

ISSARS: Instrument Simulator Suite for Atmospheric Remote Sensing and its role for the ACE and GPM missions



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14 – Univ. of Tokyo, Tokyo, Japan; 15 – Ohio State University, Columbus, OH, USA; 16 - Institute for Geophysics and Meteorology, Univ. of Cologne, Germany; 17 – McGill University, Montreal, CA; 18 – Univ. of Utah. Salt Lake City, UT,

USA; 19 – FSU, Tallahassee, FL; 20 - Gwangju Institute of Science and Technology (GIST), Gwangju, South Korea and

Leibniz Institute for Tropospheric Research, Leipzig, Germany; 21 – CIMA Research Foundation, Savona, Italy; 22 -

NOAA/STAR MD, USA;

Outline



- ① Background
- ② Approach and architecture
- ③ User Interface
- ④ Processing modules



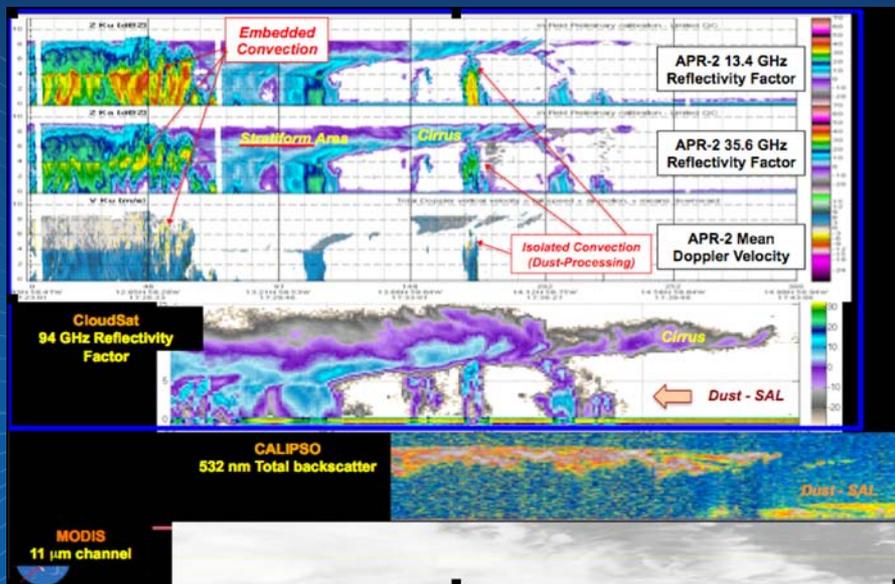
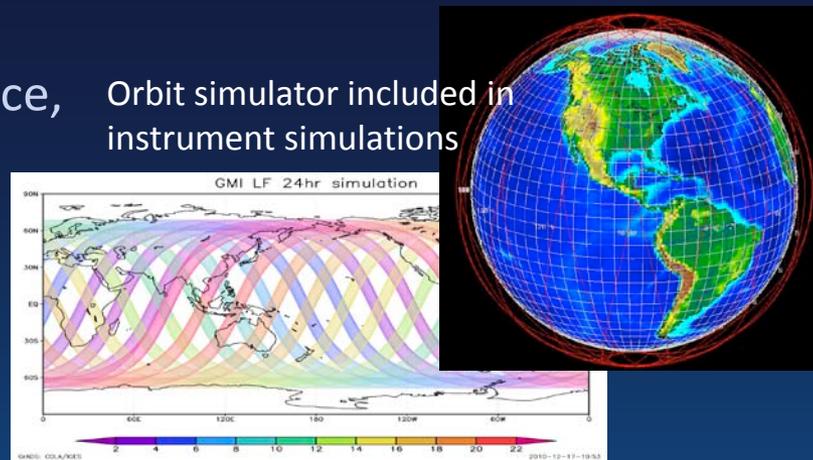
① Background

current needs of the current and planned missions

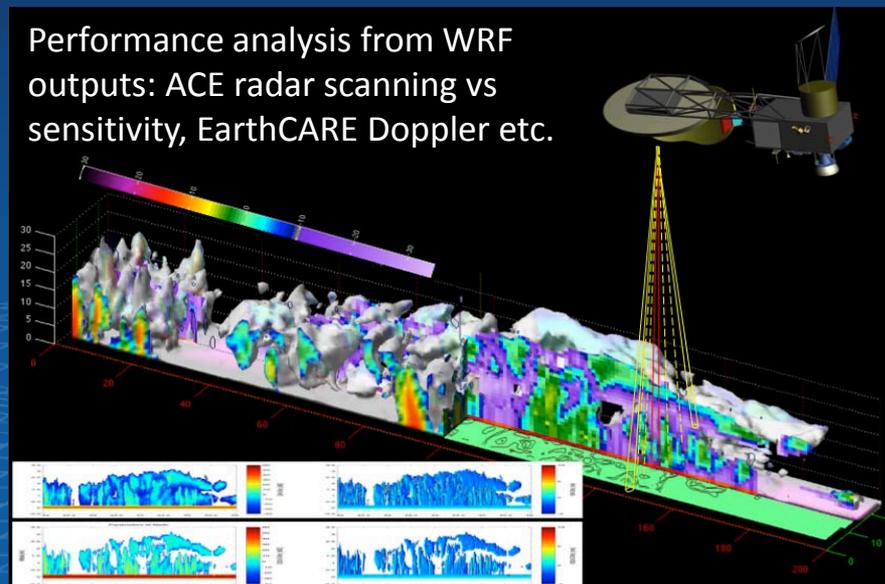
- GPM: algorithm development
- ACE: mission configuration and performance, OSSE, algorithm development
- ASCENDS: OSSE
- A-Train: synergistic/combined retrievals
- EarthCARE: algorithm development

MULTI INSTRUMENT/MISSION SYNERGISTIC RETRIEVALS

Orbit simulator included in instrument simulations



Performance analysis from WRF outputs: ACE radar scanning vs sensitivity, EarthCARE Doppler etc.





① Background

Existing simulators

- Single-instrument or focused simulators
 - Passive instrument only (e.g., CRTM, SHDOM, SOI, DISORT, 3DMC)
 - Active instrument only (e.g., QuickBeam, DS3, DOMUS, HSRLsimulator)
- Mission centric simulators:
 - GPM (e.g., G-SDSU, J-Sim)
 - EarthCARE (e.g., ECSIM)
- Model centric simulators:
 - Embedded in the Atmospheric Model
- Scattering emission and absorption libraries:
 - Calculated often for specific missions and sensors across the decades
 - variable amount of detail, accuracy and information (ranging from very mature databases such as HITRAN to in-house, semi-validated and limited scope research efforts)



② Approach and architecture

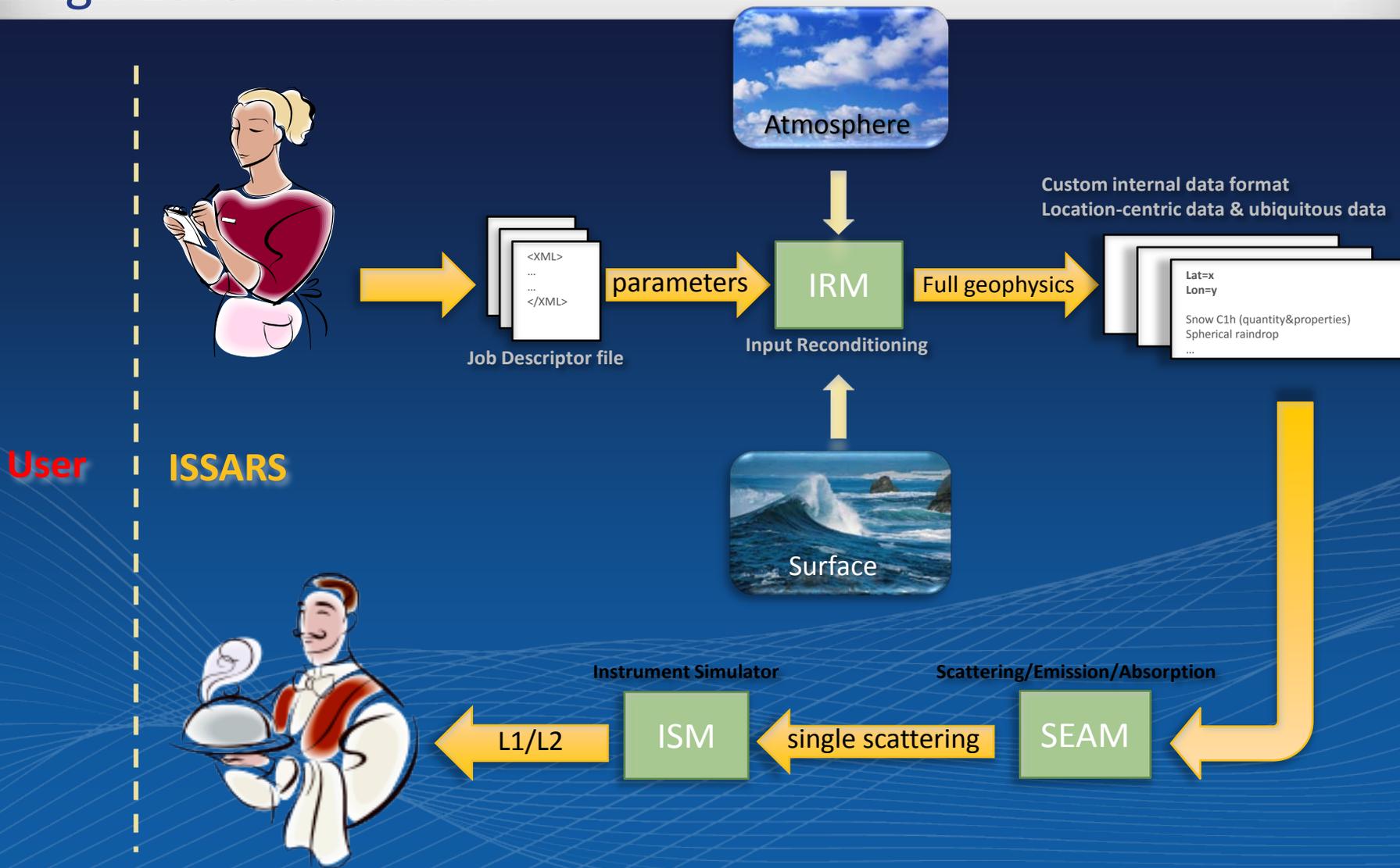
Design Principles

- Separation of user interface from processing modules via Web Services
 - Relieves burden of single-user installation
 - Relieves software release/licensing/privacy issues
 - Decouples interface server (on-line, real-time) from computation server (off-line)
 - The interface is implemented as XML Job Descriptor file
- Separation of geophysical assumptions and models from e.m./optical assumptions and models
 - The same assumptions on geophysical properties are applied to ALL instruments (e.g., particle size distributions) for self-consistency
 - The same e.m. modeling is applied to all instruments operating at the same wavelength range (e.g., refractive index) for self-consistency
- Modularity: Plug and play, dynamic libraries, Look Up Tables, etc.
 - Upgrade and expansion does not require full recompilation if upgrades respect the I/F
 - Python work managers and wrappers allow integration of contributed modules written in C or FORTRAN
 - Look up tables define comprehensive formats, grant fast calculations and are easy to expand and upgrade.
 - The price to pay is in terms of disk space, but it remains a small price compared to the typical sizes of these simulations (>10 GB).
- Heritage: Do not reinvent the wheel!
 - See background slide...
- Infrastructure designed to accommodate more advanced modules than the ones adopted in the initial configuration
- Flexibility vs. speed
 - ISSARS is slanted towards flexibility, with the goal of fostering the production of fast and accurate simulators down the road.
 - Efficiency: Exploit embarrassingly parallel nature of the problem



② Approach and architecture

High Level Workflow

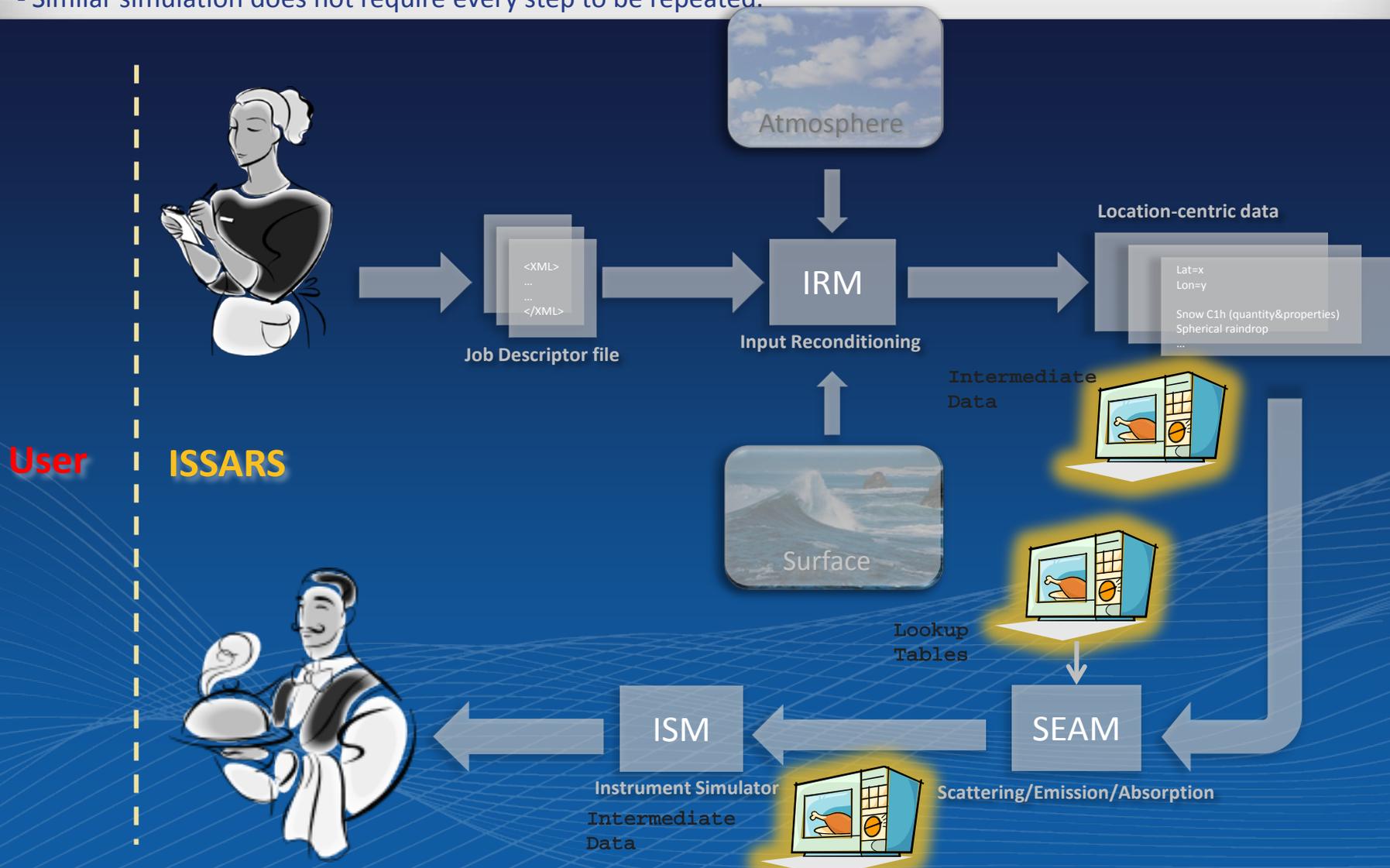




② Approach and architecture

Intermediate data files are saved internally.

- Similar simulation does not require every step to be repeated.





③ User Interface

Main user control panel (aka: login page)

Jet Propulsion Laboratory
California Institute of Technology

JPL HOME EARTH SOLAR SYSTEM STARS & GALAXIES SCIENCE & TECHNOLOGY
BRING THE UNIVERSE TO YOU: JPL Email News | RSS | Podcast | Video

Home Overview Fast Facts Missions News Images Video & Audio Interactives & Downloads

ISSARS Instrument Sensing

Job History for demo
Show 10 entries Search:

ID	Last modified time	Submission time	Status	Description	Actions
101	2010-10-06 18:19:35	Not yet submitted	D	my job description	View/Edit XML Submit Abort Delete
102	2010-10-06 22:03:23	2010-10-12 16:58:28	1s	my job description	View XML Abort Delete
103	2010-10-06 14:18:49	Not yet submitted	D	my job description	View/Edit XML Submit Abort Delete

Showing 1 to 3 of 3 entries

Each user has his/her own job list.

(1) Edit
the Job Descriptor file

(2) Submit
when ready

(3) Check
status

③ User Interface

Geophysics/Electromagnetics/Instrument interface



ISSARS Instrument Simulator Suite for Atmospheric Remote Sensing

Copy Paste Clone Delete QuickLook Geophysics Editor... Chemistry Editor... Save Save As New Back

Atmospheric assumptions > Cloud microphysics > Snow > Same as dataset

Geophysics Electromagnetics Instruments and orbit

Parameters

Name	Value	Unit
------	-------	------

Tag

Update

Help

XML

<channel description="Channel" selectable=">

<_tag>Ku-band precipitation radar (KuP

<frequency description="Frequency"

<_decimal>13.6</_decimal>

<_unit>GHz</_unit>

</frequency>

<receiver description="Receiver">

Parameters are grouped into 3 sections (with defaults)

Tree structure Deeper = Details

Toolbar

③ User Interface

Advanced User Editors



ISSARS Instrument Simulator Suite for Atmospheric Remote Sensing

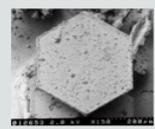
Clone Delete Reload from last saved settings Save the current settings Reset to the master default

Geophysics Descriptor

CHEM ID	SHAPE ID	Name	Probability of appearance	Size Distribution	Mass	Prolateness Ratio	Cross-section	Terminal	Area	Canting	Orientation
0.0.0.0	0.4.0.1	Snow P7b	Neglect	snow (Lin-1983)	-----	-----					
0.0.0.0	0.4.0.2	Snow S3	Neglect	snow (Lin-1983)	snow S3 (P&K-1)	-----					
0.0.0.0	0.4.0.3	Snow P7a	Neglect	snow (Lin-1983)	snow P7a (R&V)	-----					
0.0.0.0	0.4.0.4	Snow S1	Neglect	snow (Lin-1983)	snow S1 (Mitche)	-----					
0.0.0.0	0.4.0.5	Snow N2c	Neglect	snow (Lin-1983)	snow N2c (P&K)	-----					
0.0.0.0	0.4.0.6	Snow C2b	Neglect	snow (Lin-1983)	snow C2b (P&K)	-----					
0.0.0.0	0.4.0.7	Snow R1a	Neglect	snow (Lin-1983)	snow R1a (P&K)	-----	snow R1a (R&V)	-----	max. dimension	moments	moments
0.0.0.0	0.4.0.8	Snow R1b	Neglect	snow (Lin-1983)	snow R1b (P&K)	-----	snow R1b (R&V)	-----	max. dimension	moments	moments
0.0.0.0	0.4.0.9	Snow R1c	Neglect	snow (Lin-1983)	snow R1c (P&K)	-----	snow R1c (R&V)	snow R1c (H. et al.)	max. dimension	moments	moments
0.0.0.0	0.4.0.10	Snow R1d	Neglect	snow (Lin-1983)	snow R1d (P&K)	-----	snow R1d (R&V)	snow R1d (H. et al.)	max. dimension	moments	moments
0.0.0.0	0.4.0.11	Snow R2a	Neglect	snow (Lin-1983)	snow R2a (P&K)	-----	snow R2a (R&V)	snow R2a (H. et al.)	max. dimension	moments	moments
0.0.0.0	0.4.0.12	Snow R2b	Neglect	snow (Lin-1983)	snow R2b (P&K)	-----	snow R2b (R&V)	snow R2b (H. et al.)	max. dimension	moments	moments
0.0.0.0	0.4.0.13	Snow R2c	Neglect	snow (Lin-1983)	snow R2c (P&K)	-----	snow R2c (R&V)	snow R2c (H. et al.)	max. dimension	moments	moments
0.0.0.0	0.4.0.14	Snow R3a	Neglect	snow (Lin-1983)	snow R3a (P&K)	-----	-----	-----	max. dimension	moments	moments
0.0.0.0	0.4.0.15	Snow R3b	Neglect	snow (Lin-1983)	snow R3b (R&V)	-----	-----	snow R3b (H. et al.)	max. dimension	moments	moments
0.0.0.0	0.4.1.0	unrimed radiating	Neglect	snow (Lin-1983)	unrimed radiating	-----	-----	-----	max. dimension	moments	moments
0.0.0.0	0.4.1.1	densely rimed rain	Neglect	snow (Lin-1983)	densely rimed rain	-----	-----	-----	max. dimension	moments	moments

Selected Subkind

Name: Snow R1c
Description: Rimed plate or sector



DIAGNOSTICS

Particle size range

$D_{min} = 0.5 \text{ cm}$
 $D_{max} = 0.7 \text{ cm}$

Distribution size range

$D_{min} = 0.5 \text{ cm}$
 $D_{max} = 0.7 \text{ cm}$

Size Distribution

Function: Exponential PSD with implicit slope parameter

$$n(D) = n_0 \exp(-\lambda_p D)$$

where $\lambda_p = \left(\frac{\pi \rho_p n_0}{\rho_{air} q_p} \right)^{1/4}$

Parameter: snow (Lin-1983)

$n_0 = 3.00E-2$

Terminal Velocity

Function: Power-law

$$v_t(D) = \alpha_0 D^{\beta_1}, D_{min,[mm]} < 10D < D_{max,[mm]}$$

Parameter: snow R1c (H. et al.-1987)

$\alpha_0 = 92$
 $\beta_1 = 0.27$
 $D_{min,[mm]} = 0.8$
 $D_{max,[mm]} = 2.7$

Ziploc: open it, stir, and seal it again.
All settings can be modified

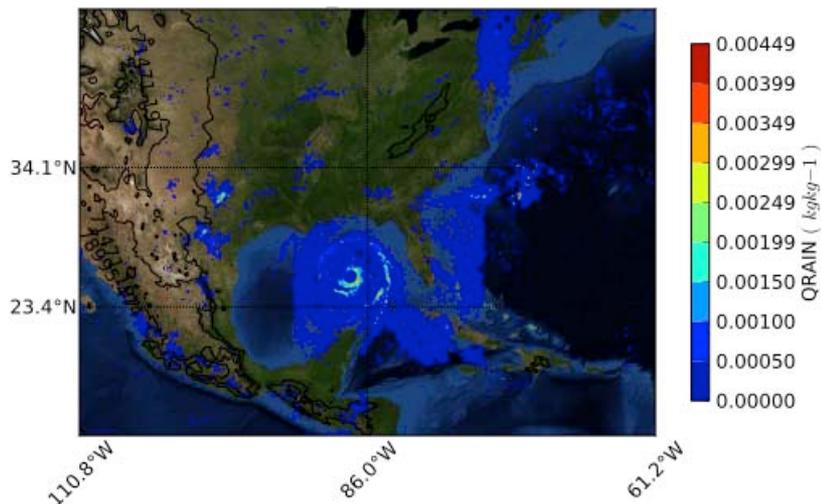
Pre-canned setting
Entered in the treeview as a
Subkind ID



③ User Interface

Quicklook Visualization

- All 2D variables and horizontal cuts of 3D variables can be plotted.
- Images are generated upon request at run-time; no image database needed.
- Downloadable images (PDF/EPS/SVG).
- TBD: Capability to download image data (binary or ASCII); facilitating off-line comparison with other sources.



Data

Image:
Line:
Altitude: kPa

Display

Bluemarble

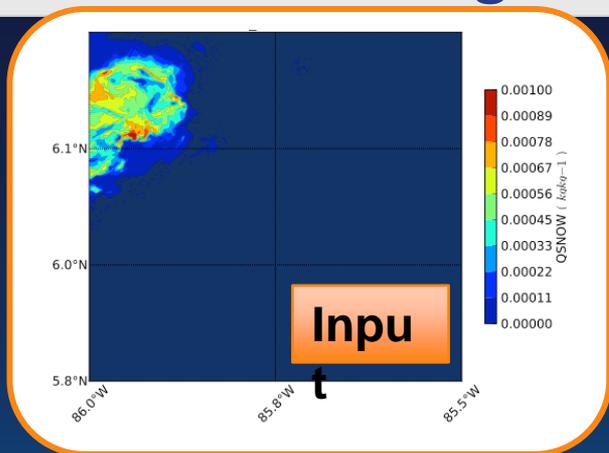
Download

File Format:

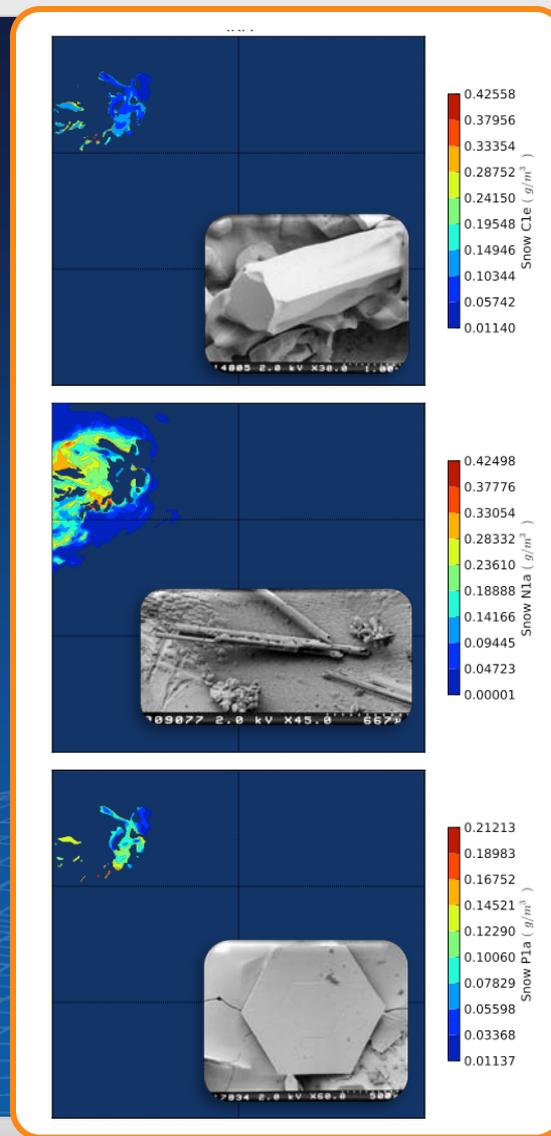
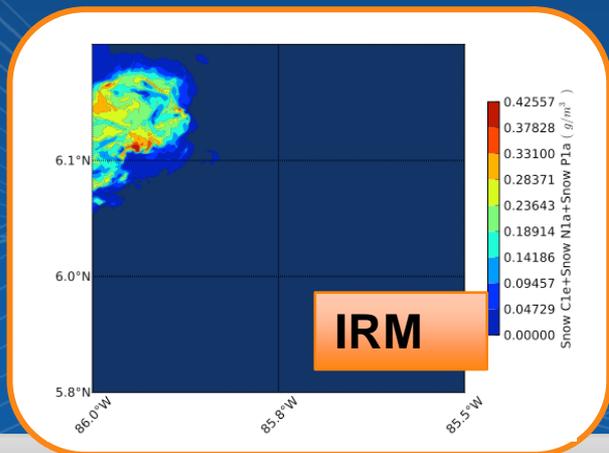
Quantities displayed

Average pressure of layer plotted

④ Processing Stage 1: IRM Input Reconditioning Module



- Snow mass density at 300 mbar altitude
- IRM was run with Multi Habit option for snow species
- Three habits of snow crystals are reported based on given temperature and relative humidity at the location.



Column

Needle

Plate



④ Processing Stage 2: SEAM

Scattering, Emission and Absorption Modules

SEAMs GUI

ISSARS MY TALK MY PREFERENCES MY WATCHLIST MY CONTRIBUTIONS LOG OUT

Main Page page [discussion](#) [edit](#) [history](#) [move](#) [watch](#)

- Main Page
- Topics: Plug-in
 - Plug-in architecture
 - Building a plug-in
 - Switch file
 - Function pointers
 - Mixed language programming
- Topics: Others
 - Database
 - Directory structure
 - Naming convention
 - Job descriptor file
 - Subkind ID
- Topics: GEI
 - Introduction
 - Geophysics
 - Electromagnetics
 - Instruments
- Topics: IRM
 - Input Reconditioning Module
 - Atmospheric Model Output
 - Surface Model Output
- Topics: SEAMs
 - Introduction
 - LookUp Table

LUT Manager

Main page

ISSARS Instrument Simulator Suite for Atmospheric Remote Sensing

New Delete

Query results

Frequency (Hz)
89000000000
91000000000
91000000000
92000000000

New-LUT dialog box

ISSARS Instrument Simulator Suite for Atmospheric Remote Sensing

New Delete Reset (D) View PLUT VLUT... Close Done

Query results

Frequency (Hz)	Subkind	Medium Properties	Single Scattering Properties	Status
10650000000	Ziad's Graupel	Maxwell-Garnett (Spherical): Water in (Air in Ice)	Mie	
10650000000	Ziad's Graupel	Maxwell-Garnett (Spherical): Water in (Air in Ice)	Lorentz-Mie	
13400000000	Ziad's Graupel	Maxwell-Garnett (Spherical): Water in (Air in Ice)	Lorentz-Mie	
13400000000	Short Column	Maxwell-Garnett (Spherical): Water in (Air in Ice)	Mie	
13400000000	Block Column	Maxwell-Garnett (Spherical): Water in (Air in Ice)	Mie	
13400000000	Long Column	Maxwell-Garnett (Spherical): Water in (Air in Ice)	Mie	
13400000000	Block Column	Maxwell-Garnett (Spherical): Water in (Air in Ice)	T-matrix	
13400000000	Short Column	Maxwell-Garnett (Spherical): Water in (Air in Ice)	T-matrix	

Table properties

Status: Ready

Testing Frequency

f_{upper} 13.5 GHz

f_{lower} 13.3 GHz

Scattering Parameters (Z_{ij})

Form Discrete angles (uniform 2-D)

N_θ 5

N_φ 4

Temperature (T)

T_{min} -180 C

T_{stop} -40,-30

N_T 1,1,1,1

Spacing lin

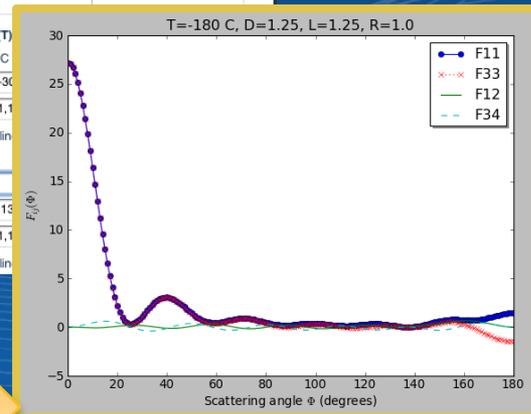
Diameter (D)

D_{min} 66

D_{stop} 100,13

N_D 1,1,1,1

Spacing lin





④ Processing Stage 2: SEAM Particles

Rayleigh/Mie



Mie

Web Interface



T-Matrix/GO



T-Matrix/DDA/GO

Scattering Hydrometeors > Refractive Index > Default method > Maxwell-Garnett

Geophysics | Electromagnetics | Instruments and orbit

- Gas
- Propagation
- Scattering Aerosol
- Scattering Hydrometeors
 - Refractive Index
 - Default method
 - Calculation strategy
 - Bruggeman
 - Maxwell-Garnett**
 - Composition
 - Shape of Inclusions
 - Customize by frequency
 - Customize by size parameter

Parameters		
Name	Value	Unit
Composition	Water in (Air in Ice)	
Shape of Inclusions	Spherical	

Tag: Update

Help

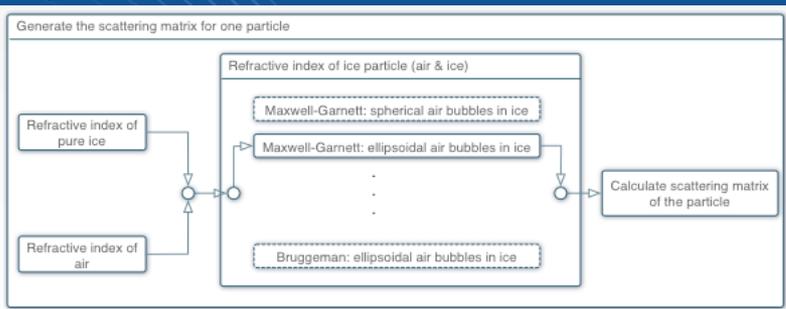


DDA



DDA

Server side plug-in: only the selected functions are loaded at run-time



- Plug-in library: libmixeps
- Library: libmixeps_0x0101 (spherical)
 - Library: libmixeps_0x0102 (ellipsoid)
 - Library: libmixeps_0x0201 (air + ice)



$$\begin{bmatrix} F_{11} & F_{12} \\ F_{21} & \dots \\ & F_{44} \end{bmatrix}$$



④ Processing Stage 2: SEAM

Gases

ISSARS Instrument Simulator Suite for Atmospheric Remote Sensing

ISSARS HITRAN Query Filters:

molecule = 2
isotope = 1
4870.0 <= trans_wavenumber <= 4880.0
line_intensity >= 1e-26

Matching HITRAN 2008 absorption lines:

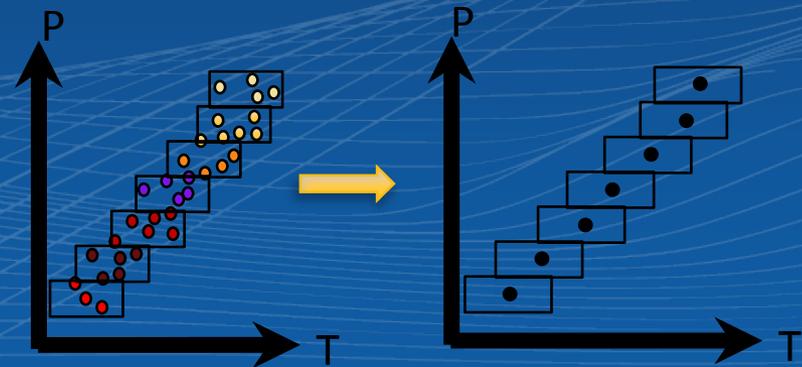
Show 10 entries

Search:

Molecule Number	Isotope Number	Transition Wavenumber (cm-1)	Line Intensity	Einstein A-Coefficient	Air-Broadened Width	Self-Broadened Width	Lower State Energy	Temperature Dependence of Air Width	Pressure Shift
2	1	4870.23	4.623e-26	1.462e-05	0.0727	0.096	197.417	0.73	-0.005543
2	1	4870.44	2.416e-22	0.06993	0.072	0.098	197.417	0.7	-0.005105
2	1	4870.63	1.772e-26	0.1364	0.0696	0.071	2462.68	0.74	-0.007084
2	1	4871.35	1.241e-26	0.1381	0.0692	0.069	2546.04	0.73	-0.007196
2	1	4871.79	2.214e-22	0.07062	0.071	0.095	234.083	0.71	-0.005257
2	1	4871.89	3.348e-26	9.927e-06	0.0742	0.098	163.868	0.71	-0.005505
2	1	4873.13	1.985e-22	0.07127	0.0701	0.093	273.868	0.73	-0.005405
2	1	4873.54	2.266e-26	6.462e-06	0.0754	0.1	133.439	0.73	-0.005462
2	1	4874.45	1.745e-22	0.07199	0.07	0.093	316.77	0.74	-0.005548
2	1	4875.19	1.415e-26	3.992e-06	0.0762	0.102	106.13	0.71	-0.005411

Showing 1 to 10 of 16 entries

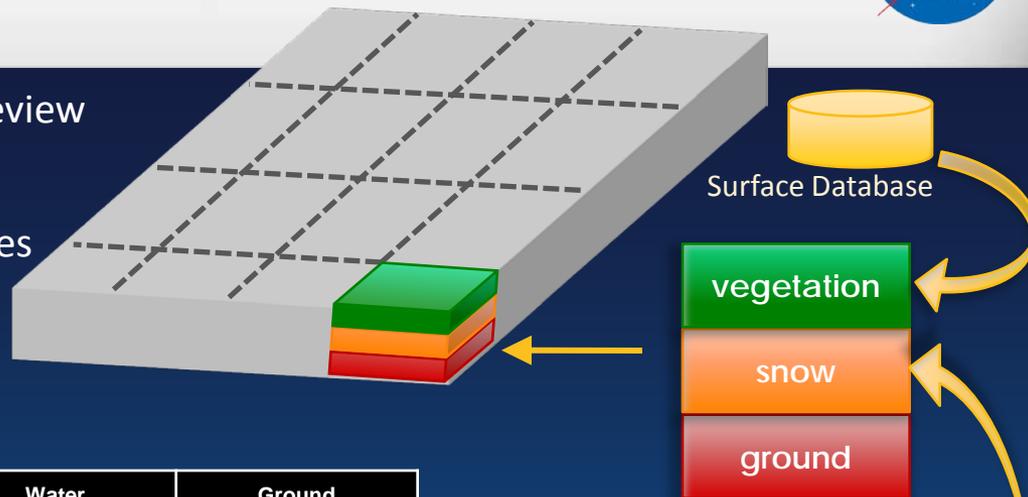
- Adopted HITRAN for UV/IR
 - LBLRTM core adopted for specific absorption calculations
 - Clustering algorithm to reduce redundant calls
- Multiple (13) millimeter wave propagation algorithms available as plug-ins





④ Processing Stage 2: SEAM Surface

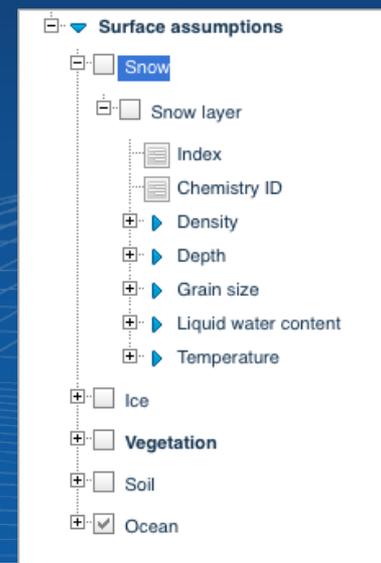
- Defaults available; also configurable via Treeview
- Defined as a stack of surface layers
- Each surface layer includes specific properties



Properties of surface layers

Vegetation	Snow	Ice	Water	Ground
Layer index				
Chemistry ID				
Thickness				
Temperature (depth)				
	Density (depth)	Density (depth)		Density (depth)
Snow Water Equivalent -- SWE				Soil Moisture -- SM
SWE: Frozen water fraction				SM: Frozen water fraction
SWE: Liquid water fraction				SM: Liquid water fraction
Surface roughness: Simple, Spectrum, or Gaussian (rms. height & correlation length)				
Canopy water	Salinity	Salinity	Salinity	Soil Texture
Veg. Type	Grain size	Grain size		Grain size

Treeview Page





④ Processing Stage 2: SEAM Surface (cont.)

- Several analytical/empirical models for calculation of Normalized Radar Cross Section (NRCS) and emissivity of the Earth surface are integrated to ISSARS.
- Many of these models are currently employed in other existing simulators such as CRTM (Community Radiative Transfer Model), Goddard SDSU (Satellite Data Simulator Unit), and ECSIM (EC simulator)

	Ground	Vegetation	Snow	Ice	Water	Generic
Microwave/mm-wave					Isotropic single scale, KA, two-scale.	SPM, KA (PO,GO), Lambertian
	Microwave land emissivity model	Microwave land emissivity model	Microwave land emissivity model		FASTEM2	SPM Lambertian
IR/Visible	RPV	RPV	RPV			Lambertian
	MODIS	MODIS	MODIS	MODIS	IR/CRTM	

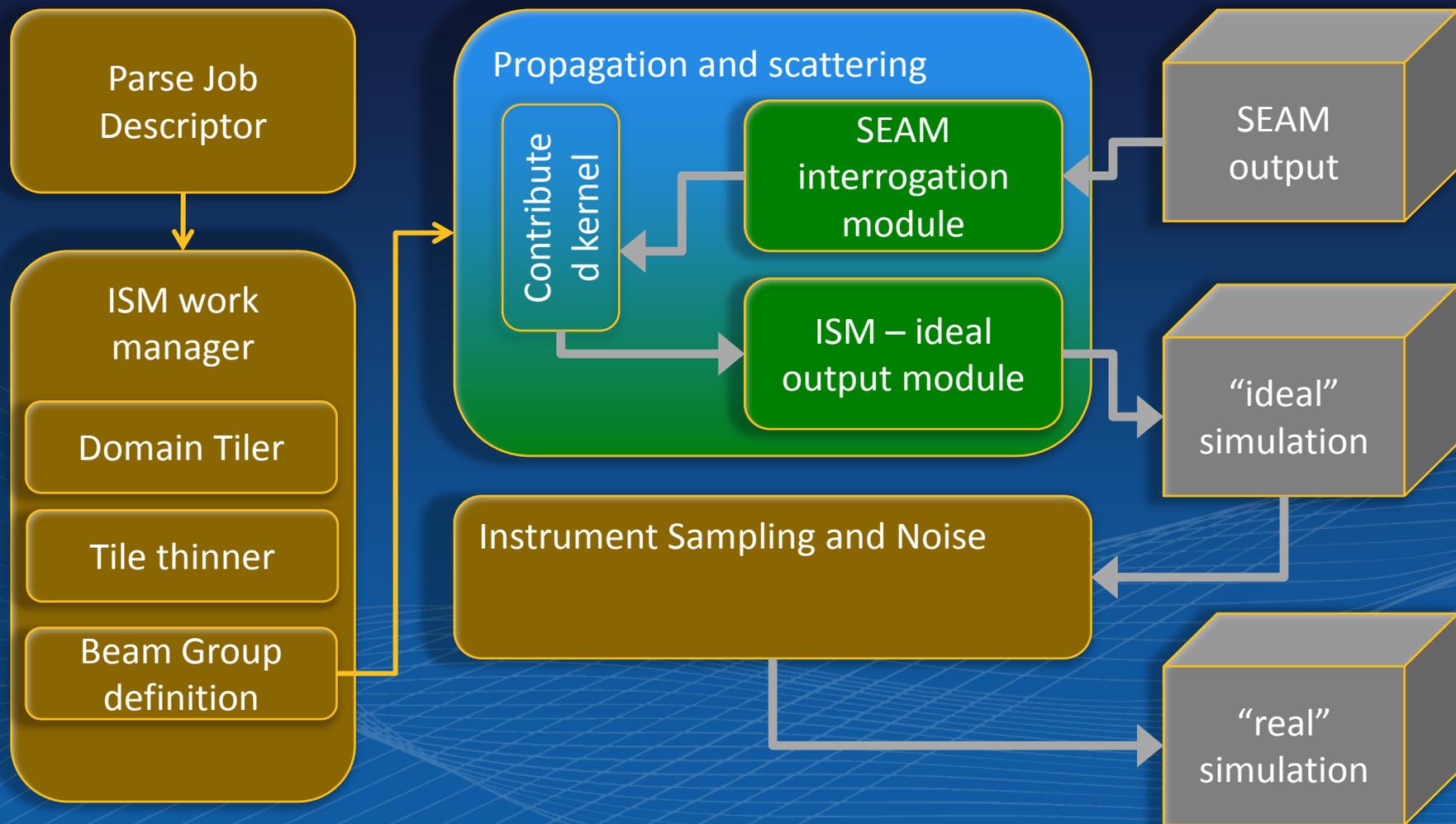
FASTEM2 (English and Hewison, 1998) –CRTM/SOI
 FASTEM4 (Liu, Weng, English, 2010) – CRTM/SOI
 Microwave land emissivity model (Weng, Yan, Grody, 2001) – CRTM/SDSU
 RPV (Rahman, Pinty, Verstraete, 1993) – ECSIM/SHDOM/SDSU
 SPM1: Small Perturbation Model
 KA: Kirchhoff Approximation
 PO: Physical Optics
 GO: Geometrical Optics

Active	[Integrating]
Passive	[Integrated]



④ Processing Stage 3: ISM

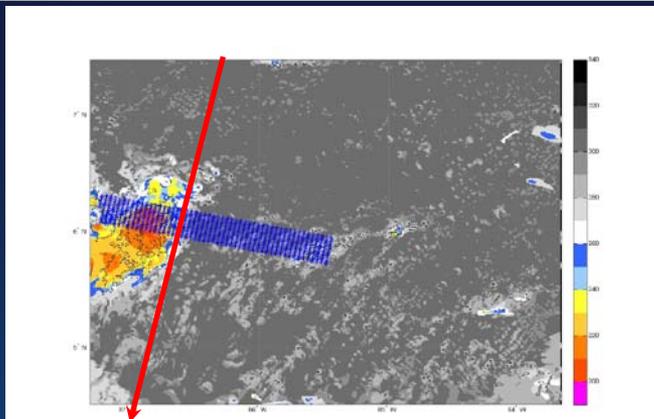
Instrument Simulator Modules: workflow



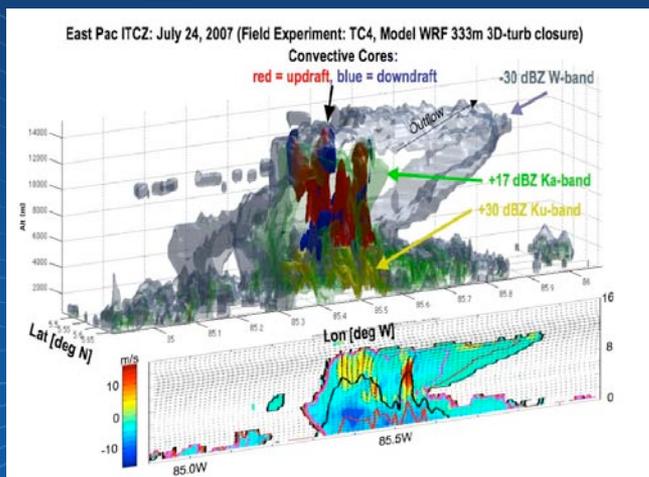
④ Processing Stage 3: ISM

Instrument Simulator Modules: expected products

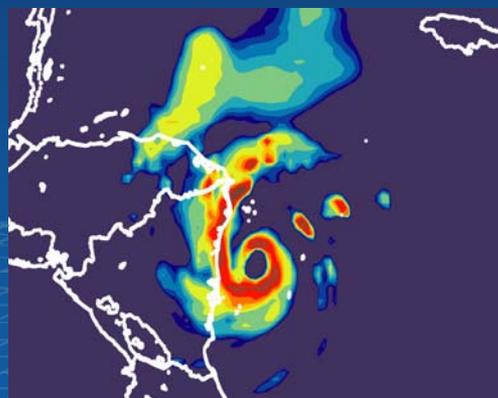
- These examples were produced by some of the stand-alone simulators that are being integrated in ISSARS



T_{IR}

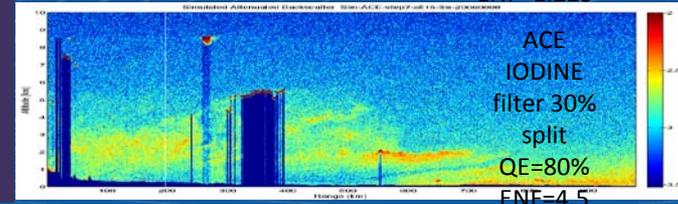
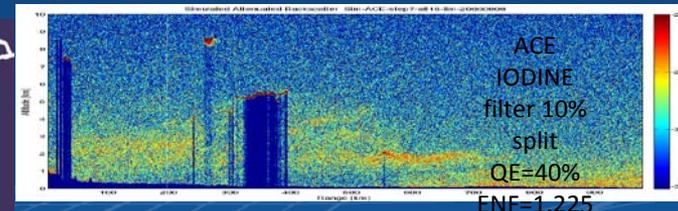
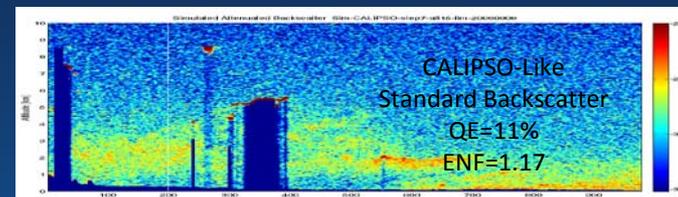


Multi-Frequency Doppler Radar



$T_{b_{\mu W}}$

Total Attenuated Backscatter



Backscatter Lidar/HDSL