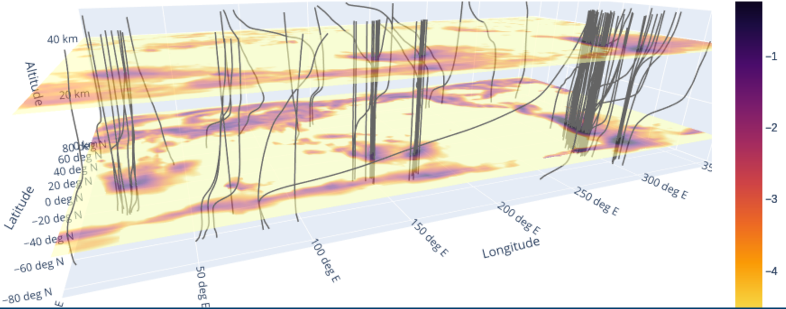


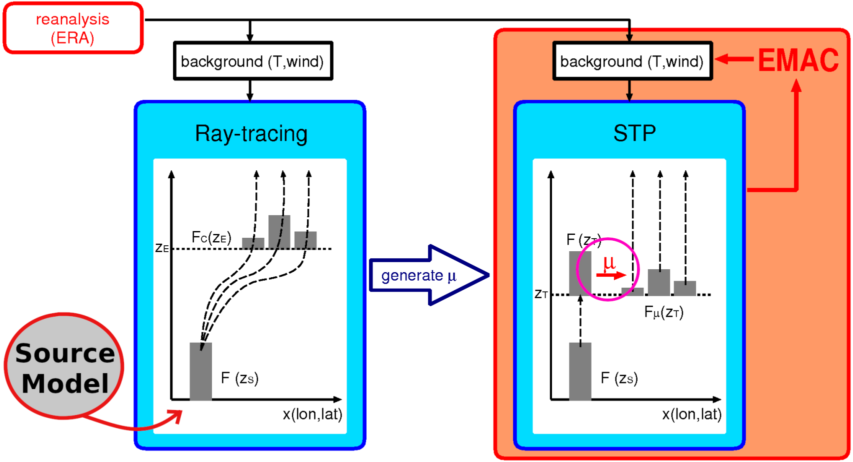
MODELLING HORIZONTAL PROPAGATION OF OROGRAPHIC GWS IN EMAC

From a source model to propagation pattern

April 24, 2023 | Rhode, S., Eichinger, R., Preusse, P., Garny, H., Ern, M., and Krasauskas, L. | EGU 2023 - Vienna

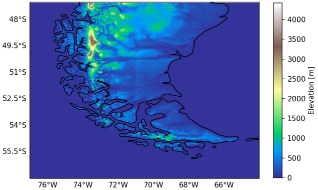
JÜLICH Forschungszentrum

Redistributing oro. GWMF using pre calculated propagation pattern

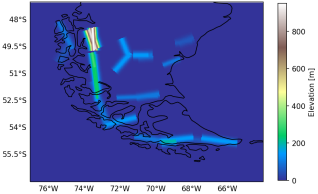


Orographic Source and Propagation Modelling

Elevation data



reduced to 2D mountains

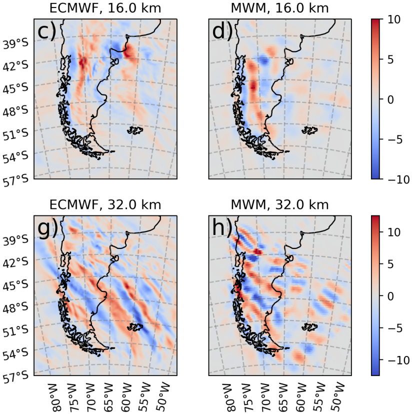


ray-

tracing

small scale MW activity

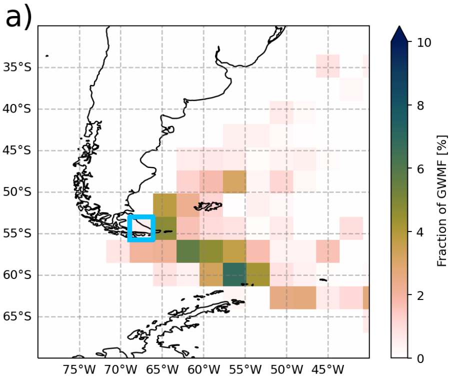
(residual temp., GWMF and prop.)



Rhode et.al., 2023, A mountain ridge model for quantifying oblique mountain wave propagation and distribution

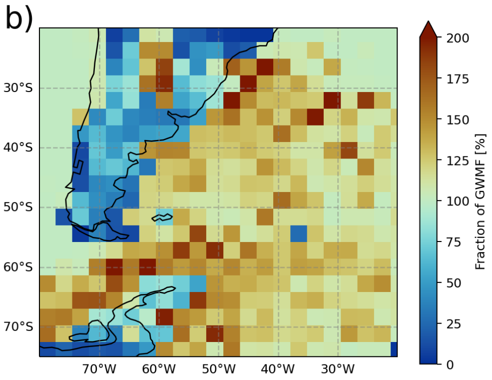
Calculation of a statistic propagation pattern

Transport matrix μ



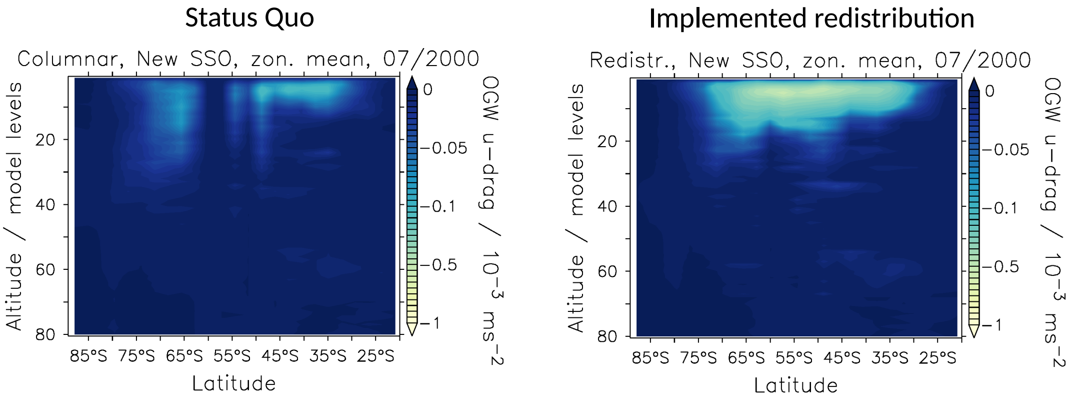
$\rightarrow$ transport of GWMF from source grid cell

General redistribution pattern



$\rightarrow$ GWMF redistribution from land to ocean

Emulating hor. GW propagation in EMAC (zonal mean drag)



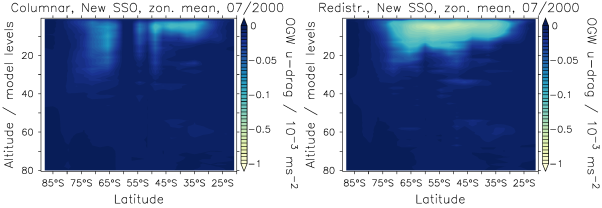
Eichinger et.al., 2023, Emulating lateral gravity wave propagation in a global chemistry-climate model (EMAC v2.55.2) through horizontal flux redistribution

Estimating oro. GW propagation from a Mountain Wave Model

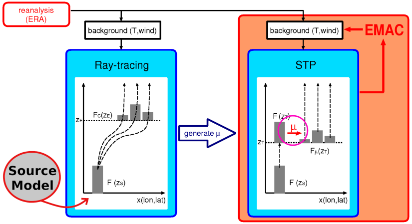
1. Improving GW drag in EMAC

Standard oro. GW Drag

Redistributed oro. GW Drag

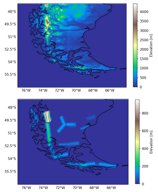


2. Schematic Approach

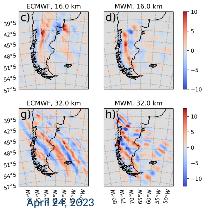


3. MW Source Model

Simplified Topography

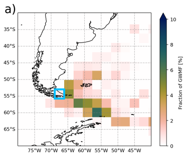


MW activity

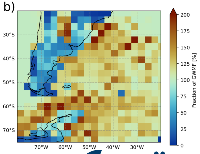


4. Transport pattern μ

Transport Matrix

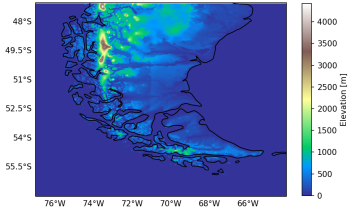


General Redistribution

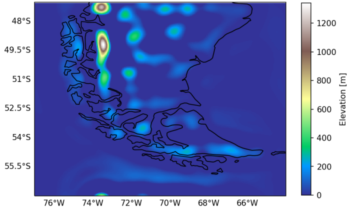


Source Finding Algorithm - Preparing steps

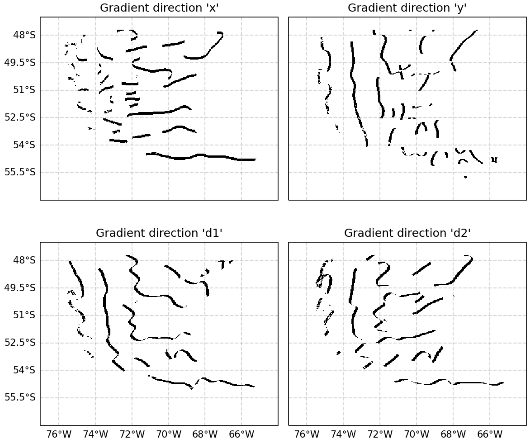
Topography data:



1. Bandpass filtering:



2. Reduction to skeleton

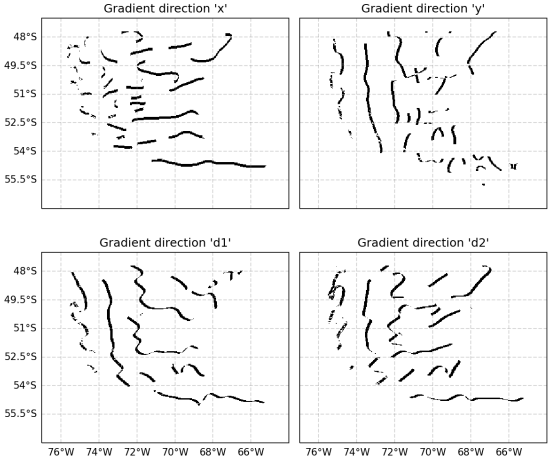


Source Finding Algorithm - Hough Transformation

The idealized mountain ridges lie along the ridge lines

⇒ Hough transformation allows to detect (more-or-less) straight line features

2. Reduction to skeleton



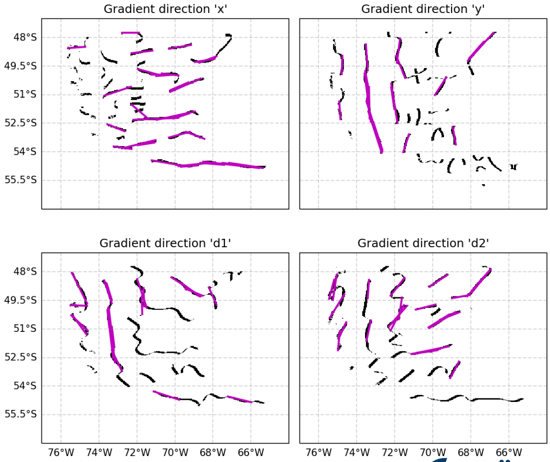
Source Finding Algorithm - Hough Transformation

The idealized mountain ridges lie along the ridge lines

⇒ Hough transformation allows to detect (more-or-less) straight line features

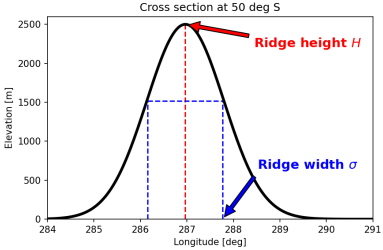
⇒ **location**, **orientation** and **length** of *possible* mountain ridges

3. Hough transformation

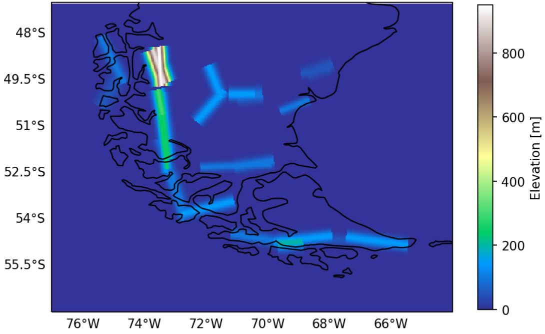


Source Finding Algorithm - Fit of idealized ridges

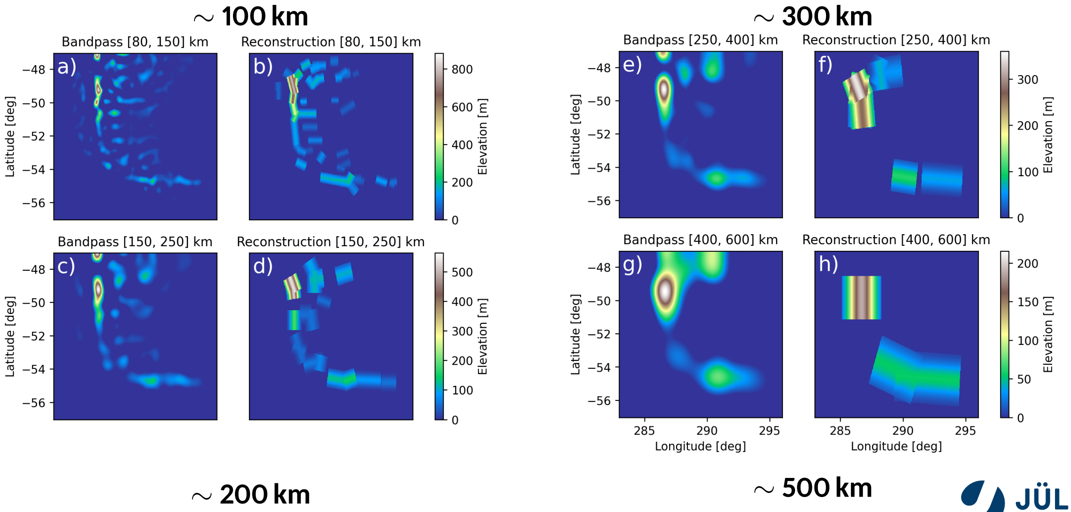
Final step is a fit with Gaussian shaped mountain along the length of the detected features



4. Fit with 1D Gauss-shaped ridges



Elevation approximation of different scales



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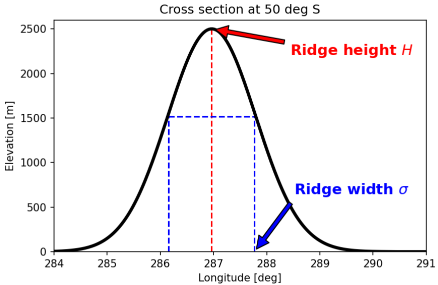
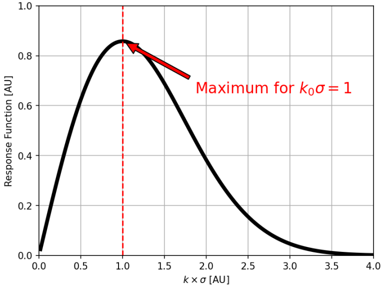
GW parameter estimation

Idealized Ridges with shape:

$$h(x) = H_{\max} \exp\left(-\frac{x^2}{2\sigma^2}\right)$$



Excited MWs can be calculated via FT

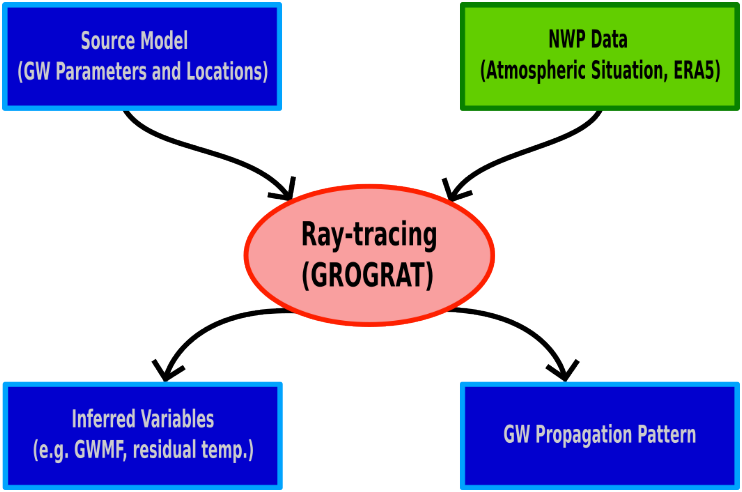


$$\Leftrightarrow \lambda_0 = \frac{2\pi}{k_0} = 2\pi\sigma \quad (1)$$

Initial displacement amplitude: $\frac{1}{\sqrt{2\pi}}\boldsymbol{H_{\max}}$

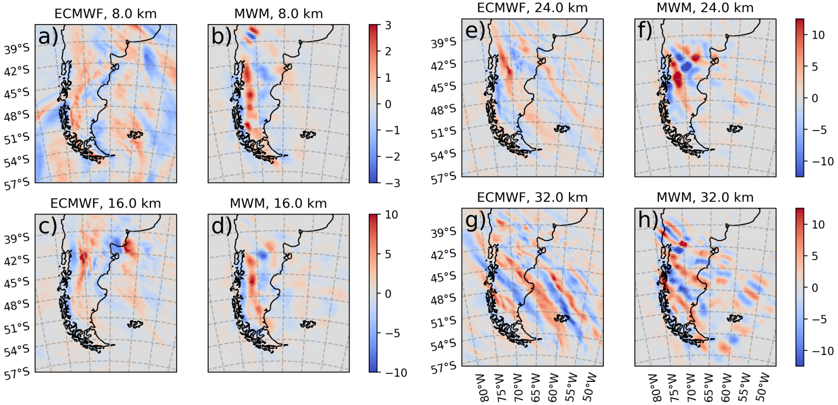
Main Wavelength: $\boldsymbol{2\pi\sigma}$

Mountain Wave Model



Temperature perturbation – 22.09.2019 00:00

8 km



24 km

16 km

32 km

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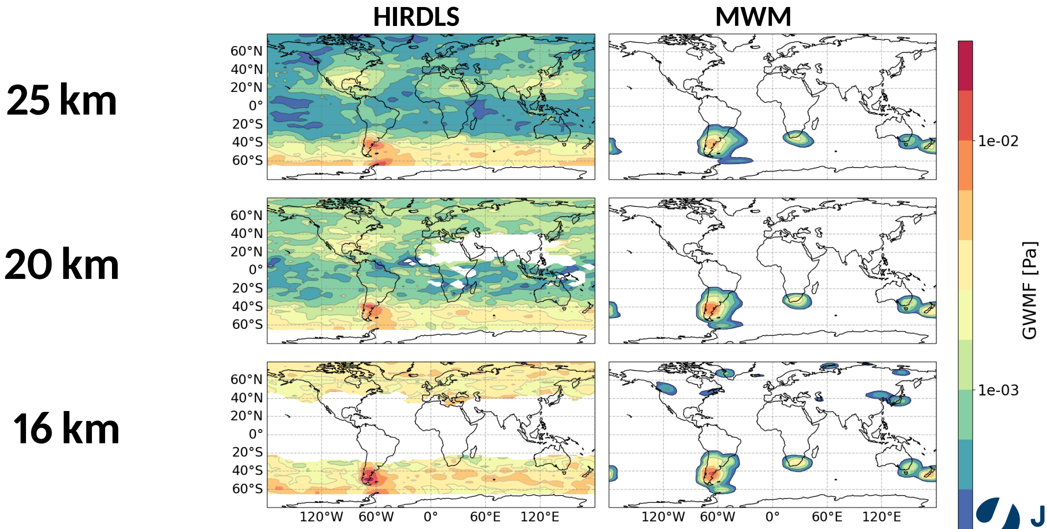
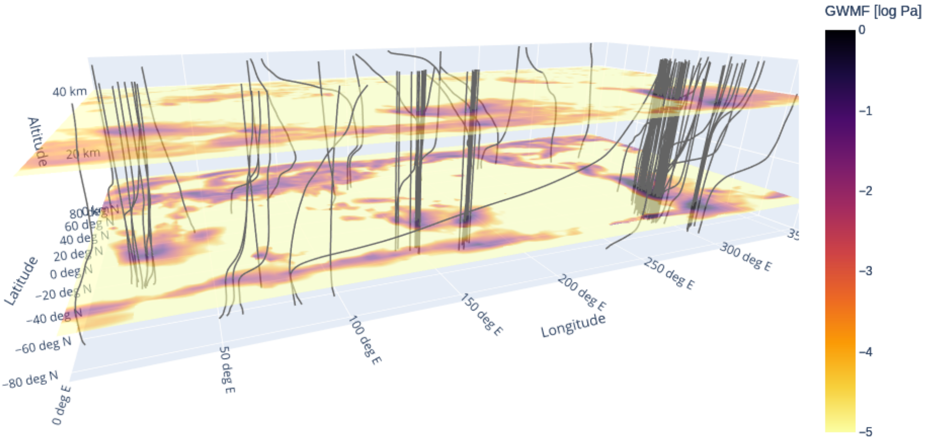
Horizontal GWMF Distribution – July 2006

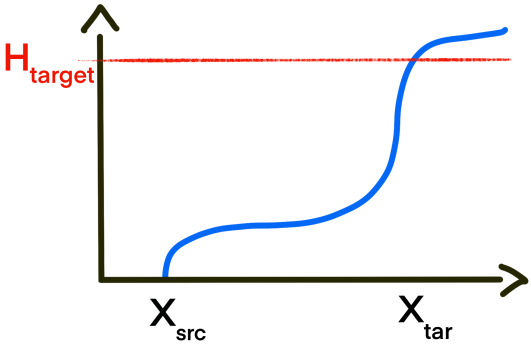


Combination of hor. GWMF distributions and ray-traces



⇒ Information where each contribution to the horizontal distribution originates

Generating Redistribution/Transport Functions



For each GW:

- target location X_{tar} as location at specific altitude
- weight by the rays GWMF
- here chosen at H_{tar}

$\Rightarrow$ redistribution of given GWMF from

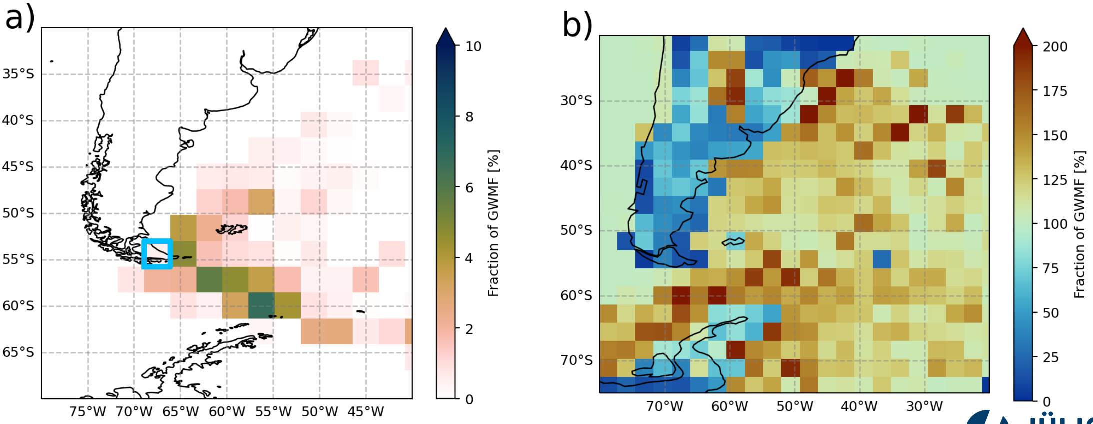
$$X_{\mathrm{src}} \to X_{\mathrm{tar}}$$

$\sim$ total GWMF transported from X_{src} to X_{tar}

$$\hat{\mu}(X_{\mathrm{src}}, X_{\mathrm{tar}})$$

Example of a transport function

- Transport matrix for each source grid point
- In general, GW flux will be reduced over land and increased over the ocean

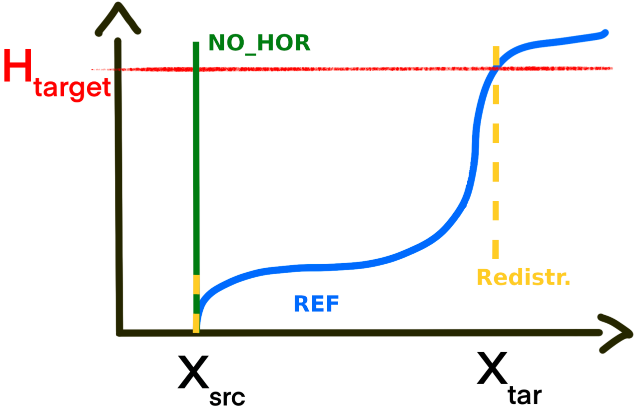


Performance Estimation of propagation approximation

Compare *horizontal propagating* ***reference** run* to:

1. ***vertical** propagation*
2. *vertical data **redistributed***

In terms of **Drag** difference vs. reference run for different values of H_{tar}



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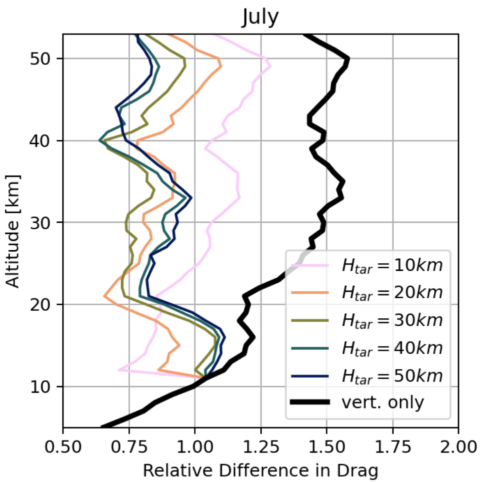
July Case – Drag Approximation



Monthly mean relative error to reference run

$\rightarrow \frac{\overline{|\text{drag - }\mathbf{ref}|}}{\overline{\mathbf{ref}}}$ as measure for approximation quality

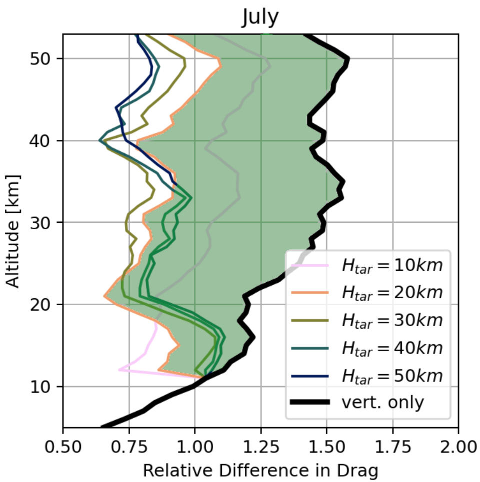
(global and monthly mean)

GW Drag typically increases with height $\rightarrow$ especially higher level need to be approximated well

Deviation reduces by about a factor of 2 in the upper middle-atmosphere

Trade-off in H_{tar}

July Case – Drag Approximation



Monthly mean relative error to reference run

$\rightarrow \frac{\overline{|\text{drag - } \mathbf{ref}|}}{\overline{\mathbf{ref}}}$ as measure for approximation quality

(global and monthly mean)

GW Drag typically increases with height $\rightarrow$ especially higher level need to be approximated well

Deviation reduces by about a factor of 2 in the upper middle-atmosphere

Trade-off in H_{tar}

$\Rightarrow$ Improvement is proportional to shaded area

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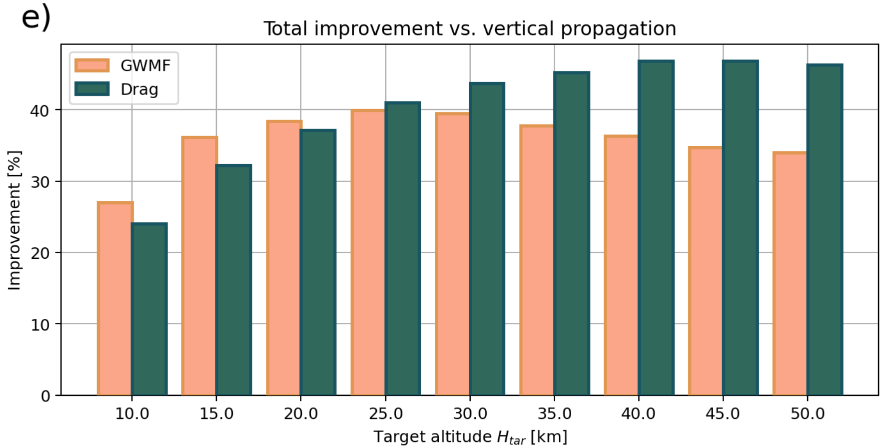
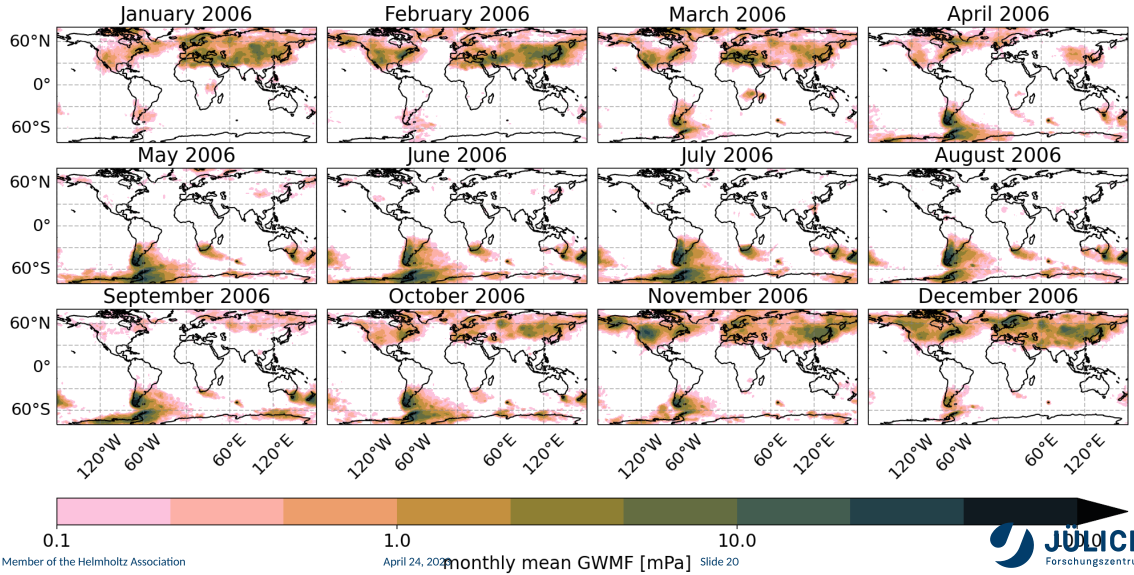
July Case – Improvement



$\Rightarrow H_{tar} \sim$ 40 km approximates up to 45% of drag transport

Seasonal Patterns - is propagation that seasonal?



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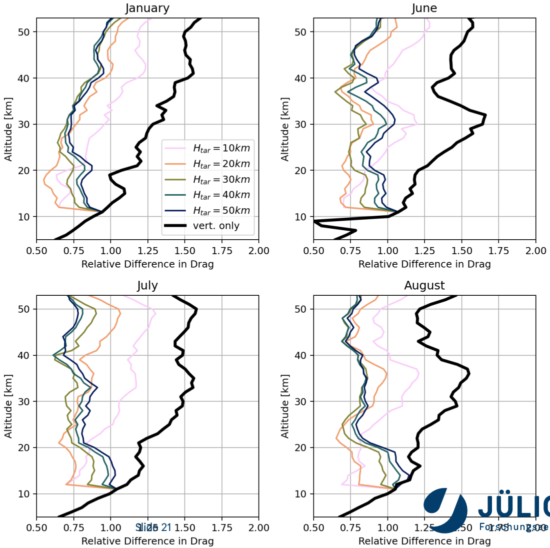
More Rays, more fun!

Propagation pattern for full year of ray-tracing (about 2.5M rays).

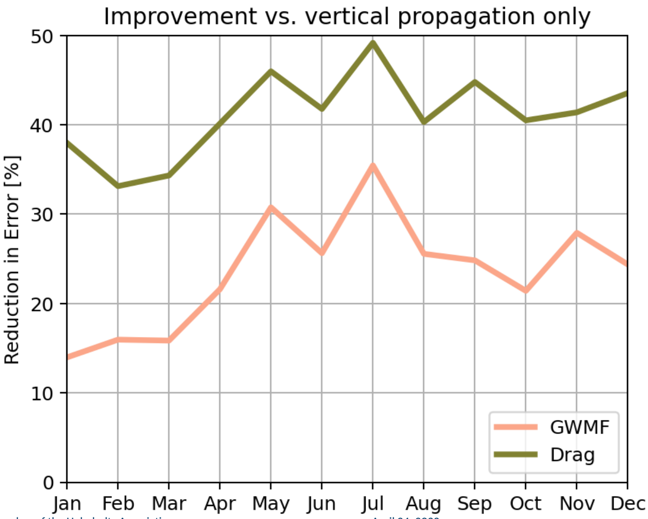
$\Rightarrow$ is there a general-ish propagation pattern that can be used throughout the year?

Similar improvement to the monthly redistribution

About half the drag relocation is described in higher altitudes



Improvement throughout the year

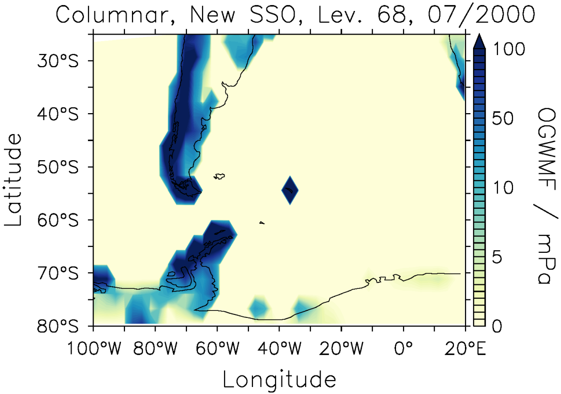


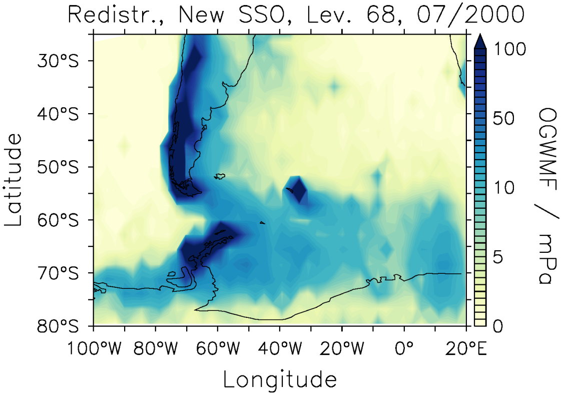
Good performance throughout the year:

Around 40% of the Drag transport is approximated

⇒ A large part of horizontal oro. GW propagation can be approximated by a **single propagation pattern**!

Application in EMAC – GWMF





$\Rightarrow$ The redistributed GWMF is much closer to satellite observations

Further Reading

Pre-Print on the MWM:

(Rhode, 2023)

Pre-Print on the implementation in EMAC:

(Eichinger, 2023)