims to investigate the long-term variability and trends of the AMOC Northward Heat Transport (NwHT), temperature, and precipitation for historical and future projections of the CIMP6 under the scenarios of SSPs 245 and 585. The effects of the AMOC NwHT phases in the upper Atlantic Ocean on precipitation in ENEB are quantified through EOF, Singular Value Decomposition (SVD) and Crosswavelet analysis. The ERA5 data and 17 output models from CIMP6 models show a warmer upper ocean, which could be related to the heat convergence by the AMOC NwHT weakening, as shown in trends under SSPs scenarios. As AMOC weakening contributes to an increase in surface temperatures along SAWP, it can affect, consequently, the precipitation variability over the ENEB.

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Past, present, and future impacts of the Atlantic equatorial mode of variability on the boreal summer Guinea Coast rainfall characteristics

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Over the 20th century and the last decades, the Atlantic equatorial mode (AEM) of variability has been the dominant oceanic forcing on the interannual variability of the Guinea Coast (southern region of West Africa) rainfall during the boreal summer [1]. Positive phases of the AEM are characterized by anomalous surface warming in the eastern equatorial Atlantic, which is associated with an anomalous increase in the mean rainfall and extreme rainfall events over the Guinea Coast. Historical simulations performed with climate models participating in the sixth phase of the coupled models intercomparison project (CMIP6) indicate that the tropical Atlantic sea surface temperature response to the AEM phases is relatively well represented. However, these models struggle in representing the tropical Atlantic and Guinea Coast rainfall response to this oceanic internal mode of variability [2]. Furthermore, under the warmest emission scenario of greenhouse gases for the future (SSP5-8.5), the AEM variability is projected to decrease in the near-term, mid-term, and long-term future periods, respectively, relative to the present-day situation. The weakened variability of the AEM in the future is associated with a decrease in its impact on the boreal summer mean rainfall over the Guinea Coast. Moreover, while there is a projected increase in the total variance of the extreme rainfall indices over the Guinea Coast under future global warming, the contribution of the AEM to this variability is reduced [3].

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P26

Boosting effect of the strong western pole of the Indian Ocean Dipole on El Niño decay

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Although the impact of the Indian Ocean on the decaying pace of El Niño events has been documented previously, contrary to the consensus that the Indian Ocean Basin (IOB) mode favors the decay of El Niño via modulating the zonal wind anomalies in the equatorial western Pacific [1], the contribution of the Indian Ocean Dipole (IOD) mode on the following year's El Niño remains highly controversial [2-4]. Through investigating the evolution of fast and slow decaying El Niño, respectively, this study demonstrates that the positive IOD with a strong western pole prompts the termination of El Niño, whereas no significant effect of the IOD with a weak western pole. The responsible physical mechanism is that the strong western pole of a positive IOD can lead to a strong IOB pattern peaking in the late winter (earlier than normal), enhancing local convection and causing anomalous rising (sinking) motions over the tropical Indian Ocean (western Pacific Ocean). The surface easterly wind anomalies on the western flank of the sinking motions stimulate oceanic upwelling equatorial Kelvin waves, which shoal the thermocline in the equatorial eastern Pacific and rapidly terminate the equatorial warming during El Niño. However, a weak western pole of IOD induces a weak IOB mode that peaks in late spring, and the above cross-basin physical processes will not appear.

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P27

Non-ENSO Precursors for Northwestern Pacific Summer Monsoon Variability with Implications for Predictability

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The influence of the El Nino-Southern Oscillation (ENSO) in the Asian monsoon region, including a large-scale anomalous anticyclone (AAC) in the lower troposphere that spans the Indo-Northwestern Pacific and the Sea Surface Temperature (SST) warming in the North Indian Ocean, persists through the post-ENSO summer after the SST anomalies in the tropical Pacific have dissipated. Positive feedback from the interbasin ocean-atmospheric coupling, known as the Indo-Western Pacific Ocean Capacitor (IPOC) effect, is responsible for the long persistence of the post-ENSO coherent anomalies, though the feedback mechanism itself does not necessarily rely on the antecedence of ENSO events. To investigate the ENSO forcing and non-ENSO internal variability, we conduct ensemble "forecast" experiments with a full-physics, globally coupled atmosphere-ocean model initialized from a multi-decadal tropical Pacific pacemaker simulation. The leading mode of internal variability as represented by the forecast-ensemble spread resembles the post-ENSO IPOC, despite the absence of antecedent ENSO forcing by design. The persistent atmospheric and oceanic anomalies in the leading mode highlight the positive feedback mechanism in the internal variability. The large sample size afforded by the ensemble spread allows us to identify robust non-ENSO precursors of summer IPOC variability, including a cool SST patch over the tropical Northwestern Pacific, a warming patch in the tropical Northern Atlantic, and downwelling oceanic Rossby waves in the tropical Indian Ocean south of the equator. The pathways by which the precursors develop into the summer IPOC mode and the implications for improved predictability are discussed.