SASAS 2021 On-line conference 18 and 19 November 2021

Abstracts

Session 1: Climate change and variability

Chair: Hector Chikoore

1.1 AR6 and COP26: what are the implications for southern Africa?

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The IPCC Assessment Report Six (AR6) Working Group I (WGI) report, published in August 2021, is widely regarded as a 'code red' for humanity. The report assesses that global warming has reached a level of 1.1 °C with respect to pre-industrial levels, close to the dangerous thresholds of 1.5 and 2 °C. Even under a 'best effort' mitigation by the nations of the world, through which CO2 emissions are cut in half by 2030 and carbon neutrality is achieved by 2050, the report assesses that it is more likely than not that the 1.5 °C threshold of global warming will be exceeded. This best estimate for the timing of this exceedance to occur is in the early 2030s. But what are the implications of these findings for southern Africa, and does the report contain new insights into the climate change futures of the region? In this talk the main assessments of the report in terms of future rainfall and temperature patterns over southern Africa will be reviewed. From this foundation an interpretation will be provided of the main risks southern Africa may face in the near-term (the next twenty years) given committed further warming: more frequent and intense multi-year droughts, heat-waves, and landfalling tropical cyclones. It will also be discussed how these risk will amplify deeper into the 21st century under low mitigation futures. The outcomes of the 26th Conference of the Parties (COP26) will finally be considered, within the context of whether these commit the world (and southern Africa) to a high or low mitigation future.

1.2 Integrated assessment of the influence of climate change on current and future intra-annual water availability in the Vaal River catchment

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Increasing water demand due to population growth, economic expansion and the need for development puts a strain on the supply capacity of the Vaal River catchment in South Africa. Climate

change presents additional challenges in the catchment which supports the country's economic hub, more than 30% of its population and over 70% of its maize production. This study evaluates the influence of climate change on current and future intra-annual water availability and demand using a multi-tiered approach where climate scenarios, hydrological modelling and socio-economic considerations were applied. Results shows exacerbated water supply challenges for the future. Temperature increases of between 0.07 and 5 °C and precipitation reductions ranging from 0.4 to 30% for Representative Concentration Pathways (RCPs) 4.5 and 8.5, respectively, are also predicted by the end of the century. The highest monthly average streamflow reductions (8–10%) are predicted for the summer months beyond 2040. Water Evaluation and Planning (WEAP) simulations project an increase in future water requirements, gaps in future water assurance and highlights limitations in existing management strategies. The study recommends a combination of adaptation plans, climatic/non-climatic stressor monitoring, wastewater-reuse, conservation, demand management and inter-basin transfers to reduce future uncertainty in monthly water sustainability.

1.3 Climate change and fire regimes in Limpopo Grasslands

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Wildfires are becoming more frequent largely due to the increased fuel load, human activities and climate change and are some of the major hazards in the southern Africa region. The delay in the onset of the rainy season coupled with rising surface air temperatures have increased fire risk in the region. We investigate the interactions between climate change and fire regimes in the grasslands of Limpopo, South Africa. We seek to understand how the Conformal Cubic Atmospheric Model (CCAM) simulates the present-day fire season and ask the following questions: -

- How many days with fire risk?
- How are the fire risk days projected to change?
- Will future high fire danger days increase?

We also employ fire indices such as the McArthur Forest fire danger index which link rainfall, temperature and wind to fire danger. The study aims to determine which weather systems bring high fire days. We use CCAM (8 km res) to simulate climate change projections for the period 2021-2040, 2041-2060 and 2080 – 2099 and the historical baseline from 1961 – 1980. Results of this study will contribute to the understanding of changing fire regimes in response to recent unprecedented temperature increases coupled with repeated heat waves, which appear to be modulating fire intensity in the study area.

1.4 Impacts of Antarctic stratospheric ozone recovery on climate variability and change over southern Africa

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In the Southern Hemisphere (SH), increased greenhouse gases (GHGs) and depletion of Antarctic stratospheric ozone significantly influence the atmospheric circulation. During the last quarter of the 20th century, the depletion of the stratospheric ozone was greatly associated with the positive phase of Southern Annular Mode (SAM). This led to the poleward shift of SH westerlies as well as the mid-latitude storms. Coupled carbon-climate Earth systems models are the prominent tools to analyze the influence of stratospheric ozone variability and concentration of GHGs on both atmosphere and ocean circulations in the SH. In this study, we evaluate whether the climate models of the Coupled Model

Intercomparison Project Phase Six (CMIP6) are capable to represent the trends that have occurred in the SH westerlies in recent decades, in response to both Antarctic stratospheric ozone depletion and increasing GHG concentrations. The accuracy of the model projections is being determined through comparison to the corresponding reanalysis data from the European Centre for Medium-Range Weather Forecasting (ECMWF). We find that the models are capable of simulating the general trend of a poleward displacement of the westerlies and the shift towards a positive SAM. Moreover, most models are capable to capture the partial recovery of the westerlies in response to recovering ozone concentrations following implementation of the Montreal protocol.

1.5 Projected changes in mid-latitude storm tracks over the Southern Ocean under future climate change

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Southern Hemisphere (SH) extratropical cyclones are the dominant feature of weather in the mid-latitudes, and also critical for climate processes via their latitudinal transports and forcing of the Southern Ocean. The tracks of storms affect regional weather and climate by bringing heavy precipitation and strong winds. Future changes in the position, intensity frequency and tracks of storms can additionally have substantial impacts at the local scale. It is therefore of great importance to understand how storm tracks may respond to increased anthropogenic influences. In this study, we applied an objective storm tracking algorithm to the European Centre for Medium-Range Weather Forecasts (ECMWF) interim reanalysis (ERA5-Interim), for the period 1979 to 2020, in order to represent storm tracks in the Southern Hemisphere. A Lagrangian objective cyclone tracking algorithm of Hodges (1994, 1995 and 1999) is used for tracking features and is implemented in an identical manner as described in Hoskins and Hodges (2002). We use the storm tracker to show how dry and wet years in South Africa's winter rainfall region relate to anomalous storm tracks over the Southern Ocean. From this foundation, we will proceed in future work to analyse the projected near and far future of storm tracks as represented in the Coupled Model Intercomparison Project Phase Six (CMIP6) under dissimilar Shared Socio-economic Pathways (SSPs). These include, SSP1- 1.9, SSP1-2.6, SSP2-4.5, SSP3 -7.0 and SSP5-8.5.

1.6 Africa's Climate Extremes Response to Stratospheric Aerosol Injection

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Anthropogenic warming is projected to increase the magnitude and frequency of extreme events, whose impacts are already being felt in vulnerable regions in sub-Saharan Africa. Solar radiation management (SRM) has been proposed as an interim measure to offset warming while emissions are reduced; however, the impact of stratospheric SRM on regional climate extremes have not yet been explored, particularly in the Paris agreement context. We investigate the potential impact of SRM on temperature and rainfall means and extremes over sub-Saharan Africa using simulations from the Geoengineering Large Ensemble. We found SRM significantly reduces temperature means and extremes; however, the effect on precipitation is not as linear. The results should be interpreted with caution as they are particular to this approach of SRM and this modelling experiment.

Session 2: Climate change and variability

Chair: Sheldon Strydom

2.1 Impacts of climate variability on soil water content in three different agro-climatic zones of South Africa

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Water stored in the soil profile is the main source of water for plants. Therefore, examining the impacts of climate variability on soil water availability is critical for the development of effective mitigation and/or adaptation strategies. In this study, modelled soil water estimates from 1980 through 2018 (39 years) were used to investigate the potential impacts of climate variability on soil water content for three selected weather stations, representing different agro-climatic conditions of South Africa. The non-parametric Mann-Kendall and Theil-Sen Slope were used for the trend analysis. The results showed a non-significant decreasing trend of soil water content at a rate of between -0.001 to -0.02 mm per annum for the Bainsvlei and Bronkhorstspruit stations that are located in an inland region. In contrast, the results showed a statistically significant (at 5% level) increasing trend of soil water content at a rate of 0.1131 mm per annum for the Mandeni station that is located in a coastal region. These findings suggest that inland regions are gradually becoming drier as a result of decreasing trends of rainfall and increasing air temperatures, while coastal regions are becoming wetter as a result of increasing trends of rainfall, despite an increase in air temperatures. The study also suggests that climate variability is likely to affect soil water content, although various regions will be affected differently. Therefore, the development of informed adaptation strategies at the local scale is critical to cope effectively with climate variability.

2.2 Impact of the El Nino Southern Oscillation on the Benguela upwelling.

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The impact of El Niño Southern Oscillation (ENSO) on Southern African climate is well documented and provides skill in the seasonal forecast of rainfall but less is known on the impact of ENSO on the Benguela Current west of Southern Africa. There is a significant correlation between ENSO and the Benguela Current upwelling sea surface temperature (SST) in late austral summer. Correlation is positive for the Southern Benguela and negative for the Northern Benguela. Significant correlation exists with up to 8 months lag when ENSO leads. The impact of ENSO is due to weaker than normal upwelling favorable south-easterly winds during El Niño in the Southern Benguela leading to warmer than normal coastal SST while during La Ninã, stronger than normal south-easterly winds lead to cooler than normal SST. The opposite effect applies for the Northern Benguela. The coastal wind change is part of an ENSO large-scale basin-wide perturbation in the South Atlantic. However, non-ENSO related SST variation in the Benguela upwelling can be as important as ENSO related SST perturbation and some ENSO events do not lead to the expected changes. Change in the Benguela upwelling are linked to change in the intensity of the trade winds associated with a shift of the South Atlantic Anticyclone. In the Southern Benguela, changes are also associated with variations in mid-latitude low-pressure system and associated upwelling unfavorable westerly winds. La Niñas also to favor the development of Benguela Niños in Angola and Namibia. This study shows the potential for

SST seasonal predictability in the Benguela upwelling due to the existing leading lag correlation between ENSO and the Benguela upwelling SST.

2.3 Maximum Energy Producing Synoptic Weather Types of South Africa's Eastern Cape Province

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In terms of growth, measured as a percentage of the total global energy production, onshore wind energy facilities (WEF's) could provide 25% of the total generation by 2050 [IEA 2018]. No research and related modelling have to date been undertaken in quantifying the future variability and systematic changes in the wind resource as it relates to WEF's in temporal and spatial dimensions, within the context of a changing climate. Moreover, how South Africa's wind potential relates to the occurrence of specific synoptic types has not yet been quantified. Obtaining such a quantification will be valuable in understanding how and why South Africa's wind energy potential may change in a changing climate. To quantify the energy-meteorology climatology, a novel approach of using self-organising maps is used. These maps identify the most common synoptic types occurring in the Eastern Cape Province of South Africa and are mapped onto correlated time resolution energy production to identify which synoptic types are associated with what type of wind energy production. Further research will use climate models to understand how these synoptic types change in geospatial position and occurrence over time and provide the tools needed to develop adaptation roadmaps to deal with such changes.

2.4 Spatial-temporal investigations of ERA5 versus ERA-Interim precipitation over Africa

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Over data sparse regions such as Africa, reanalysis datasets can provide a useful alternative to enable climate investigations. Here, a detailed comparison of ERA5 and ERA-Interim precipitation over Africa is done at annual and seasonal temporal scales, over various subregions, to identify biases. Additionally, the spatial pattern of interannual variability in the models is evaluated for ENSO events. Overall, there have been many improvements in ERA5 compared to ERA-Interim. ERA-Interim's wet bias in both the annual and seasonal rainfall over tropical Africa has been substantially reduced in ERA5. ERA5's representation of the annual cycle has improved over most selected subregions, notably over the Southwestern Cape, Cape South Coast and the Northern Subcontinent. ERA5 shows higher correlations with observations in the spatial patterns of interannual variability across all seasons, but particularly DJF and MAM. Finally, both models capture the ENSO signal remarkably well, although the spatial extent of positive/negative anomalies could be improved in some seasons and regions.

2.5 Future crop suitability assessment and the integration of Orphan crops into Kenya's food systems

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Climate change is seen to be playing an increasingly key role in determining the level of food security within Kenya. In 2020, around 3.1 million people in the country faced acute food insecurity as a result of extreme climate. There has been a concentration of research on major crops, such as maize and

common bean. This study, therefore, seeks to contribute to the research gap in future projections of crop suitability for major and minor crops in Kenya. Temperature and rainfall data, downloaded from CORDEX, under the Representative Concentration Pathways (RCP) 8.5 and 4.5 were used to run the Ecocrop model. The output was the suitability index spatially plotted over the country for maize, finger millet, common bean, broad bean and sweet potato, within three time periods: historical (1980-2009), near term (2010- 2039) and mid-century (2040-2060). To further understand the influence soil pH has on the climate suitability of these five crops, QGIS was used to overlap Ecocrop suitability outputs and Soilgrids soil pH raster's. Along the RCP4.5 pathways, there is a greater increase in suitability for maize in counties along the coast and western Kenya. Results also project a significant suitability increase (50%) of the orphan crop- broad bean- during the dry season. The spatial distribution of suitability is widespread within many arid and semi-arid counties. This presents an opportunity to integrate legumes such as broad bean into the cropping system within a crop rotation with maize. Soil pH mapping results indicated the dominance climate has on determining overall suitability. For instance, pH suitability of finger millet was achieved in majority of the counties however, climate suitability does not favour the planting of this crop.

2.6 Climate change impact on water availability in the olifants catchment (South Africa) with potential adaptation strategies

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Increasing population and economic growth has intensified water supply pressure on the Olifants River Basin causing it to become water-stressed. Climate change is expected to aggravate existing water supply challenges in the basin if urgent interventions are not implemented. This study evaluates the impacts of climate change on water availability and demand in the Olifants River Basin of South Africa, and assesses to what extent a combination of management strategies can mitigate current and longer-term impacts using the Water Evaluation and Planning (WEAP) model. The results demonstrated by the two projected climate change scenarios (RCP4.5 and RCP8.5) showed a rise in temperature of approximately 1 ◦C–4 ◦C, and a decrease in precipitation of 5%–30%, as compared to the baseline climate of 1976–2005. Results also showed that pressure on water supply due to increased economic activities and a decline in streamflow will increase unmet water demand by 58% and 80% for the mid and end century periods respectively. Results further revealed that the combination of management measures proposed by decision makers is expected to decrease future unmet water demand from 1006MCM to 398MCM, 1205MCM to 872MCM and 1251MCM to 940MCM for reference, RCP4.5 and RCP 8.5 scenario respectively. The study therefore concludes that the combination of management strategies provides a much better and more efficient solution to water scarcity issues in the basin, compared to a reliance on a single strategy.

2.7 Assessment of smallholder crop farmers' awareness, use, and impact of climate services on household food security in Elundini local municipality, South Africa

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In South Africa, there is mounting concern over the negative impacts of climate change and variability on agricultural production, consequently food security and livelihood (Olabanji et al., 2021). Smallholder crop farming systems are at the forefront of the impacts of climate change, given that they are predominantly rain-fed and characterized by high climate exposure sensitivity. Therefore, as opinioned by Buckland& Campbell (2021), smallholder farmers' future well-being is tightly connected

to their capacity to innovate and adapt to unfamiliar climate conditions. Among other adaptation strategies that could be used by smallholder farmers to respond to the impacts of climate change, climate services are increasingly seen as an important tool for adaptation (Hansen et al., 2019) and for improving smallholder farmers' food security (World Meteorological Organization, 2016). However, studies such as Coulibaly et al. (2017): Krell et al. (2020) done elsewhere in Africa, have observed that there is low awareness, accessibility, and usage of climate services among smallholder crop farmers compared to commercial farmers (Kusunose& Mahmood, 2016). Furthermore, it is still unclear whether the benefits offered by climate services are observable on smallholder farmers or not. Hence, the current study is aimed at assessing the smallholder crop farmers awareness, access, use of climate services. The study also aimed at quantifying the impact of climate services on household food security in the study area. This is not only aimed at filling research gaps but also aimed at improving smallholder farmers knowledge, skills, understanding, access, and adoption of climate services. To achieve the aim the study will engage with 370 smallholder crop farmers from the municipality using a multistage sampling procedure. The study will be largely depending on primary data collected directly from farmers using structured questionnaires and face to face interviews. Data collection process is expected to take 3 weeks from first week of February 2022. The collected that will be analyzed using a descriptive statistics and econometric models.

Session 3: Dynamic Meteorology and Observations

Chair: Michael Barnes

3.1 The Characteristics of Long-lived Summer Rossby Wave Breaking Events in the South African Domain

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This study examines the characteristics of summer RWB events that propagate through the South African domain. To do this, RWB was identified on five isentropic levels (320K to 360K, Δ = 10K) and multiple potential vorticity (PV) contours using 42-years' worth of ERA5 PV data. Following this, geographical centres of RWB events that occur in summer and propagate through the South African domain were used as the basis for composite analysis. The compositing was applied on the PV, mean sea-level pressure (MSLP), zonal wind, and anomalies of both the MSLP and meridional wind. Analysis reveals that most of the RWB events that meet this criterion occur on the higher isentropic surfaces (i.e., 340K to 360K). This can be attributed to the upward shift of the dynamical tropopause during the summer months. Composite analysis indicates that these RWB events are associated with amplifying baroclinic waves originating upstream of the RWB centre. Furthermore, it is shown that these RWB events are associated with a jet streak that behaves the same way as when cut-off lows develop in the region. The difference between these jet streaks is that for the RWB events a 'split jet' is not observed. At the surface, these RWB events are associated with ridging highs. However, this behaviour is only found for the 330K to 350K isentropic surfaces.

3.2 The interaction of equatorial Rossby waves with a western boundary barrier: A numerical investigation

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A linear shallow-water is used to study the propagation of westward propagating equatorial Rossby waves through one or more gaps in a western boundary. The numerical and theoretical investigation show that when at least one gap is centered around a deformation radius of the equator, energy flux is reflected into eastward-propagating equatorial Kelvin waves. The efficacy of this process to play an integral role in sustaining low-frequency El Nino oscillations in the equatorial Pacific Ocean is determined by the efficiency with which incident waves reflect energy into Kelvin waves. We investigate further propagation properties.

3.3 Investigating Rossby Wave packets over South Africa

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Rossby Waves are known and appreciated for their significant role in the atmospheric general circulation, as well as their role in the formation of weather systems. Central to this study are a specific type of Rossby waves, known as Rossby wave packets (RWPs). These are Rossby waves that are characterized by a finite number of trough-ridge systems associated with a local maximum amplitude, and undulations progressively decaying in the zonal direction. Their importance lies in their dispersion of energy between local undulations, effectively giving rise to new trough-ridge systems in previously undisturbed areas, a process known as downstream development. Furthermore, several studies have established the link between RWPs and high impact weather, as well as the potential implication on its predictability. In light of the above, this study sought to diagnose the key characteristics of RWPs in the South African (SA) domain through the use of a local finite amplitude wave-activity (FAWA) diagnostic. Of particular interest, are those RWPs that mature and decay over the region of interest and associated subdomains. Results highlight the following features of RWPs over SA: their general characteristics and associated climatology, energetics associated with downstream baroclinic development, relationship with the southern hemisphere wave guides, and their potential association with weather phenomena over SA.

3.4 Magnetohydrodynamic Rossby waves in the tachocline

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A review of the existing literature on solar MHD Rossby waves observed in the solar tachocline show that they are linked to solar seasons and are responsible for space weather predictions. We describe the propagation of these waves from the solar tachocline through to the surface of the Sun as well as investigate how the results will impact or improve current space weather prediction models.

3.5 Two types of ridging South Atlantic Ocean anticyclones over South Africa and the associated dynamical processes

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In this study, two types of ridging high pressure systems have been identified and characterised. Type-N ridging highs generally occur north of the 40°S latitude line and have a more zonal structure as. The anticyclonic circulation of leading edge of the ridging process, that eventually breaks off to be amalgamated with the Indian Ocean high pressure system is weaker than the circulation it leaves behind in the South Atlantic Ocean. Type-S events extend across the South African domain in a less zonal fashion compared to Type-N ridging events, with the anticyclonic circulation of the ridging component much stronger than its Type-N counterpart. Therefore Type-S events are characterised by a much weaker parent anticyclonic circulation in the South Atlantic Ocean, once the ridging process has matured and completed. In the upper levels, Type-N (Type-S) events are associated with a double (single) jet streak structure that is embedded in propagating baroclinic waves. The vertical coupling in the Type-S baroclinic wave is stronger than in the Type-N case. The waves are characterised by three energy centres, referred to as energy centre I, II, and III. Energy centres II and II (in particular the latter) grows from baroclinic conversion. Energy centre III grows from downstream development, which is facilitated by the subgeostrophic flow across the trough axis. This is different from that is observed for cur-off lows, where downstream development occurs across the ridge axis.

3.6 Variability of Total Column Ozone over China

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Using 14 years data from 2005 to 2018, we have used total column ozone data (TCO), ultraviolet index (UVI) and temperature to investigate the possible link between depletion of TCO and increase in solar UV index levels over Xianghe, Waliguan, Linan and Kunming in China. The monthly, seasonal and annual variations of TCO, UVI and temperature were analyzed. The TCO and Solar UVI displayed opposite monthly variation over Xianghe and Waliguan. For the monthly averages, maximum TCO values were observed from January to April and minimum from July to October for the two locations. Our monthly variations over the four locations showed the maximum TCO to be occurring in late winter to early spring, and the TCO maximum values to be increasing across from Kunming in low latitudes through Linan, Walignan to Xianghe in the high latitude. Ozone is transported from equatorial to polar latitudes in the winter hemisphere due to the temperature difference. This leads to ozone column depletion in the equatorial latitudes and a corresponding accumulation in the high latitudes in late winter to early spring.

3.7 Spatio-temporal characterisation of particulate matter plumes using weather radar observations

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South Africa face unique air quality problems. Dense low-income settlements are major areas of concern and increasing concentrations of harmful pollutants exacerbate the adverse health impacts. While the transport, fate and sources of major criteria pollutants are well documented in literature,

large uncertainties about the spatial and temporal characteristics of particulate matter plumes and their impacts on air quality monitoring and management still exist. Current management approaches depend on spatially limited ambient monitoring networks to provide measurements about the state of the air. However, the air quality of dense low-income settlements is impacted by pollution from different areas and sources other than in the immediate vicinity. Understanding the spatial and temporal characteristics of particulate matter plumes and the impacts thereof on air quality in dense low-income settlements is therefore critically important. This study employed a novel approach to characterise the spatial and temporal characteristics of particulate matter plumes using weather radar observations. High-resolution historical radar data from the S-band Irene weather radar was used to identify significant particulate matter plumes from critical sources. Ground-based and remote sensing data for several dense, low-income settlements on the South African Highveld is evaluated to determine the impact of particulate plumes on air quality. Integrating weather radar observations will assist air quality management and mitigation measures to account for the impact of spatial and temporal variability in particulate matter concentrations. Weather radar observations of plumes also provide an additional use of the already indispensable tool. Furthermore, weather radar observations of plumes also serve to validate satellite products and refine the integration of aerosol properties in numerical weather models.

3.8 Gravity wave refraction: Cause and consequence

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Without gravity waves (GWs) the atmospheric circulations as we know them cannot exist. Gravity waves help drive stratospheric and mesospheric circulations and act to slow down the stratospheric polar vortex. These affect surface weather over timescales from a few weeks to years. Gravity waves affect the circulations and mean flow by taking GW momentum flux from one location to deposit at another, altering the wind. A GW absorbs or deposit momentum fluxduring formation, dissipation and refraction. In an attempt to gain an improved understanding of the propagation and dissipation of GWs the SouthTRAC campaign was composed. This study uses observational data from this campaign collected by the German research aircraft in September and November 2019. During the campaign the minor sudden stratospheric warming occurred, heavily influencing GW propagation and refraction. Observations include measurements from the troposphere collected using GLORIA (Gimballed Limb Observer for Radiance Imaging of the Atmosphere) and the stratosphere collected with ALIMA (Airborne Lidar for the Middle Atmosphere). In this case study, the effect of refraction is identified and explained during this abnormal sudden stratospheric warming. Refraction is identified in two different GW packets as low as ~4km and as high as 58km from both orographic and non-orographic origin. Supplementing the observations is GROGRAT (Gravity-wave Regional Or Global Ray Tracer), a simplistic mountain wave model, ERA5 data, high-resolution (3km) WRF data and satellite imagery. Contrary to previous low-resolution model studies (like Hasha et al., 2008) we find that refraction indeed makes a noteworthy contribution in the amount and the location of GW momentum flux deposition.

3.9 An unusual 2020/21 summer over southern Africa

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Southern Africa is vulnerable to the occurrence of Pacific El Niño and La Niña events which impact on the atmospheric circulation, summer rainfall and surface air temperatures. The most severe droughts have occurred during El Niño, whilst La Niña tends to favour above normal seasonal rainfall. This study focuses on the anomalous 2020/21 La Niña summer rainfall season over the subcontinent. NOAA Pacific sea-surface temperature and circulation anomalies from the ERA5 reanalyses were analysed to determine impact on rainfall characteristics, including temporal distribution and anomalies from long-term means. Results show that large areas extending from 15-25°S, between 20 and 45°E (including the Mozambique Channel) experienced above average seasonal rainfall. Angola and the Indian Ocean east of Madagascar were anomalously dry. An interesting finding was that temporally; some areas did not experience the traditional mid-summer dry spell (drought). Several tropical cyclones made landfall including TC Guambe that returned to the Mozambique Channel and intensified; and TC Jobo that went far north near Tanzania. Despite La Niña, Indian sea temperature anomalies also contributed to anomalous circulation, rainfall and tropical cyclone activity. The study also found that cyclones caused several fatalities but the high rainfall and soil moisture resulted in bumper maize harvests over the wet region, with very green and dense savanna grasslands for livestock and wildlife.

Session 4: Science communication, Air Quality and Pollution

Chair: Anzel de Lange

4.1 Atmospheric Science and Renewable Energy

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The aim of this abstract, and our presentation, is to introduce the atmospheric science related research conducted by Stellenbosch University's Centre for Renewable and Sustainable Energy Studies (CRSES) to the SASAS audience. CRSES's research interests largely focus on South Africa's energy transition from coal towards renewable energy, particularly solar PV and wind. Indeed, based on South Africa's national energy policy, the IRP 2019, a very significant increase in renewable energy is anticipated by 2030. The overarching problem associated with the proliferation of variable renewable energy (VRE) onto power systems lies in the variability of electricity produced by VRE sources. A variable power source causes numerous power system challenges, including adequacy of reserve requirements, load-demand balancing, system stability and adequacy of network infrastructure. Wind and solar resource variability is greatly impacted by the weather. Thereby, to ensure security of electricity supply on a 'greener' network, the development of a mature understanding of the relationship between the South African climate and its VRE resources, along with the ability to forecast these resources, is necessary. Accordingly, several research projects are currently being conducted through CRSES. From a long-term network planning perspective, projects include determining the optimal siting of VRE generators based on the complementarity of wind and solar profiles; assessing the impact of climate change on VRE potential; and the representation of weather systems in power flow studies. From a short-term network operations perspective projects include short-term wind and solar resource prediction; and quantification of VRE variability resulting from large-scale atmospheric circulation.

4.2 Source apportionment for PM2.5 and trace elements for 2017 - 2020, Pretoria.

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Positive matrix factorisation model (PMF) was run three times for three (5, 6 and 7) factor configurations for a 2017-2020 dataset. The input variables including the seed number remained the same for each run. A bootstrap, displacement and a bootstrap with displacement is performed for each run. The 7-factor source contribution is assigned to the 2017-2020 dataset with Resuspended dust matrix (7%), Biomass/coal burning (1.1%), Exhaust (49%), Refined oil (13.5%), Secondary sulphur (14%), Coal burning (5.1%) and Vehicular emissions (10%) contributing to the total annual PM2.5 concentration. As discussed in chapter 3, the transport analysis of the total PM2.5 is performed using the Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT) which produced four main transport clusters for this period. The four-cluster transport configuration demonstrates a scene where 42% of the wind trajectories are from the westerly direction (W). The remaining three main clusters are from the easterly direction, 29% from the north easterly (NE), 15% from the south easterly (SE) and 14% from the long-range Indian Ocean (LRIO) direction.

4.3 Time Series Analysis and Forecasting of Temporal Trends of Atmospheric Mercury in Svalbard, Mace Head and Cape Point: A Machine Learning Approach

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Mercury (Hg) is a tenacious toxic element that bio-accumulates in our environment and is harmful to both humans and animals. Mercury is known to be released into the environment by natural processes and by anthropogenic activities, cycles between the atmosphere, water, and land reservoirs. Major anthropogenic sources include coal burning, gold mining, base metal smelting, and cement manufacturing. And, natural sources include volcanic eruption, rock weathering, windblown dust, vegetation, soils, and the ocean. Continuous monitoring of concentrations of mercury in our atmosphere is essential. Thus, the aim of this study is to perform an in-depth time series analysis of atmospheric mercury measured at Svalbard (77.87°N, 20.97°E), Mace Head (53.32°N, 9.90°W) and Cape Point (34.35°S, 18.49°E) and also to forecast the time series of Mercury using hybrid deep learning neural networks models. A hemispheric comparison of variability and trends of the Hg time series is performed. Hybrid data-driven forecasting models, based on long short-term memory networks (LSTM) recurrent neural networks (RNNs), are developed and applied to Mercury data. These models are robust data-driven hybrid time series-forecasting models that are based on signal decomposition techniques such as Ensemble Empirical Mode Decomposition (EEMD), and Empirical Wavelet Transforms (EWT). In order to compare the modelled data to the ground truth, the Mercury data is divided into 70% training time series and 30% testing time series. There is a significant positive trend of 0.74% per year of the Cape Point Hg concentration while the Northern Hemisphere sites indicate a downwards trend of approximately -0.50% per year for both Svalbard and Mace Head, respectively. In general, the results highlight that the EWT-LSTM model outperforms the other models in terms of accuracy and error reduction in all the study sites. Decomposition seems to enhance the performance of the model when compared to using the LSTM model as a standalone.

4.4 Investigation of the spatio-temporal variation of stratocumulus cloud fraction in association with AOD over the Benguela region

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This study considers the Aerosol Optical Depth (AOD) and cloud fraction, simulated by CCAM-CABLE, over the Benguela region. The seasonal spatial patterns of maximum simulated AOD are discussed in connection with the cloud fraction. Consistent with previous observation-based studies, CCAM outputs reflect that AOD has its peak in spring. The peak is explainable by the fire activity prevalence during the season in the southern Africa. The model outputs also suggests that low-level clouds are present across all seasons. There are differences in the spatial correlation between AOD and cloud fraction across the domain. To explore this variability two sub-domains were analysed (one in the northern region of the modelling domain and one in the southern region). The is a direct relationship between the parameters at the northern region because when AOD increases, so does the cloud fraction. Also, the concentrations between the two variables are within the same range. The northern region of the studied domain shows a weak positive correlation between AOD and cloud fraction in summer (R= 0.37), autumn (R= 0.31) and winter (R= 0.35), with no correlation seen in the spring (R= 0.007). The cloud fraction has higher concentrations compared to AOD in the southern region. The highest cloud fraction is found mostly in winter, followed by summer. In the southern region of the domain, there is a weak positive correlation in summer only (R= 0.34) and a weak negative correlation for winter (R= -0.54), autumn (R= -0.24), and spring (R = -0.43).

4.5 Health Risk Assessment of PM2.5 and PM2.5-bound trace elements in Pretoria, South Africa

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The objective of the present study is to assess the human health risks associated with fine particulate matter (<PM2.5) and six of the trace elemental constituents in Pretoria, South Africa. Outdoor ambient PM2.5 was sampled at the School of Health Systems and Public Health from April 2017 to March 2020. The total PM2.5 and the trace elements were processed and quantified using the Quantitative X-ray Analysis System (QXAS) and the Analysis of X-ray spectra by Iterative Least-square fitting (AXIL) at the University of Göteborg, Sweden. Positive matrix factorization and HYSPLIT is modelled to determine the potential sources of emissions as well as the transport mechanism on a seasonal basis. The health risk assessment method followed the United States Environmental Protection Agency's (US EPA) health risk assessment method. Reference doses for PM2.5 are taken from the World Health Organization (WHO) guidelines and the South African National Ambient Air Quality Standards (NAAQS). The average annual PM2.5 concentration was 21.1 ng/m3 (observation = 122), 21.6 ng/m3 (observation = 124) and 27.1 ng/m3 (observation = 105) respectively, which are above the annual WHO guidelines, but below South African NAAQS. The autumn and winter months are higher than the spring and summer months. The calculated (Health Quotient) HQ for Adults, Children and Infants are annually above the guideline and the standard for PM2.5 and demonstrate seasonal variability. Adults are consistently three times higher at risk in autumn and winter than in spring for PM2.5. Children and Infants are three times higher at risk than adults throughout the year for summer and in winter for K and Si. Particle-bound nickel posed both non-cancer and cancer risks throughout the year. Seasonal temperature and humidity thus demonstrated an influence on PM2.5 and trace concentrations which in turn influenced the HQ value. It can be concluded that PM2.5 poses health risks in central Pretoria and cognizance of the seasonal nature of PM2.5 and the trace elements patterns should be considered for public health management.

Session 5: Extreme weather and Seasonal to sub seasonal forecasting

Chair: Lesetja Lekolane

5.1 Developing a realtime tropical-extratropical cloud band monitor for the Southern Hemisphere

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Tropical-extratropical cloudbands have long been known as a fundamental feature of the subtropics in the Southern Hemisphere. Known as TTTs over southern Africa; SACZ events over South America; and Northwest cloudbands over Australia, these weather systems are crucial to regional rainfall climatologies and are often associated with daily extremes. In this paper, we present satellite-era changes in the likelihood of these cloud bands, noting substantial declines in early season events across the Southern Hemisphere. To better diagnose these events season-by-season, the development of a near-realtime cloudband monitor is presented. We are particularly interested in how best to adapt this monitor to the needs of the southern African research and forecast community and look forward to engagement on this question.

5.2 Skill of the multi-model seasonal forecasting system at SAWS

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Operational seasonal forecasts at the South African Weather Service are generated once a month for lead times of one to three months using a multi-model ensemble system. The models used are the CCSM4, GFDL-SPEAR and the SAWS coupled model (SCM). Model output is combined after a calibration process that follows after processing the model output to a common horizontal grid. For the calibration process, hindcasts for each model used in the multi-model ensemble system are needed. The hindcast period for the three models used here are different in length, but the common period is from 1992 to 2009. The calibration process for each ensemble member involves a normalization procedure relative to the ensemble mean and the three models used in this specific forecast system. Probability forecasts are then derived for three equi-probable categories from each individual model, before an equal weight averaging is used to produce the multi-model seasonal forecasts. In this talk, the rainfall skill assessment of the multi-model system is presented for the southern African region for lead 1 to 3 forecasts, initialized from January to December. CHIRPS rainfall data were used as the observational data in this assessment.

5.3 Innovative, Tailored Seasonal Forecasting for Farming Systems in Namibia

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Namibia is rich with natural resources such as land and water. These resources play an important role in agriculture. The agricultural sector, in Namibia, plays an important role in socio-economic development, contributing between 3-5% to the GDP. Seasonal Climate Forecasts (SCF) have been developed for the prediction of seasonal- to-interannual variability of rainfall and surface temperatures. Previous research has established the existence of seasonal rainfall and temperature forecast skill over parts of the southern African region. Seasonal forecasts can, if properly used, guide farmers with regards to decision making. The aim of this study is to create useful, tailored seasonal rainfall forecasts for two groups of farms within Namibia. The two groups are divided by location with one group falling into the Eastern Omaheke region being in close proximity to Botswana, and the other group falling into central Otjozondjupa, which can be classified as Northern Namibia. Forecasts are made for five seasons, using three different North American Multi-Model Ensemble models (COLA-RSMAS-CCSM4, CM2p1-aer04 and FLOR). The seasons that have been chosen are OND, NDJ, DJF, JFM and FMA since it is evident that the most rainfall over the study area is received for the October-March period. For each season, a one to five month lead time is investigated. The verification results are calculated over an 8-year hindcast period. The hindcasts based on the FLOR and CM2p1-aer04 models outscore the COLA-RSMAS-CCSM4 model. The Farms within Otjozondjupa show better predictability than the farms in Omaheke.

5.4 Exploring fire weather conditions for a Cape Town fire event in 2021

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Ecosystems over the world are affected by fires. Numerous factors may influence the fire regime of an area. These factors can be linked to seasonality, fire intensity, fire frequency, vegetation characteristics, topography, synoptic weather types (SWT), soil moisture availability and land use and land cover change (LULC). Variables of fire weather can include relative humidity, air pressure, wind velocity and ambient temperature. The flammability of vegetation is not only dependent upon the moisture content of plants and dead organic matter but also on the prevailing short-term weather conditions in the days before a fire event occurs. Extraordinarily little is understood about the role of synoptic weather systems in fire size, location, frequency and spread over time. Yet, the characterisation of weather at large spatial scales into SWT can significantly improve our understanding of current, and prediction of future fire events. It is forecast that the western parts of southern Africa will experience an increase in heatwave frequency and in high-fire danger days. In addition, a shift in the rainfall season may occur which could lead to a prolonged dry season thereby increasing the fire risk. This region also includes the Fynbos biome, where recent fire events have caused significant financial losses and loss of historic documents at a prominent higher education institution. Consequently, it is vital to examine the fire weather conditions in the Fynbos biome.

5.5 Severe convective storm characteristics under varied urbanization scenarios

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Using the Weather Research and Forecasting model (WRF) on a convective permitting scale, the paper examines the effects of land-use and cloud condensation nuclei (CCN) modifications on the characteristics of a convective storm event over Johannesburg, Gauteng. In total six scenarios are simulated, in the first three scenarios the explicit effect of CCN changes over the urban area are examined. A low aerosol loading scenario where surface CCN concentration is 300cm3, decreasing exponentially to 50cm3 above 2000m. Secondly, a moderate CCN loading where surface CCN of 1000cm3, decreasing exponentially to 500cm3 above 2000m, and a high CCN loading where surface CCN is 2140cm3, decreasing exponentially to 680cm3 above 2000m. These simulations show that increased CCN concentration results in delayed precipitation and a decrease in simulated hail over the region. The highest accumulated rainfall and hail is simulated in the low aerosol scenario. Following this the paper examines the effect of land-use changes with a constant CCN profile of 300cm3, decreasing exponentially to 50cm3 above 2000m.

Three possible scenarios are examined, first, a polluted city, characteristic of a township, where highly reflective building material increases albedo, but vegetation cover is low. Secondly, a traditional urban heat island (UHI) scenario where albedo is low and vegetation cover low, and lastly a green city scenario with moderate albedo, high vegetation cover similar to that of a mixed forest under the current WRF-MODIS classification. These changes has implications for the initiation, duration and intensity of rainfall and hail over the city. Under a green city scenario, storm initiation is delayed, however, simulated dBZ, accumulated precipitation and accumulated surface hail are the highest compared to the polluted city cases.

5.6 A case study on cumulus parameterization within the gray zone

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Cumulus parameterization, also referred to as cumulus convection schemes, mainly describe and compute physical processes and transports within individual cumulus clouds, and predict the time evolution of how the individual convective clouds collectively influence the large-scale environment. These physical processes and transports include updrafts/downdrafts, entrainment/detrainment, convection trigger, convection intensity and vertical moisture transport.

Convective parameterization must include three main aspects, namely, the trigger function, closure assumptions and the cloud model. Cumulus parameterization schemes may be classified into at least three categories, namely, scale aware, adjustment and mass flux schemes.

This study investigates the effectiveness of different cumulus schemes in predicting a case of severe convection over parts of South Africa using the WRF model. The model simulations were done over the South African domain at 3 km horizontal resolution. Results will be shown in the presentation.

5.7 Detection of extreme weather events over Enkangala escarpment using monthly precipitation series for the period between 1968-2019 and teleconnection with low level circulation model

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We used functional data analysis (FDA) methods are reliable for uncovering extreme events against traditional methods of analysis. In this research, functional data analysis (FDA) tool was used for the purpose of the detection of extreme events in rainfall data of the complex topographic Enkangala escarpment of South Africa for the period between January 1968 to December 2019. The monthly rainfall data was obtained from the South African Weather Service (SWS) from 54 stations covering the study area. The average monthly rainfall data were subjected to functional outlier detection procedures namely the depth density (bagplot) function and the high-density region (boxplot) function using FDA and rainbow packages in R-studio statistical software. The graphs were plotted with rainbow plots. The extreme events were detected using the two methods, but the high-density region functional boxplot proved to be more effective and robust in the detection of the outliers. Four extreme weather events, in the Enkangala escarpment, were detected over the periods 1989-2015, these were in years, 1989, 1996, 2003 and 2015. The seasonal anomalies of geopotential at 850 hPa for the seasonal period (OND, DJF and JFM) of the extreme years was used to validate the pattern of the extreme rainfall distribution. The geopotential positive anomalies of DJF 2015/16 show high-pressure in the Mozambique Channel. This prevents the flow of moist air and the movement of low-pressure systems into eastern southern Africa. This is associated with of drought over the eastern escarpment as result of the offshore flow.