An upper-atmosphere extension of the ICON-model to study gravity waves from the troposphere to the lower thermosphere

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Outline

- DFG research group MS-GWaves
  - Our sub-project GWING
- Upper-atmosphere extension of ICON
  - Dynamics
  - Physics
- Plans for 2nd phase of GWING

The DFG research group: *MultiScale dynamics of Gravity Waves** …

Subject and goals:

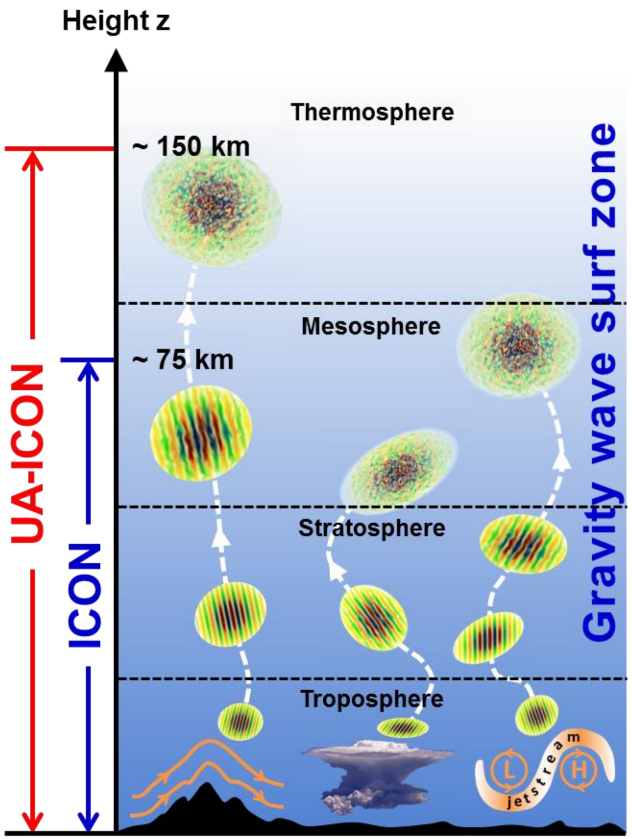
- Spatial, temporal and spectral distribution of gravity waves (GWs) in the atmosphere
- Processes causing and controlling the corresponding GW dynamics
- Role of GWs for global atmospheric circulation and its variability
- Improvement of parameterizations of GWs as a sub-grid scale phenomenon in weather prediction and climate models
- Now in its 2nd phase

* https://ms-gwaves.iau.uni-frankfurt.de/index.php

… and our sub-project *Gravity Wave INteractions in the Global atmosphere*

- **Upper-atmosphere configuration: UA-ICON**
  - UA physics package (MPI-M)
  - Dynamics modification (DWD)
  - Evaluation with benchmarks: HAMMONIA model, measurements, …

- **In collaboration with our partners**
  - Climate simulations and simulations of episodes from the measurement campaigns
  - Investigation and implementation of newly developed GW parameterizations:



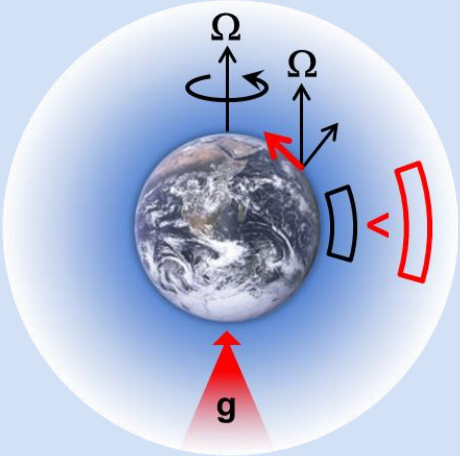
Modification of the dynamical core of ICON

- **Shallow-atmosphere approximation:**
  - Standard configuration in ICON
  - Geometrically atmosphere is ‘plane’

- **Deep-atmosphere modifications:**
  - Increase of grid cell extension with height
  - Consider Coriolis acceleration due to $\mathbf{\Omega_h}$
  - Gravitational acceleration **g** decreases with height

Shallow atmosphere

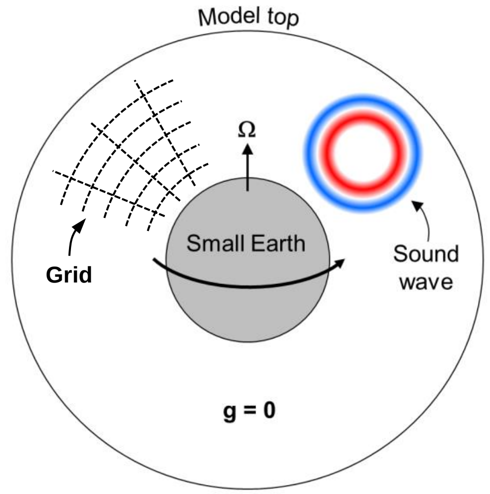
Deep atmosphere

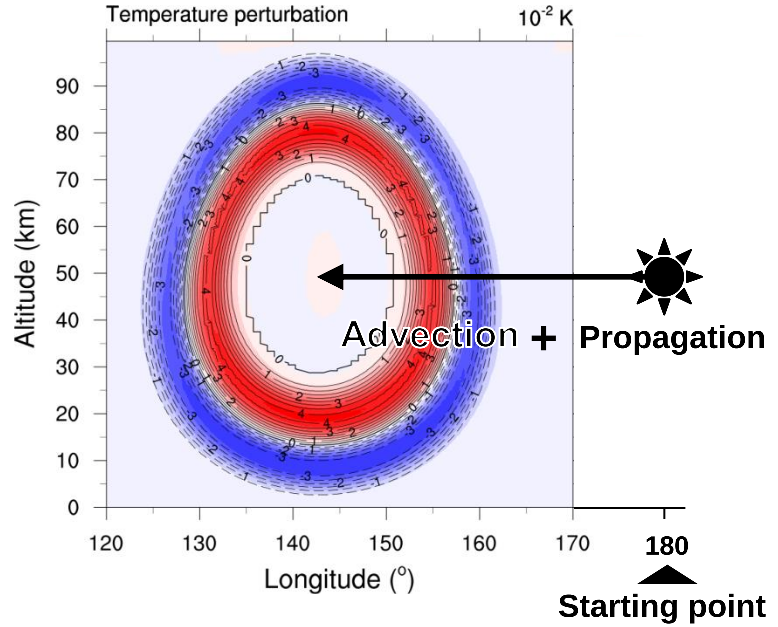


Testing of modifications (example)

- **Sound wave test case*:**
  - Homog. atmosphere at rest in abs. frame + spherical sound wave perturbation
  - Rotating, small Earth: increase deep-atmosphere effects
  - Gravitational acceleration: OFF
    Centrifugal acceleration: ON
- **Features:**
  - Analytical solution available
  - Test dycore performance on spherically curved grid
  - Test conservation of 'balance':

dv/dt + Coriolis + Centrifugal = 0

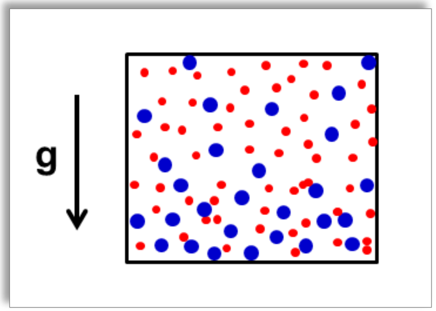




Implementation of UA-specific physics packages in ICON (at MPI-M)

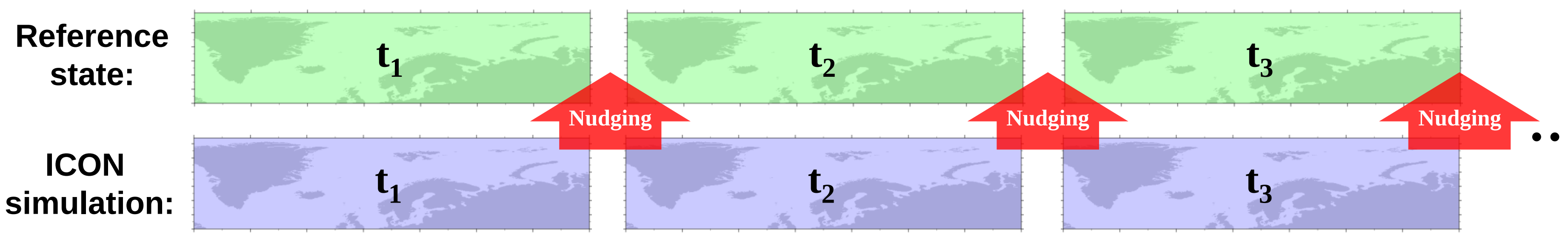
- Physics packages come mainly from the HAMMONIA model (MPI-M, hydrostatic)
- Implementation in (non-hydrostatic) ICON required modification and retuning

Kinetics	
Molecular diffusion	Huang et al. 1998; Banks and Kockarts 1973
Frictional heating	Gill 1982
Gravity wave-induced turbulent diffusion	Hines 1997a,b; Akmaev et al. 1997
Radiation	
Schumann-Runge bands and continuum (O_2)	Strobel 1978
Extreme ultraviolet (N_2, O, O_2)	Richards et al. 1994
Non-LTE infrared cooling (CO_2, NO, O_3)	Fomichev and Blanchet 1995; Fomichev et al. 1998
NO infrared cooling at 5.3μm	Kockarts 1980
Ionization	
Ion drag	Hong and Lindzen 1976
Joule heating	Hong and Lindzen 1976
Others	
Chemical heating	Climatology from HAMMONIA



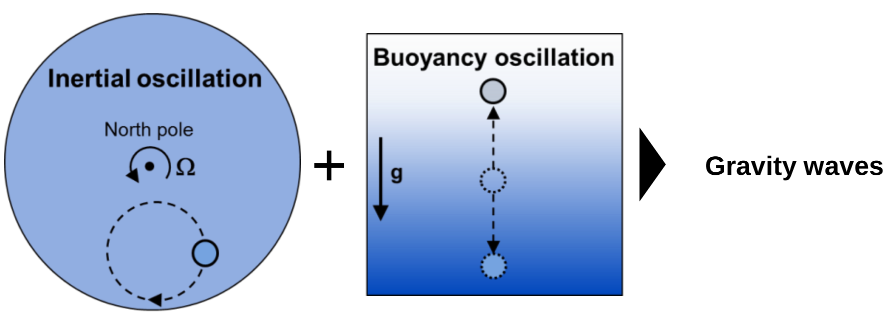
Plans: a nudging option for ICON

- **Motivation:** allow for simulations of contiguous episodes longer than a few days without explicit coupling to a data assimilation scheme, e.g., for comparison with field campaigns



- Preparation & modification of code infrastructure, e.g., for reference data prefetching & reading
- Theoretical considerations: reduce excitation of spurious gravity waves from forcing towards reference state

Do not kick off too strong:

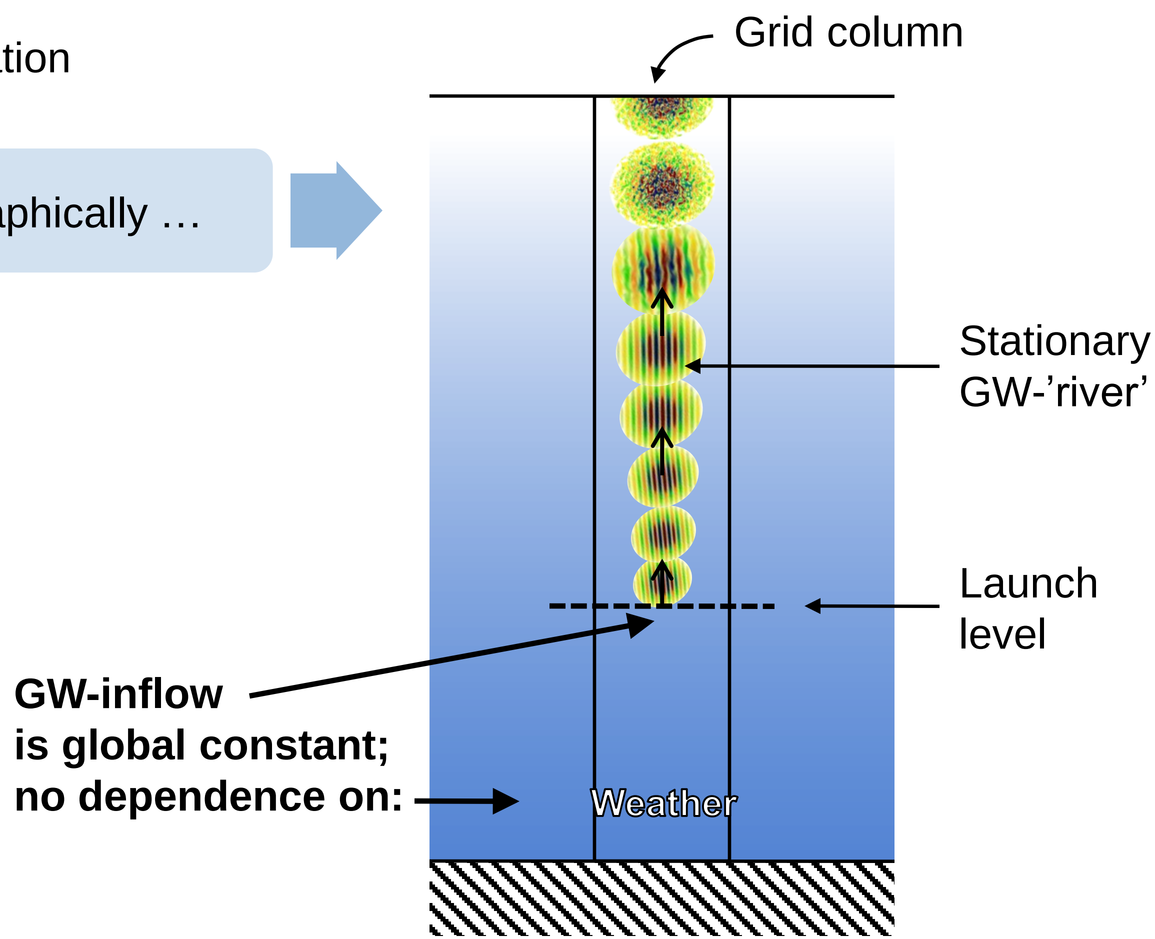


Plans: investigate potential of gravity wave parameterizations

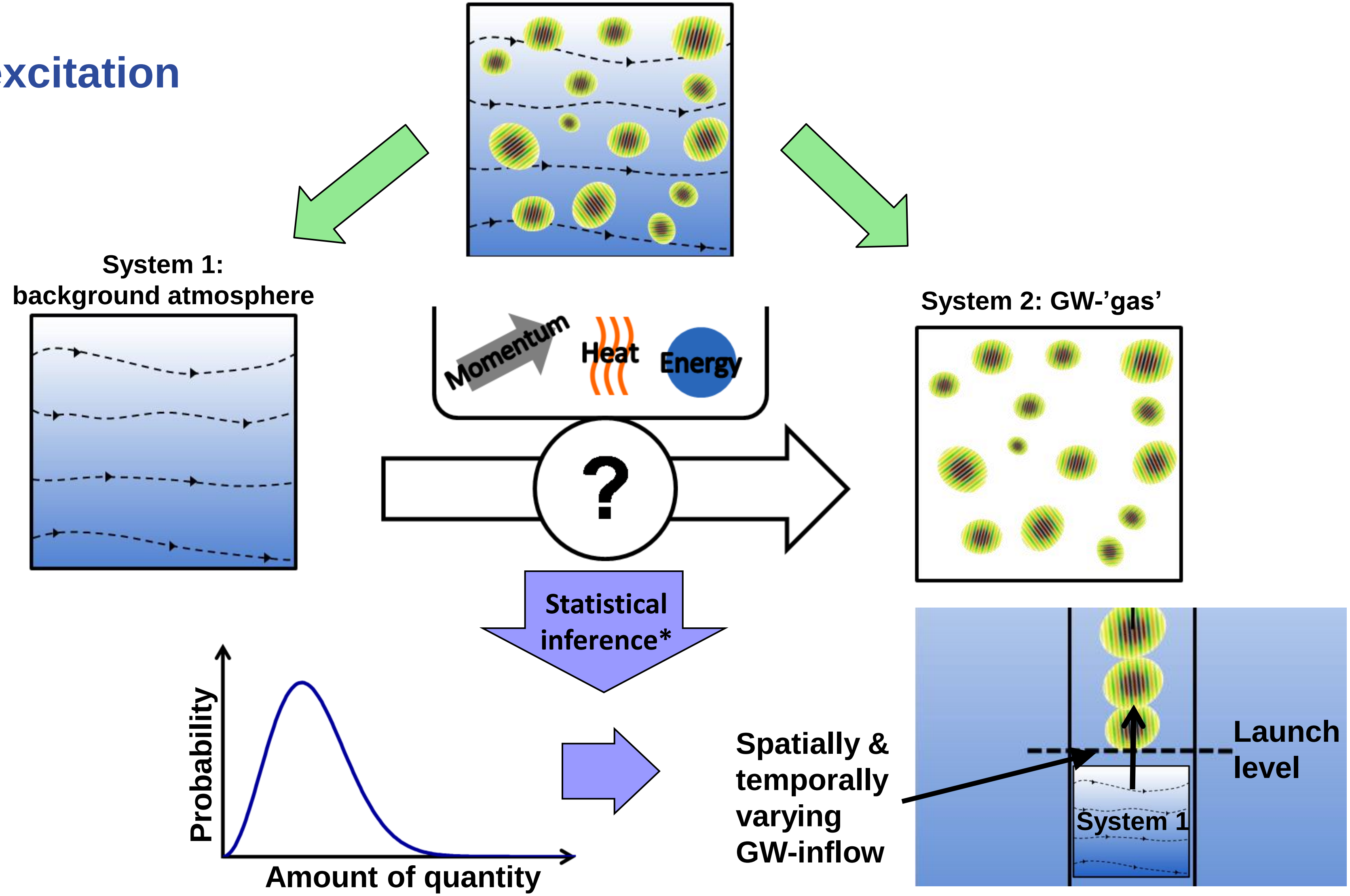
Models require parameterization
of non-resolved …

… orographically & non-orographically …

… forced gravity waves



GW excitation



* E.g., Eckermann (2011) JAS, Lott et al (2012, 2013) Geophys. Res. Let.

Max-Planck-Institut für Meteorologie

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Summary

Within the GW research group MS-GWaves:

- Extension of ICON by an upper-atmosphere configuration
  - Deep-atmosphere dynamics
  - Implementation of additional parameterizations for upper-atmosphere physics
  - Evaluation
- Examples for plans in 2nd phase: Nudging & Potential for improvement of 'standard' GW parameterizations

Thank you!