SAANGRIA: A program to study gravity wave coupling from the troposphere into the mesosphere and lower thermosphere

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Global radiances fluctuations at ~40 km measured by AIRS on Aqua on 20 June 2007
Why the Southern Andes & Antarctic Region?
Rich Prevalent Large-Amplitude GW Structures

- Linear Mountain Waves?
  - Andean & Antarctic Mountain Waves?
  - 16 Aug 2003 2.5 hPa

- Mountain Waves from South Georgia and Alexander Island?
  - 13 Jul 2007 60 hPa

- Mountain & Jet Waves?
  - 20 Aug 2007 80 hPa
  - 20 Jun 2007 80 hPa

- Nonlinear Breaking?
  - 21 Jun 2007 2.5 hPa
  - 21 Jun 2007 60 hPa
Why the Southern Andes & Antarctic Region?
Stable Propagation Channel from Ground to MLT

NOGAPS-ALPHA Analysis: July 2007-2008

Warm Polar Stratopause
Polar Vortex
PSCs
SAM
QBO
SAO
MSAO

Pressure height (km)
Pressure (hPa)
SAANGRIA
The Southern Andes – ANtarctic Gravity-wave InitiAtive
Pls: Dave Fritts (Colorado Research Associates), Ron Smith (Yale)

OBJECTIVE
• to better understand, model & parameterize gravity waves (GWs) by observing and fully characterizing them over their entire life cycle (0-100 km altitude)

LOCATION
• the planetary “hotspot” region for GWs in/around southern Andes, Drake Passage & Antarctic Peninsula, where GWs are intense, prevalent, generated by all relevant sources (orography, jets, convection), and routinely propagate to 100 km altitude

TIMELINE (proposed)
• 10-week measurement campaign during June-September 2013 (250 flight hours)

ASSETS
• 0-100 km GW-resolving measurements from NSF/NCAR Gulfstream V (NGV), supported by extensive ground-based and satellite GW observations
• extensive forecast and postanalysis modeling component (low & high altitude, mesoscale & global, weather & climate)

TANGIBLE DELIVERABLES
• GW momentum fluxes from 0-100 km, from source (“birth”) to dissipation (“death”)
• Objective validation/improvement of orographic & nonorographic GW parameterizations
SAANGRIA
Tropospheric Science Objectives

• What are the dominant tropospheric sources of gravity waves in this region?
• How does the regular passage of cyclonic baroclinic storms across the region affect GW generation?
• What upstream/local processes most influence GW generation and predictability?
• How do winds and tropopause structure affect GW activity in the troposphere and lower stratosphere?

TOOLS

• Targeted upstream dropsondes guided by forecast model adjoint, ensemble and singular-vector sensitivities
• NGV flights guided by GWs in forecast model predictions
• Mesoscale modeling, idealized GW models, parameterization, theory

SAANGRIA (55°S) vs. T-REX (34°N)

NGV Dropsonde Flight to Sample Regions of Greatest Forecast Sensitivity

00Z 8 August 2008 (24-h)
SAANGRIA
Stratospheric Science Objectives

- Validate/understand GW signals from stratospheric limb/nadir remote sensors
- How does local intense GW momentum deposition affect the Antarctic vortex?
- Why does GW activity peak downstream over the Drake Passage?
- What are the dominant sources of GWs in the stratosphere?
- How do GWs from the Antarctic Peninsula affect PSCs (types 1a, 1b, 2)?

TOOLS
- NGV remote sensing instruments (lidar, MTP) guided to GWs by forecast model predictions & satellite overpasses
- Mesoscale/global modeling, idealized GW models, parameterization, theory
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MLT Science Objectives

- Which GWs reach the MLT and drive the local MLT climate and meteorology?
- How do large local tidal amplitudes modulate GW transmission & dissipation?
- What are the dynamics of GW instability and breakdown?
- How strongly does the “hotspot” region drive the local MLT environment?
- Do GWs damp/amplify tidal structures?

TOOLS

- NGV flights guided by GWs in forecast model predictions and overpassing various ground-based MLT observatories
- Global modeling, DNS GW-turbulence models, idealized GW models, parameterization, theory

Semidiurnal Wind & GW Variances
Rothera radar (68°S) June 2008

Stationary Gravity Wave Structure in Airglow Temperature over Andes
Experimental Design Overview (EDO)

10-week field program in austral winter ~June to September 2013

NSF/NCAR Gulfstream V (NGV)
## SAANGRIA

### Proposed NGV Instrument Suite

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Parameters</th>
<th>Altitudes</th>
<th>Impact</th>
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</thead>
</table>
| **In situ instruments** (gust probe, GPS..) | Winds, temperature, O₃, aerosol, humidity  
  • 1-5 Hz (Δx~50-250 m) | Flight level (5-13 km) | Along-track hires GW & turbulence data                                                       |
| Dropsondes                          | Wind & temperature profiles  
  • Δz~100 m | Below aircraft (0-13 km) | Flow environment, GW structure below flight                                                  |
| Microwave Temperature Profiler (MTP) | Temperature profiles  
  • ±1-2 K, Δz~0.7-3 km, 10-15 s integration (Δx~2-4 km) | ~5-20 km | GW structure above & below NGV                                                            |
| Rayleigh lidar                      | Temperature profiles  
  • ±2-8 K, Δz~2 km, 20s integration (Δx~5 km)  
  aerosol (PSC) backscatter  
  • Δz~0.5-1 km | T~30-50 km  
  PSC ~20-30 km | GW structure  
  GW-induced PSCs                                                                          |
| Sodium (Na) resonance lidar         | Na densities, temperature  
  • ±1-3 K, Δz~3-5 km, 20s int. (Δx~5 km)  
  vertical wind  
  • ±1-3 m/s, Δz~3-5 km, 20 s int. (Δx~5 km) | ~15-30 km  
  ~84-96 km | GW structure                                                                               |
| Mesospheric Temperature Mapper (MTM) | All sky OH airglow and temperature  
  • ±2 K, 5s integration (Δx~1 km) | ~87 km | Two-dimensional GW structure, propagation directions                                      |

**Existing Facility Instruments**

**New Facility Instruments being developed for SAANGRIA**
SAANGRI A measurement capabilities

NGV lidar $w'(x,z)$ & $T'(x,z)$ ~80-100 km

NGV MTM $T'(x,y)$ ~87 km

t meteor radar enhanced meteor radars (winds, tides, GWs)
MF radar airglow imagers (KGI and TdF)
airglow imager (Rothera)

Na lidar meteor radar airglow imager (CP and EL)

NGV lidar $\rho'(x,z)$, $T'(x,z)$ ~30-60 km, PSCs ~15-30 km

NGV lidar $w'(x,z)$ & $T'(x,z)$ ~15-30 km

NGV in situ winds, MTP $T'(x,z)$ drops sondes

Antarctic Pen. Southern Andes

Rothera (68°S) KGI (62°S) TdF (54°S) CP/EL (30, 32°S)
<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone</th>
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<tbody>
<tr>
<td>Dec 2009</td>
<td>NGV Facility Instrument proposals submitted to NSF (2 new lidars, 1 new MTM)</td>
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<tr>
<td>Jan 2010</td>
<td>Science Program Overview (SPO) &amp; Experimental Design Overview (EDO) proposals submitted to NSF and EOL</td>
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<tr>
<td>Feb 2010</td>
<td>SAANGRIA formally briefed to NSF Program Managers in Arlington, VA</td>
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<tr>
<td>June 2010</td>
<td>Facility Instrument proposal funded, NGV instrument development begins</td>
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<tr>
<td>August 2010</td>
<td>SPO, EDO reviews positive, decision delay due to heavy 2012 NGV commitments; SAANGRIA enters formal list of potential future NGV missions</td>
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<tr>
<td>February 2011</td>
<td>Discussions of ground station support along eastern Chile via ONR &amp; South Americans</td>
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<tr>
<td>June 2011</td>
<td>Resubmission of SAANGRIA SPO and EDO for 2013 mission time frame, plus report on Facility instrument and FAA NGV certification progress for the NGV</td>
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<tr>
<td>January 2012</td>
<td>Formal NSF mission decision: Go/No Go</td>
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<td>March 2012</td>
<td>Install coastal weather stations</td>
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<tr>
<td>May 2012</td>
<td>Science and field planning meeting</td>
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<tr>
<td>July-September 2012</td>
<td>Practice (off-site) field phase (one month)</td>
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<td>February 2013</td>
<td>NGV instrument tests and test flights in Boulder</td>
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<tr>
<td>June-September 2013</td>
<td>Deploy to Punta Arenas, execute SAANGRIA Field phase</td>
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<tr>
<td>Sep. 2013 to 2016</td>
<td>Data analysis, modeling and publications</td>
</tr>
</tbody>
</table>
1. Ground-based, airborne, satellite measurements
   - Cerra Pachon & El Leoncito - Swenson, Liu, Franke (UI), Taylor (USU), Smith (BU)
   - Tierra del Fuego & King George Island - Janches (NASA), Martinis (BU), Gobbi (INPE)
   - Rothera - Hibbins (BAS), Mitchell (U. Bath), Taylor (USU)
   - ground stations, radiosonde soundings - de la Torre (ARG), Garreaud (CHI)
   - Satellite data - Preusse, Ern, Hoffmann (Forsh. Julich, DE), Wu (UCLA/JPL), de la Torre (ARG)
   - Falcon - Dönnbrack (DLR/DE), other aircraft - Grubisic (U. Wien), Hacker (U. Ade.)

2. NGV data analysis
   - Woods (Yale), Williams, Yue (NWRA), Taylor, Pautet (USU), Smith (BU)
   - Alexander, de la Torre (ARG), Swenson, Liu, Franke (UI)
   - Reinecke, Billings, Jiang, Sassi (NRL)

3. Modeling - GW source, propagation, instability dynamics
   - Snyder (NCAR), Zhang (PSU), Durran (UW), Broutman (CPI), Snively (USU)
   - Reinecke, Billings, Jiang, Sassi (NRL), Lund, Vadas, Wang (NWRA)
   - Hickey (ERAU), Lane (U. Melbourne)

4. Modeling - mesoscale simulations and forecasting
   - Alexander, de la Torre, Pulido (ARG)
   - Jiang, Reinecke (UCAR), Kirshbaum (U. Reading)

5. GCM modeling, GWD parameterization
   - Vosper, Shutts, Wells, Webster (UK Met Office)
   - Bacmeister, Liu (NCAR/WACCM), Becker (IAP)
   - Scinocca (Can. Ctr. Climate Mod.) Reinecke, Billings, Jiang, Sassi (NRL)
We solicit and encourage involvement/support/input from broad range of communities with potential interest:

- international community (esp. southern hemisphere)
- climate and NWP communities
- ground-based and satellite GW observational communities
- GW parameterization & GW modeling communities
- troposphere, stratosphere and MLT communities
- mesoscale and global modeling communities
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The Southern Andes – ANtarctic Gravity-wave Initiative

Thank you...
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Backup Slides
Inter-relating Observed, Resolved & Parameterized Waves

Maximum GW Momentum Fluxes

SAANGRIA Suborbital Observations

Nadir

Microwave Limb & Sublimb

Infrared Limb

GCMs

adapted from Preusse et al. (2008)
Observe Gravity Waves in Planetary “Hotspot” where they are intense, deep, persistent and generated by all sources considered relevant for parameterization.

**MLS**: 32 km Altitude
Aura Satellite
(Wu and Eckermann 2008)

**CRISTA**: 60 km Altitude
Shuttle Pallet Satellite
(Preusse et al. 2006)
**Why the Southern Andes - Antarctic?**

1. Planetary “hot spot” for gravity-wave activity deduced from satellites
2. All sources of gravity waves relevant for parameterization exist here strongly
   1. Orographic gravity waves (from southern Andes, Antarctic Peninsula, nearby islands)
      - Eckermann and Preusse (Science 1999); Jiang et al. (JGR, 2002); Alexander et al. (JGR, 2008), and many more references….
   2. Jet-generated waves (jet deformation by baroclinic storms, stratospheric vortex instabilities)
      - Yoshiki and Sato (JGR, 2000); de la Torre et al. (GRL, 2006); Hei et al. (JGR, 2008); Sato and Yoshiki (JAS, 2008)
   3. Convective gravity waves (intense thunderstorms, cellular convection, fronts)
      - Spiga et al. (Ann. Geophys. 2008); Llamedo et al. (Adv. Space Res. 2009)
   4. Large wave amplitudes & scales that suborbital & satellite instruments can more easily resolve.
3. Strong stable low-level forcing environment
   1. Regular passage of low pressure systems and baroclinic storms
   2. Multiscale orography throughout the region that forces waves
4. Stable propagation channel from troposphere to MLT
   1. Strong stable mean eastward flow from surface to the lower thermosphere
   2. No major stratospheric sudden warmings to block GW propagation into the MLT (stable vortex)
5. Southern Hemisphere is poorly observed & understood relative to North
6. Well instrumented with ground-based assets (radars, airglow imagers…)
7. Good airfield support via existing NSF/NASA ops out of Punta Arenas