Development of Korea Land Data Assimilation System with MODIS-derived land data and Its Application Using WRF

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1. Introduction

As it has been widely accepted that land-surface processes play an important role in weather and climate, governing exchanges of heat, moisture, and momentum between the surface and atmosphere, it is necessary to represent them more realistically in predicting weather phenomenon. In the modeling framework, it depends on both the performance of land surface model (LSM) and the accuracy of land surface initial conditions. In this regard, many land surface models with reasonable physical processes have already been coupled to not only general circulation models but also regional and mesoscale models.

In addition, initialization methods of producing land-surface states reflecting the real world are under development (Lu et al. 2005). Among them, Land Data Assimilation System (LDAS), consisting of uncoupled LSMs forced by observations and unaffected by the biases caused by mother model, can be valuable sources of accurate initial land surface conditions for NWP models. Now, some LDAS projects like North American Land Data Assimilation System (NLDAS; Mitchell et al. 2004), Global Land Data Assimilation System (GLDAS; Rodell et al. 2004), High Resolution Land Data Assimilation System (HRLDAS; Chen et al. 2007) have been developed. On the success of these, their applications to large-scale and regional model has been undertook (Trier et al 2004; Cosgrove and Alonge 2006).

In this study, in order to meet the demand for an accurate representation of land-atmosphere interaction over East Asia, we have developed Korea Land Data Assimilation System (KLDAS) loading with MODIS-derived land surface characteristics and investigated the impact of realistic land surface condition on the numerical simulation using a mesoscale model.

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2. Korea Land Data Assimilation System

KLDAS, which follows the concept and methodology used in many LDAS projects, is an uncoupled the Noah land surface modeling system based on MODIS-derived static surface fields and time-varying vegetation characteristics. KLDAS has some unique aspects in that it attempts to improve land surface parameters of off-line LSM using MODIS-derived land data, and presents generation methods of observation-based input forcings available over East Asia region.

The main component of KLDAS is the off-line Noah LSM V2.5.2, which has the same version as the Noah LSM coupled with Weather Research and Forecasting (WRF ; Skamarock et al. 2005). For more information on the uncoupled Noah LSM, one can refer to Chen et al. (1996), Ek et al. (2003). As for the HRLDAS by Chen et al. (2007), to facilitate direct transfer from KLDAS to WRF-coupled LSM, all vegetation and soil parameters commonly required by the uncoupled Noah LSM in the KLDAS and the coupled one in WRF model are identified.

At first, KLDAS reads the WRF Preprocessing System (WPS) output file, which is set up to run on East Asia (between 10°N ~ 50°N and 110°E ~ 155°E) with 10 km grid spacing (see Fig. 1 for a map of domain), that contains grid configuration (resolution, grid points, and projection), land use, and soil texture maps, and monthly vegetation fraction and assigns these surface fields to each point of KLDAS.

Then, using global land surface state variables maps using data from Moderate Resolution Imaging Spectroradiometer (MODIS) of the National Aeronautics and Space Administration (NASA)'s Terra satellite we have improved the WPS-based land surface parameters within both KLDAS's off-line Noah LSM and the Noah LSM coupled with WRF. Land cover, green vegetation fraction, and LAI are improved using Collection 4 MOD12C1 land cover, Collection 5 MOD13C1 Enhanced Vegetation Index (EVI) and MOD15_BU LAI data (Mynemi et al. 2002), respectively (Figure 1). Note that since the MODIS land cover map supplies the different classification type from USGS category used in WRF WPS, translation to the USGS classification has been carried out as in Strahler et al. (1999). Green vegetation faction (GVF) is obtained by using Enhanced Vegetation Index (EVI) as in Mu et al. (2007) as:

$$GVF = \frac{EVI - EVI_{\min}}{EVI_{\max} - EVI_{\min}}$$

where $EVI_{\min}$ and $EVI_{\max}$ are the signals from bare soil (LAI $\rightarrow$ 0) and dense green vegetation (LAI $\rightarrow \infty$) (Gutman and Ignatov, 1998), which are set as seasonally and geographically invariant constants 0.05 and 0.65, respectively. Land cover and GVF are assigned KLDAS grid using the nearest neighbor information and LAI is bilinearly interpolated considering land-sea mask information.

Hourly atmospheric forcing data used to drive the uncoupled LSM at each grid point are classified into two main groups: atmospheric conditions near surface based on model or analysis and surface conditions based on observation. Analysis-based fields are temperature, dew point depression at 2m, U, V wind component at 10m, and surface pressure. They are derived from 0.5625° 6-hourly the Global Data Assimilation and Prediction System (GDAPS; Park et al. 2002) analysis fields of Korea Meteorological Administration. Temperature and dew point depression at 2m are translated to relative humidity using the preprocessing equation. All variables are interpolated bilinearly from 0.5625° GDAPS grid to 10km KLDAS grid, linearly from their native 6 hourly to the hourly time step required by KLDAS, respectively. As KLDAS topography differs from the topography of GDAPS, adjustment procedures are also done as in Cosgrove et al. (2003).

The rest are observation-based precipitation and short-wave radiation. Generally, NWP models have hard time on accurately simulating these variables, which greatly impact on land surface processes. In this regards, we estimate the shortwave radiation using Li et al. (1993) algorithm and geostationary satellites data without the help of NWP models. This is a simple algorithm to produce the solar radiation absorbed by the ground using TOA visible channel reflectance. The input data required for the algorithm are cloud fraction, precipitable water, effective cloud height, and angle information on sun and satellite (the

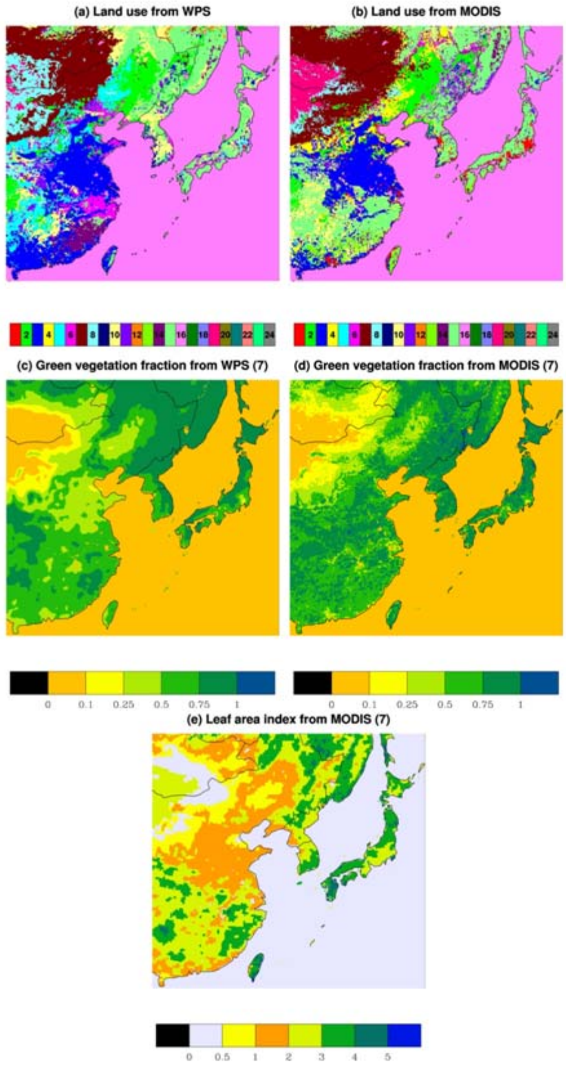

Figure 1. Improved land surface parameters using MODIS. Left panels are the WPS-based parameters and Right panels are the MODIS-based fileds.

solar zenith angle, satellite viewing angle and the relative azimuth angle). The estimation of the cloud fraction is based on cloudy imager pixels detected in 5 × 5 horizontal points around each point. For the detection of clouds, a bi-spectral threshold technique based on Jedlovc and Law (2003) with 3 hourly infrared and near-infrared channel data of GOES-9 and MTSAT-1R has been investigated. Precipitable water and effective cloud height for conversion relation from narrow band to broad band (Li and Trishchenco 1999) are estimated using GDAPS and the brightness temperature derived from infrared channel data. The estimated downward solar radiation is spatially interpolated using budget interpolation and also accomplished with a zenith angle-based temporal interpolation.

Sources of KLDAS precipitation forcing are approximately 1000 WMO Global Telecommunication System (GTS) 6 hour accumulated precipitation reports over East Asia, 75 synoptic station and 500 Automatic Weather System hourly precipitation gauge data over Korean Peninsula. For the quality control, a duplication station check, an extreme value check and a standard deviation check have been examined. GTS 6hourly data are temporally disaggregated into hourly fields with the criteria of clear sky (0.25 > cloud fraction) in the estimated cloud fraction. The spherical version of Shepard's distance-weighting method (Willmott et al. 1985) is also used for the production from these hourly irregular observation data to KLDAS gridded data.

3.1. Verification of KLDAS input forcings.

Land surface models depend heavily upon accurate forcing data to produce realistic simulations of land surface processes. With this in mind, it will be useful to analyze how well the generated forcings in KLDAS agree with the observation prior to the long-term simulation.

Input forcings, which are obtained from the GDAPS data, are compared with hourly observation from 10 synoptic stations over the Korean Peninsula in 2006 (Fig. 2). Some analysis-based input forcings shows the time lag for the daily maximum and minimum values and smaller diurnal variation than observation because the time resolution of the source data is 6 hourly (00, 06, 12 and 18 UTC is corresponding to 09, 15, 21 and 03 LST, respectively). It causes to somehow larger RMSE values than other LDAS studies. RMSEs against hourly observation data in 2006 are 7.5 hPa for surface pressure and 2.8 K for temperature and about 14 % for relative humidity.

For the download radiation, the peak problem has been solved by using 3-hourly satellite data. However, the estimated solar radiation is overestimated during all day time and the RMSE is about 120 Wm^{-2}. The spatial distribution of the estimated solar radiation r eflects well the cloud distribution shown on visible satellite image (not shown).

3.2. Verification of KLDAS output

The offline Noah LSM have been integrated for 24 months from 1 August 2004 to 1 July 2006 using hourly forcing data. The KLDAS is initialized with NCEP GDAS land surface data on 1 August 2004 for

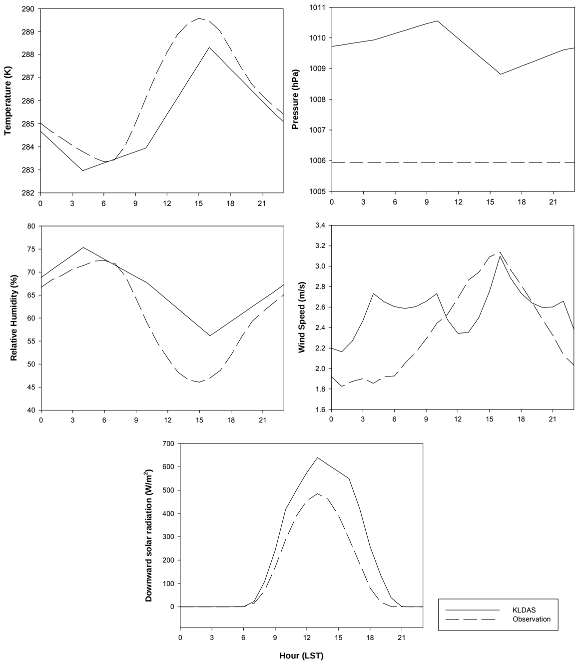

Figure 2. RMSE of KLDAS input forcings computed with Station data over the Korean Peninsula for January-December 2006.

the shorter spinup time. This spunup fields have been verified with Koflux data. Korea Flux network is designed to monitor the exchanges of water and carbon between the atmosphere and key terrestrial ecosystems in and around the Korea Peninsula (Kim et al. 2006). Study sites are the deciduous forest site in Gwangneung Experimental Forest (DK; 37.7487°N, 127.1489°E) and the farmland site in Haenam (FK; 34.5539°N, 126.5697°E) in Korea Flux network.

Table 1 documents the verification statistics (averaged for 1 January - 31 December in 2006) for Koflux sites. In DK, Surface fluxes have high bias. It can be explained by overestimated solar radiation forcings and the difference between land surface parameters in LSM and these of observation site. DK has mostly deciduous broadleaf tree with dense and tall canopy height (about 30m) and also total soil layer less than 1m because it is located on mountain slope. However, in KLDAS these environments of observation are not shown. The mismatch of vegetation phenology in the growing and decaying season of vegetation also causes to the overestimation of latent heat flux. Overestimated solar radiation in cloudy and rainy day has an impact on the positive bias in simulated surface fluxes. In FK, latent heat flux is less dependent on vegetation phenology than DK. However, like DK, overestimated solar radiation drives the higher RMSE for sensible heat flux.

KLDAS soil moisture has generally better agreement with observation in terms of soil moisture evolution. But, in all sites, KLDAS produces slightly smaller seasonal variation than observed in soil moisture. In particular, KLDAS produced erroneously soil moisture in drought season and winter season. Note that because it is difficult to measure accurately soil moisture at the day when temperature is below 0 we must deal with the data considerately. Also, KLDAS Noah LSM does not reflect the irrigation around FK (paddy field), it has drier soil moisture in comparison with observation. For soil temperature, despite of slightly larger diurnal variation than observed, KLDAS captures well the daily mean variation of the observation in all sites. Despite some discrepancies these results show that KLDAS is able to capture the observed daily tendency of surface fluxes and soil condition.

Table1. RMSE and bias, averaged for 2006, of KLDAS sensible heat flux, latent hear flux, soil moisture and soil temperature at 10cm verified against Koflux sites

	RMSE				Bias			
Site	SH	LH	SM1	ST1	SH	LH	SM1	ST1
DK	56.02	54.58	0.07	2.14	11.28	25.81	0.06	0.14
FK	67.75	45.92	0.08	2.08	8.99	14.23	-0.06	-0.5

4. Application using WRF

To understand the impact on WRF model forecasts of using KLDAS land surface states as WRF model initial land surface condition, Two case studies have been selected. One is a rainy case and the other is a clean day case. Control experiment has been run using GDAPS data. However, because GDAPS does not have any land surface data, control experiment (CON) is initialized with NCEP GDAS land surface conditions. We compare results of CON with an identically configured and executed simulation (KLDAS) that utilized the much higher initial specification of soil conditions from KLDAS.

Analyzing of CON and KLDAS simulation is going and many validations against observations will be investigated in detail.

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