Modeling the Spatial and Temporal Variability of Fog in the Namib Desert with COSMO

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ICCARUS

DWD, Offenbach, 26th February 2018

Outline

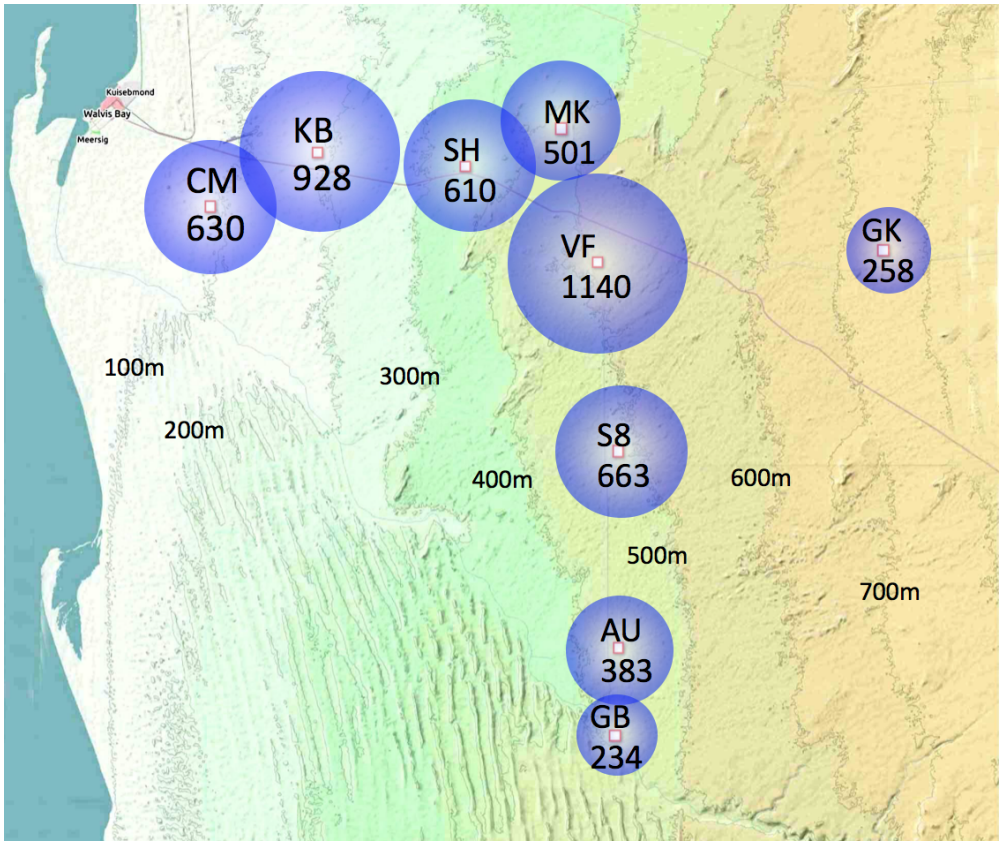
Relevance and NaFoLiCA

Model Setup

Preliminary Results

Conclusion and Outlook

Relevance



Fog precipitation (mm). 7/14 - 6/16. R. Vogt

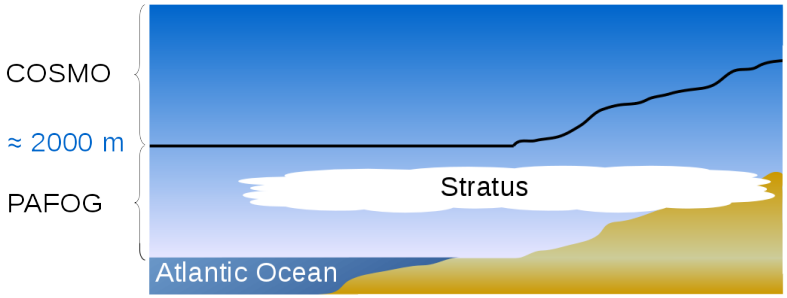
- Namib is one of the driest deserts on earth
- only a few millimeters precipitation per year
- up to 200 days with fog
- fog water deposition is important water source

NaFoLiCA – Namib Fog Life Cycle Analysis

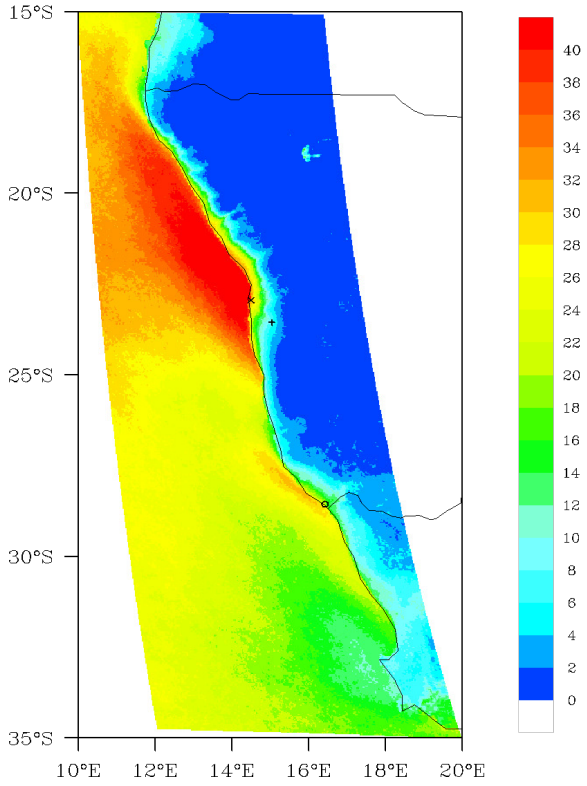
NaFoLiCA-F: Field

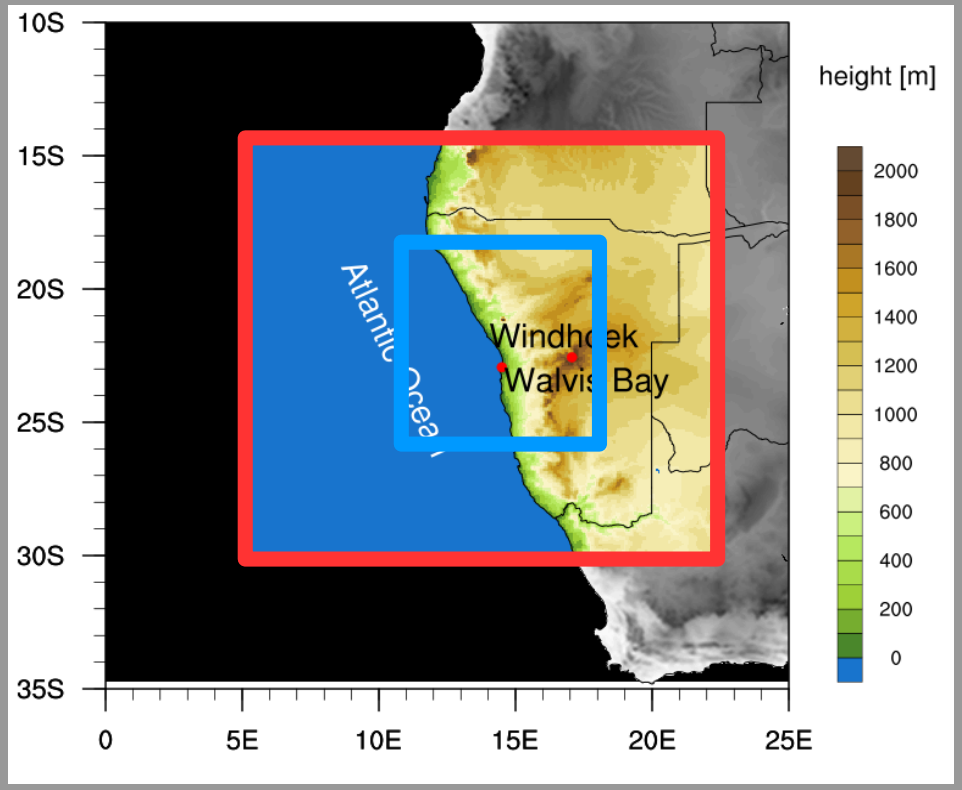
NaFoLiCA-M: Modeling

COSMO PAFOG COSMO-PAFOG



NaFoLiCA-S: Satellite



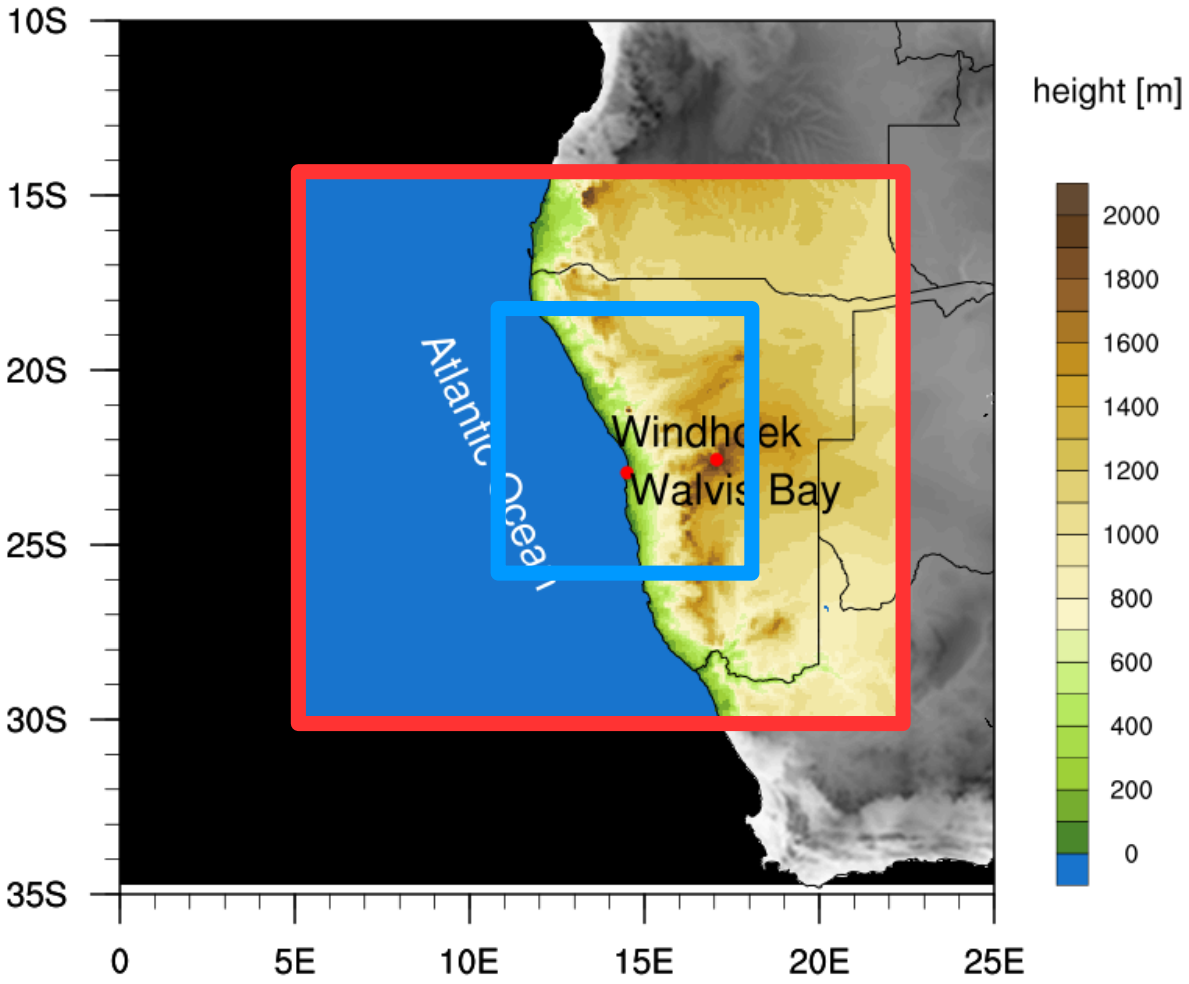

10S
15S
20S
25S
30S
35S
0
5E
10E
15E
20E
25E
height [m]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Windhoek
Walvis Bay

Model Setup

Model Setup

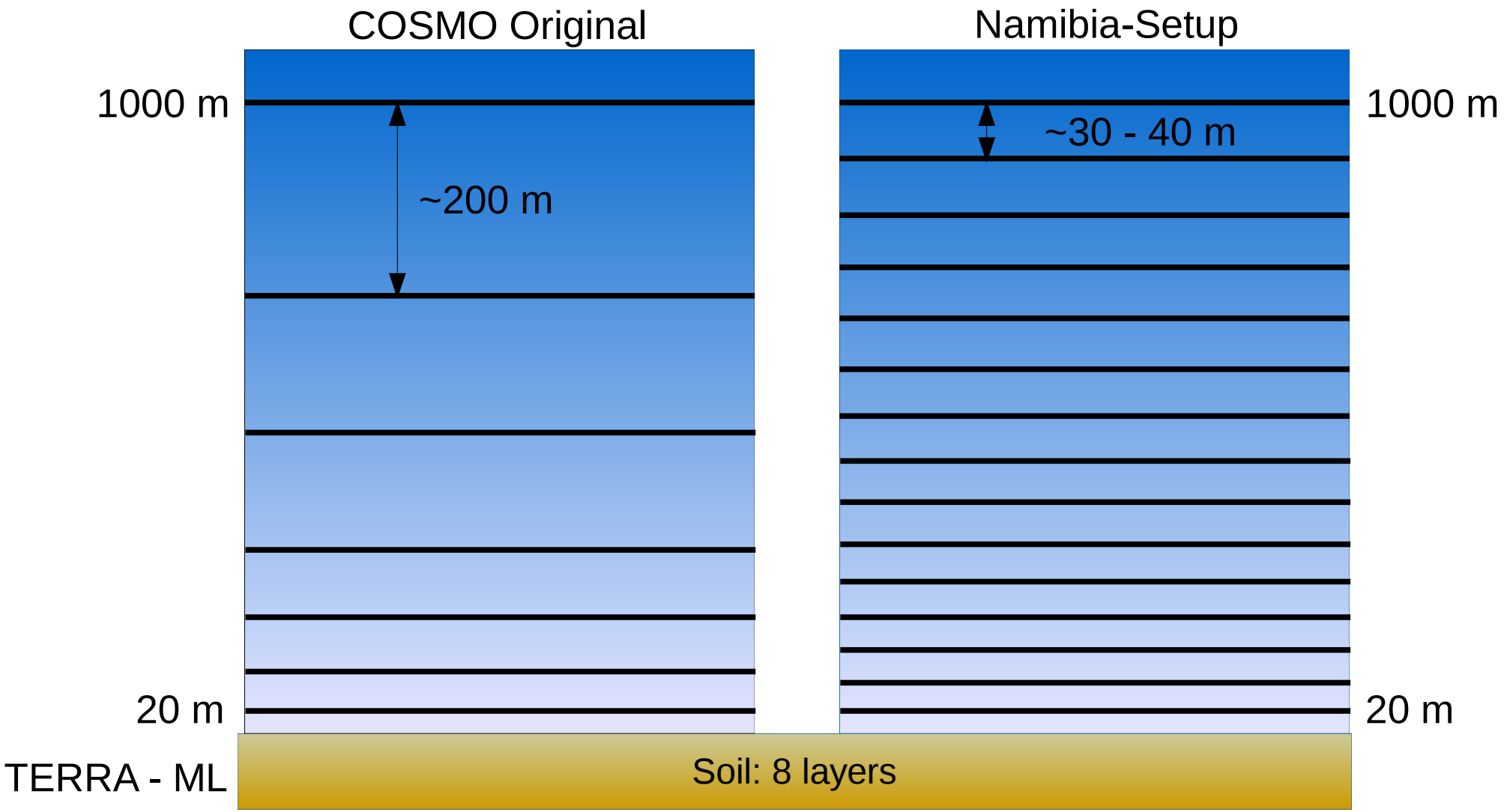
Namelist Parameter	COSMO-DE Setup	Tropical Setup (2.8 km)
domain height	22 000	30 000
number of vertical layers (ke)	50	57
reference temperature on sea level (t0sl)	288.15	300
temperature difference sea level ↔ stratosphere (delta_t)	75	90
scale height (h_scal)	10 000	12 000
coordinate value to change to z-system (vcflat)	11 357	15 000
bottom height of Rayleigh sponge layer (rdheight)	15 000	18 000

Model Setup

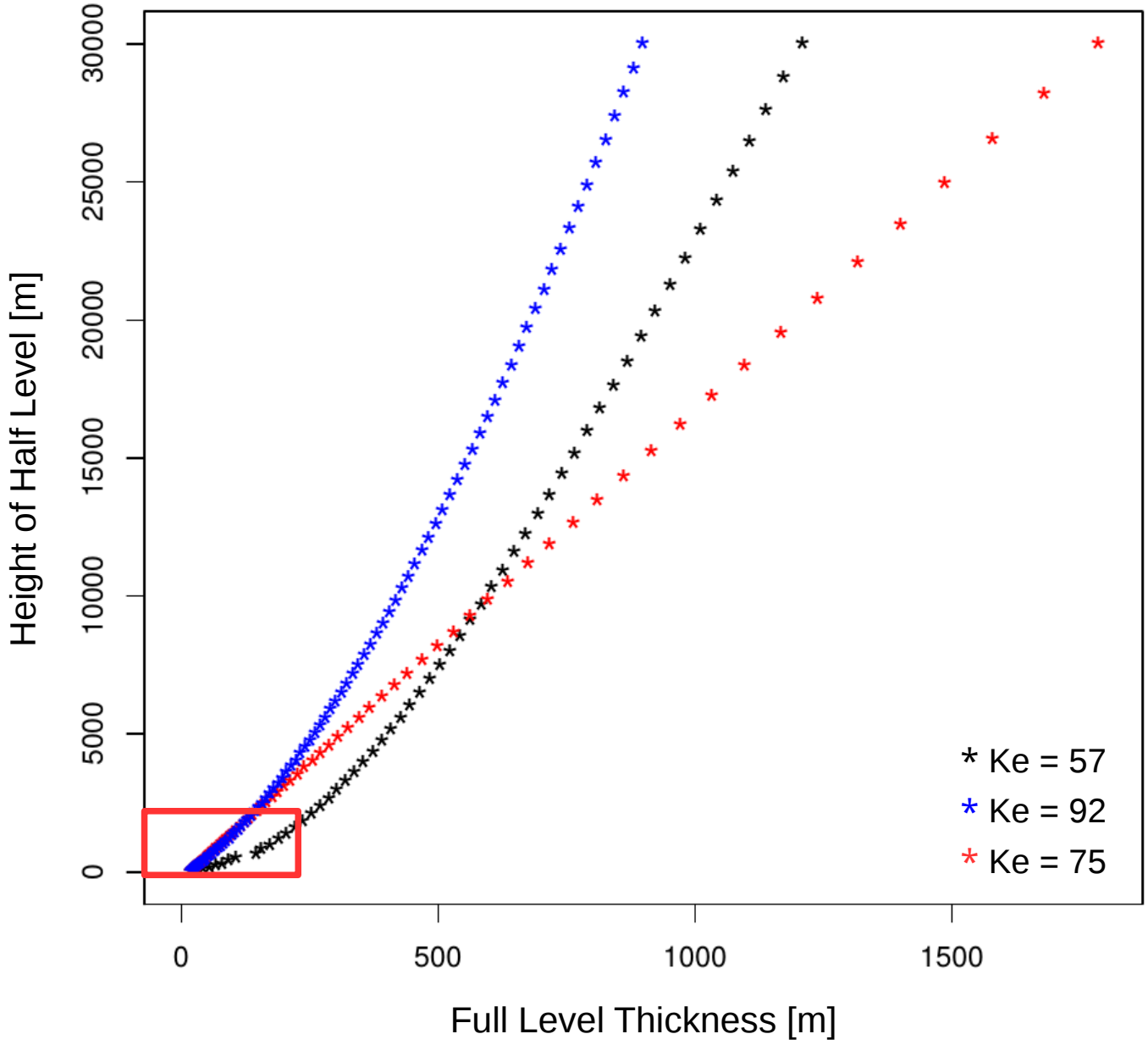


- COSMO-Version 5.01
- initialization at 12 UTC
- forecast time 30 hours
- twofold nesting
  - COSMO 7 km driven by ICON
  - COSMO 2.8 km driven by COSMO 7 km
- three different vertical grids, Δz_{min}=20m
- 1D TKE-based closure on level 2.5 (Mellor and Yamada, 1982)
- one-moment bulk scheme (Reinhardt and Seifert, 2006)

Vertical Grid Spacing



Vertical Grid Spacing



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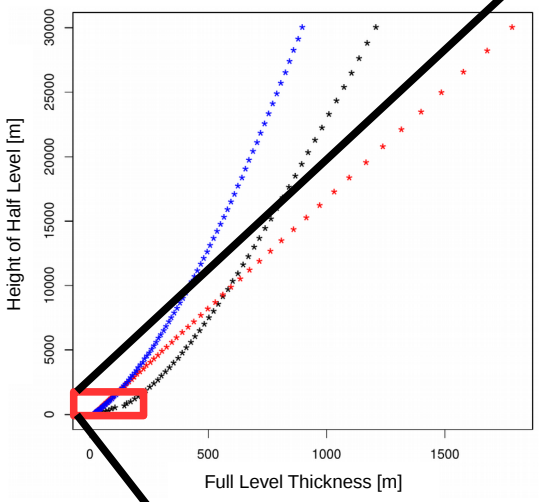
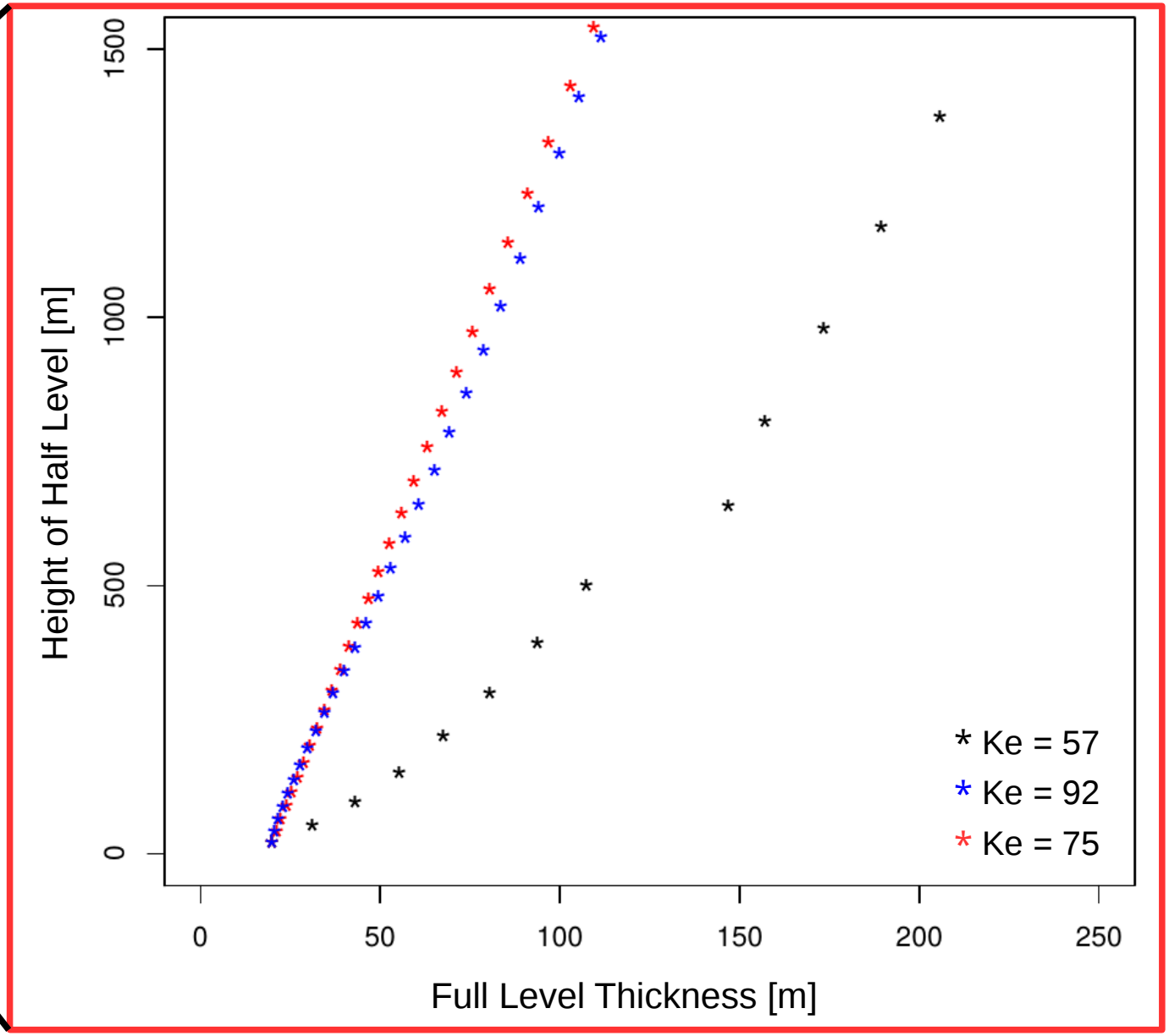
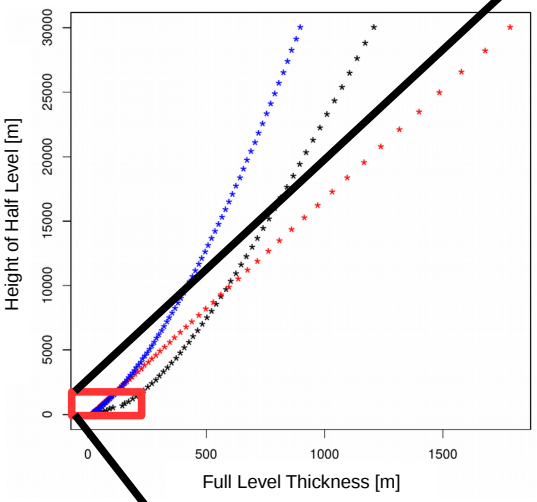
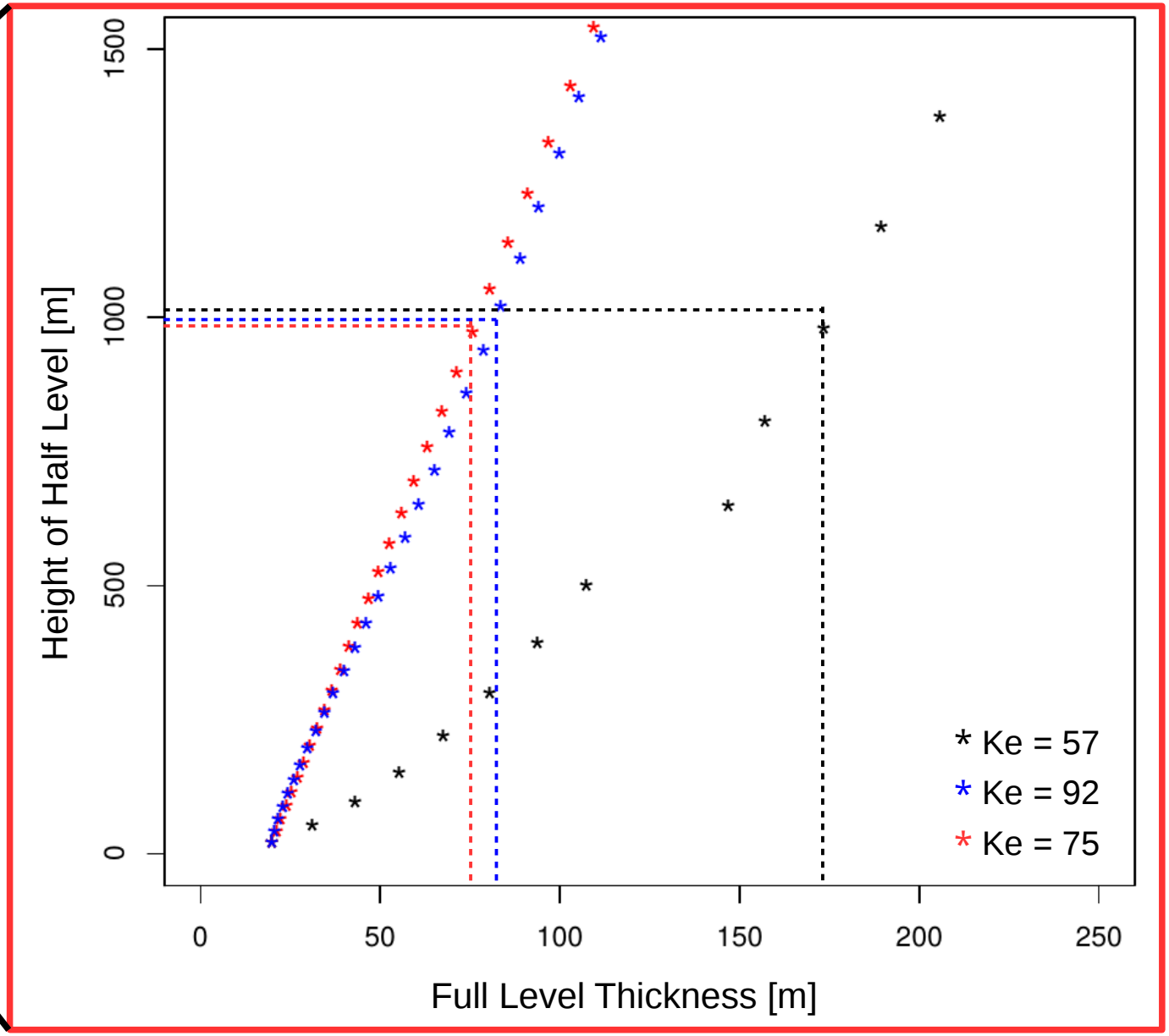
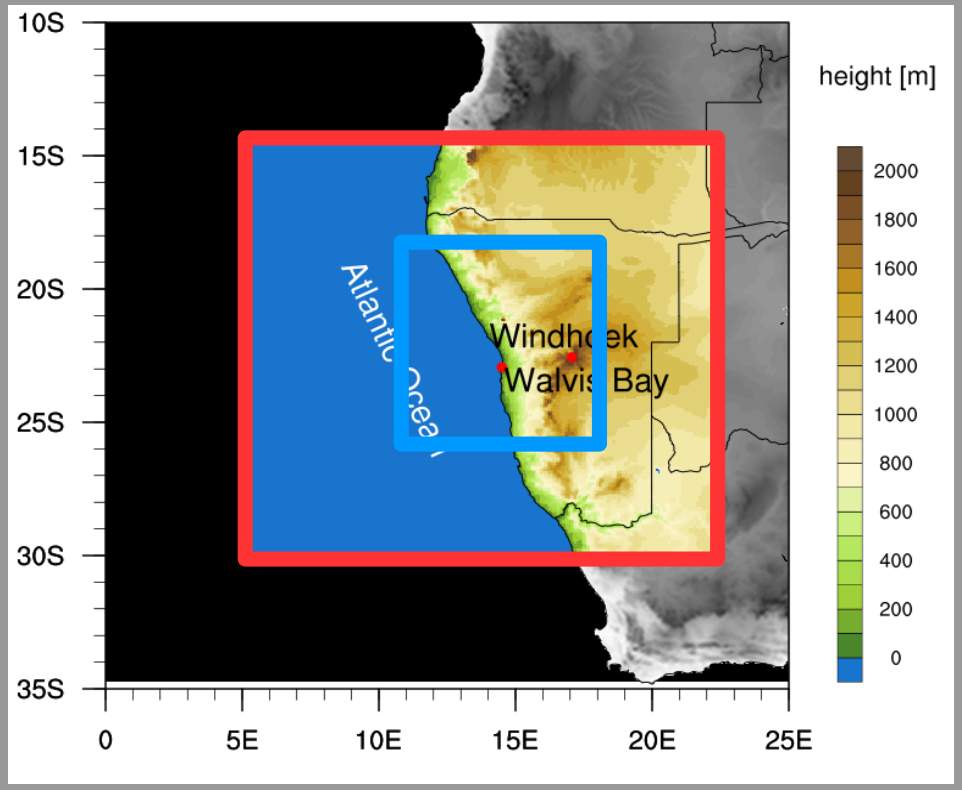




Vertical Grid Spacing







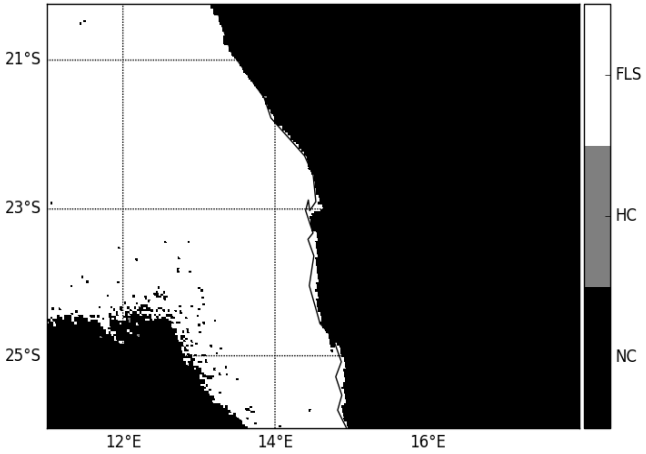
Preliminary Results

Case Study 18./19. September 2017

Horizontal Extension of Fog and Stratus

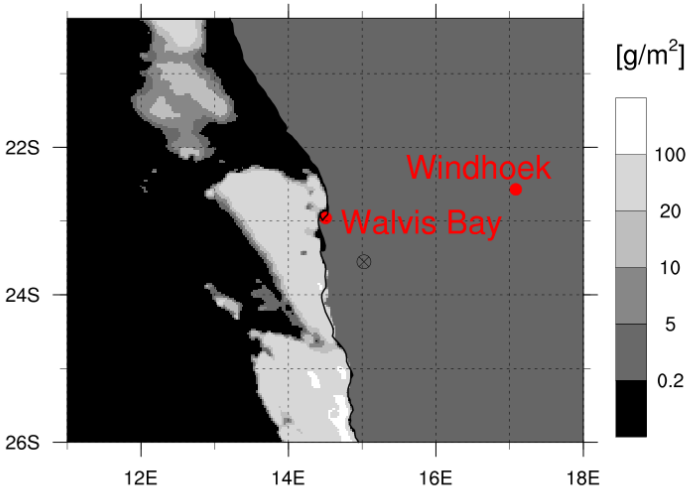
Fog and Stratus Defined by Liquid Water Path

12 UTC

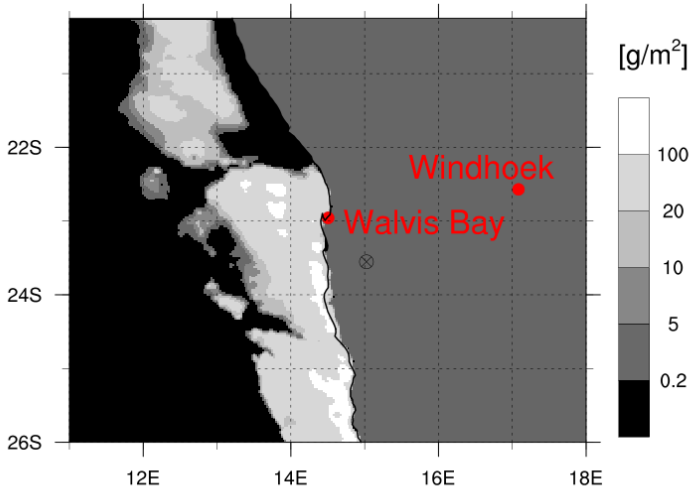


H. Andersen

Ke = 57



Ke = 75



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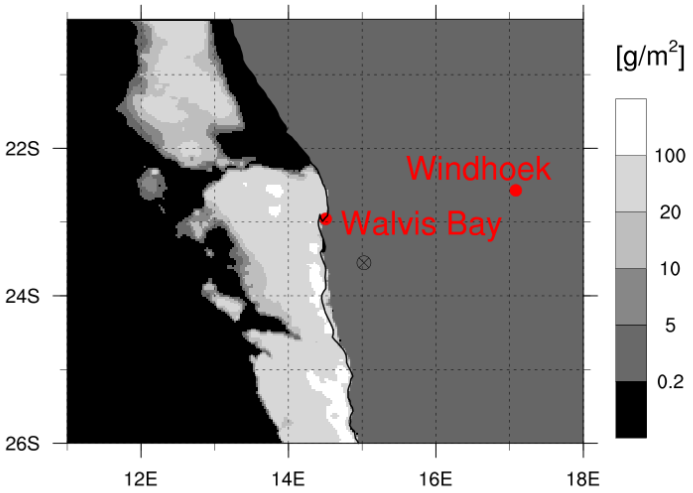
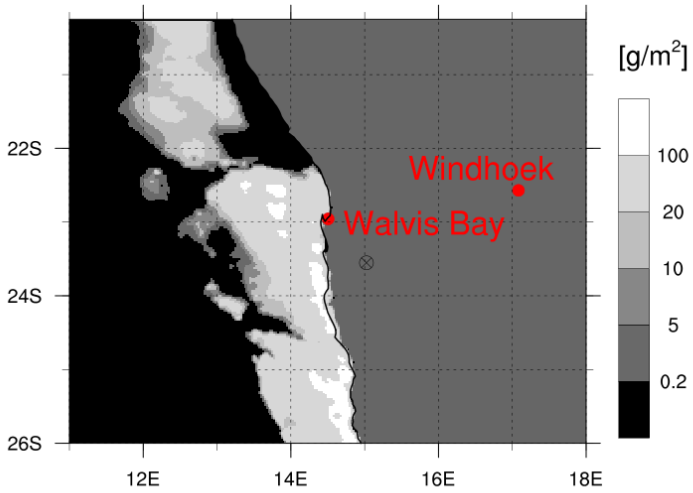


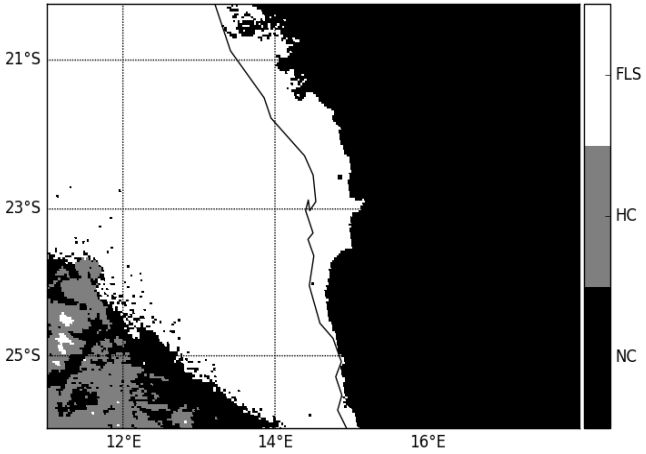
Ke = 75, tkvmin = 0.05



Horizontal Extension of Fog and Stratus

Fog and Stratus Defined by Liquid Water Path

20 UTC



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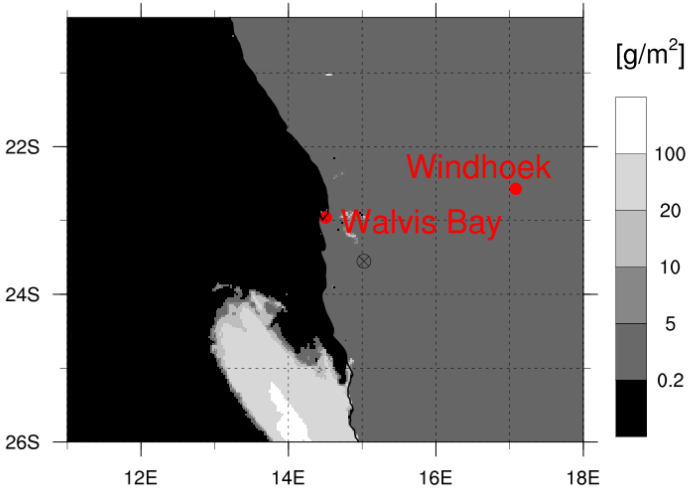

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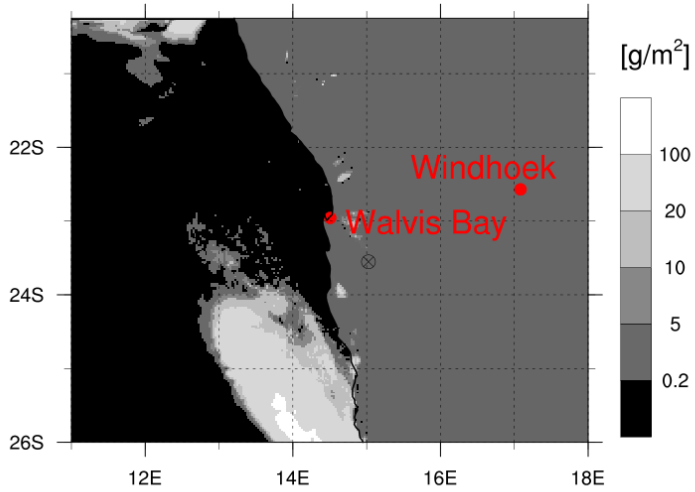
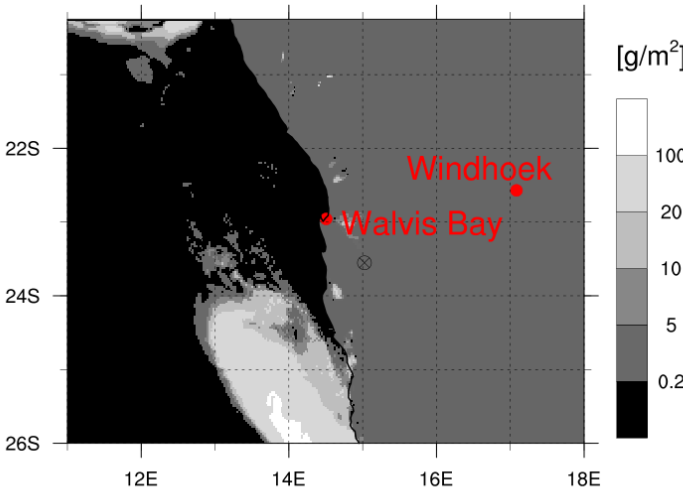
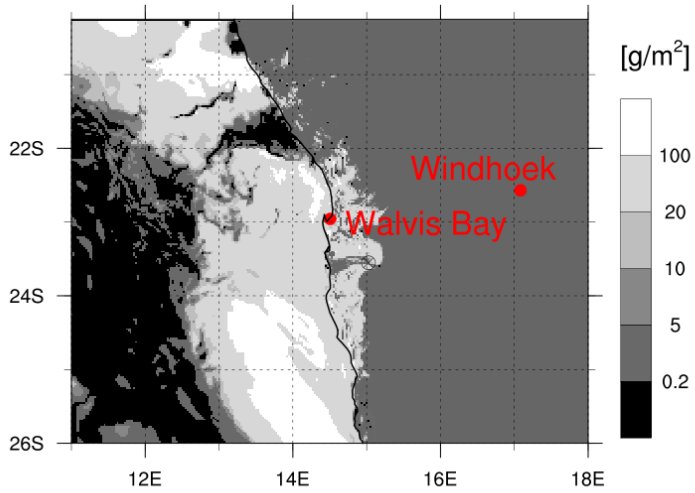


Ke = 92



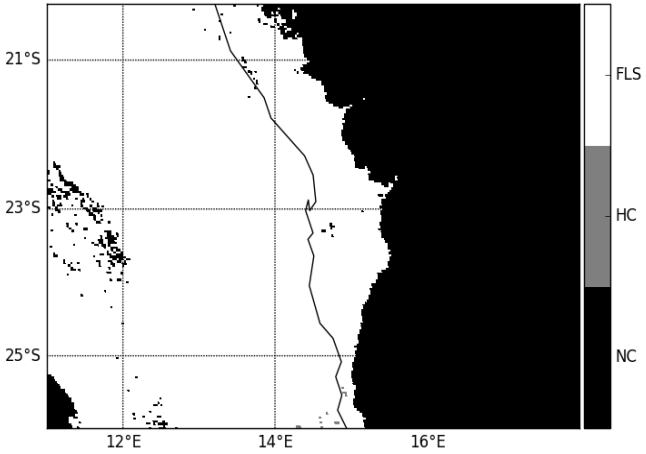
Ke = 75, tkvmin = 0.05



Horizontal Extension of Fog and Stratus

Fog and Stratus Defined by Liquid Water Path

06 UTC + 1d



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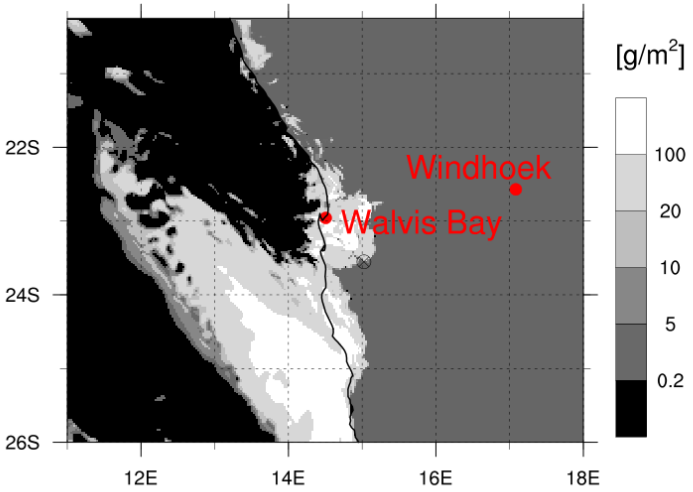

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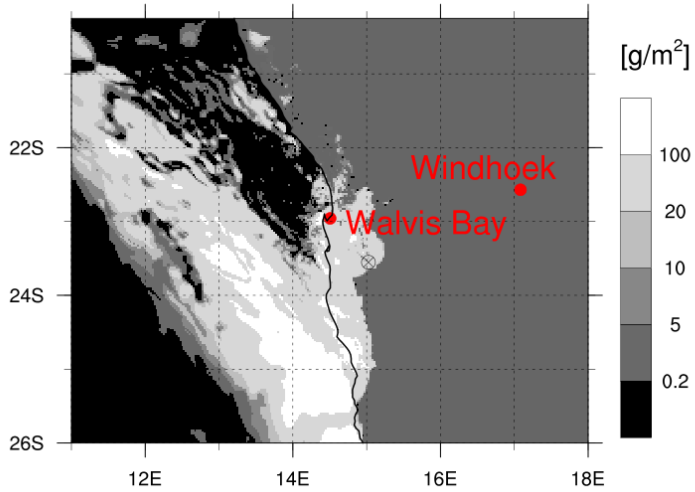

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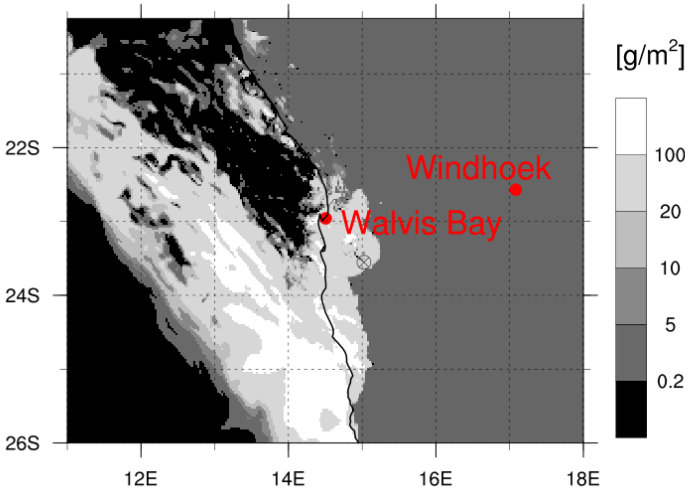
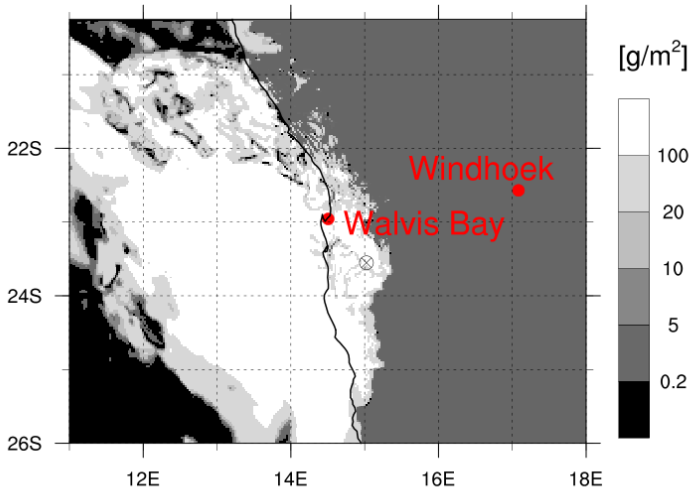


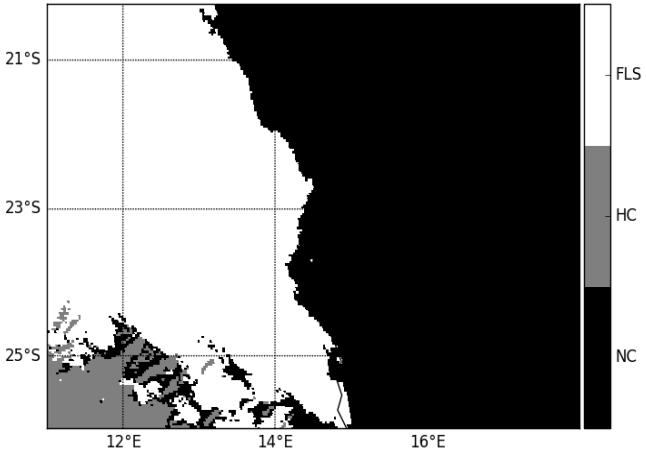
Ke = 75, tkvmin = 0.05



Horizontal Extension of Fog and Stratus

Fog and Stratus Defined by Liquid Water Path

12 UTC + 1d



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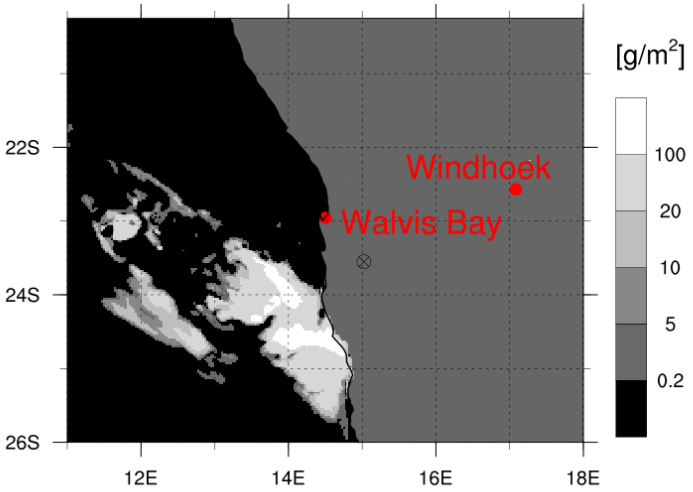

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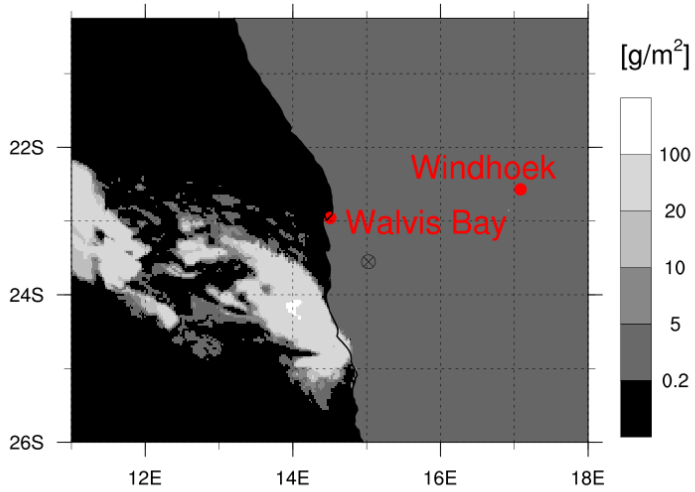

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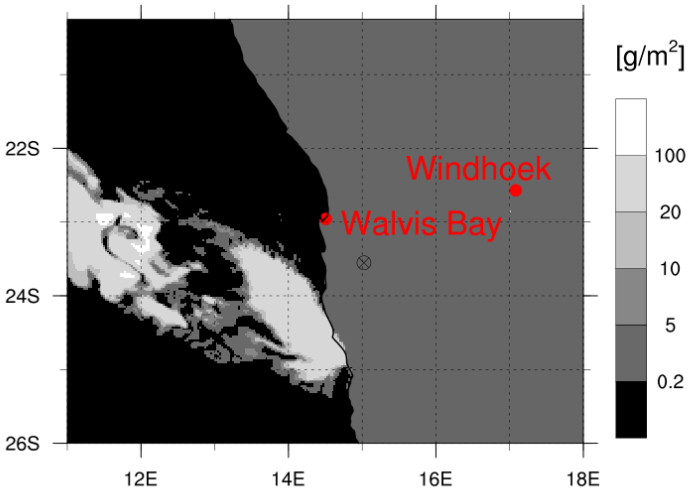
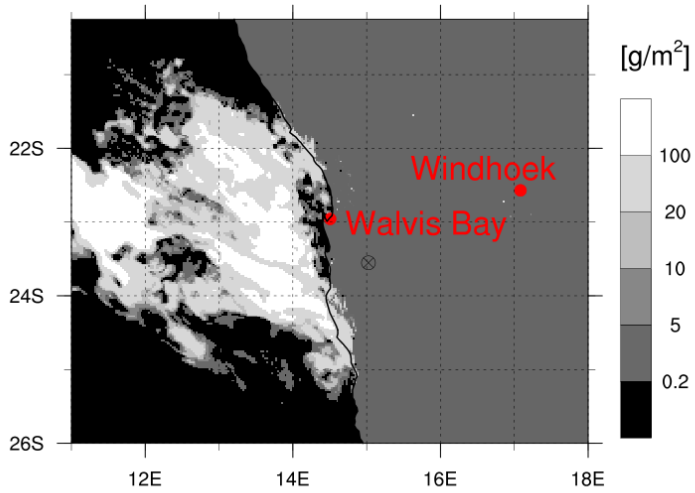
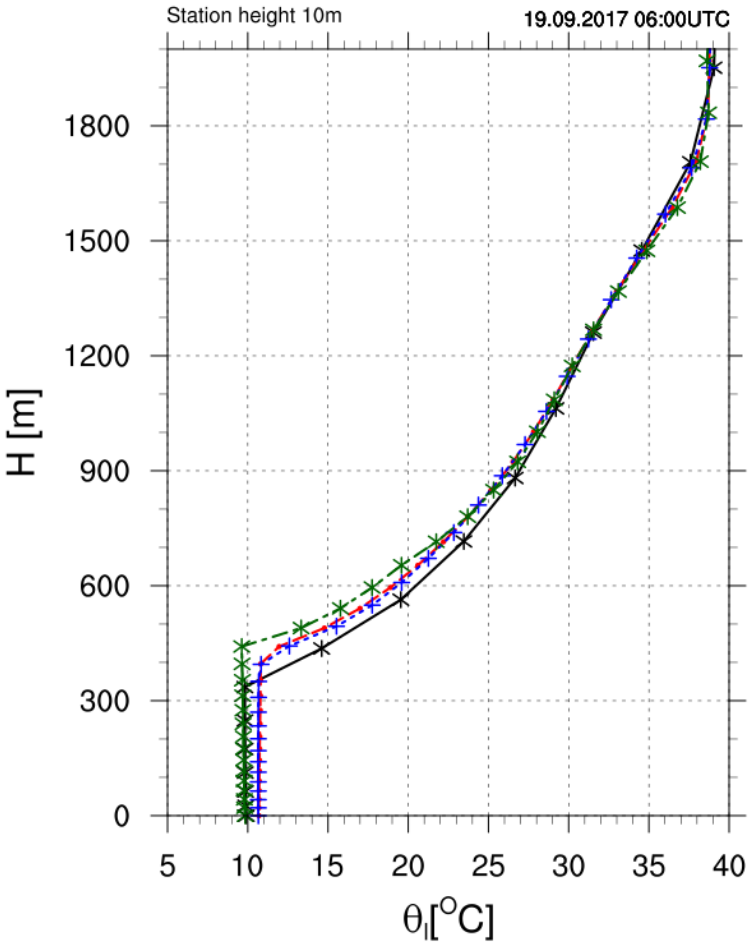


Ke = 75, tkvmin = 0.05

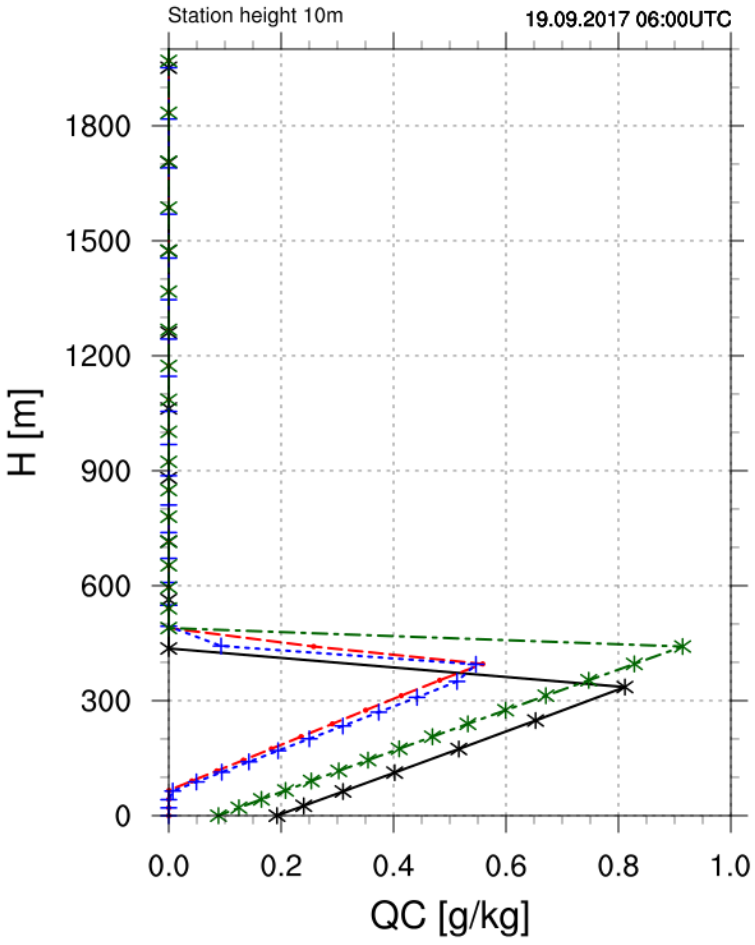


Comparison of Model Configurations

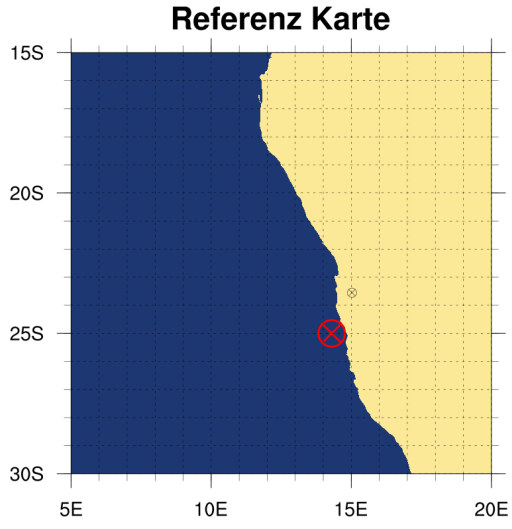
Liquid Water Potential Temperature



Specific Cloud Water Content



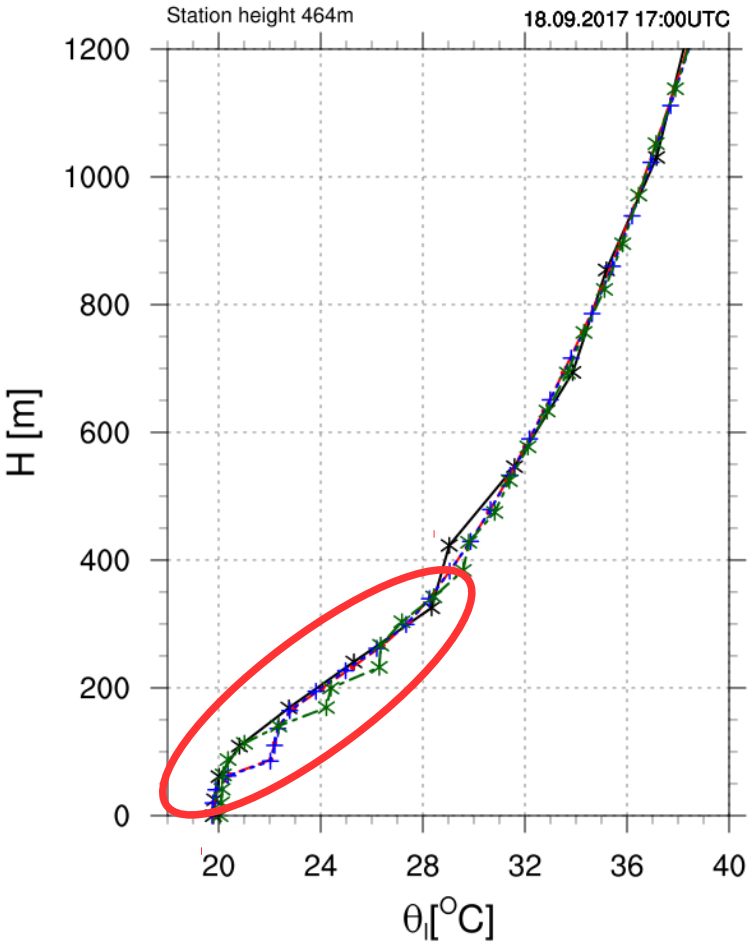
- Ke = 57
- Ke = 92
- Ke = 75
- Ke = 75 + tkmin = 0.05



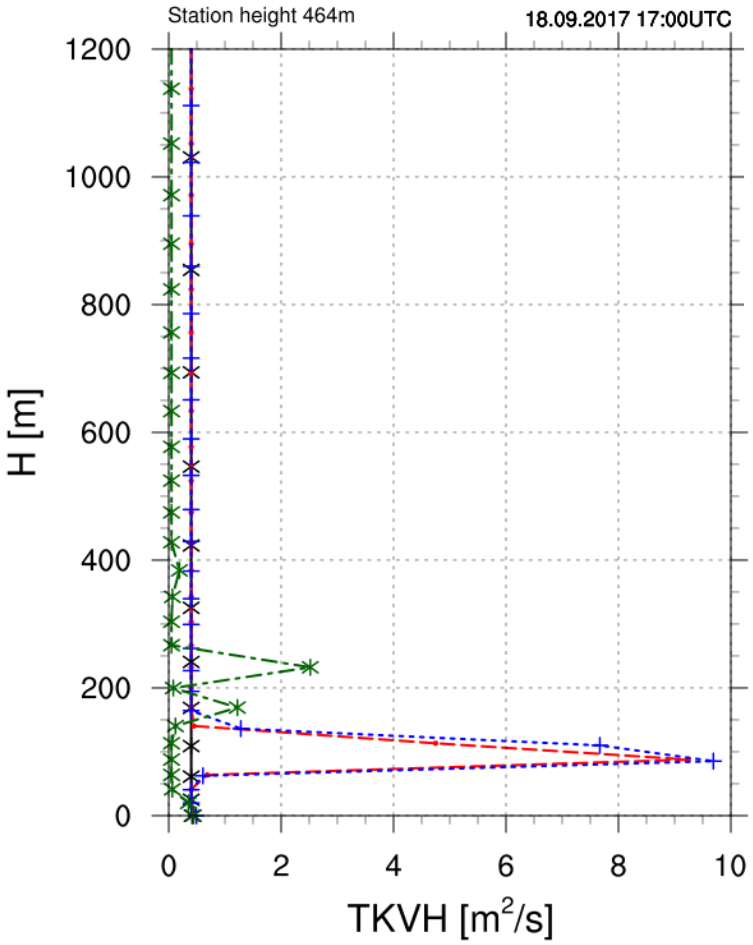
- well-mixed layer of 300 to 500 m thickness
- fog layer beneath the inversion
- slight improvement by increased number of vertical layers
- tuning of turbulence scheme is more effective than change of vertical layers

Numerical Instabilities in Turbulence Scheme

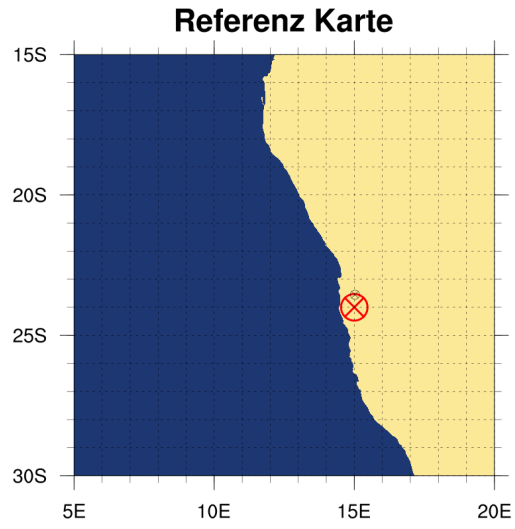
Liquid Water Potential Temperature



Turbulent Exchange Coefficient (heat)



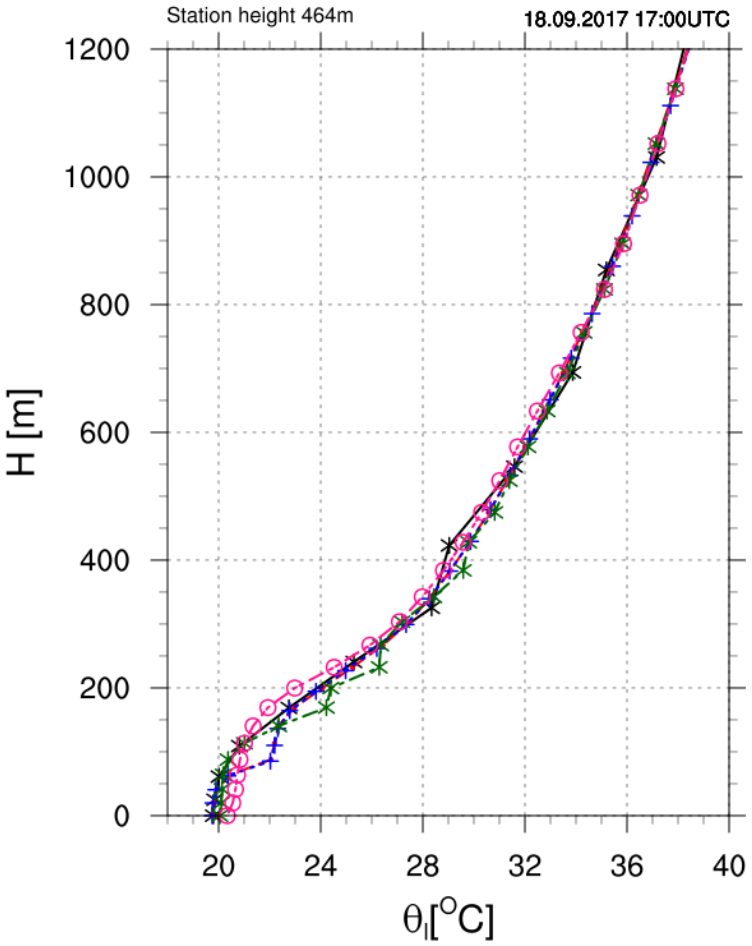
- Ke = 57
- Ke = 92
- Ke = 75
- Ke = 75 + tkmin = 0.05



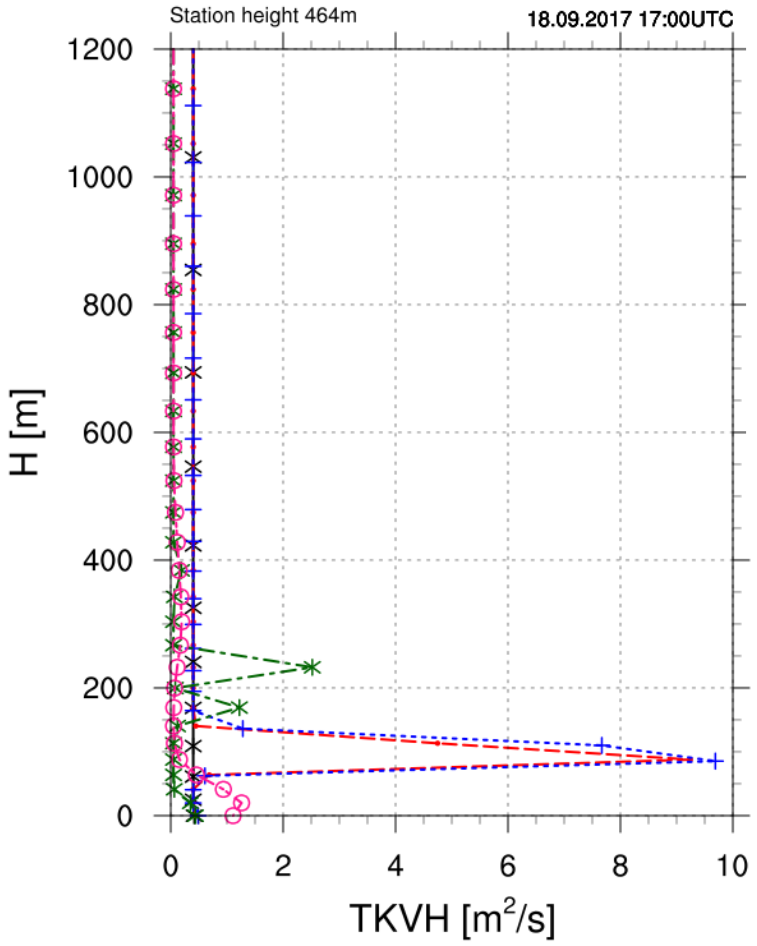
- unphysical behavior of temperature profiles for decreased minimal turbulent exchange coefficients
- oscillations of turbulent exchange coefficients
  → numerical instabilities

Numerical Instabilities in Turbulence Scheme

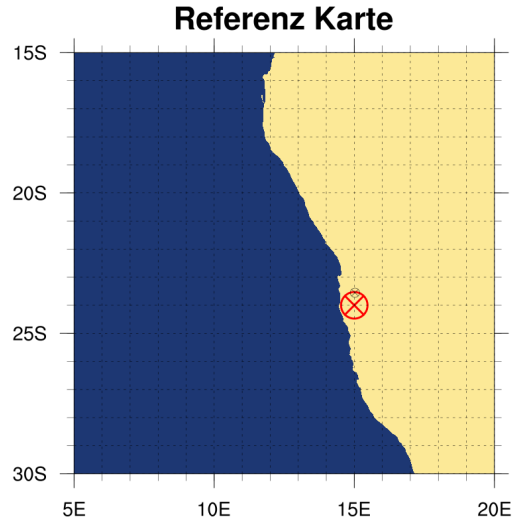
Liquid Water Potential Temperature



Turbulent Exchange Coefficient (heat)



- Ke = 57
- Ke = 92
- Ke = 75
- Ke = 75 + tkmin = 0.05
- Ke = 75 + tkmin = 0.05 + filter

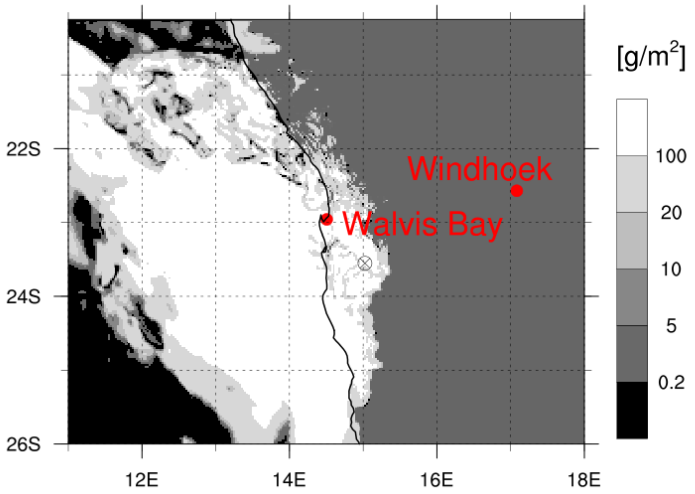


- filtering based on Buzzi et al. (2011):
  $K^{new}_k = 0.5K_k + 0.2\,[K_{k+1}+K_{k-1}] + 0.05\,[K_{k+2}+K_{k-2}]$
- oscillations of turbulent exchange coefficients are eliminated

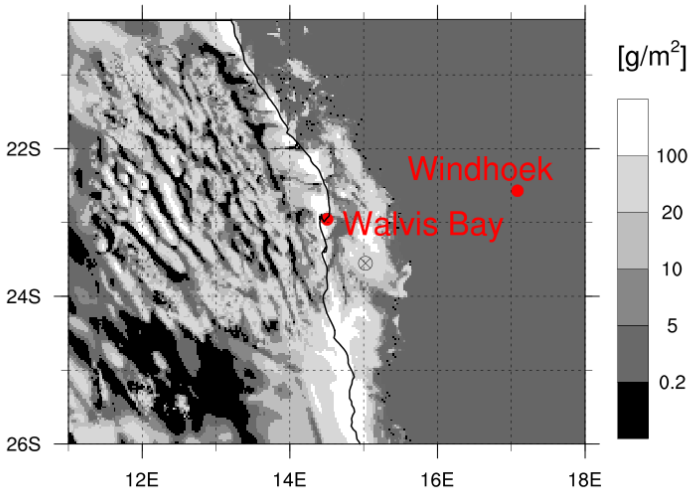
Numerical Instabilities in Turbulence Scheme

Changes in Boundary Layer Dynamics due to Filtering

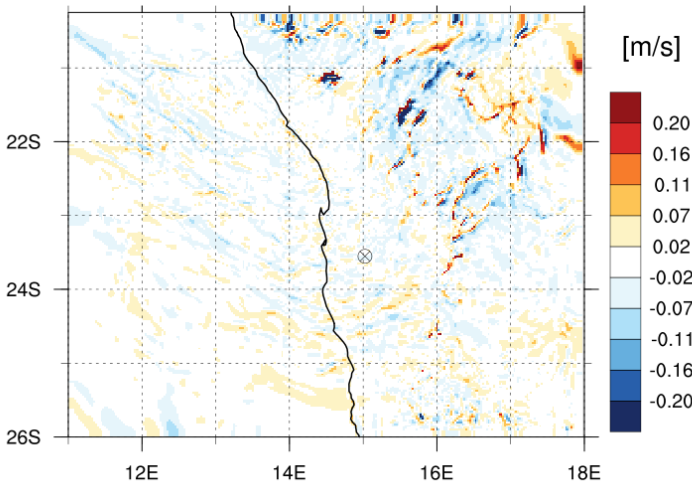
Before Filtering



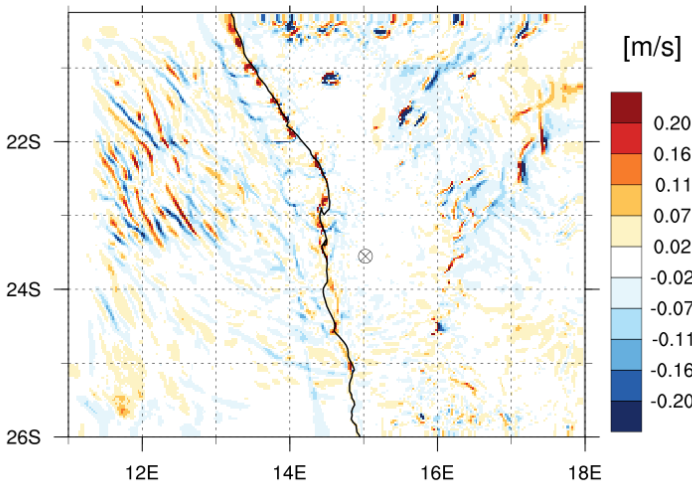
After Filtering

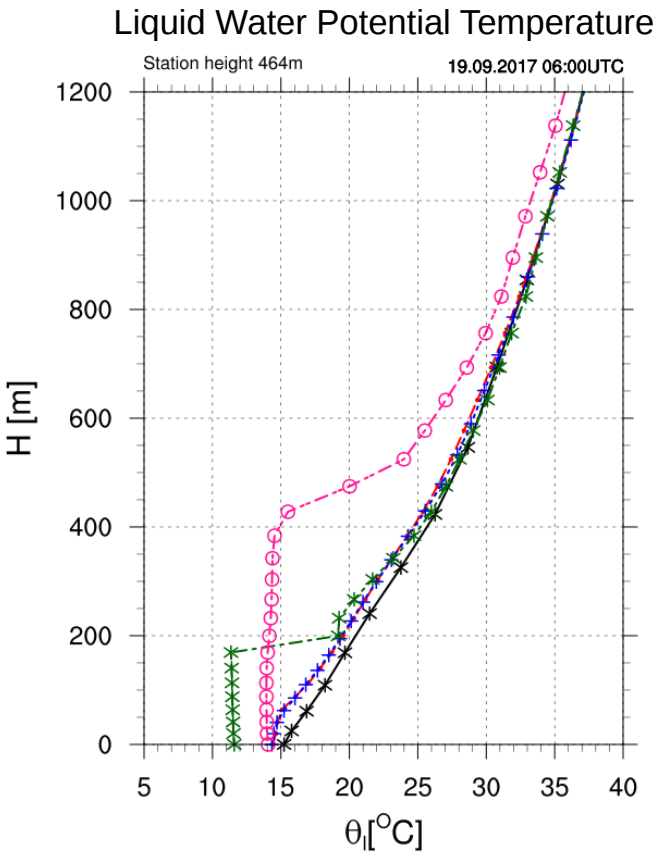


z ≈ 500 m



z ≈ 500 m

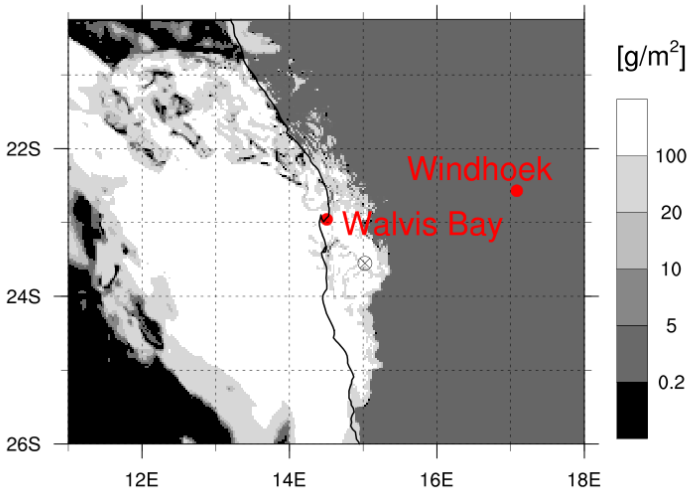




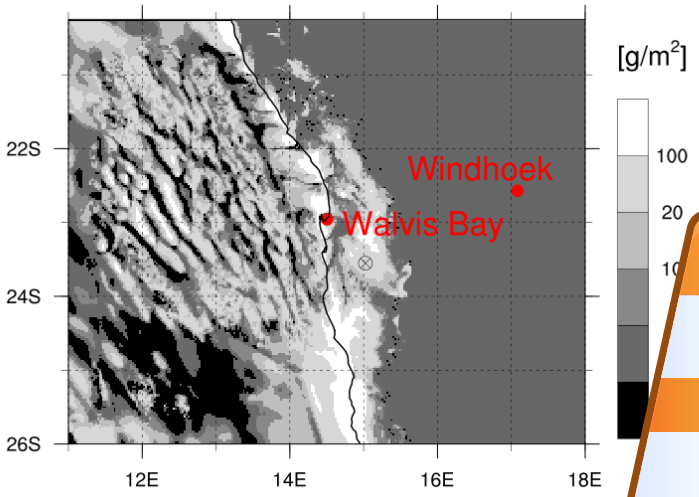
Numerical Instabilities in Turbulence Scheme

Changes in Boundary Layer Dynamics due to Filtering

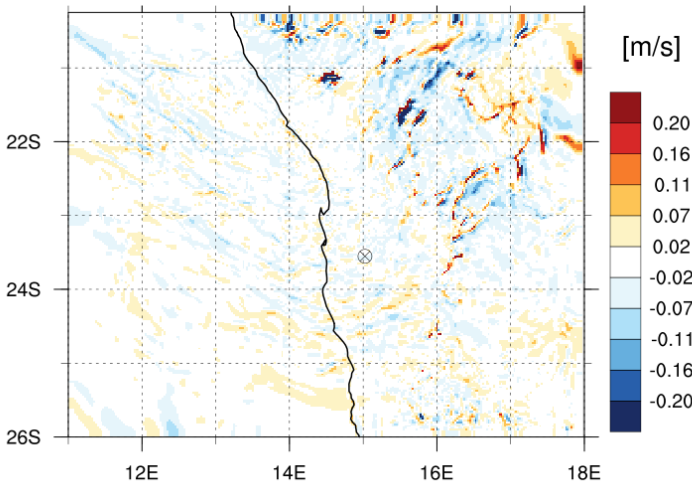
Before Filtering



After Filtering



z ≈ 500 m



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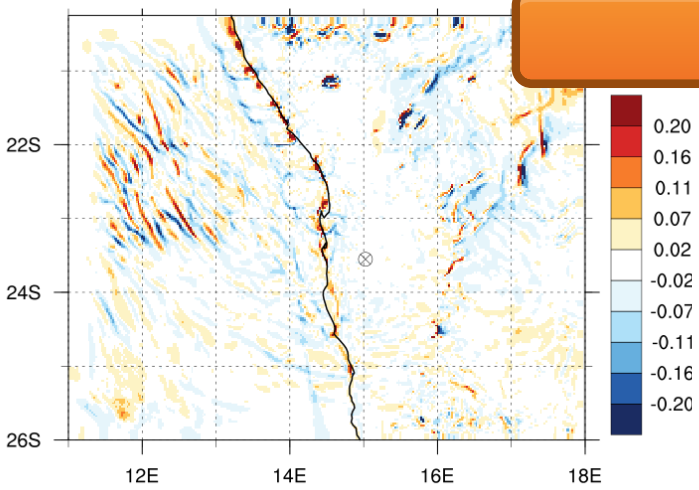
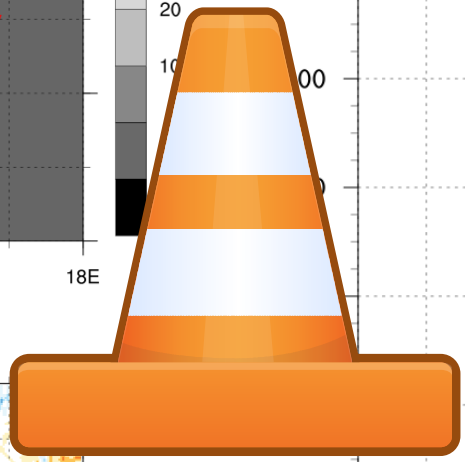
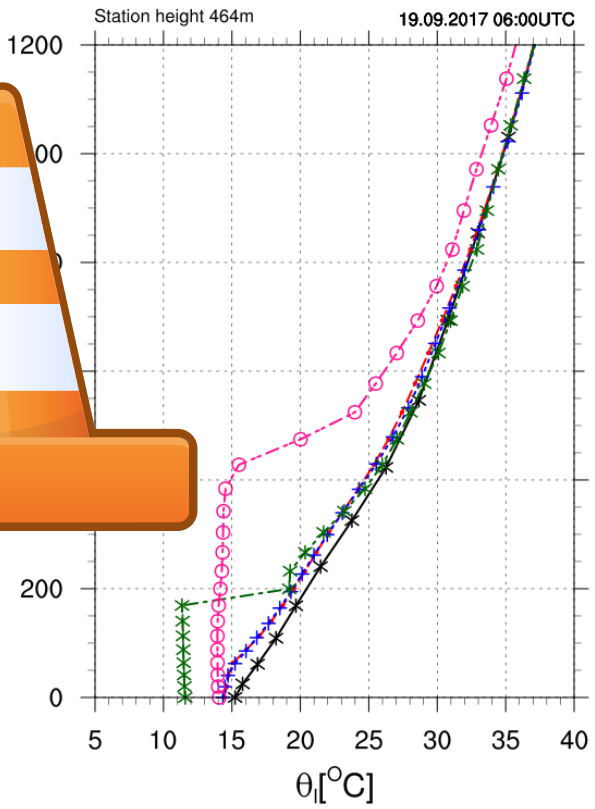




Liquid Water Potential Temperature



Conclusion

Setup of COSMO Simulations

- ✔ tropical setup
- ✔ increase of vertical resolution in the planetary boundary layer

Comparison of Model Configurations

- ✔ initialization from ICON reproduces spatial distribution of stratus and fog
- ✗ COSMO strongly underestimates fog and stratus
- ✗ decrease of model layer thickness has no significant influence on results
- ✔ reduction of $TKVH_{min}$ and $TKVM_{min}$ is very effective
- ✗ numerical instabilities occur for configurations with decreased mixing and increased number of vertical layers
- ✗ filtering of exchange coefficients changes boundary layer dynamics

Outlook

Treatment of Numerical Instabilities

- objective detection of numerical instabilities
- investigate behavior of dimensionless gradients and stability functions
- improve filtering
- other solutions to instability problem?

Tuning of Model Parameters

- further decrease minimal exchange coefficients
- …

Dissolution of Fog and Stratus

- sensitivity to initial time

Simulations with COSMO-PAFOG

Modeling the Spatial and Temporal Variability of Fog in the Namib Desert with COSMO

Maike Hacker, Andreas Bott

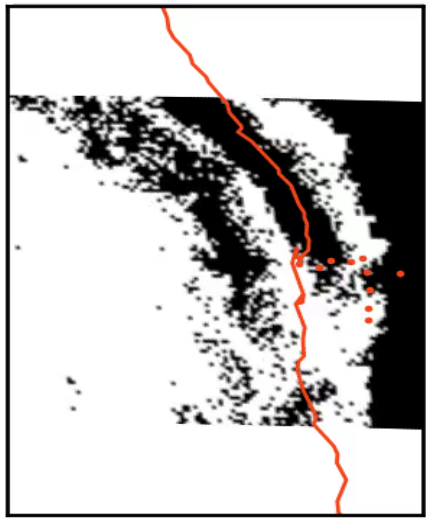
ICCARUS

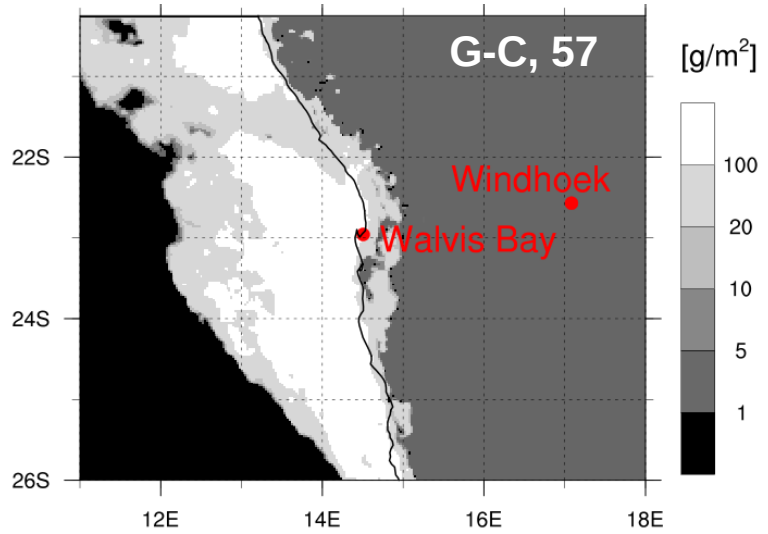
DWD, Offenbach, 26th February 2018

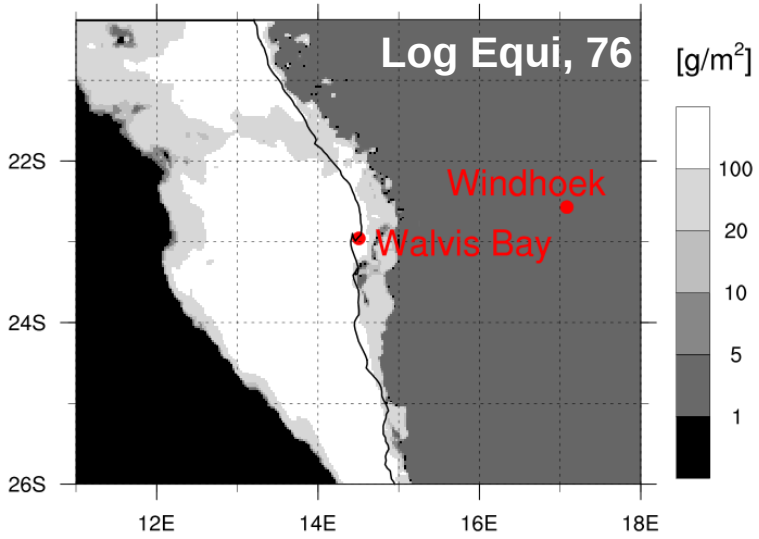
Horizontal Extension of Fog and Stratus

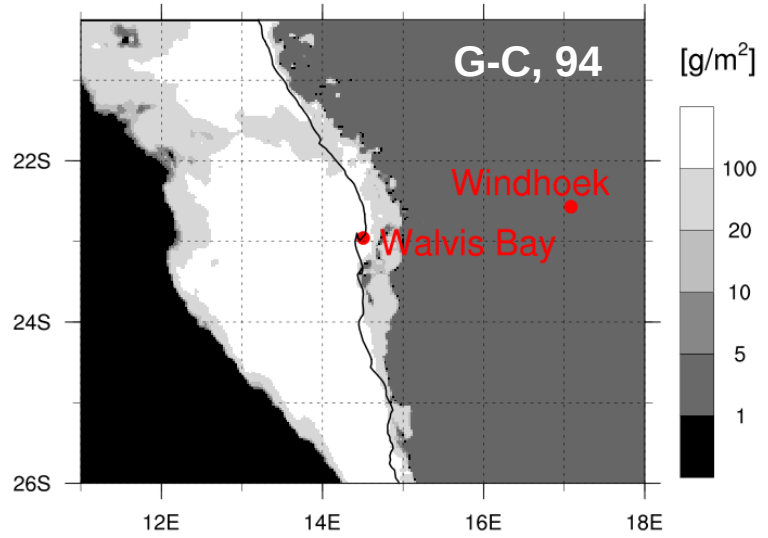
Fog and Stratus Defined by Vertically Integrated Liquid Water Content

00 UTC





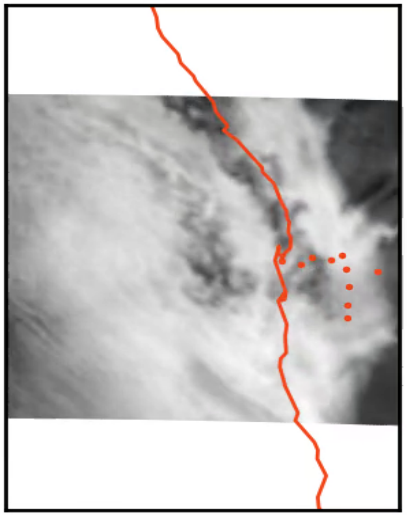


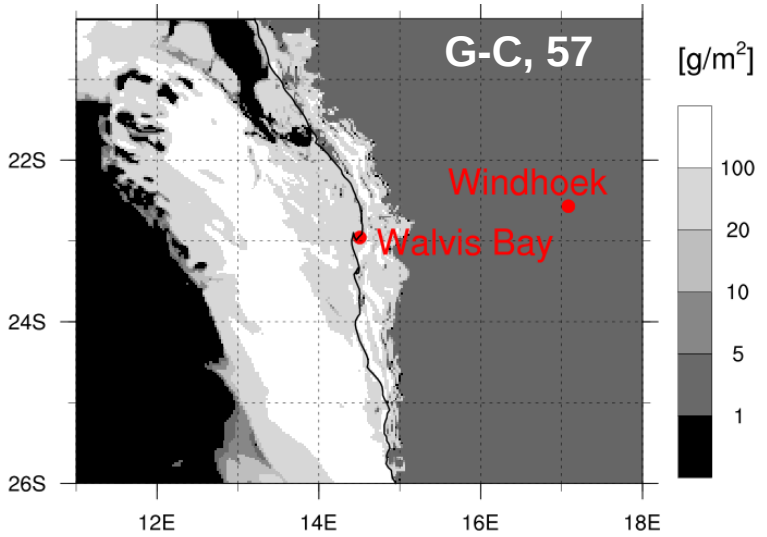


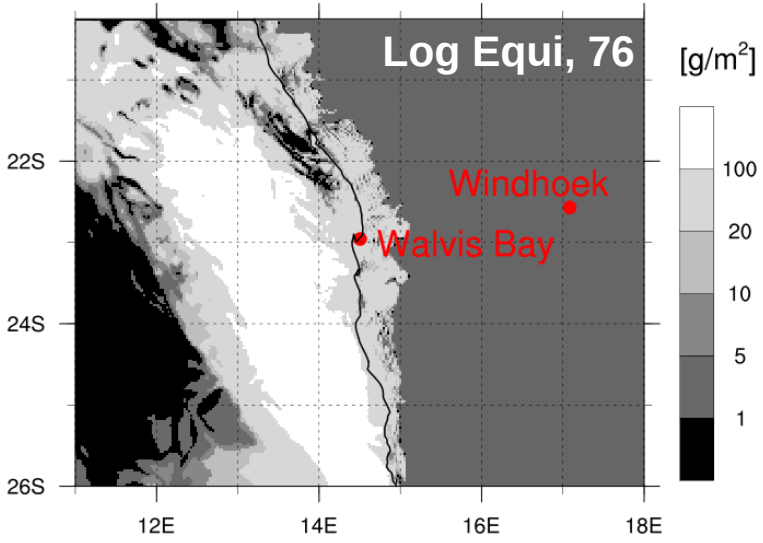
Horizontal Extension of Fog and Stratus

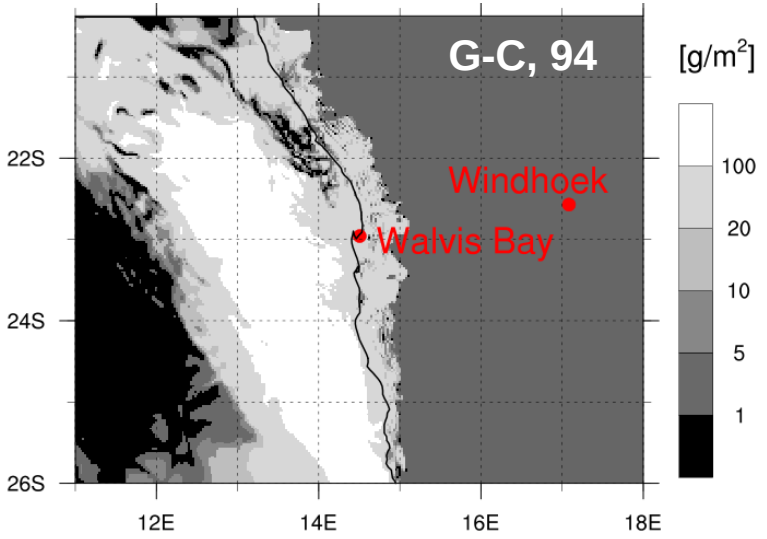
Fog and Stratus Defined by Vertically Integrated Liquid Water Content

06 UTC





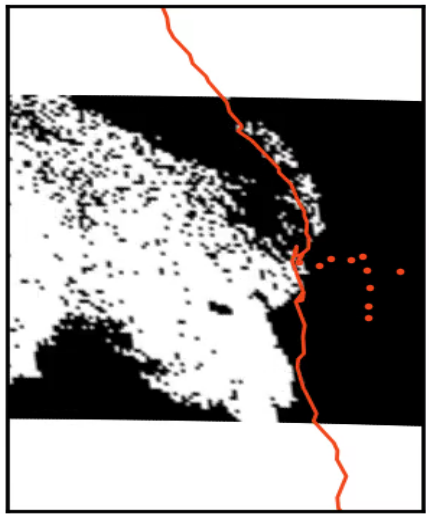


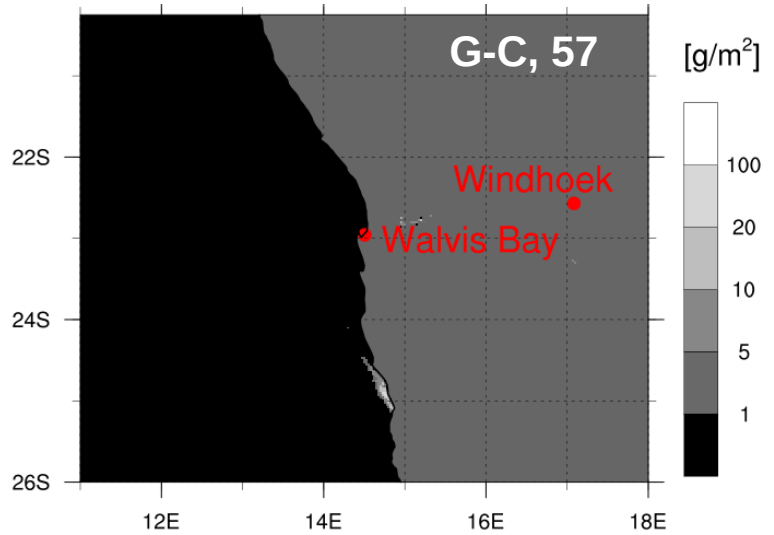


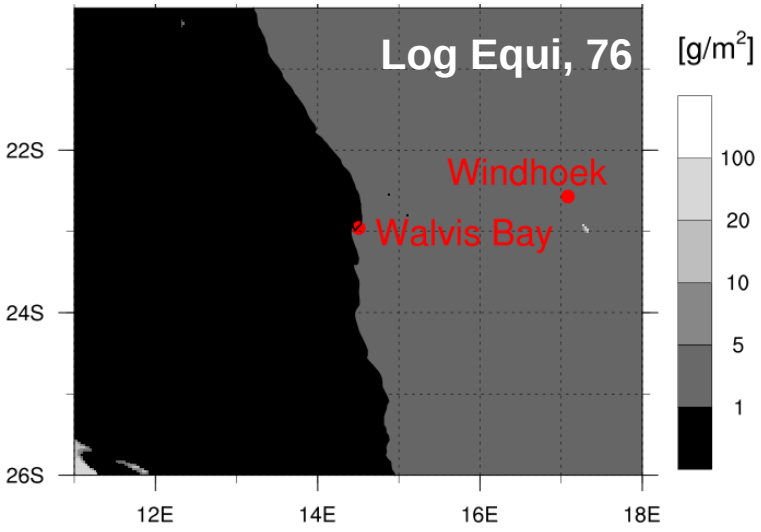
Horizontal Extension of Fog and Stratus

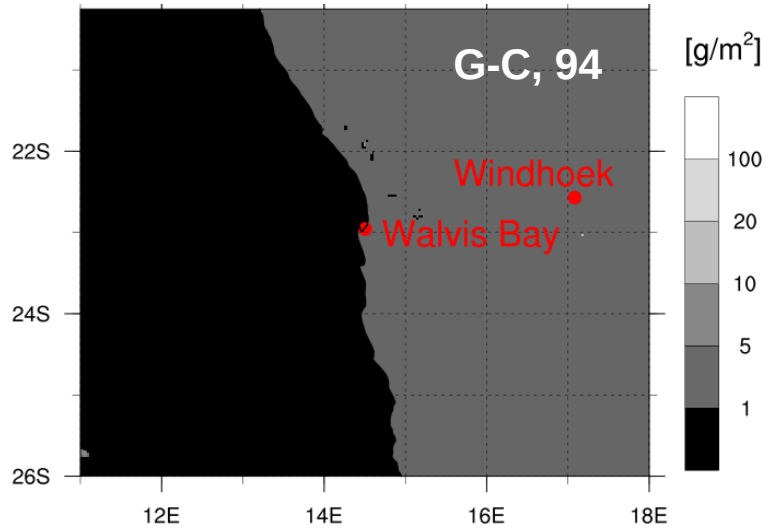
Fog and Stratus Defined by Vertically Integrated Liquid Water Content

17 UTC





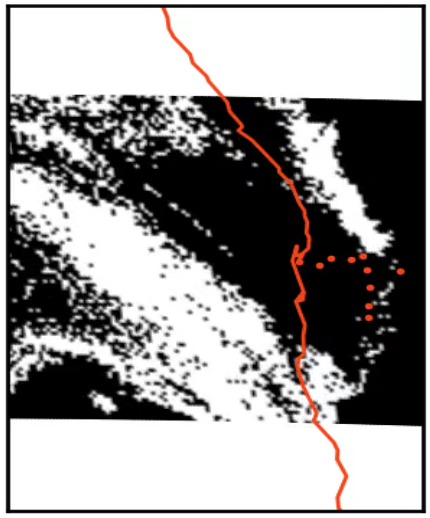


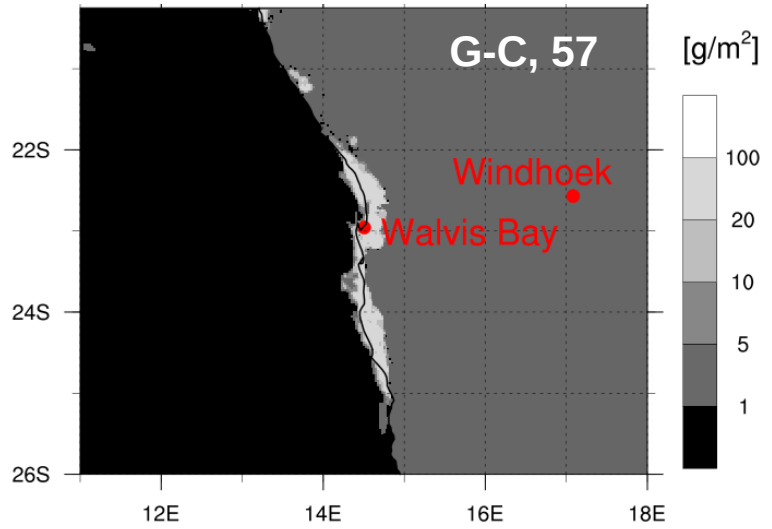


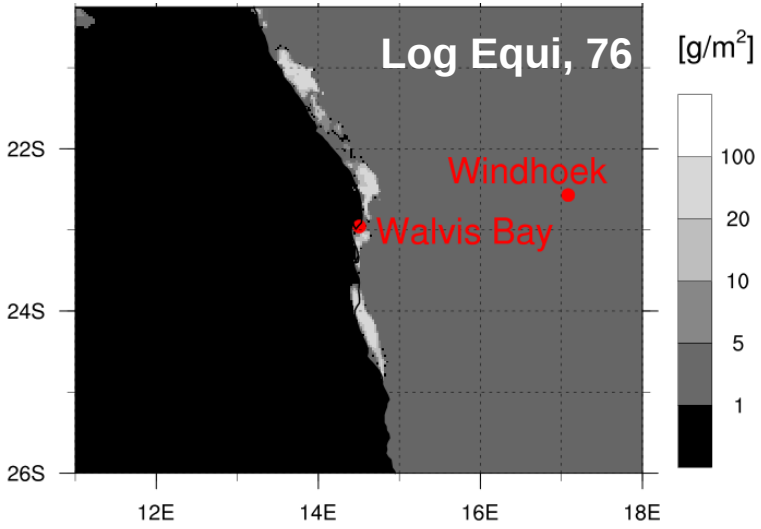
Horizontal Extension of Fog and Stratus

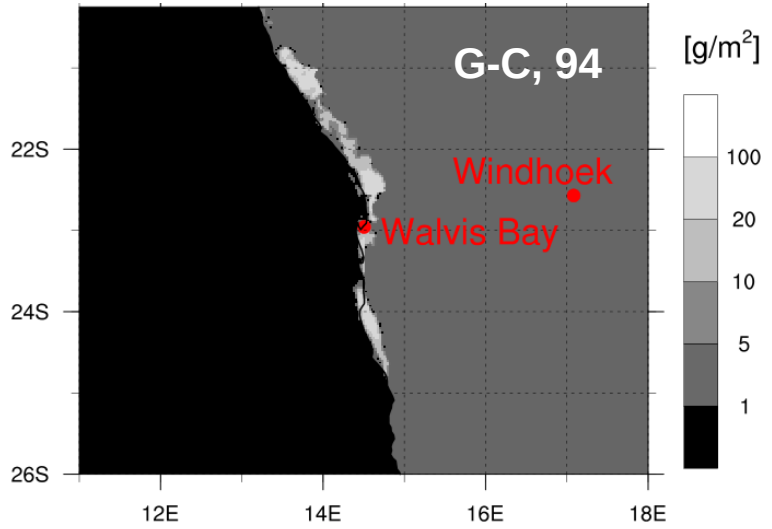
Fog and Stratus Defined by Vertically Integrated Liquid Water Content

02 UTC + 1d



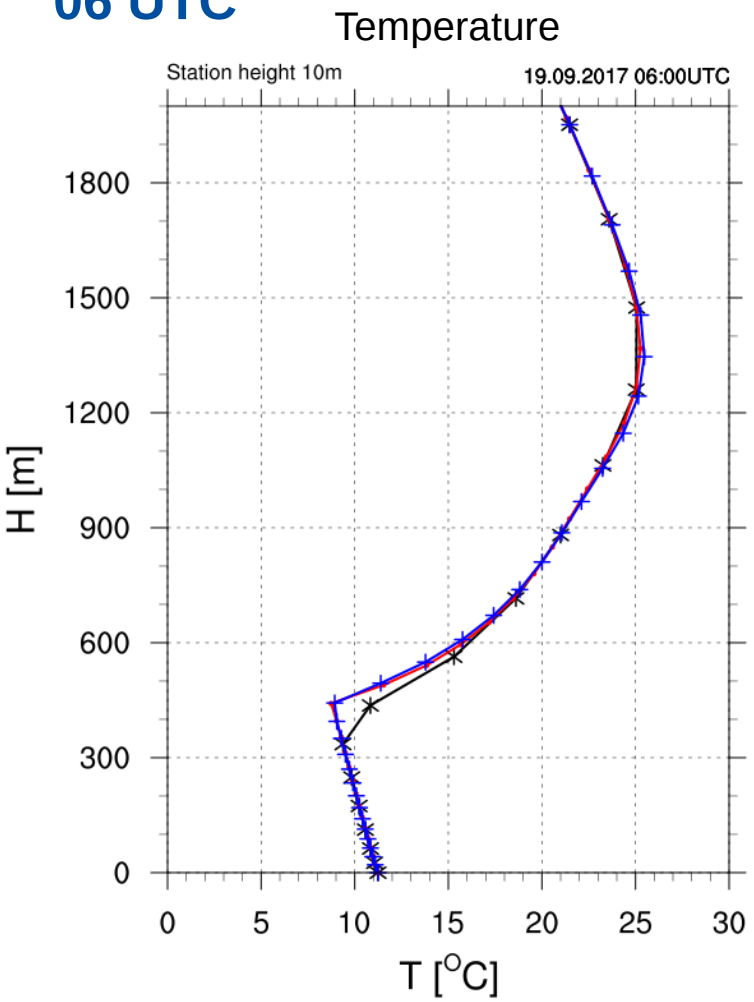


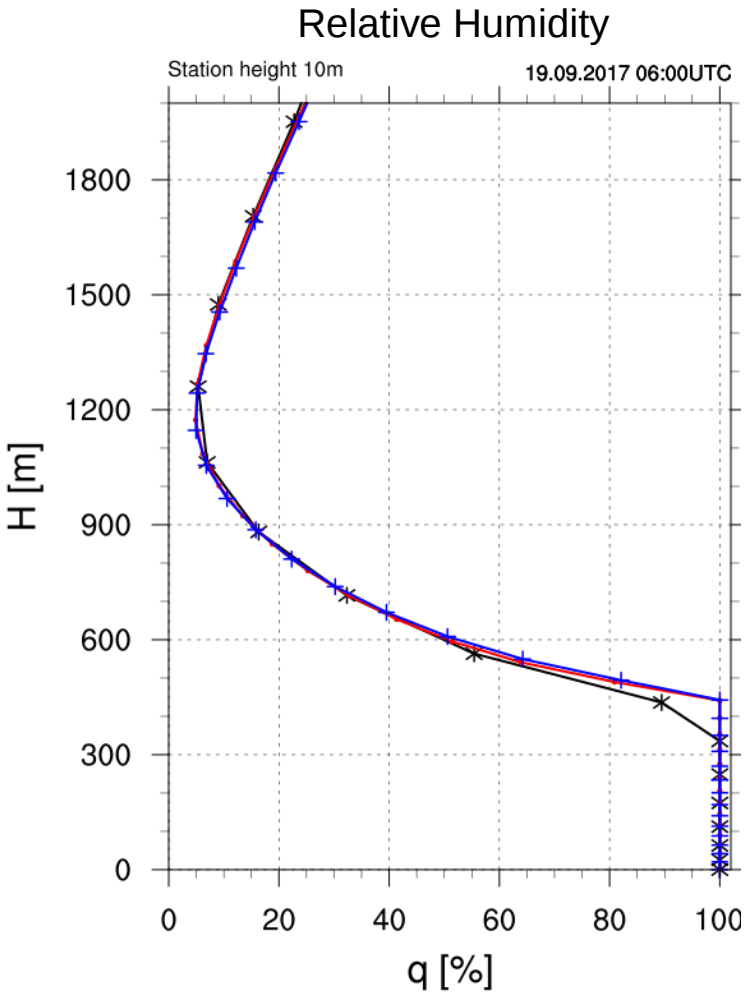




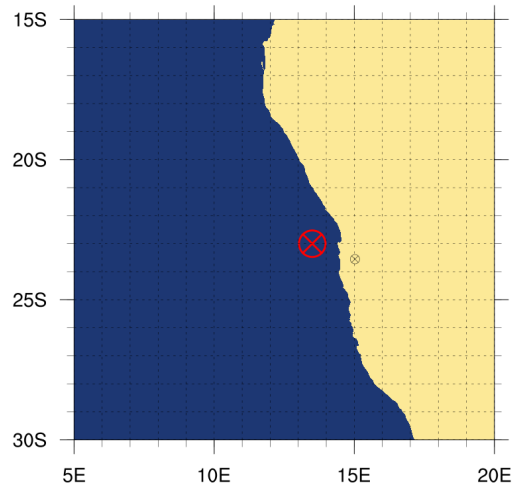
Dissolution of the Stratus Over the Atlantic

06 UTC





* Gal-Chen 57
+ Gal-Chen 93
● Log Equi 76

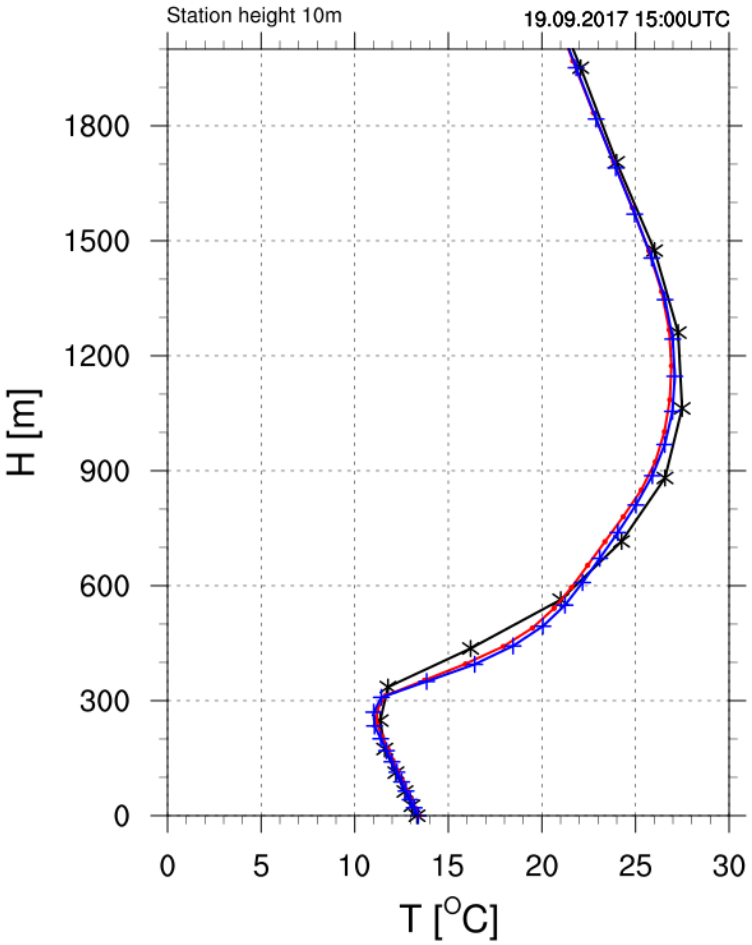


- temperature inversion between 300 and 500 m
- saturated layer beneath the inversion
- slight improvement by increased number of vertical layers, but inversion still too weak

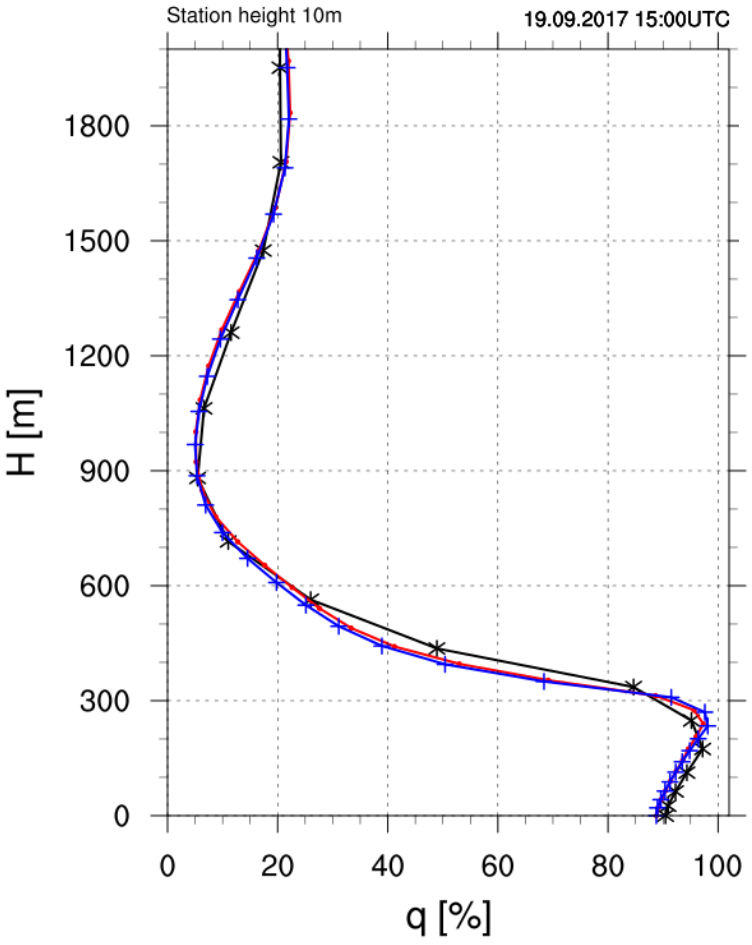
Dissolution of the Stratus Over the Atlantic

15 UTC

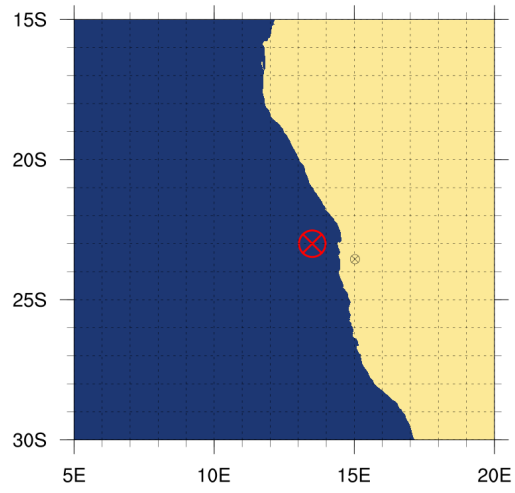
Temperature



Relative Humidity



* Gal-Chen 57
+ Gal-Chen 93
• Log Equi 76

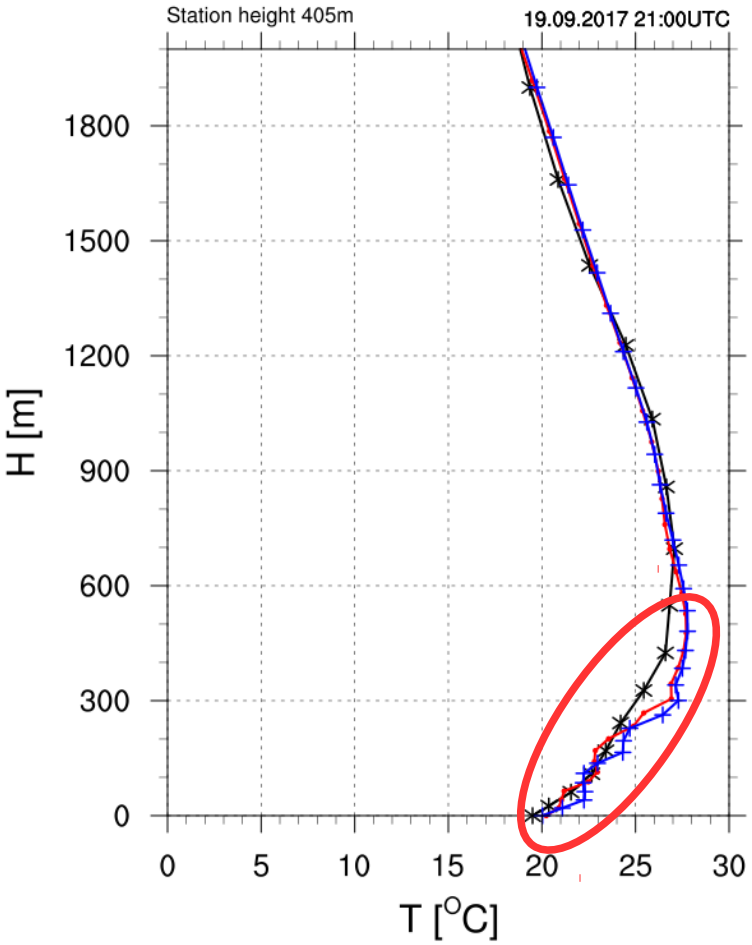


- moist layer close to inversion layer is still present, but not saturated
- dissolution of the stratus

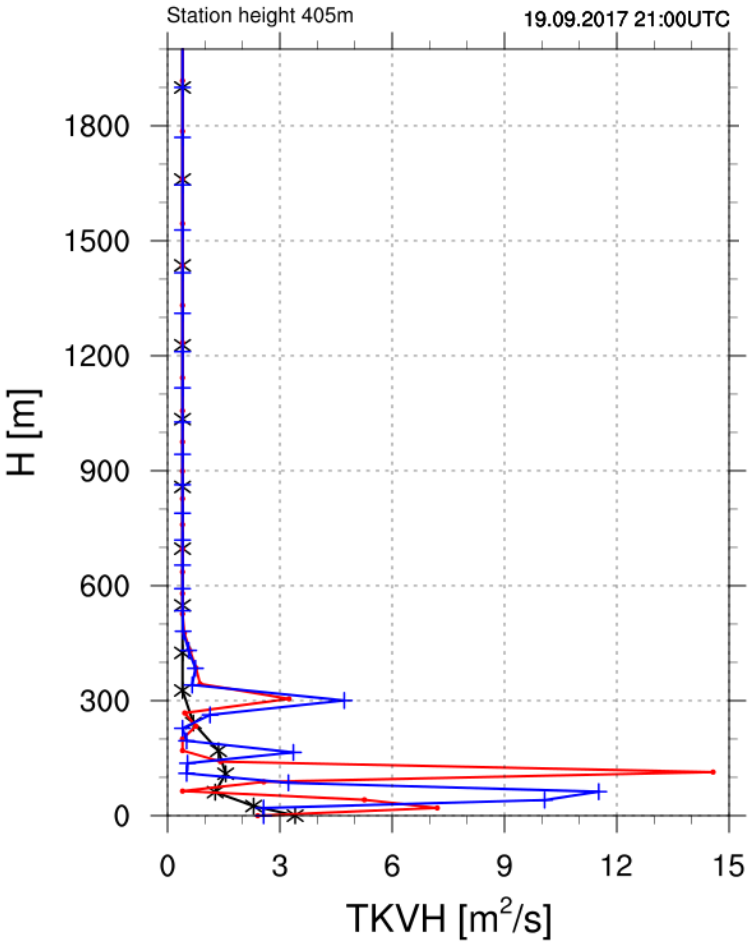
Numerical Instabilities in Turbulence Scheme

21 UTC

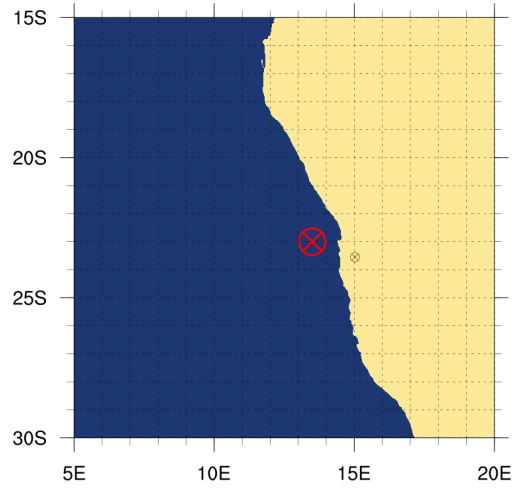
Temperature



Turbulent Exchange Coefficient (Heat)



* Gal-Chen 57
+ Gal-Chen 93
● Log Equi 76



- unphysical behavior of temperature profiles for changed vertical coordinates
- unexpected oscillations of turbulent exchange coefficients
  → numerical instabilities