EVEREST: AN INTEGRATED WEATHER PRODUCTS TESTBED FOR ENVIRONMENTAL REMOTE SENSING SATELLITE SYSTEMS

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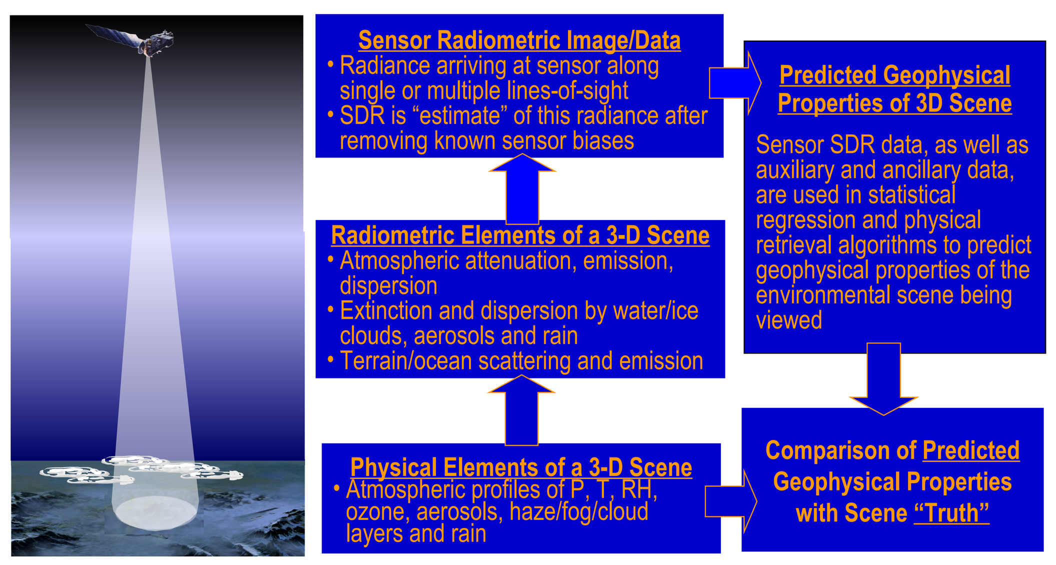
Introduction

An essential tool for an environmental remote sensing mission developer or system integrator is the ability to predict the impact various elements of the system on the performance of the environmental data products (EDR) delivered by the system. EVEREST is an end-to-end modeling and simulation testbed developed by Northrop Grumman to support the NPOESS program, as well as other similar programs, in assessing the performance of EDR during the various phases of the program. It supports design trades early in the development phase, verification testing of sensor data and weather retrieval algorithms, independent performance assessment of impact of sensors developed on EDR, and support of on-orbit calibration and validation of the data products.

The testbed is comprised of five main components: global environmental databases covering typical and extreme environmental conditions, radiative transfer models covering the microwave, optical, and ultra-violet frequency regimes, detailed sensor models capable of reproducing the effects observed by the actual sensors being build, spacecraft models for pointing and jitter, and retrieval algorithms to calculate the weather data records. In addition, EVEREST is also comprised of a detailed event-based simulation that computes latency and processing load for the system.

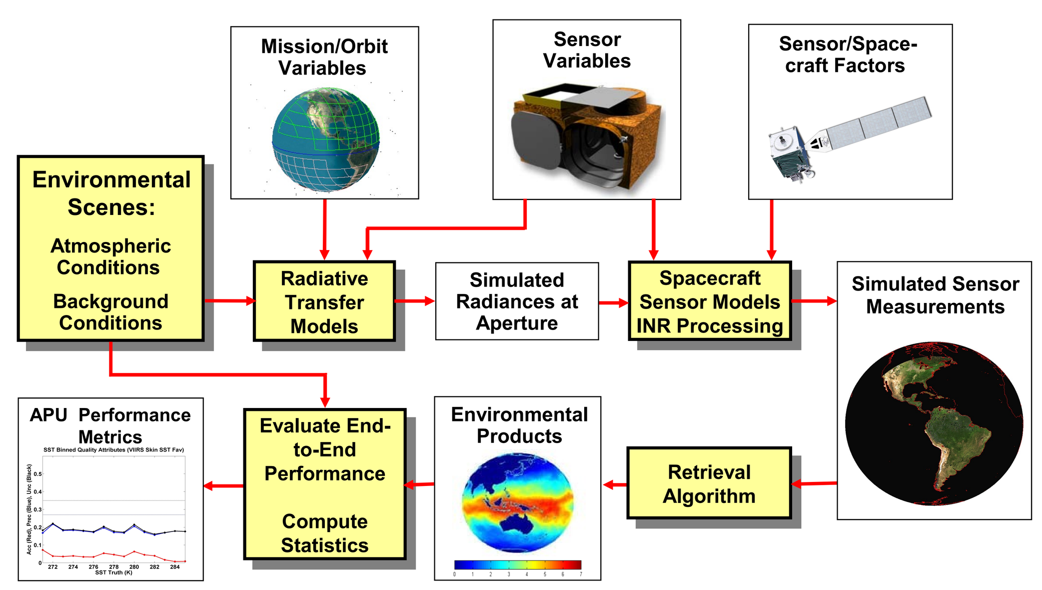
The presentation will highlight the main features of the testbed and how it is used to assess performance of the data products.

What Does EVEREST Do?

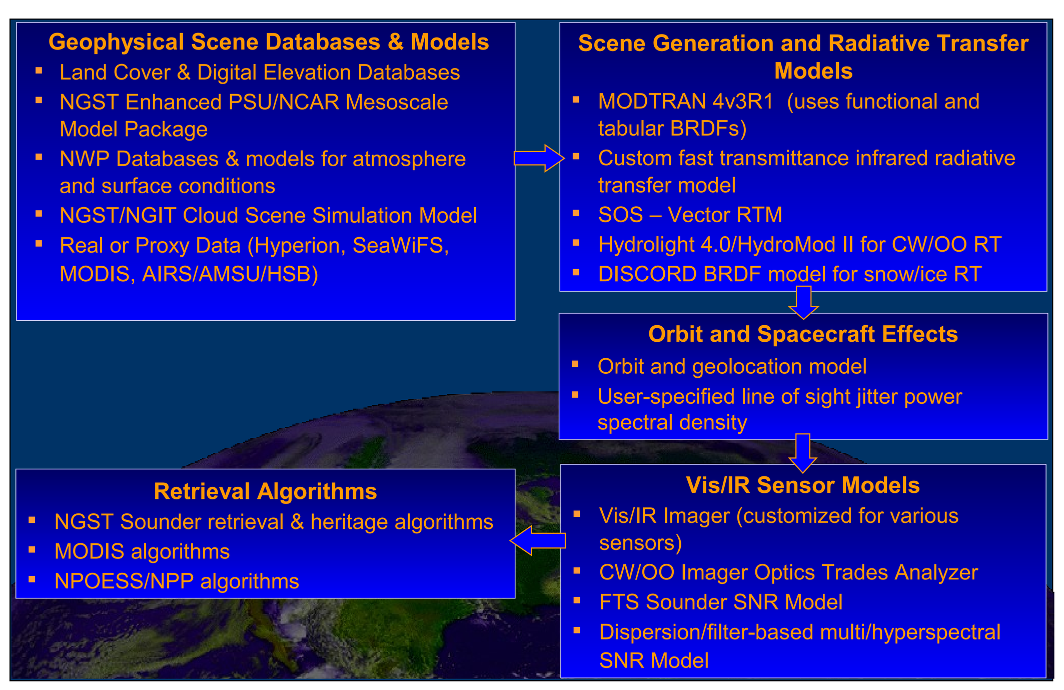


Physics-based phenomenology and sensor/spacecraft models to verify data products performance within required precision, accuracy and uncertainty

EVEREST Block Diagram



Community Standard and Custom Models & Datasets

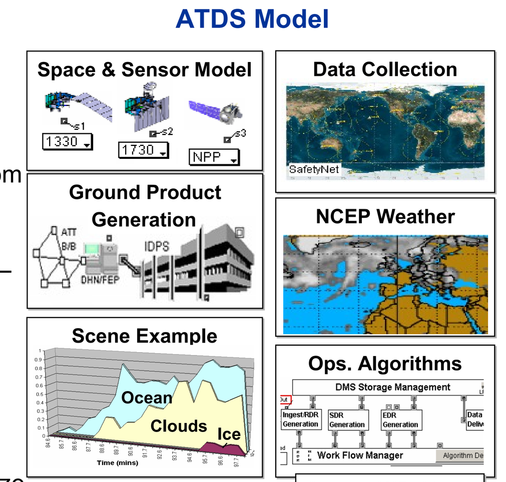


Algorithm Timing & Dependency Simulation Predicts System Latency

Models Latency from Sensor Data Collection to Product Generation

- Space and Sensor Modeling
  - Configurable satellites and sensors
  - Dynamic data collection & retrieval from NPOESS orbits
- Ground Product Generation
  - Models algorithm data dependencies – wiring diagrams
  - Models algorithm sensitivity to scene weather, terrain & day/night
- Data Processing Architecture
  - Supports architectural & cost/latency/quality trades
  - Uses orbital & weather dynamics to size algorithm processing

ATDS Model



ATDS Models Data Latency from Sensors to Product Generation for Systems like NPOESS & GOES-R

Radiative Transfer Models

Frequency Regime	Radiative Transfer Model	Status of EVEREST RTMs
Vis/IR	MODTRAN-4 LBL-RTM 6S & 6SV HydroLight BRDF DISCORD ISBRDF	• MODTRAN, 5S(V), and UCLA's LBLRTM are community standard atmospheric RTMs with known fidelity and limitations • Modifications to MODTRAN and 6S(V) allow input of ocean/terrain BRDF tables • HydroLight BRDF (H-BRDF) ocean RTM, and DISCORD & ISBRDF snow/ice RTMs generate BRDF tables read by MODTRAN & 6S(V) to provide coupled ocean-atmosphere and snow/ice-atmosphere RTM capabilities
IR/m-wave Sounder	HS IR, NGST- ARMSS	• High spectral resolution atmospheric RTM for modeling hyperspectral IR sounders • NGST's ARMSS model for microwave RTMs (see below)
UV	MODTRAN-4+ HERMAN	• Community standard, useful for: TC, NP & LP • HERMAN used in Limb Profile retrieval software [Not a flat earth & horizontal inhomogeneity to be implemented into EVEREST scene generation]
Microwave/ Millimeter-wave	NGST-ARMSS+	• Components verified with published results for other μW models • End-to-end RT compared with field experiments on previous NGST programs • Sanity check with simulated SSM/I and AMSU data • Ongoing validation effort using SSM/I, TMI, AMSR-E and WindSat data

Sensor Models

Frequency Regime	Model Name	EVEREST Capability
Vis/IR	VIRRISM*	• Detailed Vis/IR sensor model • Validated against other VIS/IR models • Includes effects of optical aberrations and line-of-sight jitter • Currently used to model VIIRS, HES CWI and ABI
IR Sounder	NGSTFTS	• Fourier Transform Spectrometer (FTS) radiometric model • Developed 1st principles model; initial comparison with other model gives good results • Includes effects of optical aberrations and line-of-sight jitter • Used to model GIFTS and HES DS • Developed generic m-wave sensor model (used to model AMSU-A and AMSU-B) can also be used as back-up for ATMS
Microwave/ Millimeter-wave Sounding & Imaging	ARMSS+ Model	• Developed generic m-wave sensor model used to model AMSU-A and B, and test performance of SSM/I and AMSR on EVEREST • Used to produce millimeter wave imaging scene and signature

**VIRRISM – Visual/Infrared Radiometric Imaging Sensor Model (Copyright - Northrop Grumman Corp.)*

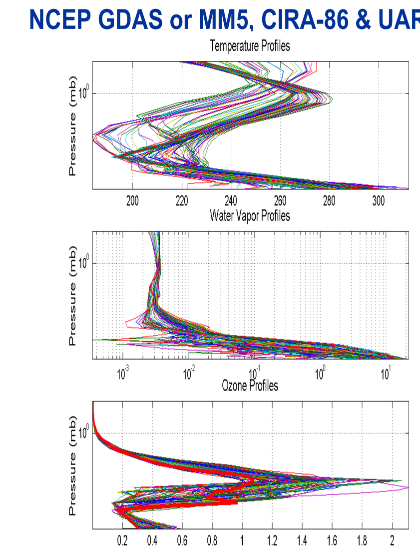
+ ARMSS – Advanced Radiometric Microwave/Millimeter-wave Scene Simulation (Copyright – Northrop Grumman Corp.)

Environmental Scene Requirements for Test Data

- Complete
  - Scene data should provide a "complete" description of the geophysical parameters needed in modeling measurements made by the sensors as they view the scene
  - Must also provide the necessary horizontal, vertical and temporal coverage and resolution needed in simulating TOA radiances and assessing each EDR
- Realistic
  - Geophysical parameter values for a given scene should be those that occur in nature
  - All natural correlations that exist between the various geophysical parameters should be contained in the scene data
- Representative
  - Both the range and frequency of occurrence of the geophysical parameter values should be representative of that observed in nature, and also as viewed by sensors on the spacecraft
- Comprehensive
  - A significant range of all naturally occurring scenes, both typical and extreme, must be adequately sampled in the test data
  - There must be a sufficient number of samples to assess EDR performance over all required stratifications

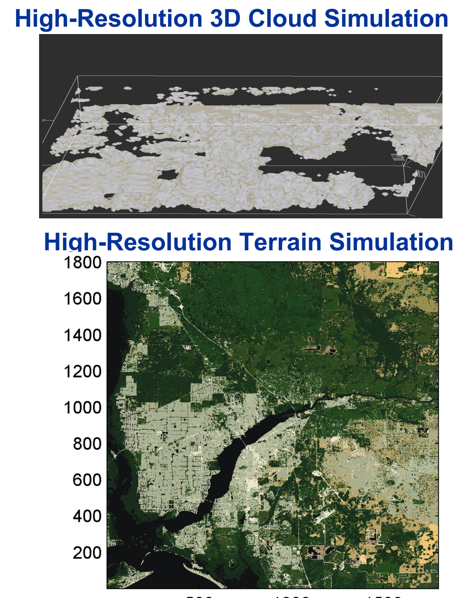
Complete

Atmospheric Profiles of Temperature, Moisture and Ozone Constructed from NCEP GDAS or MM5, CIRA-86 & UARS



High-Resolution 3D Cloud Simulation

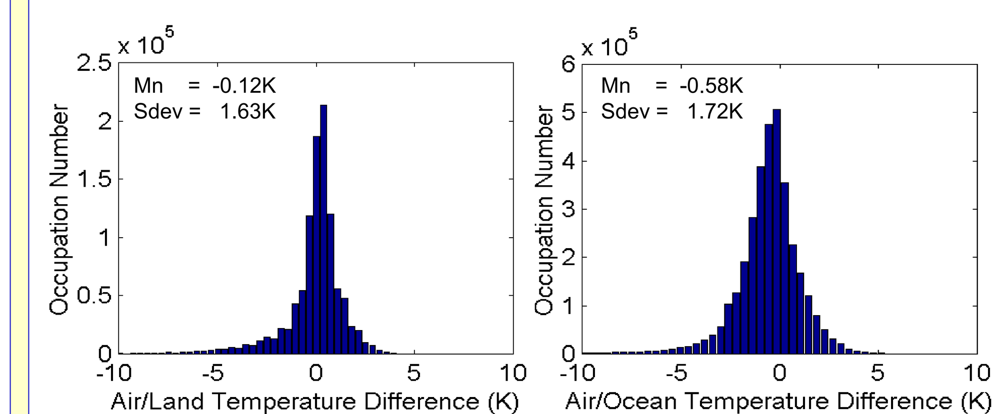
High-Resolution Terrain Simulation



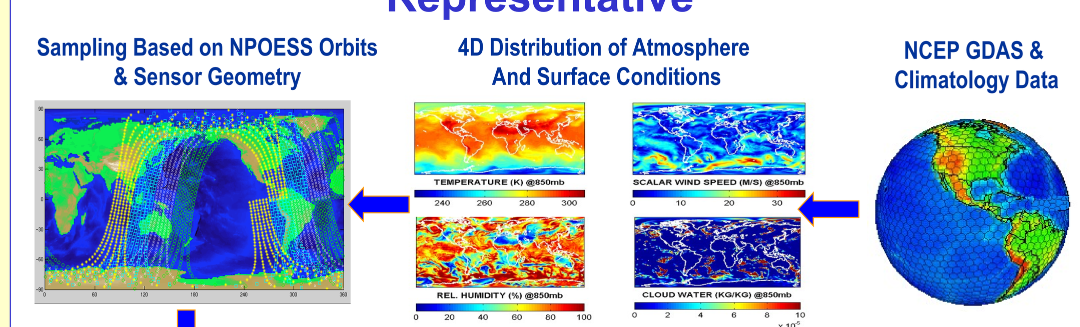
Global dataset based on 12 days of NCEP analyses (1 day/month) resulting in over 3 million atmosphere/surface situations

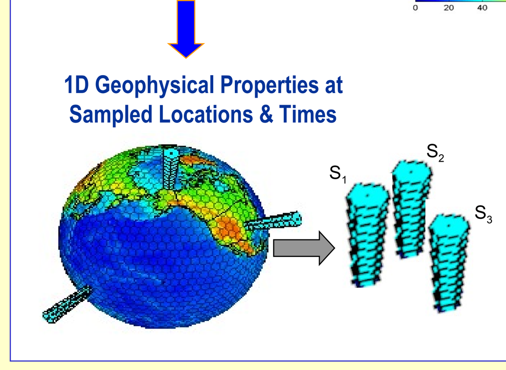
Realistic

- By utilizing a consistent set of atmospheric and surface environmental data, natural correlations that exist between the various geophysical parameters should be contained in "realistic" data
- Below, NCEP distributions of the difference between the near-surface air temperature and the land and sea skin temperatures exhibit these correlations



Representative

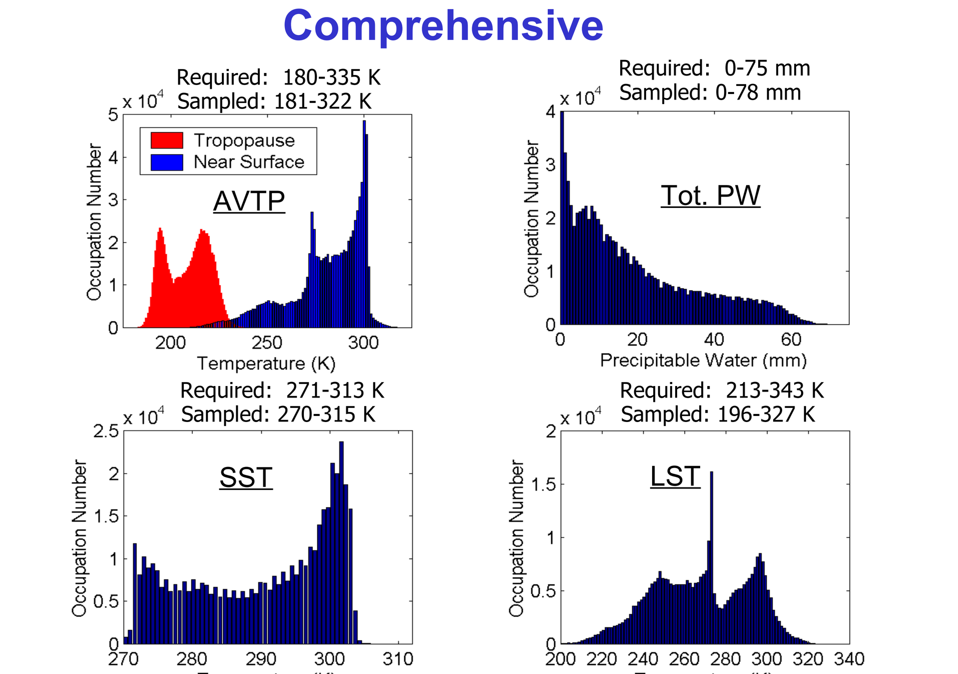




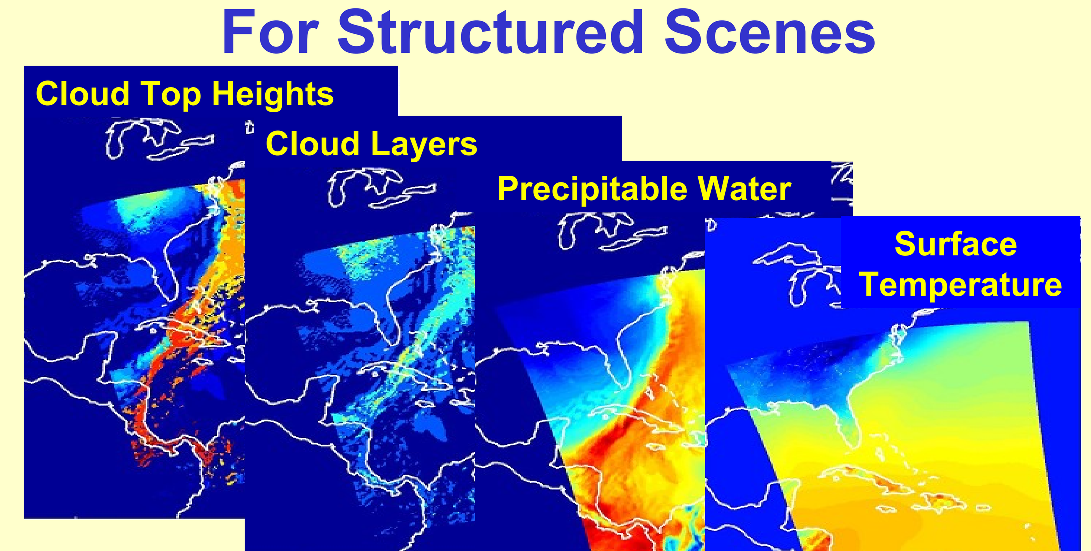
Sampling Approach

- Distribution of atmosphere/surface conditions in space & time is provided by NCEP & climatology
- Sampling of global positions, times and solar/sensor viewing angles is obtained by "flying" sensor for NPOESS 1330 and 1730 orbits
- Produces ~540,000 atmosphere/surface conditions representative of what the sensor should observe on orbit

Comprehensive



Full Resolution Sensor Sampling For Structured Scenes

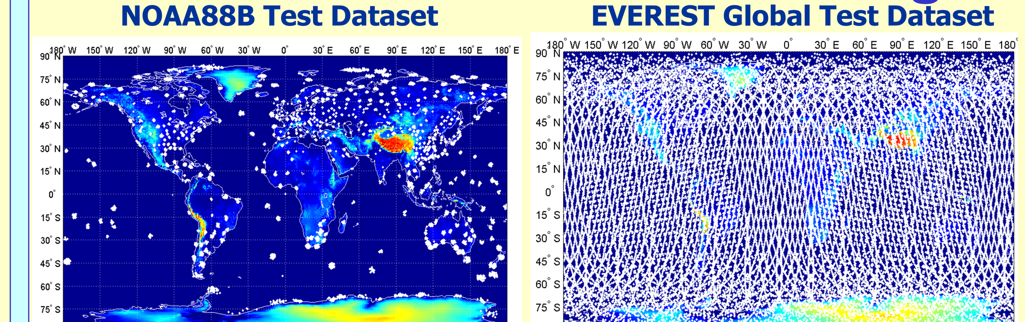


Environmental Properties Displayed at Vis/IR sensor Pixel Locations

Sampling Approach Provides Near Uniform Global Coverage

NOAA88B Test Dataset

EVEREST Global Test Dataset



- Total of 7,547 samples clustered around specific geographic locations
- Only 1,270 samples for open ocean
- Insufficient samples for stratified testing of EDR retrieval algorithms

- The 22,344 samples for 2 orbit planes on a single day provide uniform coverage
- Total of 536,256 samples from 24 days covering a year provide comprehensive testing with global, diurnal and seasonal effects

Summary

Northrop Grumman has developed a world-class simulation laboratory for assessing the performance of environmental data products generated by sensors onboard polar and geo-synchronous orbiting satellites, as well as airborne platforms

- EVEREST remote sensing capability spans the EM spectrum - from Ultra-violet to Microwave
- EVEREST is physics-based capable of assessing global and local accuracy, precision, and uncertainty performance of environmental data products, given a set of sensor performance parameters
- EVEREST leverages recognized capabilities in the larger community as well as a dedicated team trained to be both scientists and engineers
- EVEREST is an essential capability for a remote sensing system integrator