Gravity Wave Breaking and Instability Dynamics
- New Observations and Modeling Capabilities
and relevance to DEEPWAVE

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21 June – Large-Amplitude MWs 12 UT

- scales vary from ~12 to 80 km
- "sawtooth" $T(x) \Rightarrow$ strong overturning at ~87 km
- dominant MWs at ~85 km have $\delta z > 2$ km, $T' \sim 20$ K, $T \sim 210$ K, $N \sim 0.02$ s$^{-1}$, $\lambda_h \sim 65$ km, $\lambda_z \sim 20$-32 km $\Rightarrow$
  
  $<u'w'> \sim 400$ m$^2$s$^{-2}$ or greater
- MWs seen by AIRS for ~4 days
- MW response is larger than NZ
- MW structure predicted by ECMWF
21 June Lauder – MWs at ~87 km, $\lambda_h \sim 12-80$ km
GW breaking and instabilities over Scandinavia (viewed in PMCs)

G. Baumgarten

- instabilities are closely tied to specific phases of the larger-scale GW field
GW breaking via vortex rings over Scandinavia – G. Baumgarten
PMCs exhibiting vortex rings over Antarctica – Miller et al. (2015)
Idealized GW breaking

$$\omega = N/3.2$$

$$a = u'/(c-U) = 0.9$$

formation & breakdown of streamwise vortices and vortex rings (left)

airglow signatures (right)

$$\Delta t = 1 \, T_b$$
Idealized GW breaking

\[ \omega = \frac{N}{3.2} \]

\[ a = \frac{u'(c-U)}{1.1} \]

formation & breakdown of streamwise vortices and vortex rings (left)

airglow signatures (right)

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Idealized GW breaking

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\[ \omega = \frac{N}{1.4} \]
\[ a = \frac{u'}{(c-U)} = 0.9 \]
Idealized GW breaking

$\omega \sim N/3.2, \ a = 0.9$

3D vortices

$T(x, z)$ mean

$u(x, z)$ mean

$I(x, z)$ mean

$T'(x, z)$ slice $t=22 \ T_b$

$I'(x, z)$ slice

$T'(x, z)$ slice $t=23 \ T_b$

$I' \ (x, z)$ slice
GW in shear

\[ \omega = N/7 \]

\[ A > 1 \]

- dynamics also include vortex rings,

but also strong spanwise modulation at warmest phase
DEEPWAVE  Lauder AMTM

- captures the same GW breaking dynamics
- with a more accurate sky projection, but coarser resolution
- and with much better knowledge of atmospheric structure

\begin{align*}
\text{~95 km} & \quad \text{U \sim 60 m/s} \\
\text{~87 km} &
\end{align*}
11-11:22 UT, FOVs 30x50 km, warm phase, likely MW superposition
DEEPWAVE
- Lauder 21 June
- Instability Event 2

40x100 km

11:34-11:40 UT
DEEPWAVE
- Lauder 21 June
- Instability Event 3

120x120 km

12:06-12:10 UT
DEEPWAVE
- Lauder 21 June
- Instability Event 4

75x75 km
12:10-12:26 UT
DEEPWAVE
- Lauder 21 June
- Instability Event 5

80x130 km

12:40, 44, 46, 48, 50, 52 UT
New compressible, large-domain modeling applications (developed by Tom Lund)

- 2500x1600x200 km domain
- initial Southern Andes app.

$\Delta x = 500 \text{ m}$

$\Delta z = 500 \text{ m}$ at surface
winds and temperatures from WACCM

- strong SD tide ~60 m/s
Summary

- high-resolution PMC observations & model comparisons appear to have revealed the major instability pathways to GW dissipation, and mean wind/tidal interactions

- DEEPWAVE applications will include high-resolution, simulations of multiple cases where MW breaking or secondary GW generation appear to occur in the AMTM imaging or lidar curtains
 PMC Turbo – an LCAS Antarctic stratospheric balloon mission
- to study turbulence best where it is least accessible

- PMC Turbo motivated by EBEX star camera images that revealed spectacular turbulence structures

- PMCs occur where gravity wave dissipation and turbulence are strong

=> PMC are sensitive tracers of turbulence morphologies spanning 4 decades of scales

- without including correlative CIPS observations

\[ T(z) \]

\[ T < 130 \text{ K} \]

PMC layer (ice clouds)

PMC Turbo imaging
PMC Turbo flight requirements:
- desired altitude: ~35-38 km (higher is better)
- balloon specification: 29 MCF
- minimum duration: ~10-15 days
- number of orbits: 1 (possibly 2 if an early launch)

Payload components
- cameras, wide FOVs (4)
- cameras, narrow FOVs (3)
- Rayleigh lidar
- OH camera
- power system
- SIP Crate
- CSBF Rotator

Payload specifications
- weight 1600 lb
- power system 1.3 kW
- average power ~940 W
PMC Turbo balloon and imaging
anti-sun viewing

PMC Turbo scale sensitivity:
~10 m – 100 km

lidar T(z)

OH imager

100 km