Retrieval and Evaluation of Atmospheric Temperature and Humidity Profiles using FY-4A/GIIRS

National Meteorological Satellite Center

Hye-In Park, Byung-il Lee, Junhyung Heo (jhheo89@korea.kr), Junyeob Choi, Myoung-Hee Lee, Yoonjae Kim

National Meteorological Satellite Center (NMSC) / Korea Meteorological Administration(KMA)

Introduction

The hyperspectral Infrared (IR) Sounder is useful for monitoring climate change, weather forecasting, and data assimilation of NWP (Menzel et al., 2018). It has thousands of channels and high vertical resolution, so more detailed vertical temperature and humidity information can be obtained (Yang et al., 2017). The FY-4A GIIRS is the first hyperspectral IR sounder on board a geostationary weather satellite, complementing the IR sounder in a polar orbit (XUE et al., 2022). The GIIRS data will be useful for precipitation analysis, such as low-level jets and lower troposphere water vapor because it provides the temporal, horizontal, and vertical resolution required for the diagnosis and prediction of severe weather (XUE et al., 2022). KMA has been developing a 1DVAR-based atmospheric profiles using FY-4A GIIRS and GK2A AMI Atmospheric Profiles (AAP) algorithm for application to nowcasting.

Data & Method

Input Data

- ✓ FY-4A GIIRS L1B data
- ✓ GK2A Cloud detection (CLD)
- ✓ NWP model (UM) forecast fields
- ✓ Background error covariance matrix
- ✓ Observation error covariance matrix (NEdT of the GIIRS)

Forward model

- ✓ RTTOV v13.1 (predictor v13)

Spatial & temporal resolution

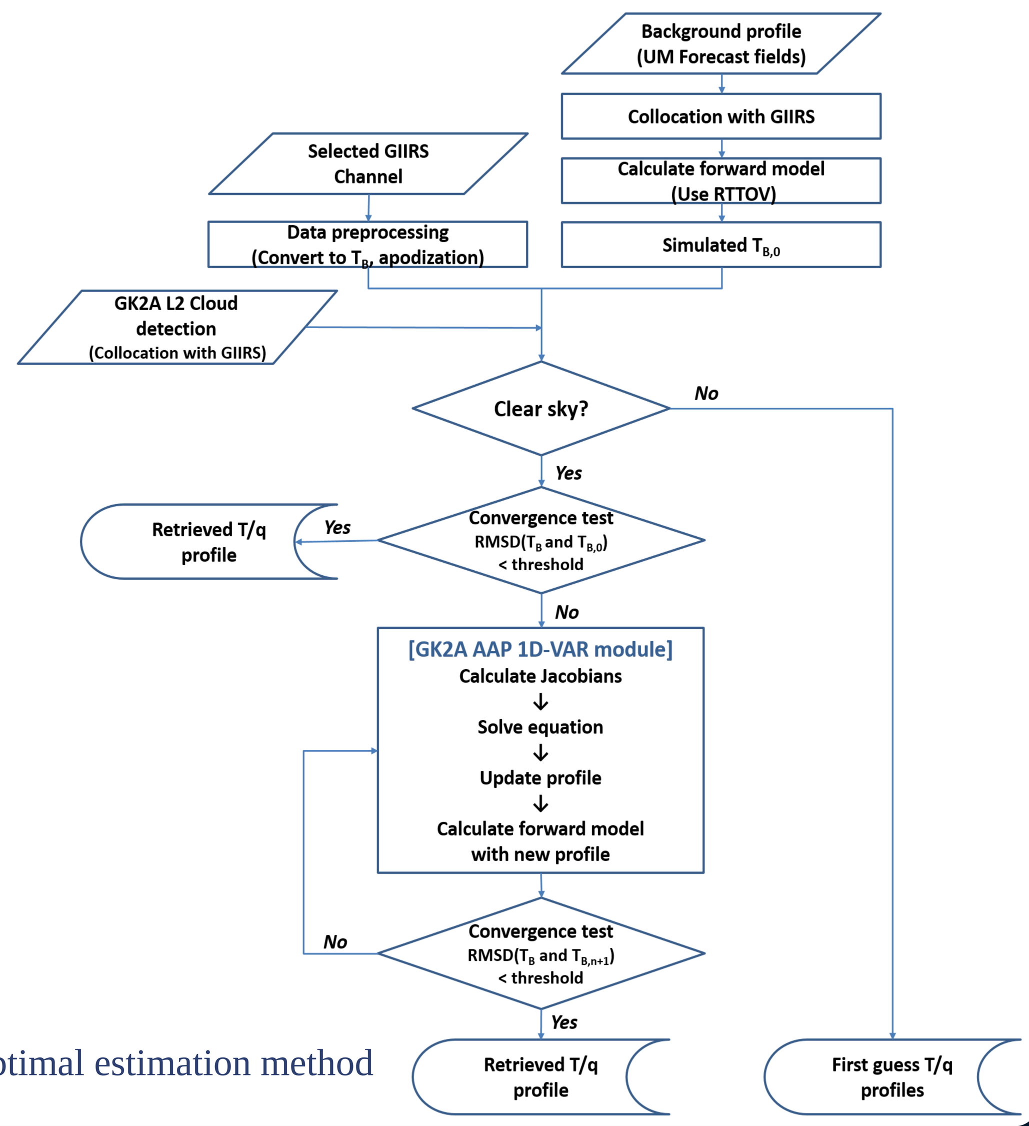
- ✓ 16 km / 1 hour (China area)

Product

- ✓ 54-levels T & q profiles

Method

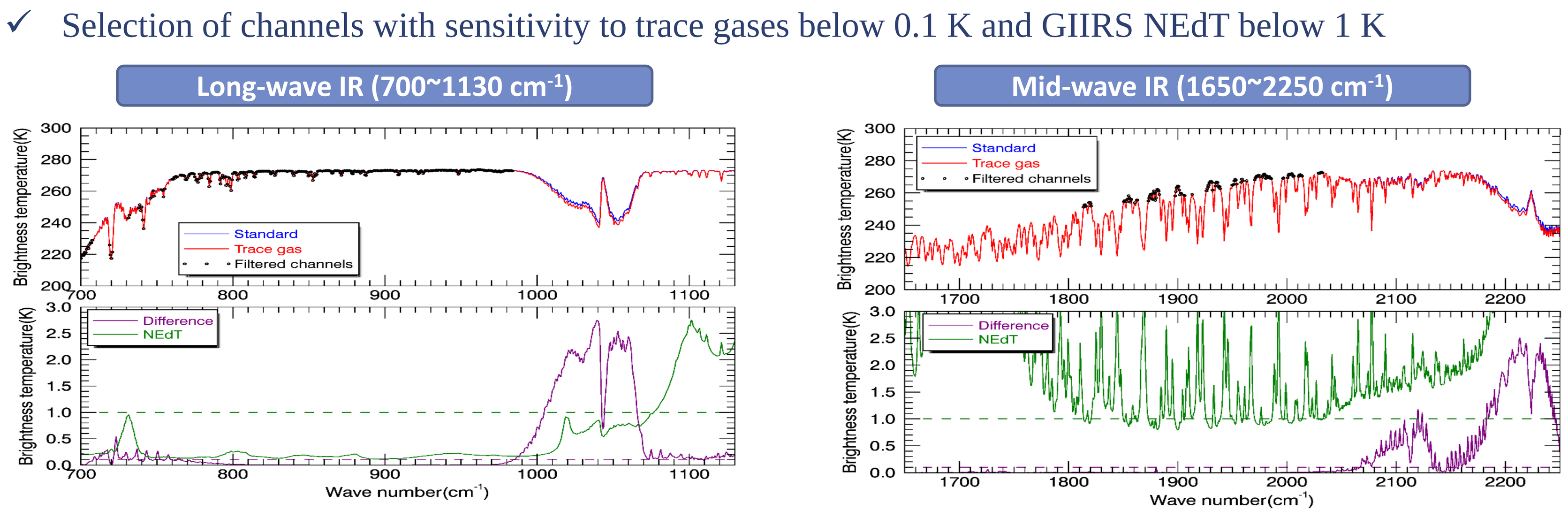
1) Selection of FY-4A GIIRS channels
2) Pre-processing of FY-4A GIIRS data
3) Retrieval of T & q profile using iterative optimal estimation method



Channel Selection

(Step 1) Excluding channels with large NEdT or strong trace gases (O_3, N_2O, CO, CH_4) absorption

- ✓ Using the difference between background BT and BT when the trace gas concentration is increased by 20 %
- ✓ Selection of channels with sensitivity to trace gases below 0.1 K and GIIRS NEdT below 1 K

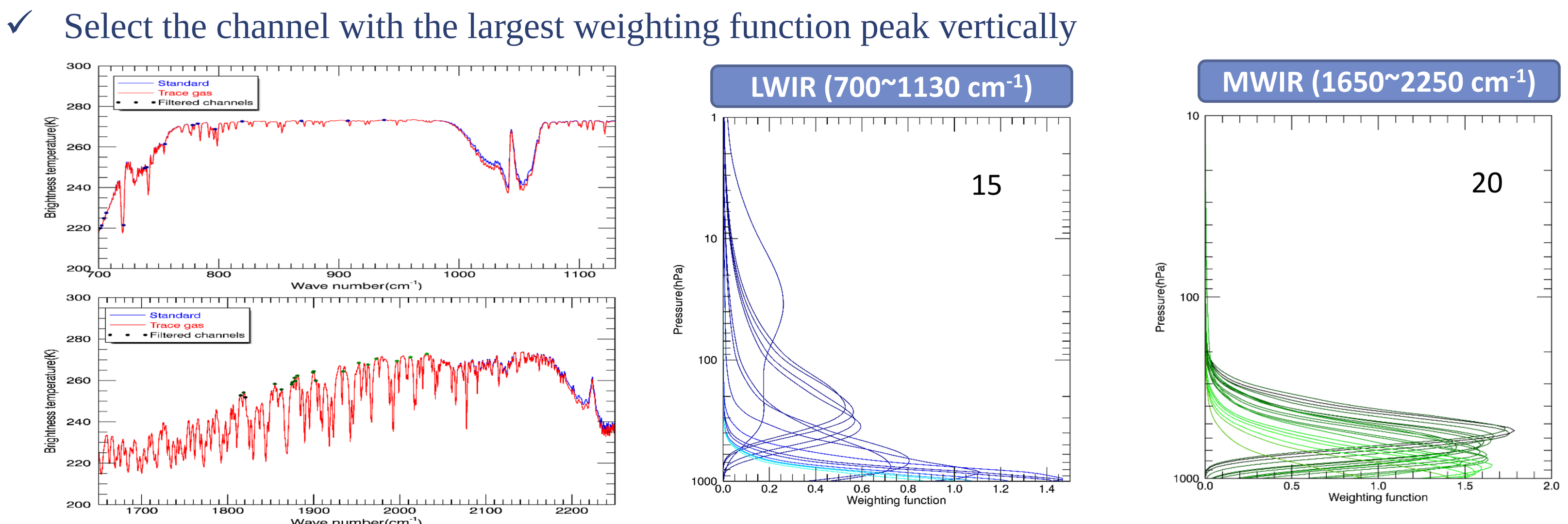


(Step 2) Channel selection considering absorption of other trace gases (171 channels)

- ✓ Excluding absorption of other trace gases that may be included in the RTTOV model simulation
- ✓ Select the channel with the highest BT (local maximum) by grouping 3 adjacent channels, starting with the lowest wavenumber of the channels selected in step 1

(Step 3) Selection considering the vertical distribution of the channel weighting function (35 channels)

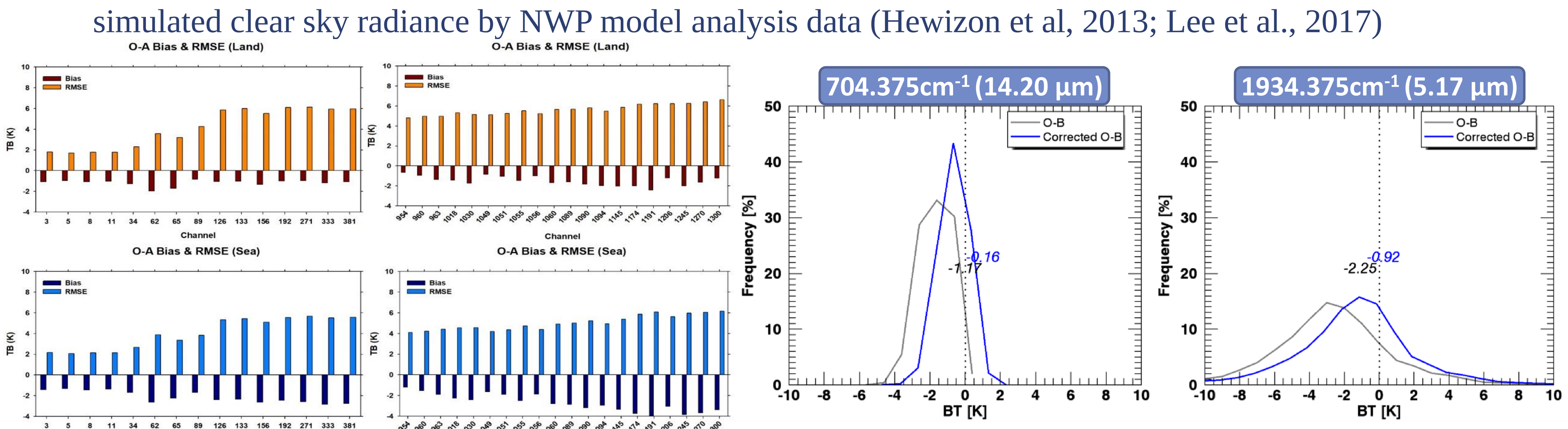
- ✓ Select the channel with the largest weighting function peak vertically



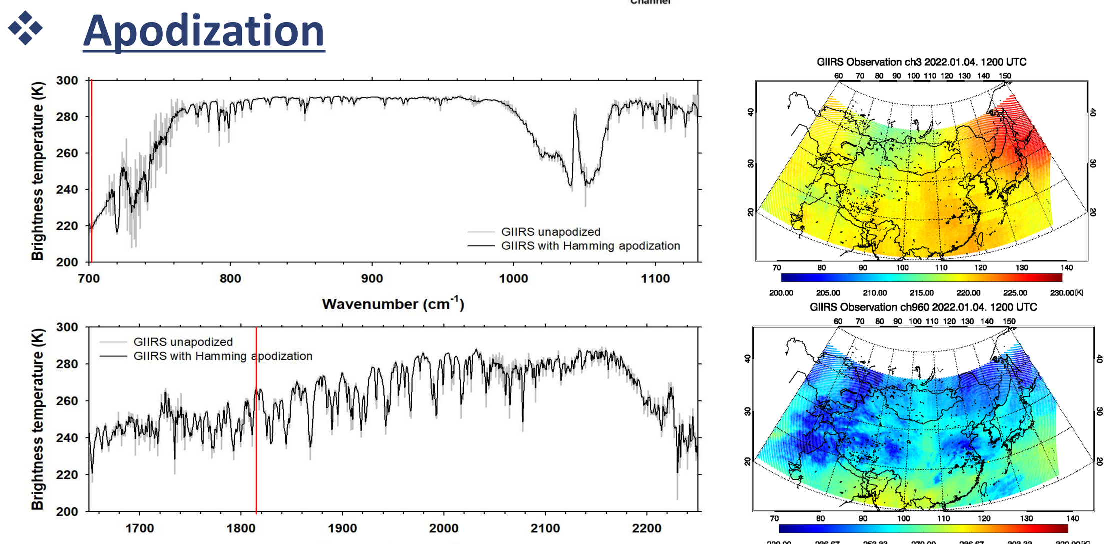
Pre-processing of GIIRS

Systematic bias correction

- ✓ Bias correction of GIIRS radiance using coefficients calculated from GIIRS observed radiance and the simulated clear sky radiance by NWP model analysis data (Hewizon et al, 2013; Lee et al., 2017)



Apodization

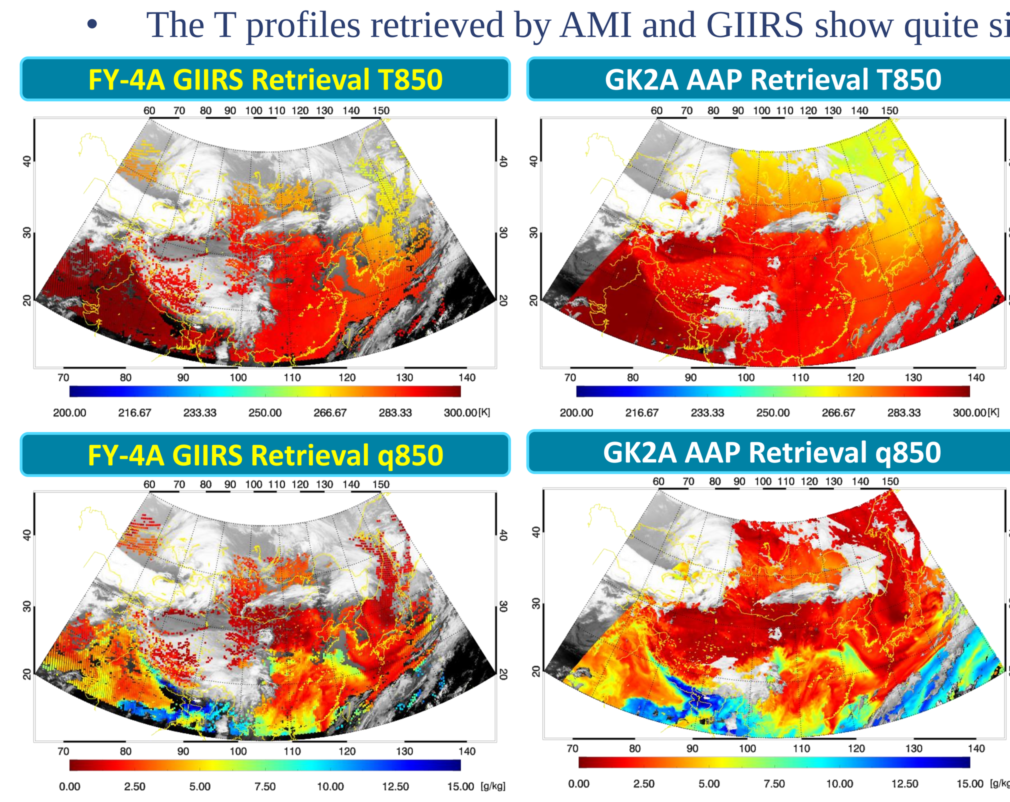


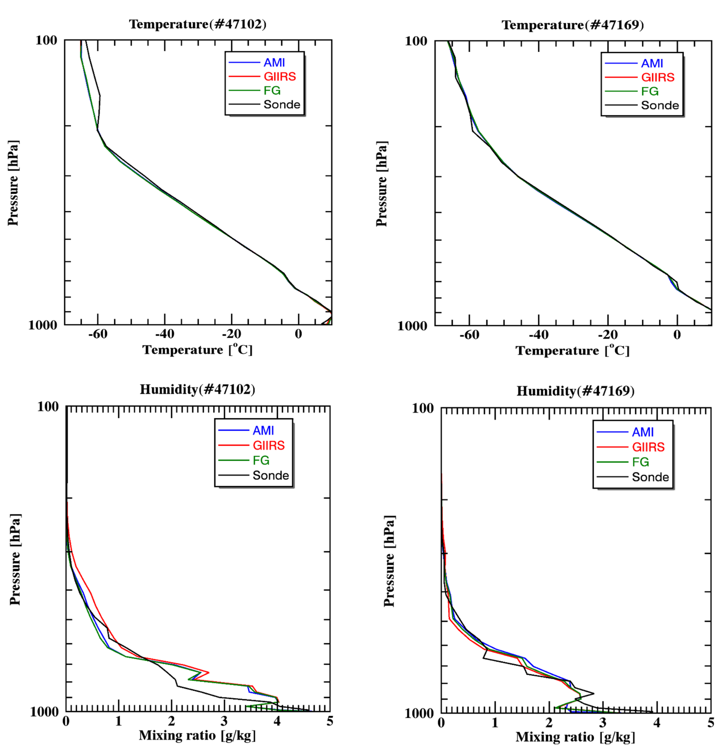
- ✓ Remove noise term caused by diffraction around an intensity peak
- ✓ Hamming apodization(Han et al., 2013)
  - $R_i' = 0.23R_{i-1} + 0.54R_i + 0.23R_{i+1}$
- ✓ R_i' → BT: Inverse Planck function

Result & Validation

Retrieval of T& q profiles

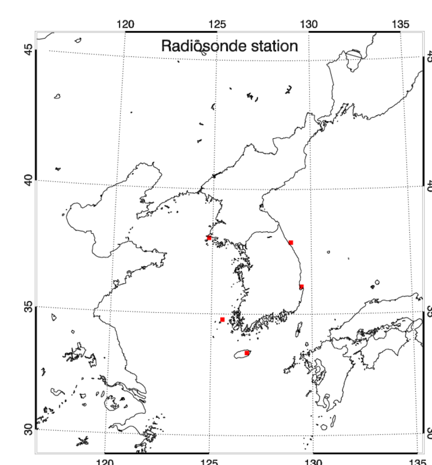
- ✓ 8 April 2022, 0000 UTC
  - Compared to the GK2A AAP result, the number of retrieved pixels is small, but the distribution is similar
  - The T profiles retrieved by AMI and GIIRS show quite similar vertical distributions

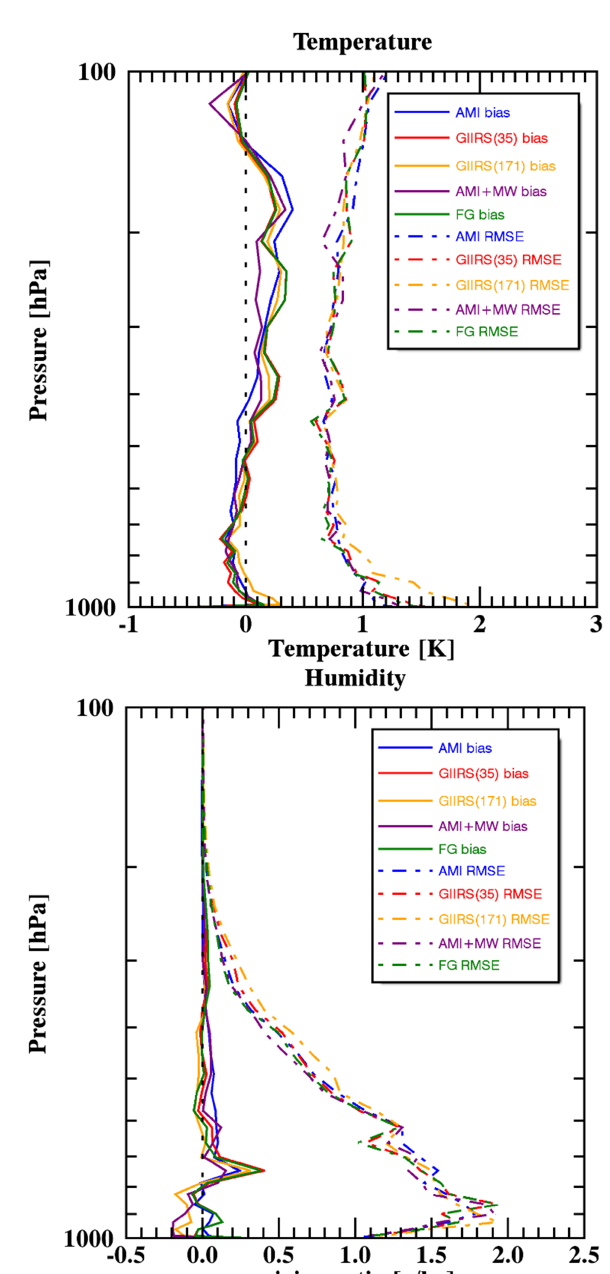




Validation

- ✓ Data
  - Radiosonde at 0000 and 1200 UTC from June to August 2022
  - Use of data from 5 sonde stations on the Korean Peninsula
- ✓ Method
  - Averaged data within ± 25km from the sonde station
  - Clear sky and successful retrieval





- ✓ Validation with sonde: GIIRS with 35 and 171 channels, AMI, AMI+MW
  - Compared with the results of 171 channels selected in step 2
  - The validation result of T & q profiles estimated by FY-4A GIIRS show similar accuracy to the GK2A even though more channels were used.
  - For GIIRS, the more channels used, the worse the results in the lower troposphere
  - It is necessary to optimize the algorithm through channel reselection, cloud-clearing, etc.

		Temperature		Humidity	
		Mean bias (K)	Mean RMSE (K)	Mean bias (g/kg)	Mean RMSE (g/kg)
Upper troposphere (100~500hPa)	GIIRS(35)	**0.17**	**0.81**	**0.01**	**0.23**
	GIIRS(171)	**0.14**	**0.81**	**0.00**	**0.26**
	First-guess	0.16	0.81	0.01	0.20
	AMI	0.12	0.80	0.02	0.21
	AMI+MW	0.09	0.77	0.02	0.19
Mid-troposphere (500~850hPa)	GIIRS(35)	**-0.08**	**0.76**	**0.08**	**1.27**
	GIIRS(171)	**-0.06**	**0.85**	**0.01**	**1.31**
	First-guess	-0.08	0.74	0.05	1.26
	AMI	-0.11	0.77	0.08	1.32
	AMI+MW	-0.10	0.76	0.05	1.26
Lower troposphere (850~1050hPa)	GIIRS(35)	**-0.26**	**1.27**	**0.16**	**1.47**
	GIIRS(171)	**-0.19**	**1.59**	**0.00**	**1.53**
	First-guess	-0.21	1.23	0.16	1.47
	AMI	-0.23	1.11	0.07	1.41
	AMI+MW	-0.14	1.12	0.01	1.48
Total (100~1050hPa)	GIIRS(35)	**0.00**	**0.90**	**0.06**	**0.81**
	GIIRS(171)	**0.01**	**1.00**	**0.00**	**0.85**
	First-guess	0.01	0.88	0.06	0.80
	AMI	-0.03	0.86	0.04	0.81
	AMI+MW	-0.02	0.84	0.01	0.80

Summary & Future plans

Summary

- ✓ Development of temperature and humidity profiles retrieval algorithm using FY-4A GIIRS
  - Channel selection considering GIIRS NEdT, trace gas absorption, and weighting function
  - Pre-processing of FY-4A GIIRS data such as apodization, systematic bias correction
  - Retrieval of temperature and humidity profiles using 1D-VAR module of GK2A AAP
- ✓ The validation result of T & q profiles estimated by FY-4A GIIRS show similar accuracy to the GK2A even though more channels were used.

Future plans

- ✓ Apply the algorithm to FY-4B GIIRS data
- ✓ Improvement of channel selection and cloud detection using GIIRS channels
- ✓ Update land surface emissivity data

Reference

Menzel, W. P. Shcmit, T. J., Zhang, P., & Li, J. (2018). Satellite-based atmospheric infrared sounder development and applications. *Bulletin of American Meteorological Society*, *99*(3), 583-603.

Yang, J., Zhang, Z., Wei, C., Lu, F., & Guo, Q. (2017). Introducing the new generation Chinese geostationary weather satellite, FengYun-4. *Bulletin of the American Meteorological Society*, *98*(8), 1637-1658.

Xue, Q., Guan, L., & Shi, X. (2022). One-dimensional variational retrieval of temperature and humidity profiles from FY4A GIIRS. *Advances in Atmospheric Sciences*, *39*(3), 471-486.

Hewison, T. J., Wu, X., Yu, F., Tahara, Y., Kim, D., & Koenig, M. (2013). GSICS inter-calibration of infrared channels of geostationary imagers using Metop/IASI. *IEEE Transactions on Geoscience and Remote Sensing*, *51*(3), 1160-1170.

Lee, S. J., Ahn, M. H., & Chung, S. R., (2017). Atmospheric profile retrieval algorithm for next generation geostationary satellite of Korea and its application to the advanced Himawari Imager. *Remote Sensing*, *9*(12), 1294.

Han, Y., et al. (2013). Suomi NPP CrIS measurements, sensor data record algorithm, calibration and validation activities, and record data quality. *Journal of Geophysical Research: Atmosphere*, *118*(22), 12-734.

National Meteorological Satellite Center