Assimilation of high temporal GIIRS radiance in GRAPES

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Outline

• Background: **WHY Geo. SOUNDER ?**

• Evaluation and Assimilation of GIIRS in 4D-Var

• **Targeted Observing** using GIIRS for HIW

• **Future Perspective:** Global Geo. SOUNDER
Why do we need GEO hyperspectral IR sounders?

- Compared with LEO: **Larger spatial coverage and higher temporal resolution** for regional models
- Compared with microwave sounders: finer vertical resolution

Q: GEO high temporal resolution observations GEO provide critical information for nowcasting, what is the impact in NWP models, for example, on storm forecasts?
Milestones of GRAPES

GRAPES = Global/Regional Assimilation Prediction System

- 1999: Initiation of GPAPES Programme
- 2001: Sponsored by the MOST and CMA
- 2003: Unified dynamic frame
- 2005: Regional physics package
- 2006: Regional 3DVar (Model-lev)
- 2008: Oper. of GRAPES-Meso V1.0
- 2009: Pre-operation of GRAPES-GFS V1.0
- 2012: Operation of GRAPES-RAFS
- 2013: Operation of GRAPES-TYM
- 2014: Upgrade of GRAPES-Meso V3.0
- 2015: Operation of GRAPES-Meso 3km
- 2016: GRAPES-GFS V2.0 oper. (2016)
- FY-3A/B/C/D
- FY-2G
- FY-4A

4D-Var
- GRAPES-GFS V2.2 oper. (2018)
- GRAPES-GFS V2.0 oper. (2016)
- GRAPES-REPS V1.0 oper. (2015)
- GRAPES-Meso 3km (2015)
Geostationary Satellite Sounding: FY-4A GIIRS

Opportunities for Targeted Observing

Forecast Oriented Observing by FY-4A GIIRS to improve HIW
GREAT opportunity with FY-4A

FY-4A: AGRI(Imager)+LMI(Lightening)+GIIRS(Sounding)

Every 5 minutes
Design of Field Of Regard (FOR)

2.0 hours to cover the Area:
15N-65N, 75E-135E
High temporal for targeted area

FOR: 648kmX112km
FOV: 16km
FOR dependent bias and std (CH6, 300hPa)
Constrained VarBC

→ Regularization: Constrained Bias Correction (CBC), CVarBC

\[ 2J(x, \beta) = (x_b - x)^T B_x^{-1} (x_b - x) \]
\[ + (\beta - \beta_b)^T B_\beta^{-1} (\beta - \beta_b) \]
\[ + [y - H(x) - h(x, \beta)]^T R^{-1} [y - H(x) - h(x, \beta)] \]

\[ ||h(x, \beta) - b_0|| \leq \delta^2 \]

\[ J_b = \min \quad m = \{ x | J_0 \leq \delta \} \]

Physical constraints

Han Wei, 2014: Constrained variational Bias Correction for satellite radiance assimilation, 19th ITSC, 26 March - 1 April 2014, Jeju Island, South Korea.

Han Wei and Niels Bormann, 2016, Constrained adaptive bias correction for satellite radiance assimilation in the ECMWF 4D-Var system, ECMWF Technical Memoranda, 783.
Bias Dependence on satellite zenith angle

O-B Bias longwave (6)

Satellite Zenith

O-B

y = 1.08 - 1.57x
r = -0.34
After FOV BC

After FOV & Satzen BC
GIIRS spectral coverage and comparisons with others

The First Hyperspectral IR sounder on GEO orbit

Yang J, Zhang Z, Wei C, Lu F. : 2017,
Introducing the new generation of Chinese geostationary weather satellites – FengYun 4 (FY-4) [J]. Bulletin of the American Meteorological Society. DOI:10.1175/BAMS-D-16-0065.1
Jacobians of FY-4A GIIRS

689 channels

961 channels

Temperature Sounding

Humidity Sounding

Jacobian_T

Jacobian_q

Local Training RTTOV coefficients for GIIRS/FY-4A

Apodization

Local training profiles
Observation Error Estimation

Channel Blacklist based on NeDT
GIIRS channel selection

\[
ER = \frac{1}{2} \log_2 \left( \frac{|B|}{|A|} \right)
\]

\[
A_i = A_{i-1} - \frac{A_{i-1}h(A_{i-1}h)^T}{1 + (A_{i-1}h)^T h}
\]

Collard, 2007

Background Error: B(temperature)
GIIRS channel selection
Yin R. W. Han, Z. Gao and G. Wang: 2019

<table>
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<tr>
<th>Chan</th>
<th>Wave Length ($\mu$m)</th>
<th>Chan</th>
<th>Wave Length ($\mu$m)</th>
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GIIRS Selected Temperature Sounding Channels

Weighting Function

Jacobian (dTb/dT)
Impact of FY-4A GIIRS on Forecast over East Asia (August 2017)

GRAPES global 4D-Var
CTRL : OPER
GIIRS : OPER
+GIIRS Temp. Sounding

120h 500hPa ACC over East Asia

500hPa ACC over East Asia

Impact on wind RMSE (green mean reduction)
Impact of FY-4A GIIRS over East Asia (November 2018)

- Neutral to positive impact
- Positive impact for high impact weather

Operational Assimilation of GIIRS in GRAPES 4D-Var Since Dec. 25th 2018
FY-4A REAL-TIME Experiments for Typhoons (2018)
REALTIME Targeted Observing for Typhoons in 2018

- **High Temporal Sounding (15 minutes)**
  - Typhoon Maria: July 9th -11th, 2018 (every 15 minutes)

- **Ambil: Clear Sky Intelligent Sounding**
  - NWP guided GIIRS sounding

- **High Temporal Sounding over Sensitive Area**
  - Typhoon Ambil: July 23rd – 24th, 2018 (every 30 minutes)
  - Typhoon Mangkhut: Sep. 12th -15th, 2018 (every 30 minutes)
GIIRS Intelligent Observation

Fully automatic plan & control

Automatic & flexible instruction generation of FY-4A NRS (navigation and registration system), based on users’ requirement, navigation and calibration requirement and sun avoiding

Yang, et al., 2019
Starting 00Z (UTC) 10 July 2018
GIIRS provides observations every 15 minutes
Starting 00Z (UTC) 10 July 2018
GIIRS provides observations every 15 minutes

2018-07-10-0000

FY-4A GIIRS
T sounding

1650 channels

Typhoon MARIA

Jul. 10th 00Z, 2018
FY-4A GIIRS humidity sounding
(Every 15 minutes)
Temperature channel peaking around 200 hPa, assimilated in GRAPES-GFS with 4D-Var system.
Impact of assimilating high temporal GIIRS observations on analysis: **Warm core is enhanced**

**Vertical structure**

0500 Z 10 July 2018 (Beijing Time)

Contour: Temp BG departure
Color: Temp AN departure
Temperature Analysis Increments with different temporal resolution

15min, 30min, 1hour, 3hour

00Z, July 10, 2018
Impact of GIIRS high temporal observations on Typhoon Maria forecasts (72-h)
Impact of GIIRS on Typhoon Maria Track forecasts

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<th>Time Resolution</th>
<th>00 (%)</th>
<th>06 (%)</th>
<th>12 (%)</th>
<th>18 (%)</th>
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2018071000UTC
Typhoon Mangkhut: Targeted Observing Using FY-4A GIIRS

\[
\langle \delta X(t_1), \delta X(t_1) \rangle_{E_1} = \langle L \delta X(t_0), L \delta X(t_0) \rangle_{E_0} = \langle L^* L \delta X(t_0), \delta X(t_0) \rangle_{E_0}
\]

Sensitive Area Based on SV(GRAPES) at 2018091200
Target observing using GIIRS Typhoon Mangkhut 2018

Date: 20180912110000 - 20180912112212 (GIIRS: Ch993)
The targeted observation received in 1 minute

Apply: NWPC apply for the target observing;
Approved: CMA and NSMC approved the application;
Targeted Observing: FY-4A GIIRS begin targeted observing!

Date: 20180912110000-001 (regx)
Improved the forecast of Typhoon Mangkhut by targeted observing using FY-4A GIIRS
FY-4A GIIRS Targeted Observing for Typhoon Forecasts

Improving high-impact weather forecasts through targeted observing strategy using FY-4A high temporal sounding data.
Data and Experience Sharing of FY-4A GIIRS

- GIIRS L1 data (brightness temperature) has been available since January 24, 2019.
  - Data download: http://data.nsmc.org.cn

- Targeted Observation Data in 2018 and 2019
  - Typhoon Maria: July 9th - 11th, 2018 (every 15 minutes)
  - Typhoon Ambil: July 23rd – 24th, 2018 (every 30 minutes)
  - Typhoon Mangkhut: Sep. 12th - 15th, 2018 (every 30 minutes)
  - Typhoon Lekima: Aug. 08th - 10th, 2019 (every 30 minutes)

- Observation Operator for GIIRS
  - RTTOV(V9.3, V12.1)
Summary and Future Perspective

- **GREAT opportunities** provided by FY-4A for targeted observing
  - Potential operational use for high impact weather prediction
  - Typhoon

- **Cooperation on the use of FY-4A**
  - Observation Operator (RTTOV coefficients)
  - Data and experience sharing
  - Cooperation on FY-4A targeted observing to improve hurricane forecasts

- **Future Perspective**

Global Geo. Sounder RING