Predicting of lightning activity in Japan using mesoscale model output statistics
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1. Introduction
Today, lightning is a major cause of natural disasters to electric power facilities and transportation including aviation. In Japan, the number of the people killed by thunder is about ten per year. 200,000,000,000,000 (in Japan) losses, only economical loss, not include human damages. Especially in the lightning activities, technologies, are extremely weak to lightning damages. (For example, computers, cell phones, etc.)
We need high accurate lightning forecast for preventing lightning disasters. Nowadays, we have powerful computer resource and also high resolution mesoscale model. Japan Meteorological Agency (JMA) is now operating 5km horizontal resolution mesoscale model (MSM) and 1-km resolution model is conducted for the research purposes.
Using these high-resolution models, we are trying to develop our lightning forecast. In this study, our operational and newly developed lightning forecasts using mesoscale models with 1-km and 5-km horizontal resolution are introduced.

2. Lightning Data and Numerical Model Data
2.1. Lightning Location System in JMA (called “LDEN”) - Japan Meteorological Agency
LDEN is now operating 5 km horizontal resolution model for operational forecast: 721x277x50 grid in x-y-z.
- 6-class in 30-hour forecast.
- Using Kain-Fritsch scheme for cumulus parameterization.
- Observing cloud-to-ground lightning.
- 6-class with cloud-ice number cloud microphysics.
- For more information, check Sato et al. (2007).

3. Lightning Activity Indices
3.1. Traditional indices - Thermodynamic and kinematic indices for thunderstorm (traditional) were calculated by NHM-1km and NHM-5km output.
S, RFD, and K-index are calculated from 850 hPa to 900 hPa.
- Tmax, T90, T30: Total Temperature. T90, T30: Temp. 90%, 30% of the atmosphere.
- CAPE: Convective Available Potential Energy.
- CIN: Convective Inhibition.
- LCL: Level of Convective Stability.

3.2. MSM-Pot (Probability of Thunderstorm) - JMA operational lightning index using NHM-5km output
- MSM-Pot is developed by JMA for aviation safety. It has operated since May 2007 (slightly updated in Jul-2009).
- Using Logistic Regression:

\[ \ln(p/(1-p)) = C_0 + C_1 X_1 + C_2 X_2 + \ldots + C_n X_n \]


- The best 5 explanatory variables in each grid from 16 candidates are independently selected for X, which consist of the following indices: (in important order)
  - SSI, SSI_Tot, CAP_E, LH_Tot, CAPE, WCAPE, VCAPE, OCAPE, VCAPE, CAP_EL, OCAPE, LCL, TCAPE
  - The latest version (50 km) uses selected variables after update 2009.
- X and C is decided in advance using the past few years data.

3.3. New indices using NHM-5km and NHM-1km
- High resolution model with detailed cloud microphysics can represent the realistic distribution of cloud microphysics highly related to lightning. Grapel are especially related to lightning.
- We developed newly lightning indices using meso-scale model (1km and 5km horizontal resolution) output, as follows:
  - Maximum vertical velocity (vertical grid).
  - Maximum graupel mixing ratio in a vertical grid.
  - Vertical accumulated graupel amount in a column. Vertical accumulated graupel amount in a column above -10C only.
- And more, 1-km resolution calculates the number concentration of graupel, snow, and cloud ice. It has already known that their collisions are important for producing electricity of thunderstorm (e.g. Takahashi, 1984). We made new indices based on the theory:
  - Multiply graupel number concentration and (snow + cloud ice) number concentration in the cloud,
    - “accumulation of (Qgr + Qsn + Qci)” from cloud base or -10C level to cloud top.

4. Results in Winter: 2008-Dec-2009 Feb
- Verification grid: 20km in space & 3 hour in time for all data.
- Observation. Cloud-to-ground lightning was observed by the Lightning Detection Network System (LDEN) operated by JMA. LDEN consists of 30 detecting stations, covering the whole land area of Japan and the surrounding sea, and measures cloud strokes in the time of Arrival method using the LF band (LDEN also detects a cloud-to-cloud lightning via the VHF band, but we don’t use the C-band in this study).
- The average distance between stations is about 200 km.
- In this study, the observed CG data was converted to 20-km horizontal grid with 3 hour time series. Using these gridded data, the lightning forecast skills were verified.

5. Results in Summer: 2008 Jun-Aug
- Rough correspondence between lightning location and precipitation amount.
- In summer, many lightning, which caused by the thunderstorm instability, is observed over inland area. And also, precipitation is observed over inland area.
- The precipitation of the models reproduce well over inland areas, but failed southern side of Japan. (We don’t know why.)
- MSM-Pot is well represented lightning potential in such situation.
- NHM-1km produces much graupel, but not consistent observed lightning.