Characteristics of Self Acceleration driven Gravity Wave Instabilities

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50 Years of Gravity Wave Research

*a Tribute to Colin Hines*

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Self Acceleration Dynamics

• What is Self Acceleration?
• Modeling Efforts
• Characteristics of Self Acceleration
  – 2D vs. 3D instabilities
  – Viscous dependence
  – Frequency dependence
  – Amplitude dependence
  – Horizontal wavelength dependence
  – Multiple breaking events
• Conclusion
What is Self Acceleration?

Gravity wave / mean flow interactions:
• Wave Breaking
• Viscous coupling
• Self Acceleration

Self Acceleration:
➢ Conservative, Transient
➢ Momentum flux divergence leads to mean flow acceleration
➢ Peak flux offset from peak response

![Graphs and images showing wave breaking and mean flow interactions.](image-url)
Evolving Mean: Self Acceleration GW Breaking
Fixed Mean: Gravity Wave Breaking
**Modeling Efforts**

Anelastic Navier-Stokes model
- No sounds waves
- Accounts for density variation with height

Current results
- Runs are isothermal (*slightly non-physical breaking altitudes*)
- Runs initialized with a headwind
- Runs initialized with a 2D wave packet periodic in the horizontal and confined in the vertical
- For 3D runs low level noise is added to seed spanwise instability
Evolving Mean: 2D precedes 3D instability onset

streamwise

spanwise
Fixed Mean: 2D and 3D instability nearly concurrent

streamwise

spanwise
Self Acceleration: $u$, $w$, $T$, and vorticity magnitude

**Velocity fields**
- $u'$
- $w'$

**Potential Temperature**
- Vorticity Magnitude
Self Acceleration: Viscous effects

Self Acceleration Breaking largely ignores viscous effects

**Vorticity magnitude**

Packet initialized at 60 km

Packet initialized at 10 km
Self Acceleration: Frequency dependence

Multiple frequencies, same amplitude
• Breaking altitude frequency dependent
• Shape of instability apparently independent
• Role of dispersion?

\[ A = \frac{u'}{c_x} \]
Self Acceleration: Amplitude dependence

- Breaking altitude amplitude dependent
- Shape of instability apparently independent
**Self Acceleration: Dispersive effects?**

**Amplitude Growth with Altitude:**

\[
A(z) = A_0 \exp\left[-\frac{(z - z_0)}{2h}\right]
\]

\[
z_T - z_0 = 2h \log\left[\frac{A_0}{A_T}\right]
\]

Works for \(N/1.414\)

- for \(N/2\), “2” = 2.5
- for \(N/3\), “2” = 4.6

*Not fully understood*

*Preliminary values*
Self Acceleration: Length scale dependence

- Horizontal wavelength affects appearance of SA breaking
- Horizontal wavelength also affects time to onset; group velocity
Self Acceleration: One wave, multiple breaking zones
Conclusions:
• Natural consequence of vertical wave propagation
• Effective Gravity Wave instability mechanism
• Dynamic signature largely determined by horizontal wavelength

Future Work:
• Characterize the potential role of dispersion
• Parameterize relationship between sources to events

• Consider realistic background environments
• Localize forcing in streamwise
• Localize forcing in spanwise, consider 3D consequences

• Comparison with observation (the future is now)