JOHANNES GUTENBERG UNIVERSITÄT MAINZ

JG|U

Impact of Tropopause Properties on Gravity Waves - Realistic Case Studies

MS-GWaves | GW-TP | High-Resolution Modelling

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Objectives

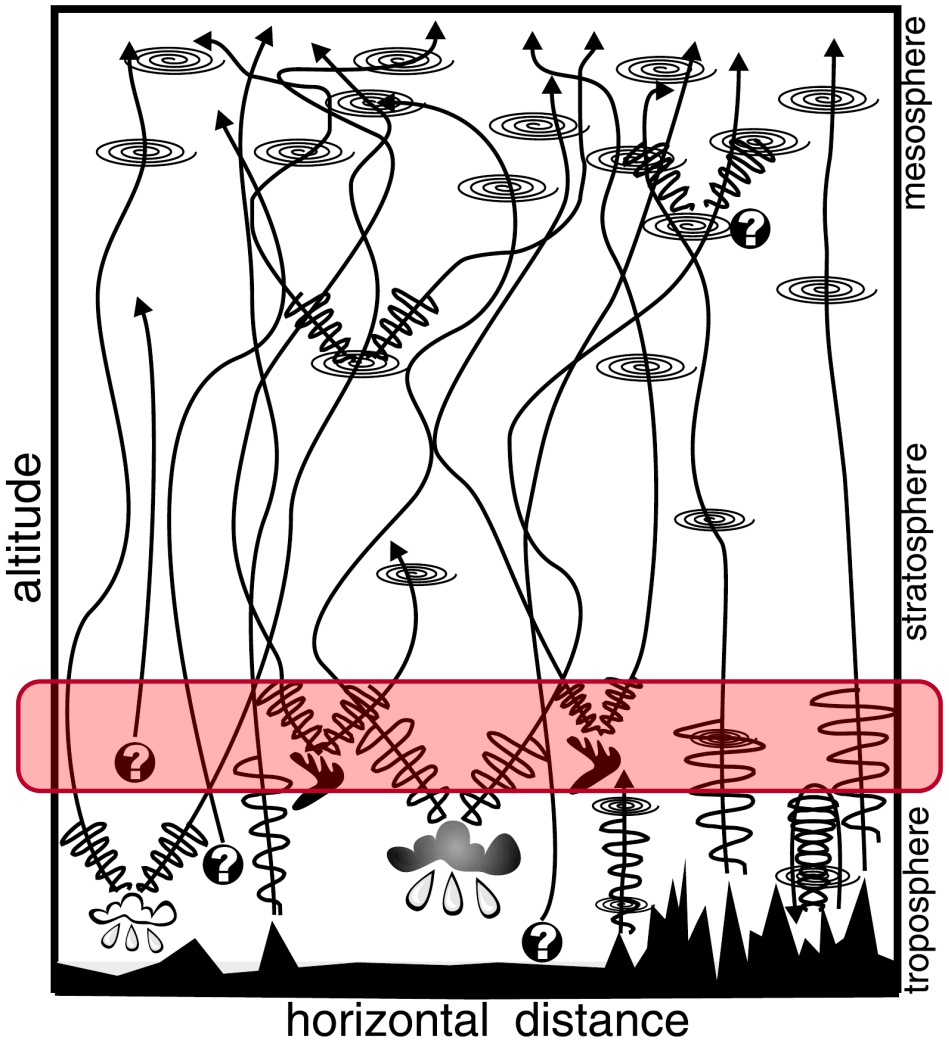


Figure: Kim et al., 2003

Tropopause region

- Partial reflection
- Trapping
- Modifying vertical wavelength
- Non-linear wave generation
- Cloud feedback

Gravity Wave Breaking and Drag
Gravity Wave Group Propagation (Ray) Path
Gravity Wave Amplitudes and Wave forms
Jet Stream Instabilities
Convection/Thunderstorms
Orography
Other Unspecified Sources of Gravity Waves

Stationary mountain waves over sinusoidal topography

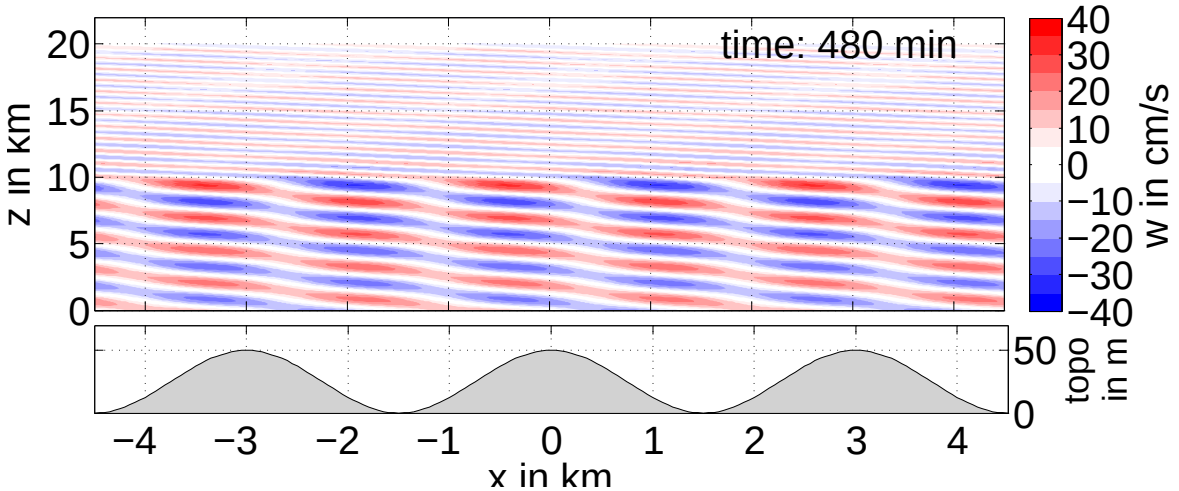


Figure: Vertical wind field w, topography

Varied parameters

- Stability
- Wind shear
- Topography
- Initial wind field

Environmental Profiles

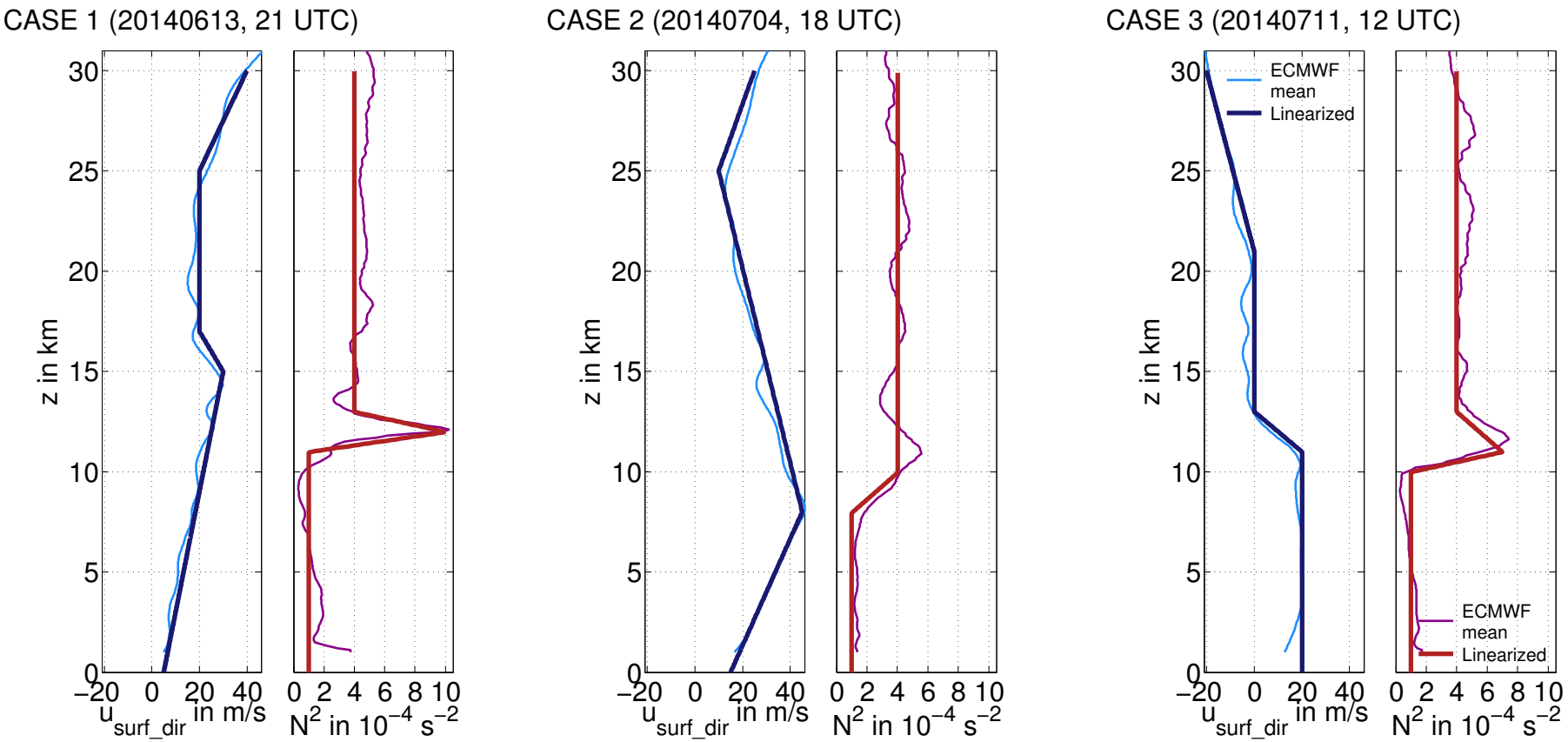
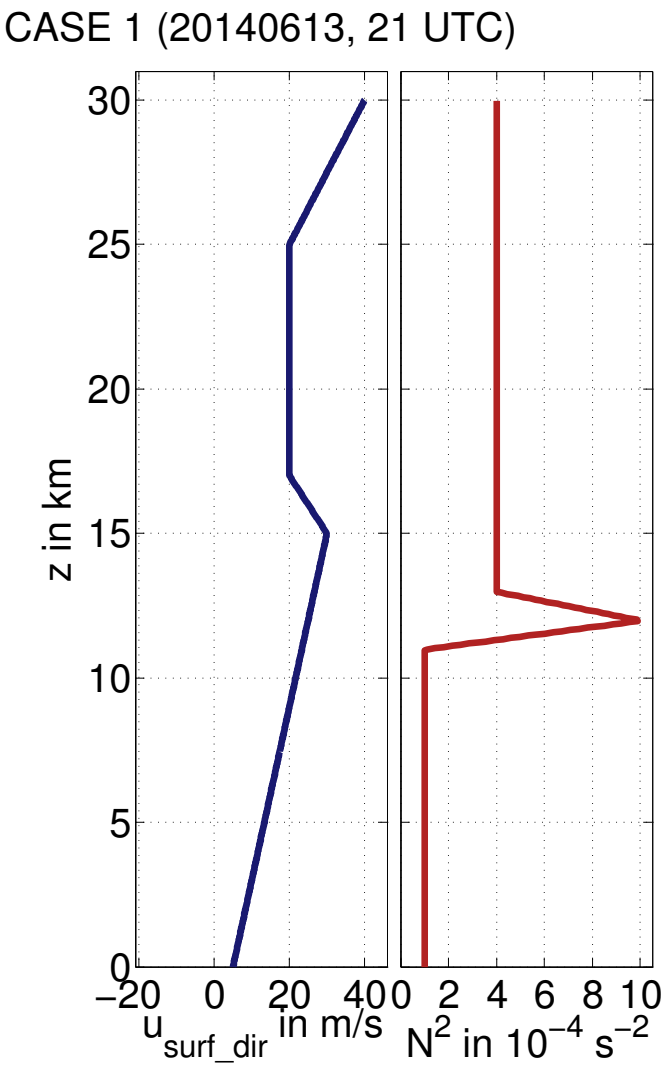


Figure: ECMWF mean profiles over New Zealand (SI) and piece-wise linearization *(S. Gisinger, DLR)*

EULAG (Prusa et al., 2008)

- Split in environmental state and deviation: $\psi' = \psi - \psi_e$
- Anelastic equations
- 2-dim on x-z plane: $90\,\mathrm{km} \times (30-55)\,\mathrm{km}$
- Periodic boundaries in x
- Absorbing layer at upper boundary
- Resolution: $\Delta x \approx 90\,\mathrm{m}, \Delta z \approx (50-90)\,\mathrm{m}$
- Topography amplitude: $H_{max} = (50-200)\,\mathrm{m}$

CASE 1 - Environment



Characteristics

- Strong tropopause inversion layer (TIL)
- Tropospheric wind speed increases with altitude
- Maximum wind speed above tropopause

CASE 1 - Wind field

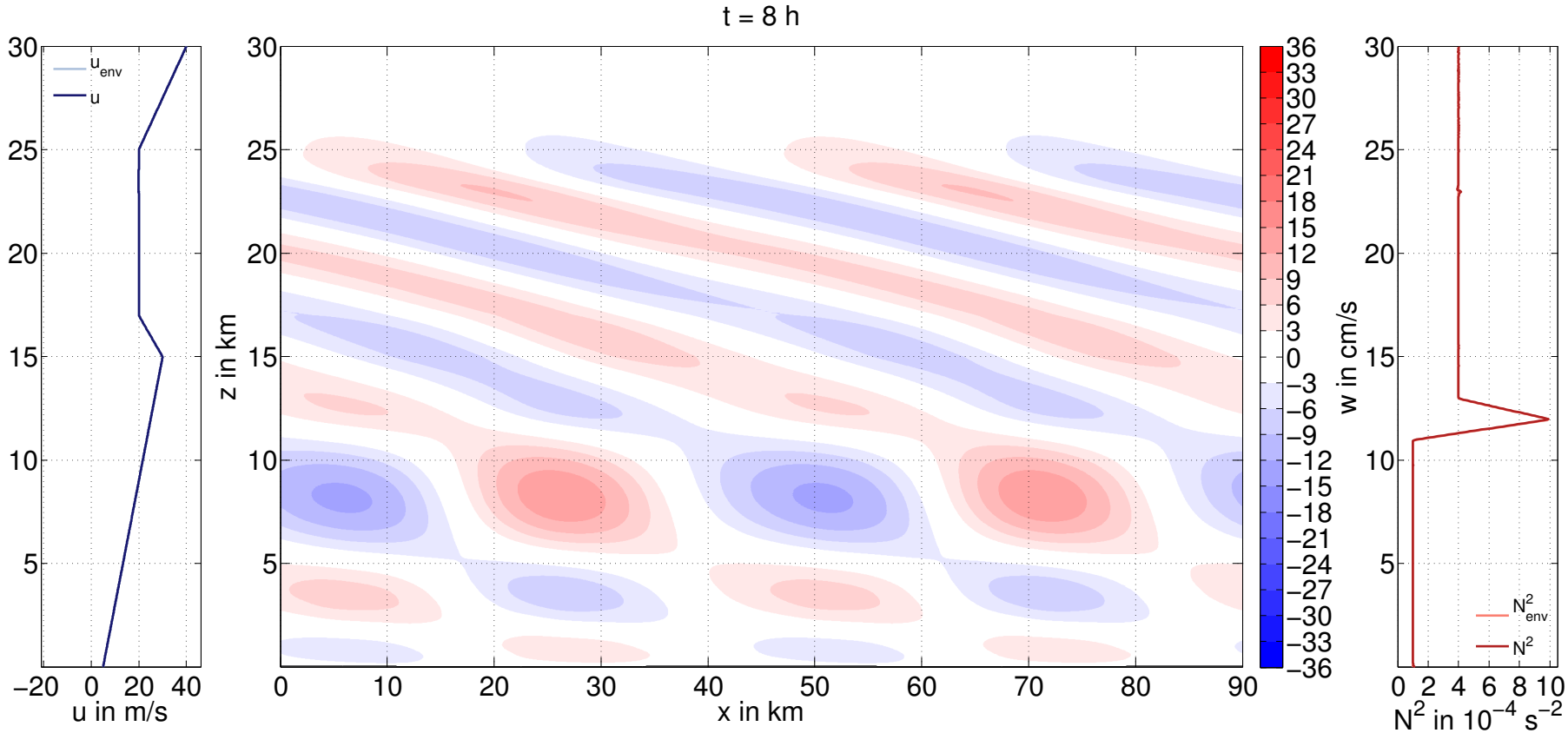


Figure: $\lambda_x = 45\,\mathrm{km}$

CASE 1 - Wind field

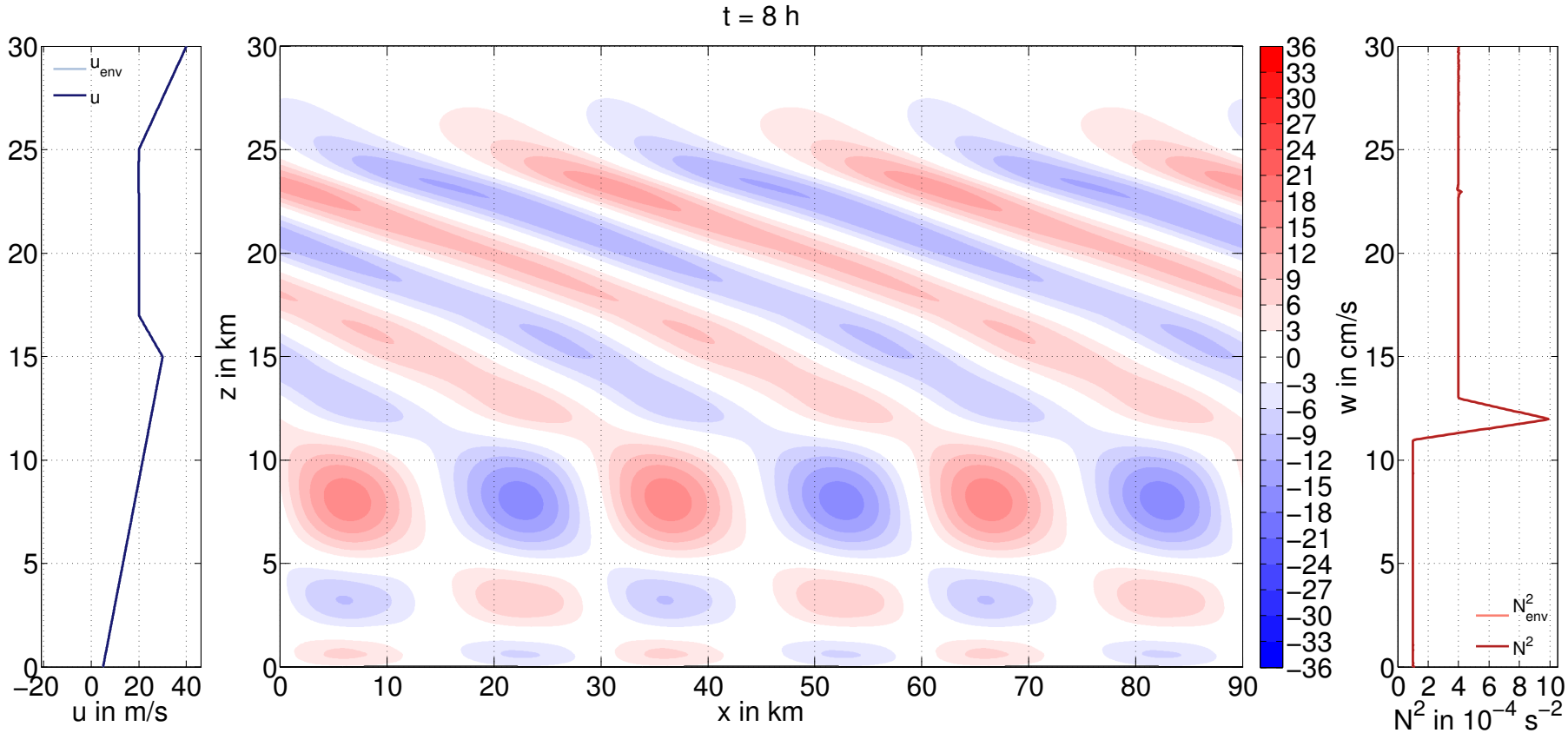


Figure: $\lambda_x = 30\,\mathrm{km}$

CASE 1 - Wind field

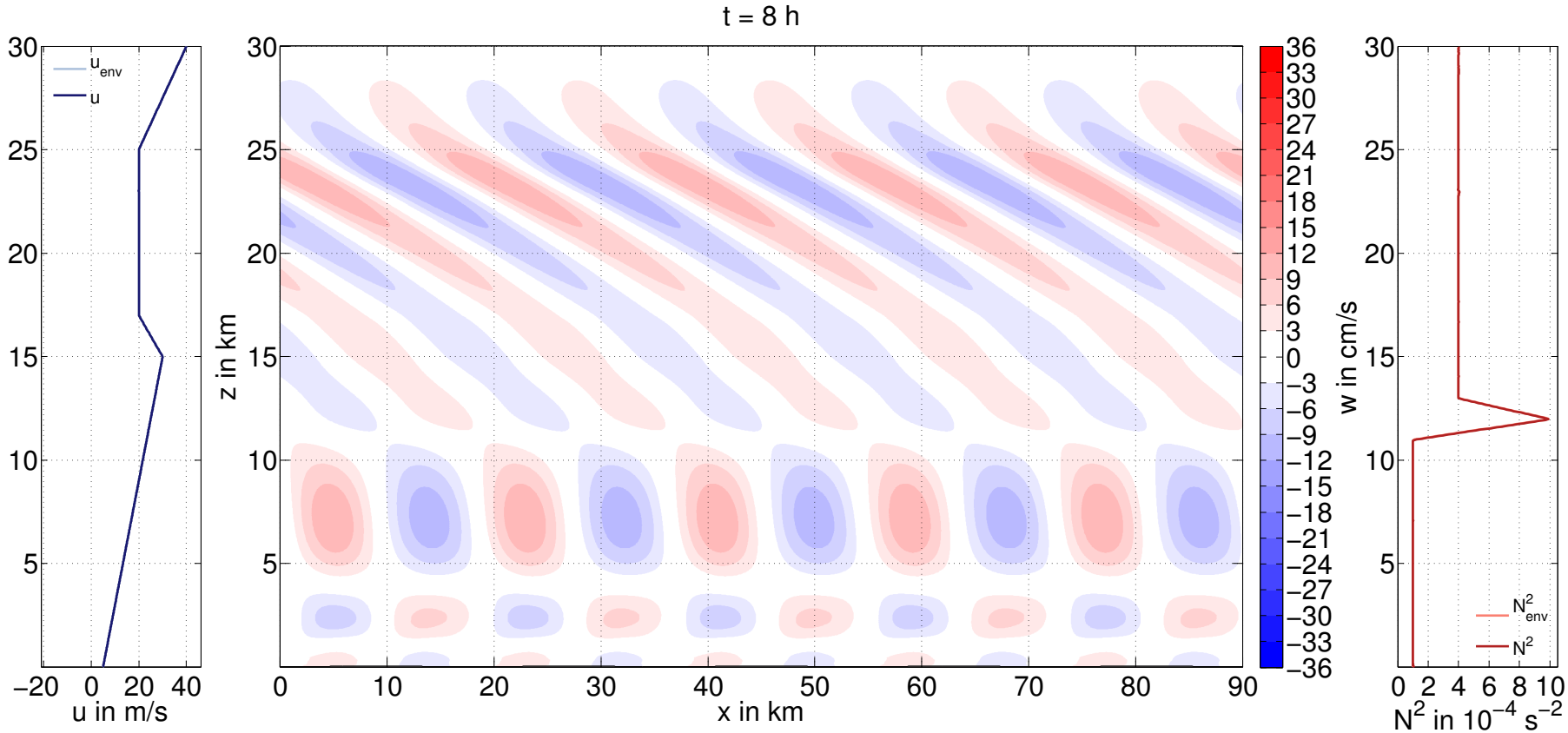
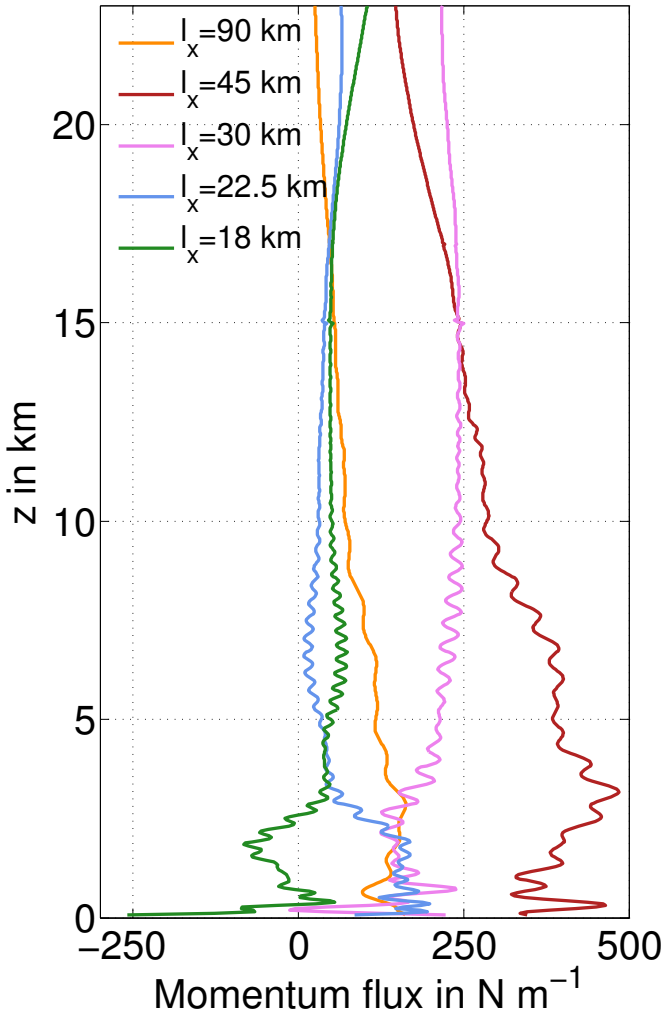


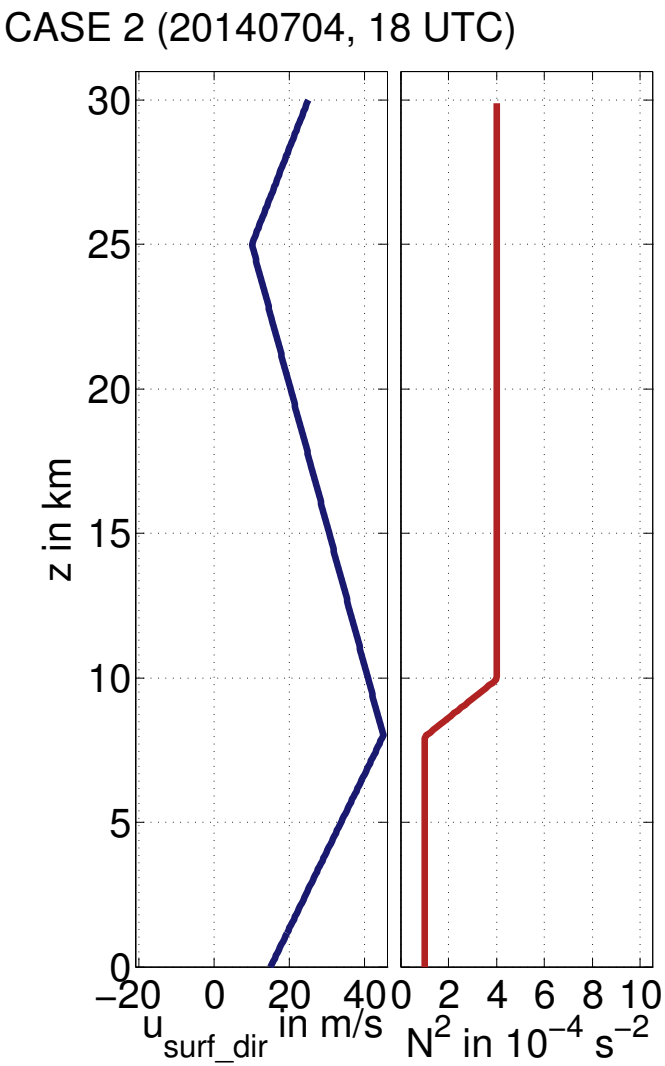
Figure: $\lambda_x = 18\,\mathrm{km}$

CASE 1 - Fluxes



- Stratospheric waves almost monochromatic
- Strongest feedback for $\lambda_x = 45\,\mathrm{km}$
- Net downward flux for $\lambda_x = 18\,\mathrm{km}$

CASE 2 - Environment



Characteristics

- Tropopause weaker than in CASE 1
- Depth of Tropopause: $2\,\mathrm{km}$
- Wind decreases with altitude in stratosphere

CASE 2 - Wind field

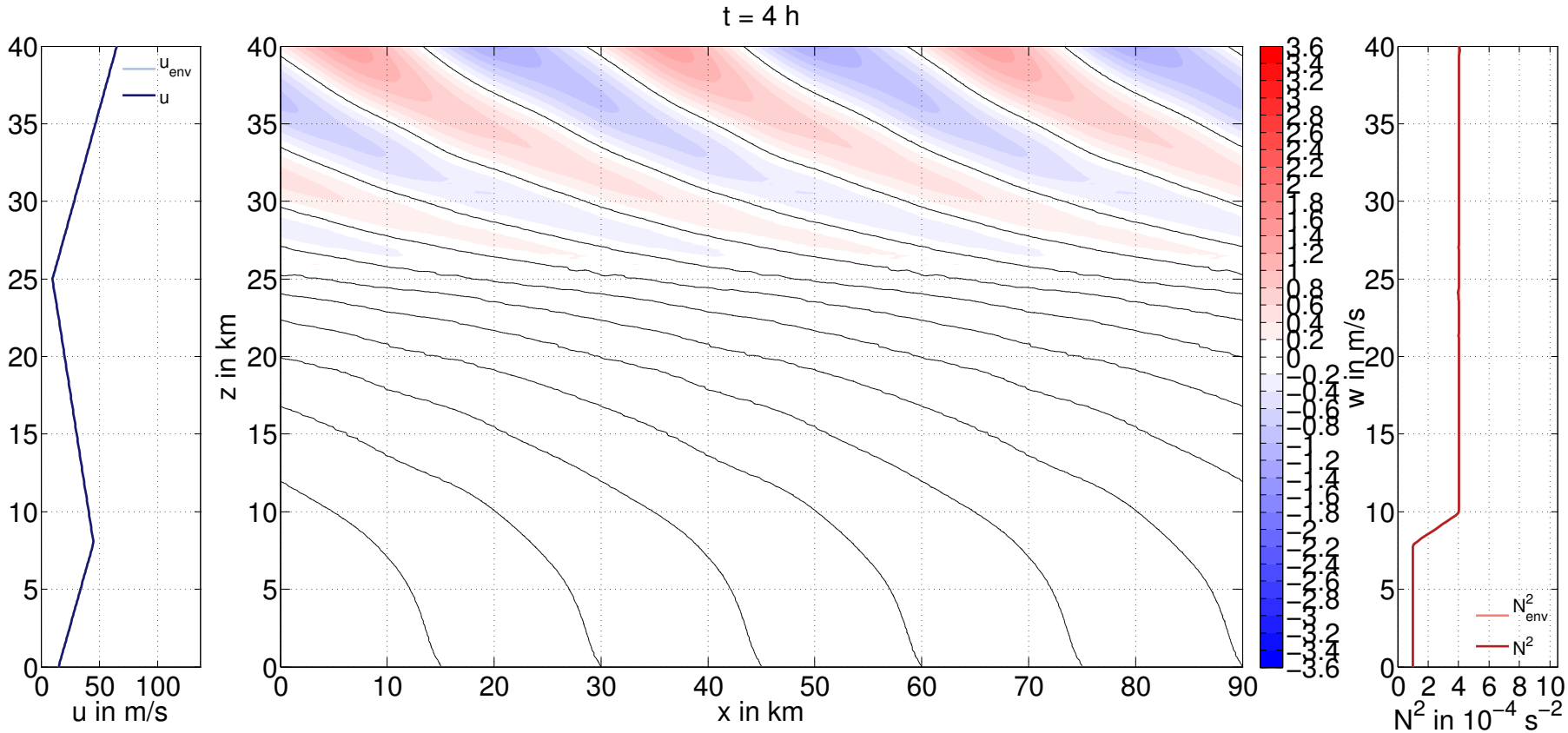


Figure: $\lambda_x = 30\,\mathrm{km}$

CASE 2 - Wind field

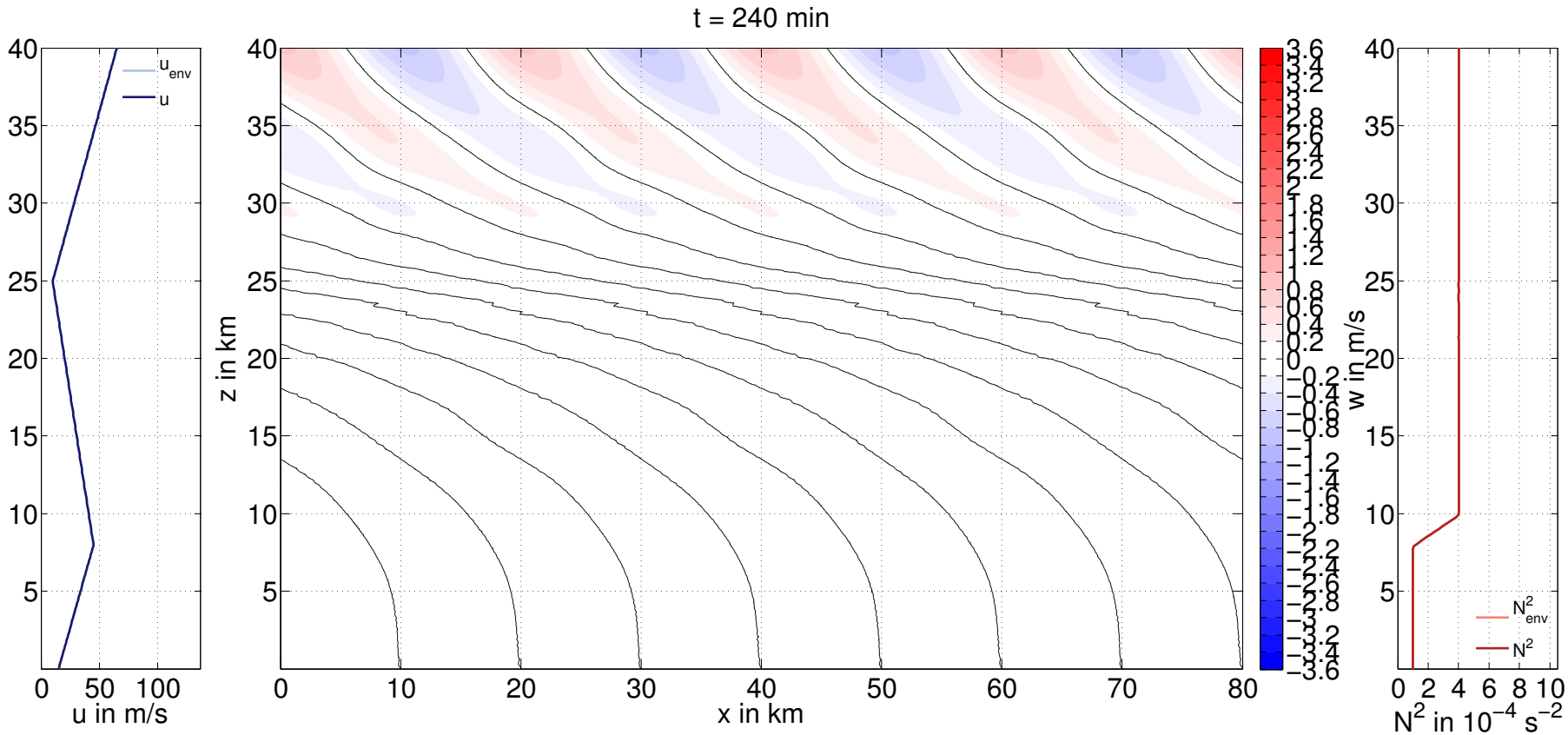


Figure: $\lambda_x = 20\,\mathrm{km}$

CASE 2 - Flightlevel Analysis

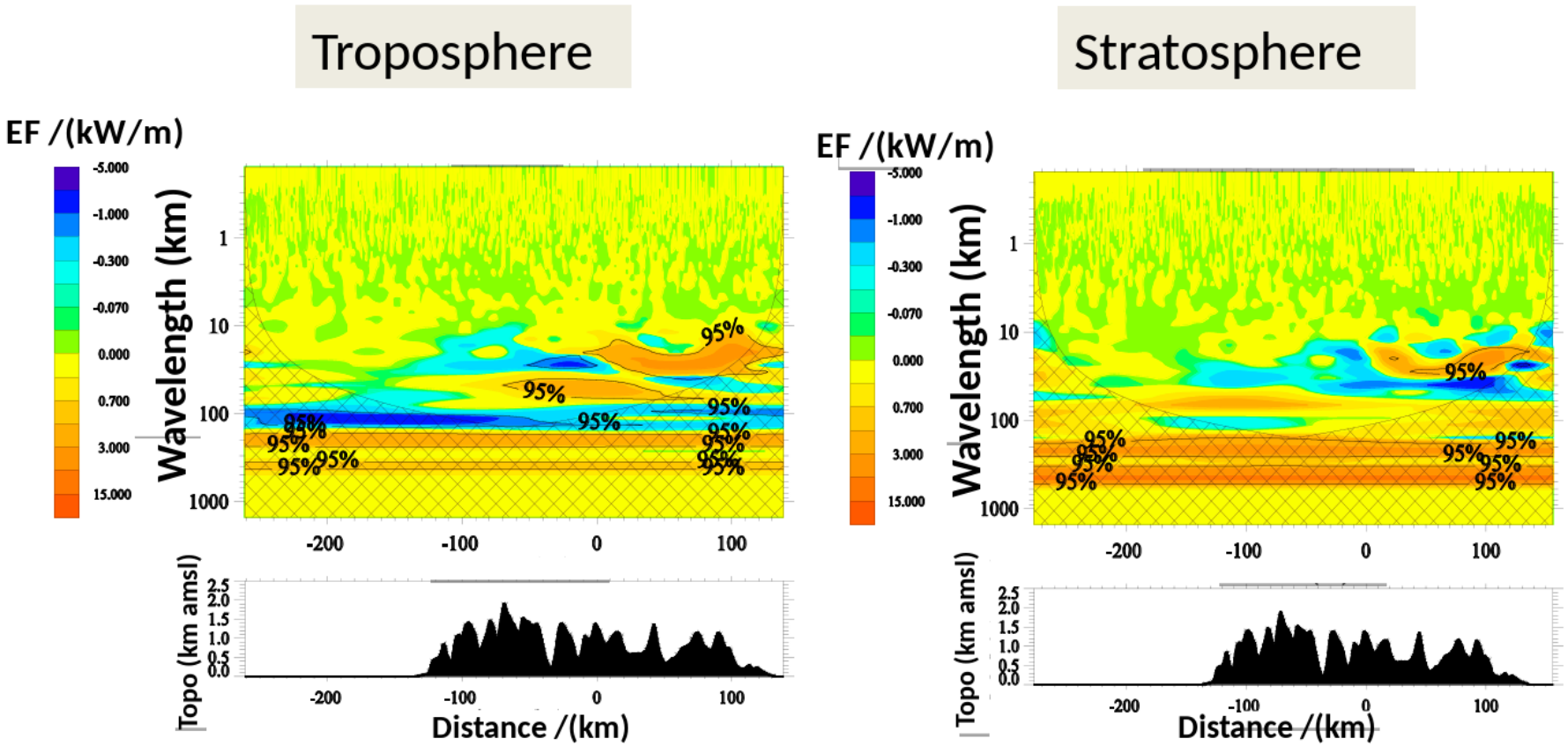


Figure: $p'w'$ Cospectra, *by M. Bramberger, DLR*

CASE 2 - Wavelet Analysis

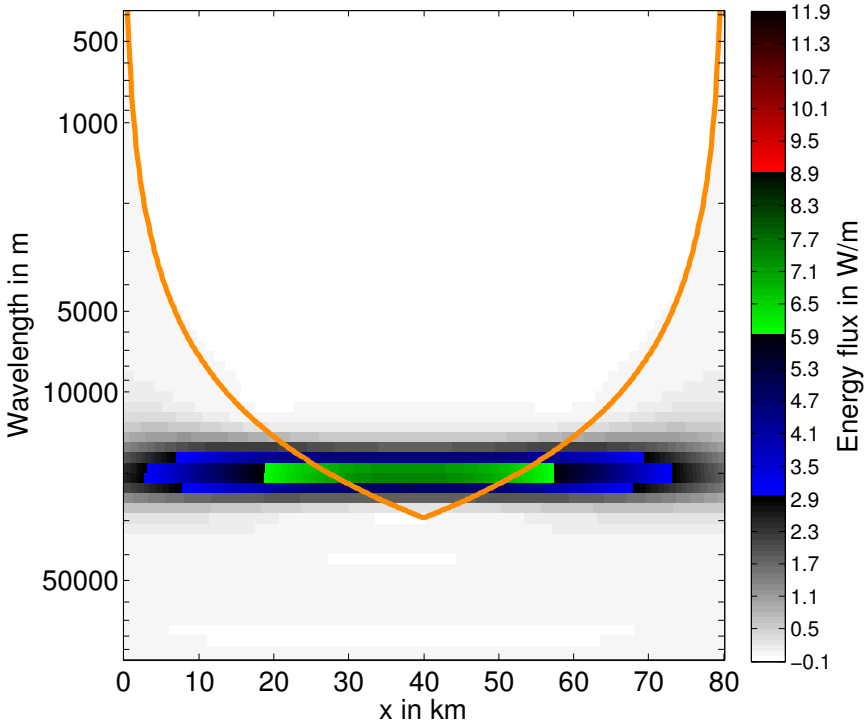


Figure: $\lambda_x = 20\,\mathrm{km}, z = 7\,\mathrm{km}$

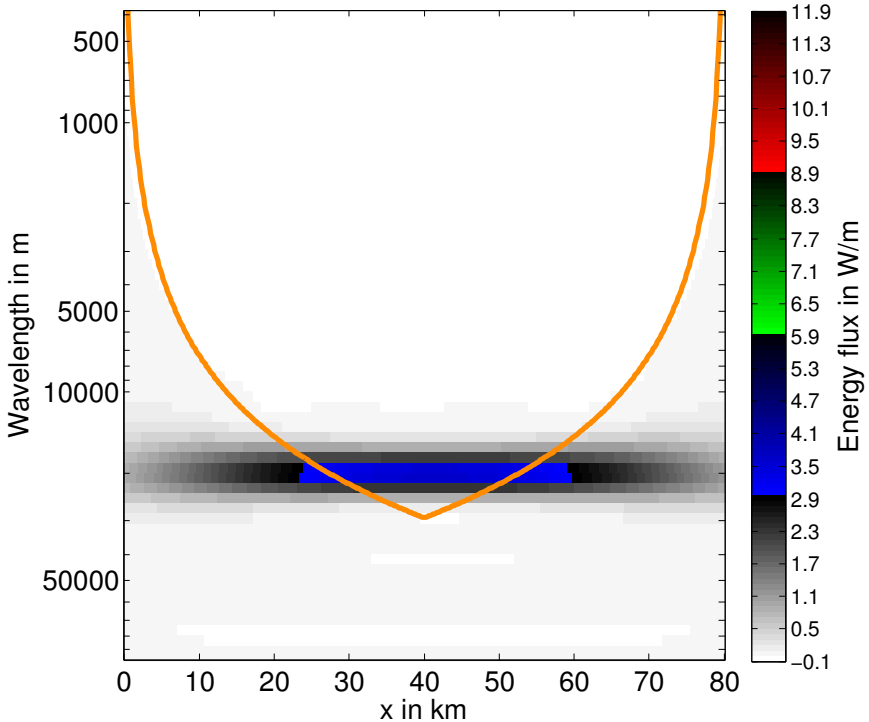


Figure: $\lambda_x = 20\,\mathrm{km}, z = 11\,\mathrm{km}$

CASE 2 - Summary

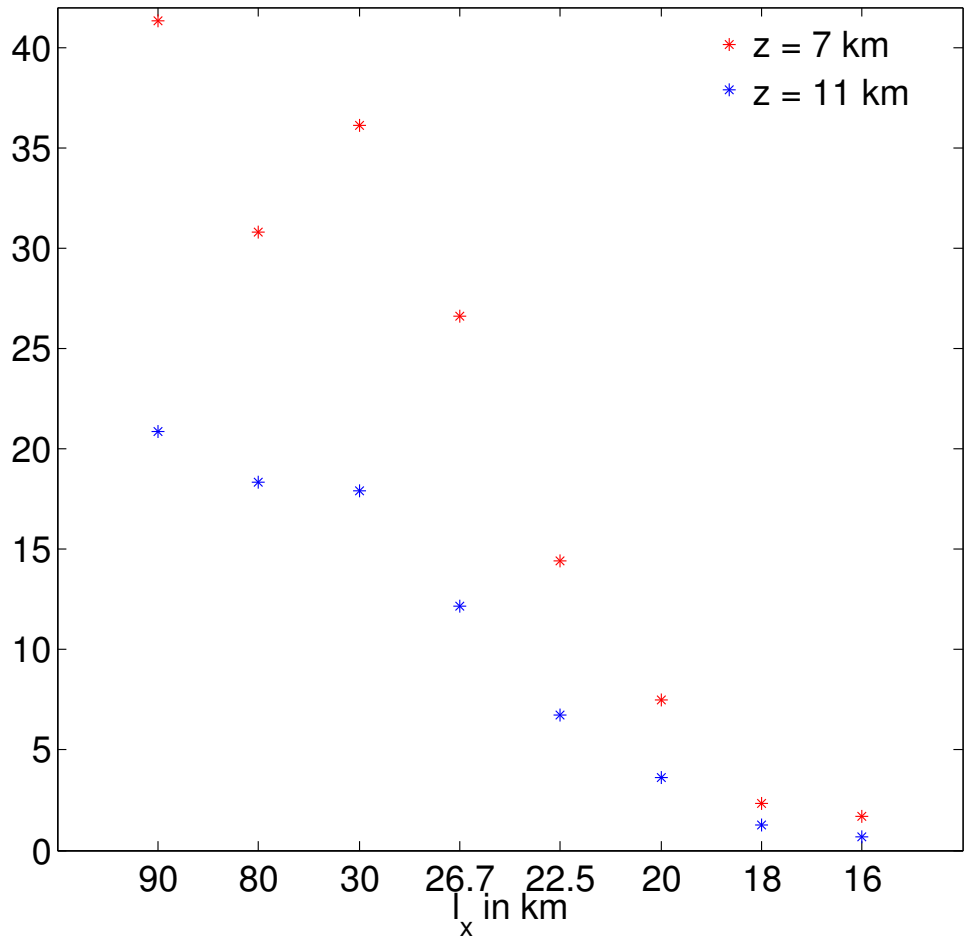
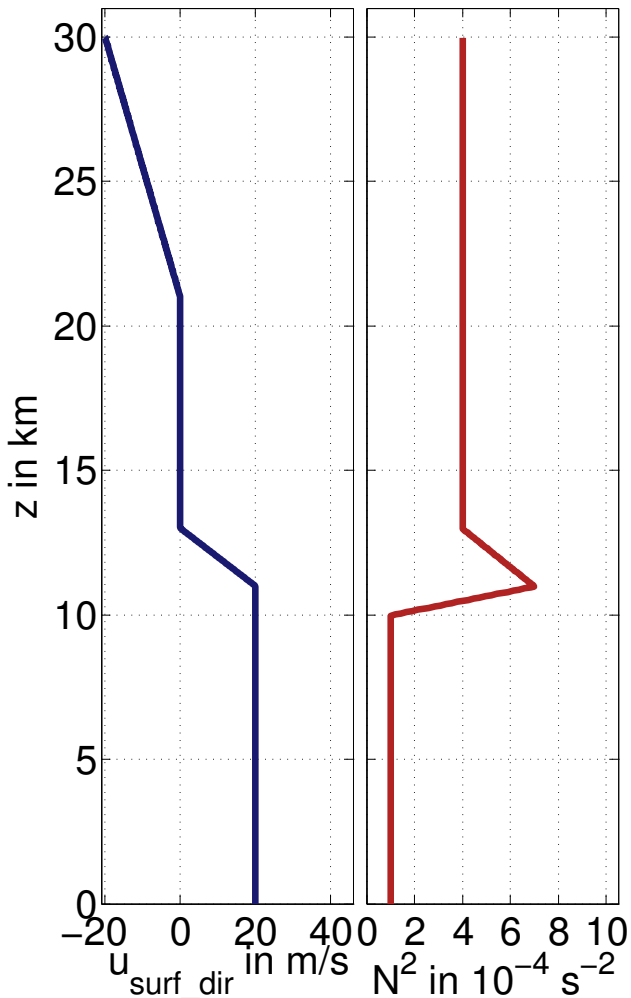


Figure: Maximum wave energy flux

CASE 3 - Environment

CASE 3 (20140711, 12 UTC)



Characteristics

- Tropopause with moderate TIL
- Critical layer between $17\,\mathrm{km}$ and $22\,\mathrm{km}$

CASE 3 - Wind field

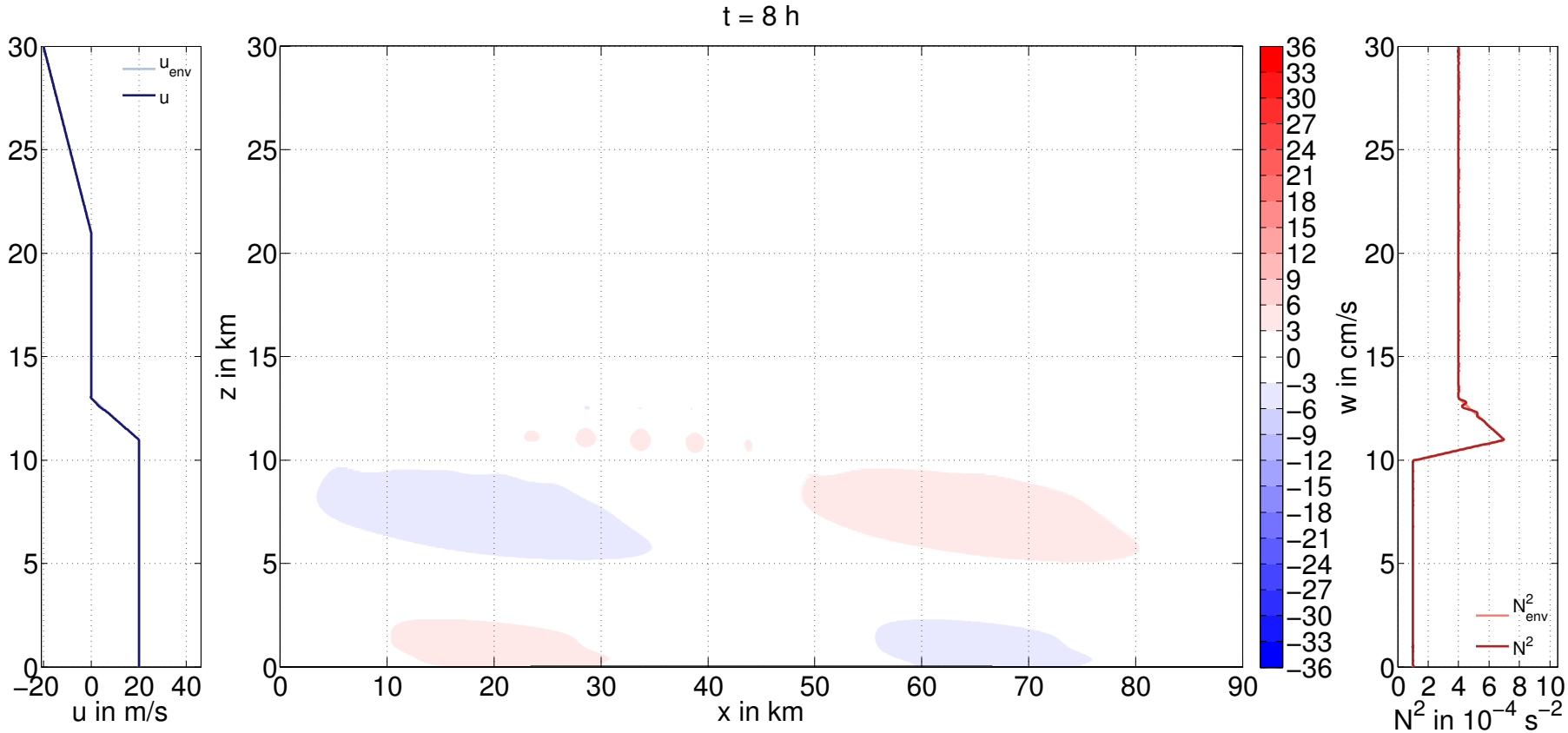


Figure: $\lambda_x = 90\,\mathrm{km}$

CASE 3 - Wind field

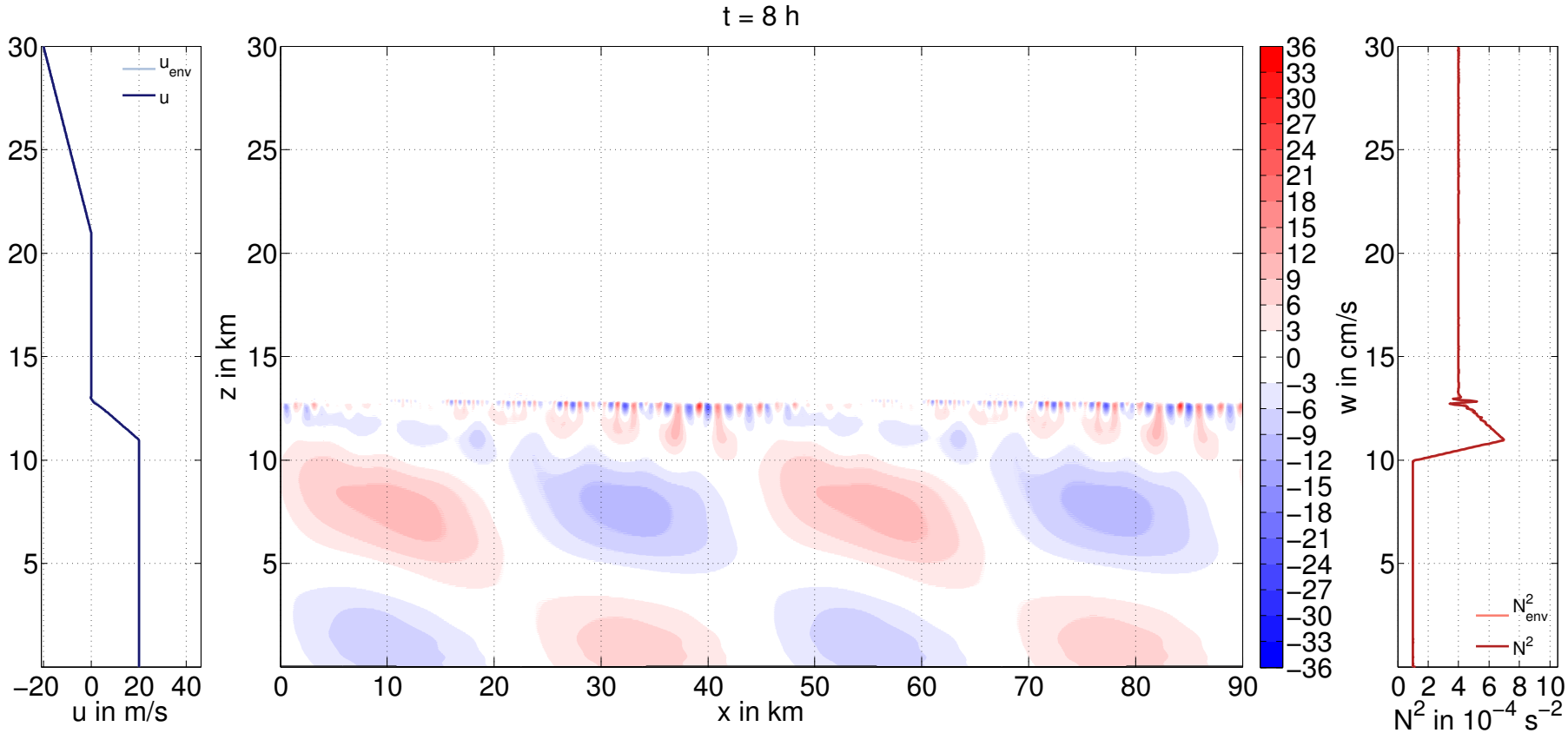


Figure: $\lambda_x = 45\,\mathrm{km}$

CASE 3 - Wind field

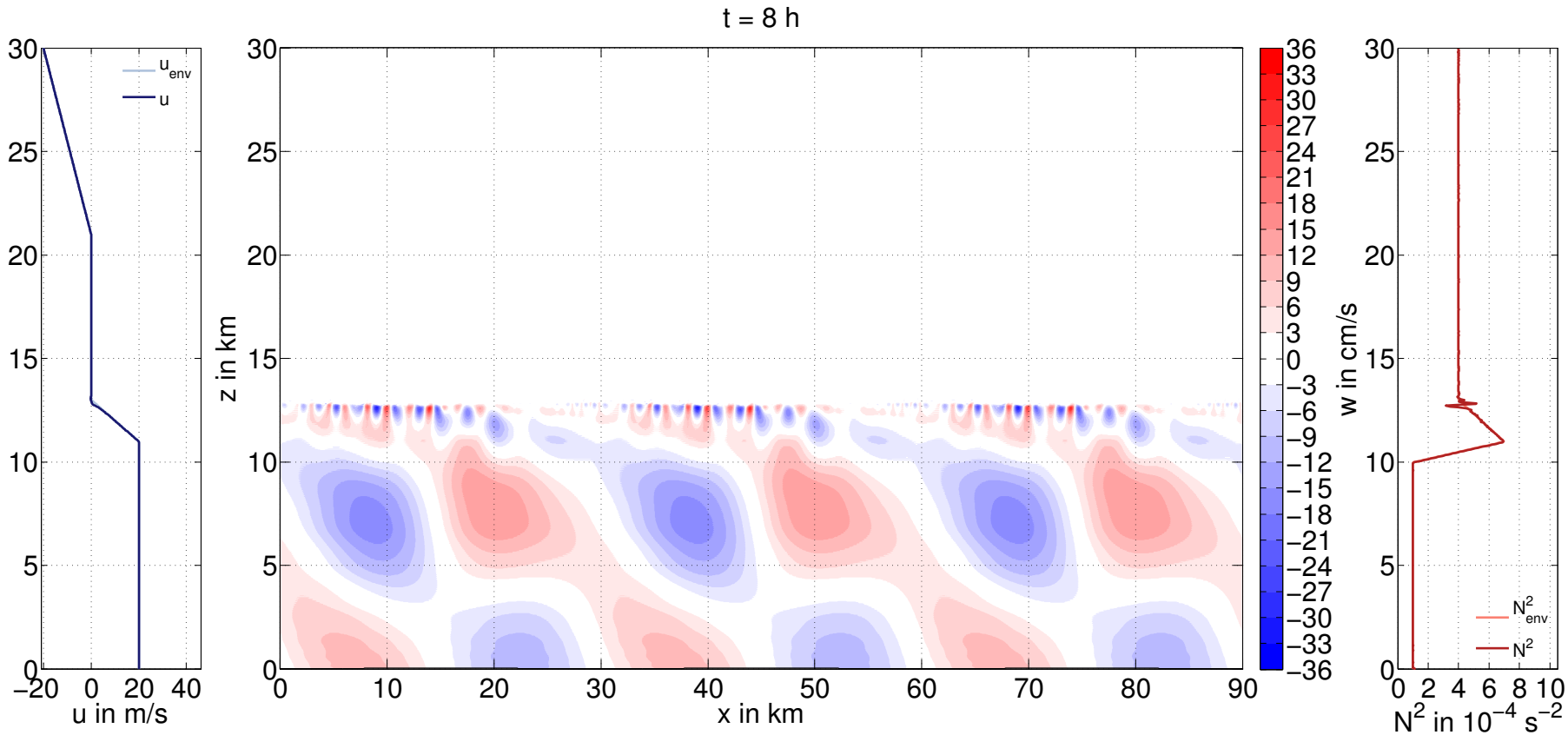


Figure: $\lambda_x = 30\,\mathrm{km}$

CASE 3 - Wind field

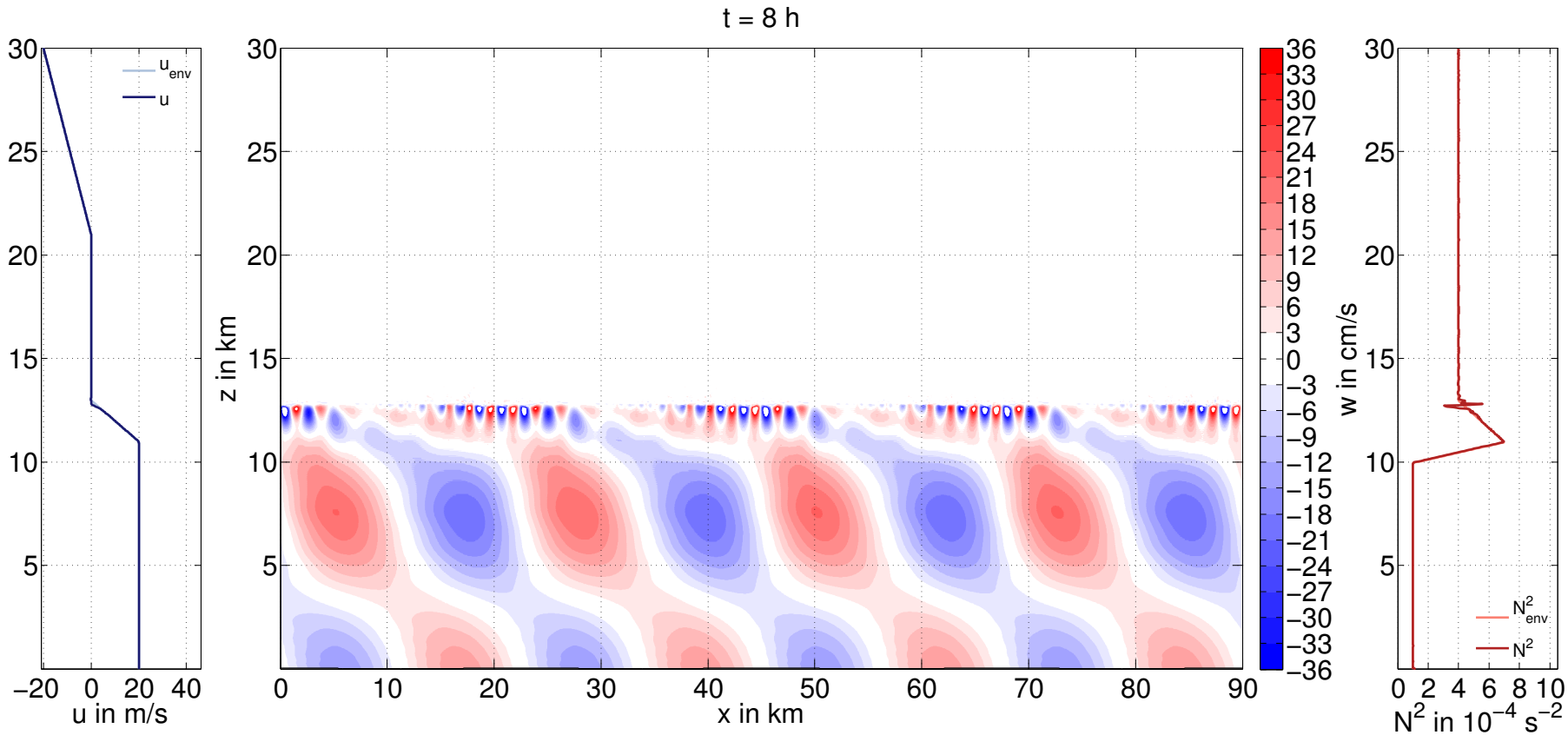


Figure: $\lambda_x = 22.5\,\mathrm{km}$

CASE 3 - Wind field

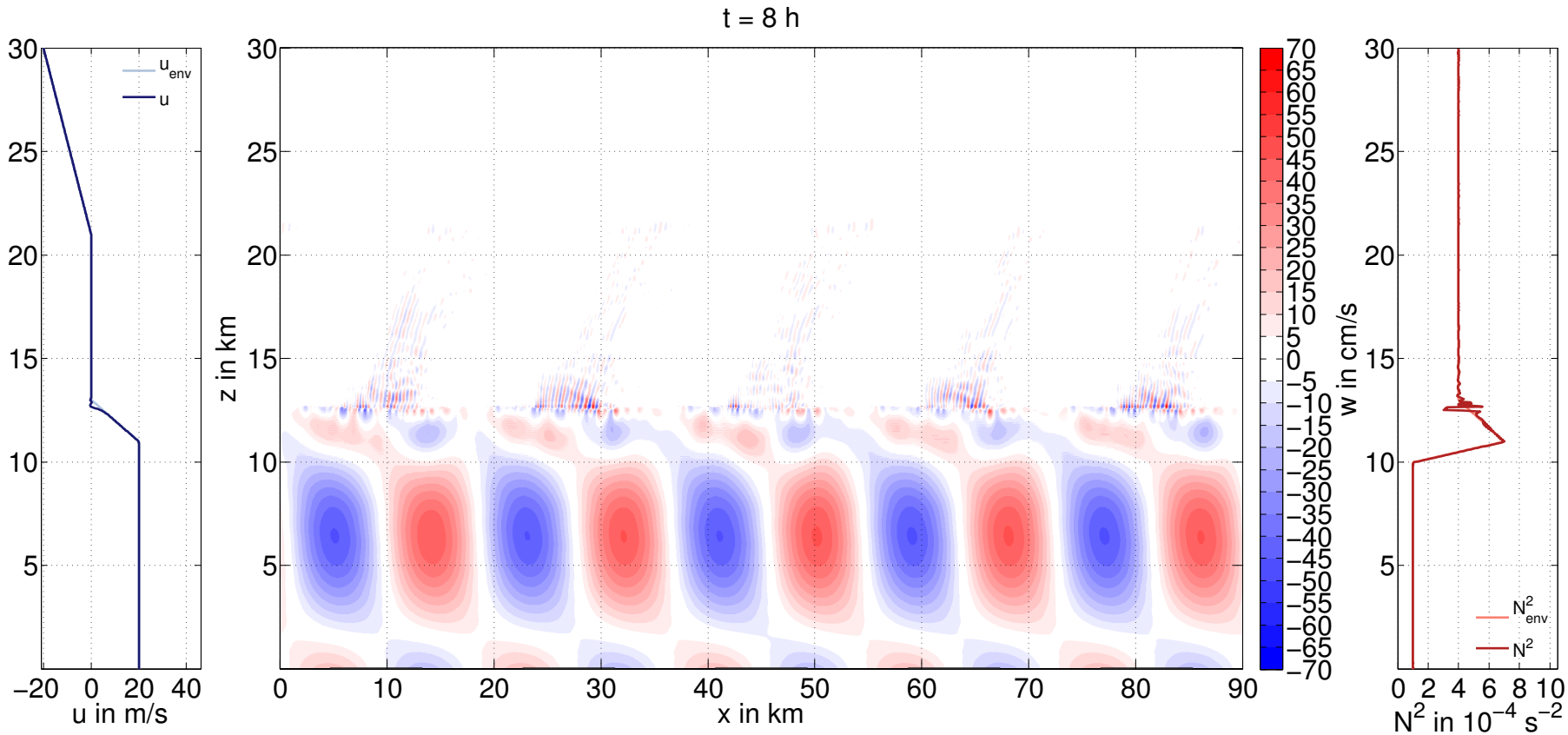


Figure: $\lambda_x = 18\,\mathrm{km}$

CASE 3 - Wind field

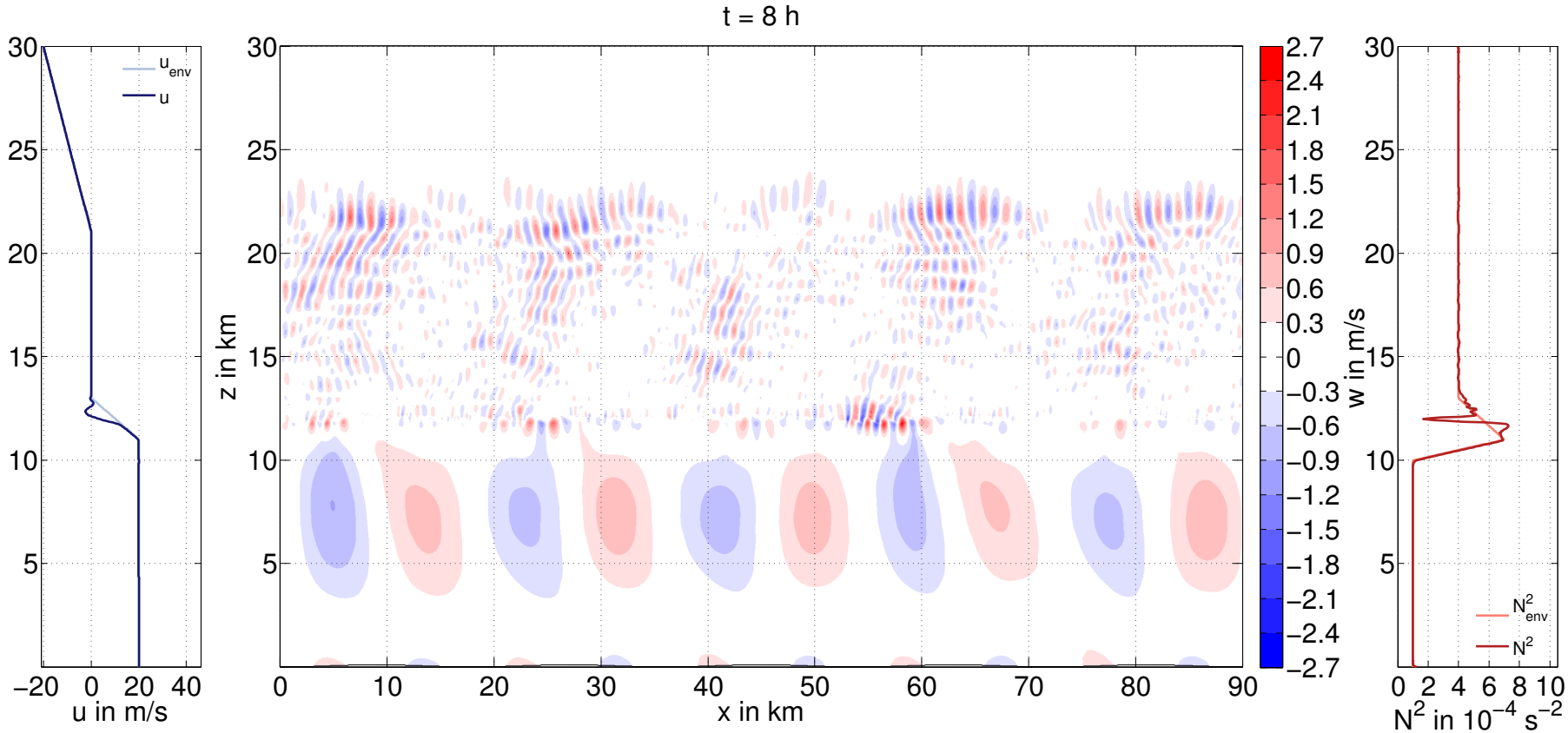


Figure: $\lambda_x = 18\,\mathrm{km}$, $H_{max} = 100\,\mathrm{m}$

CASE 3 - Wind field

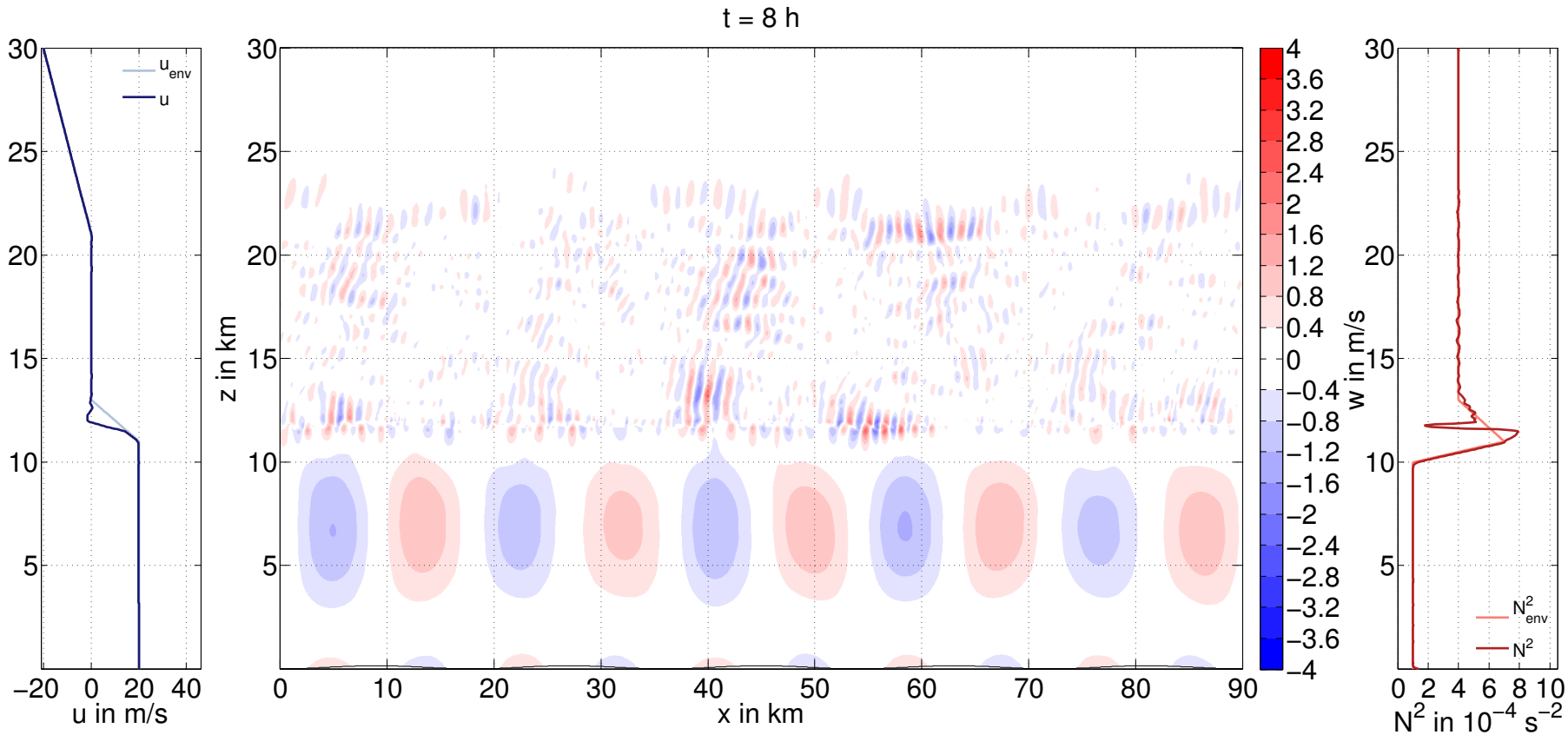


Figure: $\lambda_x = 18\,\mathrm{km}$, $H_{max} = 150\,\mathrm{m}$

CASE 3 - Wind field

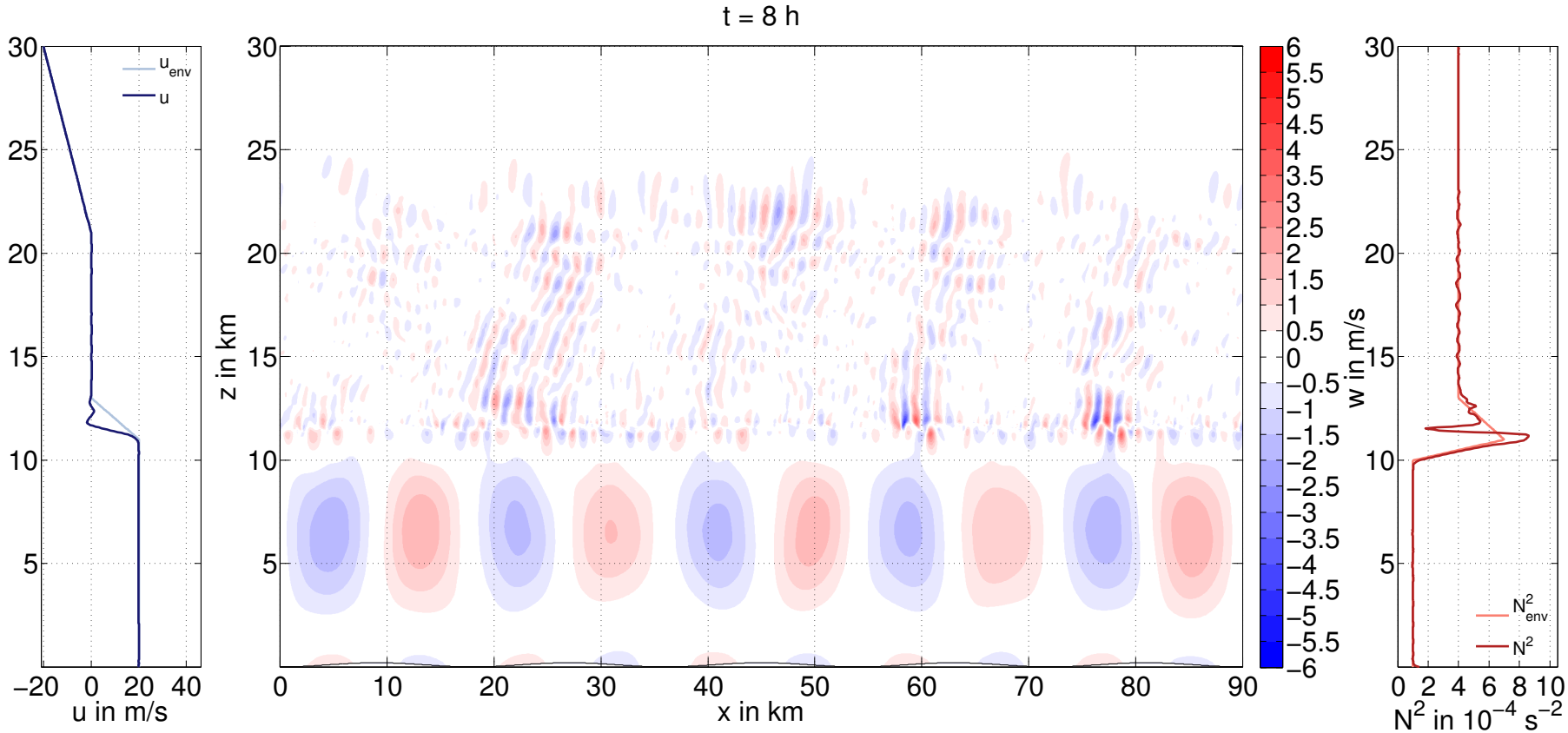


Figure: $\lambda_x = 18\,\mathrm{km}$, $H_{max} = 200\,\mathrm{m}$

CASE 3 - w Wavelet Analysis: Shear Layer

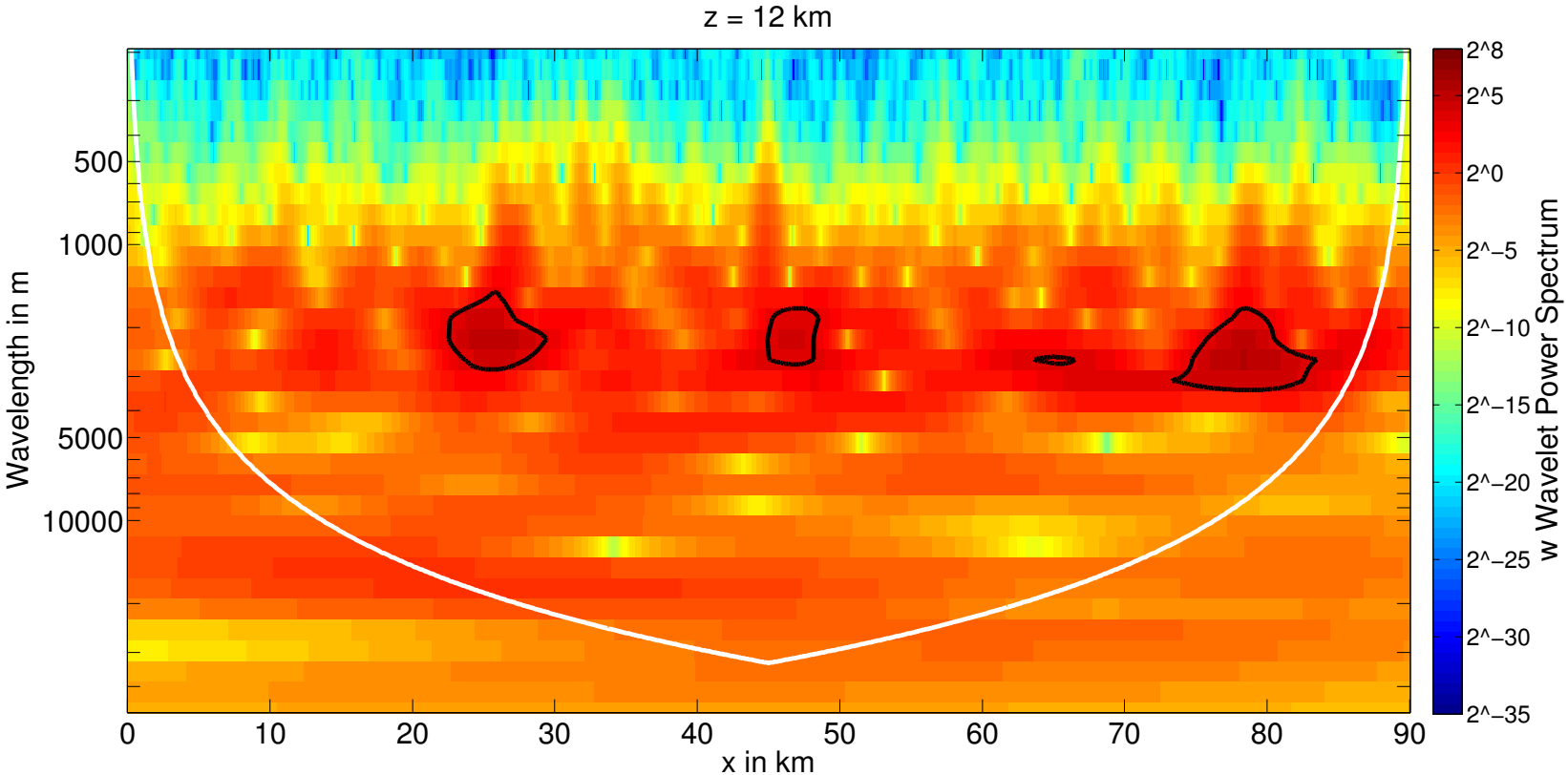


Figure: $\lambda_x = 18\,\mathrm{km}$, $H_{max} = 200\,\mathrm{m}$, $\Delta h = 0.5\,\mathrm{km}$

CASE 3 - w Wavelet Analysis: Shear Layer

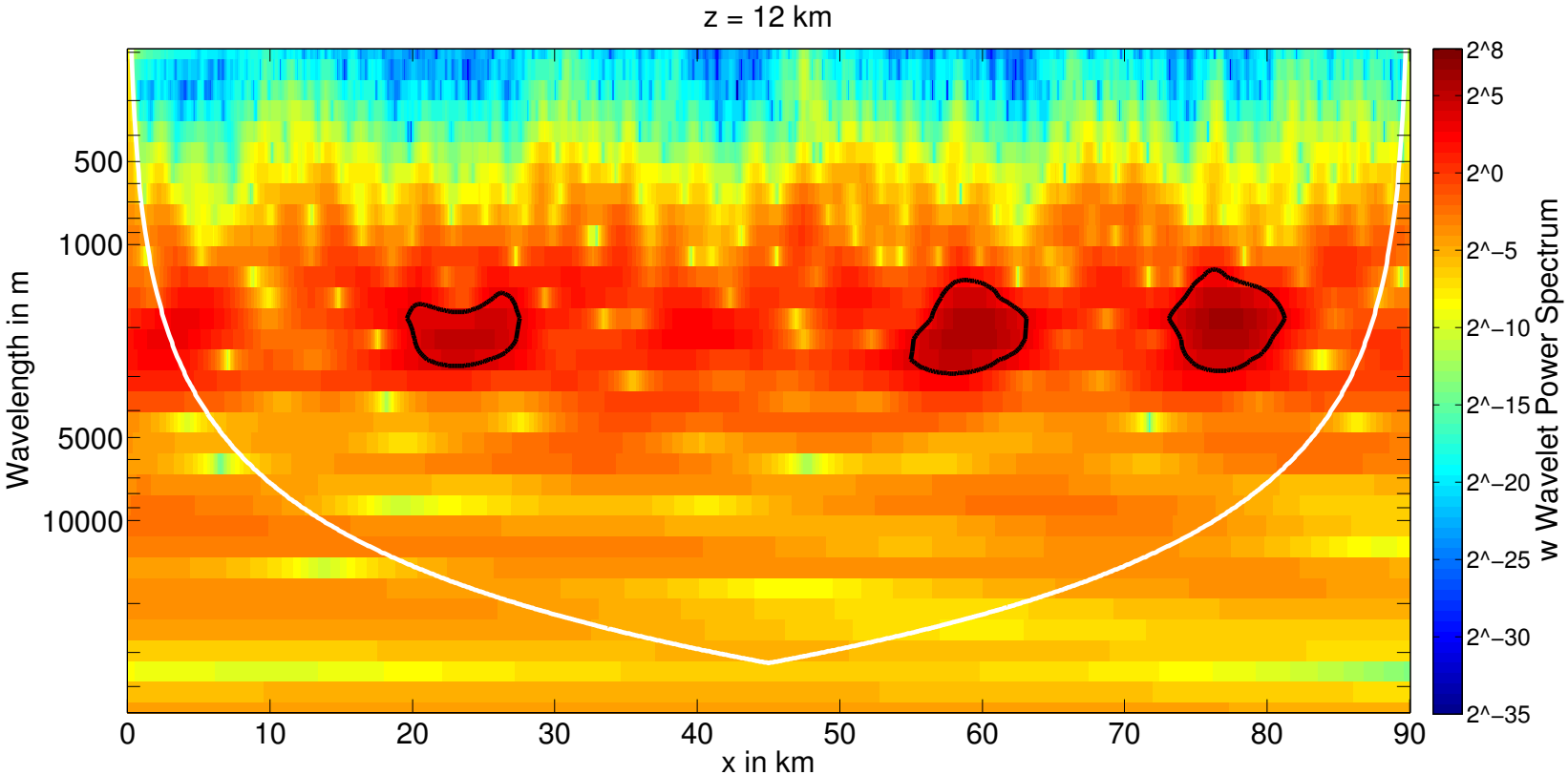


Figure: $\lambda_x = 18\,\mathrm{km}$, $H_{max} = 200\,\mathrm{m}$, $\Delta h = 2\,\mathrm{km}$

CASE 3 - w Wavelet Analysis: Shear Layer

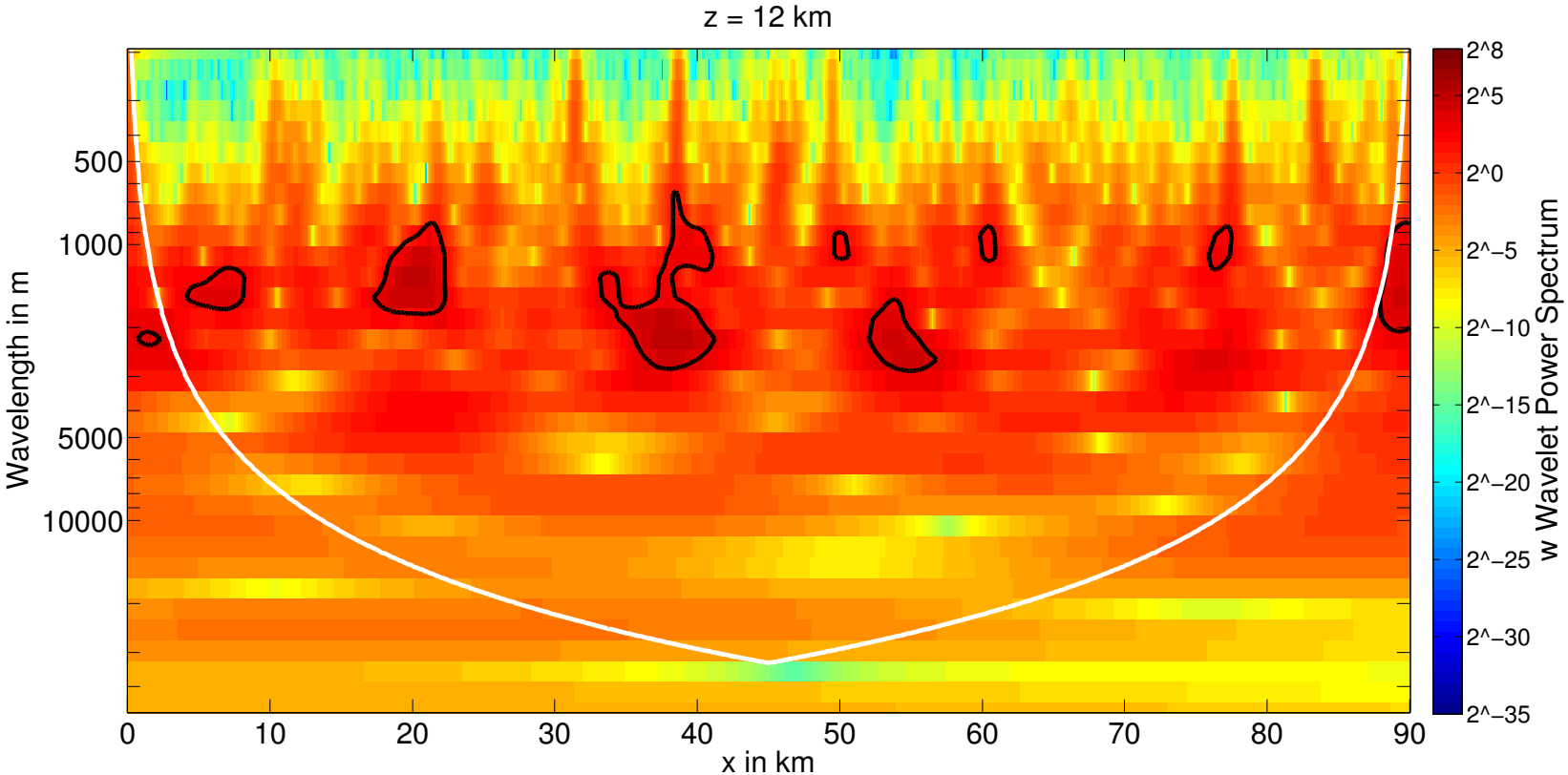


Figure: $\lambda_x = 18\,\mathrm{km}$, $H_{max} = 200\,\mathrm{m}$, $\Delta h = 4\,\mathrm{km}$

CASE 3 - TIL

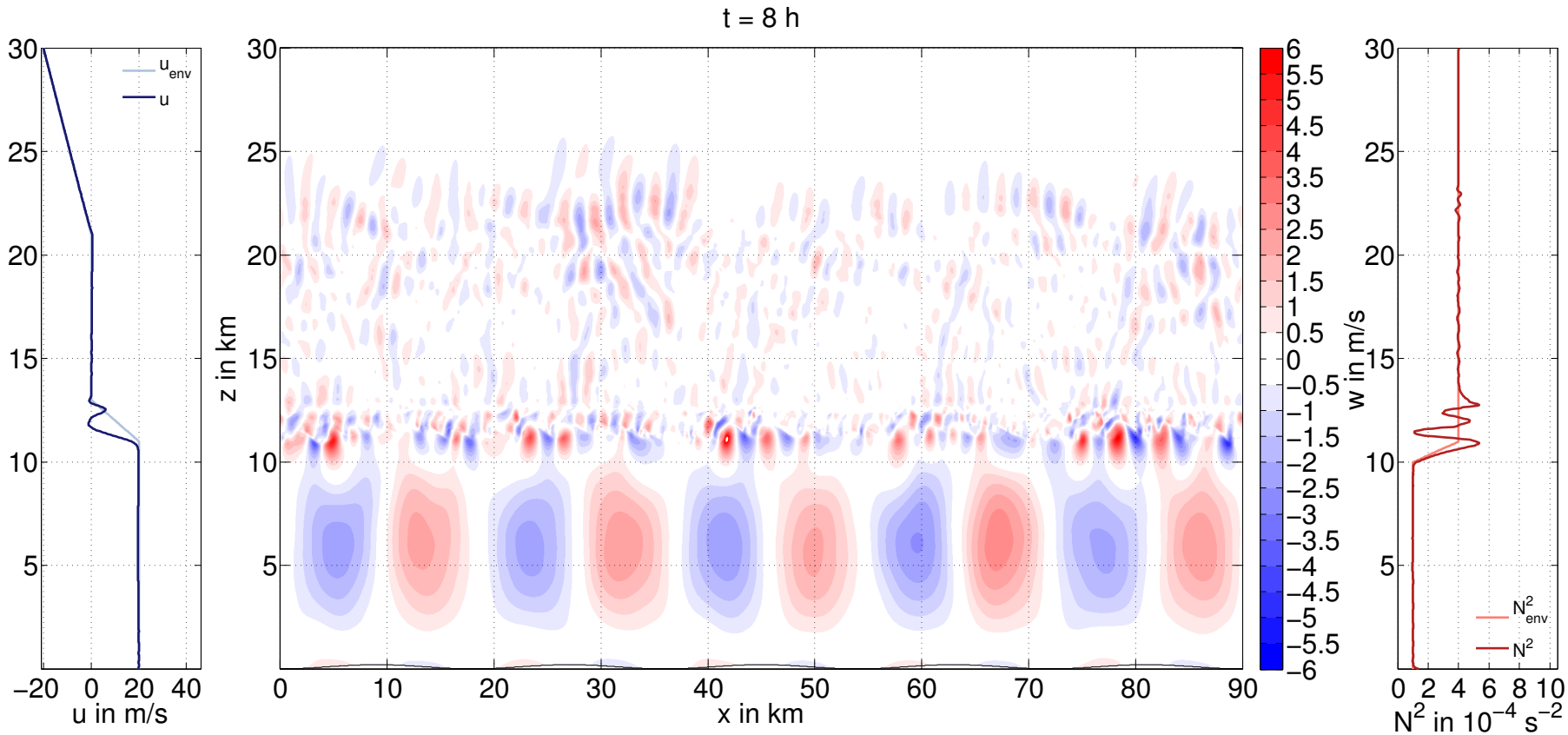
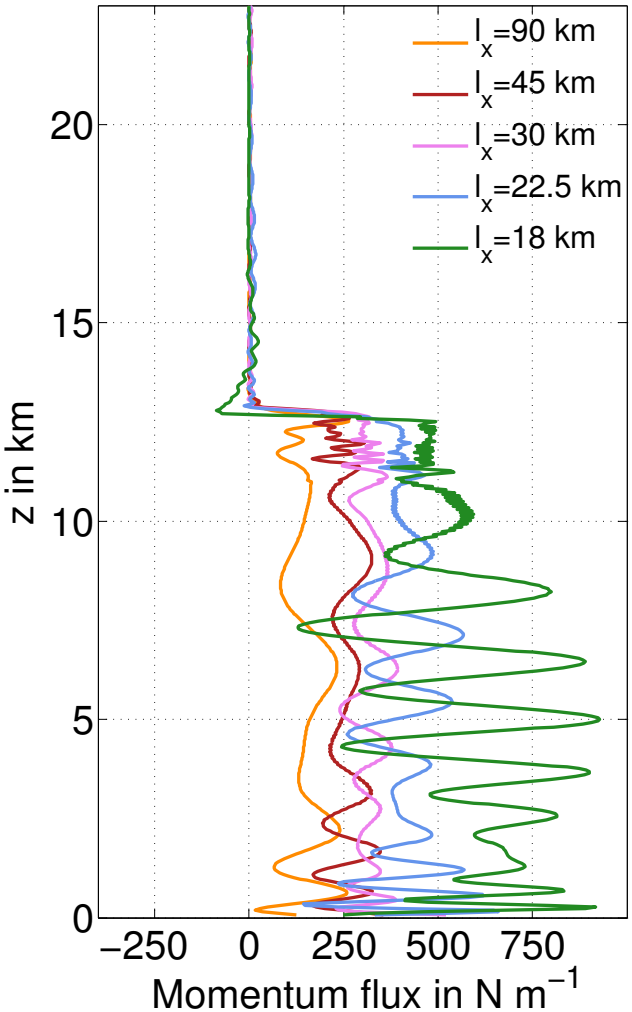
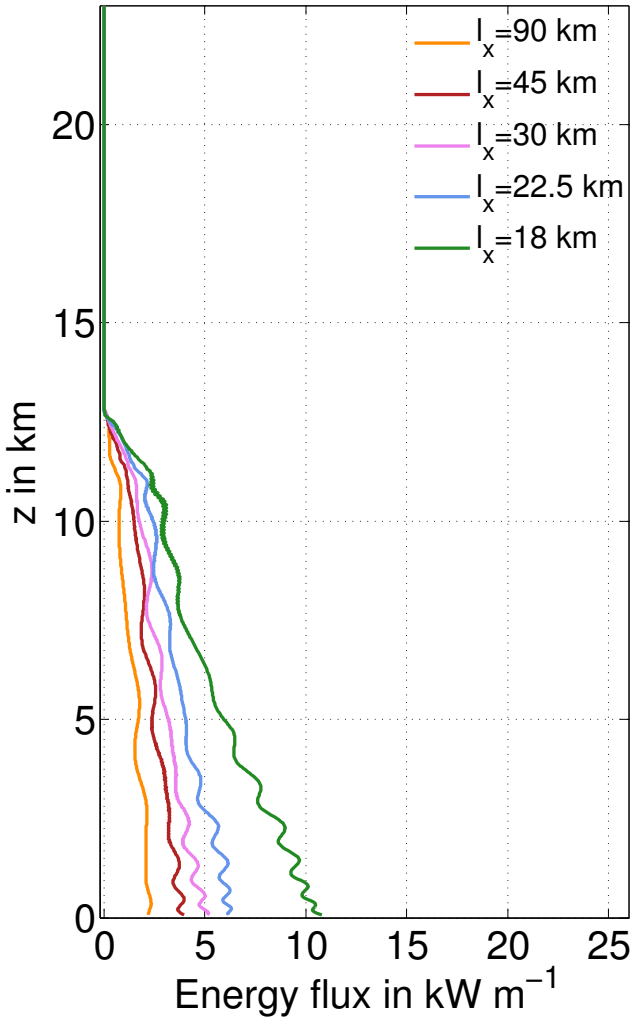


Figure: $\lambda_x = 18\,\mathrm{km}$, $H_{max} = 200\,\mathrm{m}$

CASE 3 - Fluxes





Summary

- Tool allows distinction between regimes
- Secondary wave generation, despite strong TIL
- Wave breaking
- Feedback on mean flow

Outlook

- Further comparison between simulations and observations
- Extension to larger wavelengths, higher amplitudes
- Test effect of e.g. wind speed not quite zero in critical layer
- Confirm CASE 3 with higher resolution, SGS scheme

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Thank you for your attention!

References

- Kim, Y.-J. et al. (2003). “An Overview of the Past, Present and Future of Gravity-Wave Drag Parametrization for Numerical Climate and Weather Prediction Models”. In: *Atmosphere-Ocean* 41.1, pp. 65–98.
- Prusa, J. M. et al. (2008). “EULAG, a computational model for multiscale flows”. In: *Computers and Fluids* 37, pp. 1193–1207.

CASE 1 - Single Mountain

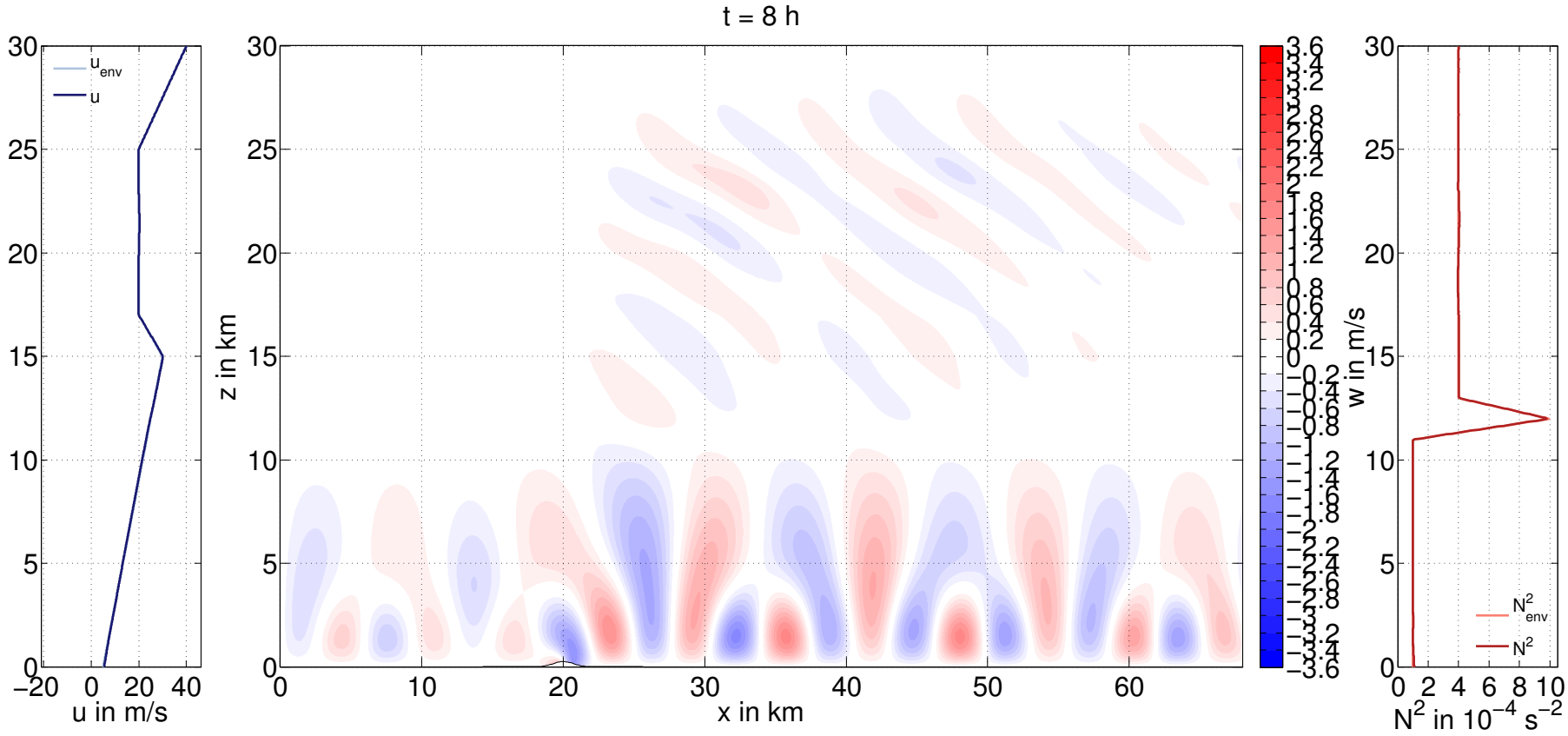


Figure: Gaussian mountain with $H_{max} = 250\,\mathrm{m}$

CASE 3 - Single Mountain

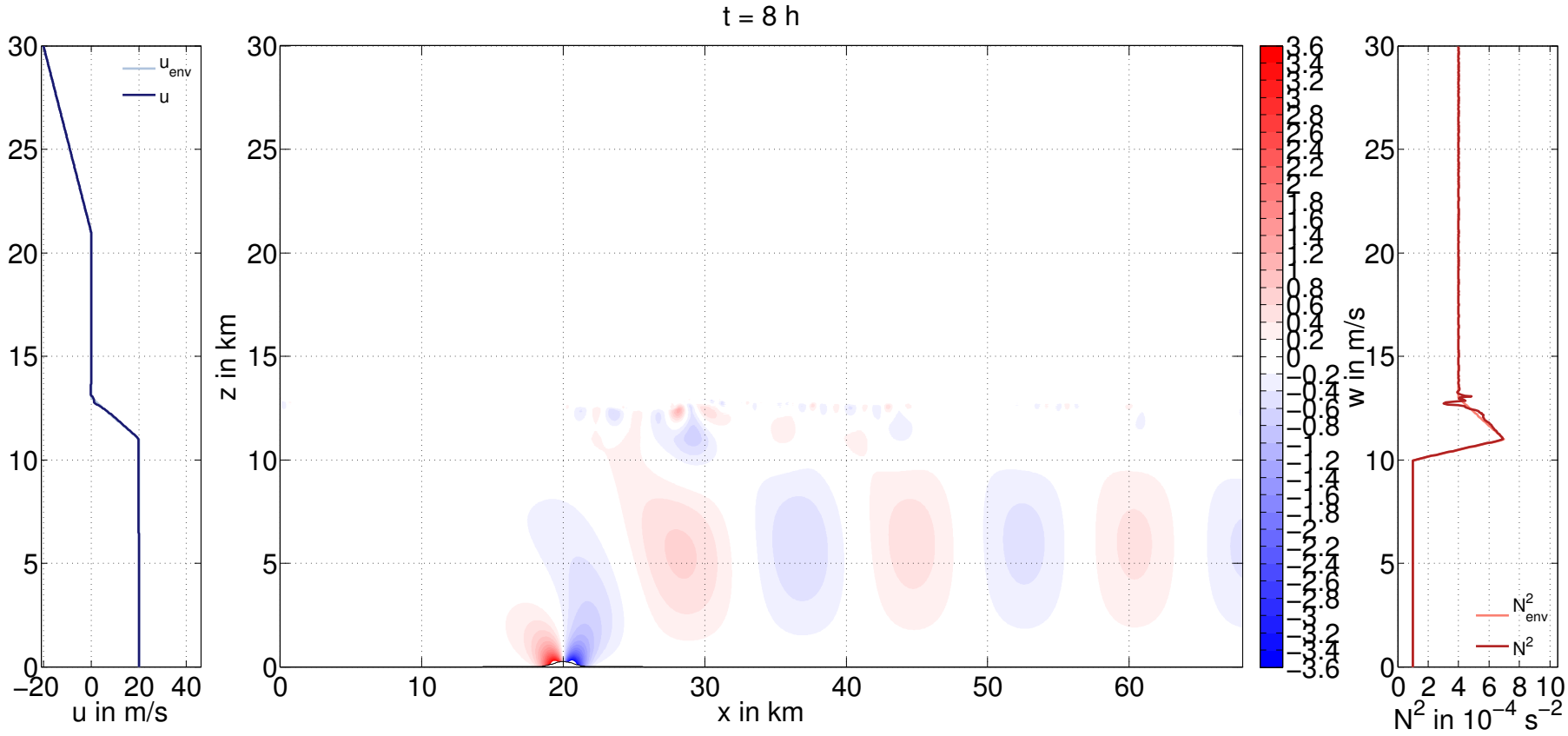


Figure: Gaussian mountain with $H_{max} = 250\,\mathrm{m}$

CASE 3 - 3D: Wind field

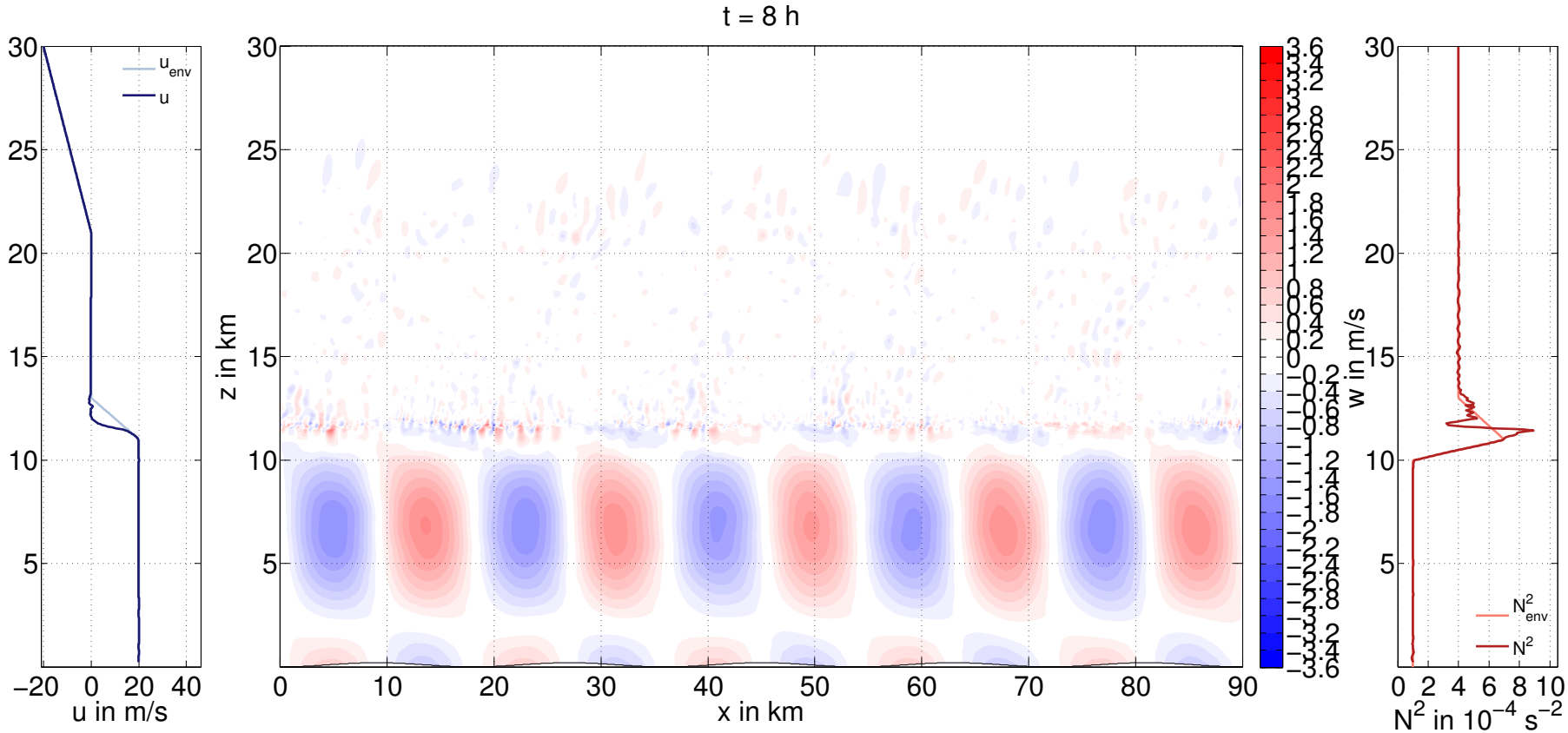


Figure: $\lambda_x = 18\,\mathrm{km}$, $H_{max} = 200\,\mathrm{m}$

CASE 3 - 3D: p’w’ Wavelet

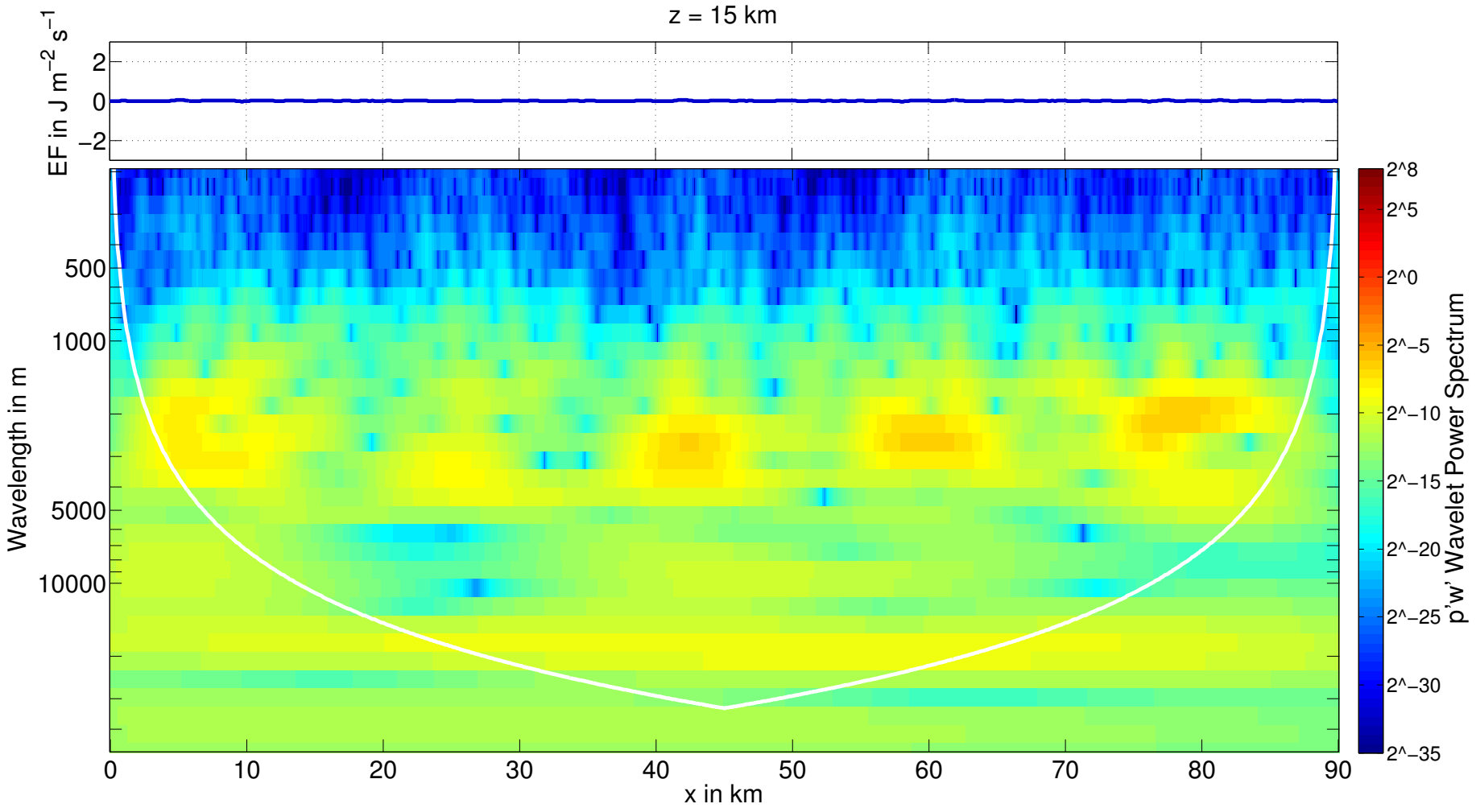
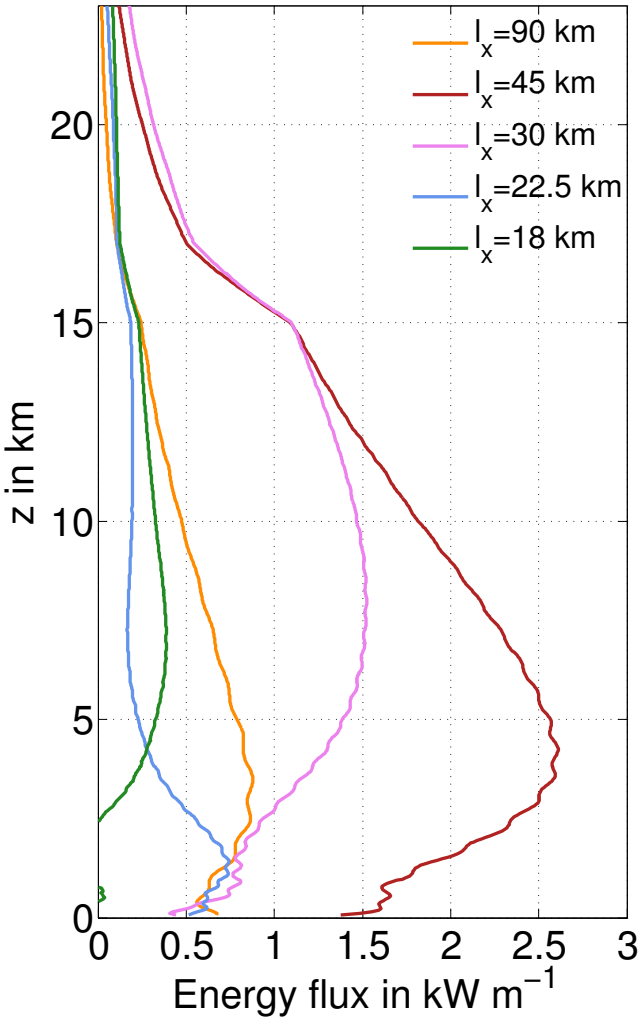


Figure: Gaussian mountain with $H_{max} = 250\,\mathrm{m}$

CASE 2 - EF


l_x=90 km
l_x=45 km
l_x=30 km
l_x=22.5 km
l_x=18 km
z in km
0
5
10
15
20
0
0.5
1
1.5
2
2.5
3
Energy flux in kW m^{-1}

CASE 2 - Fluxes