Karlsruhe Institute of Technology
LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
WAVES TO WEATHER

Disentangling the mechanisms of wave-convection coupling in the tropics

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Live chat: Wednesday, May 6 2020, CEST 16:15-18:00
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Introduction

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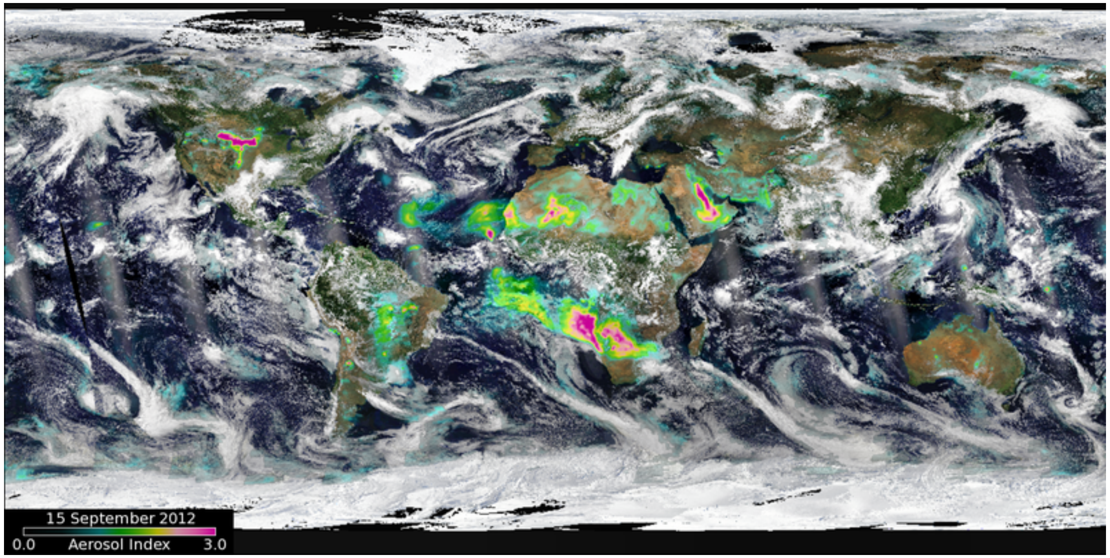

Global satellite picture of clouds retrieved on May 2, 2020 from NASA Goddard Space Flight Center

- Wave patterns in the satellite picture broadly consistent with wave theories (e.g., Matsuno, 1966)
- Importance of equatorial waves due to their coupling to convection

→ *Analyze convectively coupled equatorial waves using an idealized aquaplanet simulation*

Simulation setup

Coarse resolution simulations to reduce computational expense

ICON global aquaplanet
- $\Delta x \approx 40$ km, time step = 300 s, simulation period: 6 months

ICON global aquaplanet
- $\Delta x \approx 26$ km, time step = 225 s, simulation period: 6 months

ICON tropical channel (30S-30N)
- $\Delta x \approx 13$ km, time step = 112.5 s, simulation period: 2 years
- Boundary conditions at 30S and 30N:
  - Averaged θ_v, q_v, ρ, u and w from the 26-km ICON global aquaplanet at 30S and 30N
  - Other variables set to zero

- 90 vertical levels
- Convection parameterization
- In longitude: cyclic boundary conditions
- Coriolis force and diurnal cycle
- SST as in Bretherton and Khairoutdinov (2015)

A realistic storm-resolving ICON simulation from DYAMOND (Stevens et al, 2019) in the period of 2016-08-01 to 2016-09-10 is used to compare with the ICON tropical channel

General features of the 13-km ICON tropical channel

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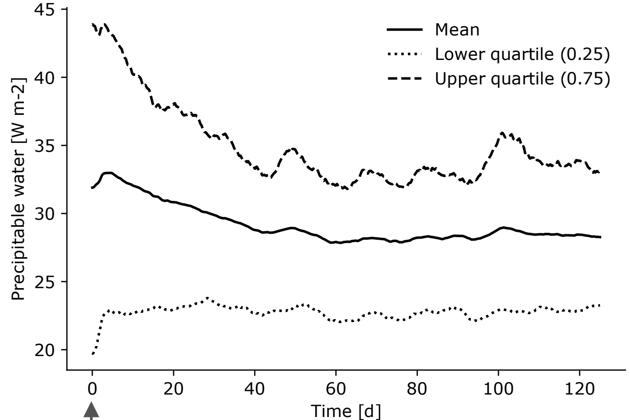
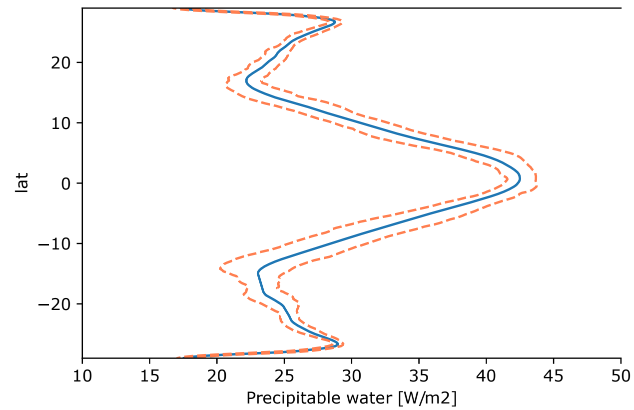
Temporal evolution of domain-mean PW



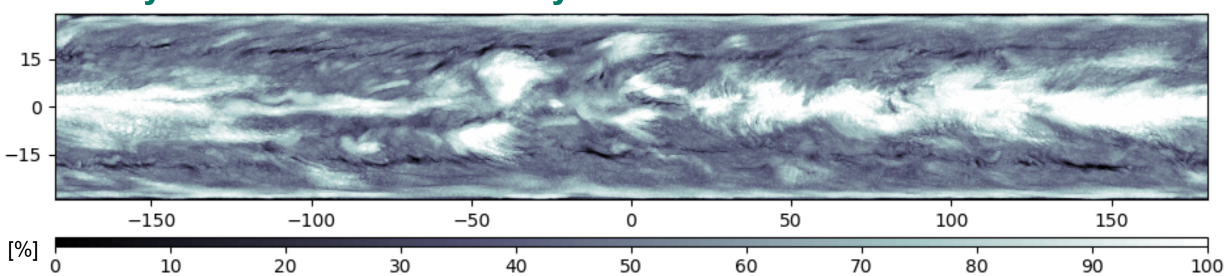
Day 0 when the 13-km tropical channel simulation begins

Zonal 30 day mean PW over day 95-125



* Dotted lines represent the 16-84 percentile range of the zonal variability

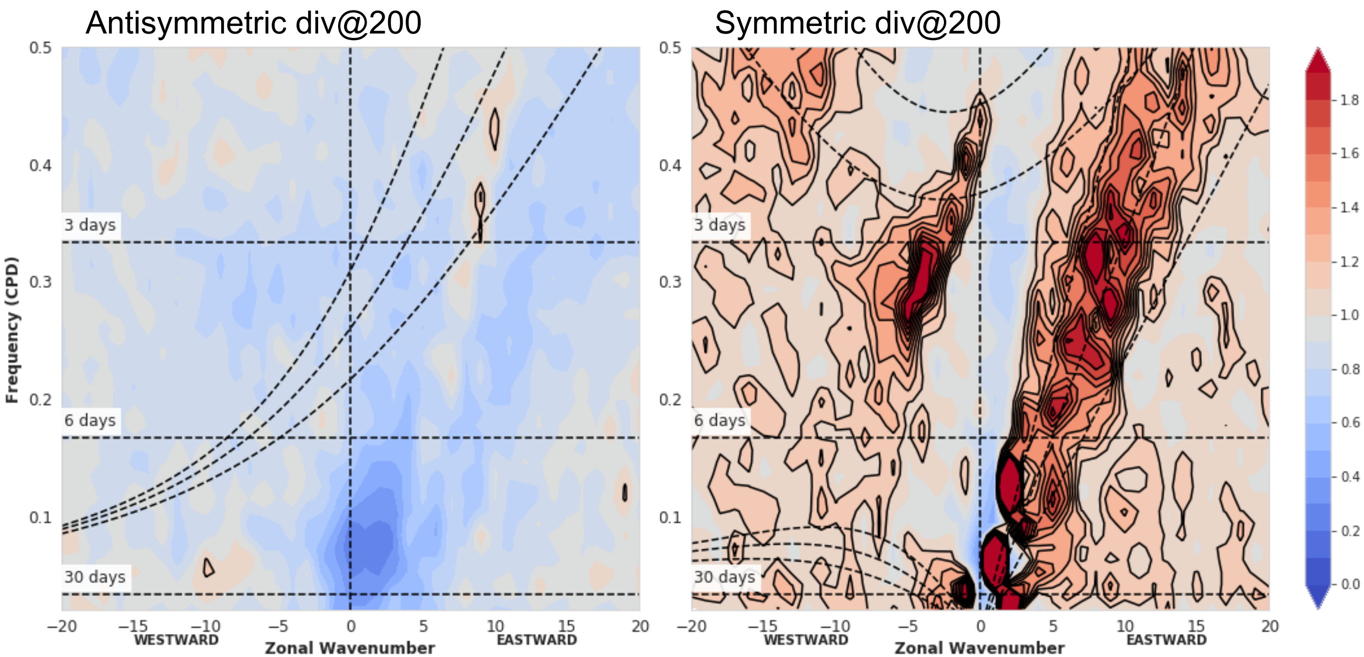
Daily total cloud cover on day 95



- 3 months of spin-up time
- Symmetry about the equator
- Single ICTZ-like structure

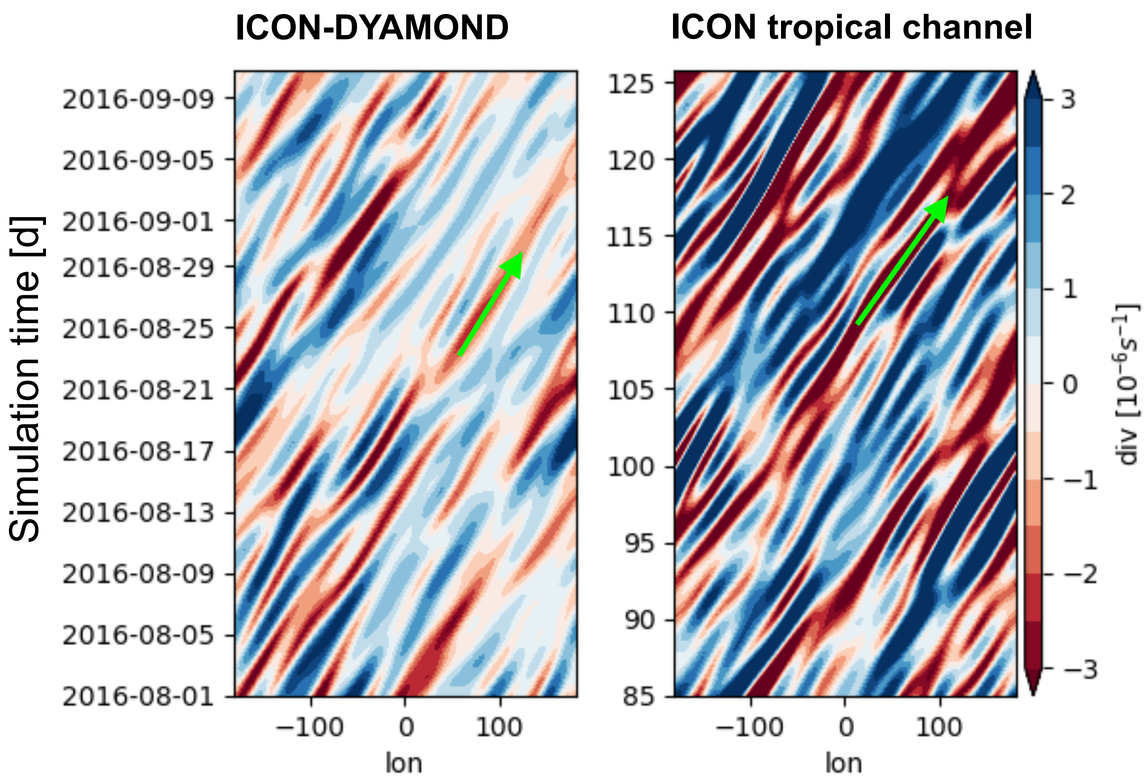
Wavenumber frequency diagram (Divergence at 200 hPa)

ICON tropical channel



- Strong signal from the symmetric waves due to the meridionally symmetric simulation setup
- Kelvin, MJO and ER are present

Filtered Kelvin waves between 10S and 10N



ICON-DYAMOND
Realistic storm-resolving simulation
$\Delta x \approx 2.5$ km
ICON tropical channel
Aquaplanet with varying SST over lat
Parameterized convection
$\Delta x \approx 13$ km

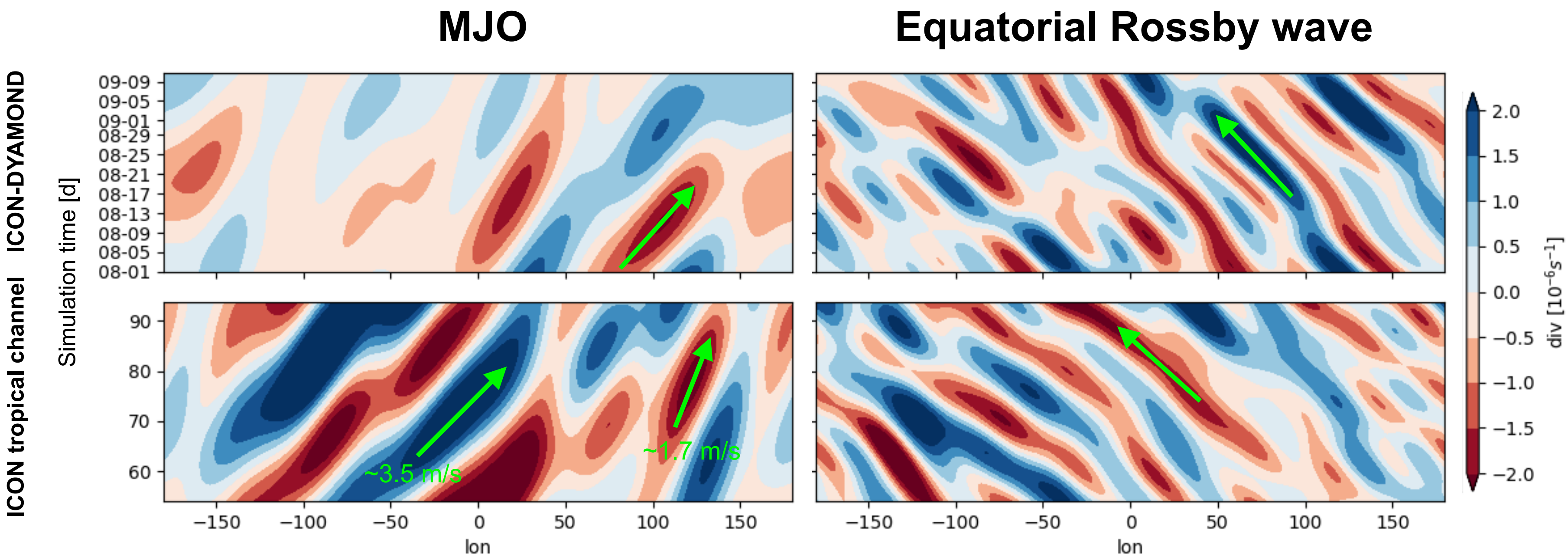
*Zero-padding method (Janiga et al., 2018) is used for the wave filtering of the ICON-DYAMOND due to the short period of the simulation (40 days)

*The same method for a higher resolution of the ICON tropical channel will be used for the future analysis

- Kelvin waves have stronger signals in the ICON tropical channel than in the ICON-DYAMOND
- Kelvin waves propagate faster in the ICON tropical channel (~30 m/s) than in the ICON-DYAMOND (~20 m/s)
  → The idealized setup (aquaplanet, and symmetric initial and boundary conditions) allows Kelvin waves to have strong signals and faster propagation speed

*The source code of wave filtering tools is provided by Michael Maier-Gerber

Other waves symmetric about the equator



- The MJO signals are stronger in the ICON tropical channel than in the ICON-DYAMOND, but the ER signals are relatively comparable between two simulations.
- For the ICON tropical channel simulation, the MJO shows different propagation speeds despite the zonally uniform boundary conditions.

*The source code of wave filtering tools is provided by Michael Maier-Gerber

Moist static energy distribution between 30S and 30N

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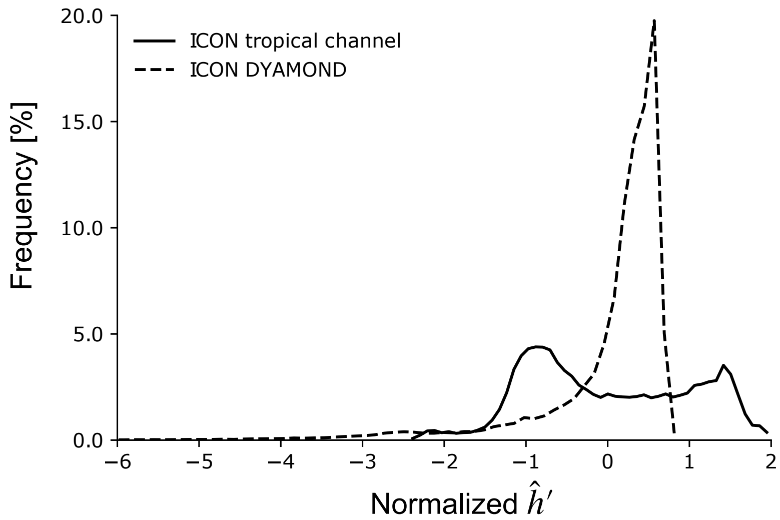
Normalized daily mean anomaly of the column integrated moist static energy



Moist static energy $h = gz + c_p T + L_v q_v$

$$\hat{h} = \frac{1}{g}\int h\,dp$$

$$\hat{h}' = \hat{h}' - \int_A \hat{h}'\,dA$$

$$\text{Normalized } \hat{h}' = \frac{\hat{h}' - \mu}{\sigma}$$

*ICON DYAMOND on August 20th
ICON tropical channel on 101 simulation day

- Bimodal shape of the normalized $\hat{h}'$ for the ICON tropical channel
  → Characteristics of convective self-aggregation
  * Distribution of the precipitable water shows the bimodal structure as well
- Negatively skewed distribution for ICON-DYAMOND
  → Positive normalized $\hat{h}'$ from the oceans, particularly in the Northern hemisphere
  → Negative normalized $\hat{h}'$ from land and very strong negative values in Southern Africa and the west coasts of the Americas

Summary

- Generally strong ***symmetric features*** about the equator and relatively uniform in longitude for the ICON tropical channel simulation due to the idealized simulation setup
- In the ICON tropical channel simulation, Kelvin waves, the MJO and equatorial Rossby waves are present, and these waves have ***stronger signals*** and ***propagate faster*** than those in the realistic ICON simulation (DYAMOND)
- The distributions of the moist static energy anomalies and precipitable water for the ICON tropical channel agree with the ***characteristics of convective self-aggregation***

Open discussion & Outlook

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We are pleased to hear any comments on our planned methods for the simulated equatorial waves

- To examine convectively coupled equatorial waves (CCEWs), we are planning to project the observed patterns on theoretical wave patterns (Yang et al., 2003)

- The quantitative examination will be done using the budget analysis of the moist static energy

$$\frac{1}{2}\frac{\partial \hat{h}'^2}{\partial t} = \hat{h}'\mathrm{netSW} + \hat{h}'\mathrm{netLW} + \hat{h}'\mathrm{SEF} + \hat{h}'\mathrm{Adv}$$

netSW: net shortwave radiation at the top of the atmosphere
netLW: net longwave radiation at the top of the atmosphere
SEF: surface enthalpy flux
Adv: advection of $\hat{h}'$

Outlook

- Higher resolution of ICON tropical channel simulation with $\Delta x \approx$ 2.5 km
  - Boundary conditions at 30S and 30N obtained from 13-km ICON tropical channel simulation
  - Explicit convection

We thank Daniel Klocke for providing the ICON-DYAMOND simulation, and thank Michael Maier-Gerber for providing wave filtering tools.

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