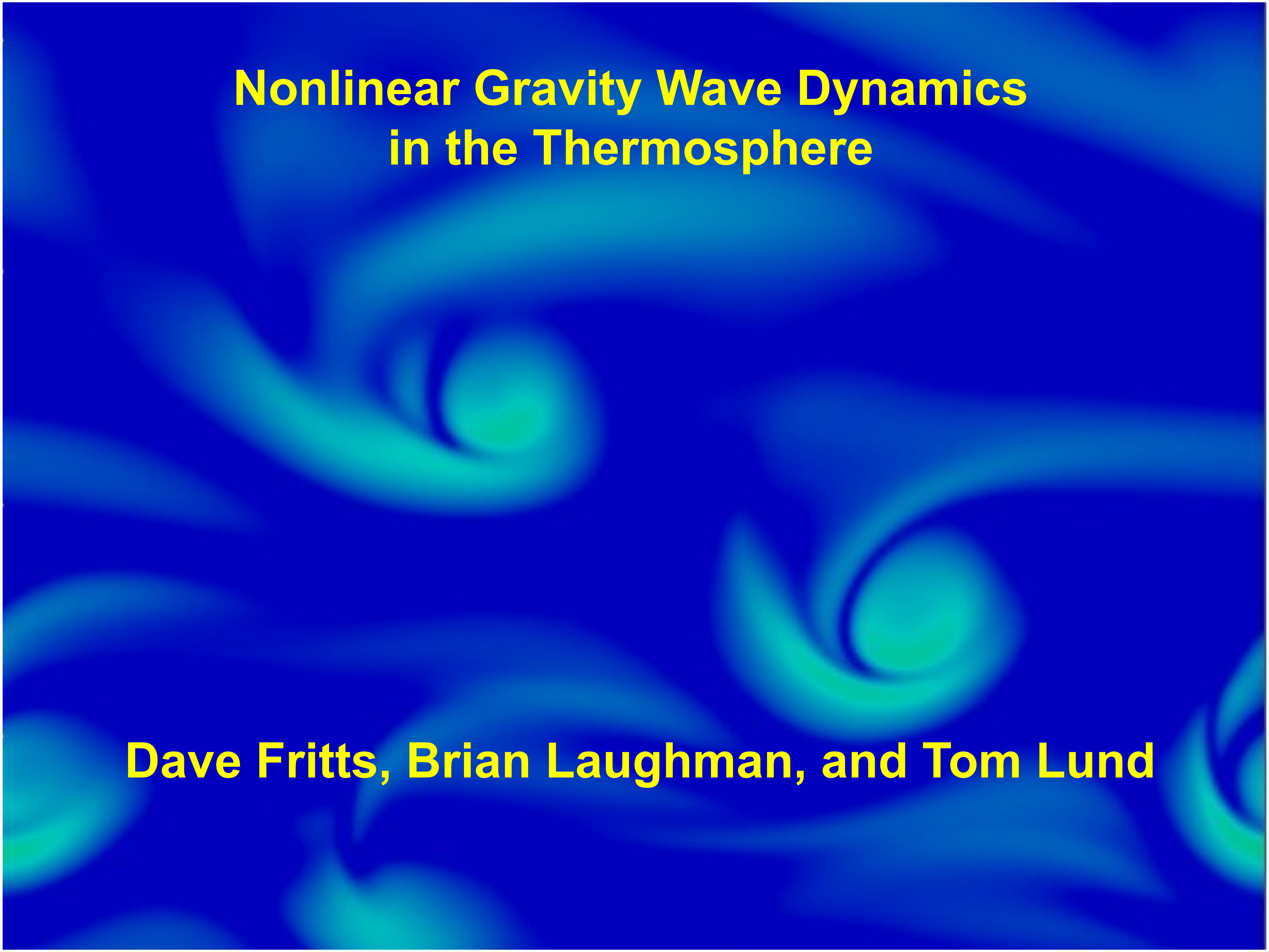
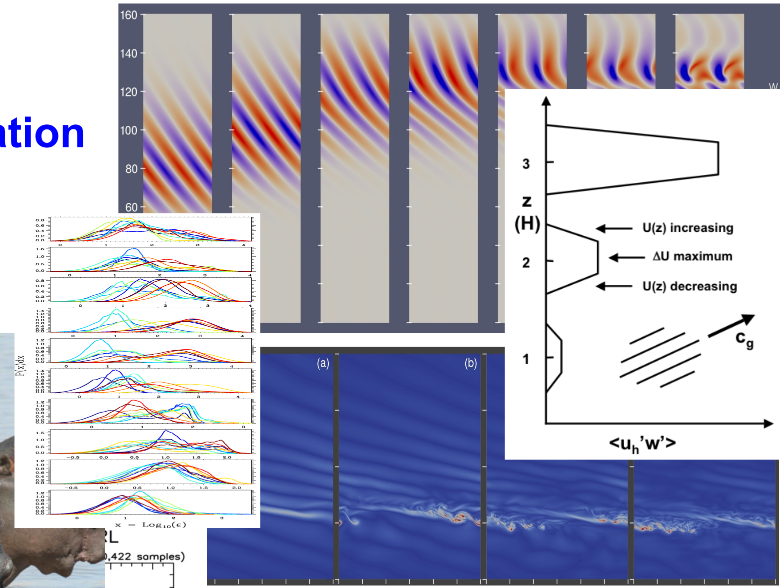


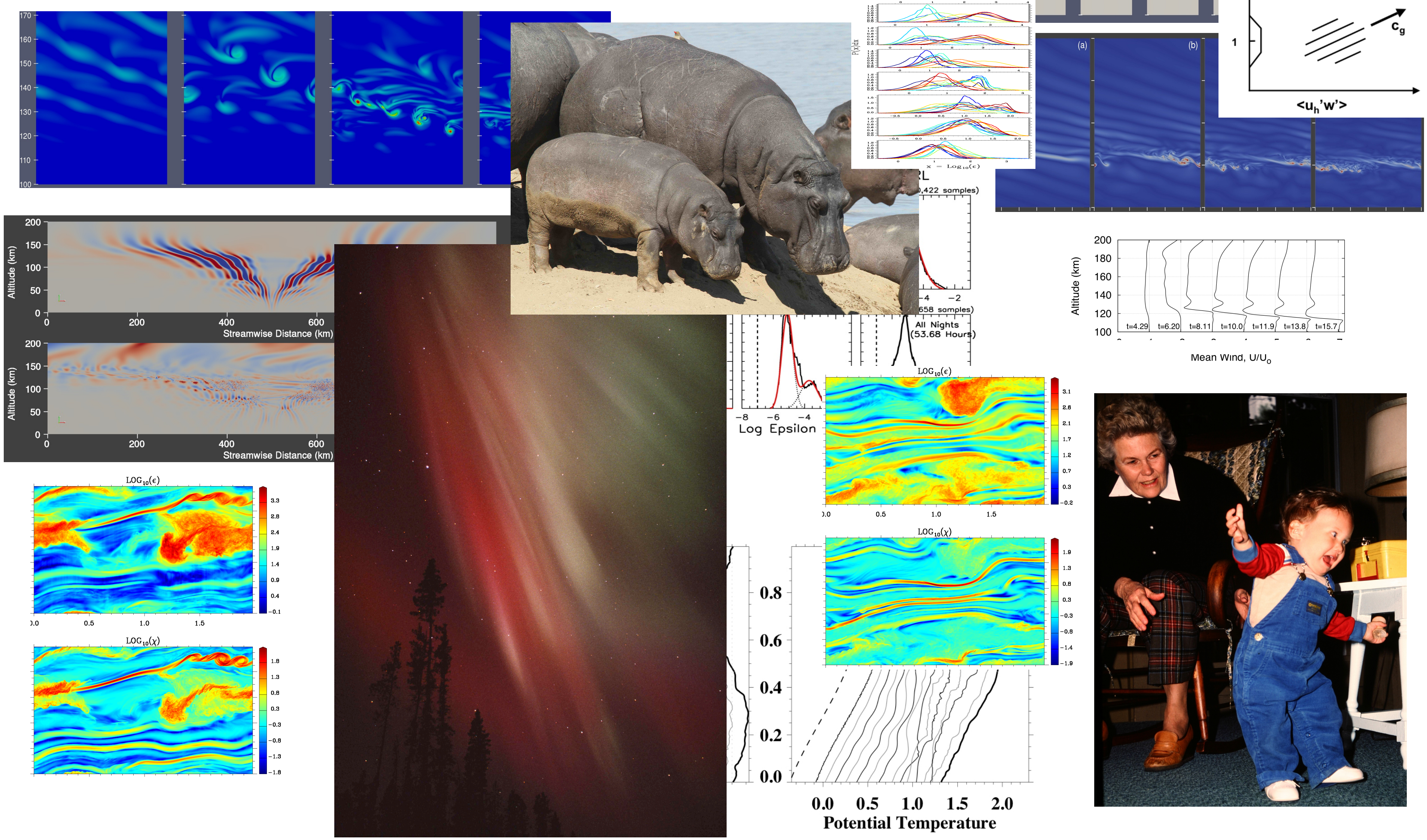
Nonlinear Gravity Wave Dynamics in the Thermosphere

Dave Fritts, Brian Laughman, and Tom Lund

Outline

- **Gravity wave momentum transport and self acceleration**
- **Gravity wave breaking in the thermosphere**

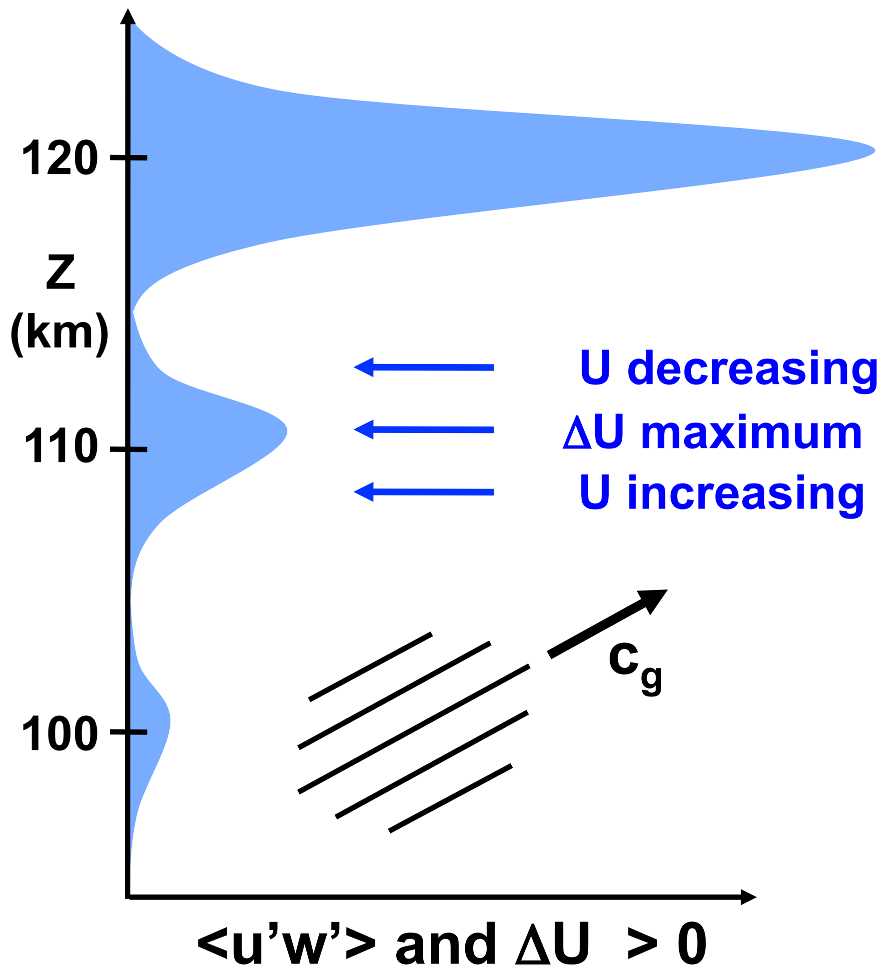




GW Self Acceleration and Effects

Decreasing mean density

=> - GW amplitudes increase as $a \sim 1/\rho^{1/2}(z)$
- $\Delta U \sim 1/\rho(z)$
- large flow accelerations, altered GW phase structures



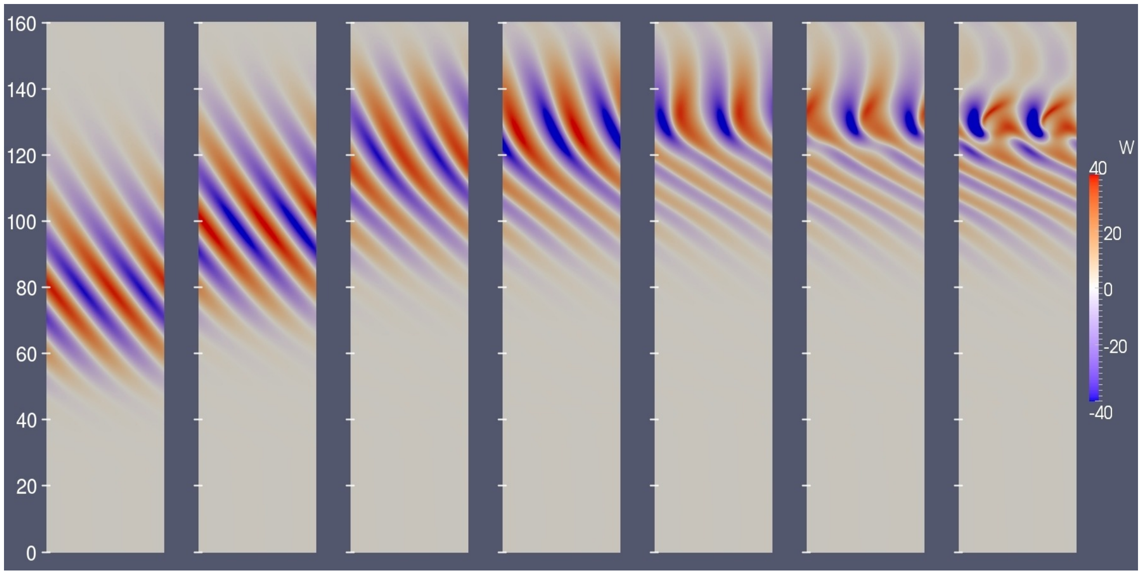
=> self-acceleration & phase distortion

=> leading edge of GW packet accelerates

trailing edge decelerates

“Self-acceleration” of a localized GW packet

=> - steepening phase structures at leading edge
- altered GW group velocities and GW instability



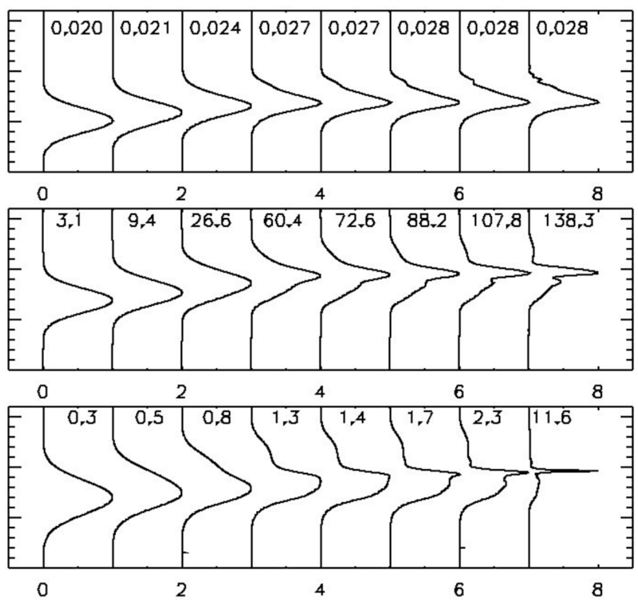
Δt ~ 3 GW periods

GW with initial
$\lambda_x = \lambda_z =$ 20 km,
N = 0.02 s^{-1},
ω = N/1.4,
c ~60 m/s

GW ρ<u’w’>

induced U(z)

GW amplitude
(*a* = *u’*/(*c-U*))

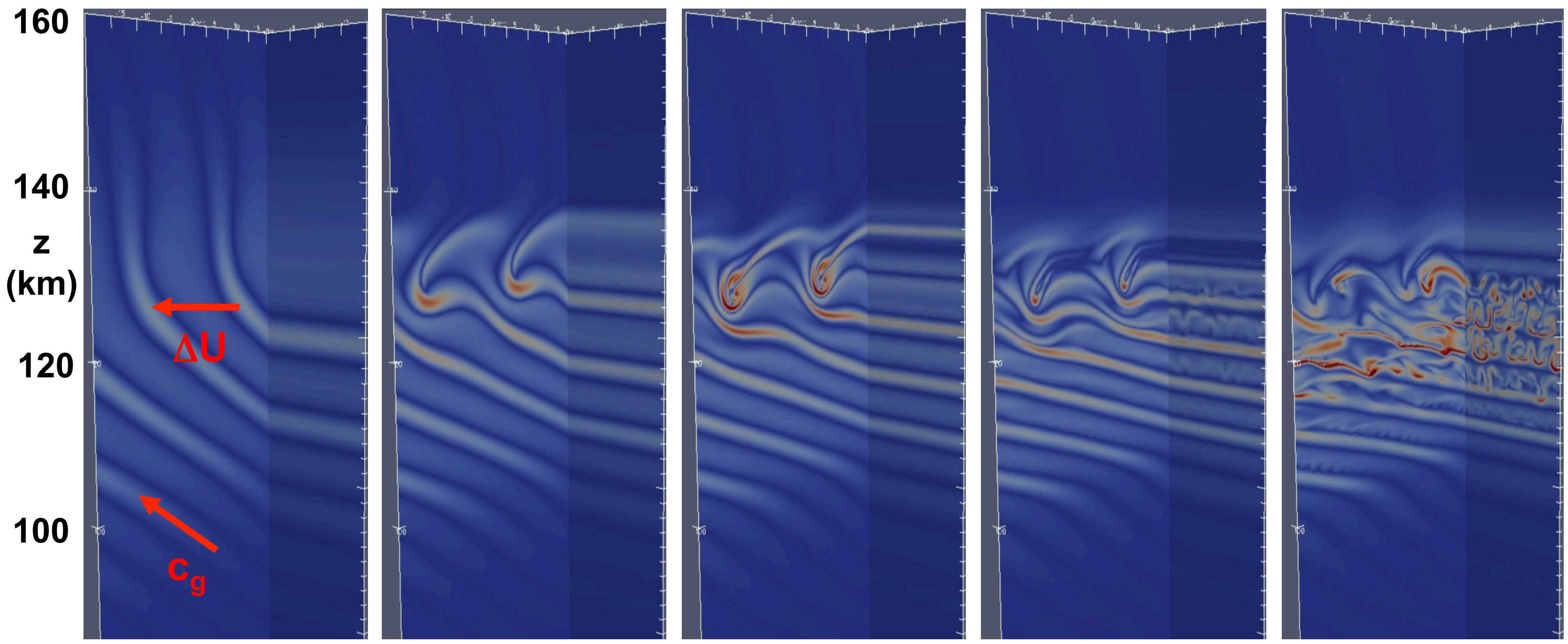


ρ<u’w’> nearly conserved

U(z) increases beyond c

GW amplitude exceeds unstable value

Self Acceleration causes 2D and 3D instability



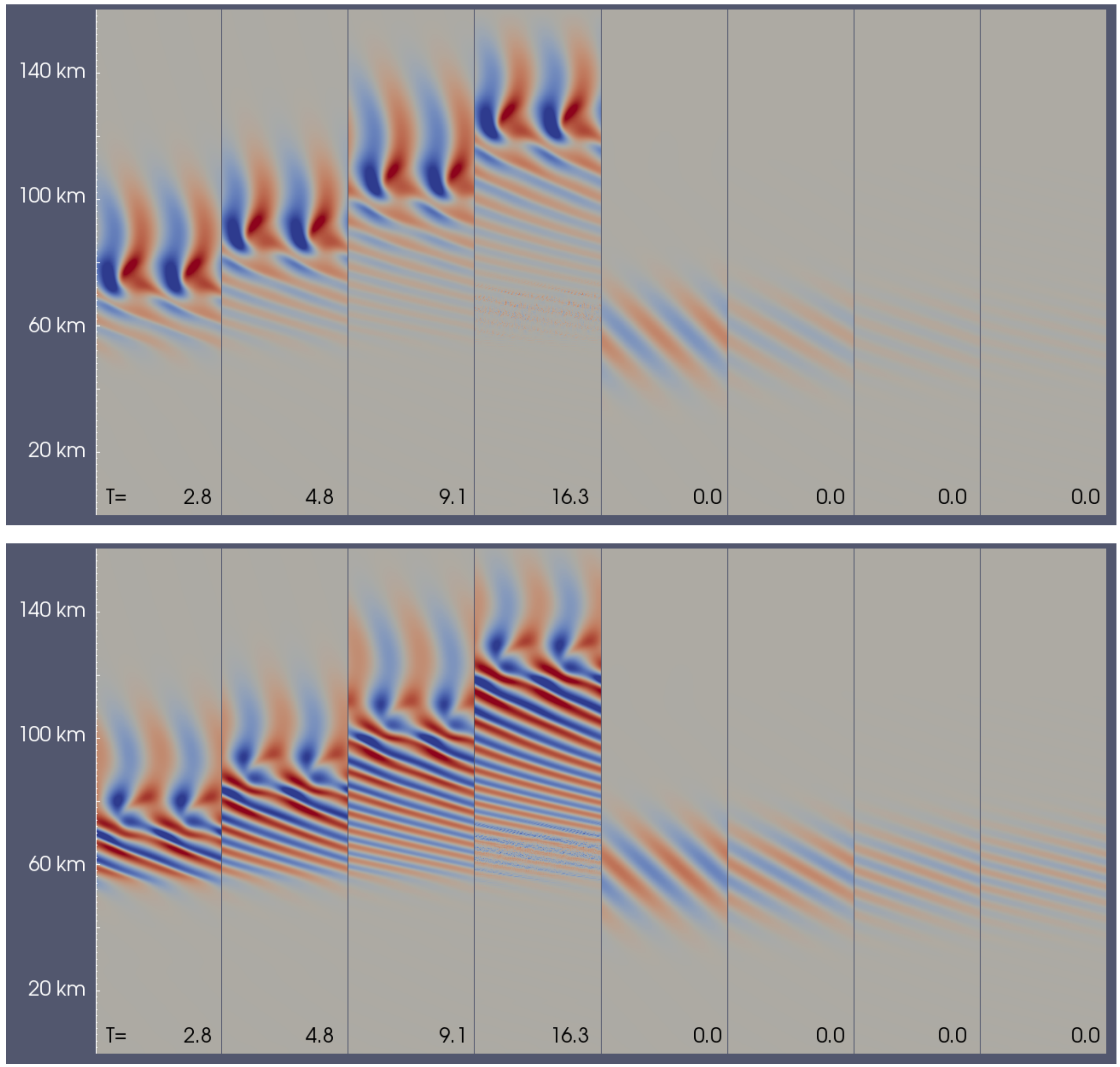
- 2D “self-acceleration” instability occurs first, drives 2D “wave-wave” interactions

- Secondary 3D instability accounts for most dissipation

Self Acceleration causes GW stalling and instability

GW w' (top), u' (bottom)

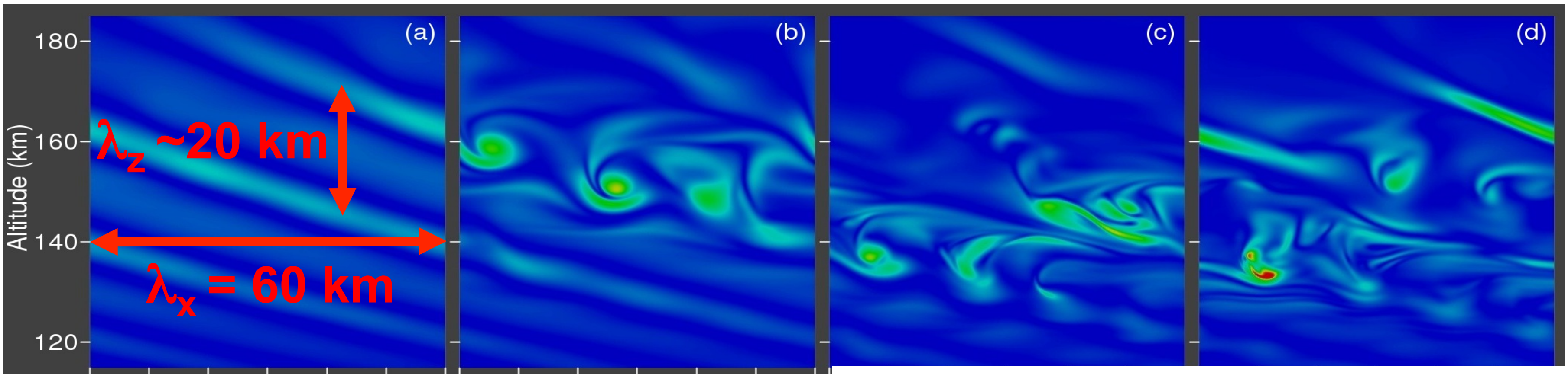
successive 4-panel sets (right and left) show forcing and responses for ω = N/1.4, N/2, N/3, and N/5 for the same u'.

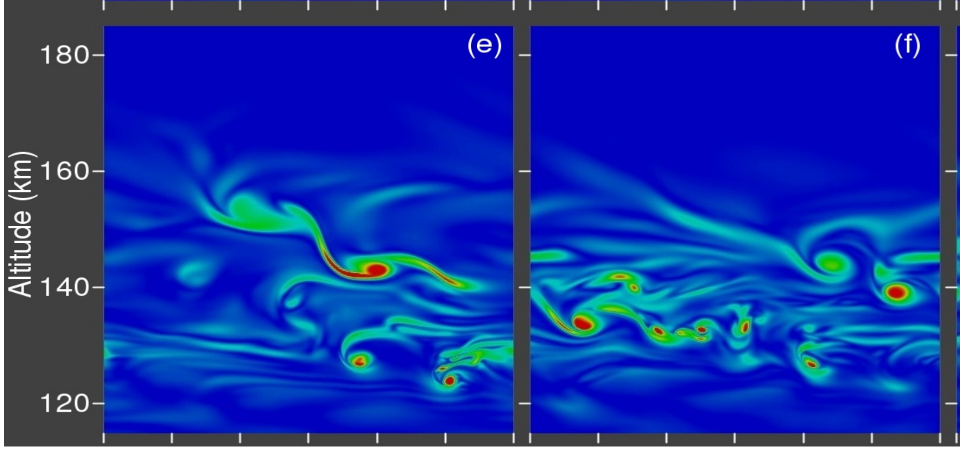


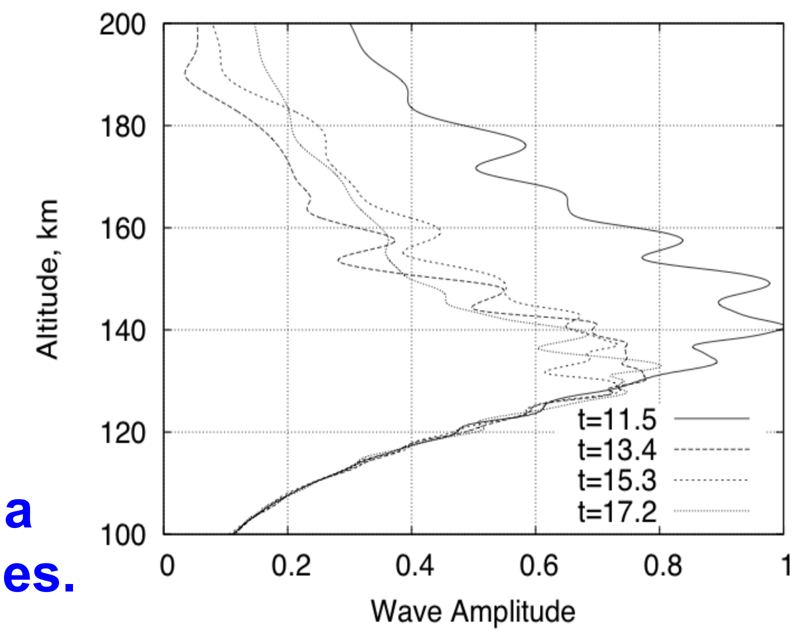
GW breaking @ z ~ 100-170 km for constant U(z)

λ_x = 60 km, λ_z ~20 km, u' ~ c-U ~ 50 m/s, ω ~ N/3, Re ~10^3 at z ~160 km

minimum scales of turbulence ~1 km







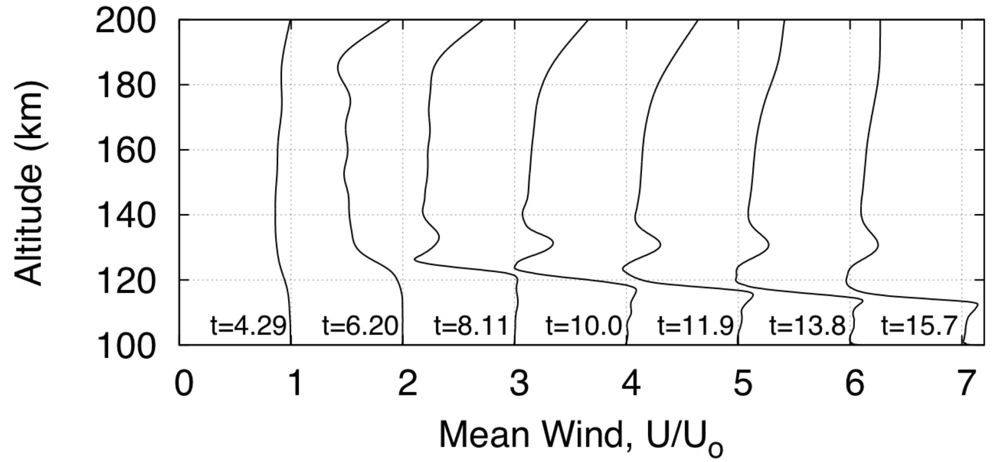
GW "saturates" at a ~0.7. This would be a better value for parameterization purposes.

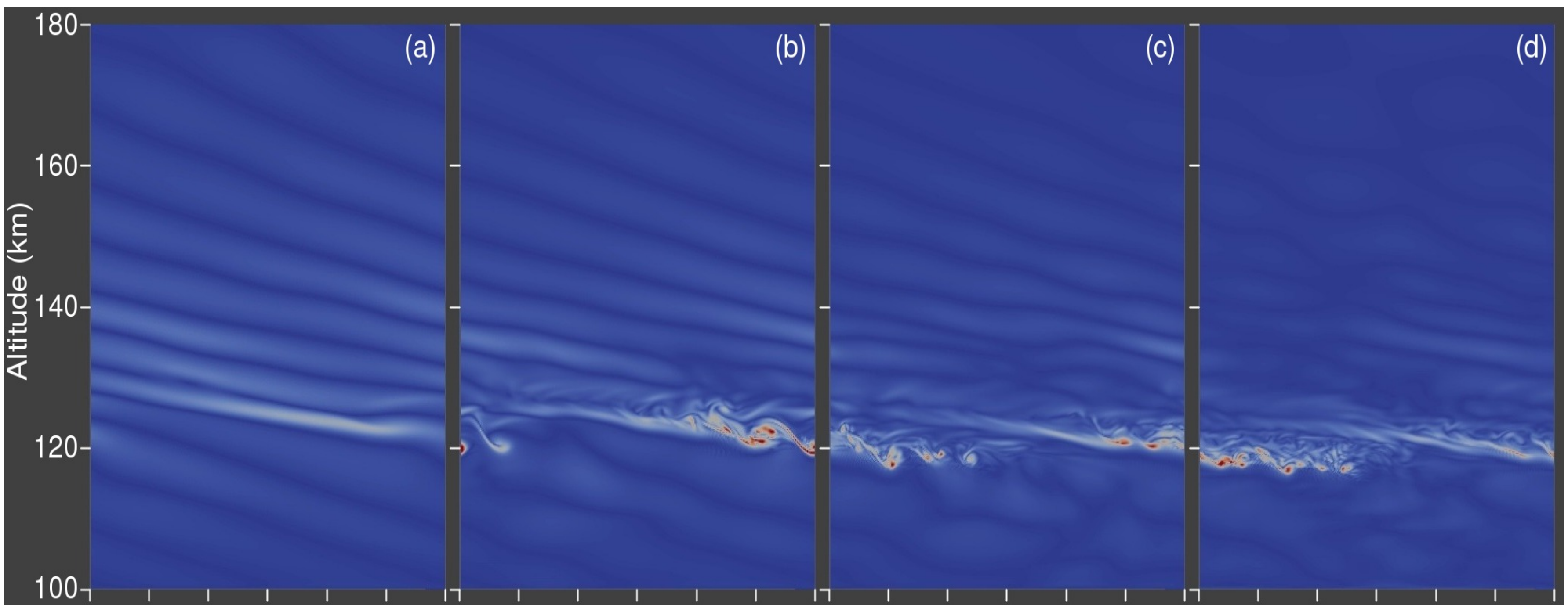
Same GW evolution allowing mean flow changes

this case exhibits large induced mean winds

=> confinement of shears and instabilities to lower altitudes

evolving U(z,t) => accelerations towards GW phase speed



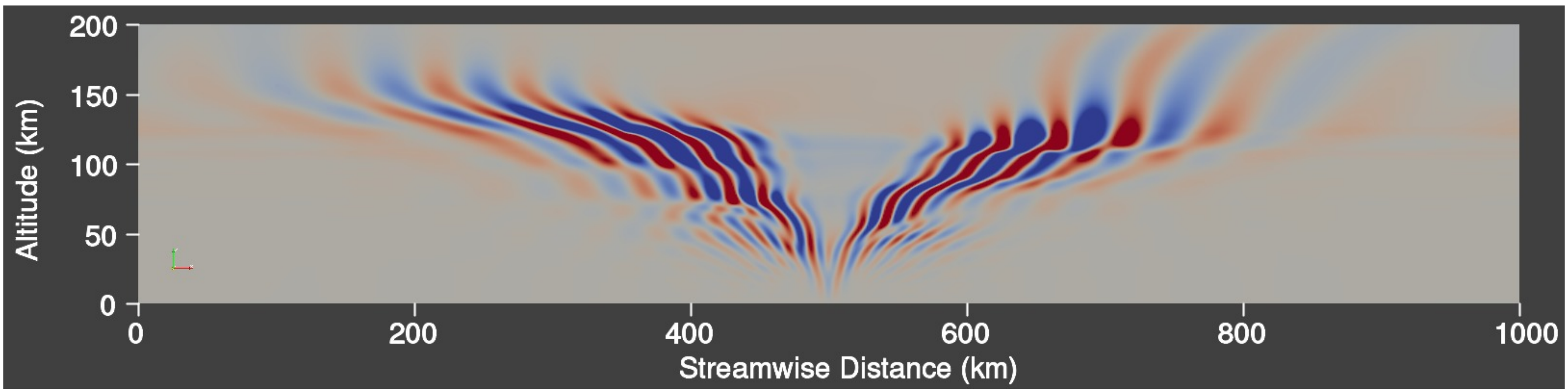


GWs are also strongly influenced by mean and tidal winds

- exhibit refraction, filtering, instabilities, and body forcing in more general environments

- example of GWs from a single convective plume propagating in TIME GCM tidal winds

t = 45 min



t = 90 min