Elimination of chaff echoes in reflectivity composite from an operational weather radar network using infrared satellite data

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Characteristics of chaff echoes

Chaff

- Aluminum-coated thin fibers & very reflective in microwave
- Routinely released by the military aircraft during training exercises
- Chaff length: one-half radar wavelength

➢ **Generate spurious radar echoes**

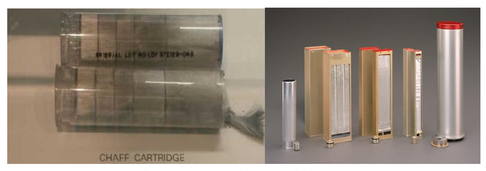


Fig. 1. chaff (from ROKAF)

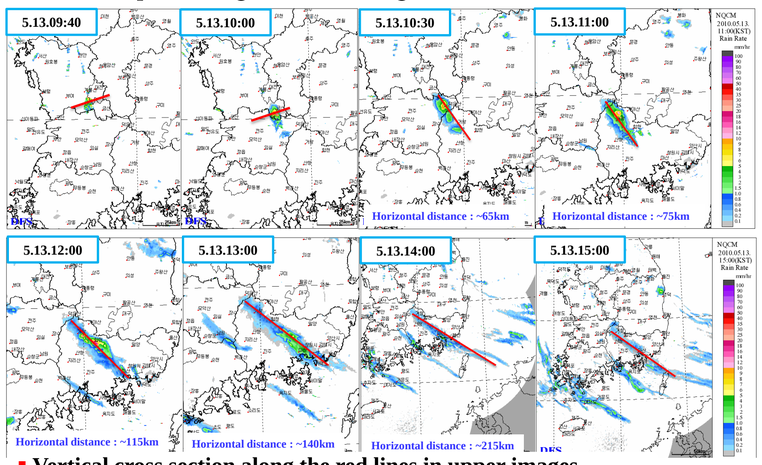
Characteristics of chaff echoes

- Release height: 3~8km
- Point echoes with high reflectivity(30~50 dBZ) when released
- Then, spread with winds and stretch to hundreds of kilometers
- Reflectivity in 1.5 km CAPPI image: 10~30 dBZ
- Diffusion time : about 5~6hrs (8hr : 2010.06.03 case)
- Radar echoes but no precipitation at surface
- Occurring places: Yellow sea (West sea) and southern province in Korean peninsula

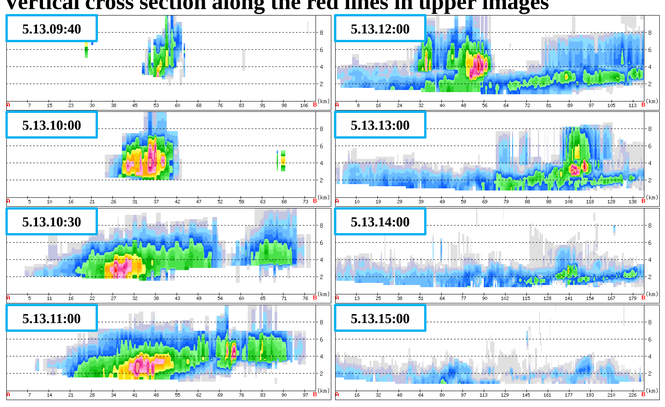
➢ **Hard to identify and remove chaff echoes due to similarity of radar reflectivity and radial velocity between chaff echoes and precipitation echoes.**

Chaff echo case of 13 May 2010

▪ **Radar composite images at 1.5 km height**

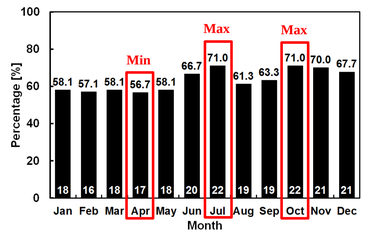


▪ **Vertical cross section along the red lines in upper images**



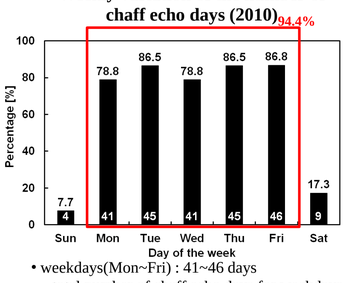
Statistical analysis of chaff echo occurrence

Monthly variation of the number of chaff echo days (2010)



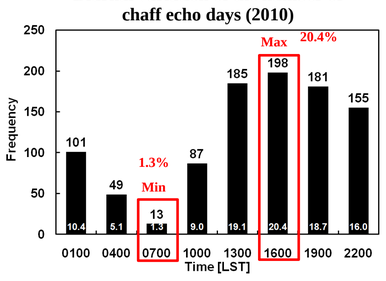
- 231 days out to 365 days (63.3%)
- about 19 days for a month

Weekly variation of the number of chaff echo days (2010)



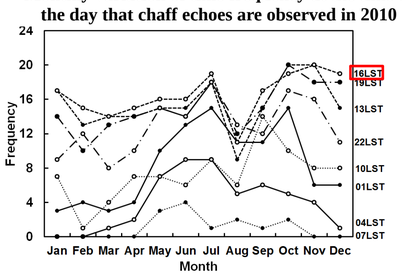
- weekdays(Mon~Fri) : 41~46 days
  - total number of chaff echo days for weekdays : 218 days (94.4%)
- weekends(Sat~Sun) : 13 days (25%)

Diurnal variation of the number of chaff echo days (2010)

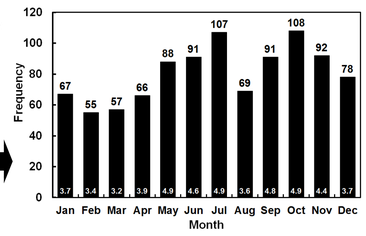


- Frequent occurrence time : 13~22 LST
  - Related to military aircraft training exercises during daytime
- chaff echoes released at daytime last nighttime (01~04 LST)

Monthly variation of time frequency at the time of the day that chaff echoes are observed in 2010

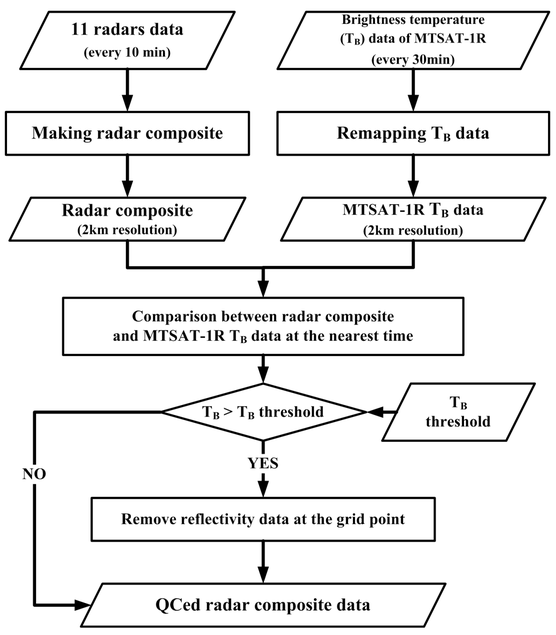


Monthly variation of time frequency(black) and normalized time frequency(white) by the number of chaff echo days in 2010



Chaff removal algorithm

Flow chart



Case studies

▪ **Chaff**

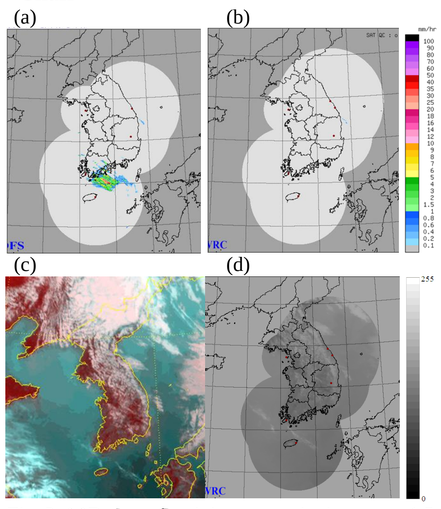


Fig. 2. (a)Radar reflectivity composite images at 1.5 km height, (b)results from chaff removal algorithm, (c)composite images of infrared and visible channel and (d)T_B image of MTSAT-1R for a chaff case at 1600LST 12 May 2010.

▪ **Chaff + Convective echoes**

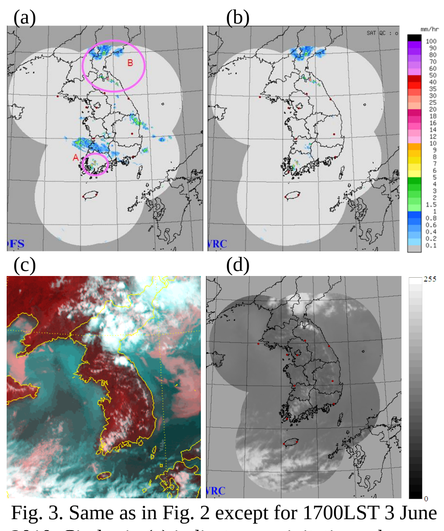


Fig. 3. Same as in Fig. 2 except for 1700LST 3 June 2010. Circles in (a) indicates precipitation echoes.

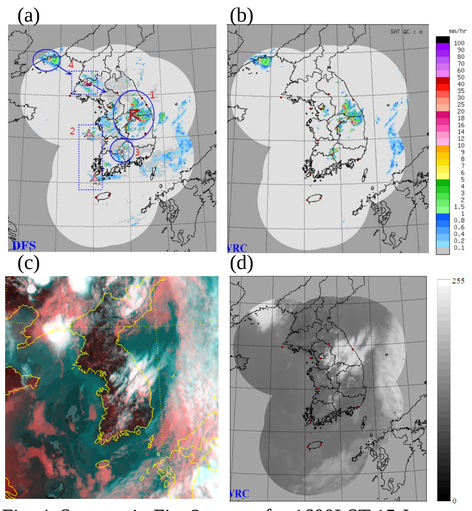


Fig. 4. Same as in Fig. 2 except for 1600LST 15 June 2010.
- In (a),
  #1: precipitation echoes with lightning.
  #2: chaff echoes.
  #3: precipitation with none precipitating clouds.
  #4: second-trip echoes.

▪ **Chaff + Clouds**

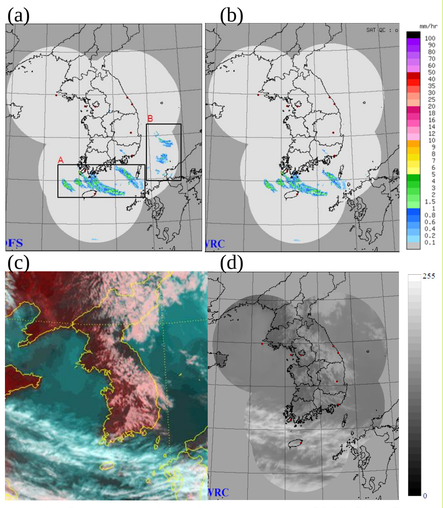


Fig. 5. Same as in Fig. 2 except for 1600LST 13 May 2010. The echoes in the area marked by A and B in (a) indicate chaff echoes.

Analysis for T_B threshold of MTSAT-1R

Monthly variation of color index threshold ranges of T_B

- T_B : Change with the temperature variation → Thus, apply statistical analysis in order to optimize the threshold of T_B
- The threshold of the chaff removal algorithm was empirically determined by changing color index to effectively remove chaff echoes while maintaining precipitation echoes
- Comparison of threshold for a given month with monthly statistical distribution of color index of T_B from MTSAT-1R.

Table 1. Cases used to analyze a threshold of T_B from MTSAT-1R in 2010.

Month	Date
Jan	18, 25, 26, 28, 29
Feb	6, 20, 21, 23
Mar	11, 13, 16, 19, 26, 28, 29
Apr	3, 13, 16, 24, 29, 30
May	3, 4, 7, 8, 10, 12, 13, 14, 19, 20, 27, 31
Jun	1, 3, 4, 8
Jul	6, 7, 9, 19, 20, 21
Aug	3, 4, 5, 8, 9, 19, 20, 21, 22, 23
Sep	7, 13, 15, 16, 17, 18, 23, 24, 28, 30
Oct	1, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 25, 26, 27, 29
Nov	1, 2, 3, 4, 5, 10, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 25, 29
Dec	1, 3, 7, 9, 10, 15, 20, 22, 23, 24, 27, 29

▪ **Case selection criteria**

- No precipitation and clouds are reported at more than 50% of total 93 surface weather stations

▪ **Period of analysis time**

- Spring (Mar. ~ May.) : 1000 ~ 1800 LST, Summer (Jun. ~ Aug.) : 1000 ~ 1900 LST
- Autumn (Sep. ~ Nov.) : 1000 ~ 1800 LST, Winter (Dec. ~ Feb.) : 1000 ~ 1700 LST

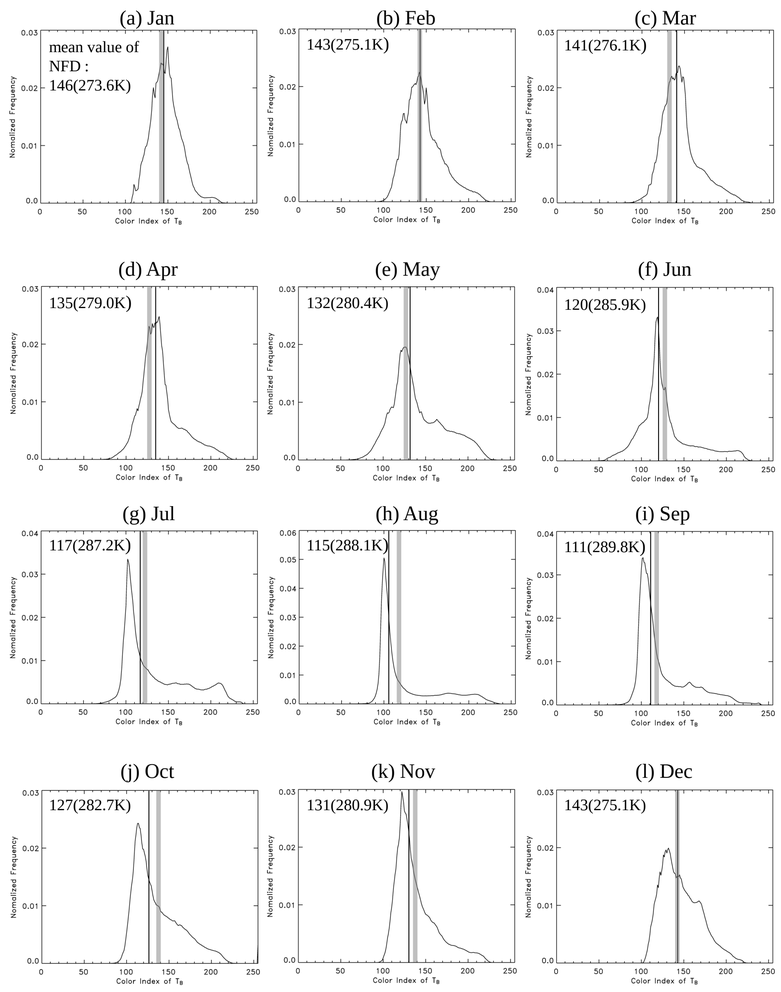


Fig. 6. Normalized frequency distribution(NFD) of color index of T_B from MTSAT-1R during the chaff cases for (a)Jan, (b)Feb, (c)Mar, (d)Apr, (e)May, (f)Jun, (g)Jul, (h)Aug, (i)Sep, (j)Oct, (k)Nov, and (l)Dec in 2010. Each vertical line indicates mean value of NFD, and gray area indicates the color index threshold ranges that is used in chaff removal algorithm.

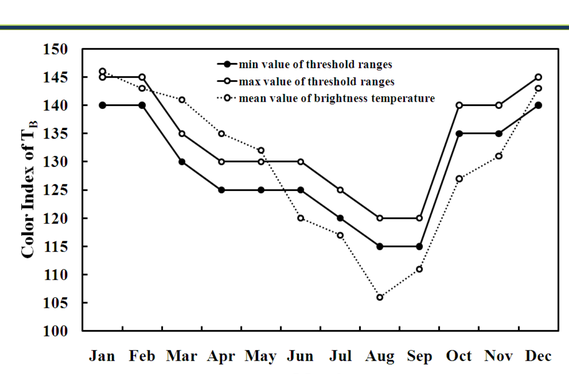


Fig. 7. Monthly variation of color index threshold ranges of T_B from MTSAT-1R recommended for the chaff removal algorithm and the mean color index of T_B(dashed line).

- Comparison of mean T_B and threshold ranges
  - Winter (Dec. ~ Feb.)
    : Mean T_B within the threshold ranges
  - Spring (Mar. ~ May.)
    : Mean T_B (color index) lower (higher) than the threshold ranges
  - Summer (Jun. ~ Aug.), Autumn (Sep. ~ Nov.)
    : Mean T_B (color index) higher (lower) than the threshold ranges

Summary

- To discriminate and eliminate chaff echoes in two-dimensional 1.5 km CAPPI reflectivity composite, a removal algorithm has been developed by using T_B obtained from MTSAT-1R.
- Evaluation for three different situations: chaff , chaff +convective storms, and chaff +clouds.
- The algorithm shows excellent performance for chaff and chaff + convective storms.
- However, the performance significantly depends on the presence of clouds.
- Need to perform a quantitative evaluation on the algorithm performance and to optimize the algorithm.
- A new chaff identification algorithm using clustering and fuzzy inference techniques is underway.