Tools and methods to analyze the effectiveness of signature reduction and soft-kill

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Outline

- Some Background / History
- 3D Flare Particle Model
- Advanced MWIR Seeker
- Sample Fly-ins

Development Milestones

- Start of project – 1990
- ShipIR (V1) – 1992
- NTCS (V2) – 1995

- NATO Ship IR Model Workshop – 1994 (ShipIR/NTCS adopted as common NATO tool)
- ShipIR adopted by USN for IR Cruise Missile Simulation – 1996

Validation and Accreditation

- Validation (NATO):
  - 1999: US-NRL Panel Validation (SPIE 3699)
  - 2003: NATO SIMVEX (SPIE 5075)
  - 2005: ShipIR v3.2 (SPIE 6329)

- Accreditation (USN):
  - 2001: DDG-51 Live Fire Test & Evaluation
  - 2004: DDX Preliminary Design Review (PDR)
  - 2005: DDX Critical Design Review (CDR)
  - 2005: DDX Initial Vulnerability Assessment

Key Model Features

- End-to-end analytical treatment of signature (geometry, materials, meteorology, temperature, radiance)
- Full-spectral analysis (per node/facet)
- Multi-bounce radiation (diffuse / specular)
- Fast and accurate exhaust plume IR model (semi-empirical, custom multi-volume / multi-surface raytrace / rendering
- Extensive use of OpenGL (in hardware)
- Active Support (25^{+} years)
- turn-key for Navy End Users (climate API, ship-engine API, operational scenarios)

More Recent Events

- May 2013: Climatic Data Analysis and IR Susceptibility Analysis (SPIE Baltimore)
- Oct 2013: NATO SET-202 Specialist Meeting Naval Platform Signature Management
- Dec 2013: Invited to speak at SCI-224 Meeting (Quebec) – Joined the group as a *special guest*
- Mar 2016: Final Meeting of SCI-224 Meeting (Rennes)
- Dec 2016: First Meeting of SCI-ET-024 (Paris) – proposed a common NATO tool using ShipIR/NTCS and SADM (Ship Air Defence Model from BAE Australia)
- May 2017: 2nd Meeting of SCI-ET-024 (Washington) – Training session on SADM and ShipIR/NTCS – using generic DDG model in Mediterranean (Italian Ligurian Sea)

3D Particle-Based Flare Model (v3.7)

- Based on Tukey distribution:
  - Ref: https://en.wikipedia.org/wiki/Tukey_lambda_distribution
  - after American Mathematician John Wilder Tukey (1915–2000)
  - Popular in simulating network traffic (i.e., fat-tail distributions)
- Flare Model Inputs:
  - Area (m^2)
  - Shape distribution parameter (λ)
  - No. of particles – new (sample points)
  - Flare temperature (blackbody-equivalent)
  - Flare spectral emission
  - Flare temporal burn characteristics
- Results (to-date):
  - Extensive analysis / study of particle distribution (Ns, IFOV, λ)
  - Tools to compute Coverage (%) and radial signature distribution (W/sr/m)
  - Custom rendering (z-buffering, 3D-particle rendering w/ alpha-blending)
  - Fitted to actual measurements of Chemring TALOS IR rounds

Flare Characterization Metrics

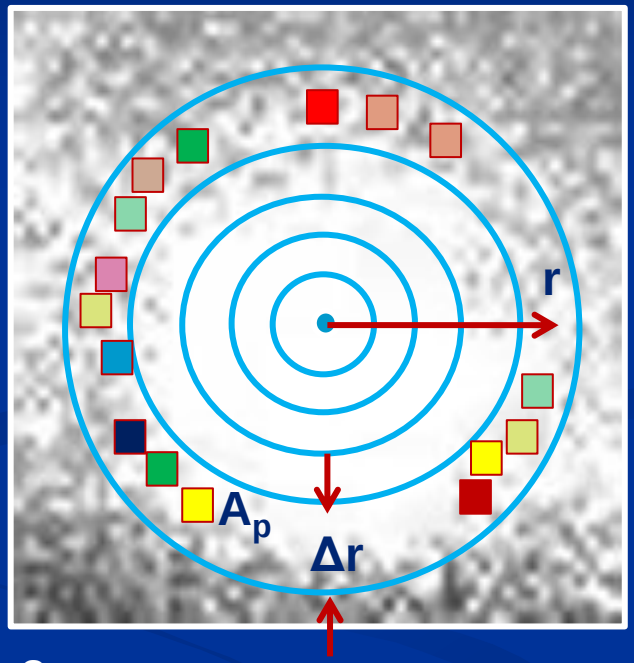
Radial distribution of:

- Signature (W/sr/m)

$$J_r(r) = \left(\frac{1}{\Delta r}\right) \cdot \sum_{bin\ pixels} L_i \cdot A_p$$

- Average Radiance L_μ (W/m^2/sr)

$$L_\mu(r) = \left(\frac{1}{N_{p,bin}}\right) \cdot \sum_{bin\ pixels} L_i$$



- Std. deviation of radiance L_σ (W/m^2/sr)

$$L_\sigma(r) = \sqrt{\left(\frac{1}{N_{p,bin}}\right) \sum_{bin\ pixels} \left[L_i - L_\mu\right]^2}$$

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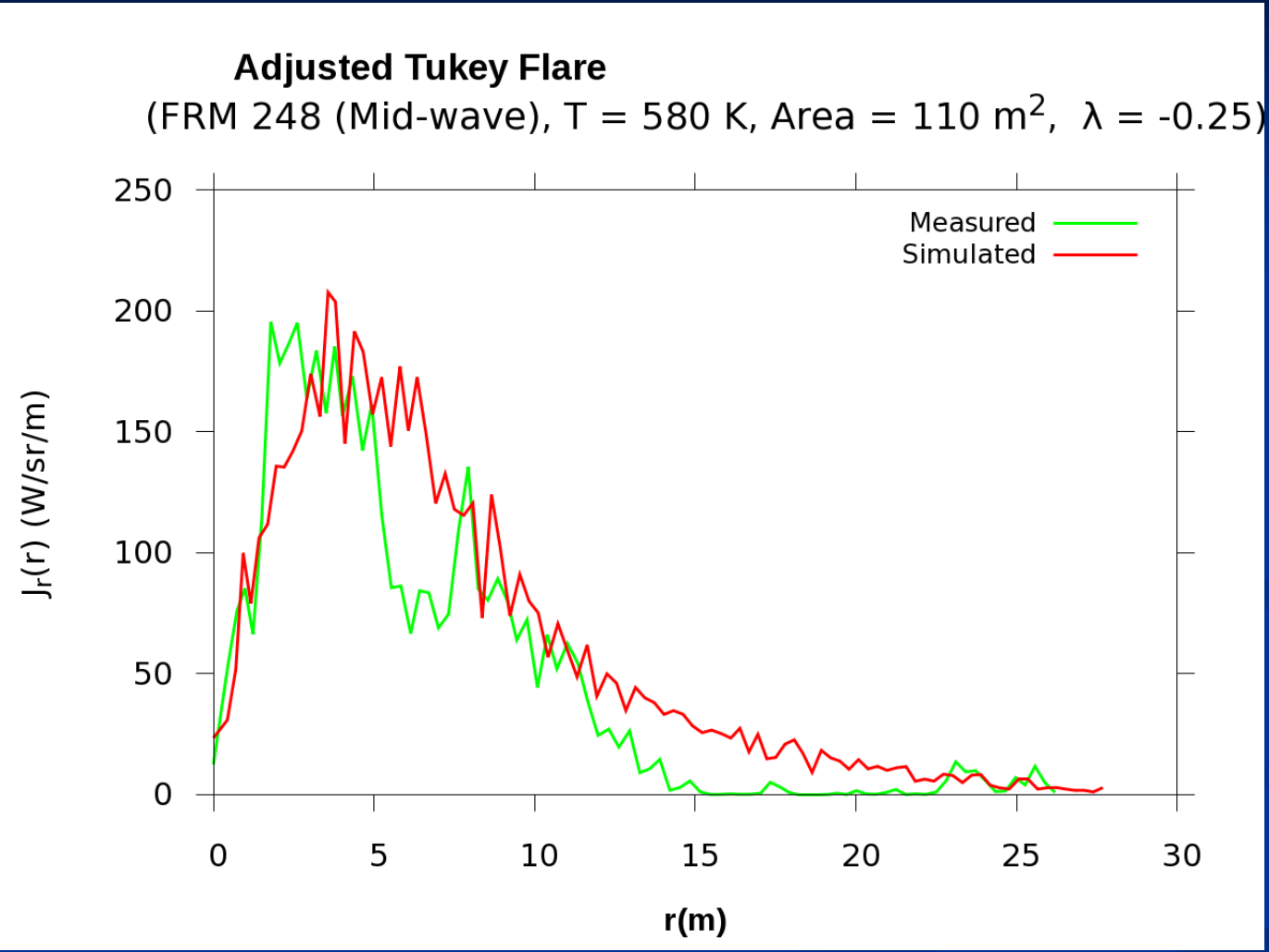

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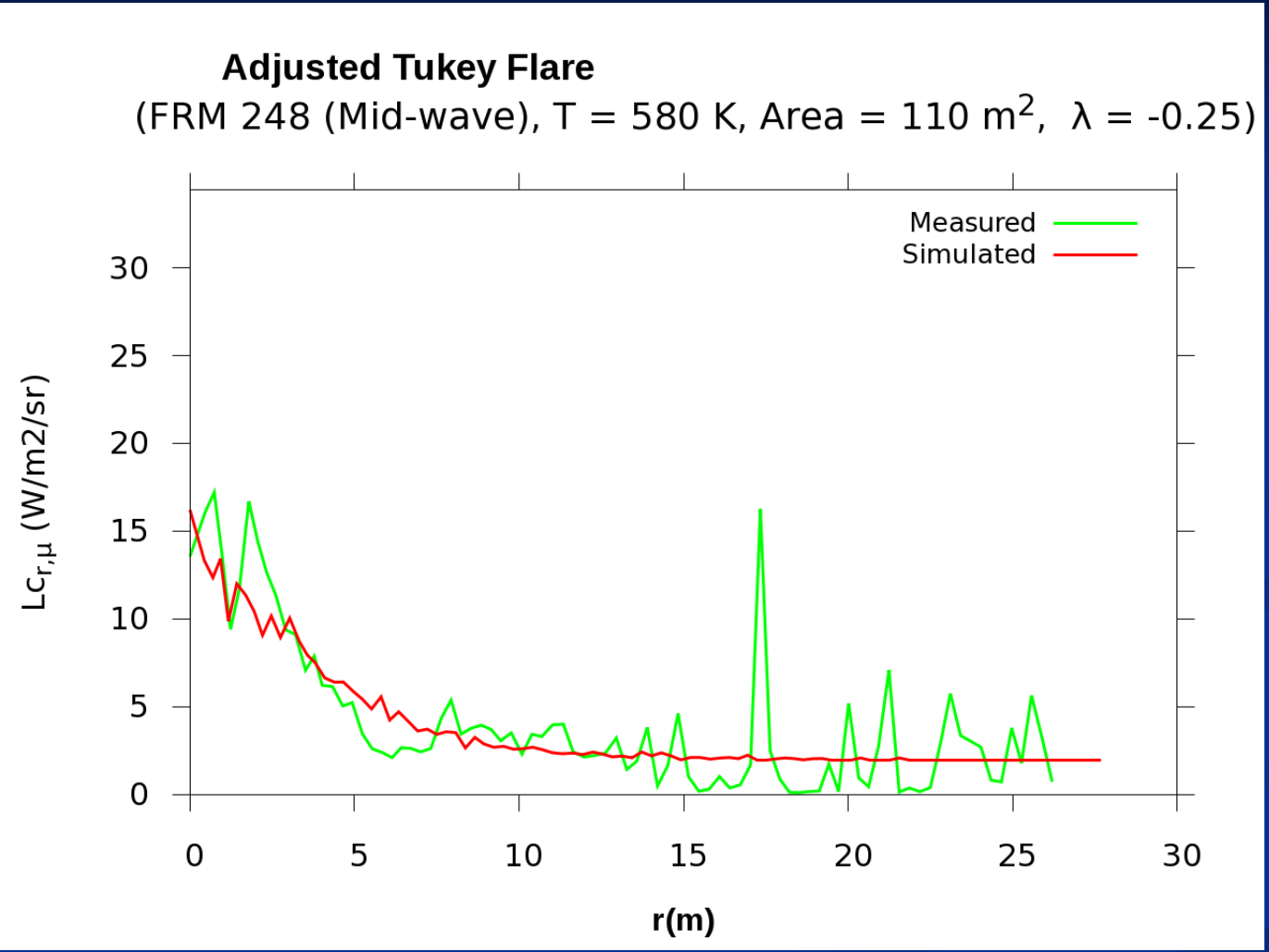

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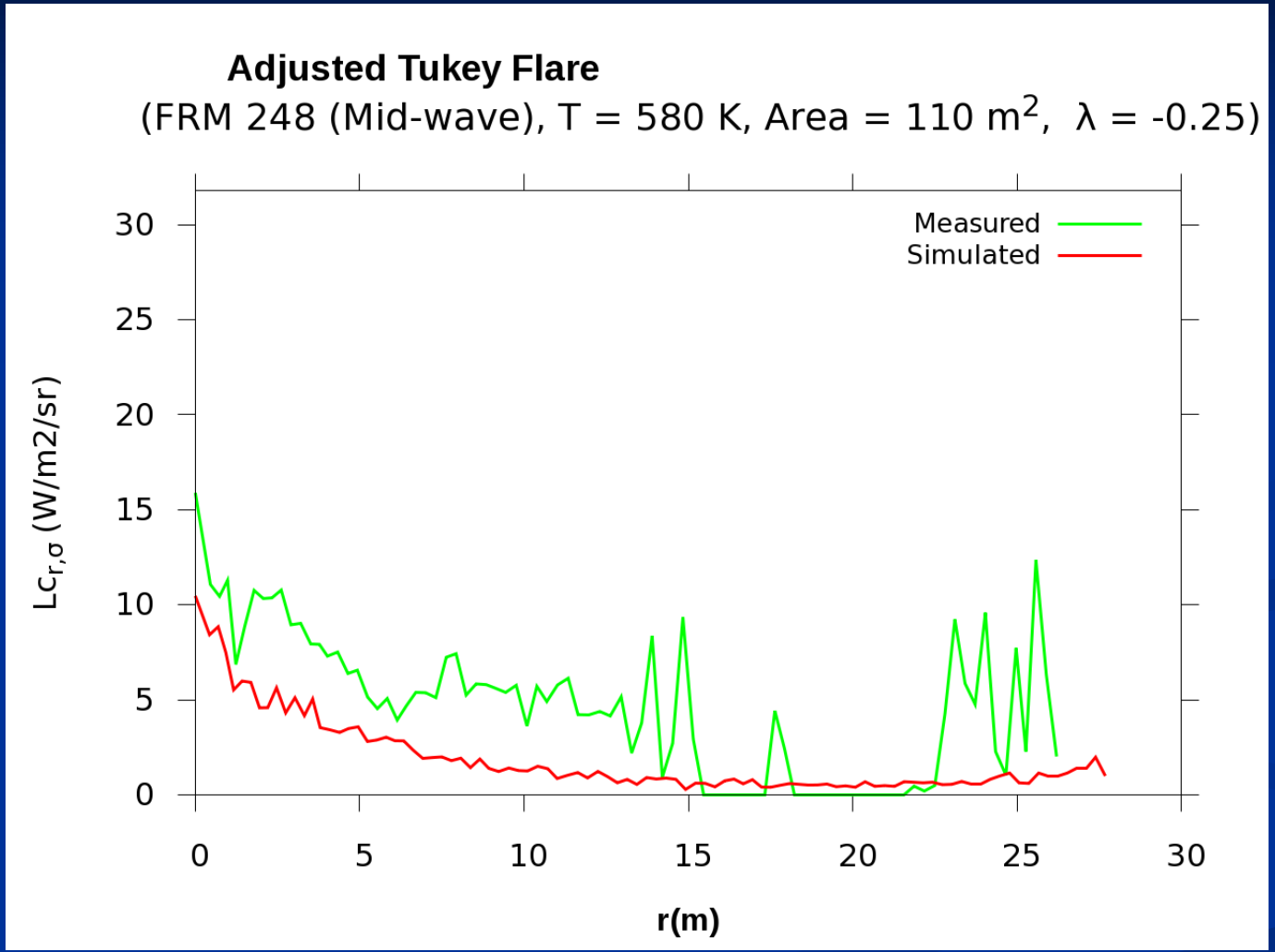

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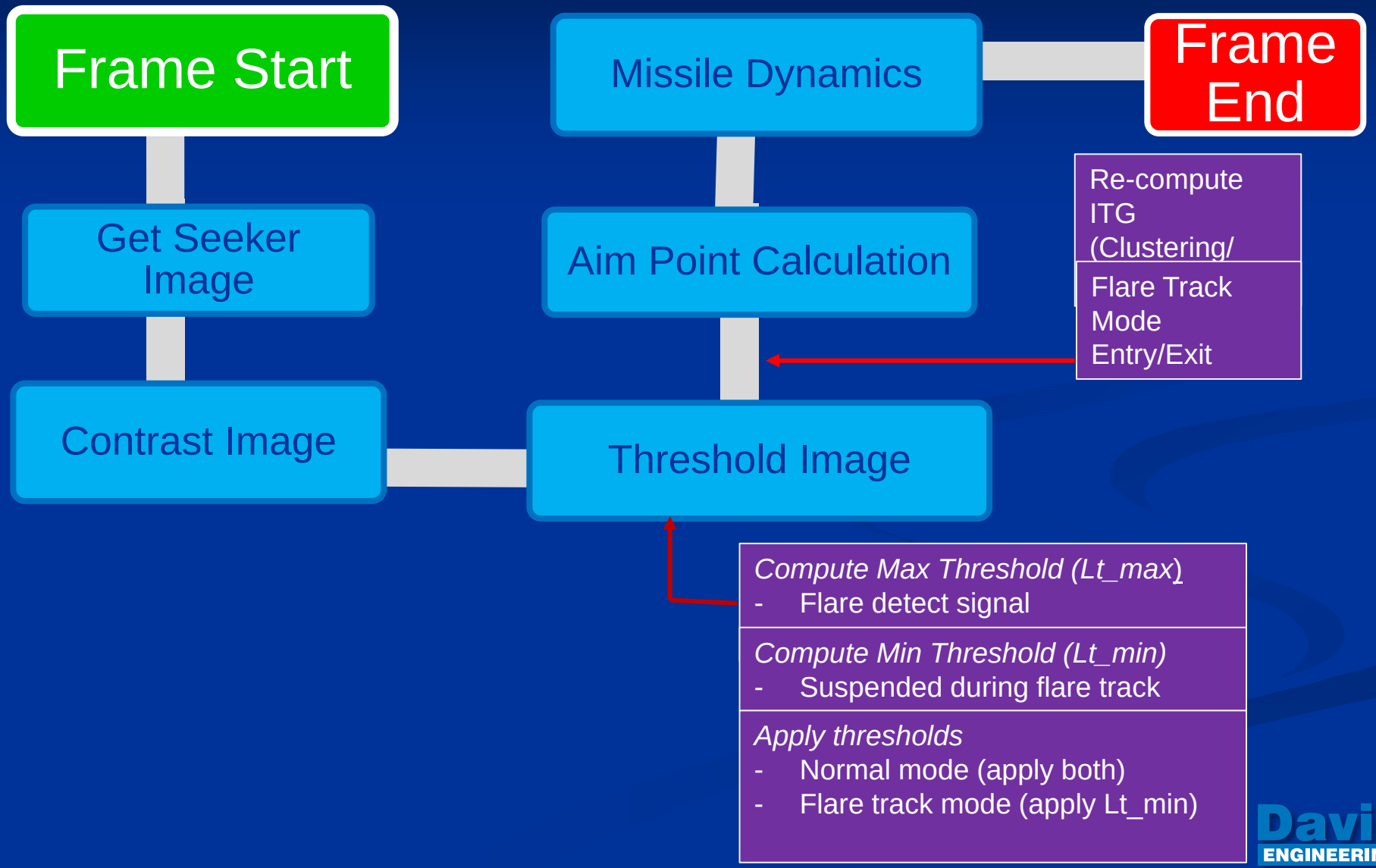
Adaptive Track Gate (v3.6)

- Dynamic thresholds:
  - Maximum Threshold (outlier rejection → flare detection)
  - Minimum Threshold (quantiling + optimum selection)
- Target Selection:
  - Inner Track Gate (ITG):
    - Clustering
    - Knapsack
    - Flare Track Mode (entry/exit)
  - Outer Track Gate (OTG) ← buffer region

ATG Seeker Framework



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Sample Fly-Ins

Moderate Resolution Sensor

Basic Characteristics	
Field of View	8° x 8°
Resolution	256x256
IFOV (mrad)	0.5454
Sampling rate (Hz)	25

Detection Criteria	
NETD	0.1 °C
SNR	5
No of pixels	1
No of frames	2

Rosell and Wilson

$L_{c,det}$ = SNR x NER

NER = f(NETD, λ)

Detection (Lock-on):

- $L_{c,max} > L_{c,det}$
- on N_p (pixels)
- for N_f (frames)

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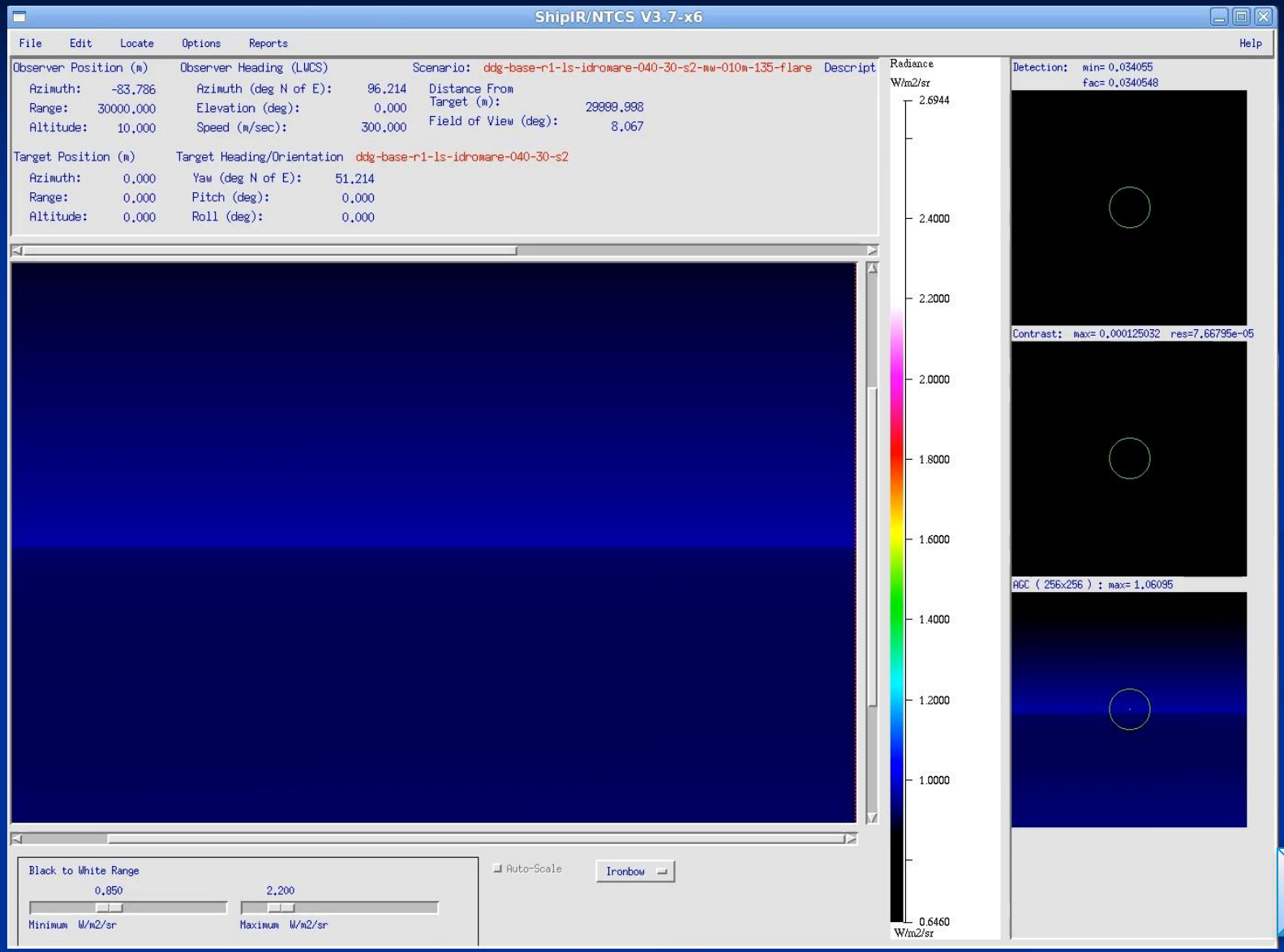
Baseline (no IRSS), High R_d climate



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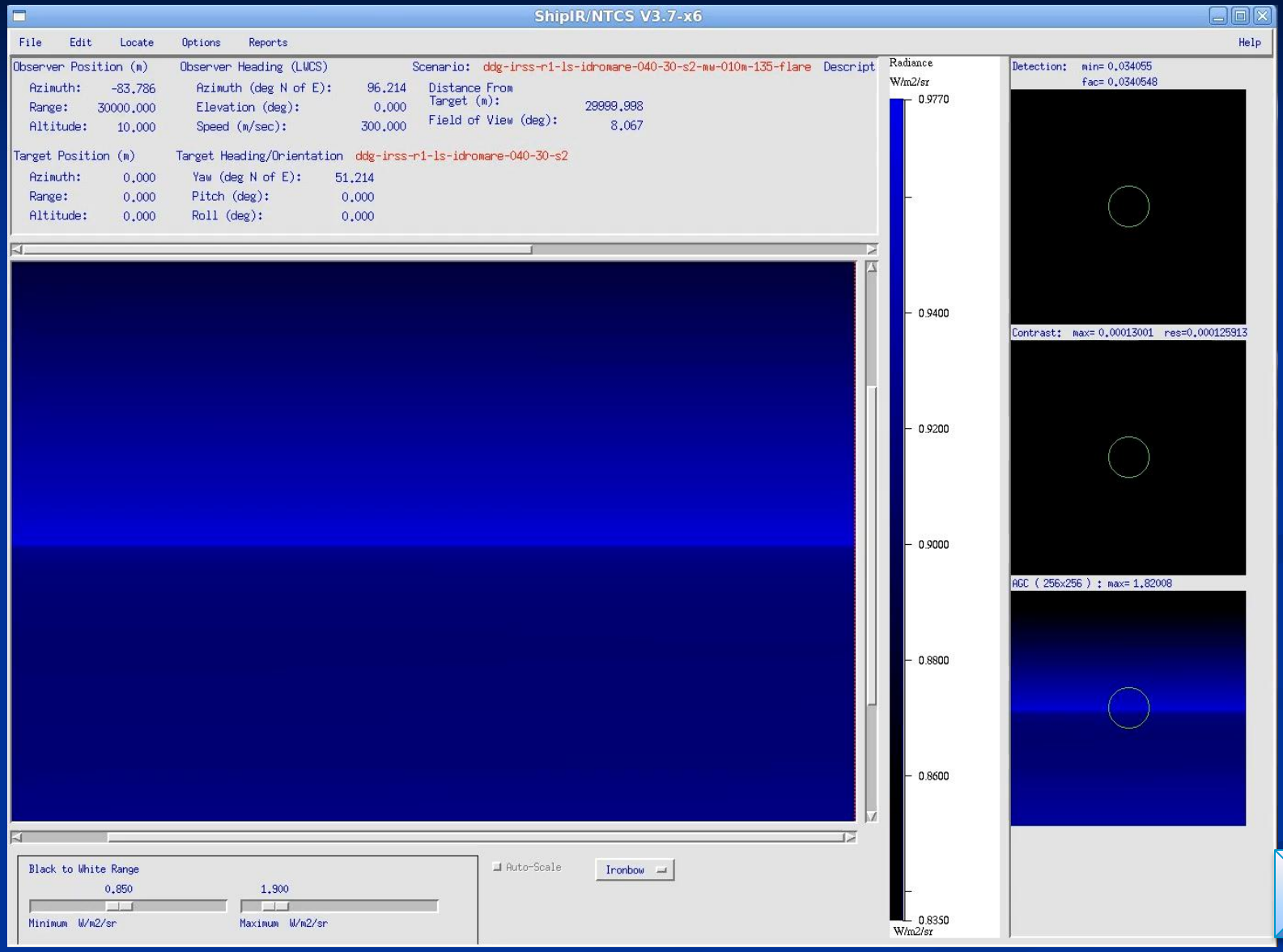
IRSS, High R_d climate



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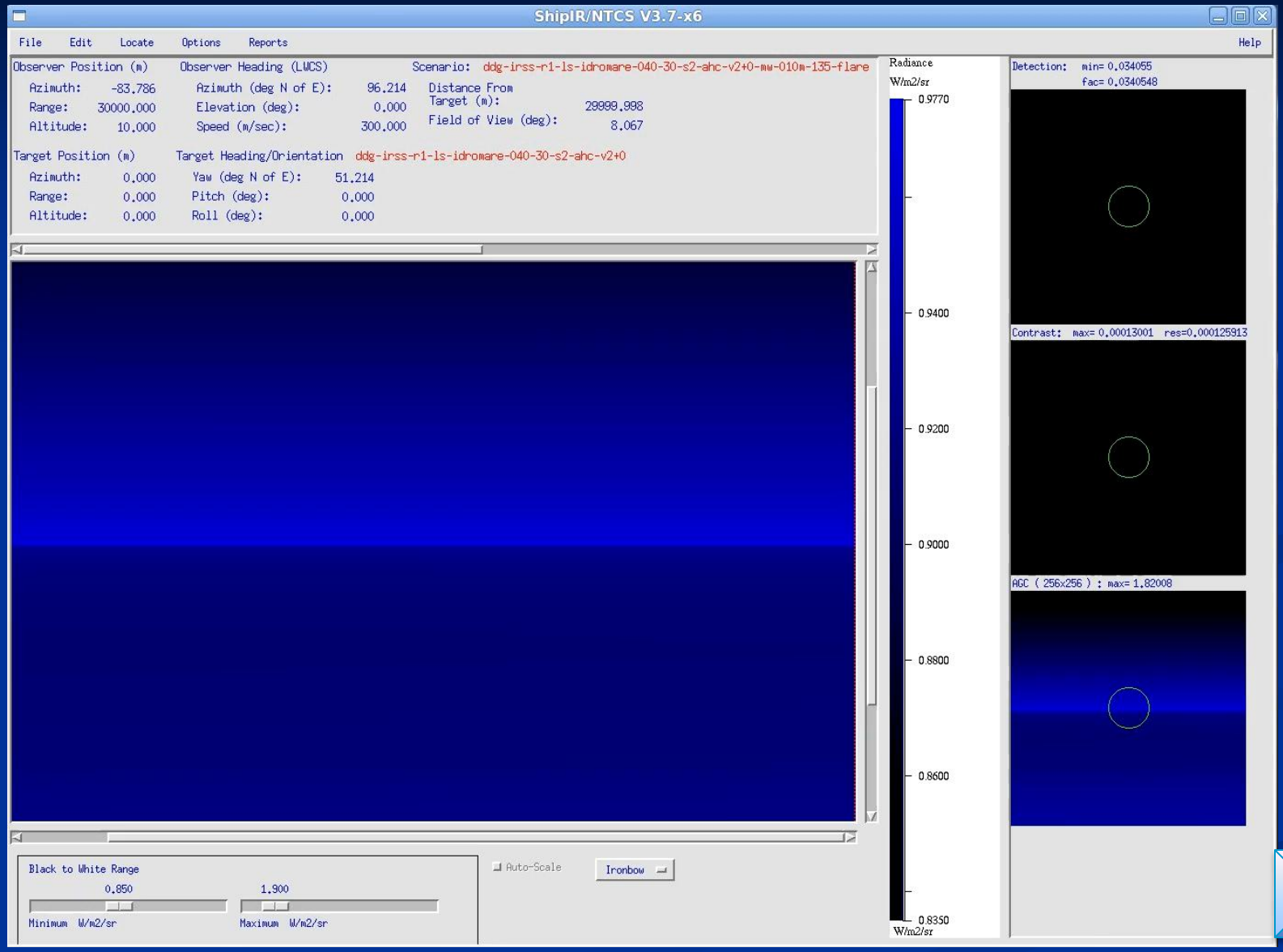
IRSS + AHC, High R_d climate



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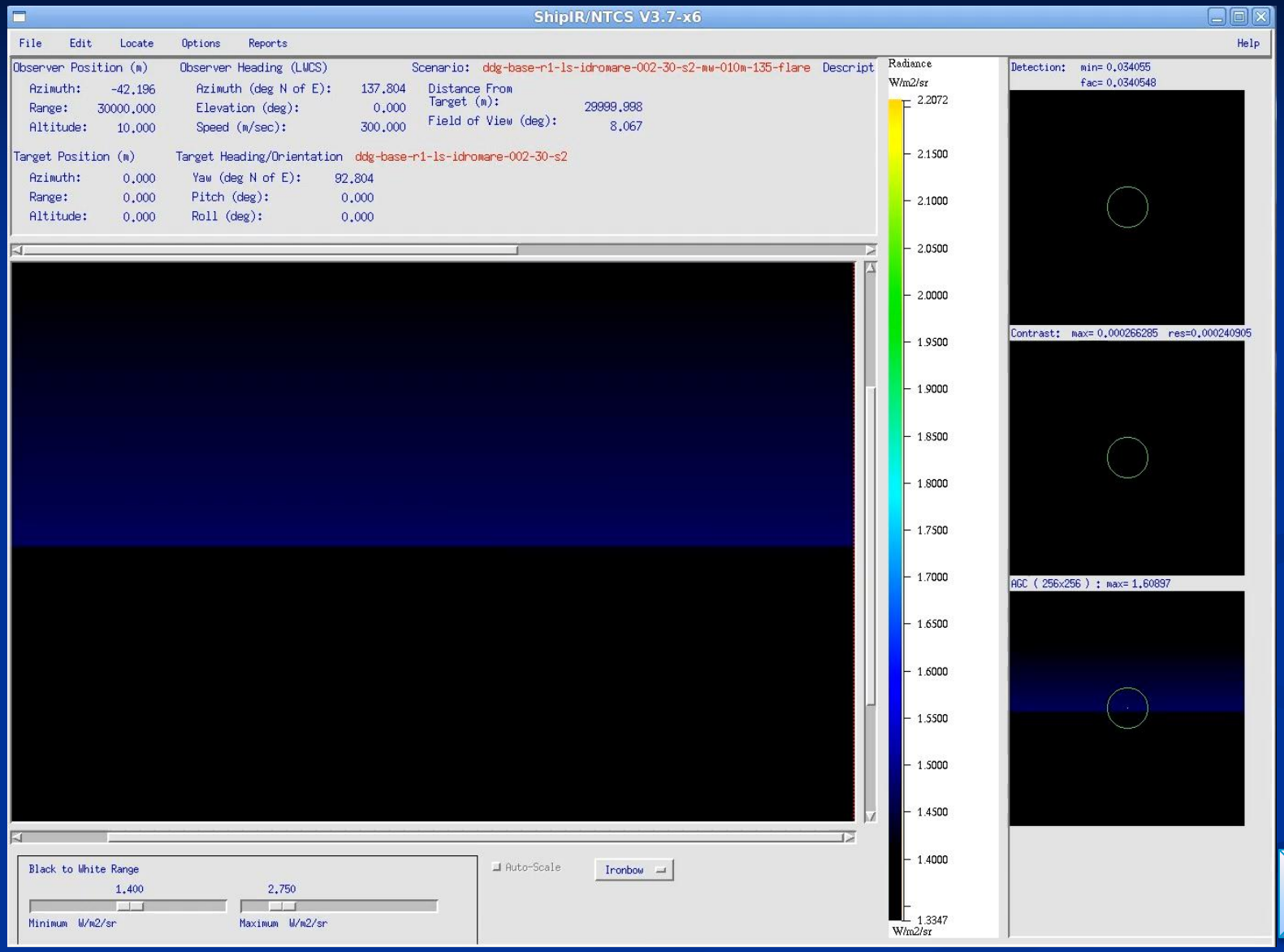
Baseline (no IRSS), Lower R_d climate



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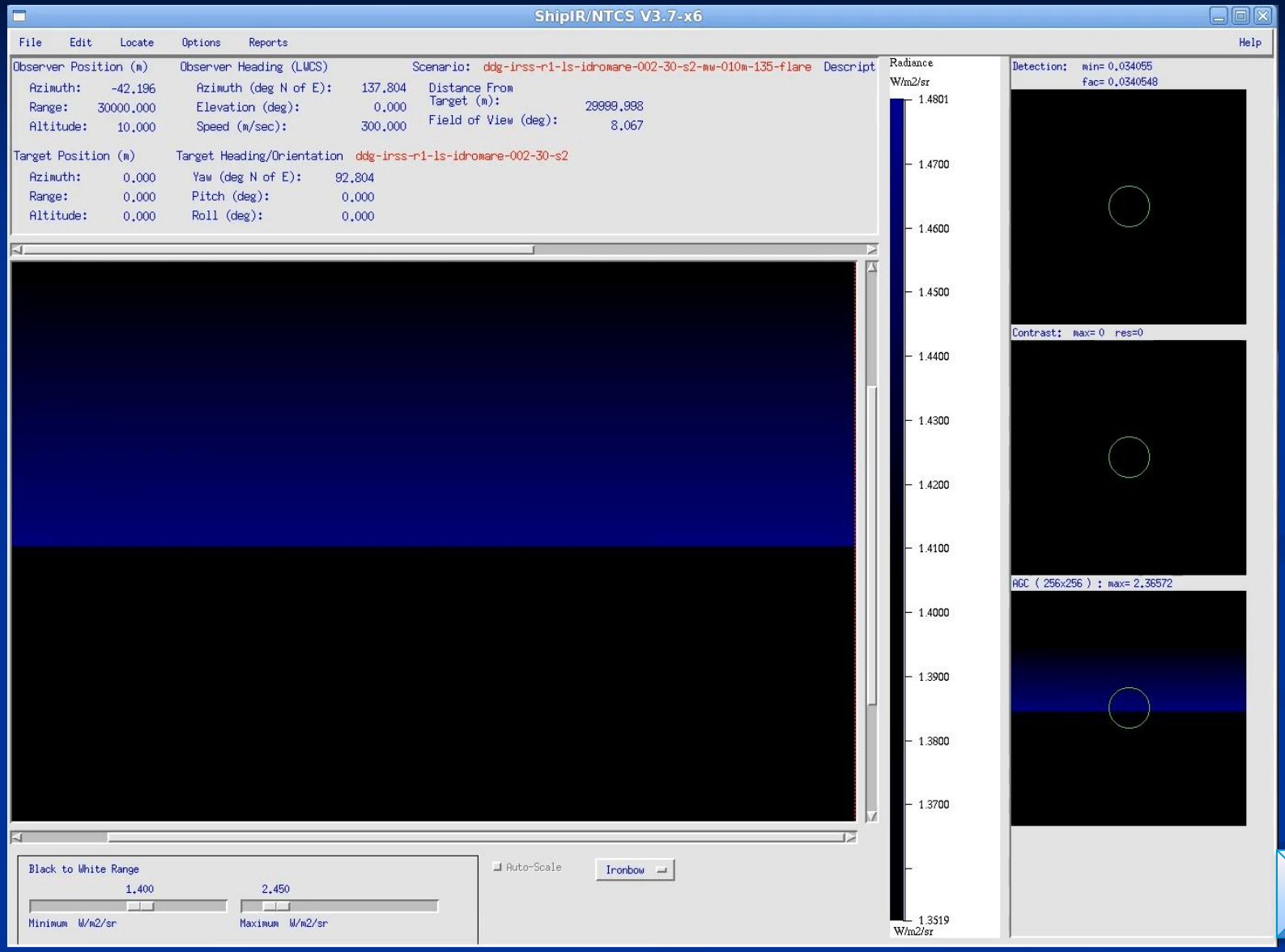
IRSS, Lower R_d climate



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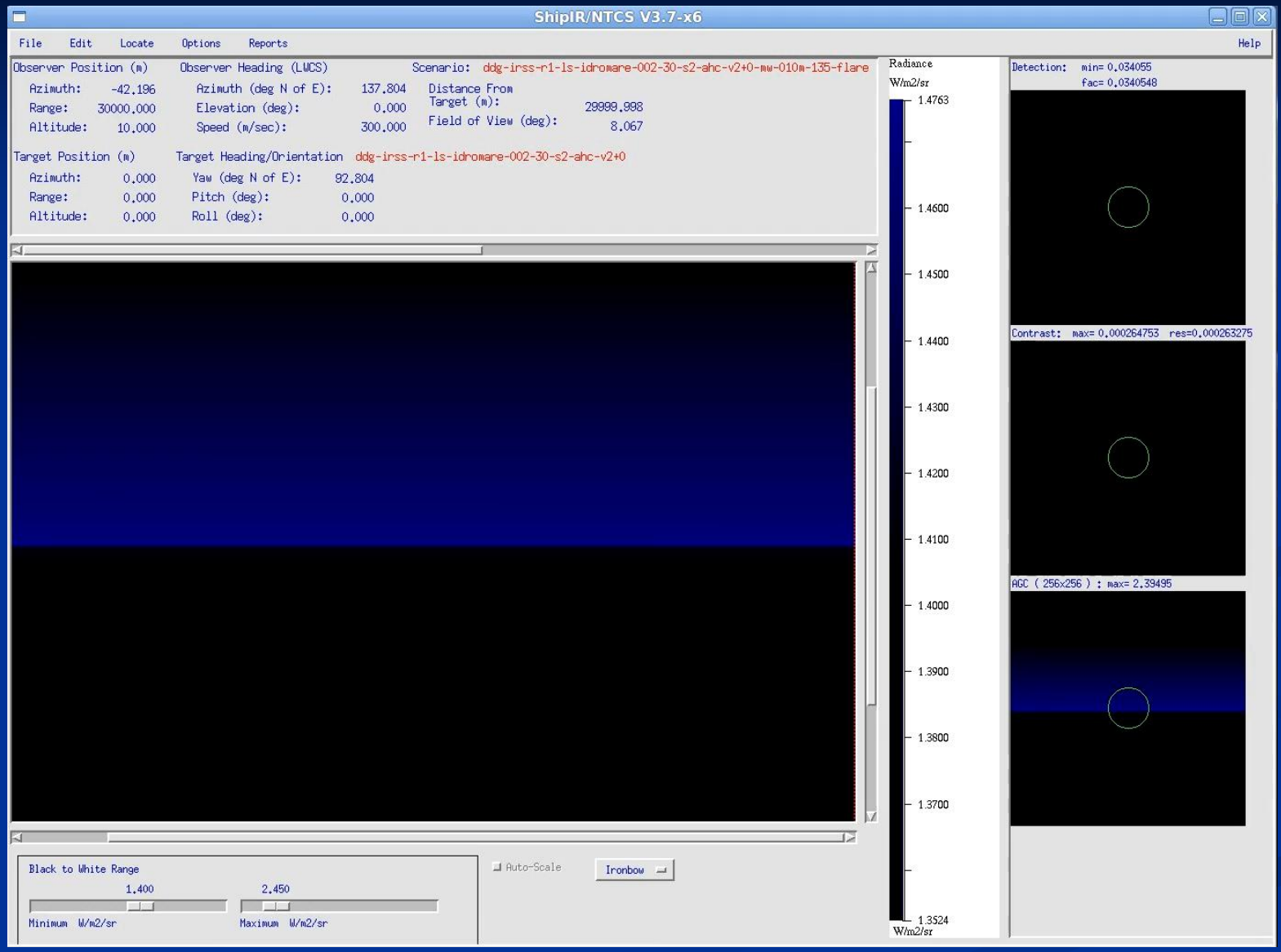
IRSS + AHC, Lower R_d climate



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End of Presentation

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