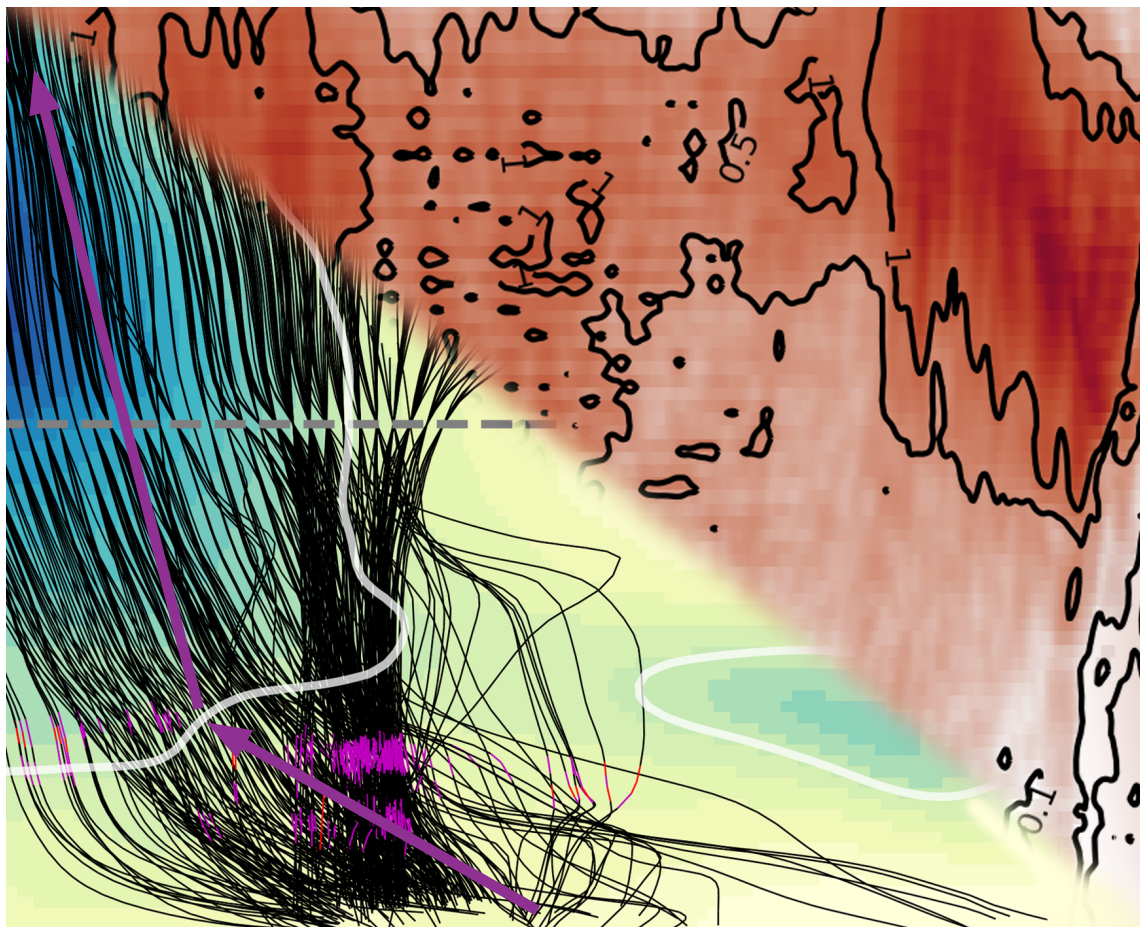




Gravity waves resolved in Numerical Weather Prediction products

Cornelia Strube

Energie & Umwelt / Energy & Environment

Band / Volume 549

ISBN 978-3-95806-567-3

Forschungszentrum Jülich GmbH
Institut für Energie- und Klimaforschung
Stratosphäre (IEK-7)

Gravity waves resolved in Numerical Weather Prediction products

Cornelia Strube

Schriften des Forschungszentrums Jülich
Reihe Energie & Umwelt / Energy & Environment

Band / Volume 549

ISSN 1866-1793

ISBN 978-3-95806-567-3

Contents

1	Introduction	1
2	Gravity wave theory	11
2.1	Perturbation effects	11
2.1.1	Phase speed and group velocity	13
2.1.2	Polarisation relations	15
2.1.3	Interaction with the background flow and momentum flux	16
2.2	Sources	18
2.2.1	Orographic waves	19
2.2.2	Jets and fronts	19
2.2.3	Convection	20
2.3	Propagation of gravity waves	21
2.4	Propagation, refraction and amplitude calculation using ray tracing	23
3	Data	25
3.1	ECMWF operational analyses	26
3.2	ERA5 temperatures	27
3.3	SABER temperatures	27
4	An analysis setup for resolved gravity waves in ECMWF products	29
4.1	Gravity wave characterisation: S3D method	30
4.1.1	Requirements to the method	32
4.1.2	Description of the algorithm	34

4.1.3	Inferred wave parameters	37
4.1.4	Implementation of the method for various data sets	37
4.2	Gravity wave propagation model: GROGRAT raytracer	39
5	Background removal	41
5.1	Spectral filtering methods	42
5.1.1	Vertical wavelength filters	44
5.1.2	Horizontal wavelength filters	44
5.1.3	Diagnostic quantities	47
5.2	Data for comparison	49
5.2.1	Artificial inertial instability perturbations	50
5.3	Horizontal vs. vertical filtering	53
5.3.1	When is the background removed?	53
5.3.2	Minimum appropriate filter cutoff for vertical and horizontal back- ground removals	54
5.3.3	A compromise between removing inertial instability remnants and preserving gravity wave signals in ERA5 temperatures	57
5.3.4	Effects for gravity wave climatologies	62
5.3.5	Horizontal and vertical filtering on a one-year time series of SABER measurements	67
5.4	Conclusion	69
6	Case study: Waves at the southern hemisphere winter polar vortex	73
6.1	Gravity wave characterization in the stratosphere	75
6.1.1	Synoptic situation and the wave field	75
6.1.2	S3D results	78
6.2	Backward ray-tracing	82
6.2.1	Categorisation of the backtraced rays	82
6.2.2	Dependency of lateral propagation on wind and wave direction . . .	87
6.2.3	The relation of ground-based phase speeds and gravity wave sources	91

6.2.4	Angle of the waves relative to the ground and to the wind	93
6.2.5	Origin areas of non-orographic rays	97
6.3	Conclusion	99
7	Summary and outlook	103
	List of figures	108
	List of tables	111
	List of acronyms	113
	List of symbols	114
	Bibliography	117

Energie & Umwelt / Energy & Environment
Band / Volume 549
ISBN 978-3-95806-567-3