DEEPWAVE Workshop

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TOPICS

• AIRS Gravity-Wave Observations
• NAVGEM Reanalysis Experiments
• Plans
AIRS DEEPWAVE Gravity-Wave Product

- GWs isolated as small horizontal scale perturbations in Level-1b swath-scanned thermal nadir radiances
- Channel averaging to reduce noise floors and increase S/N thresholds for GW detection
- For DEEPWAVE, provided “nowcast” AIRS GW product based on near-realtime (NRT) radiances
- Post DEEPWAVE, reprocessed 2014 data from 1 April to present using research-quality radiances

Eckermann and Wu, GRL, 2012
Gong, Wu and Eckermann, ACP, 2012
AIRS 40 hPa Radiance Channels

(a) 40 hPa Kernel Functions

(b) 40 hPa GW Smearing

AIRS channels 64, 88, 90, 94, 100, 106 & 118 (665.015–678.839 cm⁻¹)

Individual Channel Radiances 64,…,118

Mean Channel Radiance 64,…,118

AIRS channel 71 (666.773 cm⁻¹).

see Hoffmann and Alexander (JGR, 2009)
Eckermann et al. (GRL 2009)
South Island

- Mean (2003-2011)
- +/- 1 st. dev.
- Max/Min
- 2014 DEEPWAVE
18-28 May
2
15-16 June
3

19-24 June
3
19-24 June
S. Ocean E55S

- Mean (2003-2011)
- +/- 1 st. dev.
- Max/Min
- 2014 DEEPWAVE
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**Goals of NAVGEM Reanalysis**

- Analysis fields for DEEPWAVE MLT science above ECMWF and NIWA/UKMO upper boundaries at ~70-80 km.
- Lateral boundary conditions for COAMPS up to 90-100 km
- Backgrounds for ray models
- Platform for studying and tuning orographic and nonorographic gravity-wave drag parameterizations for DEEPWAVE
NAVGEM
Navy Global Environmental Model

Global SLSI Forecast Model

0-10 Day Forecasts

0-9 Hour Forecasts

Global observations over next 0-6 hours

Data Assimilation System

NAVDAS-AR 4DVAR

6 hourly global analysis fields
NAVGEM T119L74
DEEPWAVE Reanalysis Runs

\[ p_{\text{top}} = 6 \times 10^{-5} \text{ hPa} \]

Top Data Insertion Operationally

- Version 3.3 MLS Temperature
- MLS Water Vapor
- MLS Ozone
- Version 2.0 SABER Temperature
- SSMIS UAS Radiances
Zonal Mean Winds for June


(a) Zonal Winds: June 2007-2009 140-190°E

NAVGEM Reanalysis: 2014

Zonal Winds: June 2014 140-190° E

pressure (hPa)

zonal wind (m s⁻¹)

-50 0 50 100

Christchurch

Geopotential Height (km)

Pressure (hPa)

Latitude

m/s

min = -81.6  max = 145.8  mean = 6.23  stdv = 28.69
Zonal Mean Winds for June

NASA MERRA Reanalysis: 2014

(a) Zonal Winds: June 2014 140-190°E

NAVGEM Reanalysis: 2014

Zonal Winds: June 2014 140-190°E

min = -81.6  max = 145.8  mean = 6.23  stdv = 28.69
Zonal Mean Winds for June

NASA MERRA Reanalysis: 2002-2012

(a) Zonal Winds: June 2002-2012 140-190°E

NAVGEM Reanalysis: 2014

Zonal Winds: June 2014 140-190°E

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<td>-81.6</td>
<td>145.8</td>
<td>6.23</td>
<td>28.69</td>
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</tbody>
</table>
Summary/Plans

• Not sure yet which events to focus on with which tools (workshop priority – action items and collabs)

• AIRS-focused DEEPWAVE methods and first-results paper [?]

• Forward model Rayleigh lidar and COAMPS/WRF GW temperature fields for detailed comparisons with AIRS observations

• Continue NAVGEM analysis experiments, validate against DEEPWAVE 0-100 km observations, tuned GWD parameterizations

• Detailed GW event studies with ray models and COAMPS/NAVGEM
Questions....
Variation of Gravity-Wave Vertical Wavelength with Winds

\[ \lambda_Z = \frac{2\pi \left| c - \bar{U} \cos(\phi - \varphi) \right|}{N} \propto \bar{U} \]

- \( \phi \): wind vector azimuth
- \( \lambda_Z \): gravity-wave vertical wavelength
- \( c \): gravity-wave phase velocity \((c \approx 0)\)
- \( N \): background buoyancy frequency
- \( \bar{U} \): background wind speed
SSMIS on DMSP F16-F19

Doppler Shift

- 833 KM Altitude
- Single Footprint
- 14 KM
- 3 x 3 Footprint Average
- 12.5 KM 1.9 Sec
- 144° Active Scan
- 1707 KM Swath Width
- Direction of Scan / Along Scan
Zeeman Line Splitting by Geomagnetic Fields

US Std. Atmos. $B_{Mag} = 26 \, \mu T$ (Solid) $B_{Mag} = 60 \, \mu T$ (Dashed)

Altitude [km]

Pressure [hPa]

CH. 20 63.283248±.285271 GHz CP
CH. 19 60.792668±.357892 GHz CP
CH. 21 60.792668±.357892±.002 GHz CP
CH. 22 60.792668±.357892±.0055 GHz CP
CH. 23 60.792668±.357892±.016 GHz CP
CH. 24 60.792668±.357892±.050 GHz CP

$k m^{-1}$
NAVDAS-AR

**NRL Atmospheric Variational DAS**
(Accelerated Representer: 4DVAR)

**Background** ($x_b$)

**Observations** ($y$)

**Observation Error** ($R$)

**Initial Background Error** ($B^0$)

Data Assimilation (DA) System 4D-Var

Analysis ($x_a$)

Forecast Model NAVGEM

Short forecast: 9 hours

Long forecast: 10 days

\[ x_a = x_b + K[y-Hx_b] \]

$H$ transforms from x-space to y-space

\[ K = BH^T[R+HBH^T]^{-1} \]

\[ B = MB^0M^T \]
• Numerically minimize the scalar cost function

\[ J(x_a) = (y - \mathcal{H}(x_a))^T R^{-1} (y - \mathcal{H}(x_a)) + (x_b - x_a)^T P_b^{-1} (x_b - x_a) \]

- Observation vector \( y \)
- Observation error covariance
- Forward observation operator
- Background vector \( x_b \)
- Background error covariance
- Analysis vector \( x_a \)

• NAVDAS computes the observation-space solution

\[ x_a - x_b = P_b H^T \left[ H P_b H^T + R \right]^{-1} \left[ y - \mathcal{H}(x_b) \right] \]

Solution converts “innovation” vectors in the observation space into “correction” or “increment” vectors in the model/analysis space.
### Channel Averaging to Reduce Noise

- 50 raw stratospheric channel radiances $\rightarrow$ 12 net stratospheric channel radiances
- See Gong, Wu and Eckermann (Atmos. Chem. Phys., 2012) for details

<table>
<thead>
<tr>
<th>Pressure (hPa)</th>
<th>Channel numbers</th>
<th>Noise (K$^2$)</th>
<th>NEdT (K$^2$)</th>
<th>Zonal mean</th>
<th>Map</th>
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<td>0.078</td>
<td>2.14</td>
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<td>0.029</td>
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<td>0.020</td>
<td>0.011</td>
<td>0.50</td>
<td>3.54</td>
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<tr>
<td>100</td>
<td>132, 133, 138, 139, 149, 152</td>
<td>0.026</td>
<td>0.014</td>
<td>0.67</td>
<td>4.73</td>
</tr>
</tbody>
</table>
Global Eulerian Spectral Model

Data Assimilation System
NAVDS 3DVAR

6-hourly global 0-100 km analysis fields

0-10 Day Forecasts

0-9 Hour Forecasts

Global 0-100 km observations over next 0-6 hours

Navy Operational Global Atmospheric Prediction System – Advanced Level Physics, High Altitude

NOGAPS-ALPHA

X_a

X_b

y