WRF modelling of low clouds in the Arctic boundary layer

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YOPP
YEAR OF POLAR PREDICTION

SAF WRF
SWEDISH ARMED FORCES WEATHER RESEARCH AND FORECASTING MODEL

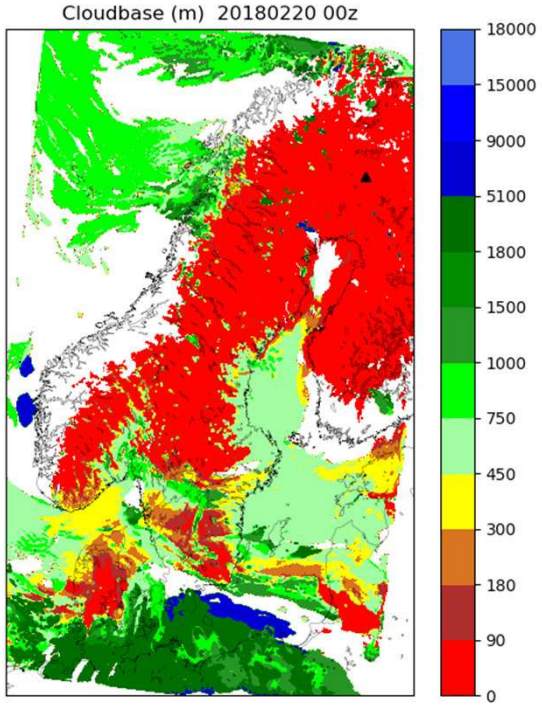
APPLICATE.eu
Advanced prediction in polar regions and beyond

Martin Hagman, MISU 191024

Outline

- Background FM – WRF – Forecast problem
- Objective
- Validation – Where, when?
- Visualisation
- What causes the problem ?
  - Resolution…
  - Interpolation…
  - Parametrization…
  - Initialisation…
- Solution?
- 3D-SCM
- Future

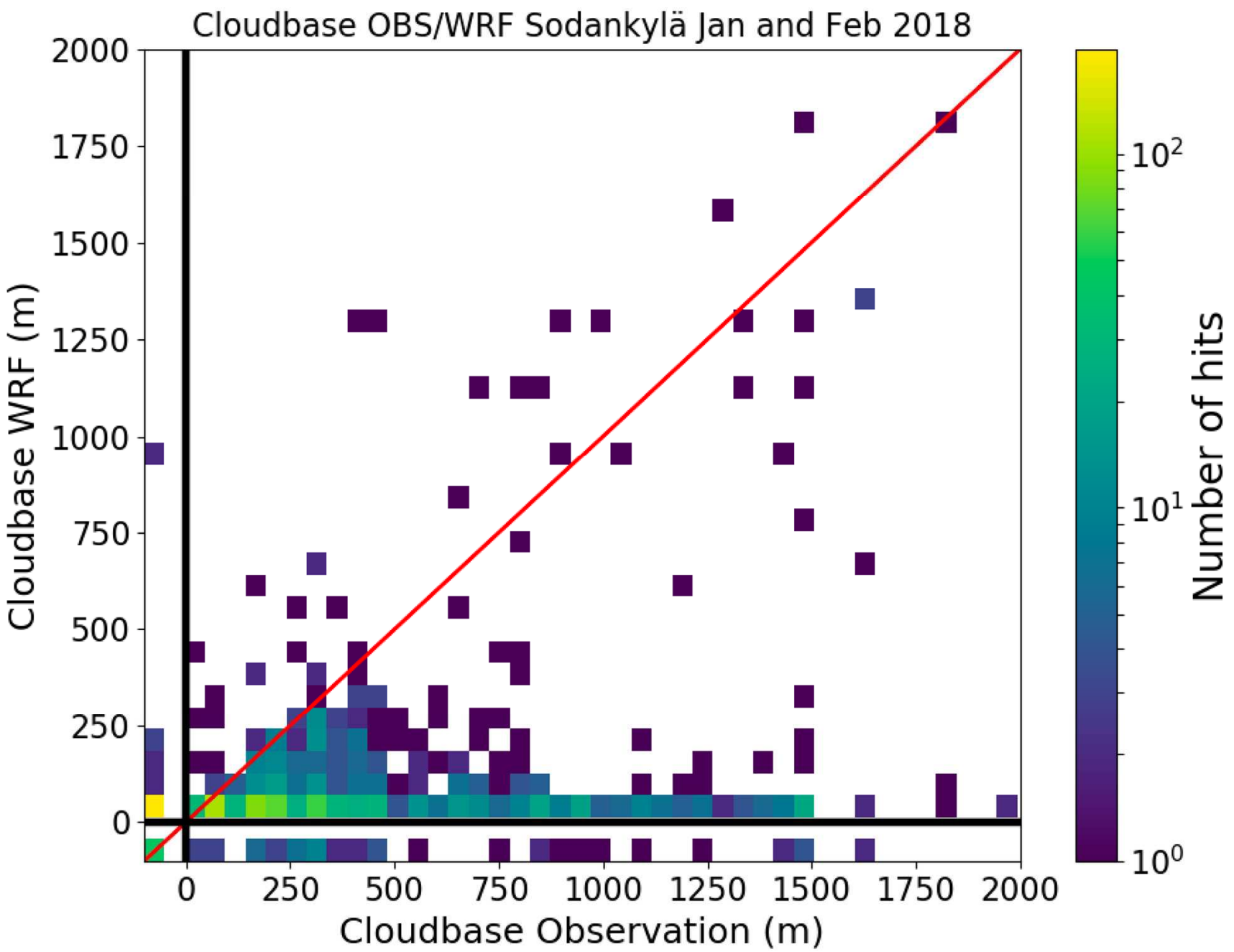
WRF 3.9.1.1 in FM – SET UP

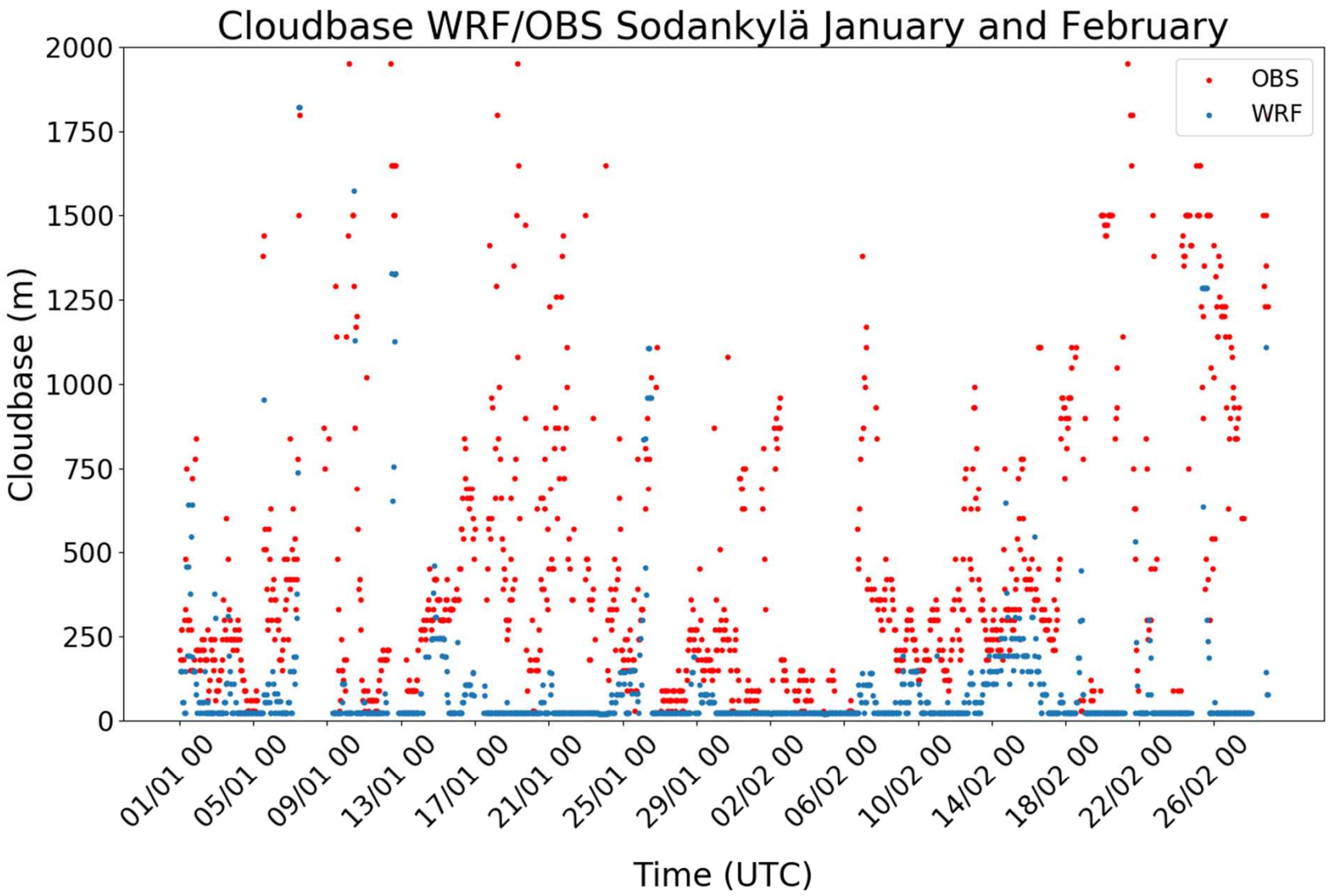


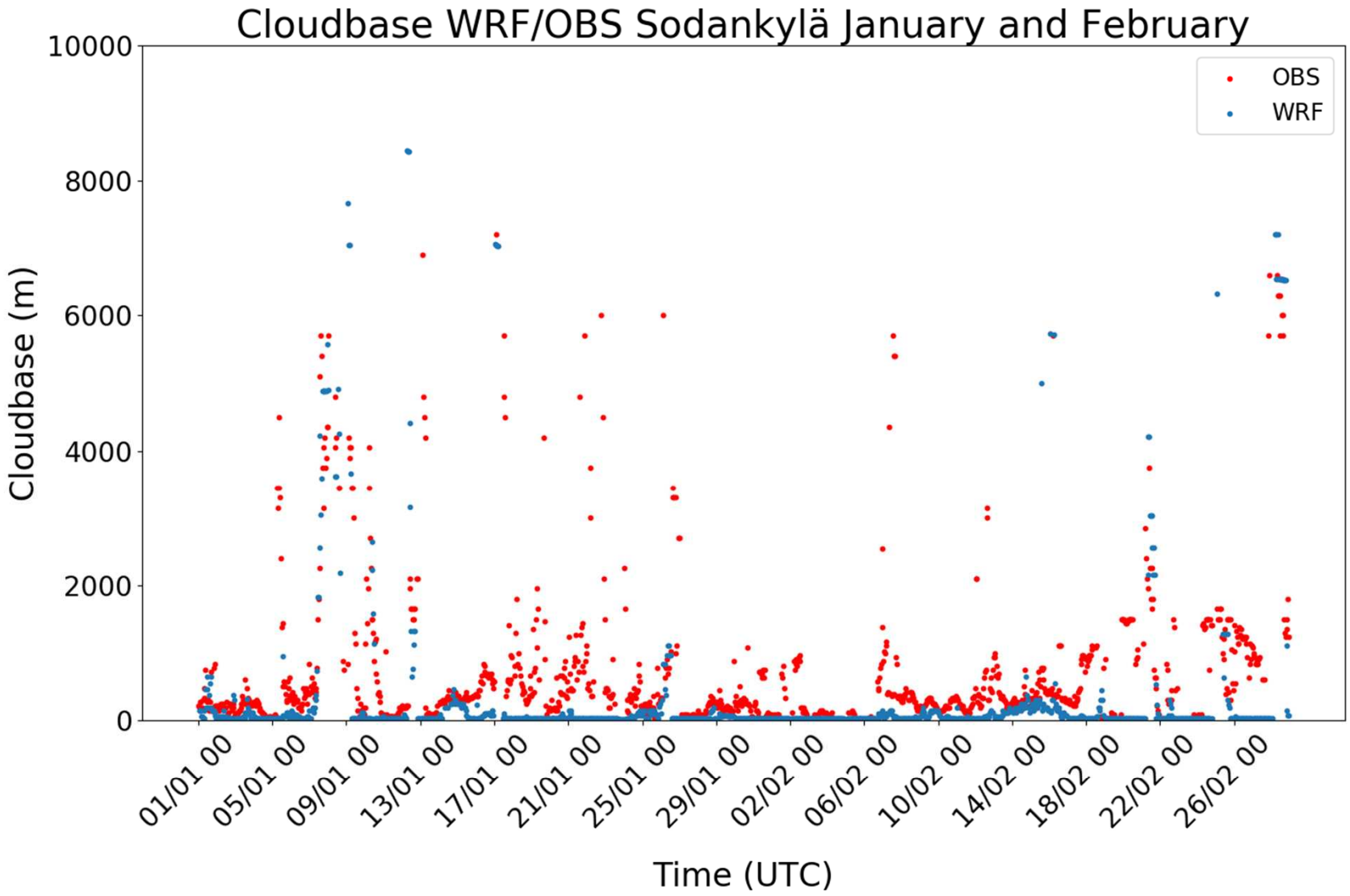
702

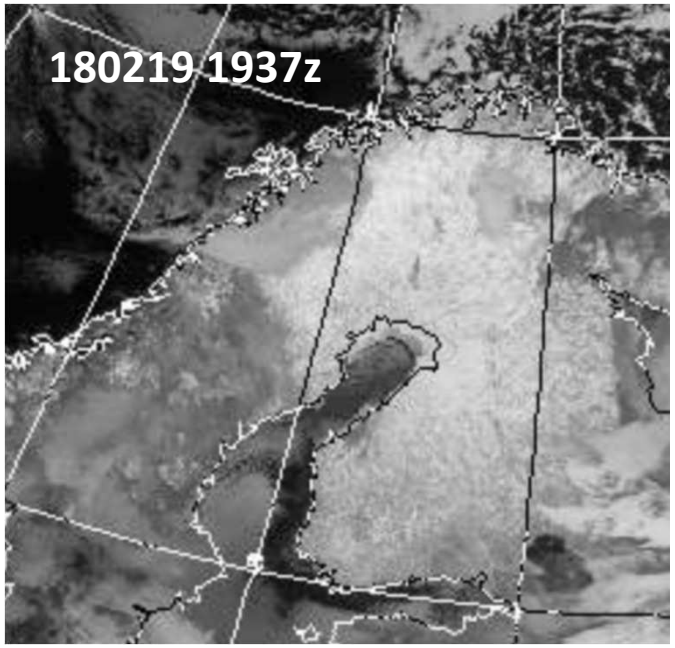
429

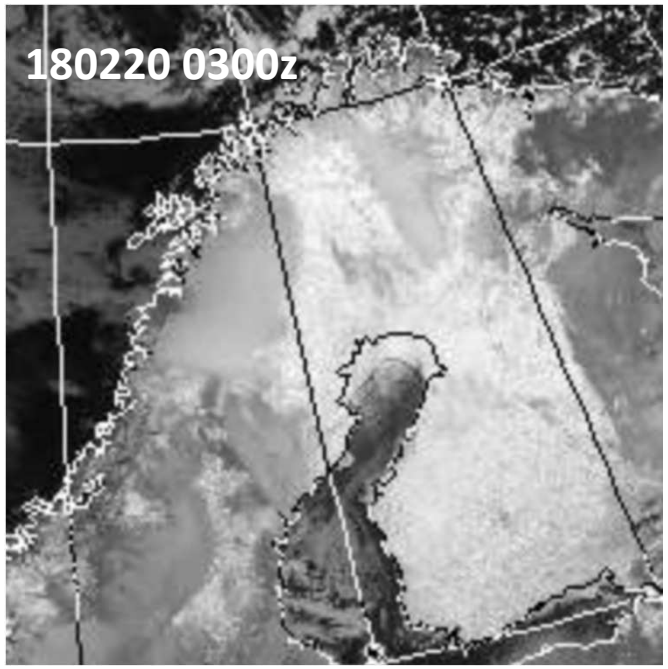
- Non-hydrostatic
- 46 vertical levels (Sigma)
- 3 km horizontal resolution
- Arakawa C-grid
- ECMWF initial and boundary conditions
- Initialised with specific humidity, not cloudwater, cloudice or cloudfraction
- Data assimilation


Cloudbase OBS/WRF Sodankylä Jan and Feb 2018
Cloudbase WRF (m)
Cloudbase Observation (m)
Number of hits
0
250
500
750
1000
1250
1500
1750
2000
10^0
10^1
10^2

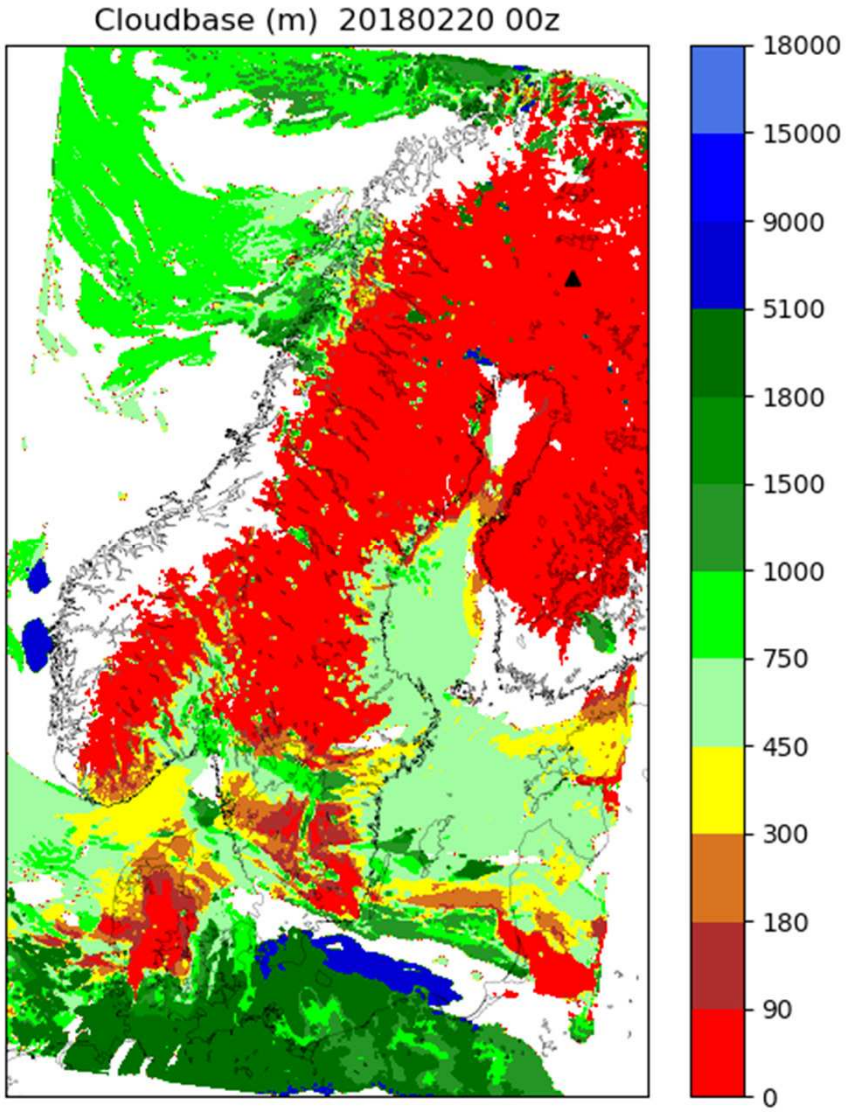

Cloudbase WRF/OBS Sodankylä January and February
OBS
WRF
Cloudbase (m)
2000
1750
1500
1250
1000
750
500
250
0
01/01 00
05/01 00
09/01 00
13/01 00
17/01 00
21/01 00
25/01 00
29/01 00
02/02 00
06/02 00
10/02 00
14/02 00
18/02 00
22/02 00
26/02 00
Time (UTC)


Cloudbase WRF/OBS Sodankylä January and February
OBS
WRF
Cloudbase (m)
10000
8000
6000
4000
2000
0
01/01 00
05/01 00
09/01 00
13/01 00
17/01 00
21/01 00
25/01 00
29/01 00
02/02 00
06/02 00
10/02 00
14/02 00
18/02 00
22/02 00
26/02 00
Time (UTC)



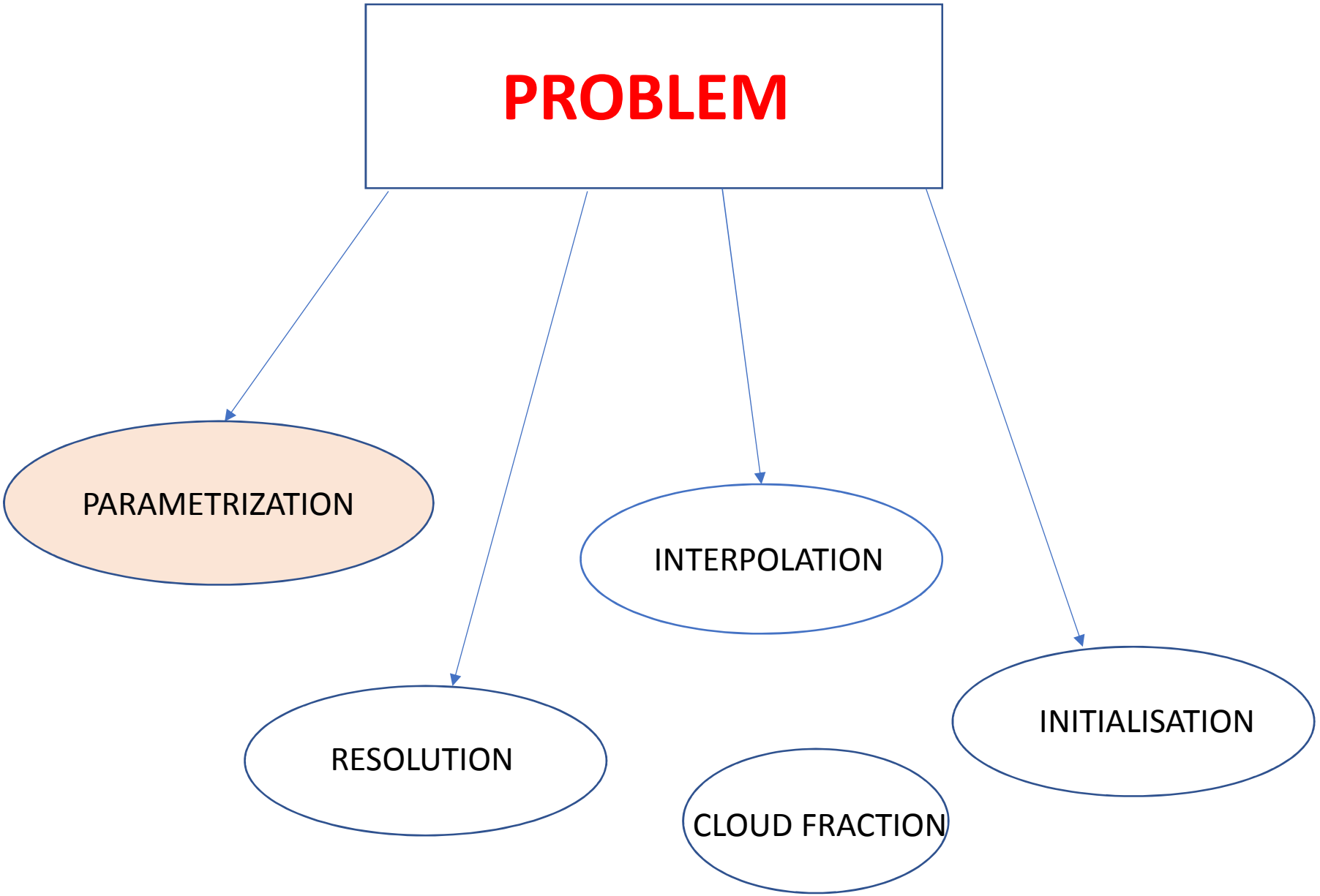


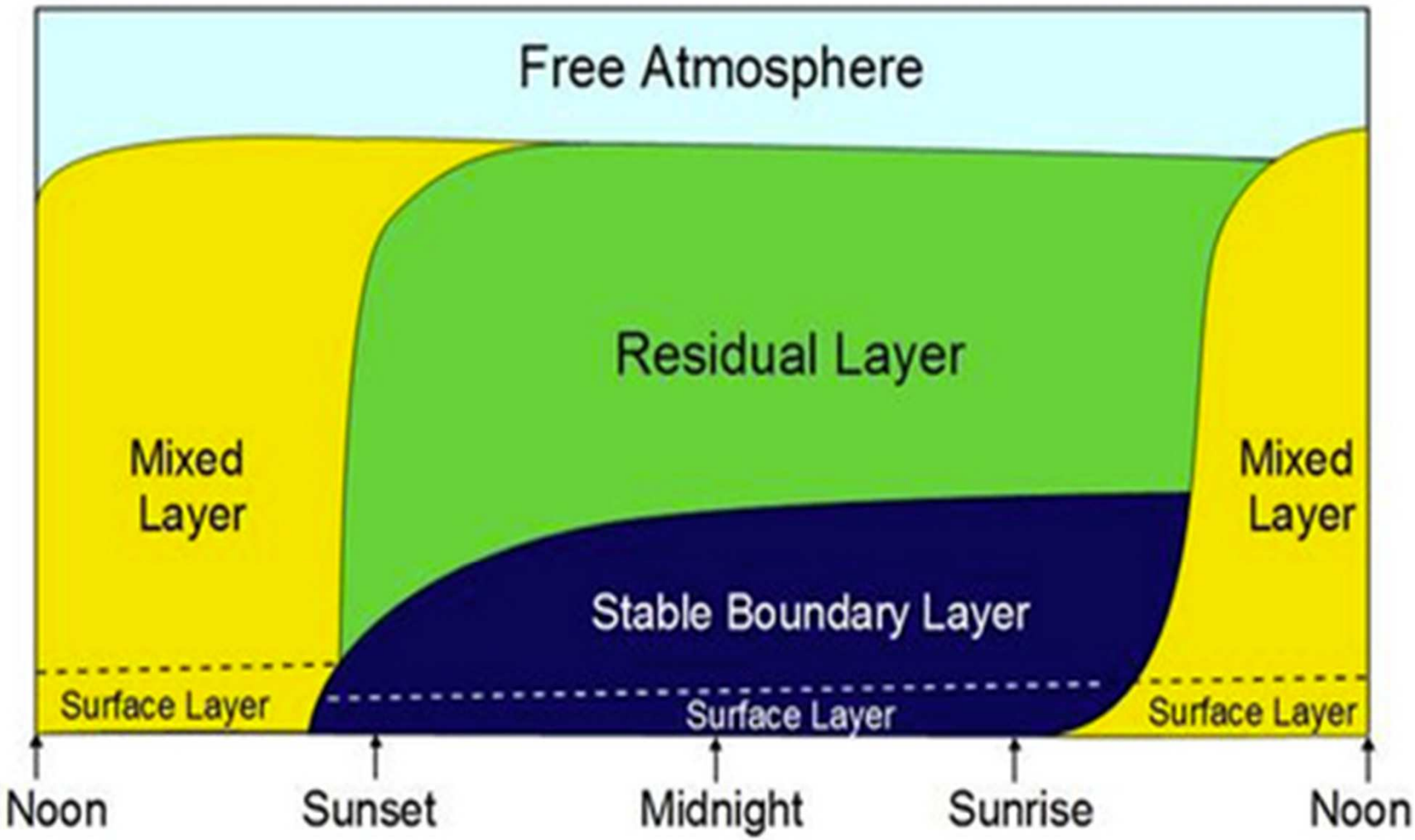
6-hour forecast 2018021918z +06



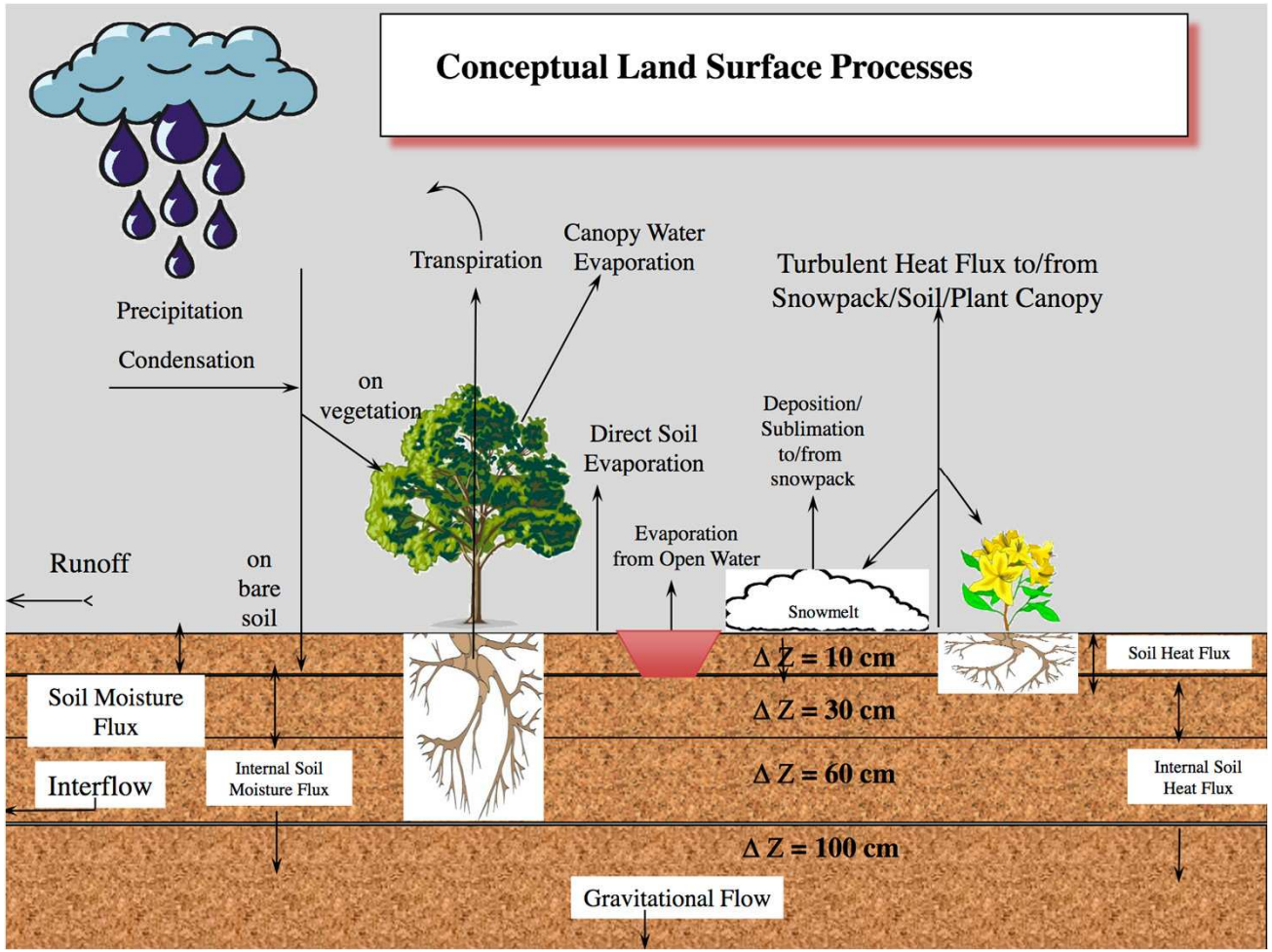
Objective

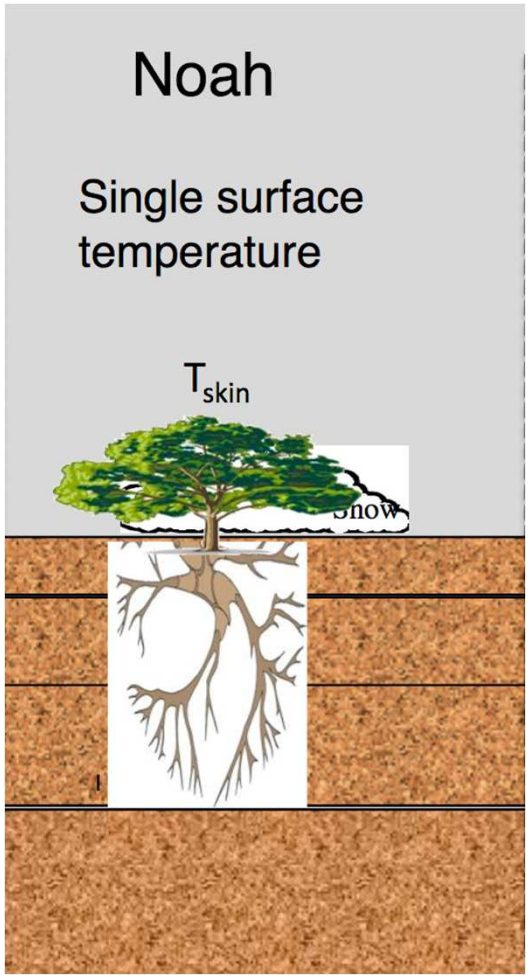
Better short range cloud forecasts!!


PROBLEM
PARAMETRIZATION
INTERPOLATION
RESOLUTION
CLOUD FRACTION
INITIALISATION


Free Atmosphere
Residual Layer
Mixed Layer
Mixed Layer
Stable Boundary Layer
Surface Layer
Surface Layer
Surface Layer
Noon
Sunset
Midnight
Sunrise
Noon

Noah Land Surface Model



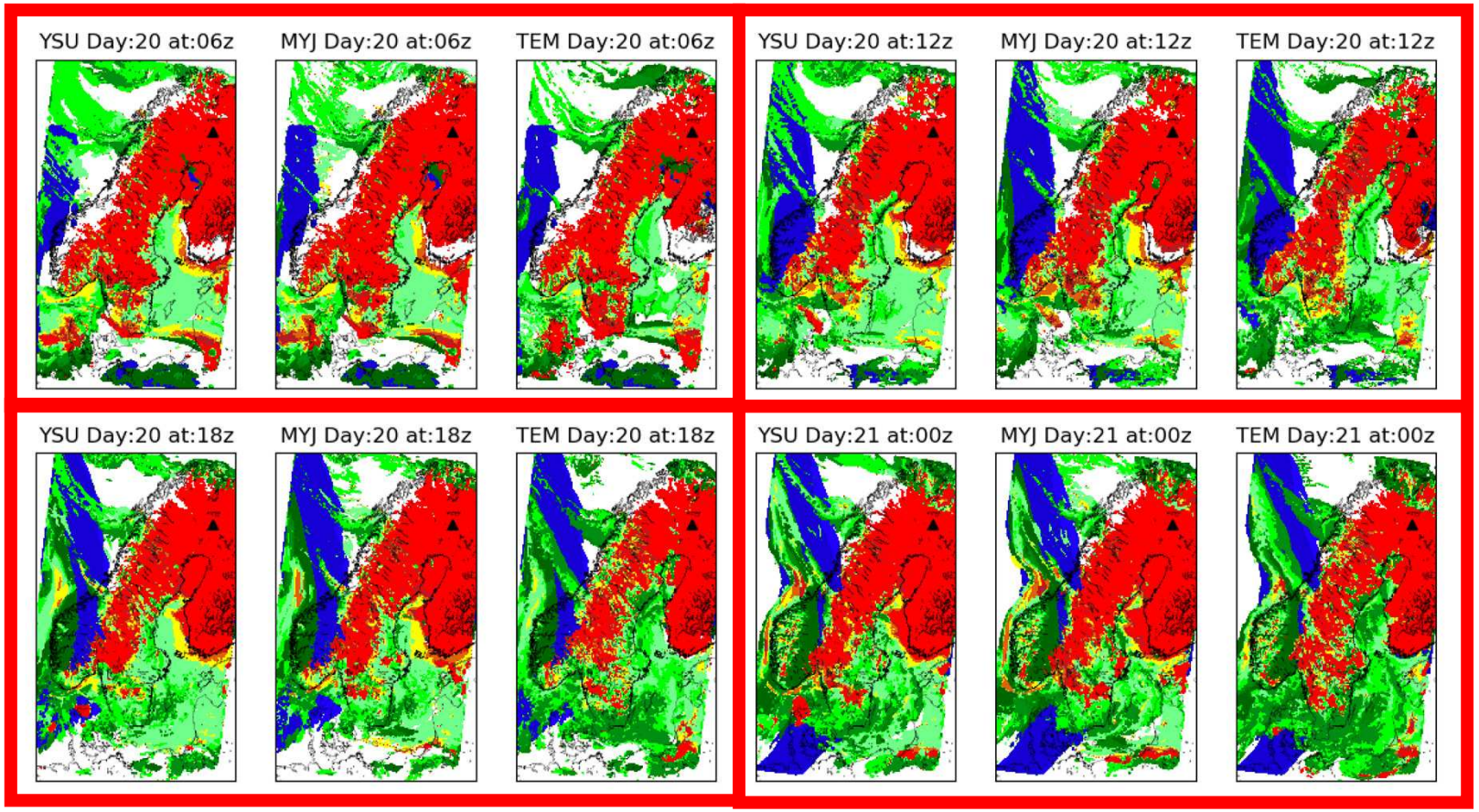


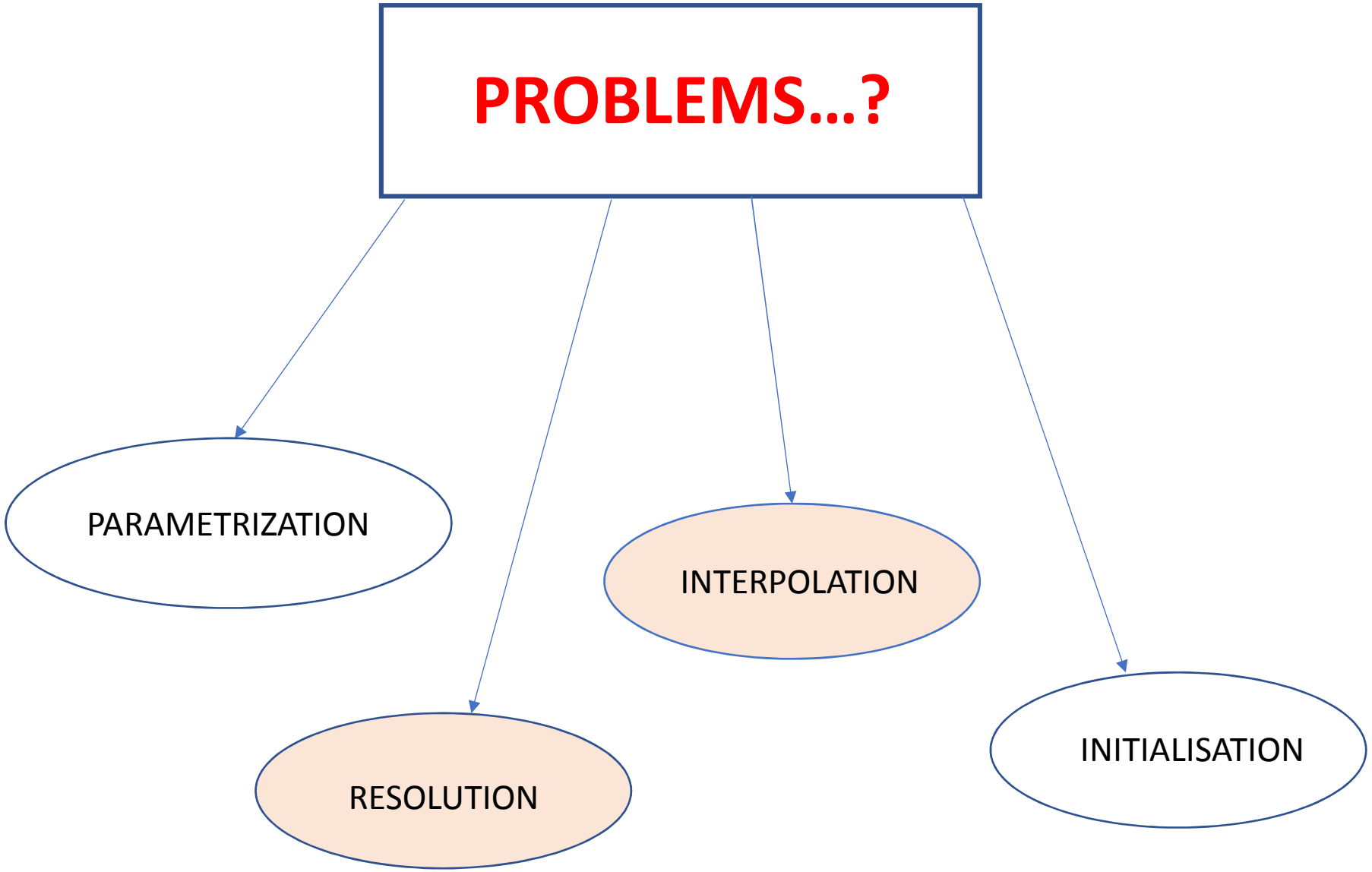
3 different PBL Parametrizations

YSU(YonSei University): Local closure, first order scheme

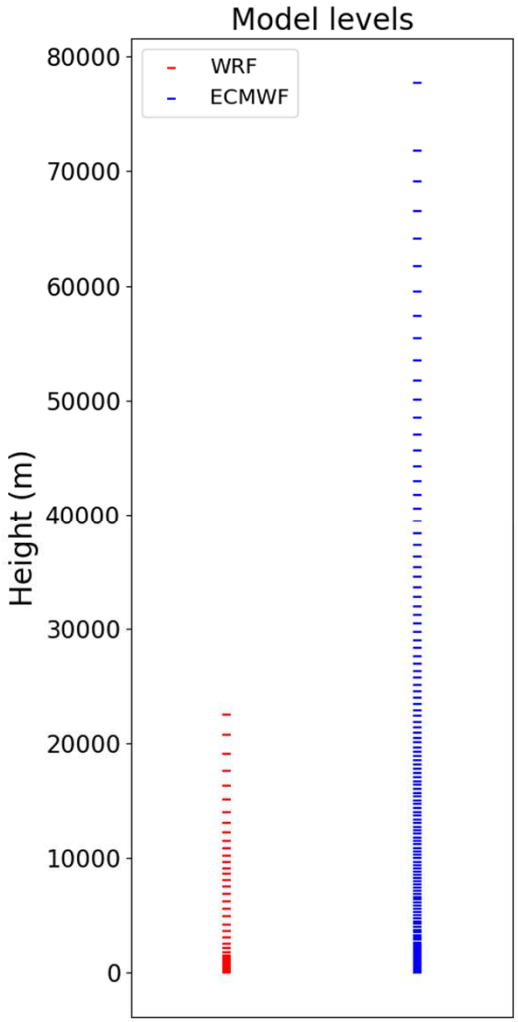
MYJ(Mellor-Yamada-Janjic): Traditional, 1.5 order, local TKE-scheme

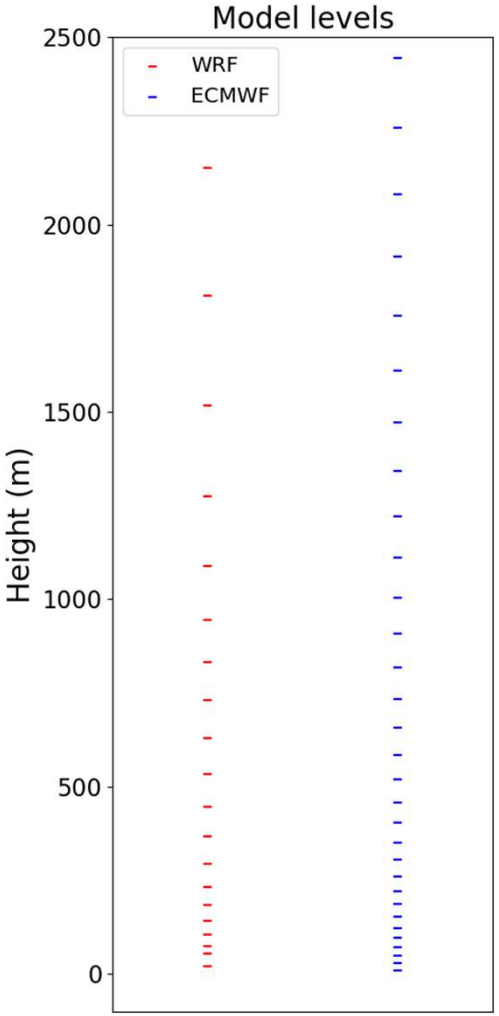
TEMF(Total Energy Mass Flux): EDMF(Eddy Diffusion Mass Flux)-type scheme



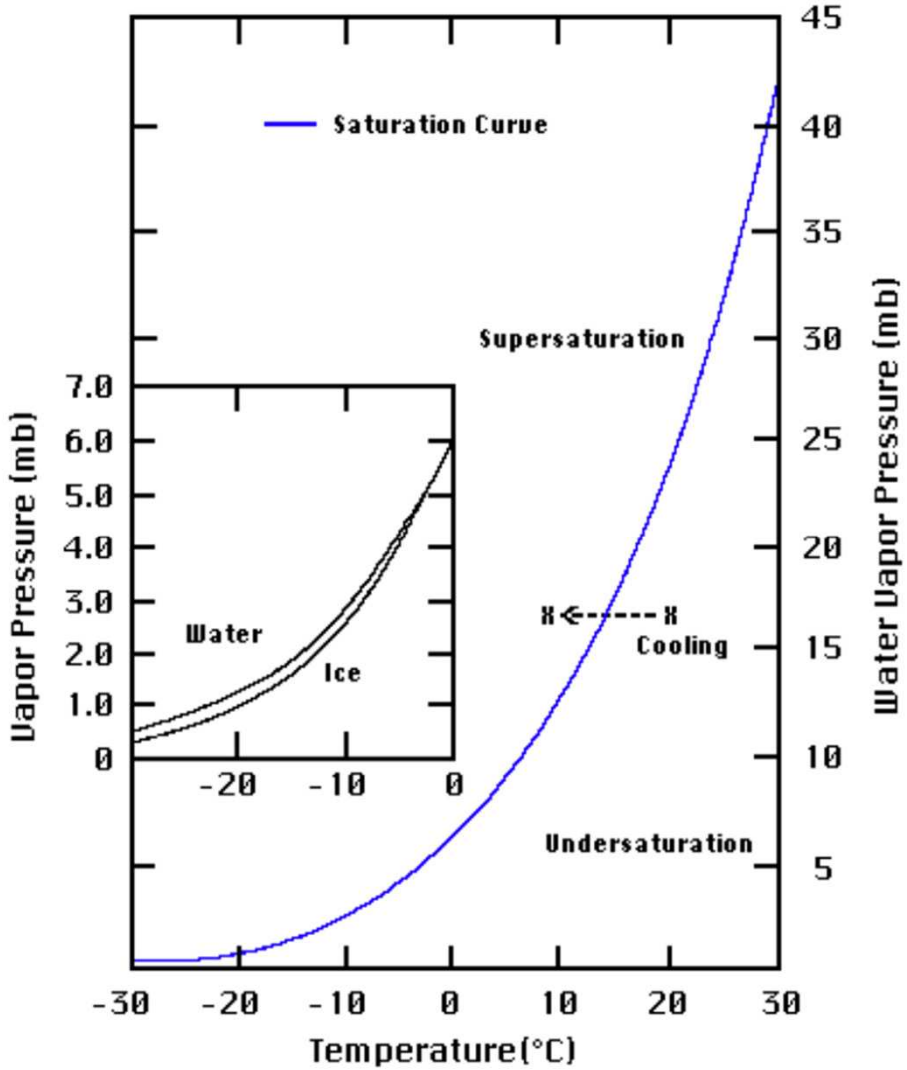

PROBLEMS…?
PARAMETRIZATION
RESOLUTION
INTERPOLATION
INITIALISATION

46 vertical levels

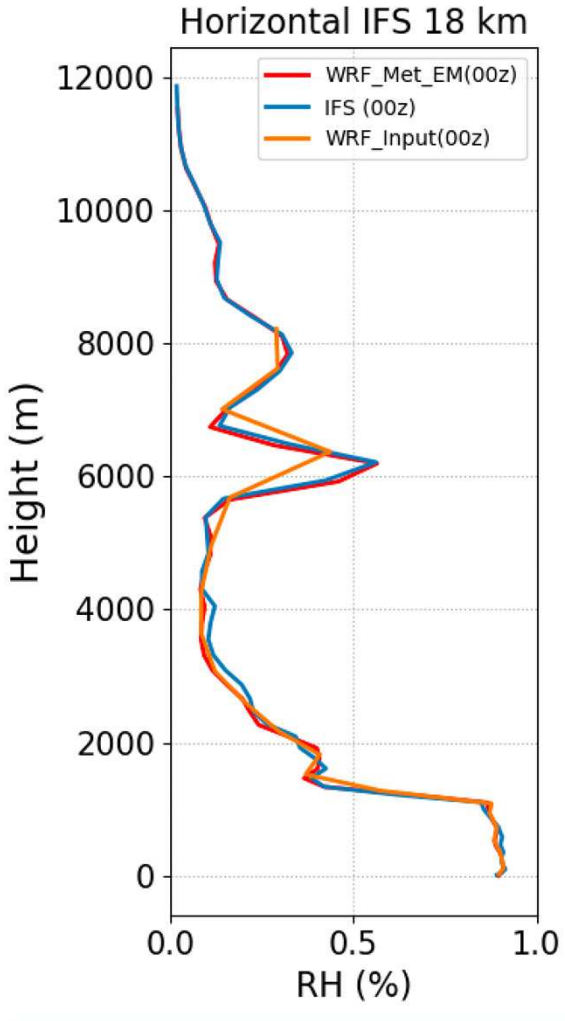


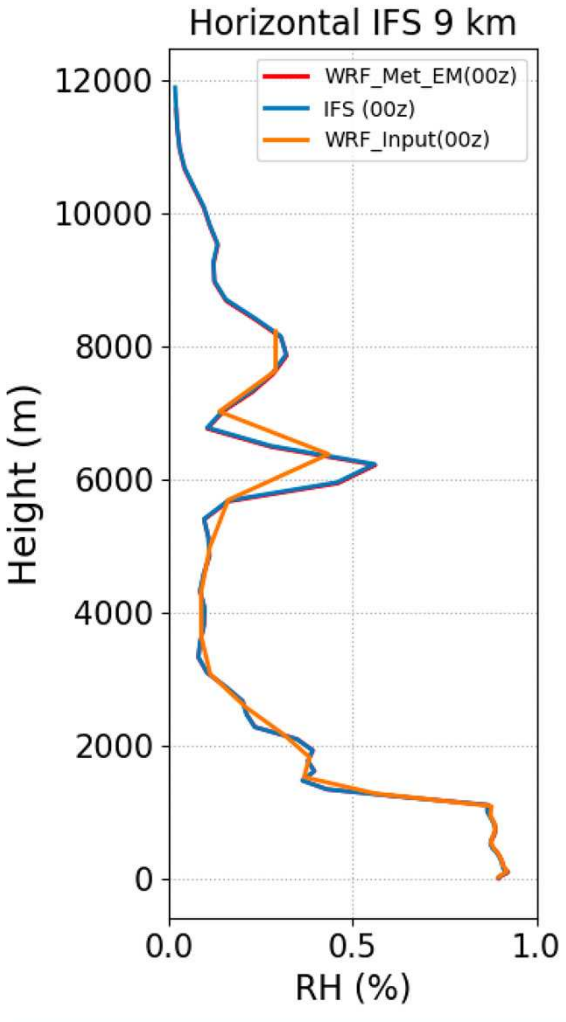


CLOUD FORMATION SENSITIVE AT LOW TEMPERATURES



Horizontal resolution IFS 18 km vs 9 km
18-02-18





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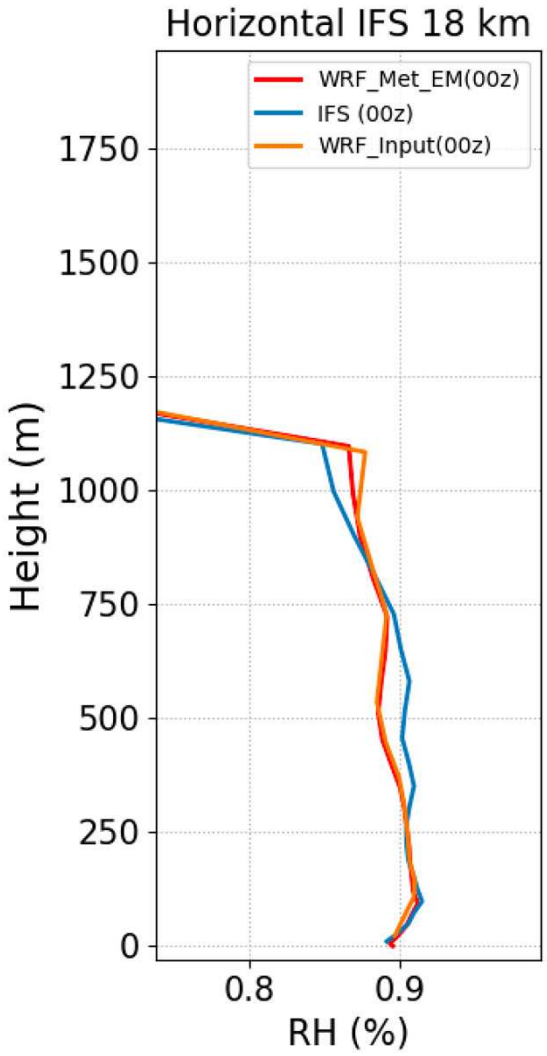
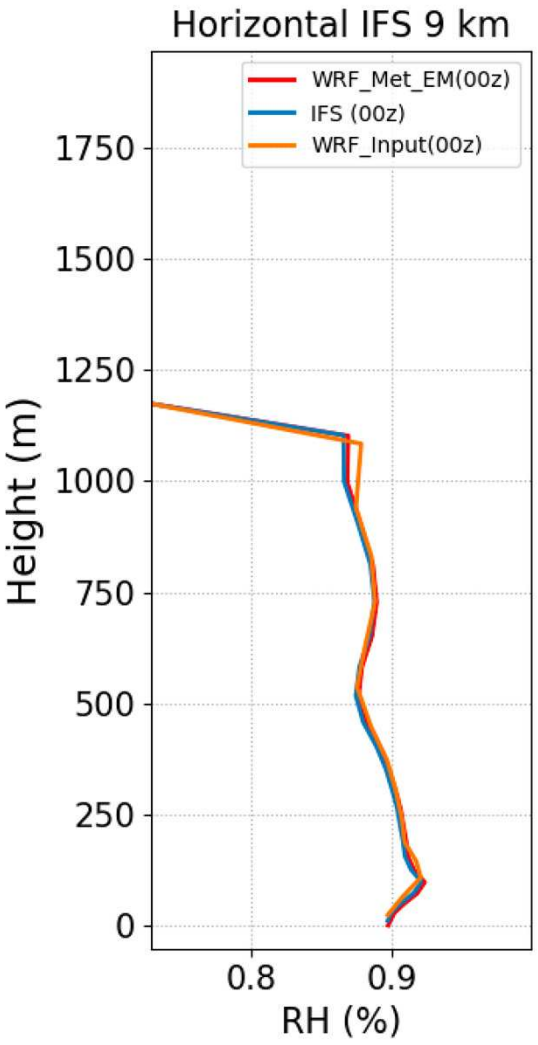
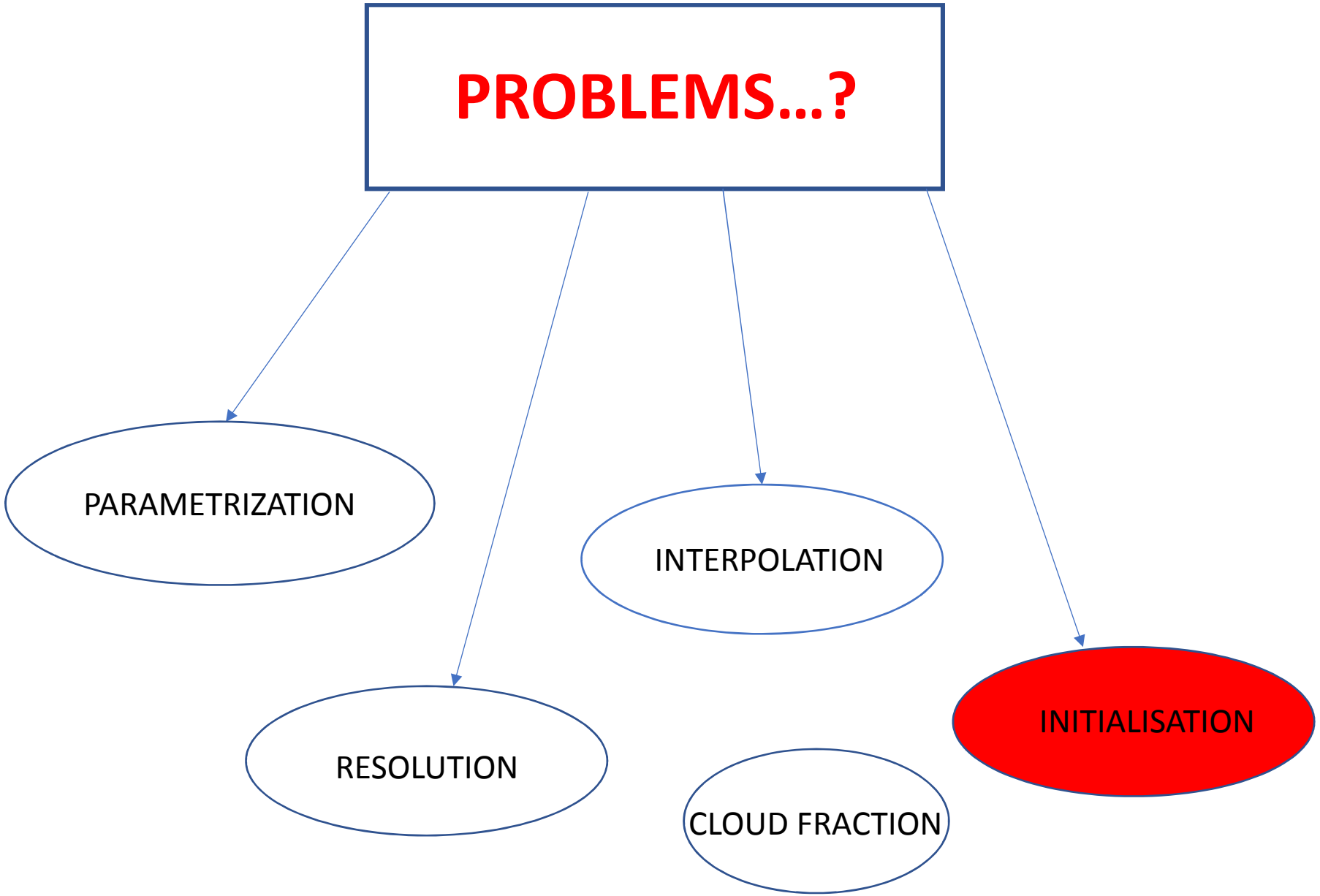
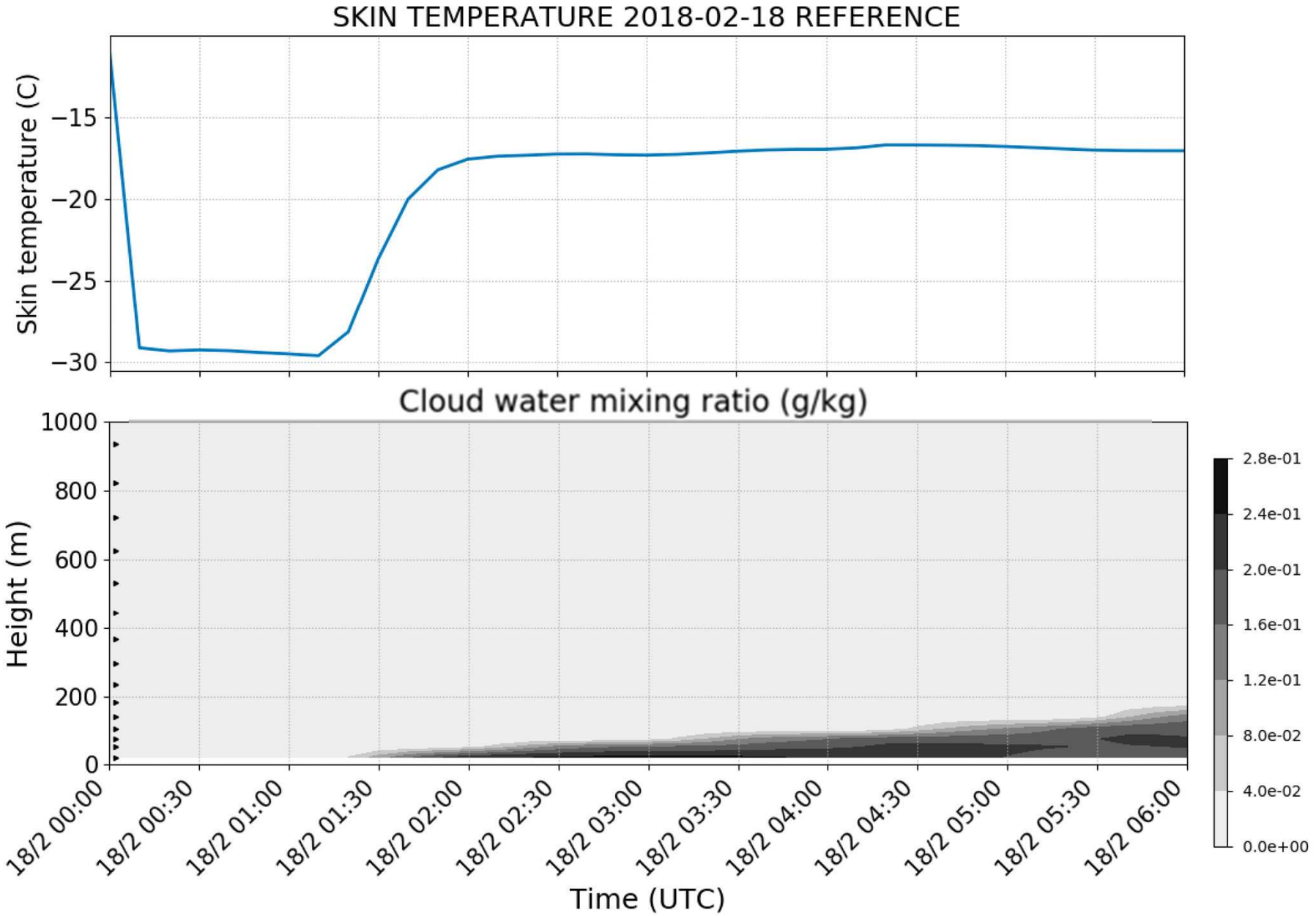


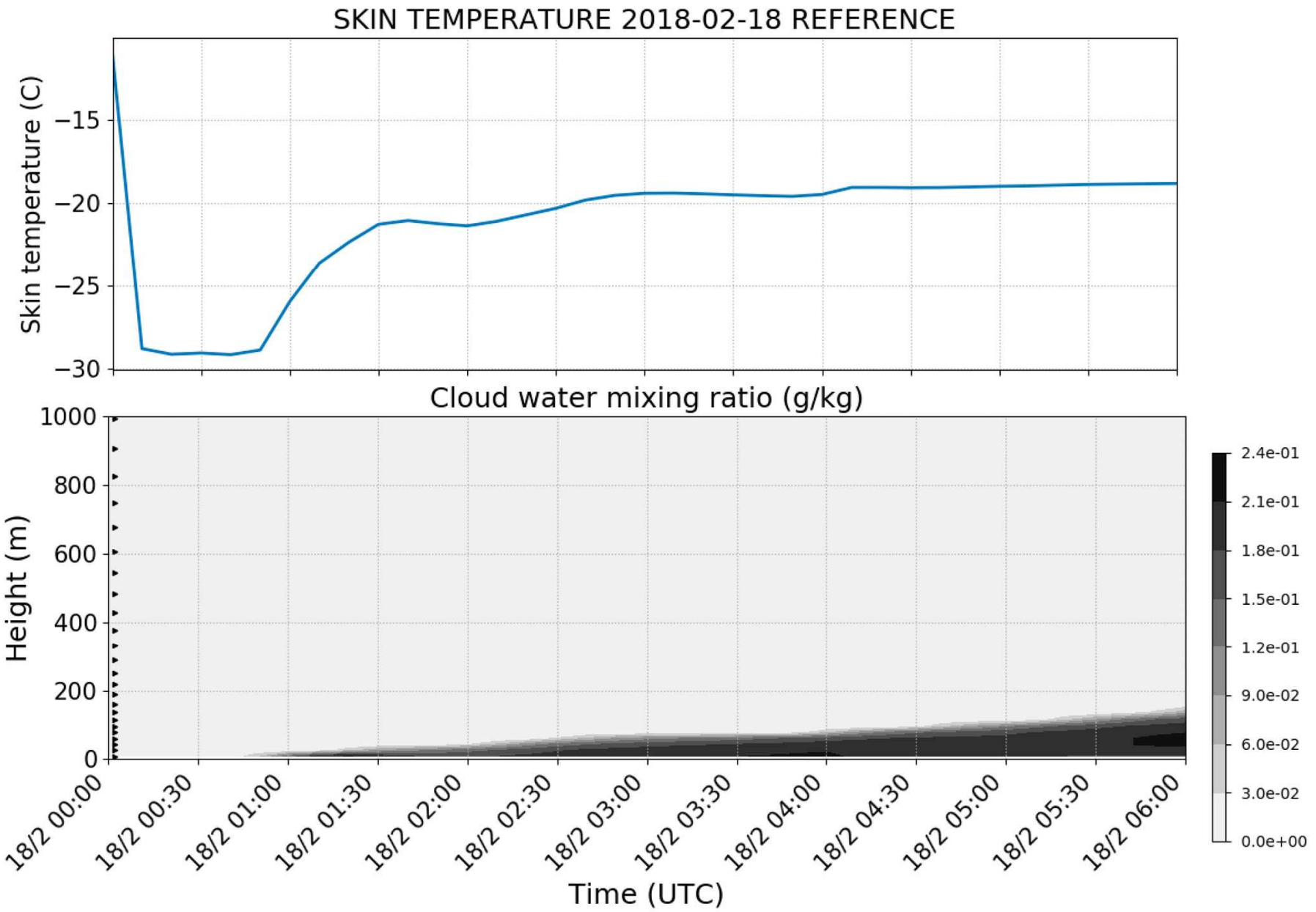



PROBLEMS…?
PARAMETRIZATION
INTERPOLATION
RESOLUTION
CLOUD FRACTION
INITIALISATION

46 LEVELS


SKIN TEMPERATURE 2018-02-18 REFERENCE
Skin temperature (C)
−15
−20
−25
−30
Cloud water mixing ratio (g/kg)
Height (m)
1000
800
600
400
200
0
18/2 00:00
18/2 00:30
18/2 01:00
18/2 01:30
18/2 02:00
18/2 02:30
18/2 03:00
18/2 03:30
18/2 04:00
18/2 04:30
18/2 05:00
18/2 05:30
18/2 06:00
Time (UTC)
2.8e-01
2.4e-01
2.0e-01
1.6e-01
1.2e-01
8.0e-02
4.0e-02
0.0e+00

91 LEVELS


SKIN TEMPERATURE 2018-02-18 REFERENCE
Skin temperature (C)
−15
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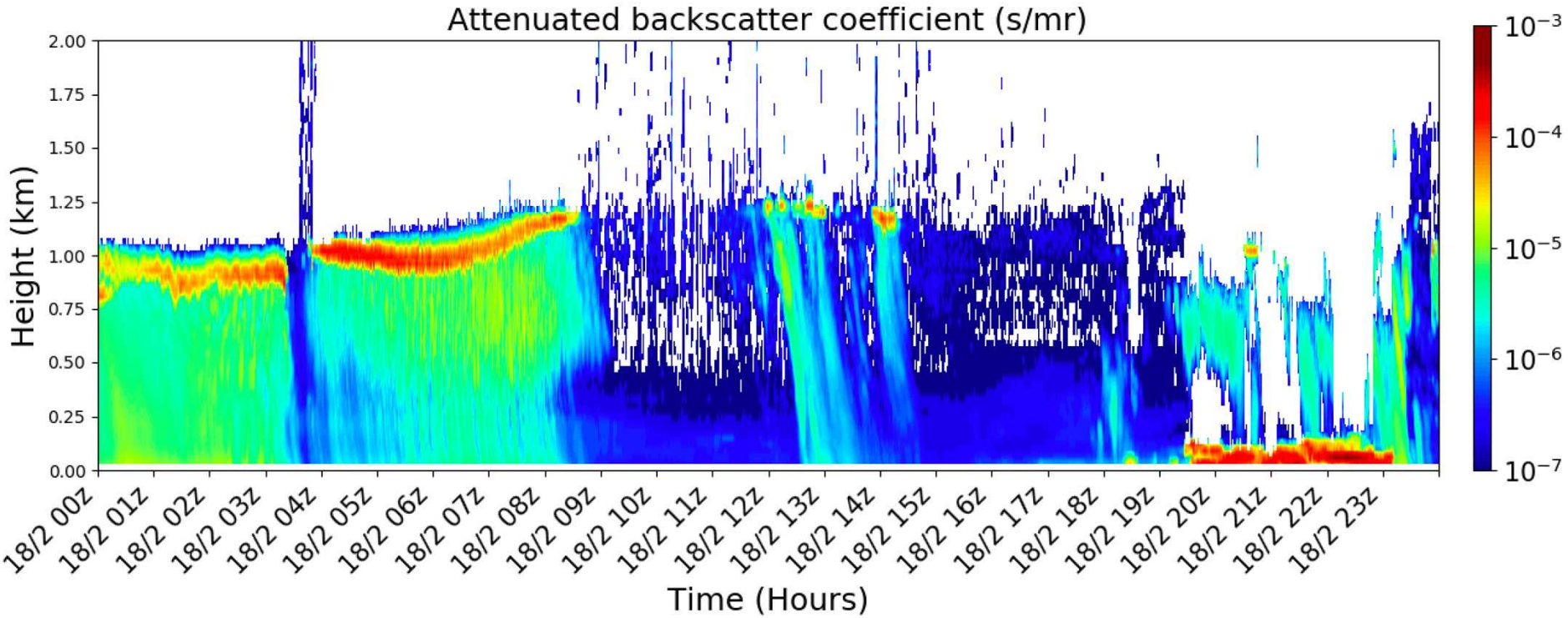
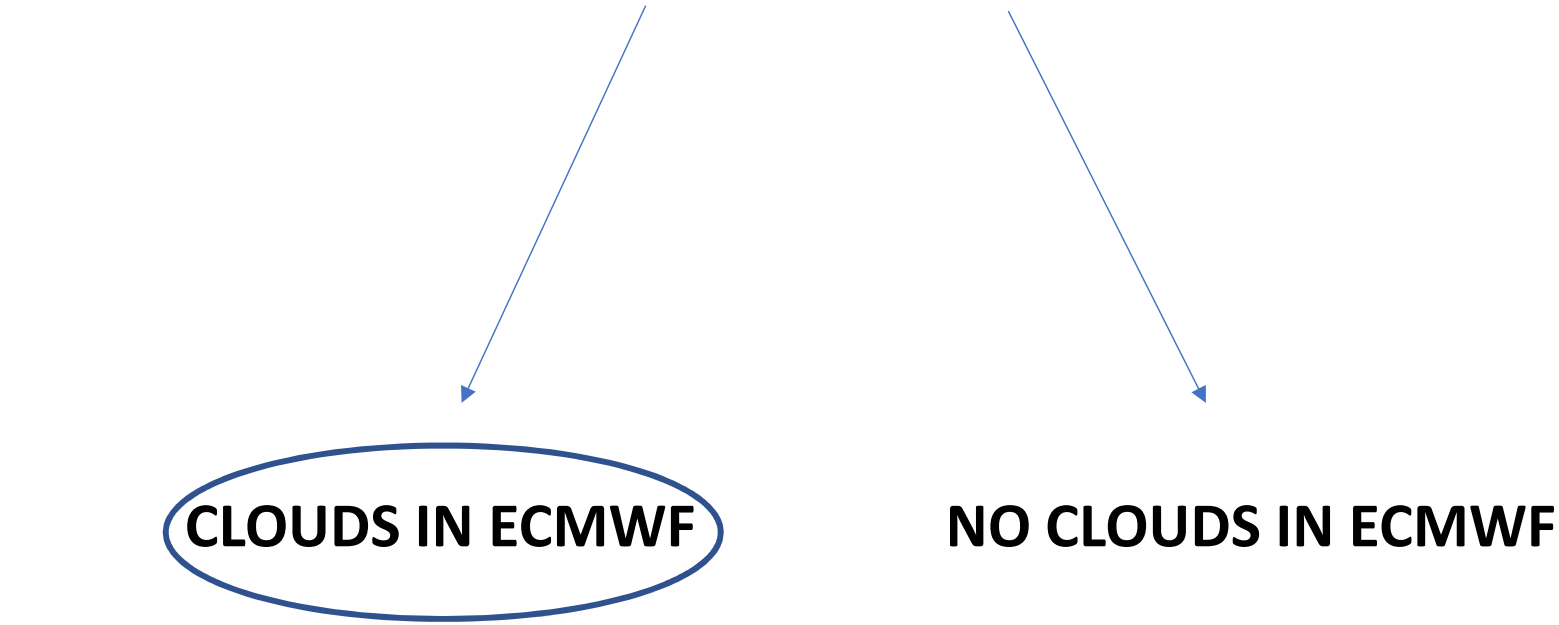
−25
−30
Cloud water mixing ratio (g/kg)
Height (m)
1000
800
600
400
200
0
18/2 00:00
18/2 00:30
18/2 01:00
18/2 01:30
18/2 02:00
18/2 02:30
18/2 03:00
18/2 03:30
18/2 04:00
18/2 04:30
18/2 05:00
18/2 05:30
18/2 06:00
Time (UTC)
2.4e-01
2.1e-01
1.8e-01
1.5e-01
1.2e-01
9.0e-02
6.0e-02
3.0e-02
0.0e+00

Reality……



….and the same clouds exist in IFS…

DIVIDE THE PROBLEM INTO 2 PARTS



How do we initialise them in WRF at time 0???

WRF SINGLE COLUMN

With a constant geostrophic wind that ”blows forever” and periodic boundary conditions (no advection).

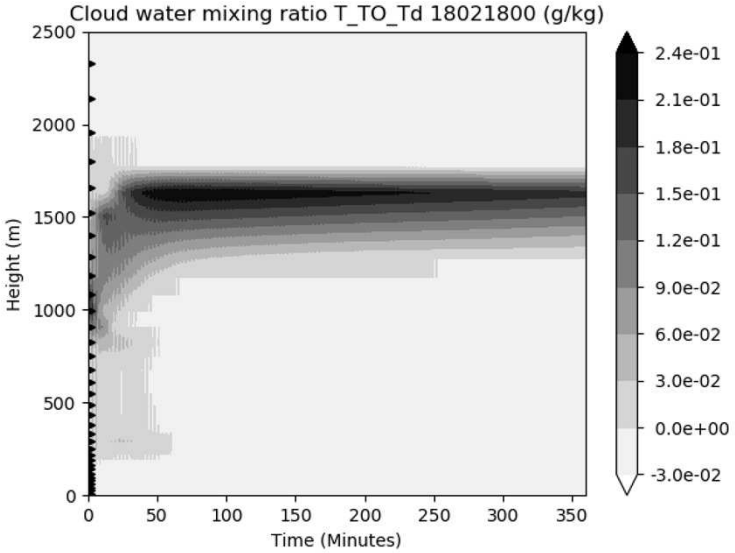
How to get them into WRF…

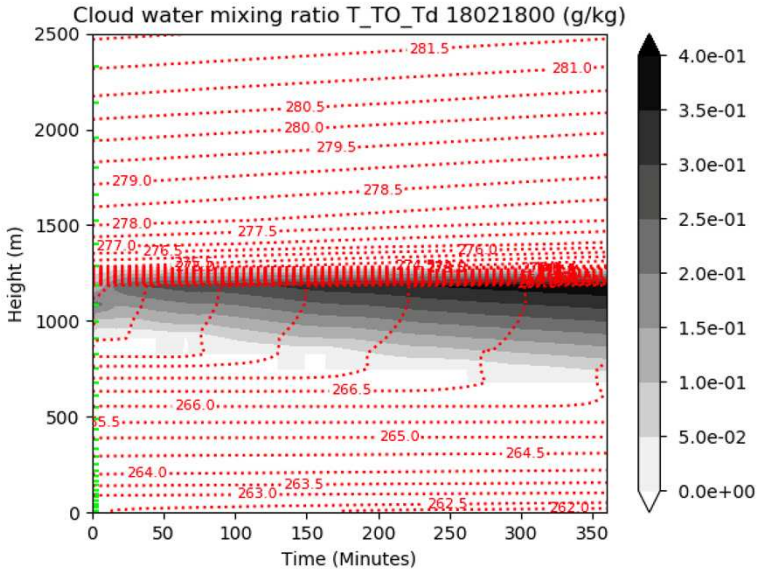
- Lower the temperature to dewpoint at levels with cloud water and cloud ice.

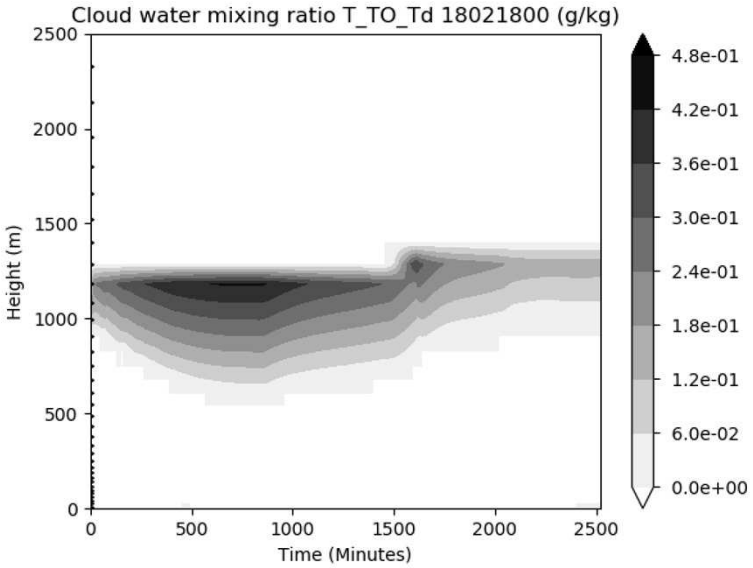
- Raise water vapor mixing ratio to saturation
- at the same levels.

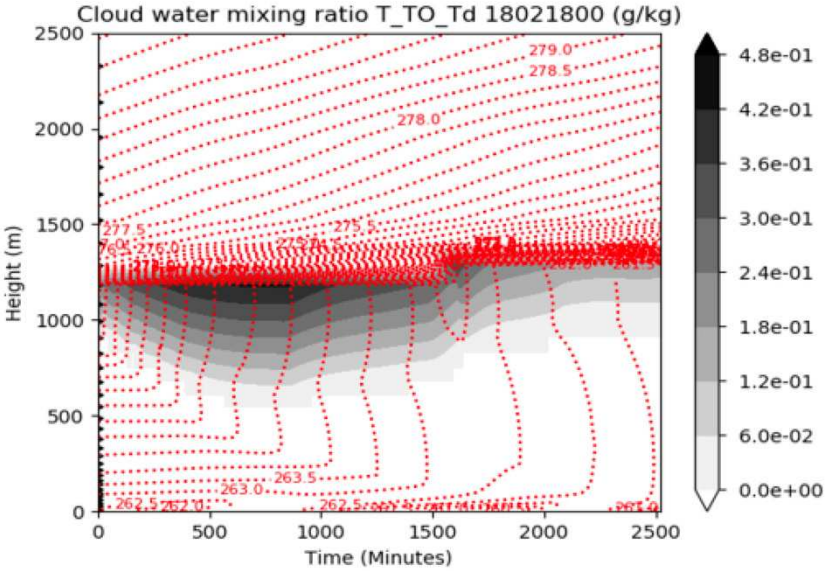
- Portion cloud water so that stratification becomes pseudoadiabatic in clouds.

Some snapshots from testing

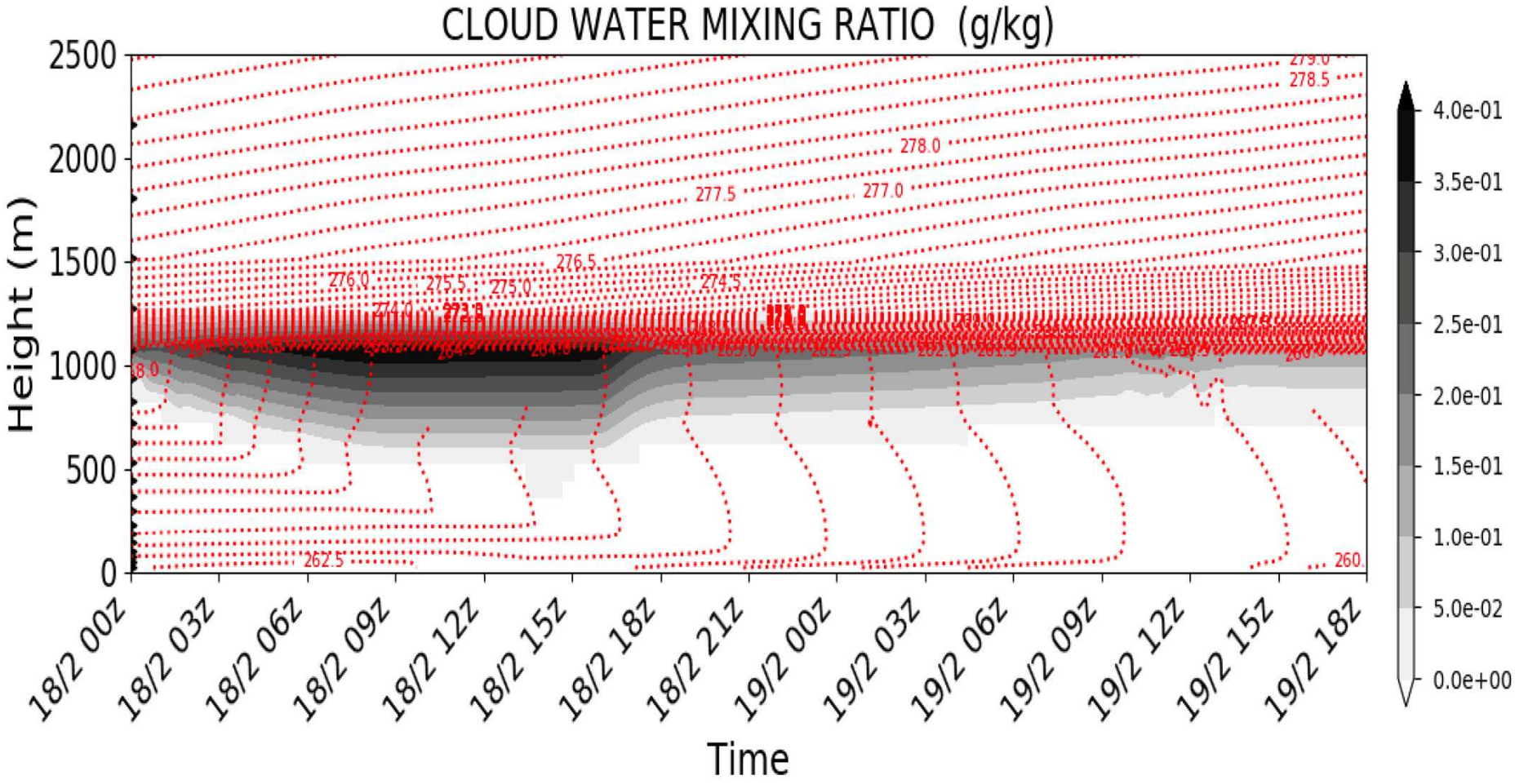




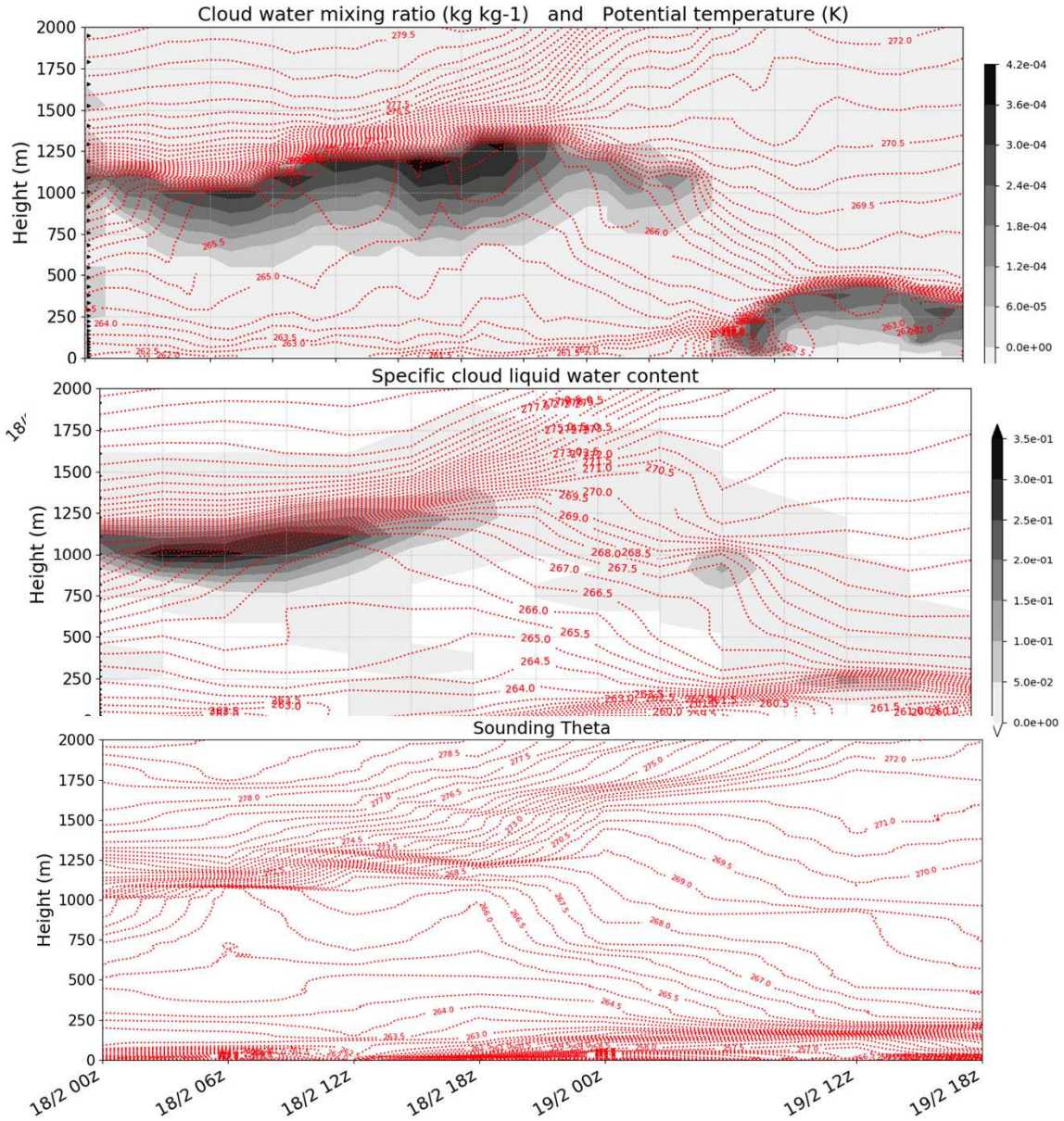




SCM


CLOUD WATER MIXING RATIO (g/kg)
Height (m)
2500
2000
1500
1000
500
0
279.0
278.5
278.0
277.5
277.0
276.5
276.0
275.5
275.0
274.5
274.0
262.5
260.
18/2 00z
18/2 03z
18/2 06z
18/2 09z
18/2 12z
18/2 15z
18/2 18z
18/2 21z
19/2 00z
19/2 03z
19/2 06z
19/2 09z
19/2 12z
19/2 15z
19/2 18z
Time
4.0e-01
3.5e-01
3.0e-01
2.5e-01
2.0e-01
1.5e-01
1.0e-01
5.0e-02
0.0e+00

Back to WRF 3D

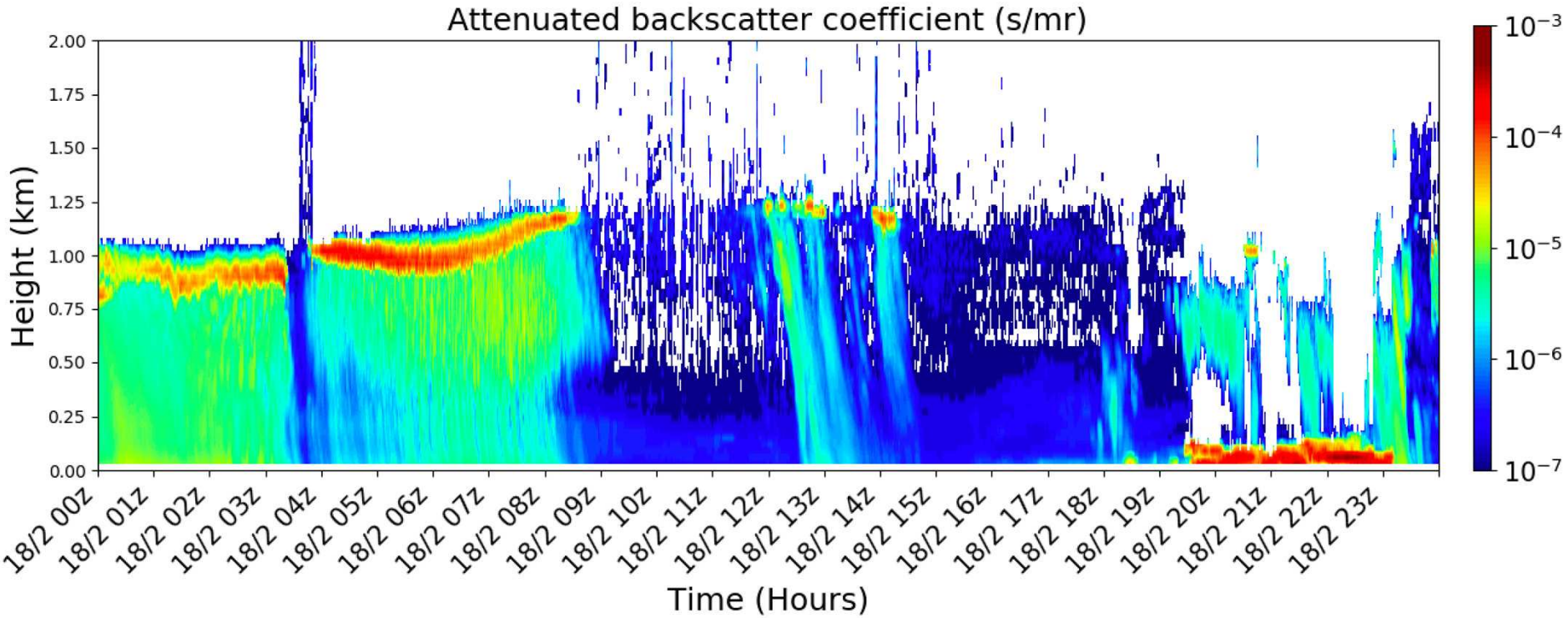


WRF

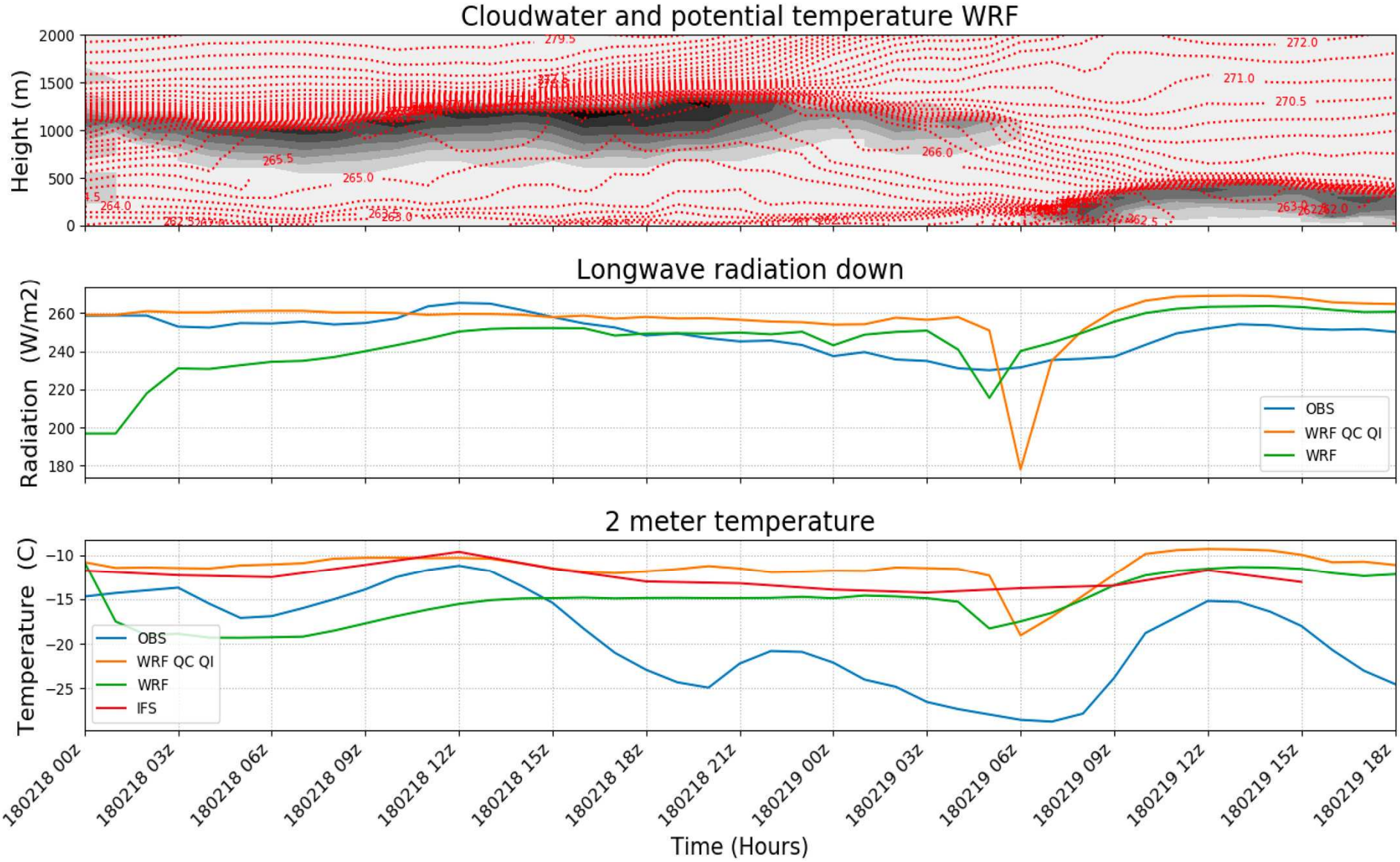
IFS

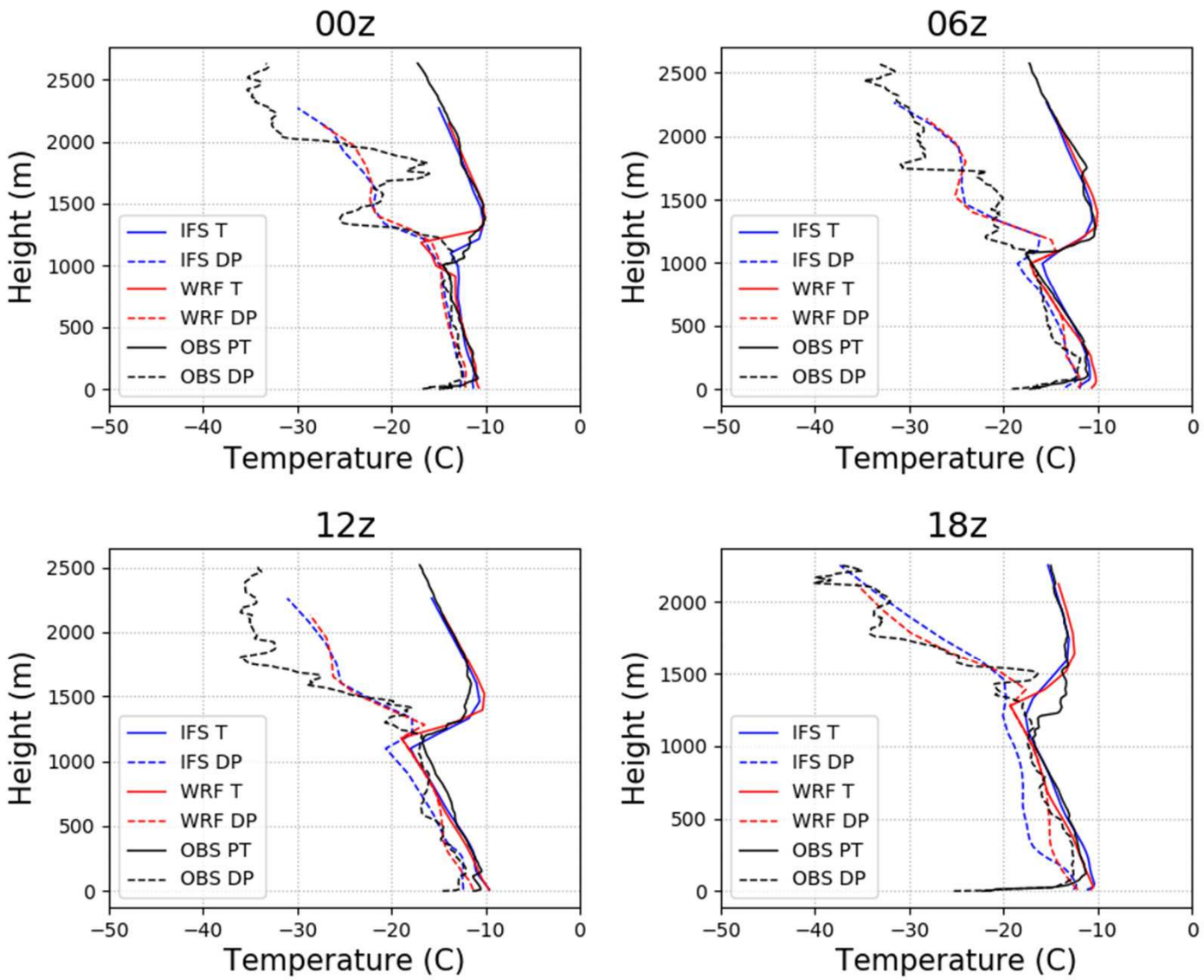
Reality

Reality

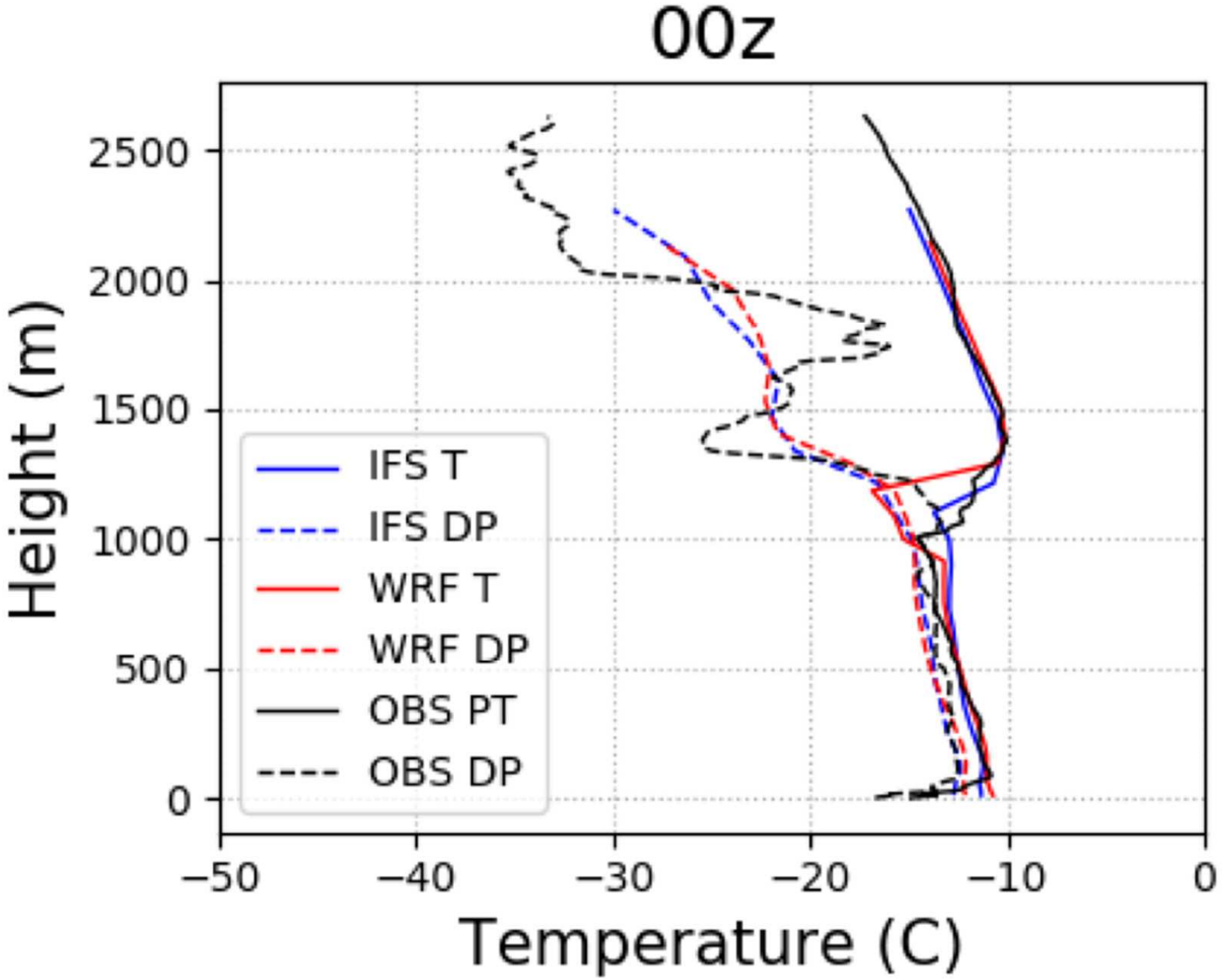

Attenuated backscatter coefficient (s/mr)
Height (km)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
18/2 00z
18/2 01z
18/2 02z
18/2 03z
18/2 04z
18/2 05z
18/2 06z
18/2 07z
18/2 08z
18/2 09z
18/2 10z
18/2 11z
18/2 12z
18/2 13z
18/2 14z
18/2 15z
18/2 16z
18/2 17z
18/2 18z
18/2 19z
18/2 20z
18/2 21z
18/2 22z
18/2 23z
Time (Hours)

Cloud water and lw radiation

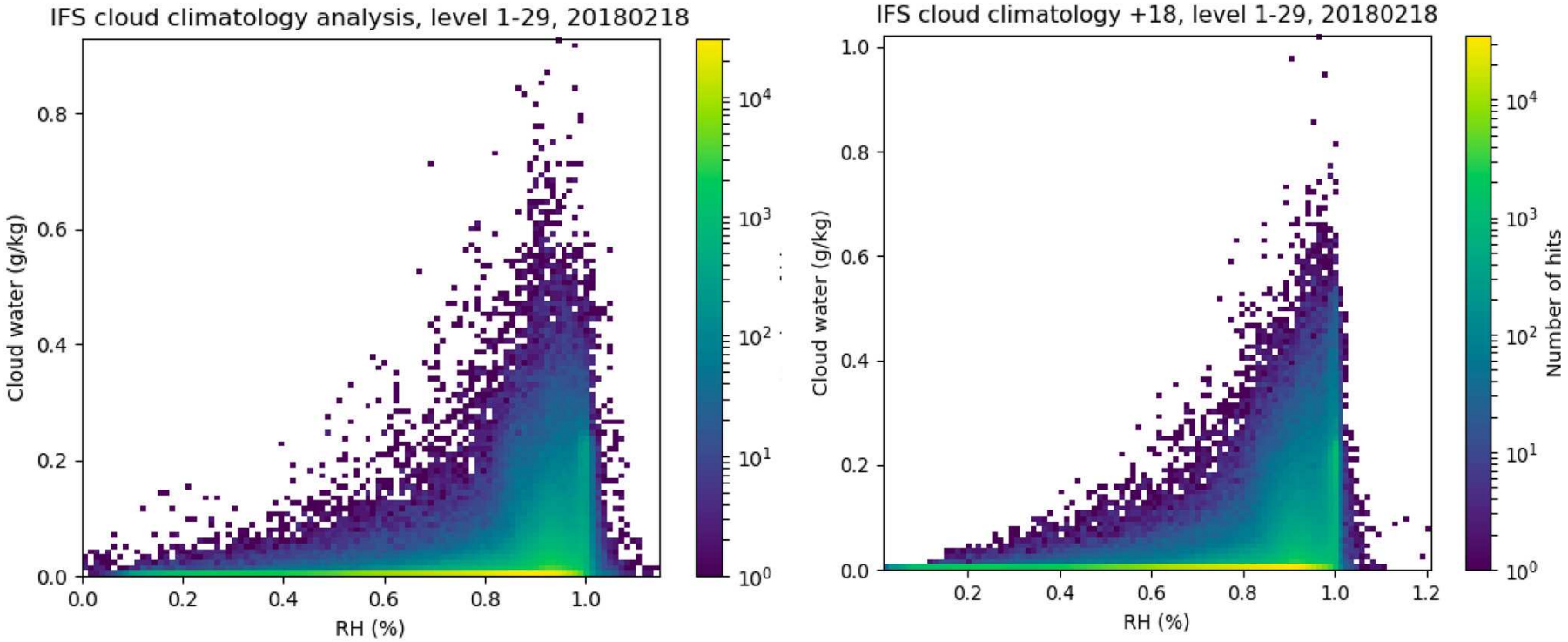



Temperature and Dewpoint 2018-02-18
00z
06z
12z
18z
Height (m)
Temperature (C)
IFS T
IFS DP
WRF T
WRF DP
OBS PT
OBS DP
0
500
1000
1500
2000
2500
−50
−40
−30
−20
−10
0

Cloud climatology IFS vs WRF

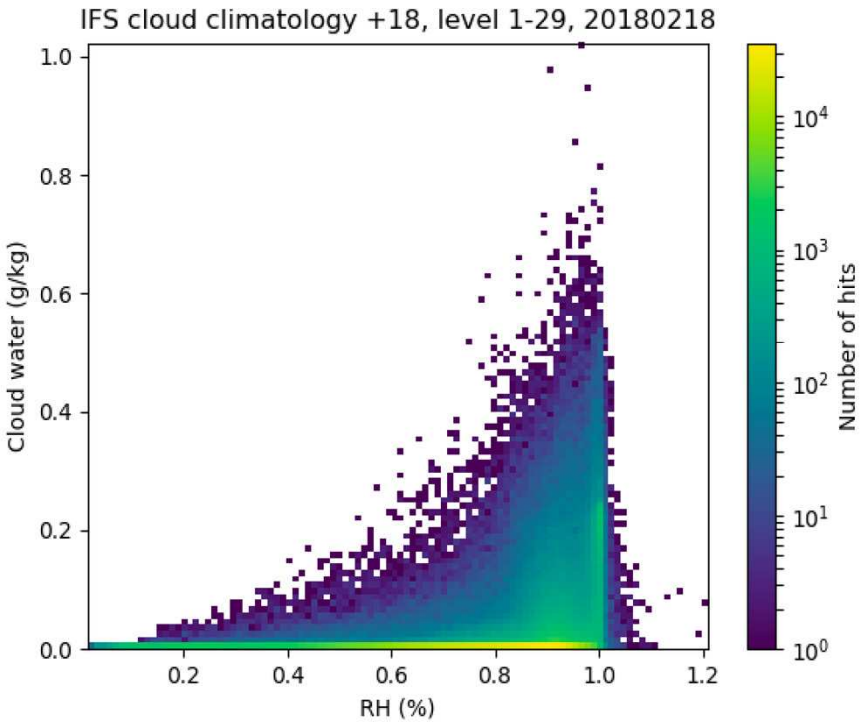


IFS CLOUD CLIMATOLOGY

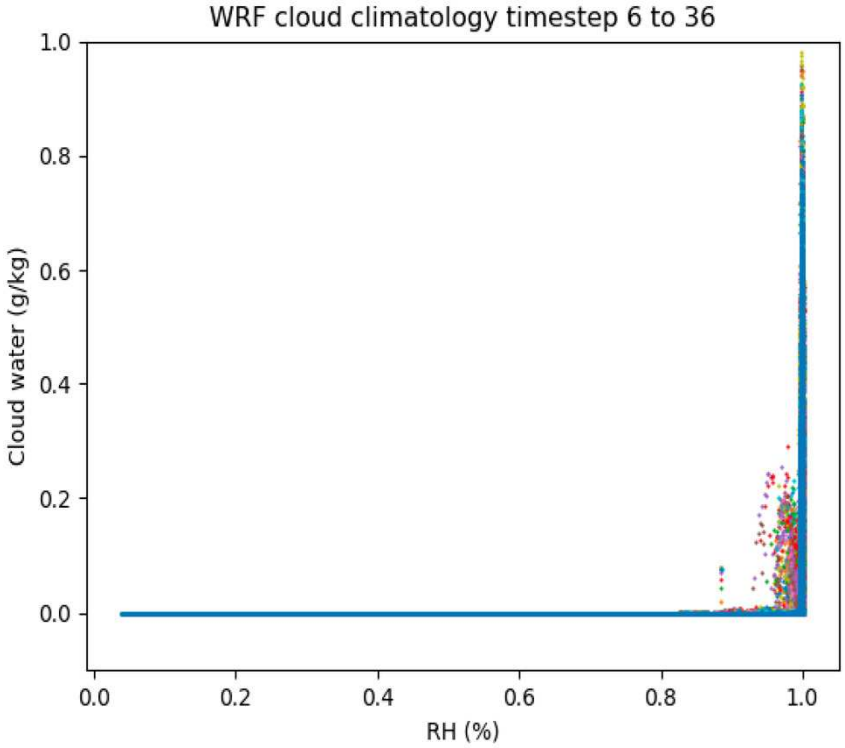


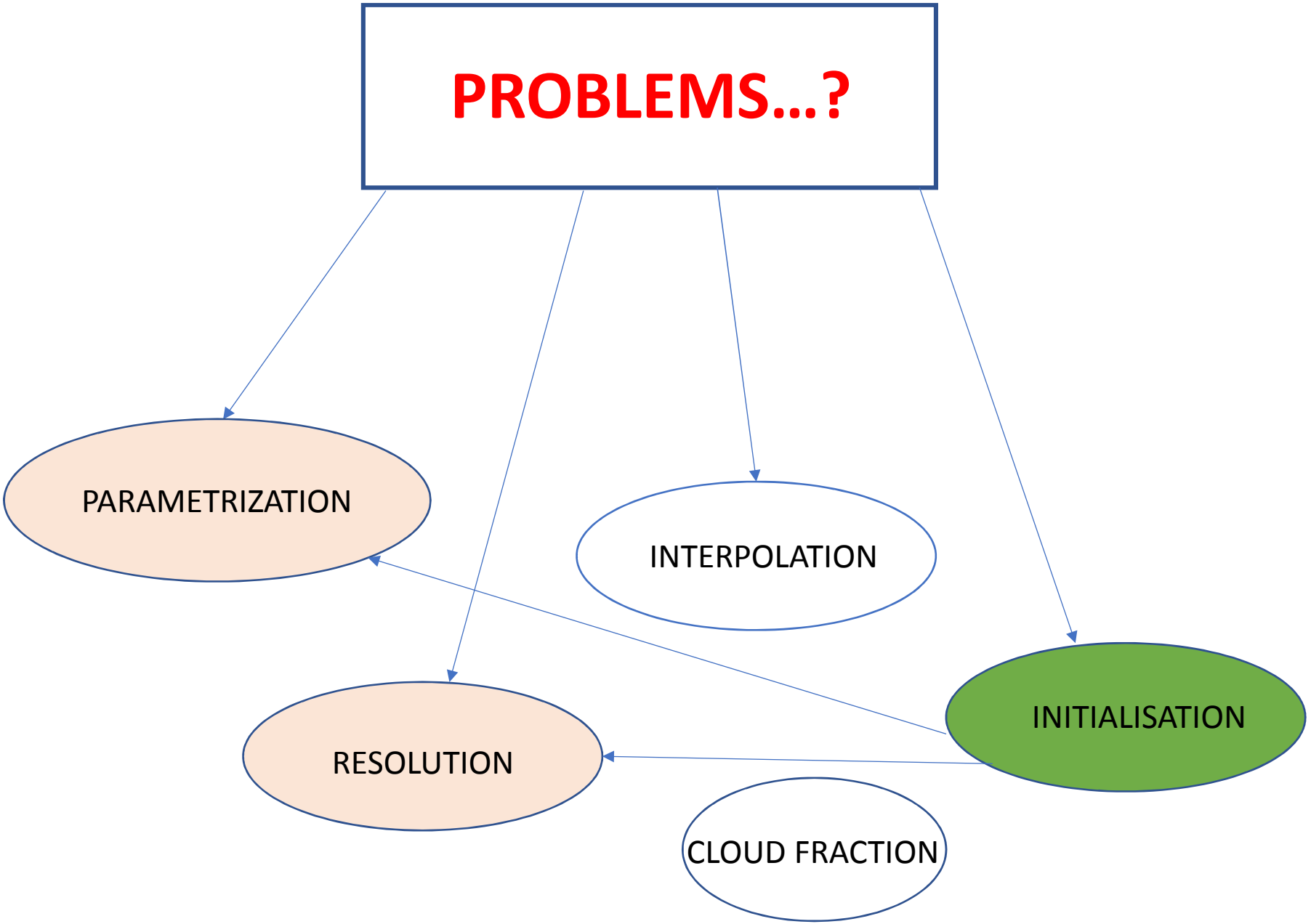
Cloud climatology IFS vs WRF

IFS



WRF




PROBLEMS…?
PARAMETRIZATION
INTERPOLATION
RESOLUTION
INITIALISATION
CLOUD FRACTION

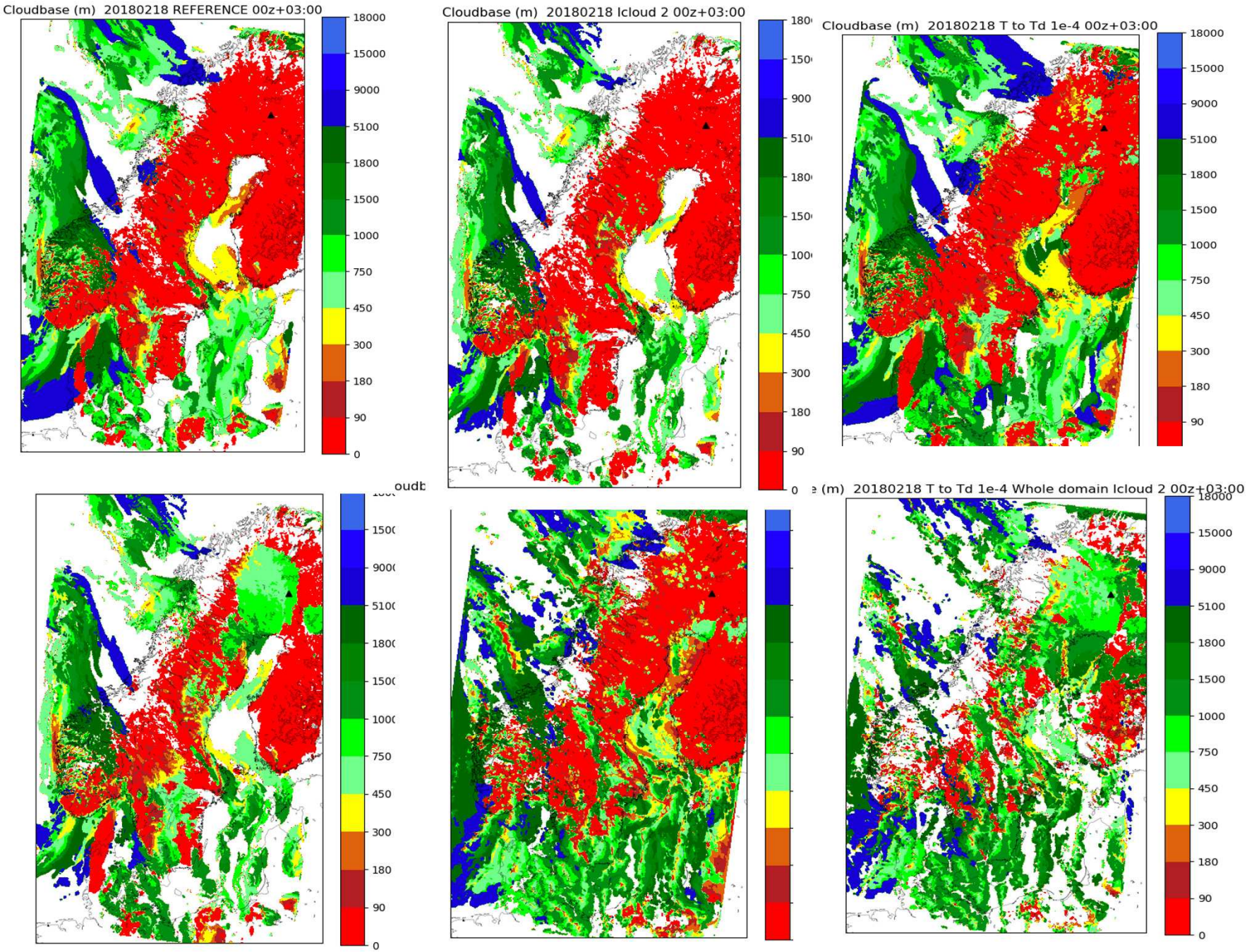
CLOUD FRACTION

Diagnostic in WRF - Prognostic in IFS

- Xu and Randall (RH + water vapor mixing ratio)
- Sundqvist scheme (RH)

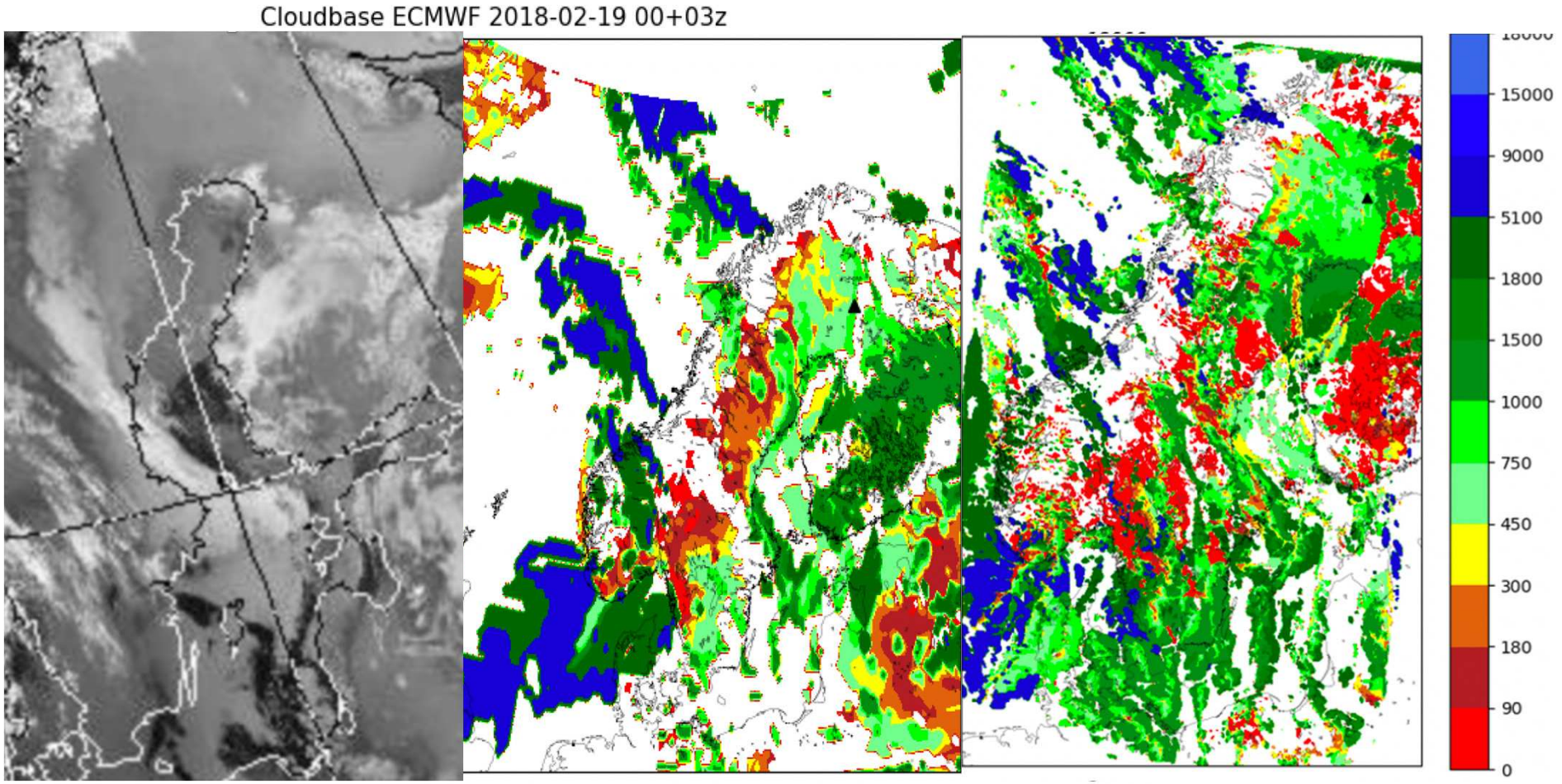
I have choosed to put cloud fraction to 1 where we have cloud water over a specific value.

Works better!!

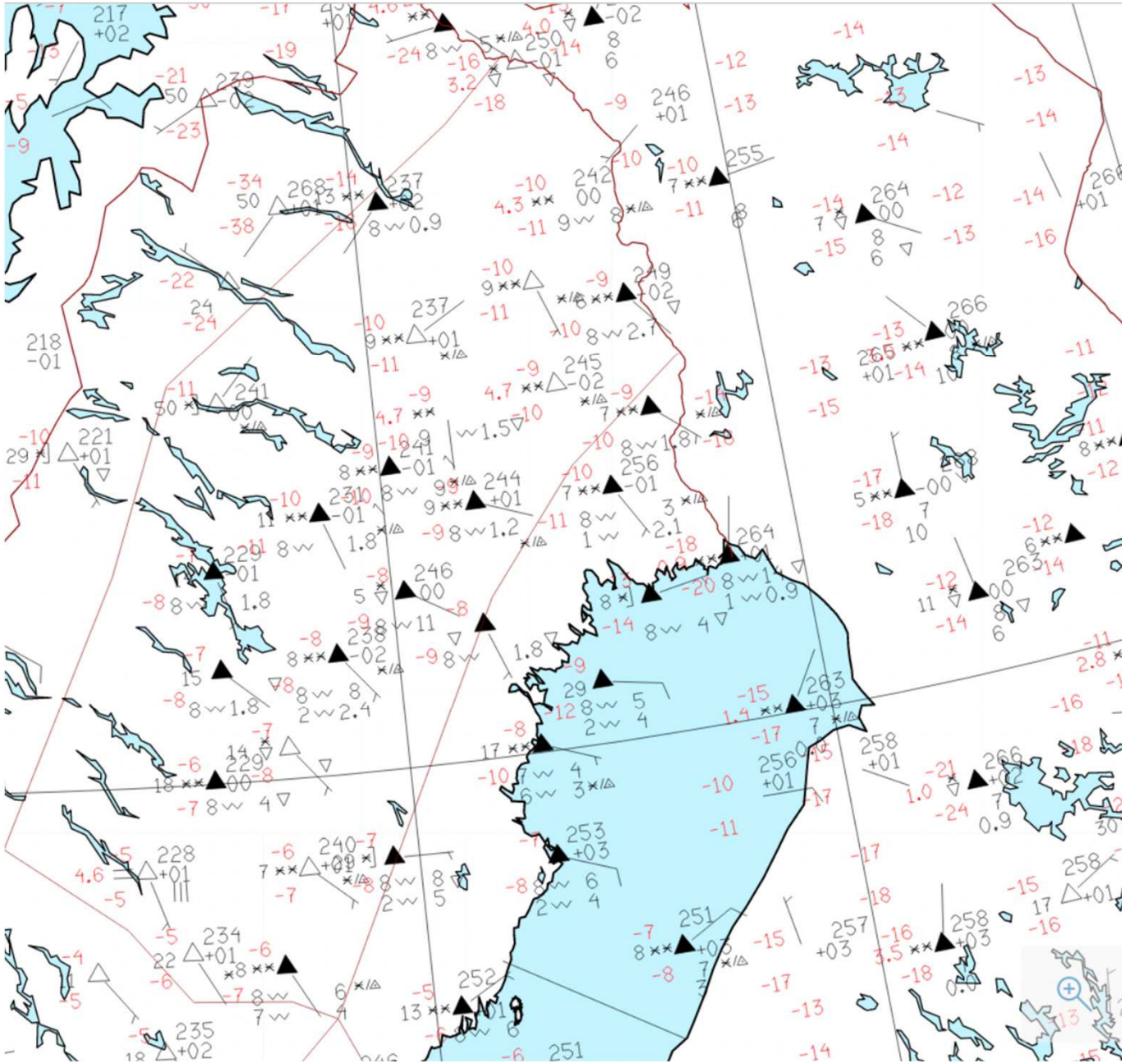

Cloudbase (m) 20180218 REFERENCE 00z+03:00
Cloudbase (m) 20180218 lcloud 2 00z+03:00
Cloudbase (m) 20180218 T to Td 1e-4 00z+03:00
Cloudbase (m) 20180218 T to Td 1e-4 Whole domain lcloud 2 00z+03:00
18000
15000
9000
5100
1800
1500
1000
750
450
300
180
90
0

IFS

WRF


Cloudbase ECMWF 2018-02-19 00+03z
15000
9000
5100
1800
1500
1000
750
450
300
180
90
0

180218 03z



NEAREST FUTURE

- DIFFERENT PARAMETRIZATIONS – AT LEAST TKE-SCHEME
- LOW CLOUDS WHERE SC DOESN'T EXIST IN IFS…?
- FORCE SCM
- TEST SNOW SCHEME WITH MORE LEVELS – Noah Microphysics
- TRY DIFFERENT CLOUD ASSIMILATION TECHNIQUES

THANK YOU! ☺

QUESTIONS?