Use of Apodization to Improve Quality of Radiometric Measurements from Interferometric Sounders

(2/11/02)

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ILS Knowledge & Apodization

What Spectral Instrument Line Shape (ILS) Uncertainty Can Be Tolerated for Advanced Sounding Missions?

Systematic Study Allowed Evaluation of ILS Uncertainty for Each CrIS Band

- **CrIS Phase 1 Studies**
  - **Concluded that CrIS EDR performance begins to degrade if ILS uncertainty grows larger than 1.5%**
  - **Based upon measures of rms temperature and moisture retrieval errors**
  - **Impact upon radiometric bias error and NEdN not evaluated**

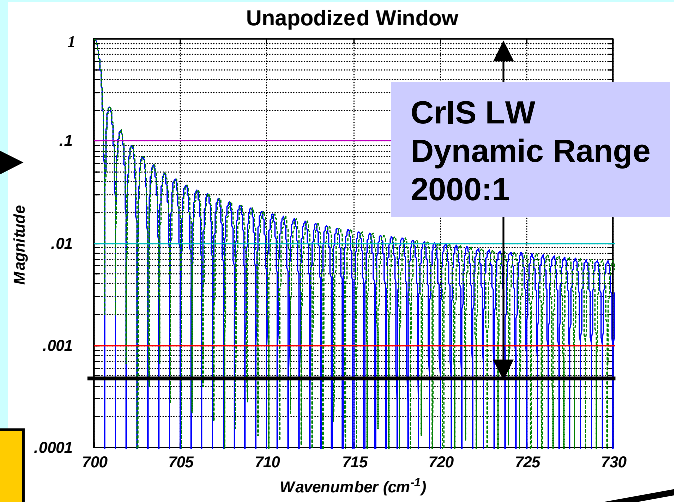
Determine if Sensitivity to ILS Uncertainty Could be Reduced by Use of Hamming or Blackman-Harris Apodization

- **More Recent Studies Have Refined Our Knowledge of this Effect to include:**
  - **Impact upon radiometric bias error**
  - **Impact upon NEdN**
  - **Specific impacts in each CrIS band (LW, MW & SW)**
  - **Scene type effects (land/ocean, cloudy/cloud free)**
  - **Sensitivity of various apodization techniques to ILS uncertainty**
    - Unapodized
    - Hamming
    - Blackman-Harris

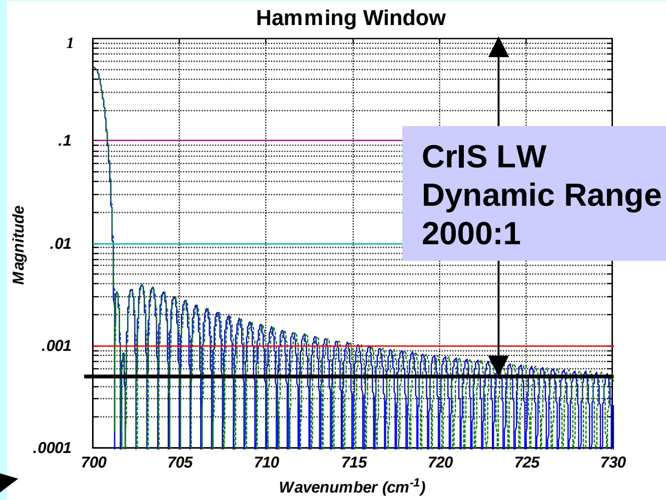
ILS Knowledge & Apodization

Apodizations Compared During this Study?

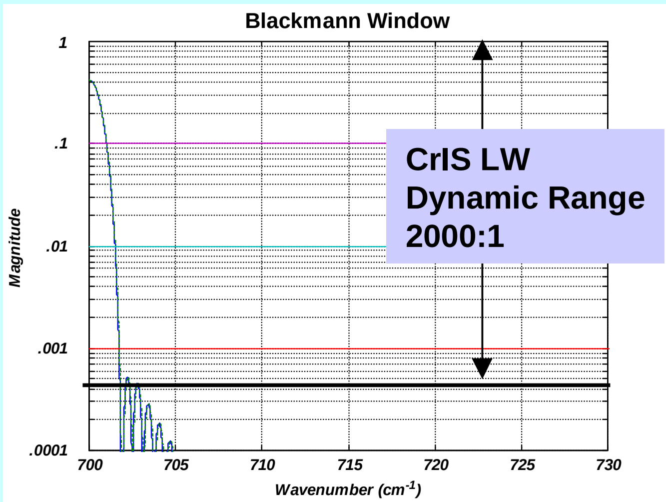
<u>Unapodized</u>
- Standard Format
- Highest Spectral Crosstalk
- Highest Uncertainty With ILS Variation



<u>Hamming</u>
- Lower Spectral Crosstalk
- Some Adjacent Channel Correlation



<u>Blackman</u>
- Lowest Spectral Crosstalk
- High Adjacent Channel Correlation
- Fastest EDR Forward Model Execution

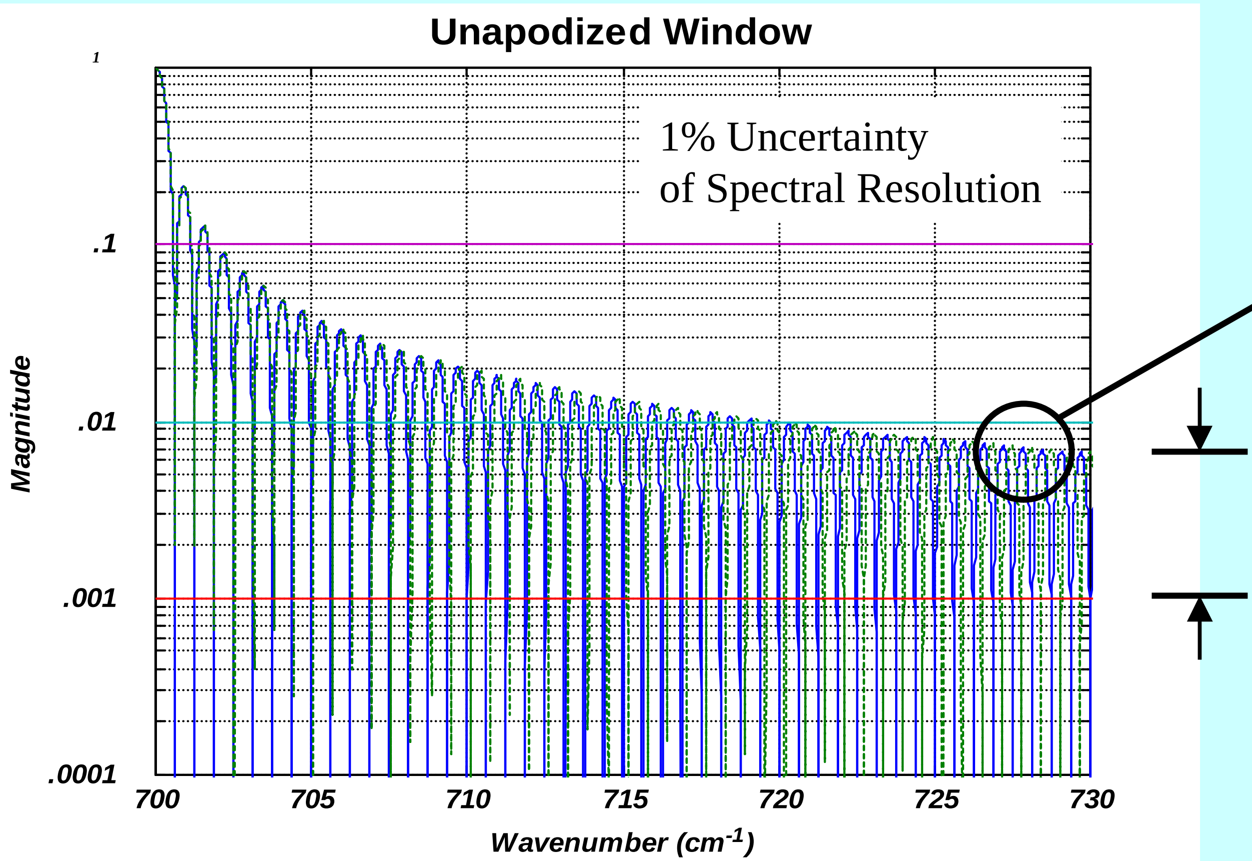


Example Illustrates Spectral Response for 700 cm^{-1} Channel Center

ILS Knowledge & Apodization

Concerns Relate to Sensor Spectral Response Uncertainty (Variation of the ILS Shape, FWHM)

- **Overlay Plot of Two Unapodized Spectral Responses Differing by only 1% Spectral Resolution**



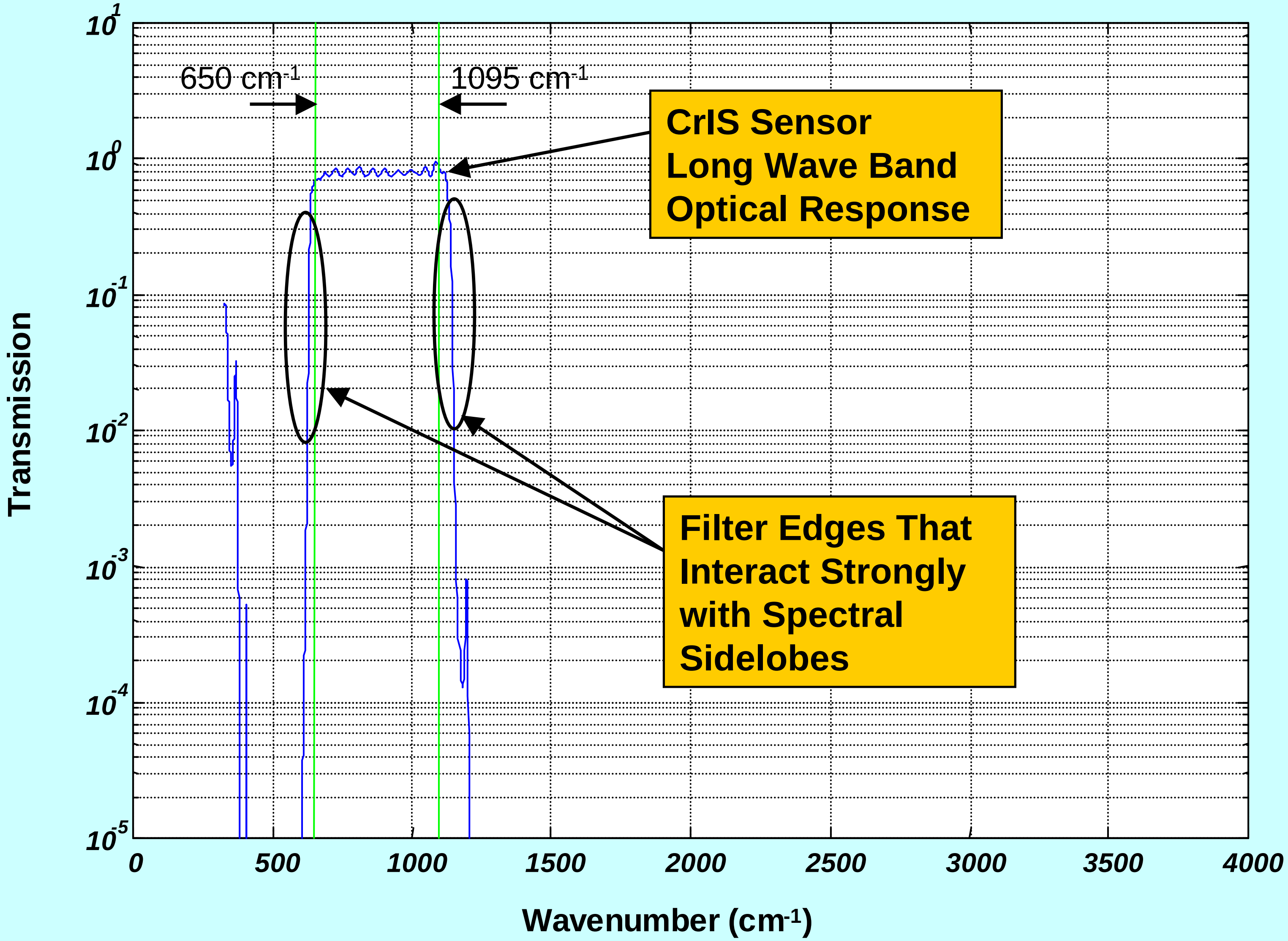
Sidelobe Suppression Below CrIS Noise Floor Is Not Achieved

Maximum Sidelobe Level Replaces Null Response Only 30 cm^{-1} from Channel Center

Error Magnitude Contributed by Each Sidelobe Bin Is Large Relative to Noise Floor

ILS Knowledge & Apodization

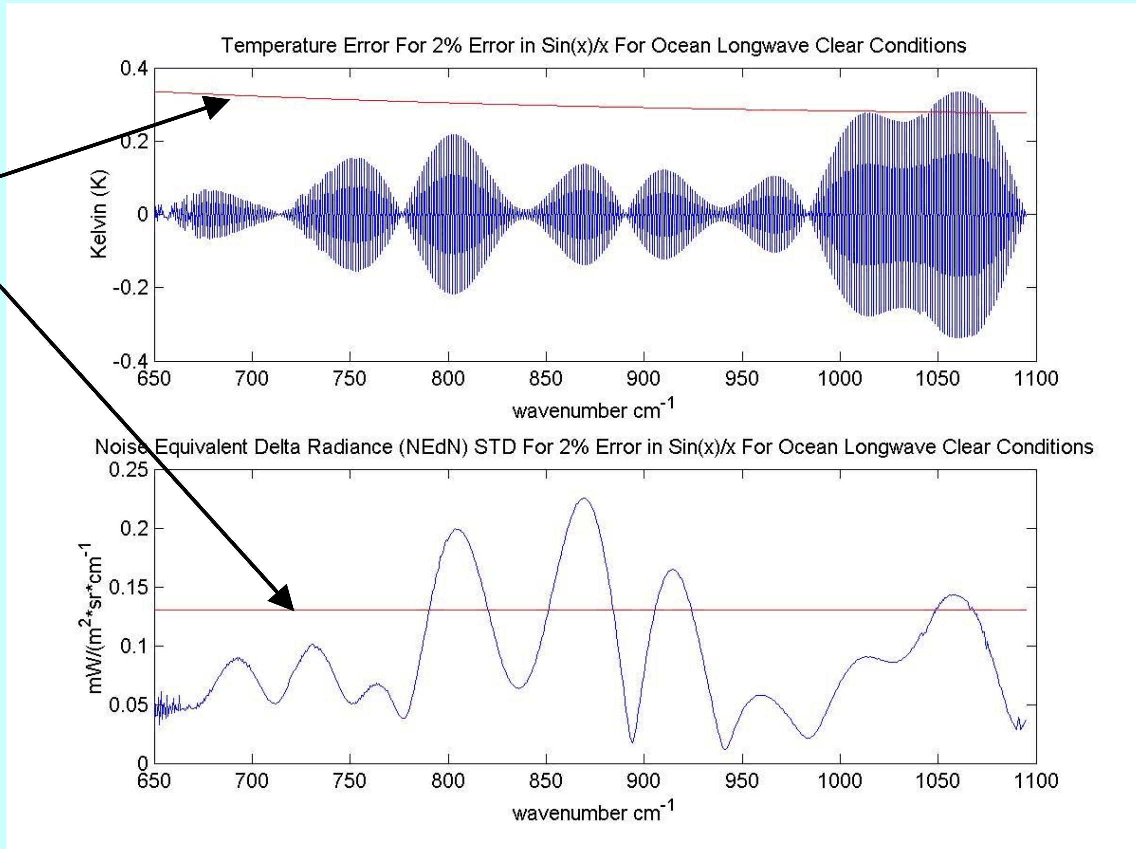
Interferometer Optical Band Pass Filter Edges Interact With an Unapodized Spectral Response



ILS Knowledge & Apodization

Resultant Error Due to 2% ILS Uncertainty With Ideal Optical Filter 650 cm^{-1} to 1095 cm^{-1}

Requirement (all sensor error sources)



Temperature Bias Error
(197 scene ensemble)

Noise Equivalent Radiance NEdN
(197 scene ensemble)

ILS Knowledge & Apodization

Can the Use Of Apodization Reduce Sensitivity to ILS and Optical BPF Uncertainties?

Uncertainty in Any One Source Leads to Significant Error

- **Sources of Error**
  - Mismatch of sensor ILS with ILS used in forward radiometric transmittance model
  - Uncertainty in the optical filter cutoff wavenumber
  - Unmodeled scene effects (solar reflection, etc)

Elimination of Error in the Unapodized Case Requires More Precise Knowledge Over a Broader Range of Wavenumbers

- **Potential Benefits of Apodization**
  - Significantly less precision of hardware components to achieve a given level of performance
  - Better independence of radiance measurements at one wavenumber to any uncertainties from any radiance source at other wavenumbers
  - Trace gas model errors
  - Imprecisely modeled solar reflection from surface or cloud
- **Trade Study Evaluations**
  - Impact on radiometric bias error
  - Impact on NEdN

ILS Knowledge & Apodization

481 Data Files Depicting Upwelling Infrared Signatures of Earth Scenes Used During the Analysis

Methodology of Synthesizing Test Scenes

- **Generation of Test Scenes**
  - 481 temperature/moisture profiles randomly selected from NOAA88 data set
  - 197 cloud free profiles over land
  - 284 cloud free profiles over ocean
  - NOAA88 provided surface emissivity used for each profile

Test Scenes Were Previously Developed During the CrIS Phase 1 Effort

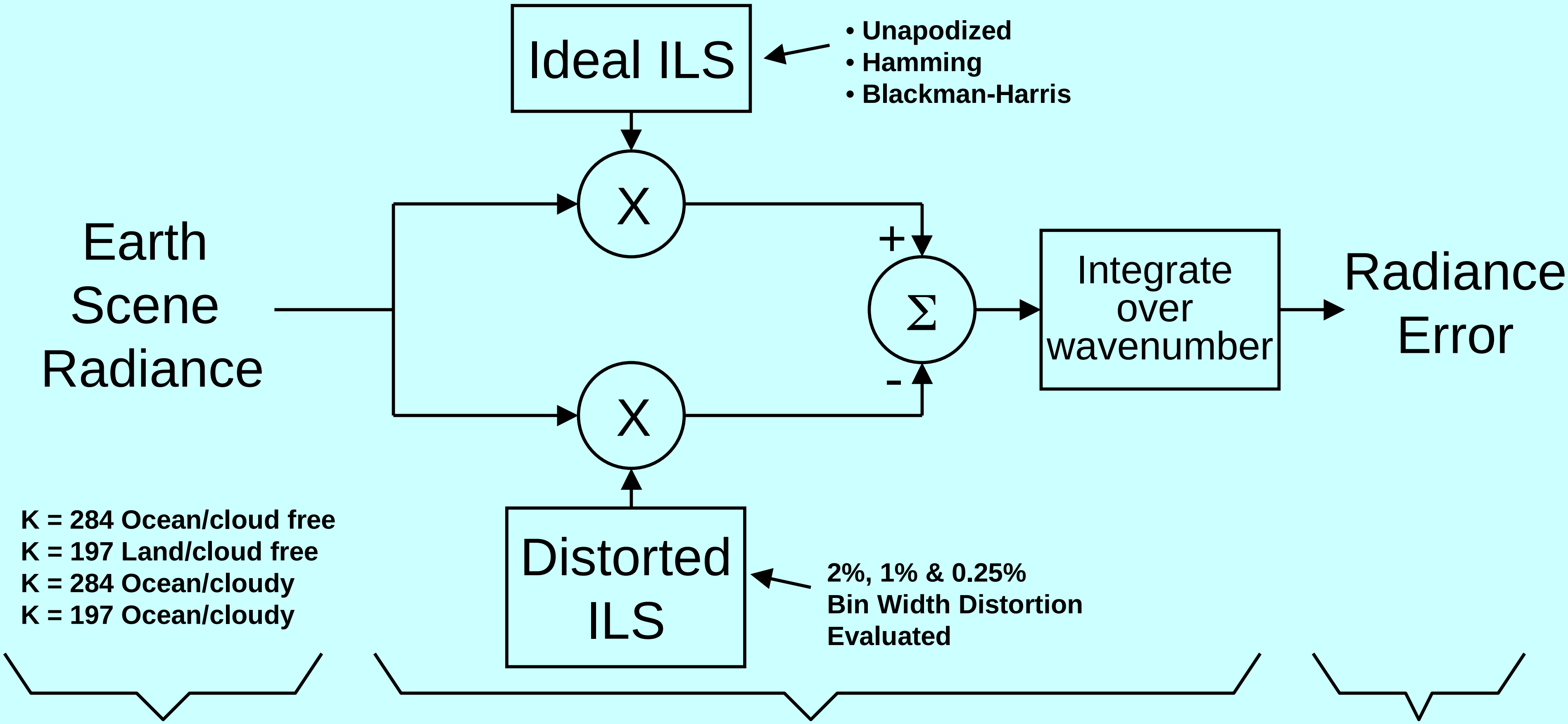
- **Converted Temperature/moisture Profiles Into Radiance**
  - Used Atmospheric Environmental Research Inc. supplied OSS forward model code developed during CrIS Phase 1
  - Spectral resolution of earth scene radiance model
    - LW = 0.04 cm^{-1}
    - MW = 0.08 cm^{-1}
    - SW = 0.16 cm^{-1}

Test Scenes Were Previously Developed During the CrIS Phase 1 Effort

- **Added Cloud Content (additional set of 481 data files)**
  - "Optically thick" clouds added
  - Cloud fraction and cloud height data bases supplied by P. Wylie (U. of Wisconsin) and T. VonderHaar (STC METSAT @ Colorado State)

ILS Knowledge & Apodization

Methodology



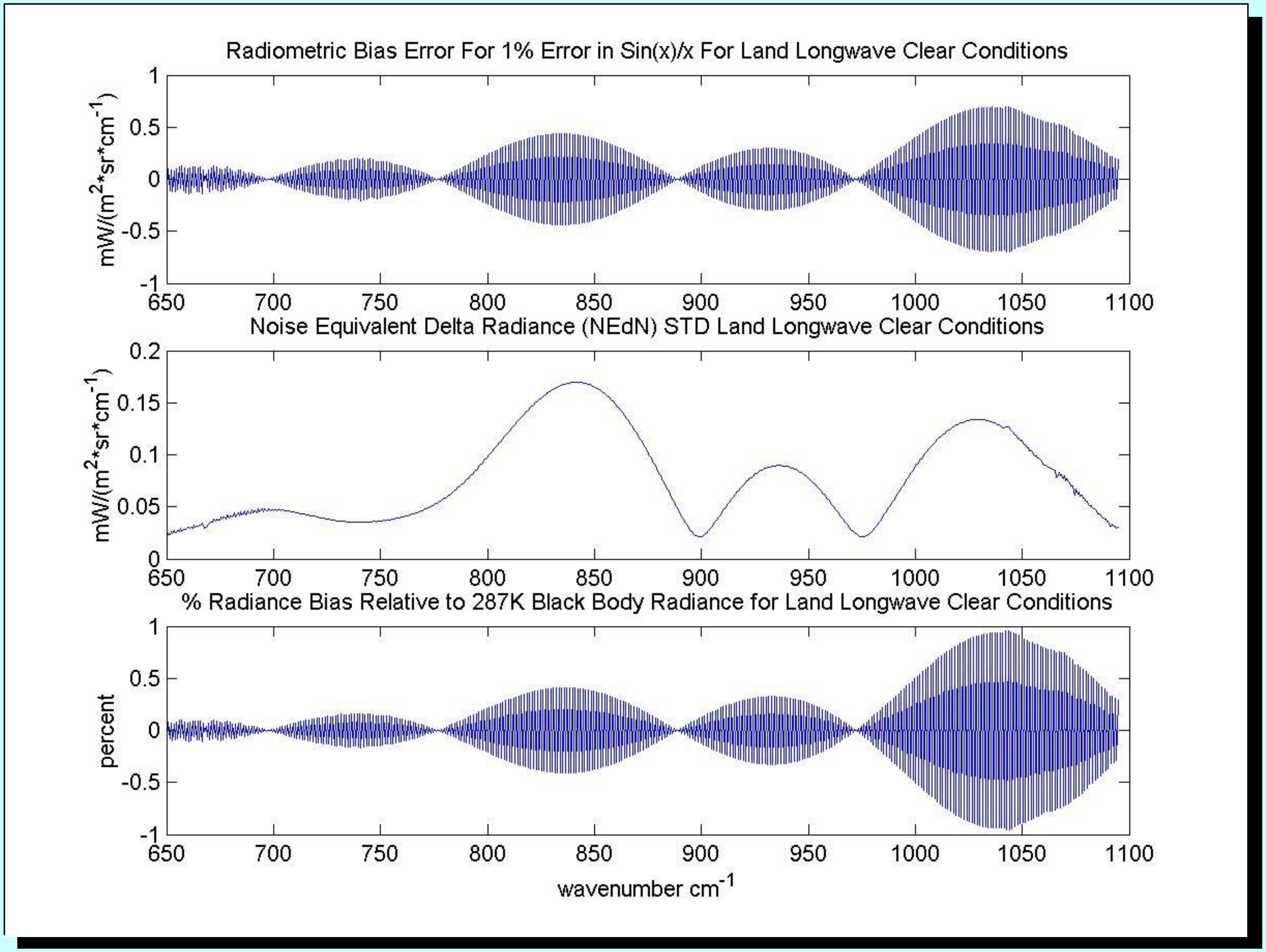
Repeat Calculation of Error for Each Earth Scene

Repeat Calculation of Error for Each Channel Center in all 3 CrIS Bands (1305 Channels)

Compute Statistics
- Mean (bias)
- STD (NEdN)
- % Error bias

ILS Knowledge & Apodization

Typical Radiance Error Plots Generated (Unapodized ILS with 1% Excessive Bin Width)



Radiometric Bias Error

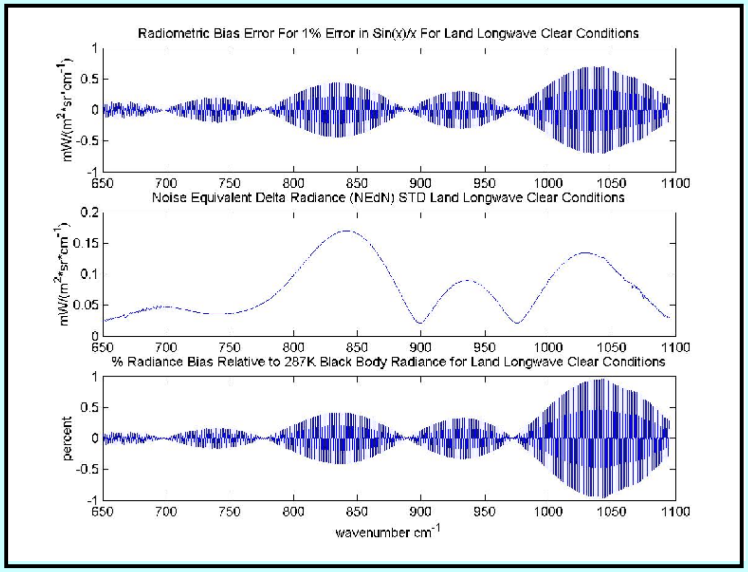
NEdN

% Radiometric Bias Error Relative to 287 K BB

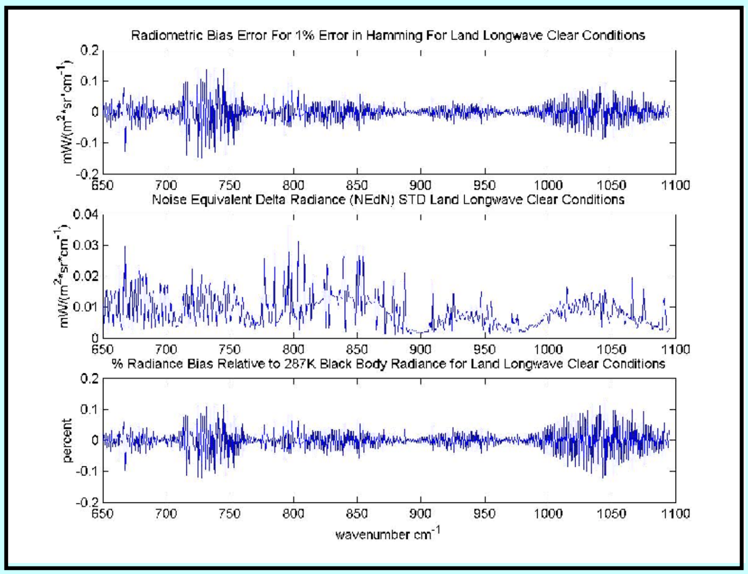
ILS Knowledge & Apodization

Comparison of Apodization Effect (Long Wave Band, Land Surface, Cloud Free)

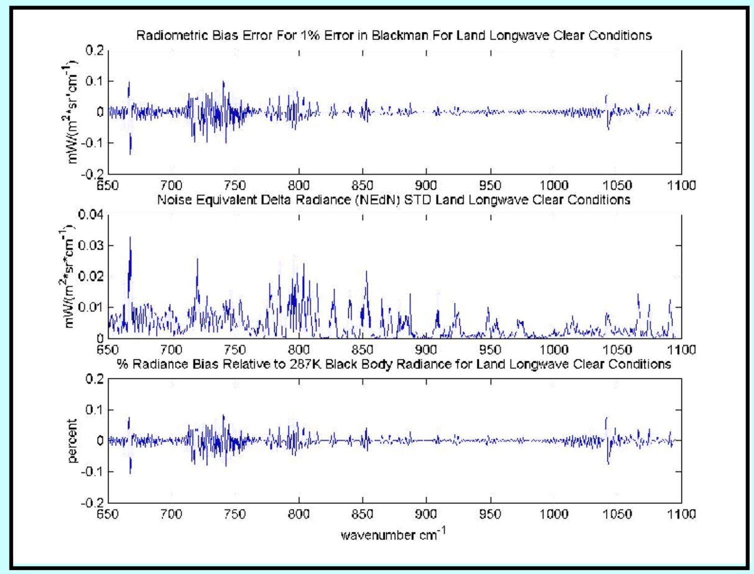
Unapodized Case with 1% ILS Uncertainty



Bias Errors Drop as Much as 8 Times Using Hamming Window



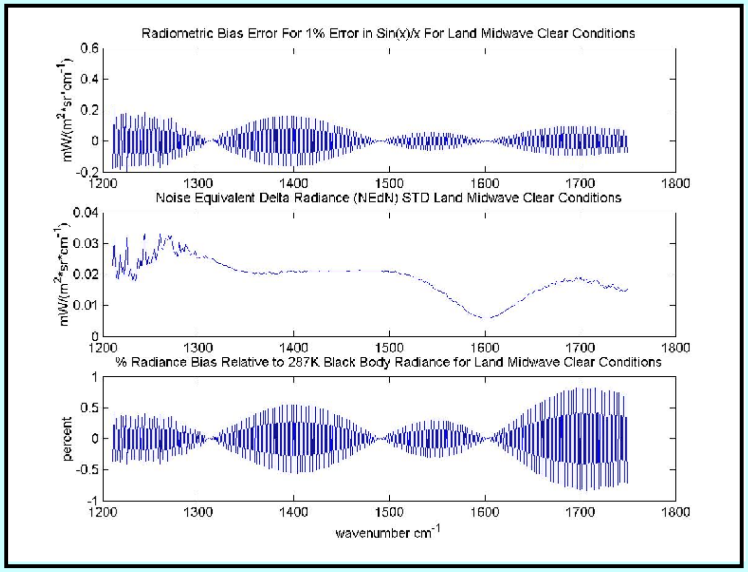
Blackman-Harris Yields Even More Improvement



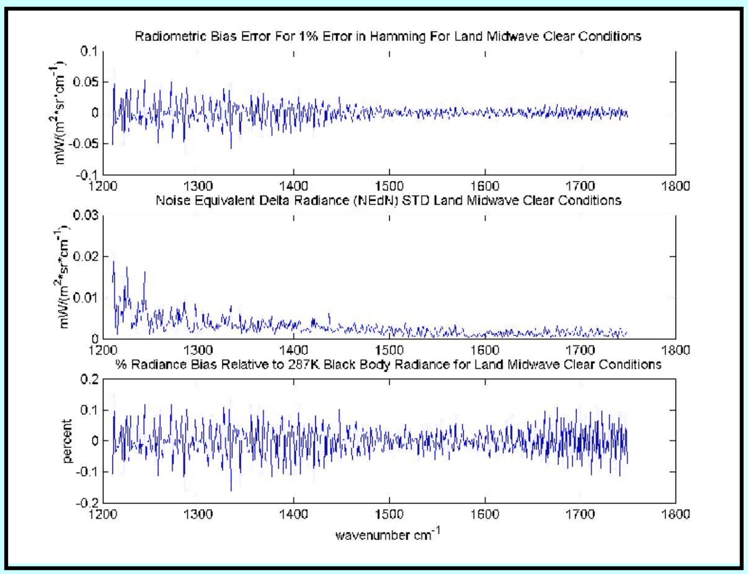
ILS Knowledge & Apodization

Comparison of Apodization Effect (Mid Wave Band, Land Surface, Cloud Free)

Unapodized Case with 1% ILS Uncertainty



Bias Errors Drop as Much as 4 Times Using Hamming Window



Blackman-Harris Yields No Improvement Over Hamming