Assimilation of SSM/I radiances in the NCEP global data assimilation system

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1. Introduction

- Although NCEP uses the precipitation rates and ocean surface wind-speed retrieved from SSM/I in the current operational global data assimilation system, no moisture information in rain-free areas from SSM/I measurements is used. Assimilating SSM/I clear or thin-cloud radiances is a first step towards making more use of information in SSM/I data. In the future, it is anticipated that cloud/rain-affected radiances can be used from various microwave (MW) imager instruments.
- Currently the data usage is restricted to clear or thin-cloud radiances over the ocean because of difficulty in simulating rain/cloud-affected radiances and estimating the MW emissivity and cloud liquid water (CLW) over land.
- The Community Radiative Transfer Model (CRTM) using the Optical Path Transmittance (OPTRAN) algorithm (Kleespies et al. 2004) is used as a fast radiative transfer and Jacobian model. For surface MW emissivity over the ocean FASTEM-1 (the operational model) is used.

2-1. Quality Control (QC)

Reject points
- for TB<70K or >320K, TB_vert<TB_horiz+2.0K
- affected by rain : Scattering Index (SI) > 10.0
  SI is based on Ferraro (1997)

Reject channels
- with large difference between observation and guess
  |O-G|>3*predefined obs.error or 6.0K
- highly contaminated by cloud, which is determined based on retrieved CLW > clw_0
  CLW is retrieved using Weng et al. (1997)
  The criteria clw_0 are estimated so that liquid water absorption at each frequency is equal to that for CLW=0.1 kg/m2 at 37Ghz

Table.1: observation error

Channel	19V	19H	22V	37V	37H	85V	85H
σ_o [K]	1.60	2.26	2.01	1.48	2.28	1.43	2.33

Table.2: cloud check criteria

Channel	19V,H	22V	37V,H	85V,H
clw_0 (kg/m^2)	0.35	0.27	0.10	0.024

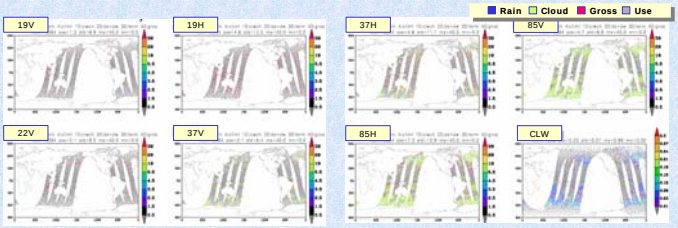


Fig.1: QC flag

2-2. Bias Correction

Unified formula for all radiance data such as AMSU-A/B, HIRS and GOES (Derber and Wu 1998)

$$b_j = s_{jm} + \sum_{k=1}^{k=5} c_{jk} p_{jk},$$

- b_j : bias to be corrected at channel j
- s_{jm} : Slowly varying component
  - Calculated at each scan position m from latest 30 days G-O datasets, and updated at every post-analysis step
- Air-mass dependent component
  - predictors p_{jk} are a constant, scan angle path (=0 for SSM/I), CLW, dT*dtau (=integrated lapse rate), (dT*dtau)^2

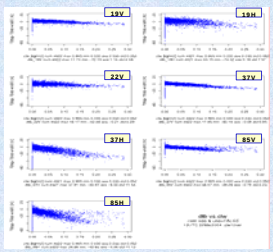


Fig.2: G-O dependency on CLW

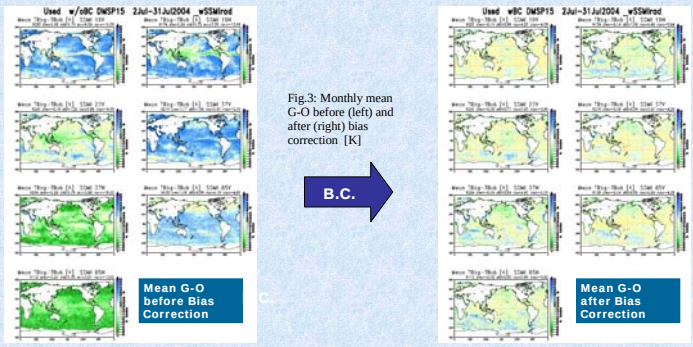


Fig.3: Monthly mean G-O before (left) and after (right) bias correction [K]

3. Cycle Experiments

- System
  - Analysis: GSI (Gridpoint Statistical Interpolation) 3DVar system [Wu et al. (2002)]
  - Forecast: operational model as of Jan.2005
- Resolution: T254L64 (FT0-FT84), T170L42(FT84-FT180)
- Cntl: operational data usage
- Test:
  - add SSM/I radiances from DMSP13,14 and 15
  - add emissivity Jacobian model with respect to wind for MW ocean emissivity model
  - discontinue SSM/I ocean surface wind-speed retrieval
- Period: 00UTC UTC 1 Jul - 18UTC 31 Aug 2004

References

Derber, J.C., and W.-S Wu, 1998: The use of TOVS cloud-cleared radiances in the NCEP SSI analysis system. Mon. Wea. Rev., 126, 2287-2299.

Kleespies, T. J., P. V. Delst, L. M. McMillin, and J. Derber, 2004: Atmospheric Transmittance of an Absorbing Gas. 6. OPTRAN Status Report and Introduction to the NESDIS/NCEP Community Radiative Transfer Model, *Applied Optics*, 43, 3103-3109

Ferraro, R. R., 1997: Special sensor microwave imager derived global rainfall estimates for climatological applications. *J. Geophys. Res.* **102**,16,715-16,736.

*Weng, F., N.C. Grody, R.R. Ferraro, A.Basist and D. Forsyth, 1997: Cloud liquid water climatology from the special sensor microwave imager. J. Climate, **10**, 1086-1096.*

Wu, W. -S., R. J. Purser, and D. F. Parrish, 2002: Three-Dimensional Variational Analysis with Spatially Inohomogeneous Covariances. Mon. Wea. Rev., 130, 2905-2916.

3-1. Analysis Impacts

- The SSM/I radiance assimilation moistens the NH and tropics, dries the mid- to high-latitude of SH.
- The field changes within about 3 days after cycle starts, and remains unchanged afterwards.
- Largest impact shows up in the surface to mid-tropospheric moisture fields.
- |G-O| of AMSU-A1 is reduced in low latitude and in the high latitude of SH
- Analysis/Guess fit to RAOB is improved for the temperature and wind. However, the moisture bias is increased in the tropics.

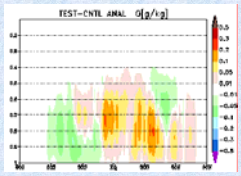


Fig.4: 1st analysis difference between Test and Cntl for specific humidity [g/kg]

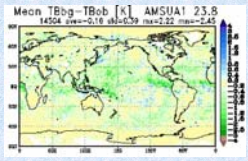


Fig.5: Difference in |G-O| for AMSU-A1 between Test and Cntl

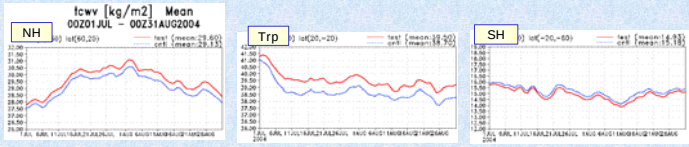


Fig.6: Time series of total column water vapour (TCWV) [kg/m2] over the 2 month

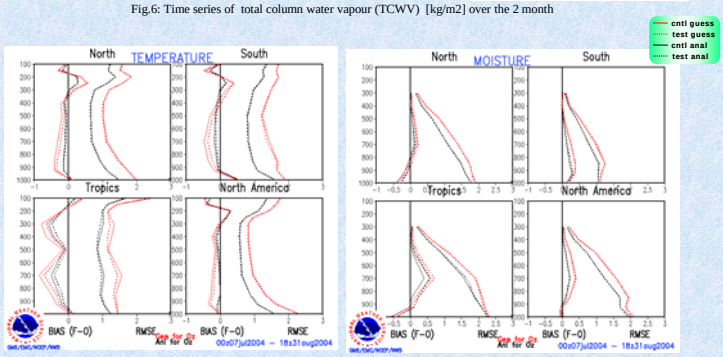


Fig.7: Analysis/Guess fit against RAOB for temperature (K, left) and moisture (g/kg, right)

3-2. Forecast Impacts

- Averaged Anomaly Correlation (AC) for 500Z is slightly and significantly improved in the NH and SH, respectively. The RMSE of the tropical upper and lower wind is substantially reduced.
- Spin-up of model precipitation is reduced in the tropics. It is also slightly reduced in the NH while marginally increased in the SH.
- The moisture added is retained for 7 days or more in the tropics and NH. It remains for 3 days in the SH.

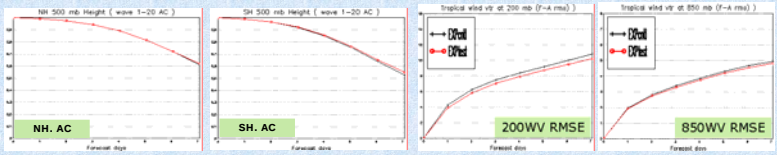


Fig.8a: Anomaly Correlation at 500hPa in the NH (left) and SH (right)

Fig.8b: RMSE of vector wind in the tropics at 200 hPa (left) and 850 hPa (right)

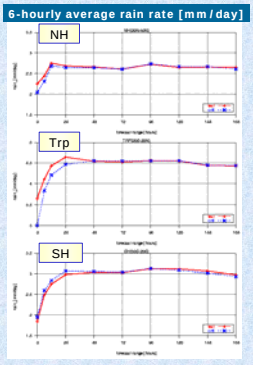
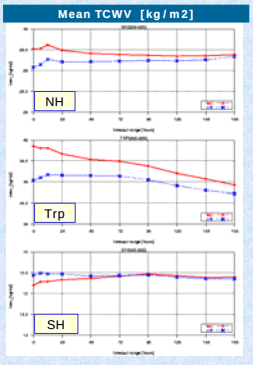


Fig.9: Monthly averaged rain and TCWV as function of forecast hours.



4. Summary

- A scheme to assimilate SSM/I clear or thin-cloud radiances over the ocean has been developed.
  - QC and bias correction procedures requires an accurate and robust CLW retrieval algorithm.

- Impacts of SSM/I radiance assimilation from 2-month cycle experiments in July – August 2004 is as follows:
  - The moisture is added in the NH and tropics while reduced in the mid- to high- latitudes of SH.
  - The moisture added in the tropics may be excessive. However, it reduces the model spin-up of precipitation in the tropics and substantially improves the mass and wind fields.
  - The reduced moisture in the mid- and high- latitude of SH improves the fit to AMSU-A water vapor channels.
  - Average forecast scores are improved slightly in NH and substantially in the tropics and SH.
  - The Hurricane track error is reduced in most cases.
  - No disruption of the Hadley circulation is found.