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

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Outline

① Background

② Approach and architecture

③ User Interface

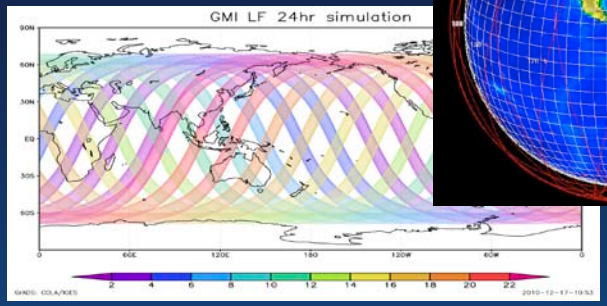
④ Processing modules

① Background

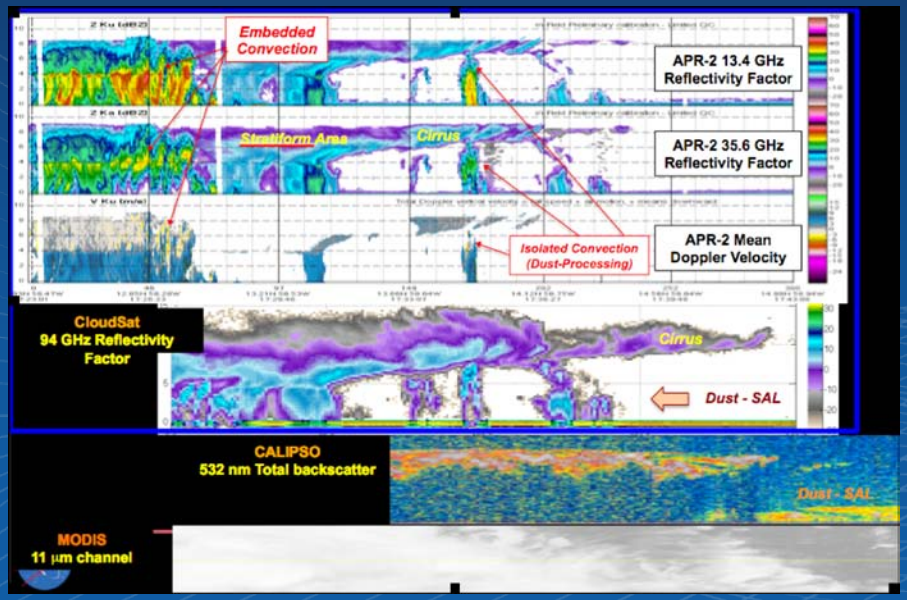
current needs of the current and planned missions

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

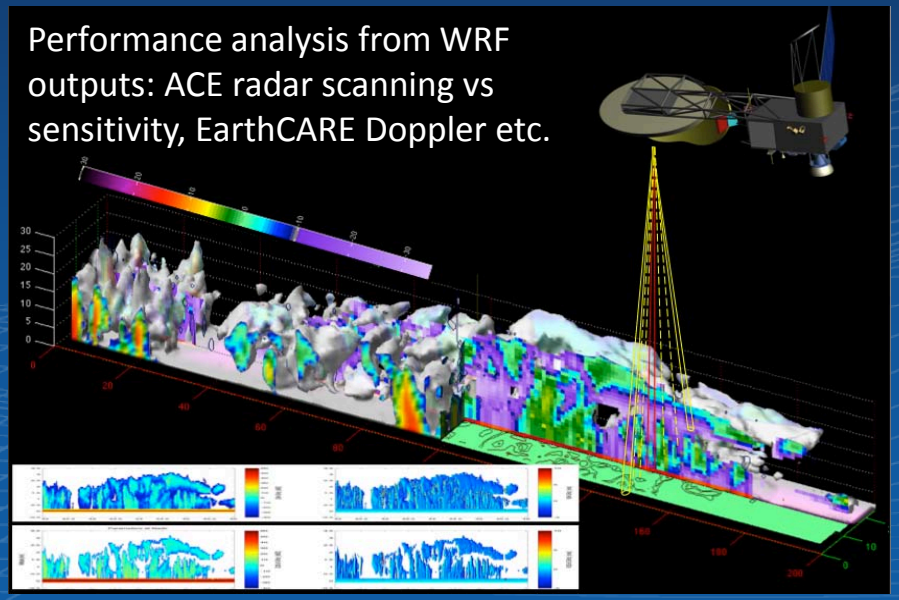
Orbit simulator included in instrument simulations



MULTI INSTRUMENT/MISSION SYNERGISTIC RETRIEVALS



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)

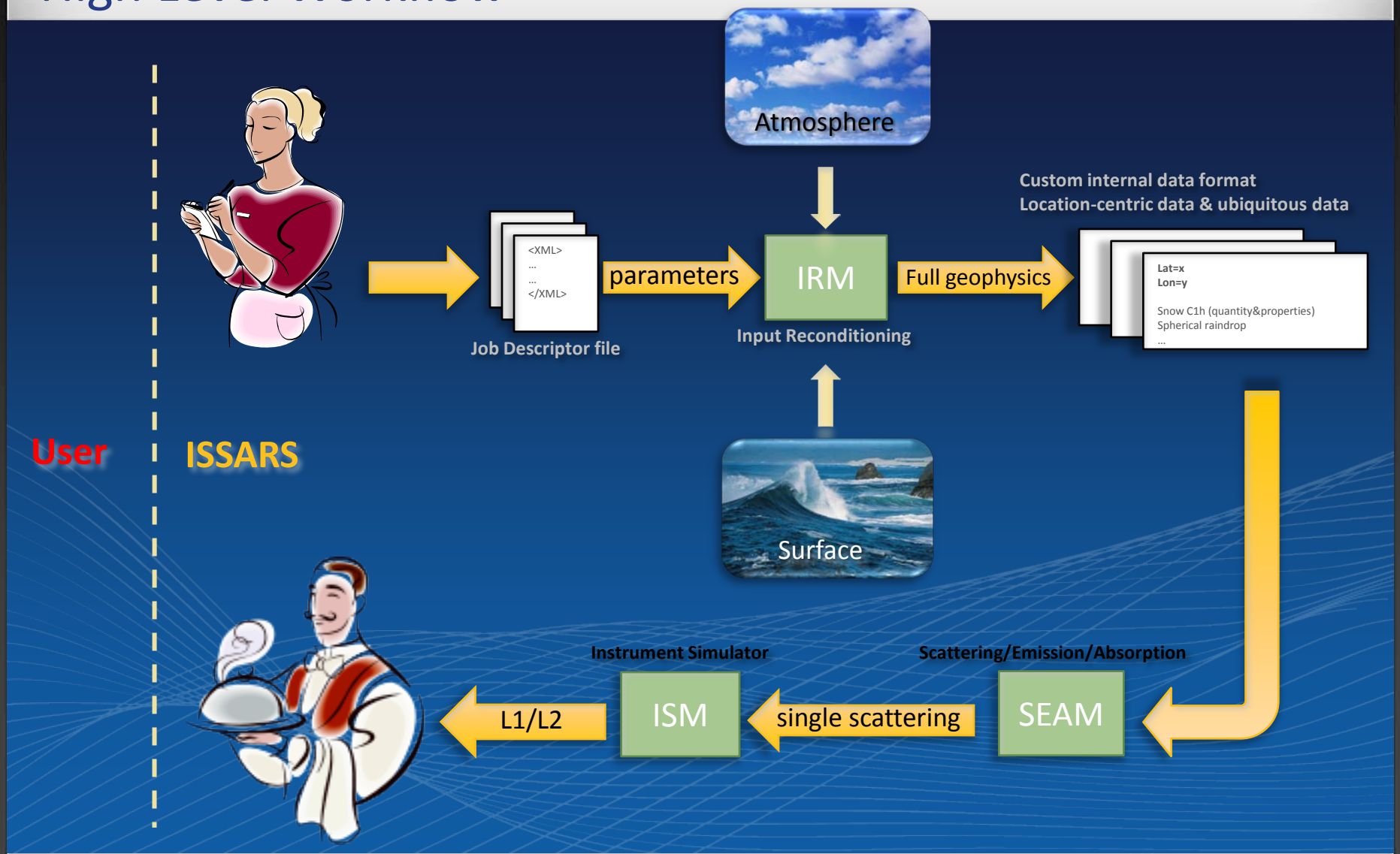
② Approach and architecture

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

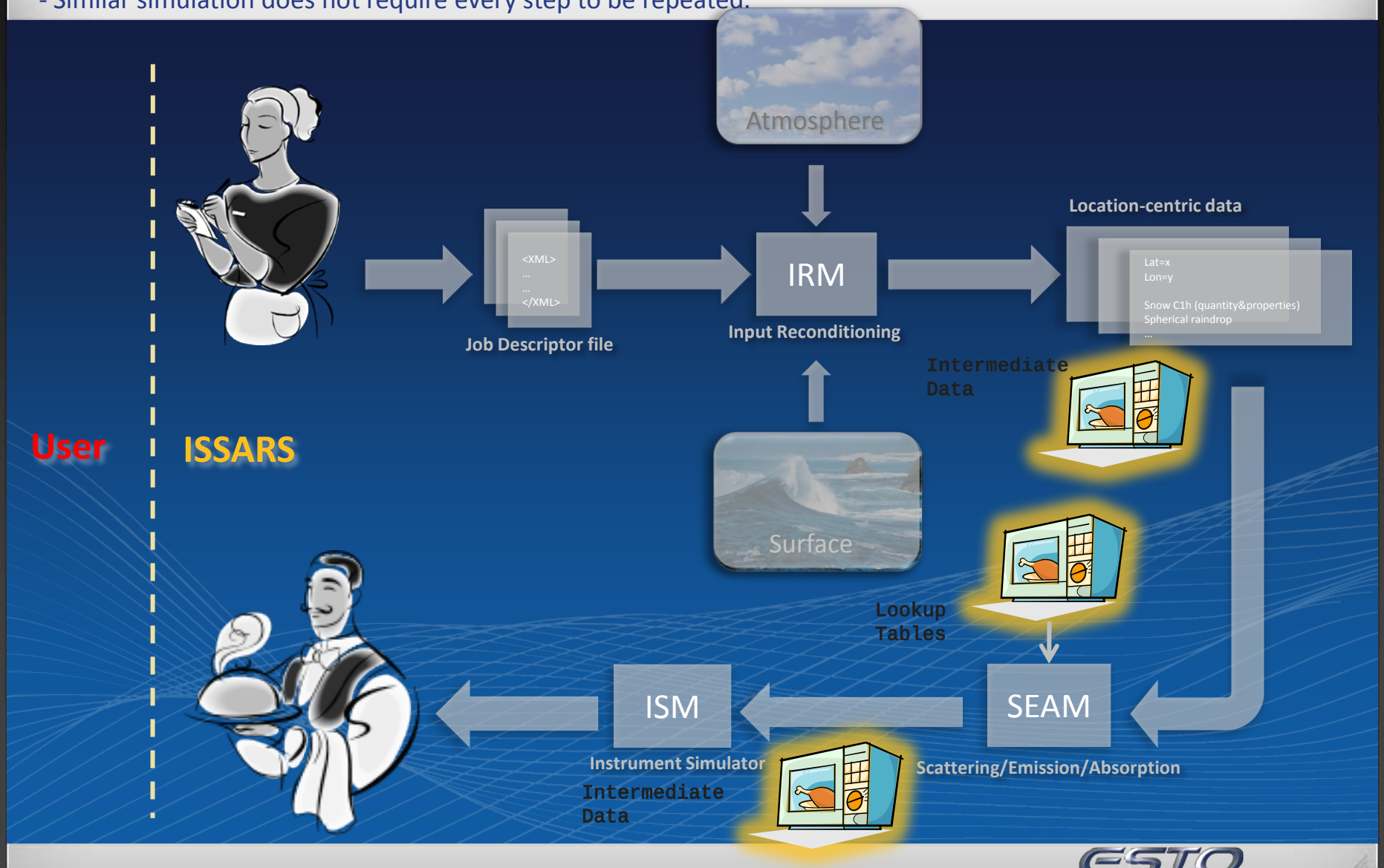
② Approach and architecture

High Level Workflow



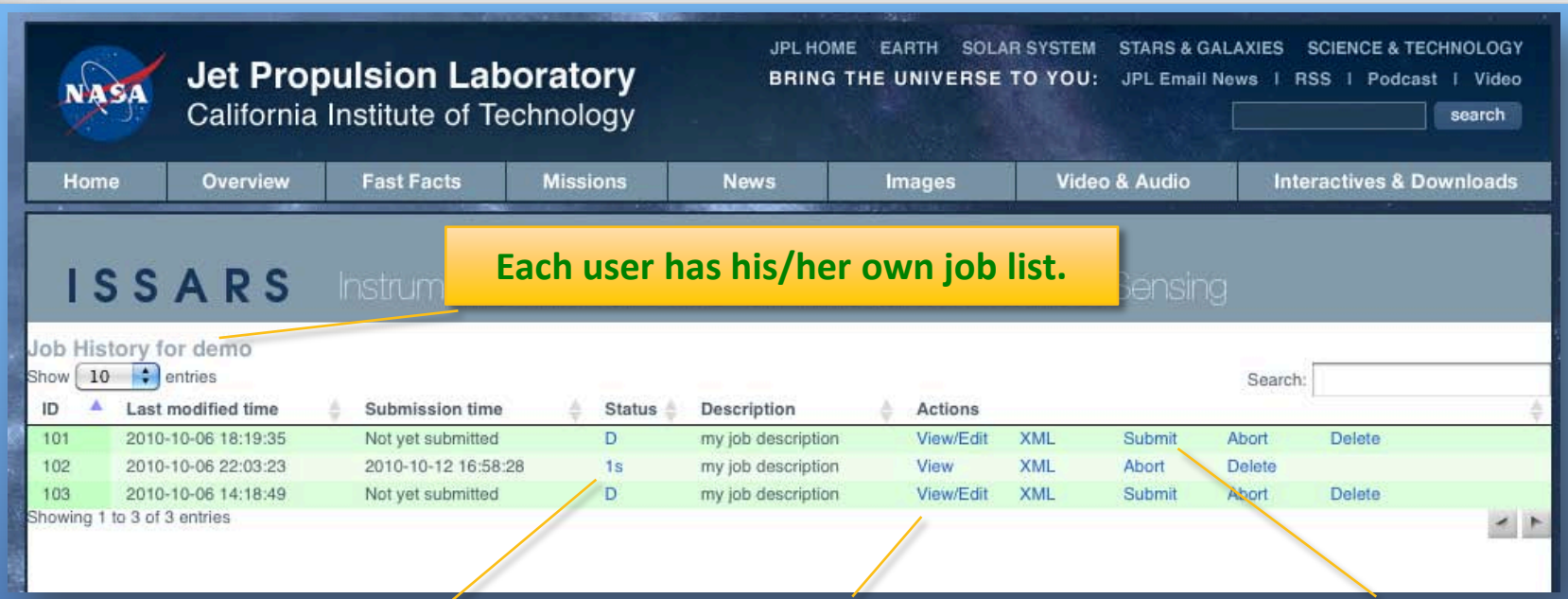
② Approach and architecture

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)



Each user has his/her own job list.

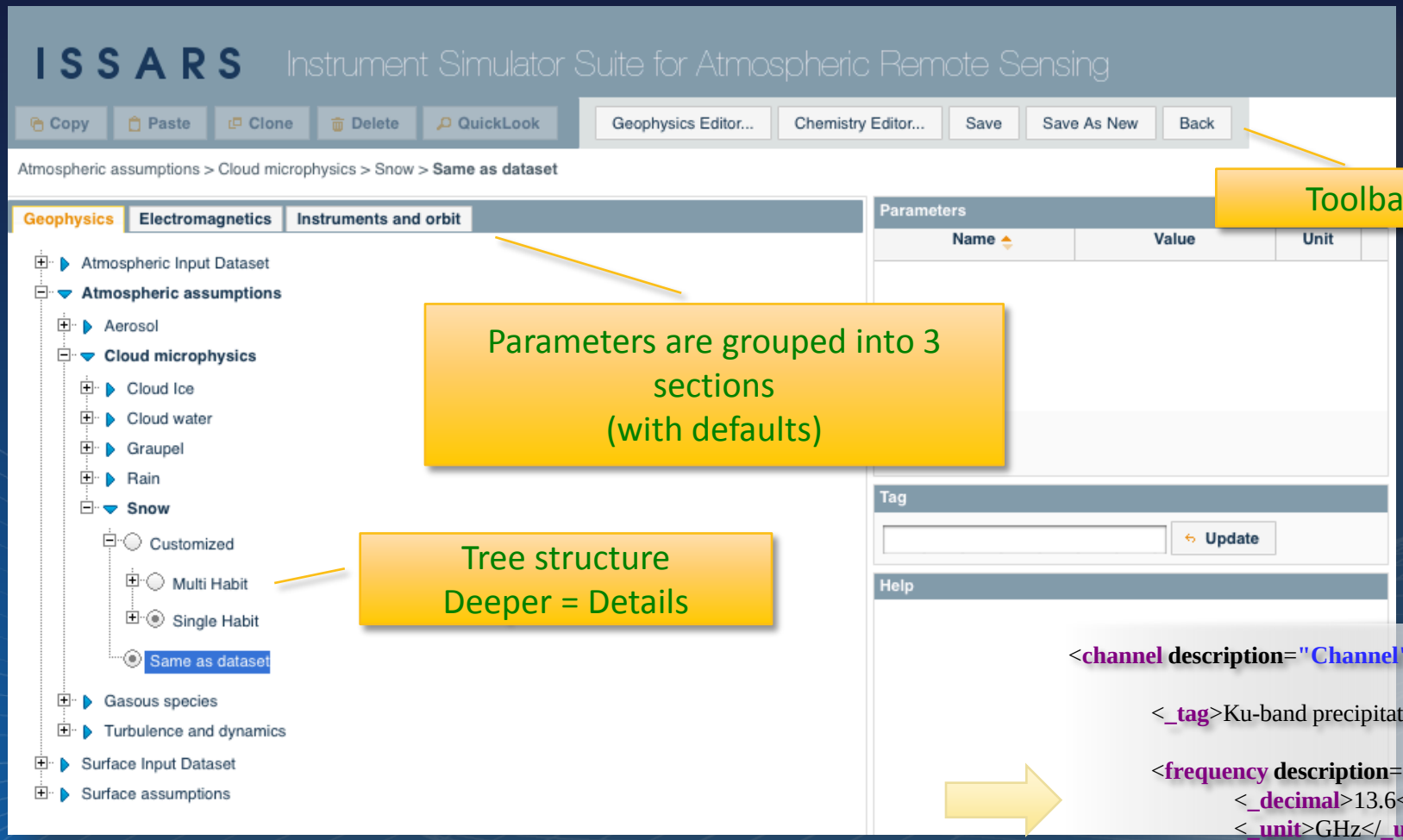
(1) Edit
the Job Descriptor file

(2) Submit
when ready

(3) Check
status

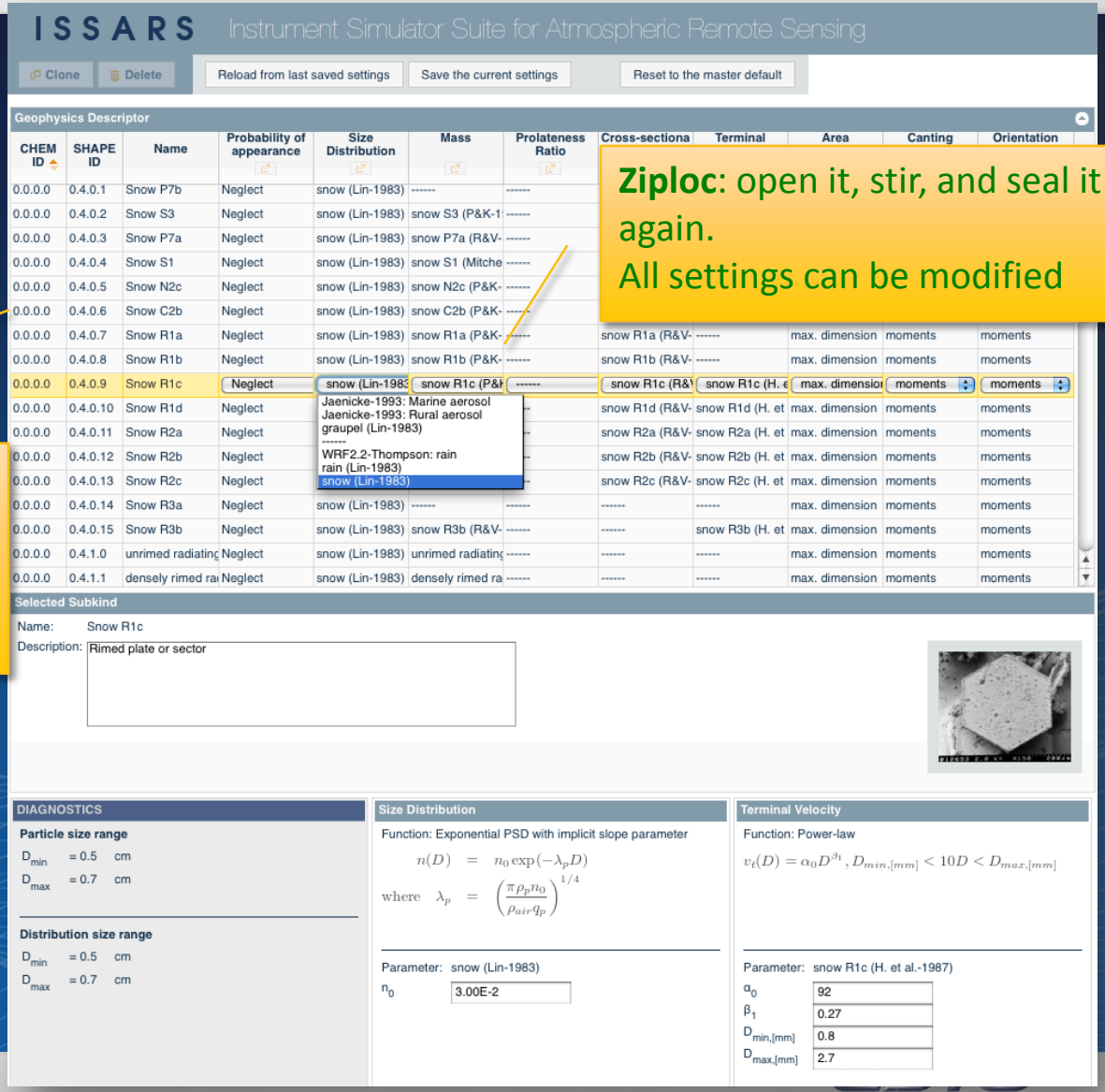
③ User Interface

Geophysics/Electromagnetics/Instrument interface



③ User Interface

Advanced User Editors

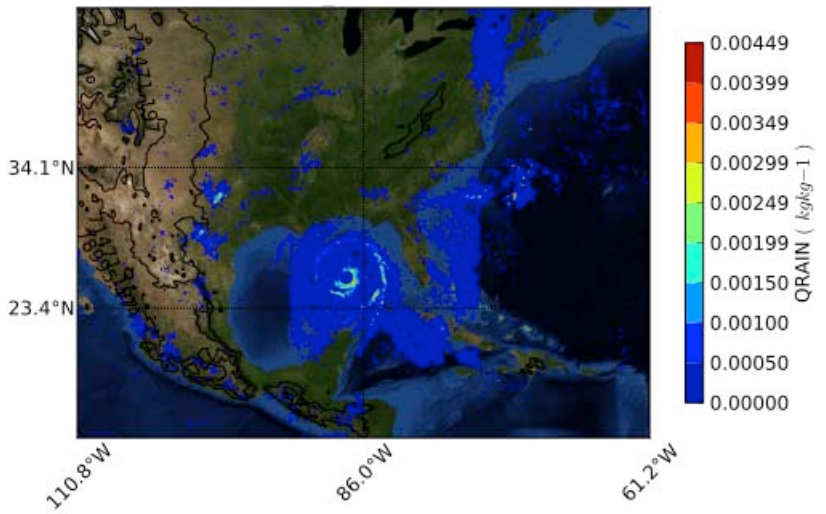


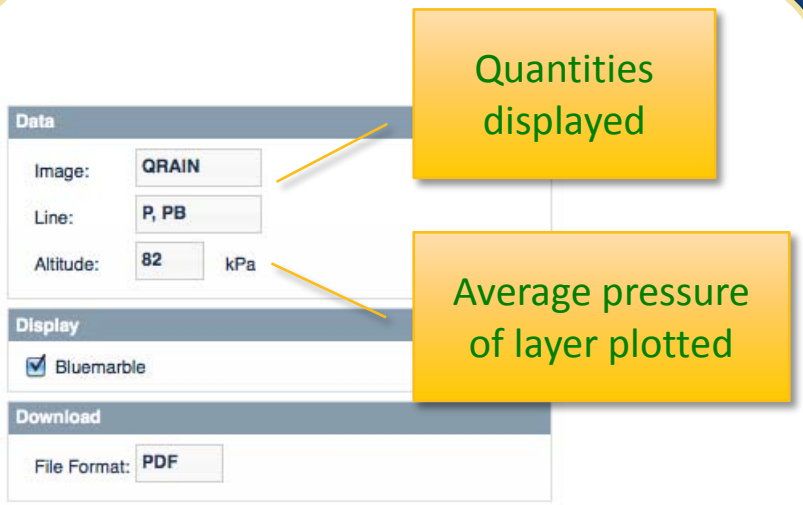
Ziploc: open it, stir, and seal it again.
All settings can be modified

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

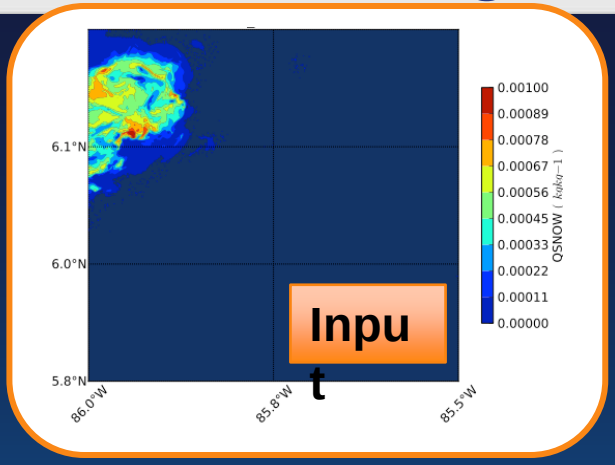
③ User Interface
Quicklook Visualization

- 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.

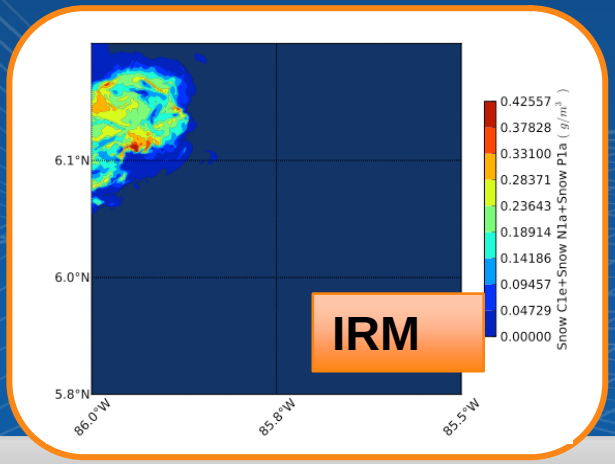


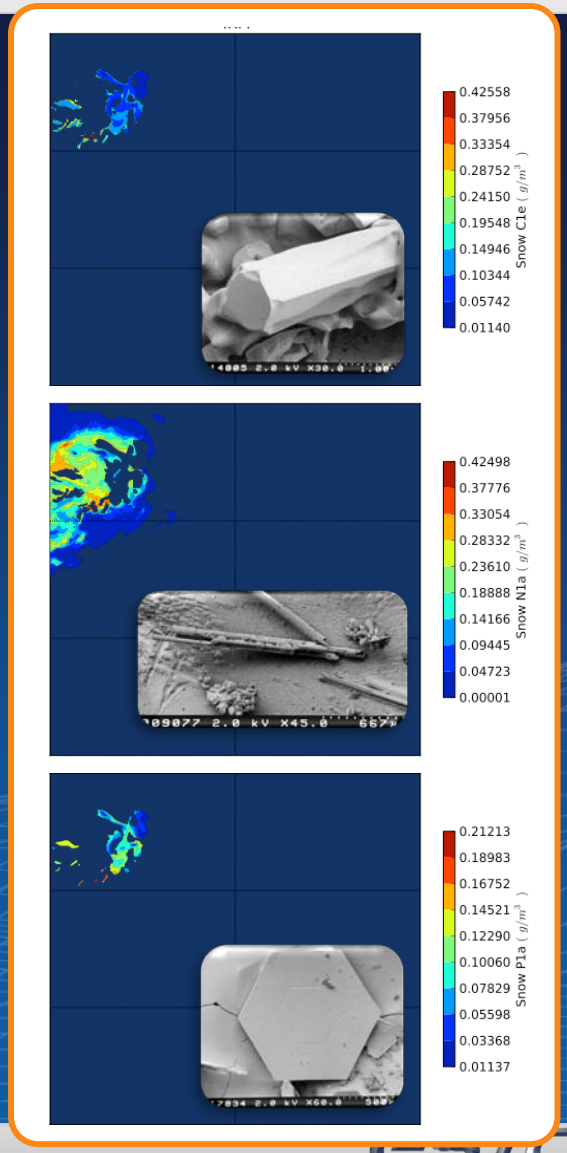


④ Processing Stage 1: IRM
Input Reconditioning Module



- 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.



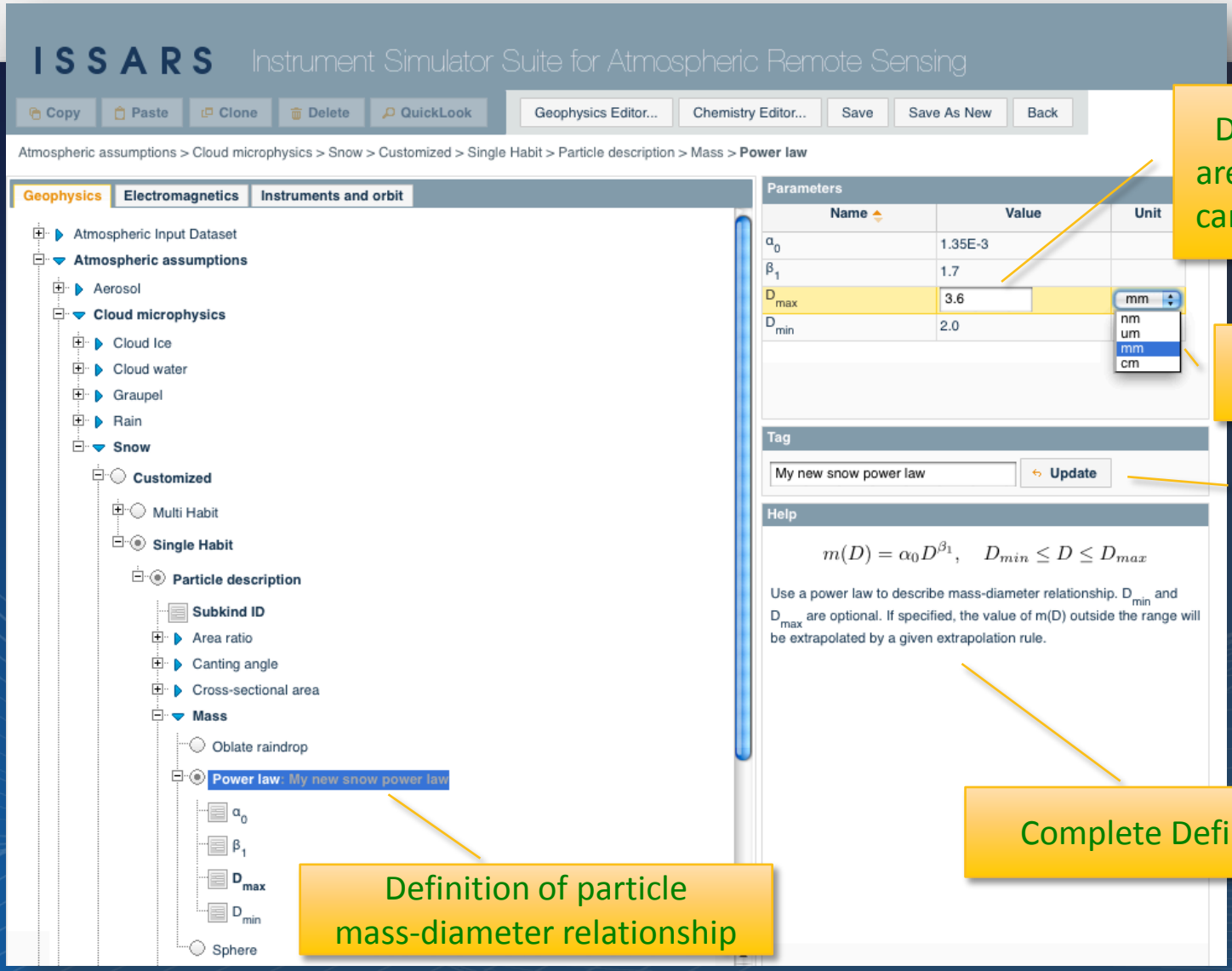


Column

Needle

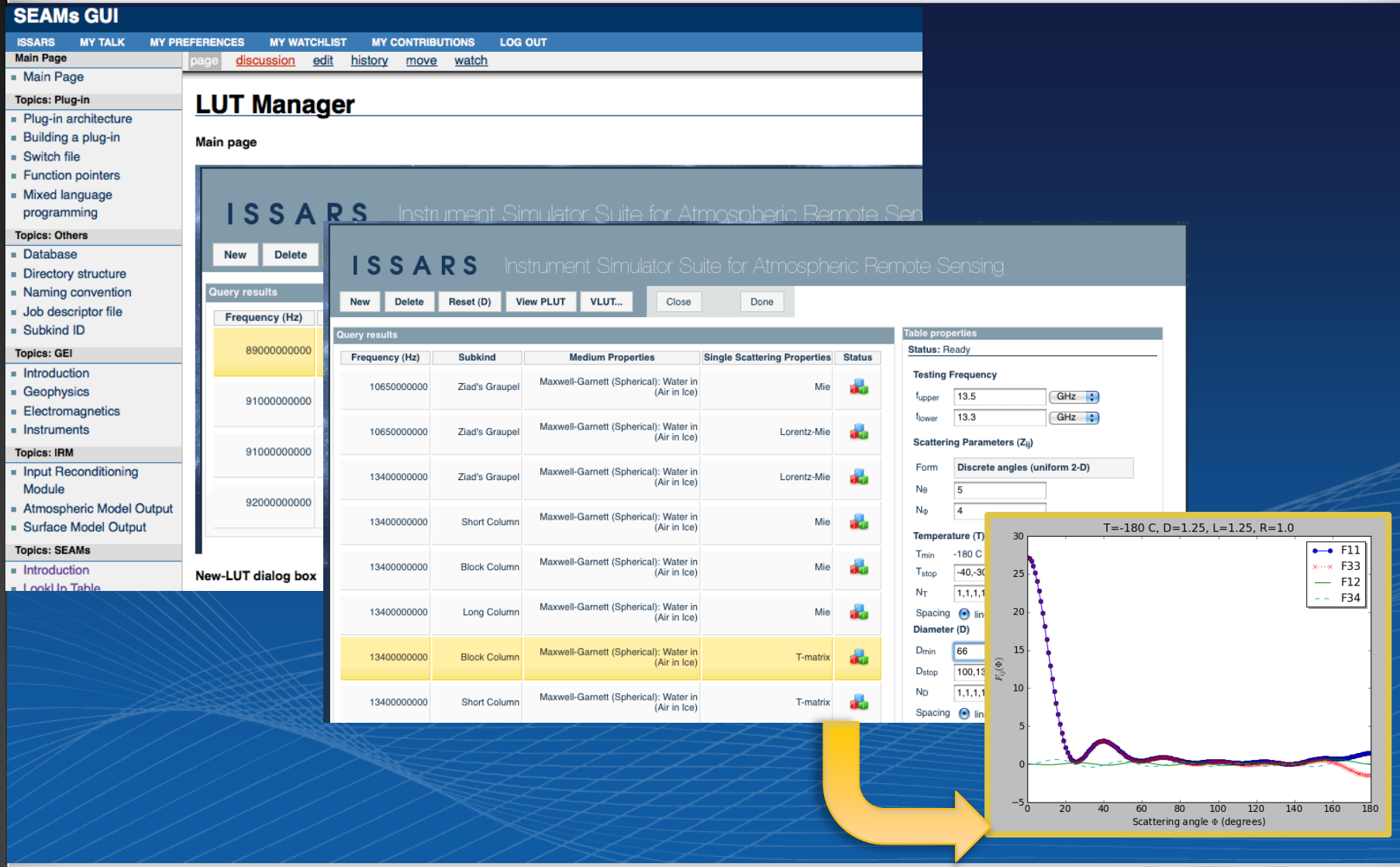
Plate

④ Processing Stage 1: IRM



④ Processing Stage 2: SEAM

Scattering, Emission and Absorption Modules



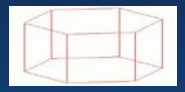
④ Processing Stage 2: SEAM

Particles

Rayleigh/Mie

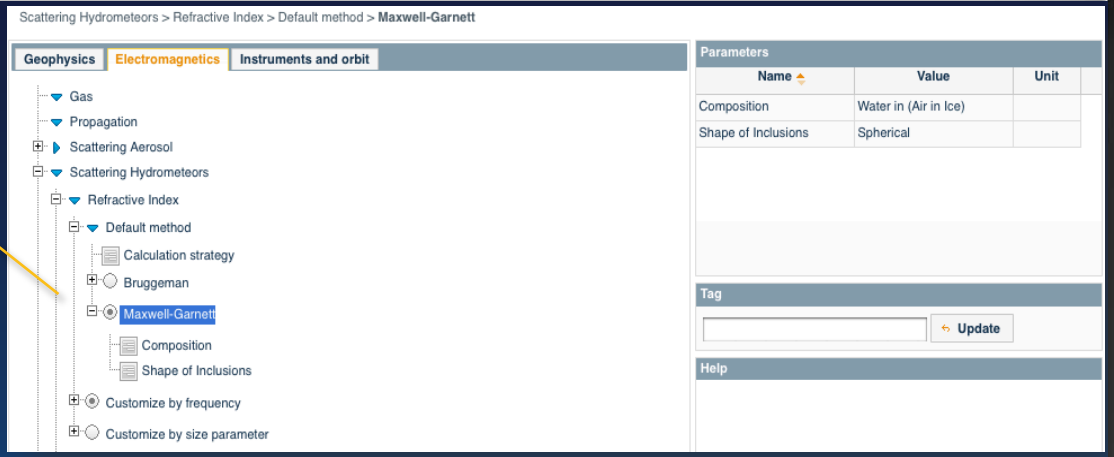
Mie

T-Matrix/GO

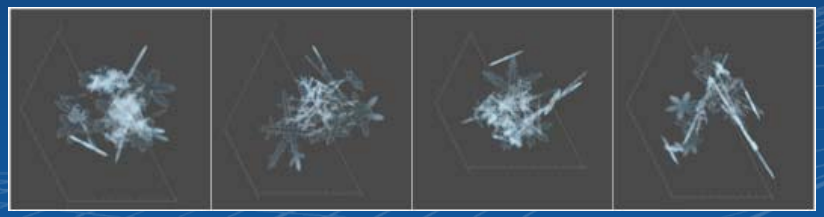


T-Matrix/DDA/GO

Web Interface

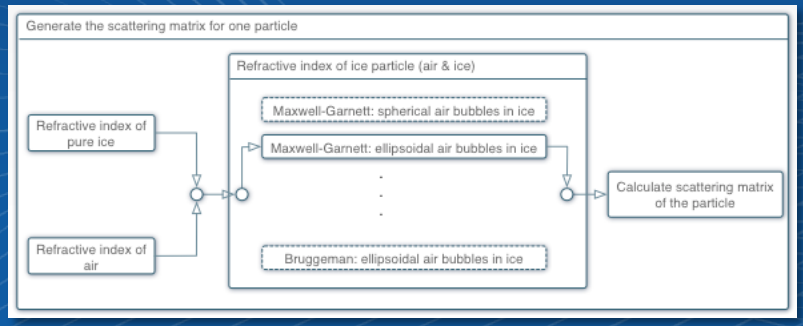


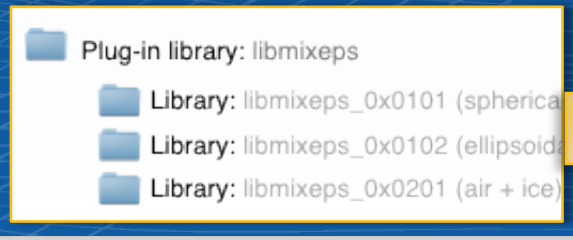
DDA

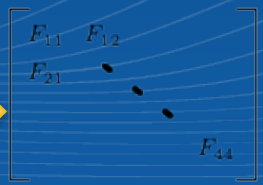


DDA

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







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_wavenum <= 4880.0
line_intensity >= 1e-26

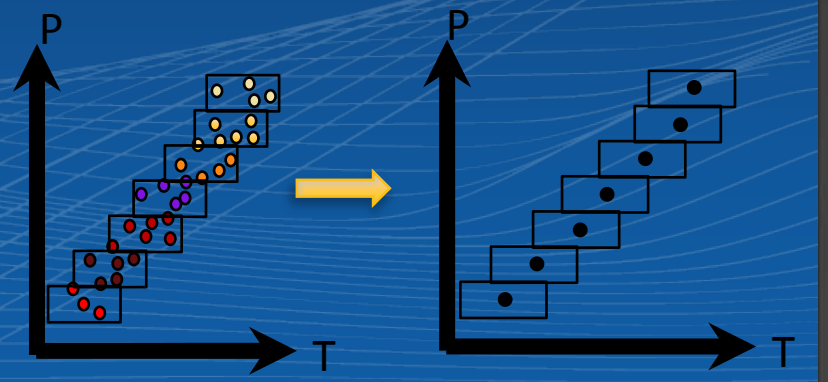
Matching HITRAN 2008 absorption lines:

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



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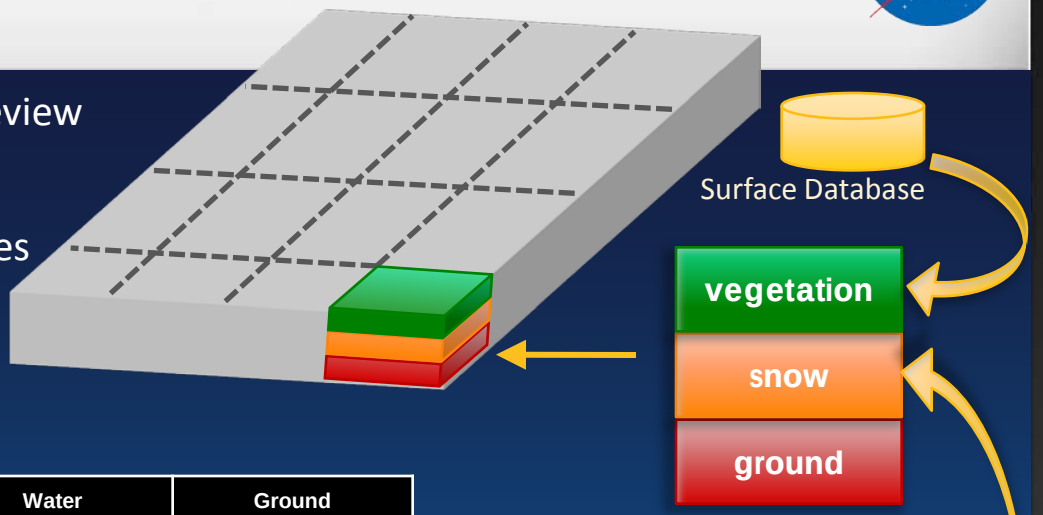
④ Processing Stage 2: SEAM

Surface

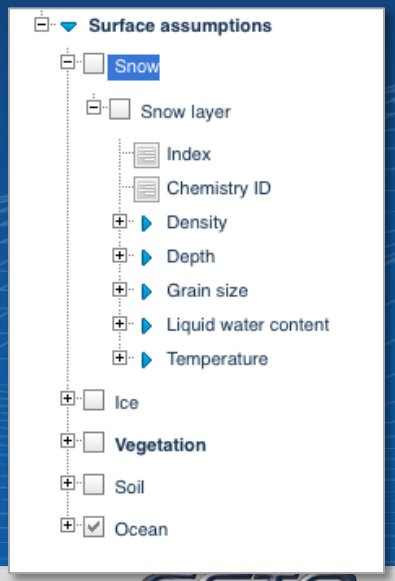
- Defaults available; also configurable via Treeview
- Defined as a stack of surface layers
- Each surface layer includes specific properties



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	

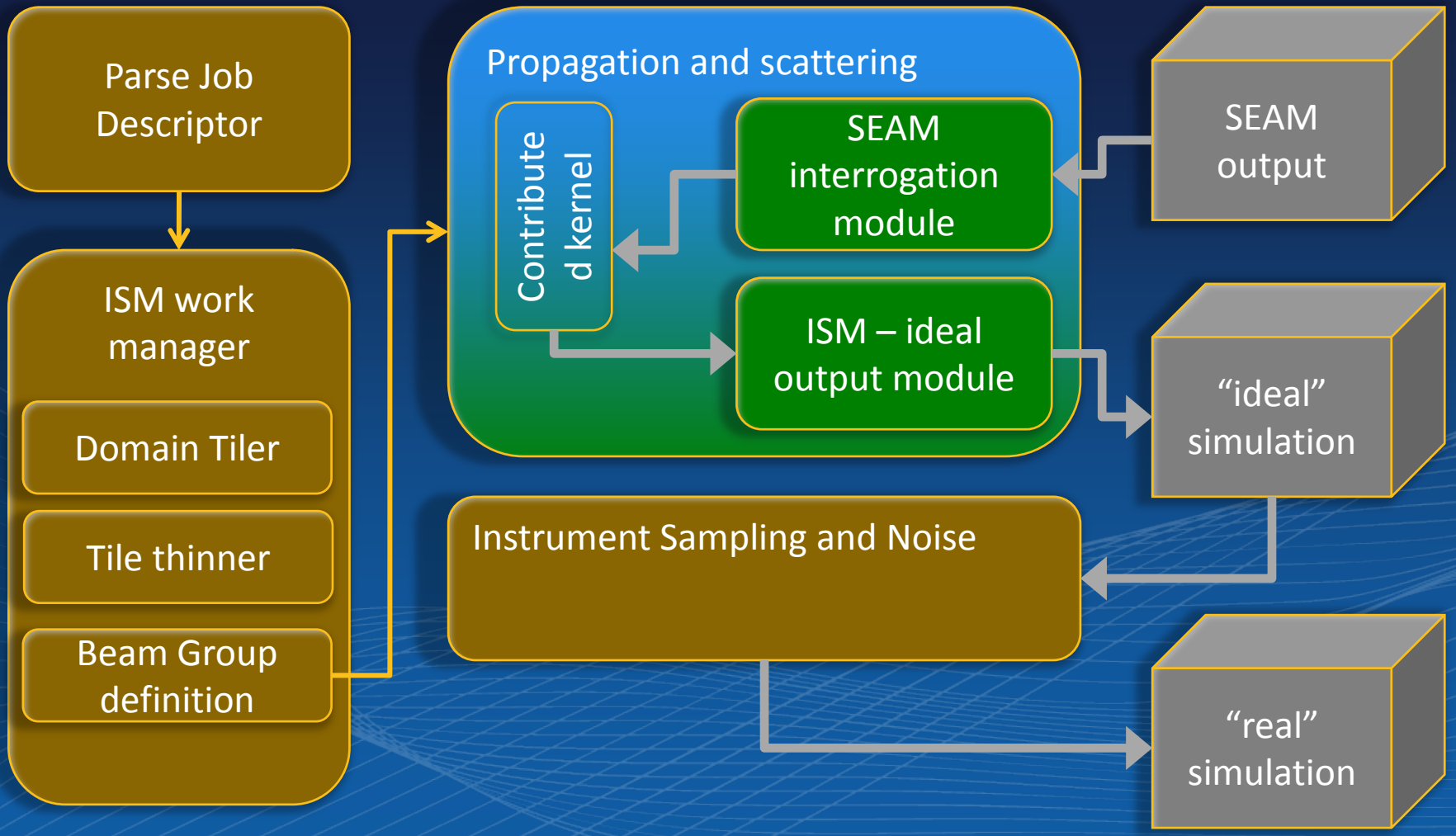
FASTEM2 (English and Hewison, 1998) –CRTM/SOI
FASTEM4 (Liu, Weng, English, 2010) – CRTM/SOI
Microwave land emissivity model (Weng, Yan, Grody, 2001) – CRTM/SDSU
RPV (Rahman, Pinty, Verstraete, 1993) – ECSIM/SHDOM/SDSU
SPM1: Small Perturbation Model
KA: Kirchhoff Approximation
PO: Physical Optics
GO: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

Active
Passive

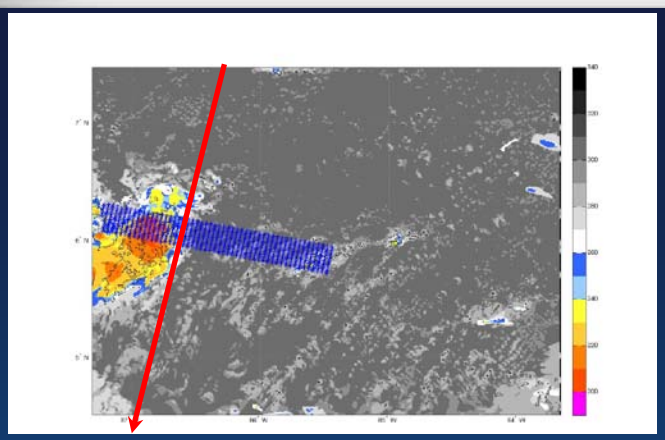
[Integrating]
[Integrated]

④ Processing Stage 3: ISM

Instrument Simulator Modules: workflow



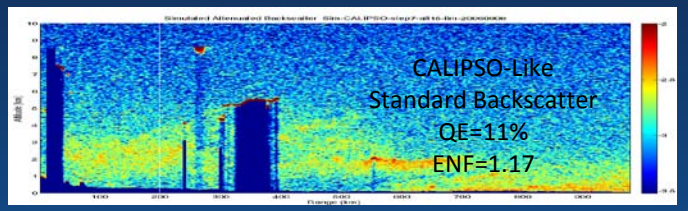
④ Processing Stage 3: ISM
Instrument Simulator Modules: expected products

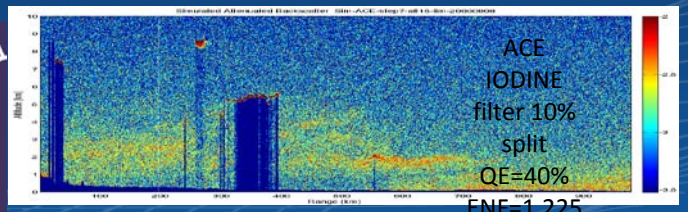


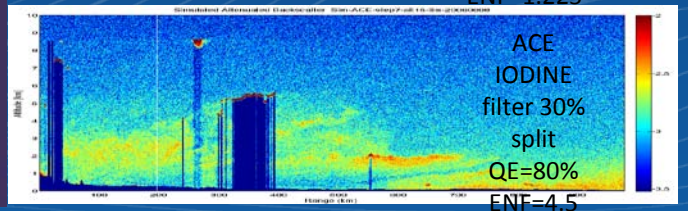
T_{IR}

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

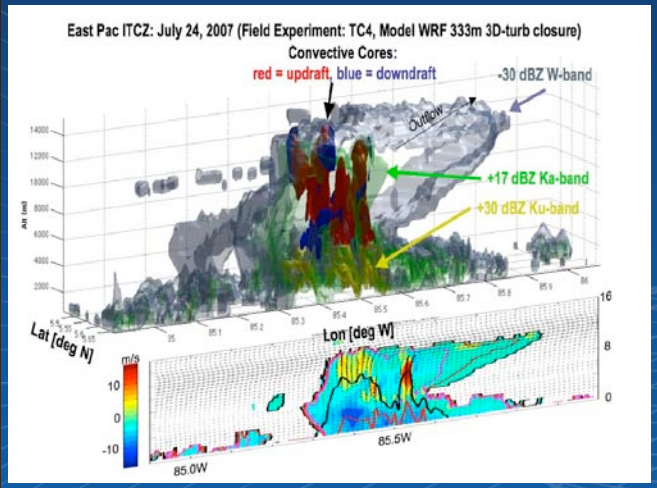
Total Attenuated Backscatter



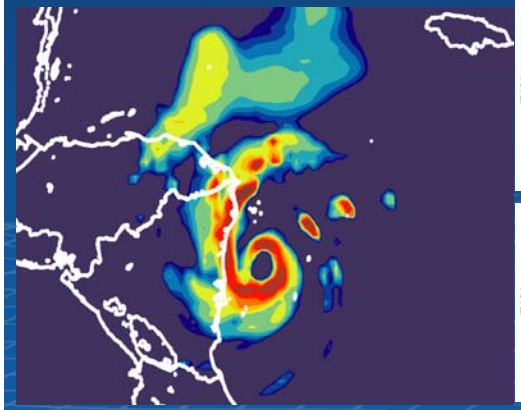




Backscatter Lidar/HDSL



Multi-Frequency Doppler Radar



$Tb_{\mu W}$