Convectively Coupled Gravity Waves and Moisture Modes*

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MOTIVATION

What is the fundamental difference between the Kelvin wave and the moisture mode?

What is the destabilization mechanism?

What is the vertical structure?

How does 2002 FR model relate to the one by Neelin and Yu, 1994?

2002 - 2007 Model Dynamics

- non-rotating atmosphere

- vertically resolved model (2002 not vertically resolved)

- heating profile $\sim \sin m_0 z$ where $m_0 = \pi/h$

2002 - 2007 Model Physics

Precipitation rate $= P_1 + P_2 + P_3$

Precipitation due to precipitable water: $P_1 = \alpha \int_0^h q(z)dz$

Precipitation due to CIN: $P_2 = \mu_{CIN}\,[e_s - e_t]$

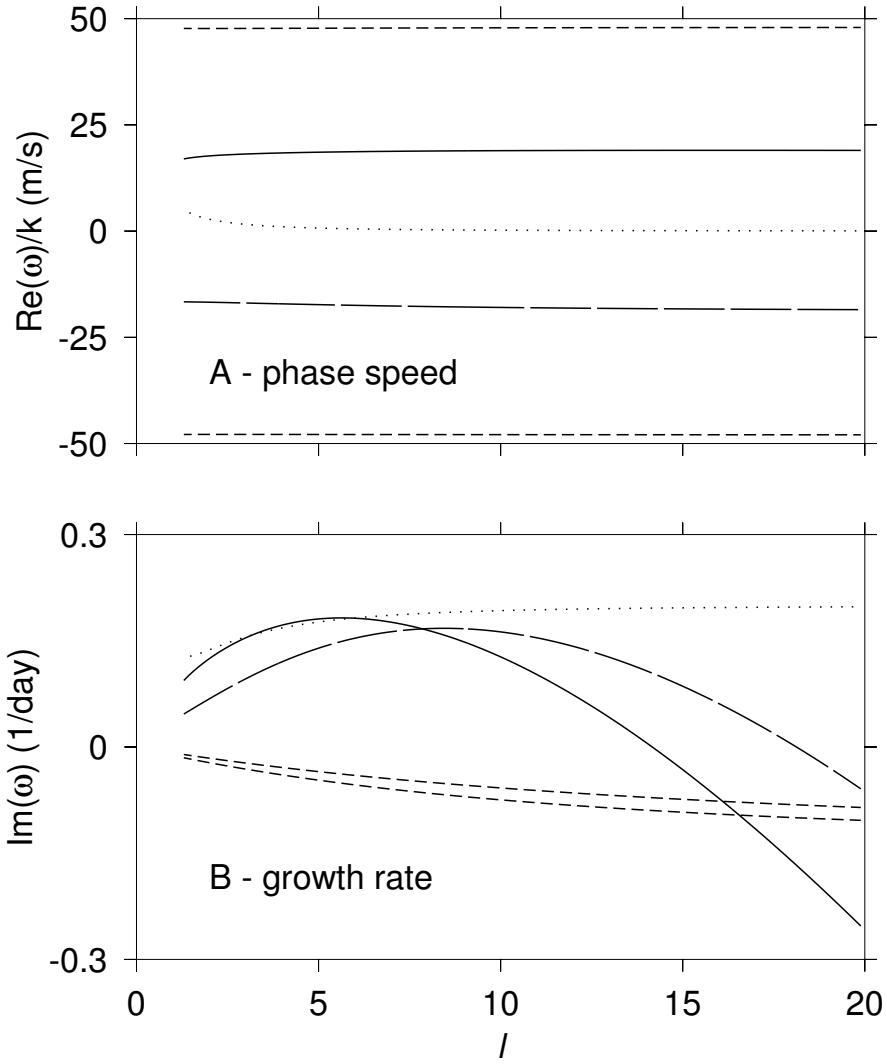
Precipitation due to CAPE: $P_3 = \mu \int_0^h b(z)dz$

- e_s is moist entropy in the boundary layer
- e_t is saturated moist entropy just above the boundary layer

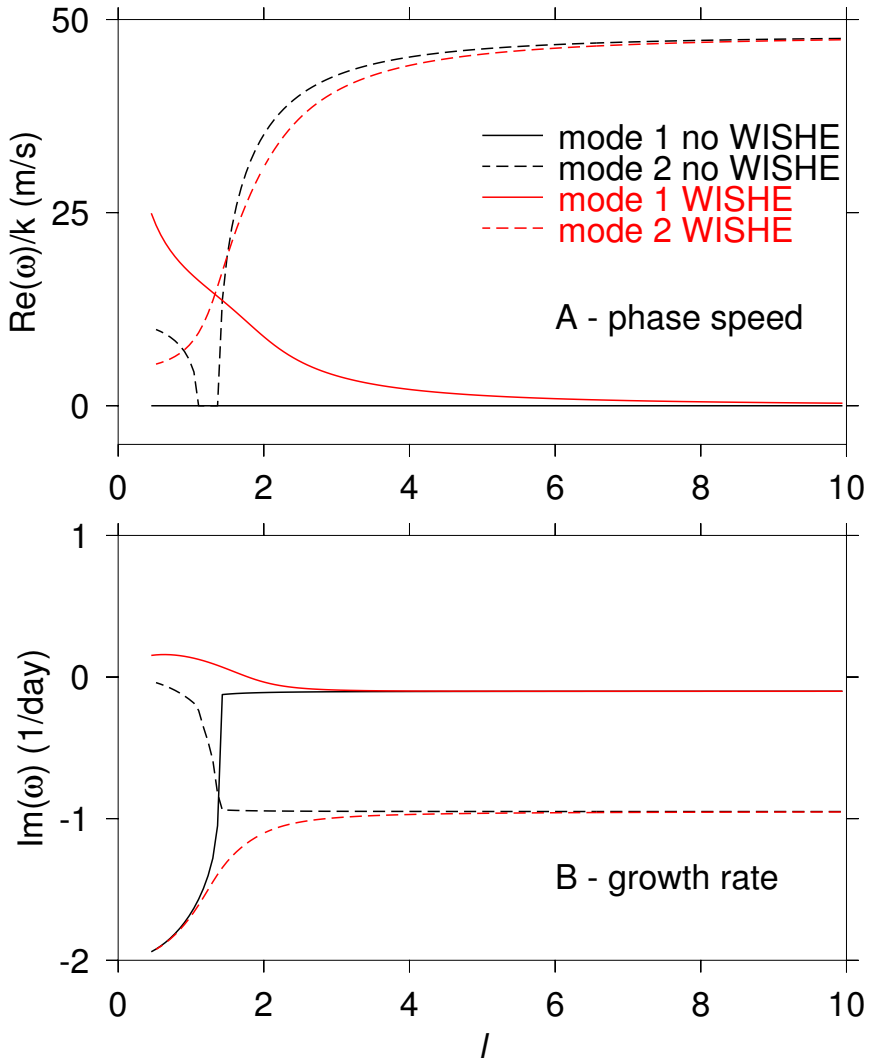
WISHE - wind induced surface heat exchange

GMS - gross moist stability $\Gamma_M = \frac{\int_0^h \Gamma_E(z) w(z) dz}{\int_0^h \Gamma_B(z) w(z) dz}$, $\Gamma_E(z) = \frac{de_0}{dz}$

Dispersion relations 2007 (WISHE, CIN, $GMS < 0$, no CAPE)



2002 FR model with CAPE, $\sigma = \frac{\alpha+\mu}{\alpha} = 2$, $GMS > 0$



Summary

$$P = P_1 + P_2 + P_3 = \alpha \int_0^h q(z)dz + \mu_{CIN} [e_s - e_t] + \mu \int_0^h b(z)dz$$

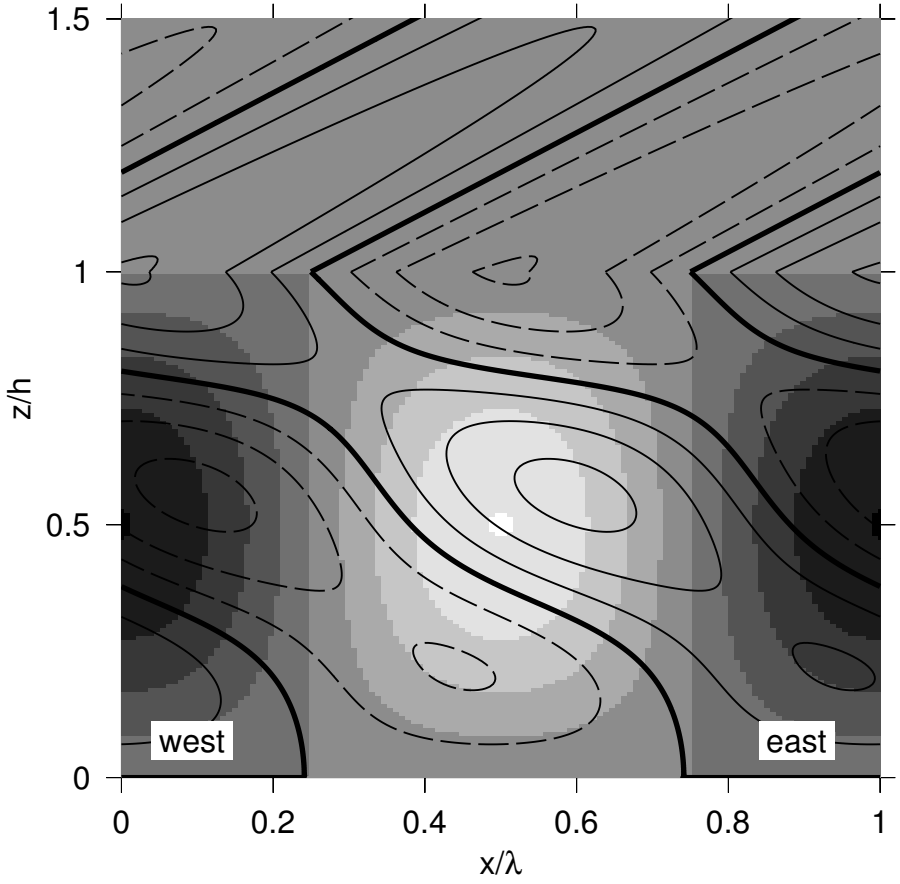
Result = Moisture mode + Convectively coupled gravity mode

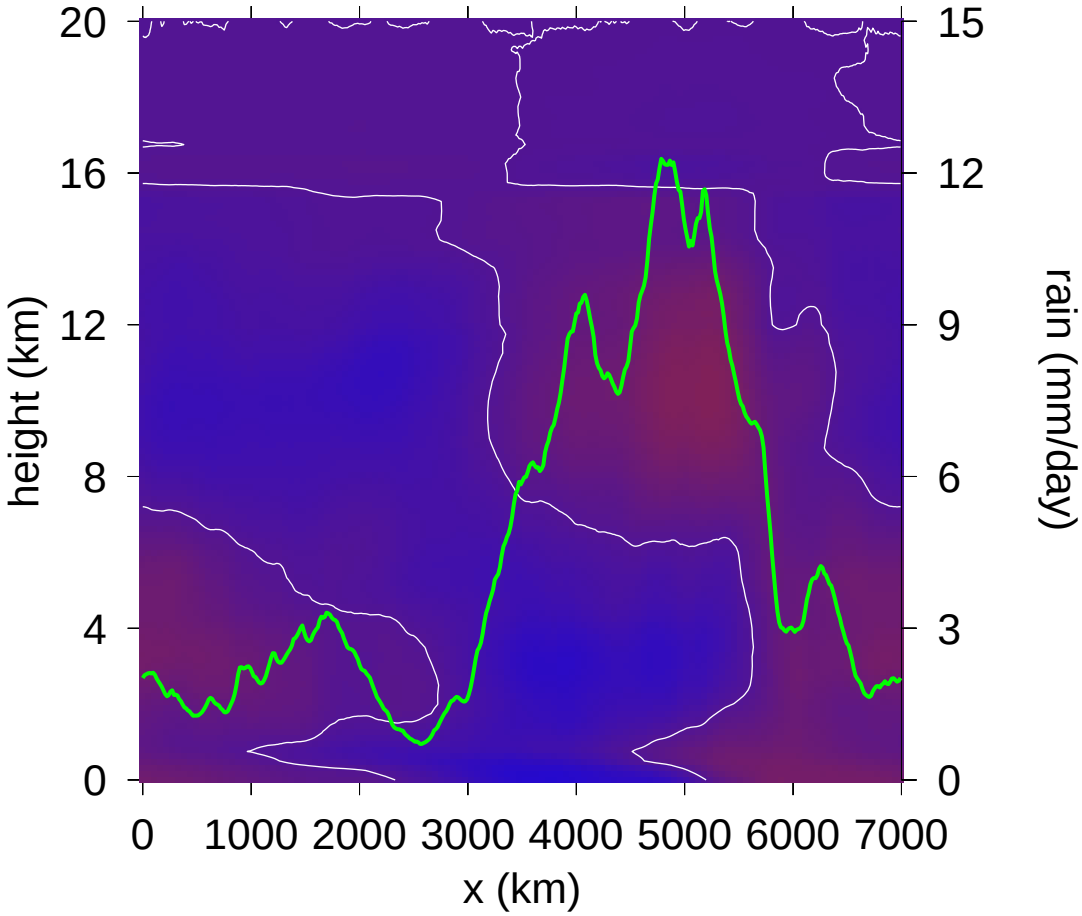
Instability=negative GMS + reduced CIN

CAPE=no instability

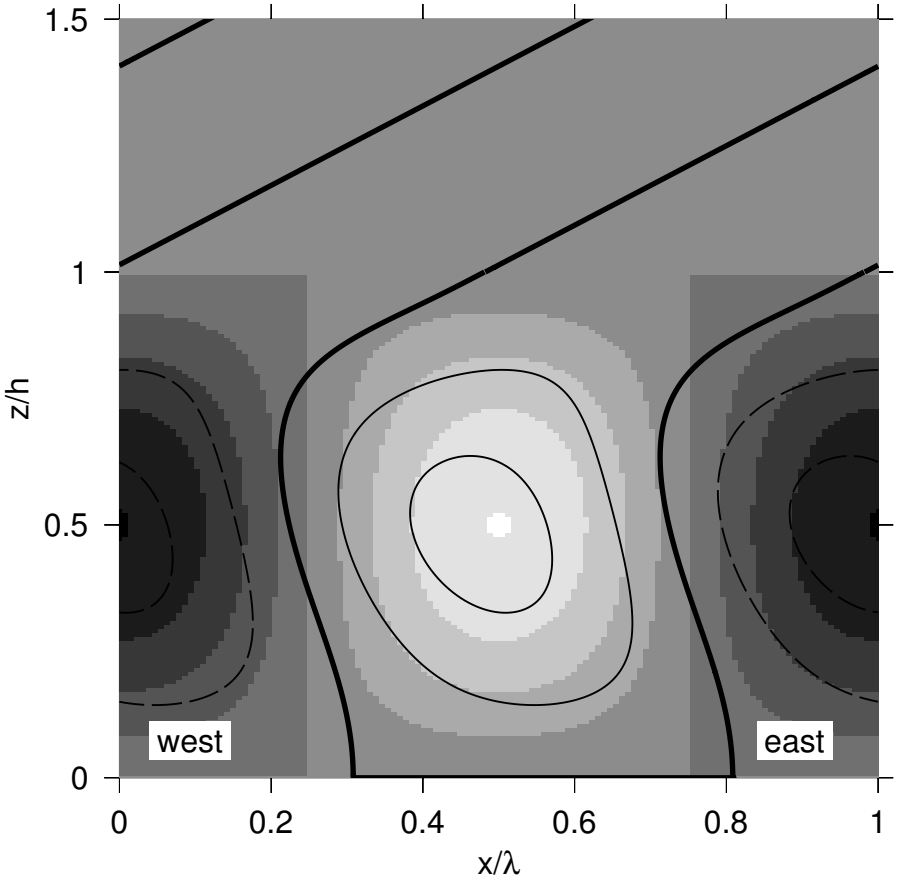
Dynamics (vertical structure)=[$\lambda_z = h/2$] and [$\lambda_z = 2h/3$]

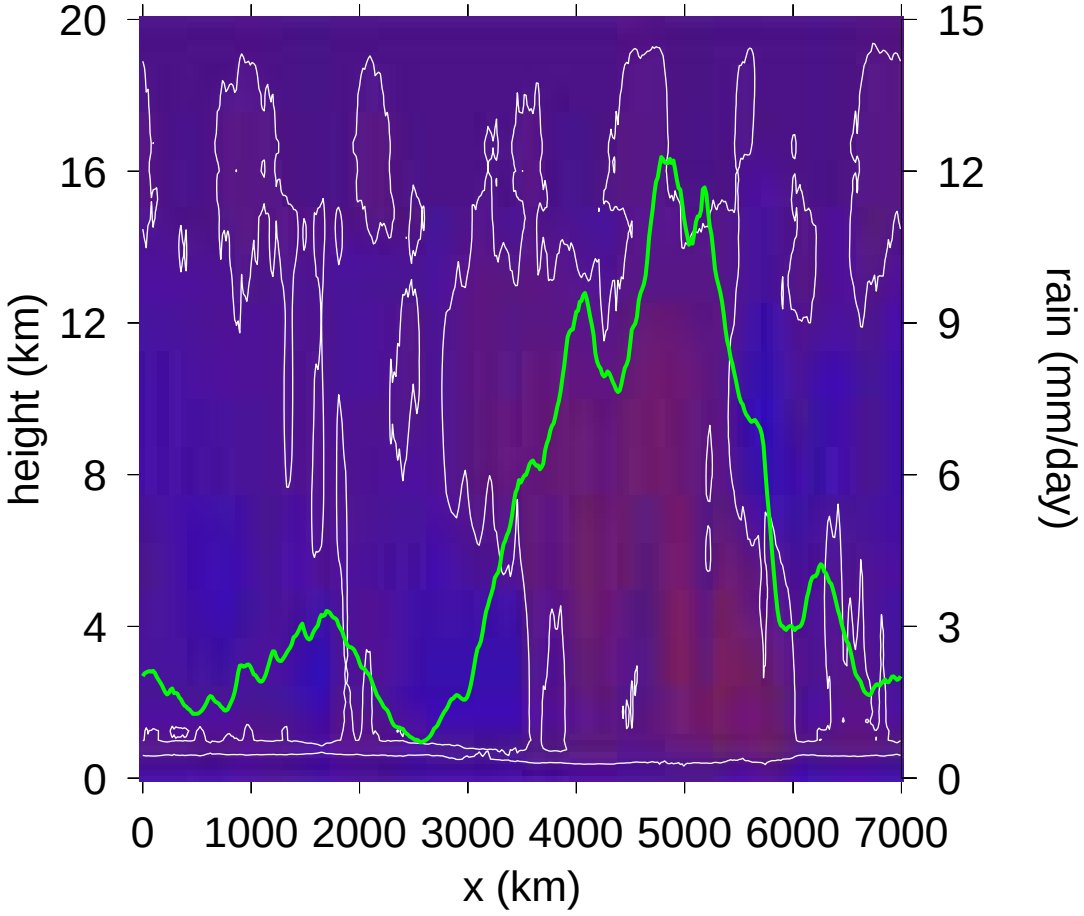
Temperature perturbation and heating anomaly for gravity wave



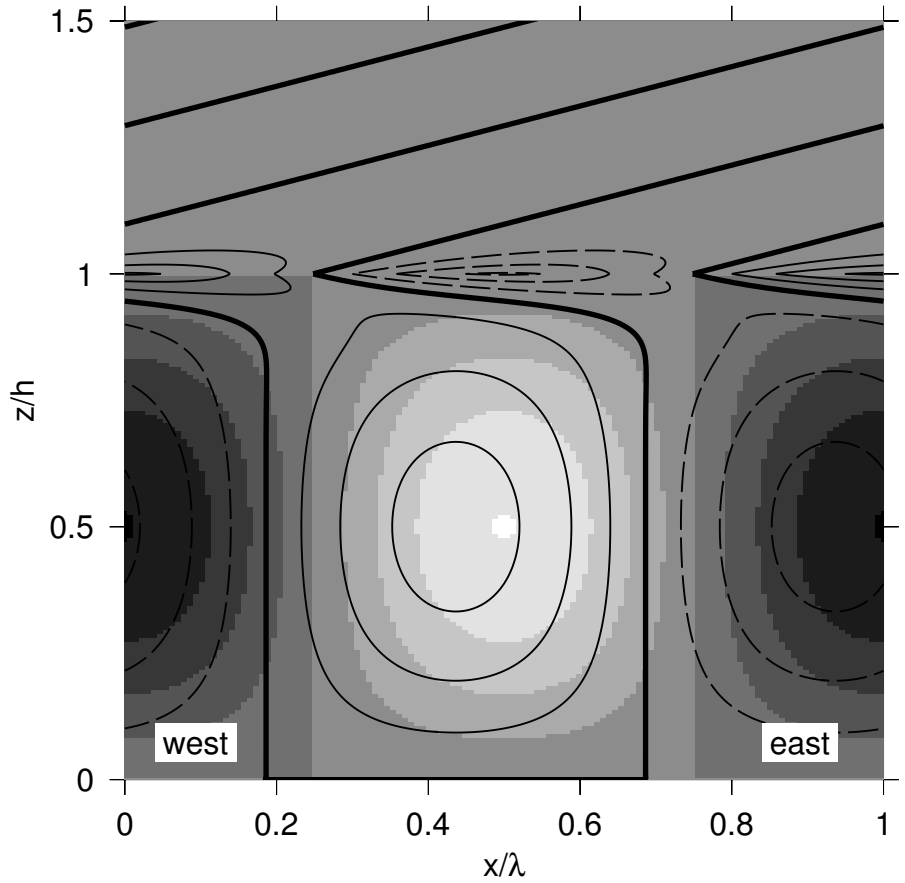


Vertical velocity and heating anomaly for gravity wave





Temperature perturbation and heating anomaly for moisture mode



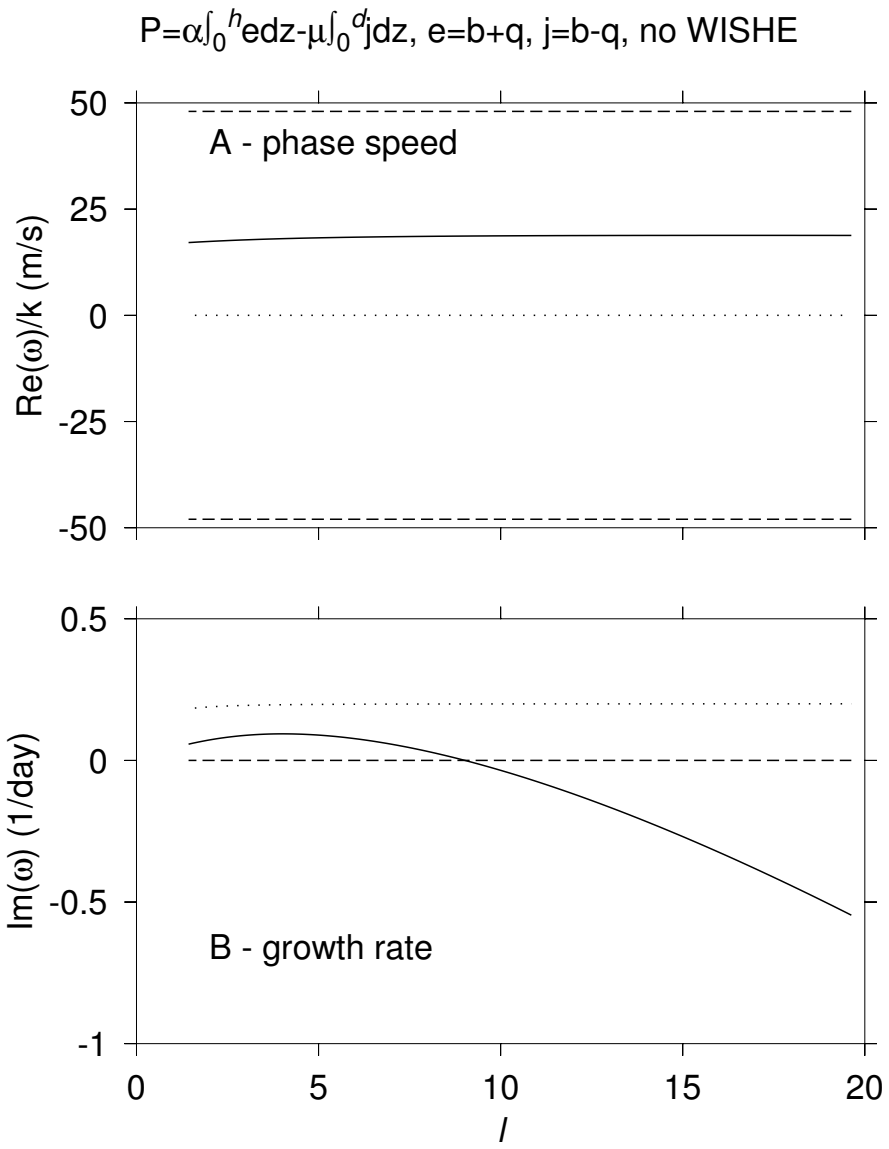
Conclusions

Two fundamentally different mechanisms destabilize convectively coupled Kelvin waves and the moisture mode.

Convection - instability in Kelvin waves is governed by fluctuations in CIN.

Convection - instability in moisture mode is governed by negative GMS.

The vertical structure of Kelvin waves and moisture modes is different.


P=α∫0^h edz-μ∫0^d jdz, e=b+q, j=b-q, no WISHE
A - phase speed
B - growth rate
Re(ω)/k (m/s)
Im(ω) (1/day)
50
25
0
-25
-50
0.5
0
-0.5
-1
0
5
10
15
20
l