



An Interconnected Workflow Design for Simulating Airborne Phased Array Radar (APAR) Data

Brad Klotz

NSF NCAR Earth Observing Laboratory

Improving Scientific Software Conference
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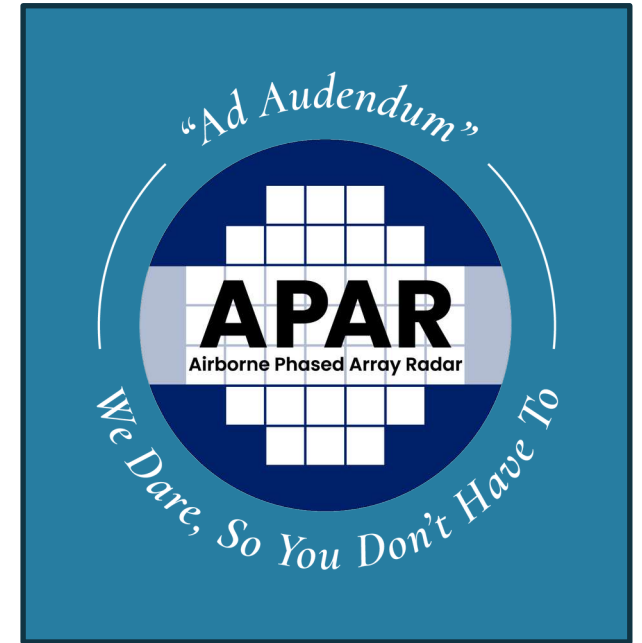
*Wen-Chau Lee¹, Kevin Manning¹, Jothiram Vivekanandan¹,
Pavlos Kollias², Nick Barron¹, and Adam Karboski¹*

1: NSF NCAR, 2: SUNY Stony Brook



Presentation Outline

- **APAR Description**
- **Science and Engineering Frontiers**
- **The Workflow for Simulating APAR data**
- **Connected Applications**
- **Data Quality Control, Visualization and Analysis**



APAR: Revolutionizing Airborne Radar



Innovation in the Weather Enterprise:

APAR will be the first airborne C-band radar with dual-Doppler and dual-pol capabilities and is critical to linking kinematic, microphysics, and thermodynamics within storms.

Next Generation Forecasts:

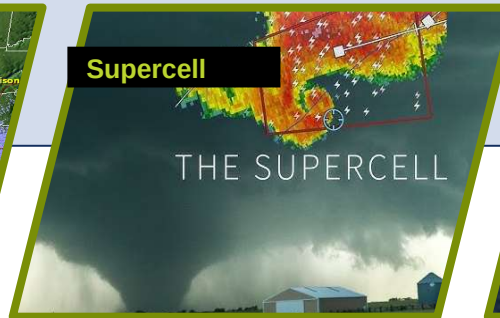
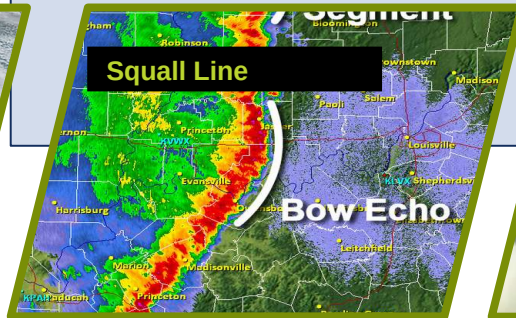
APAR observations can be assimilated into TC prediction models, resulting in more accurate predictions thanks to APAR's richer dataset (vs. TDR).

Economic Value:

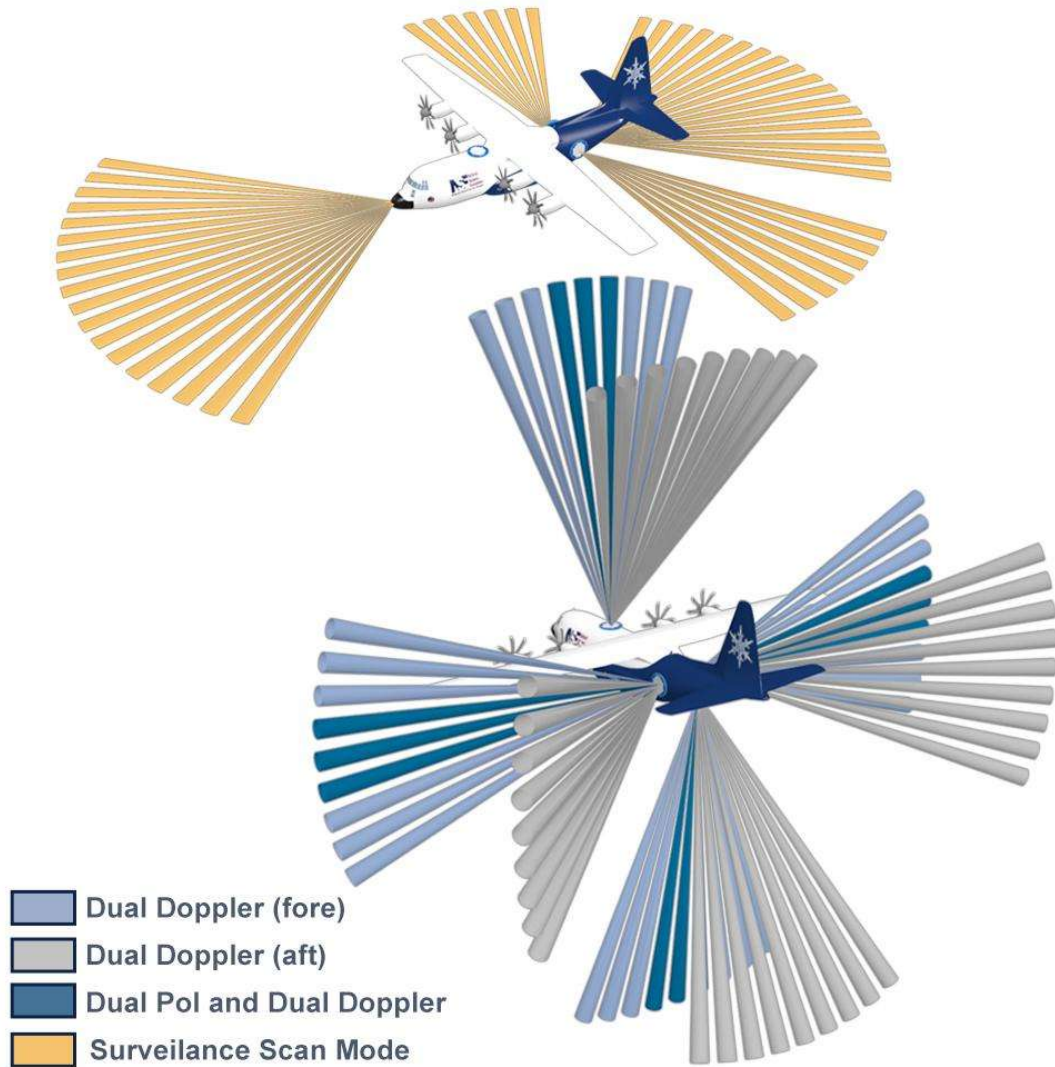
APAR is enabled through industry partnership and can save taxpayer money through more precise forecasting. For example, reducing unnecessary evacuations ahead of a hurricane.

Interagency Partnership:

NSF, NOAA, and NSF NCAR are working together across the research, academic, and operational communities to build APAR.



APAR Operations



Airborne remote sensing

- APAR will fly on the NSF NCAR C-130 aircraft
- Equipped for long duration missions over remote regions
- Part of a larger suite of other instruments

Phased Array Technology

- Advanced engineering will produce an Airborne Electronically Scanned Array (AESA)
- Each AESA has agile scanning capability to provide more control and reliability in radar beam pointing

Radar for weather analysis

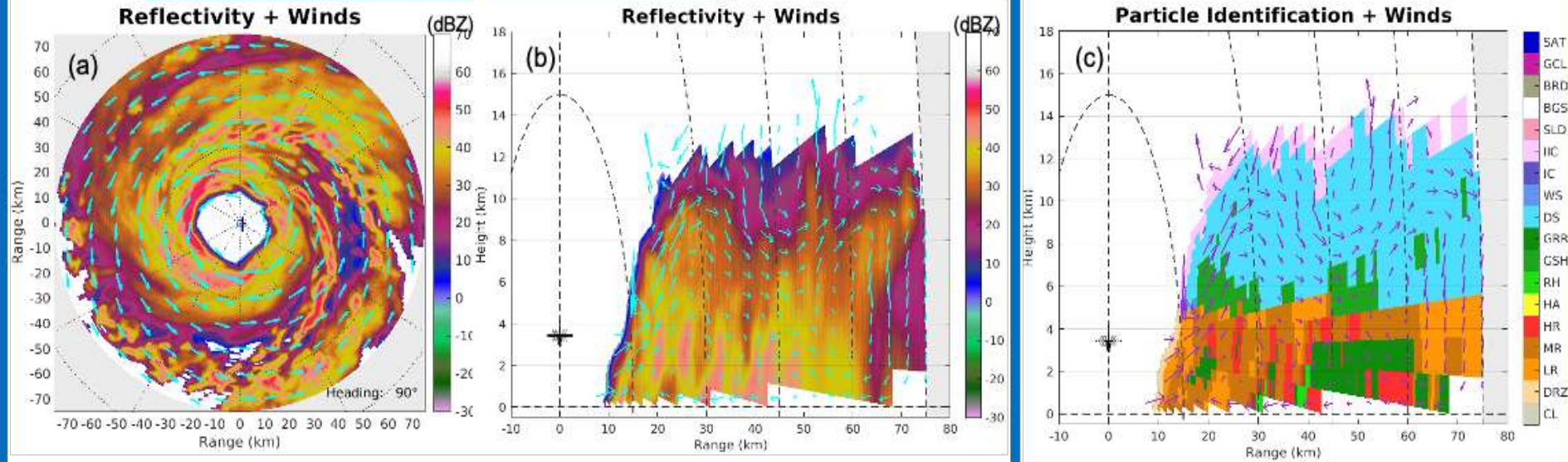
- Vertical and horizontal scanning from a 4-AESA system provides full coverage of 3-D wind and precipitation fields

Science Frontiers

APAR Science Capability

APAR

NCAR ELDORA & NOAA TDRs

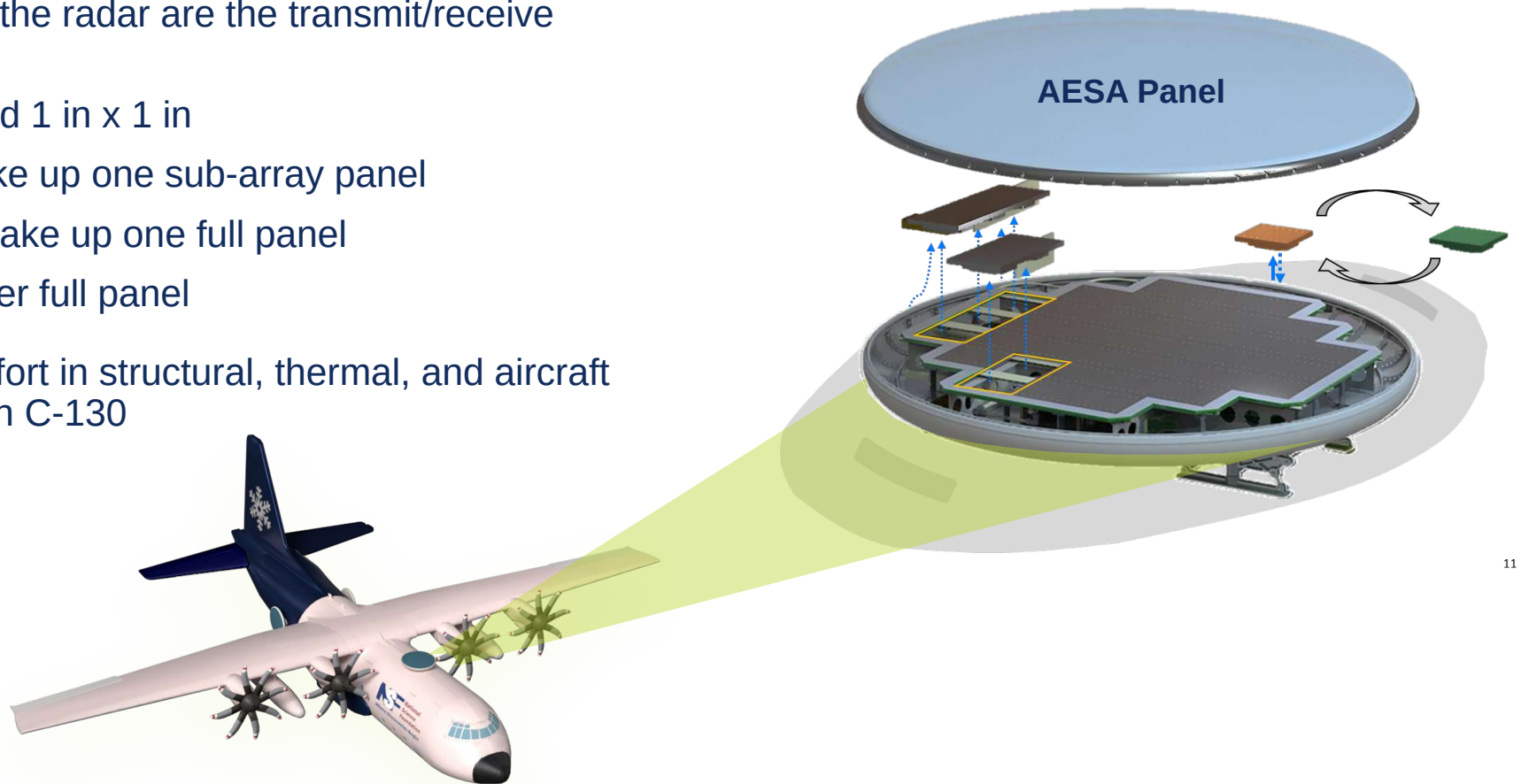


3-D Reflectivity & Winds

3-D Reflectivity, Winds & Microphysics; Vertical Pointing; Digital Beamforming

Engineering Frontiers

- Key building blocks to the radar are the transmit/receive elements
- Each element is around 1 in x 1 in
- 64 elements (8x8) make up one sub-array panel
- 37 sub-array panels make up one full panel
- 2,368 total elements per full panel
- Requires significant effort in structural, thermal, and aircraft design to implement on C-130



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Creating a Bridge for Analysis

- APAR is a complex instrument that requires collaboration across science, hardware, and software engineering teams
- While the instrument is under development, each team has developed various ways to simulate specific aspects of APAR data generation, validation, and analysis

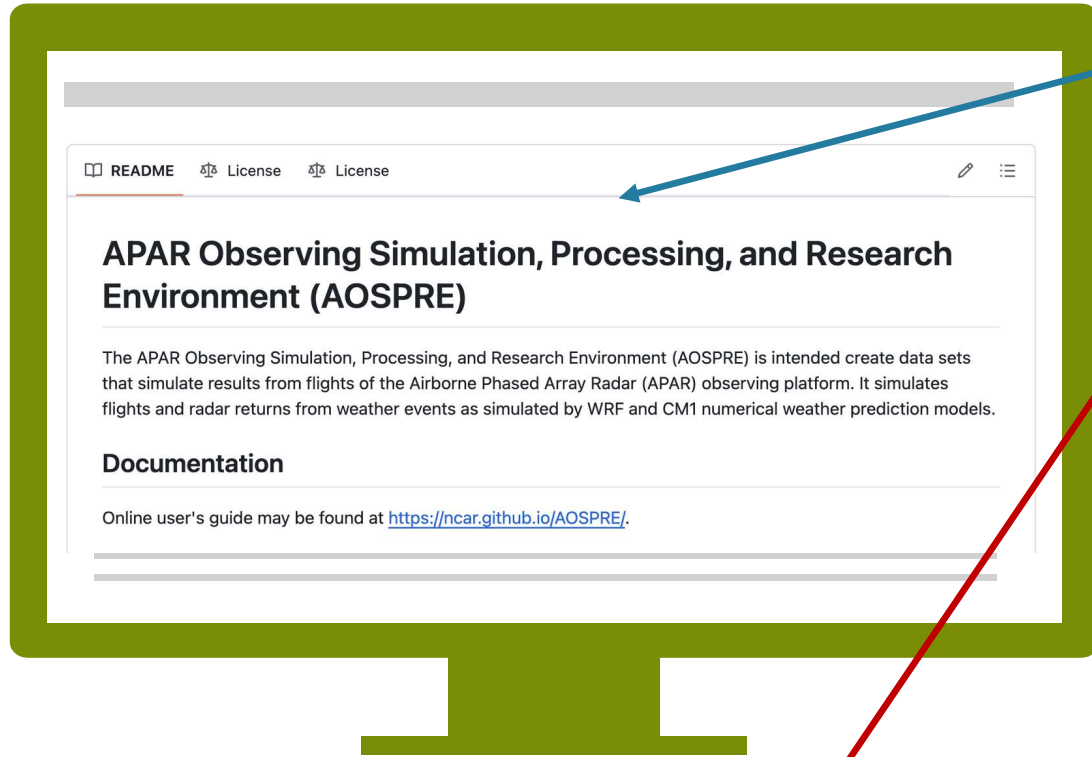
Scientific data generation from high impact weather events

Radar front end tools to understand design implications and calibration

Visualization tools that accomplish purposes across the teams

Radar back end tools for scan control, data collection and archival

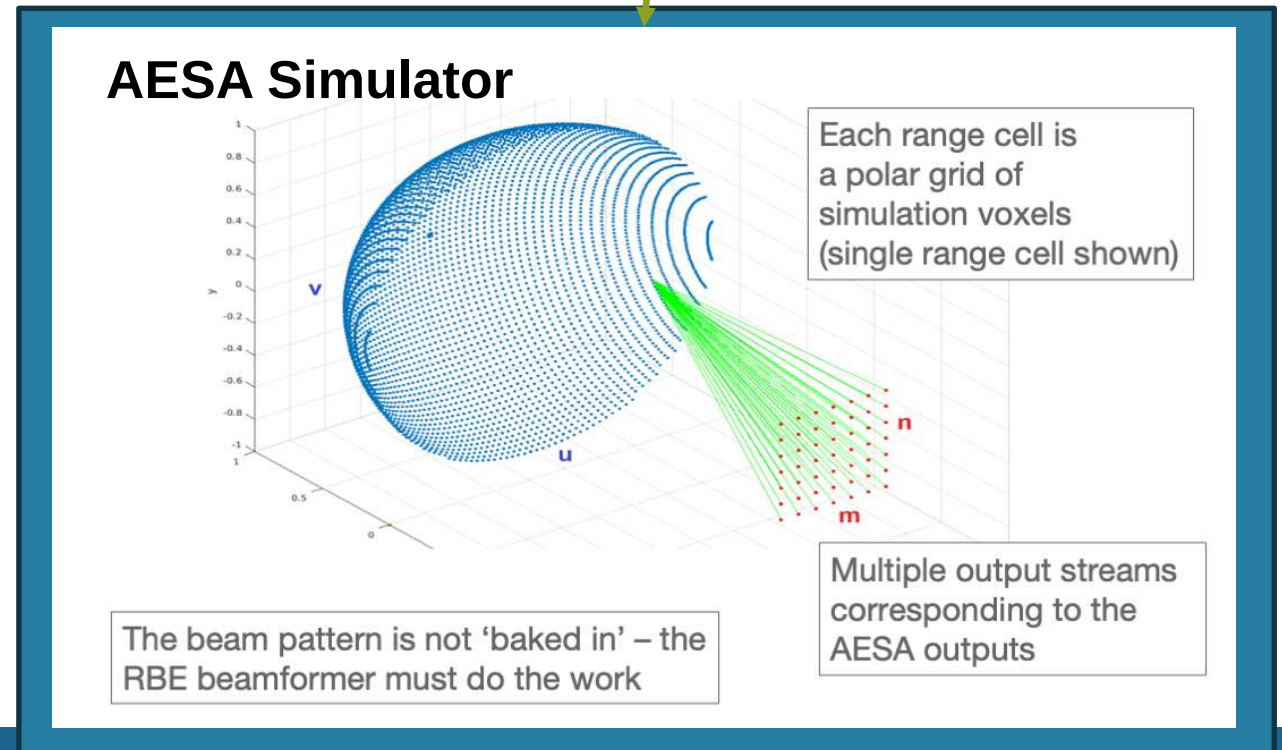
APAR Simulation and Analysis Tools



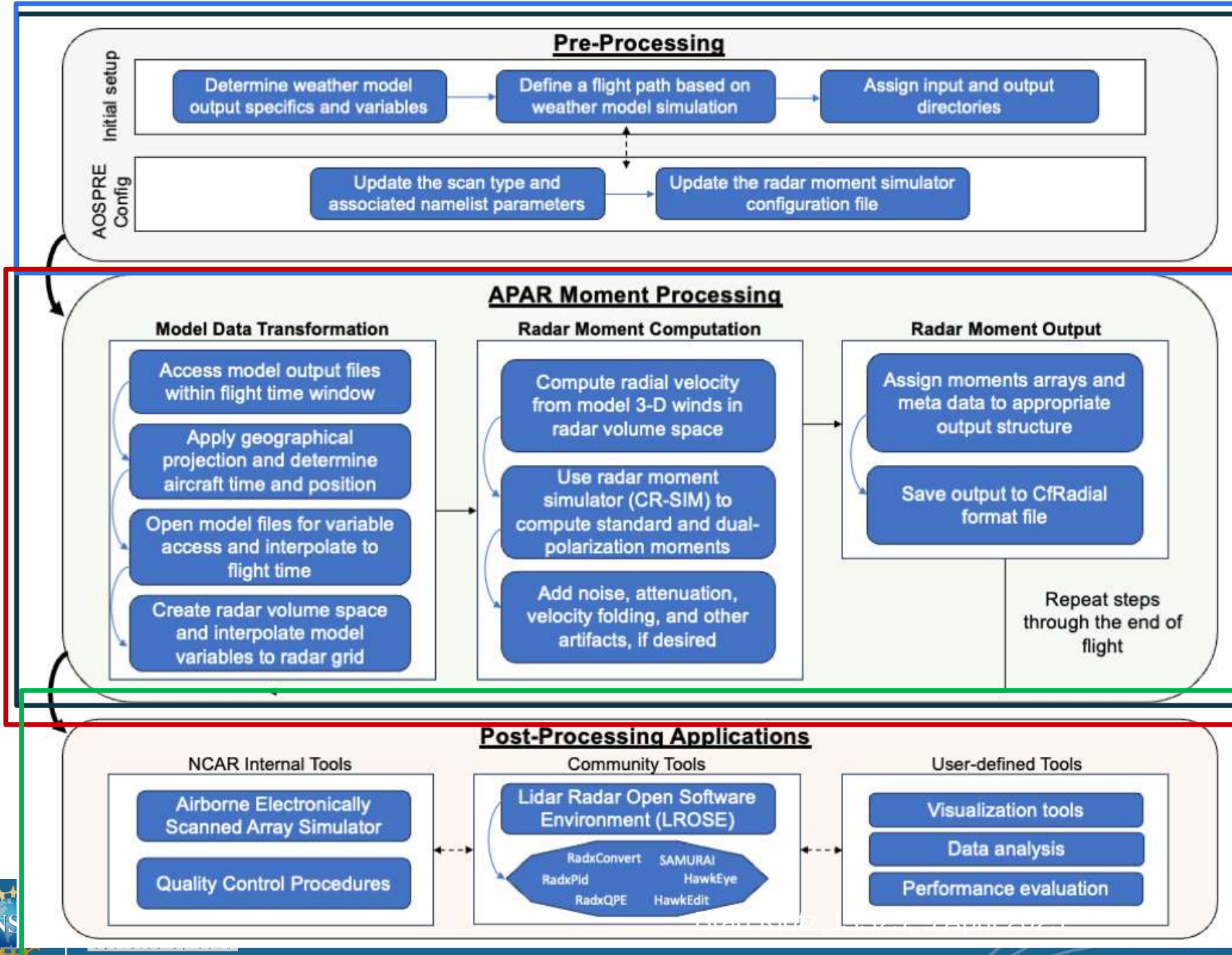
APAR Observing Simulation, Processing, and Research Environment (AOSPRES) used to generate simulated radar moments

AESA Simulator used to test I/Q timeseries data, beamforming, and waveform implementation

Lidar Radar Open Software Environment (LROSE) used for various, data QC, analysis, and visualization of radar data

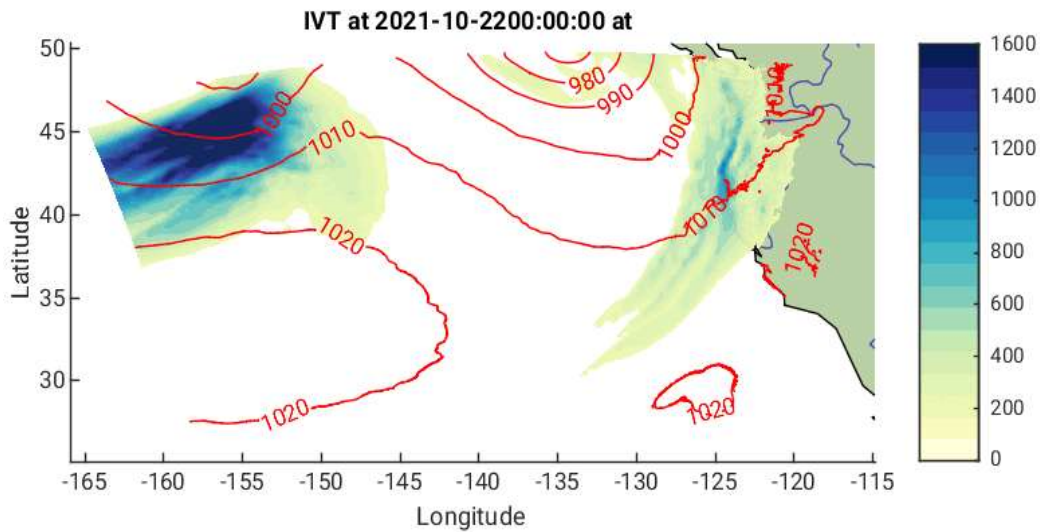
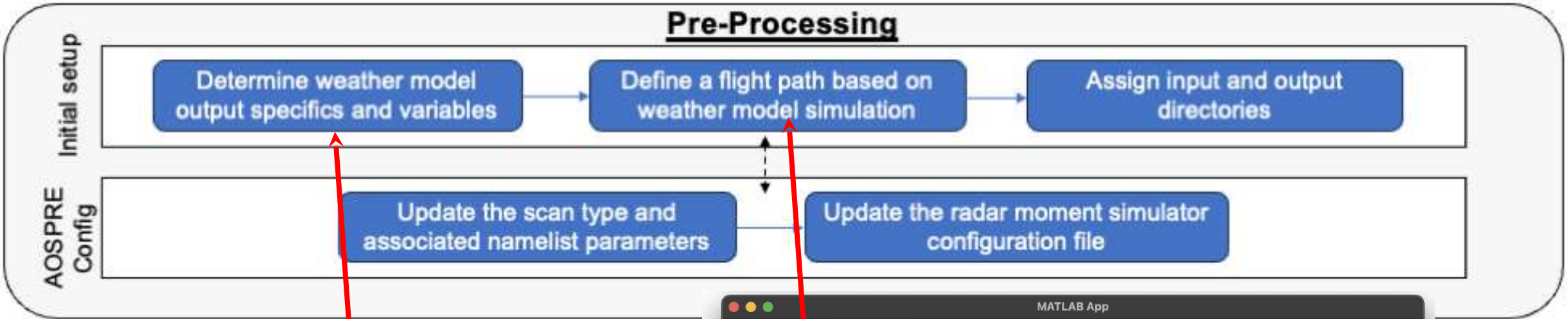


APAR Simulation Workflow



- AOSPRE is intended to serve as the basis for other applications
- The Pre-processing and Moment processing stages encompass most of the codebase
- Parallel processing with OpenMP is available in the moment computation phase
- Tie-ins to various post-processing applications, such as the AESA simulator or LROSE

AOSPRES Setup and Pre-Processing



MATLAB App

Simulation Details | Flight Planning | AOSPRES Details | Advanced Options

Interactive Target Planner ← C1

Start new flight ← C2 | Interactive Flight Planner

Manually draw path ← C3 | Edit path ← C4

Start X	Start Y	End X	End Y	Leg Time	Heading
122.5927	81.6667	94.0602	56.1205	8.6170e+03	-138.1608
94.0602	56.1205	58.3314	1.5786e+04	178.1942	

Clear Selection ← C6
Refresh Leg/Row
Add new Leg

Plot Details

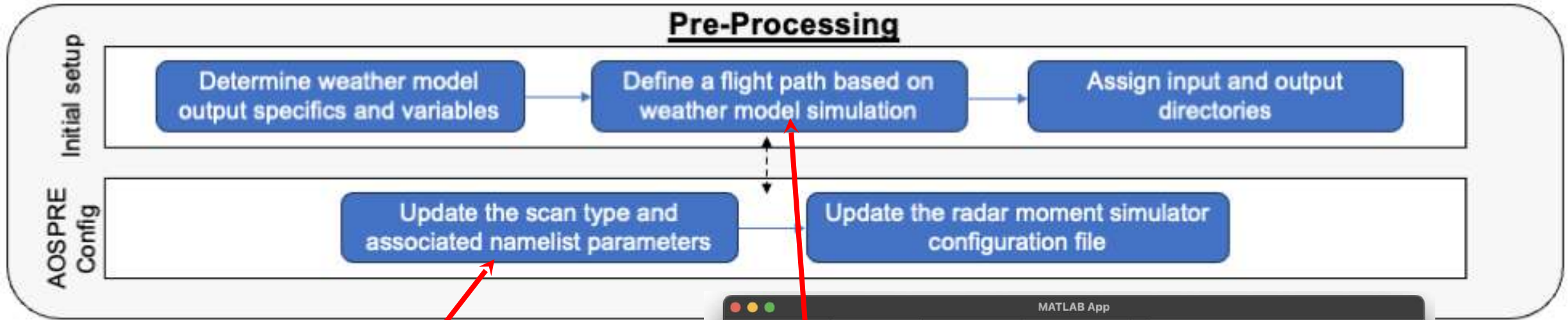
Plotted Variable: Times

Sim. Level: 1

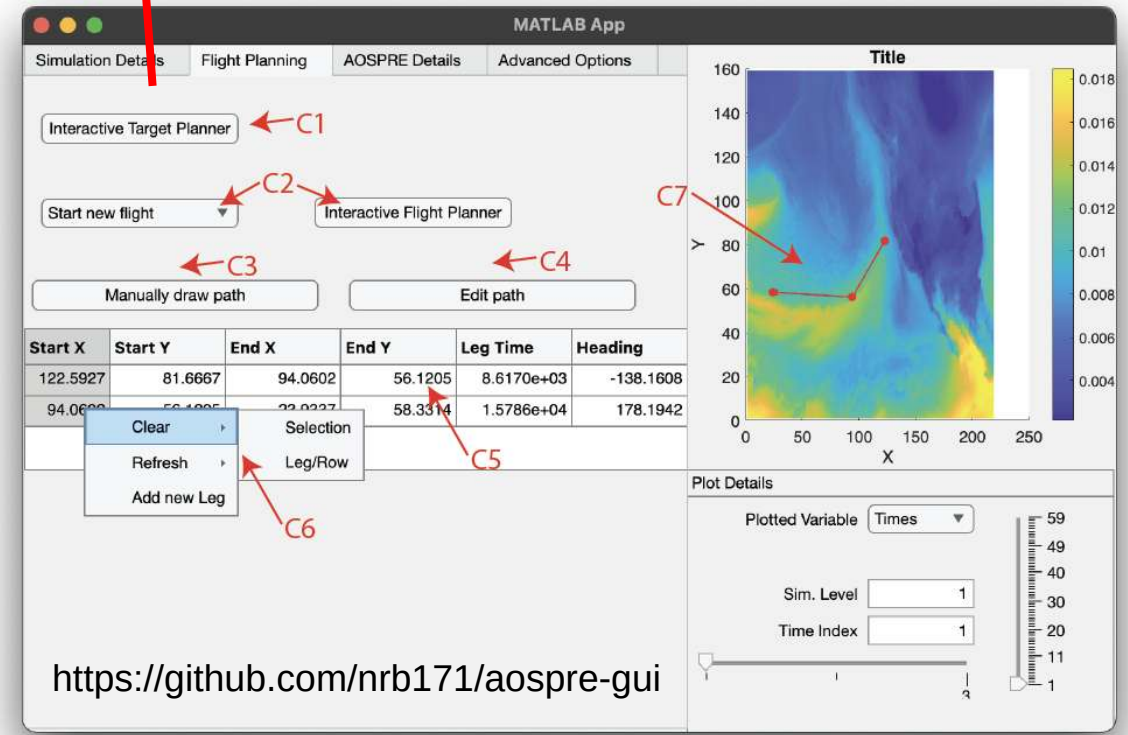
Time Index: 1

<https://github.com/nrb171/aospres-gui>

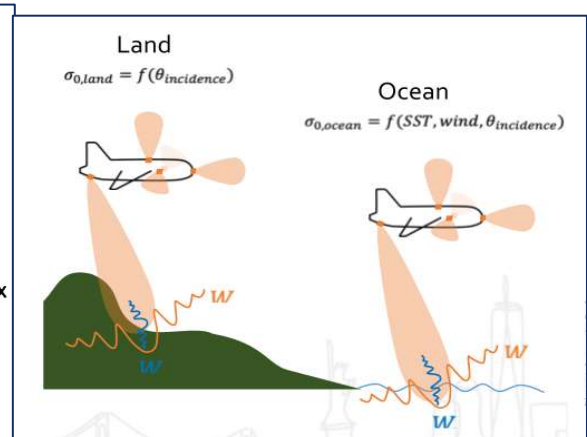
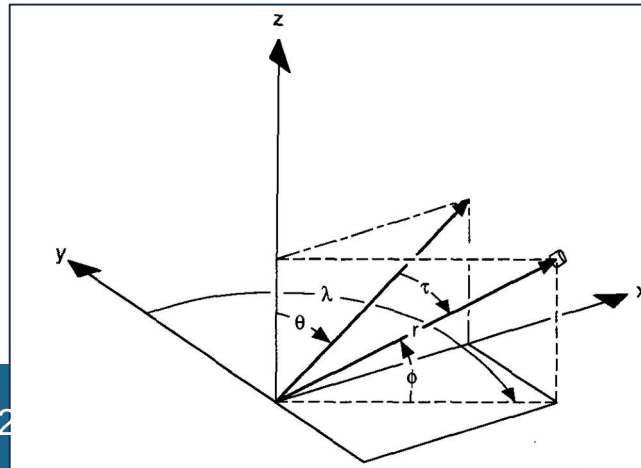
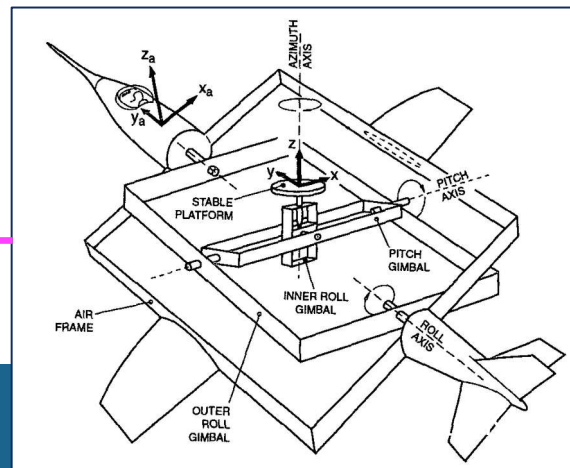
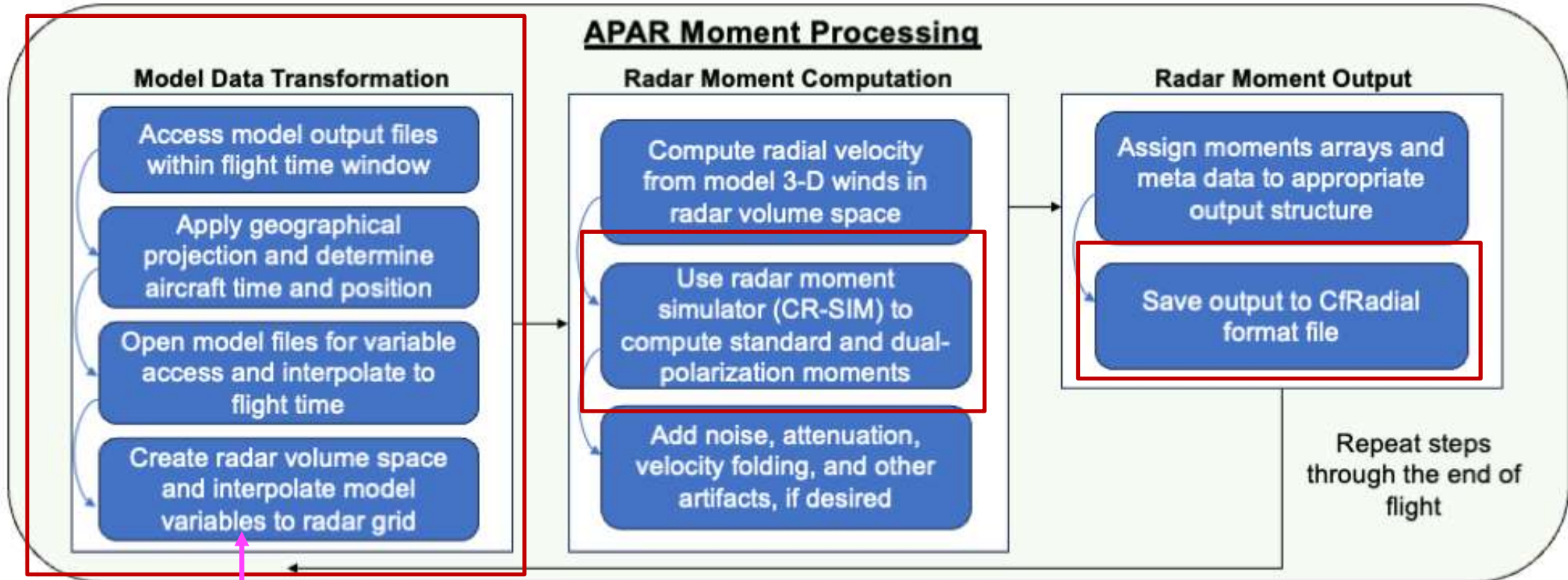
AOSPRES Setup and Pre-Processing



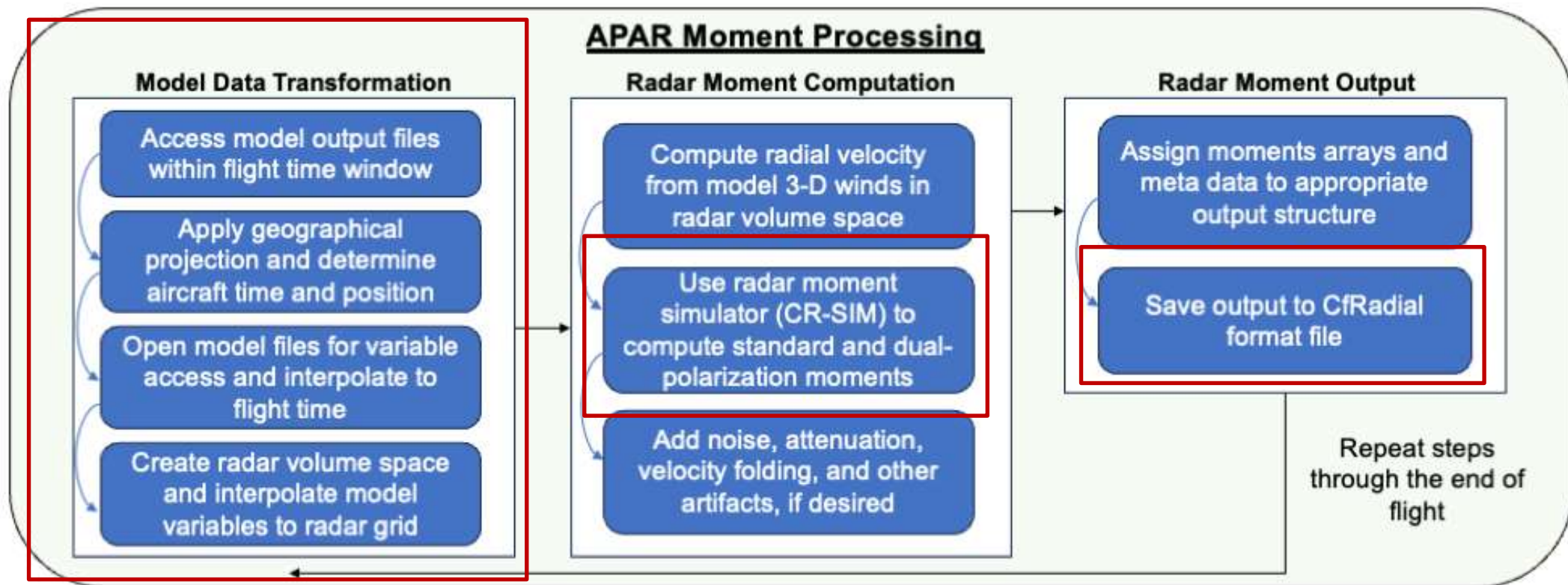
- Assignment of scan type (RHI or surveillance)
- Define radar parameters, such as beamwidth or range resolution
- Link scanning to specific beam patterns and waveforms



APAR Radar Moments Simulation

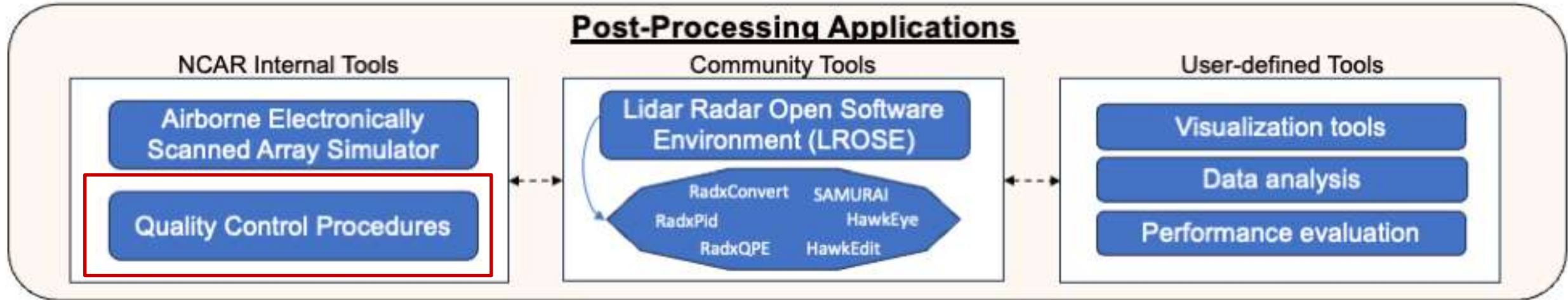


APAR Radar Moments Simulation



- Cloud Resolving Radar Simulator (CR-SIM, SUNY Stony Brook) uses known radar standards to compute radar moments from model output
- Specific APAR observing parameters are now included in an updated version
- CF-Radial format is a NetCDF output designed specifically for radar output

Connected Applications



Calibration

- **RadarCal** analyzes radar calibration
- Identifies circuit gain, coupling and noise

Clutter Removal

- **RadxClutter** is able to flag persistent clutter
- Ground, non-weather flagged

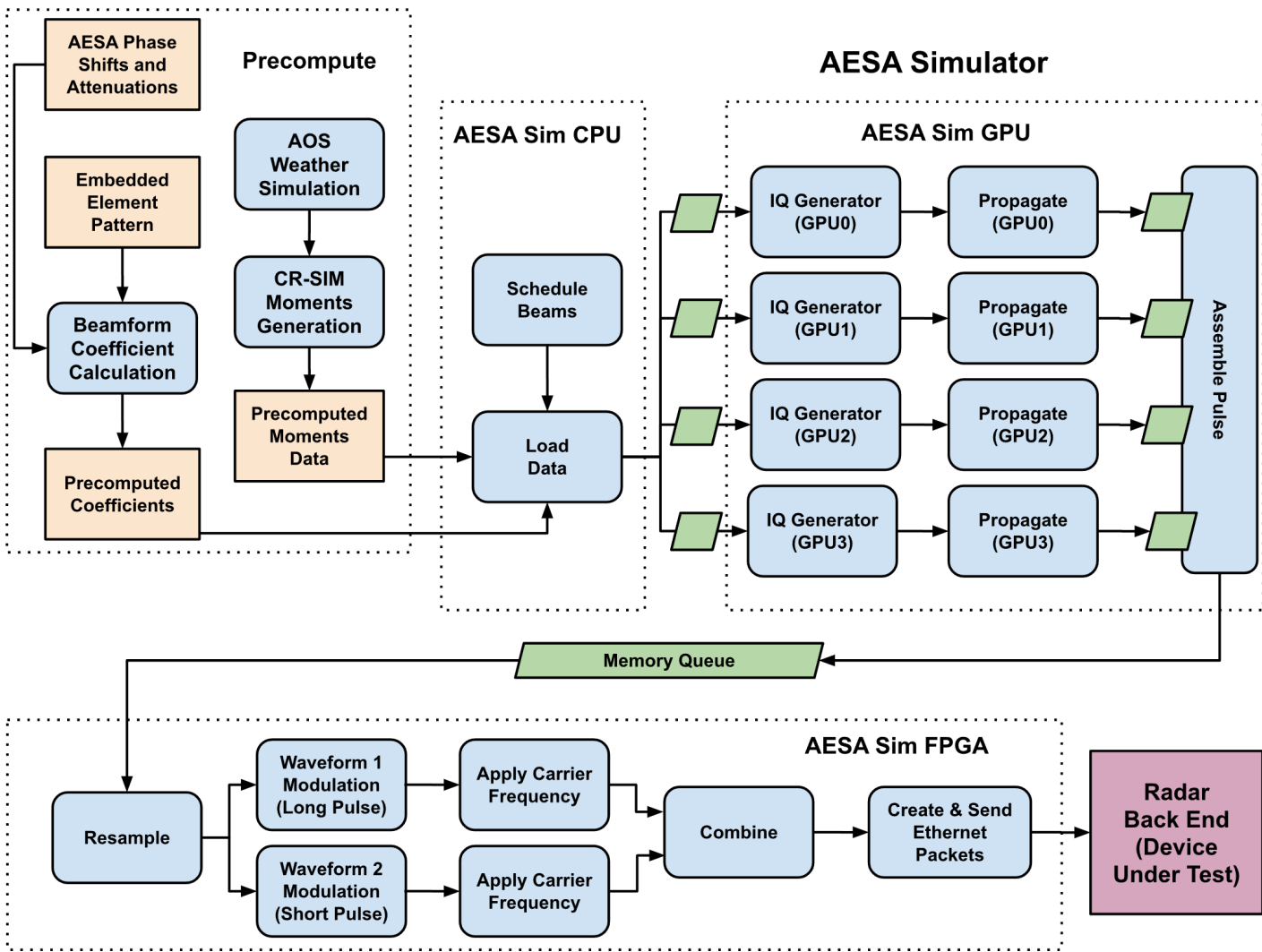
Wind Dealiasing

- **RadxDealias** unfolds winds using Nyquist velocity
- Enables proper wind analysis

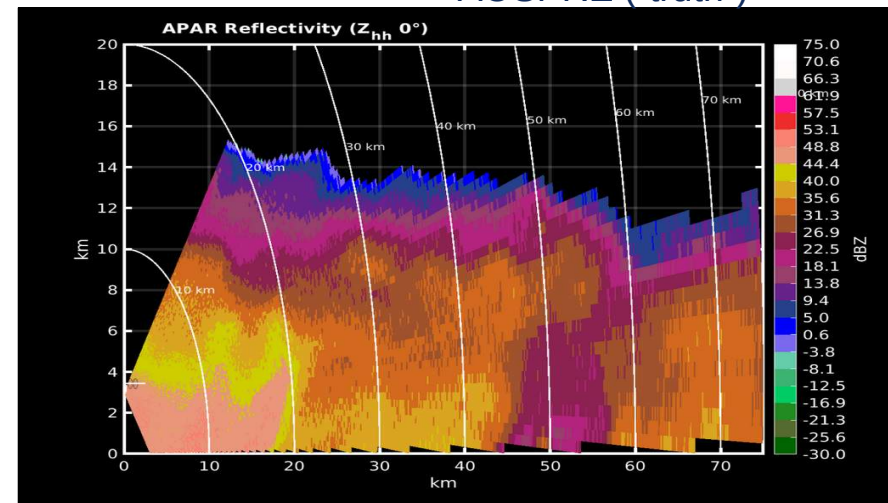
ML Tools

- **RONIN** (developed by CSU¹) automates data flagging
- Useful for winds and precipitation

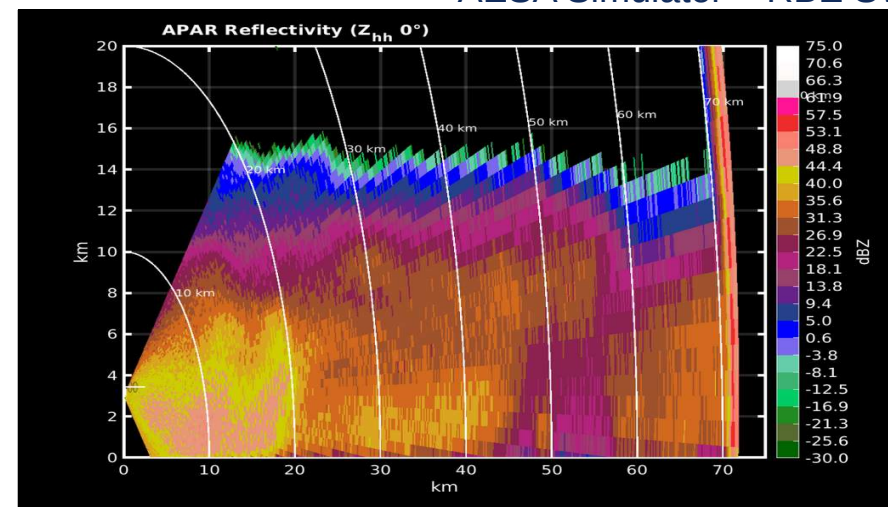
Connected Apps - AESA Simulator



AOSPRES ("truth")



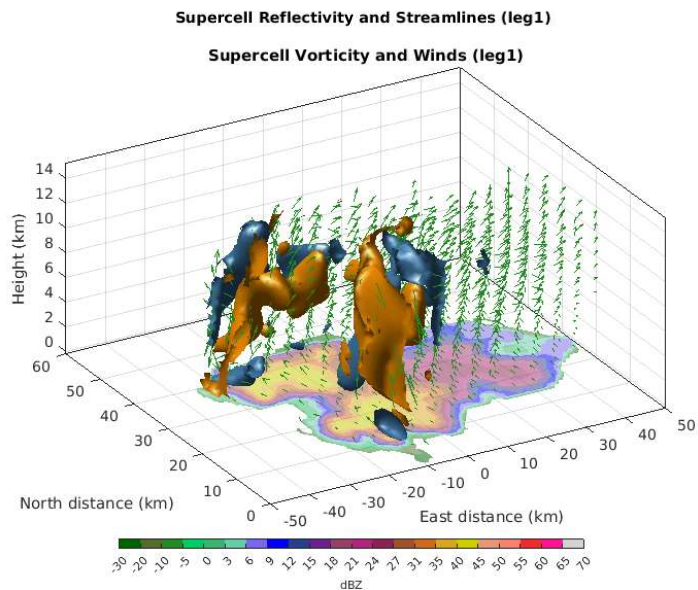
AESA Simulator + RBE SW



Connected Apps – Radar Analysis

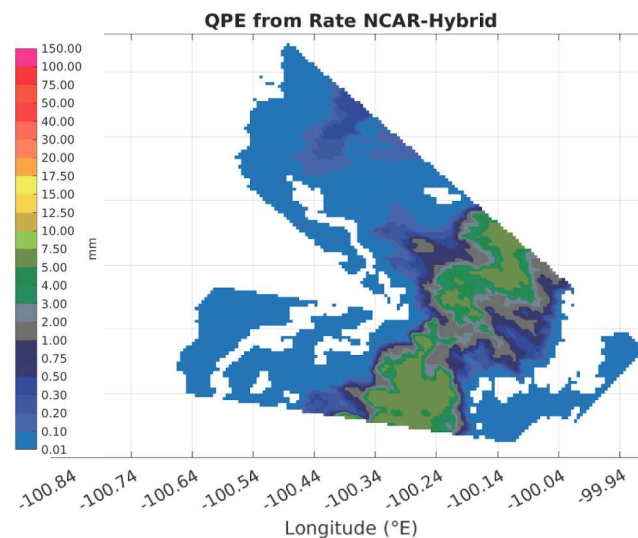
SAMURAI

- Using dual-Doppler analysis, resolve 3-D wind field
- Vital for structure analysis



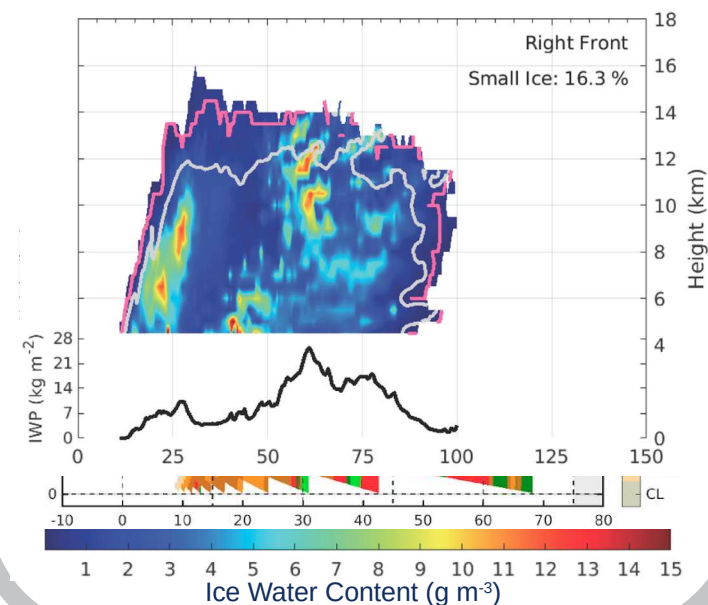
QPE

- Diagnose total precipitation amounts
- Important for diagnosing flood potential



PID

- Determine particle types
- New information about drop-size distributions and microphysics



Connected Apps - Visualization

- **HawkEye** allows displays of radar volumes in a traditional range and azimuth system
- **HawkEdit** is a version of HawkEye that allows user editing
- **LUCID** and **MICA** allow additional observations with radar data

- **AparScope** and **AparSprite** used for timeseries and power spectra display

- **User-defined** visualization allows scientists to develop other tools with possible inclusion in LROSE

Hav

File Time

Fixed i

Swi

N sa

N ga

Gate

Pulse width

PRF mode

PRF

Nyquist

Max range

U-A range

Scan mode azimuth

Pol mode

Lat

Lon

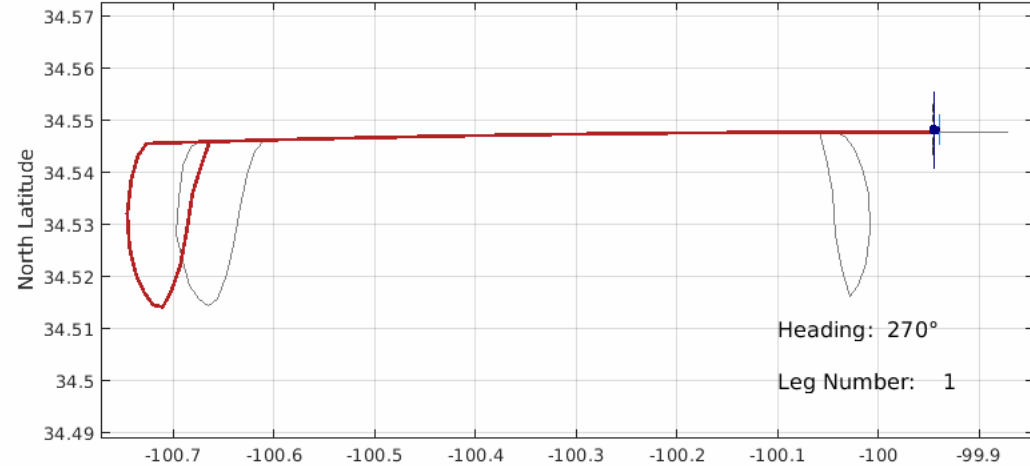
Alt(km)

Sun el (deg)

Sun az (deg)

Apa

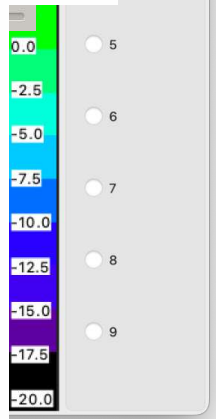
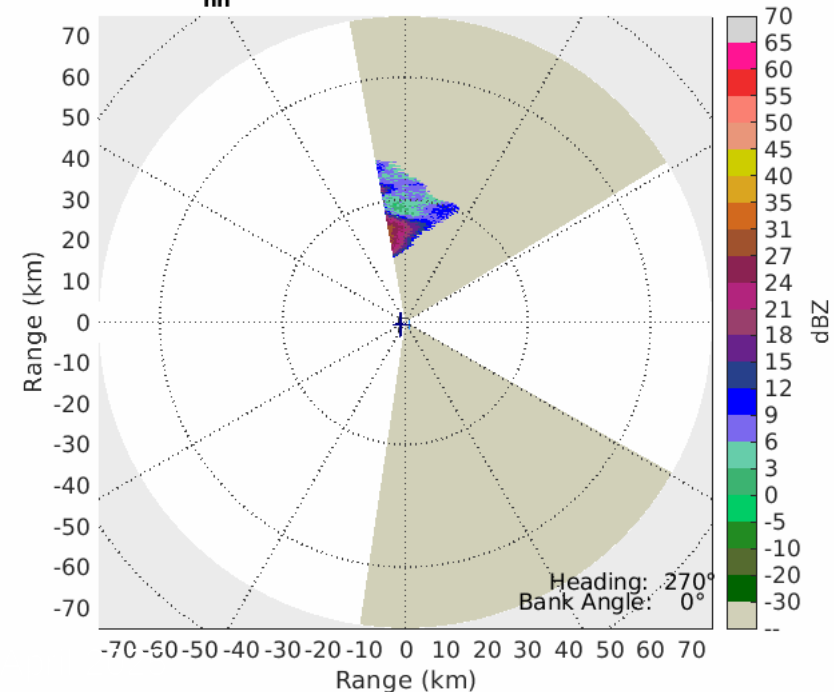
Aircraft Location: 20010101 011450 - 011451



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Numbers

Z_{hh}: 20010101 011450 - 011451



Summary and Future Development

- To understand APAR performance capabilities, several stand-alone simulation tools are linked into a large workflow that allows:
 - Simulation of APAR data from an airborne platform (AOSPRES)
 - Testing beam patterns and waveforms for time-series generation (AESAs simulator)
 - Testing radar analysis and visualization tools for specific APAR application
- Future development of these tools includes:
 - Improved efficiency and usage of parallel computing
 - Improved linkages to different tools through creating wrappers
 - Development of a true system digital twin to allow examination of engineering, backend software, and scientific analysis



Questions?