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Development of a Gridded Data Processing Tool for Coordinated Regional Climate Downscaling Experiment Data

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I. Introduction

Agrometeorological models have been developed to simulate the biophysical processes across agricultural ecosystem at different spatial scales. For example, potential evapotranspiration (PET), which has been used to determine water balance in a region, was estimated with observed point data across China (Gao *et al.*, 2007). For regional assessment, PET has been calculated using gridded climate data, *e.g.*, outputs of General Circulation Model (GCM) or Regional Climate Model (RCM) (Chattopadhyay and Hulme, 1997; Tramblay *et al.*, 2013). Regional impact assessment of climate on agricultural ecosystems would benefit from the use of Coordinated Regional Downscaling Experiment (CORDEX) data. The CORDEX data have a high spatial resolution for various regions including East Asia (Giorgi *et al.*, 2009). Still, the existing data tools have limited functionalities to process the CORDEX data for the agrometeorological models. The objectives of this study were to develop a gridded data tool to facilitate the use of CORDEX data as inputs to agricultural models.

II. Materials and methods

The gridded data tool for the CORDEX data was developed based on the Grid Analysis and Display System (GrADS), which has been used in analyzing outputs of numerical weather models. Functionalities specific to the processing of the CORDEX data were implemented using C. To support data input for gridded data, readMetaCORDEX, readCORDEX and ensemCORDEX functions were defined in the data tool. Open Multi-Processing (openMP) was also used to support parallel processing within the tool.

The values of PET were estimated using gridded climate data as inputs to the FAO 56 formula as a case study (Allen *et al.*, 1998). The climate data are collected from CORDEX East Asia website (http://cordex-ea.climate.go.kr). Four RCM datasets were used including HadGEM3RA, SNU-WRF, YSU-RSM, and RegCM4. An ensemble dataset was created by averaging four sets of PET data derived from individual RCM data. PET was calculated over

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Korean peninsula during April to October during which rice is usually grown (2001–2010). Historical and RCP85 data was used to calculate PET during past (2001–2005) and current (2006–2010) periods, respectively. Estimates of PET using CORDEX data were compared with those using AgMERRA data (Ruane *et al.*, 2015). Root mean square error (RMSE) was calculated between ouiputs from AgMERRA and each CORDEX datasets to analyze the reliability of each data set. Customized scripts to calculate PET was written in R.

III. Result and Discussion

The gridded data tool was useful for calculation of PET using CORDEX and AgMERRA data. Gridded climate data was loaded into R using the gridded data tool to create maps of PET in East Asia based on the FAO-56 formula. Spatial projection of CORDEX data was converted into WGS84 without manual operation. Ensemble set from outputs of multiple RCMs was created automatically using the tool. The use of openMP decreased running time of data loading.

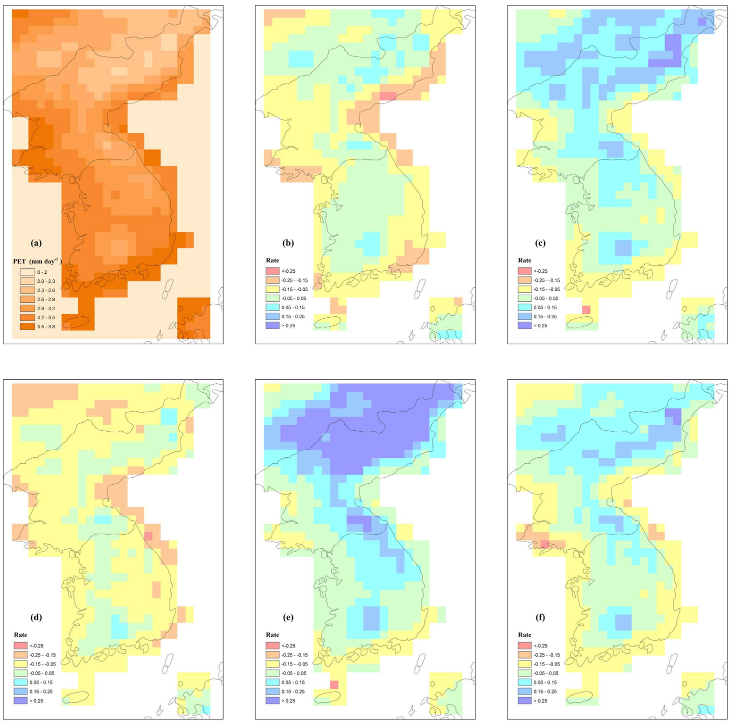

Fig. 1. Potential evapotranspiration in Korean peninsula during April to October calculated from AgMERRA (2001 - 2005) (a) and bias (%) between PET calculated using AgMERRA and CORDEX data sets including HadGEM3RA (a), YSU-RSM (b), RegCM4 (c), SNU-WRF (d) and, an ensemble of four CORDEX dataset (e).

PET from AgMERRA and CORDEX datasets had a similar spatial trend except for the SNU-WRF model (Fig. 1). For example, PET was high in coastal and plain region whereas it was low in eastern and northern mountainous region for both data sets. The difference between values of PET obtained from AgMERRA and CORDEX datasets also had a spatial trend. For example, the biases of PET between those data sets were negative in coastal and positive in inland areas with complex terrains, especially in Misiryeong and Noryeong Mountains where all CORDEX datasets have a positive bias.

Table 1. The root mean square error (RMSE; mm day^{-1}) of potential evapotranspiration using gridded data from regional climate models as inputs to the FAO 56 formula (Allen *et al.*, 1998) for past (2001-2005) and current periods (2006-2010)

Models*	2001-2005	2006-2010
HadGEM3RA	0.23	0.27
YSU-RSM	0.27	0.21
RegCM4	0.22	0.21
SNU-WRF	0.56	0.64
ENSEMBLE	0.14	0.15

* HadGEM3RA, YSU-RSM, RegCM4, SNU-WRF, and ENSEMBLE indicate potential evapotranspiration from HadGEM3RA, YSU-RSM, RegCM4, SNU-WRF, and average of the potential evapotranspiration result from four CORDEX datasets respectively.

The RMSE of PET estimates changed over time. Although PET for HadGEM3RA, YSU-RSM, and RegCM4 models had similar values of RMSE compared with that for AgMERRA dataset. These RMSE values differ by two periods that represent past and current climate conditions, respectively. For example, the RegCM4 model had the lowest RMSE in the past periods (2001–2005) whereas the YSU-RSM model had the lowest error in the current periods (2006–2010). The RMSE for the SNU-WRF model, which was considerably large in the estimation of PET, also differed by two time periods.

The RMSE of PET for the ensemble data set was lower than that of PET obtained from individual CORDEX data sets. For example, the RMSE for the ensemble set tended to have lower than that of individual models over a region. The RMSE for ensemble set was relatively small (< 0.16 mm day-1) for both period, which suggested that the ensemble of multiple scenarios would allow reliable estimation of PET over a long term period using gridded climate data.

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