Earth Global Reference Atmospheric Model (Earth-GRAM)
GRAM Virtual Meeting

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Outline

• Earth-GRAM Overview
• Current Status
• Near-term Update Plans
• Ideas for New Capabilities???
What is Earth-GRAM???

• Provide monthly mean and standard deviation for any point in atmosphere
  – Monthly, Geographic, and Altitude Variation
• Earth-GRAM is a C++ software package
  – Currently distributed as Earth-GRAM 2016
• Atmospheric variables included: pressure, density, temperature, horizontal and vertical winds, speed of sound, and atmospheric constituents
• Used by engineering community because of ability to create dispersions in atmosphere at a rapid runtime
  – Often embedded in trajectory simulation software
• Not a forecast model
• Does not readily capture localized atmospheric effects
Model Input

Range Reference
Atmosphere Option

Auxiliary Profile
Input Option
Range Reference Atmosphere (RRA) Database

- Earth-GRAM has the ability to use the RRA site specific database
  - Earth-GRAM includes 1983, 2006 and 2013 RRA database
  - 2013 RRA developed by MSFC/Natural Environments Branch for the Range Commanders Council – Meteorology Group

- Climatology built from balloon and rocketsonde measurements

- Natural Environments recommends the use of the 2013 RRA database
Values From Earth-GRAM =

Mean value + Large-scale perturbation + Small-scale perturbation

Modeled as a wave

Modeled as a stochastic (random) process

Driven by observed standard deviation
Earth-GRAM Output

Mean and Dispersed East-West Wind

1000 Monte Carlo Dispersed Profiles with January Monthly 3-Sigma Envelope
Earth-GRAM Output

Earth-GRAM dispersions are approximately Gaussian distributed
Current Status

- Earth-GRAM 2016 Version 1.0 released December 2016
- C++, object-oriented software package
- New Period of Record for NCEP data
- Ability to enter number of Monte Carlo runs from input
  - No longer need a number seed file
- Supporting users in the implementation of Earth-GRAM 2016
- Software Link: https://software.nasa.gov/software/MFS-32780-2
Near-Term Update Plans

• Upcoming release: Earth-GRAM 2016 Version 2.0
• Planned Release in 2018
• Planned Updates Included:
  – CorrMonte – hourly dispersions
  – CorrTraj – correlated Ballistic (Up-Down) Atmospheric Profile
  – Fairing between RRA and Earth-GRAM
  – Graphical User Interface (GUI)
  – Bug Fixes
Near-Term Update Plans, CorrMonte

- Program evaluates multiple profiles separated by a fixed time increment.
- Earth-GRAM can provide a monthly dispersion with Monte Carlo runs, CorrMonte can provide an hourly dispersion.
- CorrMonte does this by producing several profiles that are cross-correlated.
- CorrMonte is useful for providing less conservatism in certain design and operational situations
Near-Term Update Plans, CorrMonte

1000 3 hour dispersions

Mean of dispersions vs 1st dispersed profile
Near-Term Update Plans, CorrMonte

1000 Cycle CorrMonte, East-West Wind (2016)

1000 3 hour dispersions

Mean of dispersions vs GRAM Mean

1000 Cycle CorrMonte, Average East-West Wind (2016)
Near-Term Update Plans, CorrTraj

• Users requested the ability to correlate an atmospheric profile for a ballistic (up-down) trajectory
• Used exponential correlation from calculation of small-scale perturbation:
  \[ r(\Delta x) = \exp(-\Delta h / L_h) \exp(-\Delta z / L_z) \exp(\Delta t / \tau) \]
• Test case with \( dz = 1.0 \) km, \( \Delta \phi \) and \( \Delta \theta = 0.01 \) and apex of trajectory = 30.0 km
Near-Term Update Plans, CorrTraj

- GRAM2010 Dispersed Profile
- GRAM2016V2.0 Dispersed Profile
Near-Term Update Plans, RRA-GRAM Fairing

• Currently methodology in Earth-GRAM does not handle transitions between RRA and GRAM very well
• Generated 2013 RRA cases to examine effect on GRAM profiles of temperature, east-west wind and north-south wind
• Fairied over a region of 5 km (25-30 km) between RRA and GRAM.
• Examined effect induced feature has on Monte Carlo dispersions.
Near-Term Update Plans, RRA-GRAM Fairing

RRA observations at 30 km: 31

Magnitude of E-W Wind Delta: 10 m/s
Near-Term Update Plans, RRA-GRAM Fairing

E-W Perturbation for February 2013
Edwards Air Force Base, California

Feature Persists in MC

Monte Carlo dispersion without fairing

Monte Carlo dispersion with fairing
Earth-GRAM 2016 V2.0 GUI, User Inputs
Earth-GRAM 2016 V2.0 GUI, Plot
Additional Near-term Updates and Future Work

• Bug Fixes for Earth-GRAM 2016 Version 2.0
  – Precision error when converting NCEP data from float to double
  – Unable to do Monte Carlo runs for a trajectory input file
  – Limiting horizontal winds to 0.7*speed of sound
• Conduct testing for Earth-GRAM 2016 Version 2.0
• Develop Earth-GRAM 2016 User’s Guide
Ideas for New Capabilities

• New data sources?
  – Conduct study of available data sources
• Methodology for multi-body simulation?
• More defined User-Instructions?
• Boundary Layer Improvements?
  – Topographic Influence Limitation
  – Poorly defined coastline for surface type