Characteristics of Self Acceleration driven Gravity Wave Instabilities

Brian Laughman, Dave Fritts, *GATS, Inc.*

Tom Lund, *NWRA*

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

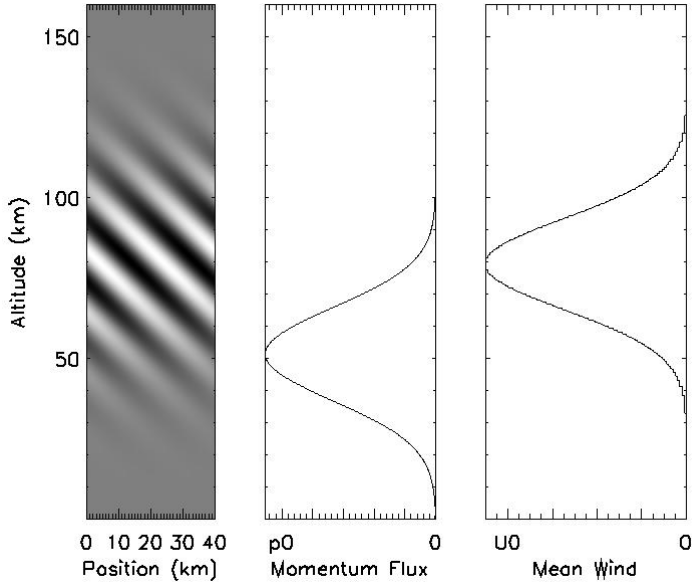
What is Self Acceleration?

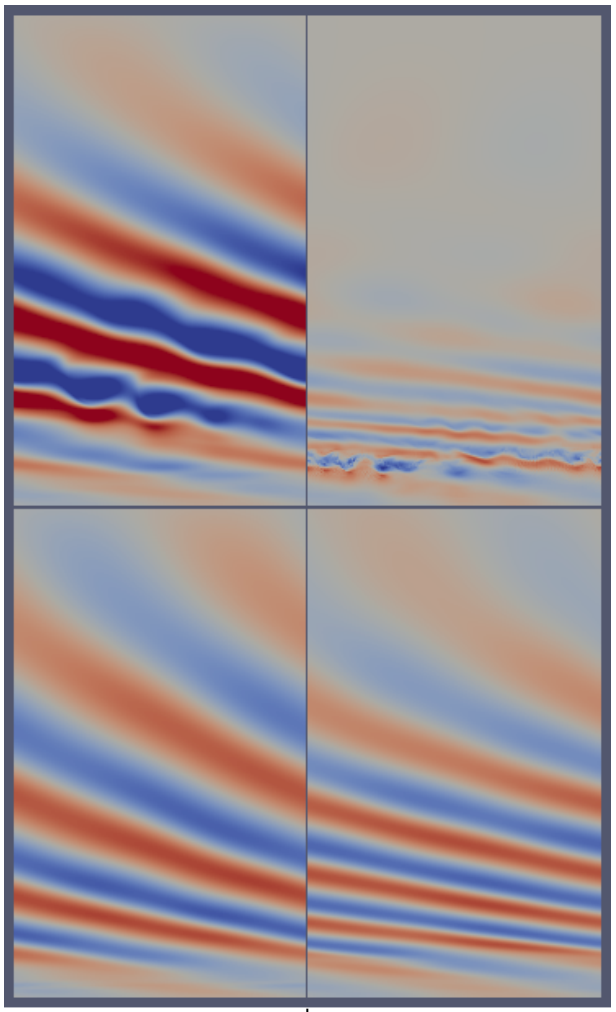
Gravity wave / mean flow interactions:

- Wave Breaking
- Viscous coupling
- Self Acceleration

Self Acceleration:

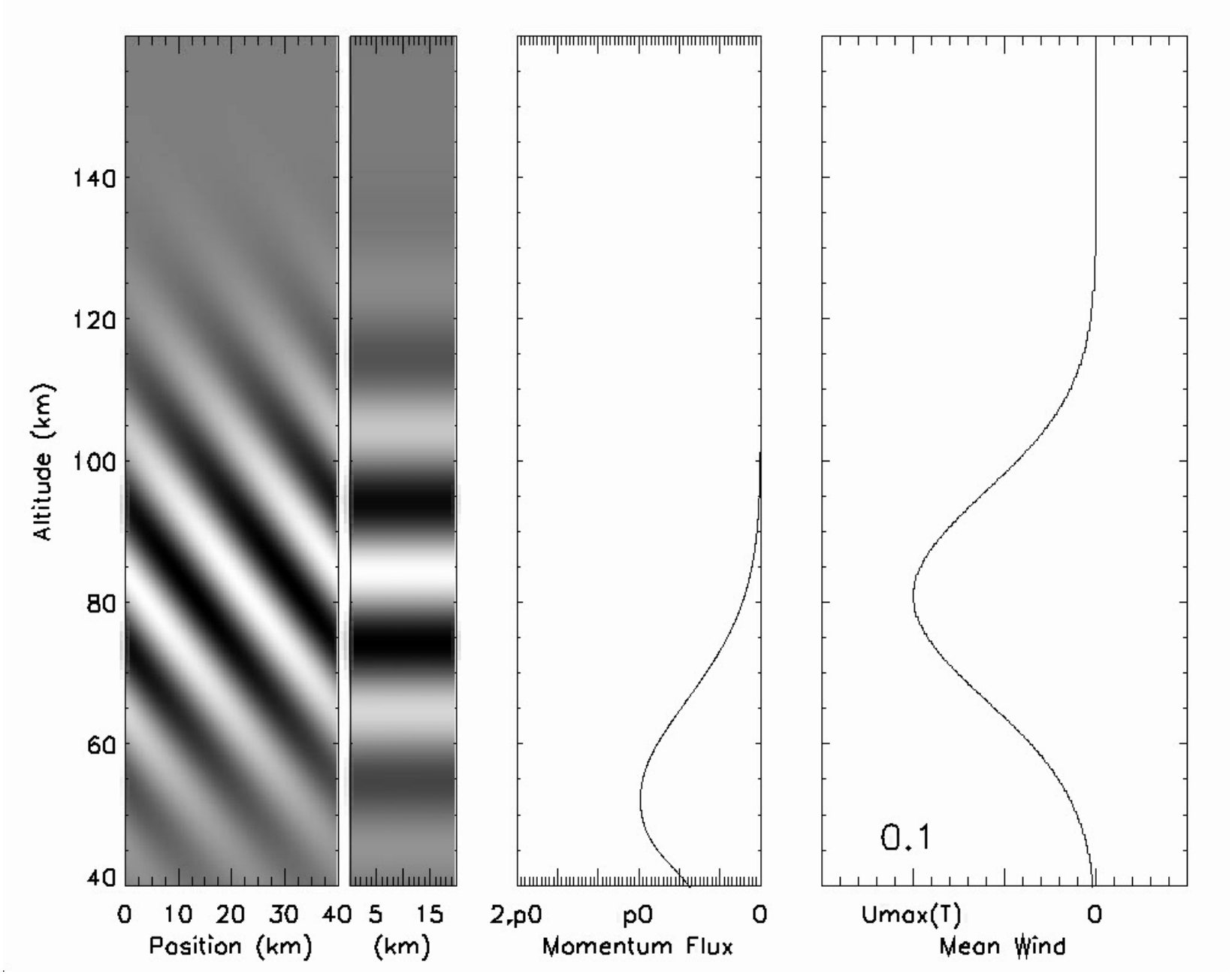
- Conservative, Transient
- Momentum flux divergence leads to mean flow acceleration
- Peak flux offset from peak response



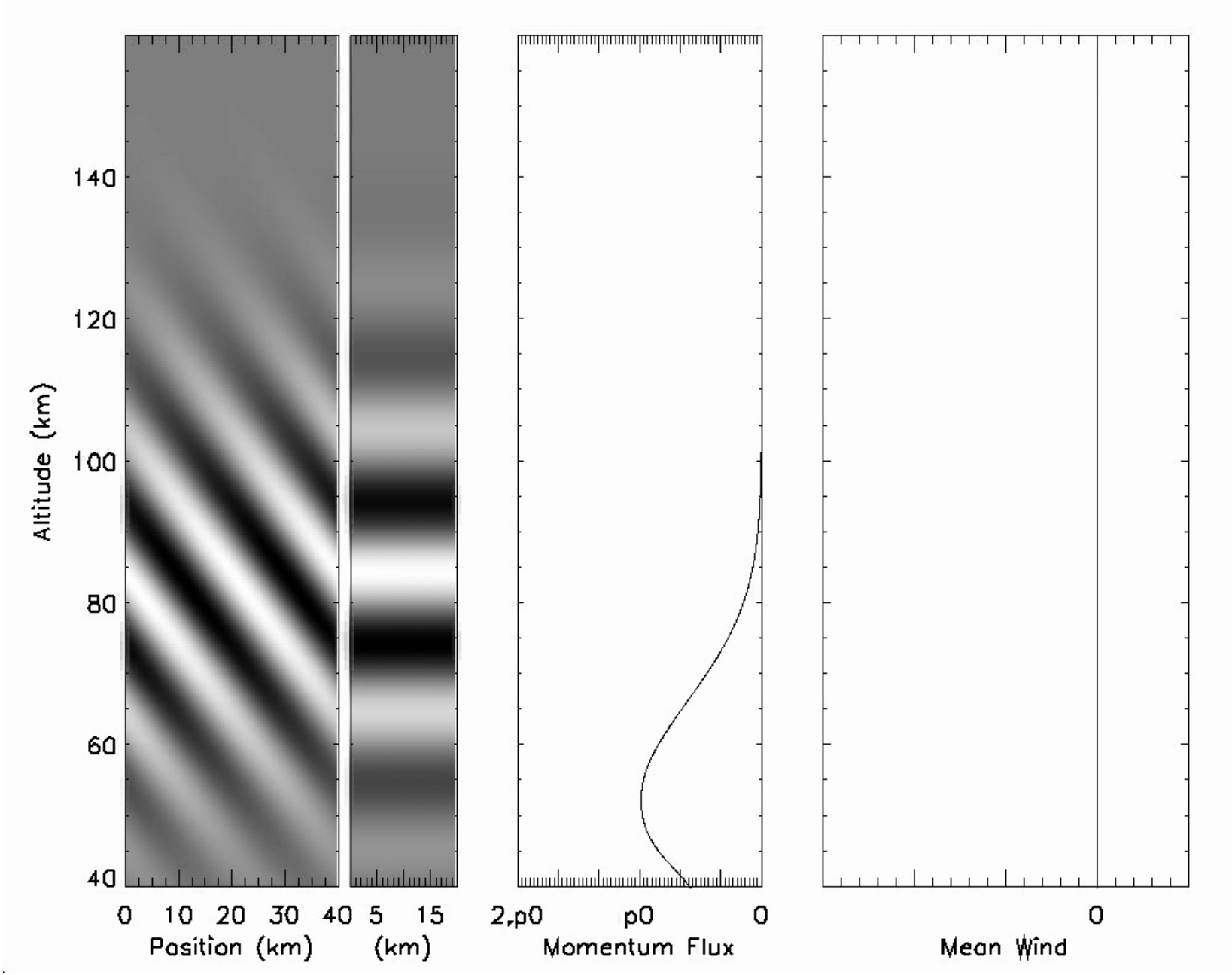


Fixed Mean | Evolving Mean

Evolving Mean: Self Acceleration GW Breaking



Fixed Mean: Gravity Wave Breaking



Modeling Efforts

Anelastic Navier-Stokes model

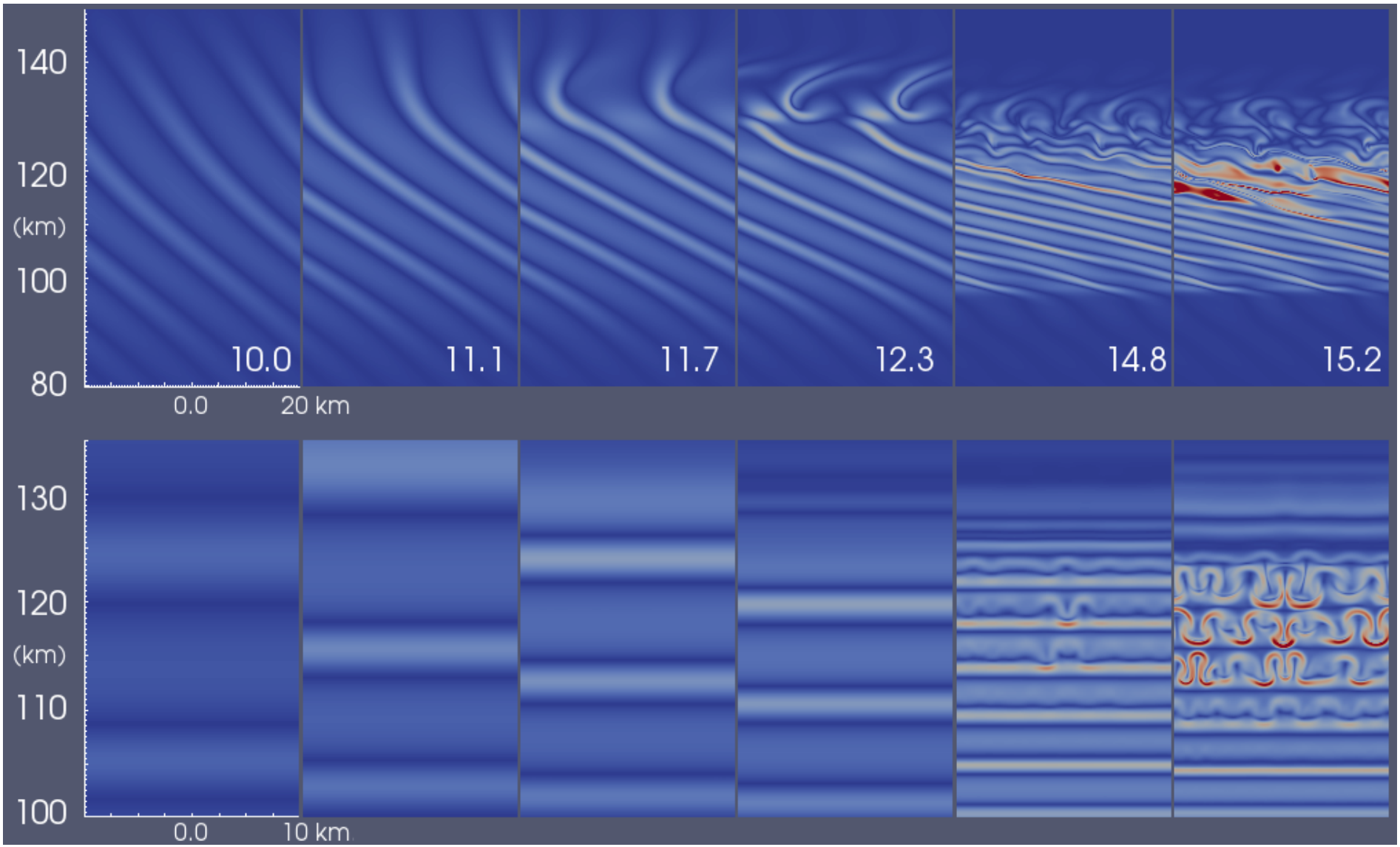
- No sounds waves
- Accounts for density variation with height

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 instabilty

Evolving Mean: 2D precedes 3D instability onset

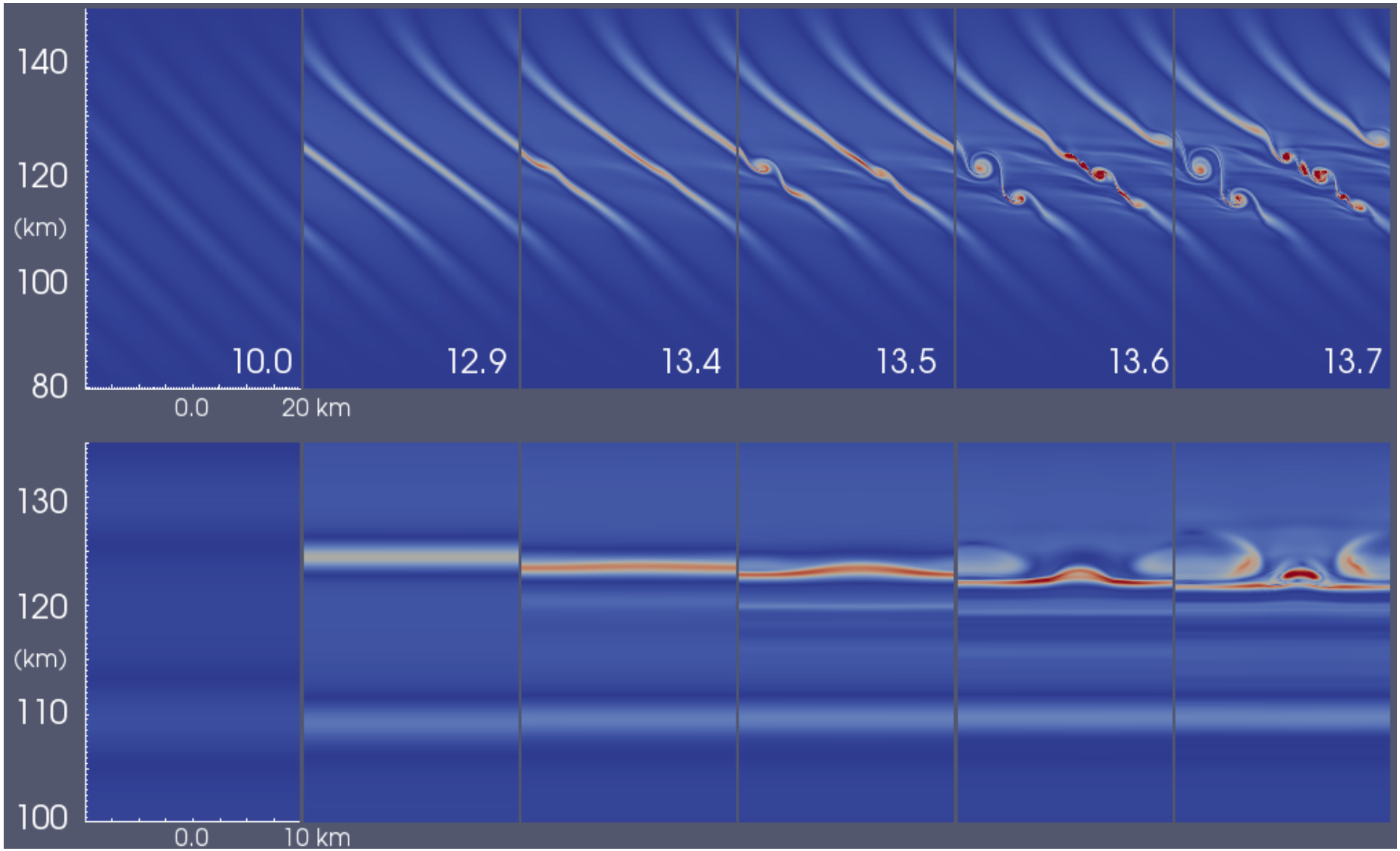
streamwise



spanwise

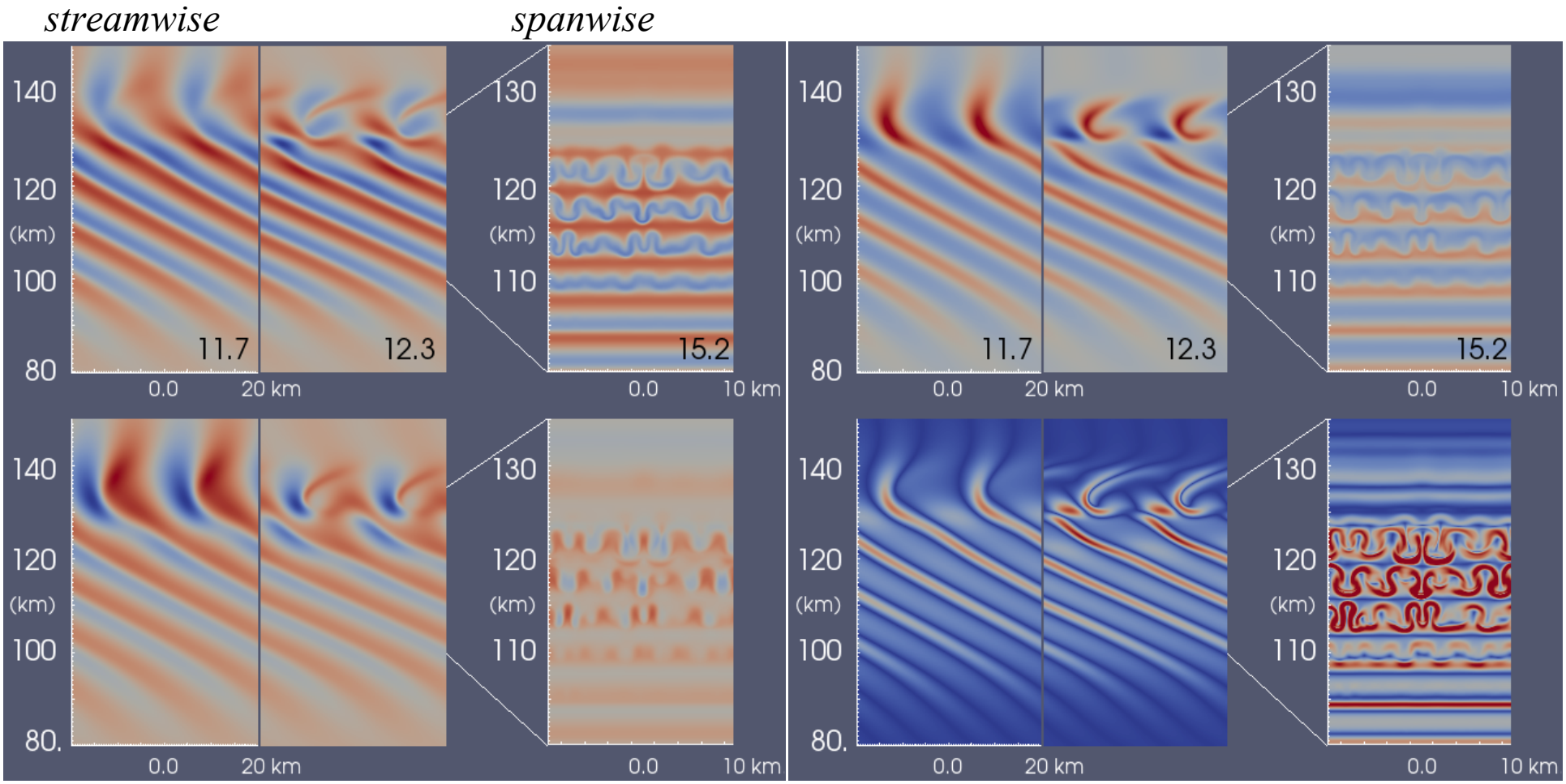
Fixed Mean: 2D and 3D instability nearly concurrent

streamwise



spanwise

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



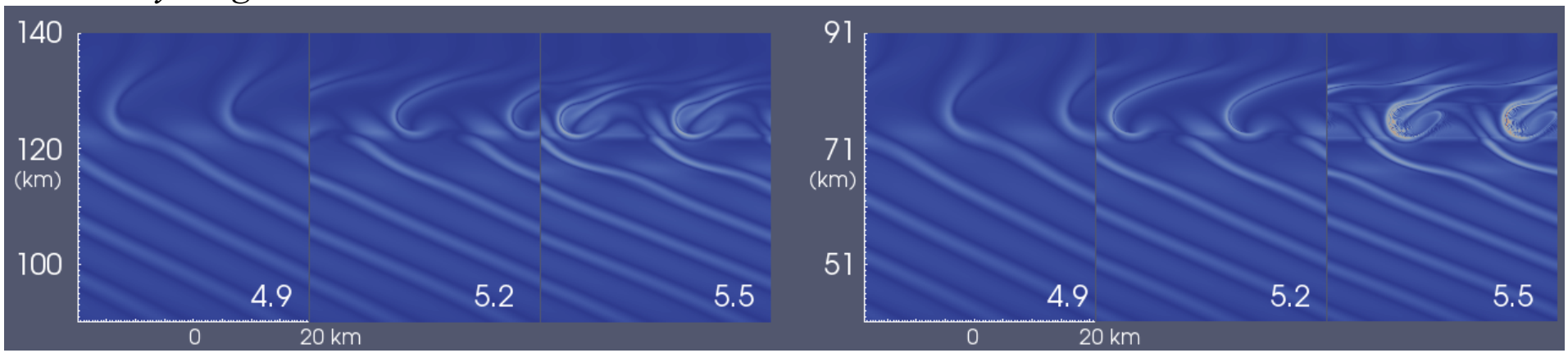
Velocity fields
u'
w'

Potential Temperature
Vorticity Magnitude

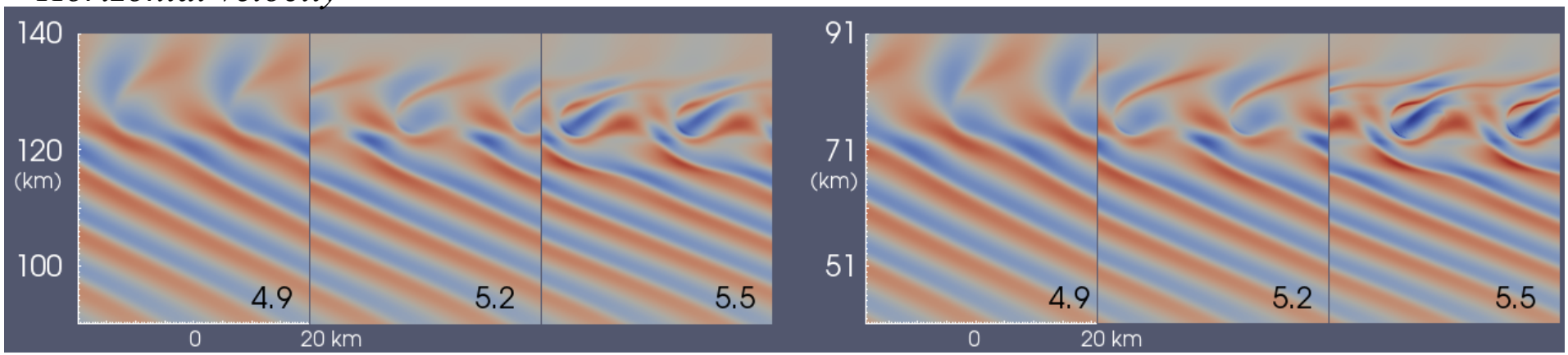
Self Acceleration: Viscous effects

Self Acceleration Breaking largely ignores viscous effects

Vorticity magnitude



Horizontal velocity



Packet initialized at 60 km

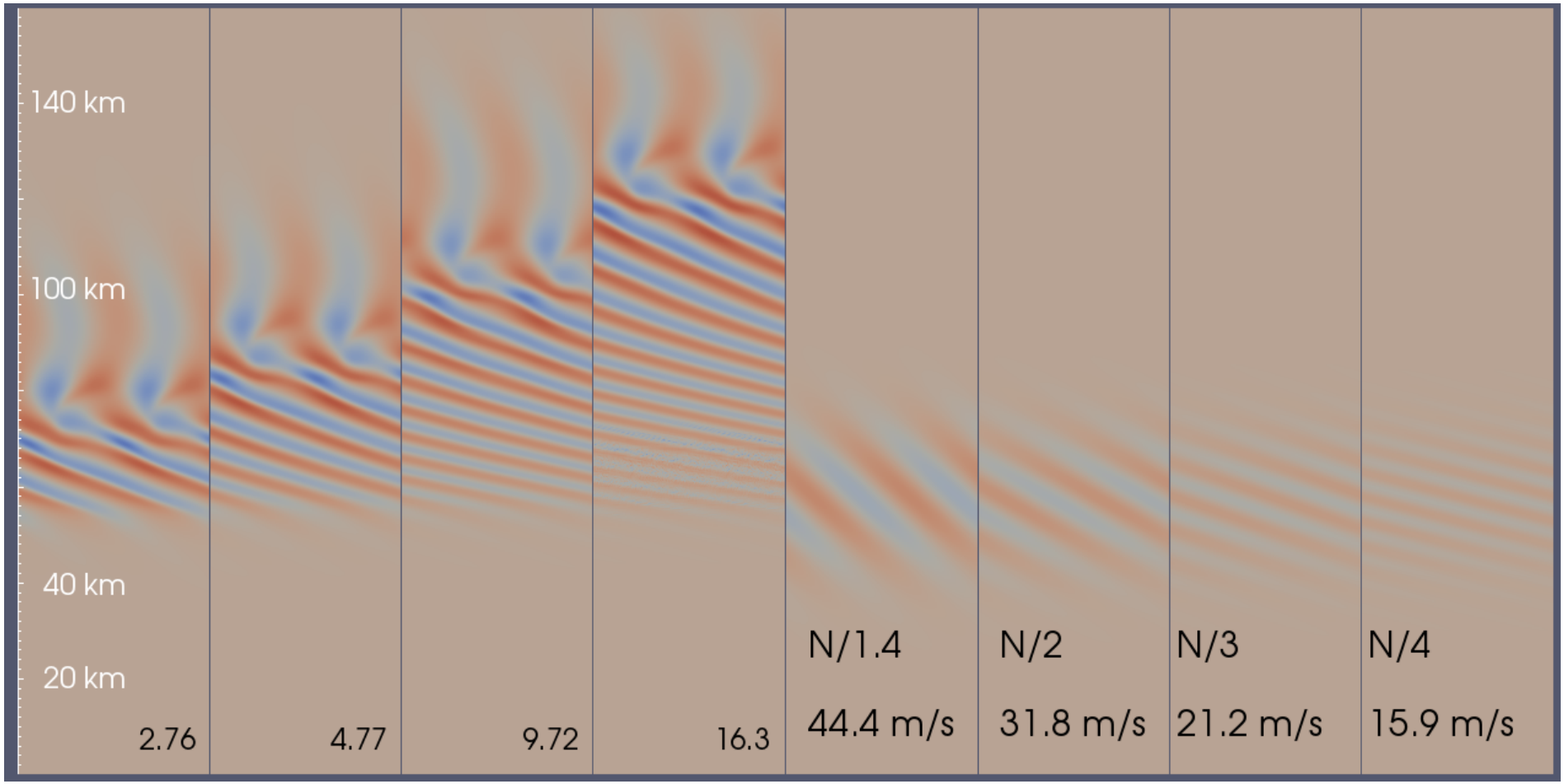
Packet initialized at 10 km

Self Acceleration: Frequency dependence

Multiple frequencies, same amplitude

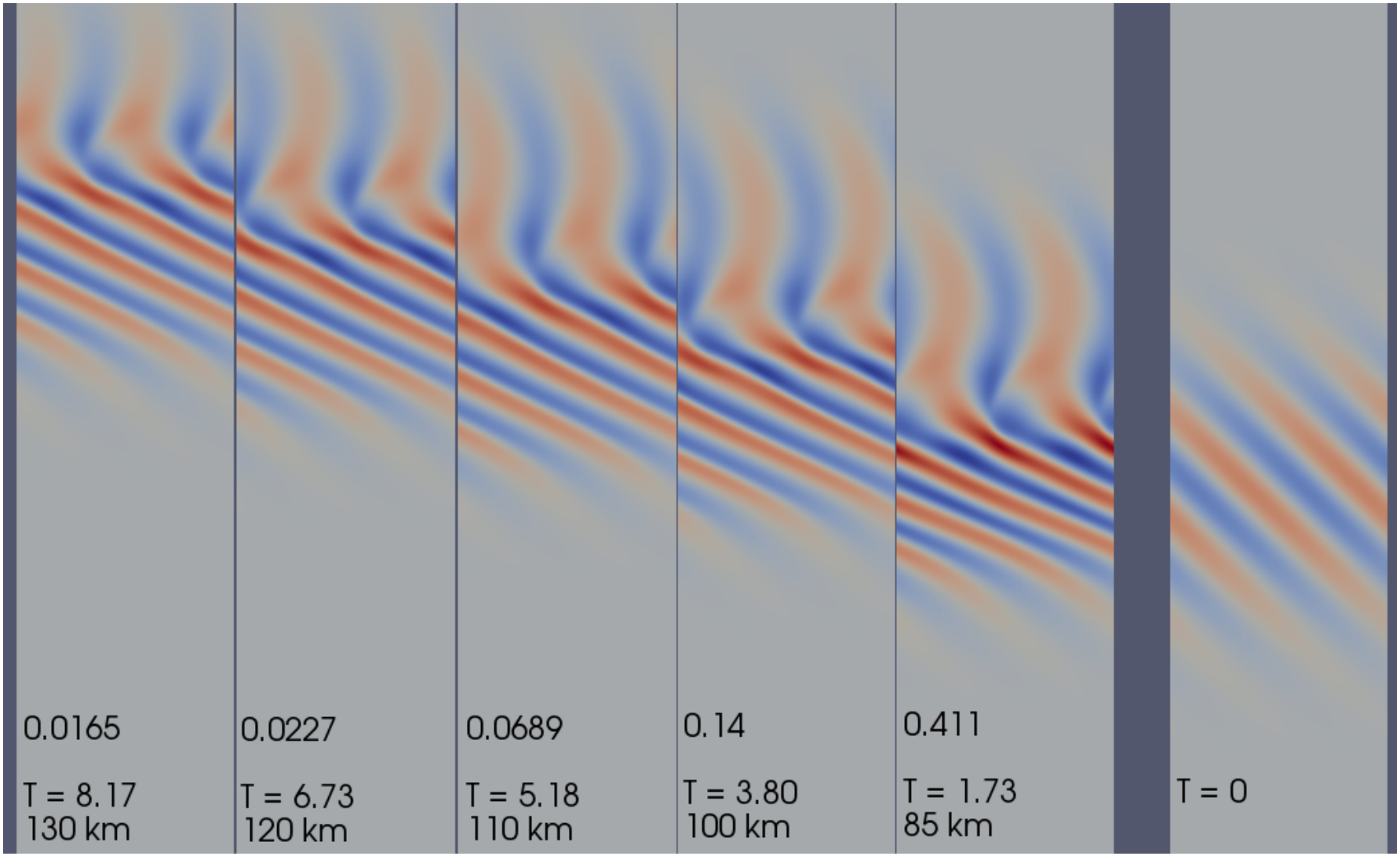
- Breaking altitude frequency dependent
- Shape of instability apparently independent
- *Role of dispersion?*

$$A = u'/c_x$$



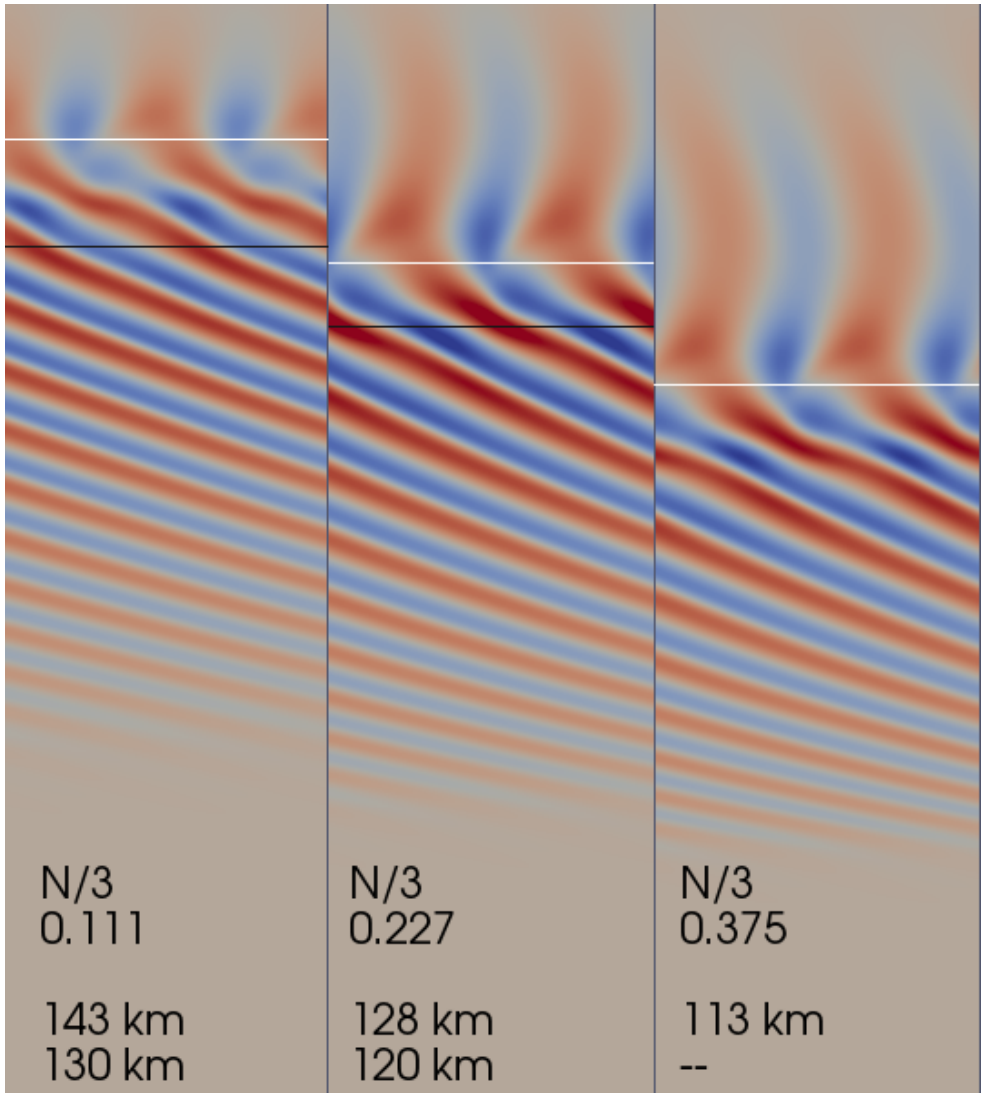
Self Acceleration: Amplitude dependence

- Breaking altitude amplitude dependent
- Shape of instability apparently independent



Self Acceleration: Dispersive effects?

Amplitude Growth with Altitude:



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

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

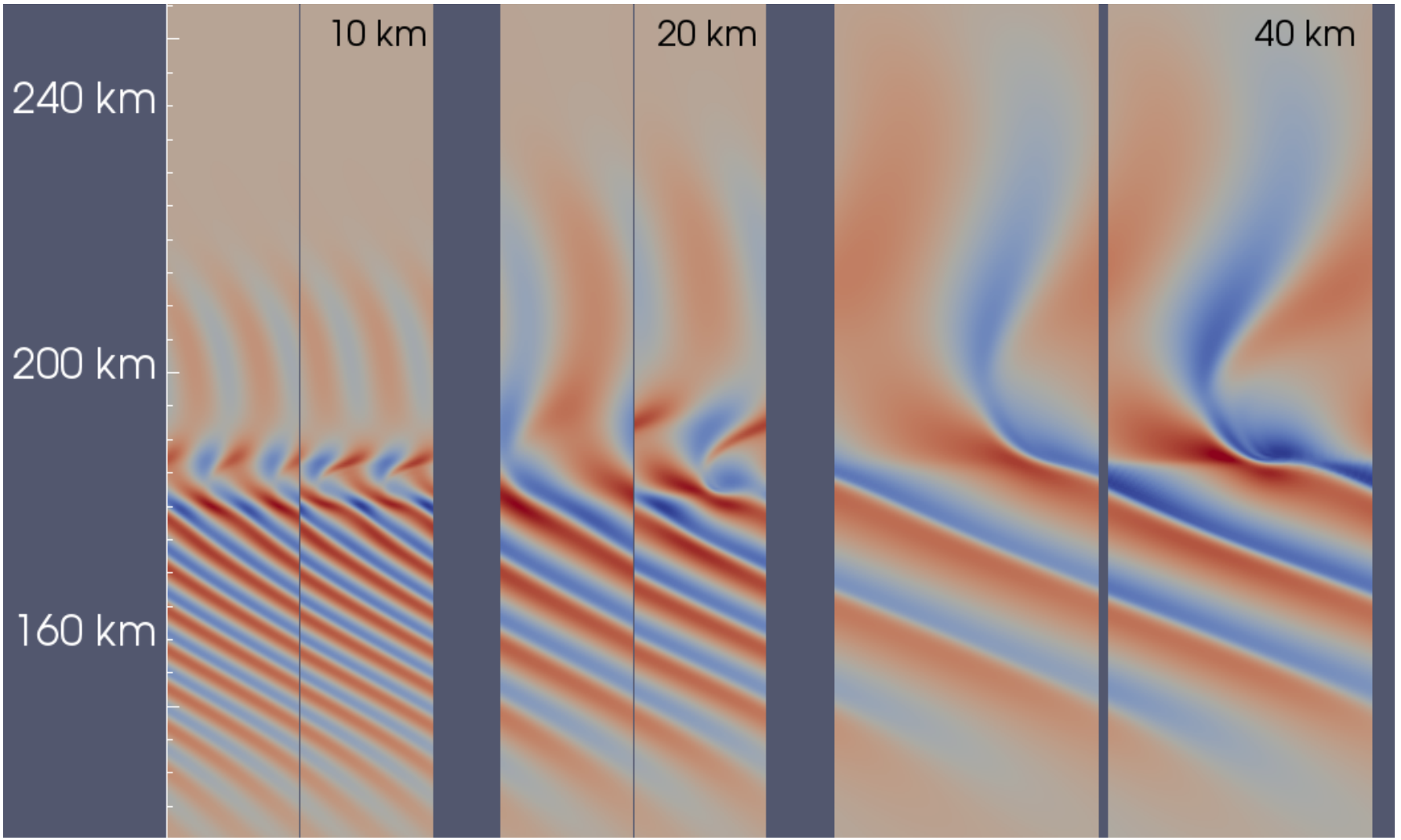
Works for N/1.414

- for N/2, "2" = 2.5
- for N/3, "2" = 4.6

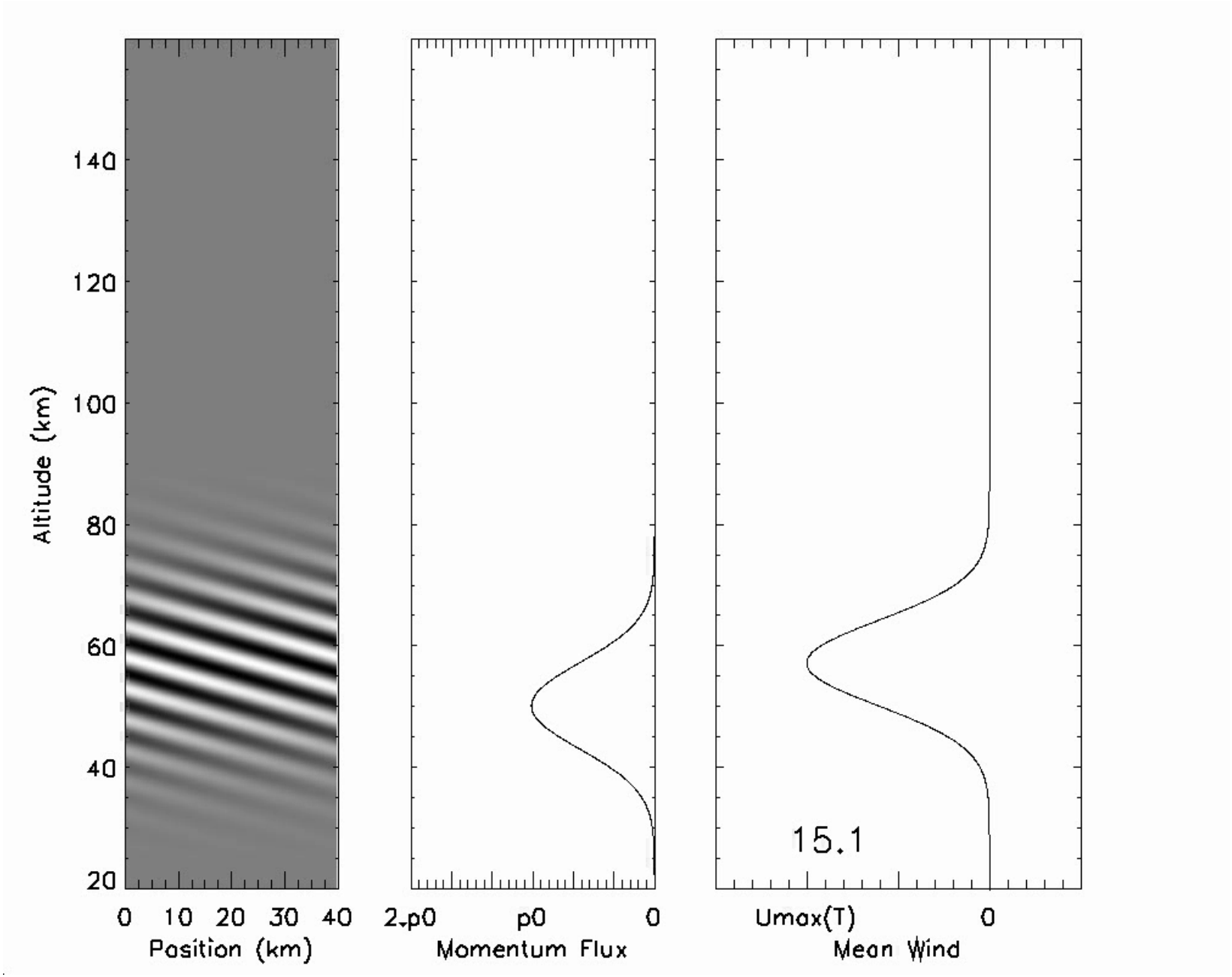
Not fully understood
Preliminary values

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



Self Acceleration: Conclusions and Future Work

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)*