Hydrol. Earth Syst. Sci. Discuss., 10, C3726–C3736, 2013
www.hydrol-earth-syst-sci-discuss.net/10/C3726/2013/

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Modeling regional evaporation through ANFIS incorporated solely with remote sensing data" *by* F.-J. Chang and W. Sun

F.-J. Chang and W. Sun

changfj@ntu.edu.tw

Received and published: 2 August 2013

Dear Professor Zehe,

Thank you for sending me the interactive comment hessd-10-C3320-2013 on our paper hess-2013-167 'Modeling regional evaporation through ANFIS incorporated solely with remote sensing data'.

We appreciate Dr. Samaniego for recognizing our research and raising valuable comments that benefit our manuscript. We have carefully studied Dr. Samaniego's comments and deliberately made responses to the comments in the response note. Spe-

cial attention is paid to 1) a polish on the statements regarding data-driven models and physical-based models to avoid misinterpretation of our concept, and 2) provide a more detailed description on the characteristics of ANNs. Our original idea is to investigate the suitability of ANNs coupled simply with remote sensing data for making evaporation estimation over large areas, where the network of ground-based meteorological gauging stations is not dense enough or readily available. The proposed model is demonstrated with reasonable and acceptable estimation results, which is quite encouraging. The relevant responses and corrections in consideration of the comments/suggestions from Dr. Samaniego will be provided in the revised manuscript accordingly.

We hope that our responses are satisfactory to you and Dr. Samaniego, and look forward to your response.

Best Regards,

Professor Dr. Fi-John Chang

Referee #2 (RC C3320): Dr. L. Samaniego

1 General Comments

In this manuscript, the authors describe a procedure to estimate evapotranspiration over Taiwan using adaptive network-based fuzzy inference system and remotely sensed products. The authors argued that the proposed method is reliable enough for prediction over large areas where the density of metereological stations is not dense enough. In my opinion publications of relevant research in this subject should be encouraged in HESS. In the present manuscript, however, several major issues should be clarified before publication.

Response: We appreciate Dr. Samaniego for recognizing our research. With a careful study on the comments raised by Dr. Samaniego, the responses to the comments are deliberately addressed accordingly. We hope that Dr. Samaniego can be satisfied with them.

2 Specific Comments

This manuscript has the following technical shortcomings:

. First of all, authors should clearly indicate what they really mean by evaporation. Do they mean solely evaporation from bare soils or water bodies? Or do they mean evapotranspiration (ET)? Please clarify. It seems that they use this term interchangeably.

Response: Evaporation discussed in this study is pan evaporation, which is measured by Class A pan (i.e. water bodies). In general, each meteorological station in Taiwan is equipped with a sheathed thermometer, a propeller anemometer, a piston mercury barometer, a pyranometer, a tipping-bucket raingauge, a Class A pan, a hair hygrometer, a solar-cell sunshine recorder and a psychrometer for measuring temperature, wind speed, pressure, global solar radiation, rainfall, pan evaporation, humidity, sunshine hours and humidity, respectively. More details can be found at the web site (http://www.cwb.gov.tw/V7e/index_home.htm) of the Central Weather Bureau, Taiwan. Evaporation data collected at 16 meteorological gauging stations distributed uniformly all over Taiwan are used to train the structure and test the performance of the ANFIS estimation model.

. I am missing a research hypothesis in this study. It should be mentioned in the introduction and it should address the shortcomings of the current state of the art. No research hypothesis, then no research paper.

Response: Thanks for the suggestion. Yes, indeed, a research hypothesis can be a pivot for a research. The topography of Taiwan is characterized by a mountainous north–south trending central belt with a summit of 3952 m, and approximately 70% of Taiwan is covered by mountainous terrains. Such topology and steep morphology raises the difficulty in building a dense network of meteorological stations over the whole Taiwan, which could be costly and laborious, and thus prevent the obtainment of island-wide ground measurements of meteorological factors such as evaporation. Bearing this in mind, we try to explore alternative tools for effectively and efficiently

estimating evaporation without the use of locally measured meteorological data. Luckily, artificial intelligence techniques and remotely sensed products can be good candidates for our task. Therefore, this study attempts to develop an evaporation estimation model over the study area through a neuro-fuzzy network based solely on remotely sensed products. Locally measured meteorological data are ancillarily used only to train the structure and test the performance of the estimation model during model construction stage. Once the model is well constructed, the only data needed for future estimation are remotely sensed data. The results demonstrate that the proposed ANN (data-driven) model can effectively produce island-wide evaporation estimation with reasonable accuracy, and thus substantially reduces the possible cost of manpower and measurements involved in ground-based models. The proposed model might not produce estimation as accurately as ground-based models; nevertheless, it can tackle the problem of estimation over large areas with acceptable estimation accuracy.

. The literature review on the estimation of evapotranspiration based on remotely sensed products is abundant. The small subset presented by the authors is not complete. The literature review should be relevant to support the research hypothesis.

Response: Thanks for the suggestion. We will add more literatures relevant to support our research hypothesis in the revised manuscript.

. The authors clearly identify the importance of estimating ET for water management. Based on this statement, I can not understand why a data-based driven model, as that one proposed by the authors, which do not have any physical conceptualization of the processes involved, should be better that a land surface hydrological model. Please justify.

Response: At first, we would like to apology for the vague statements that gave the wrong impression of data-driven models vs. physical-based models in our manuscript (P6155, L20-21; P6156, L26-29). We realize that the physical conceptualization of evaporation processes has been fully explored and gained significant and excellent

outcomes for decades. With appreciation for the foundation constructed by physical-based models, data-driven techniques could be considered for evaporation estimation. Among data-driven techniques, ANNs are known for tackling nonlinear problems. We have long term endeavored to develop/implement ANNs in diverse domains such as hydrology, eco-hydrology, meteorology, engineering and hydraulics, and already established individual estimation models associated with pan evaporation at single station, multiple stations, and ungauged sites based on ground measurements of meteorological factors (Chang et al., 2010, 2013; Chung et al., 2012). However, evaporation estimation over large area is more challenging and could be explored with great potential. Many hydro-meteorologists suggested the combined use of remote sensing observations and ancillary surface as well as atmospheric observations for estimating evaporation/evapotranspiration (Cleugh, et al., 2007; Farah and Bastiaanssen, 2011; Glenn et. al., 2011; Leuning et al., 2008; Mu et al., 2007; Rivas and Caselles, 2004; Zhang et al., 2009). Alternatively, considering the laborious and costly ground measurements of meteorological factors, particularly for the areas with less dense networks of meteorological stations, this study proposes to investigate the effectiveness of an evaporation estimation model established based solely on remotely sensed products in terms of temporal and spatial aspects. The results demonstrate that the proposed ANN (data-driven) model can effectively produce island-wide evaporation estimation with reasonable accuracy, and thus substantially reduces the possible cost of manpower and measurements involved in ground-based models. That is to say, the encouraging practicability of the proposed data-driven model can save the efforts made for obtaining observation data in ground-based models.

References:

Chang, F. J., Chang, L. C., Kao, H. S., and Wu, G. R.: Assessing the effort of meteorological variables for evaporation estimation by self-organizing map neural network, J. Hydrol., 384, 118–129, 2010.

Chang, F. J., Sun, W., and Chung, C. H.: Dynamic factor analysis and artificial neural

network for estimating pan evaporations at multiple stations in northern Taiwan, Hydrolog. Sci. J., 58, 813–825, doi:10.1080/02626667.2013.775447, 2013.

Chung, C.-H., Chiang, Y.-M., and Chang, F.-J.: A spatial neural fuzzy network for estimating pan evaporation at ungauged sites, Hydrol. Earth Syst. Sci., 16, 255–266, doi:10.5194/hess-25 16-255-2012, 2012.

Cleugh, H. A., Leuning, R., Mu, Q., and Running, S. W.: Regional evaporation estimates from flux tower and MODIS satellite data, Remote Sens. Environ., 106, 285–304, 2007.

Farah, H.O., and Bastiaanssen, W.G.M.: Impact of spatial variations of land surface parameters on regional evaporation: a case study with remote sensing data, Hydrol. Processes, 15(9): 1585-1607, 2011.

Glenn, E.P., Doody, T.M., Guerschman, J.P., Huete, A.R., King, E.A., McVicar, T.R., Van Dijk, A. I. J. M., Van Niel, T.G., Yebra, M., and Zhang, Y.: Actual evapotranspiration estimation by ground and remote sensing methods: the Australian experience, Hydrol. Processes, 25(26), 4103-4116, 2011.

Leuning R., Zhang Y.Q., Rajaud A., Cleugh H., Tu K.: A simple surface conductance model to estimate regional evaporation using MODIS leaf area index and the Penman–Monteith equation, Water Resources Research, 44, W10419, DOI: 10.1029/2007wr006562, 2008.

Mu Q.Z., Heinsch F.A.A., Zhao M., Running S.W.: Development of a global evapotranspiration algorithm based on MODIS and global meteorology data. Remote Sensing of Environment, 111, 519–536, 2007.

Rivas, R., and Caselles, V.: A simplified equation to estimate spatial reference evaporation from remote sensing-based surface temperature and local meteorological data, Remote Sens. Environ., 93(1-2), 68-76, 2004.

Zhang Y.Q., Chiew F.H.S., Zhang L., Li H.X.: Use of remotely sensed actual evapotran-

spiration to improve rainfall-runoff modeling in southeast Australia, Journal of Hydrometeorology, 10, 969–980, 2009.

. ANN (with or without fuzzy rules) are complex and overparameterized data-driven models. If the authors argue that this kind of models are better suited for estimating ET than other kinds of models, then the authors should provide evidence in favor of this hypothesis. Simply concluding that the proposed method is “reliable”, without careful model evaluation and inter-comparison is misleading if not wrong.

Response: Following our previous studies (Chang et al., 2010, 2013; Chung et al., 2012) and many others (Kim et al., 2012; Shiri et al., 2011; Shirsath et al., 2010; Tabari et al., 2010), ANNs are demonstrated suitable for evaporation estimation with good/acceptable accuracy. This study is designed to evaluate the practicability of remote sensing data on evaporation estimation, and therefore we compare four ANFIS models with different combinations, without involvement of other physical-based models.

ANNs are capable of identifying complex nonlinear relationships between input and output data sets, observed data are allocated into training, validation and testing stages. In addition if variables are of high dimension, factor analysis techniques are usually implemented to extract significant input variables for ANN models (Chang et al., 2013; Chung et al., 2012). In such ways, overparameterization can be avoided during model construction processes. We will refine our manuscript to deal with the concern of overparameterization.

References:

Chang, F. J., Chang, L. C., Kao, H. S., and Wu, G. R.: Assessing the effort of meteorological variables for evaporation estimation by self-organizing map neural network, J. Hydrol., 384, 118–129, 2010.

Chang, F. J., Sun, W., and Chung, C. H.: Dynamic factor analysis and artificial neural

network for estimating pan evaporations at multiple stations in northern Taiwan, Hydrolog. Sci. J., 58, 813–825, doi:10.1080/02626667.2013.775447, 2013.

Chung, C.-H., Chiang, Y.-M., and Chang, F.-J.: A spatial neural fuzzy network for estimating pan evaporation at ungauged sites, Hydrol. Earth Syst. Sci., 16, 255–266, doi:10.5194/hess-25 16-255-2012, 2012.

Kim, S., Shiri, J., Kisi, O.: Pan evaporation modeling using neural computing approach for different climatic zones, Water Resour. Manag., 26(11), 3231-3249, 2012.

Shiri, J., Dierickx, W., Baba, A.P.A., Neamati, S., Ghorbani, M.A.: Estimating daily pan evaporation from climatic data of the State of Illinois, USA using adaptive neuro-fuzzy inference system (ANFIS) and artificial neural network (ANN), Hydrol. Res., 42(6), 491-502, 2011.

Shirsath, P.B., Singh, A.K.: A comparative study of daily pan evaporation estimation using ANN, regression and climate based models, Water Resour. Manag., 24(8), 1571-1581, 2010.

Tabari, H., Marofi, S., Sabziparvar, A.A.: Estimation of daily pan evaporation using artificial neural network and multivariate non-linear regression, Irrigation Sci., 28(5), 399-406, 2010.

. ANN based models (with or without fuzzy rules) should be cross-validated against station based estimates, e.g. eddy covariance stations. Analysis of parameter uncertainty and predictive uncertainty is definitely necessary.

Response: Thanks for the suggestion. For remote sensing techniques, cloudiness always raises parameter uncertainty. Therefore, we pre-processd remote sensing data by filtering imagery with less cloud as model inputs to reduce the impacts of cloudiness on ANFIS models in this study. Four modelsãĂŤModel-T(EVI, LST); Model-T(LST); Model-S(EVI, LST); Model-S(LST)ãĂţwere investigated for predictive uncertainty analysis. Fig. 9 of the manuscript shows the analytical results of the ANFIS models in terms

of various performance criteria (RMSE, MAE, CE, and CC). Consequently, Model-T (EVI, LST) is considered the most suitable model for evaporation estimation. We will add, or at least discuss, the benefit of using the cross-validate strategy for ANN model training and testing in the revised manuscript.

. The advantage of land surface hydrological models over ANN stemms from the fact the former close the water and energy balance over the studied river basin or domain. In the case of the ANNs, it is imposible to know whether the model estimates fullfil these conditions. The authors should indicate how this conditions can be fulfilled with data-driven model.

Response: Agree. Physical-based models would fit the water and energy balance closely over the studied basin, while ANN-based models usually could nicely map (fit) the input vectors to the desired output variable(s). We would indicate how this condition can be fulfilled with data-driven model.

Yes, indeed, ANN models bear long criticism on their black-box character, which forbids proper comprehensions of the modelling mechanisms and thus restricts the wide acceptance of ANNs by hydrologists (Mount et al., 2013). Even when the equations of an ANN are examined, their complexity prohibits straightforward interpretation. In general, an ANN discovers the modelling mechanism directly from calibration data that are used to train it, and consequently delivers forecasts with reduced error and can be used to extend the horizon over which forecasts can reliably be made (de Vos, 2013). For example, the membership functions of the ANFIS characterize the input-output patterns and their results can be exported into figures, which implicitly reveal the mapping of input-output pairs but fail to be intuitively comprehensible.

References:

Mount, N.J., Dawson, C.W., Abrahart, R.J.: Legitimising neural network river forecasting models: a new data-driven mechanistic modelling framework, Hydrol. Earth Syst. Sci. Discuss., 10, 145-187, 2013.

de Vos, N. J.: Echo state networks as an alternative to traditional artificial neural networks in rainfall-runoff modelling, Hydrol. Earth Syst. Sci., 17, 253–267, 2013.

. The authors indicate that ANN are useful to “identifying complex nonlinear relationships between input and output data sets”, in particular for problems that “difficult to describe by physical equations”. I guess this is the wrong argument when one attempts to model ET! In this case the equations are well know, the problem is how to find effective model parameters at the scale of interest. There are already attempts to this at large scale (see Samaniego et al. WRR 2010, and J Hydrometeorology 2013, Kumar et al WRR 2013). Here again, if the hypothesis is the ANN+Fuzzy rules are better than process based models, then the authors should demonstrate that this hypothesis holds across locations and scales not used for model training.

Response: (P 6155, L20-21) For modeling ET, we agree that “In this case the equations are well known, the problem is how to find effective model parameters at the scale of interest.” We are grateful to Dr. Samaniego for providing valuable references (Samaniego et al. WRR 2010, and J Hydrometeorology 2013, Kumar et al WRR 2013) to enrich this manuscript. We will remove the sentence “particularly for problems in which the characteristics of operation processes are difficult to describe by physical equations” in order not to confuse our focus. Again, we would like to clarify that the main goal of this study is to investigate if merely using remotely sensed data can appropriate to estimate regional evaporation over large area. A comparison of our proposed model with other methods is not within this study scope. However, it could be incorporated into our future work.

References:

Samaniego, L., Kumar, R., Attinger, S.: Multiscale parameter regionalization of a grid-based hydrologic model at the mesoscale, Water Resour. Res., 46, W05523, doi:10.1029/2008WR007327, 2010.

Samaniego, L., Kumar, R., Zink, Z.: Implications of Parameter Uncertainty on Soil

Moisture Drought Analysis in Germany, J. Hydrometeor, 14, 47–68, 2013.

Kumar, R., Samaniego, L., Attinger, S.: Implications of distributed hydrologic model parameterization on water fluxes at multiple scales and locations, Water Resour. Res., 49, doi:10.1029/2012WR012195, 2013.

3 Editing Comments

The abstract should be improved. Clear overview of research hypothesis and results should be provided.

Any figure of this manuscript is publication ready. Some are even screen-shots from a windows based program.

Response: Thanks for the suggestion. The abstract will be refined with a clear overview of research hypothesis and results.

4 Final Remarks

Based on previous comments and bearing in mind the HESS publishing standards for a research article, I recommend to reject the manuscript on its present stage and invite the authors to resubmit when the major issues mentioned above are carefully addressed.

Response: We would like to apology again for the vague statements that gave the wrong impression of data-driven models vs. physical-based models in our manuscript (P6155, L20-21; P6156, L26-29). Based on the valuable and constructive suggestions provided by Dr. Samaniego, the revision can be enhanced adequately. We hope Editor and Dr. Samaniego can be satisfied with our responses to the comments and suggestions listed above, and look forward to a positive feedback.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 6153, 2013.