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

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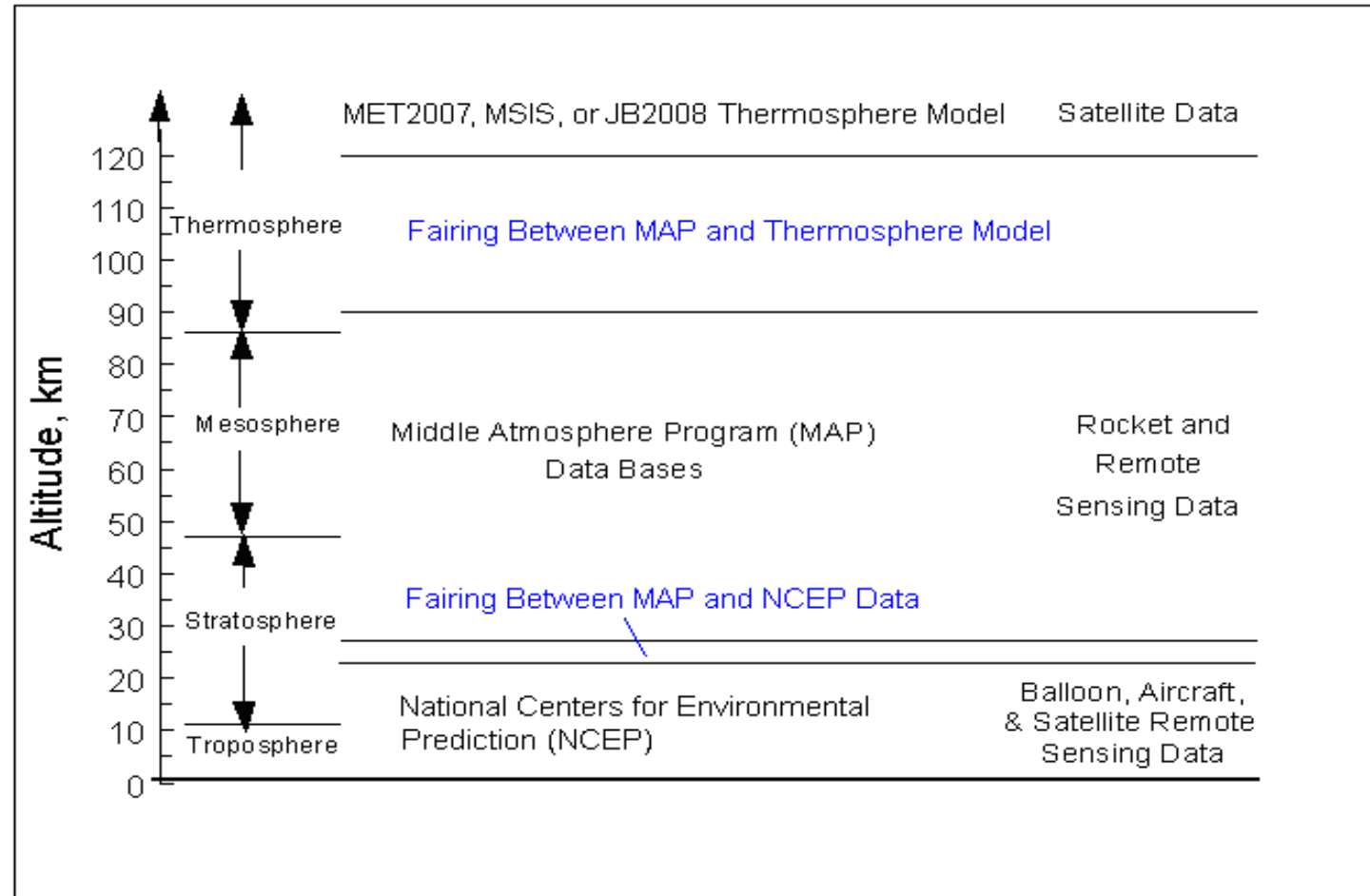
Outline

- 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

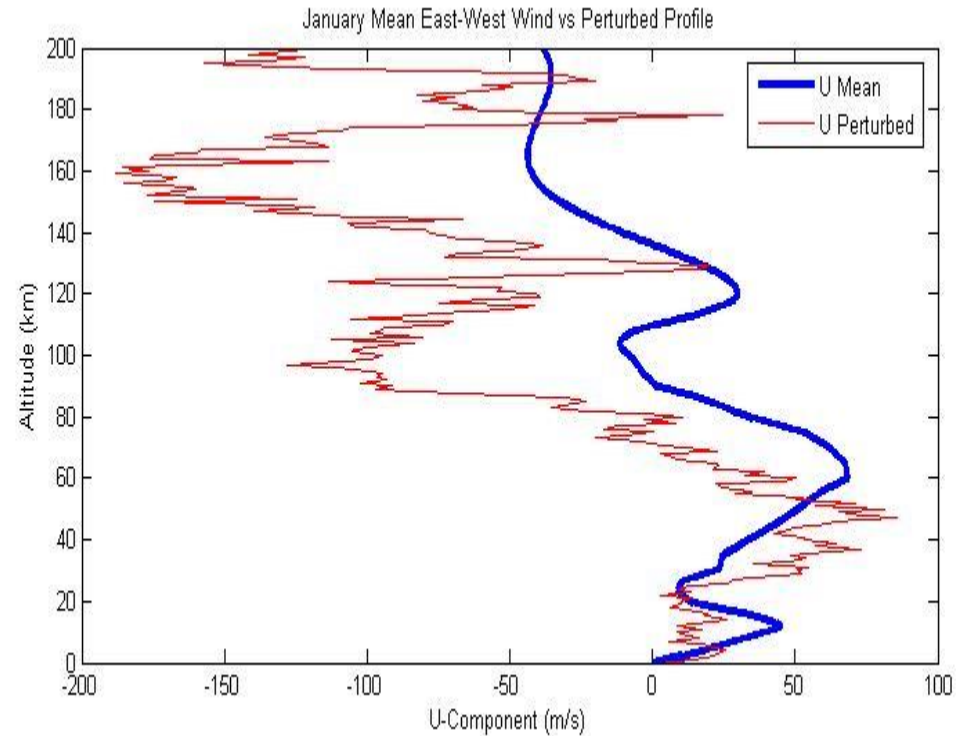
Perturbation Model

Values From Earth-GRAM =

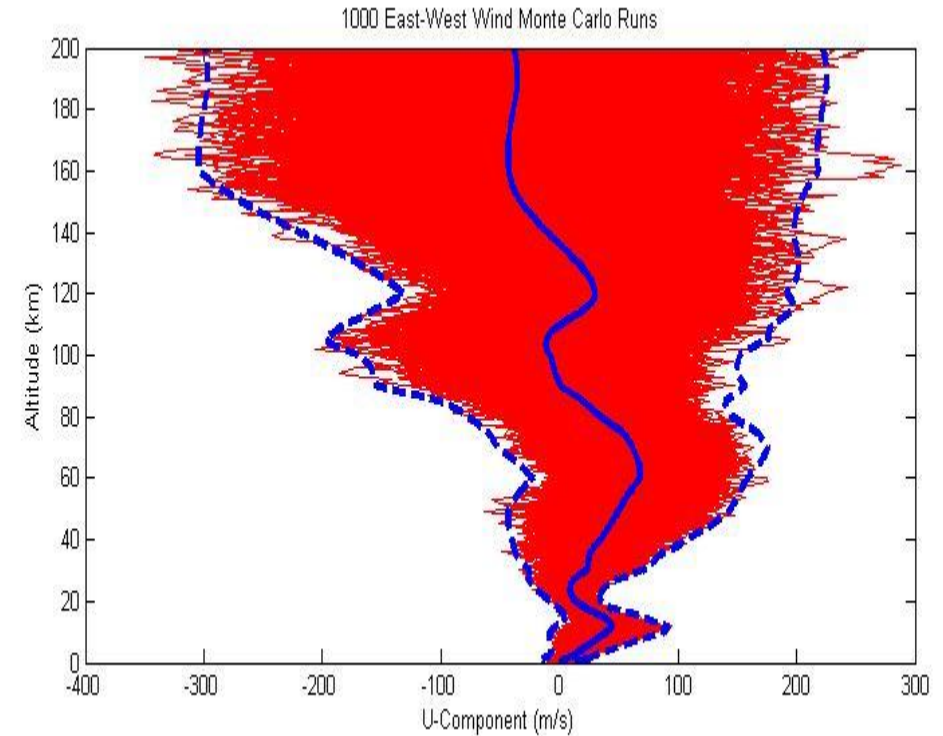
$$\text{Mean value} + \underbrace{\text{Large-scale perturbation}}_{\text{Modeled as a wave}} + \underbrace{\text{Small-scale perturbation}}_{\text{Modeled as a stochastic (random) process}}$$

Driven by observed standard deviation

Earth-GRAM Output

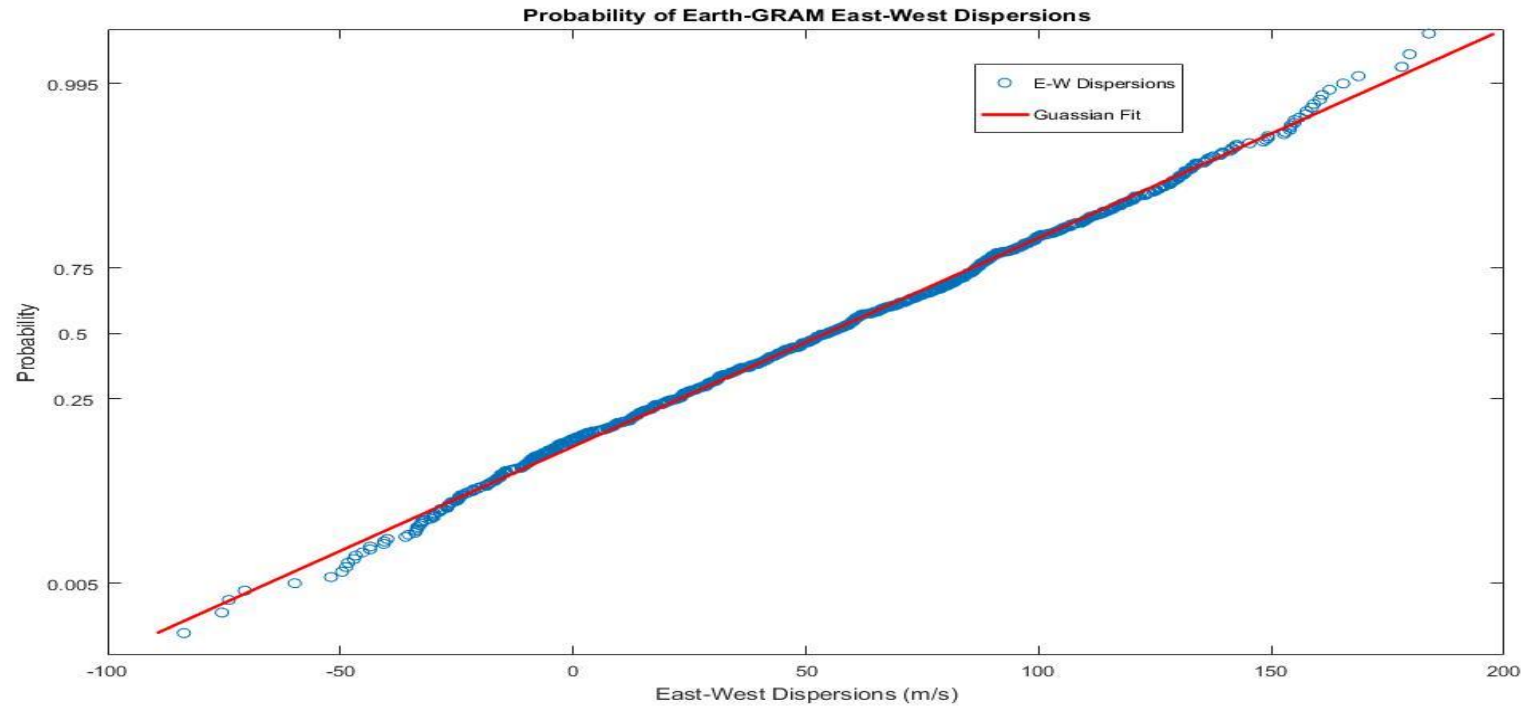


Mean and Dispersed East-West Wind



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>

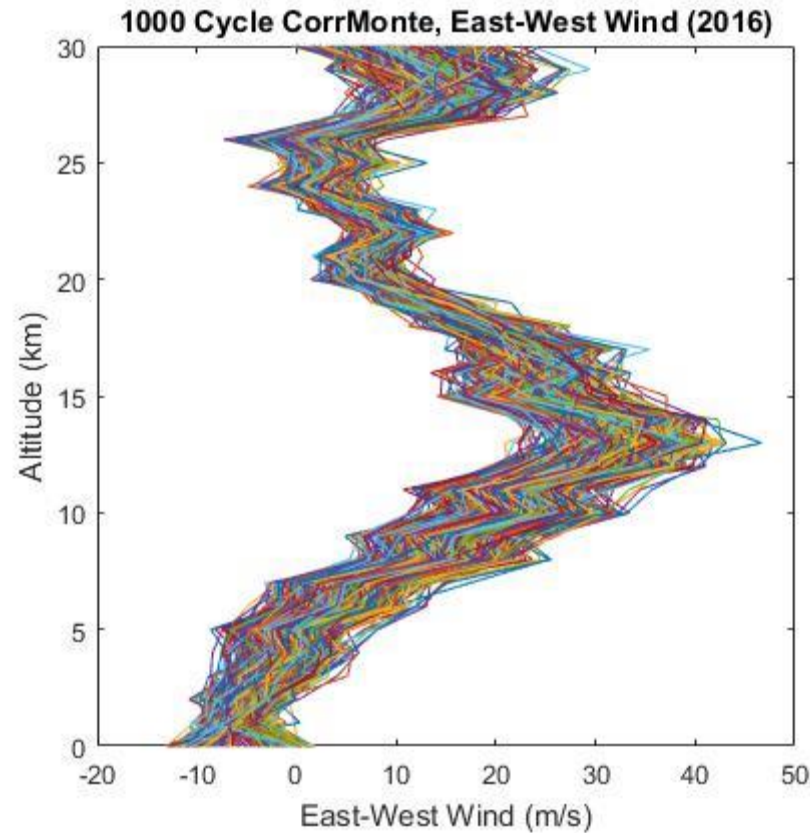
Near-Term Update Plans

- 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

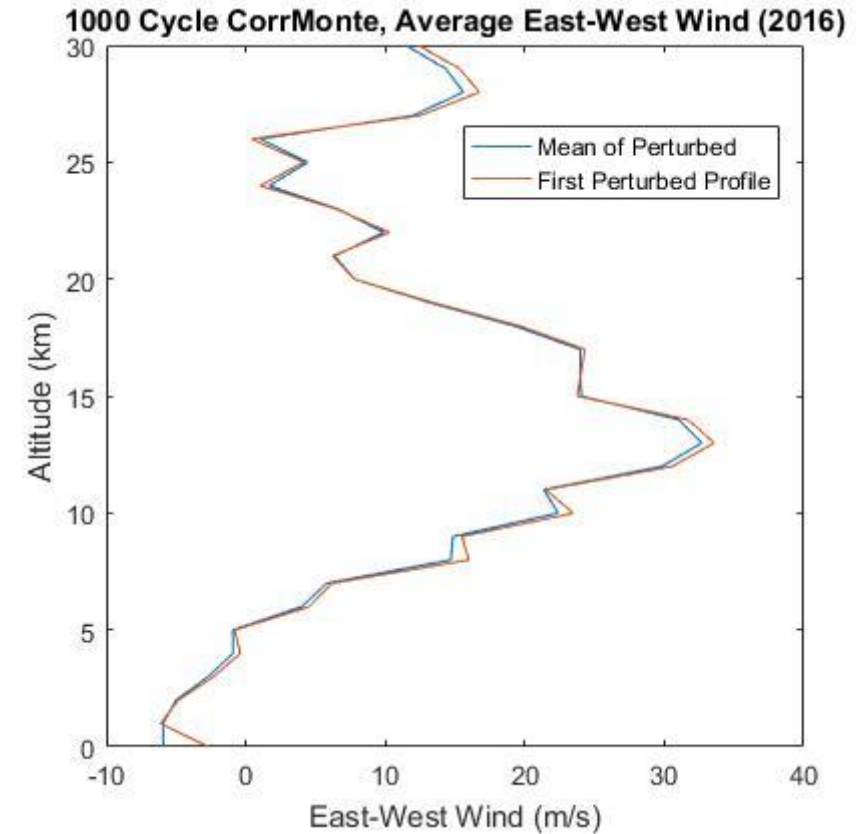
Near-Term Update Plans, CorrMonte

- 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

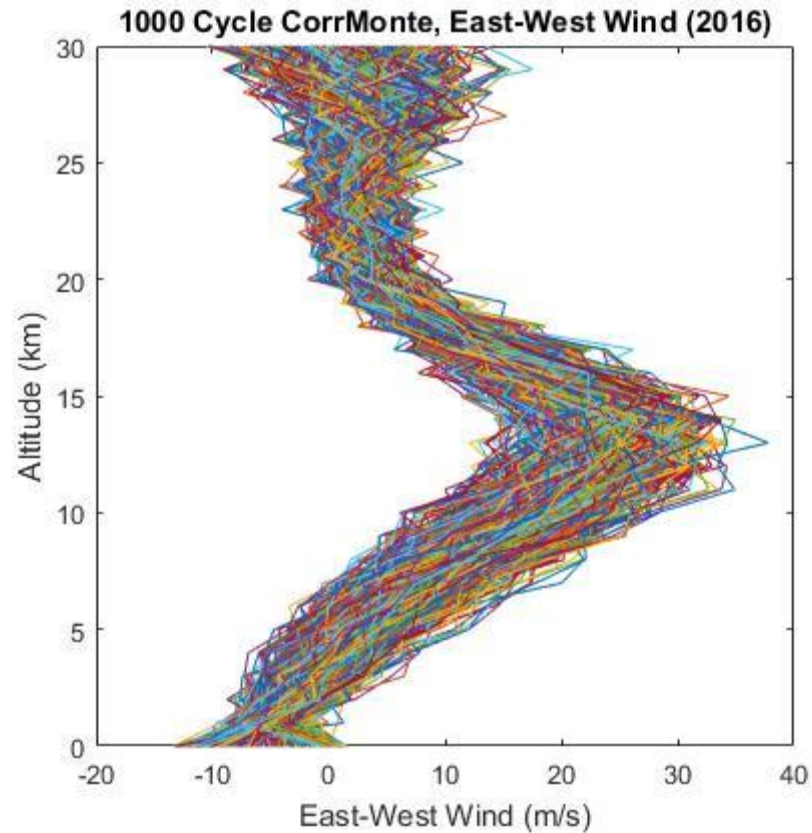


1000 3 hour dispersions

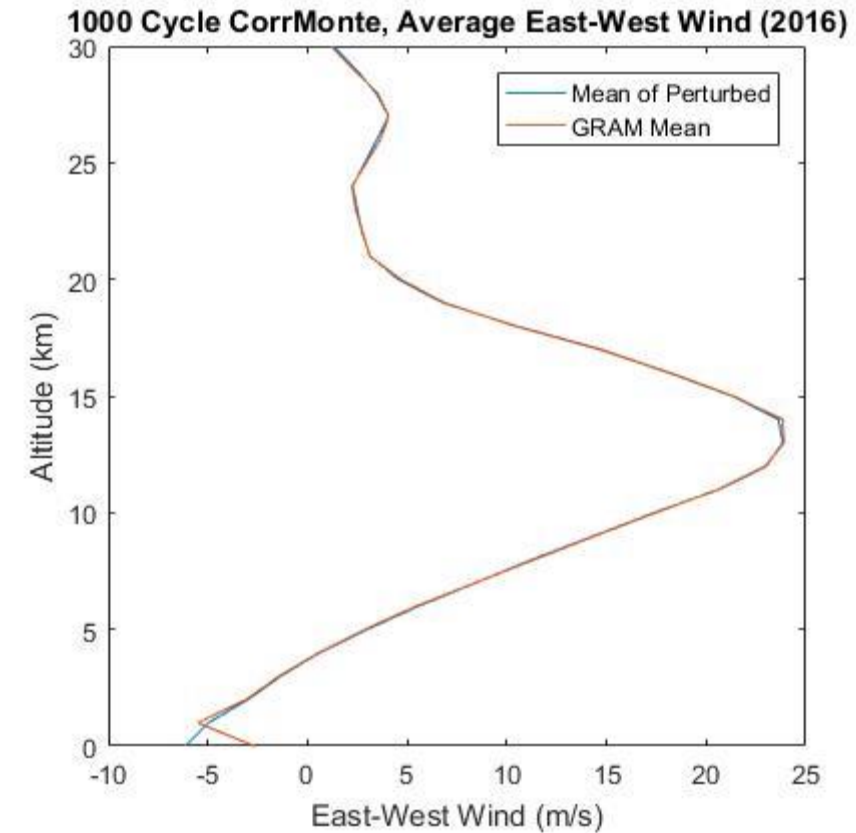


Mean of dispersions vs 1st dispersed profile

Near-Term Update Plans, CorrMonte



1000 3 hour dispersions



Mean of dispersions vs GRAM Mean

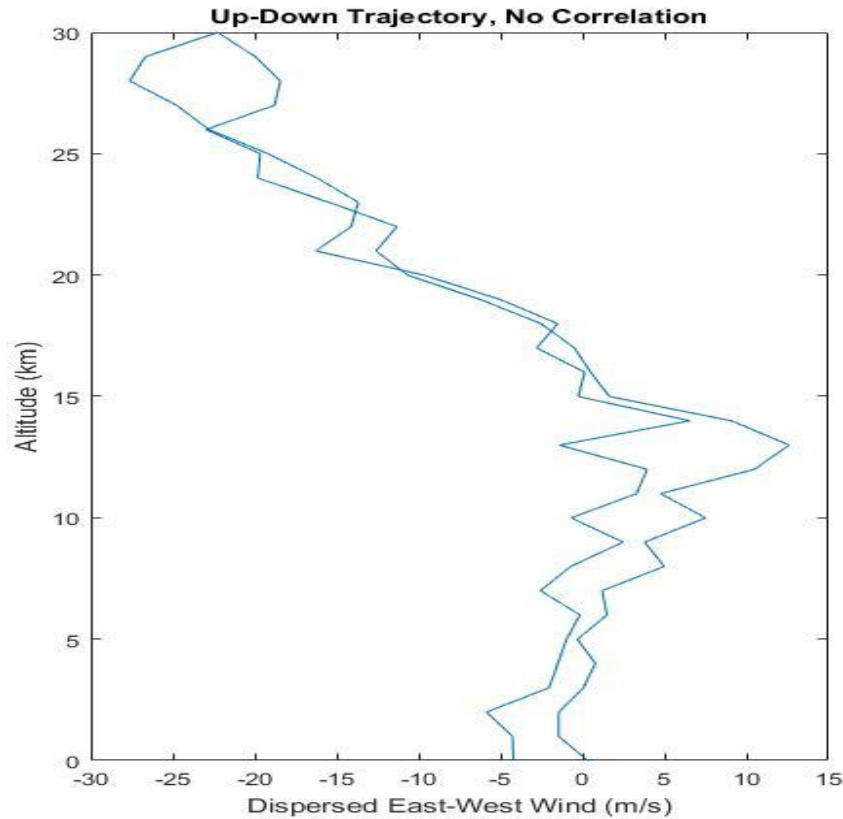
Near-Term Update Plans, CorrTraj

- Users requested the ability to correlate an atmospheric profile for a ballistic (up-down) trajectory
- Used exponential correlation from calculation of small-scale perturbation:

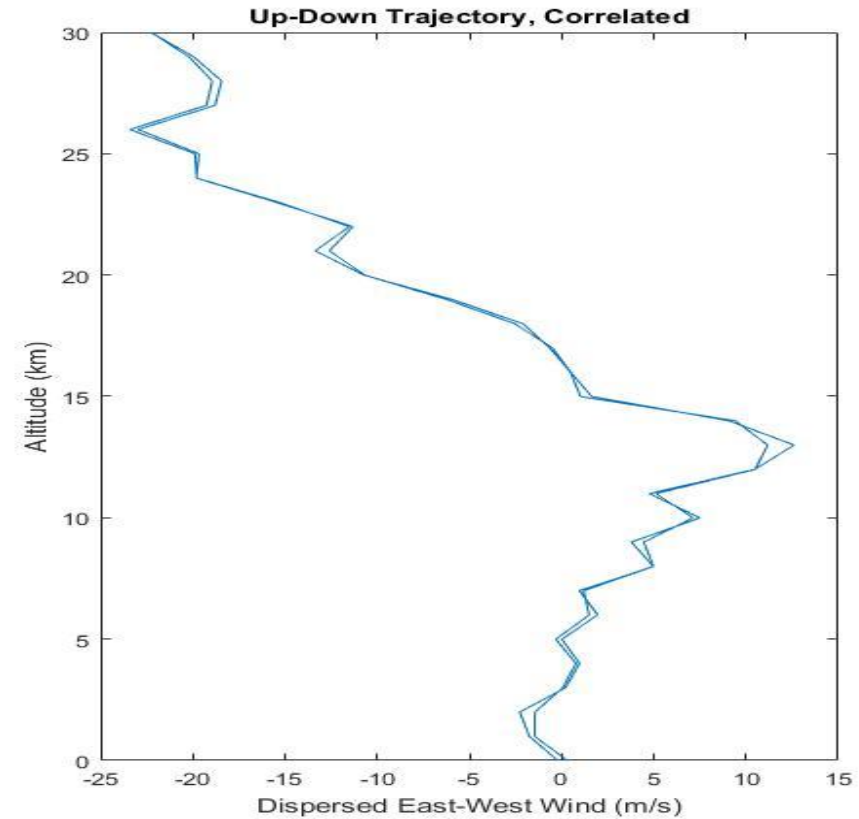
$$r(\delta x) = \exp(-\delta h / L_h) \exp(-\delta z / L_z) \exp(\delta t / \tau)$$

- Test case with $dz = 1.0$ km, $d\phi$ and $d\theta = 0.01$ and apex of trajectory = 30.0 km

Near-Term Update Plans, CorrTraj



GRAM2010 Dispersed Profile



GRAM2016V2.0 Dispersed Profile

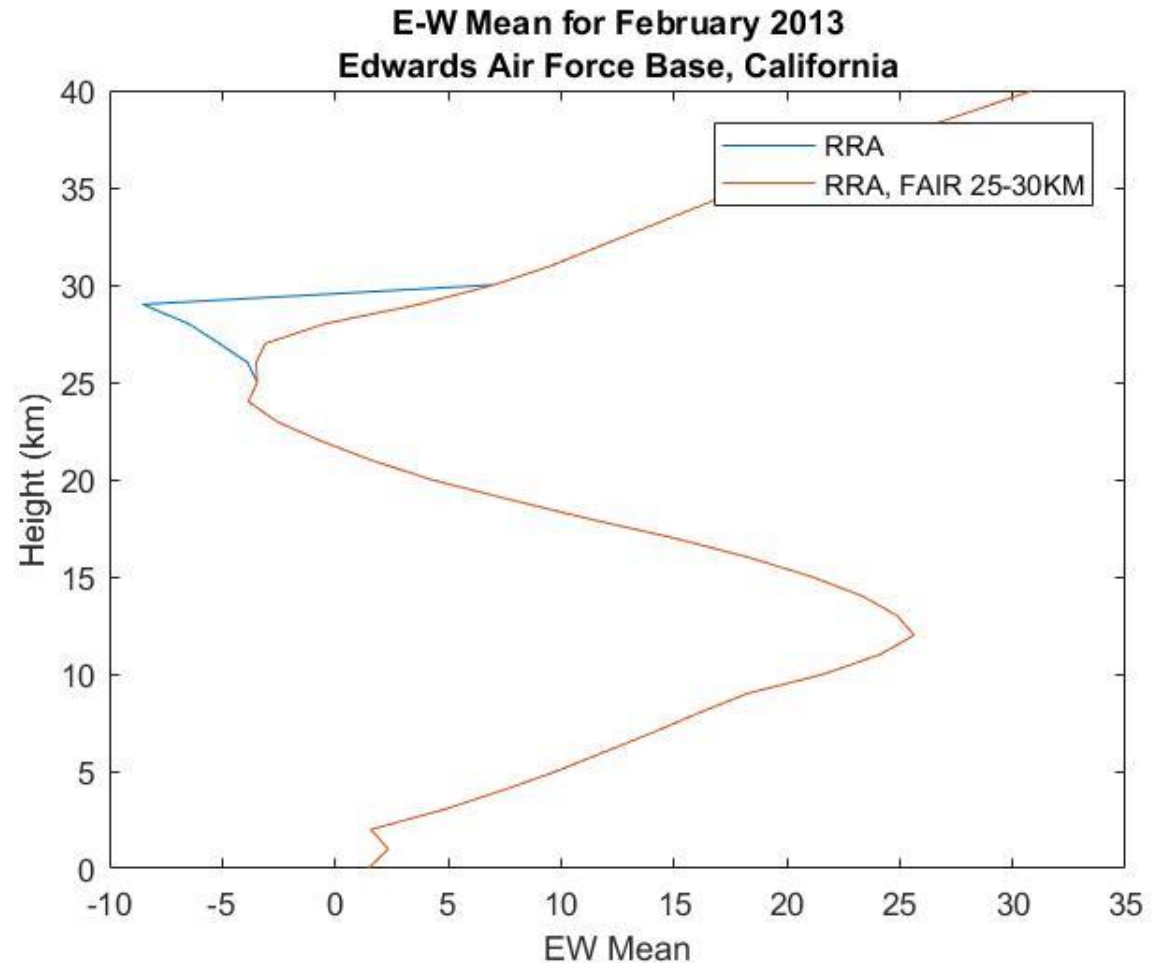
Near-Term Update Plans, RRA-GRAM Fairing

- 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
- Faired 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

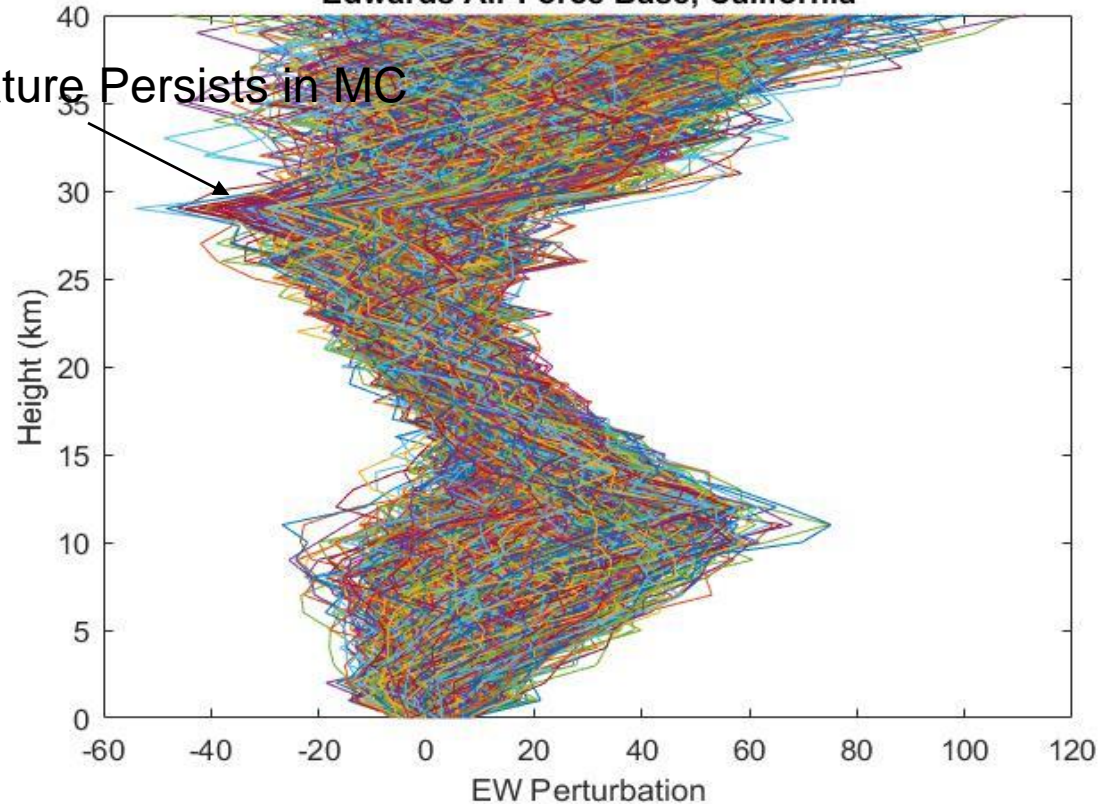
RRA observations at 30 km: 31

Magnitude of E-W Wind Delta: 10 m/s



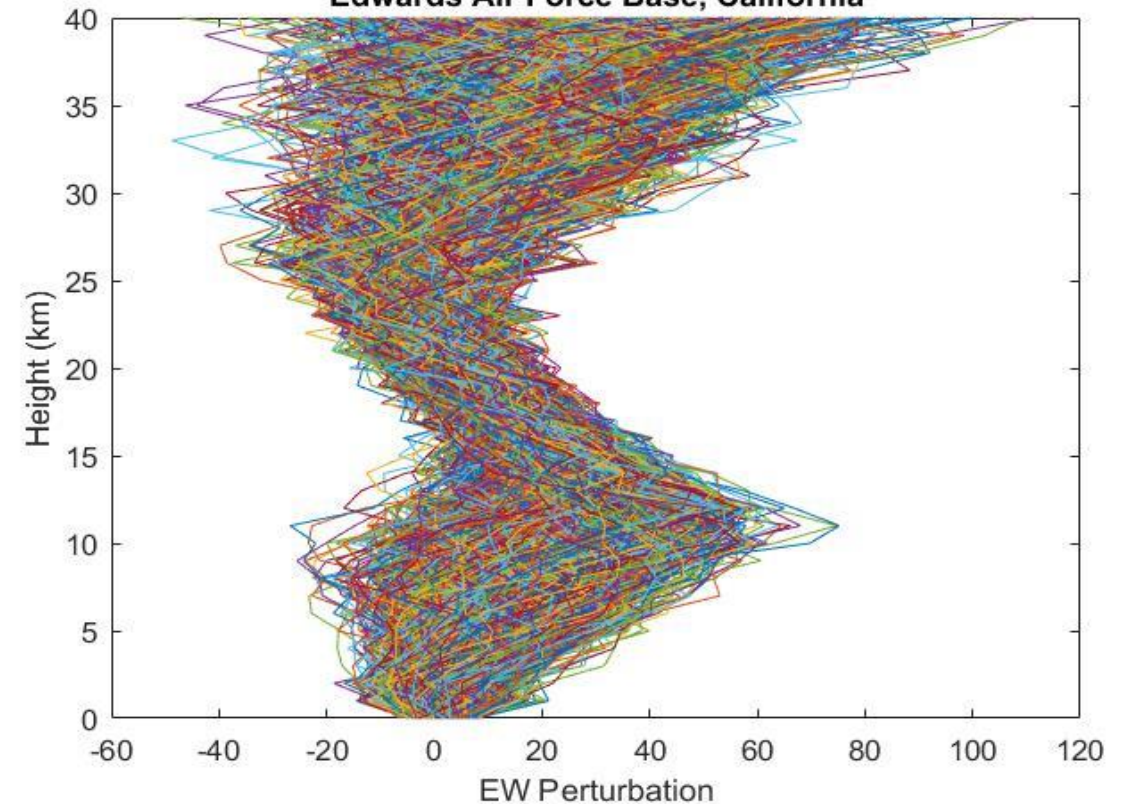
Near-Term Update Plans, RRA-GRAM Fairing

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



Monte Carlo dispersion without fairing

E-W Perturbation for February 2013 with Fairing (25-30km)
Edwards Air Force Base, California



Monte Carlo dispersion with fairing

Earth-GRAM 2016 V2.0 GUI, User Inputs

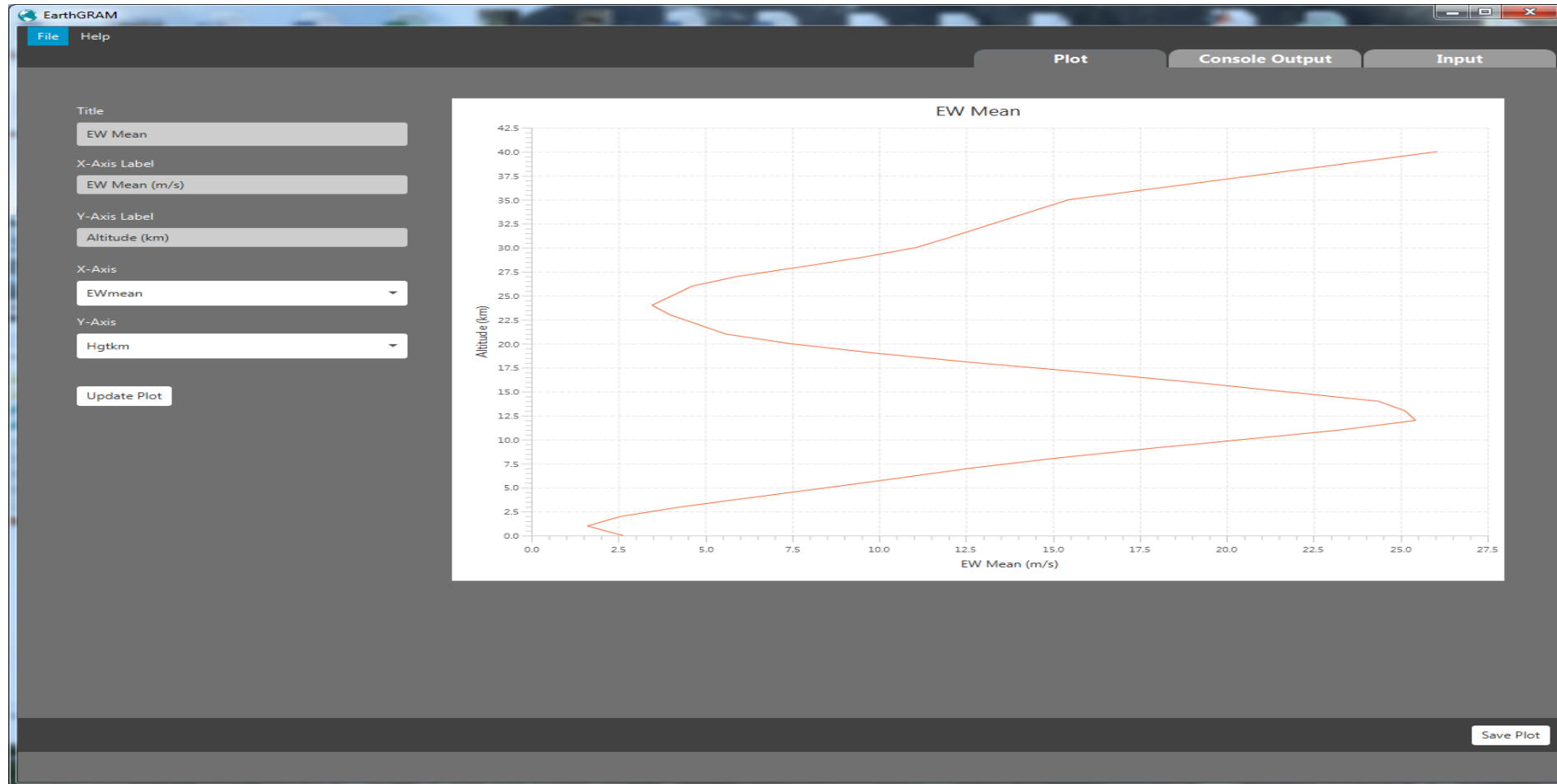
The screenshot displays the EarthGRAM 2016 V2.0 GUI. The interface includes a menu bar with 'File' and 'Help'. Below the menu bar are three tabs: 'Plot', 'Console Output', and 'Input'. The 'Input' tab is active, showing a form with various input fields and buttons. The form is organized into three main sections: 'Import NameRef', 'Pick RRA Site', and 'Pick EarthGRAM Version'. The 'Import NameRef' section contains a table of input fields for file paths and parameters. The 'Pick RRA Site' and 'Pick EarthGRAM Version' sections each contain a 'Browse...' button. The 'Input' section contains a table of input fields for parameters and data selection. At the bottom of the form, there is a status bar that reads 'Using EarthGRAM Version: GRAM.exe' and two buttons: 'Save' and 'Save and Run'.

Field	Value
My Test	C:\EarthGRAM2010V4.0\My Test\
atmpath	C:\EarthGRAM2010V4.0\IOfiles\
NCEPpath	C:\EarthGRAM2010V4.0\NCEPdata\FixedBin1\
trapath	GOTF_test.txt
prtpath	output.txt
nprpath	special.txt
conpath	species.txt
rrapath	C:\EarthGRAM2010V4.0\RRAdat\
rralist	rrasites.txt
profile	null
h1	0.0
phi1	28.5
thet1	-117.68
f10	230.0
f10b	230.0
ap	20.3
s10	0.0
s10b	0.0
dphi	0.0
dthet	0.0
dhgt	1.0
nmax	41
delt	0.0
iopt	0 - no trajectory data
iaux	0 - no auxiliar profile data
NCEPyr	9715
NCEPhr	5
nr1	1234
mc	0
rpscale	1.0
ruscale	1.0
rwscale	1.0
iurra	1 - RRA data
iyrrra	3 - 2013 RRA data
sitelim	2.0
sitenear	0.5

Using EarthGRAM Version: GRAM.exe

Save Save and Run

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 $0.7 \times \text{speed of sound}$
- 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