The PMC-Turbo Mission

Dave Fritts\textsuperscript{1}, Amber Miller\textsuperscript{2},
Michele Limon\textsuperscript{3}, Glenn Jones\textsuperscript{3},
Bjorn Kjellstrand\textsuperscript{3}, Biff Williams\textsuperscript{1},
Ling Wang\textsuperscript{1}, Jason Reimuller\textsuperscript{4},
Shaul Hanany\textsuperscript{5}, Christopher Geach\textsuperscript{5},
Bernd Kaifler\textsuperscript{6} and Mike Taylor\textsuperscript{7}

\textsuperscript{1}GATS, \textsuperscript{2}University of Southern California,
\textsuperscript{3}Columbia University, \textsuperscript{4}Integr. Space. S.,
\textsuperscript{5}University of Minnesota, \textsuperscript{6}German Aerospace Center, \textsuperscript{7}Utah State University

\textit{LPMR 2017, Kühlungsborn, Germany}
In the beginning was

EBEX

Star Tracker
Comparison between EBEX and Simulated PMC Images

Panels A and B compare apparent turbulent wakes from localized source regions.

Panels C and D show similar cusp-like features.

Comparison between EBEX and Simulated PMC Images

Panel A shows what we believe is a gravity wave breaking front.

Panel C exhibits features similar to laminar vortex rings in background turbulence.

Objectives for a New Mission: PMC-Turbo

PMC Turbo was designed to identify the dynamics driving turbulence and resolve the details to the smallest scales using PMC as tracers.

The mission seeks to obtain high resolution and high cadence observations of PMC utilizing a high altitude balloon platform.

It is based on heritage from EBEX stratospheric balloon imaging.
PMC-Turbo Experiments

- 4 wide FOV and 3 narrow FOV cameras
  main payload
  High-resolution PMC imaging (visible)

- The Balloon Lidar Experiment (BOLIDE)
  contributed by the German Aerospace Center
  PMC vertical backscatter profiles
  Temperature profiles above and below PMC layer

- OH dayglow imager
  contributed by Utah State University
  Gravity waves, PMC imaging (IR)
The PMC Turbo Gondola

Mass 800 kg
Power 1.3 kW
Anti-solar pointed
29 MCF balloon
Flight altitude 38 km
Camera Systems

- Based on EBEX star tracker heritage
- Allied Vision camera with 4864 x 3232 pixels
- 3.5 fps sustainable framerate at 100 ms exposure time
- 50 mm and 135 mm lenses
- Each of the 7 camera systems is completely independent
- Commanding capability (exposure and focus settings, frame rate)
Observation Geometry

3 narrow FOV cameras
10 x 15.2 degree, 3 m resolution

4 wide FOV cameras
39.6 x 26.9 degree, 8 m resolution

Total 150 x 40 degree FOV, 4 decades of sensitivity!
## PMC Imaging Capabilities

<table>
<thead>
<tr>
<th>Satellite: CIPS</th>
<th>Ground-based (Gerd Baumgarten)</th>
<th>Balloon: EBEX</th>
<th>Balloon: PMC-Turbo</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 x 120 degree FOV</td>
<td>127 x 85 degree and 9.5 x 6.3 degree FOV</td>
<td>4.4 x 3.9 degree FOV</td>
<td>150 x 40 degree FOV, 10 x 15 degree FOV</td>
</tr>
<tr>
<td>2 km spatial resolution at nadir</td>
<td>10-20 m spatial resolution</td>
<td>3.7 m spatial resolution</td>
<td>3-8 m spatial resolution</td>
</tr>
</tbody>
</table>

PMC-Turbo will provide a unique and dataset.
The Balloon Lidar Experiment (BOLIDE)

Miniaturized Rayleigh backscatter lidar

1 m vertical resolution

Mass 145 kg
includes pressure vessel and radiator

Power 268 W

Laser
• 5 W at 532 nm wavelength
• 100 Hz PRF

Receiver
• 0.5 m diameter telescope
• 90 µrad FOV
• 3 detectors (2 APDs, 1 PMT)
• 0.3 nm wide filters
Performance Simulations

Simulation of radiative transfer using the libradtran software package

*Emde et al., Geoscientic Model Development, 2016*

A factor of ~3 more signal than ALOMAR but same (or slightly less) background

The BOLIDE instrument will provide observations of PMC with unprecedented resolution and SNR

*ALOMAR profile courtesy Gerd Baumgarten*
Altimetry of PMC

Straight forward for ground-based lidars:

altitude is proportional to range

Balloon lidar:

Vertical motion of the gondola due to external and internal forces acting on the balloon
-> lidar profiles are shifted in altitude

Precise and accurate measurements of the state vector and attitude vector required

CORAL lidar, GERES Station
Obtaining a Navigation Solution

Chart 14

Primary sources:
- GPS, sun sensor, (star tracker)

Secondary sources:
- Rate sensors, accelerometer

Navigation solution
- Propagate forward in time
Synergy between PMC Imaging and LIDAR

Imaging

LIDAR

PMC profiles, Vertical displacement

Gravity wave-induced T perturbations: vertical wavelength, amplitude

2d view
e.g. identify wave braking, horizontal wavelength

Fantastic prospects if everything works as expected, our models are correct, …
Where do we stand now?

- We were not selected for launch from McMurdo, Antarctica, in 2017 for various reasons
- NASA suggested a launch from Kiruna, Sweden, in July 2018 (confirmation pending)
- A launch from Kiruna opens up the possibility for additional ground-based observations. Field campaigns are T.B.D., contributions and suggestions are welcome!
Trajectories of previous launches from Kiruna

4-5 day flight, termination over northern Canada

Data courtesy of CSBF
Images courtesy of Wenqian Sun (UMN)
Ground-based Observations in Europe?

Trajectories are all south of ALOMAR