Development of KIAPS Observation Processing System : (1) AMSU-A Bias Correction Modules

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Introduction

Bias and Data Assimilation

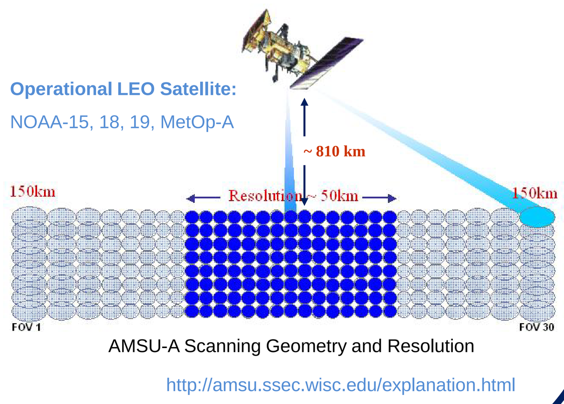
All data assimilation systems are affected by biases, caused by problems with the data, by approximations in the observation operators used to simulate the data, by limitations of the assimilating model, or by the assimilation methodology itself. A clear symptom of bias in the assimilation is the presence of systematic features in the analysis increments (Dee, 2005).

Objective

To introduce the AMSU-A radiance pre-processing and bias correction at the KIAPS Observation Processing System (KOPS)

Radiance bias correction methods of operational NWP centers

NWP Centers	Bias correction method	Algorithm
ECMWF (Europe)	Variational BC(4D–VAR)	Dee (2004, 2005)
Météo France (France)	Variational BC (4D–VAR)	Aulignė et al. (2007)
NCEP (USA)	Variational BC (3D–VAR)	Derber and Wu (1998)
Met Office (UK)	Off–line, updated once a month	Harris and Kelly (2001)
NRL (USA)	Off–line, updated every 15–day	Eyre (1992) and Harris and Kelly (2001)
DWD (Germany)	Off–line statistics	Harris and Kelly (2001)

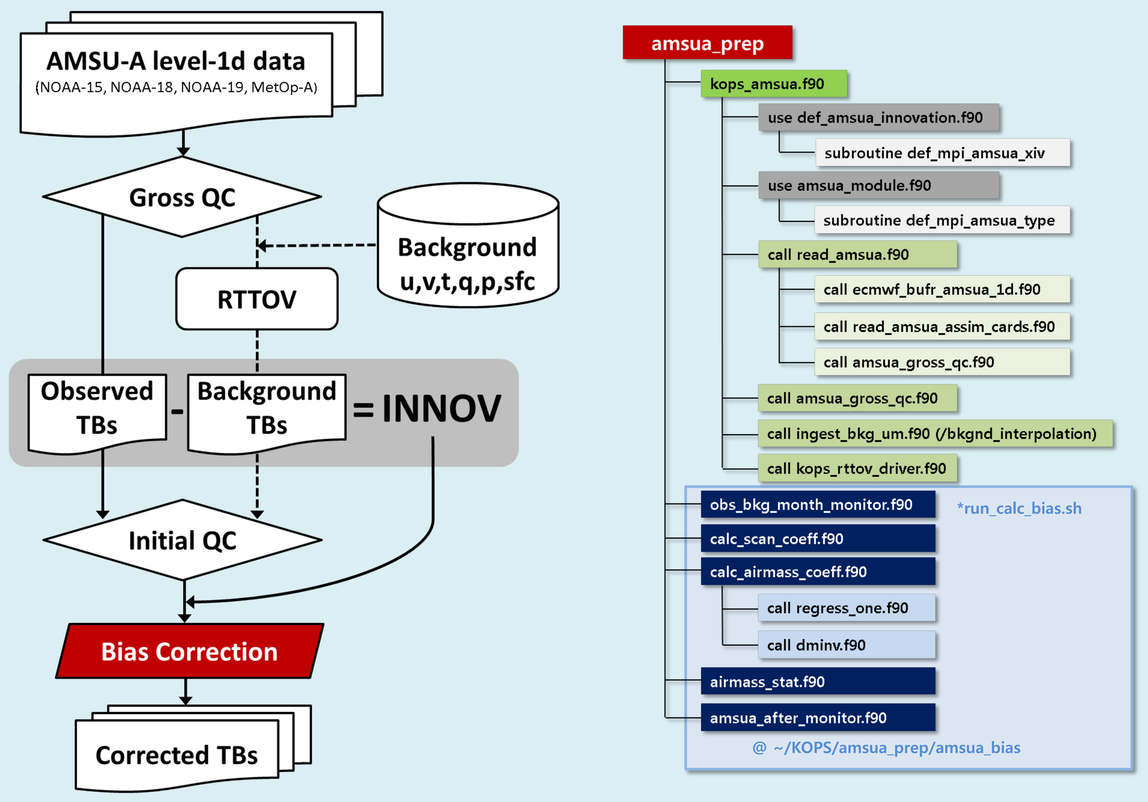


AMSU-A Scanning Geometry and Resolution

http://amsu.ssec.wisc.edu/explanation.html

Methodology

KOPS AMSU-A Flowchart



Bias Correction

(1) Scan Bias Correction

- **Goal :** To remove the systematic errors attributed to the observations, the radiative transfer model and pre-processing steps

✓ **Harris and Kelly (2001) :** $d(\varnothing, \theta) = O_j(\varnothing, \theta) - O_j(\varnothing, \theta=0)$

✓ **Weng et al. (2012)** : $(O - \mu^o) - (B - \mu^b) = O - B - (\mu^o + \mu^b)$

d : radiance difference
Ø : latitude band
θ : scan angle
O : observation (j = channel)
B : background
μ° : observation bias
μᵇ : model bias

(2) Airmass Bias Correction

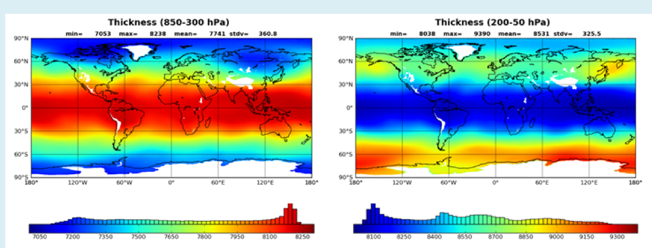
- **Goal :** To remove the systematic errors attributed to the different thermodynamics properties scanned atmosphere and the surface
- **Algorithm :** global linear regression of the scan-corrected innovations against two predictors (850-300 hPa and 200-50 hPa thicknesses) to correct the airmass bias

✓ **Harris and Kelly (2001) :** $B_j = \sum_{i=1}^{n} A_i X_i + C_j$

B : airmass bias (j = channel)
A, C : coefficients by linear regression
X_i : predictors (i = number of predictor)

➢ Model based predictors

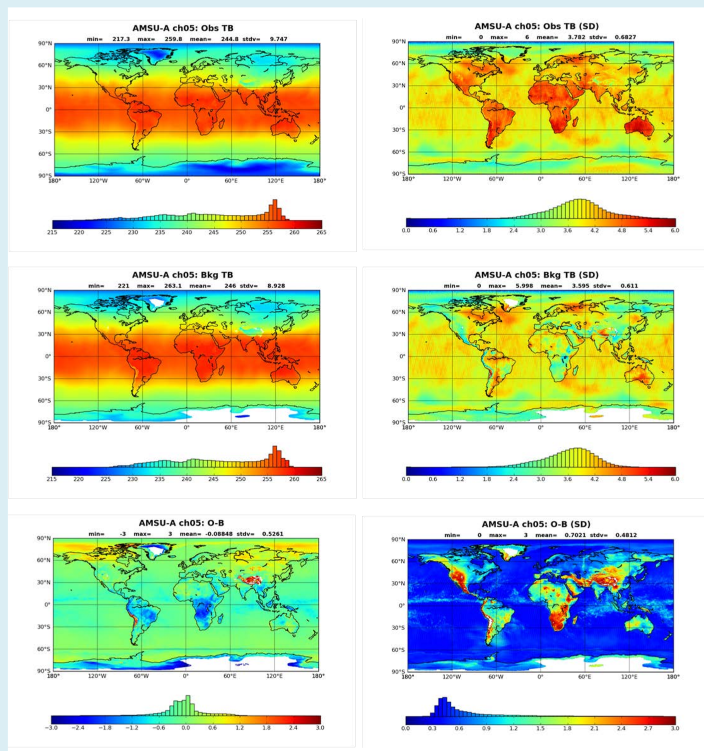
- **Thickness 850-300 hPa**
- **Thickness 200-50 hPa**
- Surface skin temperature
- Total column water vapor



✓ **Weng et al. (2012) :** O-B statistics

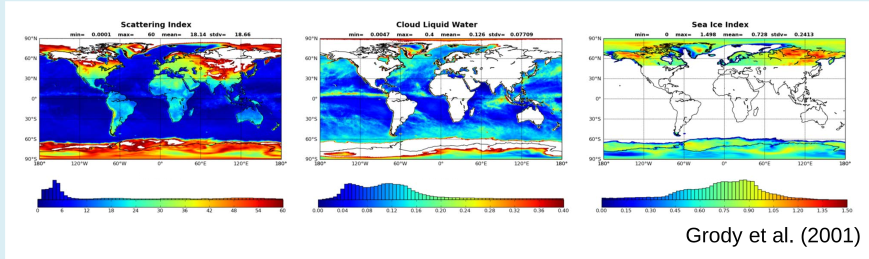
➢ Multiple linear regression : $Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_t X_{ti} + \varepsilon_i, \quad i = 1,2,\ldots,n$

Results and Discussions



Monitoring : BUFR extracted TB

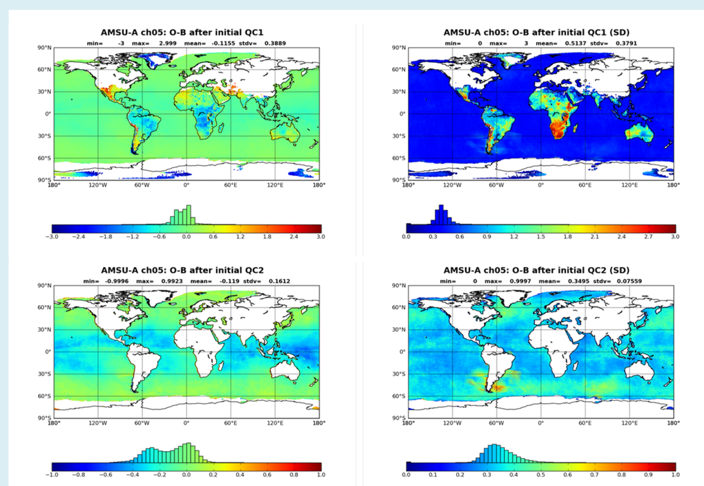
- **Observed TB (0.35° x 0.23°)**
  In channel 5, observed TB is high at low latitude, but it decreases at high latitude. The land variability (i.e., standard deviation) is more than ~4.5 K.
- **Background TB (0.35° x 0.23°)**
  Monthly mean of background (Unified Model output: e.g., qwqu00.pp_006) is similar to observed TB but land variation of background TB is less than that of observation.
- **O-B (innovation)**
  Both monthly mean and standard deviation of innovation are high in land, especially for high topography such as the Andes mountains and desert area.



Grody et al. (2001)

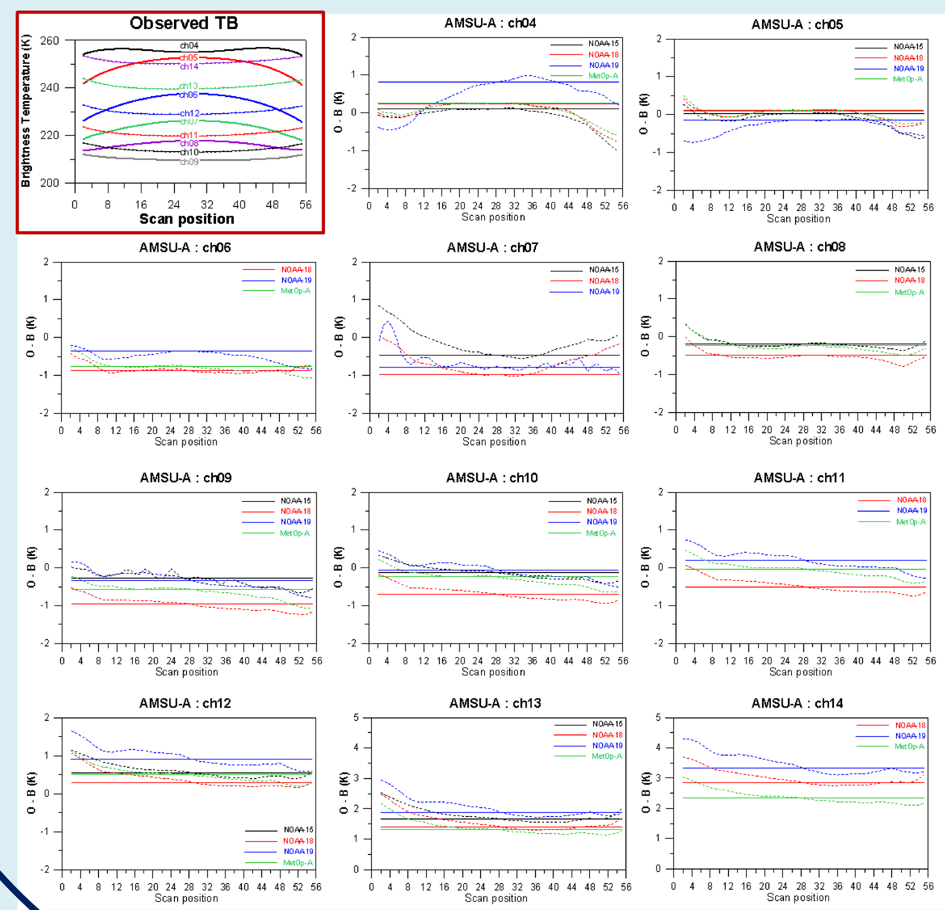
Threshold for initial QC

- Scatt Index > 40
- CLW > 0.2
- Sea-ice index > 50



Initial Quality Control

- After initial QC1, the pixels contaminated by large amounts of cloud liquid water, heavy precipitation, and sea ice are removed.
- Assimilation channels are respectively selected for surface types and topography in the initial QC2.

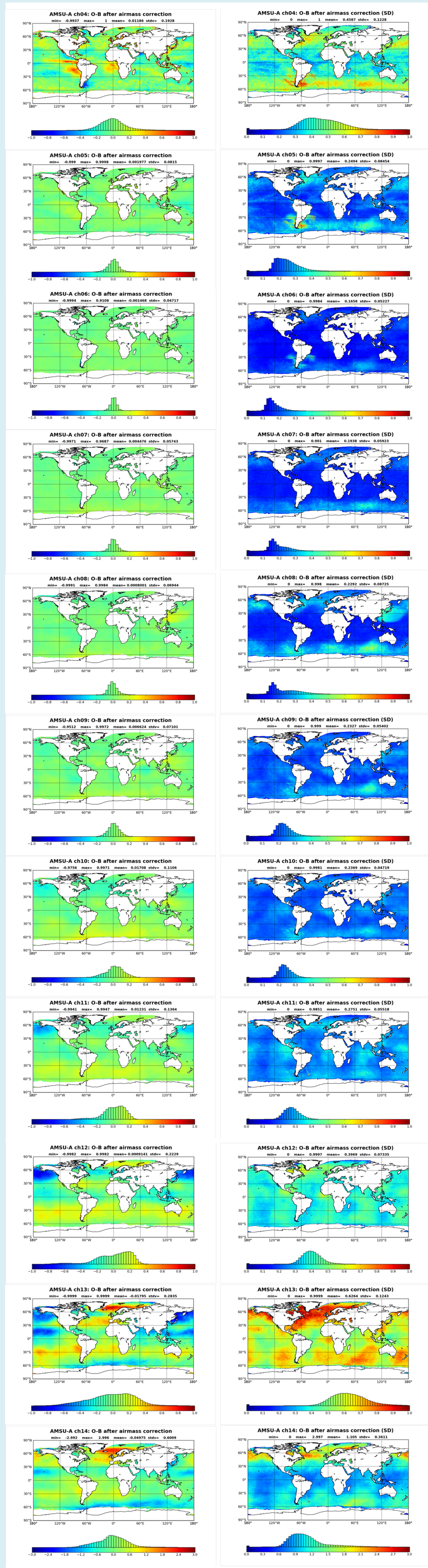


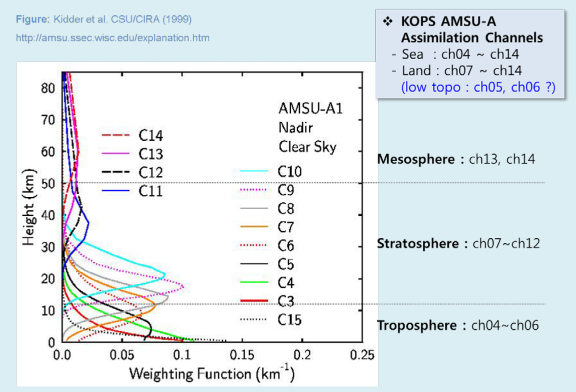
Scan Bias Correction

Scan bias correction is calculated individually for each channel, satellite, and scan position.

Global scan bias is corrected the mean innovation at each scan angle to nadir.

Warm bias remains at channels 12~14 in the upper stratosphere.





Monitoring : Bias corrected innovation

- **Channels 04~05**
  After airmass bias correction, some regions are affected by atmospheric variability due to temperature variations.
- **Channels 06~11**
  Airmass bias is successfully controlled by multiple linear regression coefficients and off-set.
- **Channels 12~14**
  Airmass bias still remains and standard deviation is high over ~0.3 K.

Coefficient of determination (R2) in multiple linear regression

Ch	NOAA–15	NOAA–18	NOAA–19	MetOp–A
04	0.89	0.79	0.57	0.78
05	0.69	0.77	0.69	0.77
06	–	0.50	0.51	0.51
07	0.45	0.49	0.50	–
08	0.36	0.47	–	0.46
09	0.55	0.50	0.52	0.52
10	0.74	0.53	0.89	0.67
11	–	0.56	0.76	0.86
12	0.60	0.75	0.56	0.63
13	0.52	0.54	0.52	0.54
14	–	0.50	0.50	0.50

Summary

- We have developed the modules of satellite radiance data pre–processing and quality control at KOPS, which include observation operators to interpolate model state variables into radiances in observation space. AMSU–A level–1d radiance data was extracted using the BUFR (Binary Universal Form for the Representation of meteorological data) decoder and a first guess was calculated with RTTOV10.2.
- For initial quality checks, (1) cloud contaminated data were removed for use of clear-sky radiance data and (2) AMSU-A channels for assimilation, rejection, or monitoring were respectively selected for surface type and topography since the errors from the skin temperature were caused by inaccurate surface emissivity.
- KOPS AMSU-A bias correction modules have developed in two steps based on 30–day innovation statistics. The scan bias correction coefficient was calculated individually for each channel, satellite, and scan position. Then a global multiple linear regression of the scan–corrected innovations against several predictors (e.g., 850-300 and 200-50 hPa thicknesses) was employed to correct the airmass bias.
- It appears to be successful in controlling the scan and airmass bias in the crucial channels which sound tropospheric and stratospheric temperature (just below 50 km altitude).

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