Seasonal forecast skill over the Greater Horn of Africa: a verification atlas of System 4 and SEAS5. Part 2: 2m air temperature.

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ABSTRACT

Presenting part 2 of an atlas of seasonal forecasts verification over the Greater Horn of Africa from System 4 and SEAS5. Results are presented for three-month forecasts of the three major seasons of the region, March-May, July-September and October-December, at all available lead times. Also included is the verification for single month targets of these seasons. Verification of precipitation has been shown in part 1; this document shows results for 2m air temperature. Mean climate, biases and ensemble mean correlations are shown, and the final section contains maps of the Relative Operating Characteristic area under curve, measuring model ability to discriminate events across a range of percentile threshold exceedance events (namely, 10, 20, 25, 33, 50, 67, 75, 80, 90%ile exceedance).

Contents

Acknowledgements

This work was supported by the NERC/DfID project ForPAc: Toward Forecast-based Preparedness Action (funded under the SHEAR programme; see www.forpac.org for more details). Thanks to ECMWF for provision of seasonal hindcast and reanalysis data, and to the Climate Hazards Group of UCSB for provision of the CHIRPS rainfall dataset.

1 Introduction

The Greater Horn of Africa (GHA) experiences rainfall seasons related to the large scale latitudinal movement of the tropical rain belt (note that the concept of the Inter-Tropical Convergence Zone is problematic over Africa and 'tropical rain belt' is seen to be more scientifically accurate Nicholson (2018)). Broadly speaking, there are three main seasons across the region. During March to May (hereafter MAM) the tropical rain belt moves northward and countries including Kenya experience the 'long' rains. As the rain belt reaches its maximum northward extent, Ethiopia, South Sudan and Sudan experience their main rain season, from July to September (hereafter JAS), concurrent with the West African Monsoon. Finally as the belt returns southward the equatorial region experiences a second rainfall season, the 'short' rains occurring from October to December (hereafter OND). Subsequently the rain belt moves to southern Africa before returning in boreal spring of the following year. For a comprehensive review of GHA climate science and predictability, see Nicholson (2017).

The seasonal predictability of these three seasons is considered here. Note that all locations within the GHA will not necessarily experience clear rainfall seasons following this pattern, with variations in timing, length and intensity, related to latitude, proximity to the coast, topography and other local factors. This is even the case within a single country; for instance semi-arid North East Kenya experiences two short seasons, with the long rains starting some time later than 1-Mar, whilst some parts of the wet highlands in the west experience continuous rainfall between the short and long rains, without a distinct 'dry' season between. However for the purposes of sketching out the broad patterns of seasonal predictability over the region, the seasons of MAM, JAS and OND are adequate. For more detail on reader is referred to Dunning et al. (2016), in which the spatial and interannual variability of onset and cessation has been mapped across the entire African continent. In addition MacLeod

(2018) has assessed the ability of the ECMWF extended-range and seasonal prediction systems to provide early warnings of anomalous onset and cessation.

Here, validation of seasonal forecasts of 2m air temperature forecasts is shown for the three seasons of the GHA; both for the current operational seasonal forecast system SEAS5 (operational from November 2017) and its predecessor, System 4 (operational since November 2011). The purpose of this report is to provide an atlas outlining the performance of SEAS5 for GHA and where improvements are seen from System 4. A detailed description of all figures is not provided, beyond a brief summary of key points.

The following short section contains details of the data and methods and a summary of key results. Subsequently the collection of verification maps is provided for 2m air temperature.

2 Data and methods

2.1 Seasonal forecasting systems

System 4 and SEAS5 are evaluated here and there are several differences between the systems. Both use different cycles of the atmosphere IFS model (CY36R4 and CY43R1), representing six years of IFS developments in terms of physics, new Earth system components and initialization methods. Atmospheric resolution is increased, moving from TL255 (80km) to TCo319 (36km). A newer version of the ocean model NEMO is used in SEAS5, at higher resolution than System 4 (moving from 1° to 0.25°). An overview of System 4 is provided in ECMWF technical memorandum number 656 (Molteni et al. (2011)), whilst full details of the differences between the systems are outlined in an article in the ECMWF Winter 2018 newsletter (Stockdale et al. (2018)).

Both systems are initialized once per month and verification metrics here are calculated for both across the hindcast 1981-2017. SEAS5 has a 25 ensemble member hindcast, whilst System 4 has 25 members for the start dates February, May, August and November, with 15 for the rest. All available members are considered for each lead time.

2.2 Reference data and verification methods

2m air temperature forecasts are compared against the ERA-Interim reanalysis Dee et al. (2011). All fields are interpolated to a 1° grid before analysis. In each section maps over GHA are presented showing climatologial mean, bias, ensemble mean correlation and Relative Operating Characteristic Area Under Curve (hereafter ROC AUC). Ensemble mean correlation is calculated using Pearson's correlation coefficient, with 95% significance levels calculated based on a two-tailed t-test. ROC AUC measures the ability of a forecast to discriminate the occurrence or non-occurrence of an event. The events considered here are based the crossing of the percentile thresholds 20%, 33%, 50%, 67% and 80%, with definitions of percentiles calculated pointwise and separately for the model and reference datasets. ROC AUC for these percentiles indicate the forecast system to anticipate a lowest quintile, lower tercile, above/below median, upper tercile and highest quintile season/month. A ROC AUC of 0.5 indicates the system is no better than climatology, whilst 0.9 indicates perfect discrimination. Statistical significance of the ROC AUC depends on both the hindcast length and the frequency of the event under consideration, and 95% significance values have been calculated here by comparison with a Mann-Whitney U test (see Mason and Graham (2002) for details and further discussion of the ROC AUC).

For each metric in turn, results are presented each season in turn, both for three-month seasonal averages (e.g. MAM) but also for individual months (e.g. March). Assessment of predictability characteristics over GHA indicate that the traditional three-month seasons are not necessarily coherent and that more information may be present in individual monthly averages. A consistent figure layout is followed throughout, with upper and lower rows showing System 4 and SEAS5 results. Longest lead forecasts are shown on the far left column (in the case of seasonal average, lead 4-6), with shorter lead forecasts shown in subsequent columns, ending in the shortest, zero lead forecast (lead 0-2) on the far right. In all cases the precise initialization date of the forecast is indicated in the subfigure.

2.3 How to search the atlas

Given the large number of figures, a unique code has been added to each figure in order to quickly navigate. This code is in the format *MetricTarget*. Options for '*Metric*' are:

- Clim (climatology plots)
- Bias (model bias against reference data)
- Corr (ensemble mean correlation)
- ROCxx (ROC AUC, where xx indicates the percentile corresponding to the event: 20, 33, 50, 67, 80 for lowest quintile, lower tercile, above/below median, upper tercile and highest quintle respectively),

and options for '*Target*' are three letter codes referring to either the three-month season or the monthly target (i.e. MAM, JAS, OND, Mar, Apr, May, Jul, Aug, Sep, Oct, Nov, and Dec)

By searching this document for a specific code one can navigate directly to the analysis of interest. For example, searching for ROC20May will navigate to the page containing the plot of ROC AUC of lowest quintile 2m air temperature for May.

3 Summary of results

- Both systems have a cold bias during all seasons, at all lead times (figures 13-15). System 4 has a large bias of over 3K in parts of the region; SEAS5 has an improved bias across all seasons, although still over 1K too cold for most of the region. Notably the cold bias for the long and short rains seasons is largest for the first month (May, October) and reduces throughout the season. The temperature bias for May for instance (figure 18) is under 1K for most of the region. Although the temperature bias for JAS is overall negative, the SEAS5 bias for June is actually positive, increasing from System 4.
- Ensemble mean correlation skill for MAM is limited to zero lead near the equator, with some improvement in SEAS5 for longer lead February forecasts over Uganda (figure 25). Some significant skill over Kenya is possible for both systems during JAS and OND (figures 26-27). Across all seasons, the highest correlations (over 0.6) can be seen over the northern Red Sea coast, even at long four month lead times. For individual month targets, forecasts over Sudan appear to be significantly skillful at long leads for April, with much lower skill for other months. Similarly to precipitation forecasts, December 2m air temperature has significant correlation out to long lead, with improvement shown in SEAS5.
- For MAM, there appears to be asymmetry in the temperature forecasts over Sudan, with lowest quintile showing much higher ROC AUC (over 0.8, figure 37) at long lead (November initialised forecasts) compared to highest quintile (0.6, figure 41). Similarly, cold events appear to be better predicted during JAS, with significant discrimination ability near to the Indian Ocean coastline (figure 42). OND forecast also appear to have high skill for cold events at long lead time in a limited area over Kenya (figure 47, some points show lower quintile ROC AUC as over 0.9, from a June issued OND forecast), with much lower regions of high skill for warm events.

4 Results: 2m air temperature

4.1 Climatology and bias

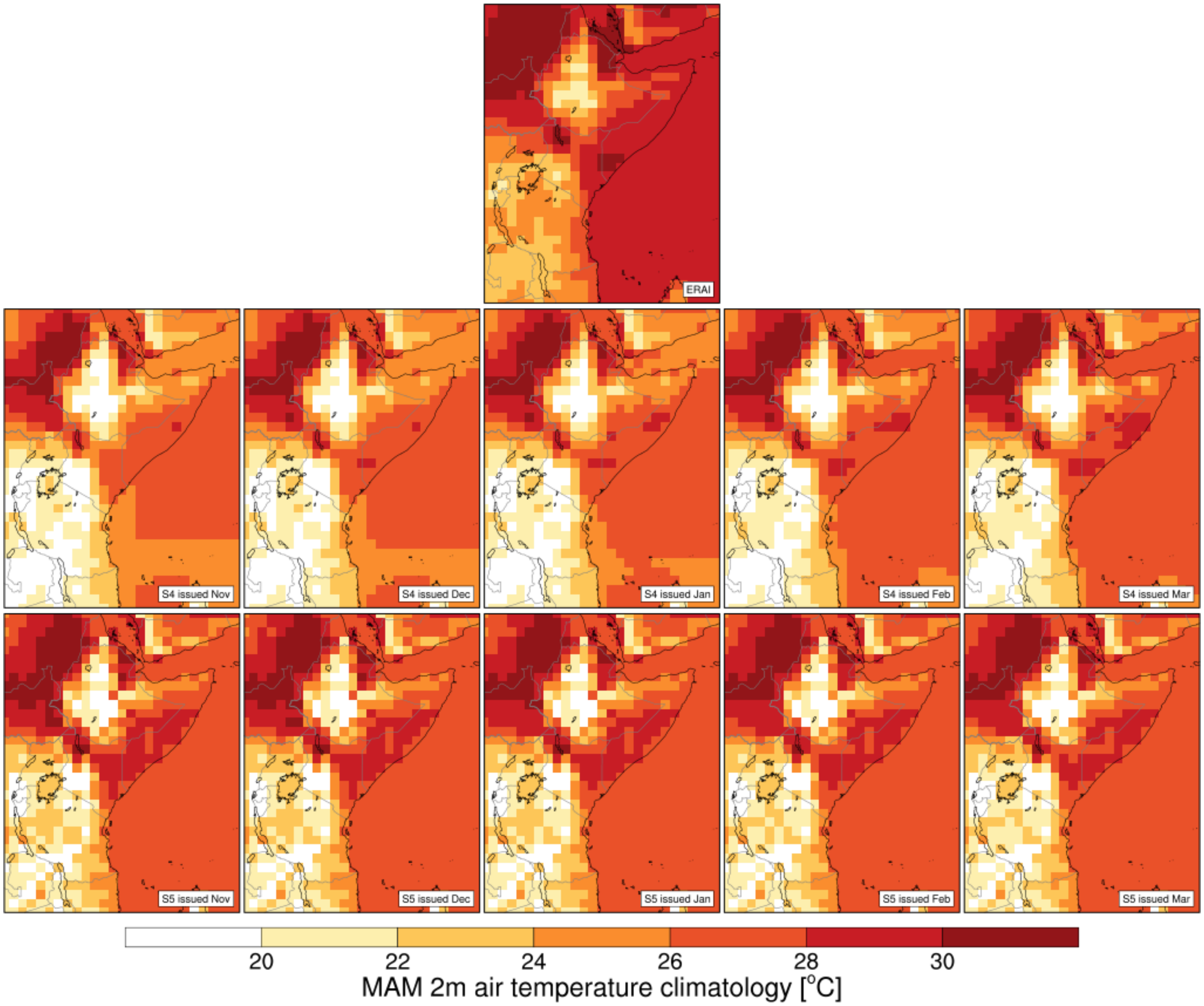

Figure 1. [ClimMAM] 2m temperature climatology for MAM: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

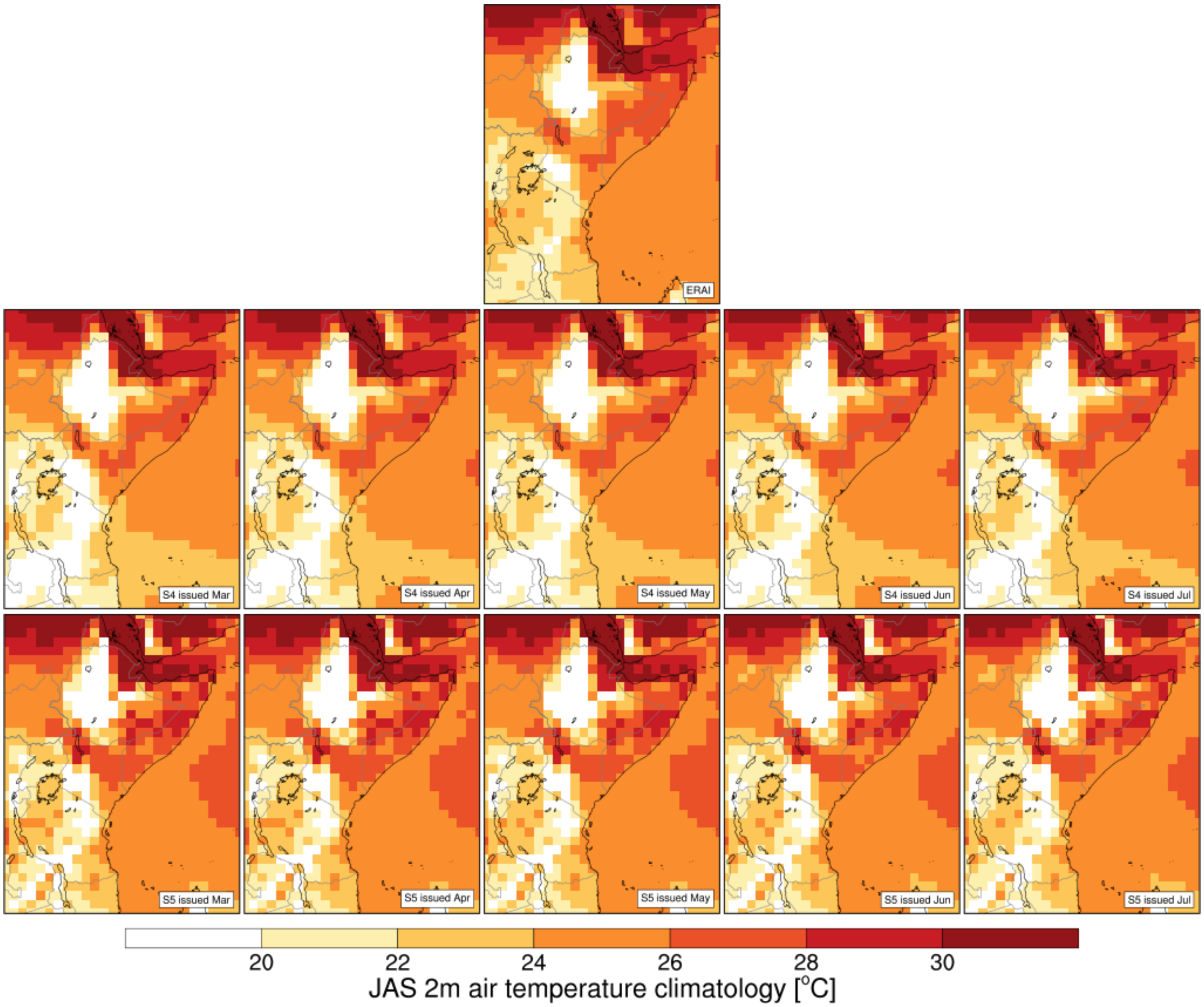

Figure 2. [ClimJAS] 2m temperature climatology for JAS: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

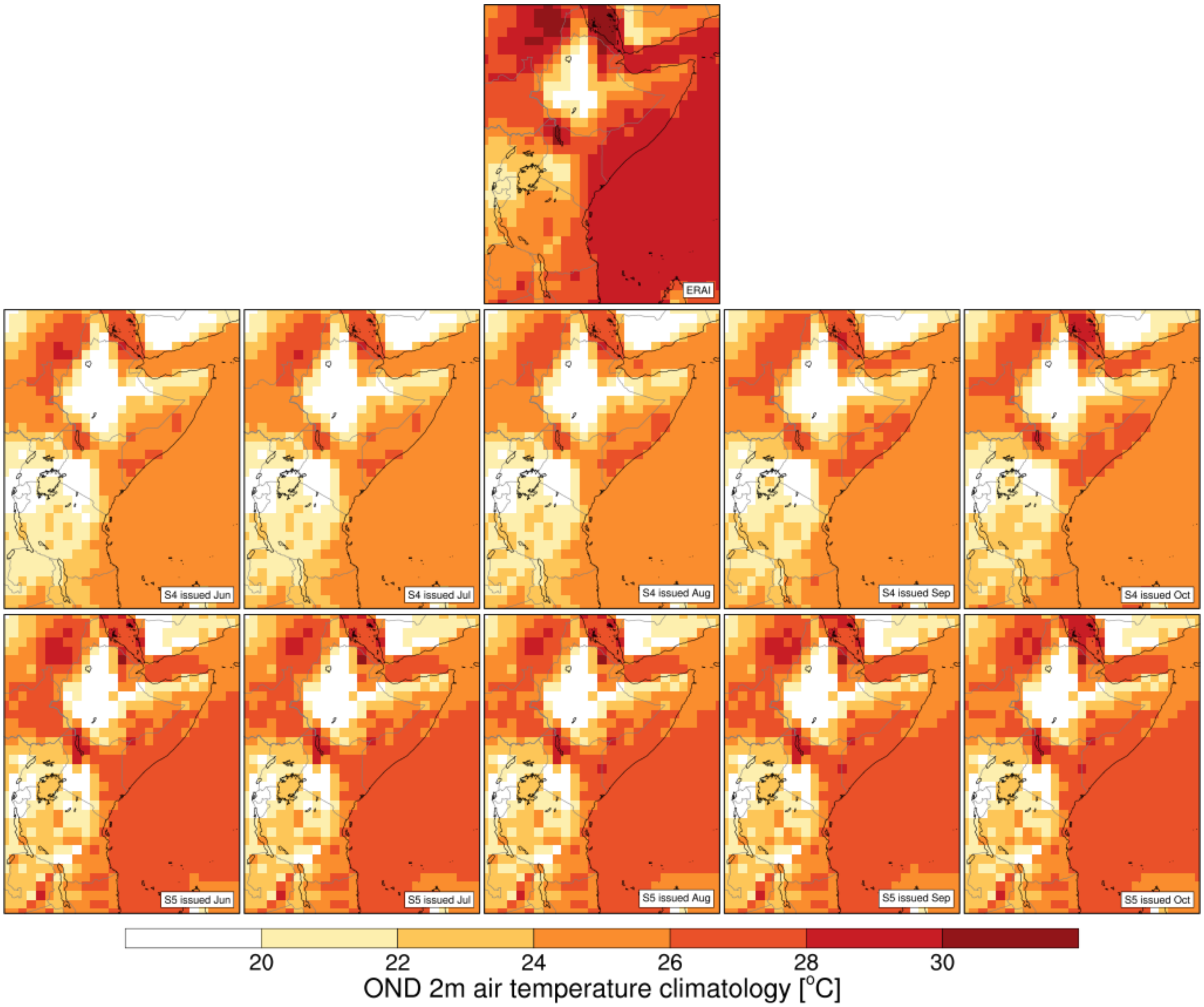

Figure 3. [ClimOND] 2m temperature climatology for OND: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

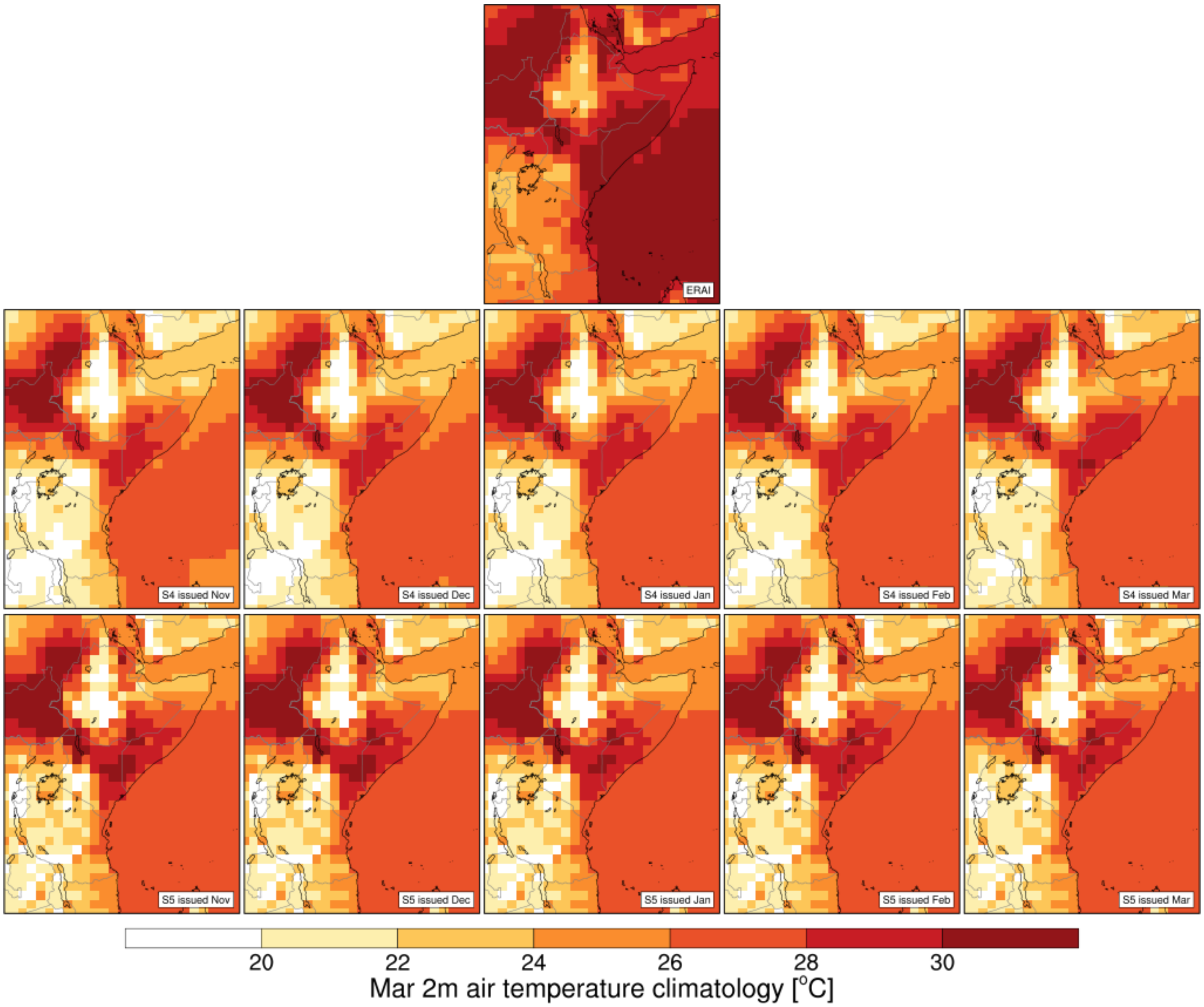

Figure 4. [ClimMar] 2m temperature climatology for Mar: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

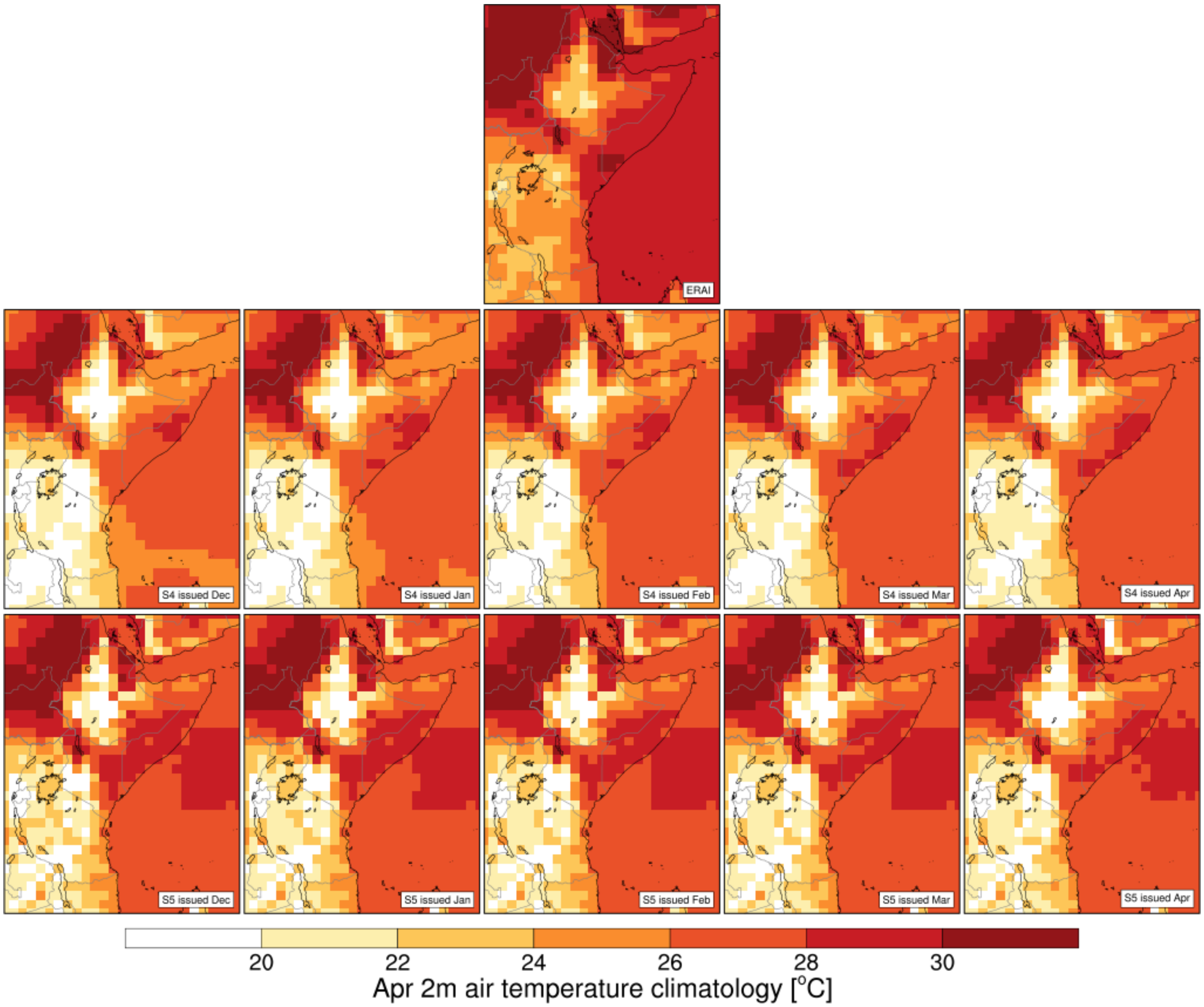

Figure 5. [ClimApr] 2m temperature climatology for Apr: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

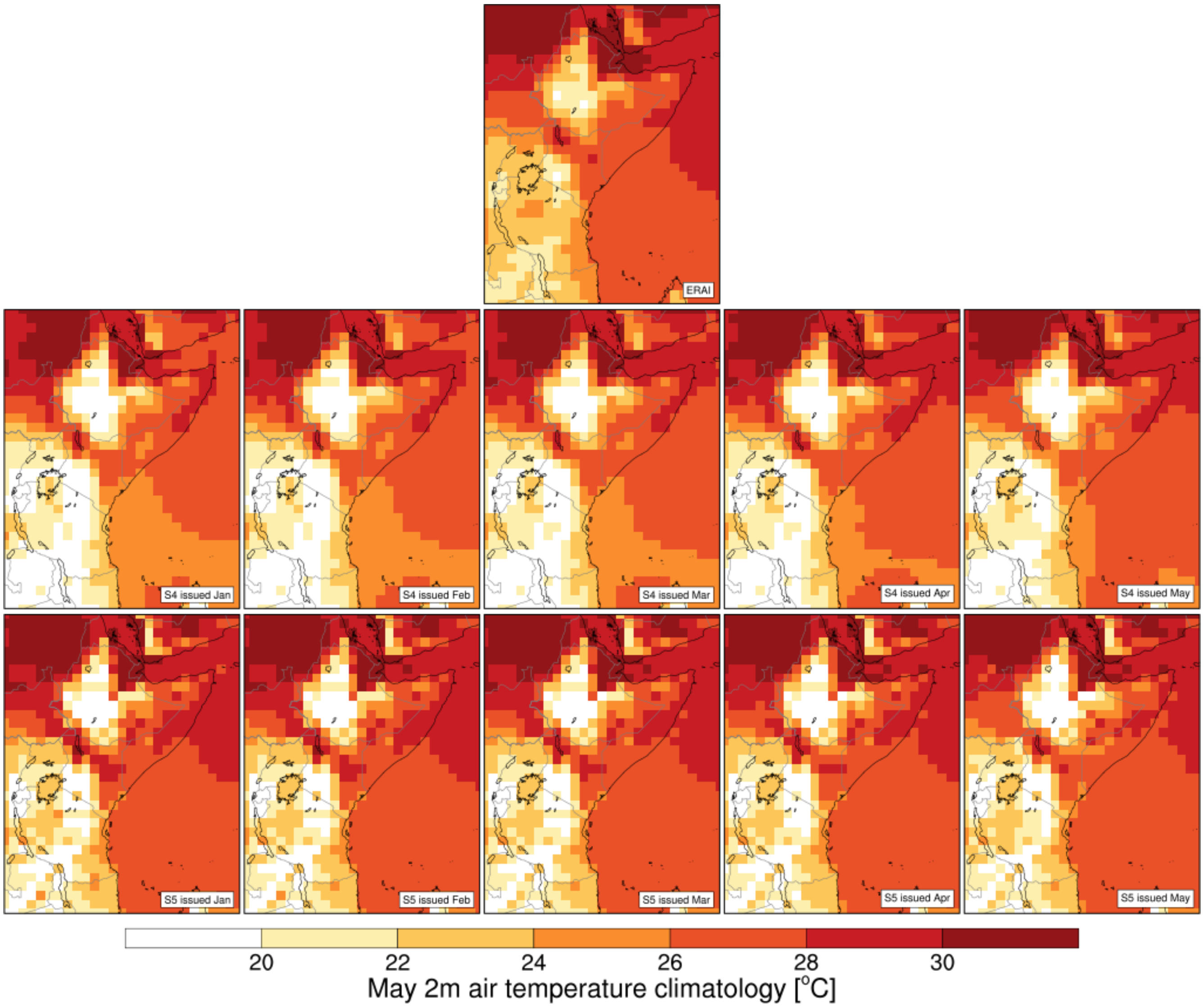

Figure 6. [ClimMay] 2m temperature climatology for May: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

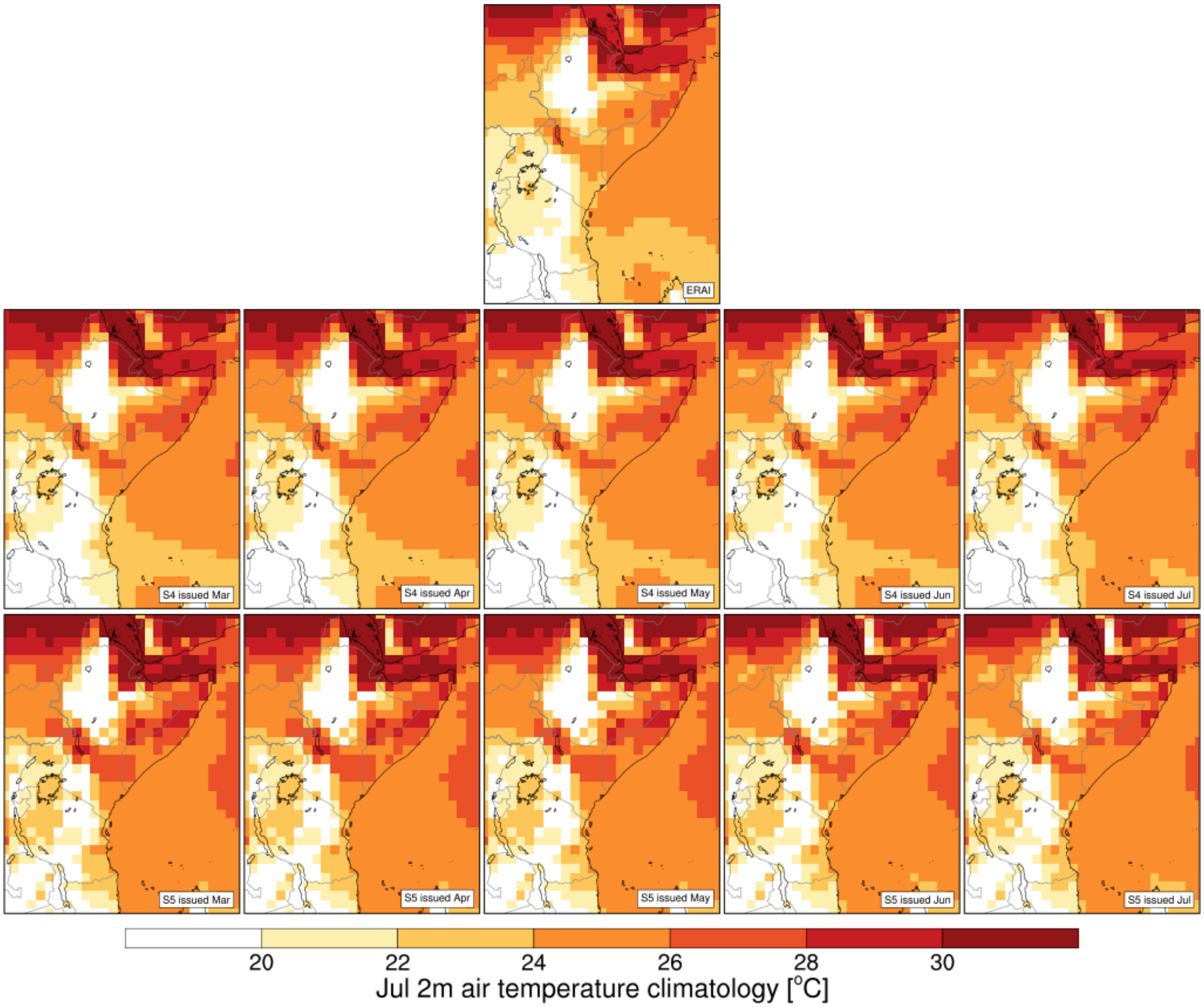

Figure 7. [ClimJul] 2m temperature climatology for Jul: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

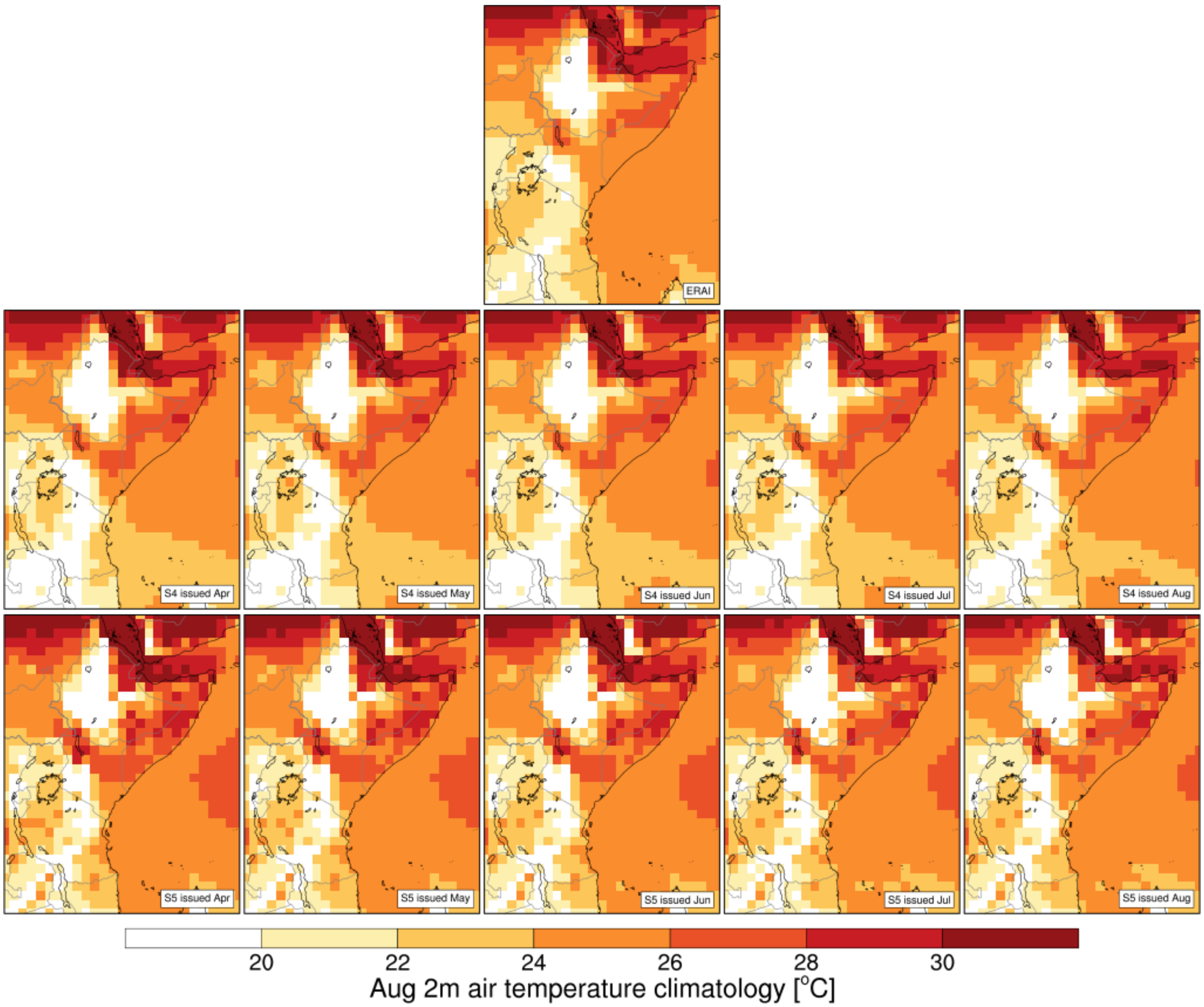

Figure 8. [ClimAug] 2m temperature climatology for Aug: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

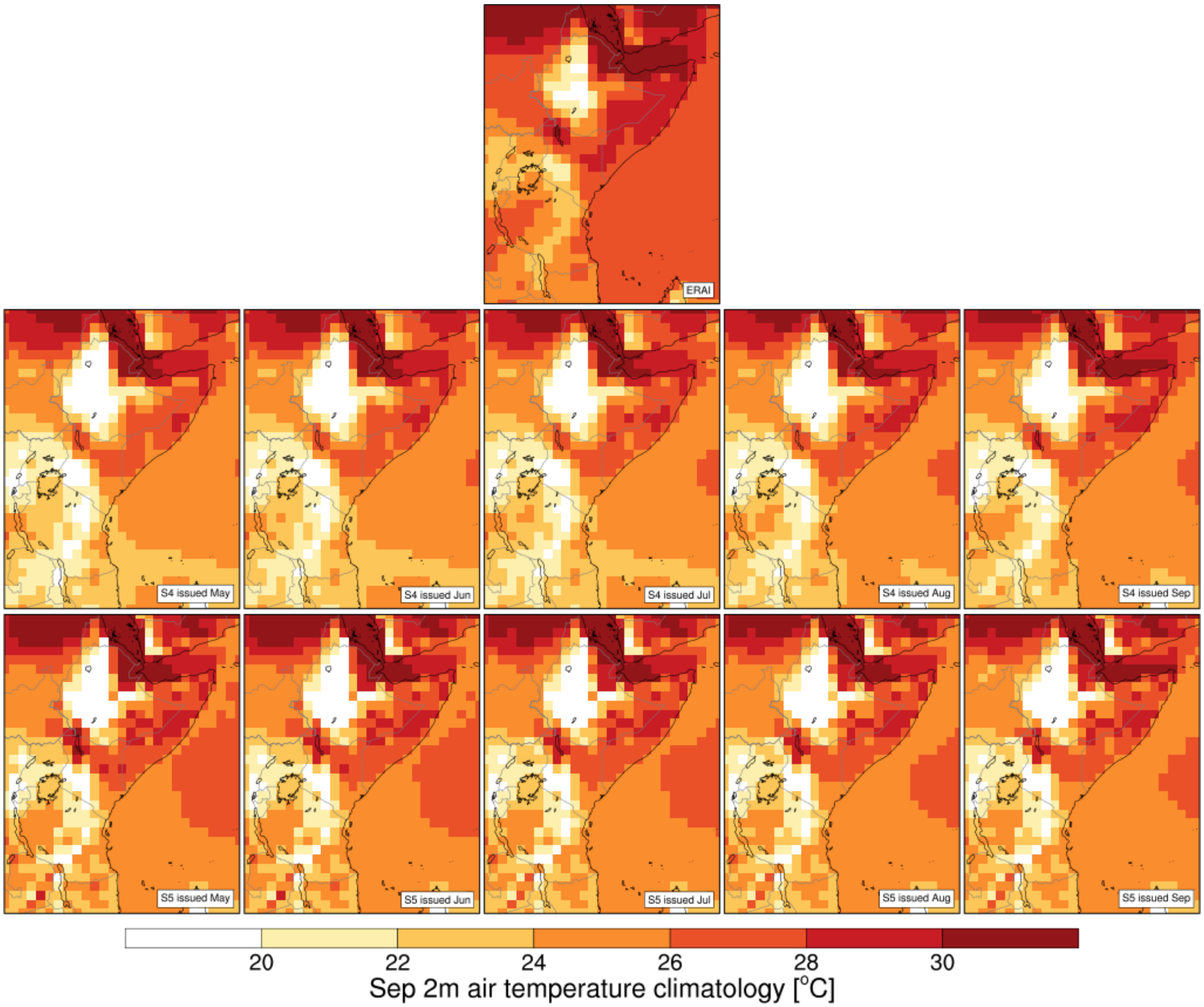

Figure 9. [ClimSep] 2m temperature climatology for Sep: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

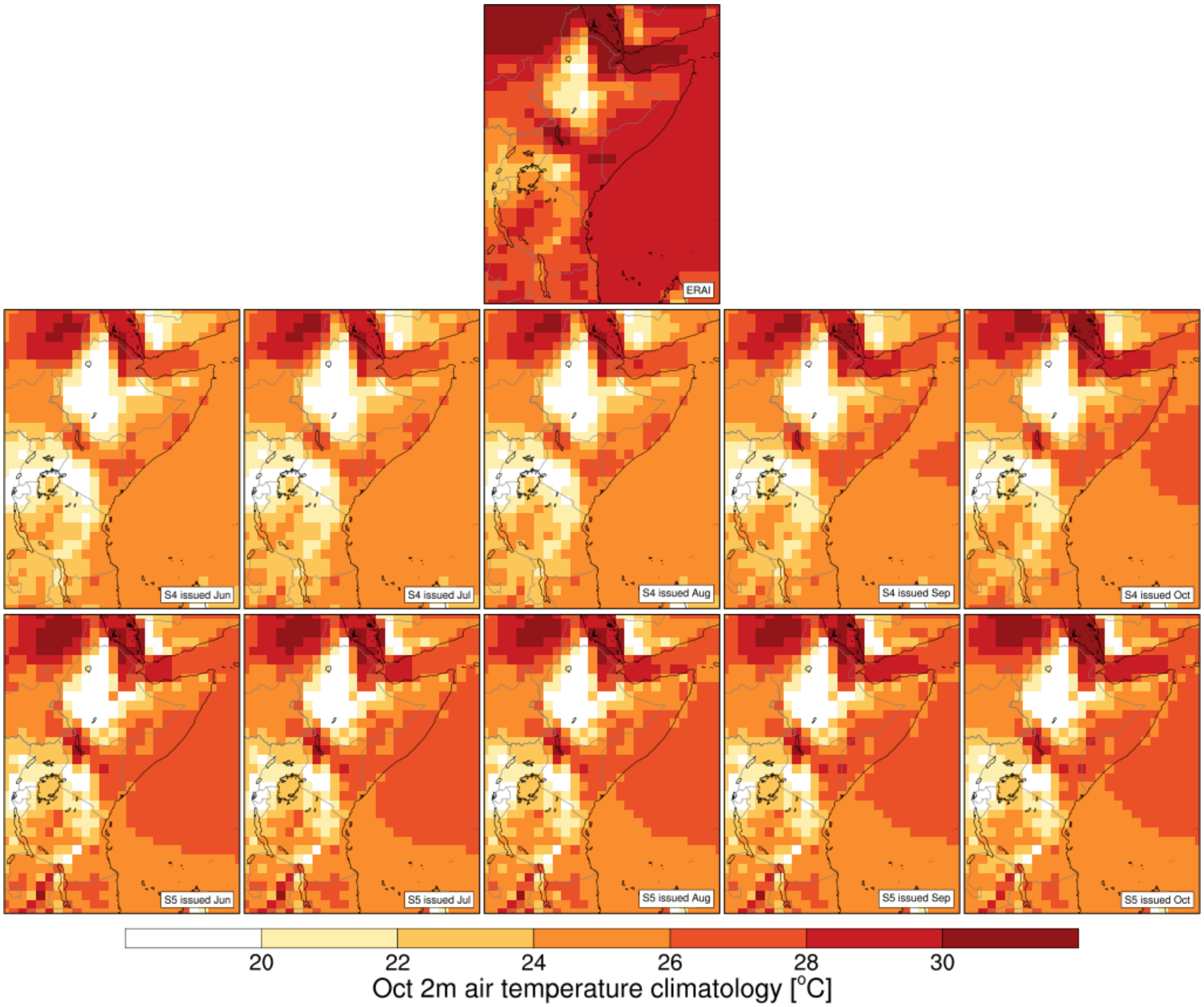

Figure 10. [ClimOct] 2m temperature climatology for Oct: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

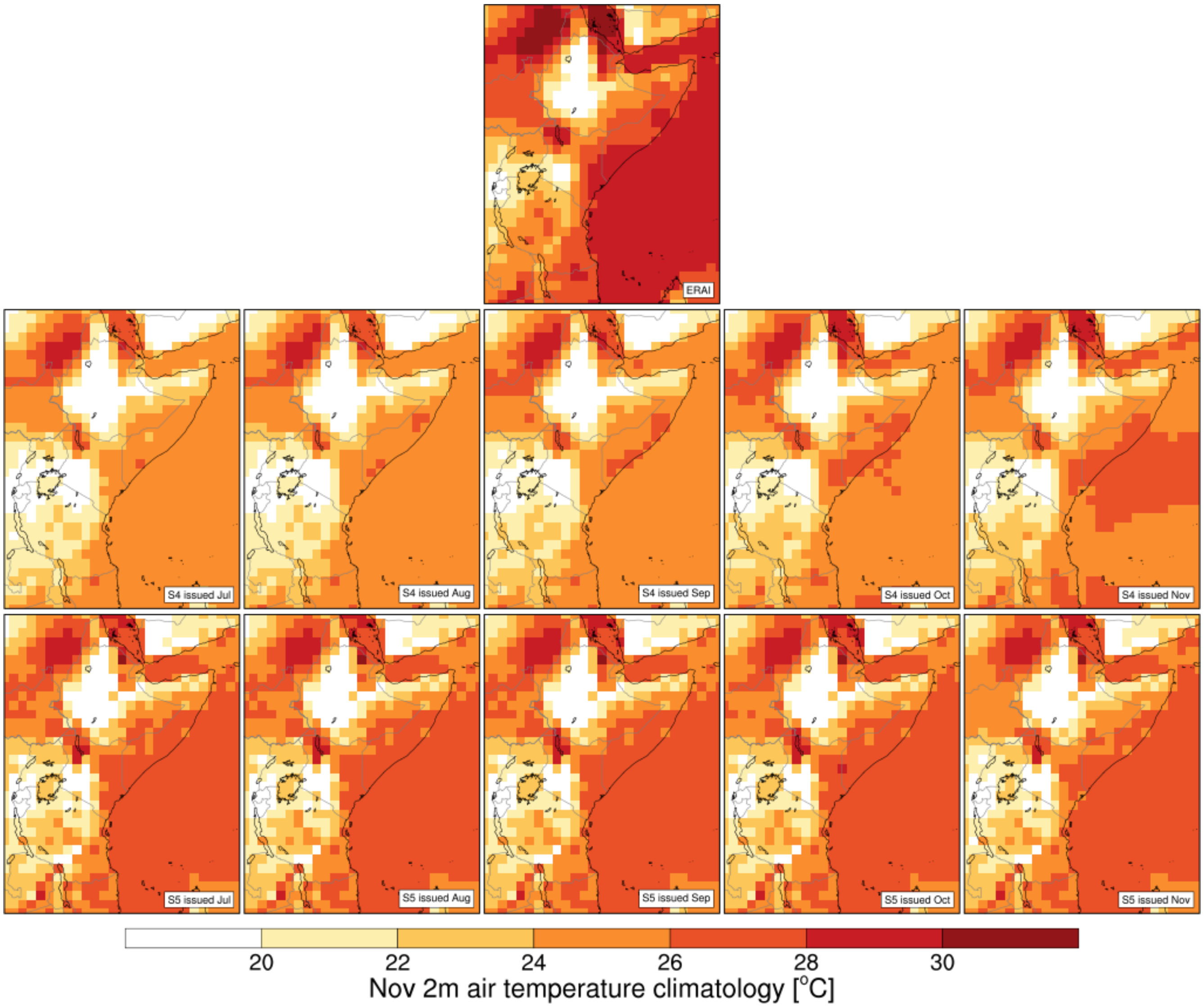

Figure 11. [ClimNov] 2m temperature climatology for Nov: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

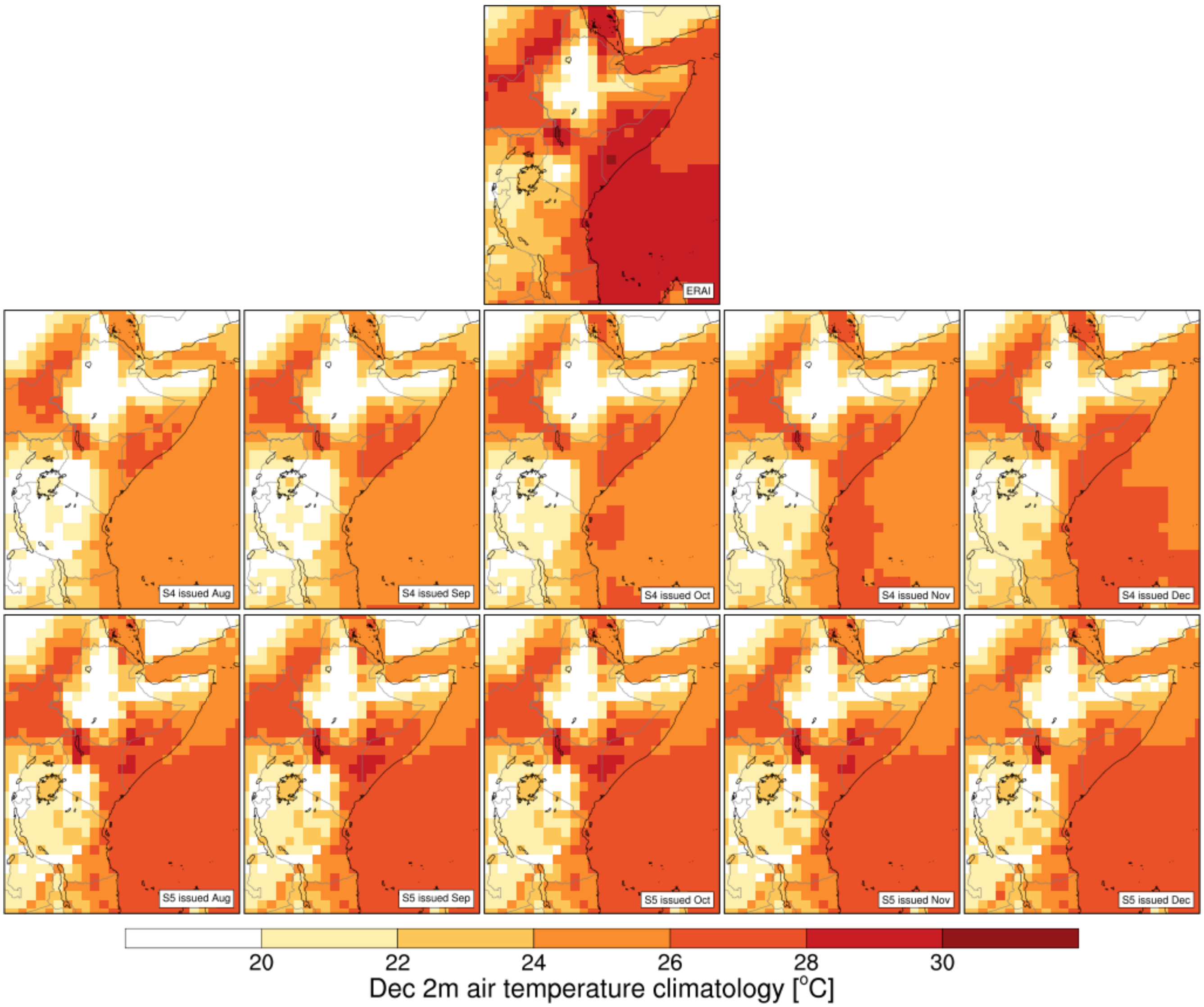

Figure 12. [ClimDec] 2m temperature climatology for Dec: ERAI (top) and ensemble mean System 4 (middle) and SEAS5 (bottom)

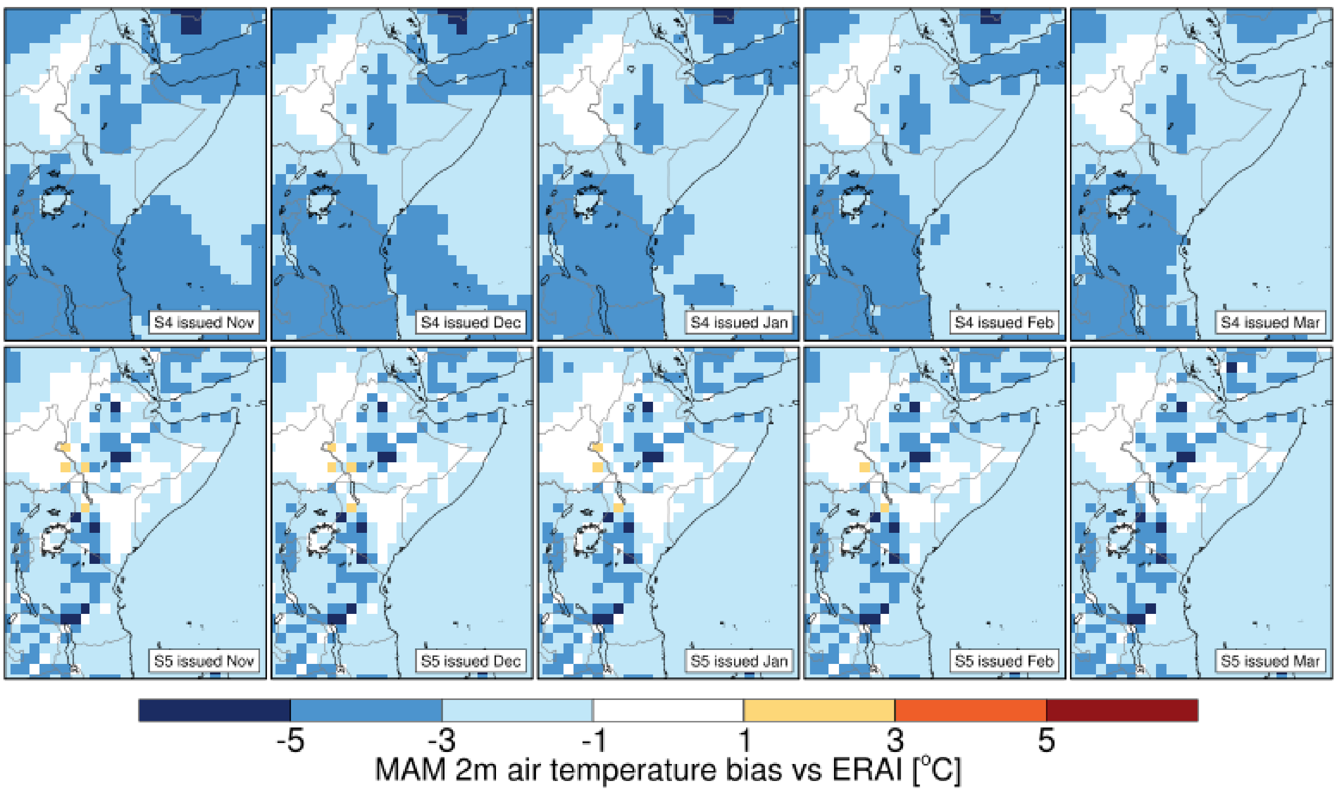

Figure 13. [BiasMAM] 2m temperature ensemble mean bias MAM, System 4 (top) and SEAS5 (bottom) vs ERAI

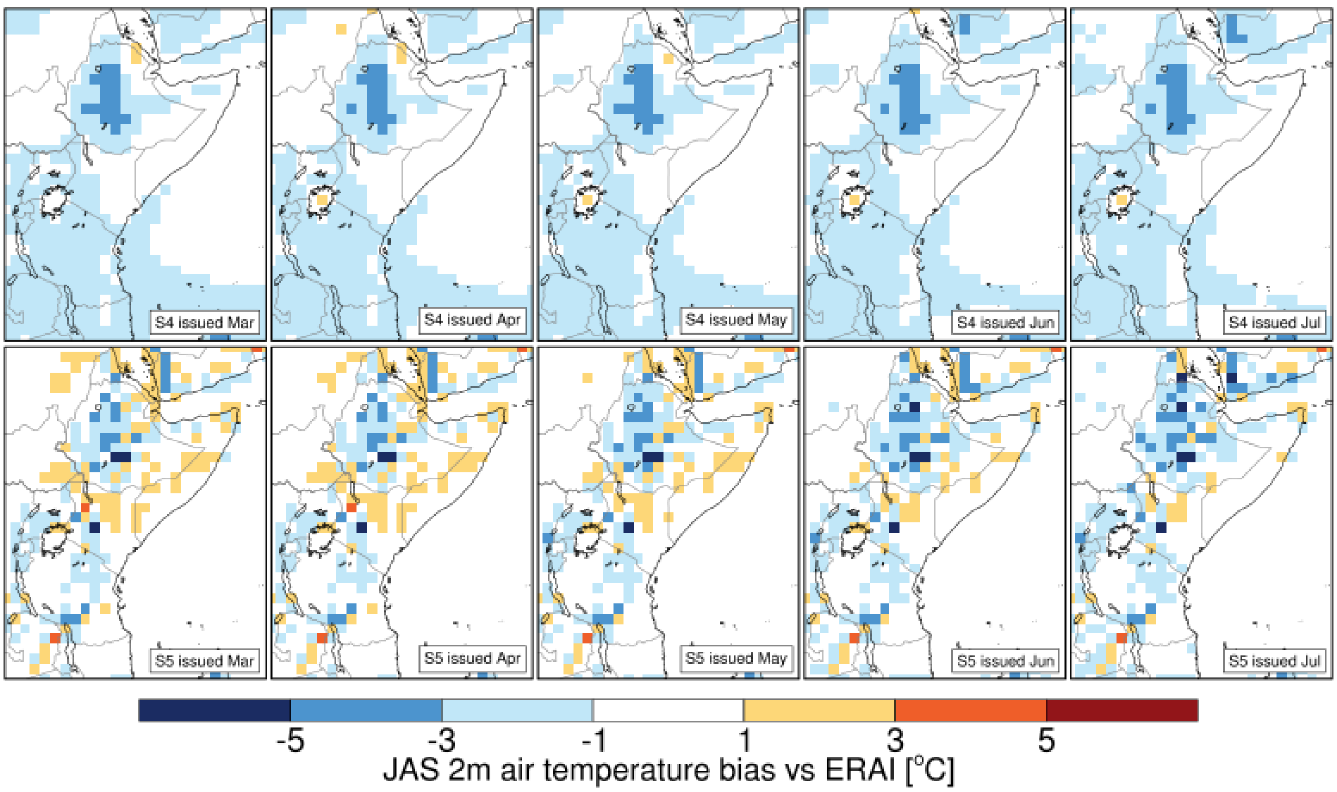

Figure 14. [BiasJAS] 2m temperature ensemble mean bias JAS, System 4 (top) and SEAS5 (bottom) vs ERAI

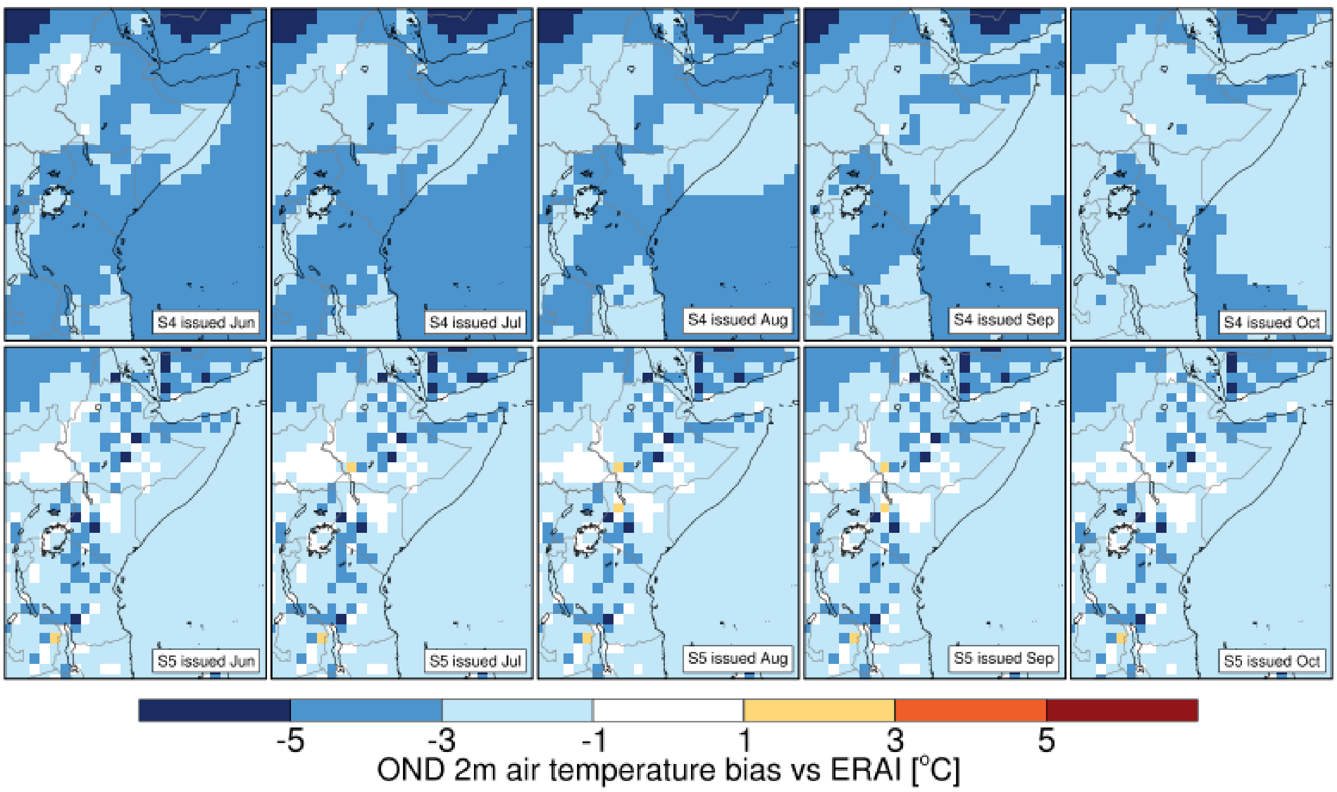

Figure 15. [BiasOND] 2m temperature ensemble mean bias OND, System 4 (top) and SEAS5 (bottom) vs ERAI

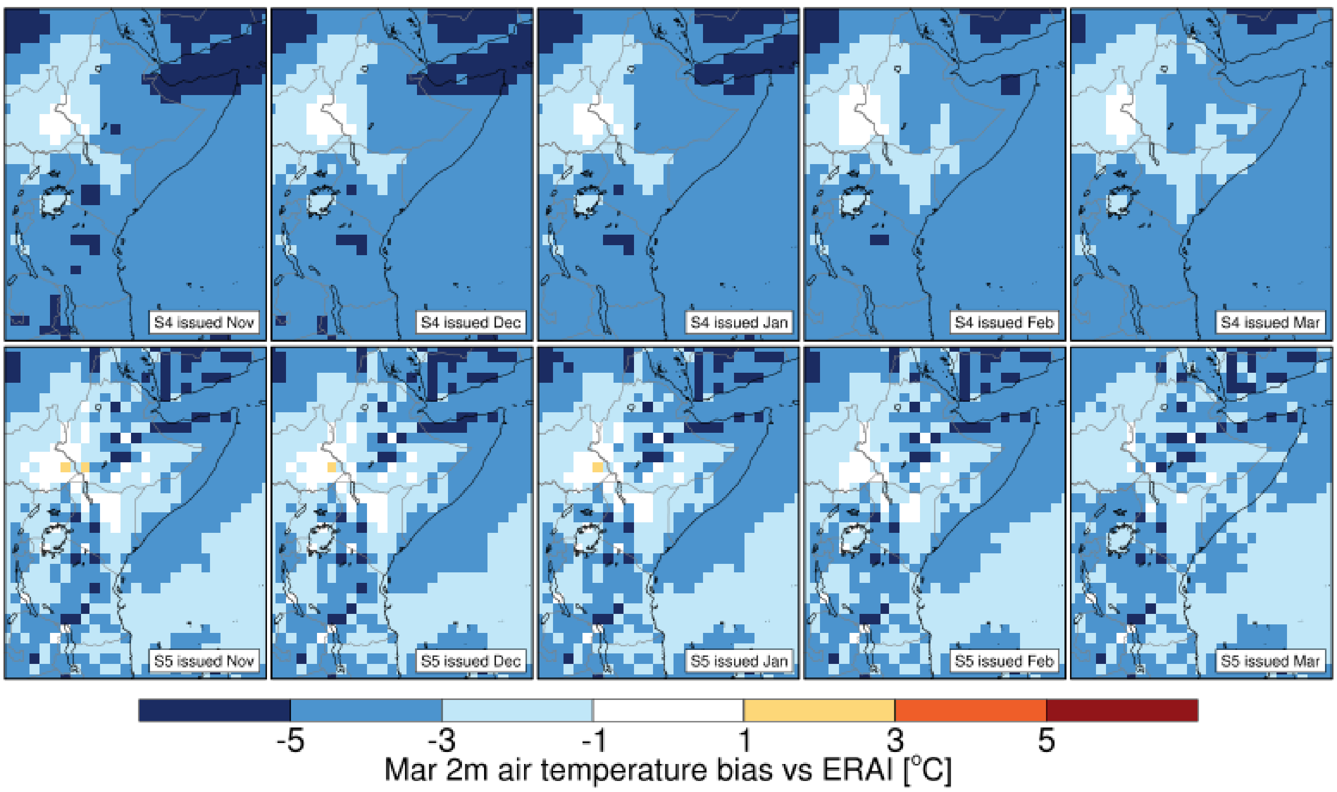

Figure 16. [BiasMar] 2m temperature ensemble mean bias Mar, System 4 (top) and SEAS5 (bottom) vs ERAI

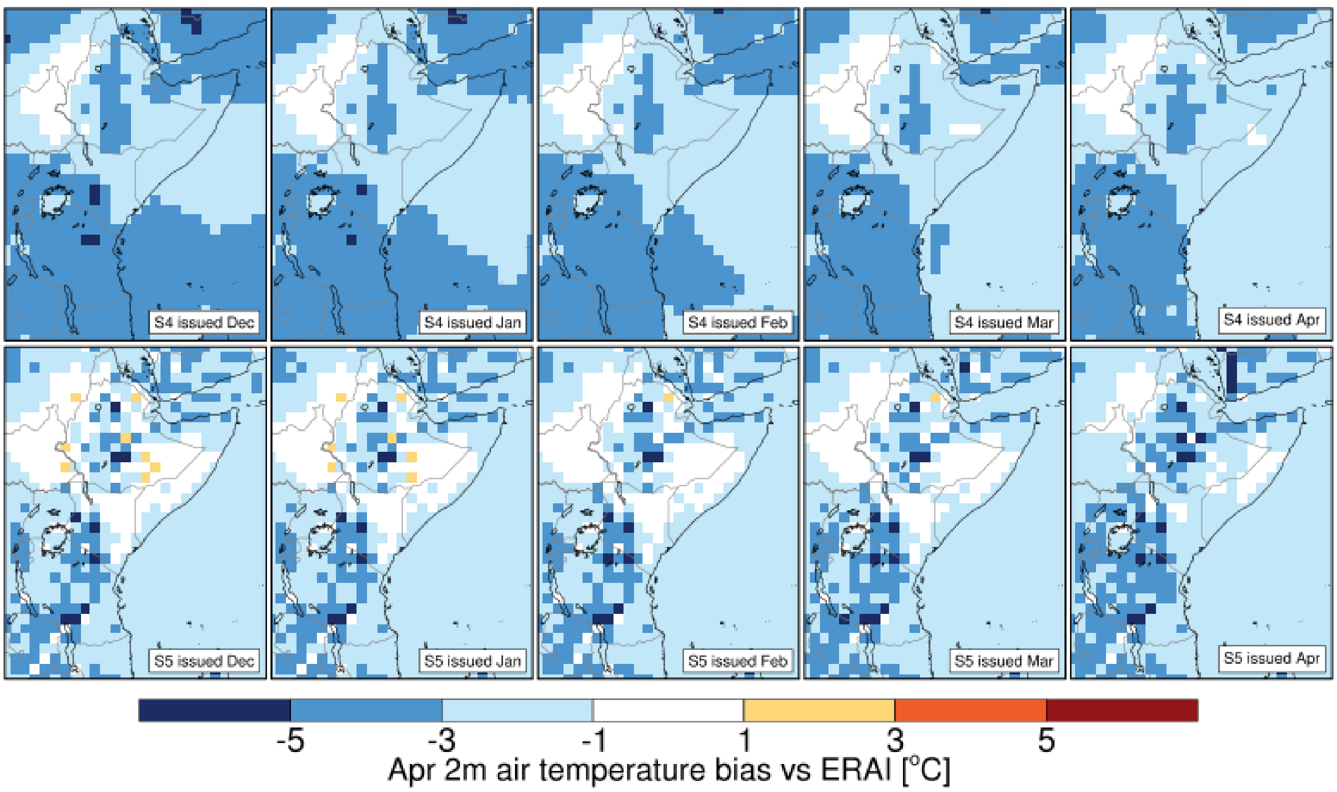

Figure 17. [BiasApr] 2m temperature ensemble mean bias Apr, System 4 (top) and SEAS5 (bottom) vs ERAI

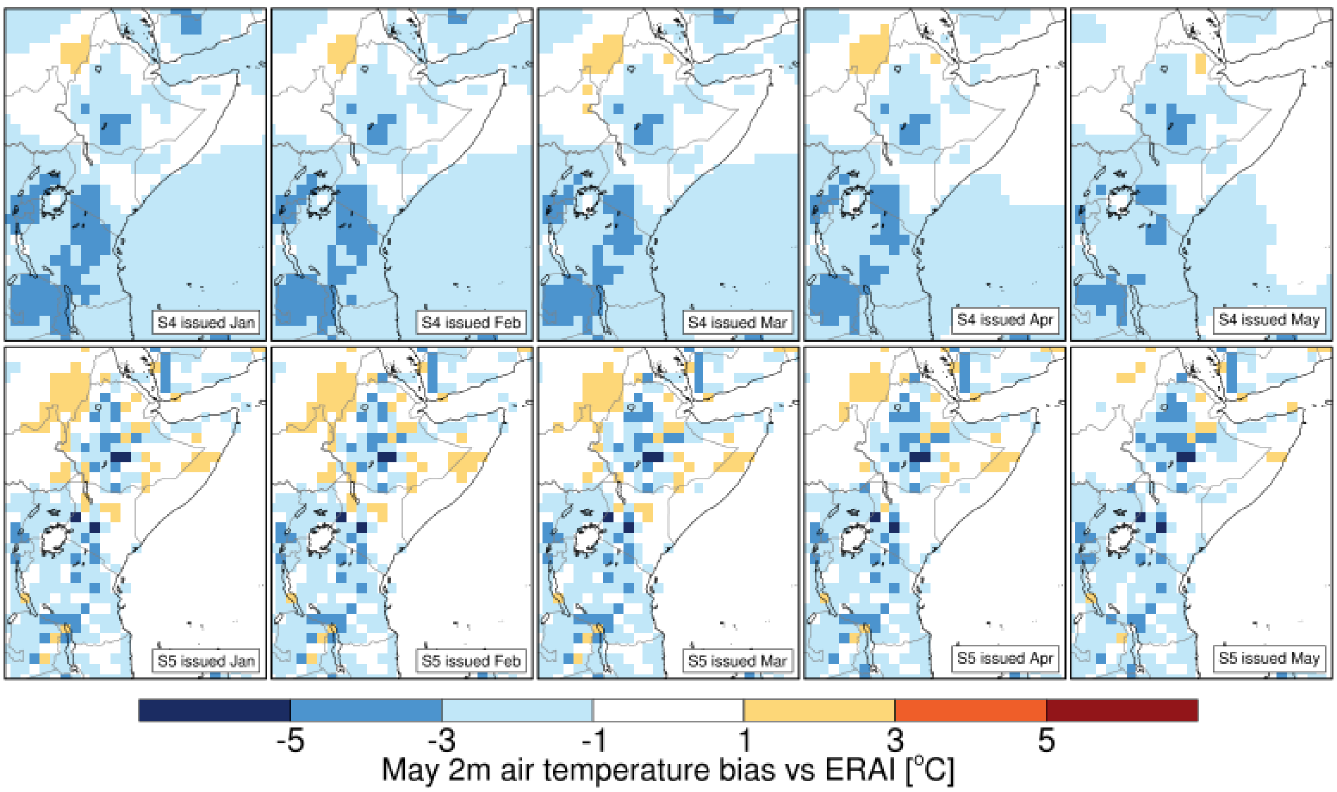

Figure 18. [BiasMay] 2m temperature ensemble mean bias May, System 4 (top) and SEAS5 (bottom) vs ERAI

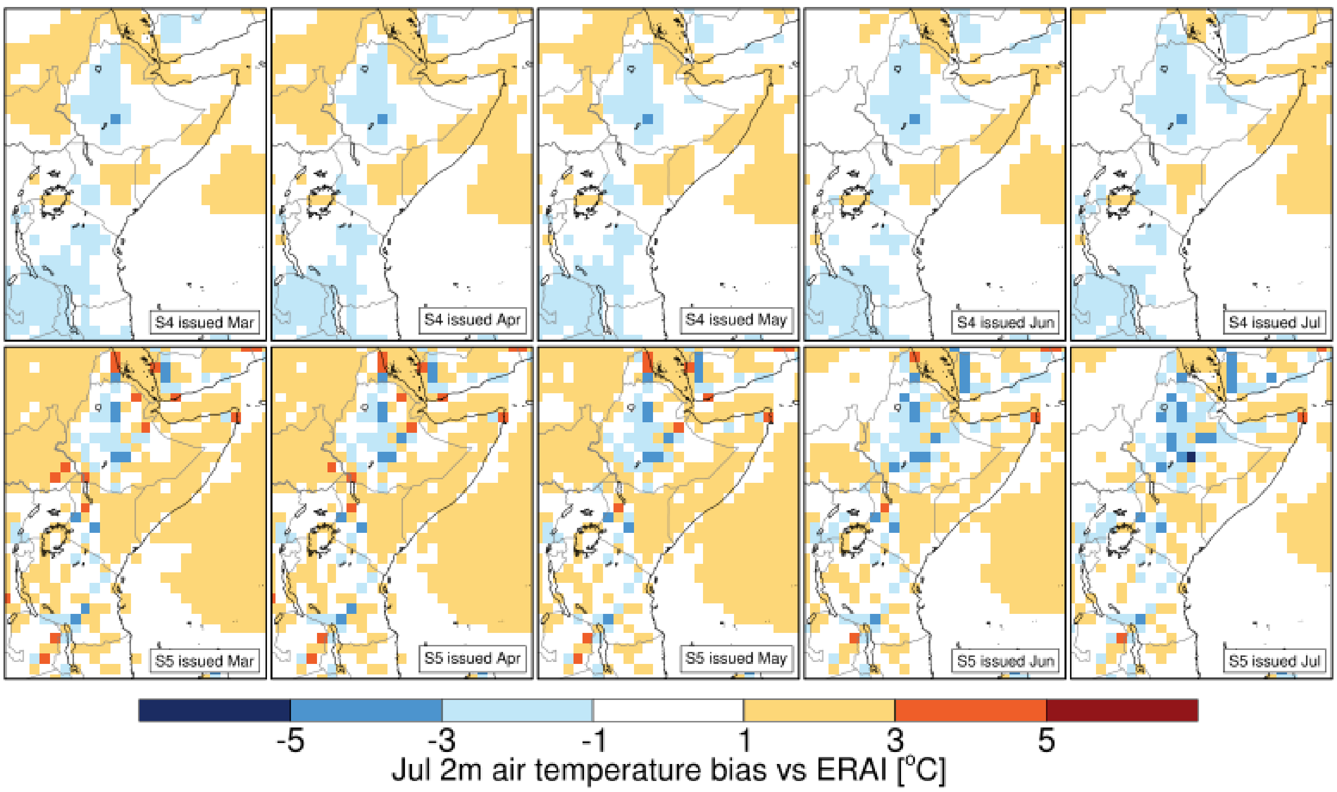

Figure 19. [BiasJul] 2m temperature ensemble mean bias Jul, System 4 (top) and SEAS5 (bottom) vs ERAI

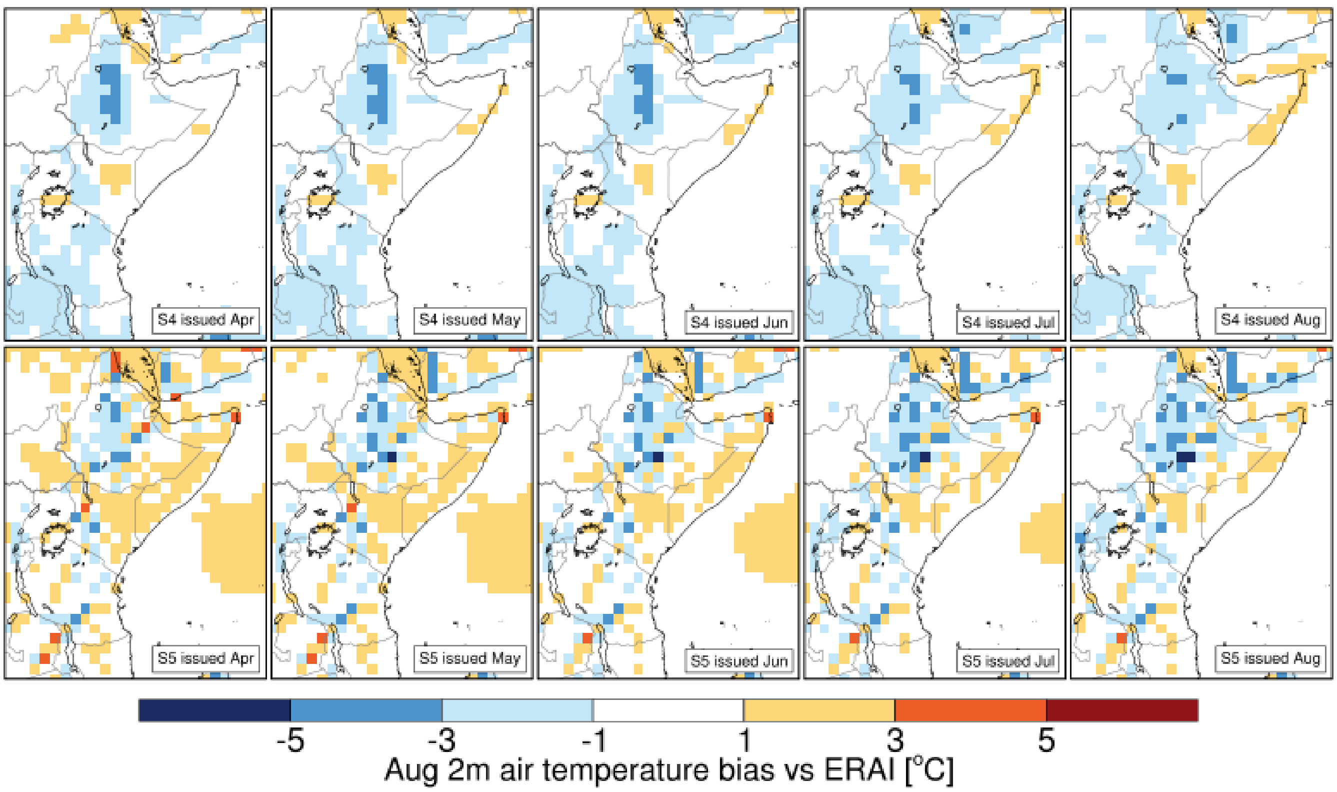

Figure 20. [BiasAug] 2m temperature ensemble mean bias Aug, System 4 (top) and SEAS5 (bottom) vs ERAI

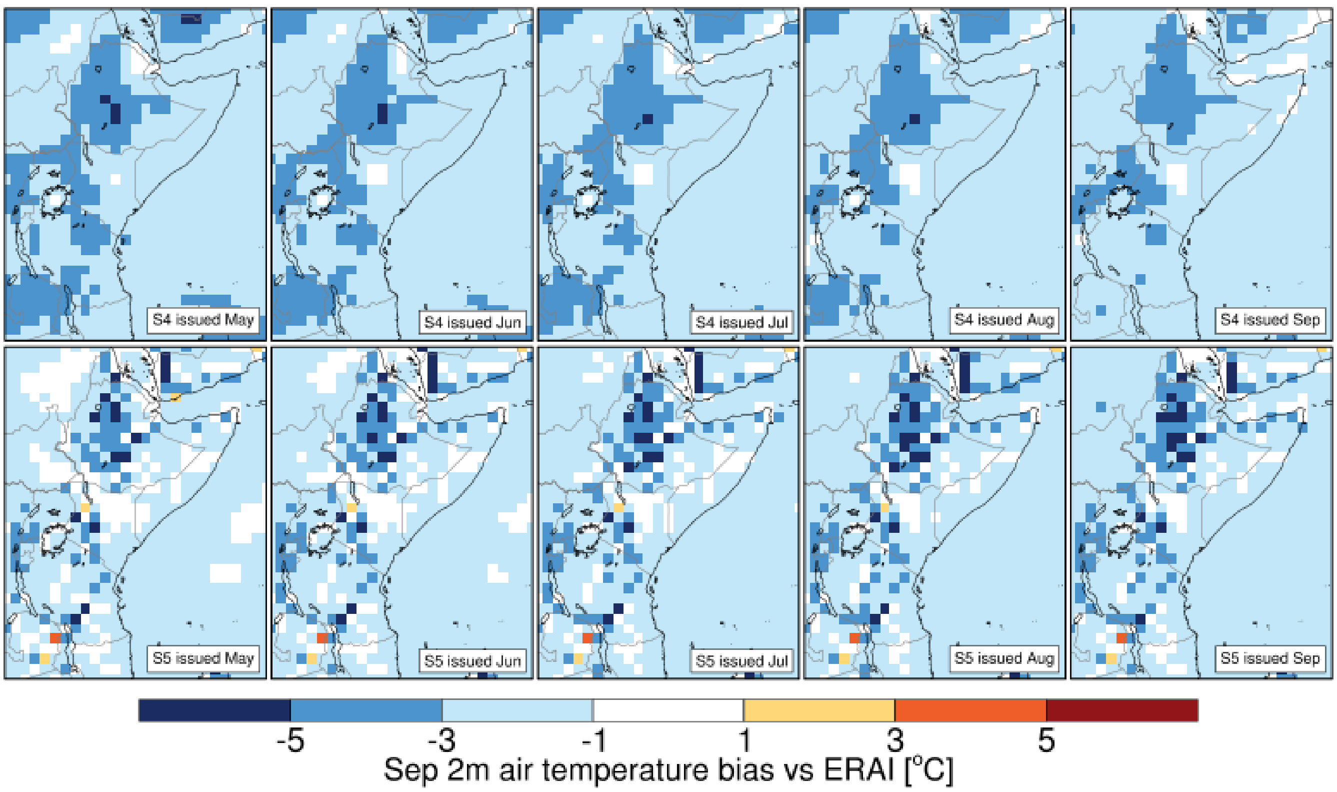

Figure 21. [BiasSep] 2m temperature ensemble mean bias Sep, System 4 (top) and SEAS5 (bottom) vs ERAI

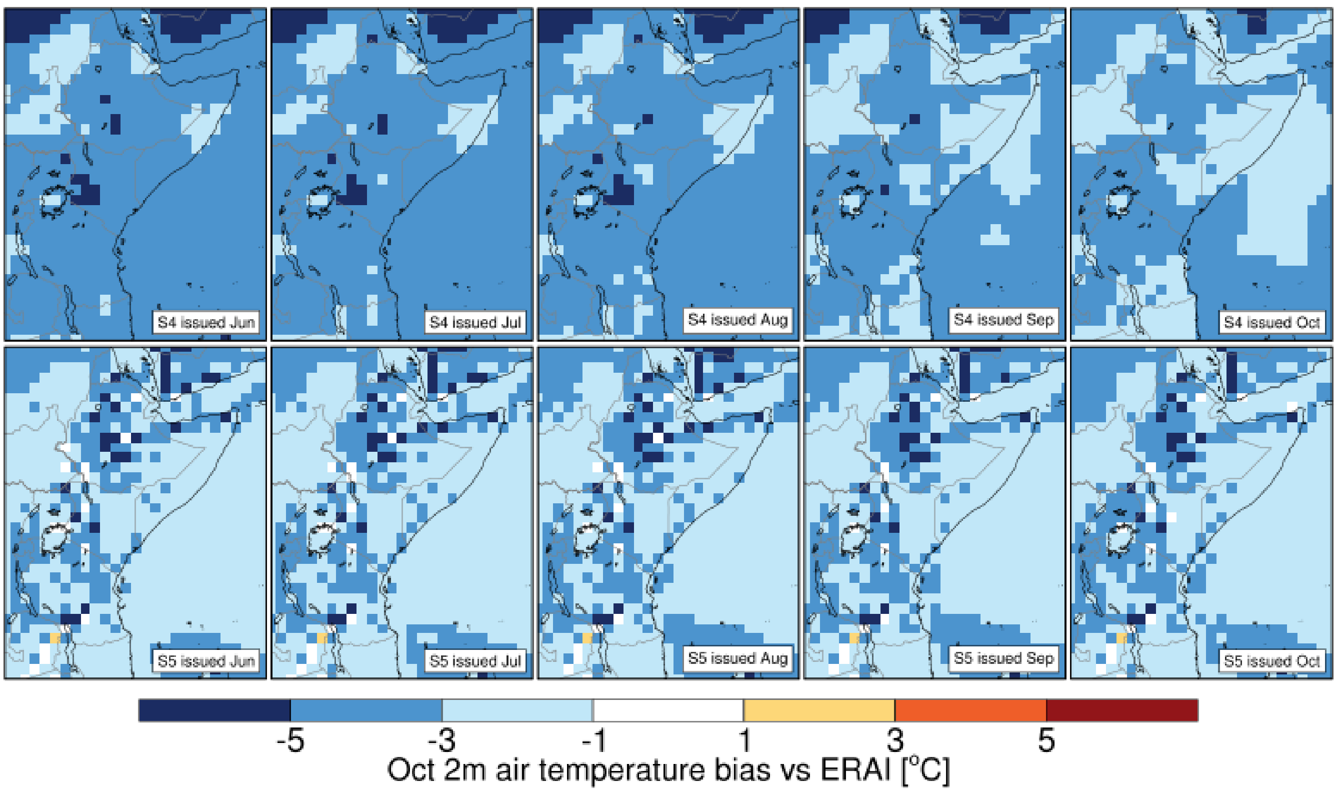

Figure 22. [BiasOct] 2m temperature ensemble mean bias Oct, System 4 (top) and SEAS5 (bottom) vs ERAI

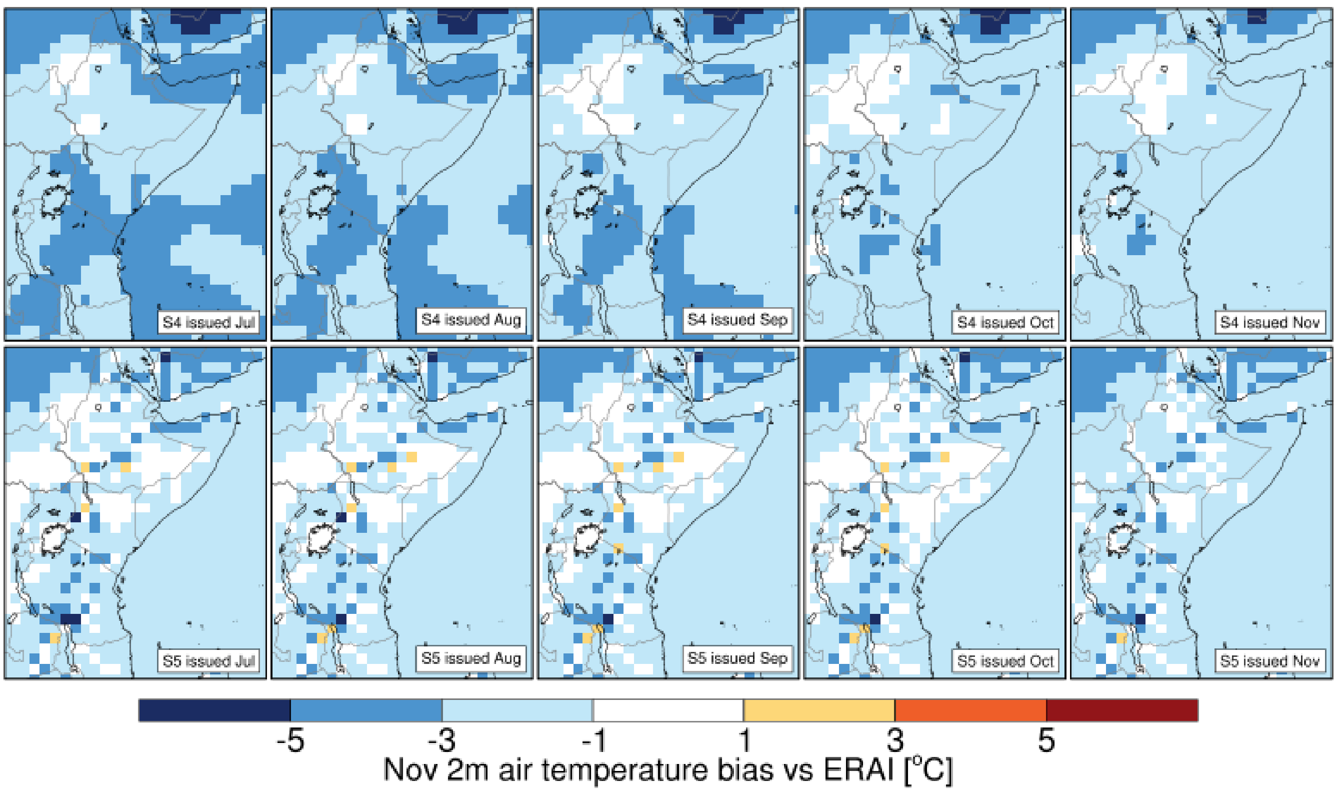

Figure 23. [BiasNov] 2m temperature ensemble mean bias Nov, System 4 (top) and SEAS5 (bottom) vs ERAI

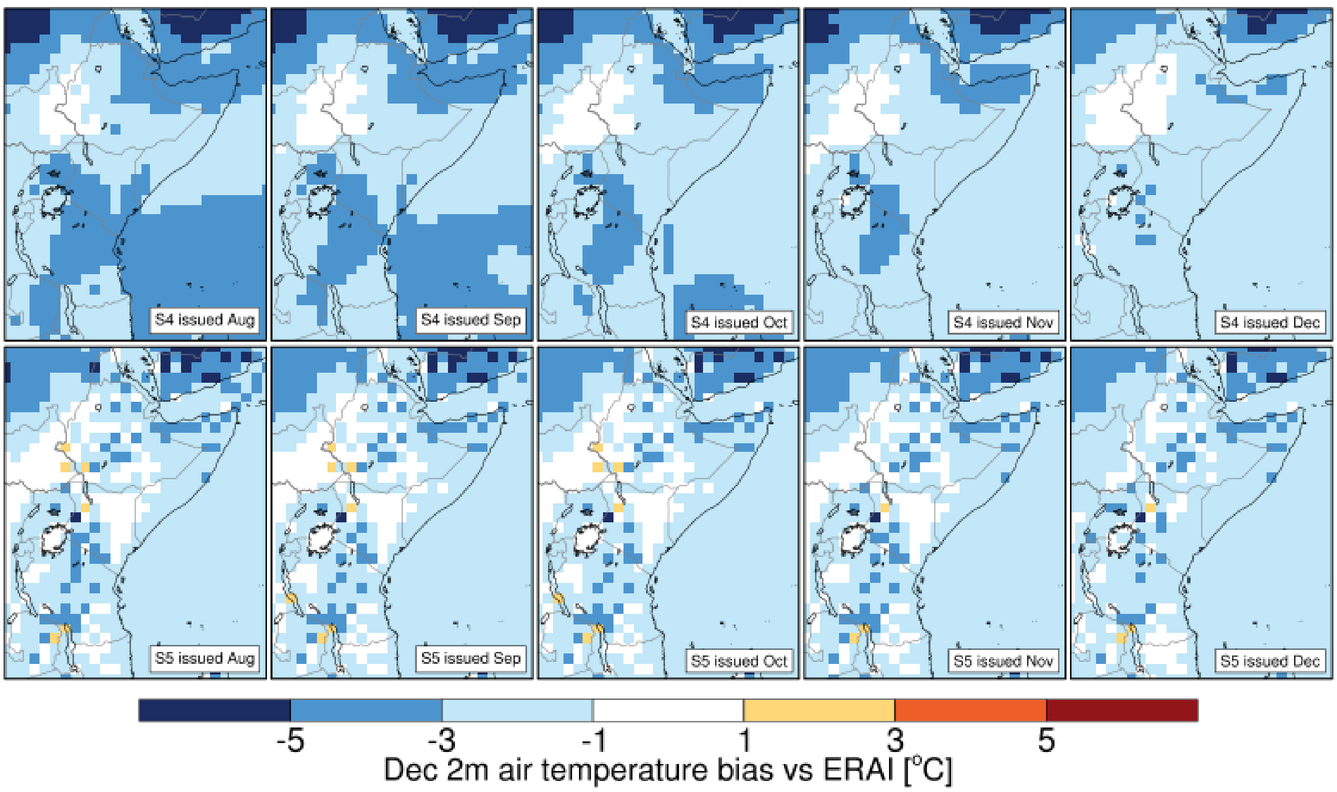

Figure 24. [BiasDec] 2m temperature ensemble mean bias Dec, System 4 (top) and SEAS5 (bottom) vs ERAI

4.2 Ensemble mean correlation

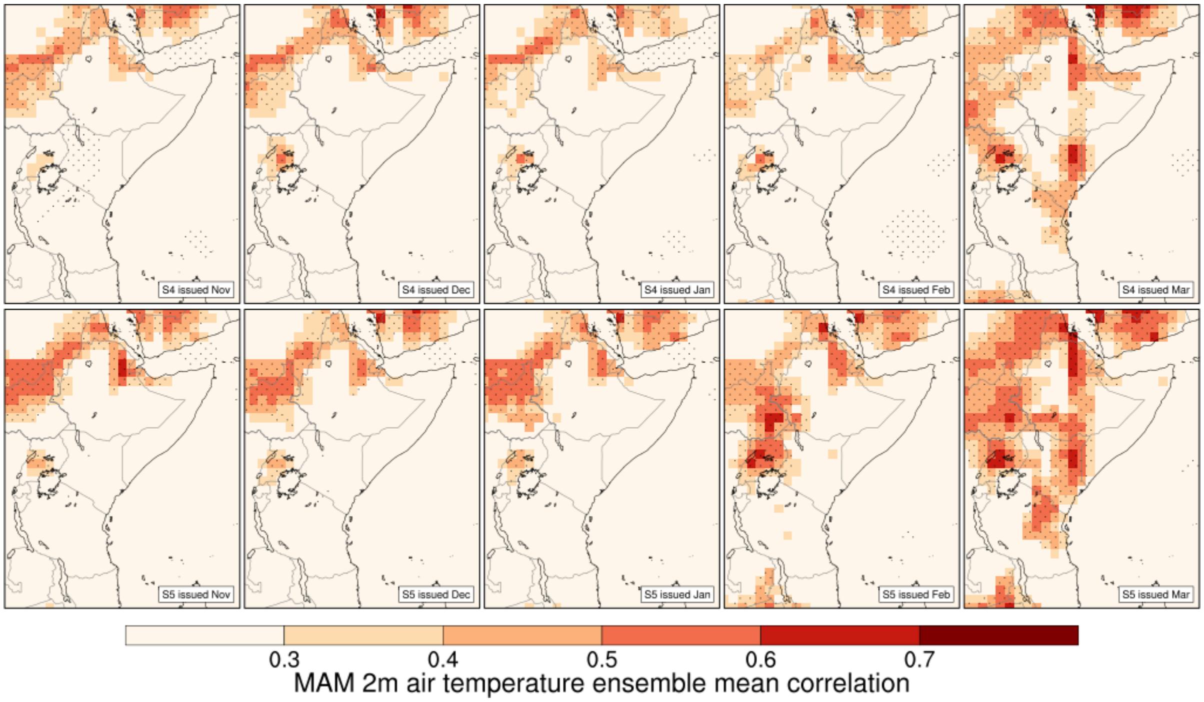

Figure 25. [CorrMAM] Peason's correlation coefficient for MAM, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

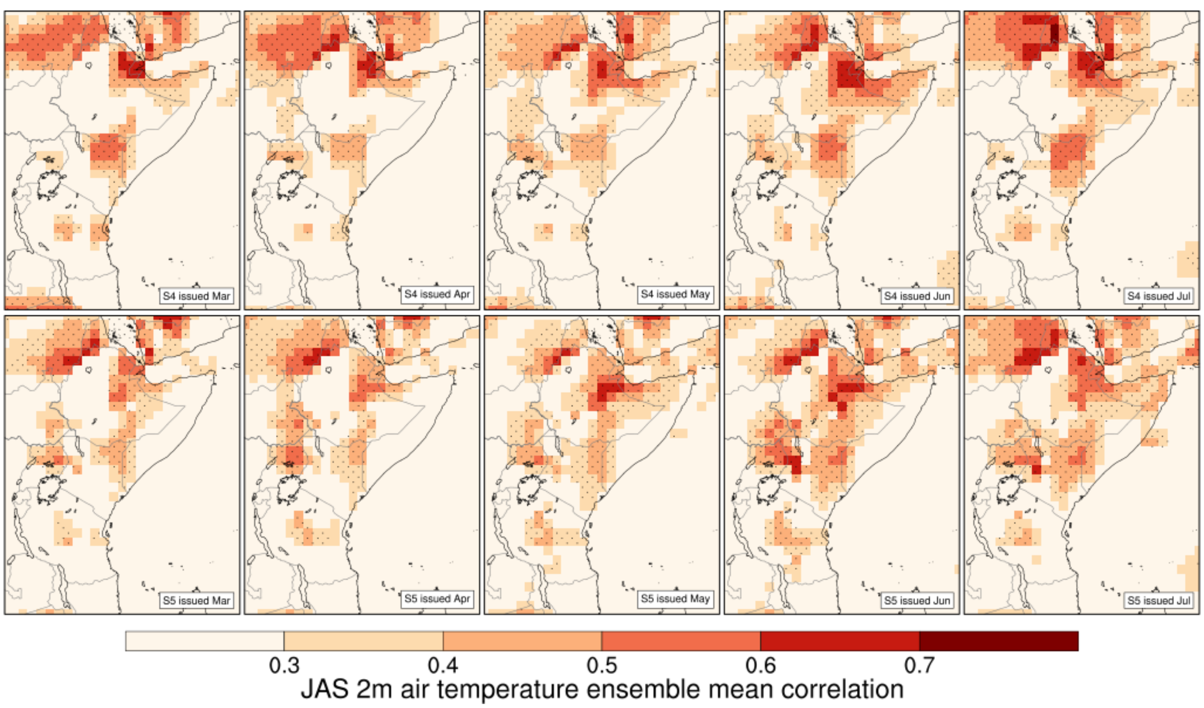

Figure 26. [CorrJAS] Peason's correlation coefficient for JAS, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

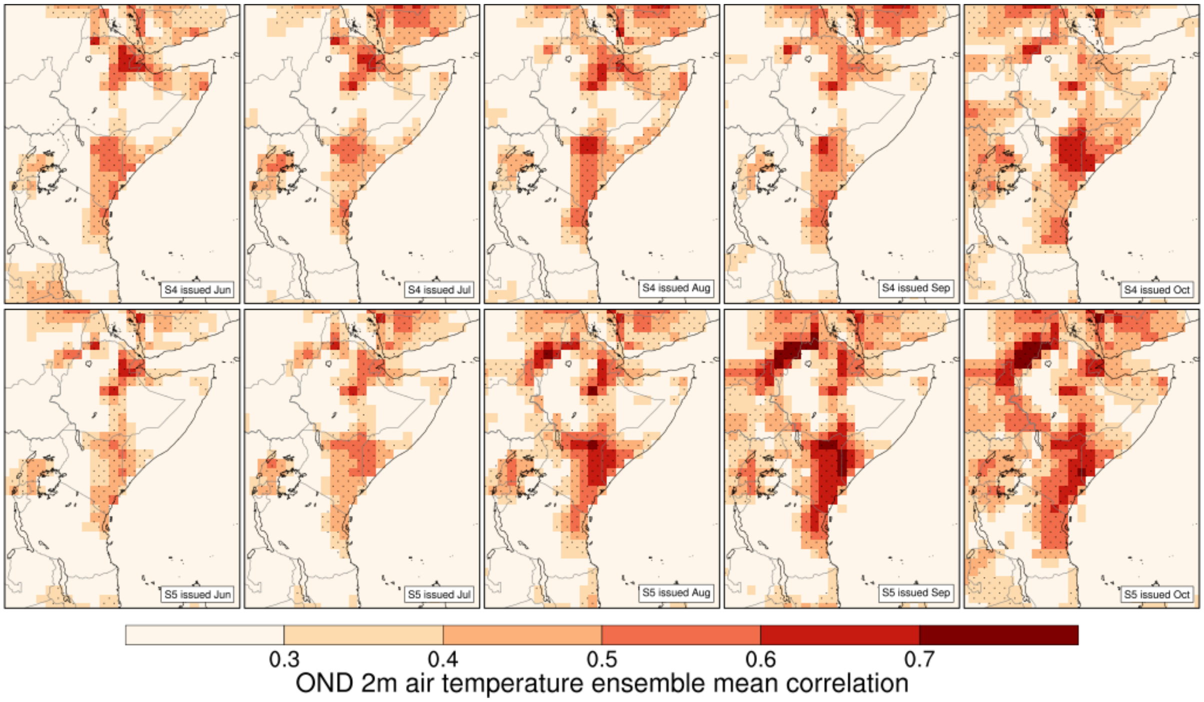

Figure 27. [CorrOND] Peason's correlation coefficient for OND, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

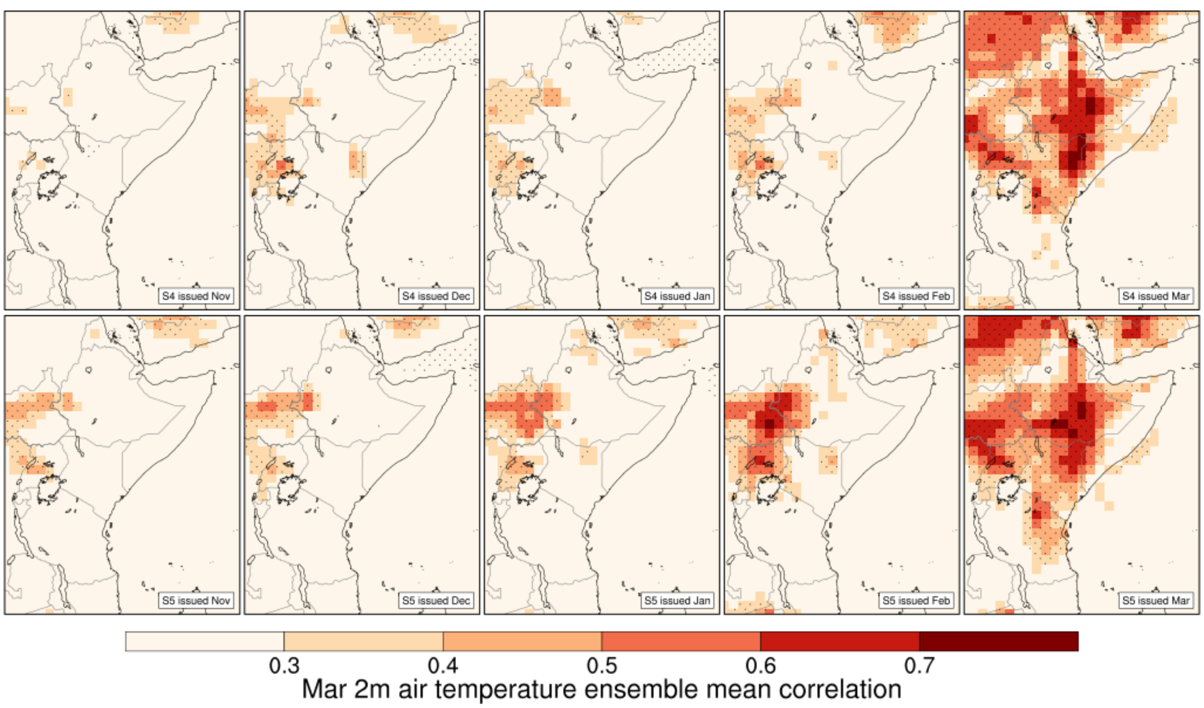

Figure 28. [CorrMar] Peason's correlation coefficient for Mar, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

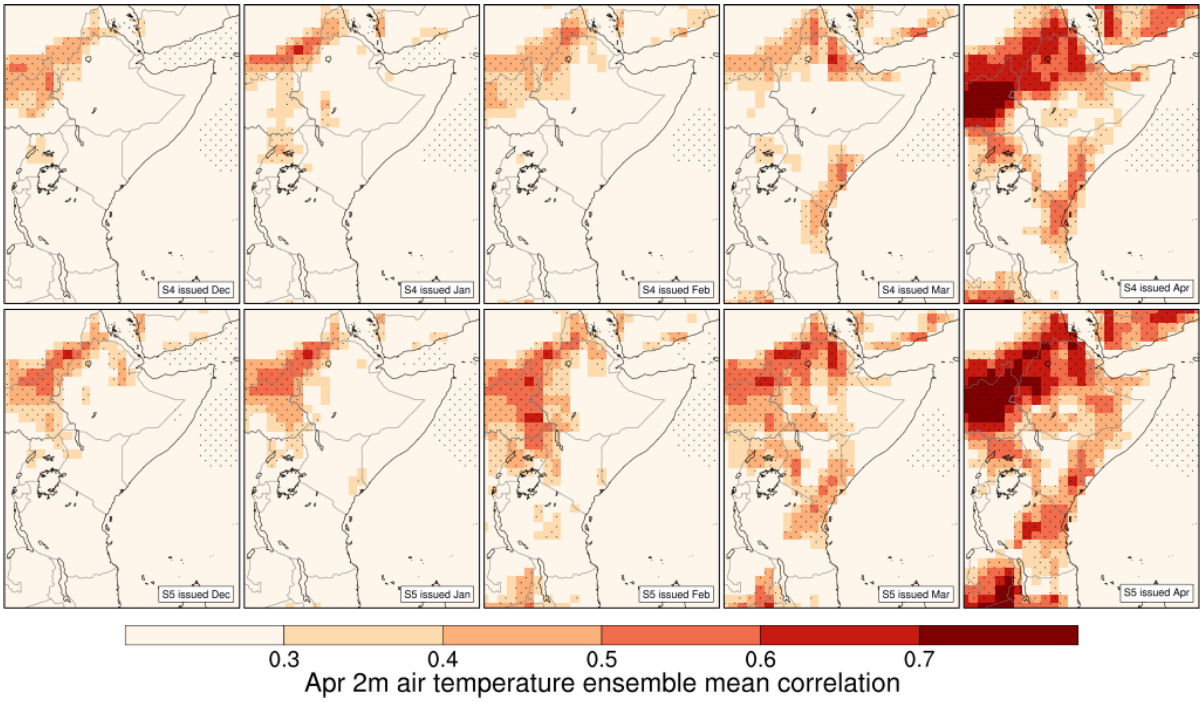

Figure 29. [CorrApr] Peason's correlation coefficient for Apr, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

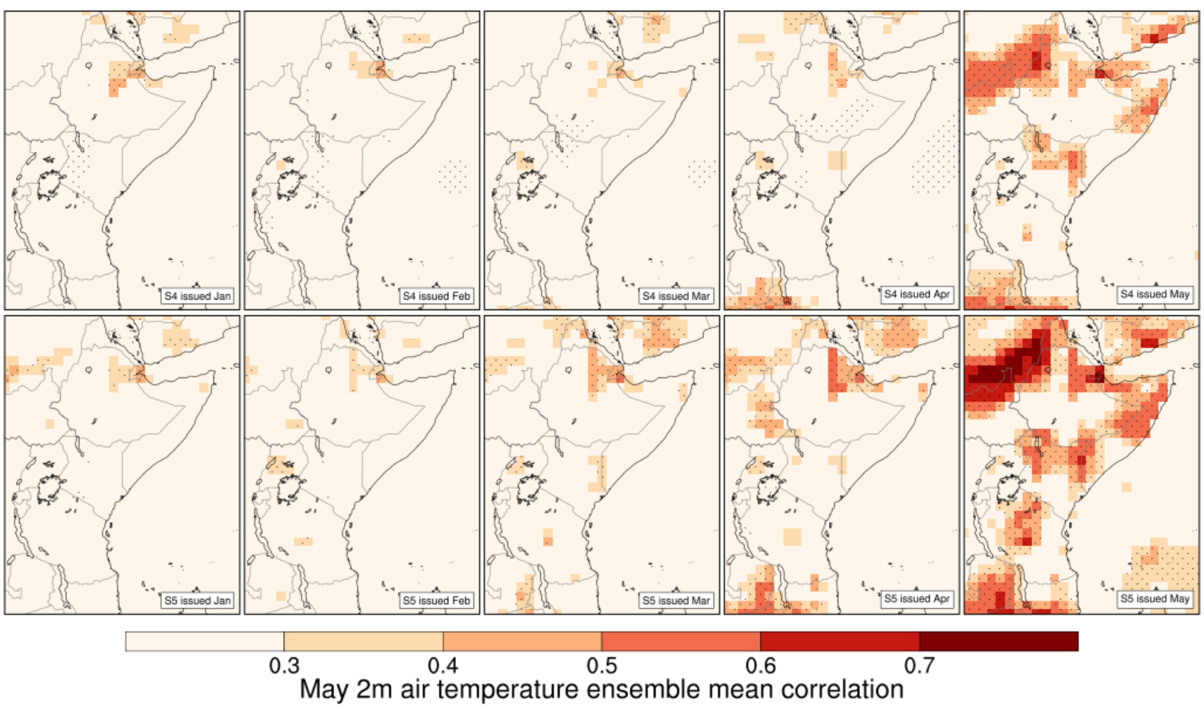

Figure 30. [CorrMay] Peason's correlation coefficient for May, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

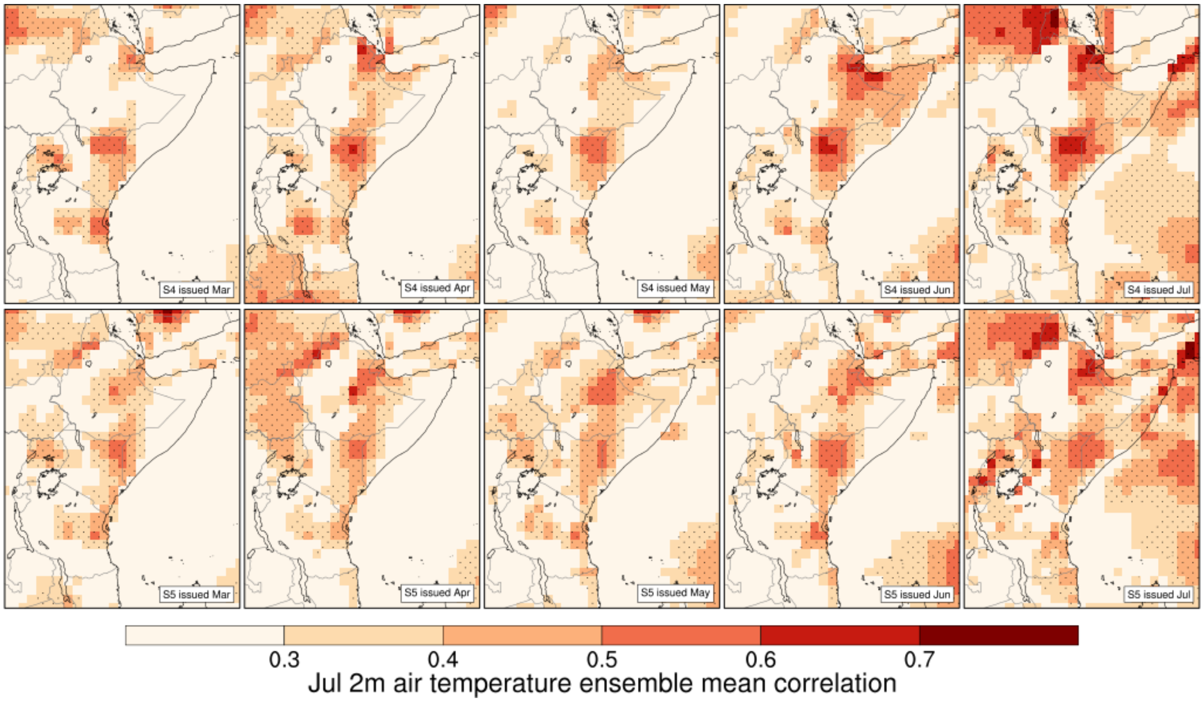

Figure 31. [CorrJul] Peason's correlation coefficient for Jul, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

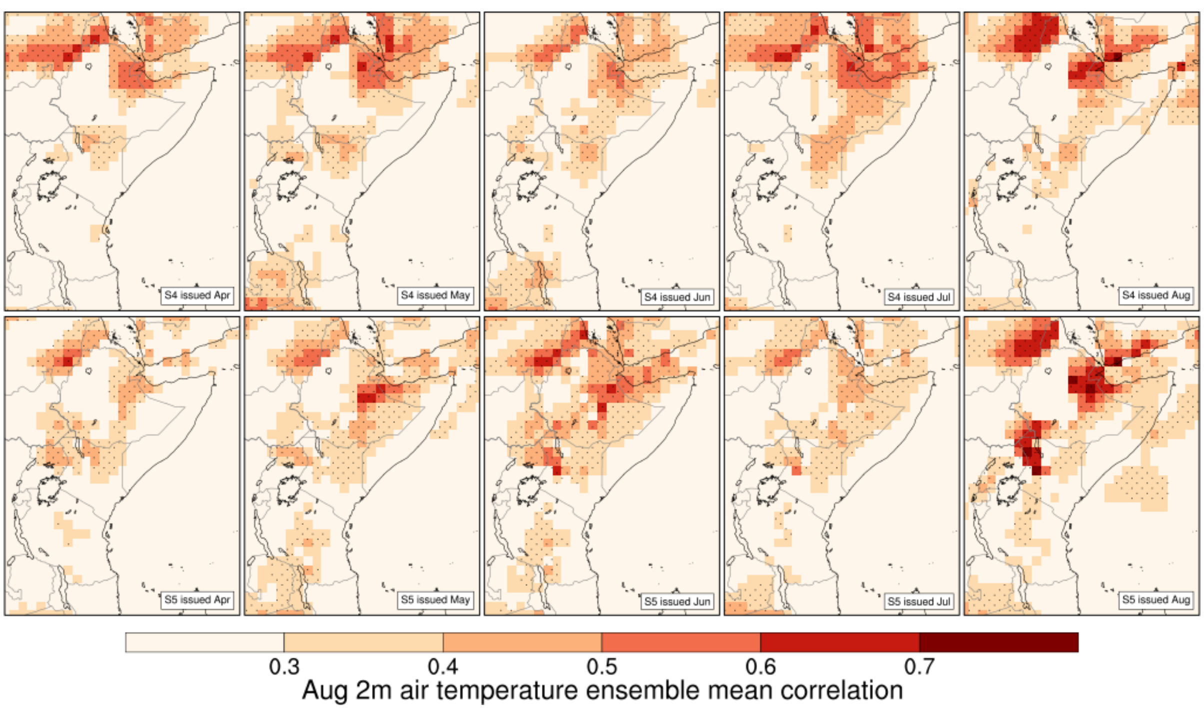

Figure 32. [CorrAug] Peason's correlation coefficient for Aug, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

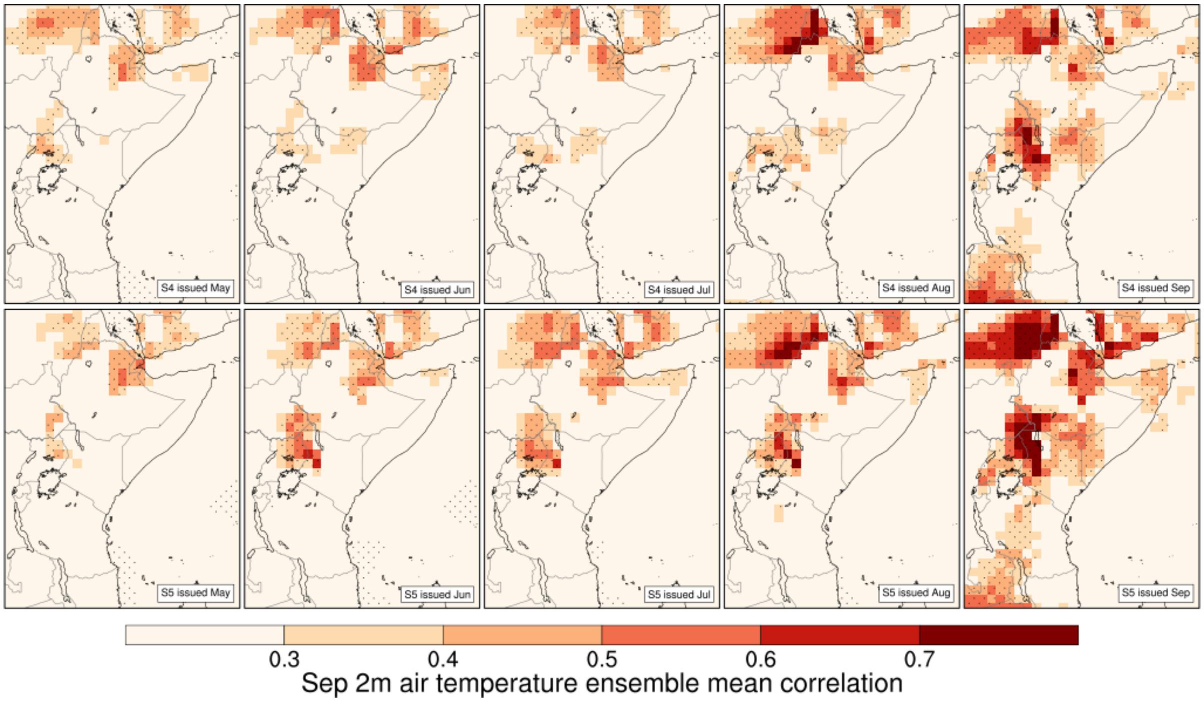

Figure 33. [CorrSep] Peason's correlation coefficient for Sep, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

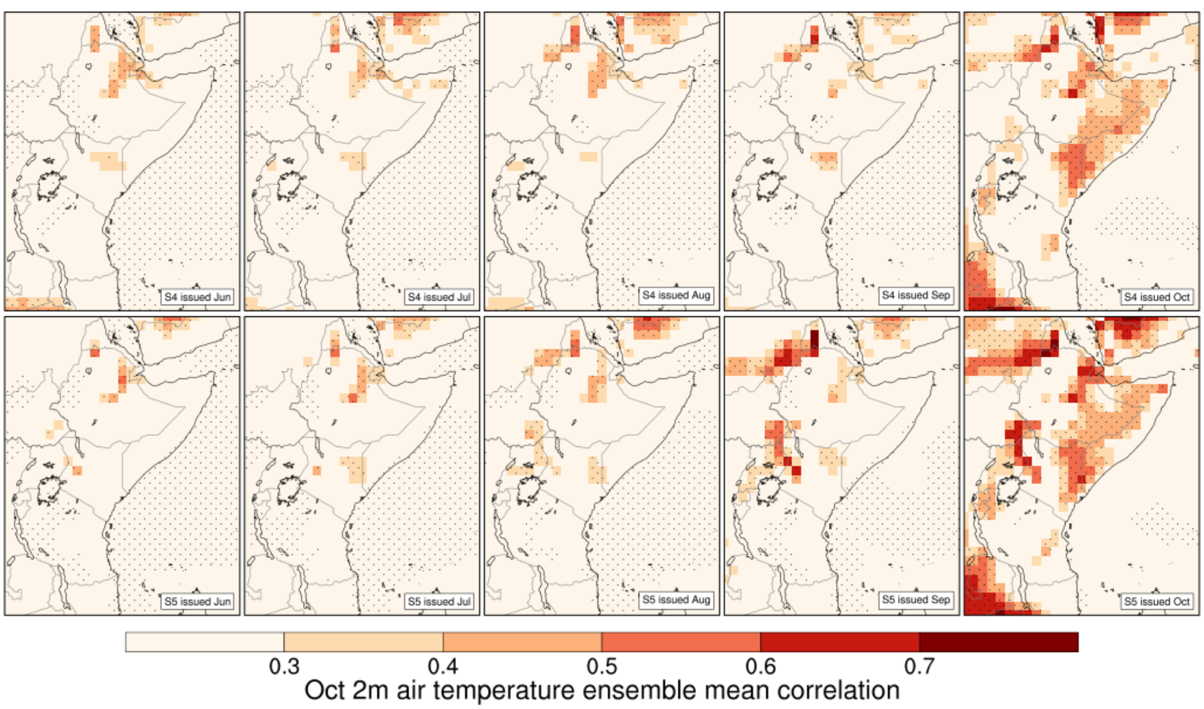

Figure 34. [CorrOct] Peason's correlation coefficient for Oct, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

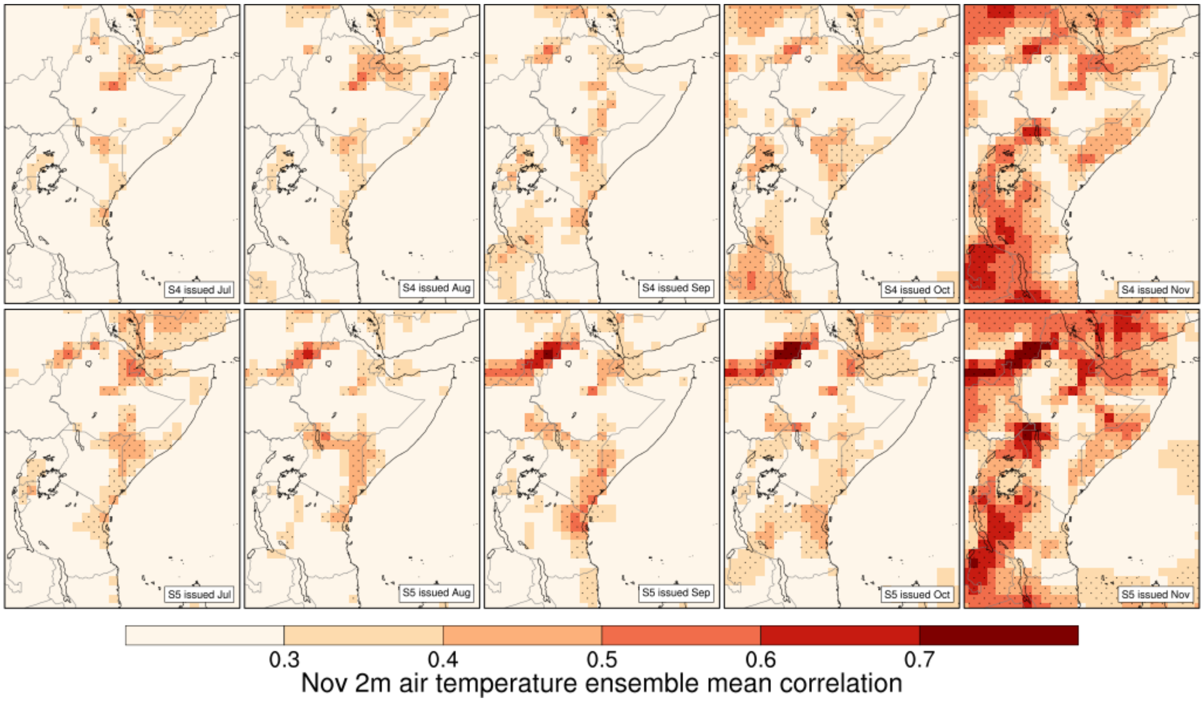

Figure 35. [CorrNov] Peason's correlation coefficient for Nov, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

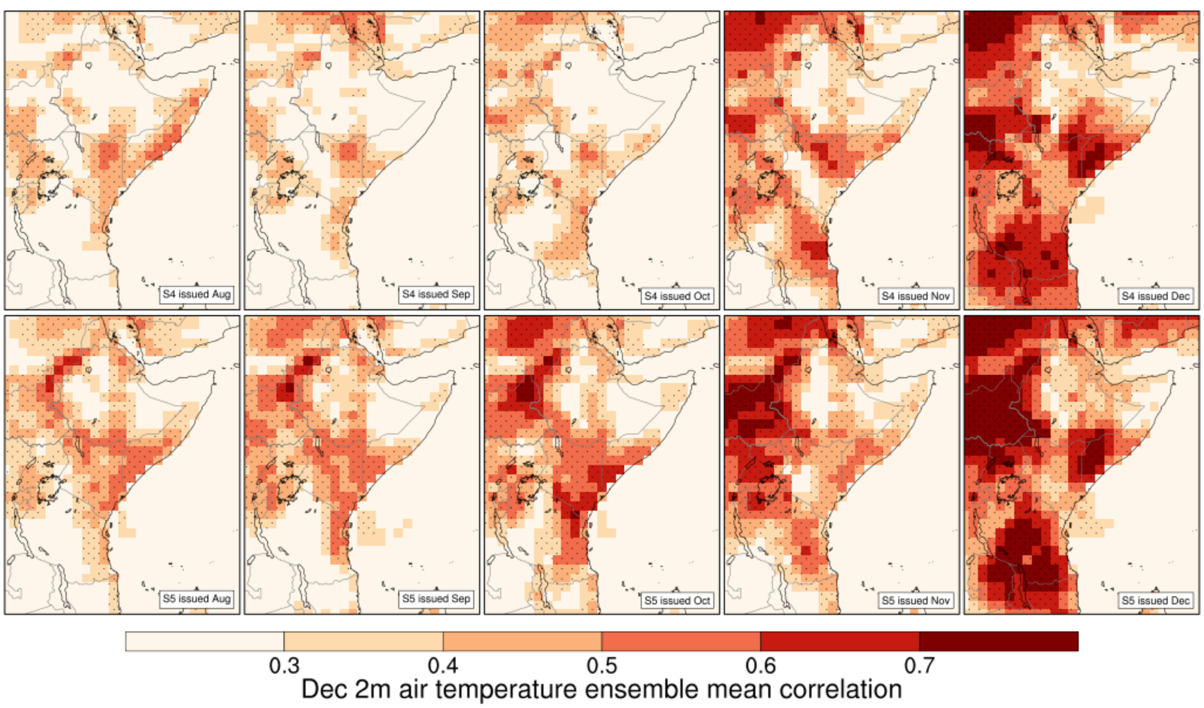

Figure 36. [CorrDec] Peason's correlation coefficient for Dec, ensemble mean 2m temperature System 4 (top) and SEAS5 (bottom) vs ERAI. Stippling indicates correlations significantly different from zero at the 95% level.

4.3 Relative Operating Characteristic AUC

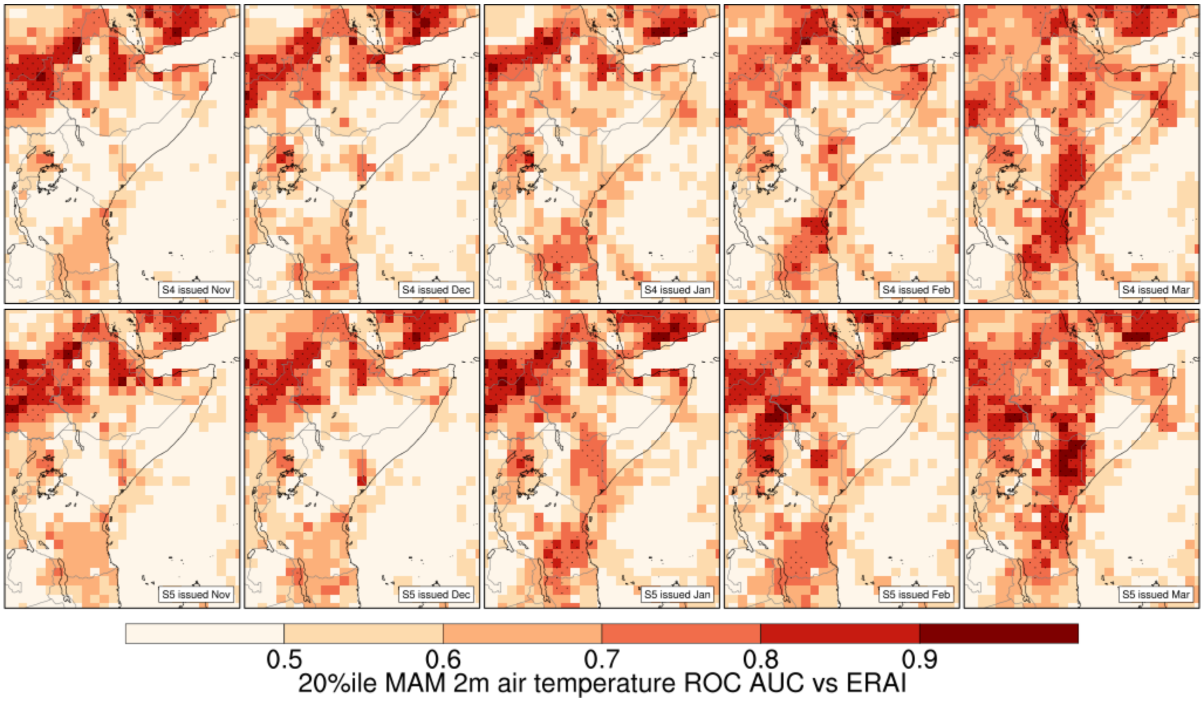

Figure 37. [ROC20MAM] ROC Area under curve for MAM: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

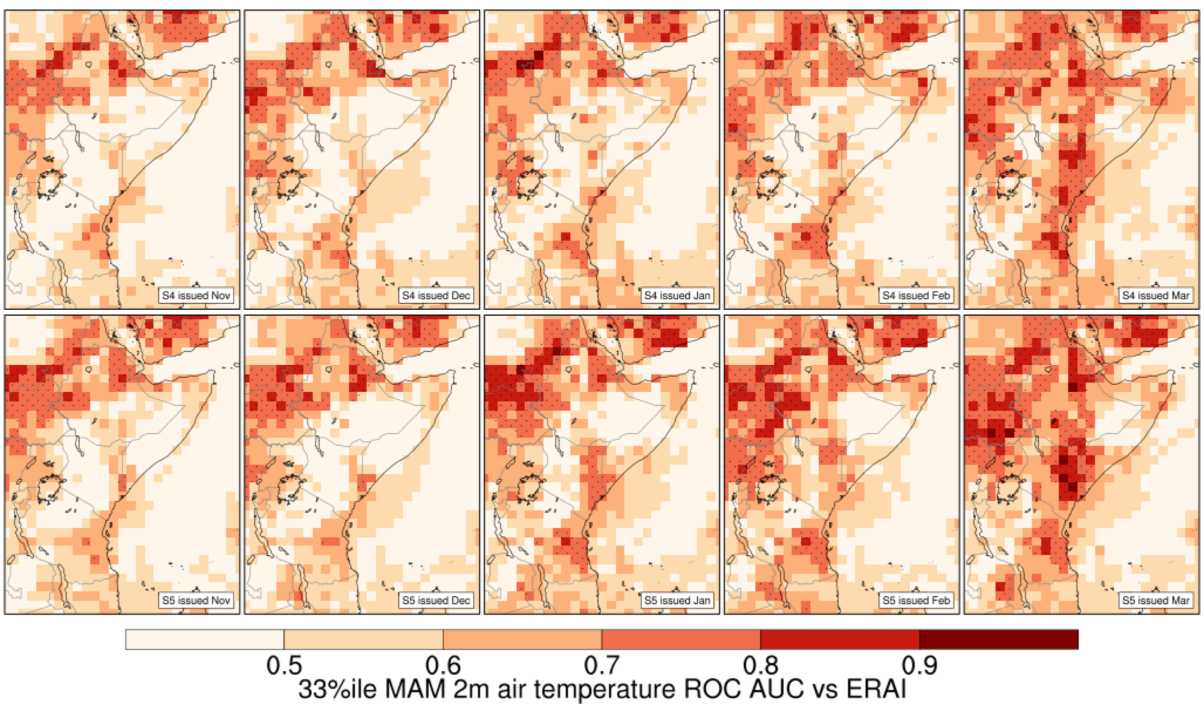

Figure 38. [ROC33MAM] ROC Area under curve for MAM: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

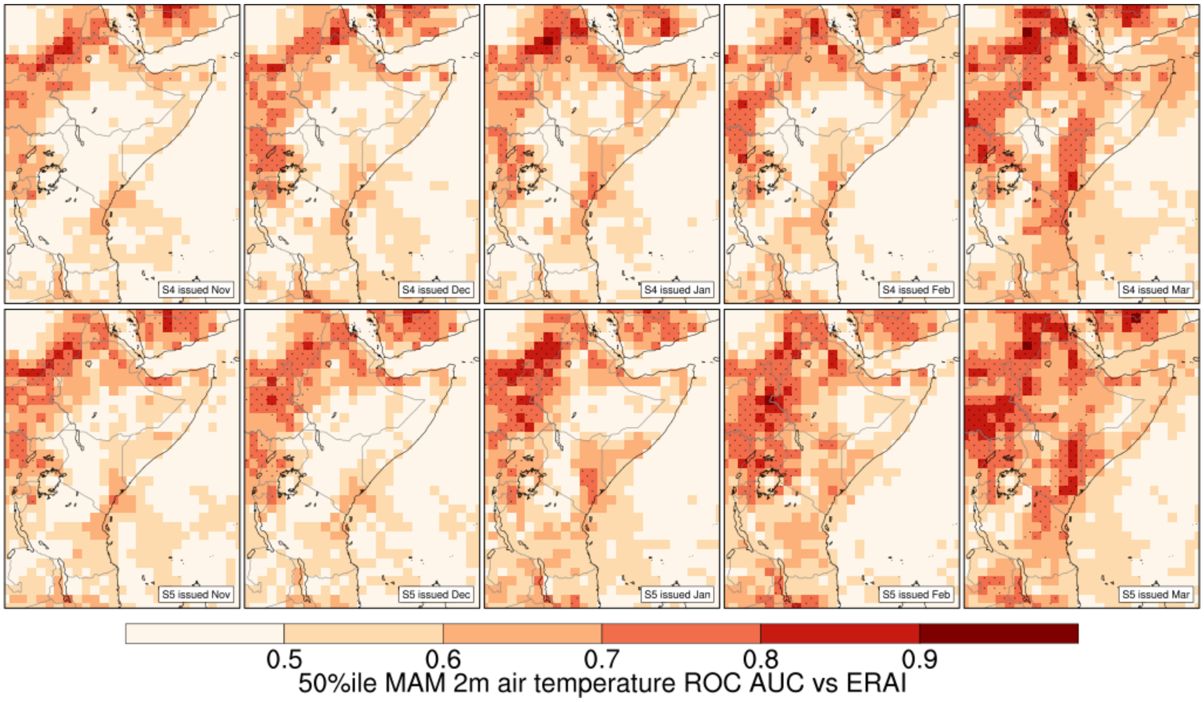

Figure 39. [ROC50MAM] ROC Area under curve for MAM: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

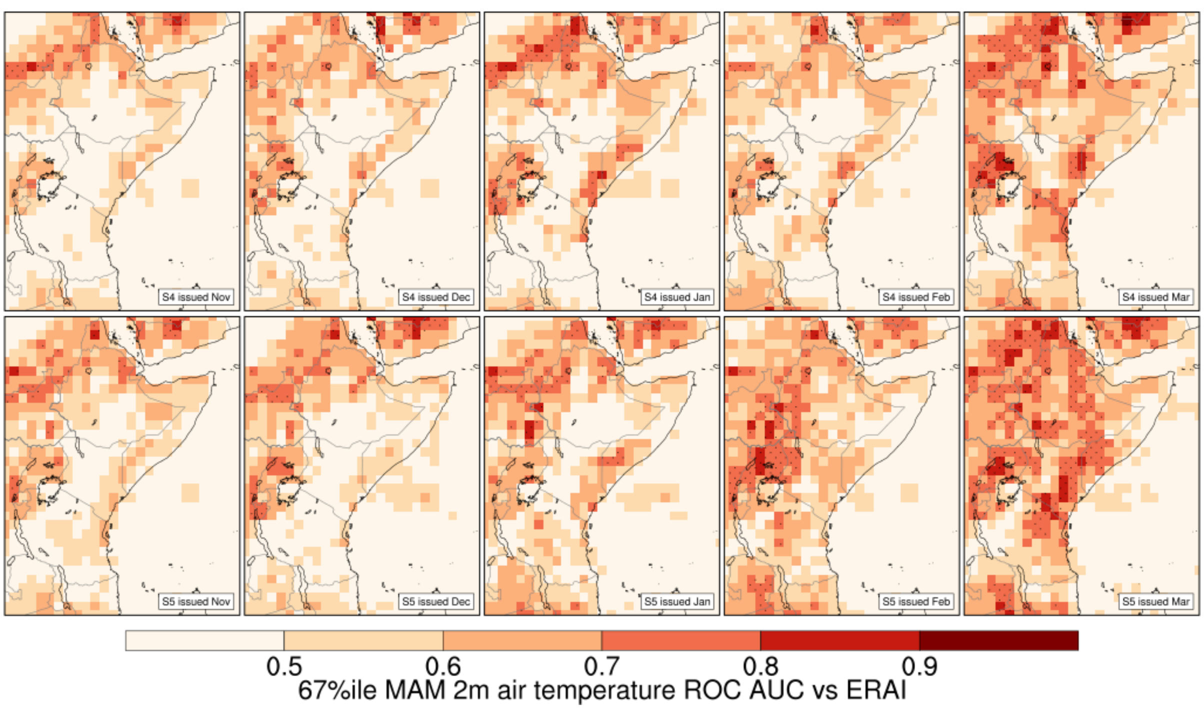

Figure 40. [ROC67MAM] ROC Area under curve for MAM: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

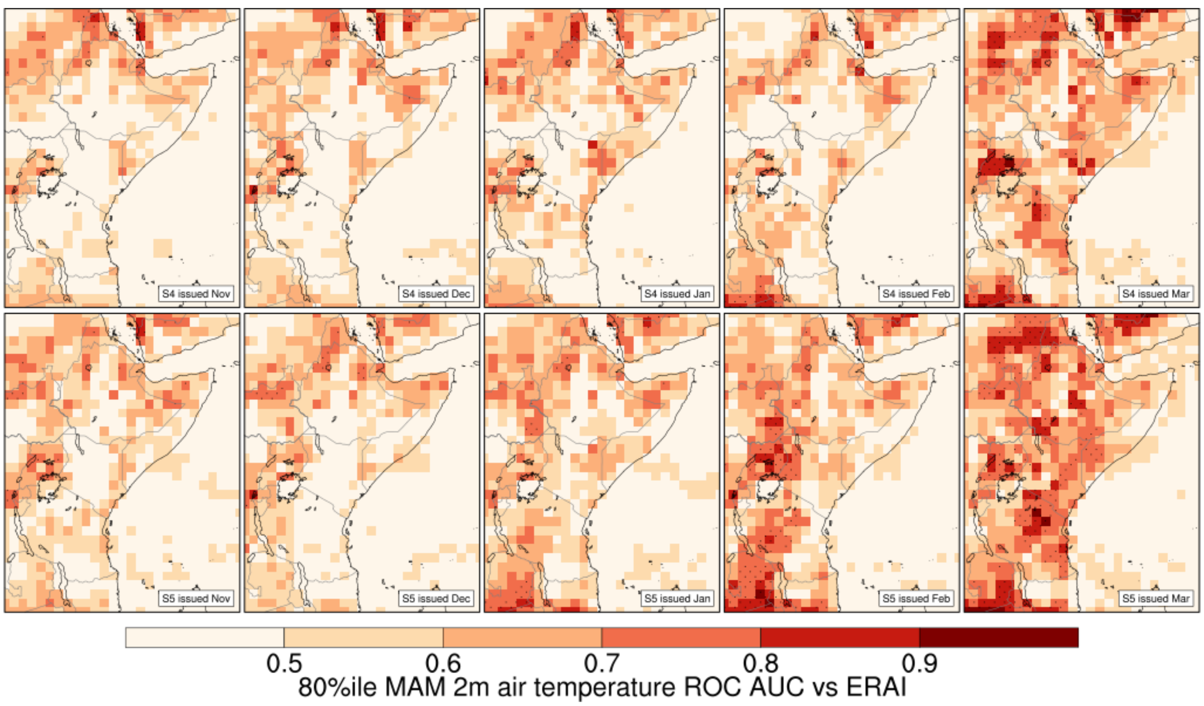

Figure 41. [ROC80MAM] ROC Area under curve for MAM: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

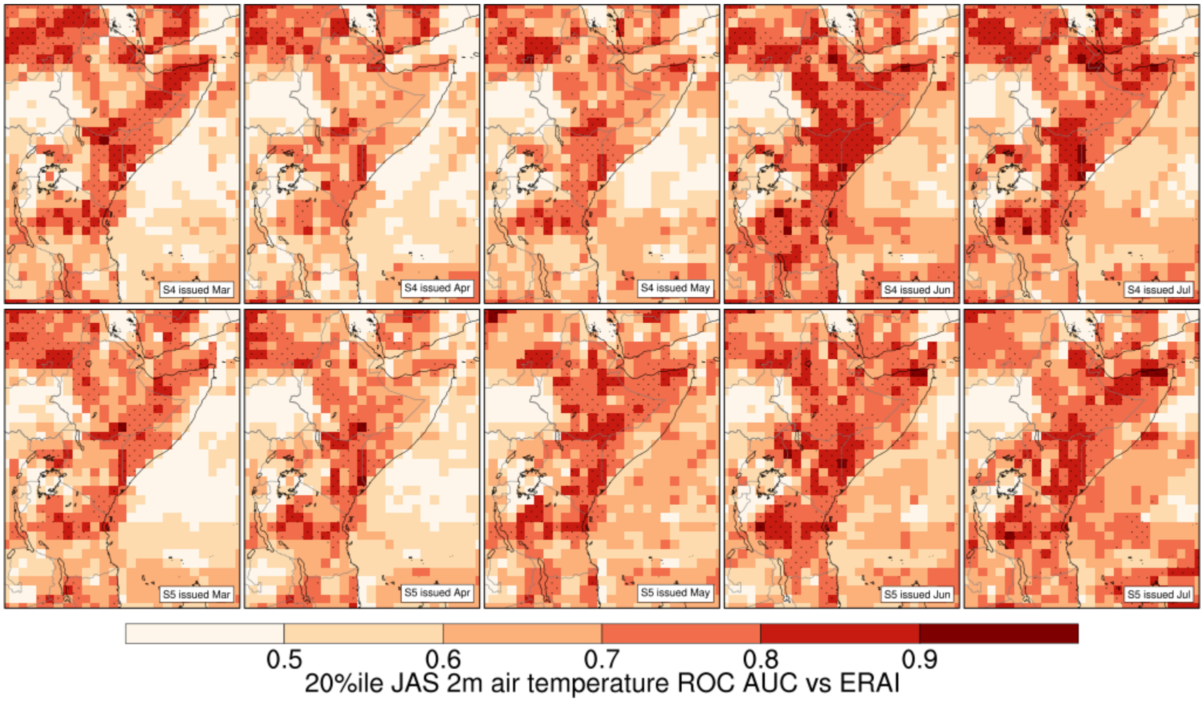

Figure 42. [ROC20JAS] ROC Area under curve for JAS: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

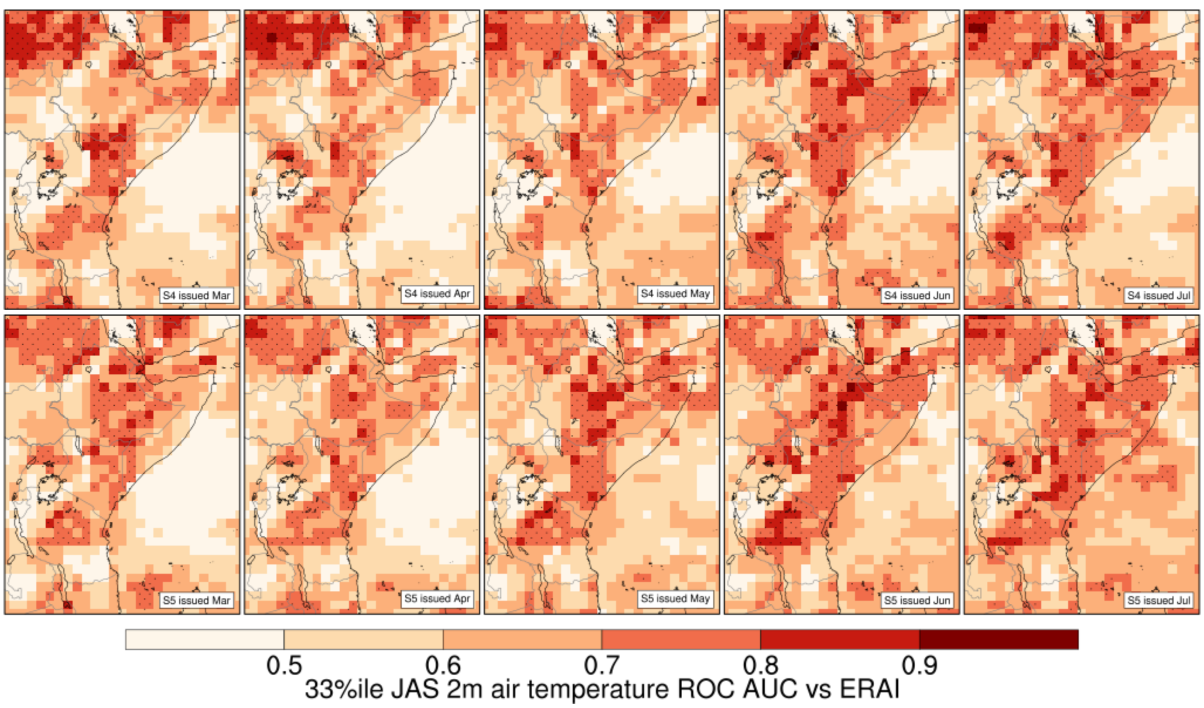

Figure 43. [ROC33JAS] ROC Area under curve for JAS: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

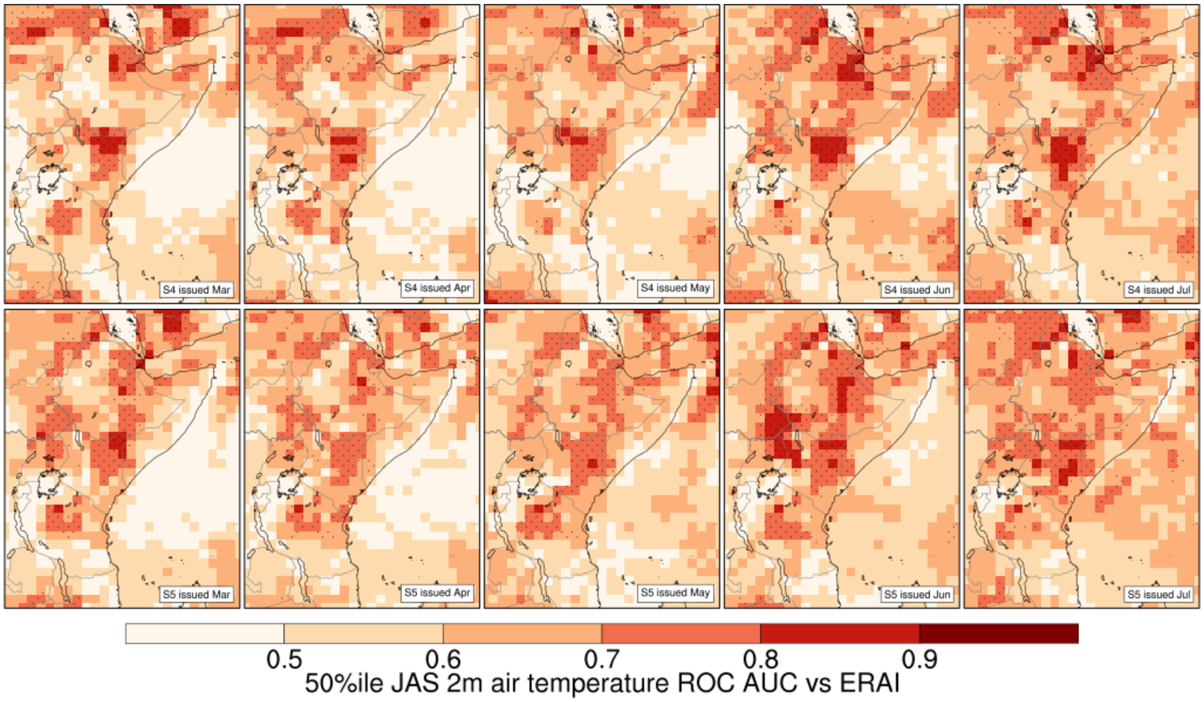

Figure 44. [ROC50JAS] ROC Area under curve for JAS: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

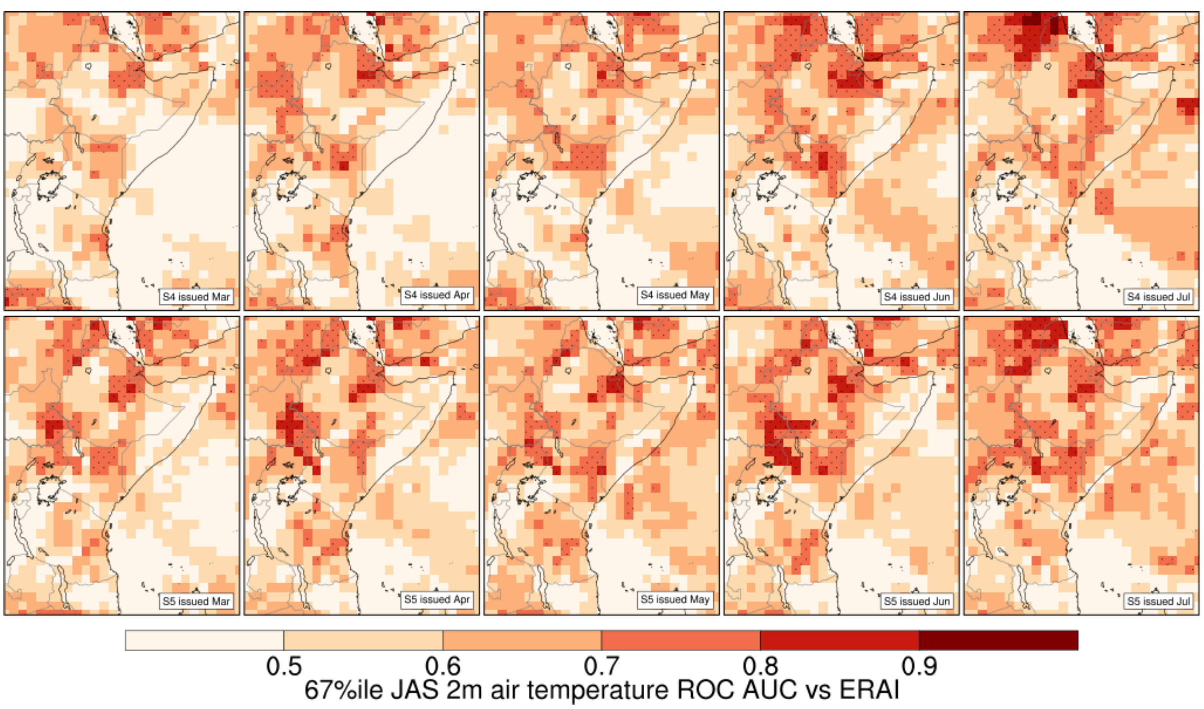

Figure 45. [ROC67JAS] ROC Area under curve for JAS: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

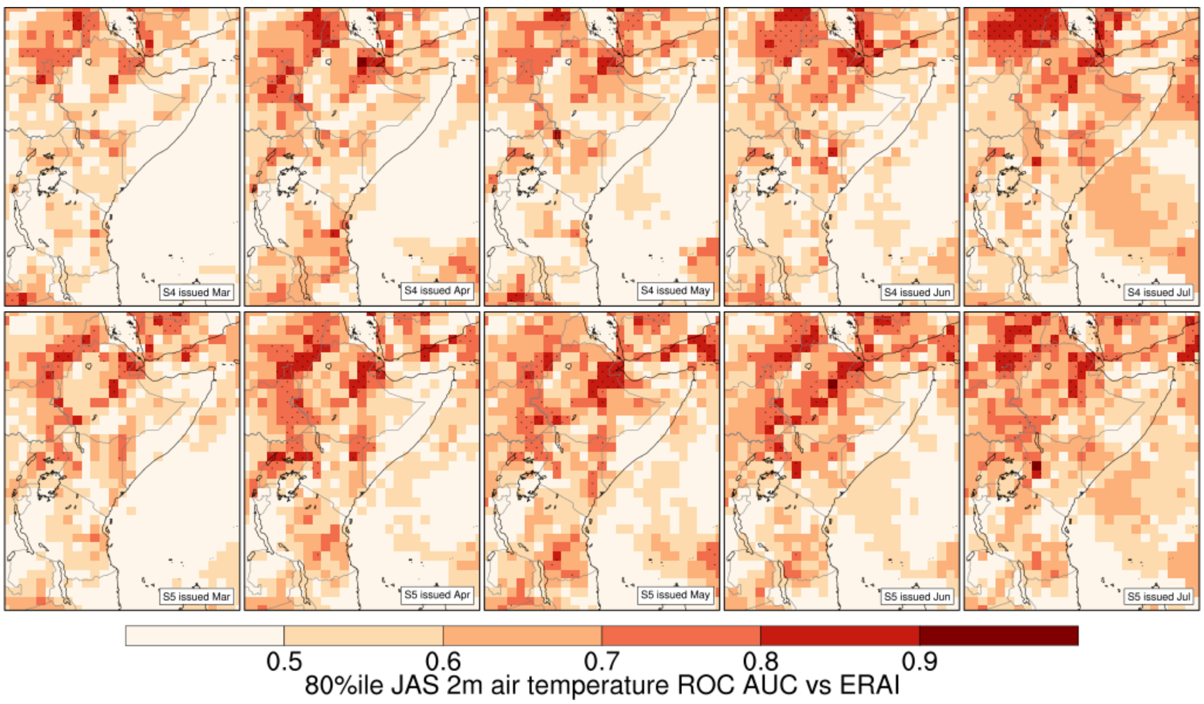

Figure 46. [ROC80JAS] ROC Area under curve for JAS: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

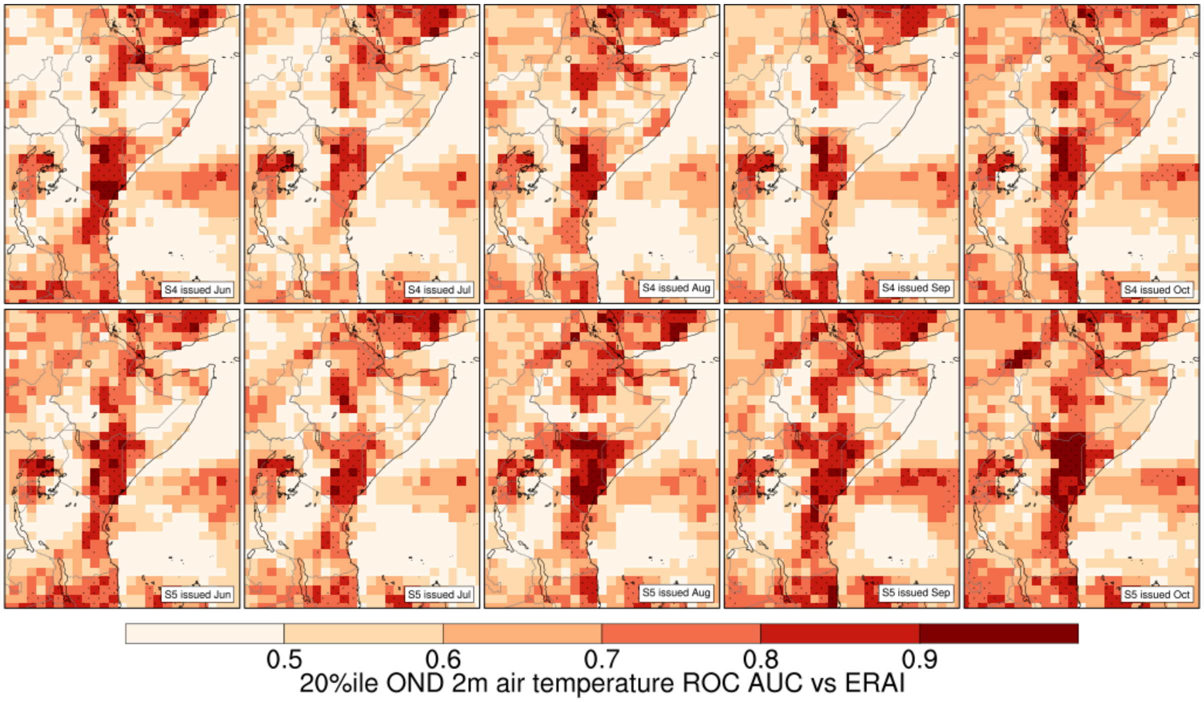

Figure 47. [ROC20OND] ROC Area under curve for OND: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

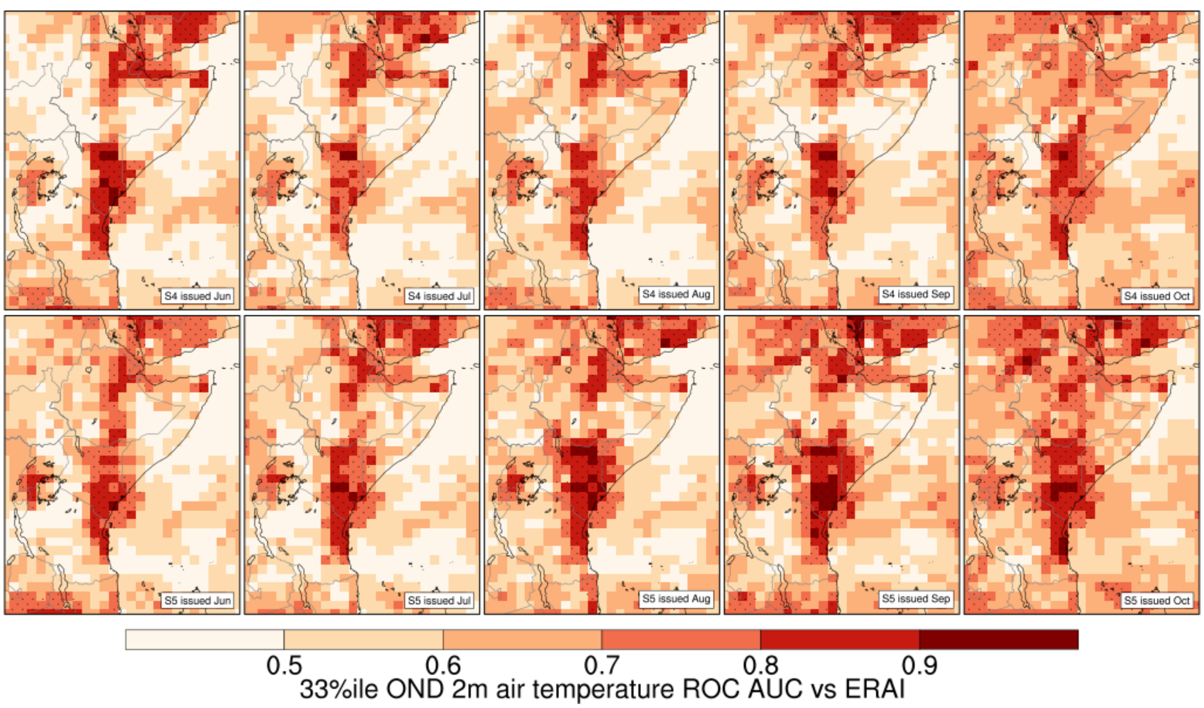

Figure 48. [ROC33OND] ROC Area under curve for OND: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

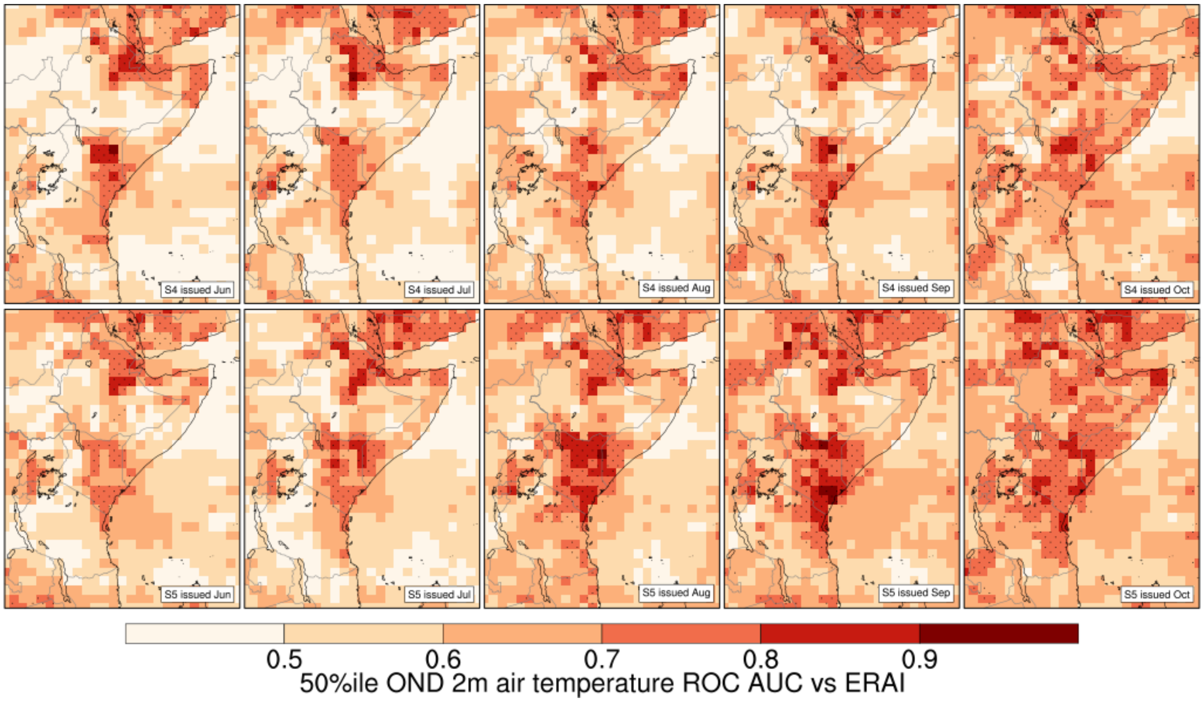

Figure 49. [ROC50OND] ROC Area under curve for OND: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

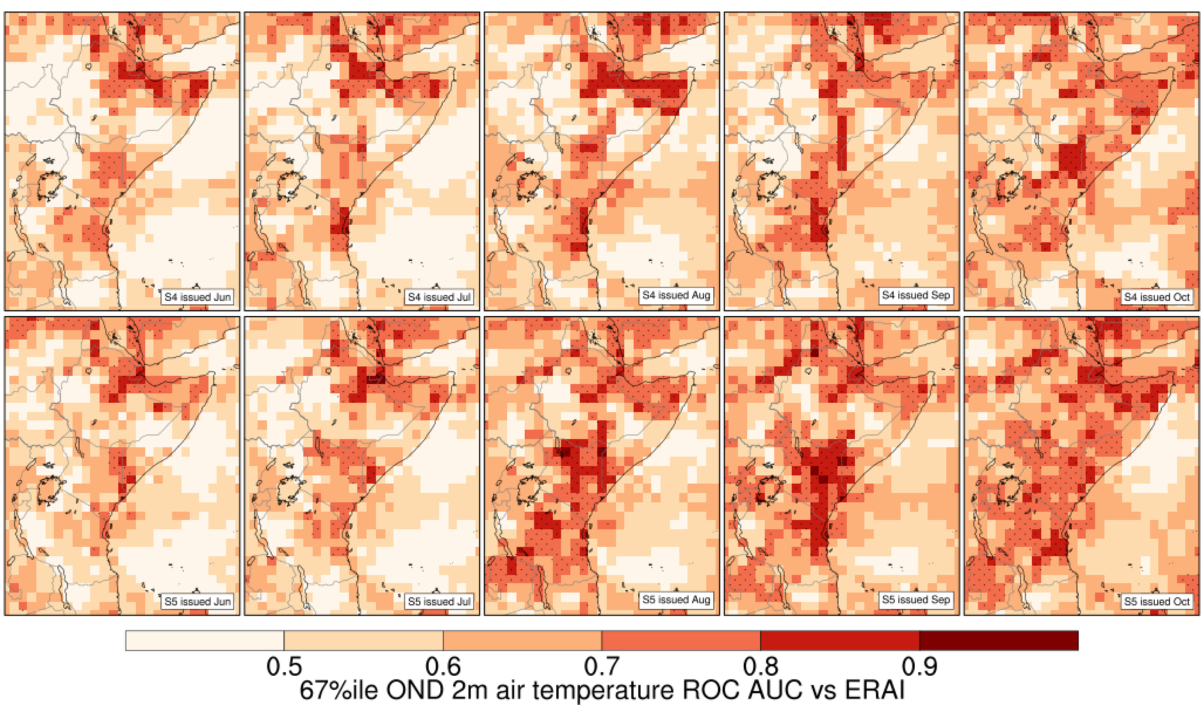

Figure 50. [ROC67OND] ROC Area under curve for OND: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

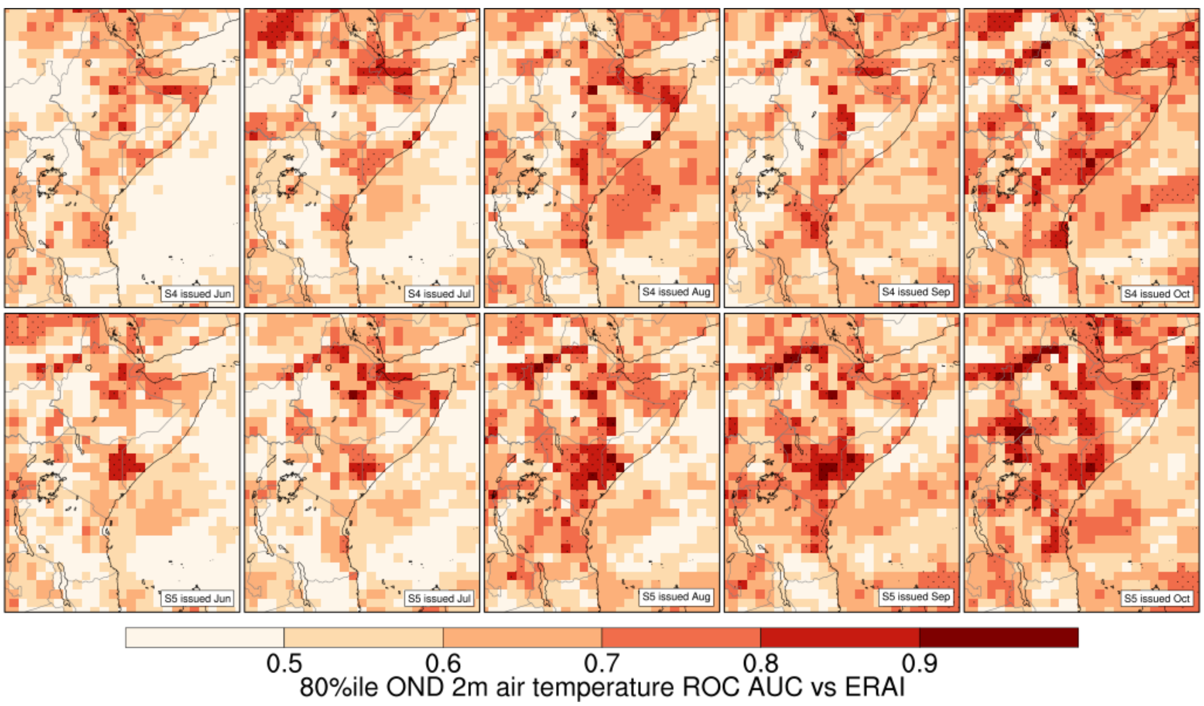

Figure 51. [ROC80OND] ROC Area under curve for OND: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

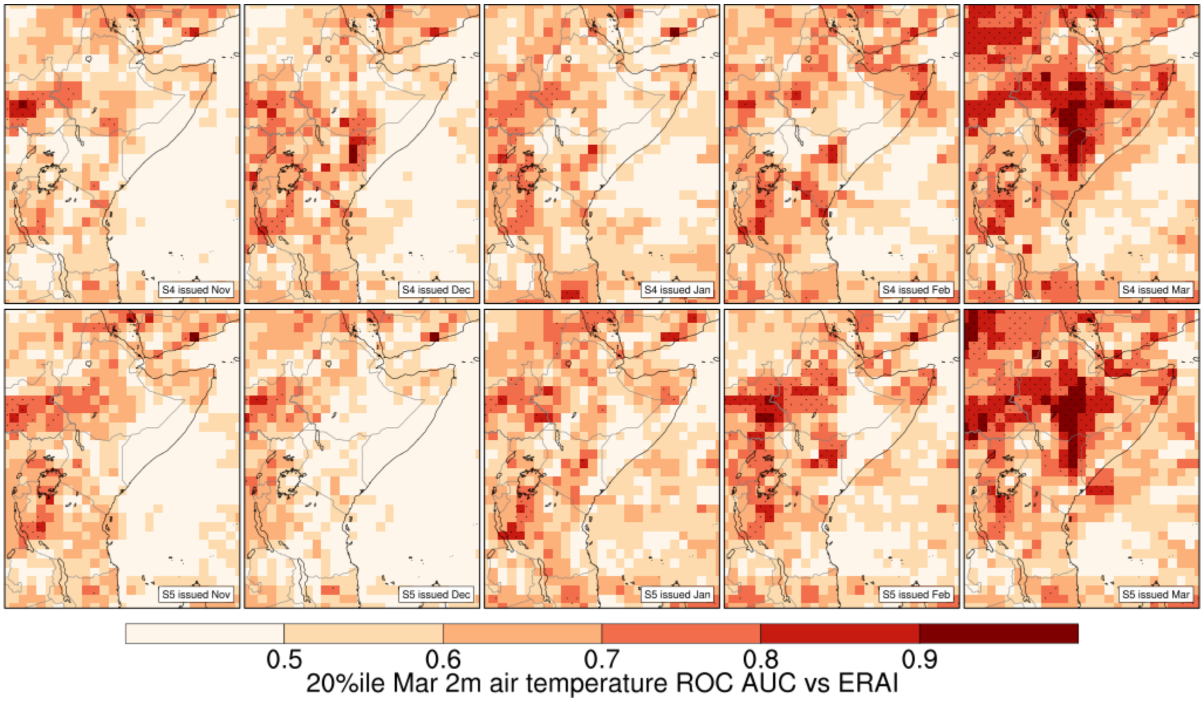

Figure 52. [ROC20Mar] ROC Area under curve for Mar: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

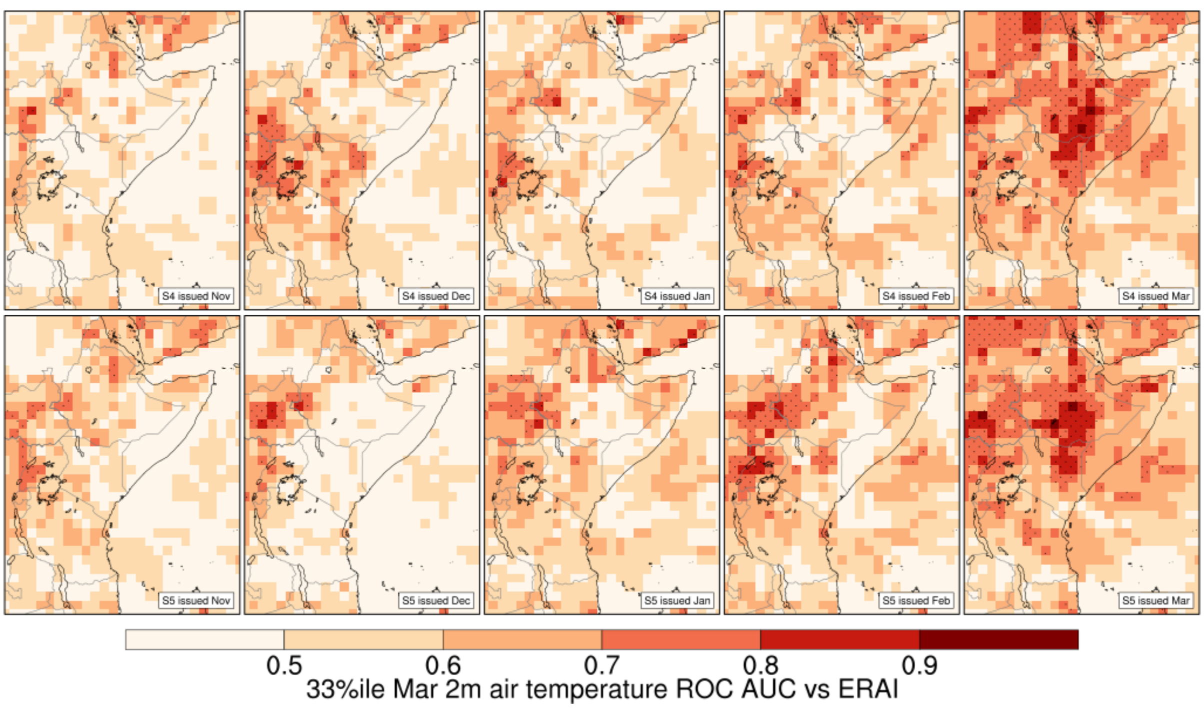

Figure 53. [ROC33Mar] ROC Area under curve for Mar: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

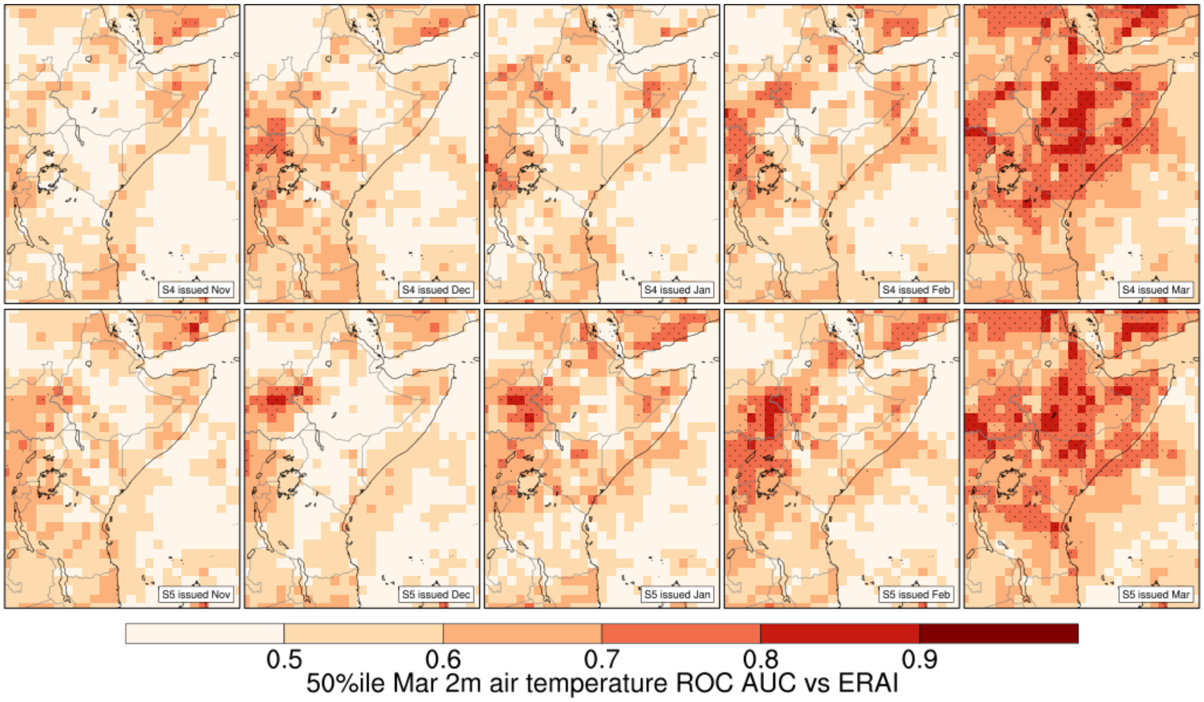

Figure 54. [ROC50Mar] ROC Area under curve for Mar: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

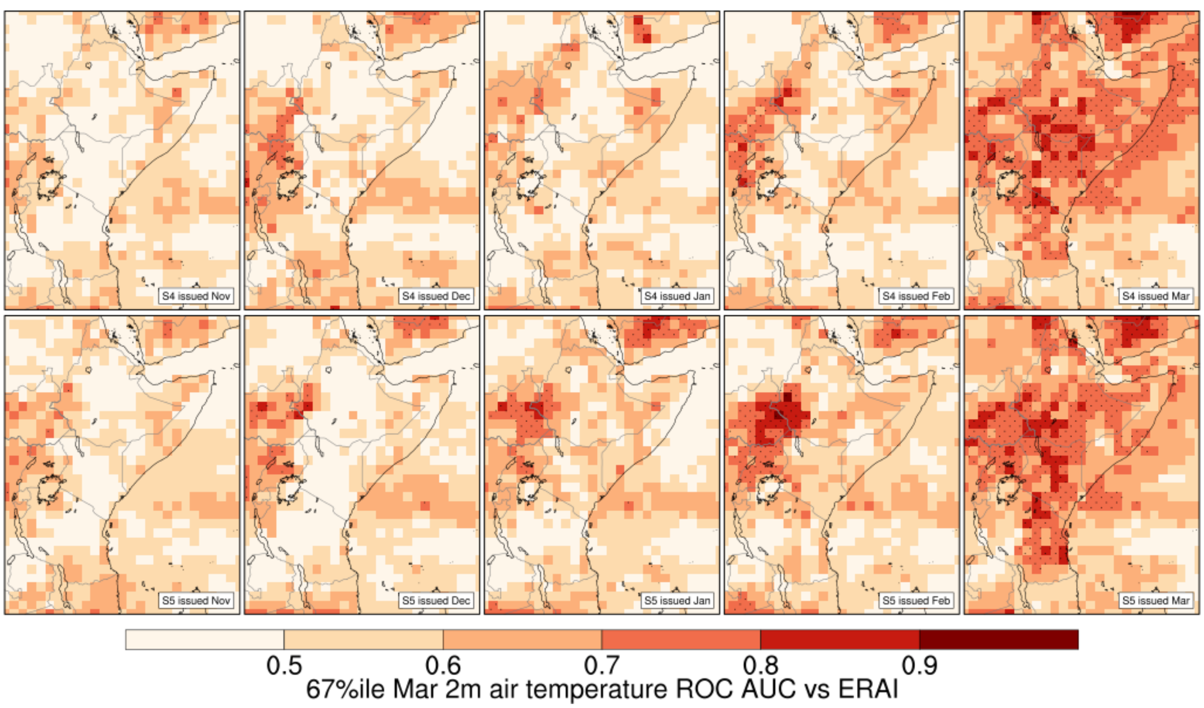

Figure 55. [ROC67Mar] ROC Area under curve for Mar: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

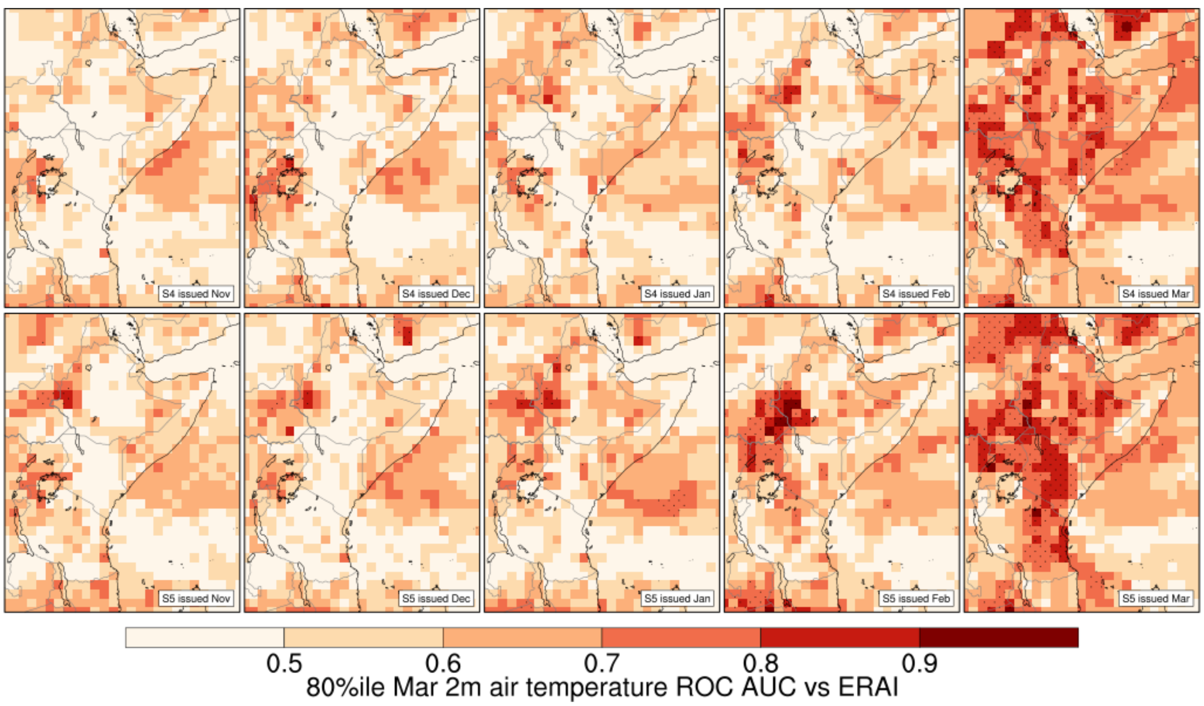

Figure 56. [ROC80Mar] ROC Area under curve for Mar: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

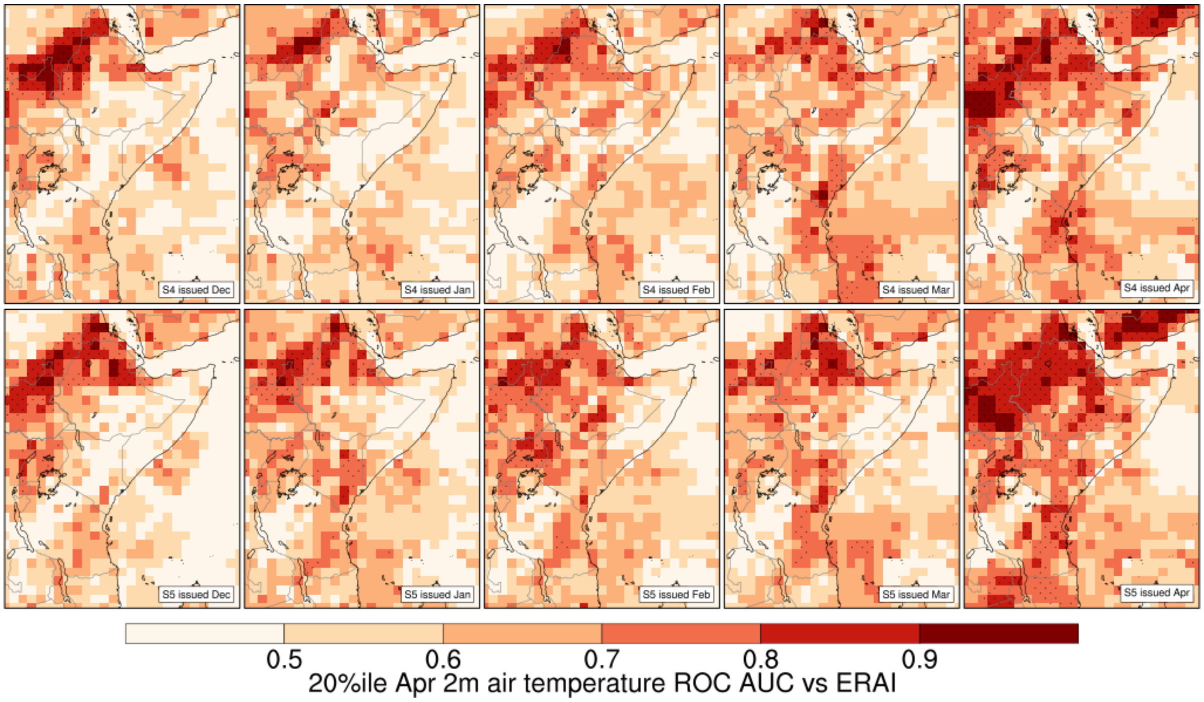

Figure 57. [ROC20Apr] ROC Area under curve for Apr: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

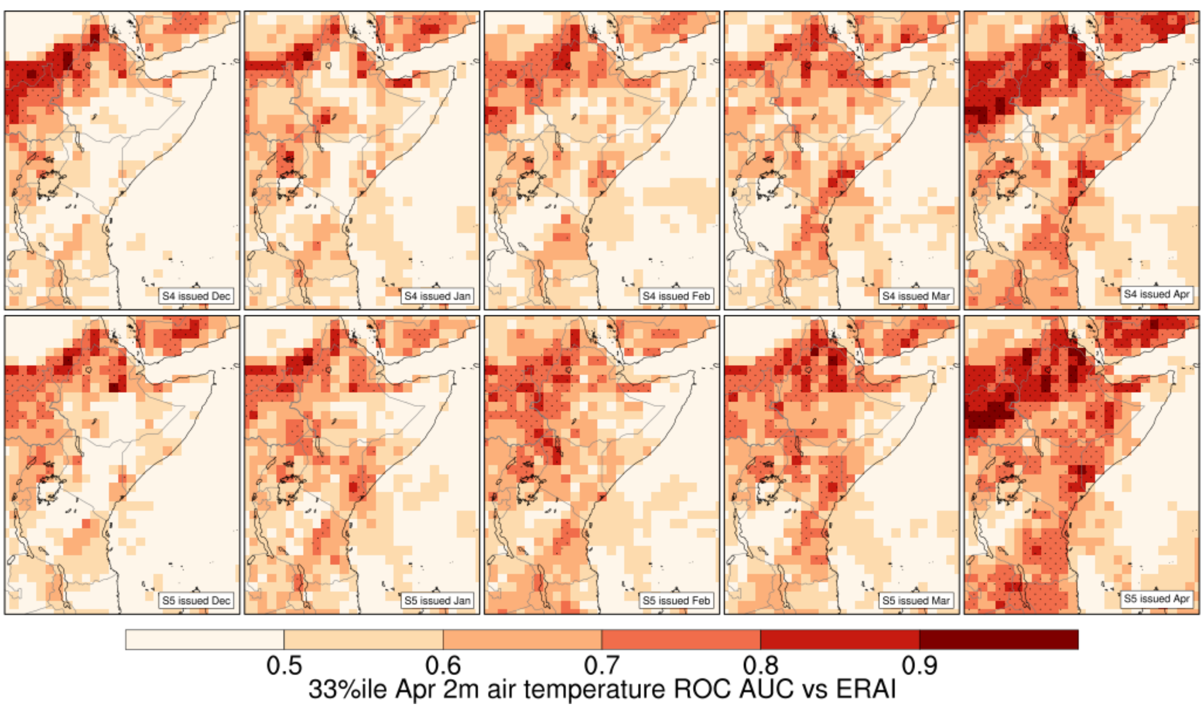

Figure 58. [ROC33Apr] ROC Area under curve for Apr: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

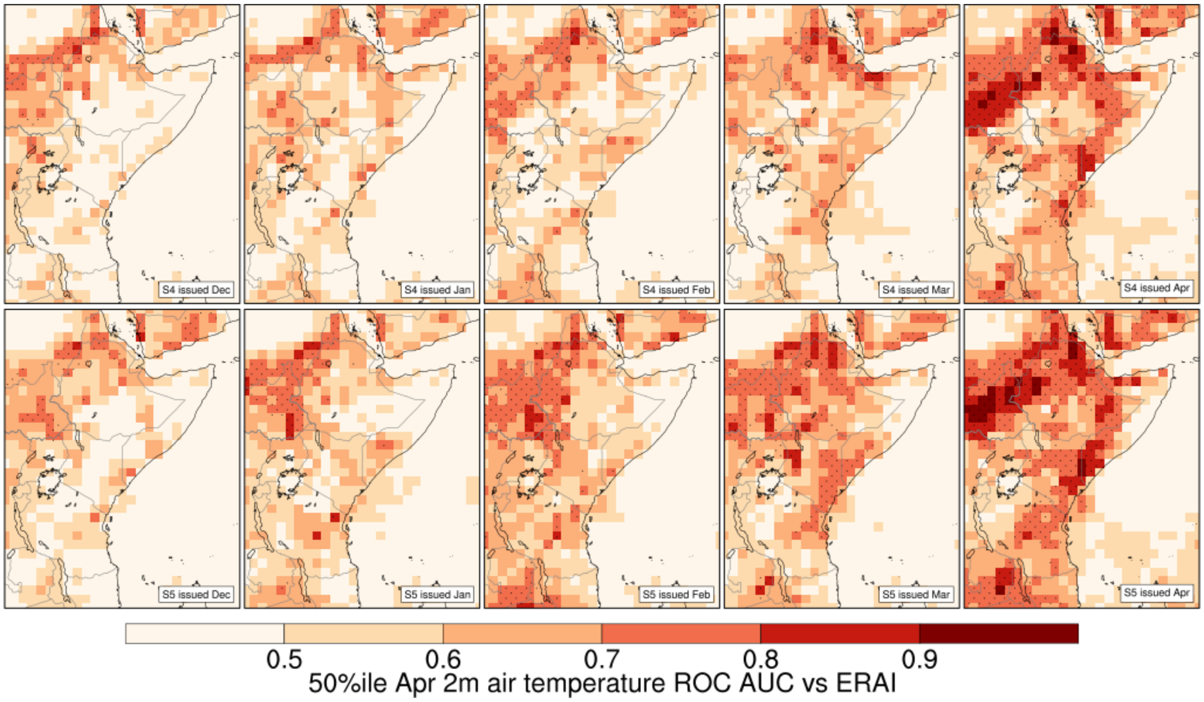

Figure 59. [ROC50Apr] ROC Area under curve for Apr: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

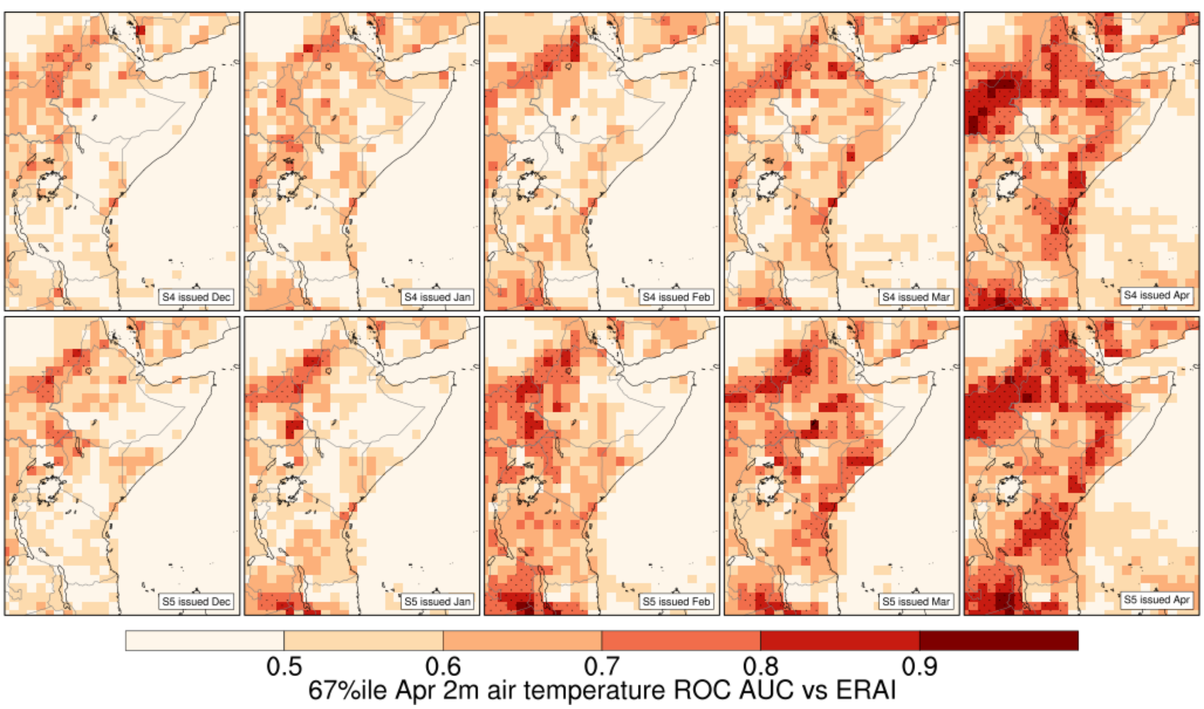

Figure 60. [ROC67Apr] ROC Area under curve for Apr: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

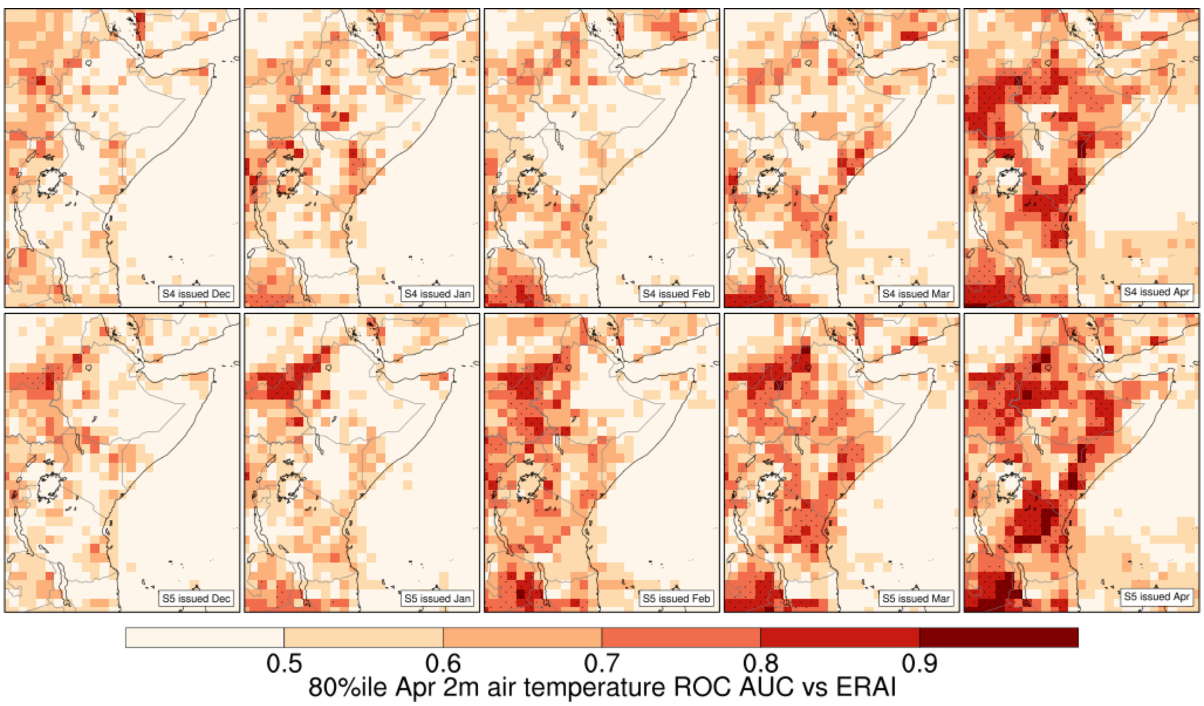

Figure 61. [ROC80Apr] ROC Area under curve for Apr: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

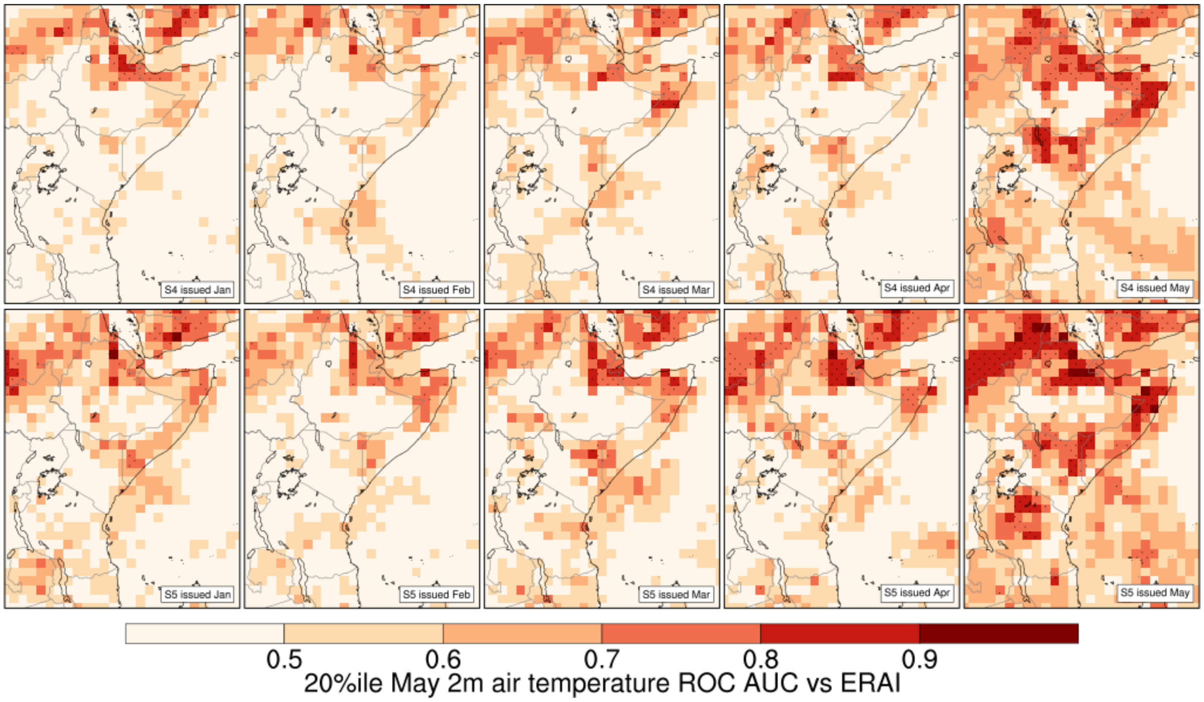

Figure 62. [ROC20May] ROC Area under curve for May: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

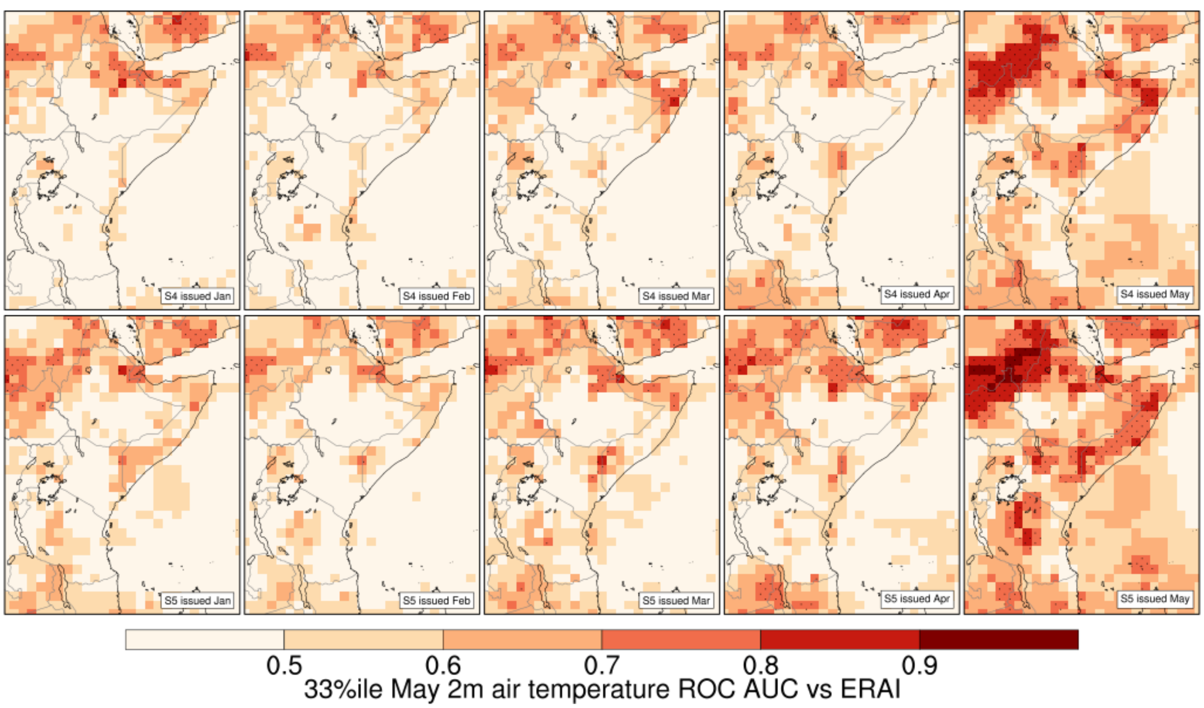

Figure 63. [ROC33May] ROC Area under curve for May: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

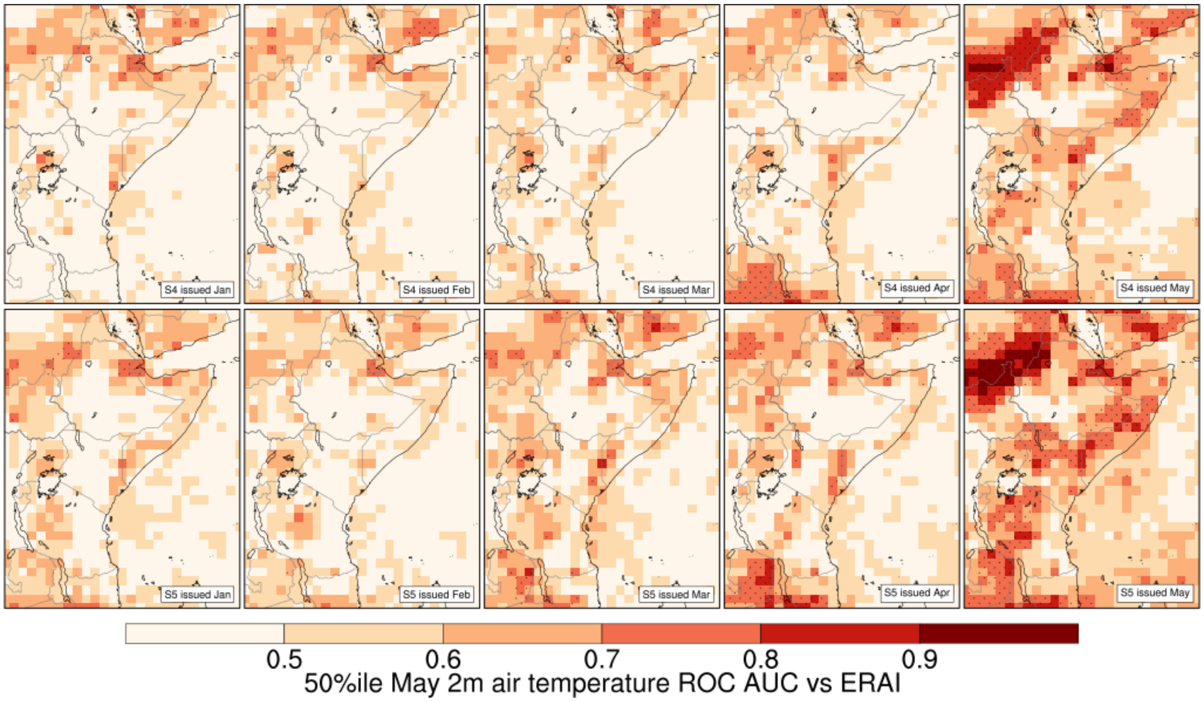

Figure 64. [ROC50May] ROC Area under curve for May: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

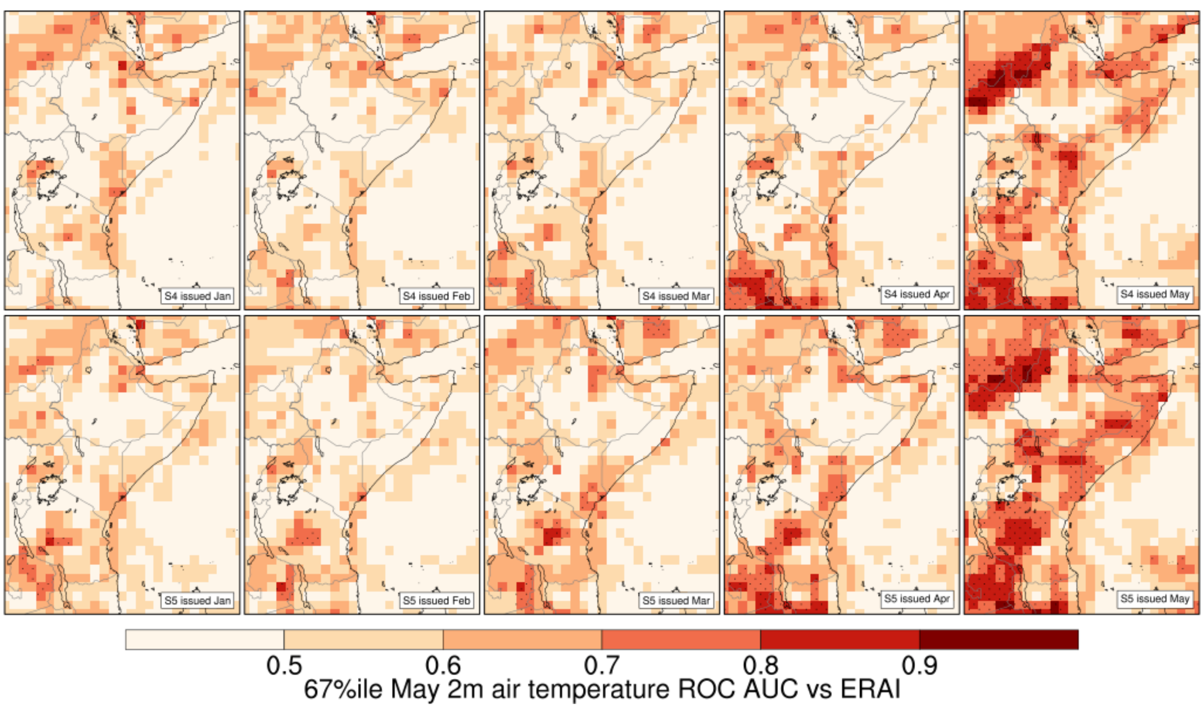

Figure 65. [ROC67May] ROC Area under curve for May: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

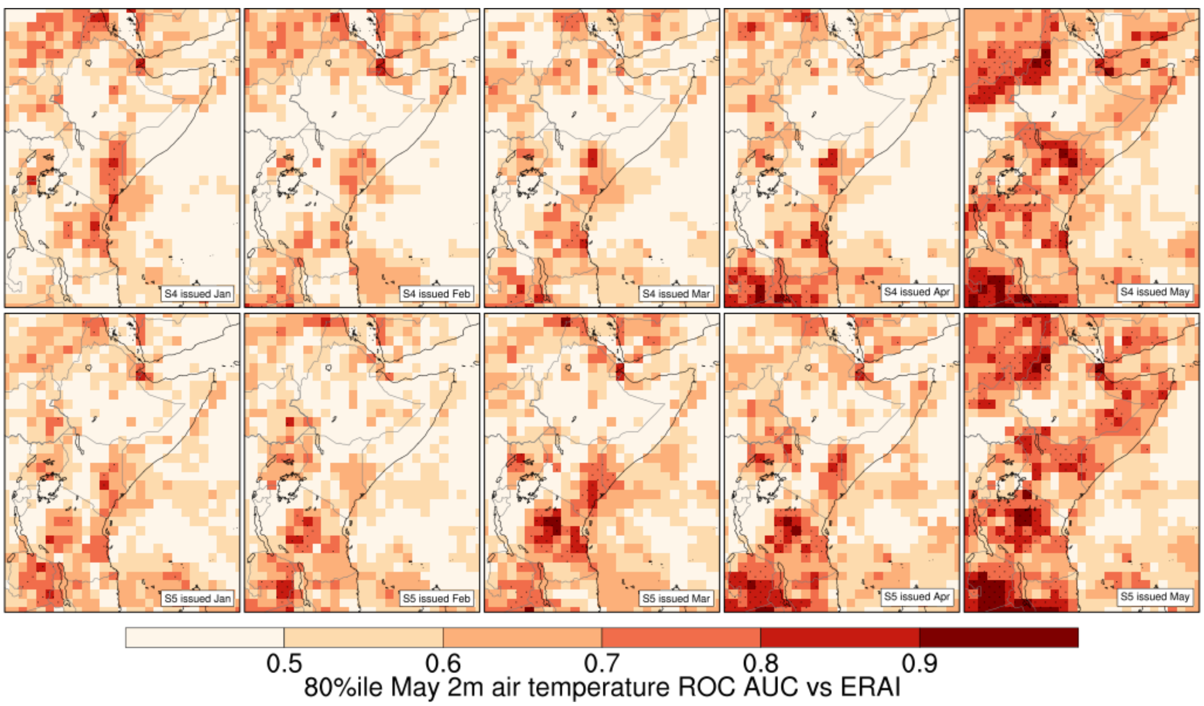

Figure 66. [ROC80May] ROC Area under curve for May: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

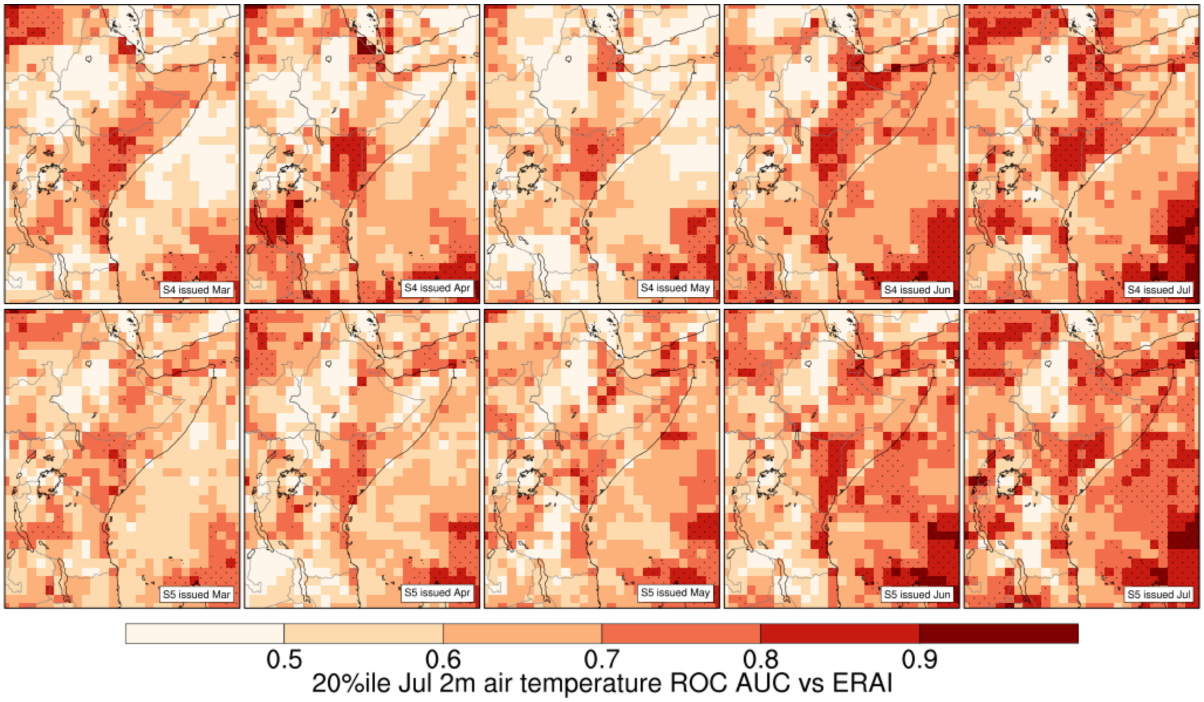

Figure 67. [ROC20Jul] ROC Area under curve for Jul: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

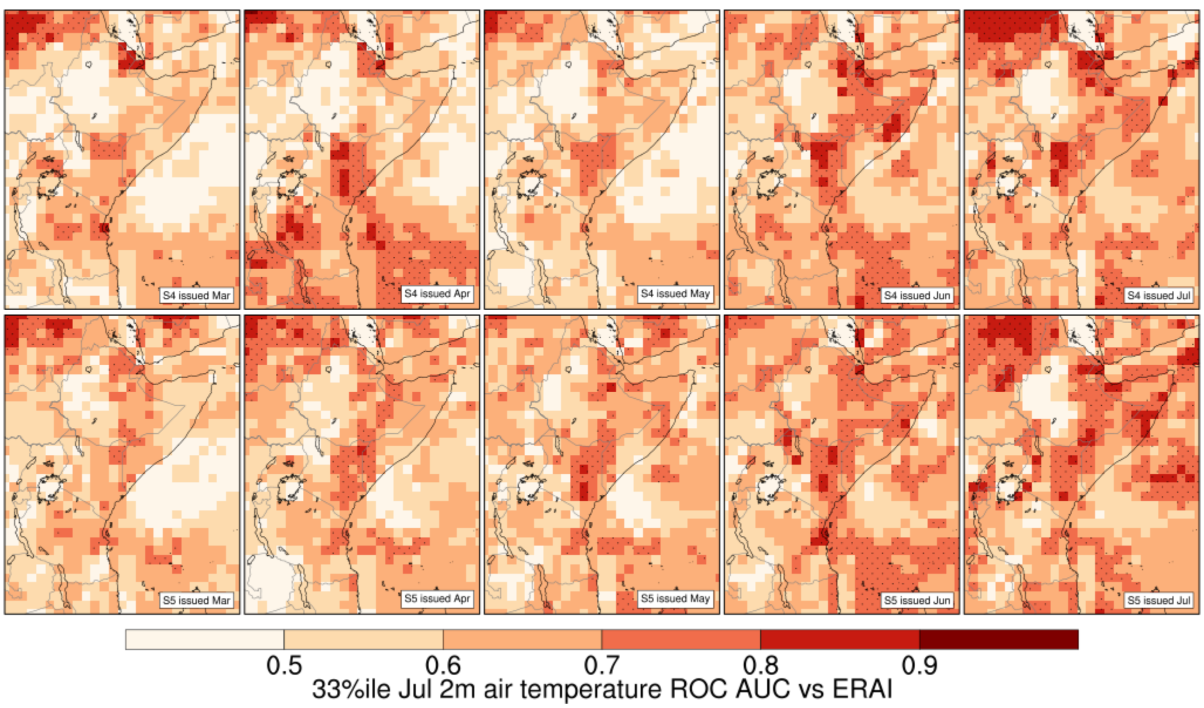

Figure 68. [ROC33Jul] ROC Area under curve for Jul: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

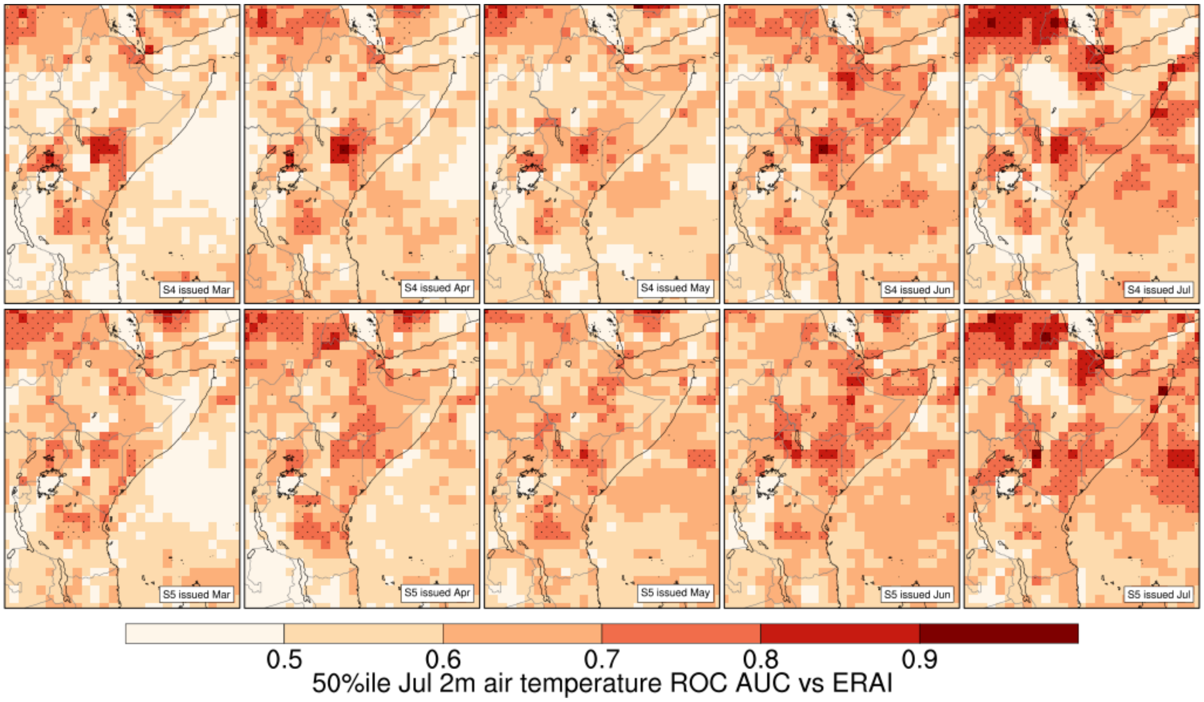

Figure 69. [ROC50Jul] ROC Area under curve for Jul: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

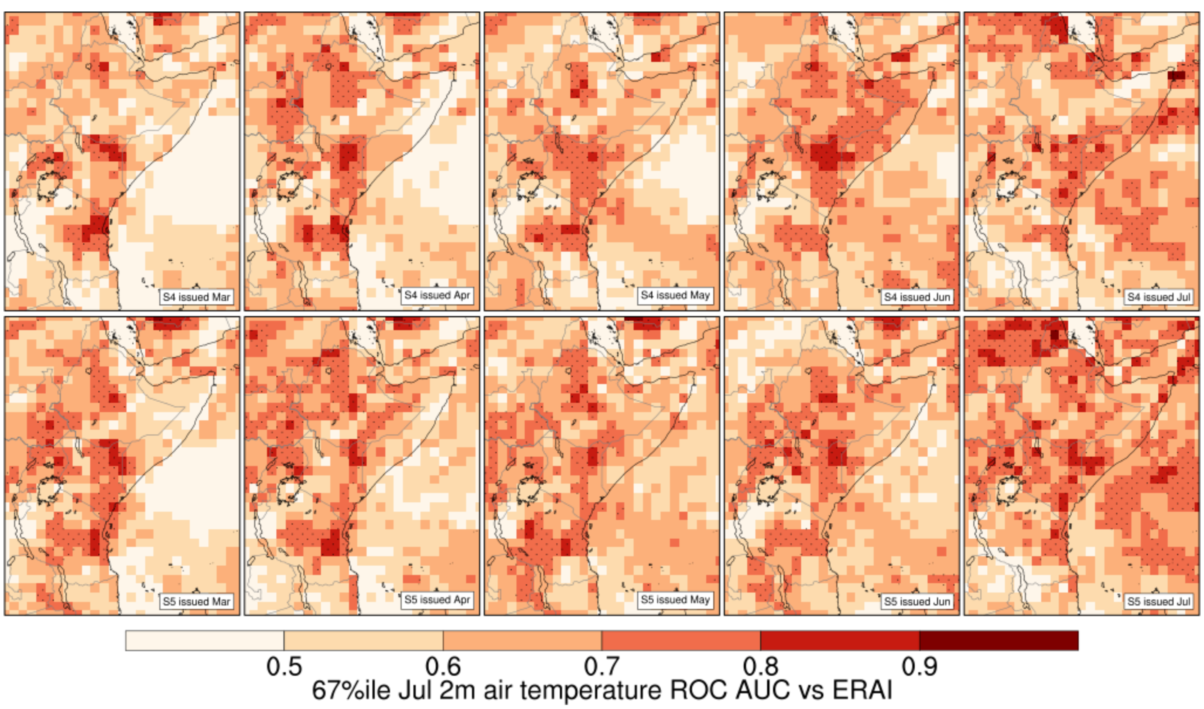

Figure 70. [ROC67Jul] ROC Area under curve for Jul: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

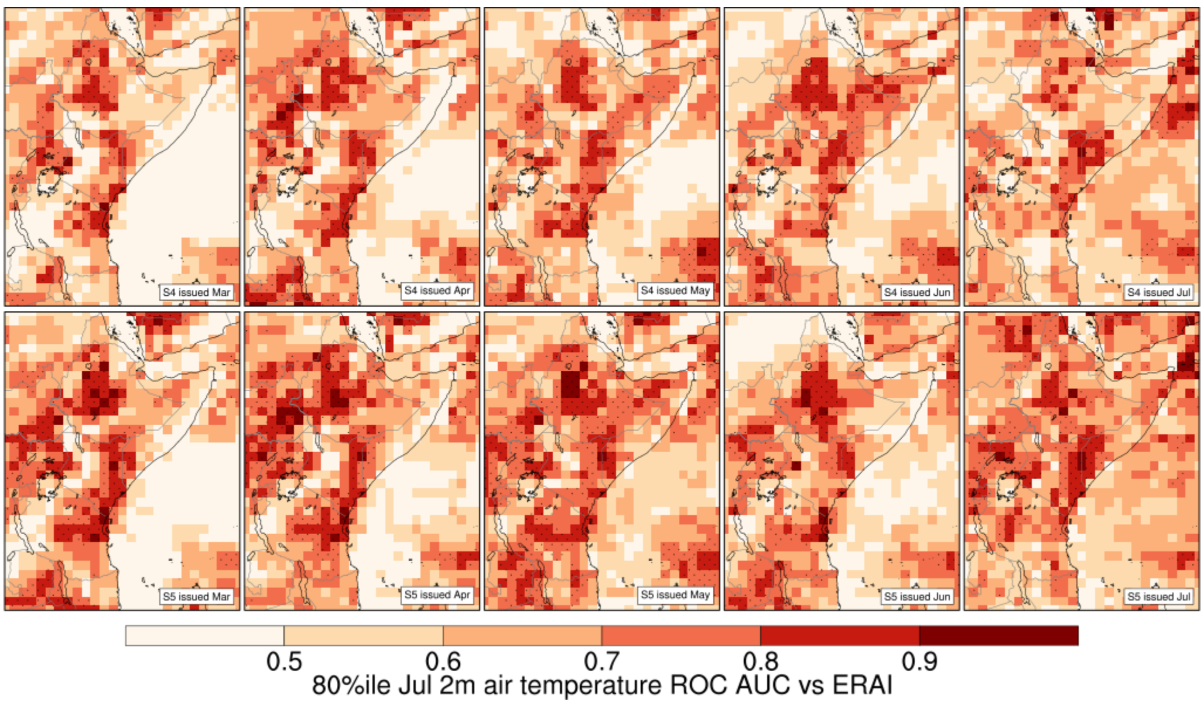

Figure 71. [ROC80Jul] ROC Area under curve for Jul: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

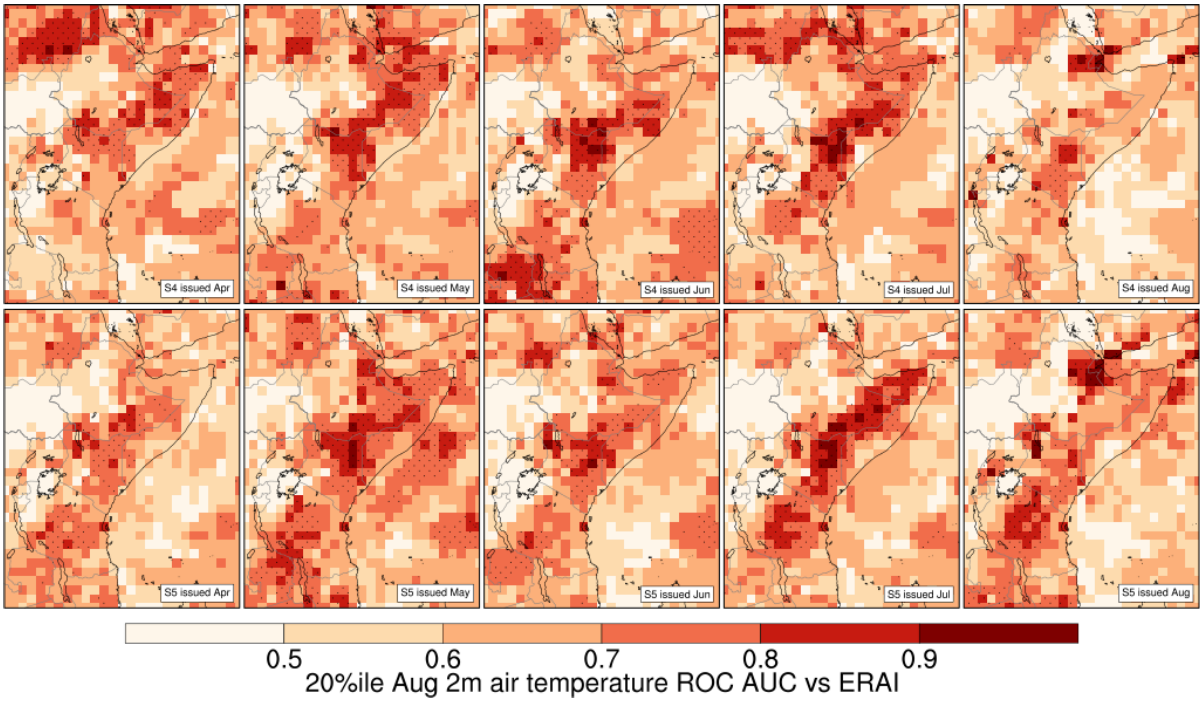

Figure 72. [ROC20Aug] ROC Area under curve for Aug: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

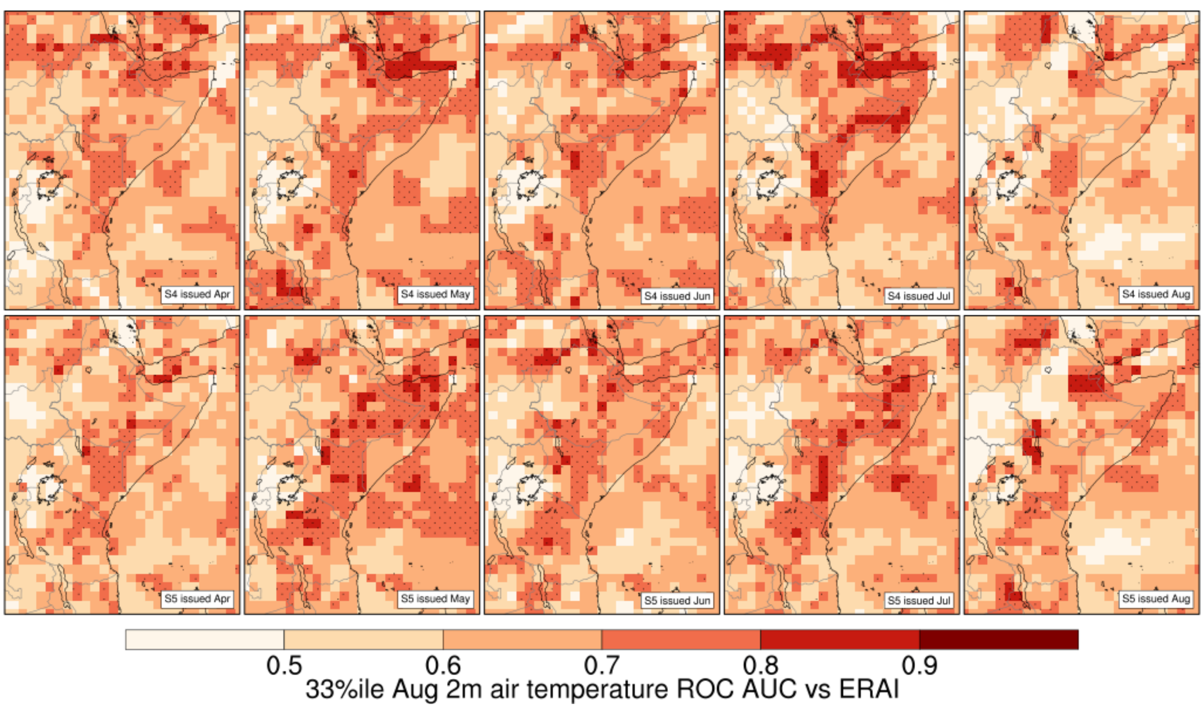

Figure 73. [ROC33Aug] ROC Area under curve for Aug: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

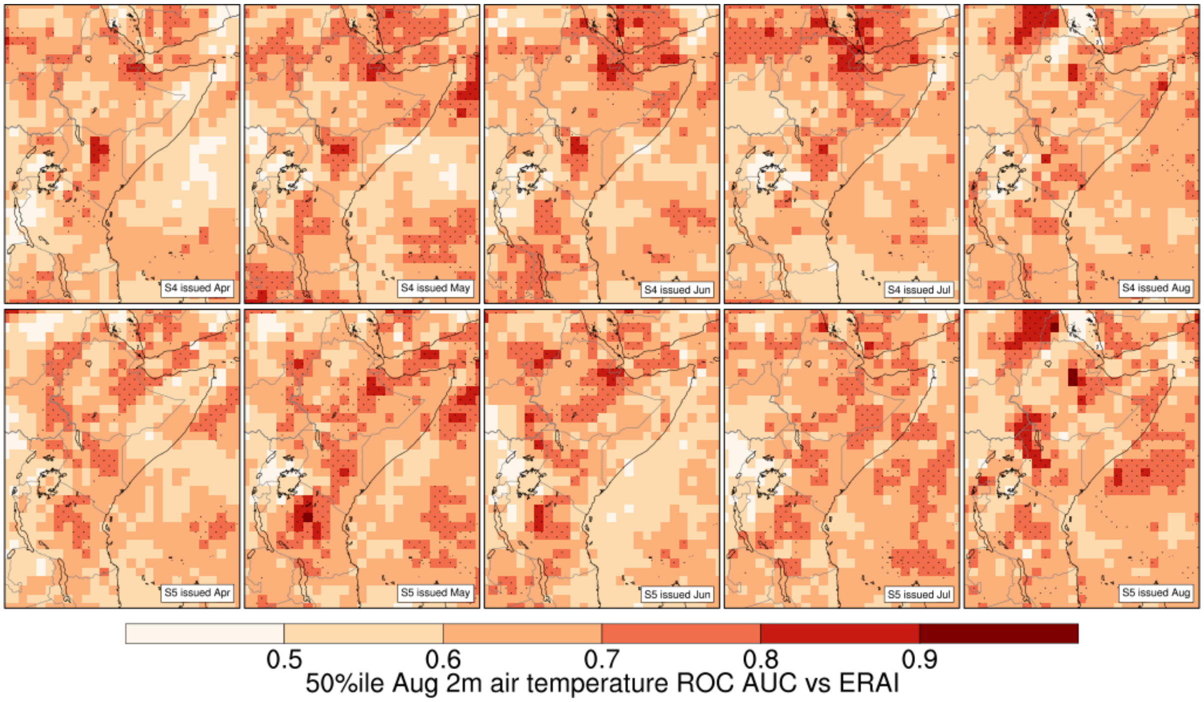

Figure 74. [ROC50Aug] ROC Area under curve for Aug: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

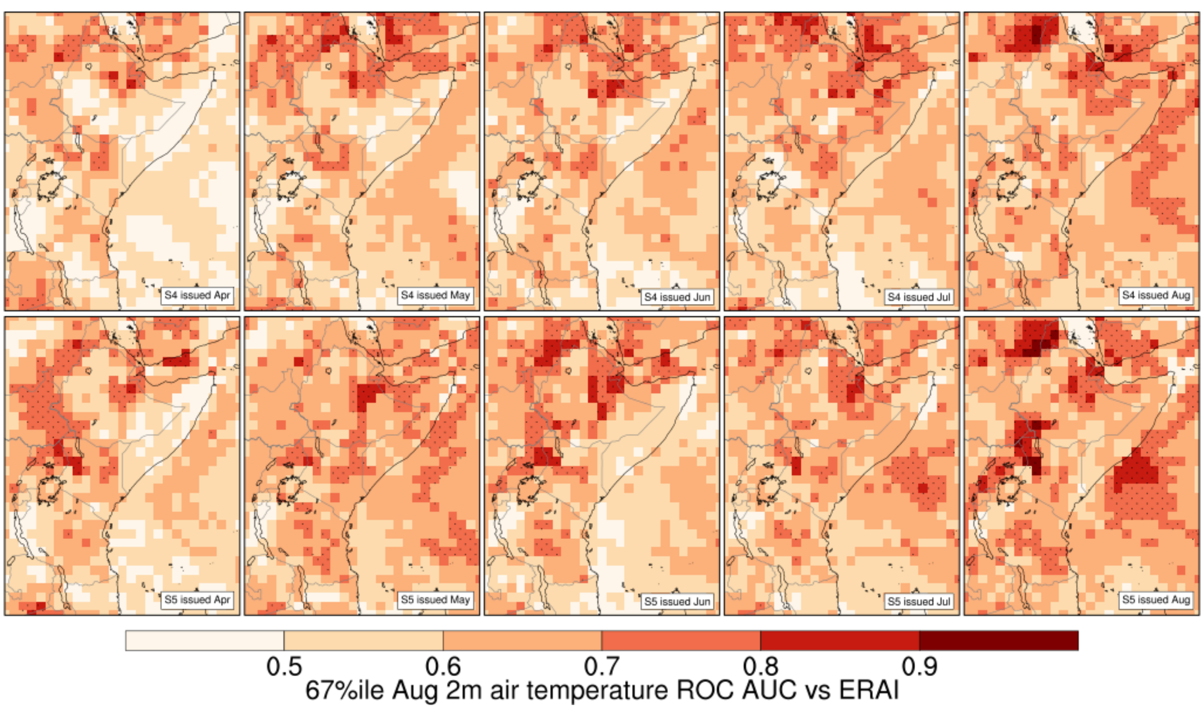

Figure 75. [ROC67Aug] ROC Area under curve for Aug: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

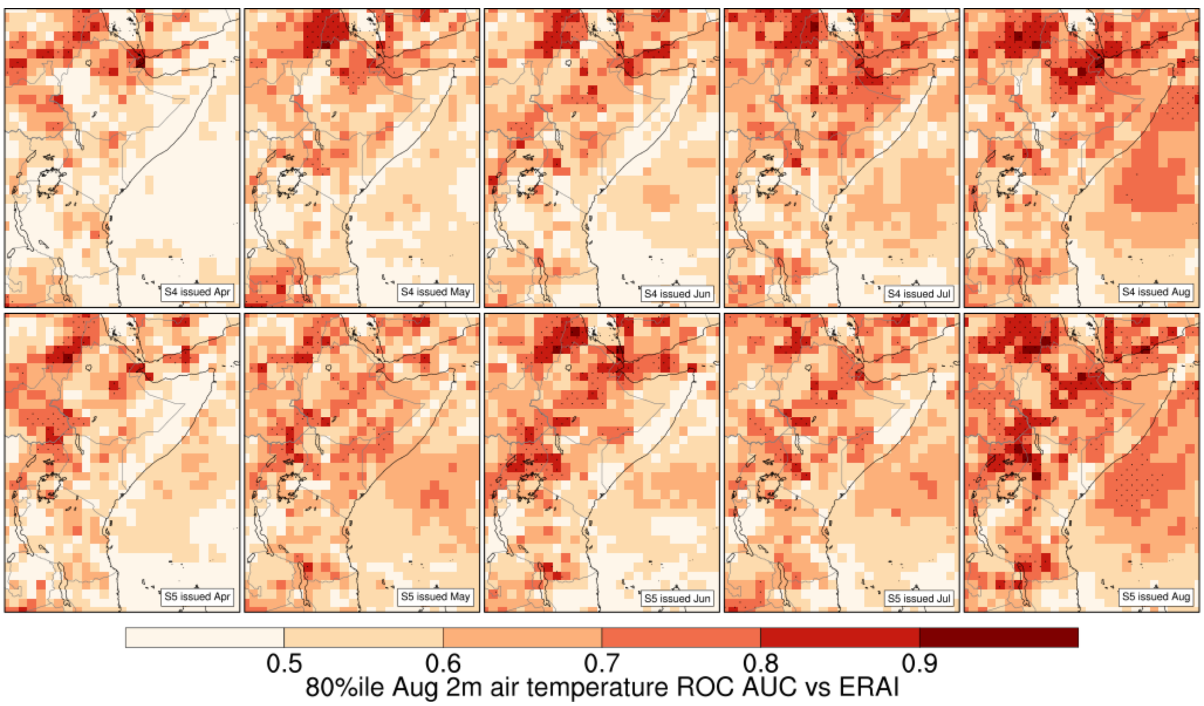

Figure 76. [ROC80Aug] ROC Area under curve for Aug: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

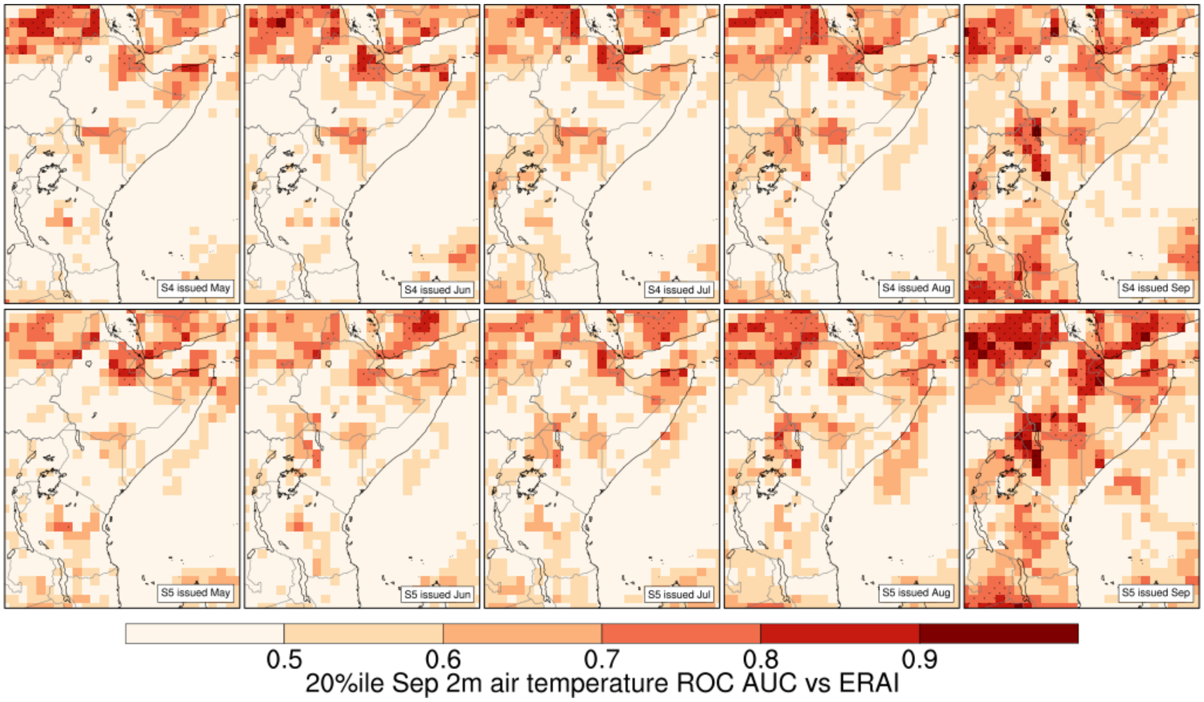

Figure 77. [ROC20Sep] ROC Area under curve for Sep: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

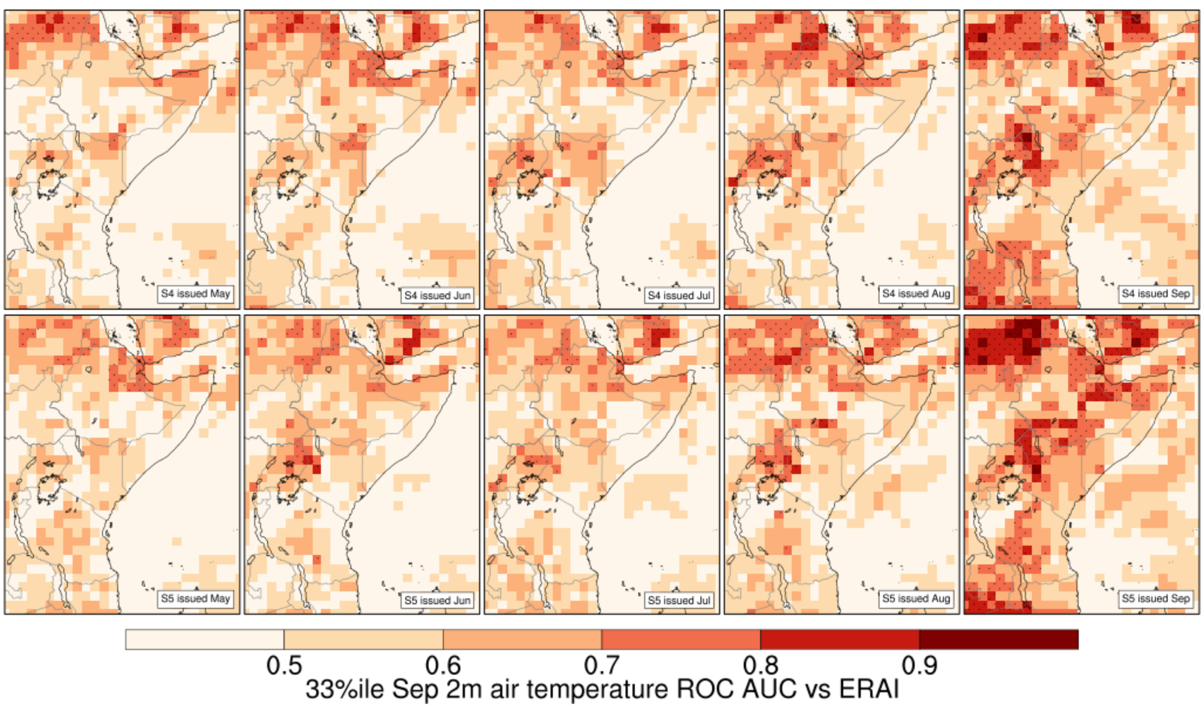

Figure 78. [ROC33Sep] ROC Area under curve for Sep: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

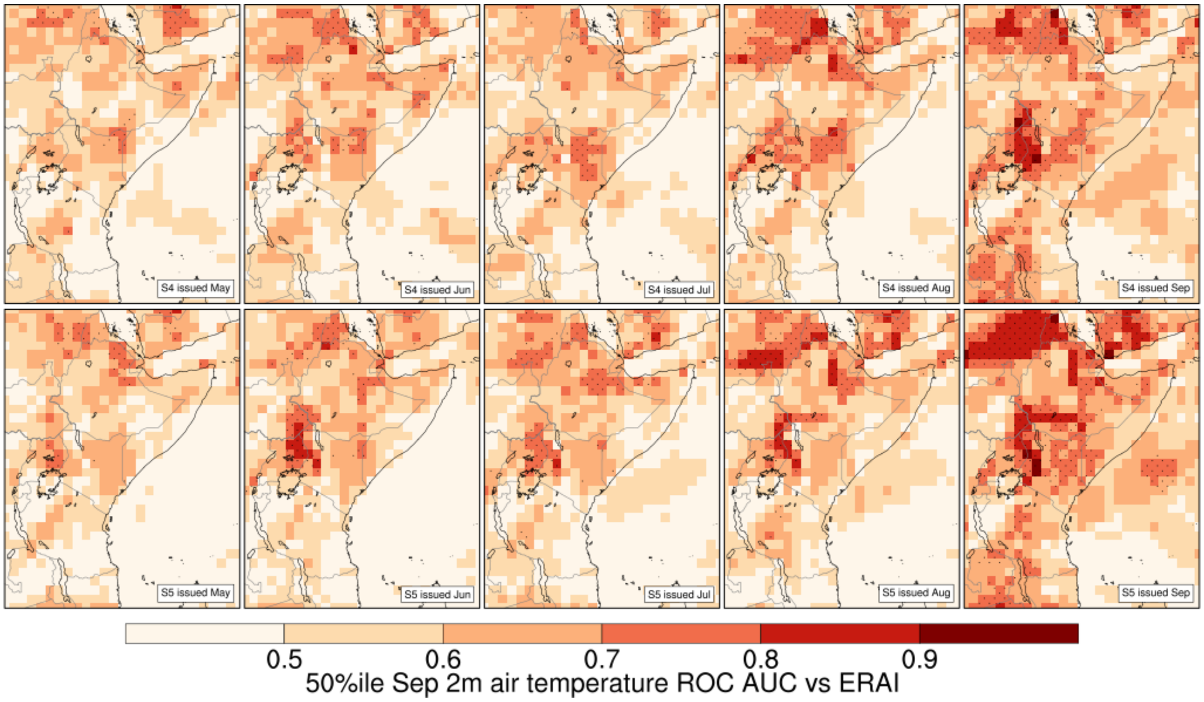

Figure 79. [ROC50Sep] ROC Area under curve for Sep: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

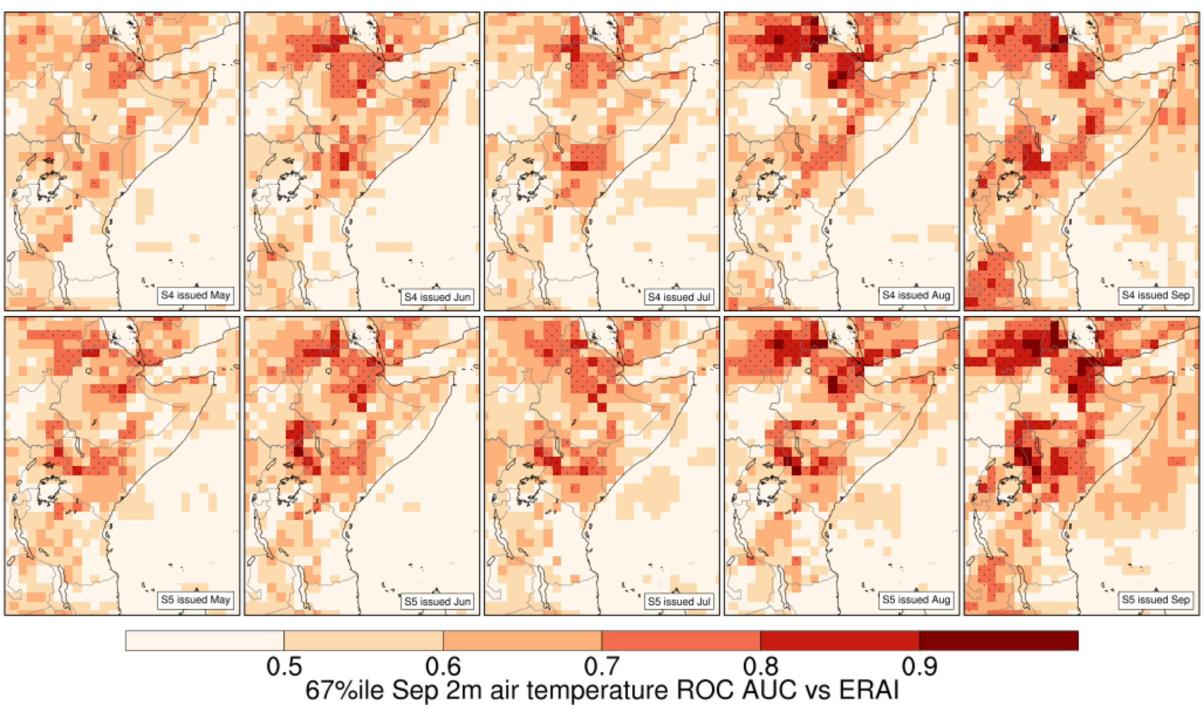

Figure 80. [ROC67Sep] ROC Area under curve for Sep: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

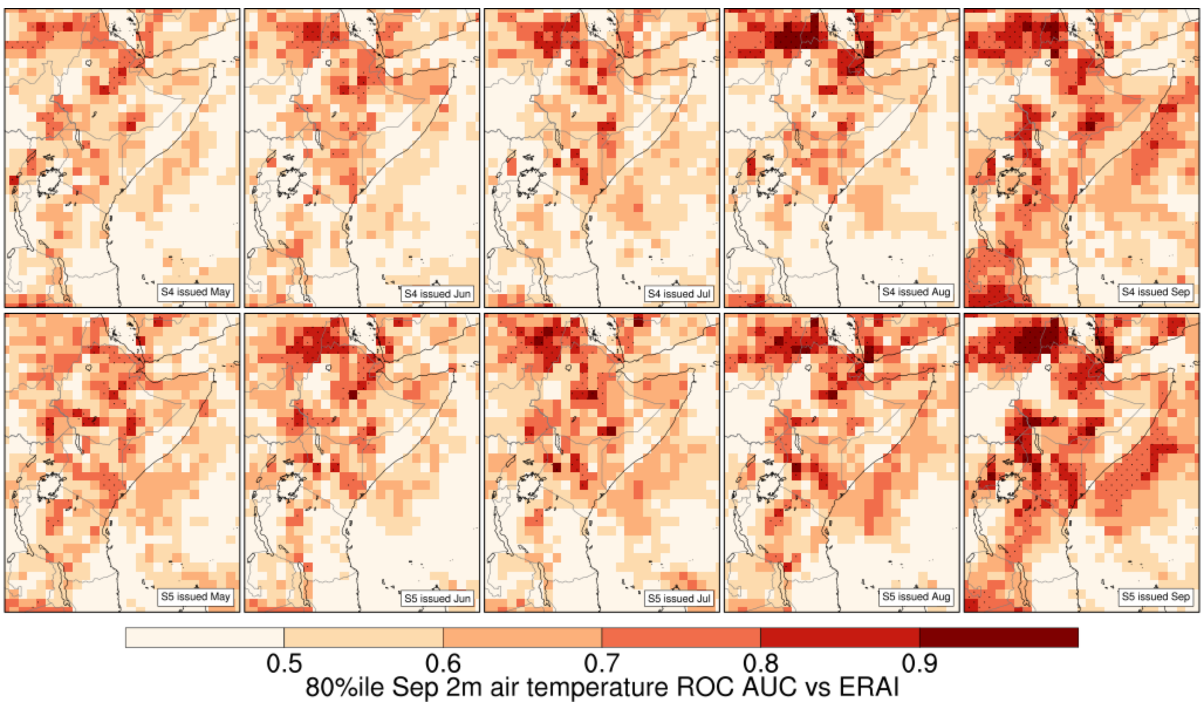

Figure 81. [ROC80Sep] ROC Area under curve for Sep: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

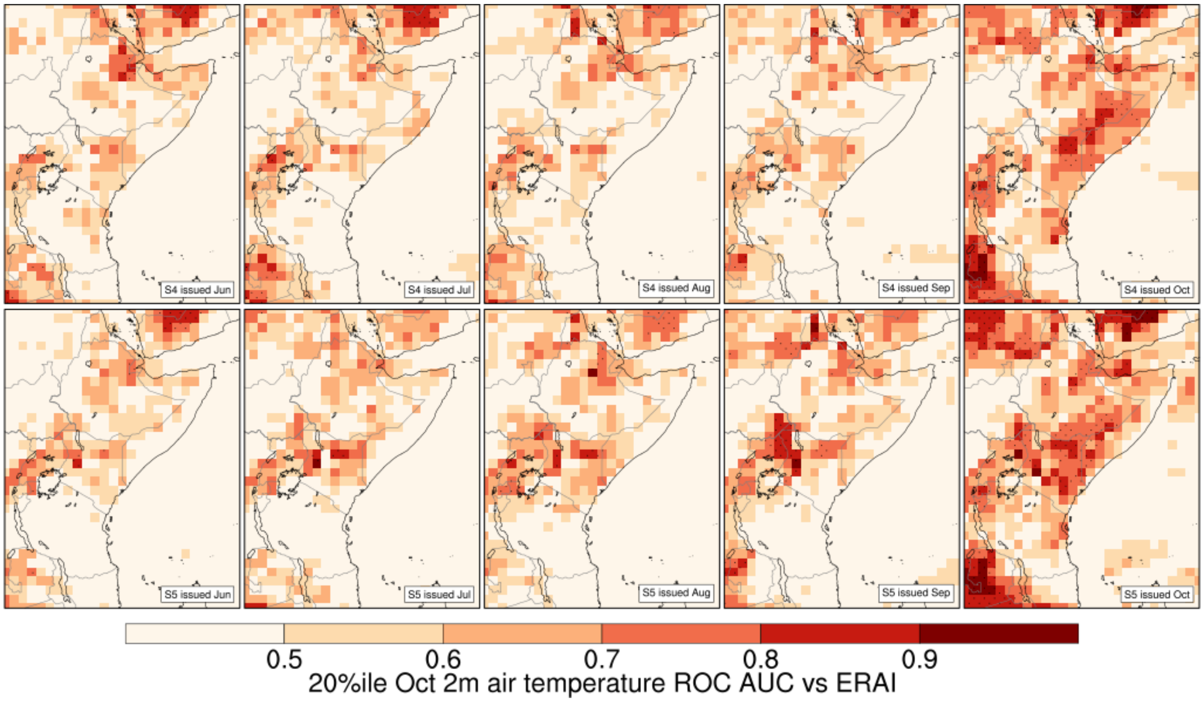

Figure 82. [ROC20Oct] ROC Area under curve for Oct: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

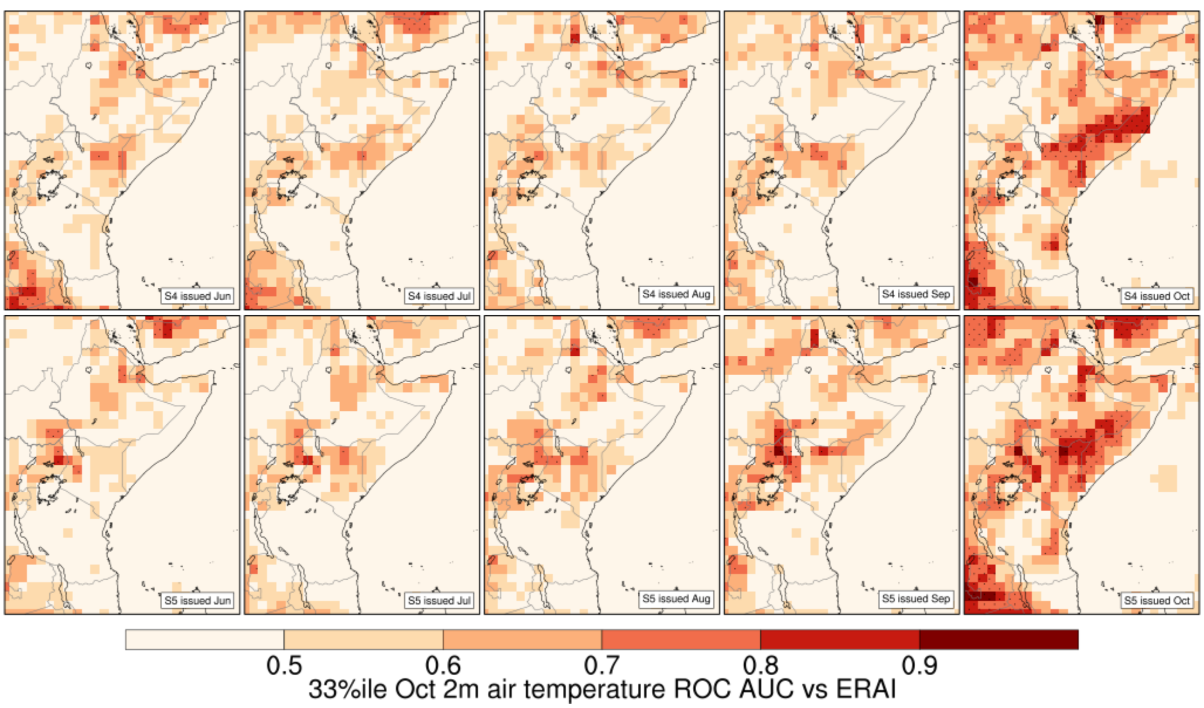

Figure 83. [ROC33Oct] ROC Area under curve for Oct: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

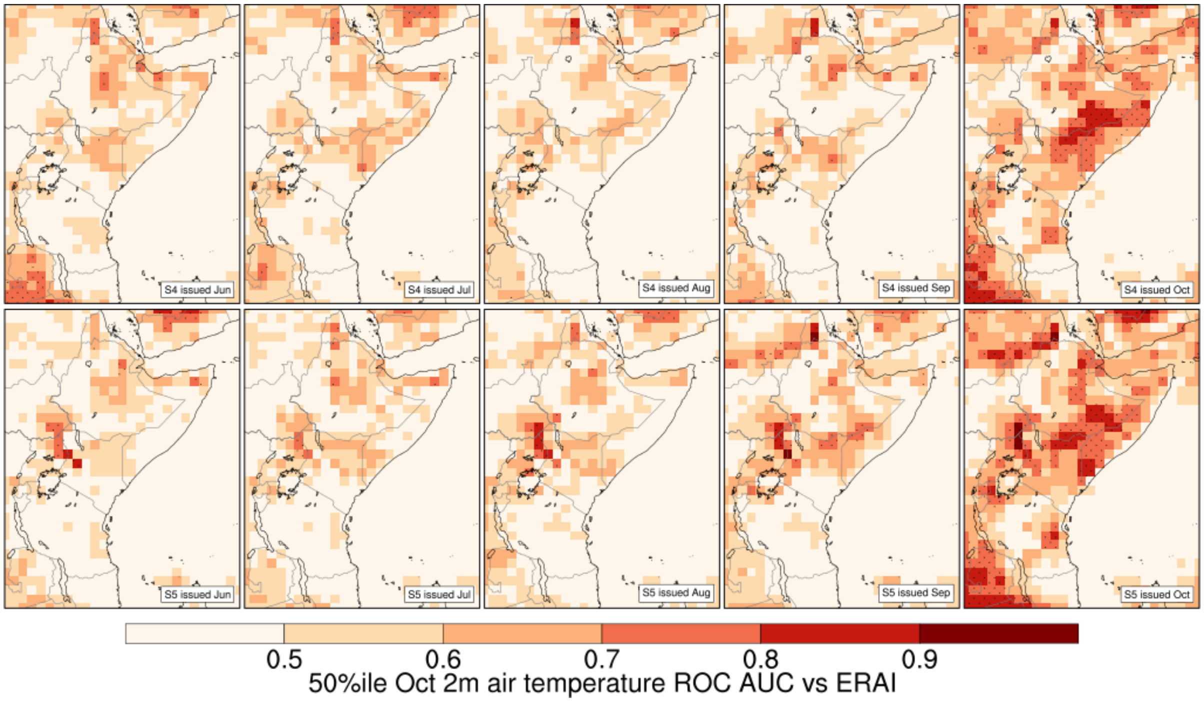

Figure 84. [ROC50Oct] ROC Area under curve for Oct: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

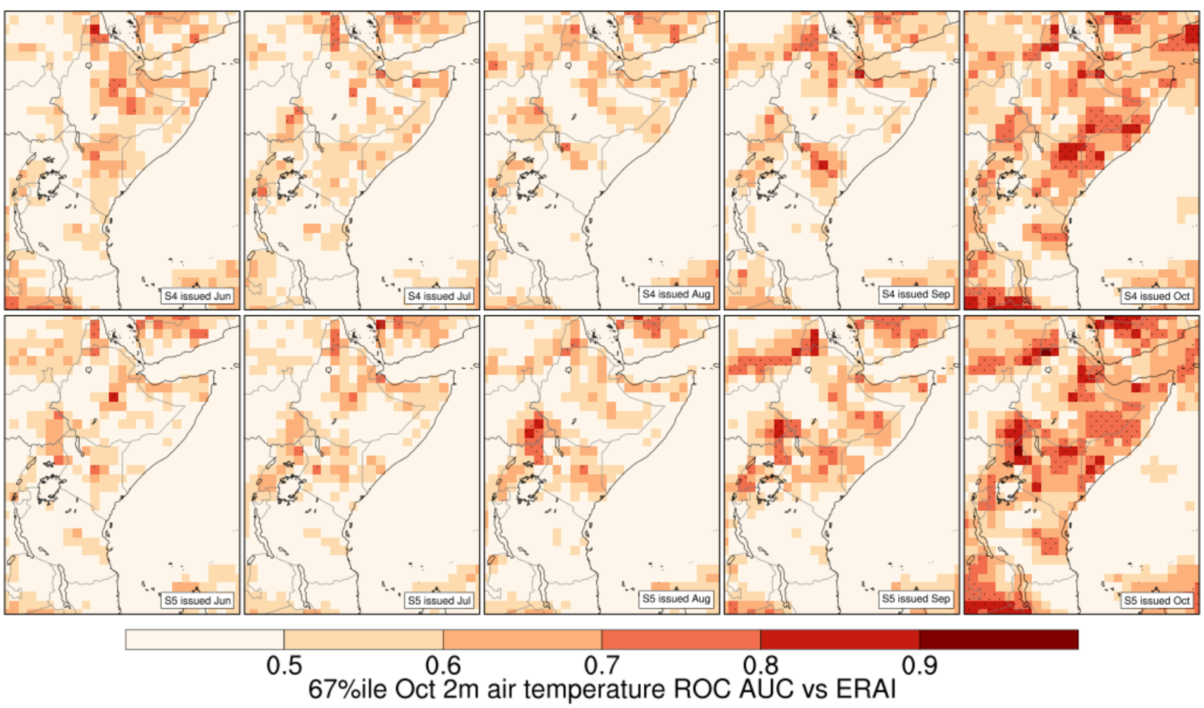

Figure 85. [ROC67Oct] ROC Area under curve for Oct: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

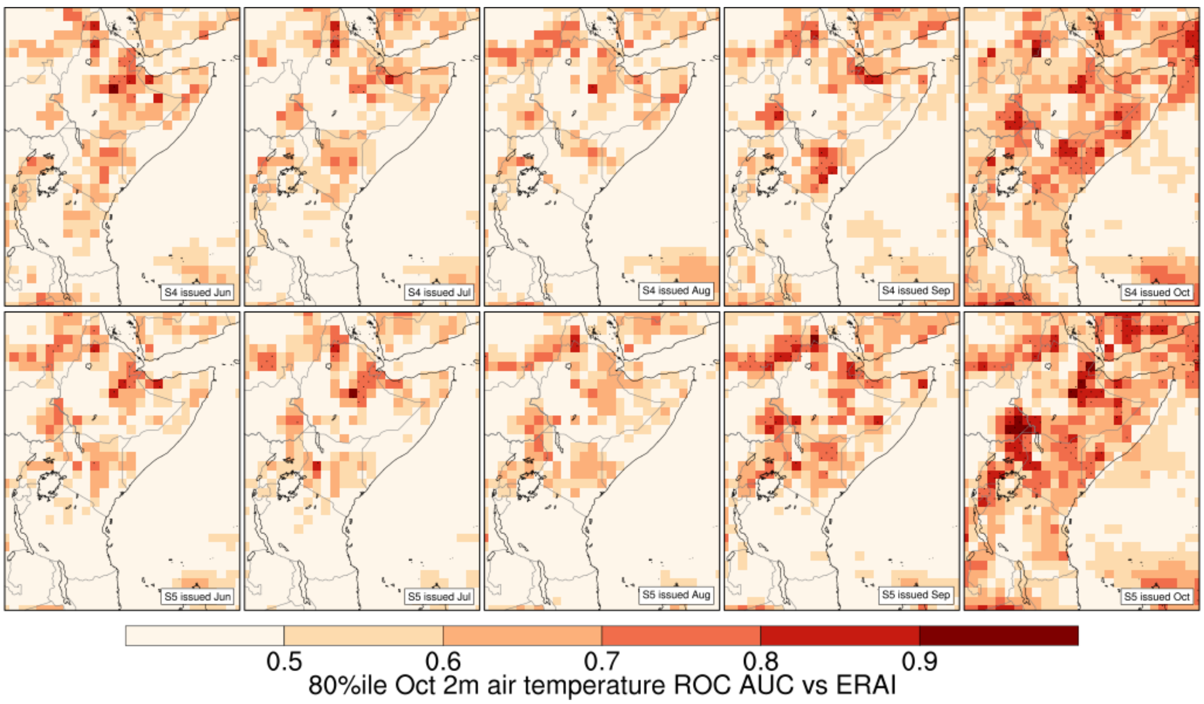

Figure 86. [ROC80Oct] ROC Area under curve for Oct: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

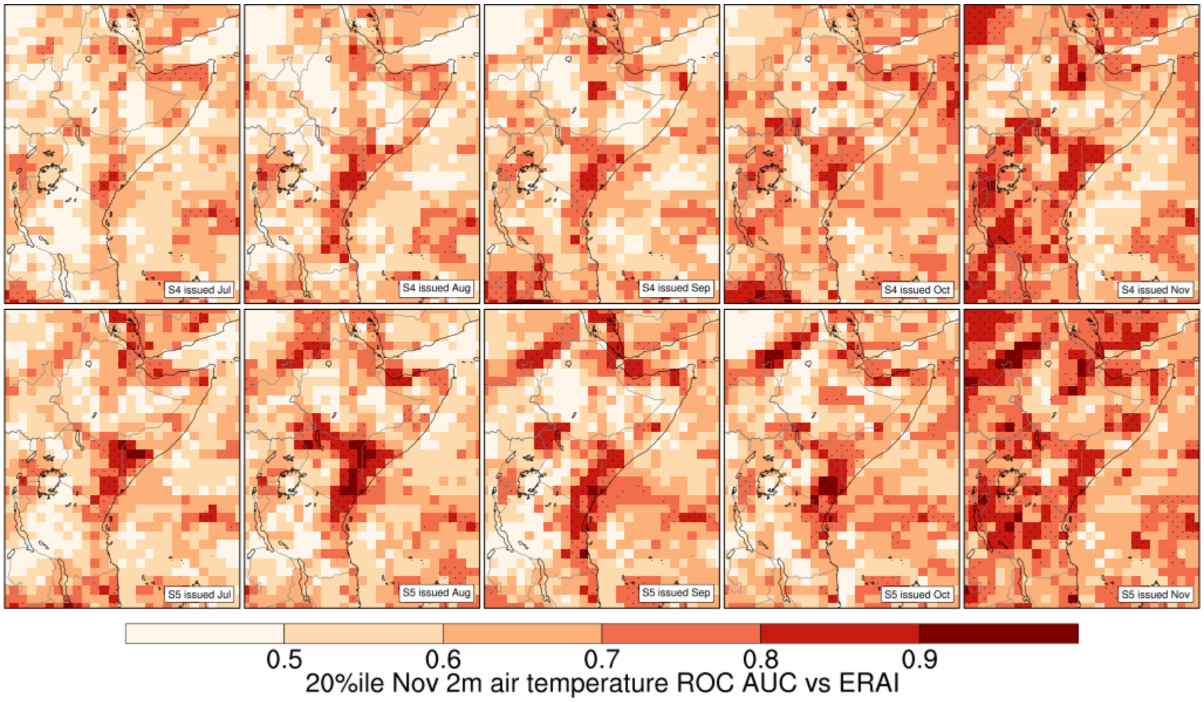

Figure 87. [ROC20Nov] ROC Area under curve for Nov: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

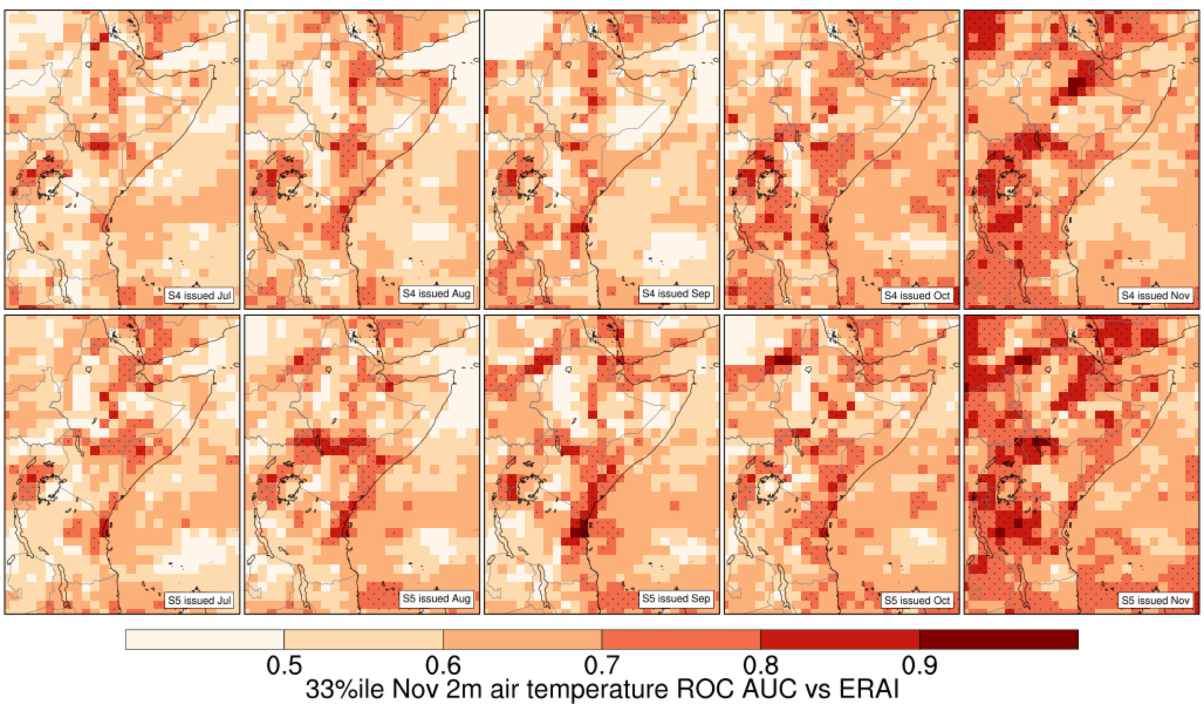

Figure 88. [ROC33Nov] ROC Area under curve for Nov: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

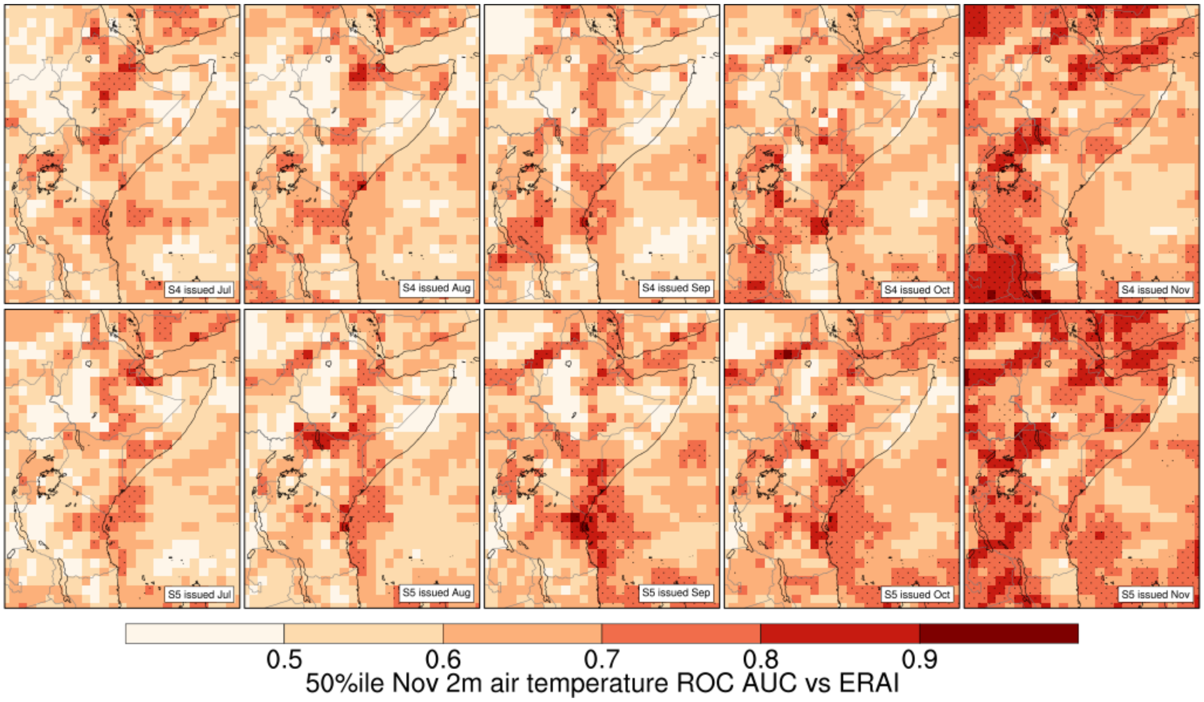

Figure 89. [ROC50Nov] ROC Area under curve for Nov: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

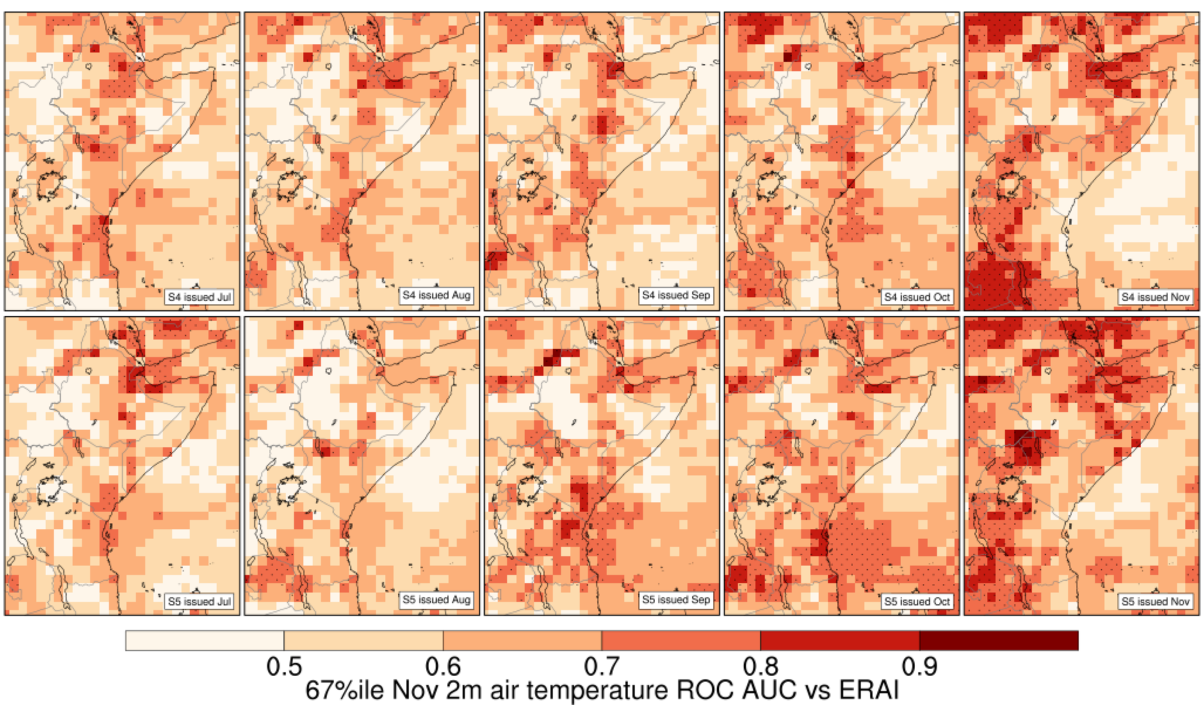

Figure 90. [ROC67Nov] ROC Area under curve for Nov: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

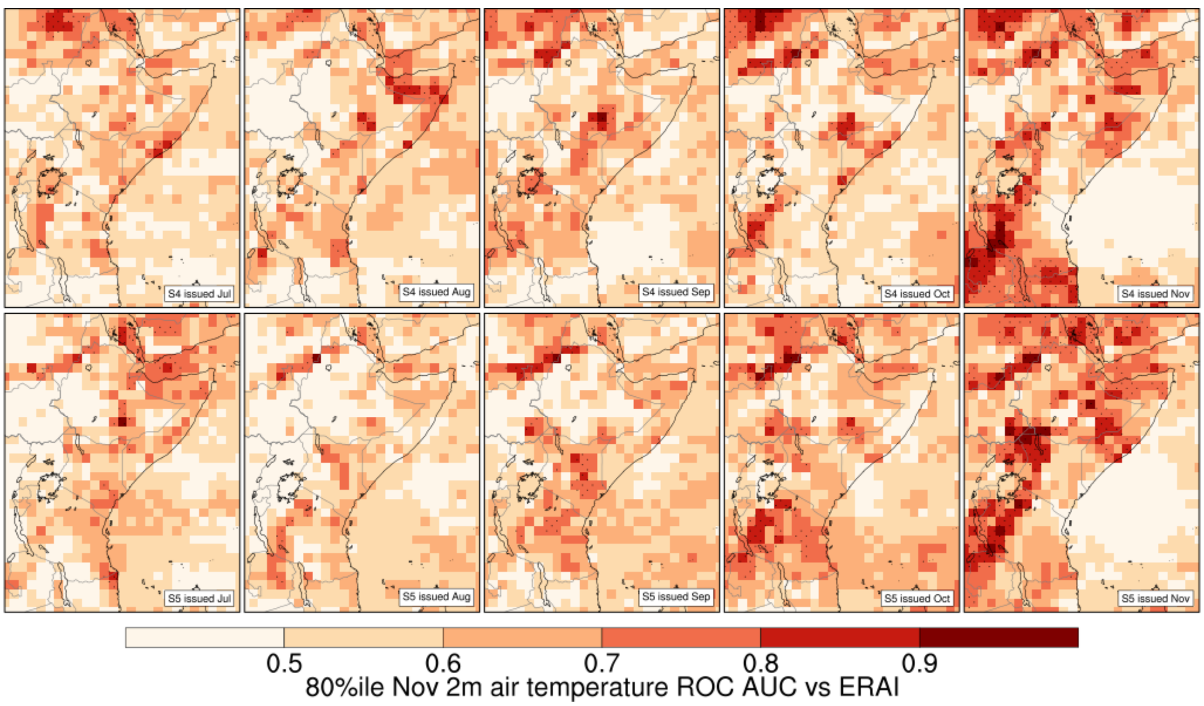

Figure 91. [ROC80Nov] ROC Area under curve for Nov: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

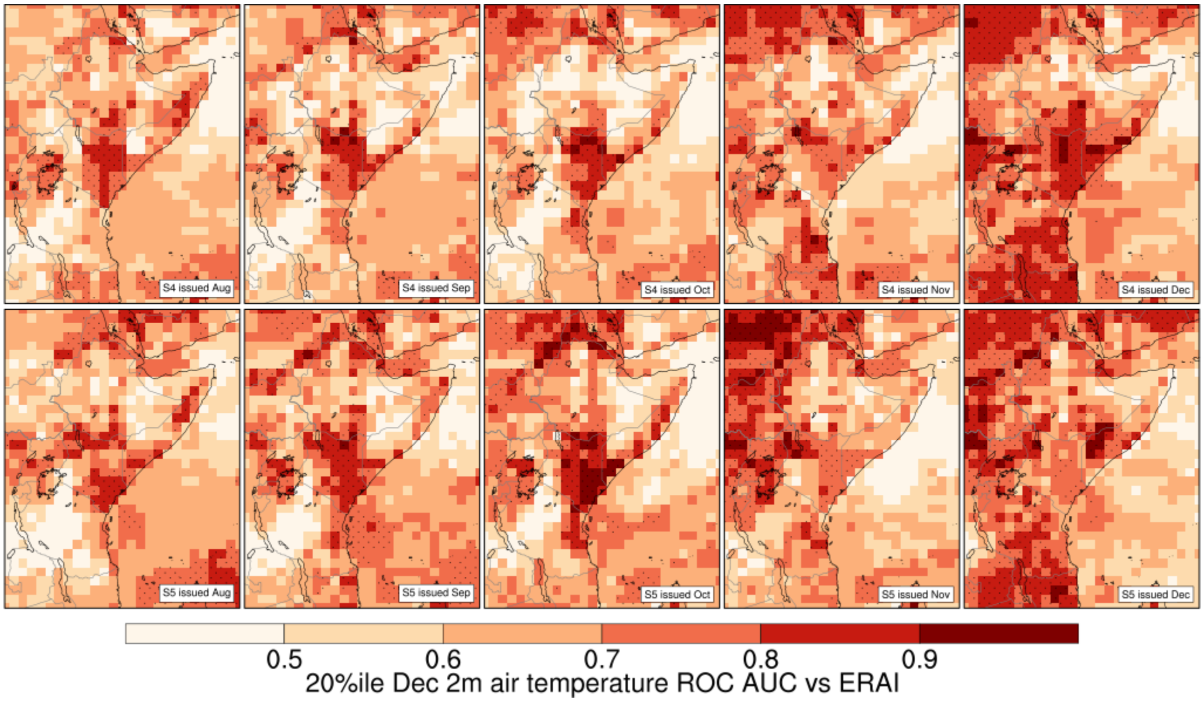

Figure 92. [ROC20Dec] ROC Area under curve for Dec: exceedance of 20%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

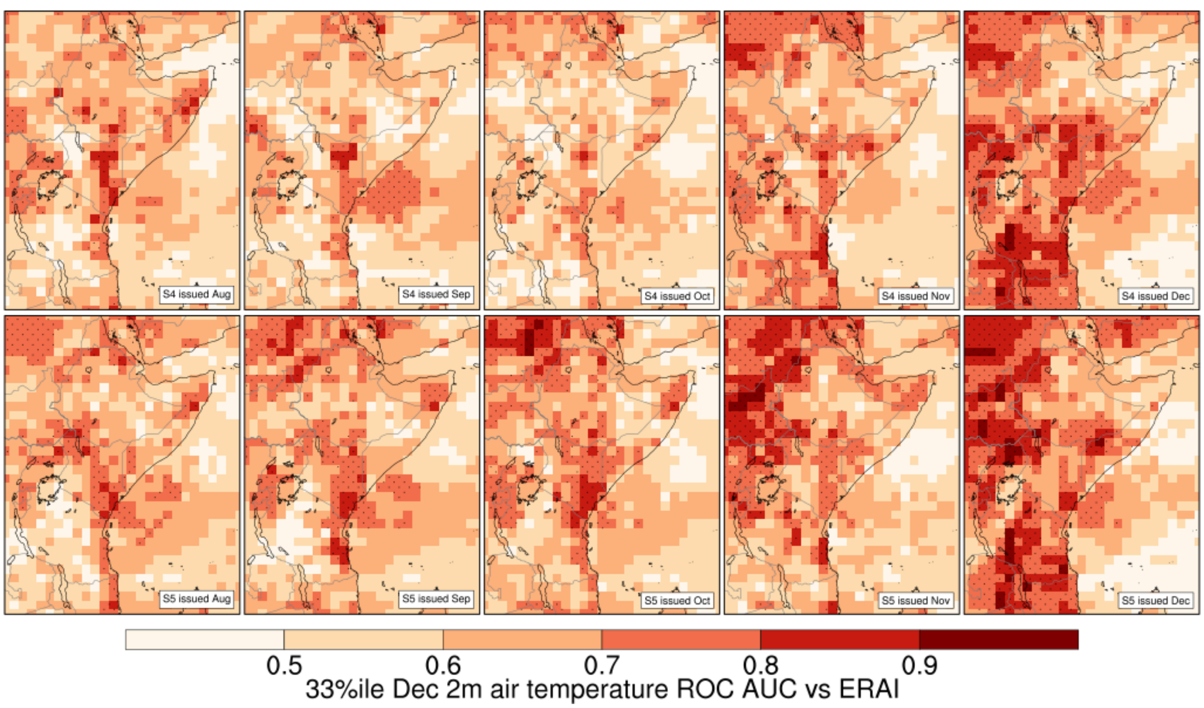

Figure 93. [ROC33Dec] ROC Area under curve for Dec: exceedance of 33%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

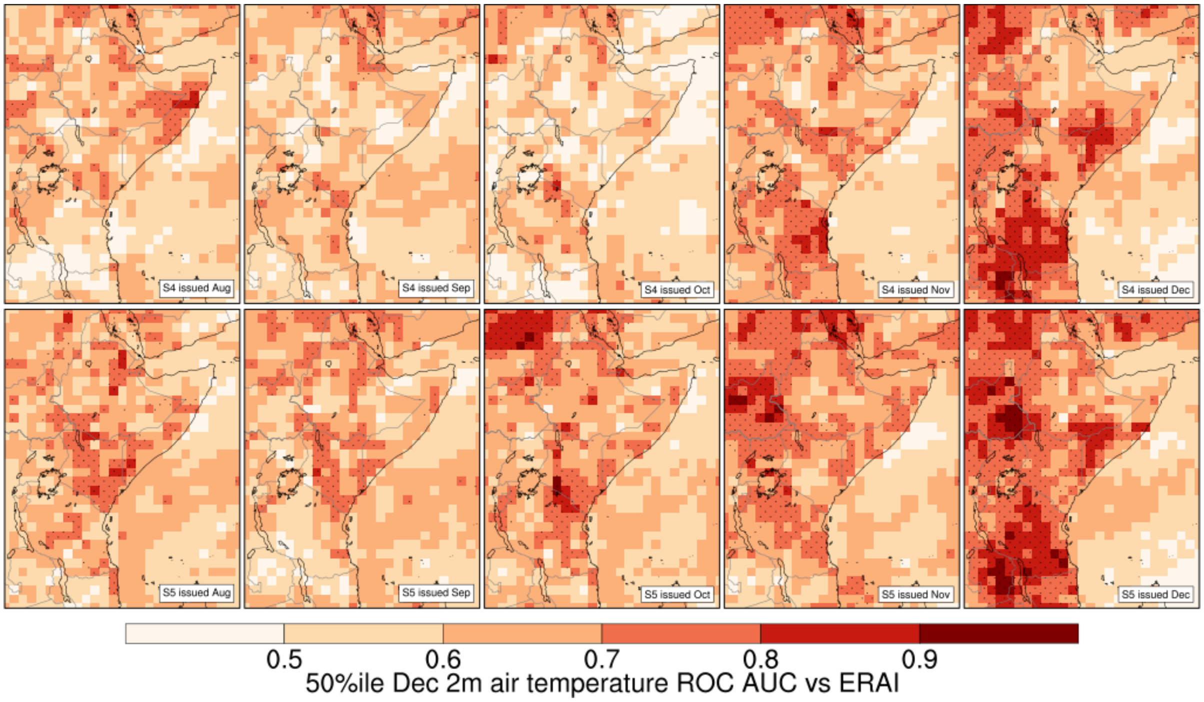

Figure 94. [ROC50Dec] ROC Area under curve for Dec: exceedance of 50%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

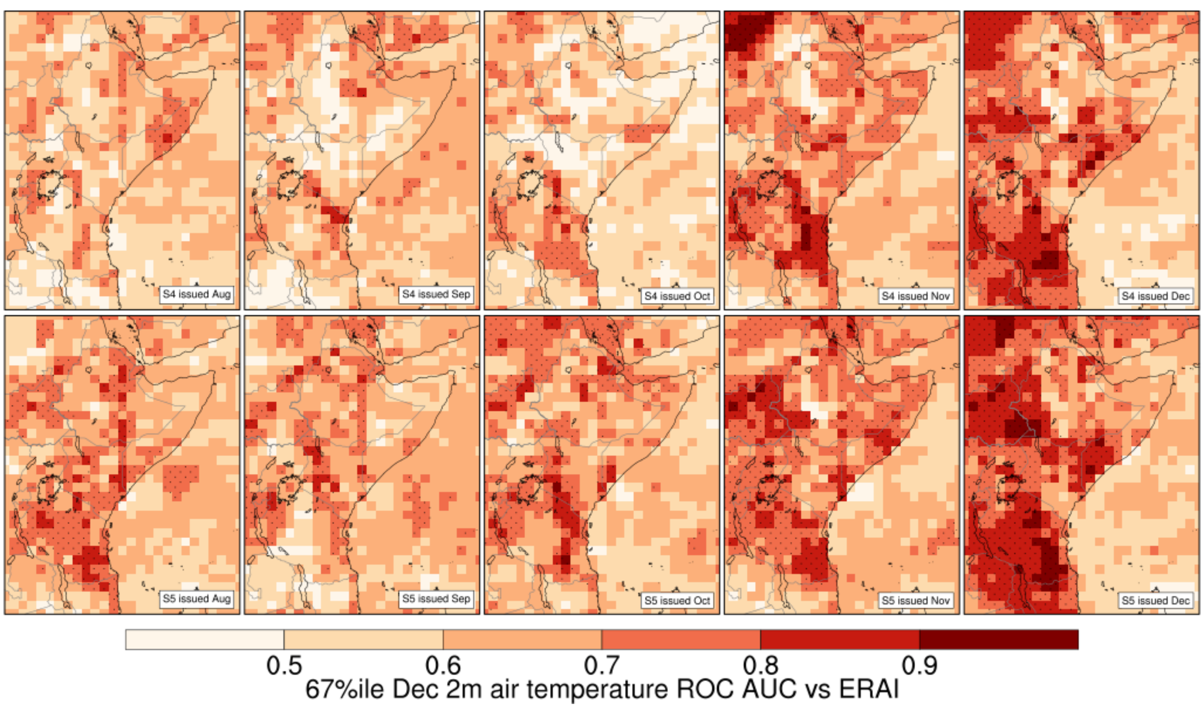

Figure 95. [ROC67Dec] ROC Area under curve for Dec: exceedance of 67%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

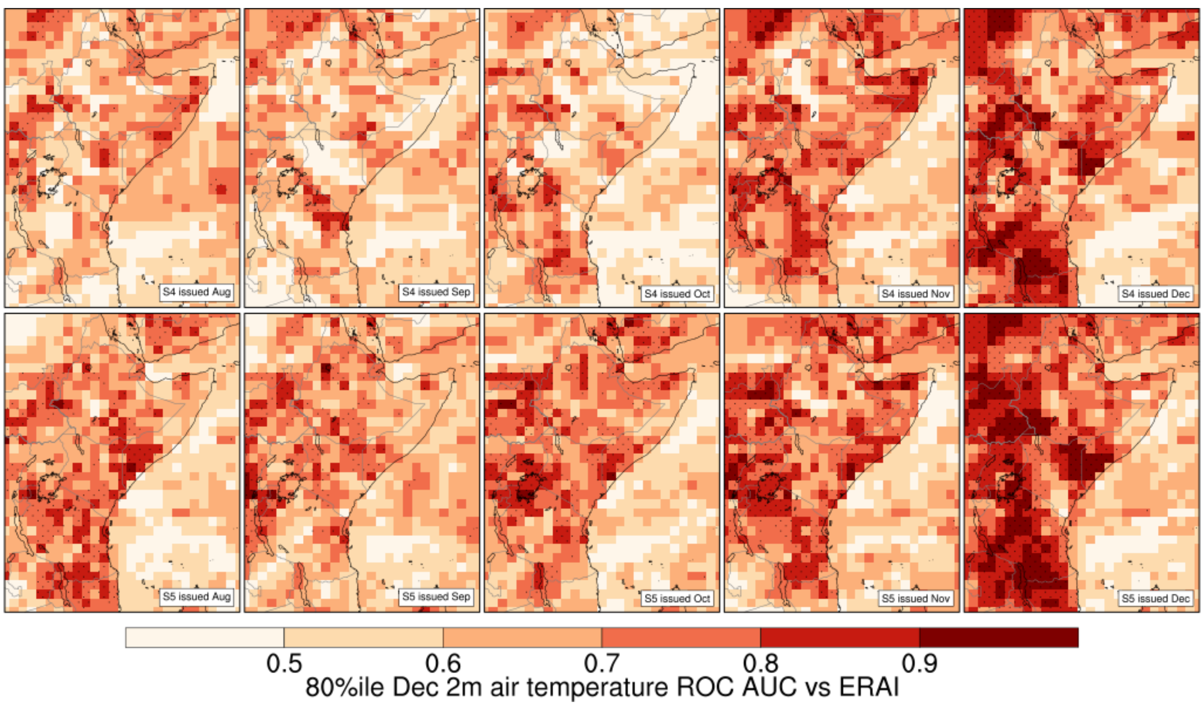

Figure 96. [ROC80Dec] ROC Area under curve for Dec: exceedance of 80%ile, for System 4 (top) and SEAS5 (bottom) 2m temperature vs ERAI. Stippling indicates correlations significant at the 95% level.

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