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Intra-annual variations of spectrally resolved gravity wave activity and observations of turbulence in the UMLT region

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Universität Augsburg University

DLR

Virtual Alpine Observatory

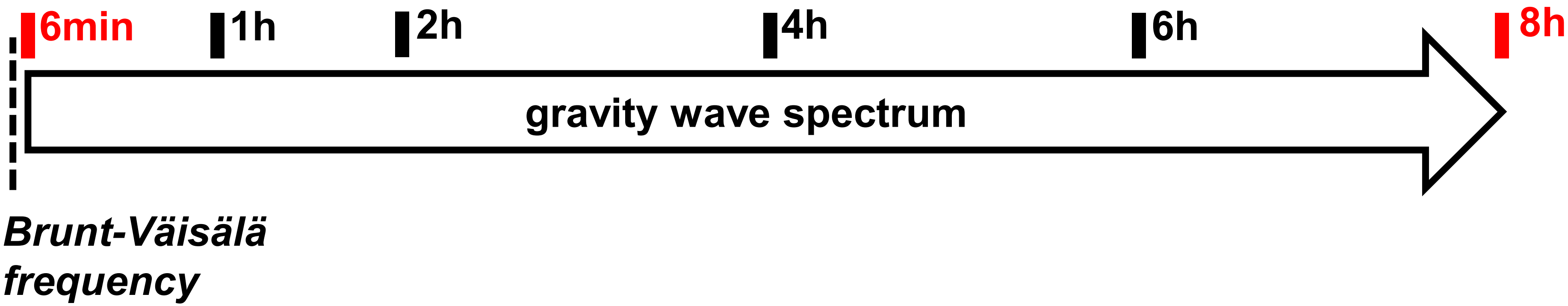
Gravity Waves

Significant influence on **large-scale circulations** in the atmosphere

small-scale phenomena
- hard to observe
- poorly represented in **climate models**

Extensive observations of entire gravity wave spectrum needed!

Spectrally resolved gravity wave activity

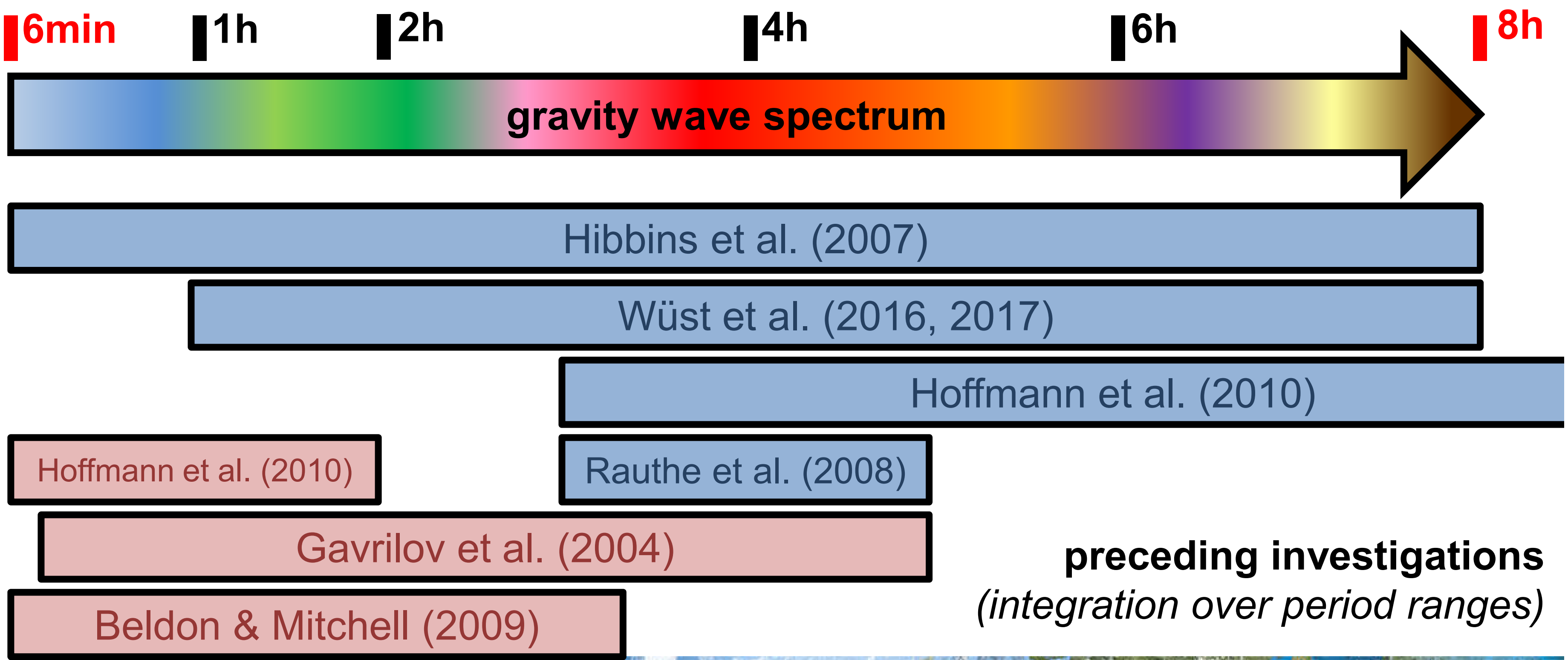


We analyse gravity wave activity for wave periods between 6 min and 8 h.

Spectrally resolved gravity wave activity

semi-annual cycle
maximum in winter & summer

annual cycle
maximum in winter
minimum in summer



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Instruments

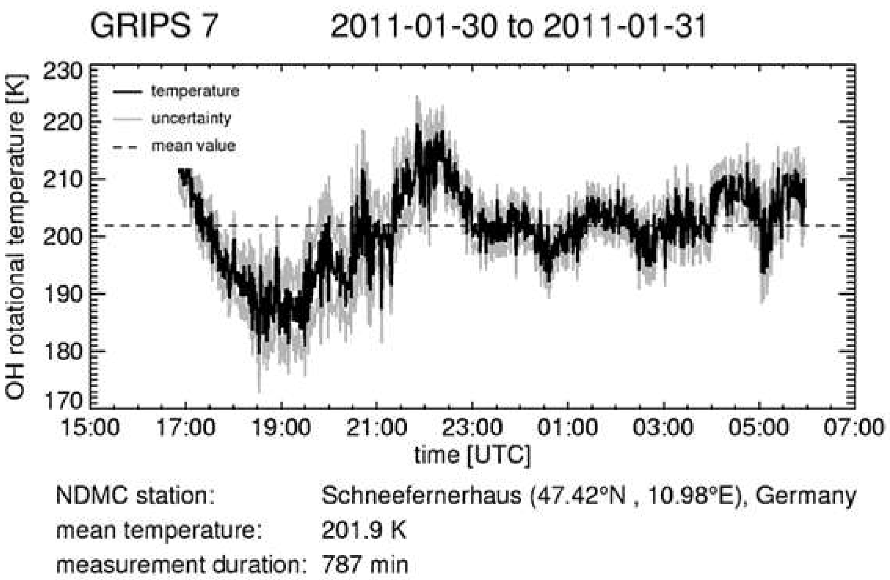
measuring nocturnal infrared emissions of OH airglow*

GRIPS

GRound-based Infrared P-branch Spectrometer

OH* rotational temperatures

Temporal resolution: 1 min



http://wdc.dlr.de

http://wdc.dlr.de/ndmc

FAIM

Fast Airglow Imager

2D grey-scale images of integrated OH* intensity

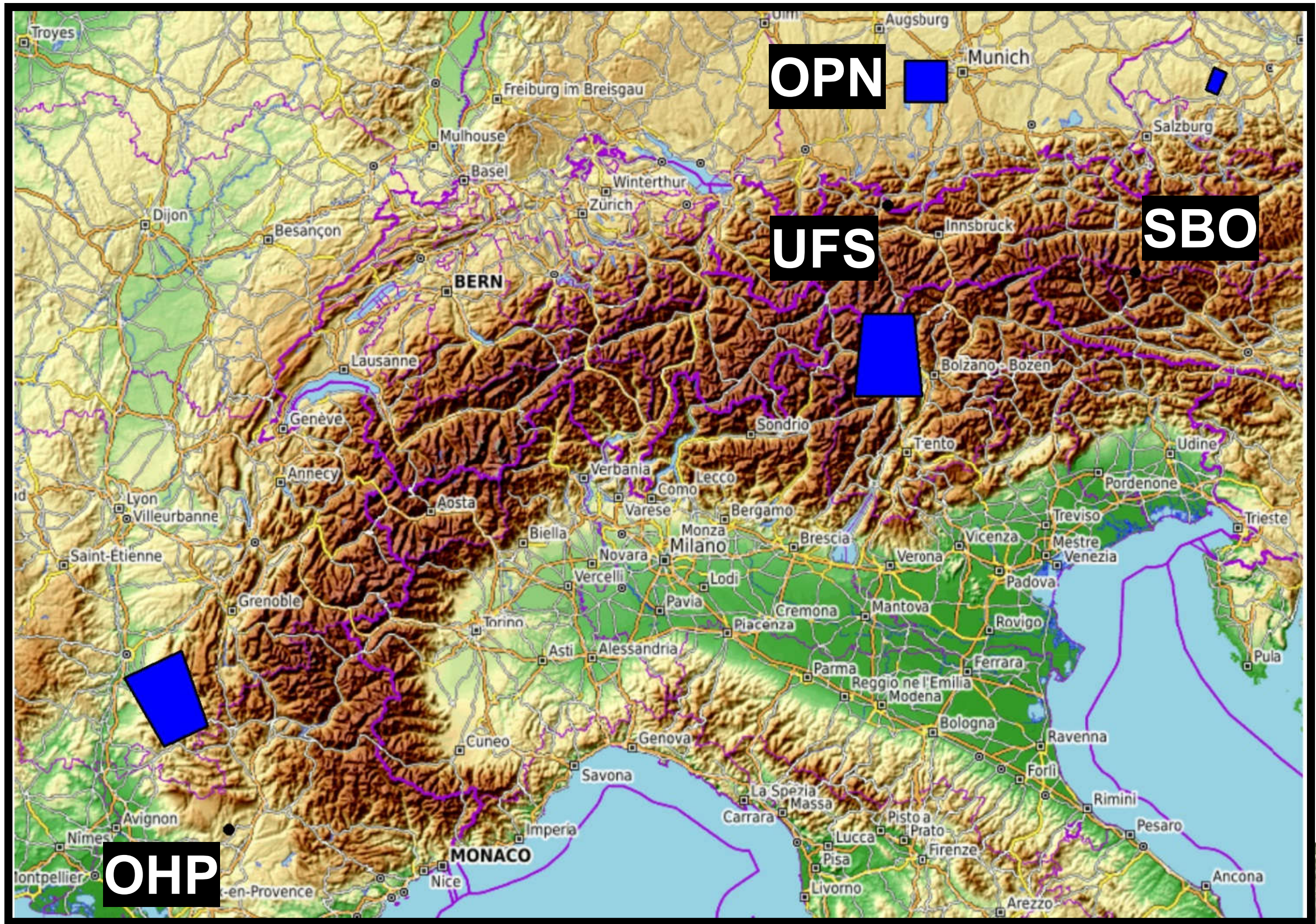
Temporal resolution: 2.8 s

Spatial resolution: 17-24 m

Measurement sites (1)
GRIPS

Virtual Alpine Observatory

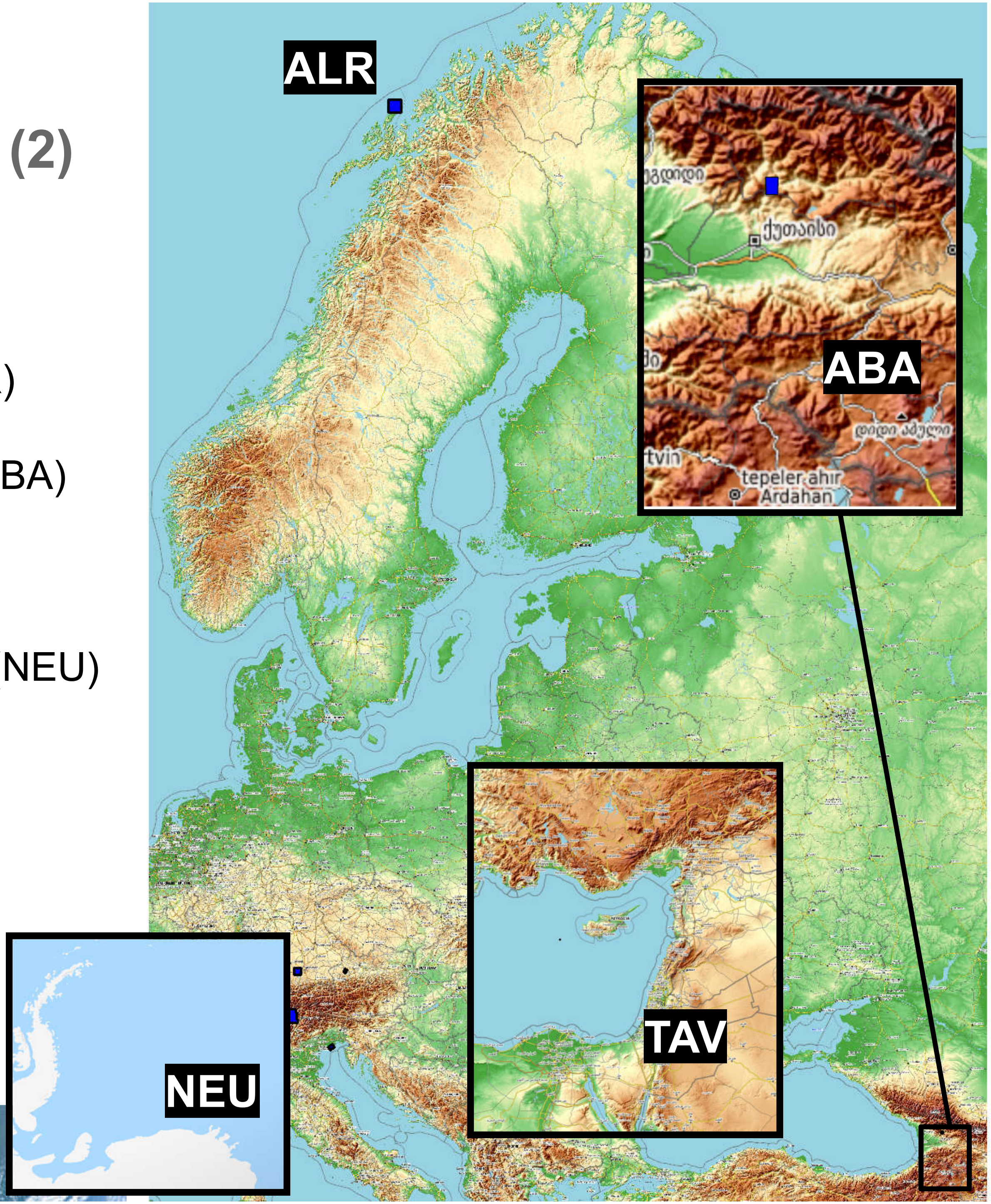
VAO stations
at least 3 years of data



- Oberpfaffenhofen, Germany (OPN)
- Observatoire de Haute-Provence, France (OHP)
- Sonnblick Observatorium, Austria (SBO)
- Schneefernerhaus, Germany (UFS)

Measurement sites (2)
GRIPS

- ALOMAR, Norway (ALR)
- Abastumani, Georgia (ABA)
- Tel Aviv, Israel (TAV)
- Neumeyer III, Antarctic (NEU)

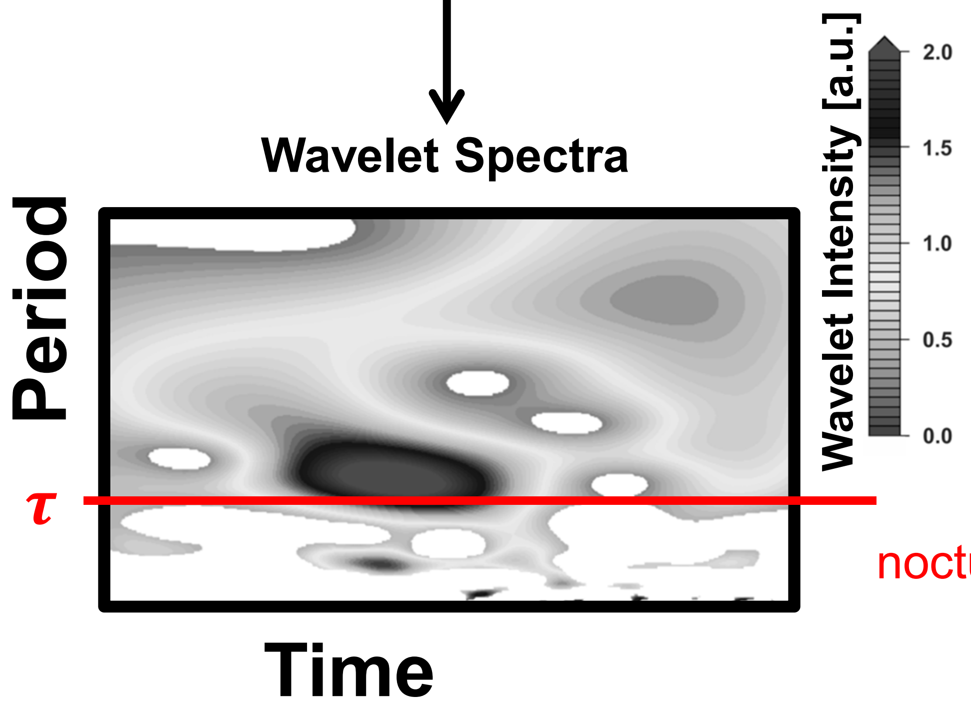


Analysis

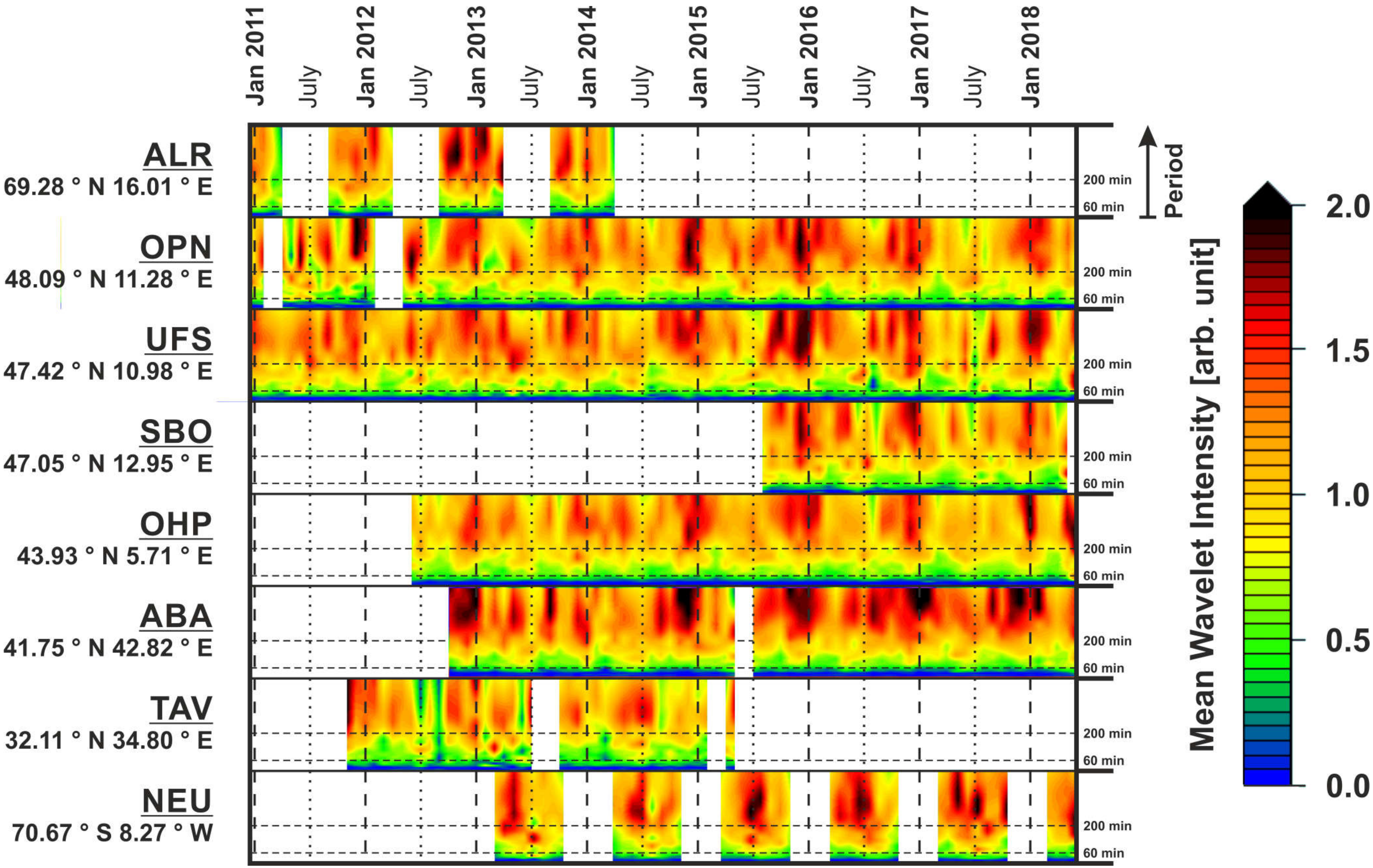
quality check

Temperature time series → Wavelet Analysis *periods 6 - 480 min*

Significance test via analysis of random spectra



mean wavelet intensity
along row corresponding to period τ
=
nocturnal activity of gravity waves with period τ



Sedlak et al., 2020 *(AMT Discussions)*

Spectrally resolved gravity wave activity

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annual cycle
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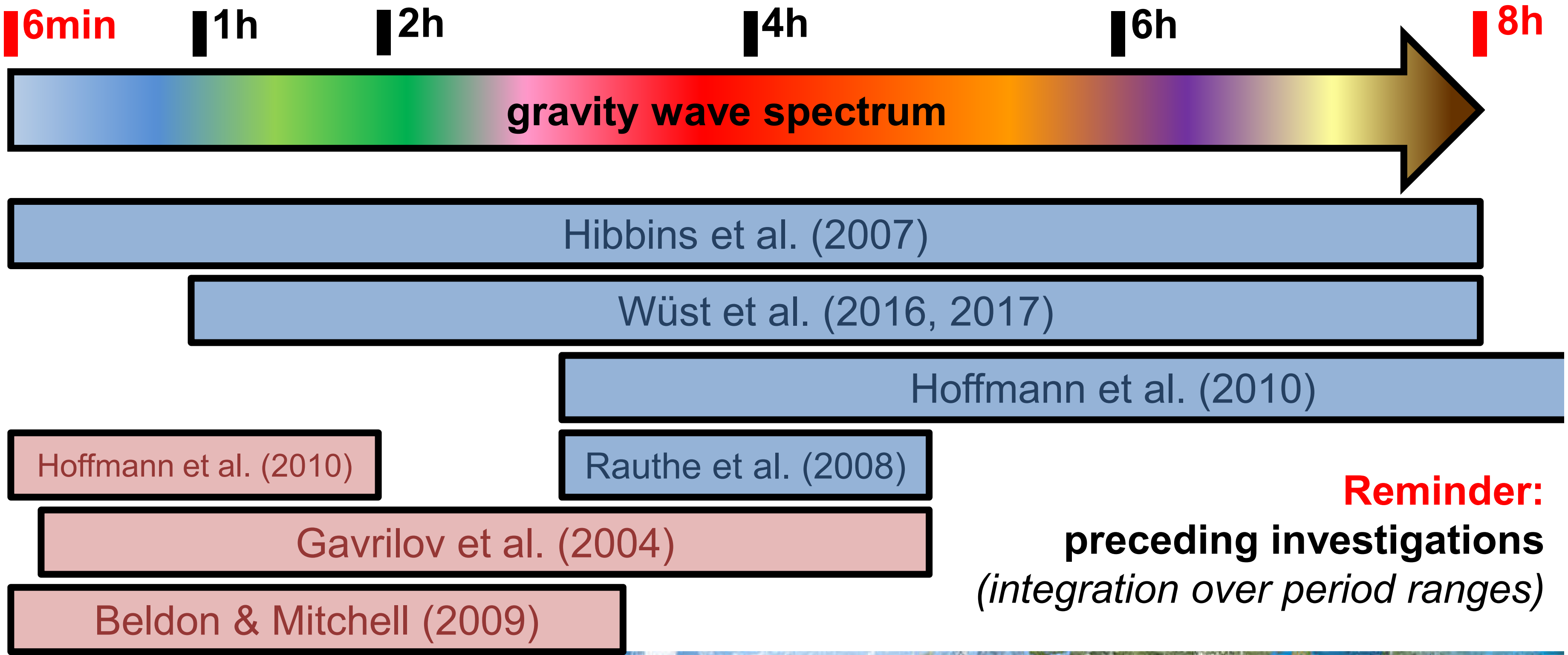
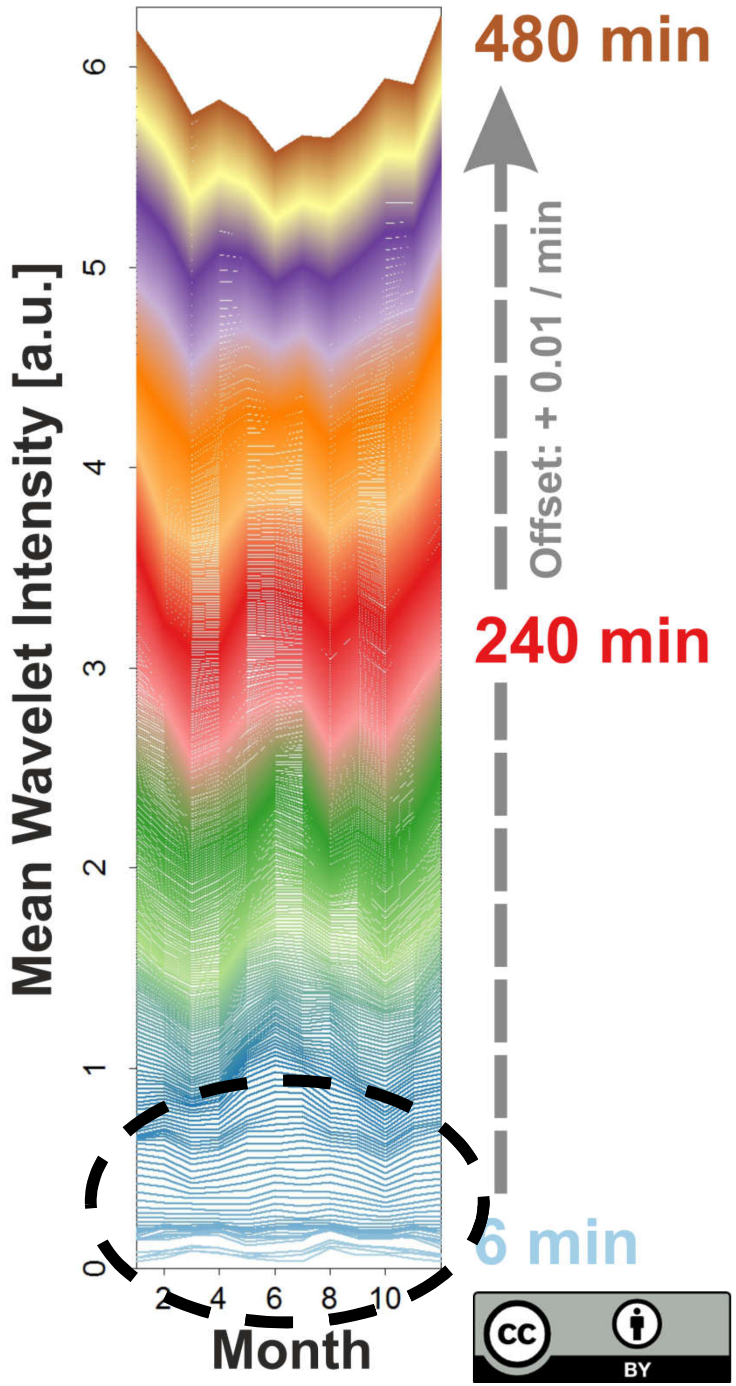


Reminder:
preceding investigations
(integration over period ranges)

Intra-annual variations
Example: OPN

- transition to annual behaviour around 200 min (maximum in winter, minimum in summer)
- strong semi-annual pattern for periods > 60 min (maxima in winter & summer)
- almost no variability for periods < 60 min



Sedlak et al., 2020

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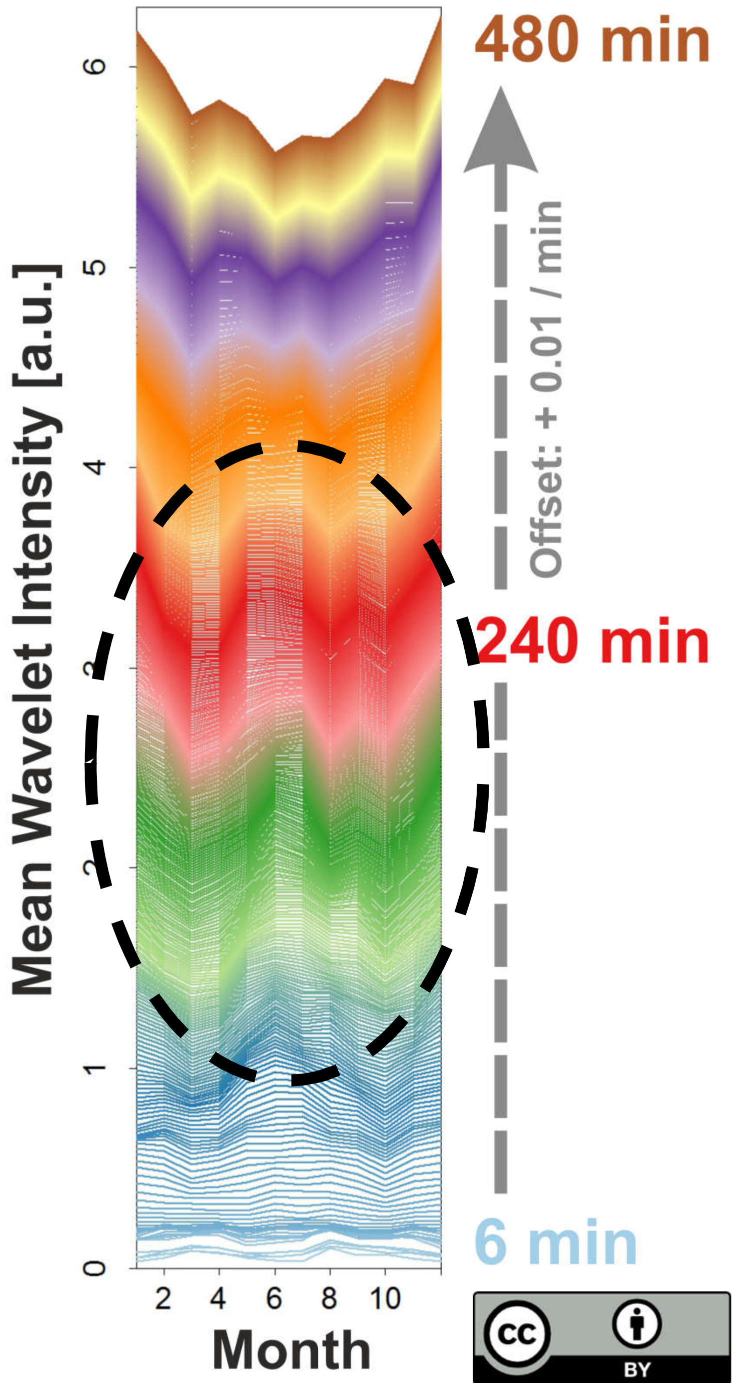

Sedlak et al., 2020

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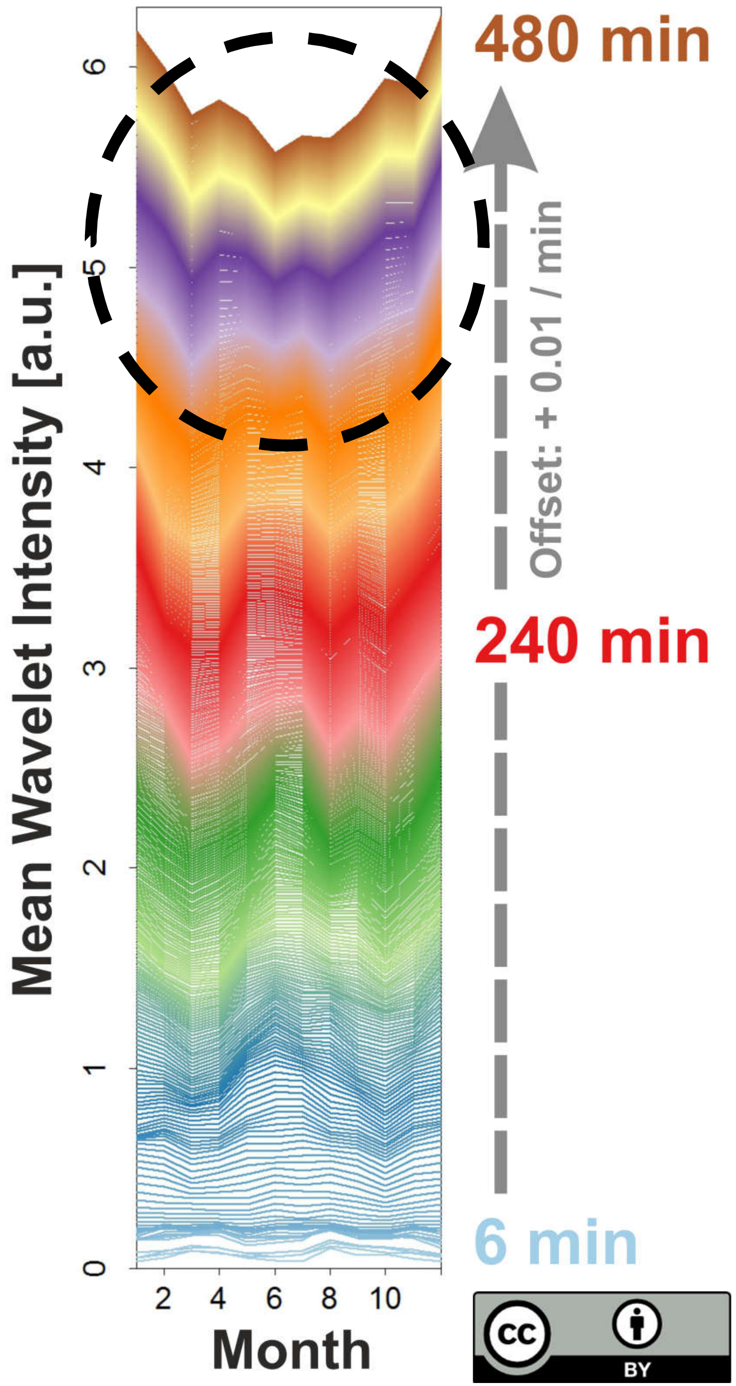
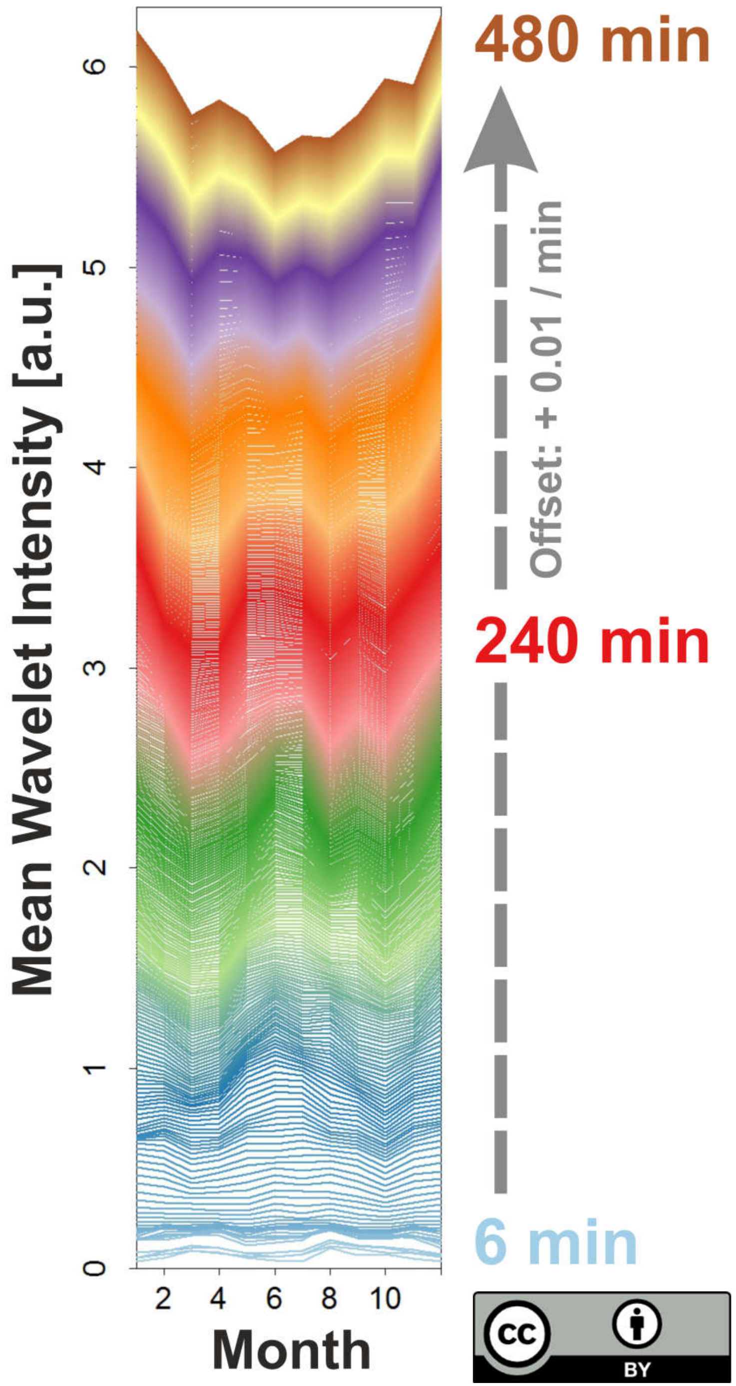


Sedlak et al., 2020

Intra-annual variations
Example: OPN

Possible explanation:
critical layer filtering

- transition to annual behaviour around 200 min (maximum in winter, minimum in summer)
  winter: all westward GWs can propagate
  summer: parts of eastward GWs can propagate
- strong semi-annual pattern for periods > 60 min (maxima in winter & summer)
  equinoctial wind reversals -
  blocking of slow GWs in either direction
- almost no variability for periods < 60 min
  fast gravity waves - unaffected by wind filtering



Sedlak et al., 2020

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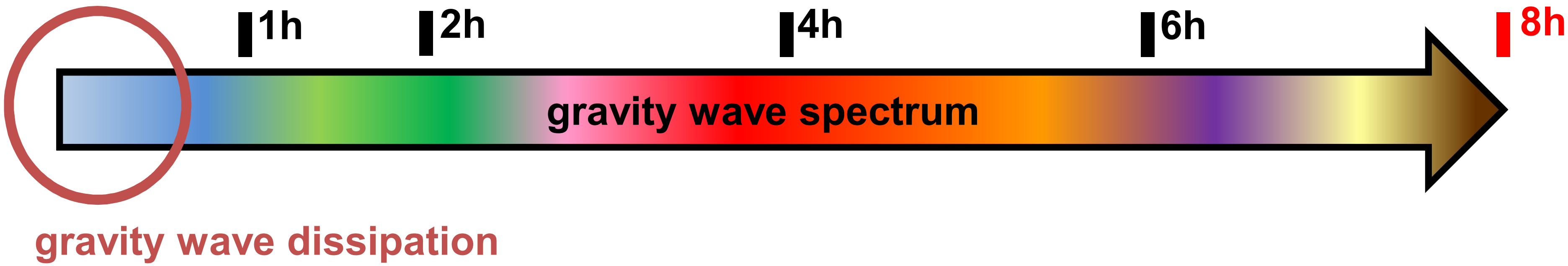

We do not only observe waves but also their dissipation.

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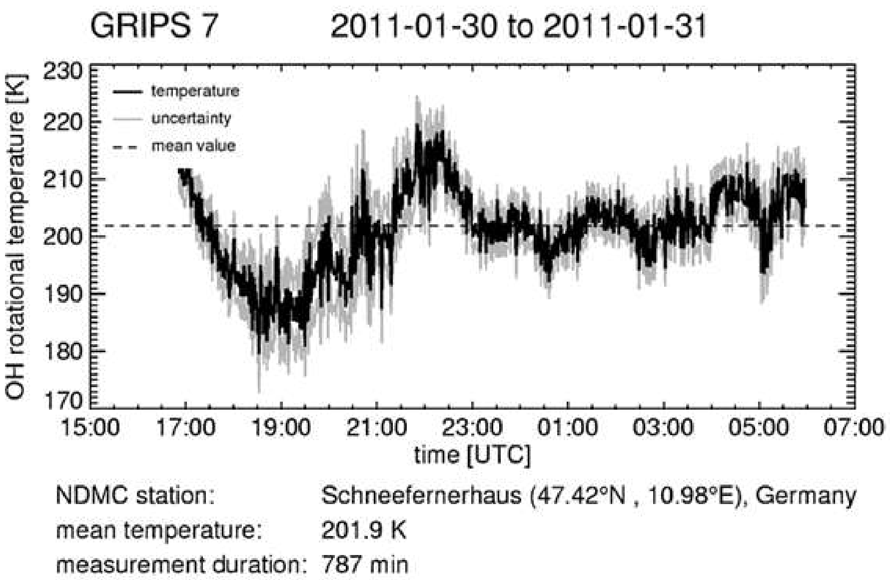

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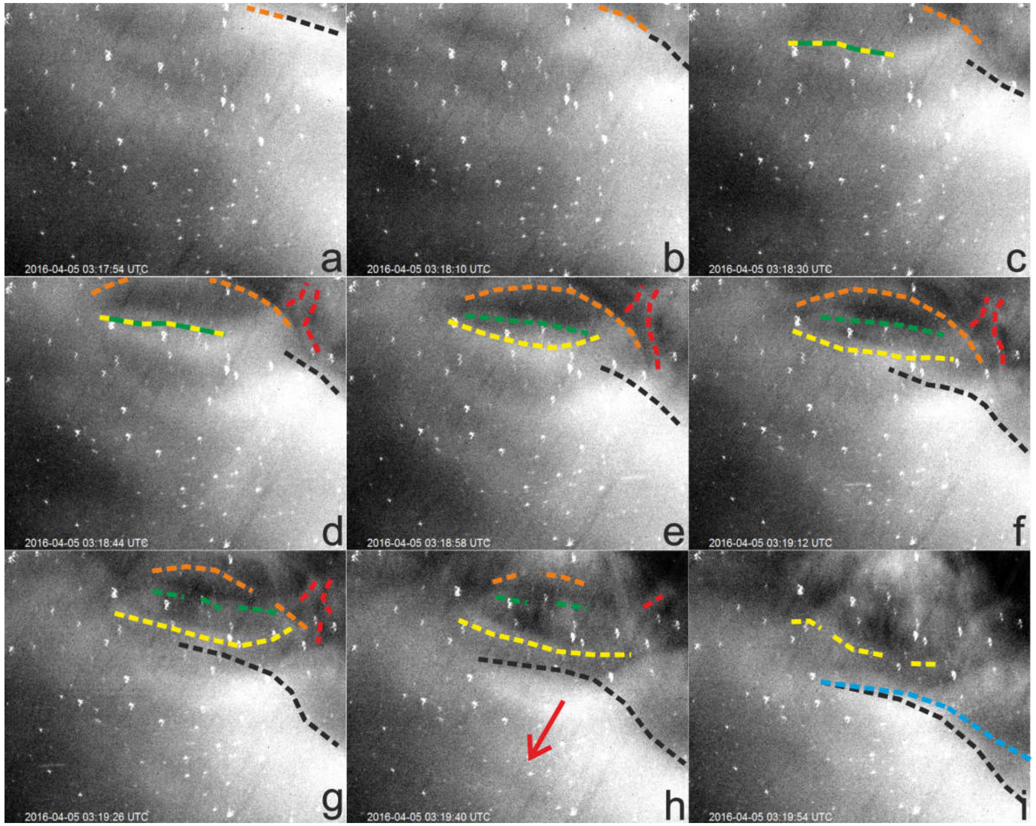
Turbulent vortex analysis



Sedlak et al., 2016

assume rotation around axis parallel to image plane

→ eddy diffusion coefficient

$$K = \frac{2}{3\pi} u_w l_w$$

$$K \approx 4.3 - 11.0 \cdot 10^3 \, \frac{m^2}{s}$$

CIRA86: $10^2 - 10^3 \, \frac{m^2}{s}$

Hodges (1969): $10^3 \, \frac{m^2}{s}$

Liu (2009): $10^2 \, \frac{m^2}{s}$

u_w circumferential velocity

l_w vortex radius

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The video sequence is available as a supplement (Video 2) at https://www.atmos-meas-tech.net/9/5955/2016/

Turbulent vortex analysis

Estimation of energy dissipation rate ϵ

$$K \approx 0.81 \cdot \frac{\epsilon}{N^2}$$ Weinstock (1978)

$$K \approx 4.3 - 11.0 \cdot 10^3 \frac{m^2}{s}$$

$$\epsilon \approx 3.0 - 7.7 \frac{W}{kg}$$

N^2 : Brunt-Väisälä frequency
→ TIMED-SABER

- duration of turbulence ≈ 5 min
- assume isobaric heating

Breaking wave would induce heating by $0.9 - 2.3\ K$.

Upcoming challenges

- turbulent episodes difficult to extract automatically from image sequences
    - various shapes of vortices (size, orientation of axis)
    - similar to clouds
    - no periodic structures

- huge amounts of data (up to 20‘000 images per night per instrument)

New approach: machine learning

currently testing which image features may be suitable for turbulence recognition

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Summary

Gravity wave activity from mesopause temperatures

- seasonal behaviour depends on gravity wave period
- zonal wind fields might influence seasonal cycles

wave activity

turbulence

Turbulence in OH* imager data

- derivation of **vortex parameters**
- estimation of **dissipated energy**

Acknowledgements

We cordially thank our **VAO partners** for hosting and maintaining our instruments

- Umweltforschungsstation Schneefernerhaus, Bavaria
- Observatoire de Haute-Provence, France
- Abastumani Astrophysical Observatory, Georgia
- Arctic Lidar Observatory for Middle Atmosphere Research, Norway
- Sonnblick Observatorium, Austria
- Otlica Observatory / Center for Atmospheric Research, University of Nova Gorica, Slovenia
- Satellite Telemetry Station and Ionospheric Observatory Panská Ves, Czech Republic

The projects VoCaS-ALP and WAVE are funded by the Bavarian State Ministry of the Environment and Consumer Protection.

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Publications

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