衛星データ同化による全球大気モデルNICAMの高度化
－雷予測モデルの構築への取り組み－

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数理構造活用

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Contents

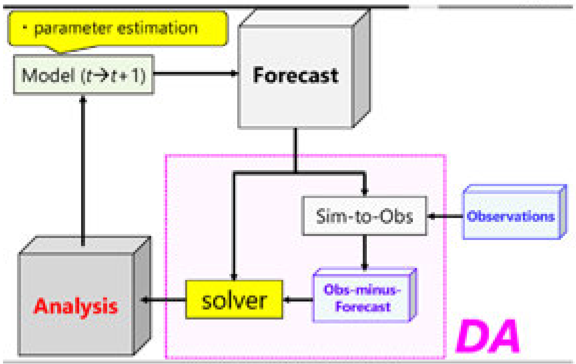
JAXA's Weather FCST System

Terasaki et al. (2015); Kotsuki et al. (2019)

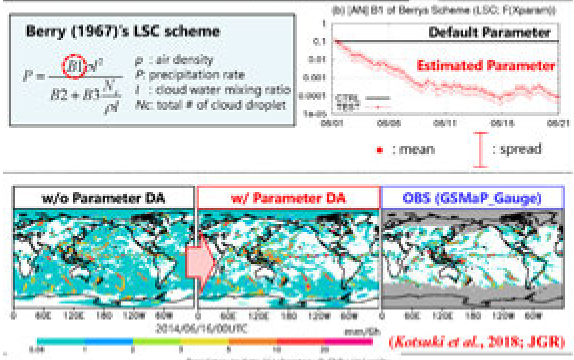
Experimental Setting

- **NEXRA: NICAM-LETKF**
  - NICAM (Satoh et al. 2008, 2014)
    - Horizontal : GL6 (approx. 110 km resolution)
    - Vertical : 38 layers up to approx. 40 km
    - Cumulus Parameterization : Arakawa and Shubert (1974)
    - Large Scale Condensation : Berry (1967)
  - Observations
    - PREPBUFR, AMSU-A, GSMaP
  - LETKF (Hunt et al. 2007) with 40 members
    - Localization: 400 km (horizontal) & 0.4 lnp (vertical)
    - Inflation by RTPS (α = 0.90)
- **For Lightning Prediction**
  - Lopez (2016)'s parameterization
  - Chikira and Sugiyama (2010) for cumulus scheme

DA for Parameter Estimation



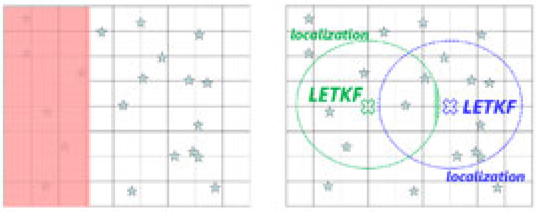
For Improving Precip. FCSTs



(Kotsuki et al., 2018; JGR)

Extension to Local Param. DA

Global Parameter Estimation By ETKF | **Local Parameter Estimation By LETKF**

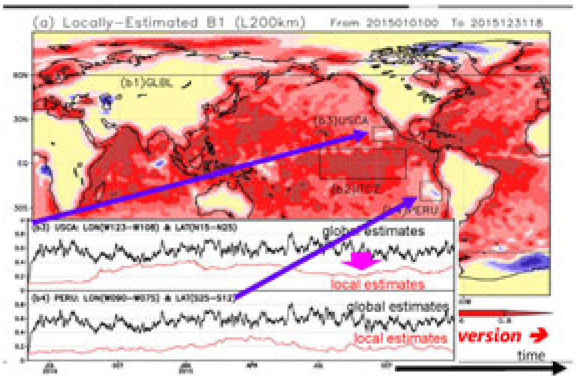


- Estimate a global constant parameter
- no localization

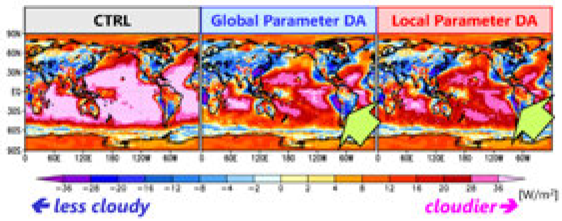
- Estimate spatially-varying parameter
- w/ localization

☆ observation

DA w/ AMSR2 LWP



OSR Bias vs. CERES 201501-201512



local parameter DA was beneficial in shallow-convection regions

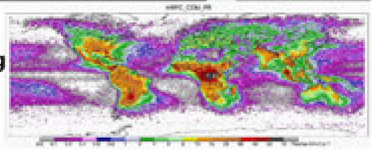
OSR: Outgoing Short Wave Radiation

Kotsuki, Sato, Miyoshi (2020; JGR-A)

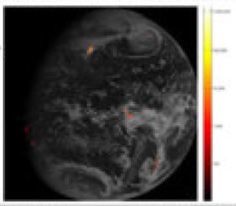
Toward Lightning Prediction

Background: Lightning Obs.

TRMM Lightning Imaging Sensor (LIS; 1998-2015)



GOES-16 & 17 Geostationary Lightning Mapper (GLM)



Can we advance NWP using lightning obs?

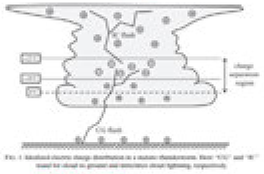
Figures from NASA

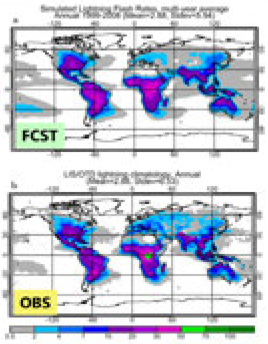
Strategy

- **雷観測の同化について**
  - 状態推定: 状態変数←→雷 関係の非線形性・確率過程が大きく・困難
    - レーダー反射強度や雷観測を使う方がstraightforward
  - → モデルパラメータ推定
- **(1) 電荷を陽に解く雷モデル (e.g. Sato et al. 2019)**
  - Cons: 計算コストが膨大であり、アンサンブル同化は難しい
- **(2) パラメタリゼーション**
  - **大気化学 NICAM-CHEM:** 雲頂高度から雷を予報 (for NOX)
    - Cons: Tracerが計算負荷が高く、ザクっとNICAMの8倍
    - Cons: 気象予測のための同化としては、あまり面白い問題ではない
      - 雲頂高度であれば、OLRで決めればよい
  - **Lopez (2016): 氷物質の衝突・融合で雷を予報**
    - 雲微物理に組み込み
      - シングルモーメント・バルクスキーム (e.g., Tomita 2008, Roh and Satoh 2014)
        - 霰や雪の終端速度の止場性に大きく影響される
      - ダブルモーメント・バルクスキーム (e.g. Seiki et al. 2015)
        - アンビルが過剰に出る事が知られている
    - 積雲対流パラメタリゼーションへの組み込み (e.g., Chikira and Sugiyama 2010)
      - チューニングの余地が大きい → パラメータ推定が活躍できる余地が大きい

ECMWF's Operational Lightning FCSTs

Parameterization





Lopez (2016; MWR)

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Flash Density (Lopez, 2016)

Basic Assumption: Charge separation of hydrometeor occurs collision between graupel and ice/snow

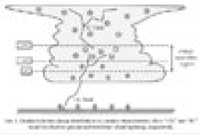
The equation was developed based on Takahashi (1978)

Total Lightning : $f_T = 32.4 \times Q_R \sqrt{CAPE}\ \min(z_{base}, \ )^2$ [km^{-2} year^{-1}]

$Q_R = \int_{z_0}^{z_{-25}} q_g (q_{cond} + q_s) \rho dz$ → corresponding to the vertically integrated amount of collision/coalescence between graupel and snow

$q_g = \beta \frac{P_f}{\rho V_g}$ $q_s = (1-\beta)\frac{P_f}{\rho V_s}$ $\beta = \begin{cases} 0.45 & (over\ ocean) \\ 0.70 & (over\ land) \end{cases}$

q_{cond} : Total condensate over convective region
V_g : Graupel terminal velocity (= 3.0 m s^{-1})
V_s : Snow terminal velocity (= 0.5 m s^{-1})
P_f : Precipitation flux of frozen (solid) hydrometor
ρ : Air density



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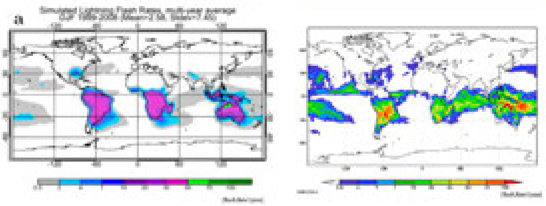
Comparison with Lopez (2016)



(1) Parameterization worked reasonably
(2) Lightning overestimated over ocean

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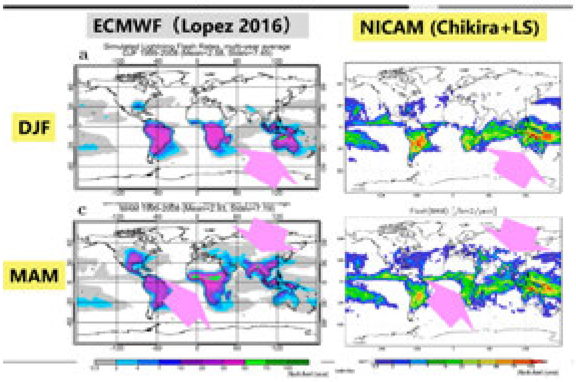
Seasonality of Lightning



Summary

- **Activities to advance NWP w/ satellite obs.**
- **(1) Model parameter estimation**
  - w/ GSMaP
    - precipitation forecasts improved
  - w/ AMSR-2/LWP
    - local parameter estimation worked reasonably
    - DA can improve radiation bias significantly
- **(2) Lightning parameterization**
  - Lopez (2016)'s scheme implemented
  - The parameterization worked with try/errors
  - Param. DA will be tried w/ TRMM/LIS and GOES/GLM

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