A Temporal/Spatial Analysis of Regional/Local Numerical Weather Prediction Models for Infrared Satellite Image Applications on the Earth Surface

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ABSTRACT: Numerical weather predictions (NWP) models provide atmospheric information with considerable quality. They have been adopted as a background data in various fields, including atmospheric correction processes of satellite images. Covering areas of the NWP models varies from global models to local models which cover around a square with a side of 1,500km. Analysis/production times and prediction intervals also differ for each NWP models, so that analysis results of spatial/temporal on NWP models can provide useful background data for selection of the models. In addition to a global model, Korea Meteorological Administration (KMA) also produces a regional model (Regional Data Assimilation and Prediction System, RDAPS) and a local model (Local Data Assimilation and Prediction System, LDAPS). In this study, an efficiency of the infrared atmospheric correction process was analyzed based on the two NWP models having different spatial resolutions and prediction intervals. LANDSAT8 TIRS infrared images and VIIRS I4 and I5 infrared images were employed for a comparison of different image spatial resolutions and infrared regions. The analysis was conducted by the results and errors of single channel sea surface temperature (SST) estimations. Thermal infrared region (TIR, 8~12μm) showed increase of an average SST estimation error 1.5℃ more than the mid-wavelength infrared region (MWIR, 3~5μm), as difference between an infrared image acquisition time and NWP prediction time become 3hours. This suggests TIR region gets more affected by prediction intervals of the NWP models. When it comes to spatial resolution, TIRS images showed similar SST estimation errors with both NWP models. On the other hand, VIIRS I band images showed increase of maximum SST estimation errors when the NWP model was changed from LDAPS to RDAPS. The amount of increase for I4 and I5 bands were about 1℃ and 7℃ respectively. The results of this study would participate as a base data of selecting the NWP data for the application of infrared satellite images, considering characteristics of both images and NWP data.

1. INTRODUCTION

Remotely sensed infrared images require atmospheric correction processes for quantitative analysis of the Earth surface. A lot of the correction methods depend on independent atmospheric information, and numerical weather prediction (NWP) models have effectively provided the information (Barsi. et. al.. 2003, Tardy. et. al. 2016). Korea Meteorological Administration (KMA) has been producing NWP model data from a local scale to a global scale with different specifications, such as spatial resolutions and time intervals (KMA, 2013).

Study focuses on assessing dependency of atmospheric correction quality on the specifications. Images from VIIRS I4 (MWIR, Mid-wavelength Infrared) and I5 (LWIR, Long-wavelength Infrared) bands were employed for a comparison between different infrared regions. LANDSAT8 TIRS Band10 (LWIR, Long-wavelength Infrared) images with a 100m spatial resolution were also employed for a comparison with results from VIIRS I-band imagery with a 375m spatial resolution.

The results would be proposed as: effects of temporal/spatial resolutions of NWP models, effects of effective wavelengths and spatial resolutions of infrared images. These will provide background information on choosing optimum NWP model data for atmospheric correction processes on spaceborne infrared images, for both precision and efficiency.

2. DATA AND METHODOLOGY

2.1 NWP Model Data

Amongst the tree NWP models, local (Local Data Assimilation and Prediction System, LDAPS) and regional (Regional Data Assimilation and Prediction System, RDAPS) models were employed. LDAPS covers an area near Korean peninsula with a spatial resolution of 1.5km and 1hour prediction interval (3hours production interval). RDAPS covers eastern Asia territory with 12km spatial resolution and 3hours of prediction interval (6hours production interval).

2.2 Atmospheric Correction and Assessment

A regression-based single-channel atmospheric correction method was applied for the assessment [Lee., 2018]. This method is based on a linear regression applied to MODTRAN transmittance simulation results. Effectiveness of the regression-based method could be showed by a comparison between sea surface temperature (SST) estimated using the method and SST data acquired from buoys. When the method was applied to nighttime VIIRS I4 band the result showed 1.05℃ RMSE and VIIRs I5 band showed 1.81℃, while MODTRAN simulation showed RMSEs of 0.808℃ (VIIRS I4) and 1.67℃ (VIIRS I5) respectively. In this study, the assessment of NWPs will be also conducted by comparing estimated SST results and in-situ SST data. SST data from 14 ocean buoys were employed for the comparison, and all of the buoys are located around coastal areas of Korean peninsula.

3. RESULTS

3.1 Assessments on Temporal Differences

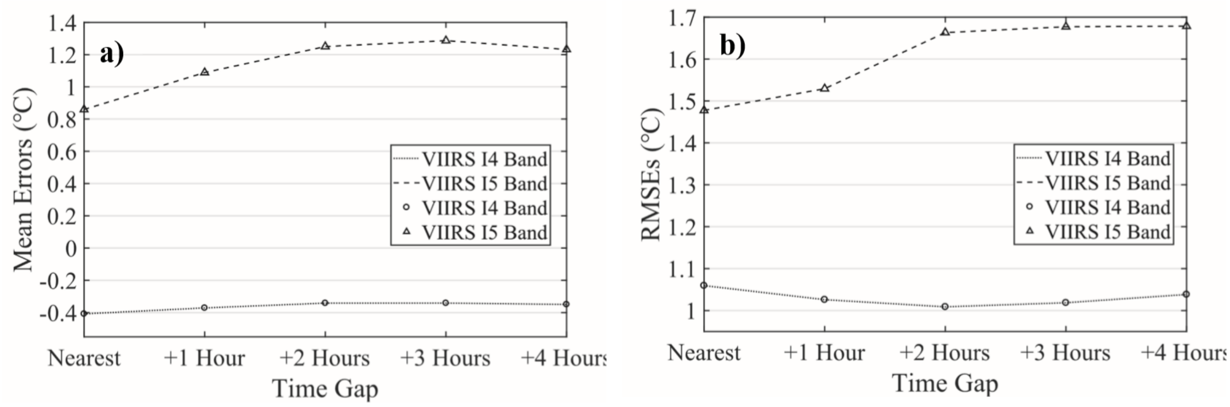

Figure 1. Errors of SST estimation results according to time gaps between satellite image acquisition and numerical weather prediction models: (a) mean errors, (b) RMSEs. (Lee., 2018)

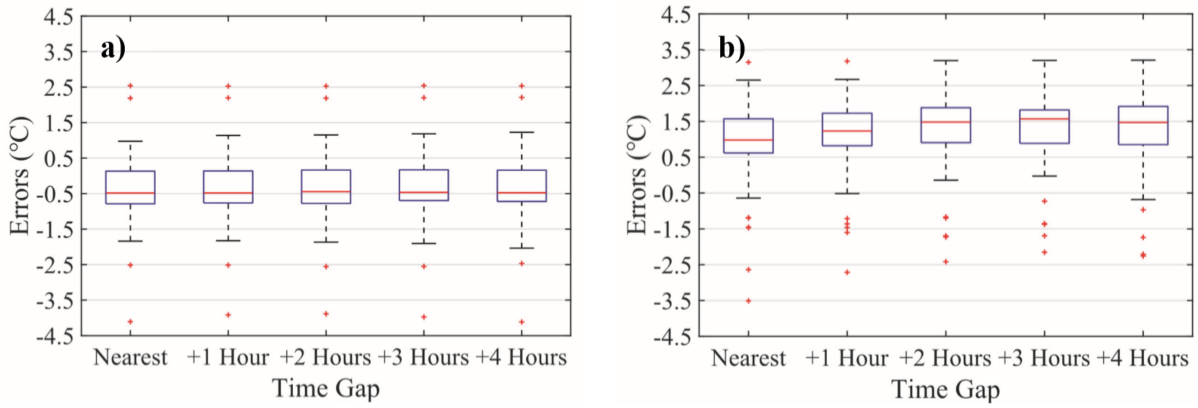

Figure 2. Box plot of SSTs according to time gaps between satellite image acquisition and numerical weather prediction models: (a) Derived from VIIRS I4 band, (b) derived from VIIRS I5 band. (Lee., 2018)

Figure 1 is displaying mean errors and RMSEs of SST estimation results, conducted with VIIRS I4 (MIWR) and I5 (LWIR) bands. The mean error of LWIR region increases until the time gap recaches +2 hours, while RMSE shows similar behavior. Considering prediction intervals of LDAPS and RDAPS are 1 hour and 3 hours respectively, the time gap would not exceed 1.5 hours. Therefore, mean error and RMSE of LWIR region can increase up to 0.4°C and 0.2°C, respectively. On the other hand, MWIR region did not show significant increase of the two error levels.

These patterns can also be recognized in overall error pattern, expressed as box plots (Figure 2.). Even though the range became wider, error levels of the MWIR region did not show significant increase (Figure 2.a.). Overall error distribution of the LWIR region was increased about 0.5~1°C at +2 hours of the time gap (Figure 2.b.).

3.2 Assessments on Spatial Resolutions

Table 1. Errors of SSTs derived from VIIRS imagery bands and LANDSAT8 TIRS Band 10 with the regression-based single-channel atmospheric correction method. (Lee., 2018)

Errors(°C) & Systems	**LDAPS (1.5km Resolution)**			
	Mean	**Std.**	**Max.**	**RMSE**
VIIRS I4 band	-0.23	0.96	3.67	0.99
VIIRS I5 band	0.98	1.01	3.16	1.41
LANDSAT TIRS B10	0.38	0.95	3.02	1.02
Errors(°C) & Systems	**RDAPS (12km Resolution)**			
	Mean	**Std.**	**Max.**	**RMSE**
VIIRS I4 band	-0.39	0.86	3.86	0.95
VIIRS I5 band	-0.07	1.80	6.39	1.81
LANDSAT TIRS B10	-0.11	1.03	3.08	1.04

Spatial resolutions of both satellite images and NWP data were assessed (Table 1.). For the MWIR region (VIIRS I4 band), a spatial resolution decrease of NWP model did not significantly affect error levels of SST estimations. In the LWIR region, images with a better spatial resolution (LANDSAT TIRS B10, 100m) did not significantly affected by the spatial resolution of NWP models, showing changes less than 0.1°C except the mean error. While images with a poorer spatial resolution (VIIRS I5, 375m) showed increase of SST estimation errors as the spatial resolution of the NWP model became poorer, also except for the mean error. Mean errors of the both LWIR images became smaller as the SST estimation was conducted using RDAPS, with a poorer spatial resolution.

4. DISCUSSIONS AND CONCLUSIONS

The assessment of the time gap indicated that the LWIR region affected relatively more than the MWIR region by the time difference between the images and the atmospheric information. The mean error and RMSE of the MWIR region did not see significant differences, however, maximum errors and outlying errors grew larger. Therefore, the atmospheric correction has to be conducted with the nearest NWP data in the time perspective to get the best results.

When it comes to the spatial resolution, the assessment results suggested that a spatial resolution improvement of the NWP models could not significantly affect the atmospheric correction process. This implies that a spatial variety of features affecting infrared radiative transfer is negligible within 12km distance. Even though further studies are required to decide acceptable level of coarse spatial resolution, computation burden by employing NWP data finer than 12km resolution is not effective to take. Considering 12km similar to spatial resolutions of global NWP models (ECMWF, KMA), the atmospheric correction using the global models would be effective for various infrared images.

5. REFERENCES

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6. ACKNOWLEDGEMENT

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