

2015.08.10 南岸低気圧とそれに伴う気象・雪氷災害に関する研究会

# 関東に大雪をもたらした 降雪雲の雲物理過程と 氷晶核の影響

荒木健太郎, 村上正隆  
気象庁気象研究所



A satellite image of an extratropical cyclone over the North Atlantic. The cyclone is characterized by a dense, swirling cloud pattern with a well-defined eye and a surrounding eyewall. The clouds are white and grey, contrasting with the dark blue of the ocean. The landmasses of North America and Europe are visible in the background, with the ocean extending to the horizon.

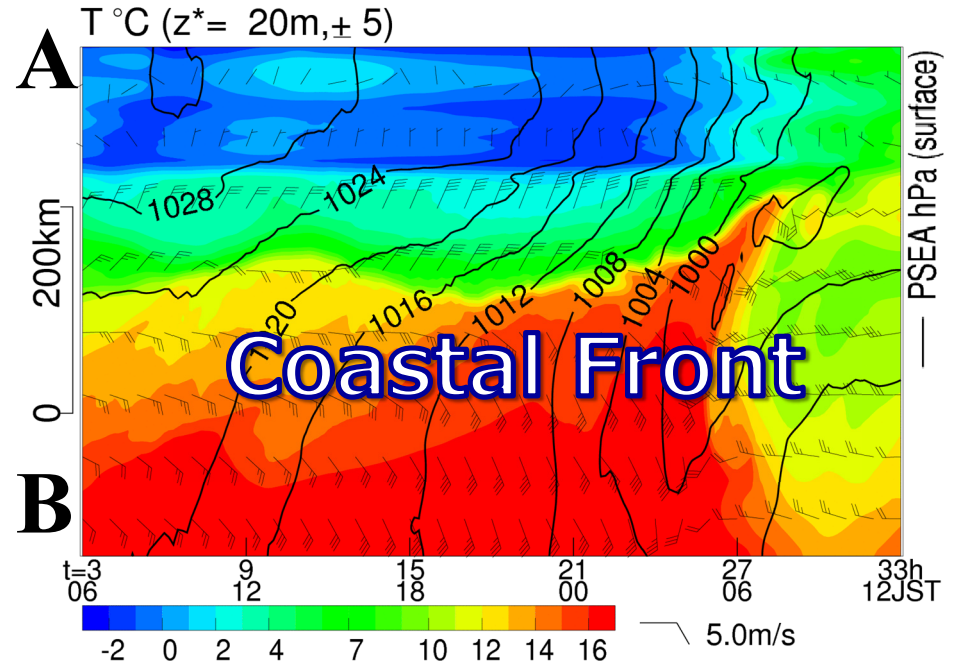
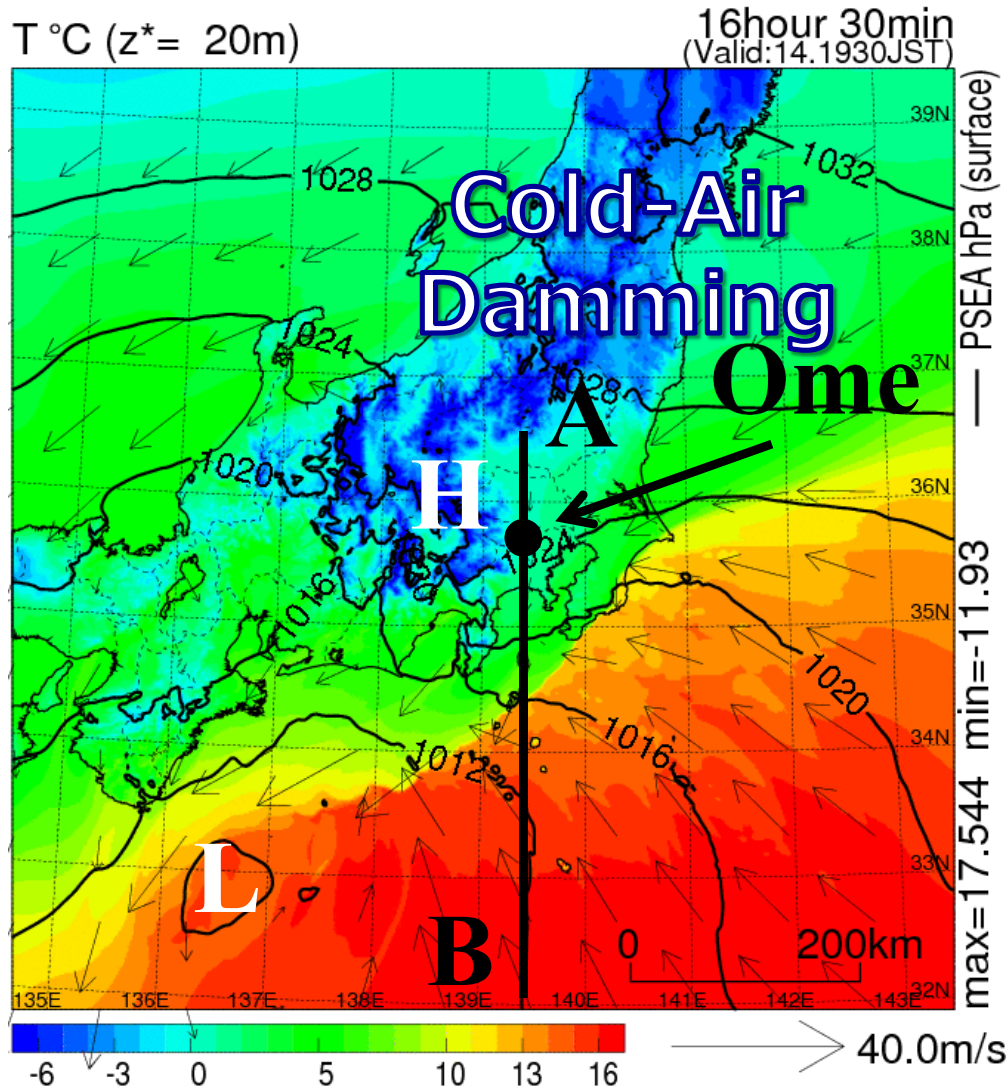
**Heavy Snowfall Event  
on 14-15 February 2014**

**Extratropical  
Cyclone**

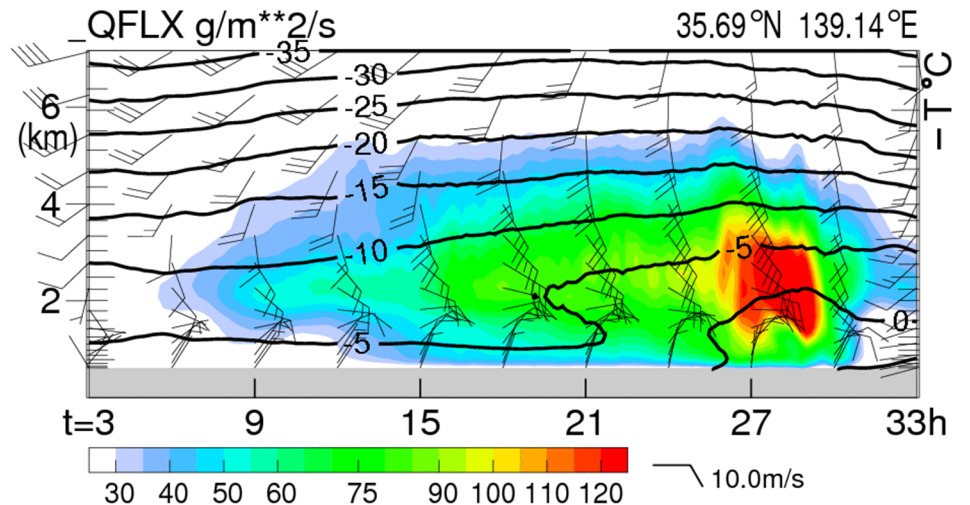


# 大雪をもたらした降雪雲のメソスケール環境場

Araki and Murakami (2015)



Time-range cross section of surface temperature

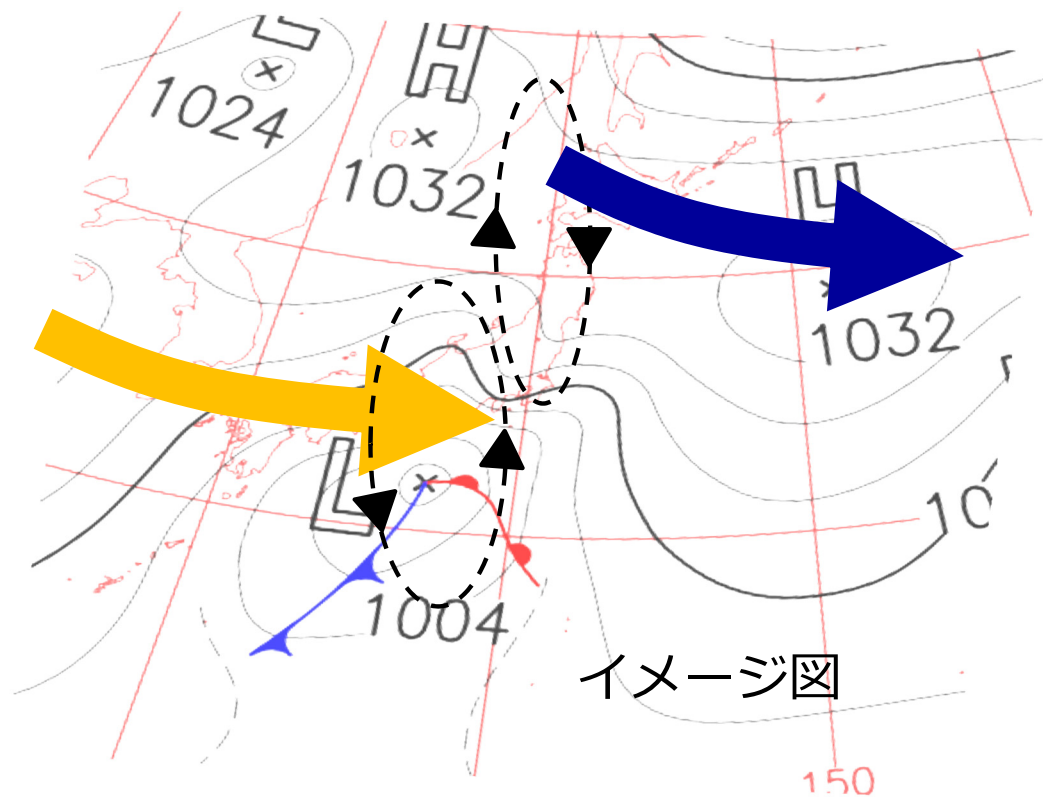
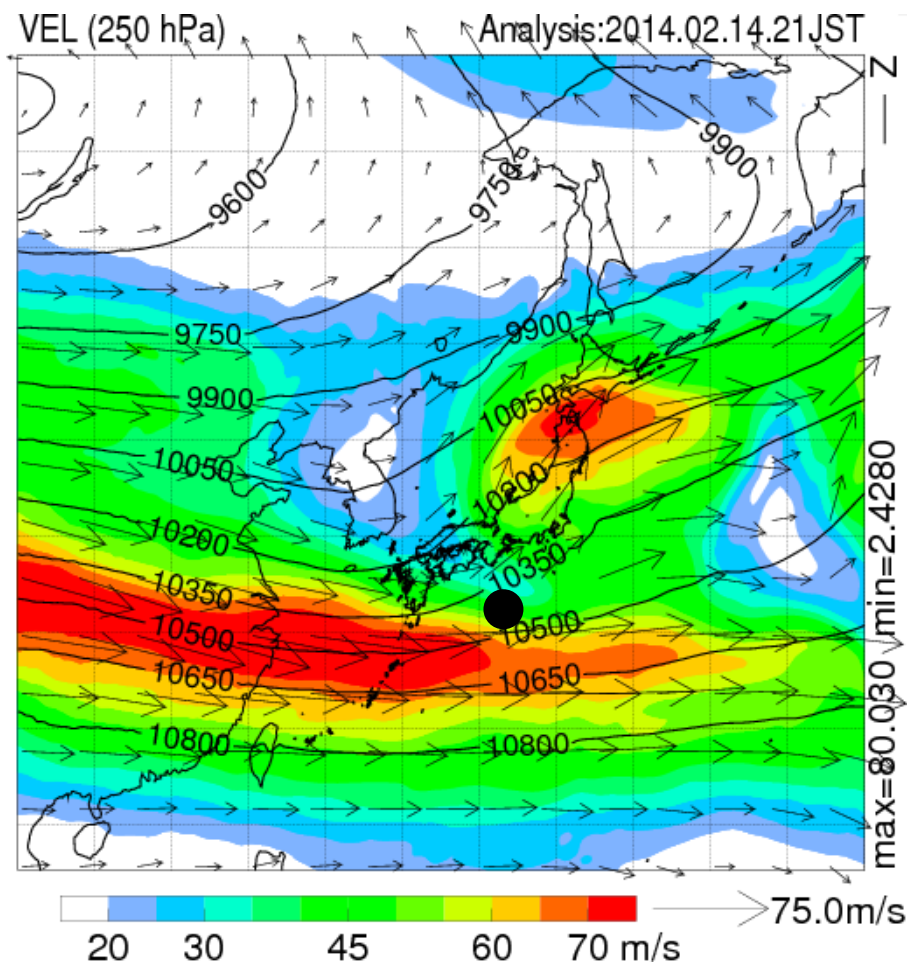


Time-height cross section of water vapor flux

CF, CAD: 荒木(2015, 天気)

# 総観スケールの環境場

アメリカ東岸での大雪環境場 (Uccellini and Kocin, 1987)



**2つのJet Streakに伴う非地衡風循環が下層非地衡風を加速  
→Cold-Air Damming/Coastal Frontの形成・強化**

Araki and Murakami (2015), 荒木ほか(2015)



大雪をもたらした

降雪雲の

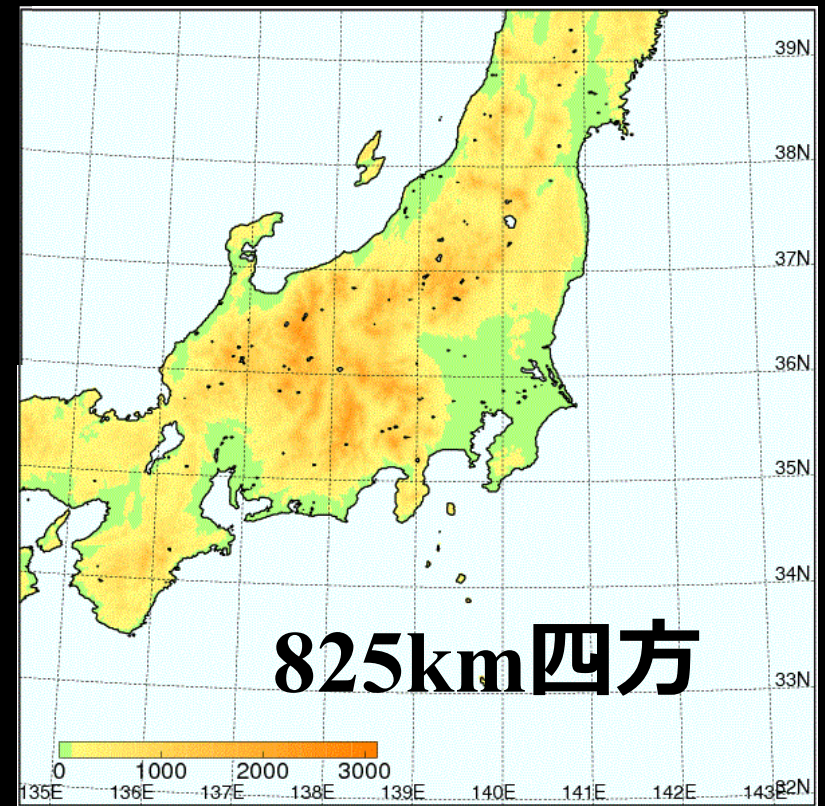
雲物理過程



# 大雪の数値実験

## 気象庁非静力学モデル (JMA-NHM)

- dx=1.5km, 格子: 550x550x50
- 雲物理過程: **バルク法**  
(雲氷・雪・霰は2-moment)
- 乱流過程: MYNN level 3
- 初期値・境界値: MANAL



2014年2月14日3時(JST)~33時間積分

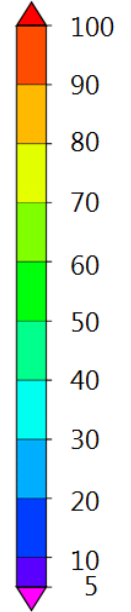
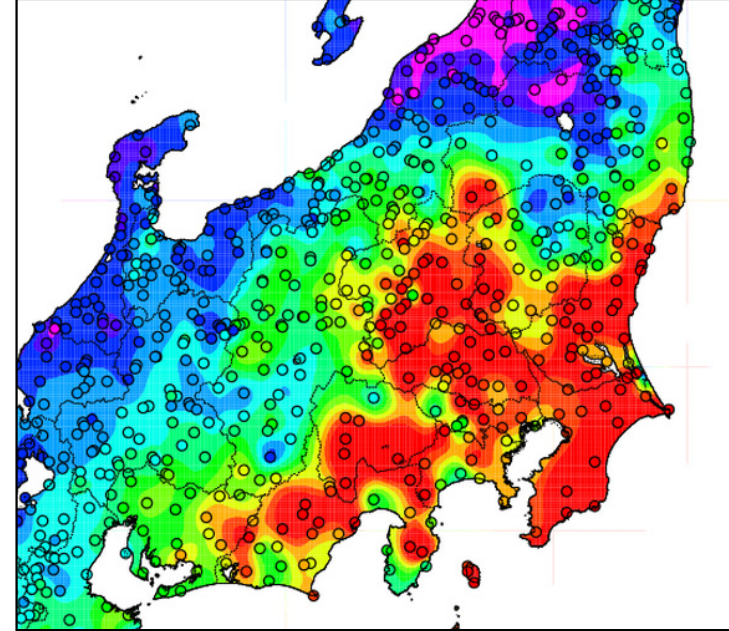
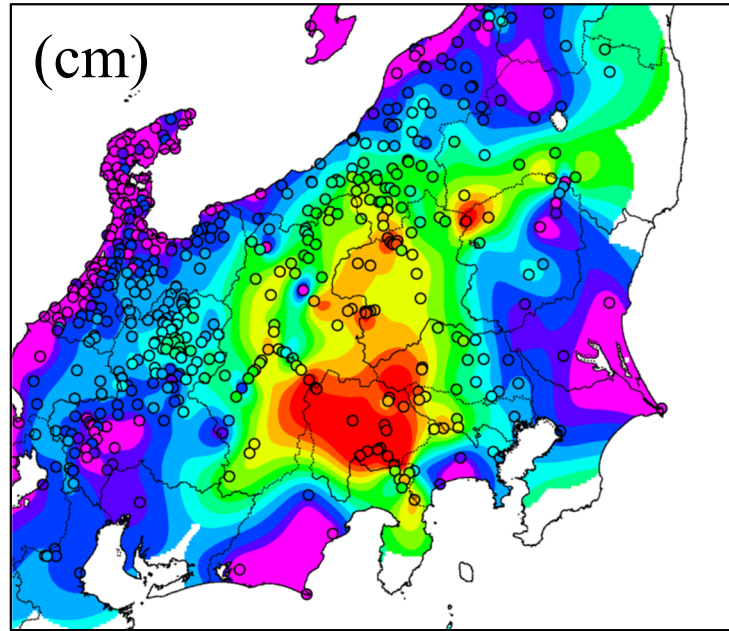


# 再現された総降雪量・総降水量

## 総降雪量

## 総降水量

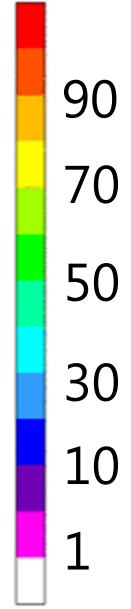
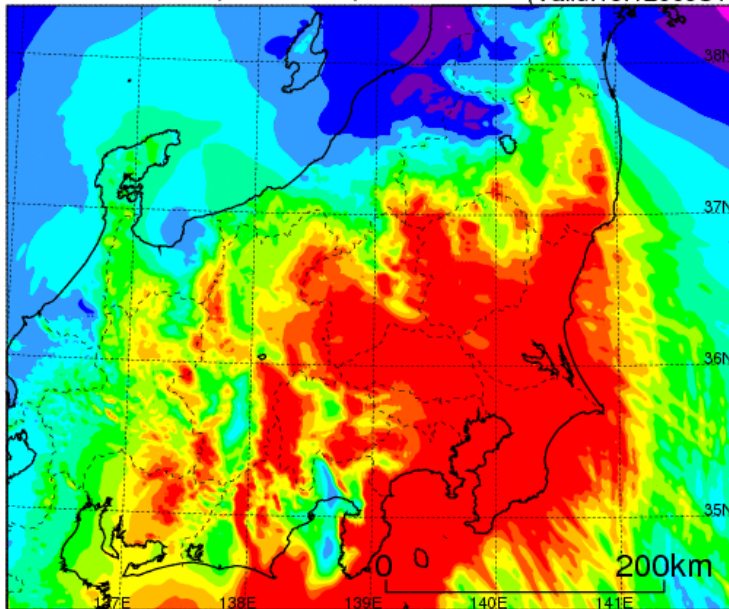
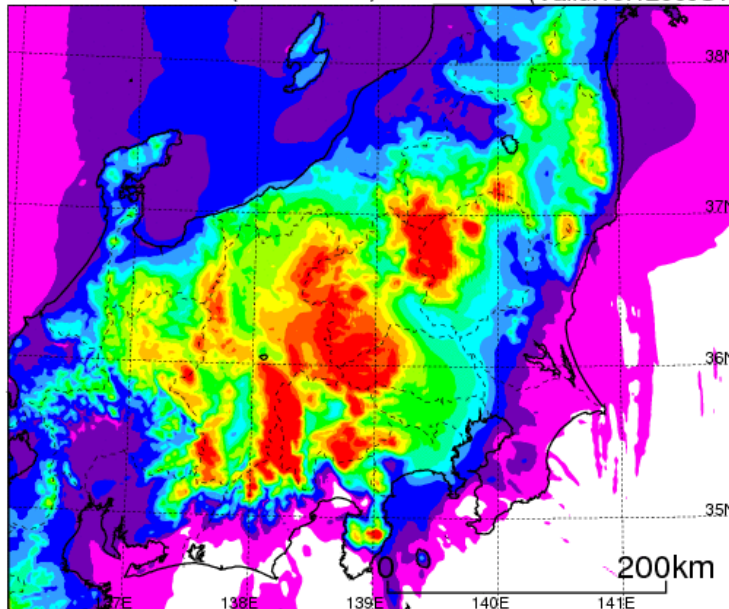
Observation



Snow mm/33h ( $z^* = 20m$ ) 33hour 0min  
(Valid:15.1200JST)

Prec mm/33h ( $z^* = 20m$ ) 33hour 0min  
(Valid:15.1200JST)

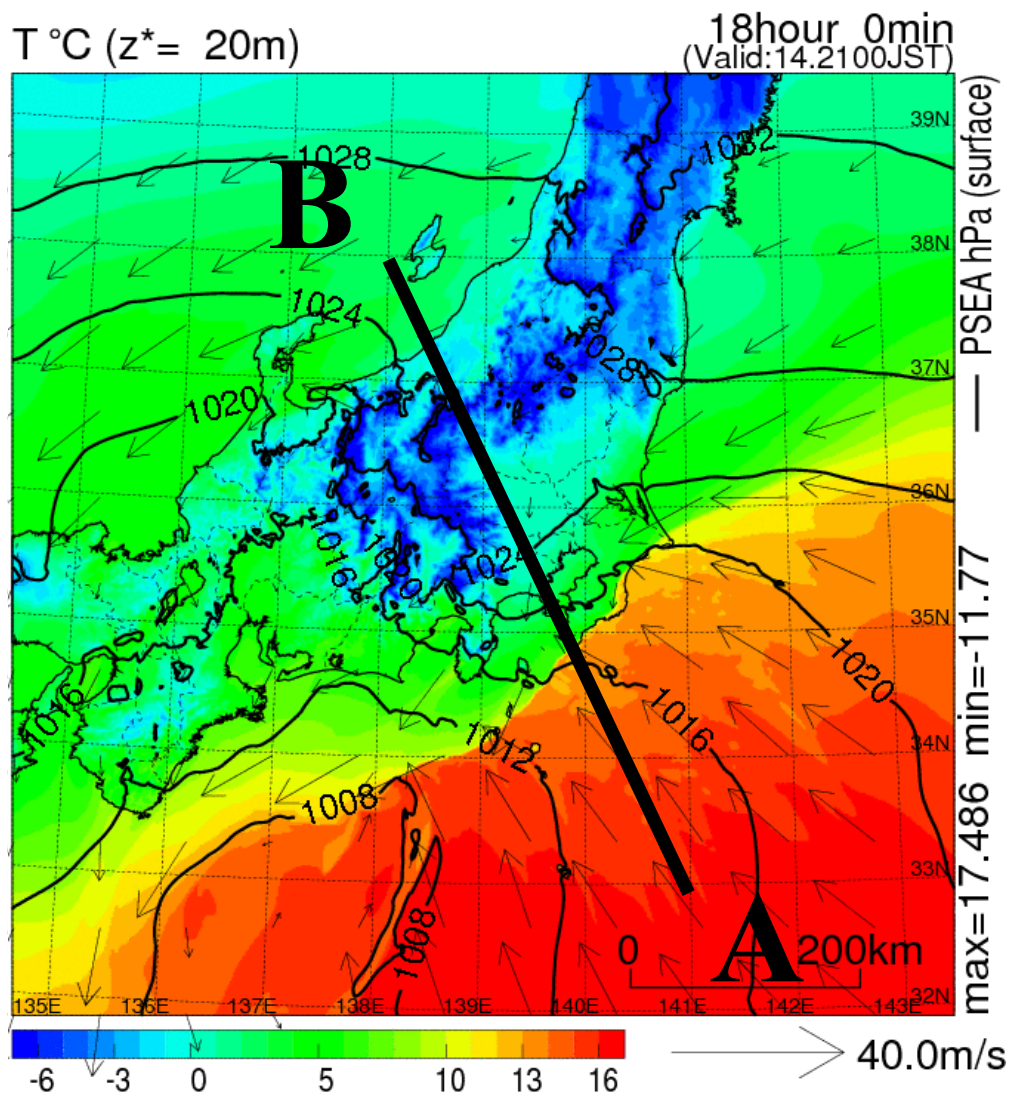
Simulation



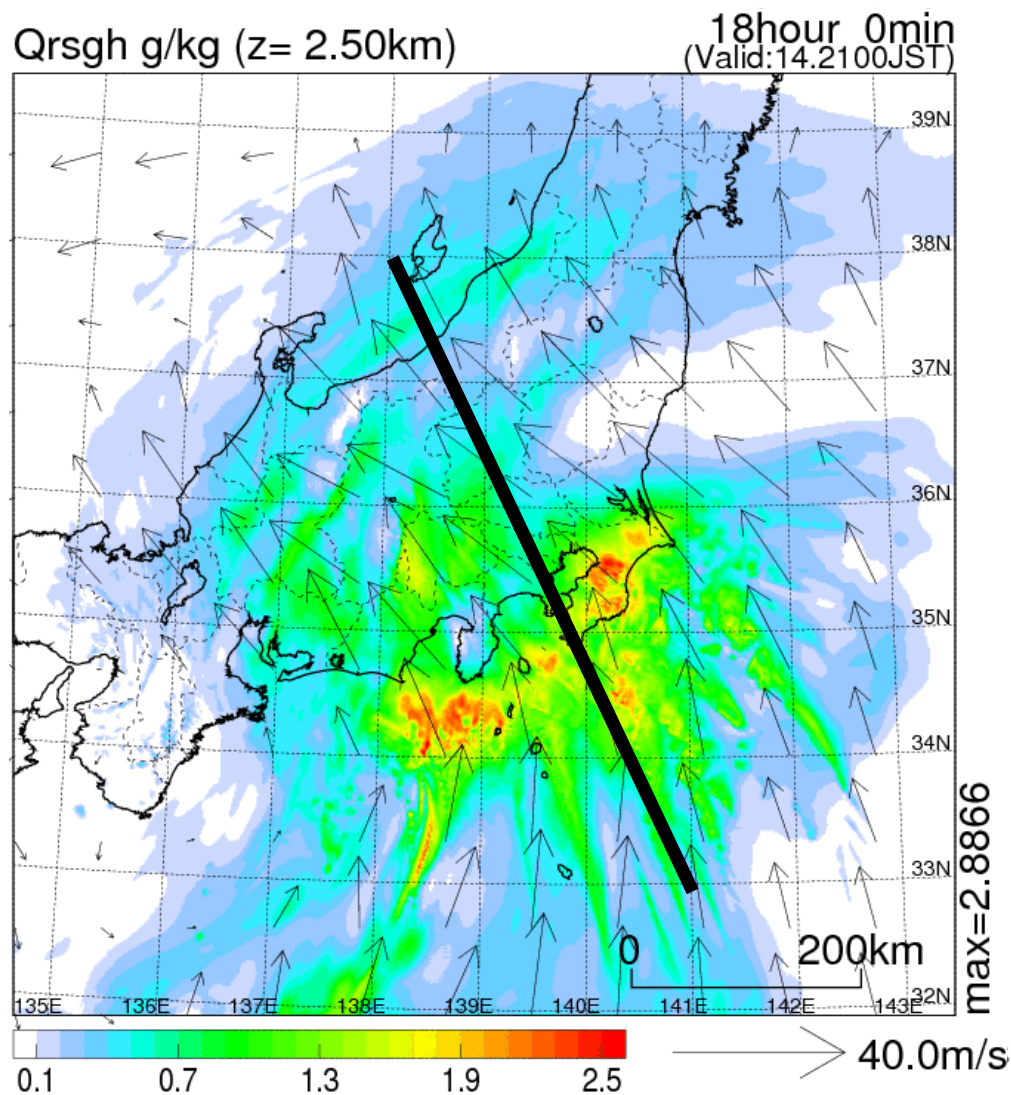


# 再現された南岸低気圧と降雪雲

## 地上気温・海面気圧



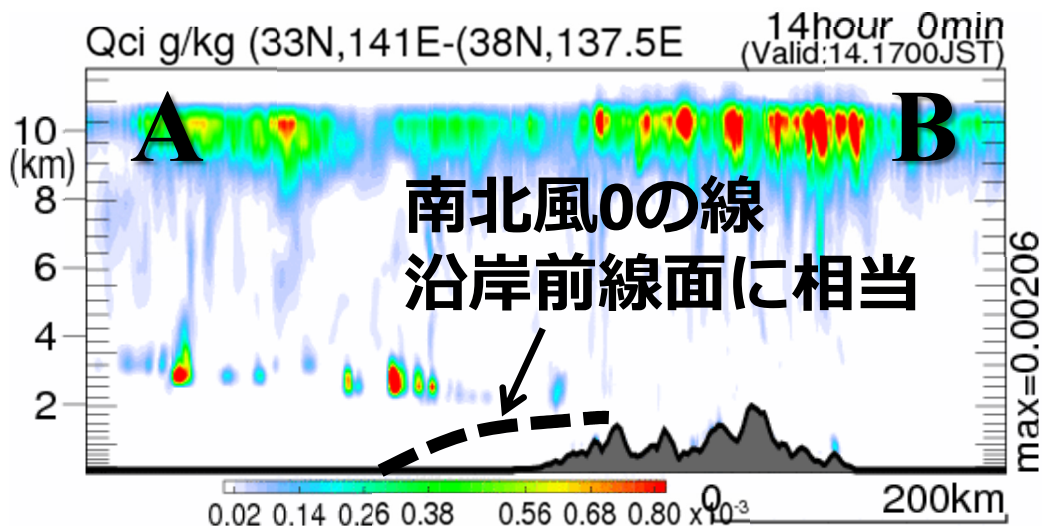
## 高度2.5kmの降水物質の混合比



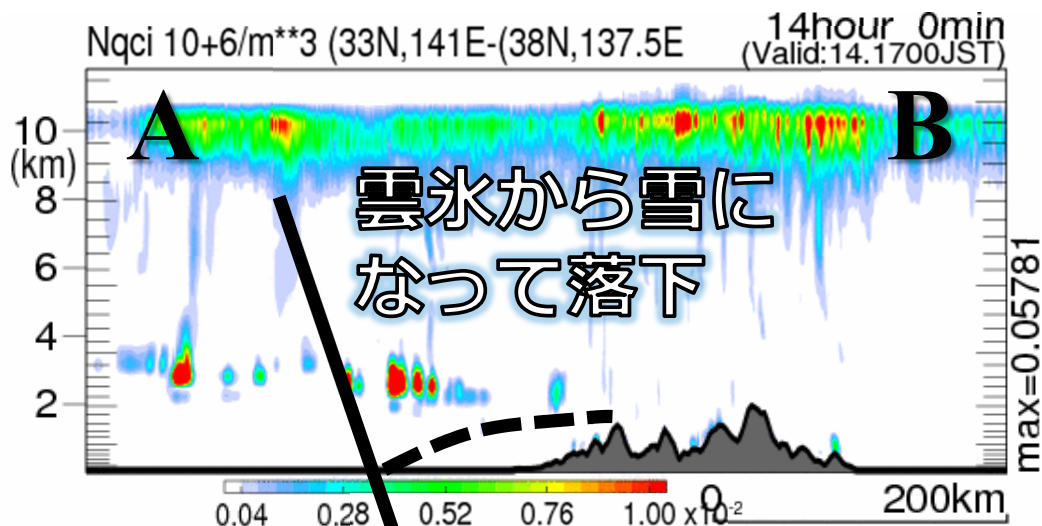


# 降雪量の増大 : Seeder-Feeder Effect

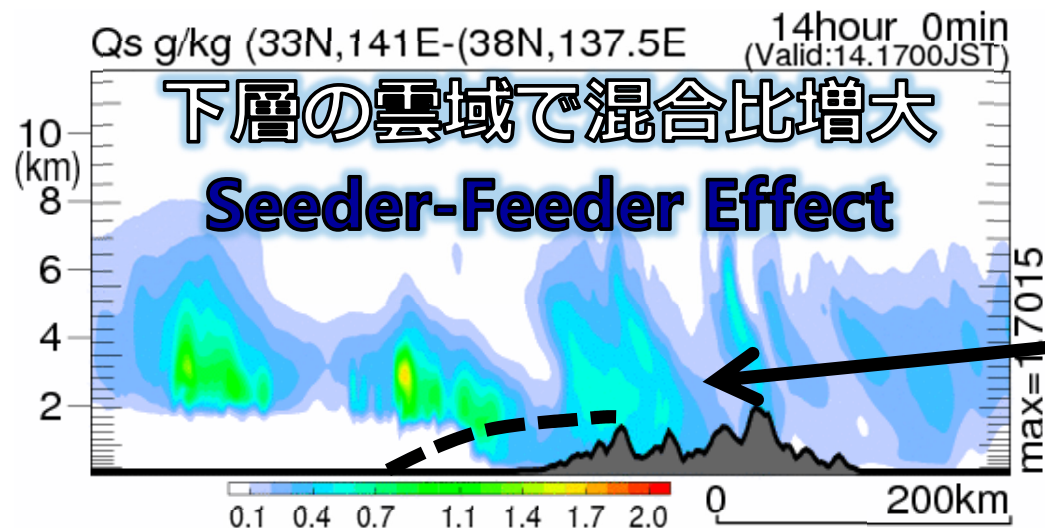
## Cloud Ice



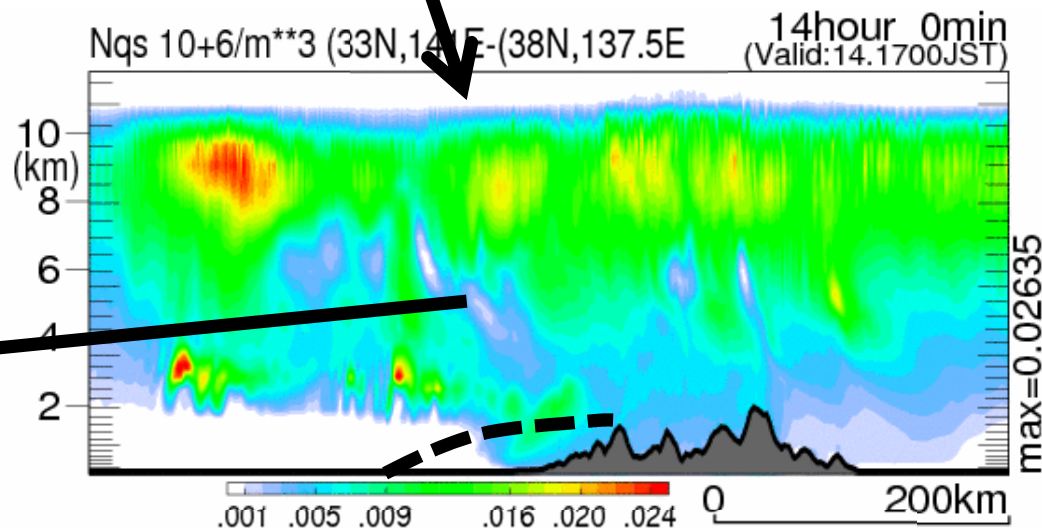
## Cloud Ice



## Snow



## Snow



Blue: Mixing Ratio

Red: Number density



エアロゾルの第二種間接効果

氷晶核 (IN) が

降水システム

に与える影響

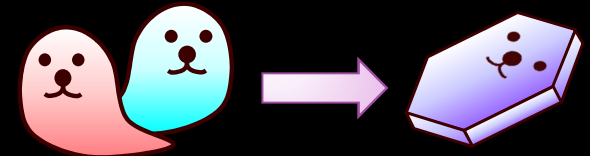


# INに関連する パラメタリゼーション

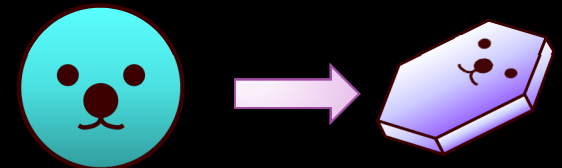
## ① 氷晶発生の式 Meyers(1992)

$$N_{\text{inocl}} = 10^3 \exp \{ a + b \times 100 (S_i - 1) \}$$

$S_i$  : 氷過飽和度



## ② 凍結の式 Bigg(1955)



IN数に相当する各係数を変更

INdef(1倍), IN01(0.1倍), IN10(10倍)



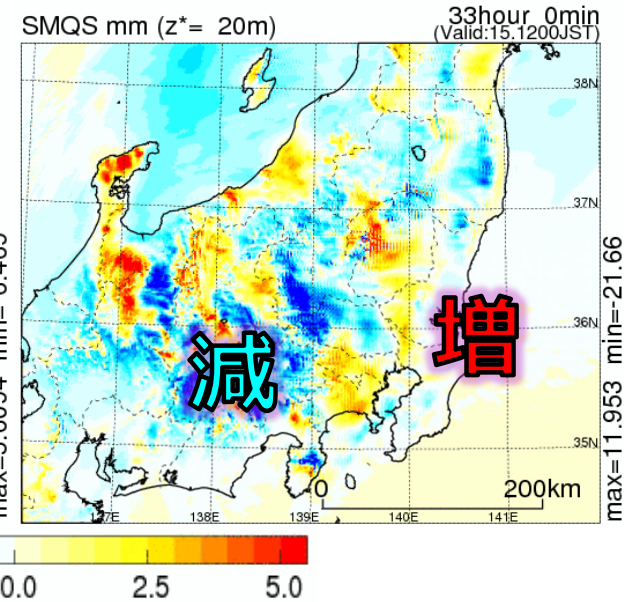
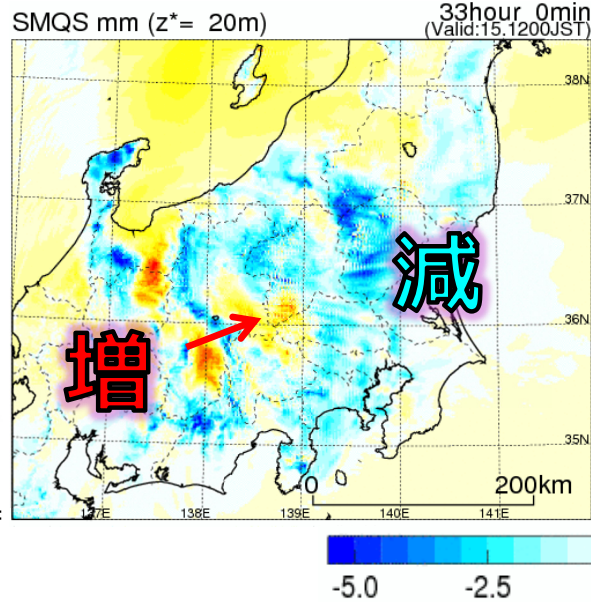
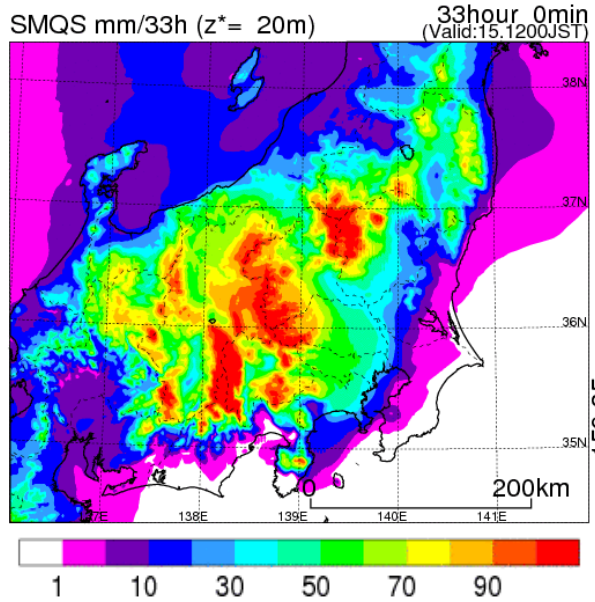
# 降水物質毎(雪・雨)の総降水量の違い

INdef

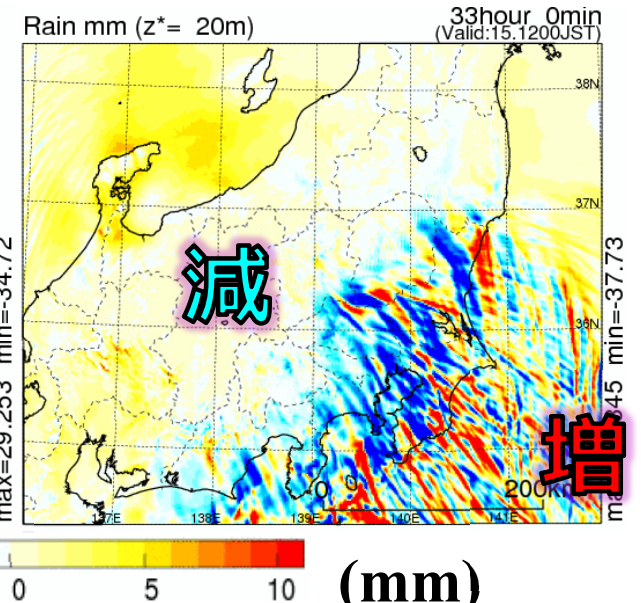
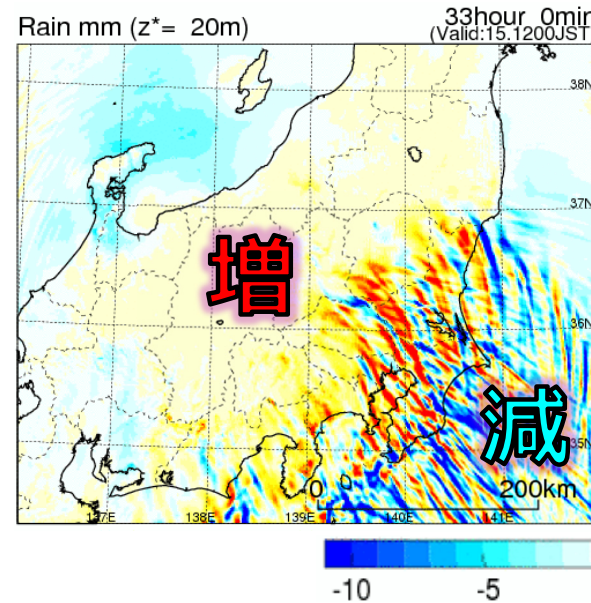
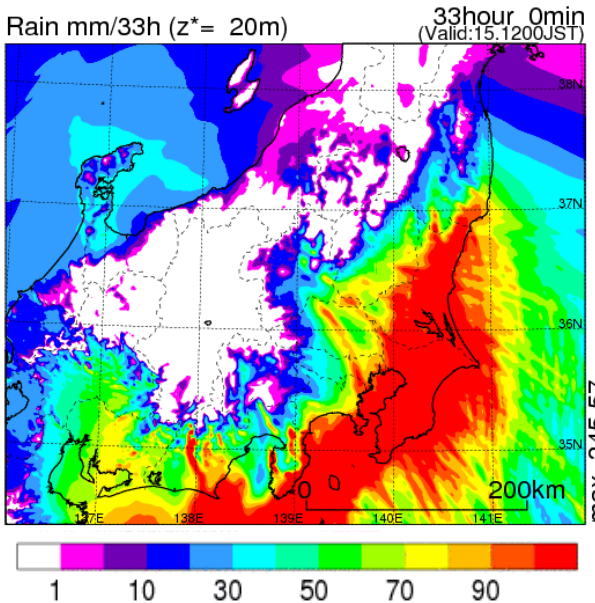
IN01-INdef

IN10-INdef

Snow



Rain

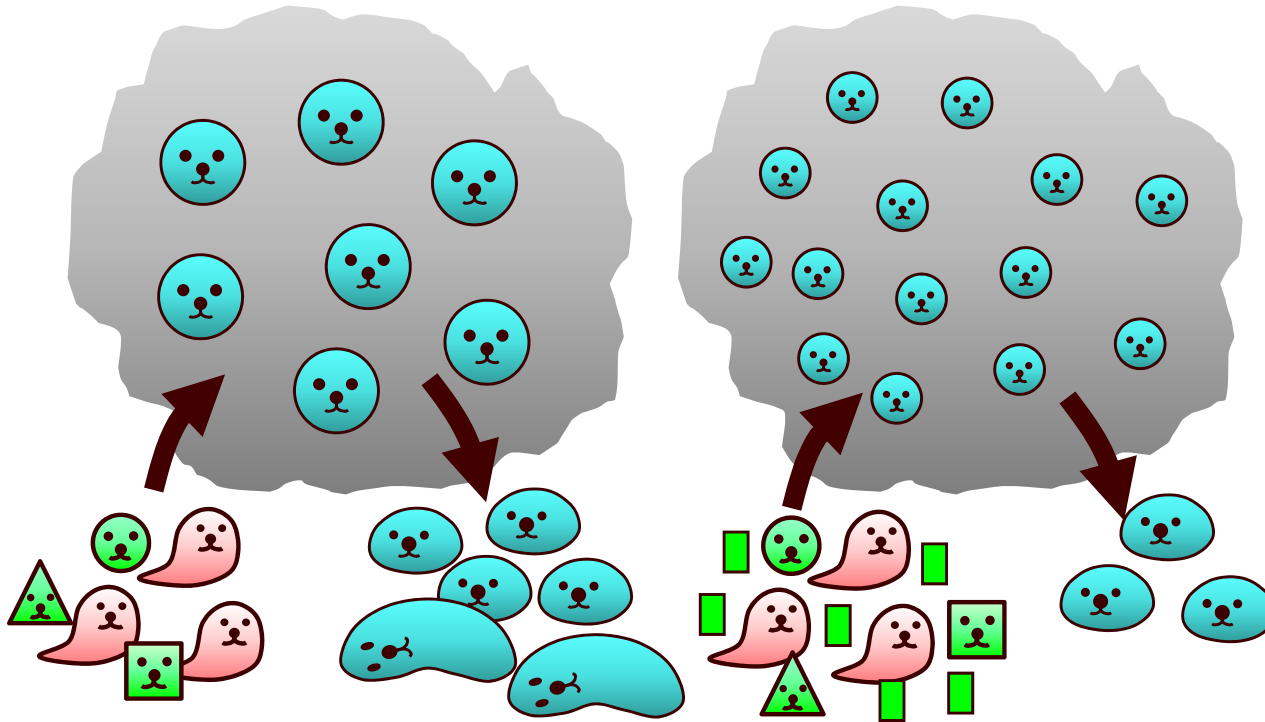


(mm)



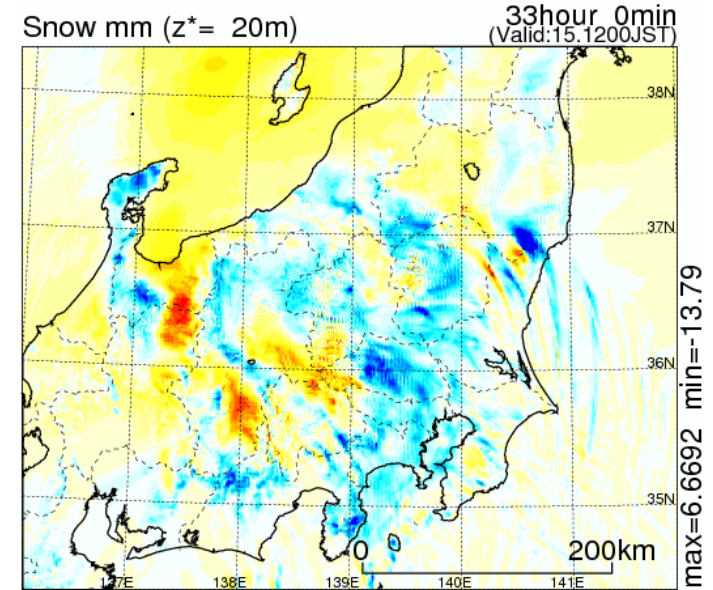
# 凝結核数と降水への影響

## 浅い水雲の場合

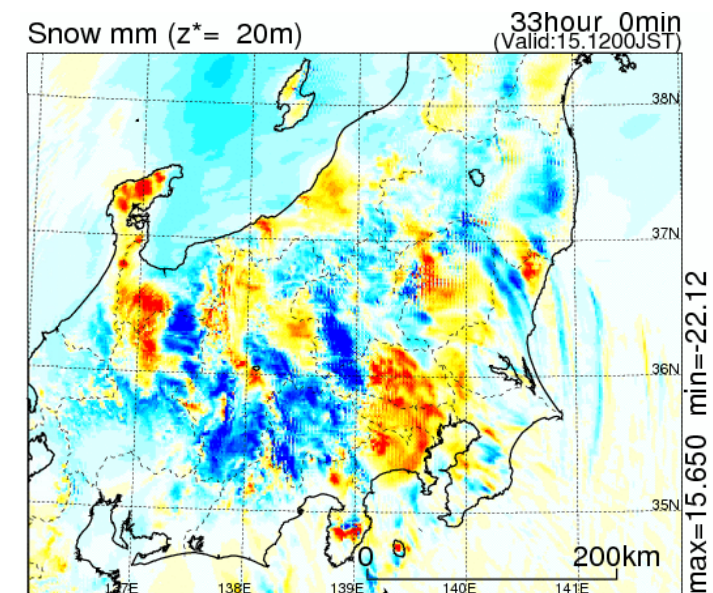


雲凝結核の**数が多い**と、互いに  
水蒸気を奪い合う  
→成長できなくて**降水量は減る**  
(Levin and Cotton 2007など)

## IN01 - INdef



## IN10 - INdef





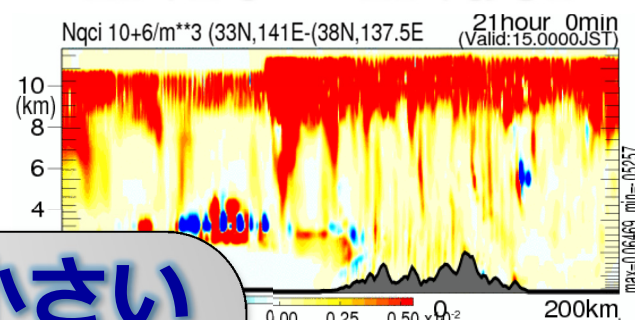
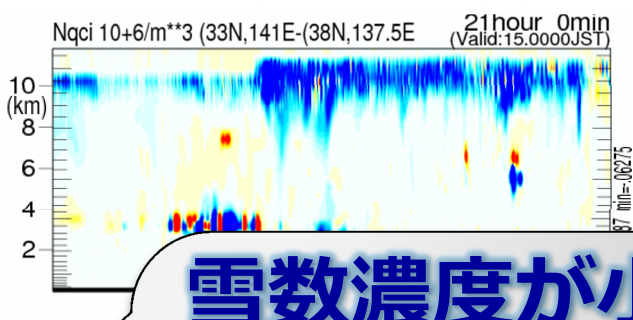
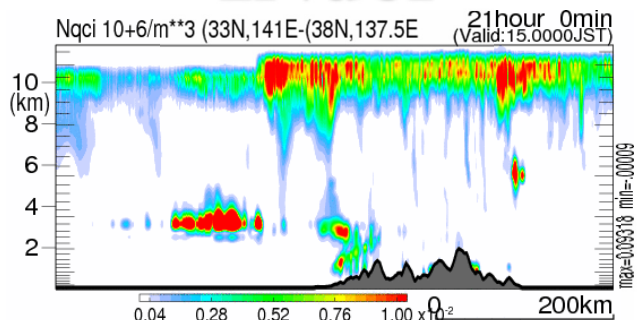
# 氷晶核による雲・降水への影響

## INdef

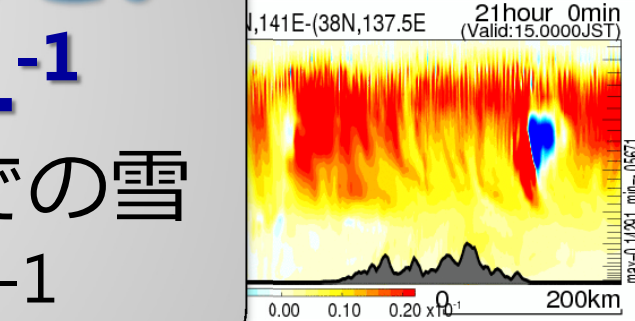
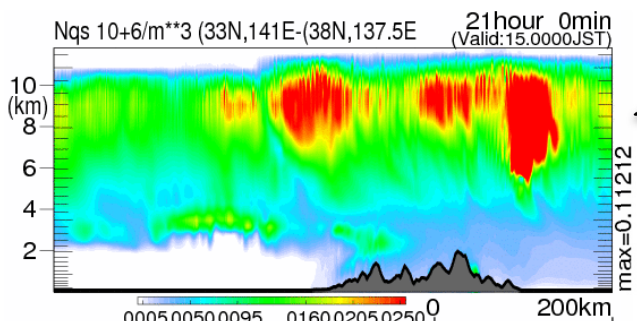
## IN01 - INdef

## IN10 - INdef

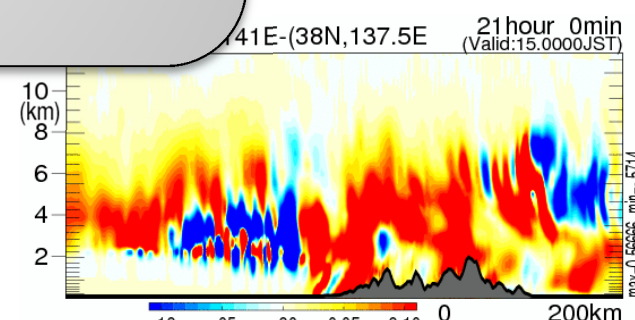
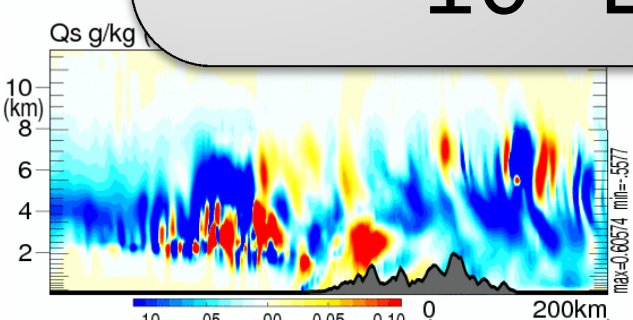
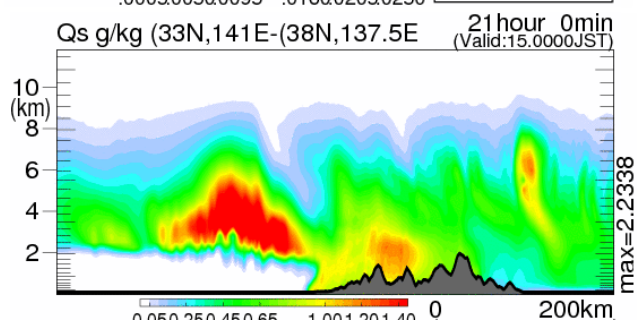
Number Density  
of Cloud Ice



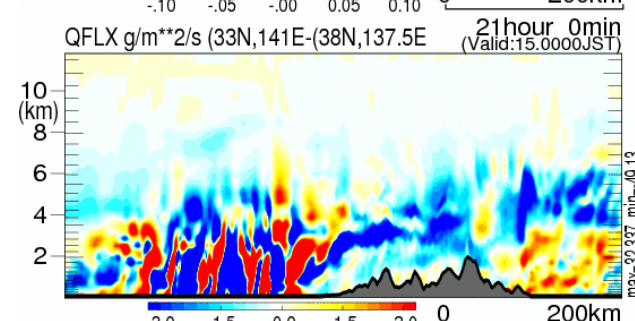
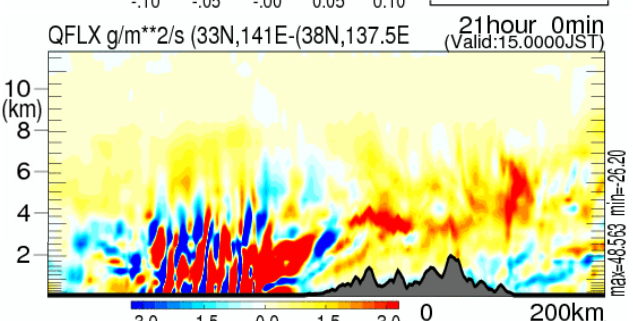
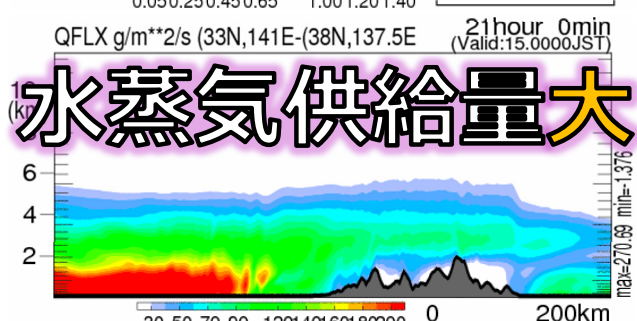
Number Density  
of Snow



Mixing Ratio  
of Snow



Water Vapor  
Flux



雪数濃度が小さい

~10<sup>-1</sup> L<sup>-1</sup>

日本海側等での雪

~10<sup>2</sup> L<sup>-1</sup>

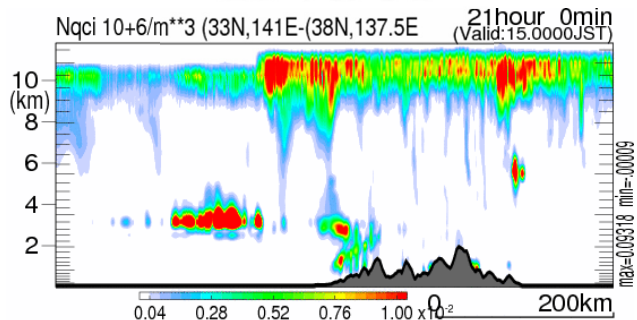
水蒸気供給量大



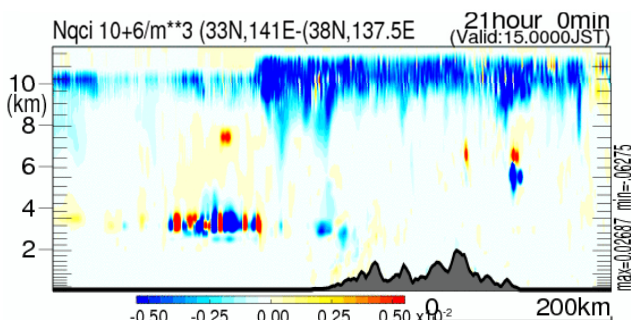
# 氷晶核による雲・降水への影響

Number Density  
of Cloud Ice

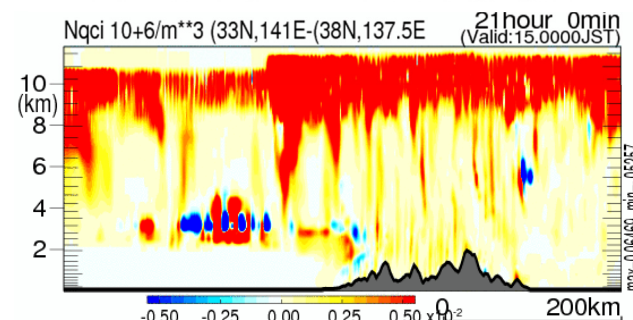
## INdef



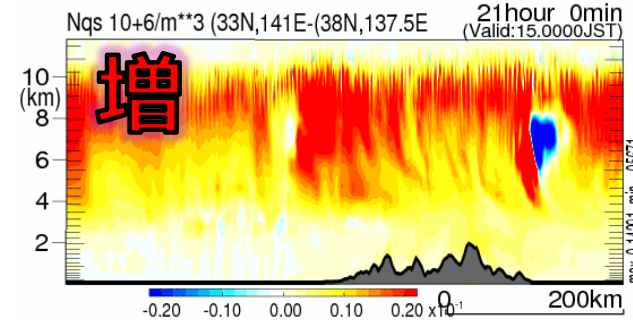
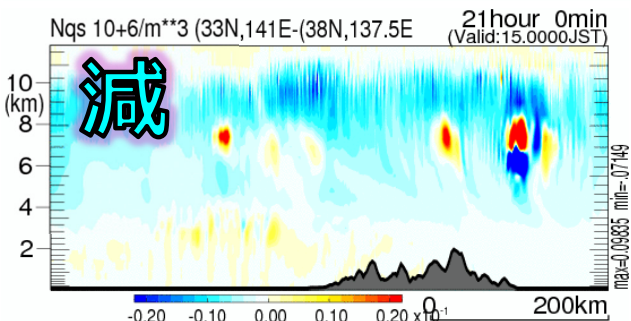
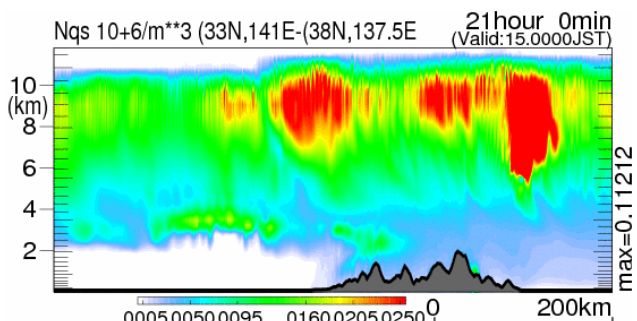
## IN01 - INdef



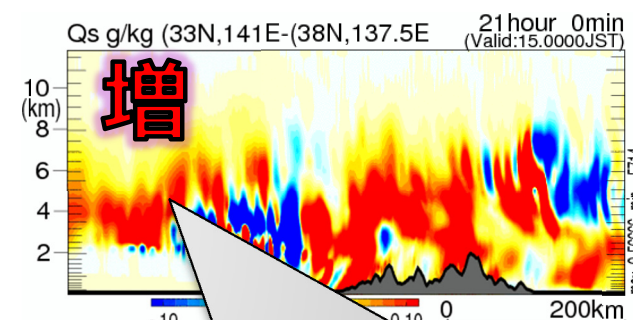
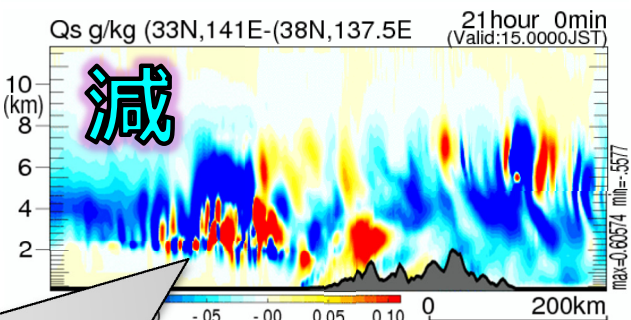
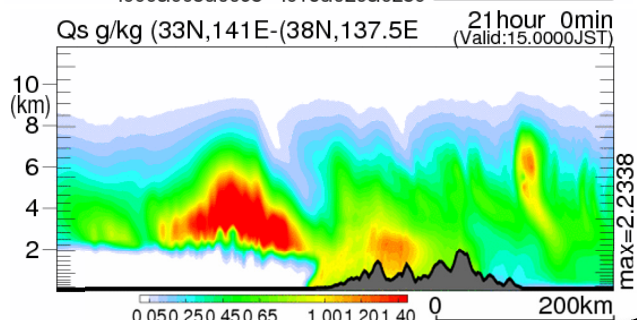
## IN10 - INdef



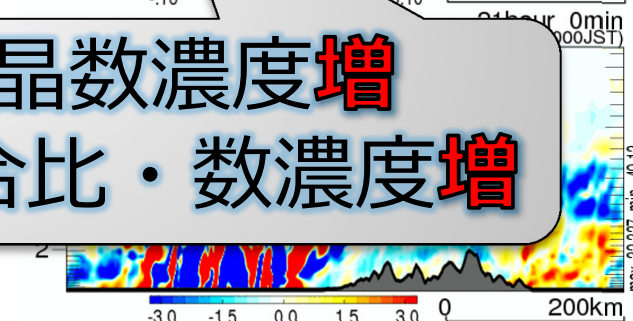
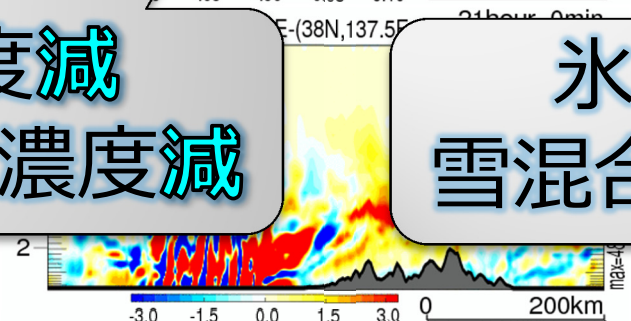
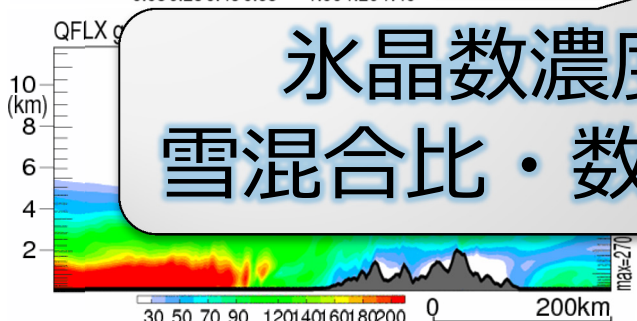
Number Density  
of Snow



Mixing Ratio  
of Snow



Water Vapor  
Flux



氷晶数濃度減  
雪混合比・数濃度減

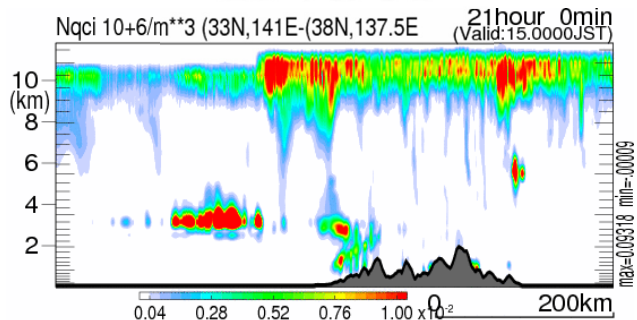
氷晶数濃度増  
雪混合比・数濃度増



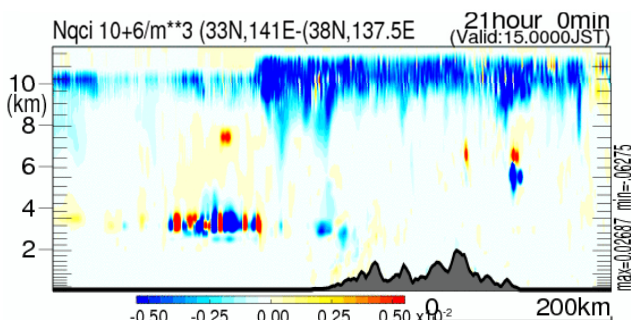
# 氷晶核による雲・降水への影響

Number Density  
of Cloud Ice

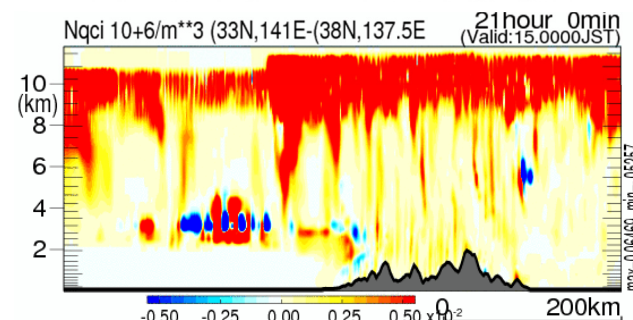
## INdef



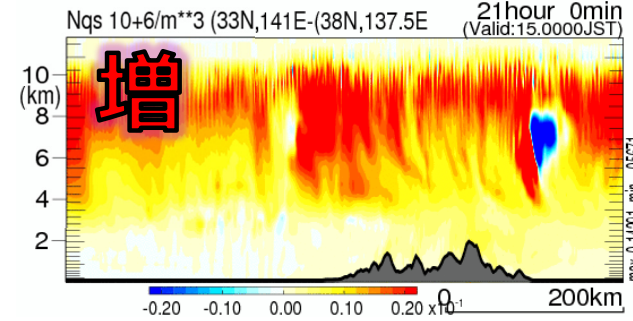
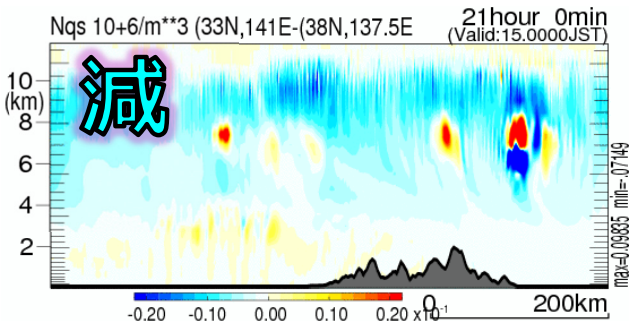
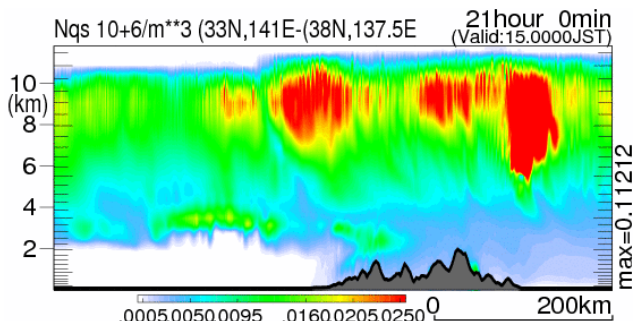
## IN01 - INdef



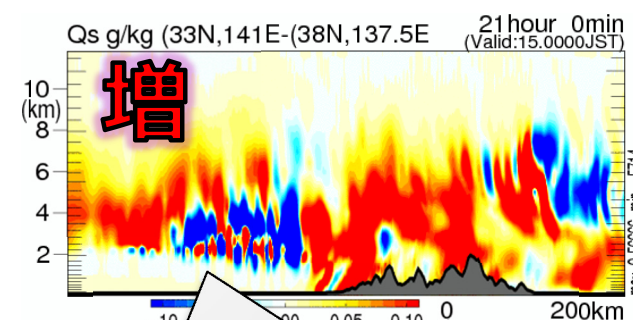
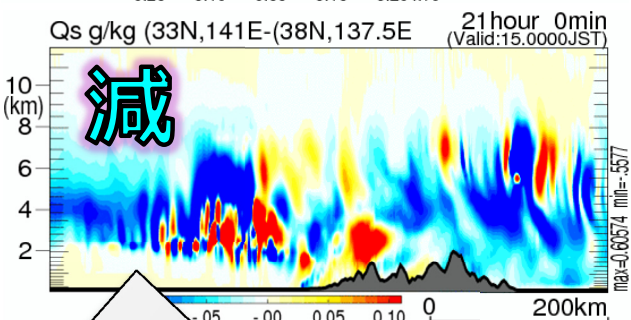
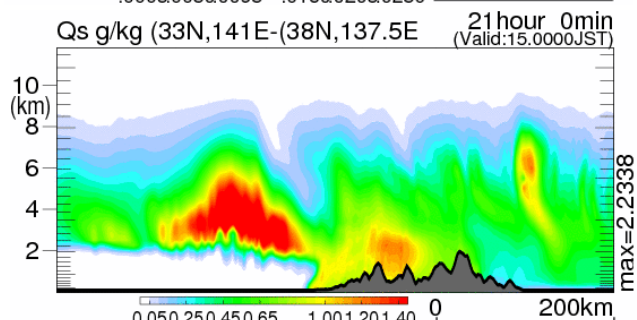
## IN10 - INdef



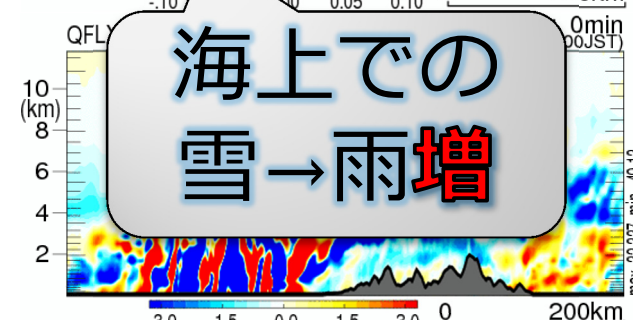
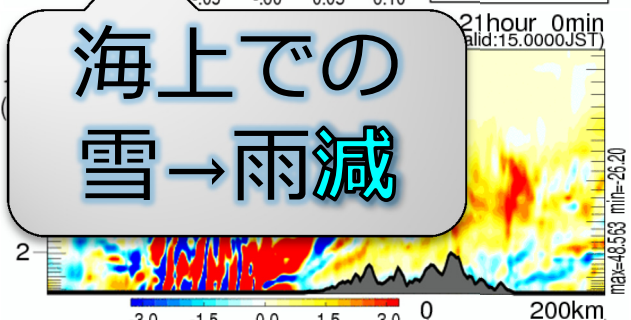
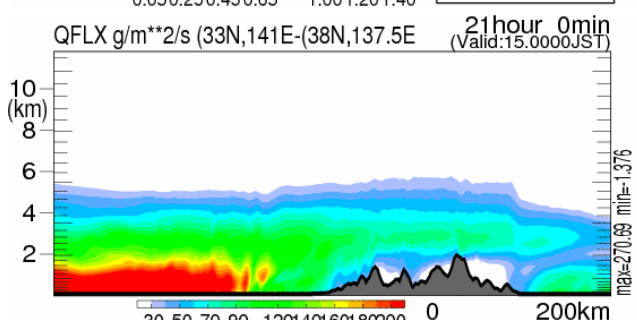
Number Density  
of Snow



Mixing Ratio  
of Snow



Water Vapor  
Flux

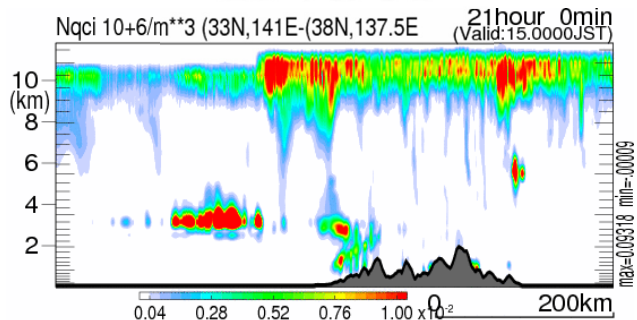




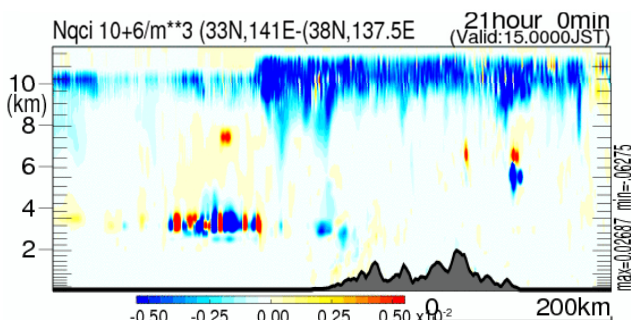
# 氷晶核による雲・降水への影響

Number Density  
of Cloud Ice

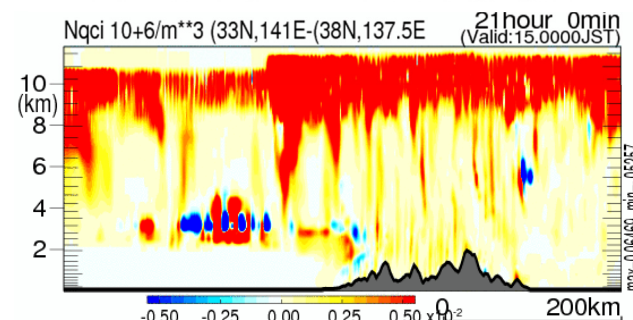
## INdef



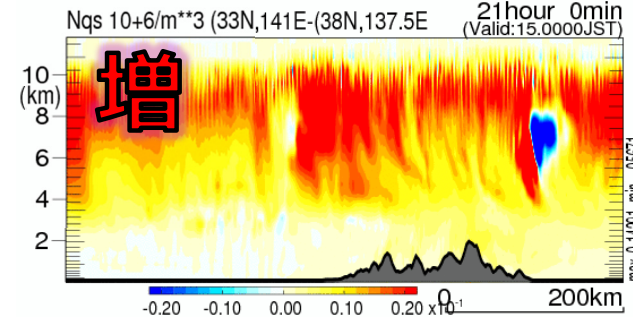
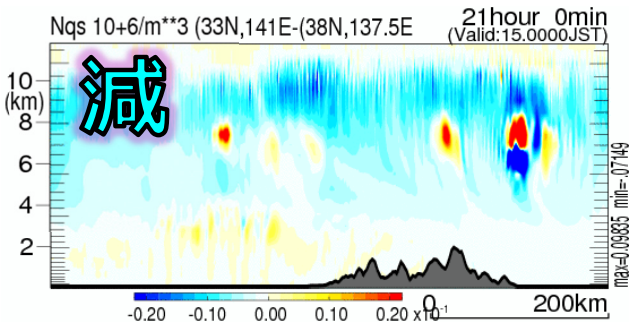
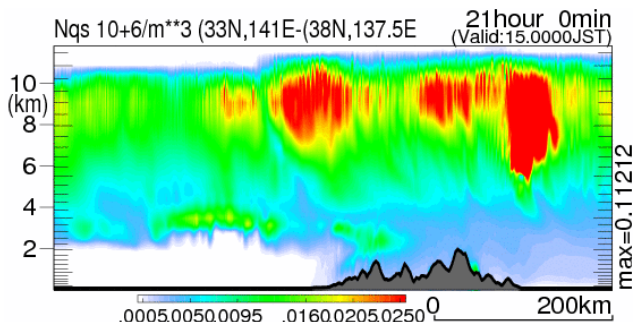
## IN01 - INdef



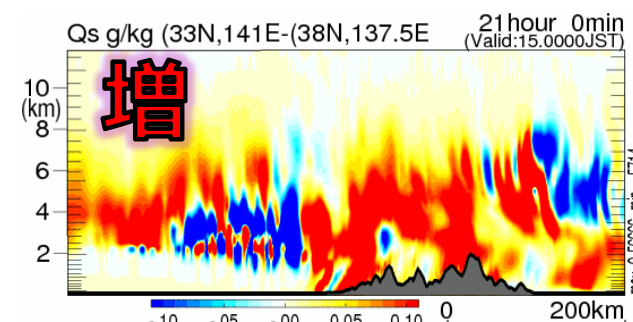
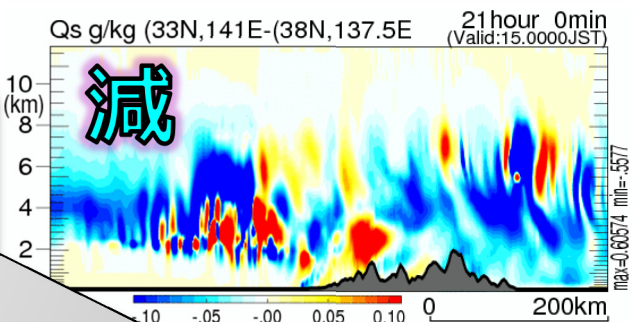
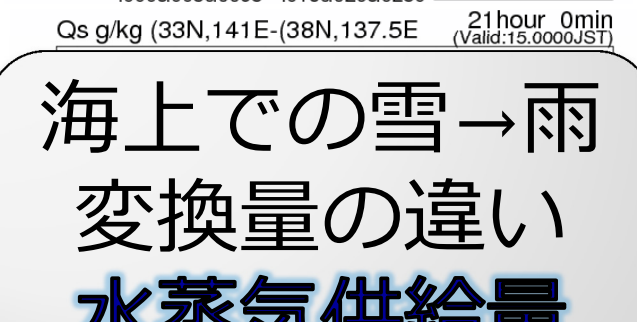
## IN10 - INdef



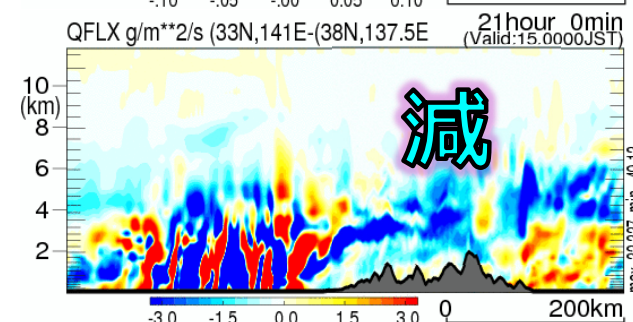
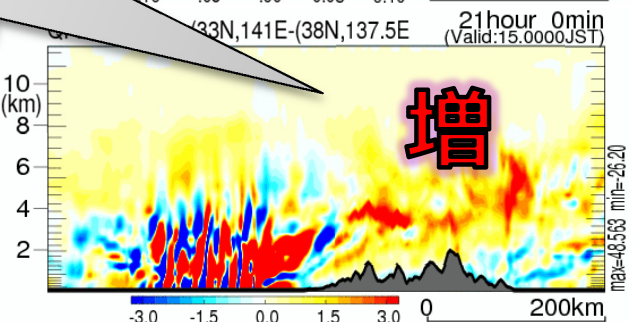
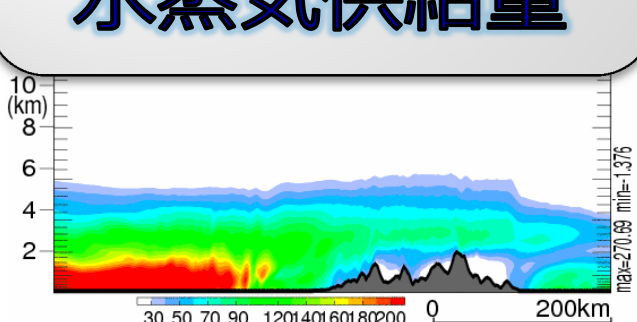
Number Density  
of Snow



Mixing Ratio  
of Snow



Water Vapor  
Flux



海上での雪→雨  
変換量の違い  
水蒸気供給量

減

増

減

増

増

減



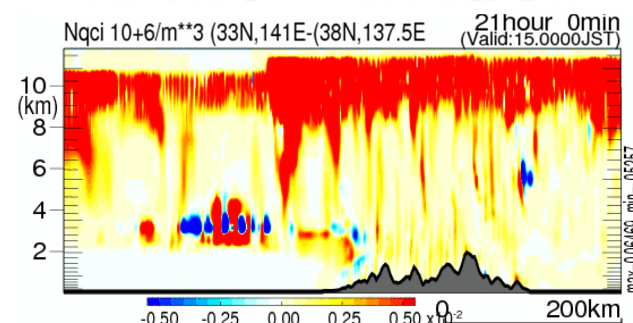
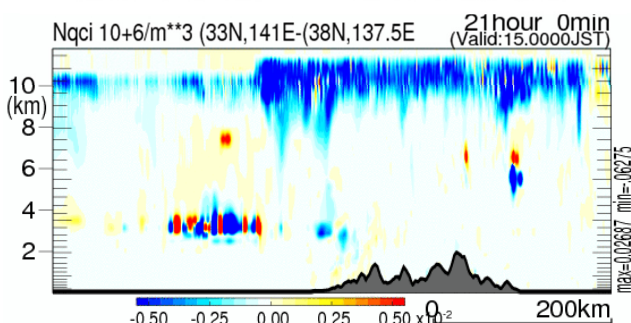
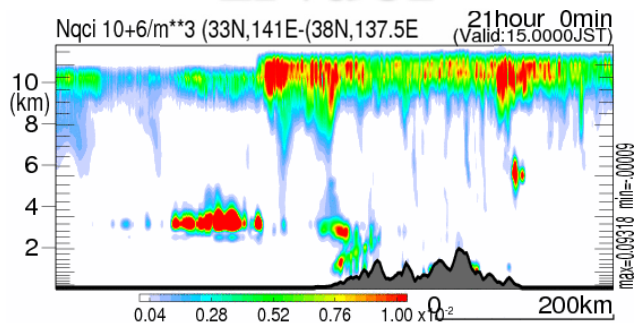
# 氷晶核による雲・降水への影響

## INdef

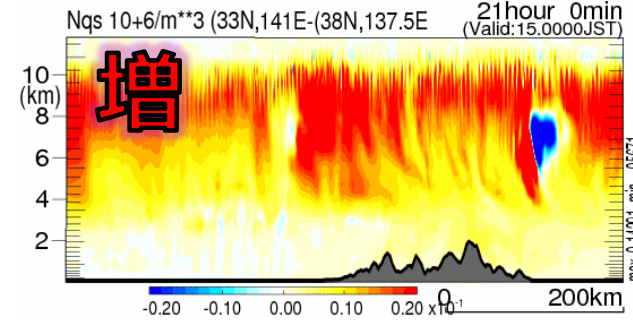
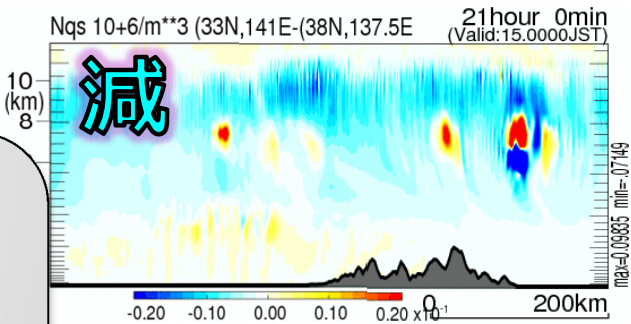
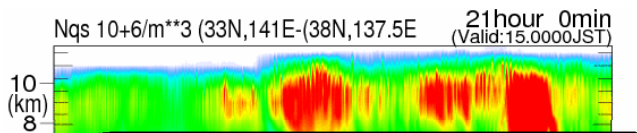
## IN01 - INdef

## IN10 - INdef

Number Density  
of Cloud Ice

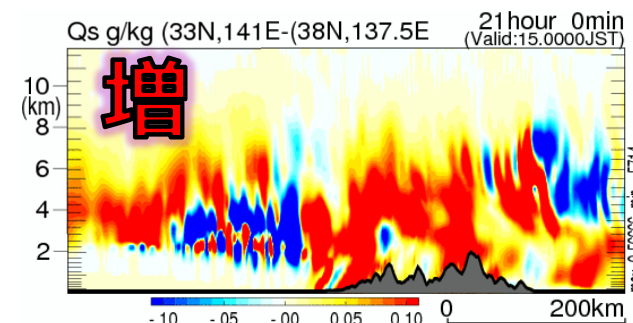
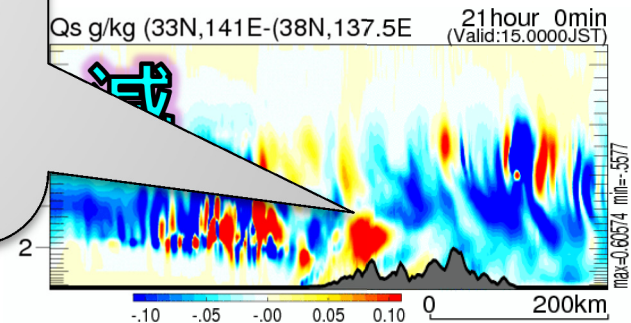
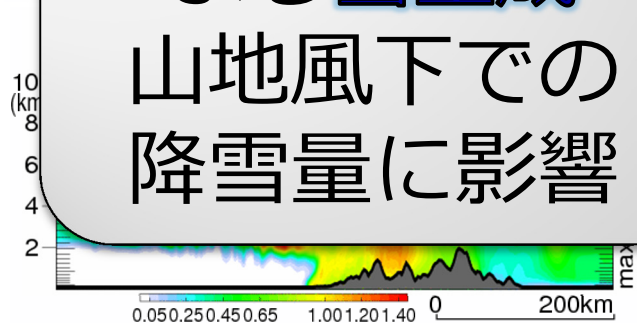


Number Density  
of Snow

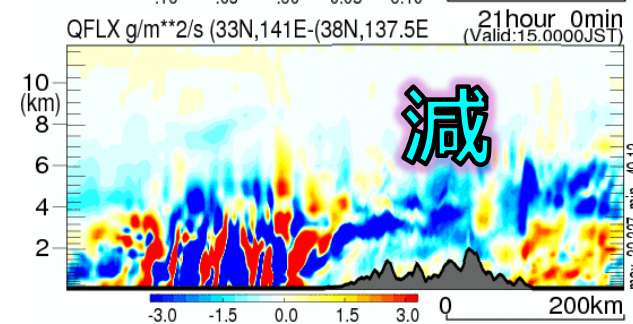
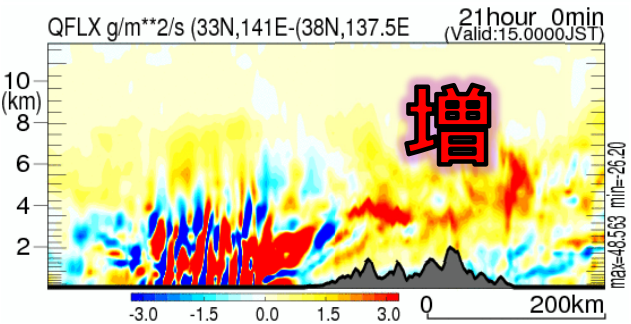
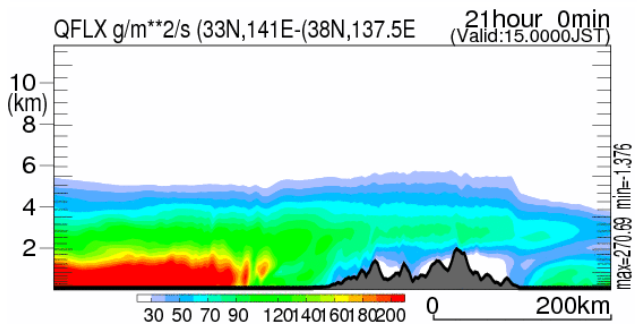


地形性上昇流による雪生成  
山地風下での降雪量に影響

Mixing Ratio  
of Snow



Water Vapor  
Flux





# 大雪をもたらした 降雪雲の雲物理過程

- **Seeder-Feeder Effect**

上層と**沿岸前線面**で発生した氷晶雲

- **氷晶核の影響**

通常の水雲とは異なる第二種間接効果

**水蒸気供給量が大・雪数濃度が小**

山地による降雪量への影響

- **間接効果のモデリングの重要性**