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TECHNICAL REPORT

Computation of CBS scores for the Global NCUM using CDO

Mohana S. Thota, Raghavendra Ashrit, Kuldeep Sharma and E.N. Rajagopal

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9	Abstract	A comprehensive procedure has been outlined for the computation of CBS scores on monthly basis using new climate data operator (CDO) tool. Using this tool monthly statistics of RMSE, Mean error, anomaly correlation coefficient etc. are prepared for the key surface and upper air meteorological variables. The procedure is applied to the global NCUM generated forecasts over 9 different regions covering the entire globe. The results obtained are agreeing well with the other WMO lead center's derived values.
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1. Introduction

This technical report presents the brief procedures and methodologies adopted for the computation of standard set of statistical *deterministic NWP* verification scores for the global NCMRWF Unified Model (NCUM; Sumit Kumar et al., 2018). The goal is to provide consistent verification of NWP products of Global data processing and forecasting system (GDPFS) which helps these NWP centers to compare and further improve their forecasts. Scores will be exchanged among the participating NWP Centers via the Lead Centre(s) for Deterministic NWP Verification (DNV). One of the major tasks of the Lead Centre is creation and maintenance of a website for DNV information **(http://apps.ecmwf.int/wmolcdnv/)**, so that the potential users will benefit from a consistent presentation of results.

In general, the term "deterministic NWP" refers to single integration of NWP model for generating products defining single future states of the atmosphere, unlike the ensemble prediction system (EPS), where multiple integrations provide a range of future states. The basic objectives of these verification procedures are of two-fold, one is that the standard verification should provide key and relevant information appropriate to represent the state of the art in NWP models. And second being as simple and as easy to implement as possible and make certain and consistent implementation across participating centers.

2. Verification Statistics and Exchange of Scores

There are two sets of verification statistics; a mandatory set shall be provided by all participating centers. The procedures for upper-airfields and for surface fields are different and are presented separately. These detailed verification procedures are required to make sure it is possible to compare results from the different participating centers in a scientifically valid manner. A set of additional recommended statistics is also defined that all centers should provide if possible. Each NWP centre shall provide monthly scores to Lead Centre for DNV. Details of the procedure and the required format for the data are provided on the website of the Lead Centre. *All scores for all forecasts verified within a month shall be provided as soon as possible after the end of that month.* Another important aspect is that the participating centers shall provide to the Lead Centre for DNV information on their implementation of the standardized verification system yearly. They shall confirm to the Lead Centre any changes to the implementation and shall inform the Lead Centre of changes in their NWP model.

3. Formulation of the CBS Scores

The following definitions are used for WMO lead center for deterministic verification

$$\boldsymbol{Mean\ error\ (ME)} = \frac{1}{S_w}\sum_{i=1}^{n} w_i (x_f - x_v)\, i$$

$$\boldsymbol{Mean\ absolute\ error\ (MAE)} = \frac{1}{S_w}\sum_{i=1}^{n} w_i |x_f - x_v|\, i$$

$$\boldsymbol{Root\ mean\ square\ error\ (RMSE)} = \sqrt{\frac{1}{S_w}\sum_{i=1}^{n} w_i (x_f - x_v)_i^2}$$

$$\boldsymbol{RMS\ vector\ wind\ error} = \sqrt{\frac{1}{S_w}\sum_{i=1}^{n} w_i (\vec{V}_f - \vec{V}_v)_i^2}$$

$$\boldsymbol{Root\ mean\ square\ anomaly\ (RMSA)} = \sqrt{\frac{1}{S_w}\sum_{i=1}^{n} w_i (x - x_c)_i^2}$$

$$\boldsymbol{Anomaly\ correlation\ coefficient\ (ACC)} = \frac{\sum_{i=1}^{n} w_i \left(x_f - x_c - M_{f,c}\right) i \left(x_v - x_c - M_{v,c}\right)}{\sqrt{\sum_{i=1}^{n} w_i (x_f - x_c - M_{f,c})_i^2 \sum_{i=1}^{n} w_i (x_v - x_c - M_{v,c})_i^2}}$$

$$S_w = \sum_{i=1}^{n} w_i$$

w_i is the weights applied at the each grid point given by $w_i = \cos\theta_i$, cosine of the latitude at each grid point.

Where;

x_f = NCUM forecast value.

x_v = NCUM analysis value.

x_c = the climatological parameter value.

n = number of grid points in the verification area.

$M_{f,c}$ is the mean value of the forecast anomalies over the verification area

$M_{v,c}$ is the mean value of the analysis anomalies over the verification area

4. Standardized Verification of Meteorological Fields

In the following sections the mandatory parameters/fields used for the verification of the NWP products are discussed along with forecast times, and the areas over which the computations are performed.

(a) Parameters:

(1) ***Extra-tropics:*** The mandatory fields are;

– MSLP (verification against analysis only);
– Geopotential height at 850, 500 and 250 hPa;
– Temperature at 850, 500 and 250 hPa;
– Wind at 850, 500 and 250 hPa.

– *Additional recommended:*

– Geopotential height, temperature, wind at 100 hPa;
– Relative humidity (RH) at 700 hPa.

(2) ***Tropics:***

– Geopotential height at 850 and 250 hPa;
– Temperature at 850 and 250 hPa;
– Wind at 850 and 250 hPa.

– *Additional recommended:*

– Relative humidity at 700 hPa.

(b) Forecast Times and Forecast Steps:

The statistical scores are computed daily for forecasts initialized at 0000 UTC. For those centres not running forecasts from either 0000 UTC or 1200 UTC, scores shall be provided for forecasts initiated at other times and must be labelled as such. And the mandatory forecast steps are 24, 48, 72, 96, 120, 144, 168, 192, 216, 240 hours or end of forecast; and additionally recommended are: 12-hourly throughout forecast (12, 24, 36 h, …).

(c) **Areas:**

Region	**Code name**	**Latitude/longitude**
Northern hemisphere	***nhem***	90°N–20°N, inclusive, all longitudes
Southern hemisphere	***shem***	90°S–20°S, inclusive, all longitudes
Tropics	***trop***	20°N–20°S, inclusive, all longitudes
North America	***namer***	25°N–60°N 50°W–145°W
Europe/North Africa	***eunaf***	25°N–70°N 10°W–28°E
Asia	***asia***	25°N–65°N 60°E–145°E
Australia/New Zealand	***aunz***	10°S–55°S 90°E–180°E
Northern polar region	***npol***	90°N–60°N, inclusive, all longitudes
Southern polar region	***spol***	90°S–60°S, inclusive, all longitudes

Note: Verification against analyses for grid points within each area includes points on the boundary.

(d) Climate Data Operator (CDO)

CDO is a large tool set for working on climate and NWP model data. NetCDF 3/4, GRIB 1/2 including SZIP (or AEC) and JPEG compression, EXTRA, SERVICE and IEG are supported as IO-formats. Apart from that CDO can be used to analyze any kind of gridded data not related to climate science. CDO has exceedingly small memory requirements and can process files larger than the physical memory. CDO is open source and released under the terms of the GNU General Public License v2 (GPL). The CDO codes developed for computation of CBS scores discussed in this report are given in Appendix-I

5. Verification Against Analyses

Skill scores from the model forecast data are computed using the centre's own analysis. This was considered to be preferable to taking one model's analysis as "truth" which would bias results in models favor (Renwik and Thompson 2001). All parameters/fields shall be verified against the respective analysis on a regular 1.5° x 1.5° uniform latitude-longitude grid. In selecting the verification grid, consideration has been given to the variety of resolutions of current global NWP models, the resolved scales of models (several grid lengths), the resolution of the available climatologies, the potential to monitor long-term trends in performance (including earlier, lower-resolution forecasts), and computational efficiency. Interpolation of higher-resolution model fields to the verification grid shall be performed to retain features at the scale of the verification grid but not to introduce any additional smoothing. The following procedures shall be used:

– Spectral fields: Truncate to equivalent spectral resolution (T120) for the verification grid;
– Grid-point fields: Use area weighting to interpolate to the verification grid.

For scores requiring climatology, the climatology is made available via the Lead Centre(s) for DNV website(s) on the verification grid and needs no further interpolation.

6. Results

As mentioned above in the section (2) the methodology is applied to the NCMRWF global forecast data and the calculations are made. The computed monthly standard verification statistics are archived, and they are uploaded on the ftp site (ftp://wmolcdnv@ftp.ecmwf.int/). Monthly statistics are computed from January 2019 to March 2019; and July 2019 to April 2020. Robustness of the statistics are examined by comparing with the computed values from other WMO lead centers. Note that, although the computations of various statistics are performed over 9 regions of the Globe, here, typical comparison for the mean sea level pressure (MSLP) is given over three regions (northern hemisphere, southern hemisphere and tropics) for the two basic and important statistics; anomaly correlation coefficient (ACC) and root mean squared error (RMSE). The ACC computed for the months January to March 2019 over aforementioned regions show well agreement between global NCUM (black curve) and other lead center values. However, the magnitudes of ACC are slightly higher over tropics from Day 7 onwards over Tropics (Figure 1). This increment in the ACC values over Tropics are also present in the skill scores from July-

December 2019 (Figure 2 and 3). However over Southern hemisphere (SH) the magnitudes of ACC values are relatively less as the lead time increases (Figure 2 and 3). On the other hand, the RMSE values over the three regions are matching well with the other lead center's scores (Figure 4-6). Forecast skill scores (ACC and RMSE) during January-March 2020 are better compared over the three regions on all lead times (Figure 7 and 8).

In spite of certain discrepancies, the qualitative comparison of the skill scores computed from the Global NCUM forecast are in reasonable agreement with other centres over different regions of the globe. As expected, the magnitude of the discrepancies increases with lead time for certain months and region (Figure 4-6). A close examination indicates that the differences in the magnitudes are more prominently seen over SH compared to other regions. This could be largely due to the relative paucity of surface and upper air observations over SH oceans (Kalnay et al., 1998). Interestingly the ranges of ACC values are slightly higher over Tropics compared to the Northern and Southern Hemispheres. Indicating that the model's prediction skill is relatively higher in tropics than the other regions as far as MSLP is concerned.

7. Impact of Covid-19 Lockdown on forecast skill

In this section an attempt to examine the impact of lockdown due to COVID-19 on the forecast skill over the three major regions of the globe, namely, NH, SH and tropics (Figure 9-10). Skill scores computed during January–April 2019 are considered for the comparison. Results show that, ACC and RMSE values of the forecasts during the 2020 indicate different skills compared to 2019. For instance over SH from Day-5 onwards there is reduction in skill scores in March 2020 (Figure 9). In contrast, the pattern of ACC curve with lead time reverses over SH and there is not much change over NH as a whole. On a similar note the RMSE values are increasing during March and April 2020 over NH and SH regions (Figure 10). This perhaps could be due to the reduction in aircraft measurements during the lockdown period.

8. Summary

A comprehensive procedure has been outlined for the computation of CBS scores on monthly basis using new Climate Data Operator (CDO) tool. Using this tool, monthly statistics of RMSE, Mean error, anomaly correlation coefficient etc. are prepared for the key surface and upper air meteorological variables. The procedure is applied to the global NCUM forecasts over 9 different regions covering the entire globe. The results obtained are agreeing well with the other WMO lead center's scores. Further, examination of impact of lockdown due to COVID-19 on forecast skill (especially RMSE) showed slight reduction over NH and SH regions due to lack of aircraft measurements.

References

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Appendix-I

CDO Codes Developed for Computation of CBS Scores

```
#!/bin/bash/
for reg in `cat regions.txt`
do
echo $reg

if [ $reg == "nhem" ]
then
	lon1=0.0 lon2=358.5 lat1=21.0 lat2=90.0
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
	mkdir $reg
	cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
	cd $reg
	. $reg'lev.sh'
	. $reg'sfc.sh'
	. write_output.sh
	cd ..
elif [ $reg == "shem" ]
then
	lon1=0.0 lon2=358.5 lat1=-21.0 lat2=-90.0
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
	mkdir $reg
	cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
	cd $reg
	. $reg'lev.sh'
	. $reg'sfc.sh'
	. write_output.sh
	cd ..
elif [ $reg == "trop" ]
then
	lon1=0.0 lon2=358.5 lat1=-21.0 lat2=21.0
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
	mkdir $reg
	cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
	cd $reg
	. $reg'lev.sh'
	. $reg'sfc.sh'
	. write_output.sh
	cd ..
```

```
elif [ $reg == "asia" ]
then
	lon1=60.0 lon2=145.0 lat1=25.0 lat2=65.0
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
	mkdir $reg
	cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
	cd $reg
	. $reg'lev.sh'
	. $reg'sfc.sh'
	. write_output.sh
	cd ..
elif [ $reg == "aunz" ]
then
	lon1=90.0 lon2=180.0 lat1=-10.0 lat2=-55.0
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
	mkdir $reg
	cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
	cd $reg
	. $reg'lev.sh'
	. $reg'sfc.sh'
	. write_output.sh
	cd ..
elif [ $reg == "eunaf" ]
then
	lon1=190.0 lon2=208.0 lat1=25.0 lat2=70.0
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
	mkdir $reg
	cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
	cd $reg
	. $reg'lev.sh'
	. $reg'sfc.sh'
	. write_output.sh
	cd ..
elif [ $reg == "namer" ]
then
	lon1=230.0 lon2=325.0 lat1=25.0 lat2=60.0
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
	sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
	mkdir $reg
	cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
```

```
        cd $reg
        . $reg'lev.sh'
        . $reg'sfc.sh'
        . write_output.sh
        cd ..
elif [ $reg == "npol" ]
then
        lon1=0.0 lon2=358.5 lat1=60.0 lat2=90.0
        sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
        sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
        mkdir $reg
        cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
        cd $reg
        . $reg'lev.sh'
        . $reg'sfc.sh'
        . write_output.sh
        cd ..
else
        lon1=0.0 lon2=358.5 lat1=-60.0 lat2=-90.0
        sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_lev.sh > $reg'lev.sh'
        sed 's/minlon/'$lon1'/g;s/maxlon/'$lon2'/g;s/minlat/'$lat1'/g;s/maxlat/'$lat2'/g'
wmo_cbs_scores_sfc.sh > $reg'sfc.sh'
        mkdir $reg
        cp grid1.5 clean.sh write_output.sh $reg'lev.sh' $reg'sfc.sh' $reg
        cd $reg
        . $reg'lev.sh'
        . $reg'sfc.sh'
        . write_output.sh
        cd ..
fi
done
```

```
#!/bin/bash/
start=`date +%s`
datdir='/home/umfcst/ShortJobs/VSDB_Input/1x1'
climdir='/home/mohant/CBS_CDO/era-dailyclim'
#######Checks the current date and runs for previous month######################
now="$(date)"
printf "Current date and time %s\n" "$now"
now="$(date +'%Y%m%d')"
yr="$(date +'%Y')"
echo $yr
pmon=`date -d "$(date +%Y-%m-1) -1 month" +%m`
printf "Current date in yyyymmdd format %s\n" "$now"
printf "Script is runnig for the month %s\n" "$pmon"
count=`cal $pmon $yr |egrep -v [a-z] |wc -w`
```

```
#countnew=`expr $count - 25`
echo $countnew
####################################################
	for cnt in $(seq 1 $count)   # loop for number of days
	do
	if [ "$cnt" -le 9 ]
	      then
	  dnum='0'$cnt
	      else
	  dnum=$cnt
	      fi
	# echo $yr$pmon$dnum

	ln -fs $datdir/$yr$pmon$dnum/* .
	y1=`expr substr $yr 3 2`
	s1='prg'
	s2='z'
	s3=$dnum$pmon$y1
	s4='rg'
		for j in $(seq 100 100 1000)
		do
		cn='100'
		ss=`expr $j / $cn`
			if [ "$ss" -le 9 ]
			then
			#  echo 'day0'$ss
			  dd='day0'$ss
			else
			 dd='day'$ss
			fi
			echo $s1$j$s2$s3
			cdo showdate $s1$j$s2$s3 > tmp1
			my_date=`cut -b 3-6,8-9,11-12 tmp1`
			my_date1=`cut -b 3-12 tmp1`
			echo $my_date
			echo $my_date1
			rm tmp1
			ln -fs $datdir/$my_date/prg000z* .
######### Center analysis ################################
	cdo -remapbil,grid1.5 $datdir/$my_date/prg000z* anadump.nc
	cdo -selname,var2 -sellonlatbox,minlon,maxlon,minlat,maxlat anadump.nc
'ana_'$s1$dd$s3$s4'_mslp'  ######
############ Forecast data remapping from 1x1 to 1.5x1.5 #########################
	cdo -remapbil,grid1.5 $s1$j$s2$s3 $s1$dd$s3$s4
	cdo -selname,var2 -sellonlatbox,minlon,maxlon,minlat,maxlat $s1$dd$s3$s4
$s1$dd$s3$s4'_mslp'
#rm $s1$dd$s3$s4
#################### ME and RMSE computation##########
################### MSLP (var2);
	cdo -fldmean -sub $s1$dd$s3$s4'_mslp' 'ana_'$s1$dd$s3$s4'_mslp'
'ME_mslp'$s1$dd$s3$s4
```

```
            cdo -expr,'var2=var2/100' -sqrt -fldmean -sqr -sub $s1$dd$s3$s4'_mslp'
'ana_'$s1$dd$s3$s4'_mslp' 'RMSE_mslp'$s1$dd$s3$s4
####### ECMWF climatology data from WMO for Anonamly Correlation Coefficiet
###################
###################### MSLP #######################################
            cp $climdir/mslp_mean.grib .
            cdo -remapbil,grid1.5 mslp_mean.grib mslp_mean_clim.nc
            cdo -daymean -setyear,$yr -sellonlatbox,minlon,maxlon,minlat,maxlat mslp_mean_clim.nc
ecmwf_mslp_clim.nc
            cdo -mulc,1.0 -seldate,$my_date1 ecmwf_mslp_clim.nc 'ecmwf_mslp_'$my_date1'.nc'
            rm ecmwf_mslp_clim.nc

            cdo -sub $s1$dd$s3$s4'_mslp' 'ecmwf_mslp_'$my_date1'.nc' 'fcst_clim'$dd$s3
            cdo -fldmean 'fcst_clim'$dd$s3 'Mfc'$dd$s3
            cdo -sub, 'fcst_clim'$dd$s3 -enlarge,'fcst_clim'$dd$s3 'Mfc'$dd$s3 'fcst_term'$dd$s3

            cdo -sub  'ana_'$s1$dd$s3$s4'_mslp' 'ecmwf_mslp_'$my_date1'.nc' 'verf_clim'$dd$s3
            cdo -fldmean 'verf_clim'$dd$s3 'Mvc'$dd$s3
            cdo -sub, 'verf_clim'$dd$s3 -enlarge,'verf_clim'$dd$s3 'Mvc'$dd$s3 'verf_term'$dd$s3
            cdo -fldmean -mul 'fcst_term'$dd$s3 'verf_term'$dd$s3 'acc_numer'$dd$s3'.nc'

            cdo -fldmean -sqr 'fcst_term'$dd$s3 out1.nc
            cdo -fldmean -sqr 'verf_term'$dd$s3 out2.nc
            cdo -sqrt -mul out1.nc out2.nc 'acc_denom'$dd$s3'.nc'
            cdo -div 'acc_numer'$dd$s3'.nc' 'acc_denom'$dd$s3'.nc' 'acc_mslp'$dd$s3

            echo $mm
                        done
            done

            for fcst in {01..10}
       do
              cdo -monmean -selmon,$pmon -mergetime 'RMSE_mslpprgday'${fcst}*
'rmse_day_mslp'${fcst}'.nc'
          cdo -monmean -selmon,$pmon -mergetime 'ME_mslpprgday'${fcst}*
'me_day_mslp'${fcst}'.nc'
              cdo -monmean -selmon,$pmon -mergetime 'acc_mslpday'${fcst}*
'ccaf_day_mslp'${fcst}'.nc'
       done
                        cdo mergetime ccaf_day_mslp* 'mslp_ccaf_out'$yr$pmon'.nc'
                    cdo mergetime me_day_mslp* 'mslp_me_out'$yr$pmon'.nc'
            cdo mergetime rmse_day_mslp* 'mslp_rmse_out'$yr$pmon'.nc'
                        . clean.sh
end=`date +%s`
runtime=$((end-start))
echo $runtime

#!/bin/bash/
start=`date +%s`
datdir='/home/umfcst/ShortJobs/VSDB_Input/1x1'
climdir='/home/mohant/CBS_CDO/era-dailyclim'
```

```
#######Checks the current date and runs for previous month#####################
now="$(date)"
printf "Current date and time %s\n" "$now"
now="$(date +'%Y%m%d')"
yr="$(date +'%Y')"
echo $yr
pmon=`date -d "$(date +%Y-%m-1) -1 month" +%m`
printf "Current date in yyyymmdd format %s\n" "$now"
printf "Script is runnig for the month %s\n" "$pmon"
count=`cal $pmon $yr |egrep -v [a-z] |wc -w`
#countnew=`expr $count - 28`
echo $countnew
##################################################
for lev in 85000 50000 25000  # loop counter for number of levels
do
cn='100'
levn=`expr $lev / $cn`
cvar='z'$levn
var7='_z'$levn

tvar='t'$levn
var11='_t'$levn

        for cnt in $(seq 1 $count)   # loop for number of days
        do
        if [ "$cnt" -le 9 ]
             then
          dnum='0'$cnt
             else
          dnum=$cnt
             fi
        # echo $yr$pmon$dnum

        ln -fs $datdir/$yr$pmon$dnum/* .
        y1=`expr substr $yr 3 2`
        s1='prg'
        s2='z'
        s3=$dnum$pmon$y1
        s4='rg'
                for j in $(seq 100 100 1000)
                do
                cn='100'
                ss=`expr $j / $cn`
                        if [ "$ss" -le 9 ]
                        then
                        #  echo 'day0'$ss
                          dd='day0'$ss
                        else
                         dd='day'$ss
                        fi
                        echo $s1$j$s2$s3
```

```
                        cdo showdate $s1$j$s2$s3 > tmp1
                        my_date=`cut -b 3-6,8-9,11-12 tmp1`
                        my_date1=`cut -b 3-12 tmp1`
                        echo $my_date
                        echo $my_date1
                        rm tmp1
                        ln -fs $datdir/$my_date/prg000z* .
######### Center analysis ###############################
        cdo -remapbil,grid1.5 $datdir/$my_date/prg000z* anadump.nc
        cdo -selname,var7 -sellevel,$lev -sellonlatbox,minlon,maxlon,minlat,maxlat anadump.nc
'ana_'$s1$dd$s3$s4$var7  ######
        cdo -selname,var11 -sellevel,$lev -sellonlatbox,minlon,maxlon,minlat,maxlat anadump.nc
'ana_'$s1$dd$s3$s4$var11  ######
############ Forecast data remapping from 1x1 to 1.5x1.5 #########################
        cdo -remapbil,grid1.5 $s1$j$s2$s3 $s1$dd$s3$s4
        cdo -selname,var7 -sellevel,$lev -sellonlatbox,minlon,maxlon,minlat,maxlat $s1$dd$s3$s4
$s1$dd$s3$s4$var7
        cdo -selname,var11 -sellevel,$lev -sellonlatbox,minlon,maxlon,minlat,maxlat
$s1$dd$s3$s4 $s1$dd$s3$s4$var11
#rm $s1$dd$s3$s4
#################### ME and RMSE computation############################
        cdo -fldmean -sub $s1$dd$s3$s4$var7 'ana_'$s1$dd$s3$s4$var7 'ME_'$s1$dd$s3$s4$var7
        cdo -expr,'var7=var7/1' -sqrt -fldmean -sqr -sub $s1$dd$s3$s4$var7
'ana_'$s1$dd$s3$s4$var7 'RMSE_'$s1$dd$s3$s4$var7

        cdo -fldmean -sub $s1$dd$s3$s4$var11 'ana_'$s1$dd$s3$s4$var11
'ME_'$s1$dd$s3$s4$var11
        cdo -expr,'var11=var11/1' -sqrt -fldmean -sqr -sub $s1$dd$s3$s4$var11
'ana_'$s1$dd$s3$s4$var11 'RMSE_'$s1$dd$s3$s4$var11
####### ECMWF climatology data from WMO for Anomaly Correlation Coefficient
####################
############################ Geopotential Height ########################
        echo '---------------ACC for Geopotential--------'
        cp $climdir/$cvar'hPa_mean.grib' .
        cdo -remapbil,grid1.5 $cvar'hPa_mean.grib' $cvar'_mean_clim.nc'
        cdo -daymean -setyear,$yr -sellonlatbox,minlon,maxlon,minlat,maxlat
$cvar'_mean_clim.nc' ecmwf_geo_clim.nc
        cdo -mulc,0.1 -seldate,$my_date1 ecmwf_geo_clim.nc 'ecmwf_geo_'$my_date1'.nc'
        rm ecmwf_geo_clim.nc

        cdo -sub $s1$dd$s3$s4$var7 'ecmwf_geo_'$my_date1'.nc' 'fcst_clim'$dd$s3
        cdo -fldmean 'fcst_clim'$dd$s3 'Mfc'$dd$s3
        cdo -sub, 'fcst_clim'$dd$s3 -enlarge,'fcst_clim'$dd$s3 'Mfc'$dd$s3 'fcst_term'$dd$s3
        cdo -sub  'ana_'$s1$dd$s3$s4$var7 'ecmwf_geo_'$my_date1'.nc' 'verf_clim'$dd$s3
        cdo -fldmean 'verf_clim'$dd$s3 'Mvc'$dd$s3
        cdo -sub, 'verf_clim'$dd$s3 -enlarge,'verf_clim'$dd$s3 'Mvc'$dd$s3 'verf_term'$dd$s3
        cdo -fldmean -mul 'fcst_term'$dd$s3 'verf_term'$dd$s3 'acc_numer'$dd$s3'.nc'

        cdo -fldmean -sqr 'fcst_term'$dd$s3 out1.nc
        cdo -fldmean -sqr 'verf_term'$dd$s3 out2.nc
        cdo -sqrt -mul out1.nc out2.nc 'acc_denom'$dd$s3'.nc'
```

```
          cdo -div 'acc_numer'$dd$s3'.nc' 'acc_denom'$dd$s3'.nc' 'acc_geo_'$dd$s3

###########################################################################
########################## Temperature ######### ########################
          cp $climdir/$tvar'hPa_mean.grib' .
      cdo -remapbil,grid1.5 $tvar'hPa_mean.grib' $tvar'_mean_clim.nc'
      cdo -daymean -setyear,$yr -sellonlatbox,minlon,maxlon,minlat,maxlat  $tvar'_mean_clim.nc'
ecmwf_tem_clim.nc
      cdo -mulc,1.0 -seldate,$my_date1 ecmwf_tem_clim.nc 'ecmwf_tem_'$my_date1'.nc'
      rm ecmwf_tem_clim.nc

      cdo -sub $s1$dd$s3$s4$var11 'ecmwf_tem_'$my_date1'.nc' 'fcst_clim'$dd$s3
      cdo -fldmean 'fcst_clim'$dd$s3 'Mfc'$dd$s3
      cdo -sub, 'fcst_clim'$dd$s3 -enlarge,'fcst_clim'$dd$s3 'Mfc'$dd$s3 'fcst_term'$dd$s3

      cdo -sub  'ana_'$s1$dd$s3$s4$var11 'ecmwf_tem_'$my_date1'.nc' 'verf_clim'$dd$s3
      cdo -fldmean 'verf_clim'$dd$s3 'Mvc'$dd$s3
      cdo -sub, 'verf_clim'$dd$s3 -enlarge,'verf_clim'$dd$s3 'Mvc'$dd$s3 'verf_term'$dd$s3
      cdo -fldmean -mul 'fcst_term'$dd$s3 'verf_term'$dd$s3 'acc_numer'$dd$s3'.nc'

      cdo -fldmean -sqr 'fcst_term'$dd$s3 out1.nc
      cdo -fldmean -sqr 'verf_term'$dd$s3 out2.nc
      cdo -sqrt -mul out1.nc out2.nc 'acc_denom'$dd$s3'.nc'
      cdo -div 'acc_numer'$dd$s3'.nc' 'acc_denom'$dd$s3'.nc' 'acc_tem_'$dd$s3
############################################################################
          echo $mm
                 done
          done

          for fcst in {01..10}
      do
             cdo -monmean -selmon,$pmon -mergetime 'RMSE_prgday'${fcst}*$var7
'rmse_day_geo'${fcst}'.nc'
         cdo -monmean -selmon,$pmon -mergetime 'ME_prgday'${fcst}*$var7
'me_day_geo'${fcst}'.nc'
             cdo -monmean -selmon,$pmon -mergetime 'acc_geo_day'${fcst}*
'ccaf_day_geo'${fcst}'.nc'

             cdo -monmean -selmon,$pmon -mergetime 'RMSE_prgday'${fcst}*$var11
'rmse_day_tem'${fcst}'.nc'
         cdo -monmean -selmon,$pmon -mergetime 'ME_prgday'${fcst}*$var11
'me_day_tem'${fcst}'.nc'
             cdo -monmean -selmon,$pmon -mergetime 'acc_tem_day'${fcst}*
'ccaf_day_tem'${fcst}'.nc'
      done
              cdo mergetime ccaf_day_geo* $cvar'_ccaf_out'$yr$pmon'.nc'
              cdo mergetime me_day_geo* $cvar'_me_out'$yr$pmon'.nc'
          cdo mergetime rmse_day_geo* $cvar'_rmse_out'$yr$pmon'.nc'

              cdo mergetime ccaf_day_tem* $tvar'_ccaf_out'$yr$pmon'.nc'
            cdo mergetime me_day_tem* $tvar'_me_out'$yr$pmon'.nc'
```

```
            cdo mergetime rmse_day_tem* $tvar'_rmse_out'$yr$pmon'.nc'
                . clean.sh
done
end=`date +%s`
runtime=$((end-start))
echo $runtime
```

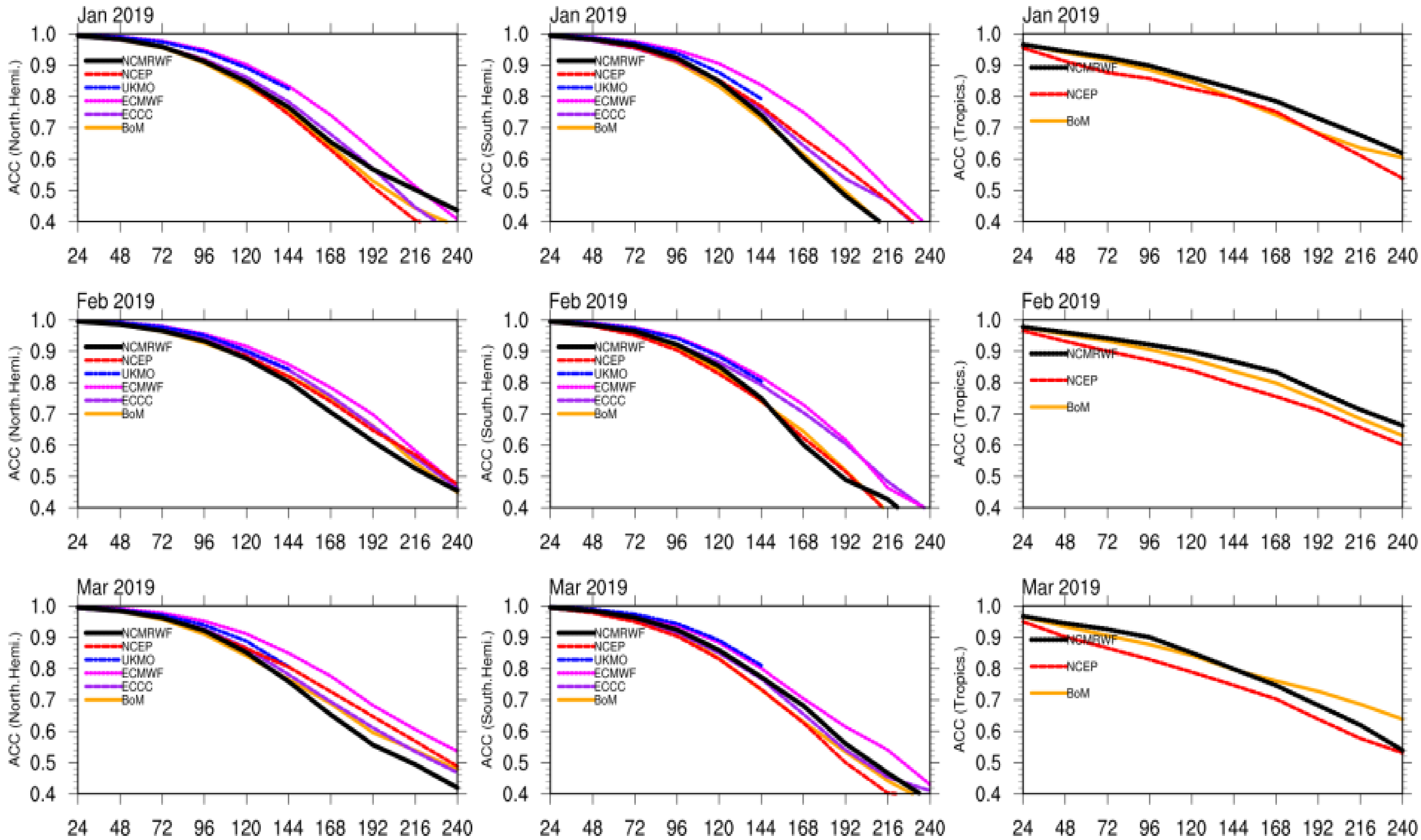

Figure 1: Anomaly correlation coefficient (ACC) over Northern (right panel); Southern (middle panel) and Tropics (left panel) during January-March 2019. Different colors in the legend indicates various WMO lead center models along with the NCUM Global (black solid curve).

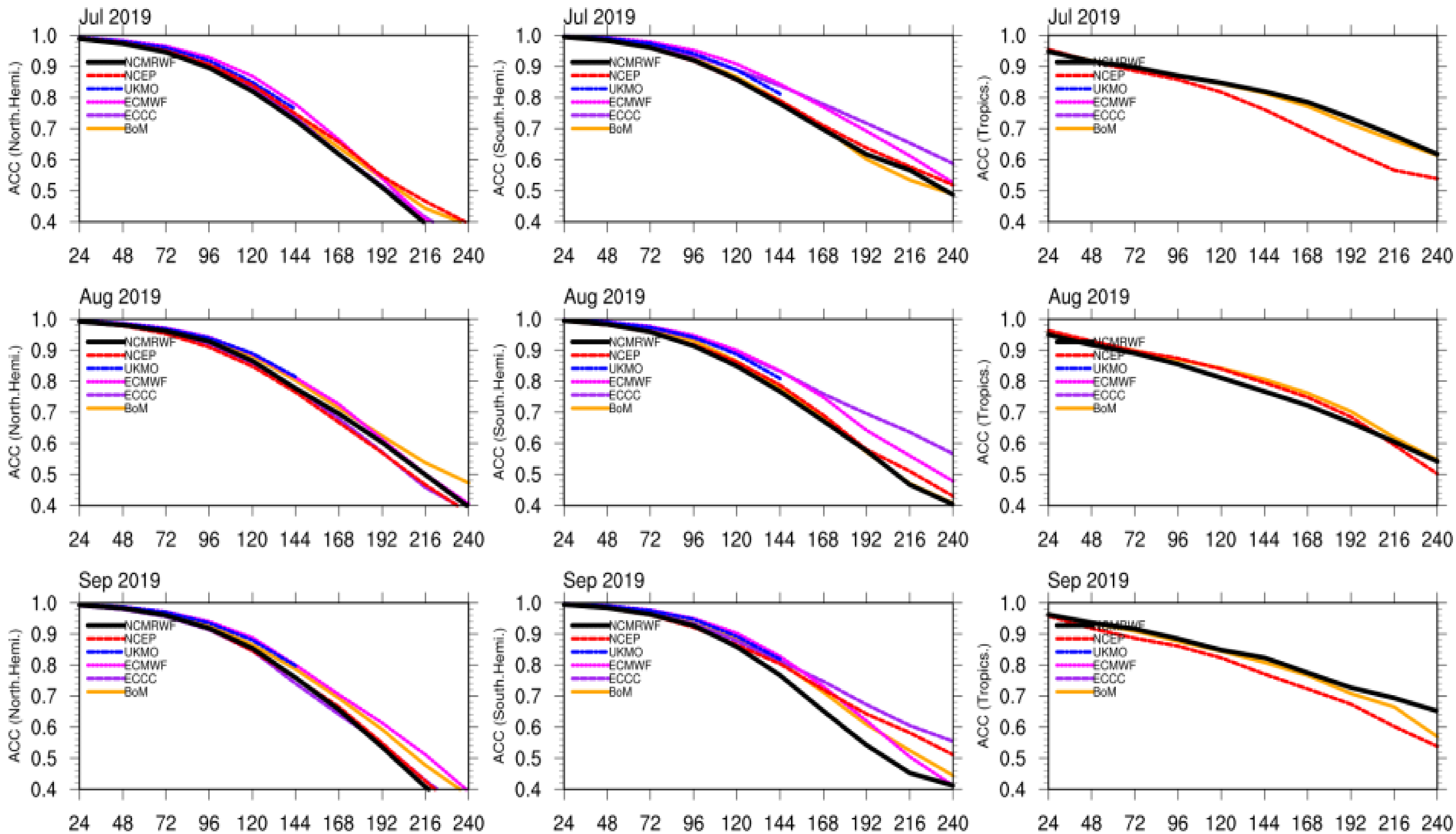

Figure 2: Same as of Figure 1, but for the months July – September 2019

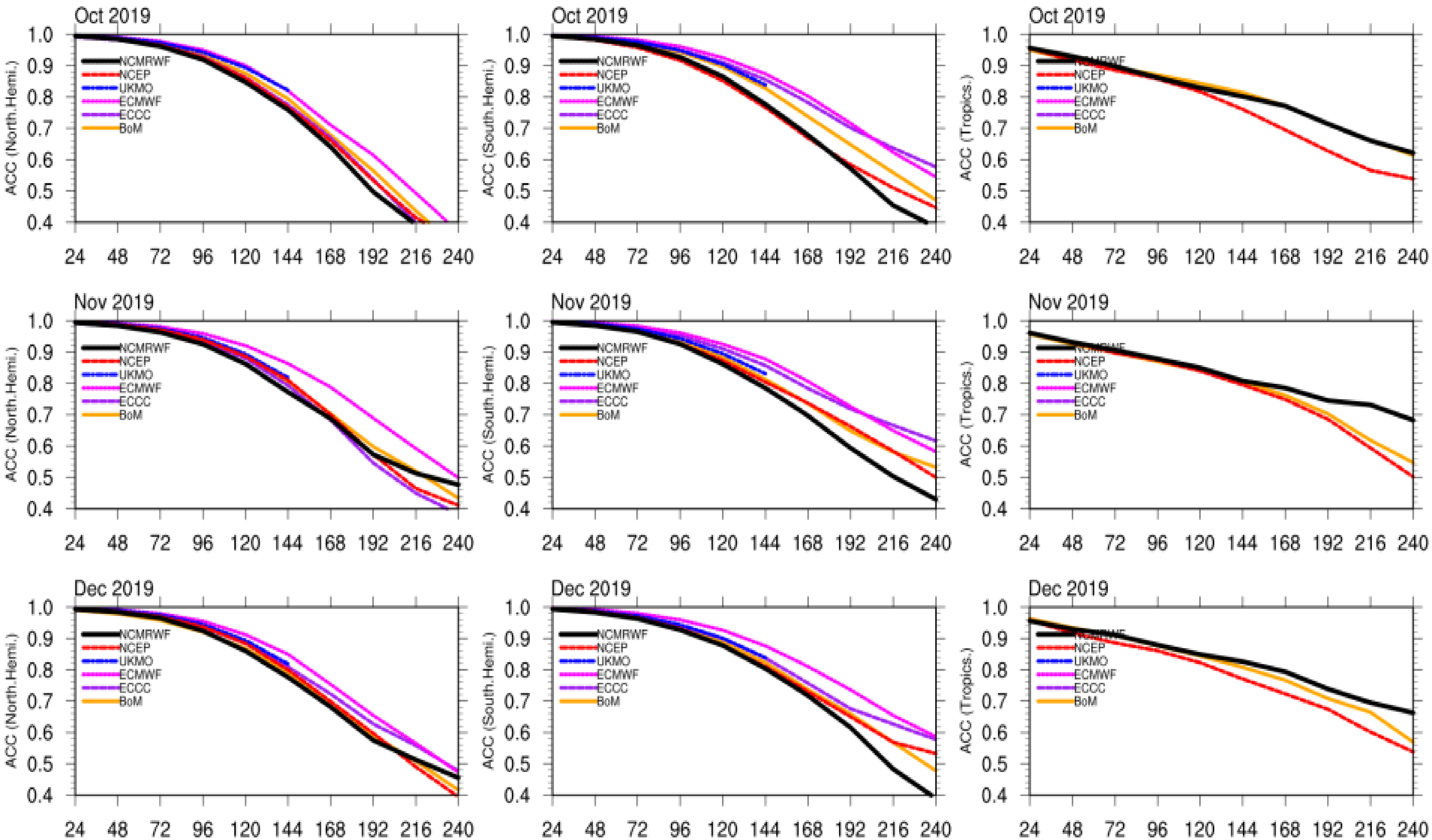

Figure 3: Same as of Figure 1, but for the months October – December 2019

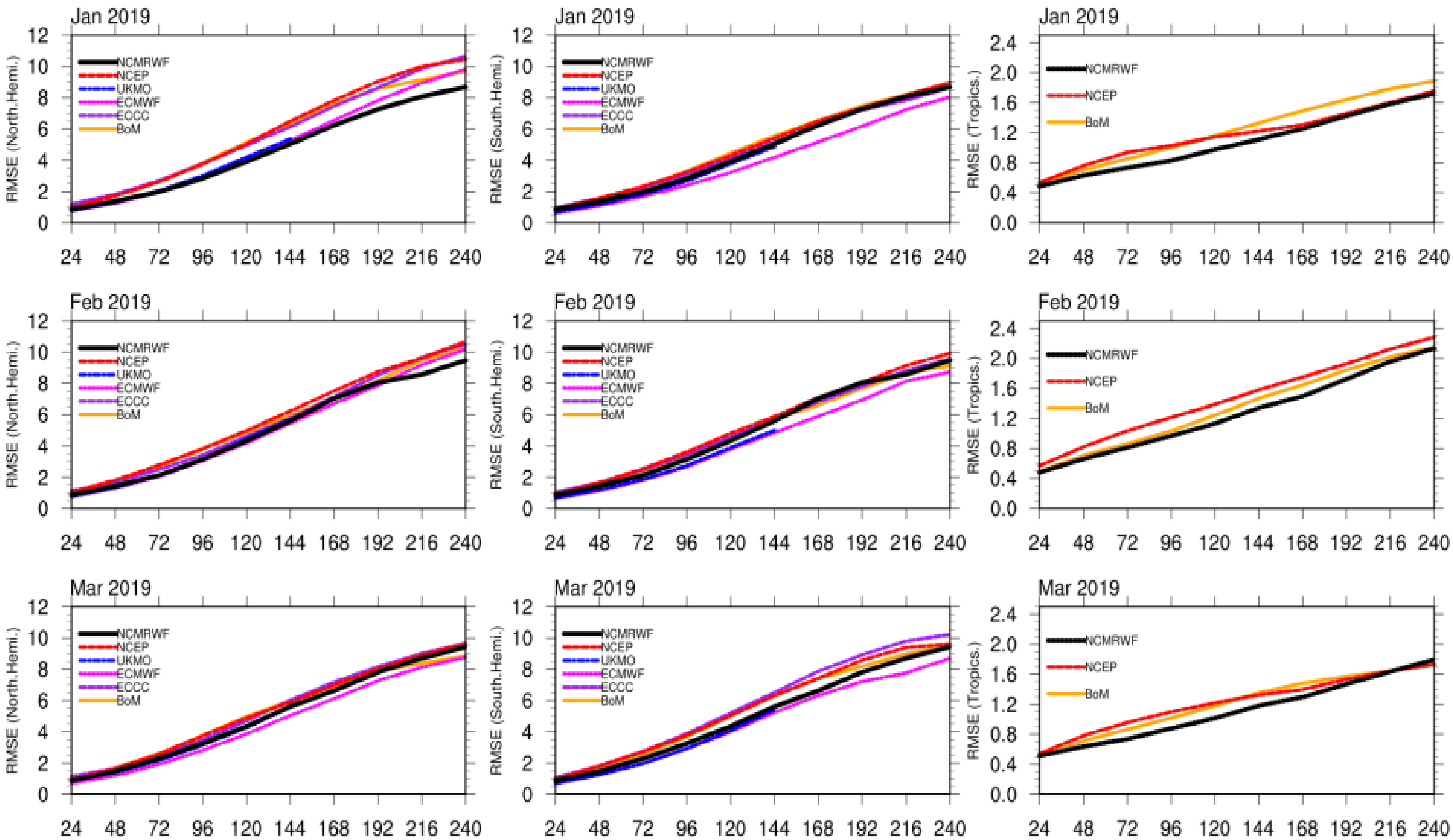

Figure 4: Same as of Figure 1, but for the parameter root mean square error (RMSE) months January – March 2019

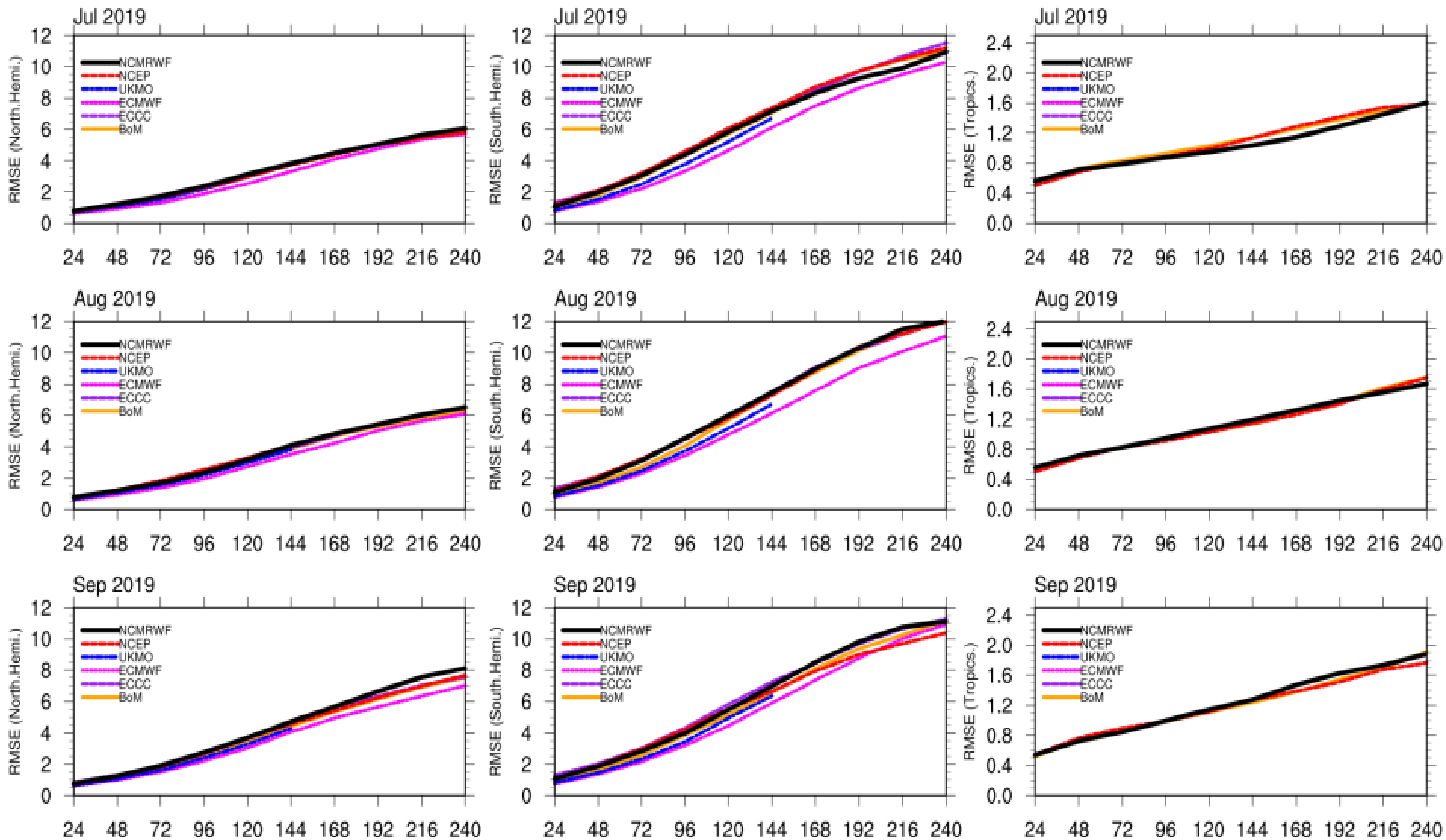

Figure 5: Same as of Figure 4, but for the months July – September 2019

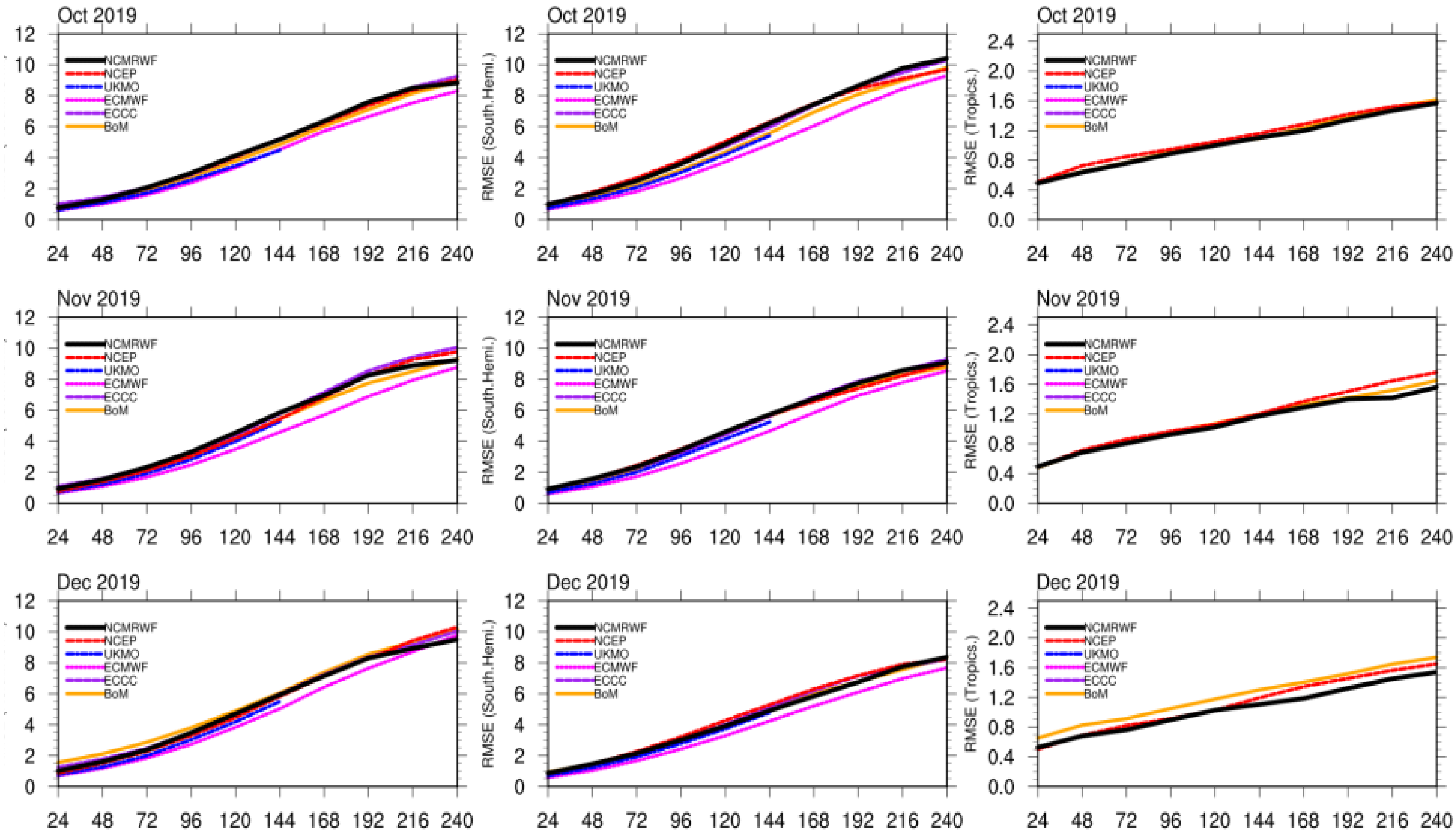

Figure 6: Same as of Figure 4, but for the months October – December 2019

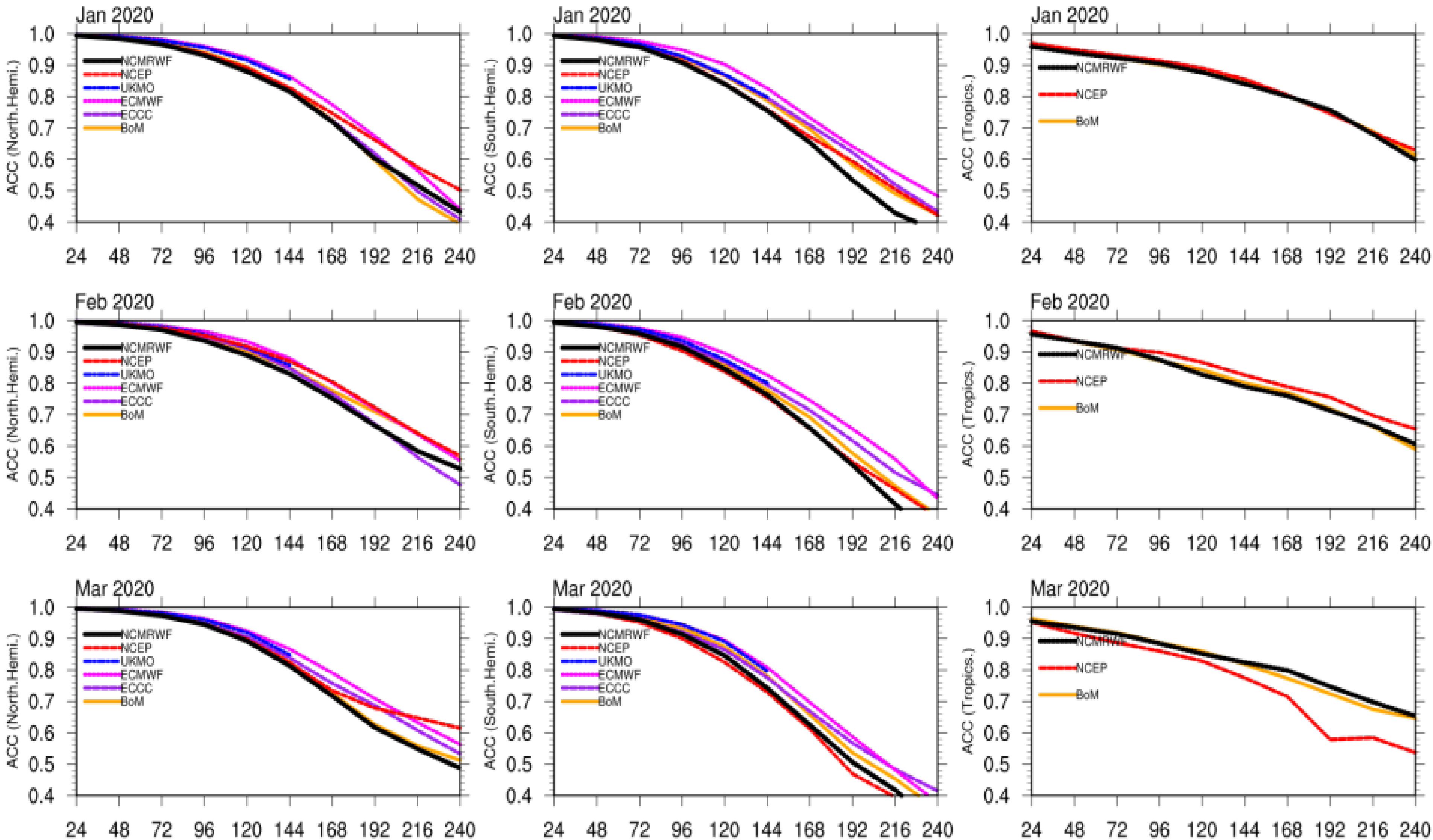

Figure 7: Same as of Figure 1, but for the months January – March 2020

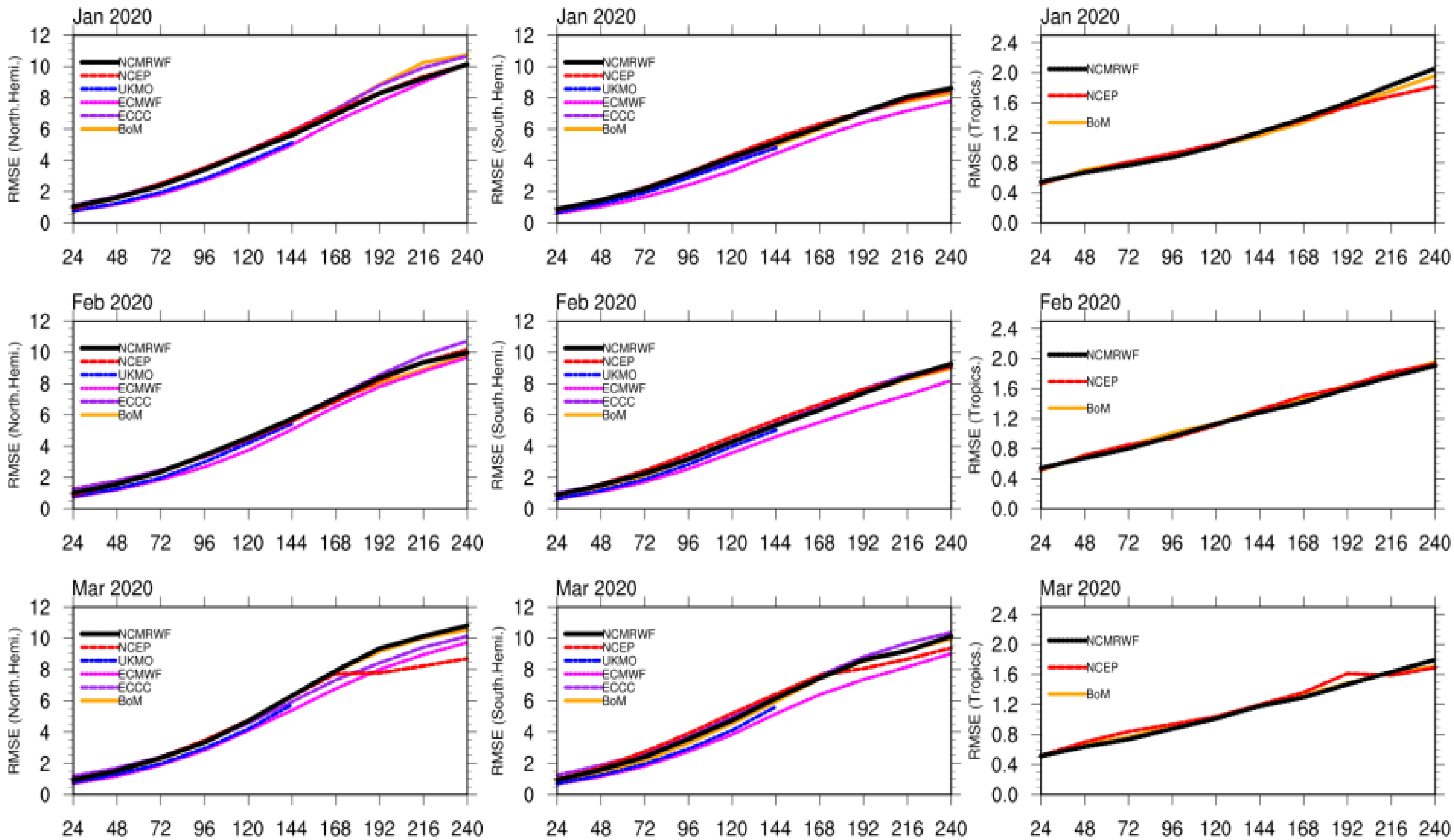

Figure 8: Same as of Figure 4, but for the months January – March 2020

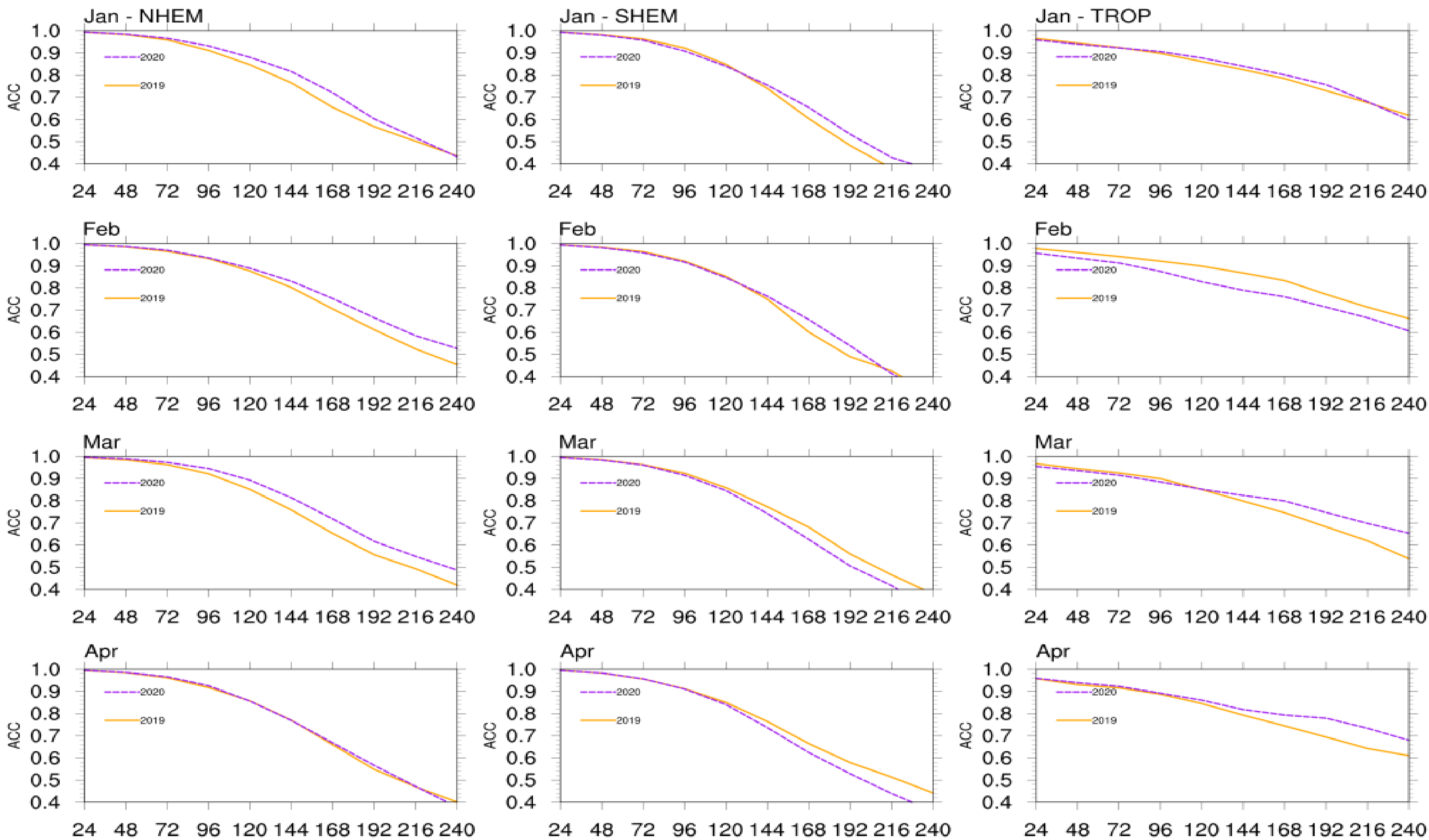

Figure 9: Comparison of ACC over three regions during the months January – April for the years 2019 and 2020.

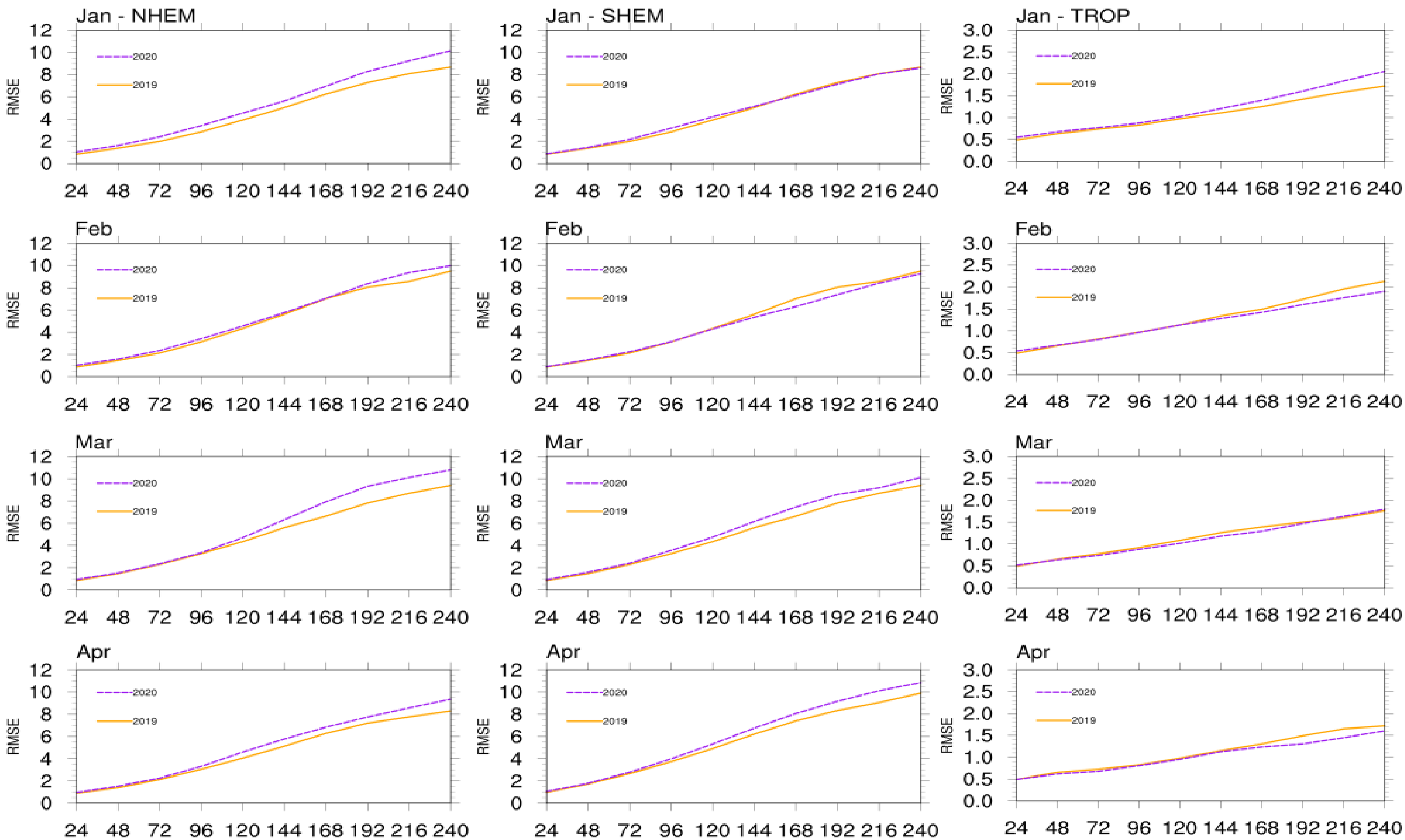

Figure 10: Same as of Figure 9, but for the parameter RMSE for the months January – April during 2019 and 2020

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