PropConfig – A Tool for Atmospheric Propagation Configuration

February 24, 2010

Amy M. Ngwele

Marcus Gualtieri

MZA Associates Corporation

2021 Girard Blvd. SE, Suite 150
Albuquerque, NM 87106
505-245-9970

1360 Technology Court, Suite 200
Dayton, OH 45430
937-684-4100

140 Intracoastal Pointe Dr. Suite 310
Jupiter, FL 33477
505-245-9970

Introduction

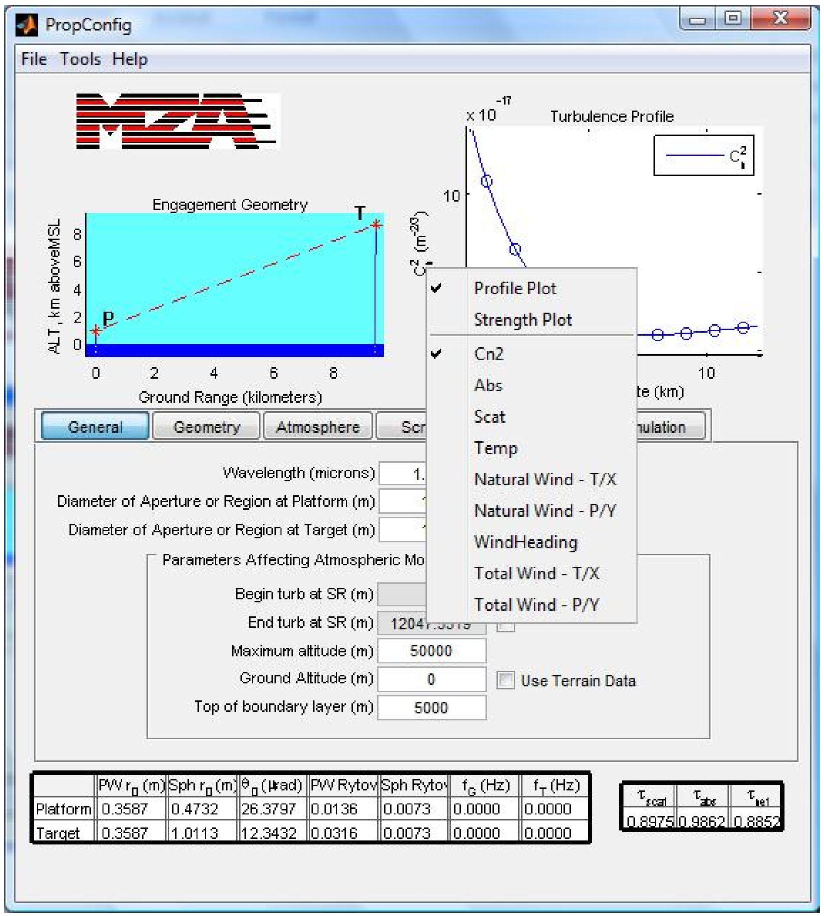
- **PropConfig is a utility in ATMTools that facilitates setup of geometry and atmosphere and gives guidance regarding settings for mesh parameters for wave optics simulation**
  - **It's new in ATMTools (since release 2009.1) but is based on the TurbTool utility that has previously been part of WaveTrain**
- **PropConfig can take in predefined atmosphere and geometry data (in multiple formats) or can be populated with default parameters and settings**
- **Data from PropConfig can be saved to a Matlab data file which can then be loaded into a runset for WaveTrain**
- **PropConfig contains much of the functionality of ATMTools and EngagementTools including many features which are not part of the older graphical utilities of these toolboxes.**
- **This tutorial will go through the utility and highlight features while setting up an example scenario.**

Example Scenario Parameters

- Consider a stationary, ground-based platform with a laser source attempting to illuminate a fast-moving airborne target at 10 km altitude
  - Source
    - Altitude – 10 m
    - Velocity – Stationary
    - Transmit Diameter – 50 cm
    - Wavelength – 1.03 μm
  - Target
    - Altitude – 10 km
    - Velocity – 200 m/s, heading East (90 deg from North)
    - Range – 30 km slant range
- Atmosphere
  - H-V 5/7 turbulence profile
  - MODFAS for absorption and scattering profiles
    - MODFAS implements lookup tables generated using a combination of data from MODTRAN and FASCODE runs
  - Constant wind profile – 5 m/s
  - Constant wind heading – East
  - US Standard 1976 temperature profile
  - Experiment with screen number, placement and distribution

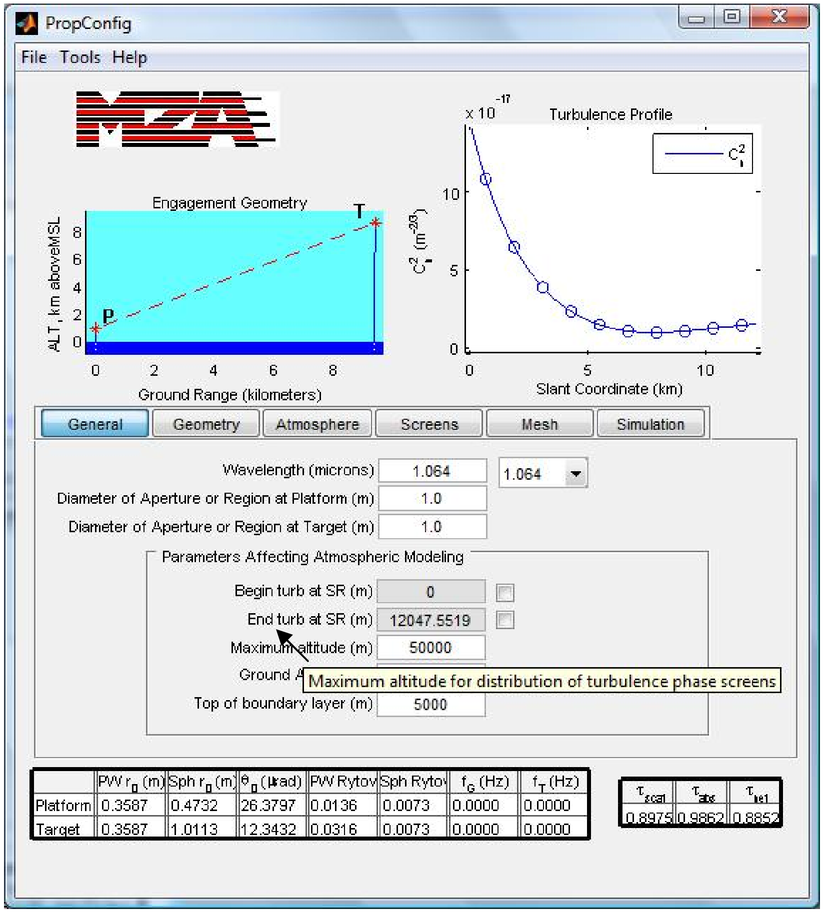
MZA Associates Corporation
Albuquerque — Dayton — Jupiter

PropConfig



- **PropConfig main window**
- **Plots of geometry (left plot) and turbulence profile (right plot)**
  - **Right+click context menu on both x- and y-labels on profile plot allow user to change plot contents**
- **Tables at bottom show computed propagation parameters (r_0, θ_0, etc) and atmospheric transmission**
- **In the middle are 6 tabs with different input settings which will be described separately**

General Parameters



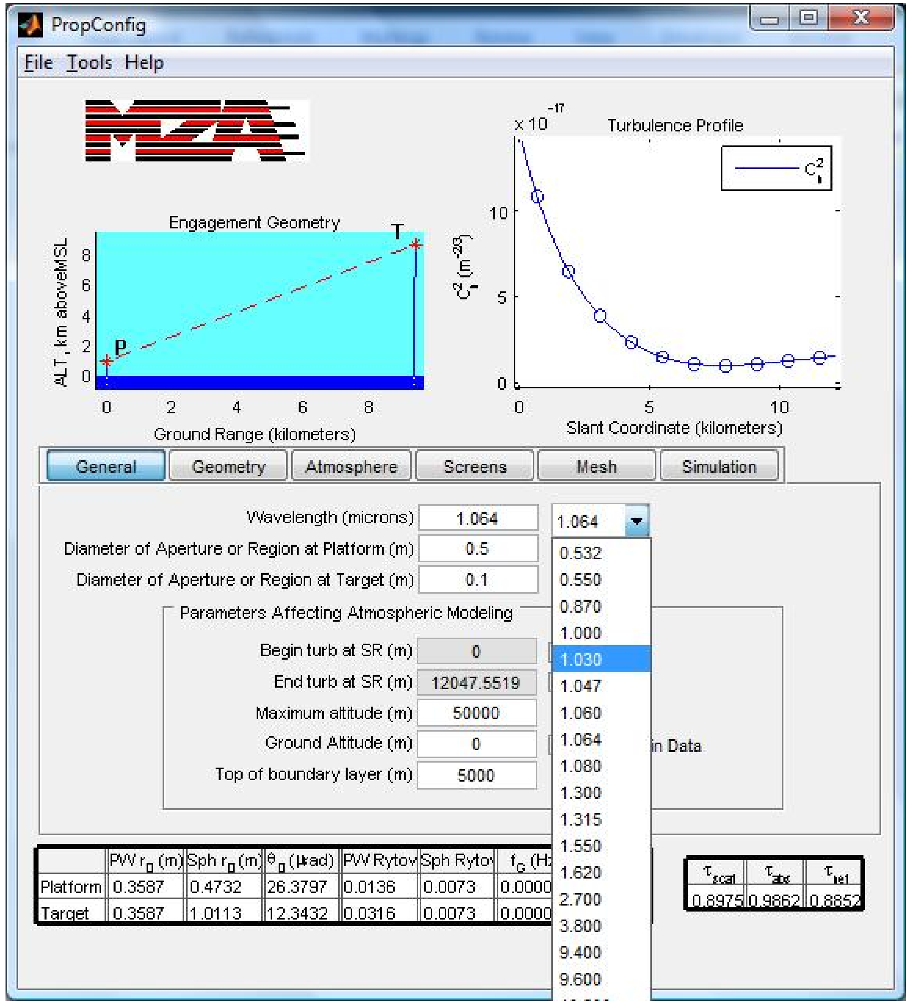
- **The image to the left shows the general tab with default settings**
  - **Wavelength**
  - **Diameters at each end of the path**
  - **Parameters affecting atmosphere**
    - **Start and end range for atmospheric models**
    - **Maximum altitude for placing phase screens**
    - **Ground and boundary layer altitudes for computing screen altitude**
- **Many of the text fields have tooltips for more detailed information about the parameter inputs**

Example General Params

Diameters:

Source = 50 cm

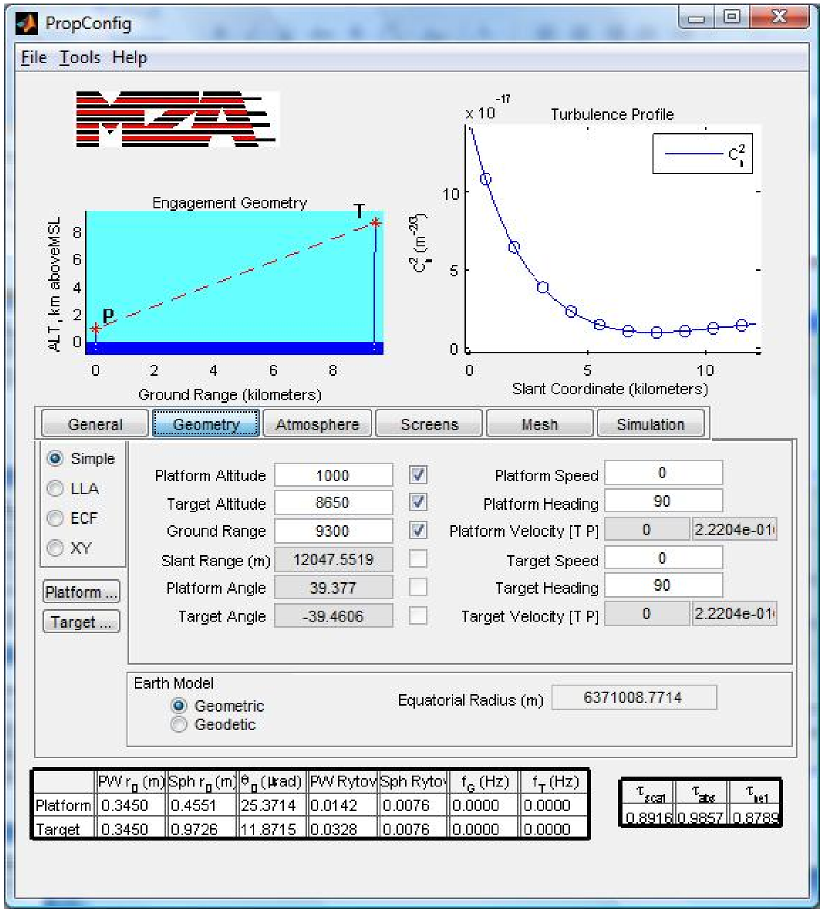
Consider diameter at target plane of 10 cm



Wavelength either select from pop-up menu or type in a value

Values in menu are those for which abs/scat data exists for MODFAS profile. Can enter other wavelengths with the option of running MODTRAN and FASCODE to get new data.

Geometry Setup



- **Geometry tab gives the user four different options for setting/changing geometry**
  - **Simple – combination of altitude, range, and elevation angles, speed and heading**
  - **LLA – Latitude, Longitude, Altitude specification**
  - **ECF – Earth Centered Fixed specification**
  - **XY – Specify velocity decomposition in the plane perpendicular to the propagation**
- **Can select platform/target location from a database of common sites using push buttons on the left**
- **Can also change earth model and radius**
  - **Geometric/spherical**
  - **Geodetic/oblate**

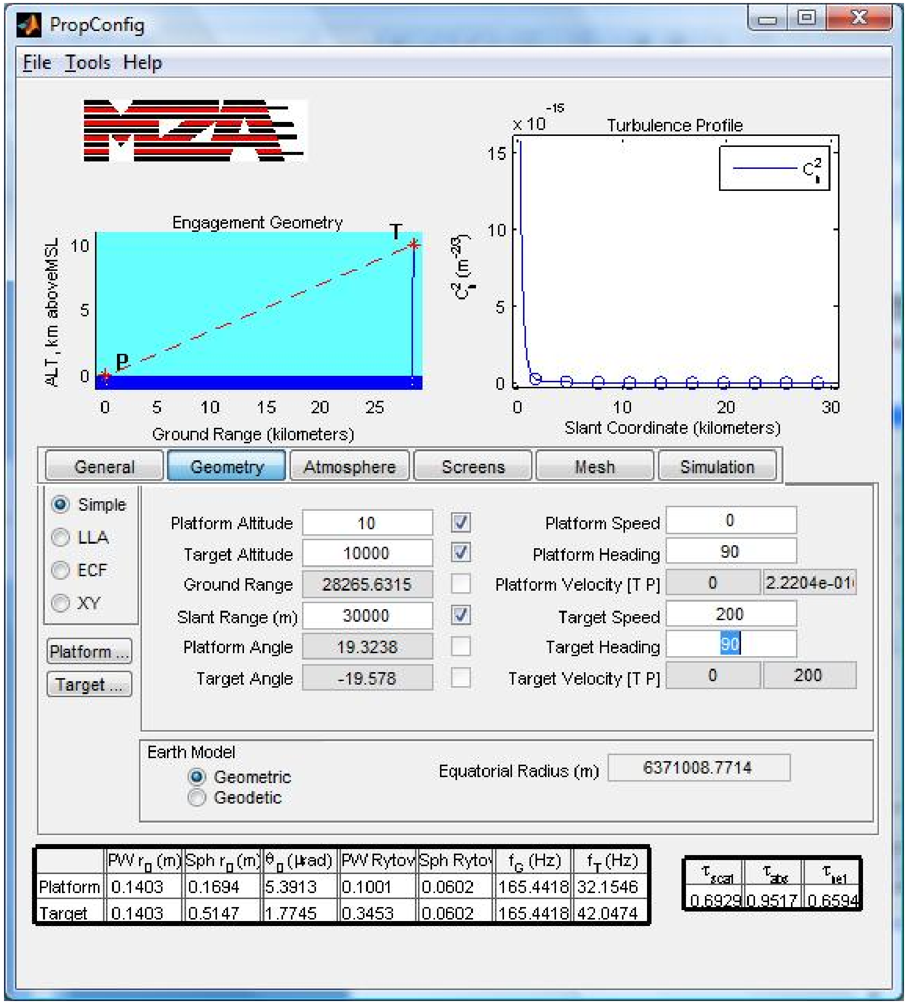
Example Geometry

Use the Simple geometry specification

- Assumes no vertical speed (can be specified using LLA or XY)

- Places Target at lat/long [0 0] and Platform South of that

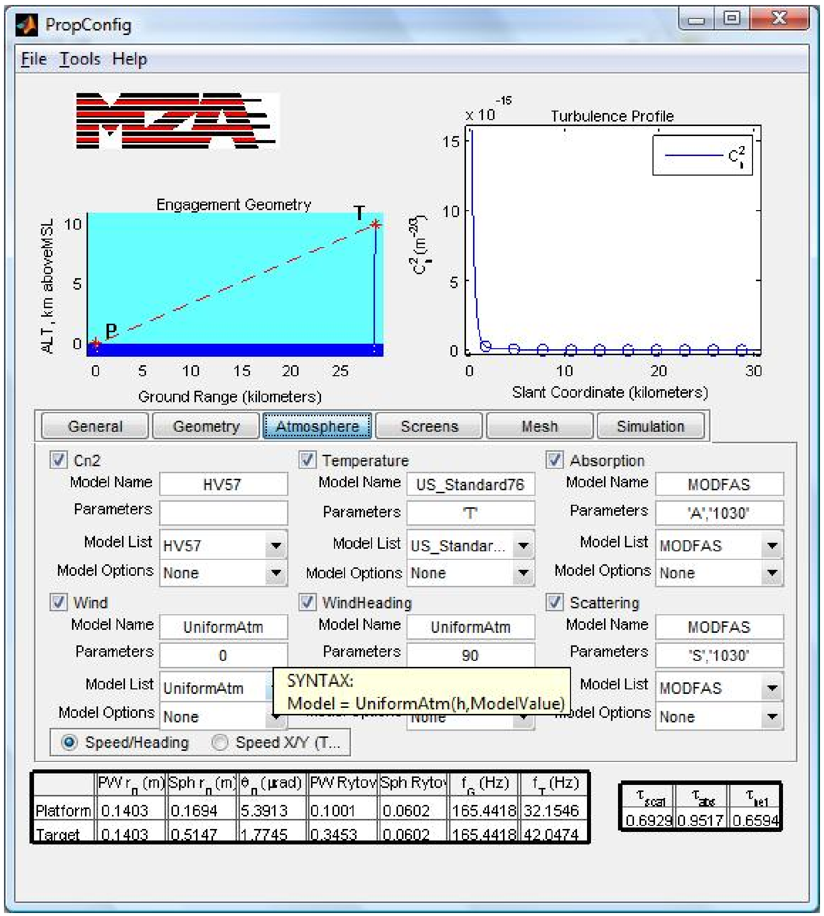
Uncheck Ground Range box and check Slant Range box to specify slant range



Set altitudes speeds and headings

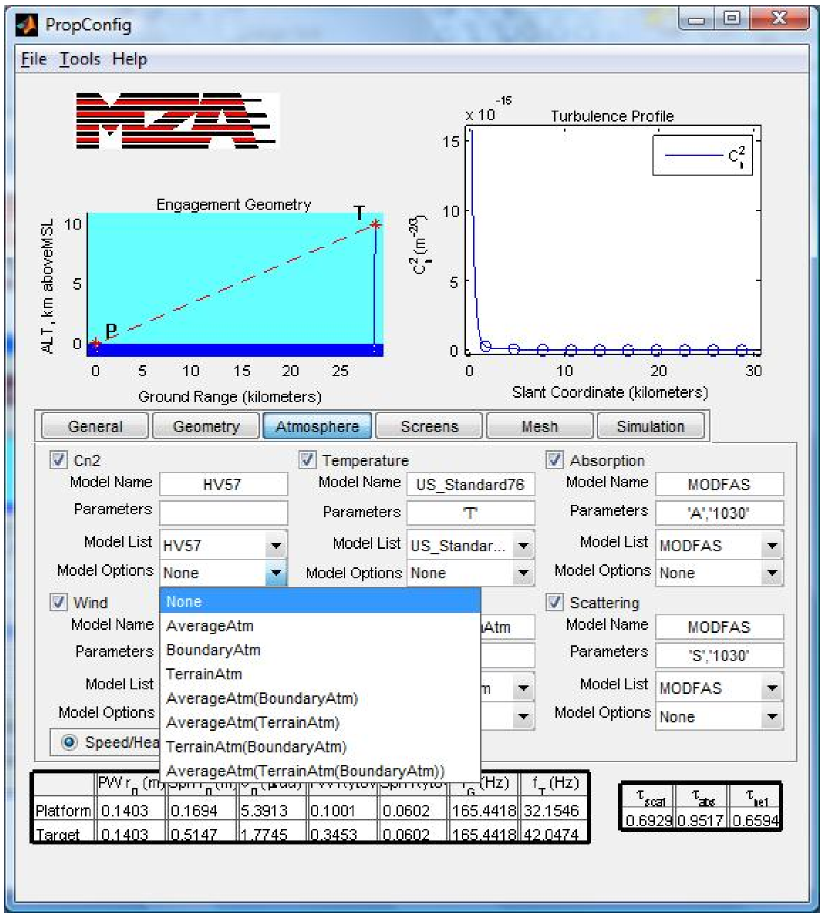
Computes velocity decomposition based on target velocity vector

Atmosphere Setup



- The Atmosphere tab is where the user specifies for each available model (C_n^2, Wind, Temperature, etc) the profile that is to be used
- Can include or exclude any of the available models
- The profiles can be any Matlab function (on the Matlab path) with altitude as the first input, including user-defined functions.
  - Model List pop-up menu contains all model functions available in ATMTools
  - Model Options pop-up menu contains options for modifying the output of the base profile
- Tooltips on Model Name box and Parameters box displays help on function syntax
  - Right+click on Model Name or Parameters fields to get more help
- Option with natural wind to specify speed and heading (like Simple geometry) or specify velocity XY decomposition (like XY geometry)

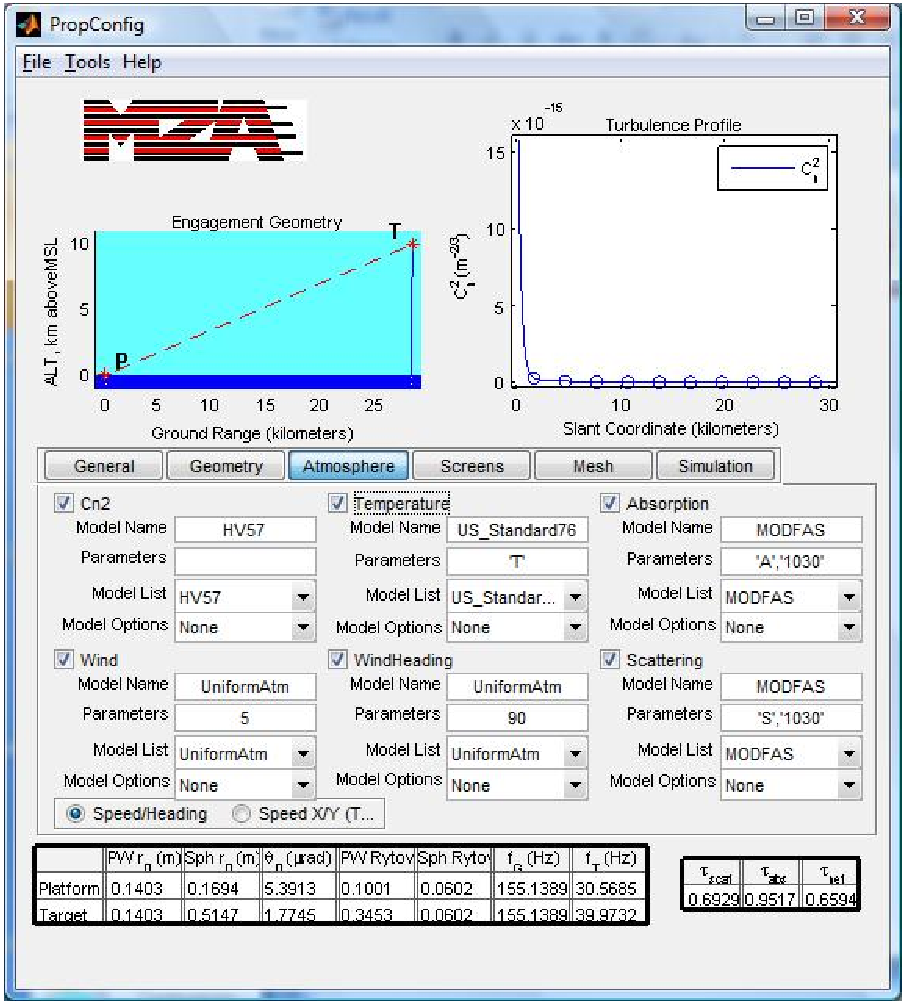
Model Options



- **Various model options for modifying the output of the base profile**
  - **AverageAtm – compute average value of model (Cn2) for each phase screen segment as opposed to using the value at the screen altitude**
  - **BoundaryAtm – scale screen altitudes in some interval (say ground to top of boundary layer) to some other interval (0 to top of boundary layer)**
  - **TerrainAtm – subtract ground altitude from all altitudes**
  - **And combinations of these**

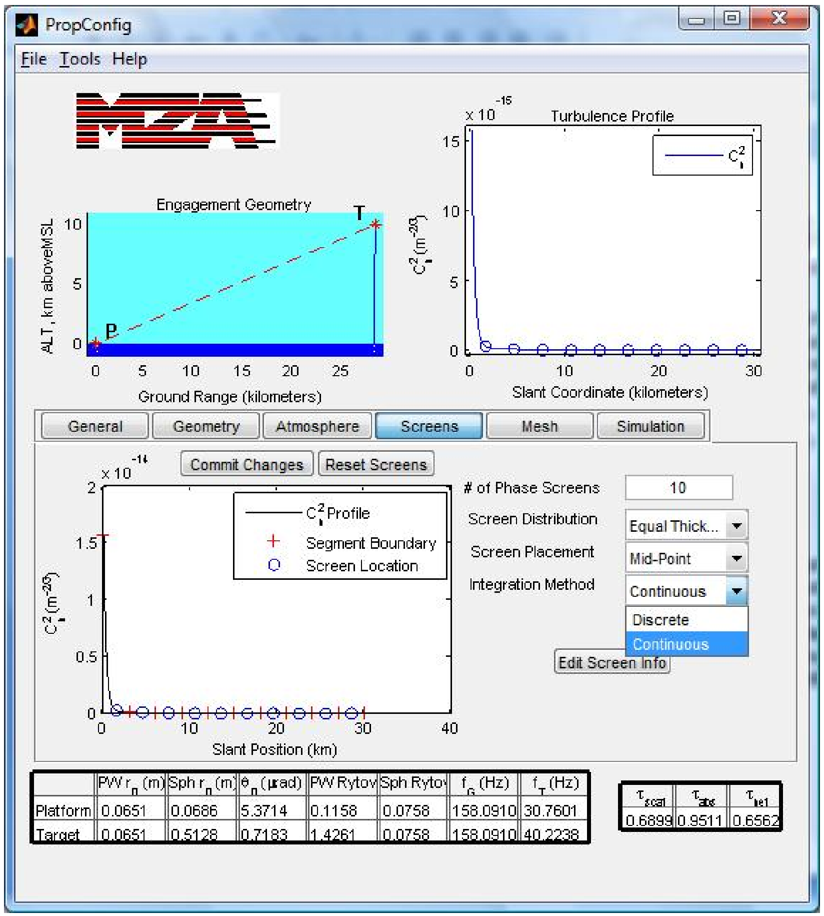
MZA Associates Corporation
Albuquerque — Dayton — Jupiter

Example Atmosphere



Using all the default settings with the exception of wind speed

Phase Screen Setup



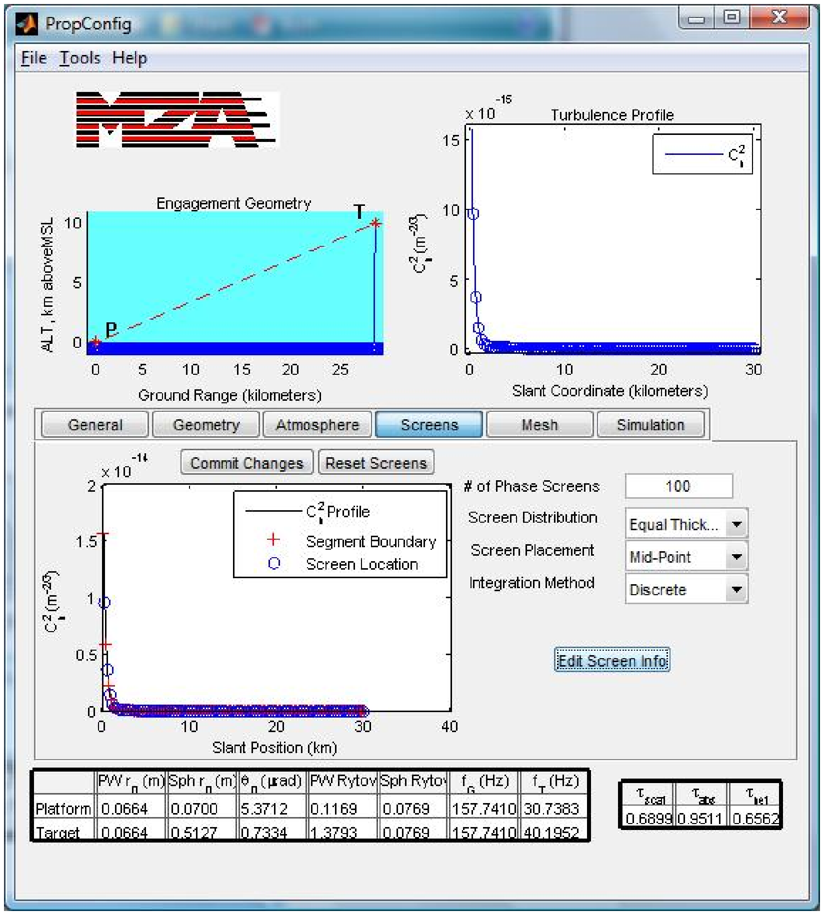
- **Screens tab allows the user to change the number of phase screens, how they are distributed and where they are located**
  - **Use standard settings or**
  - **Customize via the plot or the table that is displayed by clicking the "Edit Screen Info" button**
    - **Table described in later slides**

- **Can also specify method for computing atmospheric parameters, either continuous integration of the profile or discrete based on the screen settings**
  - **By default, PropConfig loads with discrete integration**

Variation of Screen Settings

- Will examine the affects of various settings for phase screen number, distribution, and location
- For wave optics simulation, would like the fewest number of screens possible such that using discrete integration approximates the atmospheric parameters when continuous integration is used
  - Wave-optics simulations are not continuous, need to specify screens
  - Fewer screens = faster sims
- For the example (from previous slide) using continuous integration would like r0 to be within 2%
  - Spherical r0 for Platform – between 6.72 and 7 cm
  - Spherical r0 for Target – between 0.5025 and 0.5231 m

Number of Screens

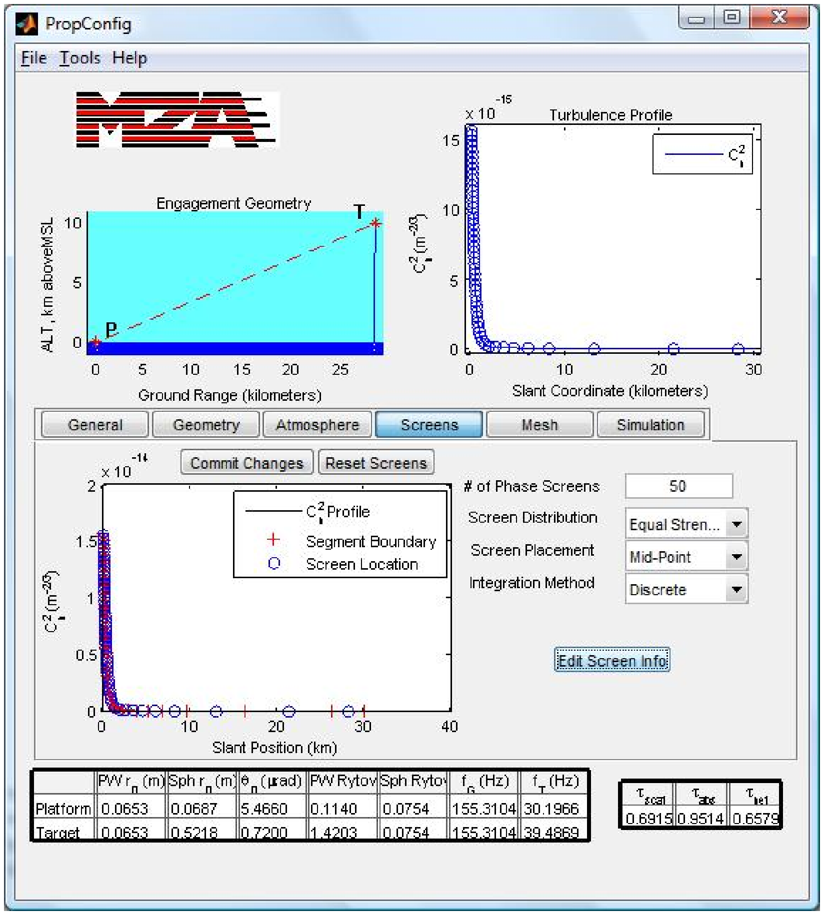


Experiment with different numbers of screens and placement with Equal Thickness screens

Need about 100 equally-spaced screens at mid-point of segments to get both spherical r0 values close (within 2%) to the continuous case

# of Screens	Platform r_0 (cm)	Target r_0 (cm)
10	16.94	51.47
20	10.29	51.12
50	7.43	51.24
100	7.00	51.27
200	6.89	51.28

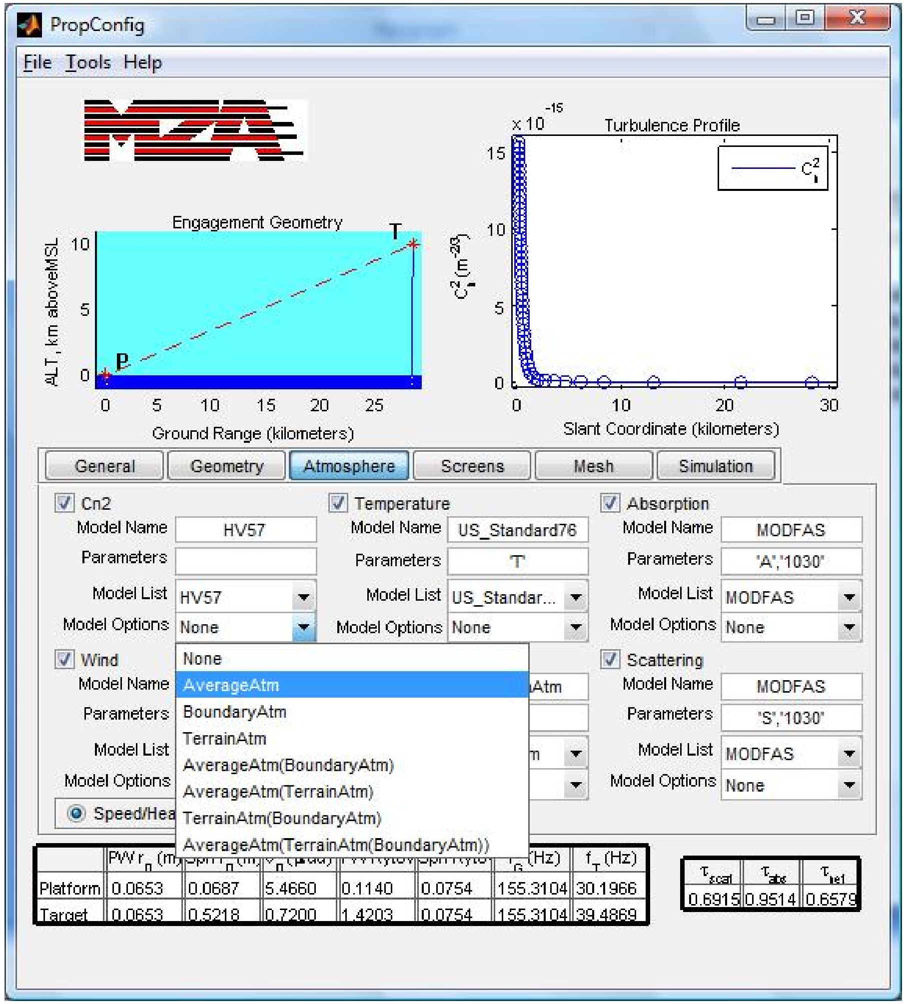
Screen Distribution



Change screen distribution to Equal Strength and experiment with screen number and placement

Need at least 50 screens located at mid-points to get close to r0 values for the continuous case

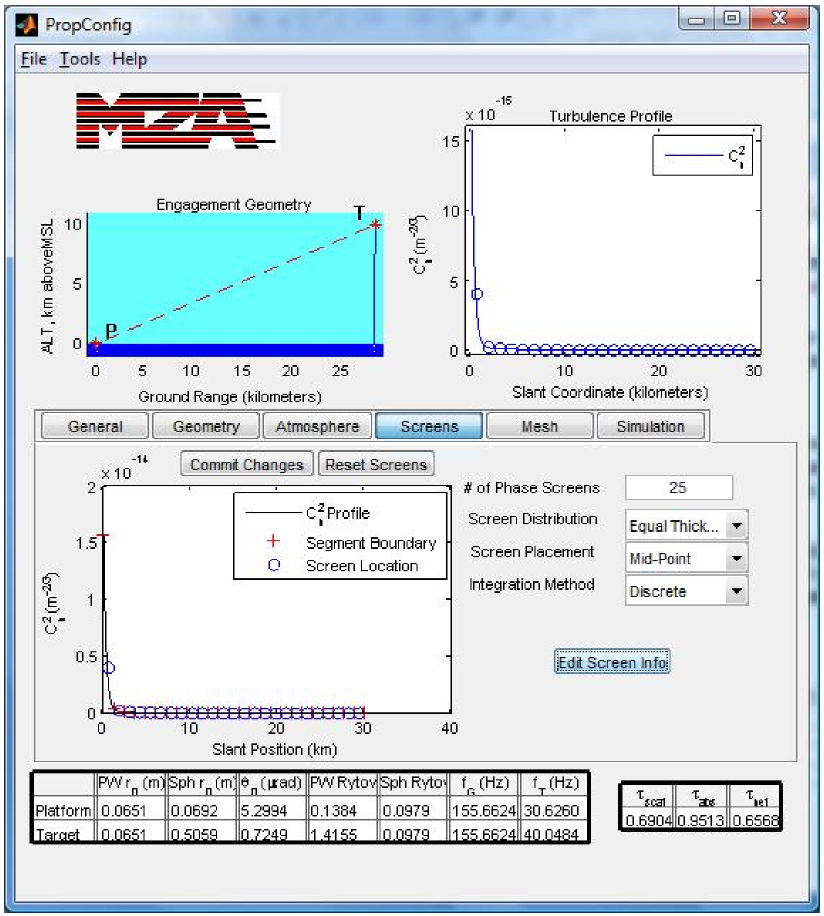
Using Model Options



Try the model averaging option for Cn2

Go back to Atmosphere tab and select AverageAtm for Cn2 model

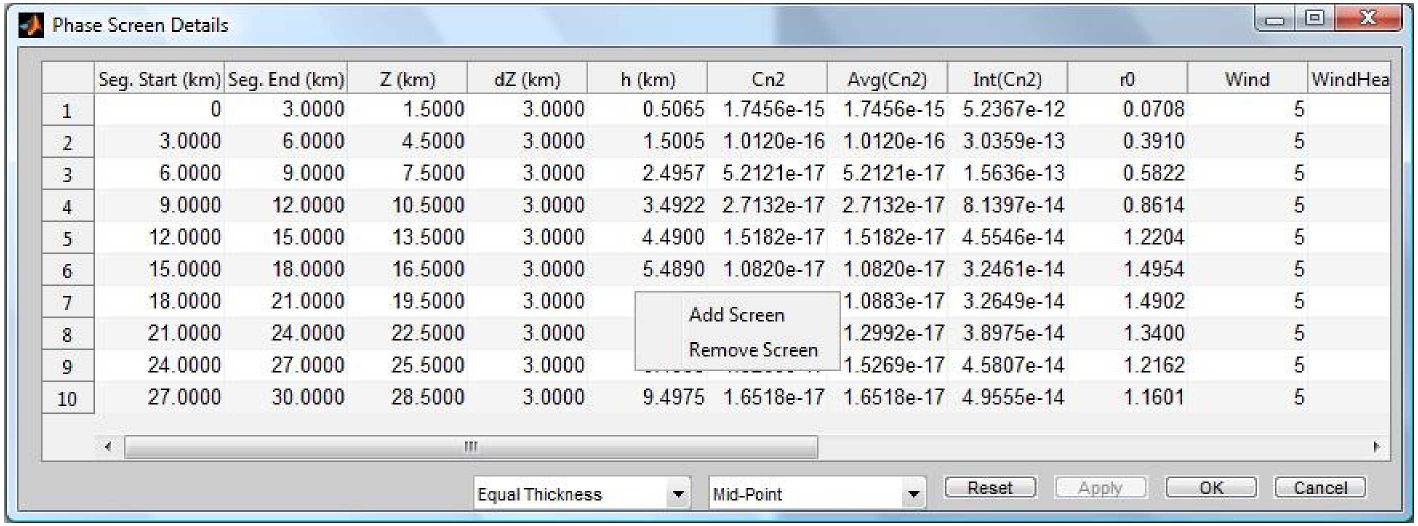
Number of Screens with AverageAtm Option



- **Change number of screens with AverageAtm option selected for Cn2 and equal thickness distribution**
- **Increasing beyond 50 screens doesn't change r0's much. Using 25 screens could be sufficient**

# of Screens	Platform r_0 (cm)	Target r_0 (cm)
10	7.10	47.11
20	6.95	50.16
50	6.87	51.14
100	6.86	51.25

Custom Screen Settings



	Seg. Start (km)	Seg. End (km)	Z (km)	dZ (km)	h (km)	Cn2	Avg(Cn2)	Int(Cn2)	r0	Wind	WindHea
1	0	3.0000	1.5000	3.0000	0.5065	1.7456e-15	1.7456e-15	5.2367e-12	0.0708	5	
2	3.0000	6.0000	4.5000	3.0000	1.5005	1.0120e-16	1.0120e-16	3.0359e-13	0.3910	5	
3	6.0000	9.0000	7.5000	3.0000	2.4957	5.2121e-17	5.2121e-17	1.5636e-13	0.5822	5	
4	9.0000	12.0000	10.5000	3.0000	3.4922	2.7132e-17	2.7132e-17	8.1397e-14	0.8614	5	
5	12.0000	15.0000	13.5000	3.0000	4.4900	1.5182e-17	1.5182e-17	4.5546e-14	1.2204	5	
6	15.0000	18.0000	16.5000	3.0000	5.4890	1.0820e-17	1.0820e-17	3.2461e-14	1.4954	5	
7	18.0000	21.0000	19.5000	3.0000	[illegible]	[illegible]	1.0883e-17	3.2649e-14	1.4902	5	
8	21.0000	24.0000	22.5000	3.0000	[illegible]	[illegible]	1.2992e-17	3.8975e-14	1.3400	5	
9	24.0000	27.0000	25.5000	3.0000	[illegible]	[illegible]	1.5269e-17	4.5807e-14	1.2162	5	
10	27.0000	30.0000	28.5000	3.0000	9.4975	1.6518e-17	1.6518e-17	4.9555e-14	1.1601	5	

- **Clicking the “Edit Screen Info” button on the Screens tab will bring up a table for viewing data in a tabular form and for customizing screen settings**
  - **In main GUI set number of screens to 10 before clicking “Edit Screen Info”**
- **Right+click to add or remove screens**
- **Can manually edit segment boundaries, screen locations, and other model data (Cn2, screen r0, Wind, Abs, etc)**
- **Can adjust screen placement and distribution to standard options**
- **After making any changes, must click “OK” or “Apply” to see how changes affect atmospheric parameters in the main window**
- **Use “Reset” or “Cancel” to discard changes**

MZA Associates Corporation
Albuquerque — Dayton — Jupiter

Example Custom Screens

Phase Screen Details

	Seg. Start (km)	Seg. End (km)	Z (km)	dZ (km)	h (km)	Cn2	Avg(Cn2)	Int(Cn2)	r0	Wind	WindHea
1	0	2.9000	0.5000	2.9000	0.1755	1.8009e-15	1.8009e-15	5.2225e-12	0.0709	5	
2	2.9000	6.0000	4.5000	3.1000	1.5005	1.0247e-16	1.0247e-16	3.1766e-13	0.3805	5	
3	6.0000	9.0000	7.5000	3.0000	2.4957	5.2121e-17	5.2121e-17	1.5636e-13	0.5822	5	
4	9.0000	12.0000	10.5000	3.0000	3.4922	2.7132e-17	2.7132e-17	8.1397e-14	0.8614	5	
5	12.0000	15.0000	13.5000	3.0000	4.4900	1.5182e-17	1.5182e-17	4.5546e-14	1.2204	5	
6	15.0000	18.0000	16.5000	3.0000	5.4890	1.0820e-17	1.0820e-17	3.2461e-14	1.4954	5	
7	18.0000	21.0000	19.5000	3.0000	6.4892	1.0883e-17	1.0883e-17	3.2649e-14	1.4902	5	
8	21.0000	24.0000	22.5000	3.0000	7.4907	1.2992e-17	1.2992e-17	3.8975e-14	1.3400	5	
9	24.0000	27.0000	25.5000	3.0000	8.4935	1.5269e-17	1.5269e-17	4.5807e-14	1.2162	5	
10	27.0000	30.0000	28.5000	3.0000	9.4975	1.6518e-17	1.6518e-17	4.9555e-14	1.1601	5	

Custom | Custom | Reset | Apply | OK | Cancel

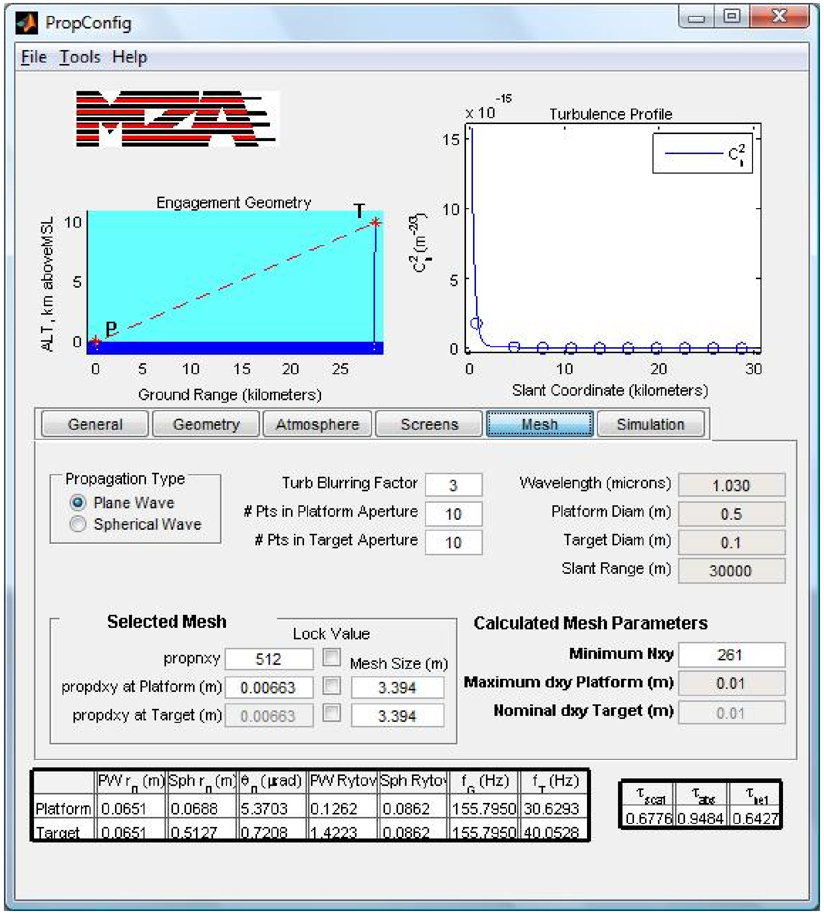
- **Adjust screen settings and click "Apply" to see how changes affect atmospheric parameters**
- **The above table shows one possible solution to achieve the r0's for continuous integration using 10 screens (move first screen to 0.5 km and decrease thickness slightly)**
  - **Spherical r0 for Platform – 0.0688 m (compared to 0.0686)**
  - **Spherical r0 for Target – 0.5127 m (compared to 0.5128)**

Screen Settings

- Many different ways to change the settings to get similar results
- May need to also monitor other atmospheric parameters
- Ultimately it is up to the user to determine when the settings are "good enough" based on what the requirements are or what is needed from the simulations

MZA Associates Corporation
Albuquerque — Dayton — Jupiter

Mesh Parameters

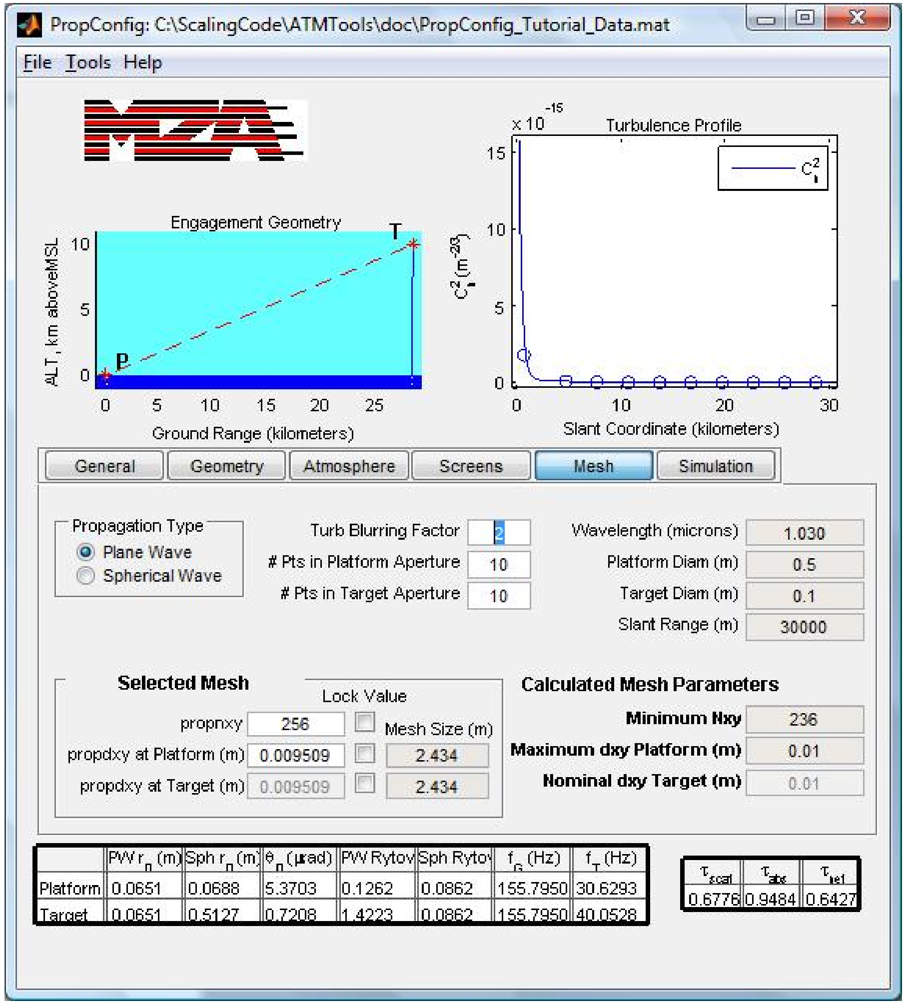


- **Mesh tab contains calculations for setting propagation mesh parameters for input to a wave-optics model.**
- **Can compute parameters for either plane wave or spherical wave propagation**
- **Computes a minimum grid size and maximum pixel spacing and recommends values to be used**
- **Can modify the turbulence blurring factor or specify minimum number of points in the aperture as needed**
- **For the example, mesh size (propdxy) is limited by the minimum number of points in aperture**

MZA Associates Corporation
Albuquerque — Dayton — Jupiter

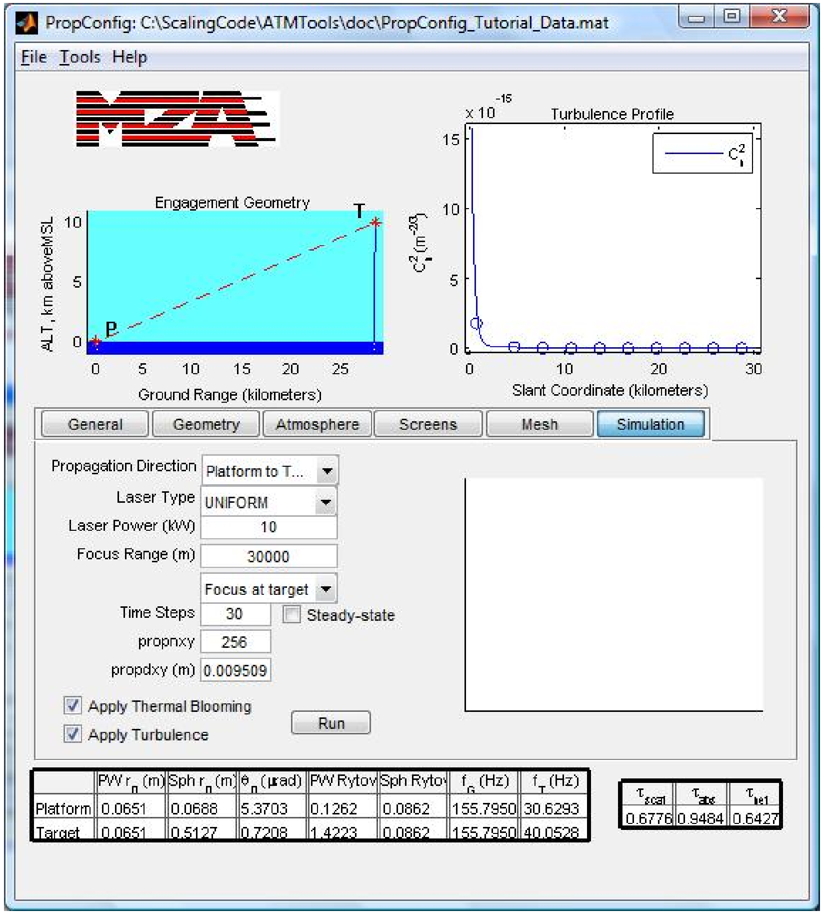
Example Mesh

From previous slide the minimum Nxy is 261, and gets rounded up to 512 (the next power of 2)



Changing the turbulence blurring factor to 2 will yield more optimistic mesh settings (smaller grid)

Simulation Setup



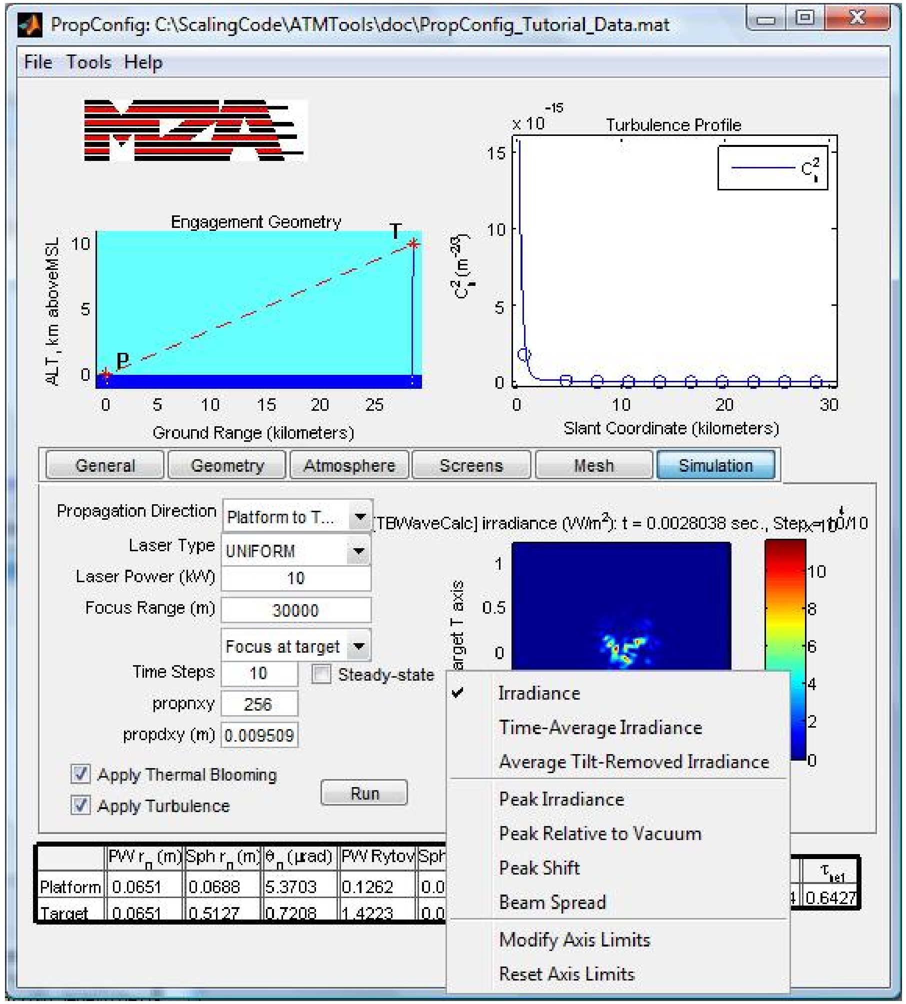
	PW r_0 (m)	Sph r_0 (m)	θ_0 (µrad)	PW Rytov	Sph Rytov	f_G (Hz)	f_T (Hz)
Platform	0.0651	0.0688	5.3703	0.1262	0.0862	155.7950	30.6293
Target	0.0651	0.5127	0.7208	1.4223	0.0862	155.7950	40.0528

τ_scat	τ_abs	τ_tot
0.6776	0.9484	0.6427

- **PropConfig has a built-in simulation capability based on TBWaveCalc in ATMTools.**
  - **Open-loop simulation that can include both turbulence and thermal blooming**
- **Options include**
  - **Propagation direction**
    - **Currently only propagates from an aperture**
  - **Laser type**
  - **Laser power (important for thermal blooming)**
  - **Focus range of the transmitting optics**
  - **Number of time steps**
  - **Mesh can be changed independently of settings on Mesh tab.**

Example Simulation

Change Time Steps to 10 and run simulation



Once simulation completes, right+clicking on the y-axis label will allow the user additional options for displaying the data

A slider bar below the image (not visible in picture at right) allows the user to display irradiance at different time steps

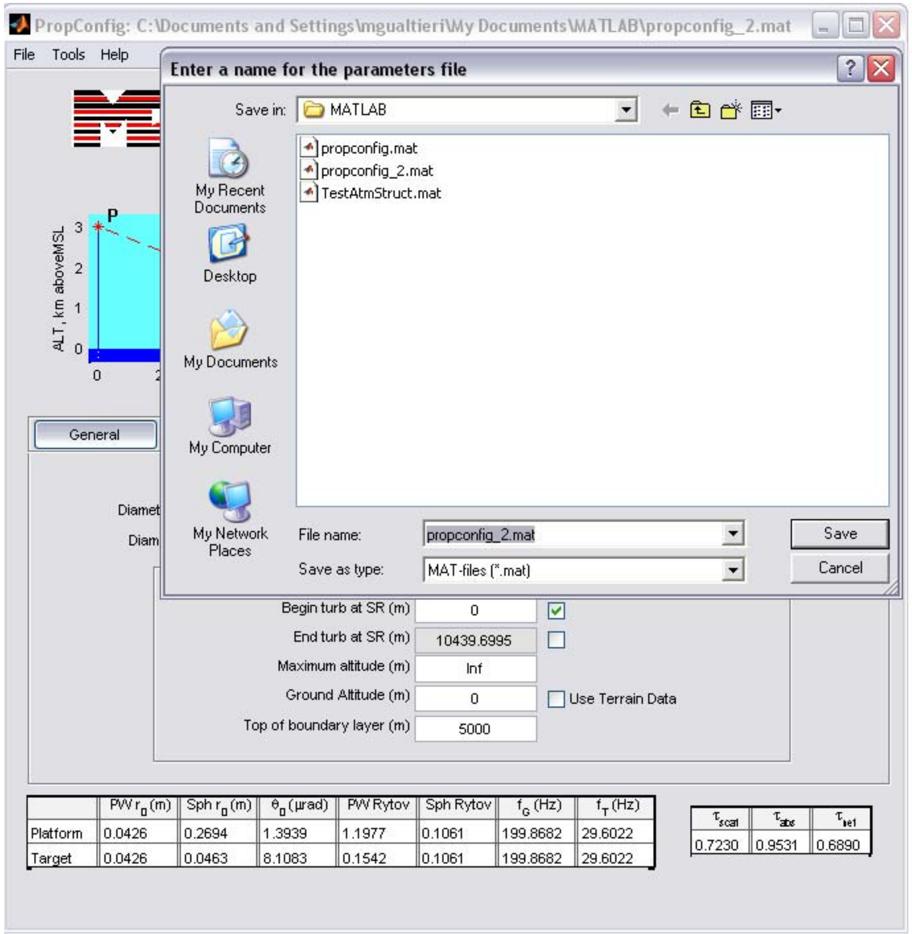
Other Capabilities

- **Output the Atm and G structures for use with other functions in ATMTools, EngagementTools, and SHaRE (via the Tools menu)**

- **Save data to a Matlab .mat file and load data files previously saved with PropConfig (via the File menu)**
  - **Saved data file contains Atm and G structures for use with other functions in ATMTools and EngagementTools and other data necessary for populating PropConfig (wavelength, diameters, etc)**
    - **The utility keeps track of recent files/directories**
  - **PropConfig can also load data files previously saved with TurbTool**
  - **Data can then be loaded into a WaveTrain runset for doing wave optics simulation or loaded into Matlab to set up an engagement in SHaRE (Scaling for High Energy Laser and Relay Engagement)**

- **Refer to the ATMTools and EngagementTools user's guides for more information**

Save to File



Save the PropConfig data to a Matlab .mat file using File->Save…

Data in a PropConfig File

- List of variables in a PropConfig data file:

ATMToolsVer	1x1	struct	Trans_Abs	1x1	double
ApDiamPlatform	1x1	double	Trans_Scat	1x1	double
ApDiamTarget	1x1	double	Wavelength	1x1	double
Atm	1x1	struct	computedScreenData	1x1	struct
FFTbase	1x1	double	meshParamsPW	1x1	struct
G	1x1	struct	meshParamsSPH	1x1	struct
GeomSpec	1x2	char	propdxy	1x1	double
GndAlt	1x1	double	propdxy2	1x1	double
HELFocus	1x1	double	propnxy	1x1	double
HELPower	1x1	double	screens	1x1	struct
PlatformPropMetrics	1x1	struct	targZenithProjection	1x2	double
S	1x1	struct	targZenithTP	1x2	double
SimResults	0x0	double	targZenithXY	1x2	double
SimStatus	1x1	cell			
TargetPropMetrics	1x1	struct			

computedScreenData

```
computedScreenData =

       platformAlt: 2755                     WindVelocityP: [20x1 double]
         targetAlt: 1231                     WindVelocityT: [20x1 double]
       groundRange: 1.9936e+004               EffVelocityP: [20x1 double]
        slantRange: 2.0000e+004               EffVelocityT: [20x1 double]
        platformVp: 50                          platformVy: 50
        platformVt: 0                           platformVx: 0
          targetVp: 2.2204e-016                   targetVy: 2.2204e-016
          targetVt: 0                             targetVx: 0
       psPositions: [20x1 double]            WindVelocityY: [20x1 double]
     psThicknesses: [20x1 double]            WindVelocityX: [20x1 double]
               Cn2: [20x1 double]             EffVelocityY: [20x1 double]
     IntegratedCn2: [20x1 double]             EffVelocityX: [20x1 double]
               Abs: [20x1 double]
              Scat: [20x1 double]
              Temp: [20x1 double]
               Lin: [20x1 double]
              Lout: [20x1 double]
         r0Screens: [20x1 double]
    wavelength4r0s: 1.3150e-006
```

Pulling Data into WaveTrain

- **With WaveTrain 2010A, there are two options for populating a run with data from PropConfig:**
  1) **Load the computedScreenData structure and any other parameters needed using mliLoad. Use mliGetField to pull the required information from the data structure. Use your favorite AcsAtmSpec constructor.**
     - **This option is available in WaveTrain 2009A as well**
  2) **Call PropConfigAtmSpec, instead of AcsAtmSpec, and/or PropConfigTBAtmSpec, instead of MtbAtmSpec, with the Matlab data file name to construct the AcsAtmSpec object**
     - **Can still use mliLoad to load any additional parameters that may be needed**
     - **The object created by PropConfigAtmSpec has methods for returning propnxy, propdxy, HEL focus range and HEL power as specified in the PropConfig data file**

PropConfigAtmSpec

```
PropConfigAtmSpec(const char* matFileName,
                  bool useGeometryForSlewWind=true,
                  float transmission=1.0,
                  int instantaneous=0);

PropConfigAtmSpec(float cn2factor,
                  const char* matFileName,
                  bool useGeometryForSlewWind=true,
                  float transmission=1.0,
                  int instantaneous=0);

PropConfigAtmSpec applyCn2Factor(float factor=1.0);

int nxy() { return _nxy; }
float dxy() { return _dxy; }
float HELPower() { return _HELPower; }
float HELFocus() { return _HELFocus; }
```

- **Requires Matlab file name, optional inputs for turbulence multiplier, including slew wind and scaling for atmospheric transmission**
- **There is a constructor for AcsAtmSpec that uses an ATKAtmStruct**
  - **However, it only pulls out turbulence and screen locations/thicknesses**
  - **This new constructor can get everything needed, i.e. turbulence, wind (natural and optionally slew), inner and outer scale, wavelength and screen information**
- **The TurbTool data file constructor for AcsAtmSpec still exists**

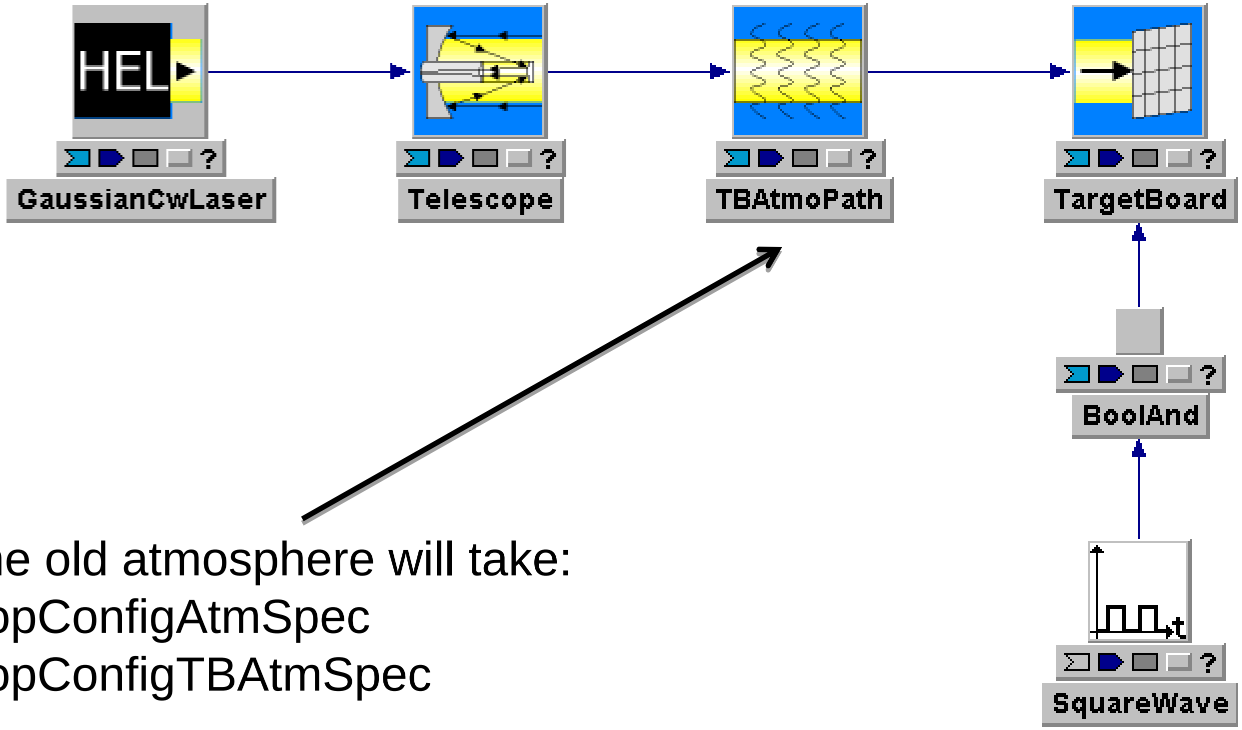
PropConfigTBAtmSpec

```
PropConfigTBAtmSpec(const char* matFileName,
                    bool useGeometryForSlewWind=true,
                    float xvs=0,
                    float yvs=0,
                    float xvt=0,
                    float yvt=0,
                    int numberSavedStates=1);

PropConfigTBAtmSpec(const char* matFileName,
                    int nxy,
                    float dxy,
                    float xmin,
                    float ymin,
                    float dtime,
                    bool useGeometryForSlewWind=true,
                    float xvs=0,
                    float yvs=0,
                    float xvt=0,
                    float yvt=0,
                    int numberSavedStates=1);
```

- **MtbAtmSpec does not have a constructor that uses ATKAtmStruct, so this new constructor simplifies things a bit**
- **Also has the option to include slew wind**

Example System



Same old atmosphere will take:
- PropConfigAtmSpec
- PropConfigTBAtmSpec

Example Runset

Run Variables

	Type	Name	Value	De
1	int	idx	$loop(1)	
2				
3	PropConfigAtmSpec	atmSpec	PropConfigAtmSpec("propconfig.mat")	
4	PropConfigTBAtmSpec	tbSpec	PropConfigTBAtmSpec("propconfig.mat")	
5				
6	int	nxy	atmSpec.nxy()	
7	float	dxy	atmSpec.dxy()	
8	float	lambda	atmSpec.lambda()	
9	float	pathLength	atmSpec.pathLength()	
10	float	HELFocus	atmSpec.HELFocus()	
11	float	HELPower	atmSpec.HELPower()	

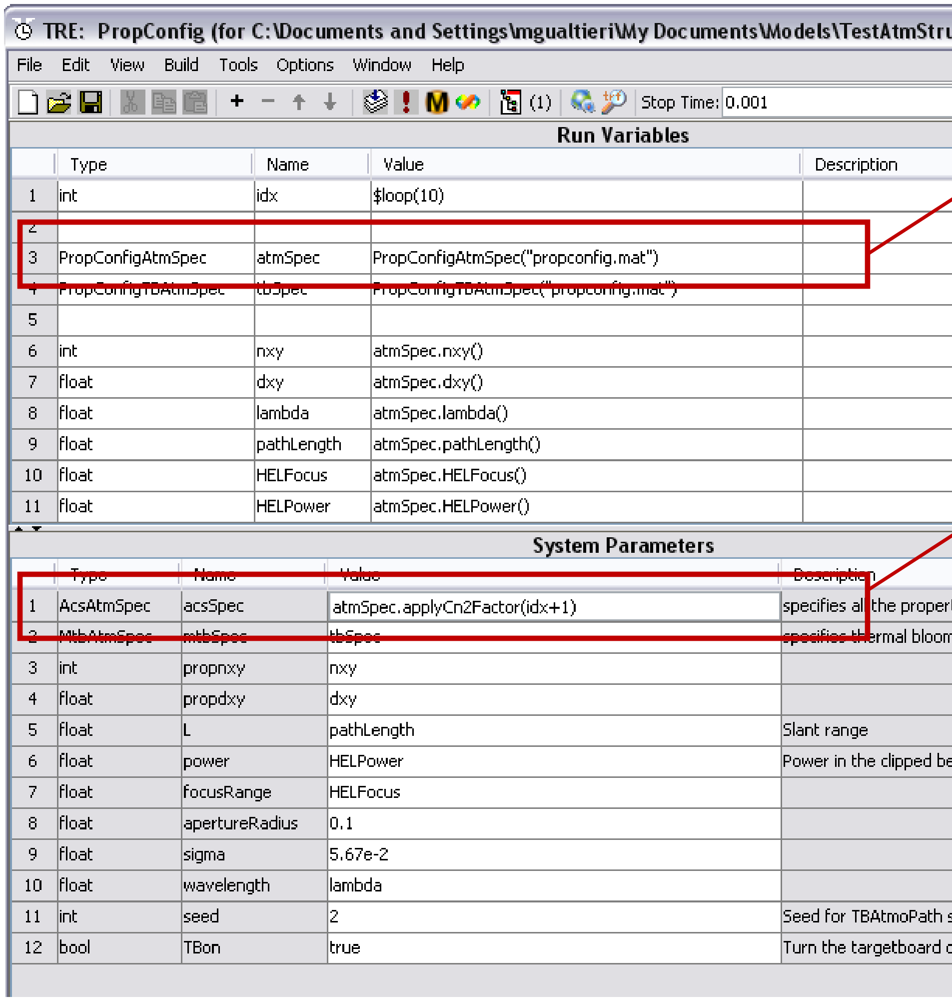
System Parameters

	Type	Name	Value	Desc
1	AcsAtmSpec	acsSpec	atmSpec	specifi
2	MtbAtmSpec	mtbSpec	tbSpec	specifi
3	int	propnxy	nxy	
4	float	propdxy	dxy	
5	float	L	pathLength	Slant r
6	float	power	HELPower	Power
7	float	focusRange	HELFocus	
8	float	apertureRadius	0.1	
9	float	sigma	5.67e-2	
10	float	wavelength	lambda	
11	int	seed	idx+2	Seed f
12	bool	TBon	true	Turn tl

- **PropConfigAtmSpec and PropConfigTBAtmSpec are classes derived from AcsAtmSpec and MtbAtmSpec**
- **They can be used in any existing atmospheric path module**

MZA Associates Corporation
Albuquerque — Dayton — Jupiter

Applying Turbulence Factor


TRE: PropConfig (for C:\Documents and Settings\mgualtieri\My Documents\Models\TestAtmStru

File Edit View Build Tools Options Window Help

Stop Time: 0.001

Run Variables

	Type	Name	Value	Description
1	int	idx	$loop(10)	
2				
3	PropConfigAtmSpec	atmSpec	PropConfigAtmSpec("propconfig.mat")	
4	PropConfigTBAtmSpec	tbSpec	PropConfigTBAtmSpec("propconfig.mat")	
5				
6	int	nxy	atmSpec.nxy()	
7	float	dxy	atmSpec.dxy()	
8	float	lambda	atmSpec.lambda()	
9	float	pathLength	atmSpec.pathLength()	
10	float	HELFocus	atmSpec.HELFocus()	
11	float	HELPower	atmSpec.HELPower()	

System Parameters

	Type	Name	Value	Description
1	AcsAtmSpec	acsSpec	atmSpec.applyCn2Factor(idx+1)	specifies all the propert
2	MtbAtmSpec	mtbSpec	tbSpec	specifies thermal bloomi
3	int	propnxy	nxy	
4	float	propdxy	dxy	
5	float	L	pathLength	Slant range
6	float	power	HELPower	Power in the clipped be
7	float	focusRange	HELFocus	
8	float	apertureRadius	0.1	
9	float	sigma	5.67e-2	
10	float	wavelength	lambda	
11	int	seed	2	Seed for TBAtmoPath s
12	bool	TBon	true	Turn the targetboard o

- **Create an original AtmSpec object**
- **Apply a turbulence factor**
  - **Makes a copy of the original AtmSpec object with a modified turbulence strength**

BLAT01

- **Successfully created versions of the runset BLAT01RunAtoG using data from PropConfig with v2010A-beta in mzadist**
  - **One version loads the computedScreenData structure and sets parameters and variables using mliGetField and uses AcsAtmSpec to set up the atmosphere**
  - **Another version uses PropConfigAtmSpec**
- **Verified that results of the three runs were the same**
  - **Once I found that the screens were being placed at beginning of segments, as opposed to mid-segment as is done in ATMTools**