Assimilation of Microwave Brightness Temperature in a Land Data Assimilation System with Multi-Observation Operators

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1. Abstract

In this study, we developed a microwave Land Data Assimilation System (LDAS) with three radiative transfer models (RTMs), including QH, LandEM and CMEM, as its multi-observation operators (LDAS-MO) and investigated the impacts of the RTMs on the assimilated results. It was found that the assimilated soil moisture for the QH model, which was more sensitive to dry soil than the other models, produced closer correlations with field observations (OBS) in arid and semi-arid regions while smaller RMSEs were observed for LandEM. CMEM agreed most closely with OBS over the areas with higher vegetation fraction due to its better simulation of the brightness temperature. To improve assimilation accuracy, a Bayesian model averaging (BMA) scheme for the LDAS-MO was developed. The BMA scheme was found to significantly enhance assimilation capability producing the soil moisture analysis, showing the lowest RMSEs and highest correlations with OBS over all areas.

2. Models and Data

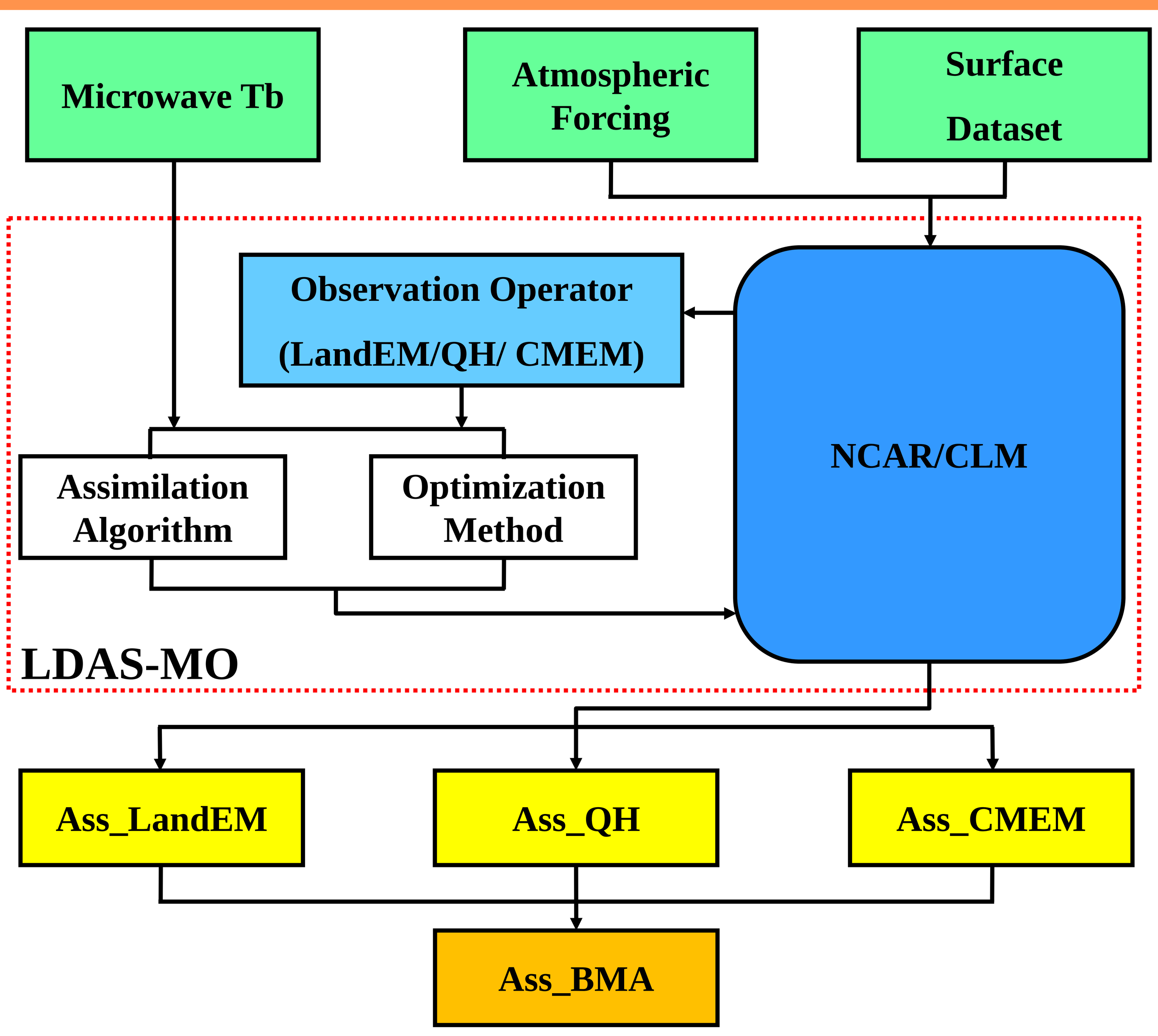

Fig. 1. The diagram of LDAS-MO.

- **Forecast operators: the soil–water hydrodynamic model in the NCAR Community Land Model (CLM) [*Oleson et al.*, 2004].**
- **Three observation operators: LandEM [*Weng et al.*, 2001], CMEM [*Drusch et al.*, 2009], QH [*Yang et al.*, 2007].**
- **Assimilation algorithm: POD-En4DVAR [*Tian et al.*, 2008].**
- **Optimization method: EnCNOP [*Tian et al.*, 2010].**

Bayesian model averaging (BMA) scheme [*Raftery et al.* 2005]:

$$p(\Delta \mid f_1, \cdots, f_N) = \sum_{k=1}^{N} w_k g_k(\Delta \mid f_k)$$

Verification data

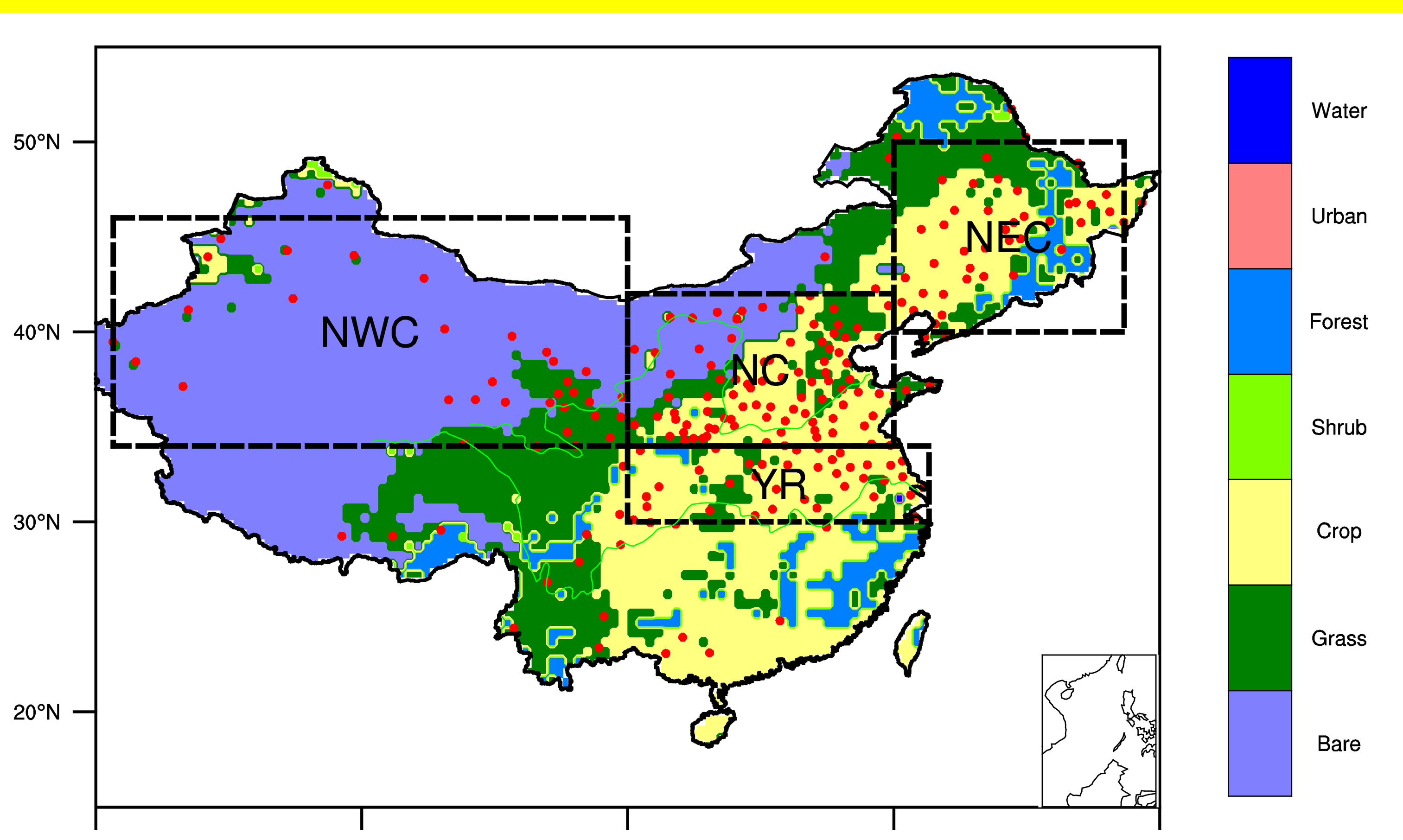

Fig. 2. The locations of 226 stations (red dots) with *in situ* soil moisture observations. Also shown (boxes) are four sub-regions in China: north-eastern China (NEC, 38), northern China (NC, 88), north-western China (NWC, 36), and middle and lower reaches of the Yangtze River (YR, 31), where the numbers in the parentheses stand for the numbers of observational stations.

3. Assimilation of AMSR-E in LDAS-MO

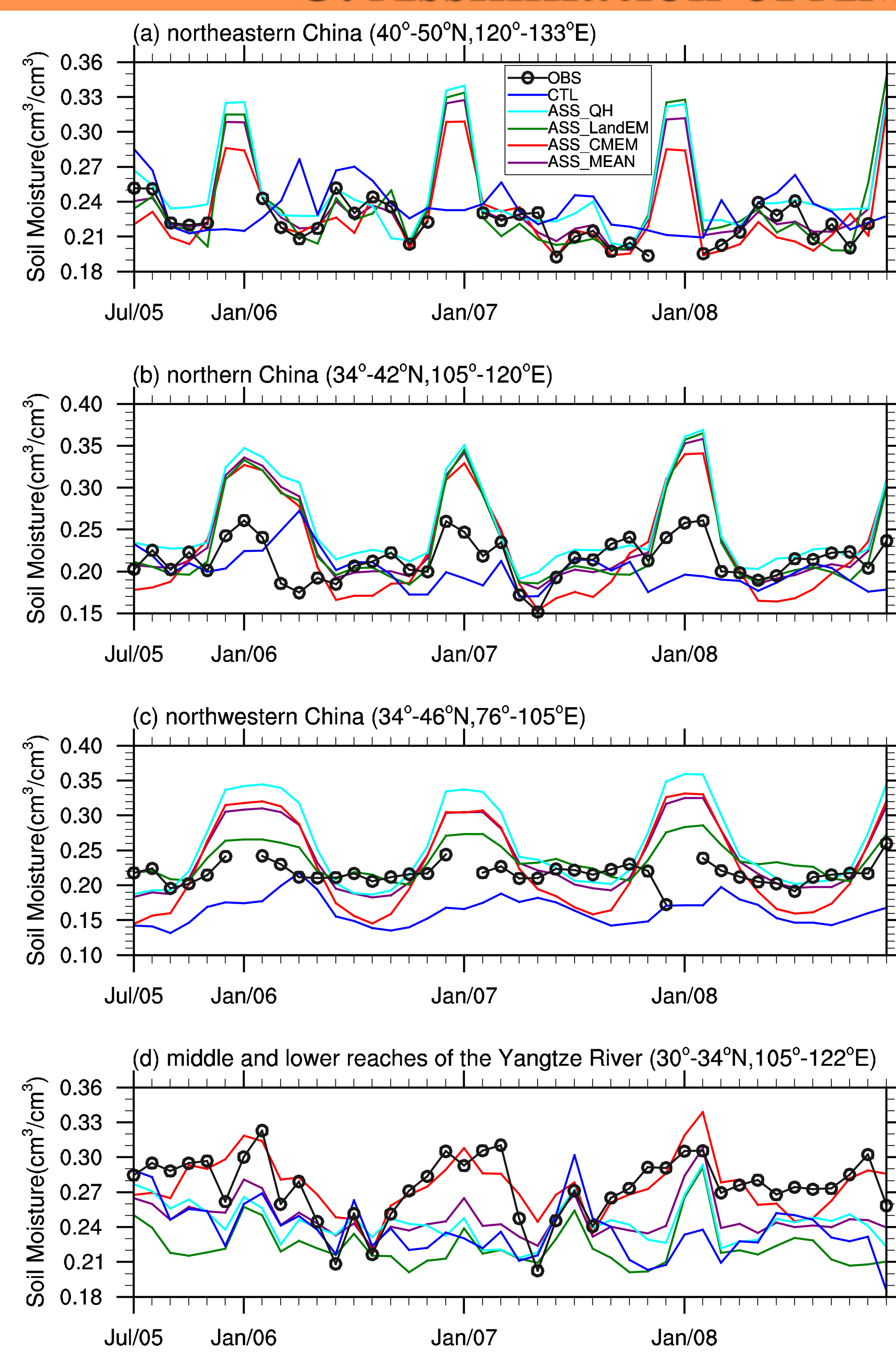

Fig. 3. Time series of monthly mean volumetric soil moisture content from ground observations (OBS), control run (CTL), and three assimilated cases (ASS_QH, ASS_LandEM, ASS_CMEM) and their simple arithmetic average (ASS_MEAN) over four sub-regions in China during July 2005 – December 2008.

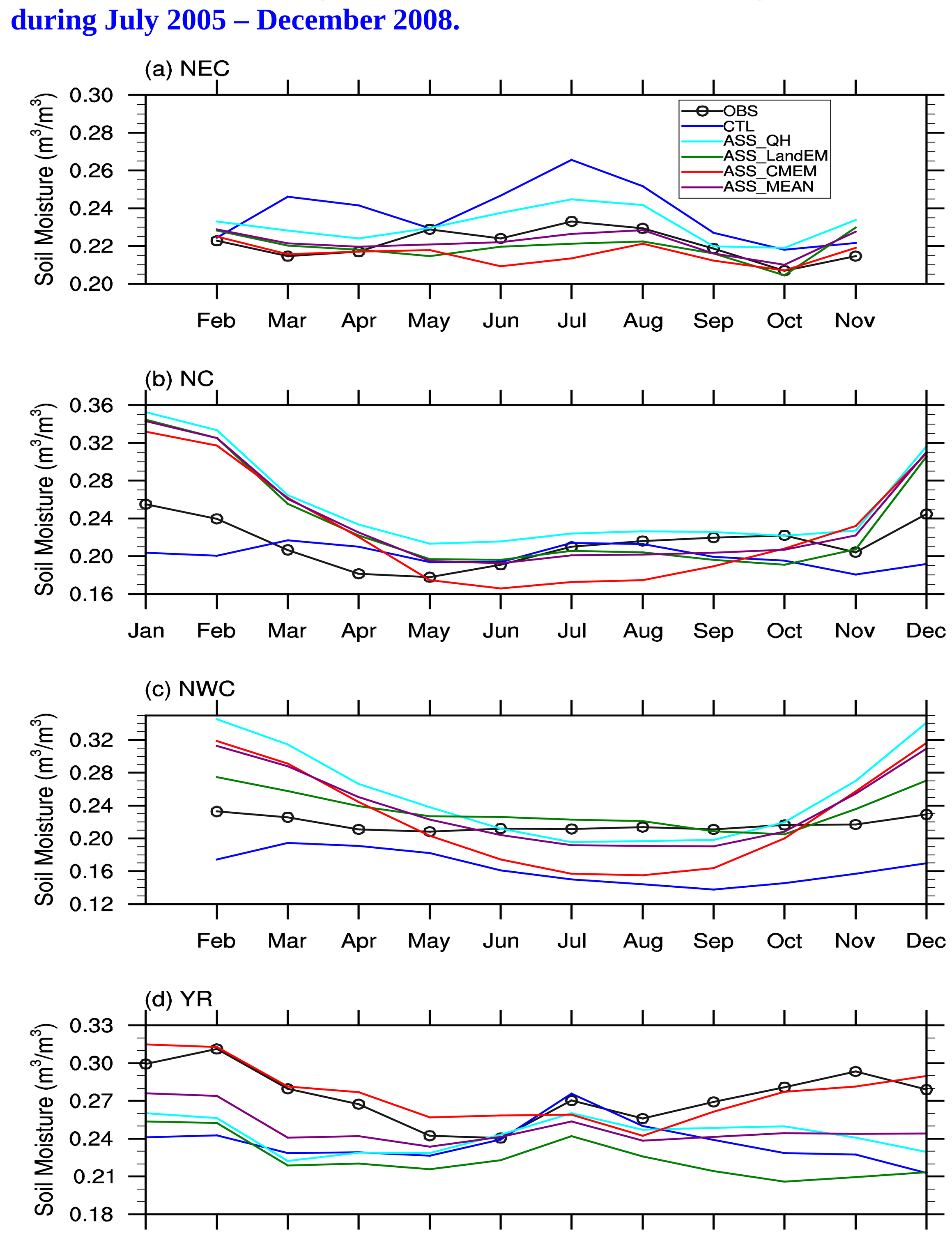

Fig. 5. Seasonal variation of volumetric soil moisture from Fig 3. for four sub-reigons in China.

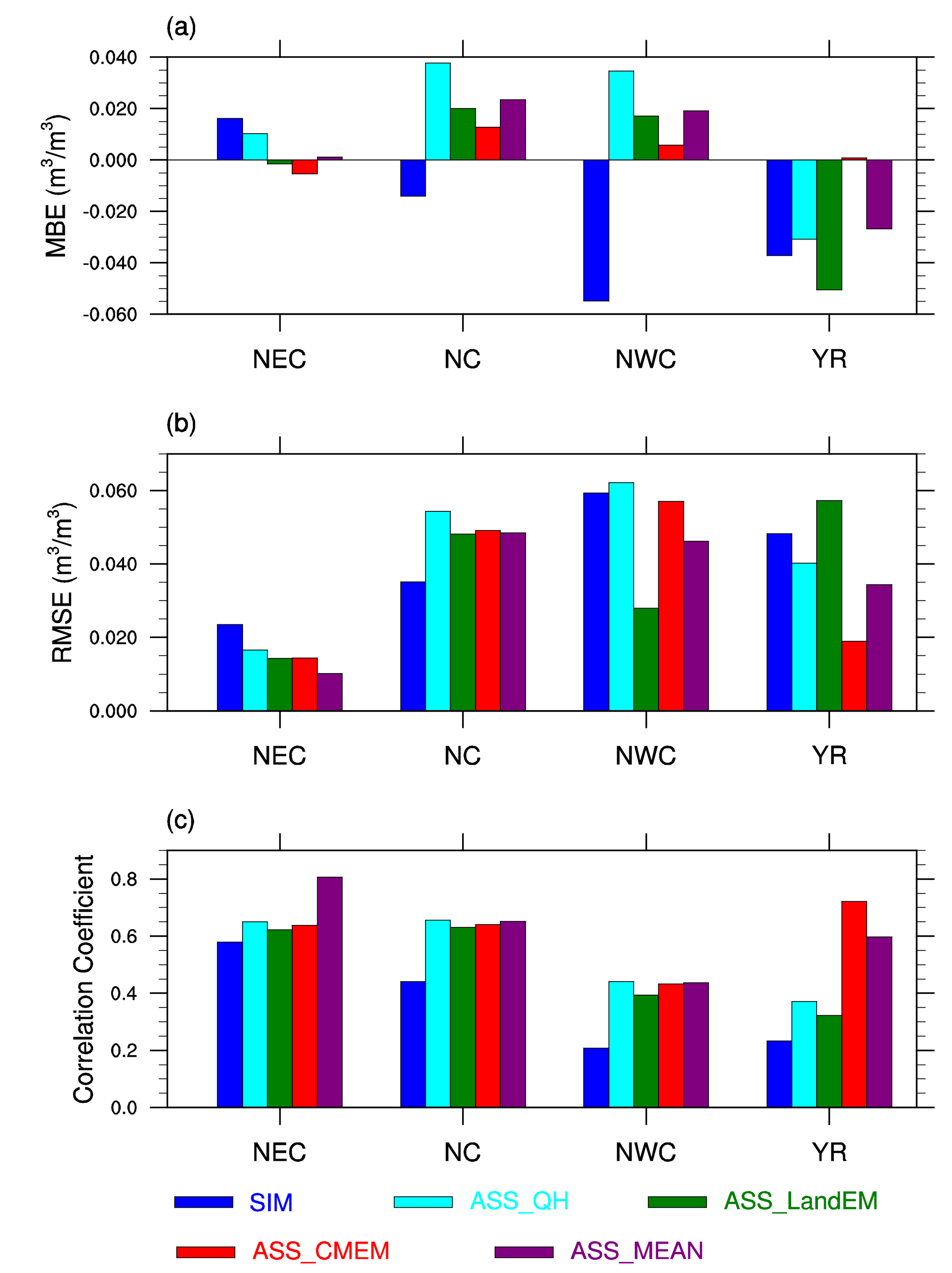

Fig.4. Mean bias error (MBE), root mean square error (RMSE), correlation coefficient of monthly volumetric soil moisture from Fig. 3 compared with in situ measurements for July 2005 – December 2008.

Table 1. The Bayesian model averaging (BMA) weights for three assimilated cases (ASS_QH, ASS_LandEM, ASS_CMEM) over four sub-regions in China.

Region	ASS_QH	ASS_LandEM	ASS_CMEM
NEC	0.5822	0.0020	0.4158
NC	0.6759	0.0153	0.3088
NWC	0.8832	0.0048	0.1120
YR	0.0005	0.0013	0.9982

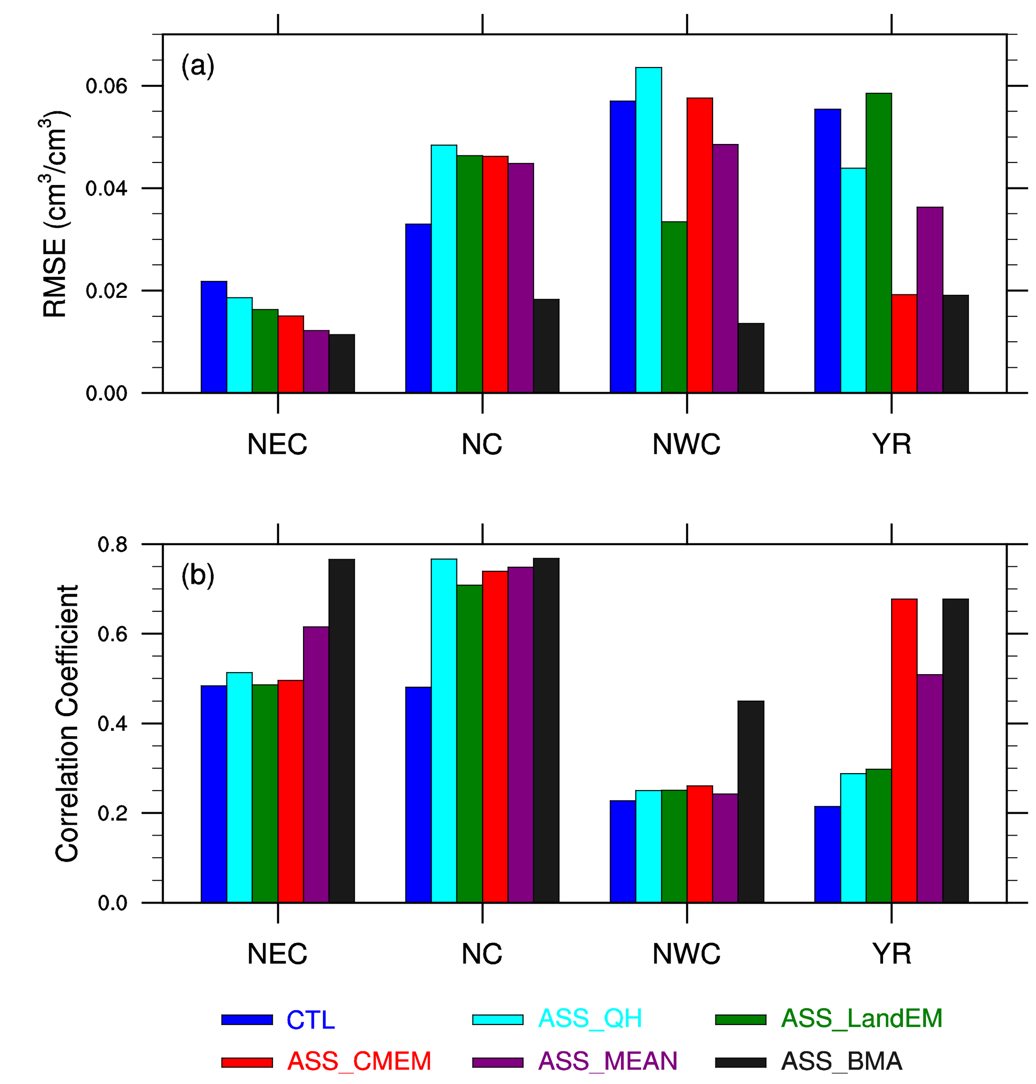

Fig. 6. (a) RMSEs, and (b) correlation coefficients between the observed and simulated monthly volumetric soil water content over four sub-regions in China during January 2007 - December 2008. ASS_BMA is the ensemble average of three assimilated cases using BMA method.

4. Conclusions

- **Large discrepancies were observed over different areas between the assimilated results for each of the three observation operators individually, although they all improved the soil moisture estimation to a certain extent .**
- **The assimilated soil moisture for QH showed higher correlations with OBS over arid and semi-arid regions due to its higher sensitivity to dry soil, where the smaller RMSEs were observed for LandEM. CMEM, in which the vegetation opacity model simulated the Tb data in best agreement with satellite observations over densely vegetated areas, agreed most closely with OBS over YR.**
- **It was demonstrated that the BMA scheme with LDAS-MO has the potential to estimate soil moisture with high accuracy.**

References:

1. Jia, B. H., Z. H. Xie, X. J. Tian, and C. X. Shi. A soil moisture assimilation scheme based on the ensemble Kalman filter using microwave brightness temperature. *Sci. China Ser. D-Earth Sci.*, 2009, doi: 10.1007/s11430-009-0122-z.
2. Tian, X. J., Z. H. Xie, A. G. Dai, C. X. Shi, B. H. Jia, F. Chen, and K. Yang. A Dual-Pass Variational Data Assimilation Framework for Estimating Soil Moisture Profiles from AMSR-E Microwave Brightness Temperature. *J. Geophys. Res.*, 2009, 114, D16102.
3. Tian, X. J., Z. H. Xie, A. G. Dai, B. H. Jia, and C. X. Shi. A microwave land data assimilation system: Scheme and preliminary evaluation over China. *J. Geophys. Res.*, 2010, 115, D21113, doi:10.1029/2010JD014370.