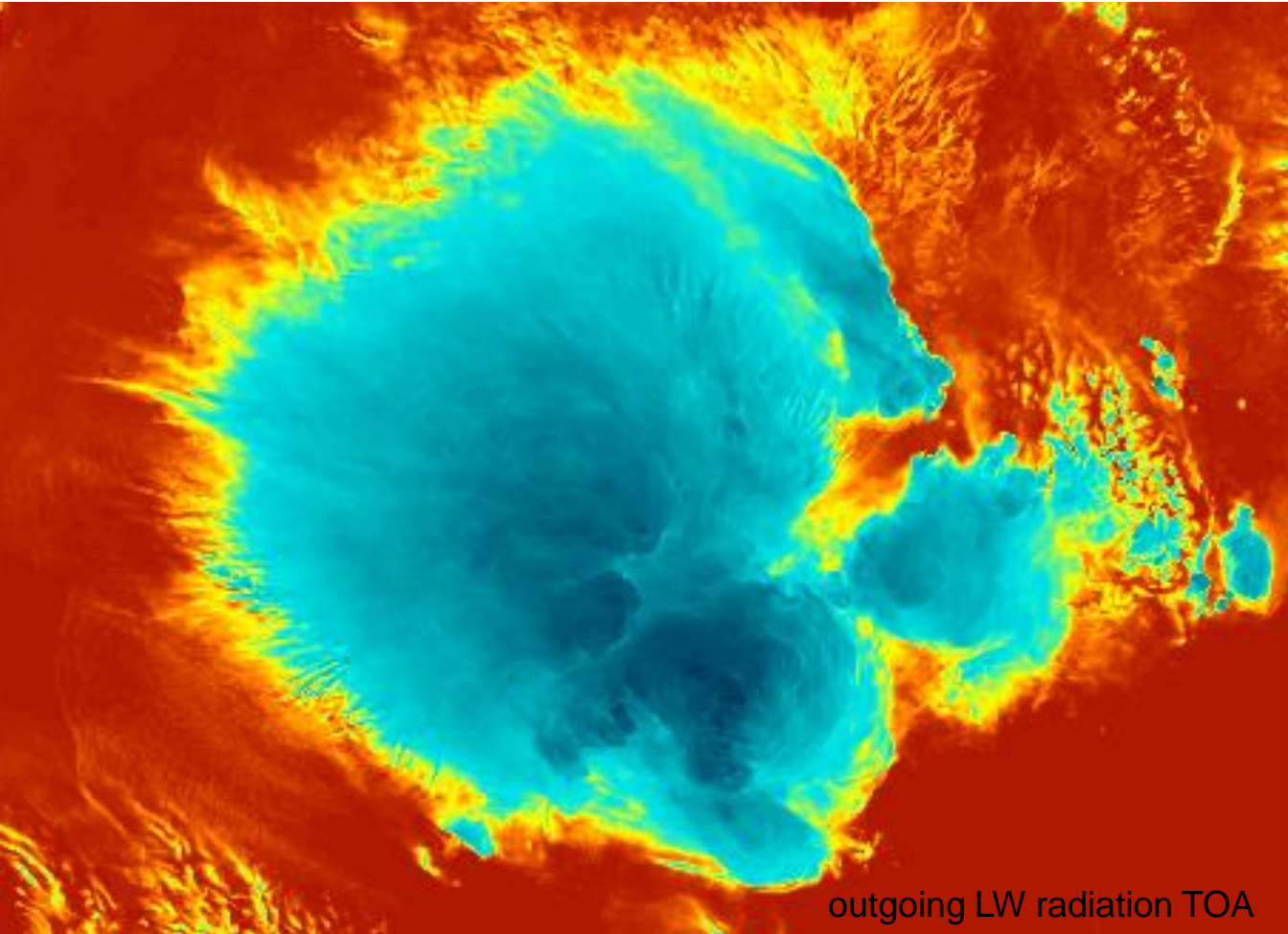


Tropical Anvil with ICON-LES



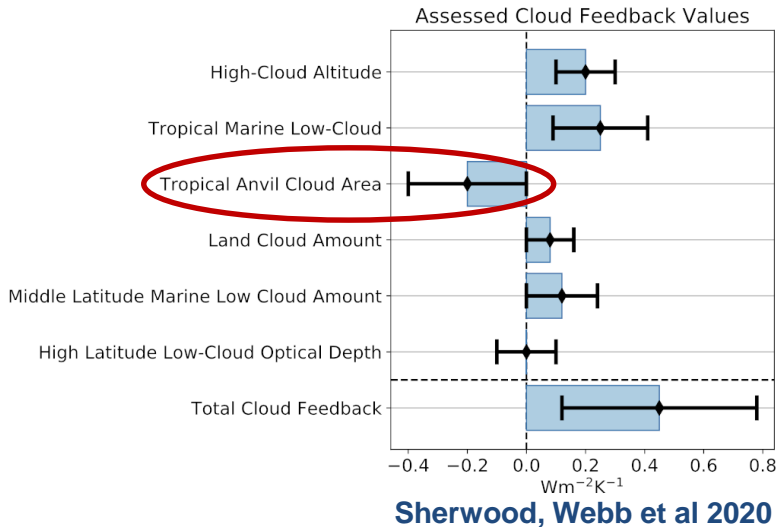
Martin Köhler, DWD and Leo Donner, GFDL



75-600m (ICON-LES)
Darwin, North of Australia
TWP-ICE

outgoing LW radiation TOA

Anvil Cloud Area Feedback



anvils and radiation (Kiehl 1994):

- balance of large SW cooling and LW warming effects

“precip iris” feedback (Lindzen et al 2001):

- precipitation efficiency increases in warmer climate
- smaller anvils
- negative feedback with LW cooling dominating
- no clear GCM evidence

“stability iris” feedback (Bony et al 2016):

- weaker radiatively driven divergence in the upper troposphere (UT) in warmer climate
- stronger stability in upper troposphere
- less detrained cloud mass

GCM evidence:

- **not trustable** because
 - microphysics in convective parameterisation highly simplified
 - anvil decay highly parameterized

CRM evidence:

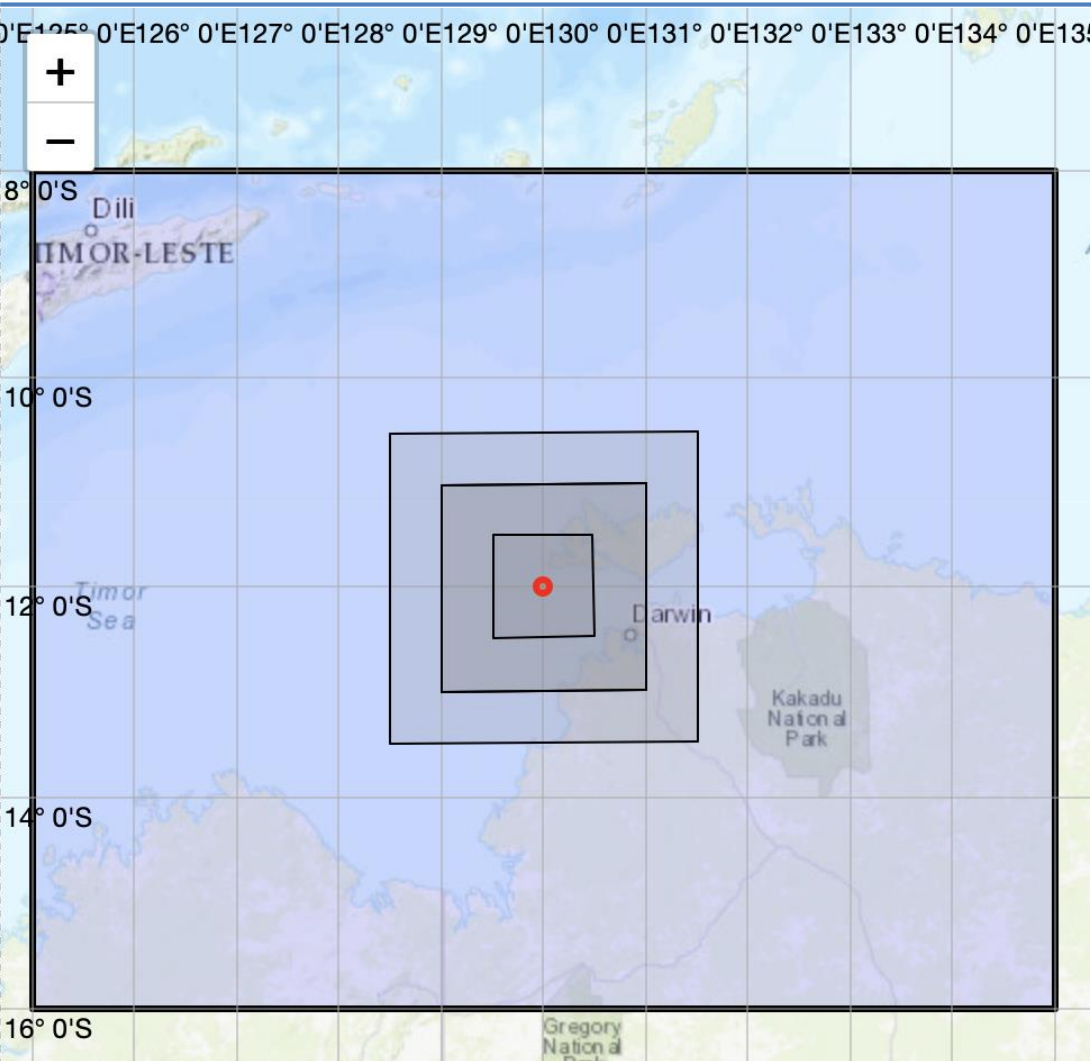
- **too low resolution for anvil turbulence**
- sensitive to cloud microphysics and turbulence
- CRM studies: Bretherton et al., 2014; Bretherton, 2015; Tsushima et al., 2014; Bony et al., 2016; Chen et al., 2016; Cronin & Wing, 2017; Narenpitak et al., 2017.

Understand and quantify anvil feedback

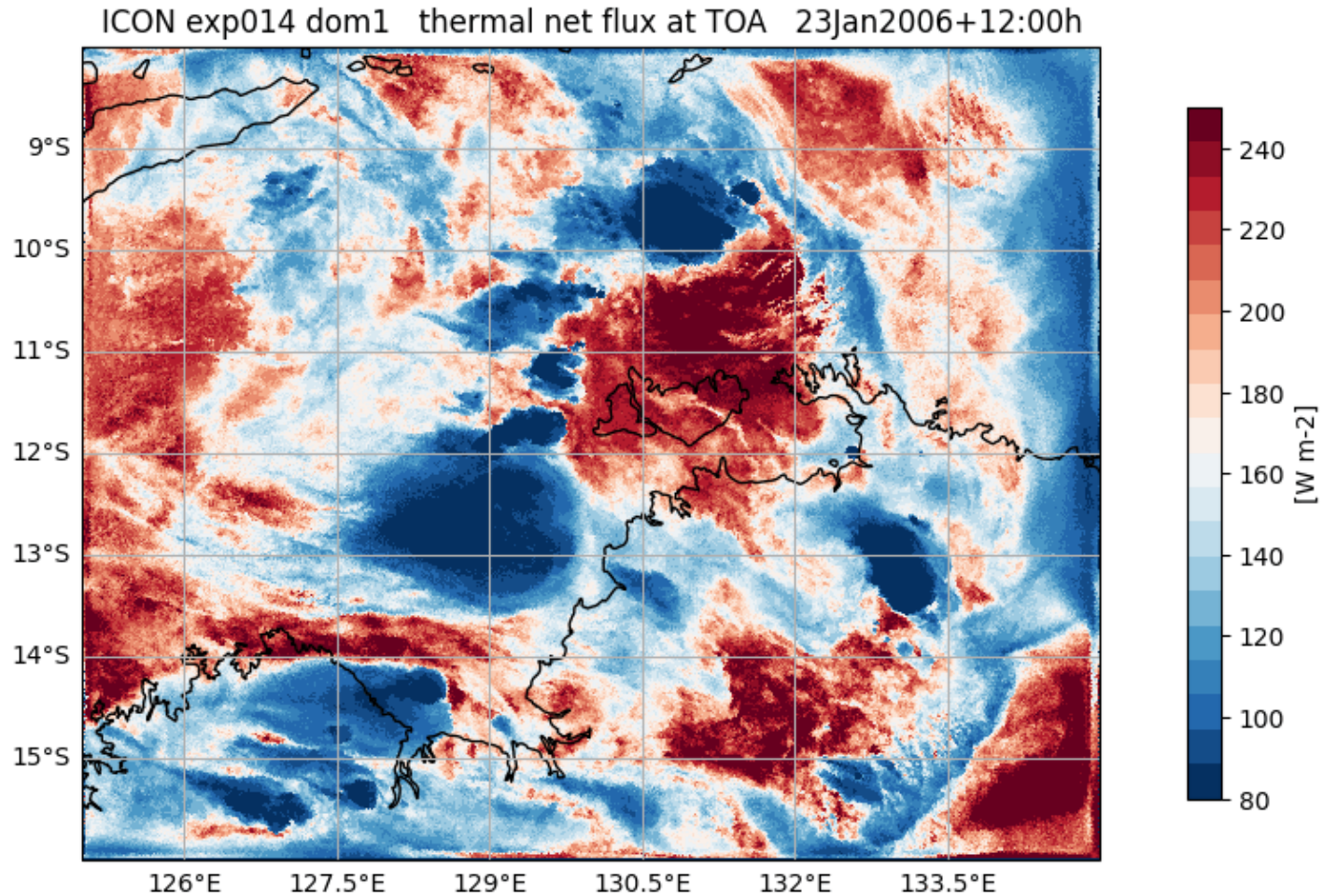
- quantify anvil physical processes:
 - **convective source**
 - **radiative destabilisation**
 - **turbulence**
 - **ice sedimentation**
- climate change forcing:
 - SST/ T_g + 2/4/6K
 - RH constant
 - tropopause height increase (same $T_{\text{cloud top}}$)
- reference run for ML cloud cover parameterisation development

Tropical Warm Pool – International Cloud Experiment (TWP-ICE)

ICON-LAM simulation 600m-75m



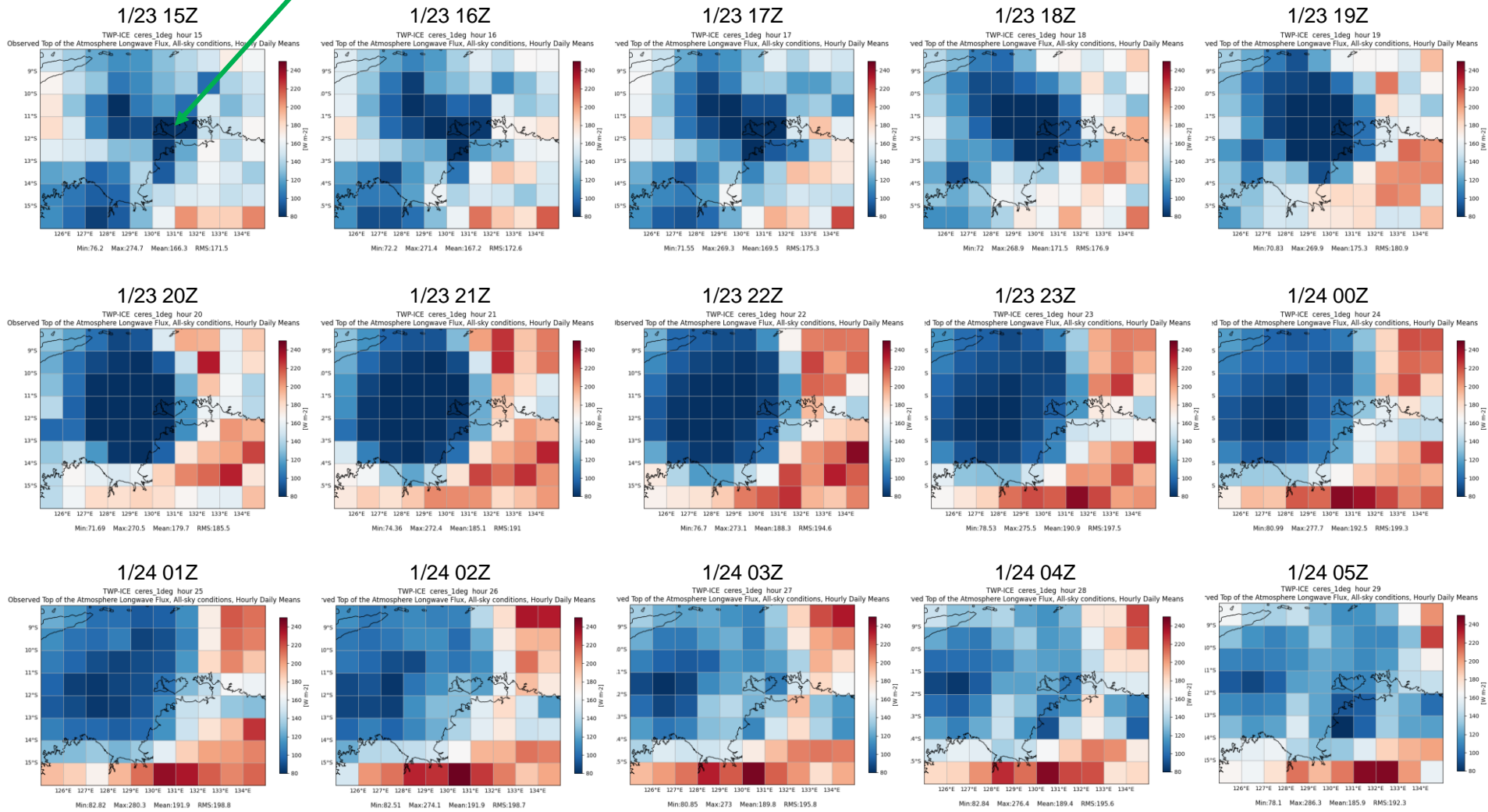
- dx: 625m / 312m / 156m / 78m
one-way nesting
- dz: 150m for 8-14km
- dt: 8s/4s/2s/1s
- double-moment microphysics:
Seifert and Beheng (2006)
- radiation:
ecRad, dt=360s
optical properties all ice species
- turbulence:
TKE (dx=600m)
Smagorinsky (dx=300/150/75m)



0-20S
120-140E
year 2006

Tropical Warm Pool – International Cloud Experiment (TWP-ICE)

CERES SYN1deg TOA - LW



0-20S
120-140E
year 2006

Tropical Warm Pool – International Cloud Experiment (TWP-ICE)

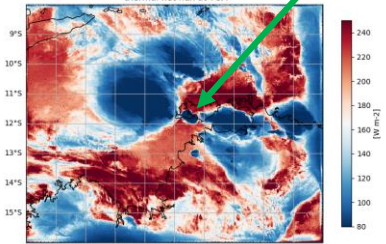
ICON 625m TOA - LW

exp010



1/23 15Z

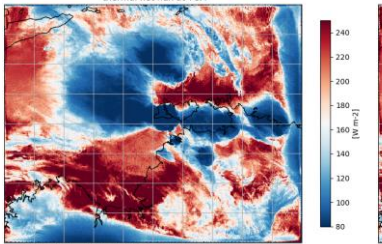
TWP-ICE exp010 step 15
thermal net flux at TOA



Min:-0 Max:274 Mean:164.1 RMS:173.3

1/23 16Z

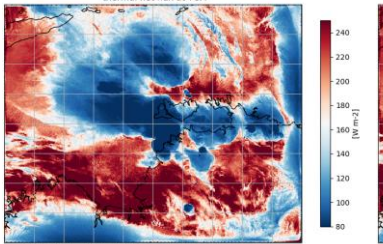
TWP-ICE exp010 step 16
thermal net flux at TOA



Min:-0 Max:273.8 Mean:165.2 RMS:174.9

1/23 17Z

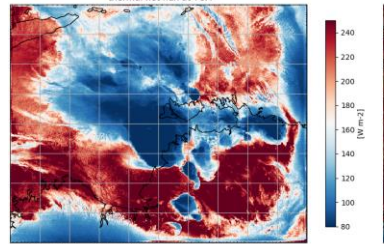
TWP-ICE exp010 step 17
thermal net flux at TOA



Min:-0 Max:273.6 Mean:166.7 RMS:176.8

1/23 18Z

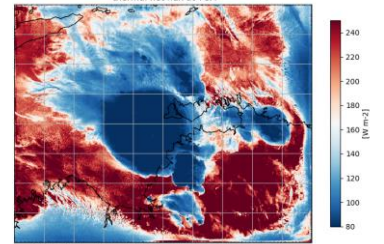
TWP-ICE exp010 step 18
thermal net flux at TOA



Min:-0 Max:276.3 Mean:167.4 RMS:178.5

1/23 19Z

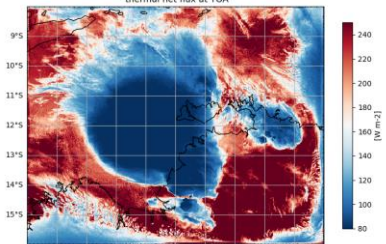
TWP-ICE exp010 step 19
thermal net flux at TOA



Min:-0 Max:277 Mean:167.3 RMS:179.2

1/23 20Z

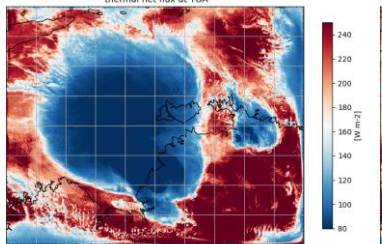
TWP-ICE exp010 step 20
thermal net flux at TOA



Min:-0 Max:276.6 Mean:166.7 RMS:179.4

1/23 21Z

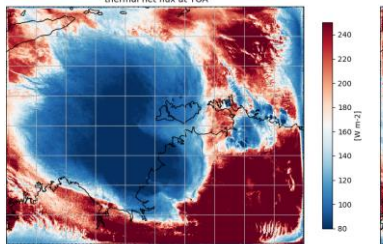
TWP-ICE exp010 step 21
thermal net flux at TOA



Min:-0 Max:276.1 Mean:165.2 RMS:178.5

1/23 22Z

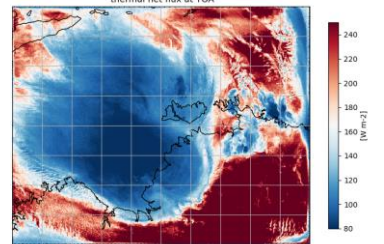
TWP-ICE exp010 step 22
thermal net flux at TOA



Min:-0 Max:277.2 Mean:161.7 RMS:175.1

1/23 23Z

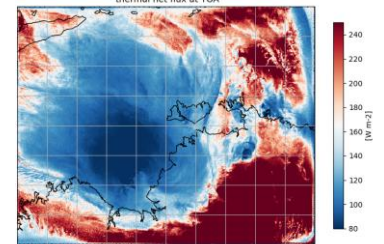
TWP-ICE exp010 step 23
thermal net flux at TOA



Min:-0 Max:277.9 Mean:158.8 RMS:171.4

1/24 00Z

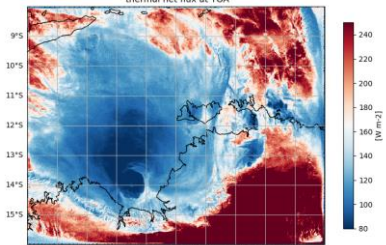
TWP-ICE exp010 step 24
thermal net flux at TOA



Min:-0 Max:278.5 Mean:158.9 RMS:170.5

1/24 01Z

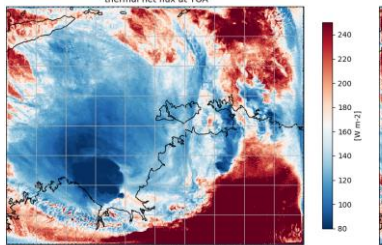
TWP-ICE exp010 step 25
thermal net flux at TOA



Min:-0 Max:281.6 Mean:159.7 RMS:170.1

1/24 02Z

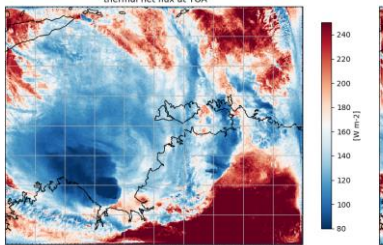
TWP-ICE exp010 step 26
thermal net flux at TOA



Min:-0 Max:284.2 Mean:160.5 RMS:170

1/24 03Z

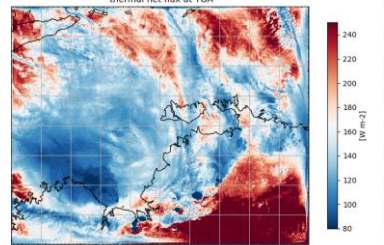
TWP-ICE exp010 step 27
thermal net flux at TOA



Min:-0 Max:285.7 Mean:160.2 RMS:168.7

1/24 04Z

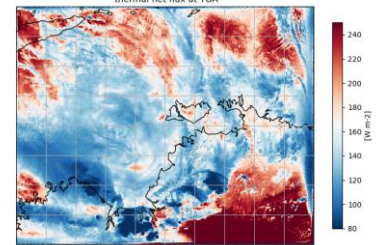
TWP-ICE exp010 step 28
thermal net flux at TOA



Min:-0 Max:284.5 Mean:158.8 RMS:166.2

1/24 05Z

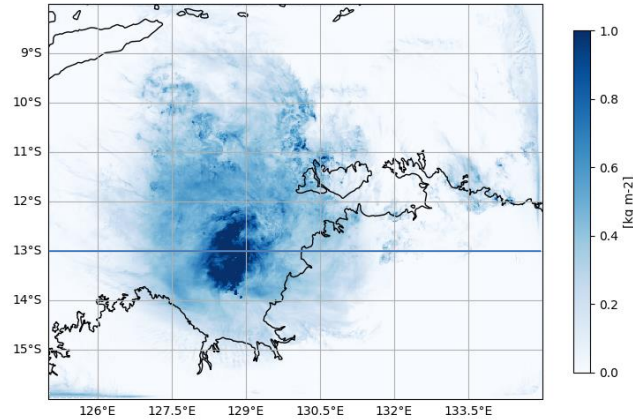
TWP-ICE exp010 step 29
thermal net flux at TOA



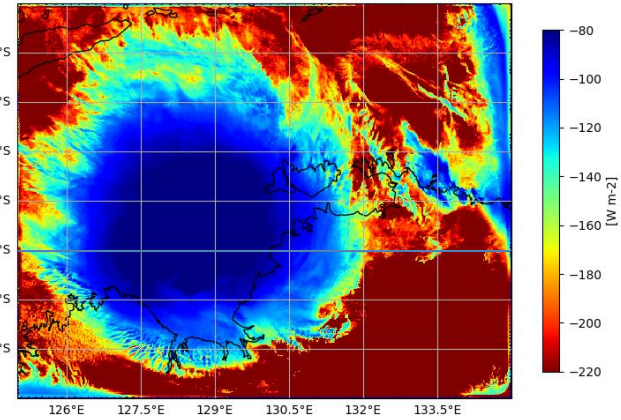
Min:-0 Max:287.5 Mean:157 RMS:164

TWP-ICE: 2006-01-23+24h (09LT)

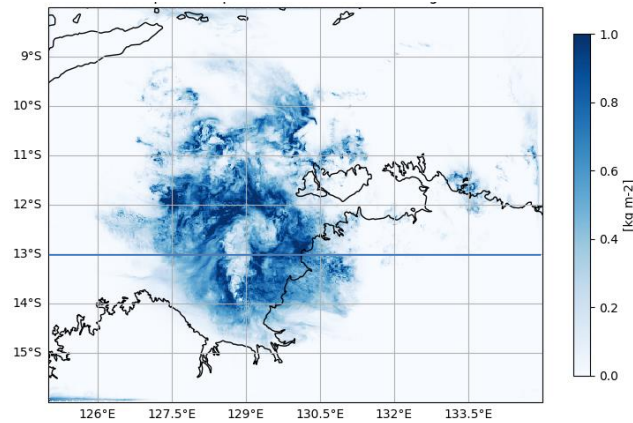
cloud ice



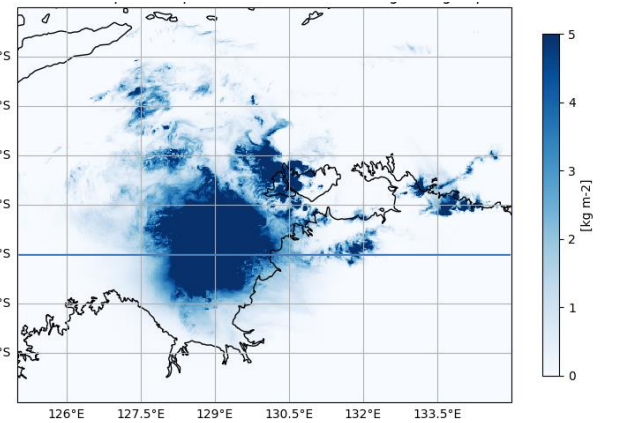
TOA LW



snow



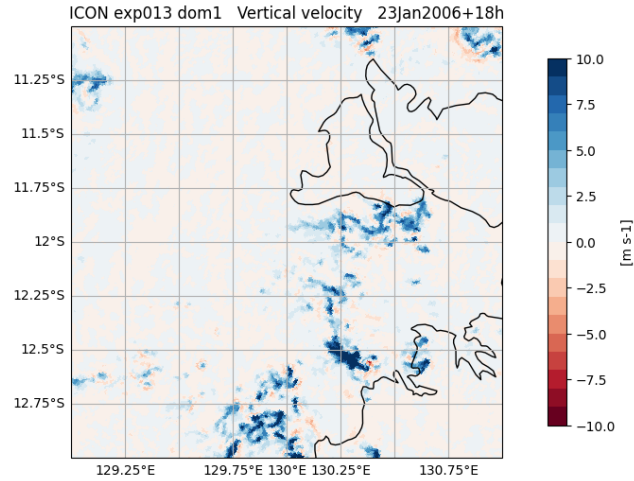
graupel



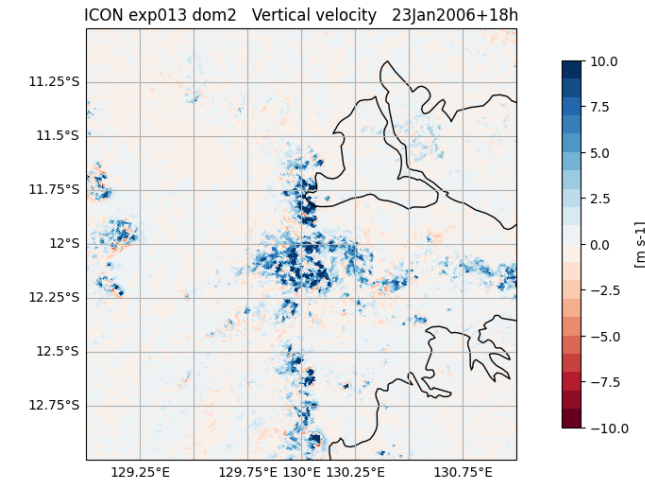
vertical
velocity
8027m

600m

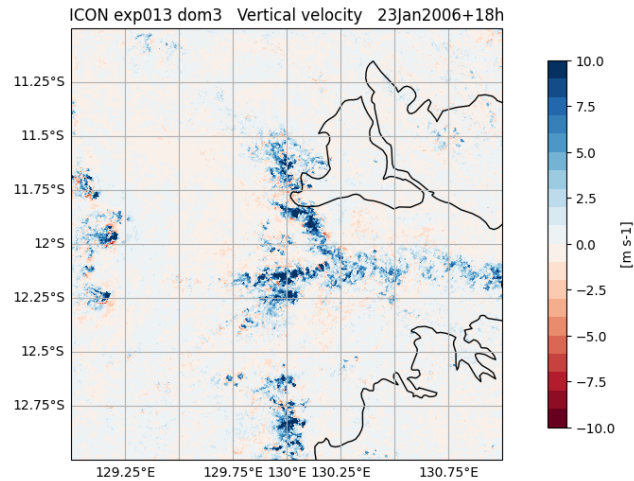
150m



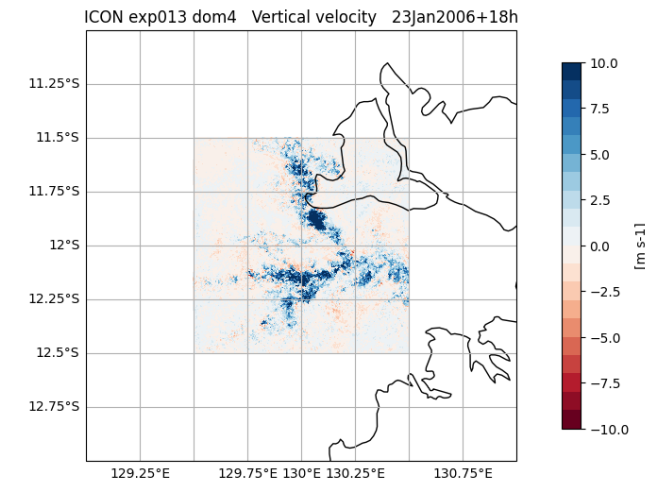
Min:-7.59 Max:22.84 Mean:0.03983 RMS:0.5399



Min:-13.22 Max:32.64 Mean:0.2367 RMS:1.383



Min:-8.993 Max:25.95 Mean:0.2958 RMS:1.487



Min:-8.424 Max:24.25 Mean:0.5661 RMS:2.24

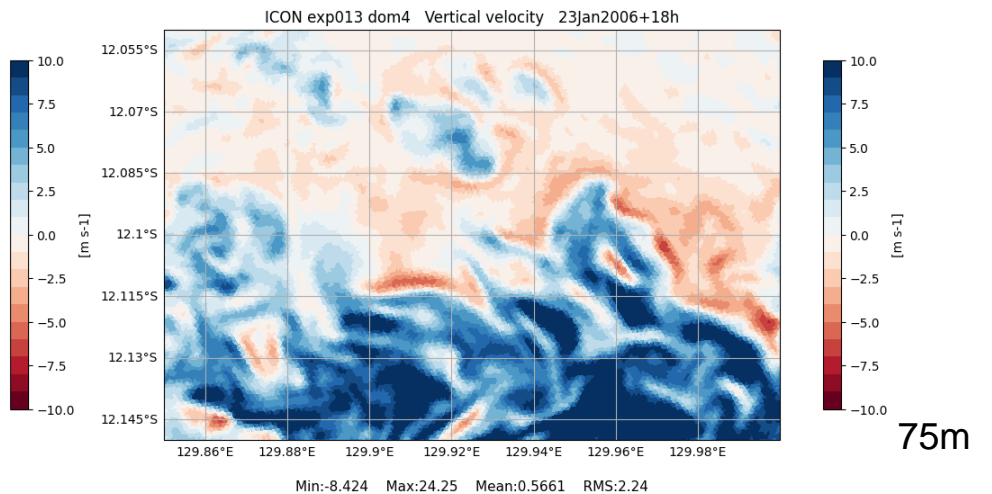
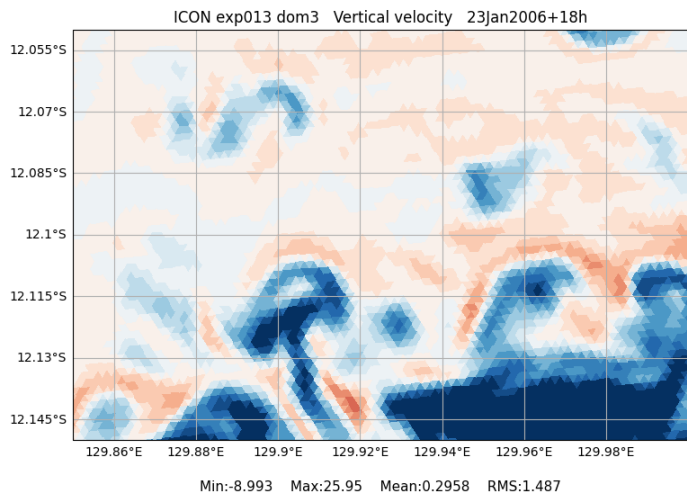
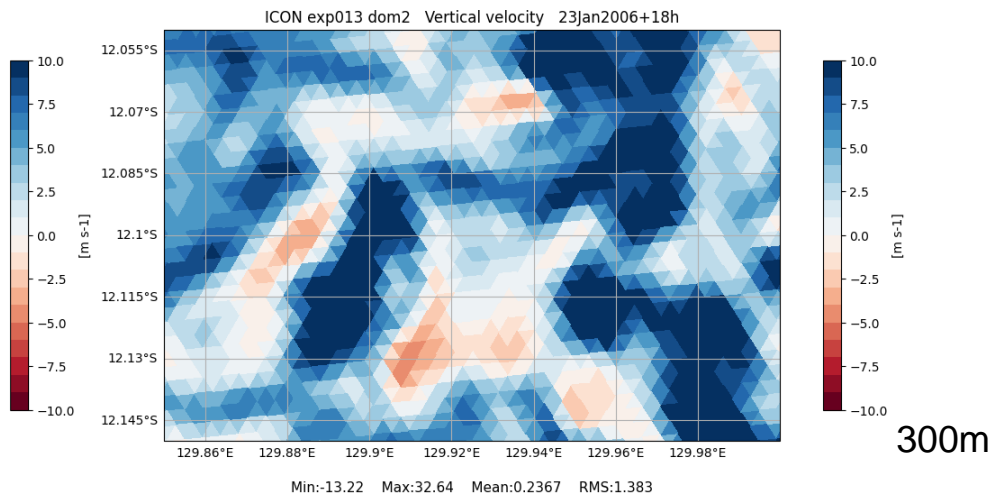
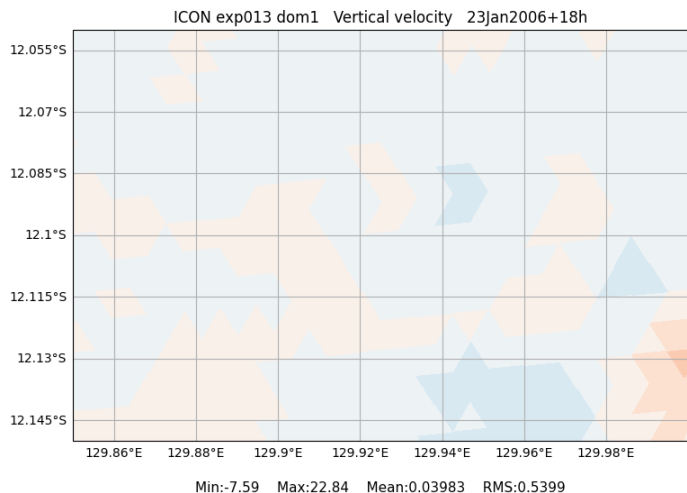
300m

75m

vertical
velocity
8027m

600m

150m



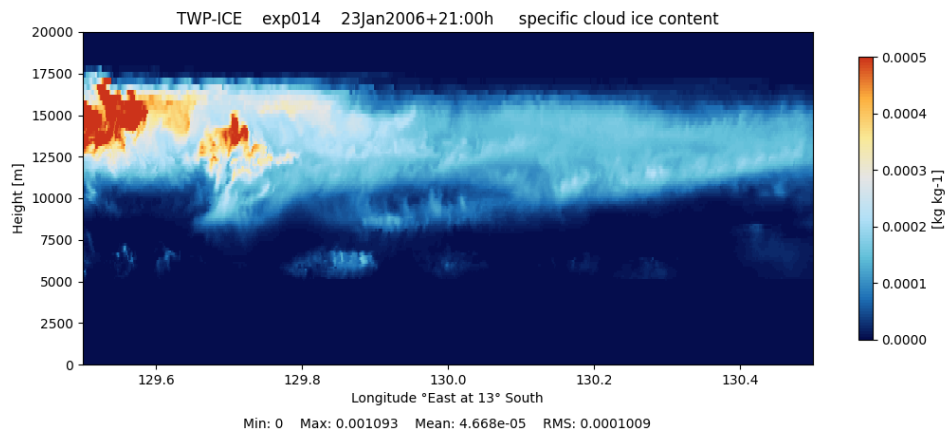
q_i, q_s, q_g

2006-01-23+21h (06LT)

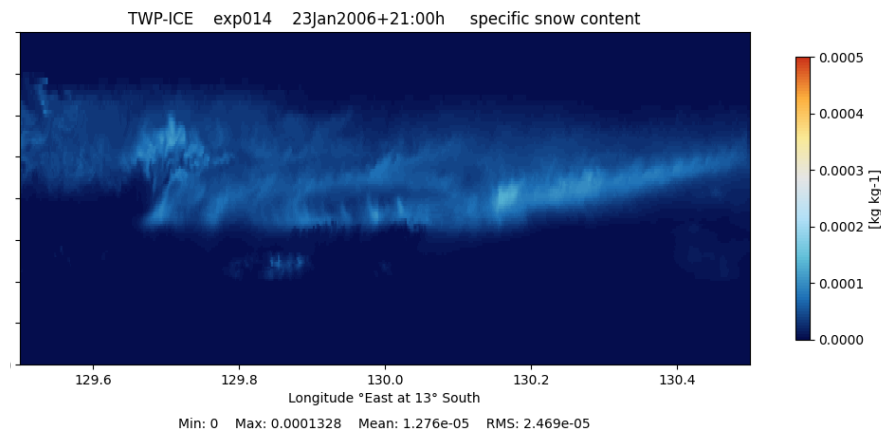


exp014

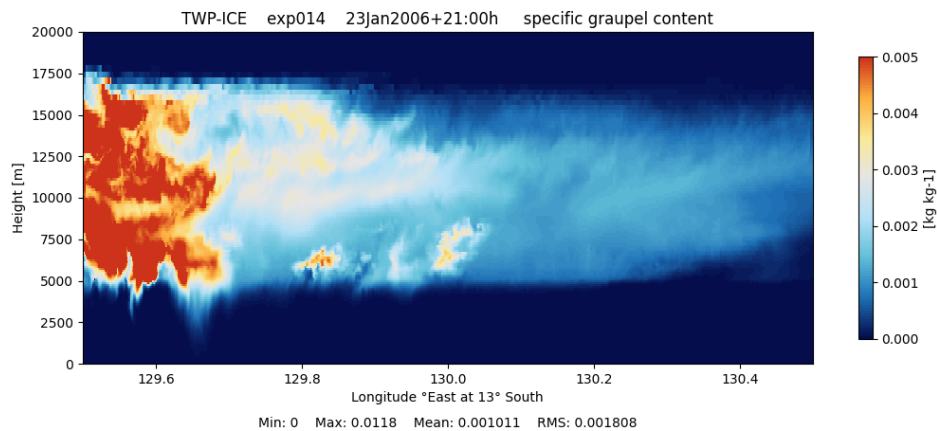
cloud ice



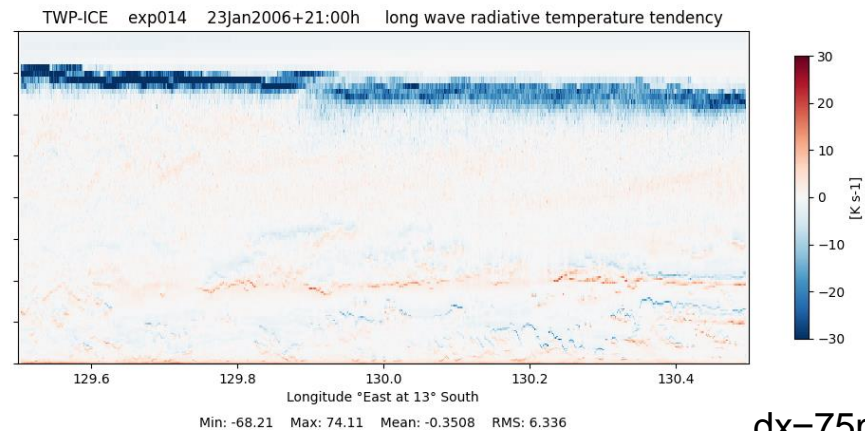
snow



graupel

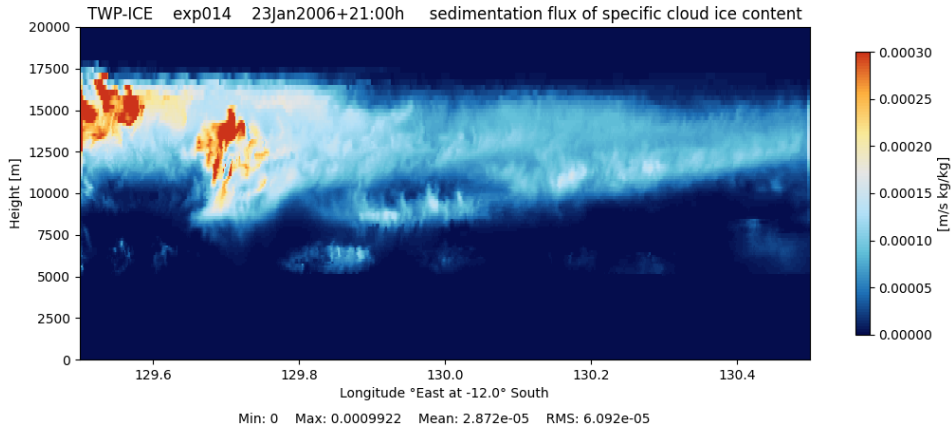


LW cooling

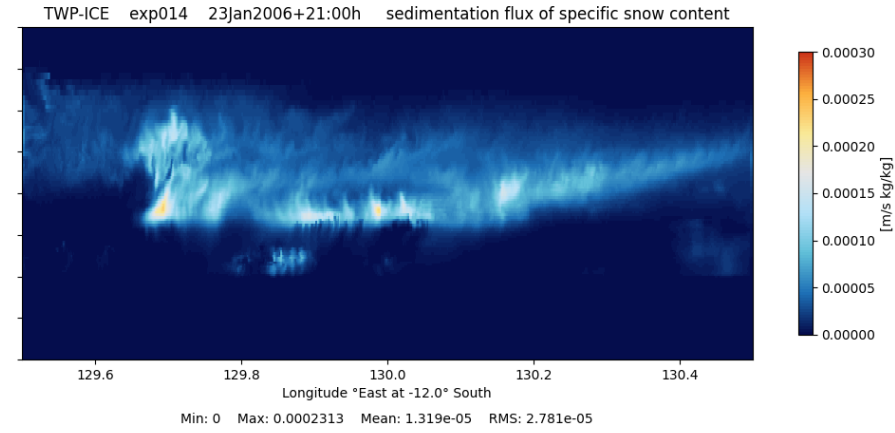


dx=75m

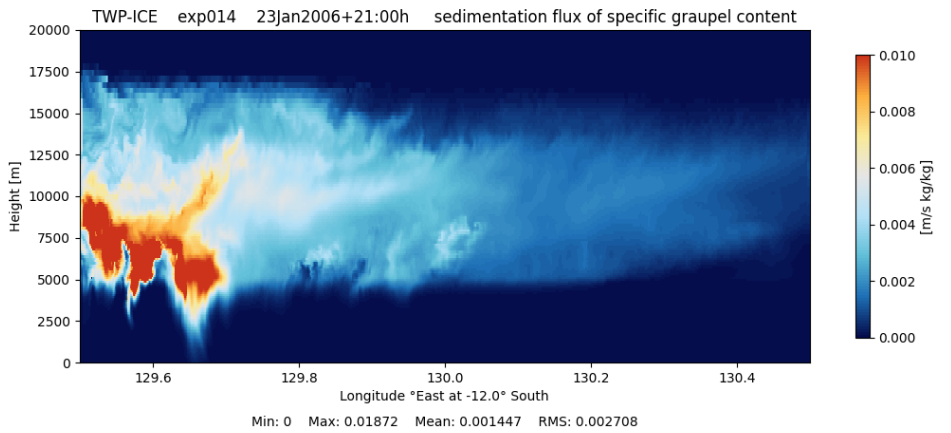
cloud ice



snow

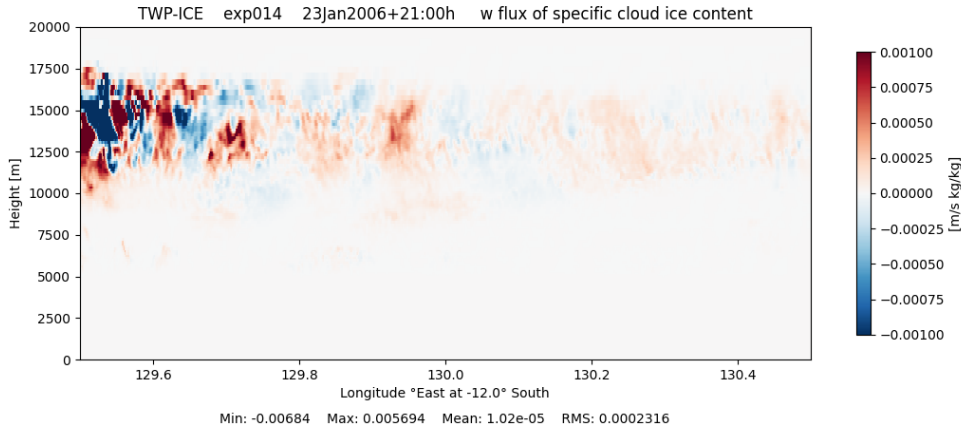


graupel

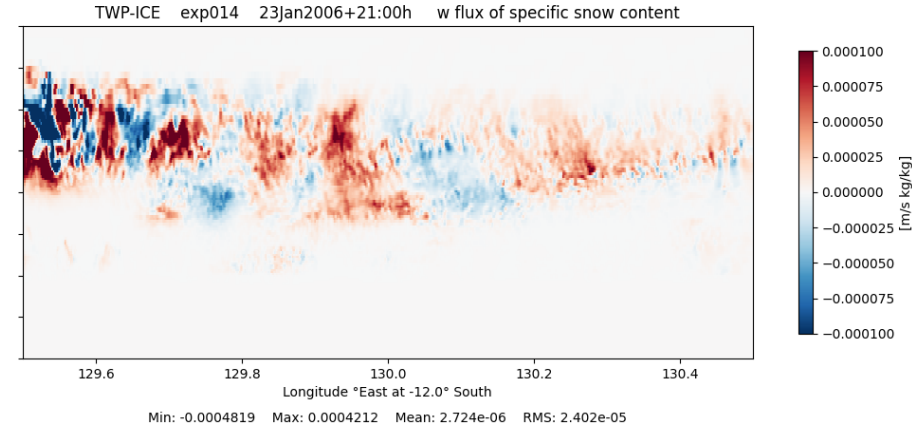




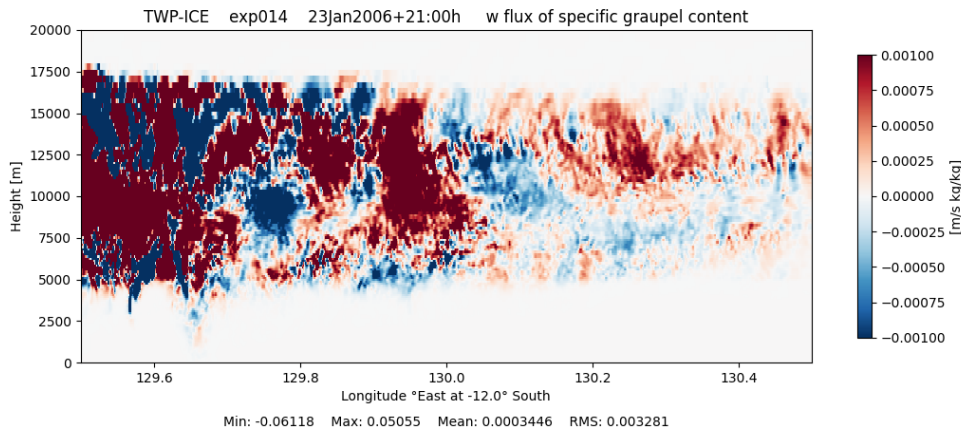
cloud ice



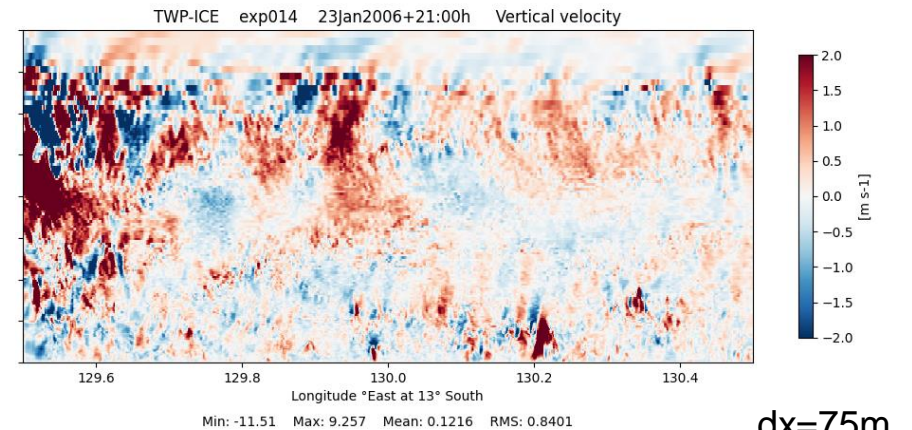
snow



graupel

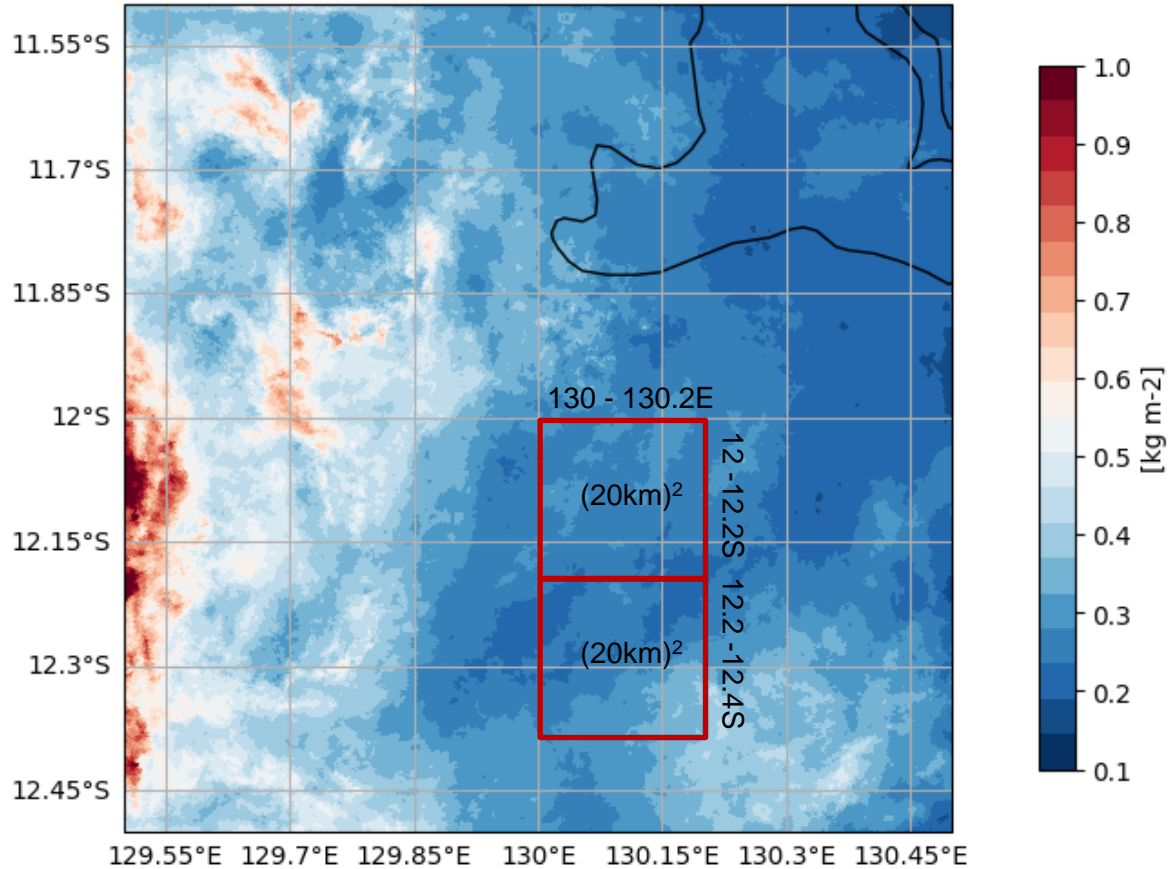


vertical velocity



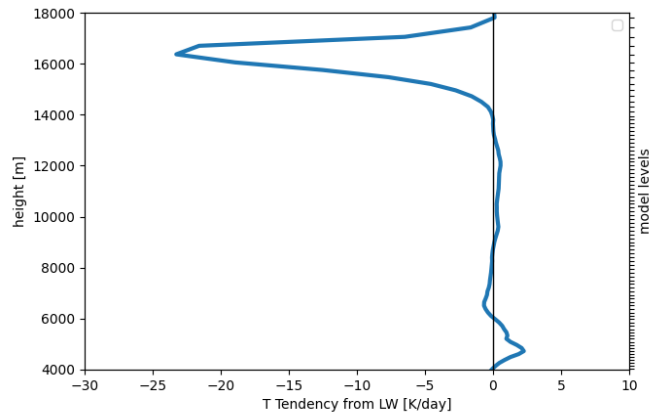
total qi 2006-01-23+21h (03LT)

ICON exp014 dom4 total column integrated cloud ice 23Jan2006+21:00h

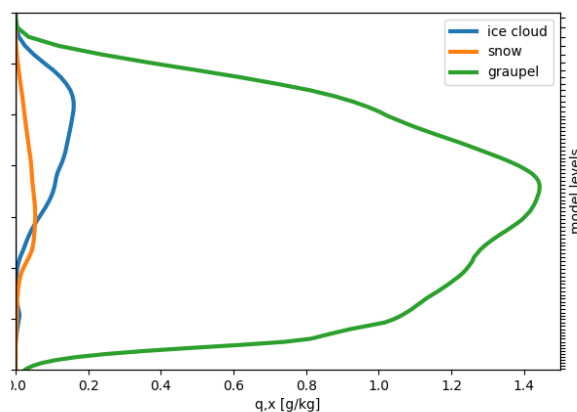


Min:0.1561 Max:1.275 Mean:0.3414 RMS:0.3619

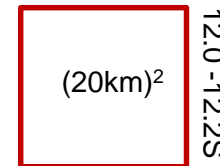
IR cooling



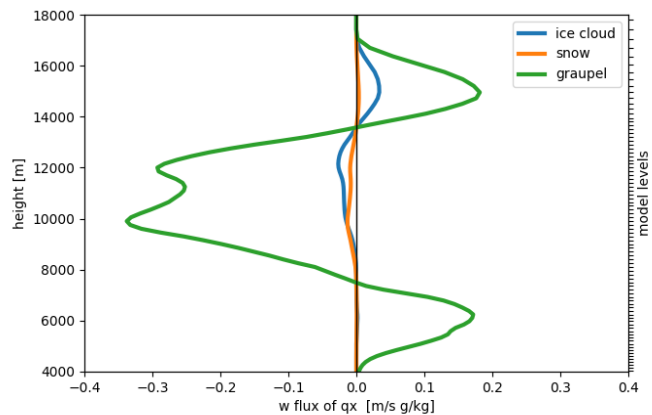
cloud ice, snow, graupel



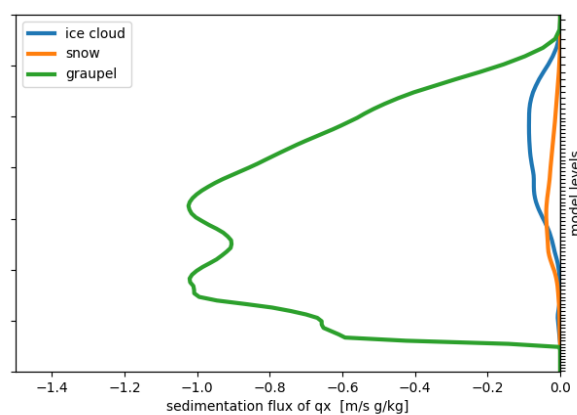
130 - 130.2E



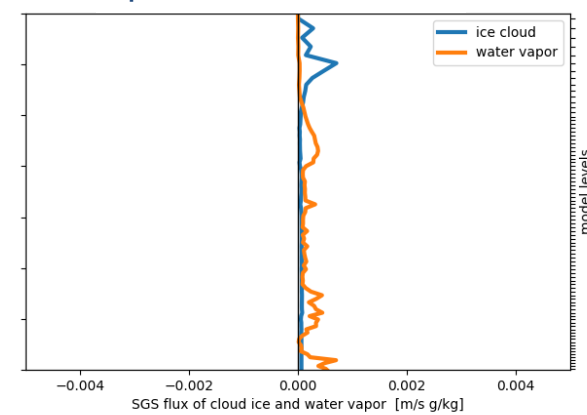
resolved flux



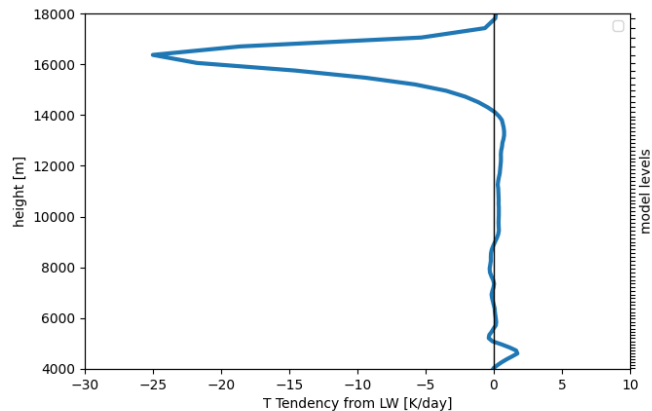
sedimentation flux



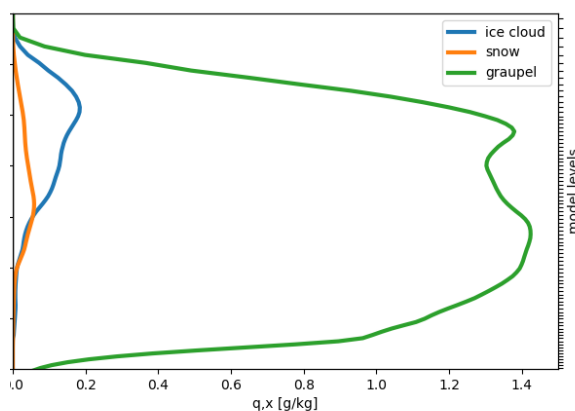
parameterised flux



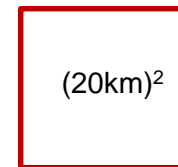
IR cooling



cloud ice, snow, graupel



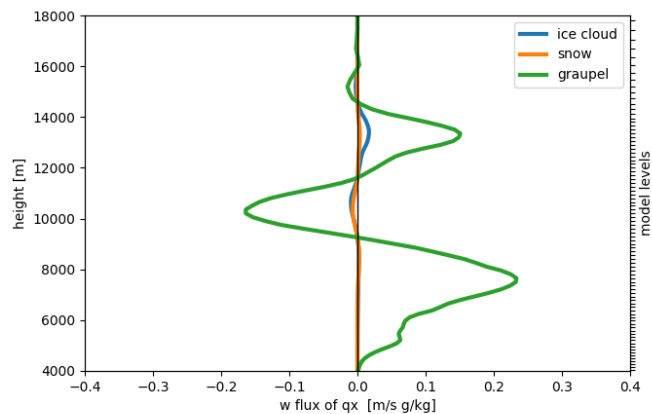
130 - 130.2E



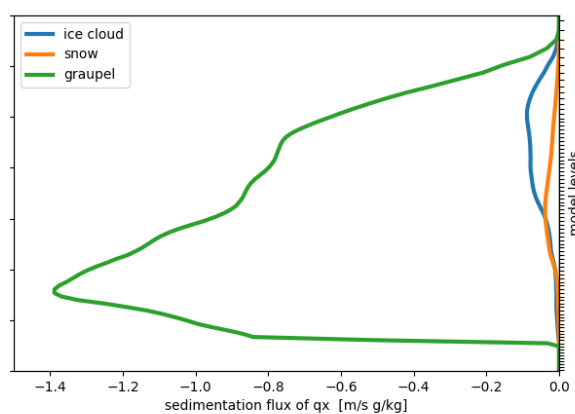
(20km)²

12.2 - 12.4S

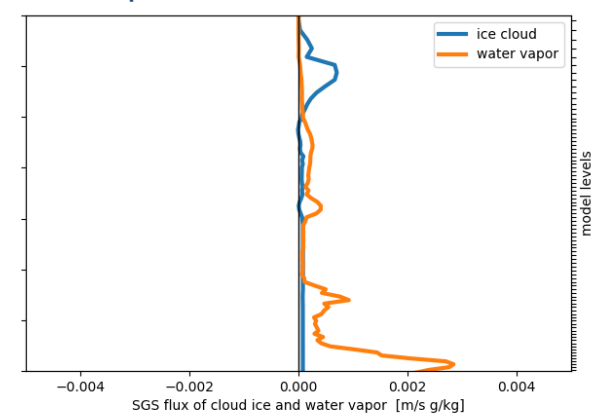
resolved flux



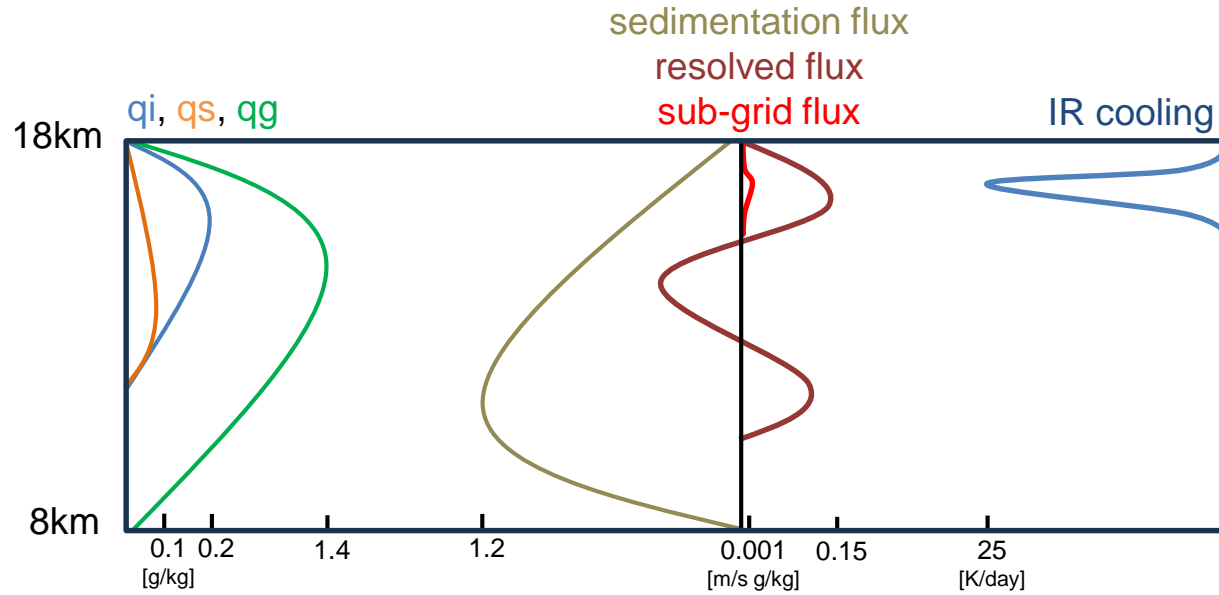
sedimentation flux



parameterised flux

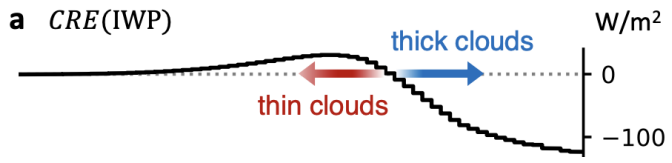


schematic anvil physics

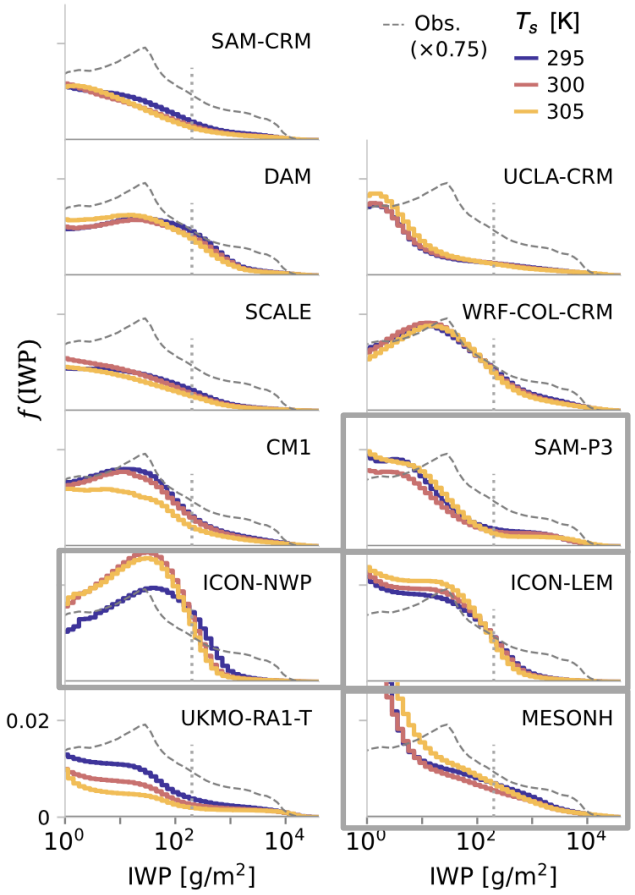


“Anvil Cloud Thinning”: Adam Sokol, Casey Wall and Dennis Hartmann

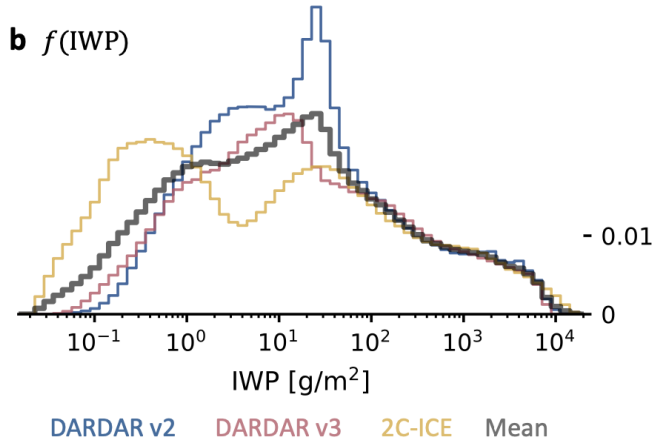
Cloud Radiative Effect
RCE-MPI (SST=300K, dx =3km)



Distribution of IWP
RCE-MPI (SST=295, 300, 305K)

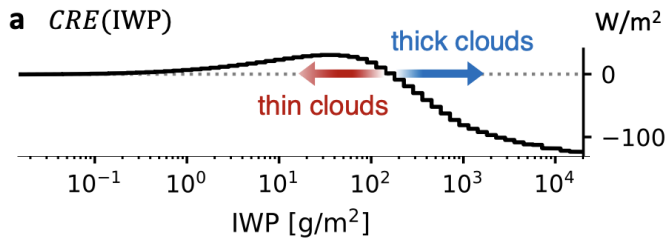


Distribution of IWP
tropical West Pacific

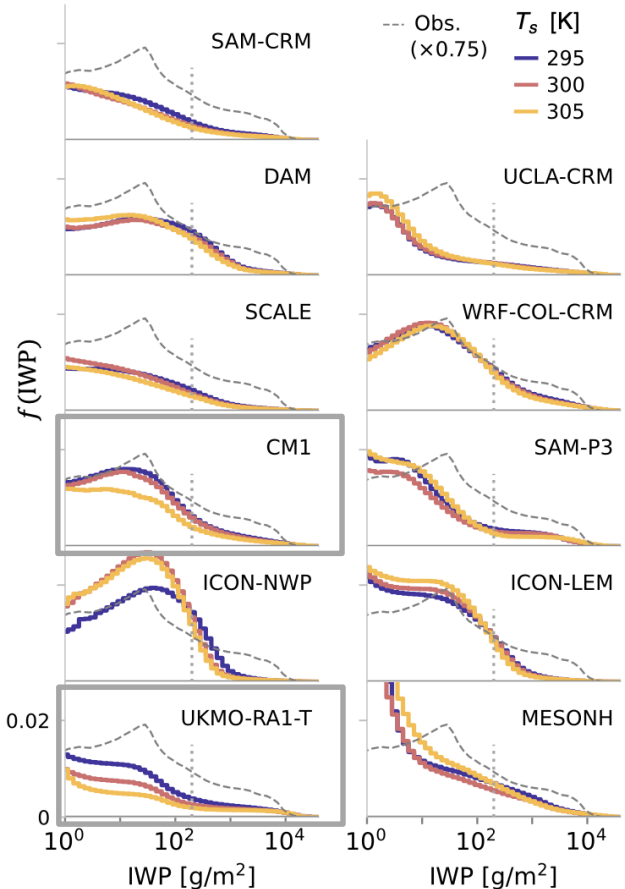


"Anvil Cloud Thinning": Adam Sokol, Casey Wall and Dennis Hartmann

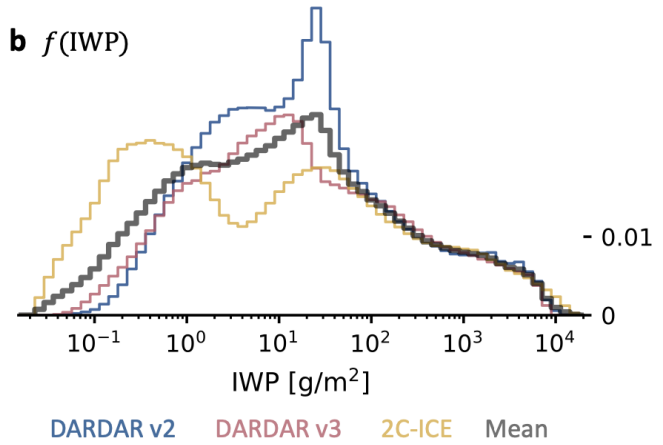
Cloud Radiative Effect
RCE-MPI (SST=300K, dx =3km)



Distribution of IWP
RCE-MPI (SST= 295, 300, 305K)

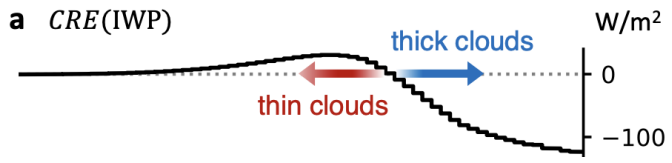


Distribution of IWP
tropical West Pacific

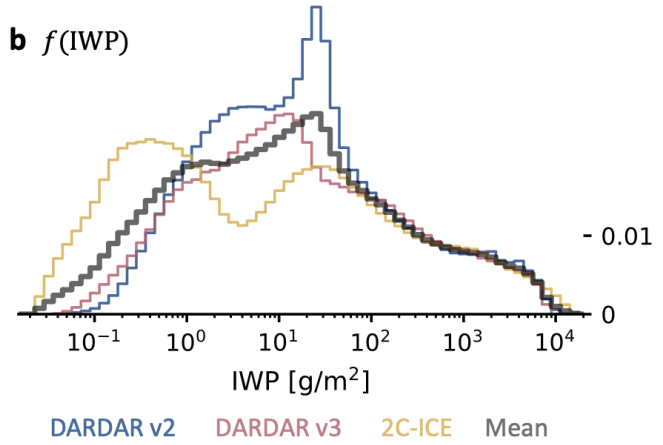


“Anvil Cloud Thinning”: Adam Sokol, Casey Wall and Dennis Hartmann

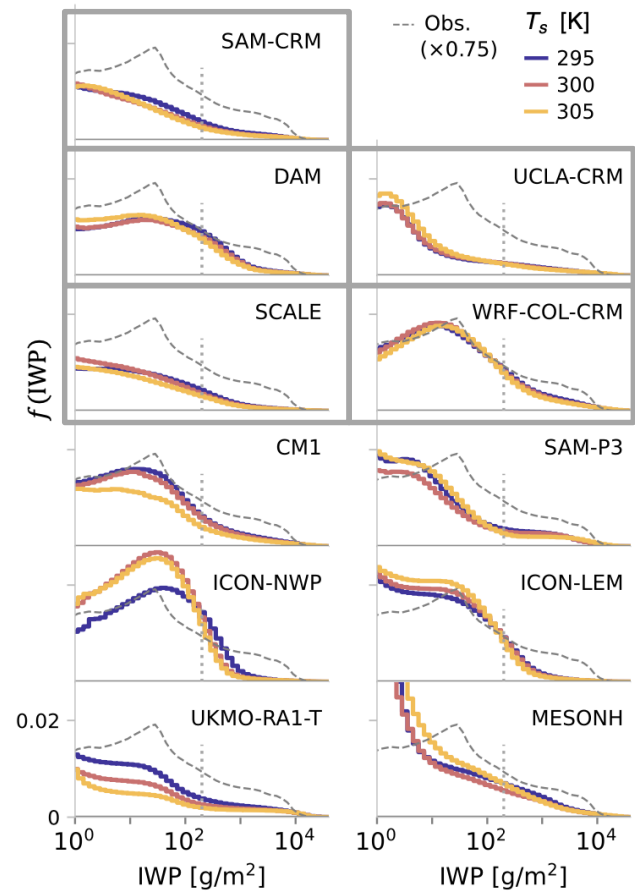
Cloud Radiative Effect
RCE-MPI (SST=300K, dx =3km)



Distribution of IWP
tropical West Pacific

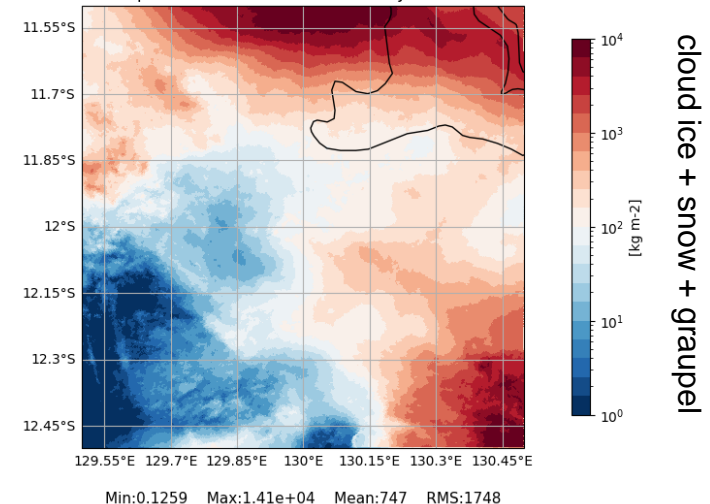
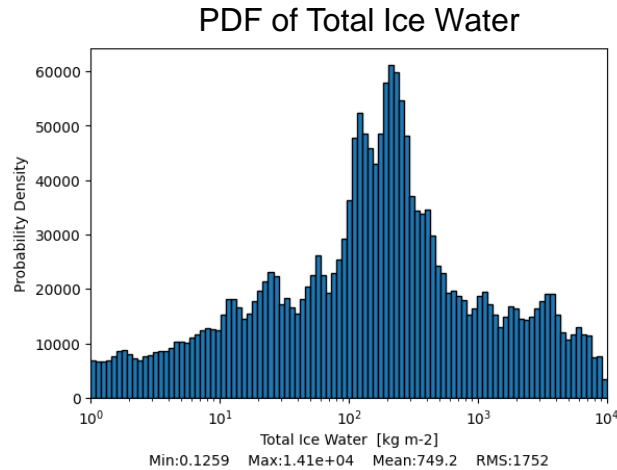
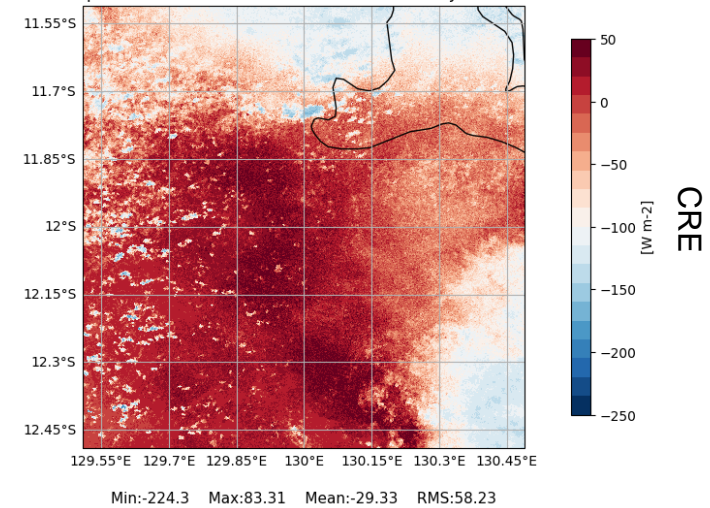
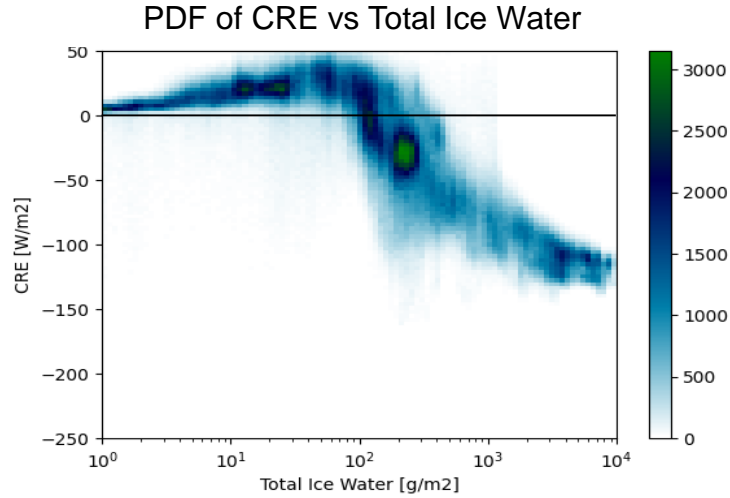


Distribution of IWP
RCE-MPI (SST= 295, 300, 305K)



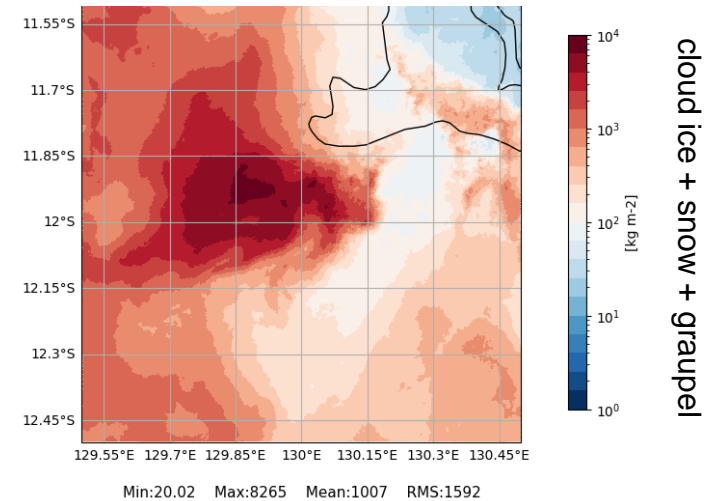
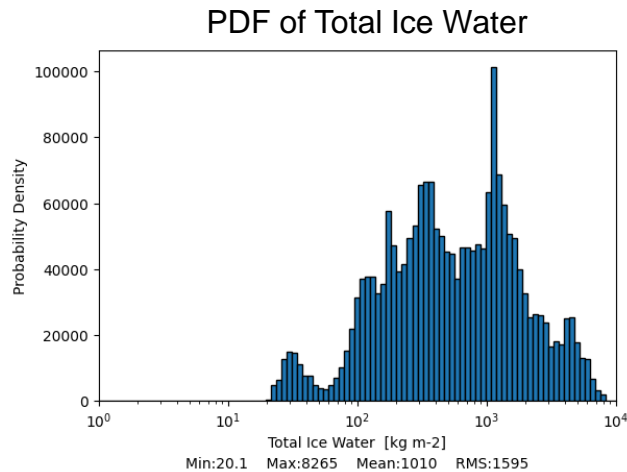
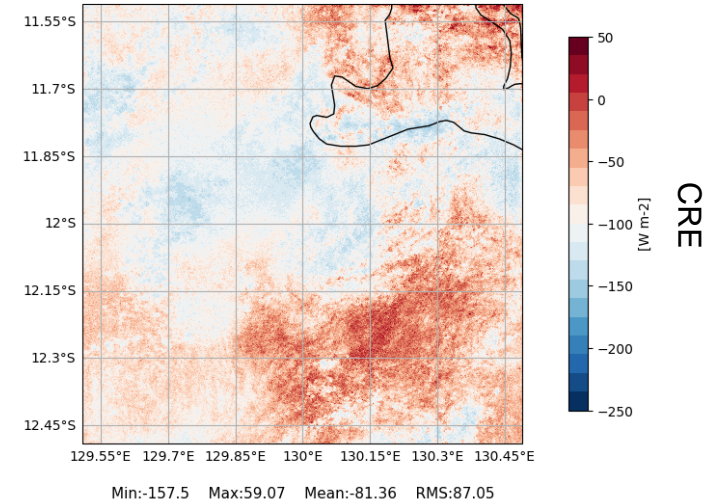
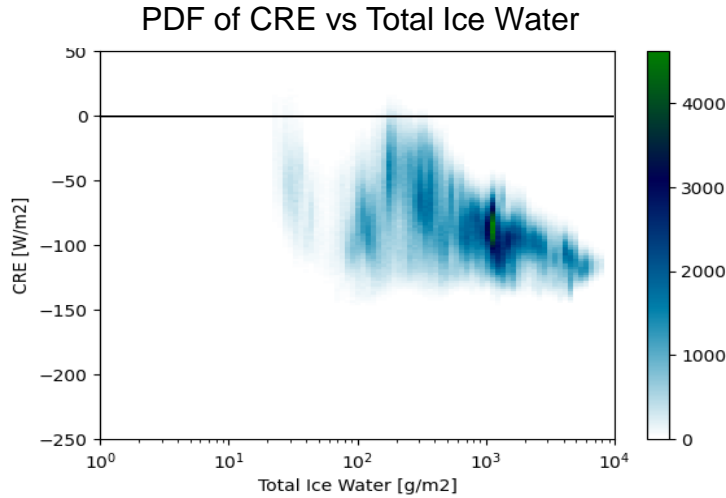
cloud radiative effect (CRE)

23. Jan. 6UTC
75m resolution



cloud radiative effect (CRE)

24. Jan. 2UTC
75m resolution

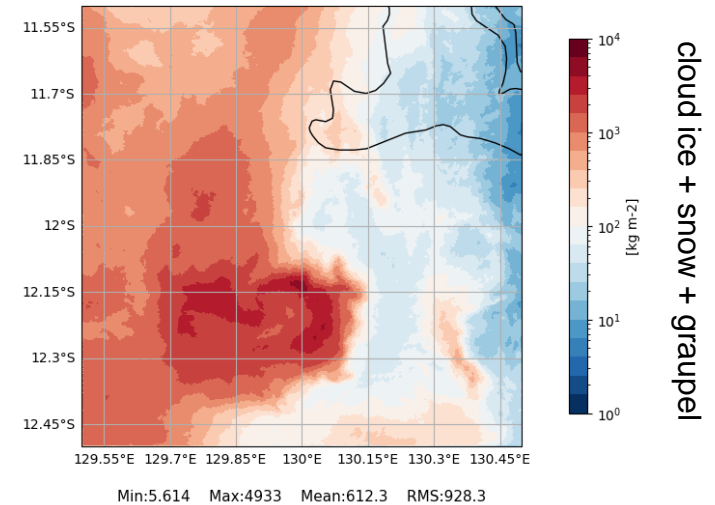
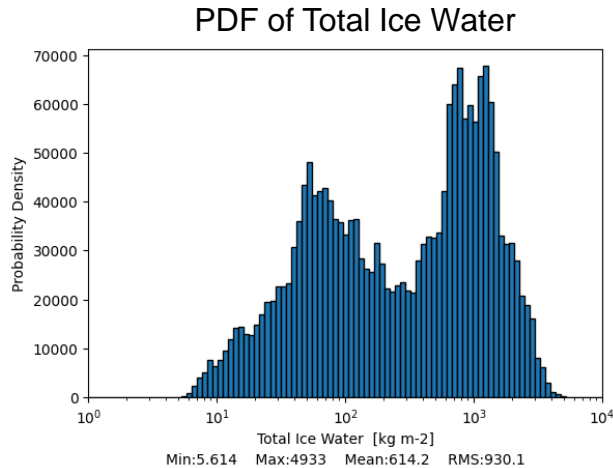
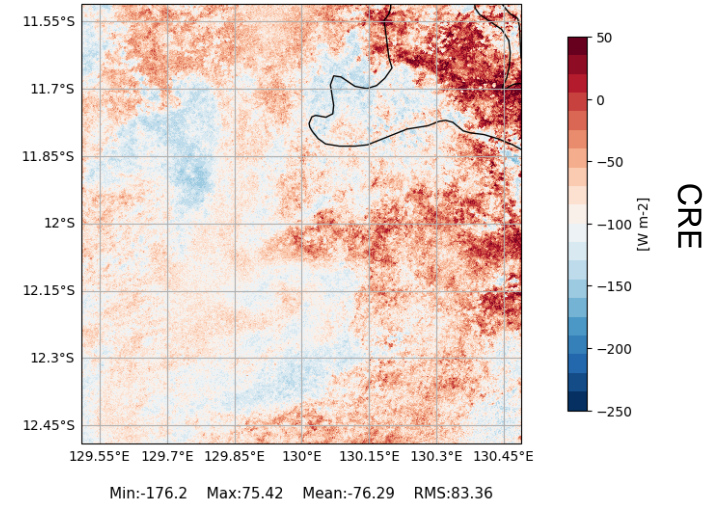
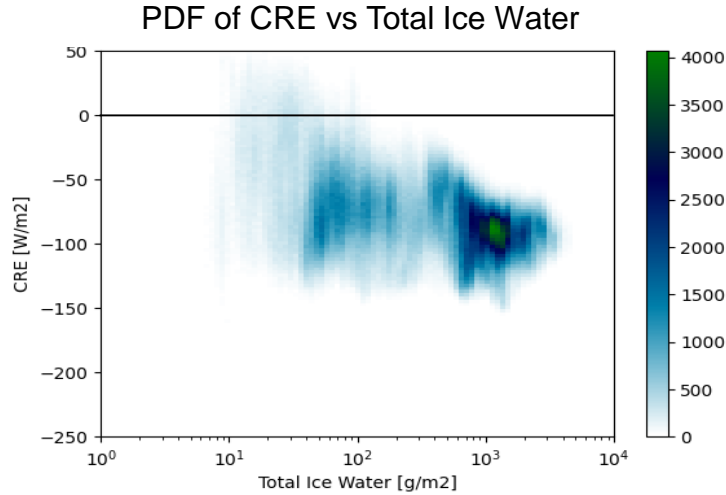


- **ICON-LES** at **<100m** resolution
- **20-30K** cloud top IR cooling
- turbulent **up-transport** of moisture near cloud top
- **sedimentation** dominating in lower part of cloud
- deep anvils close to convection cool by **$\sim 100-120\text{W/m}^2$**
- thin cirrus as remnants of convective updrafts warm by **$\sim 20-40\text{W/m}^2$**

extra slides

cloud radiative effect (CRE)

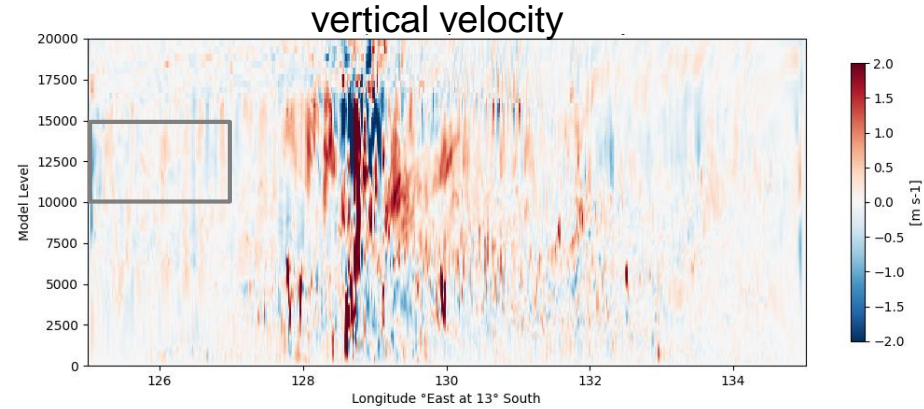
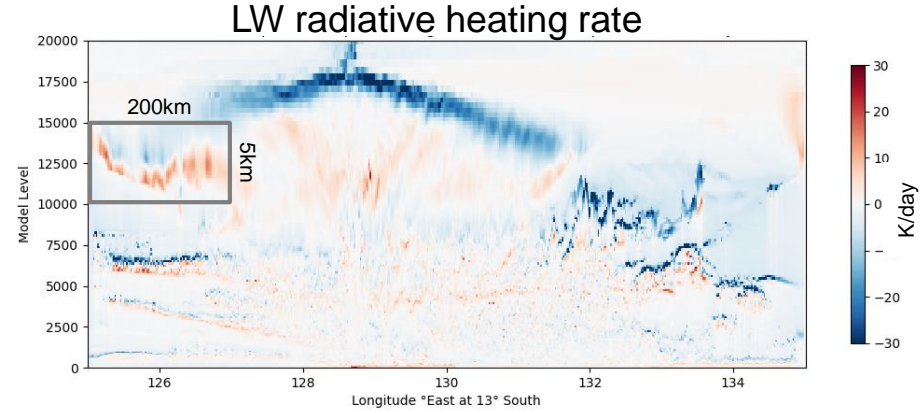
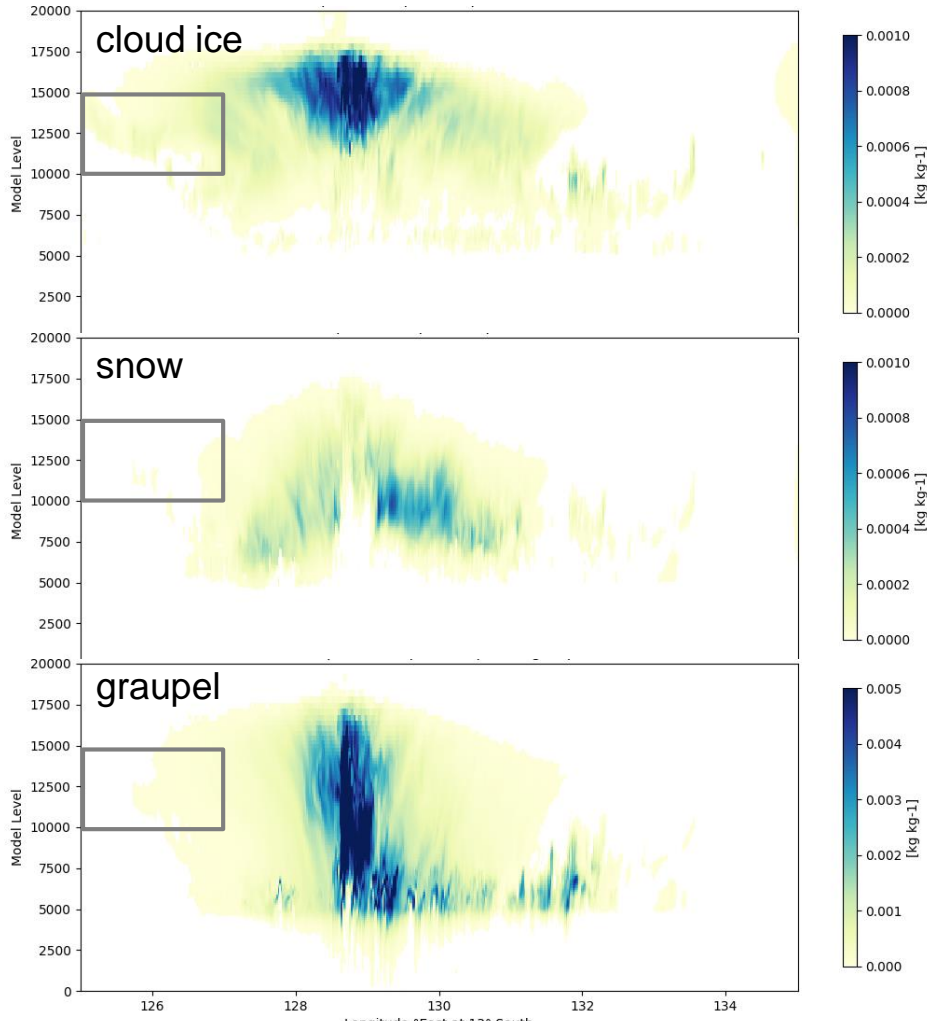
24. Jan. 3UTC
75m resolution



TWP-ICE: 2006-01-23+24h (09LT) 13S



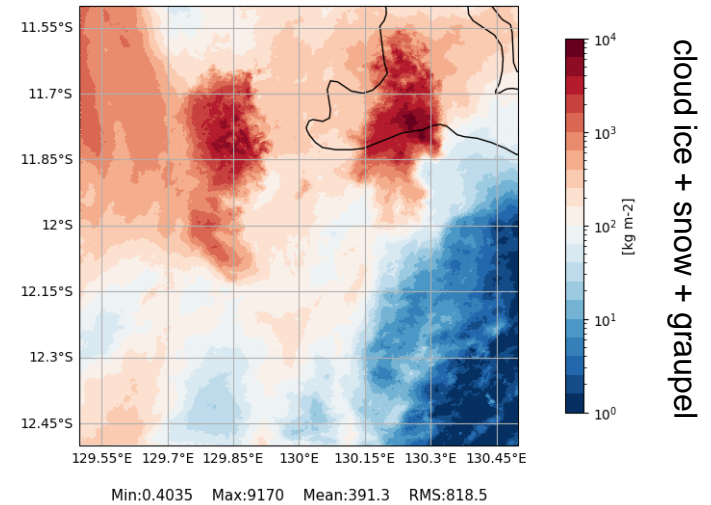
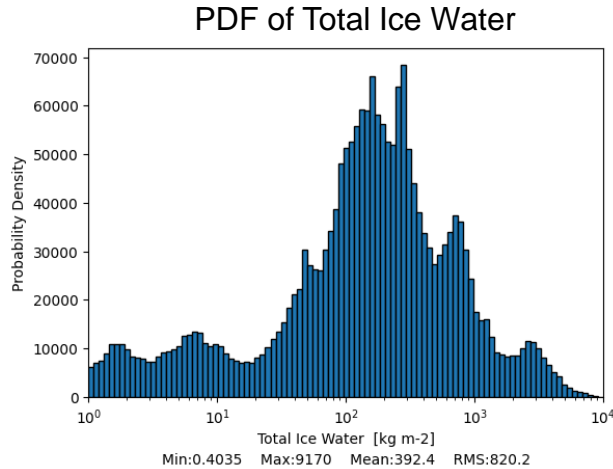
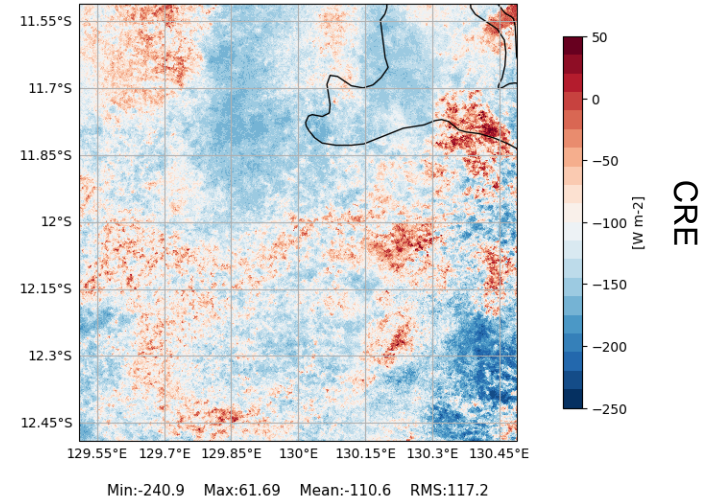
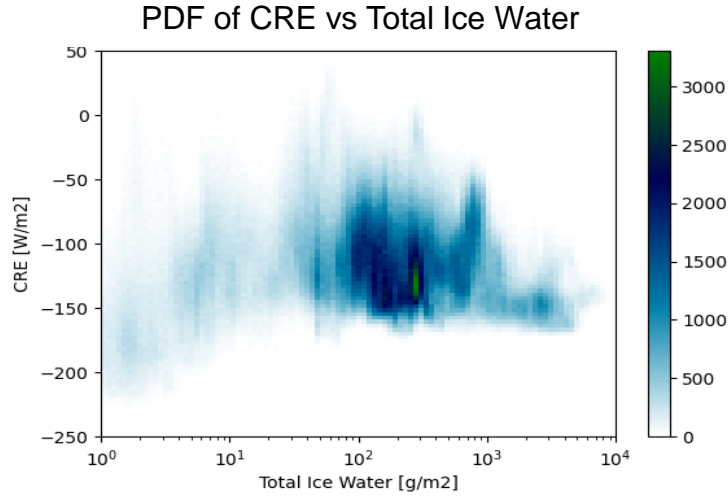
exp008



dx=615m

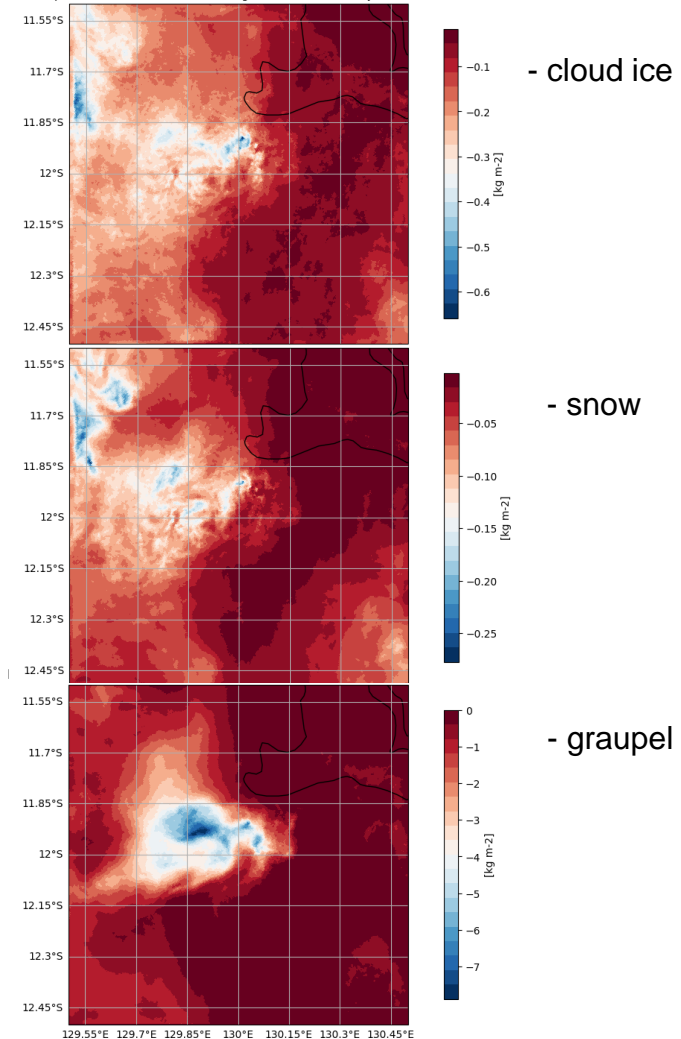
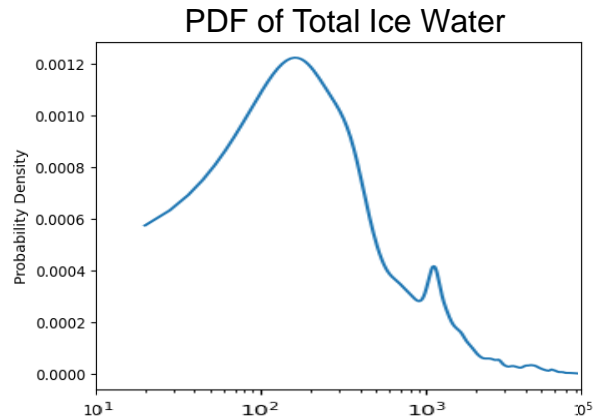
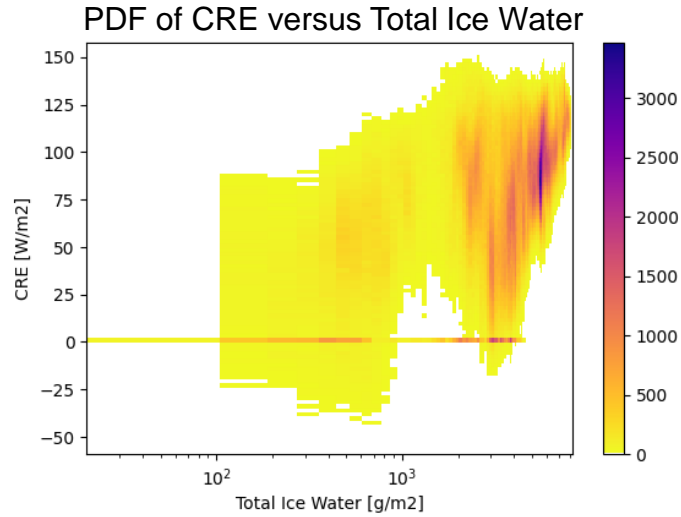
cloud radiative effect (CRE)

24. Jan. 5UTC
75m resolution



cloud radiative effect (CRE)

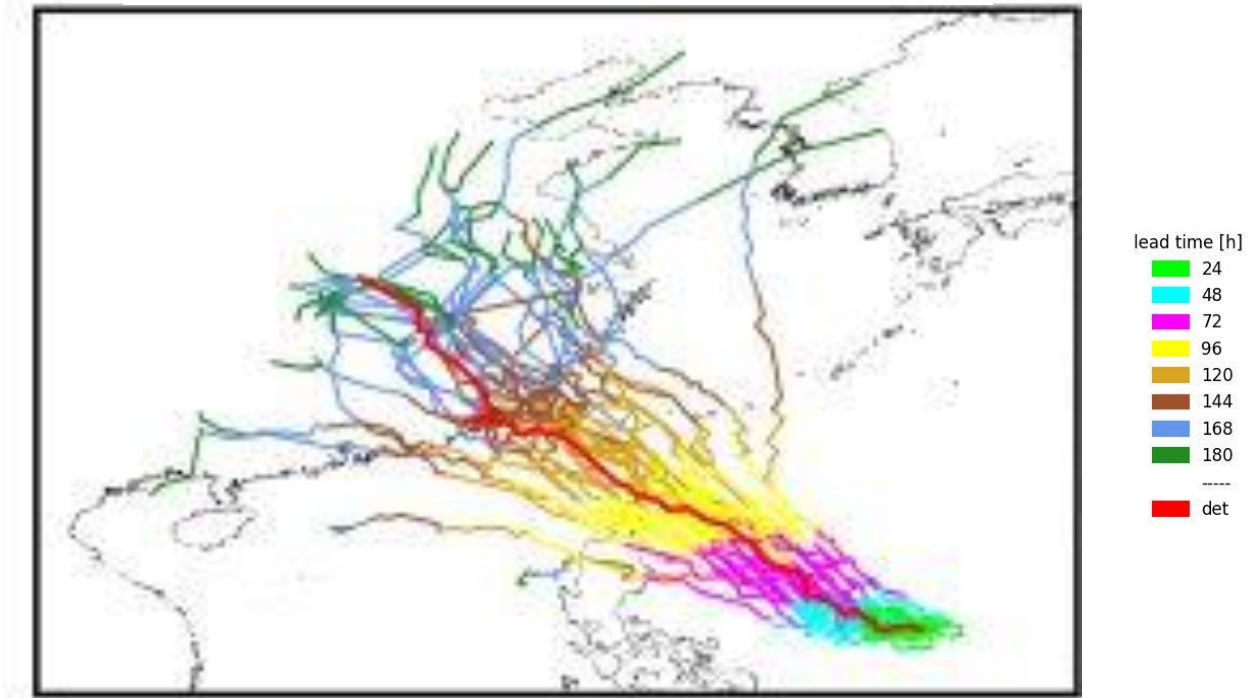
24. Jan. 2UTC
75m resolution



Typhoon Doksuri July 2023

ICON tracks

22 July 2023 00UTC
deterministic: 13km
ensemble: 26km



ICON-LES Typhoon Doksuri



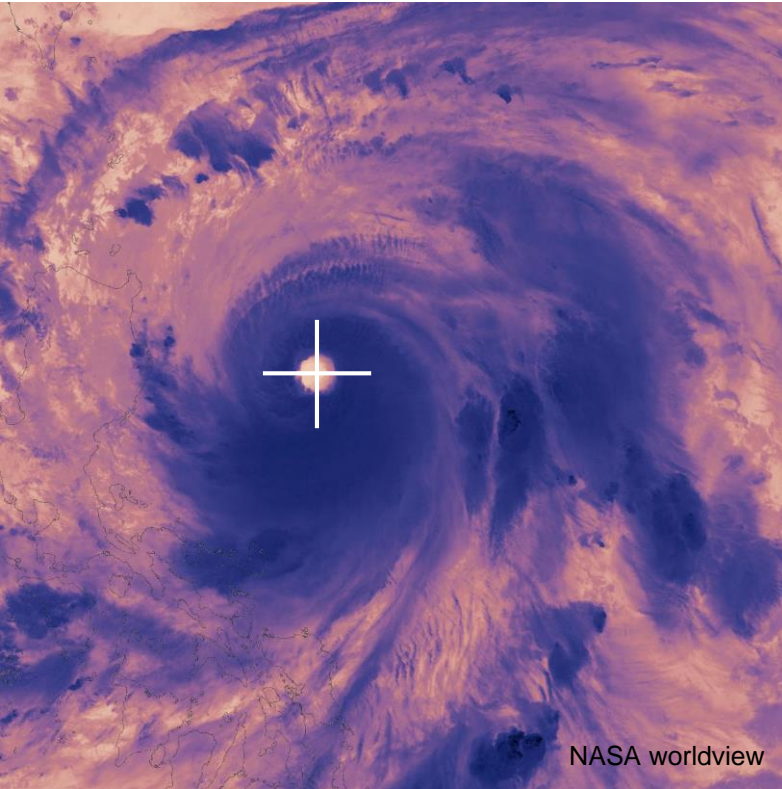
DOM01: R02B12 (616m) 120.5-129.5E, 11.5-20.5N

DOM02: R02B13 (308m) 123.5-126.6E, 15.5-18.5N

DOM03: R02B14 (154m) 124.0-126.0E, 16.0-18.0N

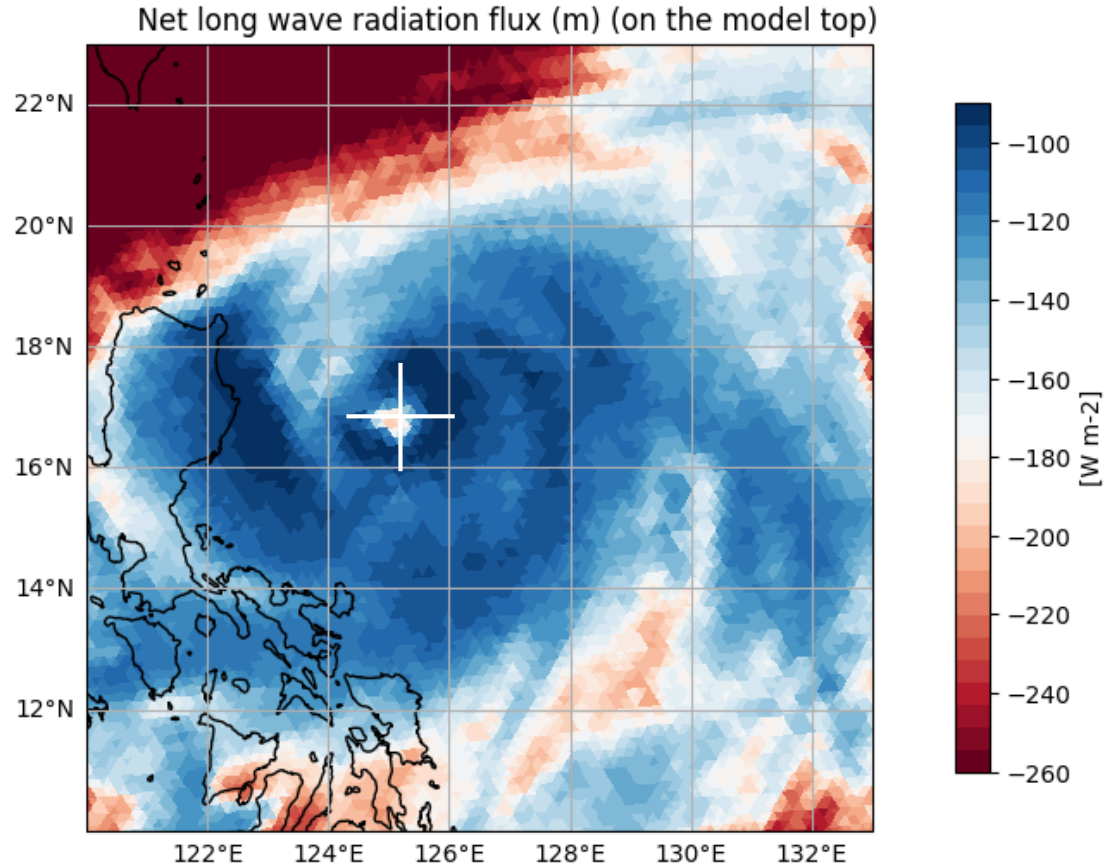
Typhoon Doksuri: ICON-NWP-13km

Brightness Temperature (NOAA-20 VIIRS)
2023-07-24 17:20



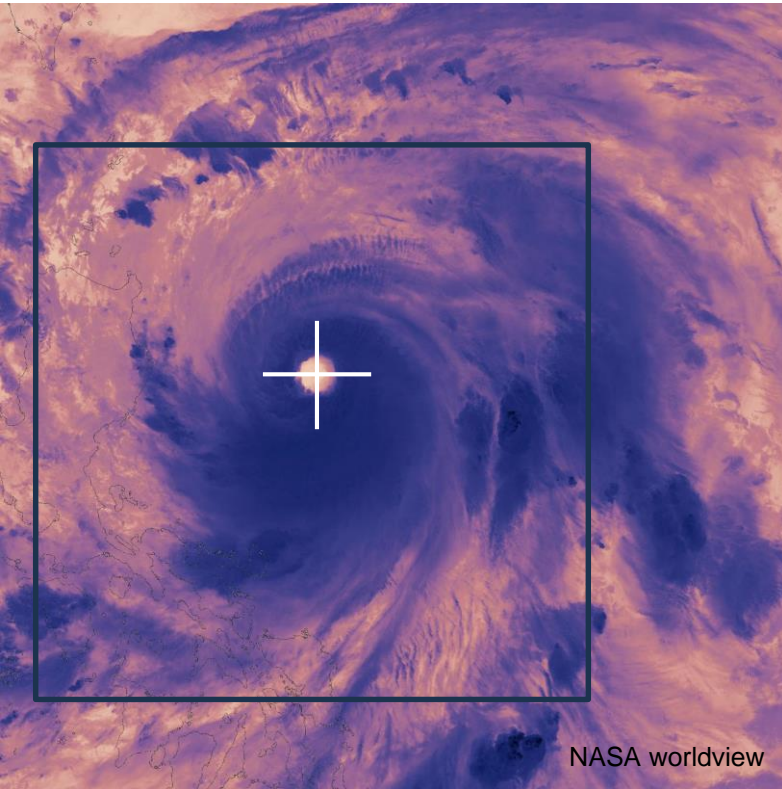
120-133E 10-23N

Outgoing Long-Wave Radiation (ICON-13km)
2023-07-24 17:00-18:00 18h forecast



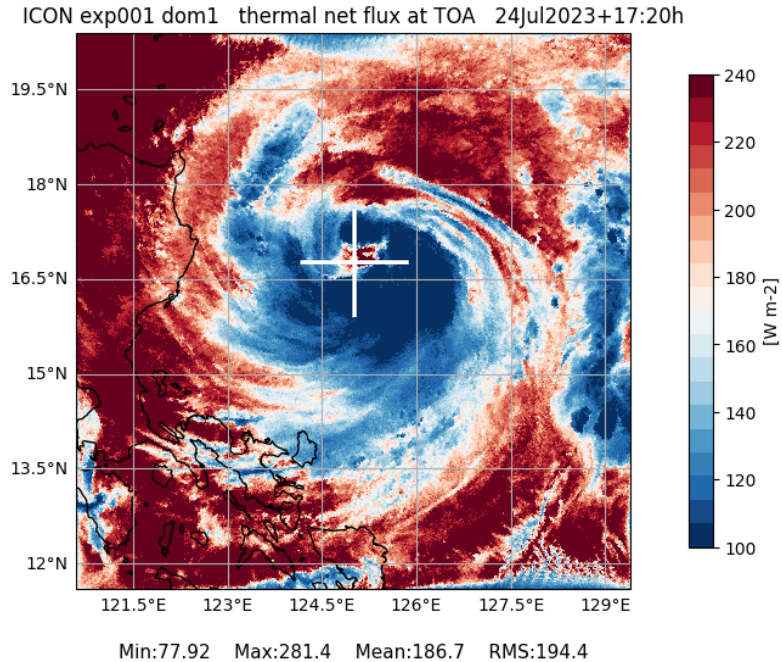
Typhoon Doksuri: ICON-NWP-600m

Brightness Temperature (NOAA-20 VIIRS)
2023-07-24 17:20



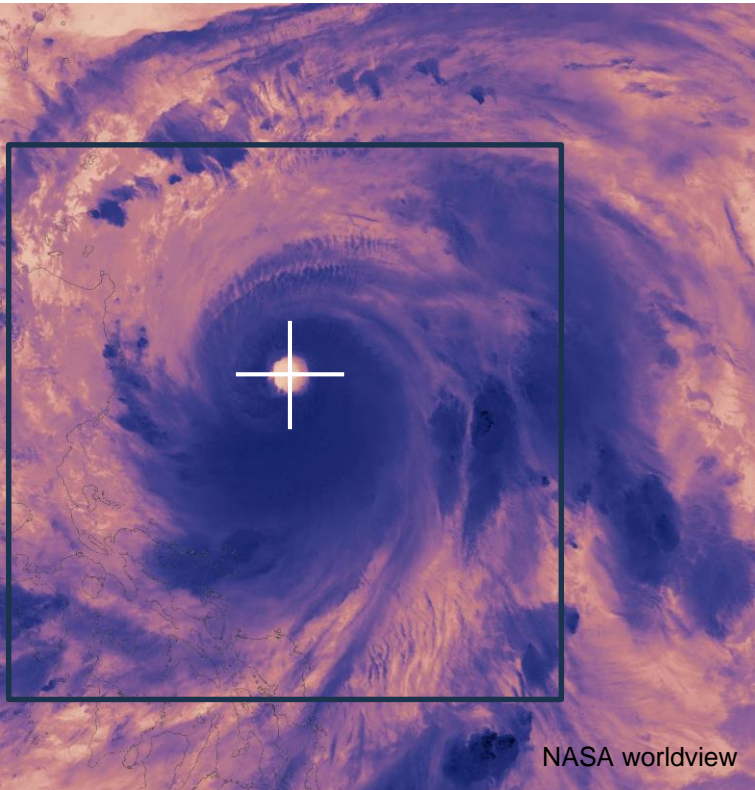
120-133E 10-23N

Outgoing Long-Wave Radiation (ICON-NWP-600m)
2023-07-24 17:20 42h forecast



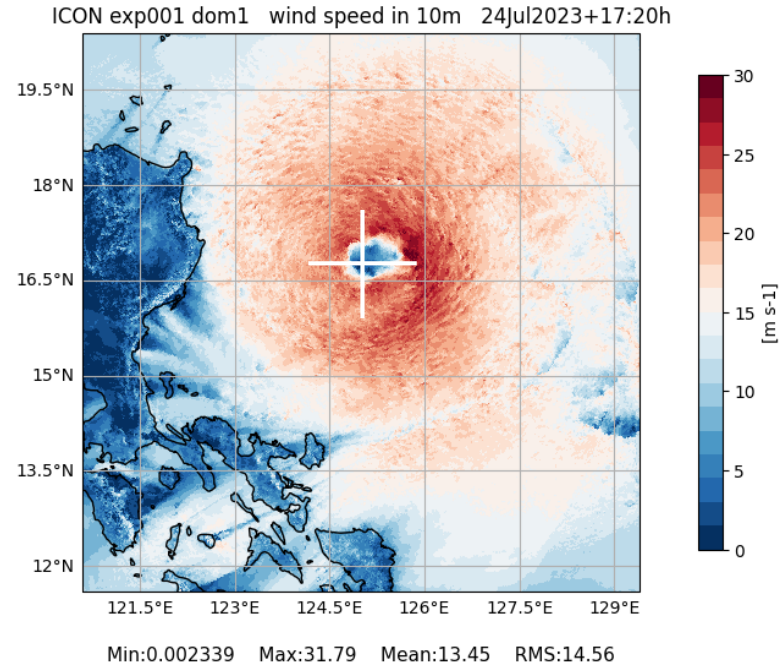
Typhoon Doksuri: ICON-NWP-600m

Brightness Temperature (NOAA-20 VIIRS)
2023-07-24 17:20



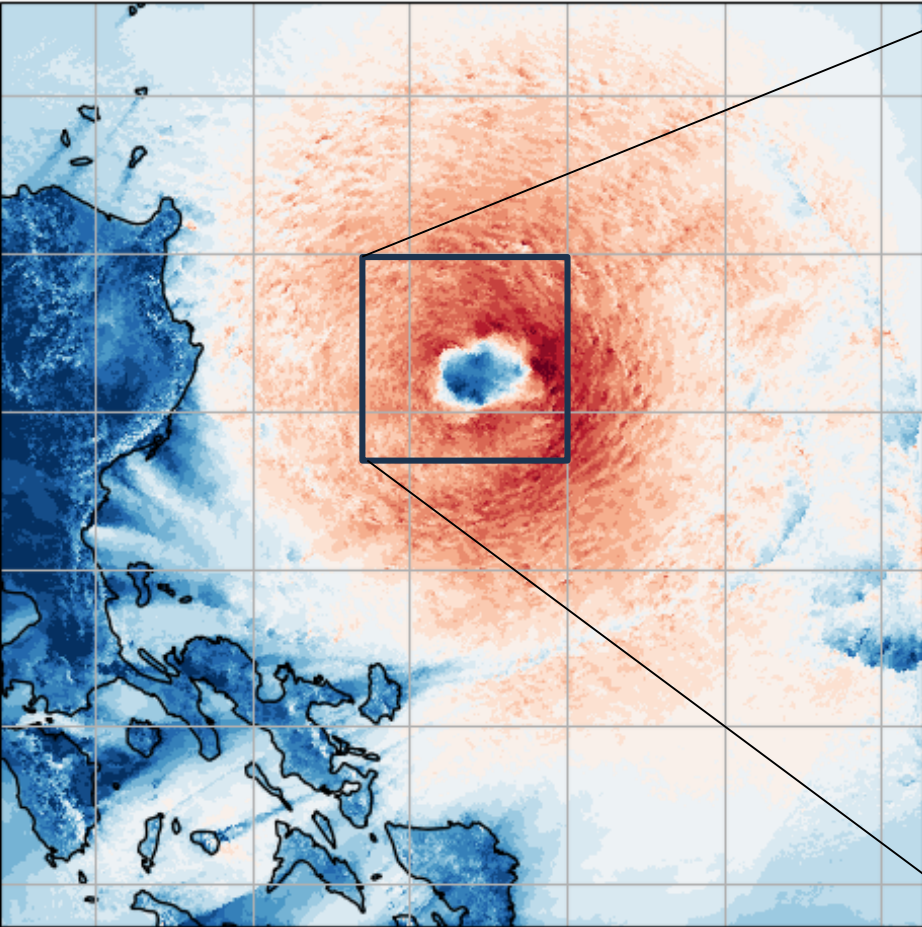
120-133E 10-23N

wind speed 10m (ICON-NWP-600m)
2023-07-24 17:20 42h forecast

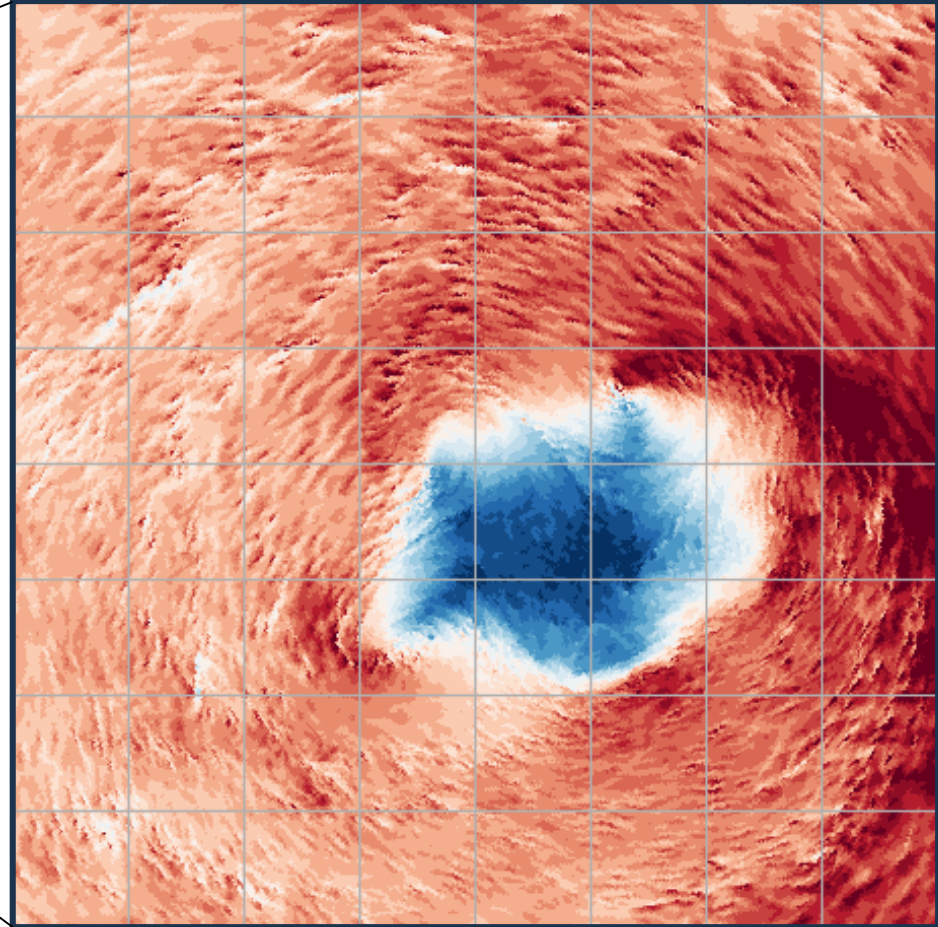


Typhoon Doksuri

wind speed 10m (ICON-LES-600m)
2023-07-24 17:20 42h forecast

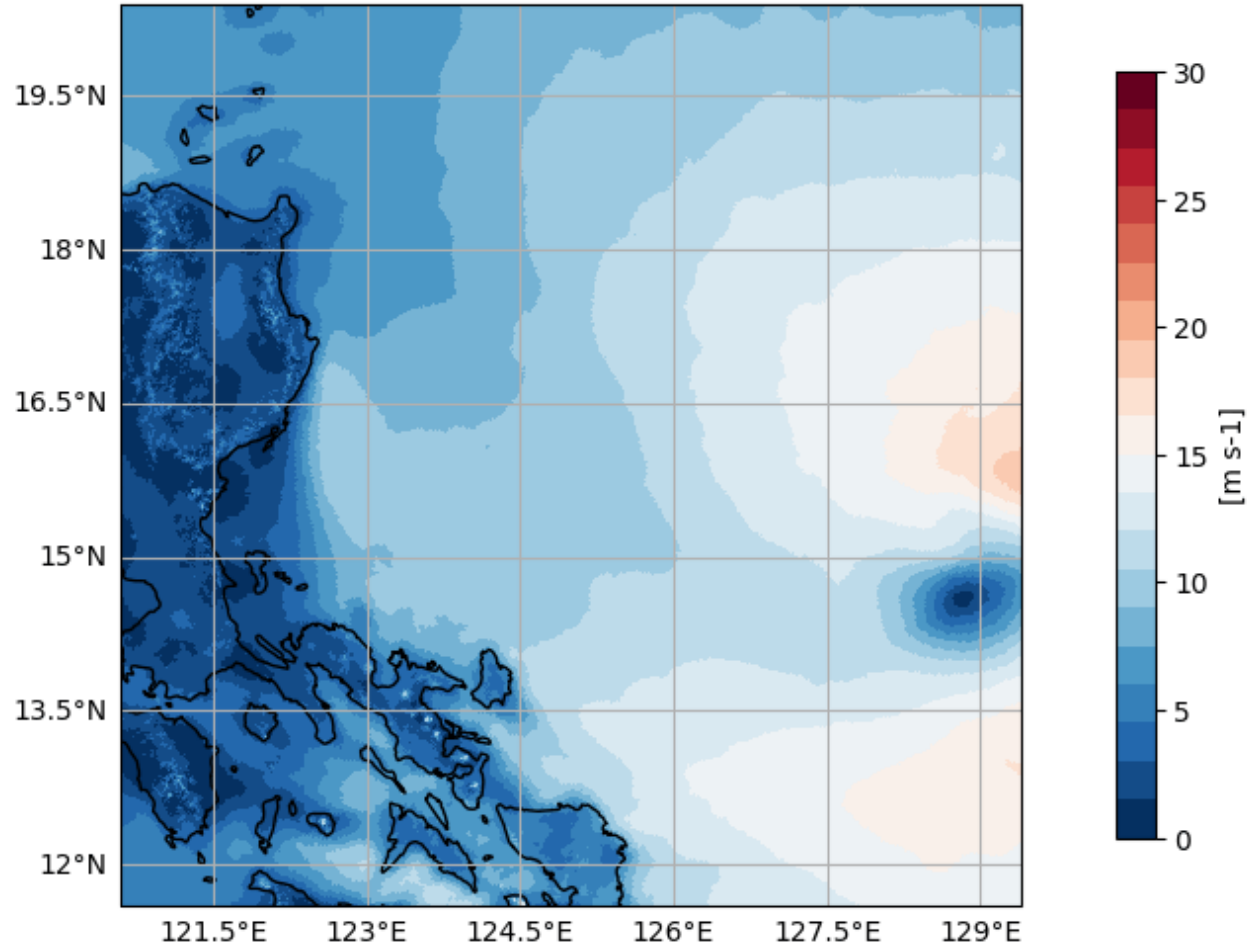


wind speed 10m (ICON-LES-150m)
2023-07-24 17:20 42h forecast



ICON-LES wind speed 10m Typhoon Doksuri

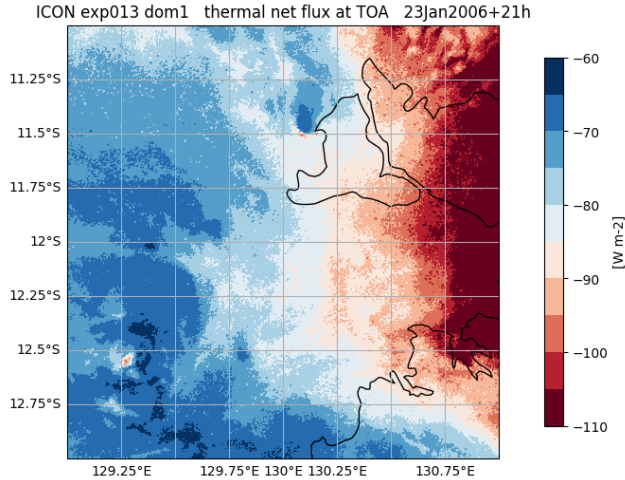
ICON exp001 dom1 wind speed in 10m 23Jul2023+00:00h



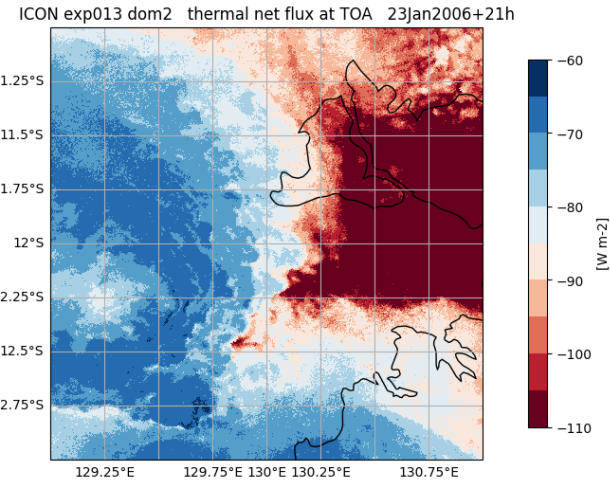
TWP-ICE: 2006-01-23+21h (06LT)

Outgoing
LW Radiation

600m

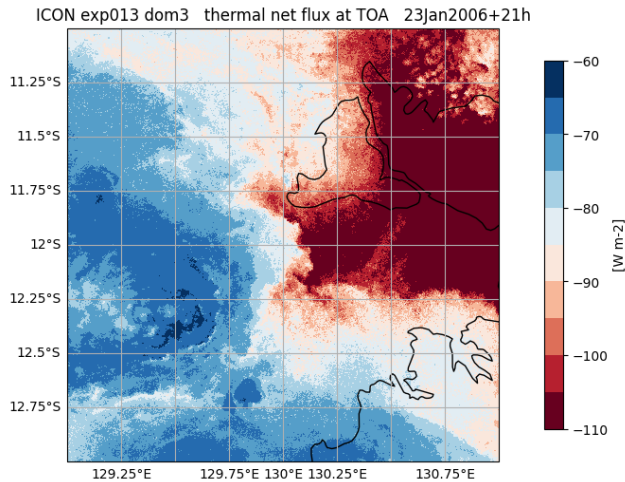


Min:-276.9 Max:-61.91 Mean:-168.2 RMS:180.8

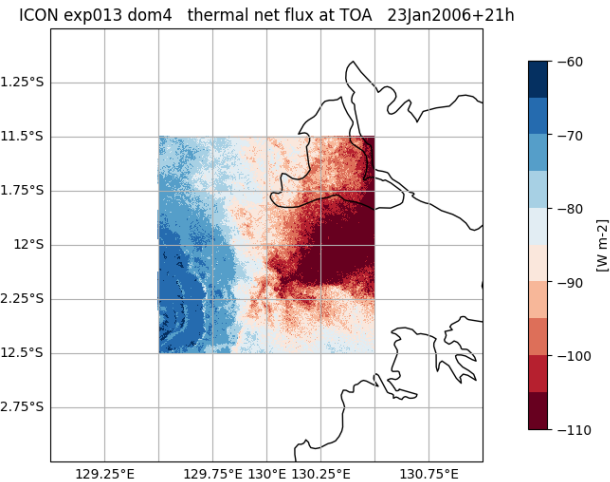


Min:-231.6 Max:-62.41 Mean:-89.87 RMS:93.43

150m



Min:-215.2 Max:-60.07 Mean:-86.81 RMS:88.86



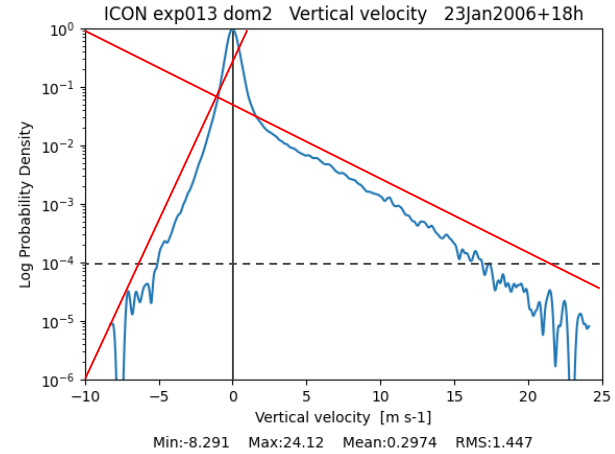
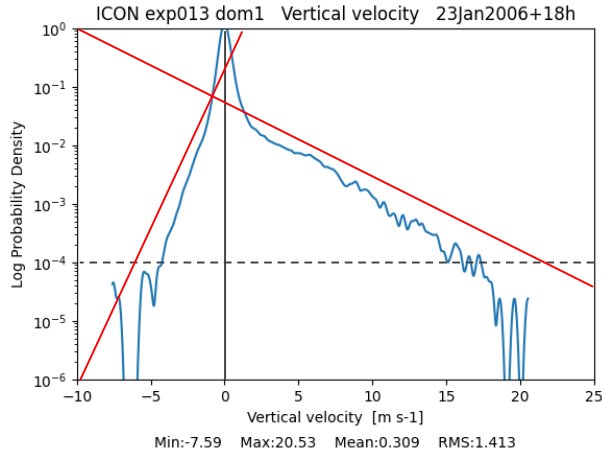
Min:-128.4 Max:-60.98 Mean:-86.89 RMS:87.88

TWP-ICE: 2006-01-23+18h (03LT)



exp013

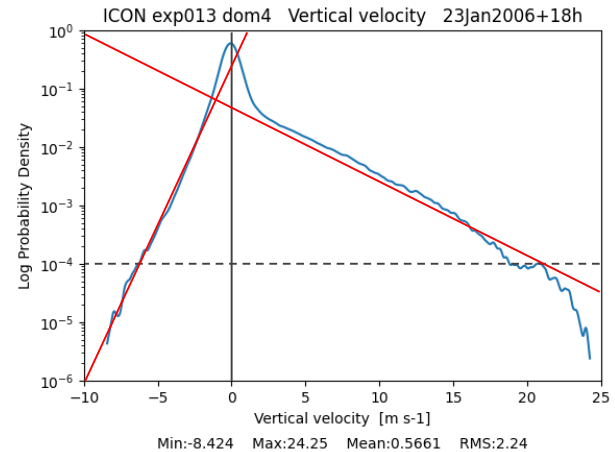
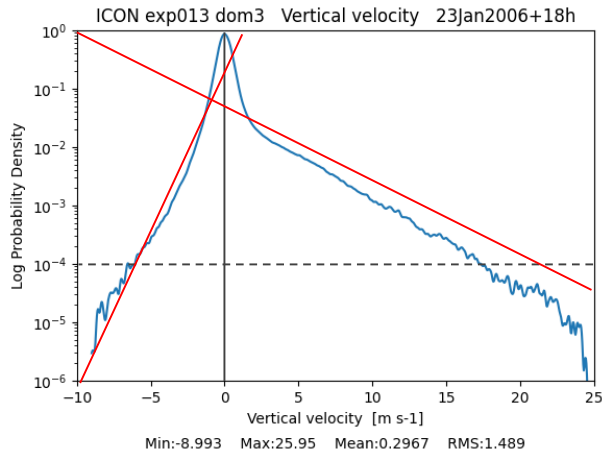
PDF
vertical
velocity
8027m



600m

300m

129-131 East
11-13 South



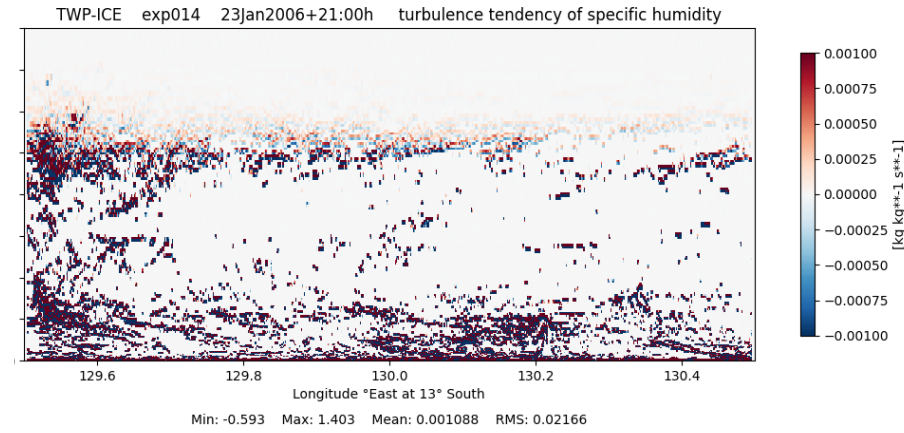
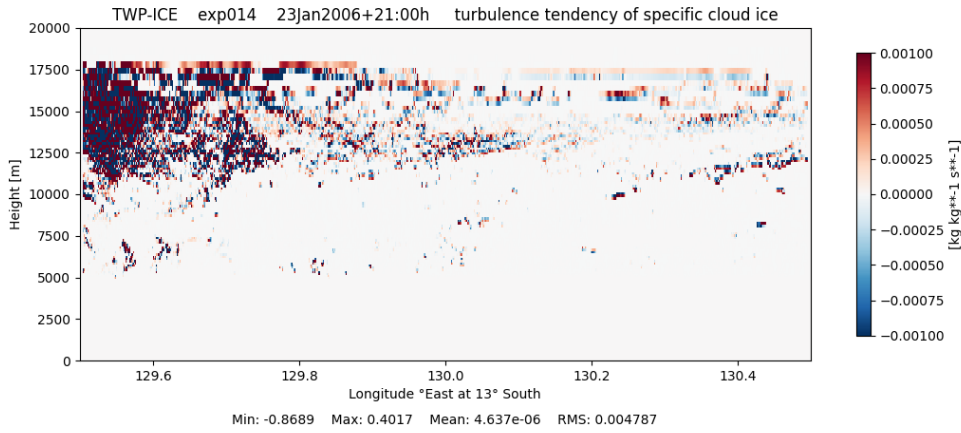
150m

75m

Turbulent tendency of q_i , q_v

2006-01-23+21h (06LT)

exp014

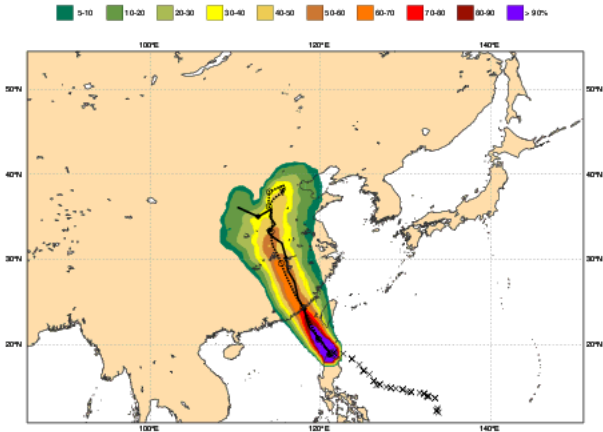


dx=75m

Typhoon Doksuri

Date 20230726 00 UTC @ECMWF

Probability that **DOKSURI** will pass within 120 km radius during the next 240 hours
tracks: **solid=HRES; dot=Ens Mean** [reported minimum central pressure (hPa) 925]

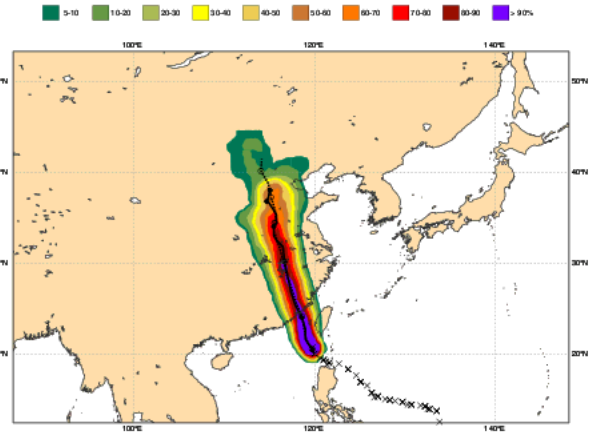


List of ensemble members numbers forecast Tropical Cyclone Intensity category in colours: TD [up to 33] TS [34-63] HR1 [64-82] HR2 [83-95] HR3 [96-100]

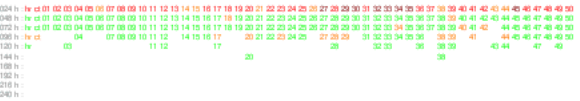


Date 20230727 00 UTC @ECMWF

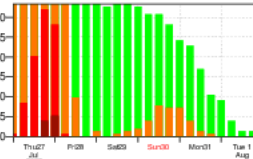
Probability that **DOKSURI** will pass within 120 km radius during the next 240 hours
tracks: **solid=HRES; dot=Ens Mean** [reported minimum central pressure (hPa) 955]



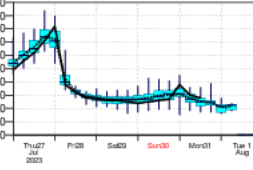
List of ensemble members numbers forecast Tropical Cyclone Intensity category in colours: TD [up to 33] TS [34-63] HR1 [64-82] HR2 [83-95] HR3 [96-100]



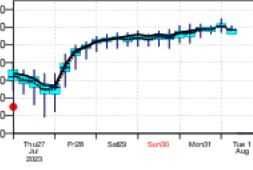
Probability (%) of Tropical Cyclone Intensity falling in ea
TD [up to 33] TS [34-63] HR1 [64-82] HR2 [83-95] HR3 [96-100]



10m Wind Speed (kt) solid=HRES; dot=Ens Mean

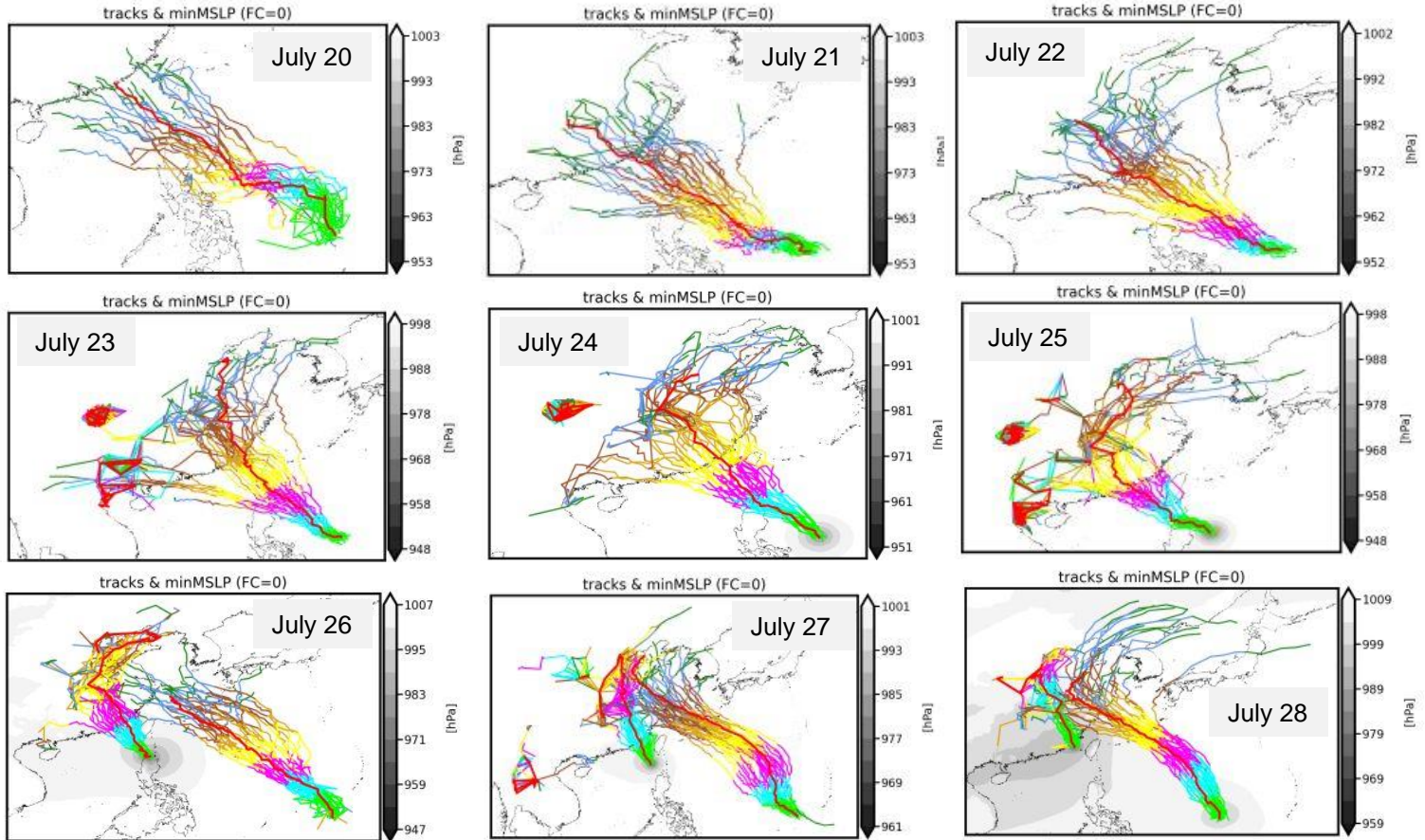


Mean Sea Level Pressure in Tropical Cyclone Centre (hPa) solid=HRES; dot=Ens Mean



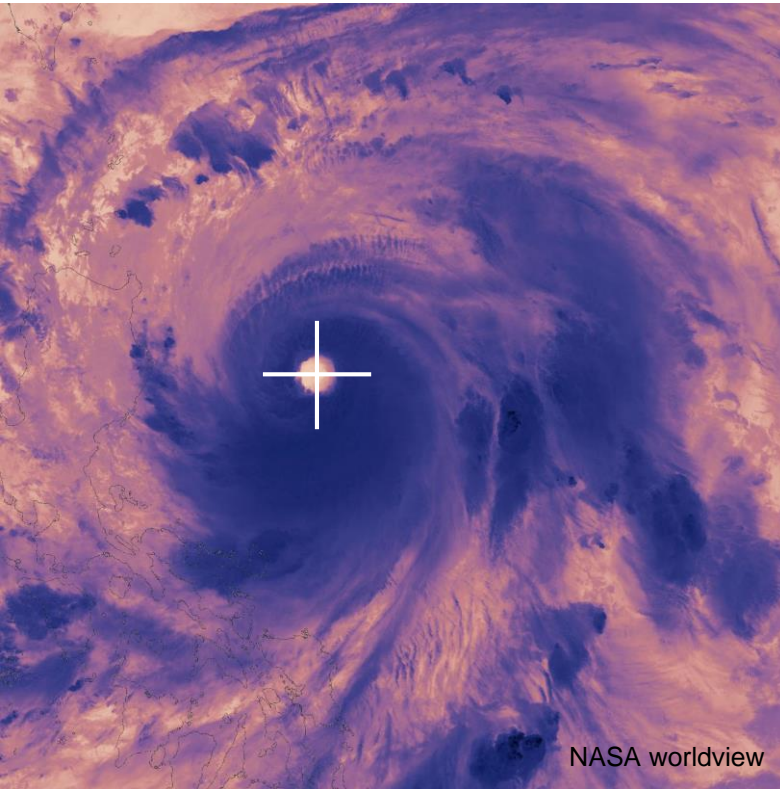
Doksuri / ICON 00UTC forecasts

- lead time [h]
- 24
 - 48
 - 72
 - 96
 - 120
 - 144
 - 168
 - 180
 - det



Typhoon Doksuri

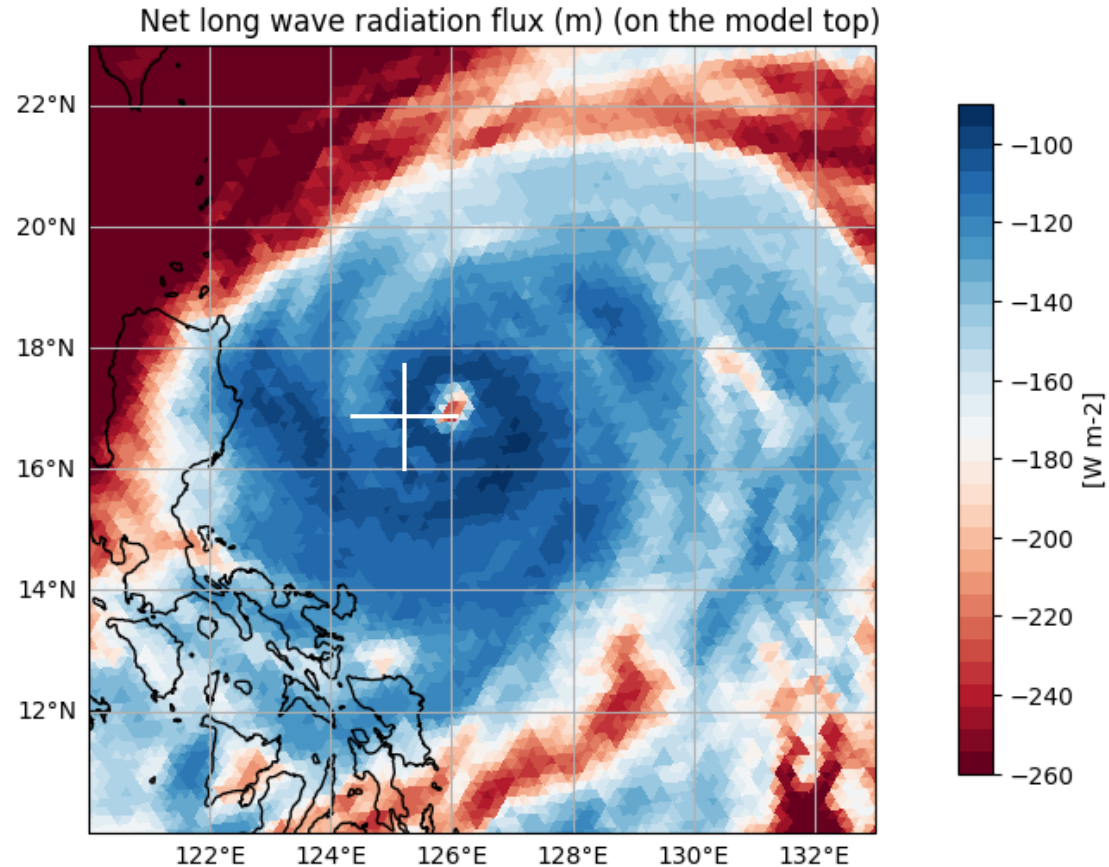
Brightness Temperature (NOAA-20 VIIRS)
2023-07-24 17:20



120-133E 10-23N

NASA worldview

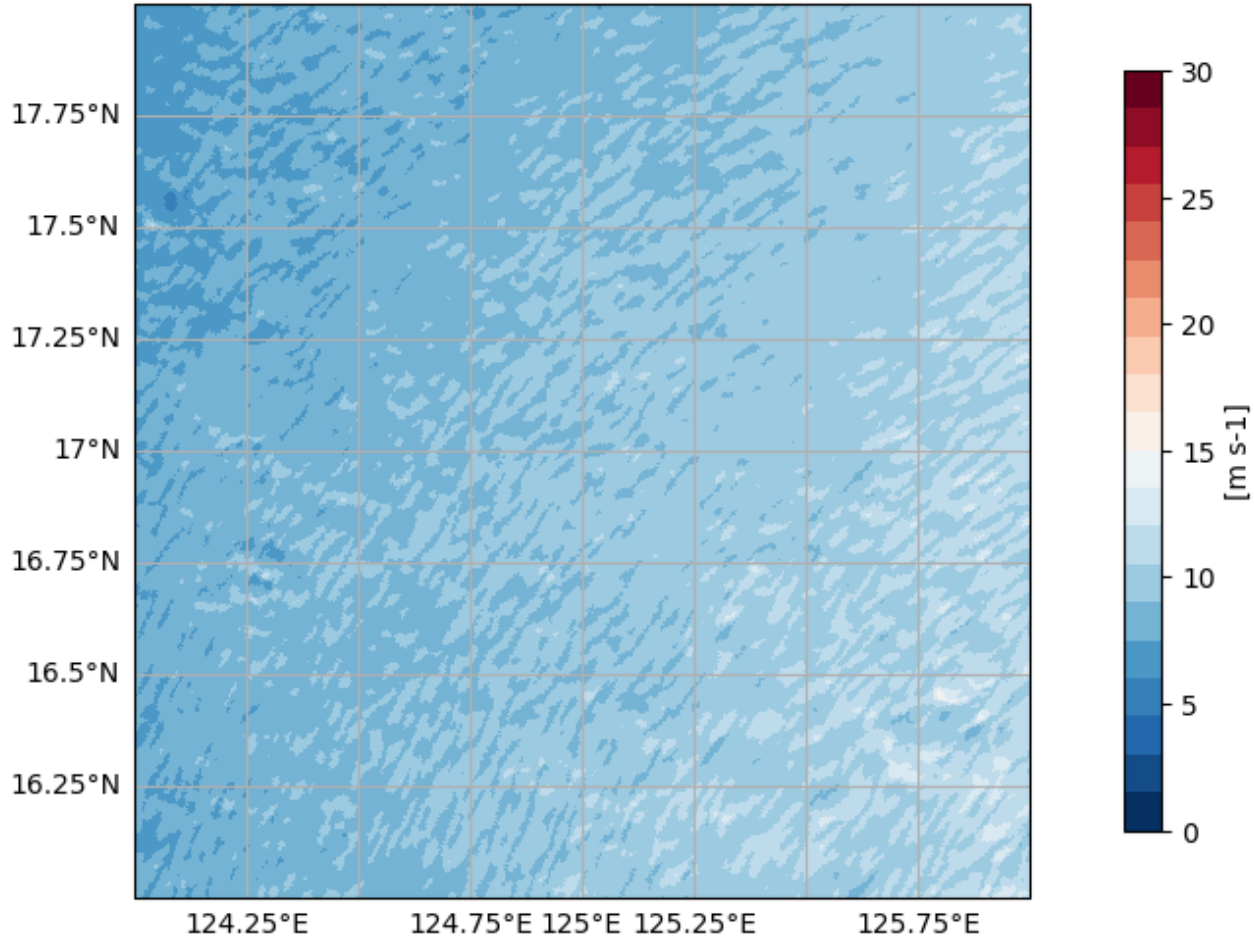
Outgoing Long-Wave Radiation (ICON-13km)
2023-07-24 17:00-18:00 42h forecast



ICON-LES wind speed 10m Typhoon Doksuri

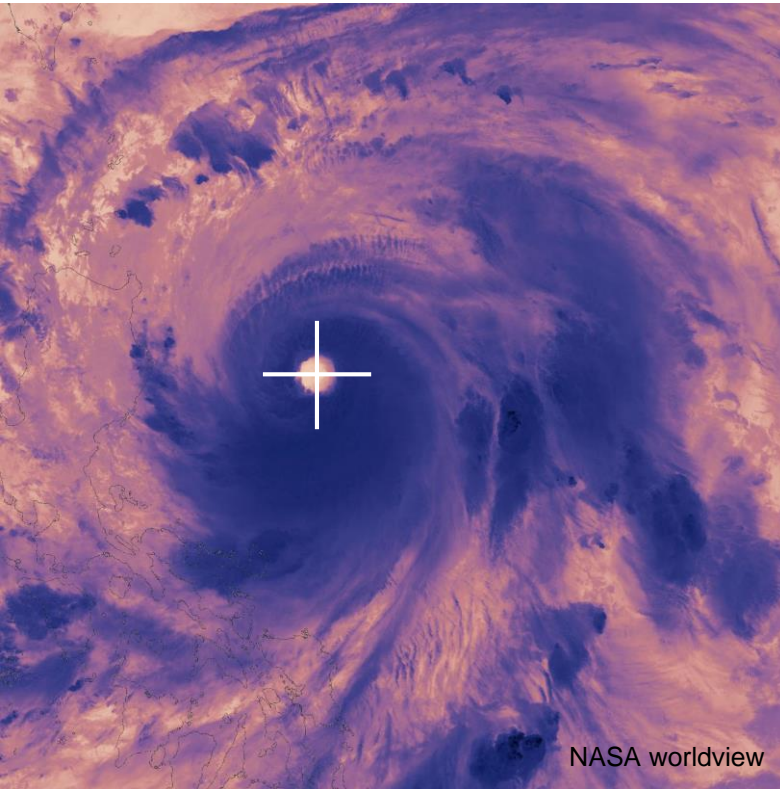


ICON exp001 dom3 wind speed in 10m 23Jul2023+06:00h



Typhoon Doksuri

Brightness Temperature (NOAA-20 VIIRS)
2023-07-24 17:20



120-133E 10-23N

NASA worldview

Outgoing Long-Wave Radiation (ICON-13km)
2023-07-24 17:00-18:00 66h forecast

