Transfer Calibration from ERBS WFOV Nonscanner to NOAA-9 WFOV Nonscanner and to NOAA-9 Scanner

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4th March, 2013

2013 GSICS Annual Meeting

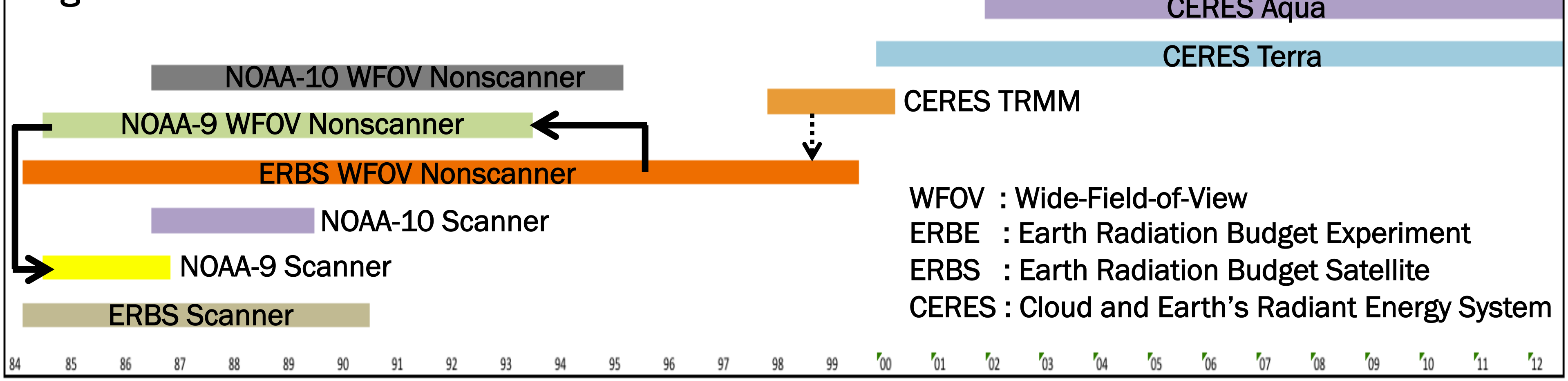
March 4-8, 2013, Williamsburg, VA, USA

We thank Drs. Bruce Wielicki, Norman G. Loeb, and David Johnson for useful discussions.
This work was supported by the NOAA Climate Data Record Program.

Objectives

- To generate CERES-Like ERBE climate record that is consistent with present-day CERES data.
- To achieve this:
  - Reprocess ERBE data using
    - CERES algorithms and ADMs instead of ERBE algorithms and ADMs.
  - Transfer Calibration from CERES to ERBS WFOV nonscanner and to NOAA-9 and NOAA-10 instruments.
    - We present calibration of
      - ERBS WFOV nonscanner to NOAA-9 WFOV nonscanner
      - NOAA-9 WFOV nonscanner to NOAA-9 scanner

Fig 1: ERBE and CERES Instruments Observation Time Chart



Introduction

- ERBS (Earth Radiation Budget Satellite) , NOAA-9, and NOAA-10 are part of Earth Radiation Budget Experiment (ERBE), and conducted during the second half of 1980's.
- These satellites were launched on
  - NOAA-9 => Dec 1984 into Sun-synchronous Orbit
  - ERBS => Oct 1984 into Precessing Orbit
  - NOAA-10 => Sep 1986 into Sun-synchronous Orbit

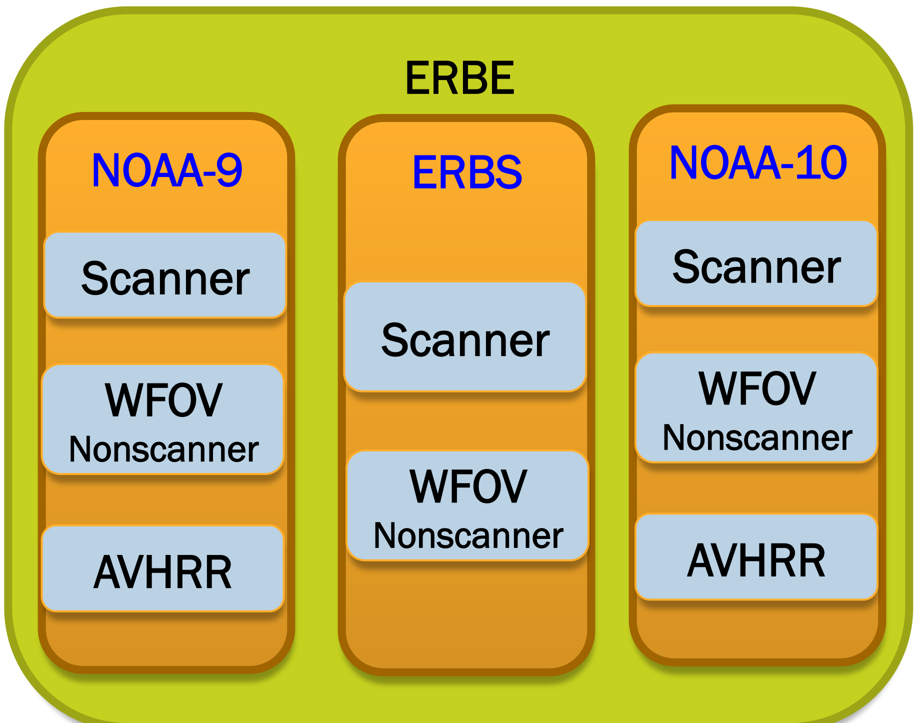


Fig 1: Instruments on NOAA-9 and ERBS

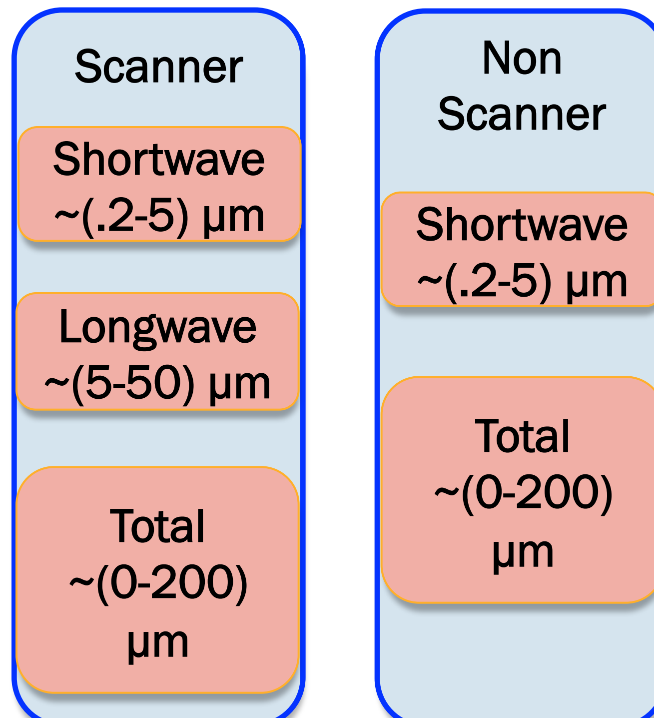


Fig 2: Broadband Channels on Scanner and Nonscanner

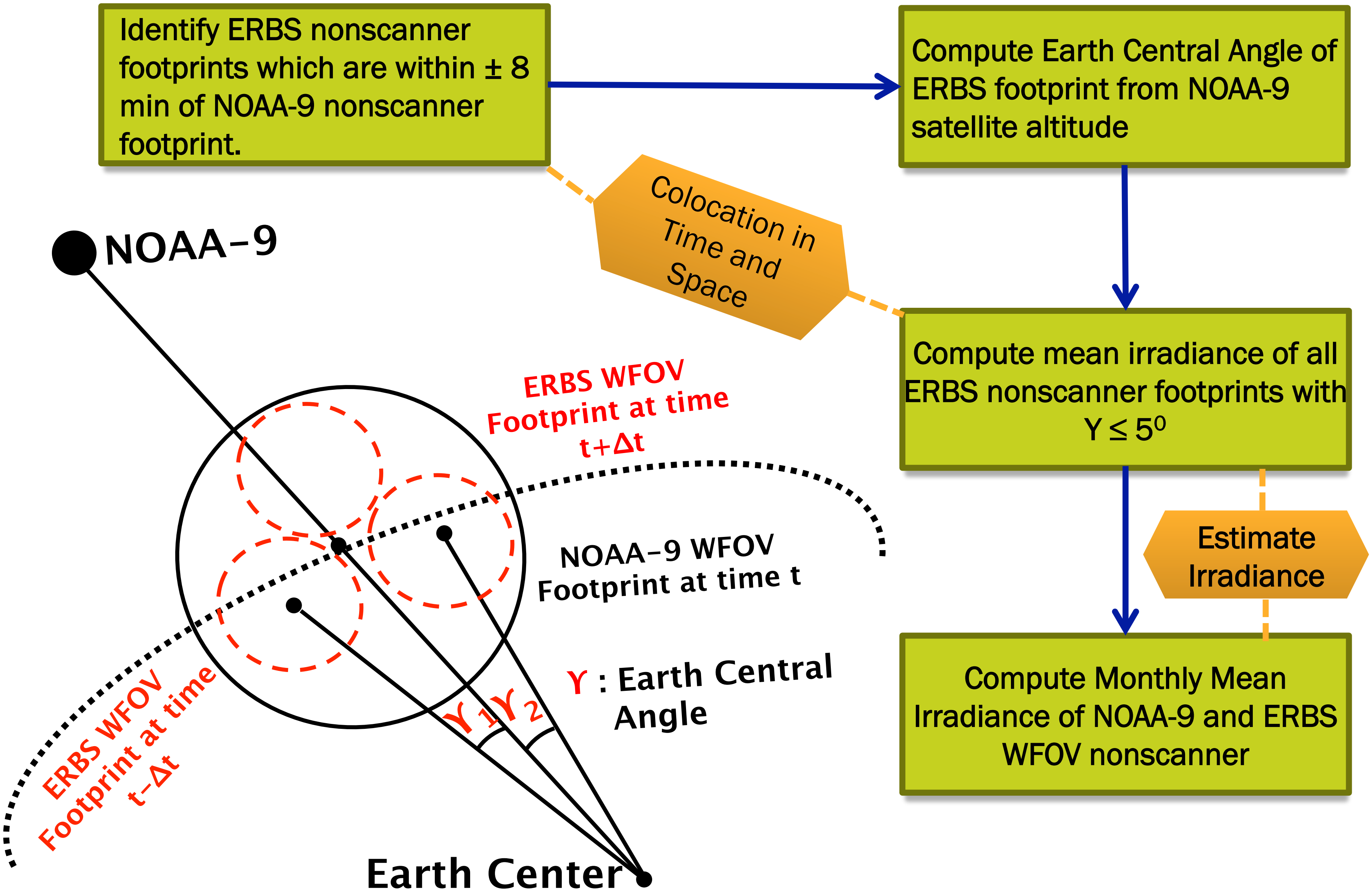
NOAA-9 and ERBS Datasets

- In this study,
  - To Compare NOAA-9 and ERBS WFOV nonscanner, we use two years (1985, and 1986) data
  - To Compare NOAA-9 scanner and WFOV nonscanner, we use 4 months (Apr, July, Oct, and Dec 1986) of reprocessed NOAA-9 scanner data
  - NOAA-9 scanner data is reprocessed using CERES algorithms and CERES-ADMs instead of ERBE algorithm and ERBE ADMs
    - Cloud properties needed to use CERES algorithms and CERES ADMs is derived from NOAA-9 AVHRR observations.

Methodologies

- Two major Steps:
  - Co-location of Footprints in Time and Space
    - The nonscanner observes entire FOV at one instant of time, while scanner takes ~16 min to view the same area.
  - Estimate Irradiance
    - WFOV and WFOV nonscanner Comparison
      - Compute average irradiance of all WFOV footprints colocated in other WFOV footprint
    - Scanner and WFOV nonscanner Comparison
      - Compute integrated scanner radiance using all scanner footprints colocated in WFOV nonscanner footprint

WFOV and WFOV Comparison Process



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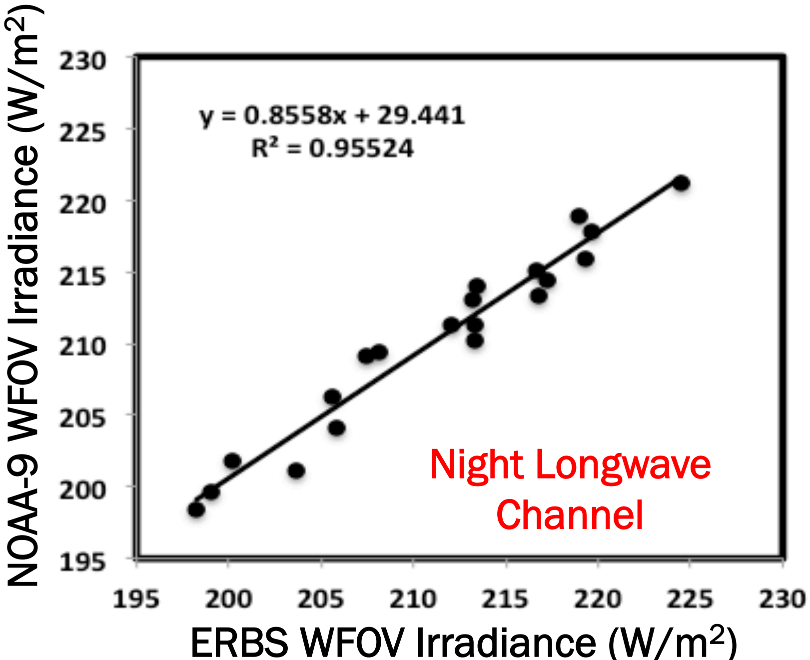
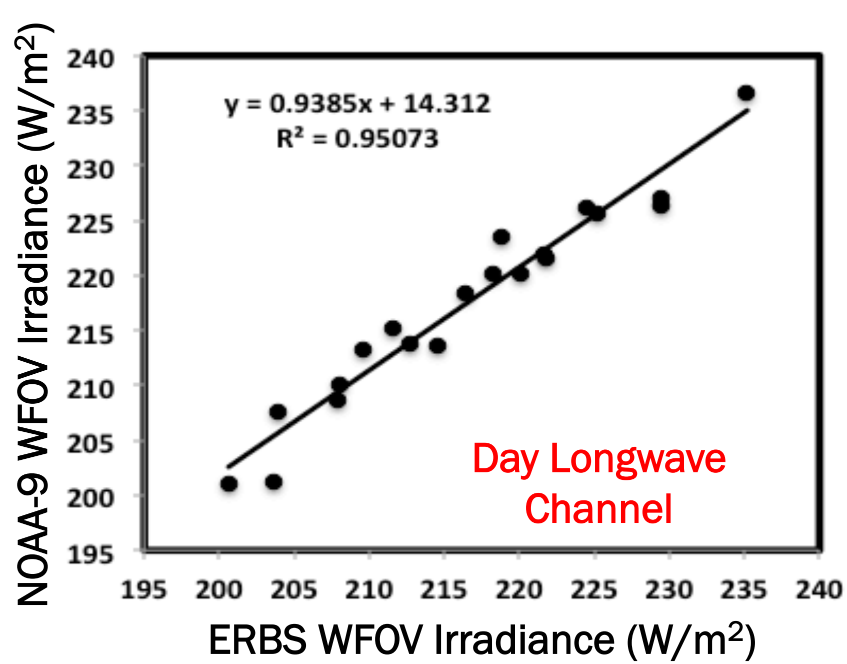
Monthly Irradiance of NOAA-9 & ERBS WFOV





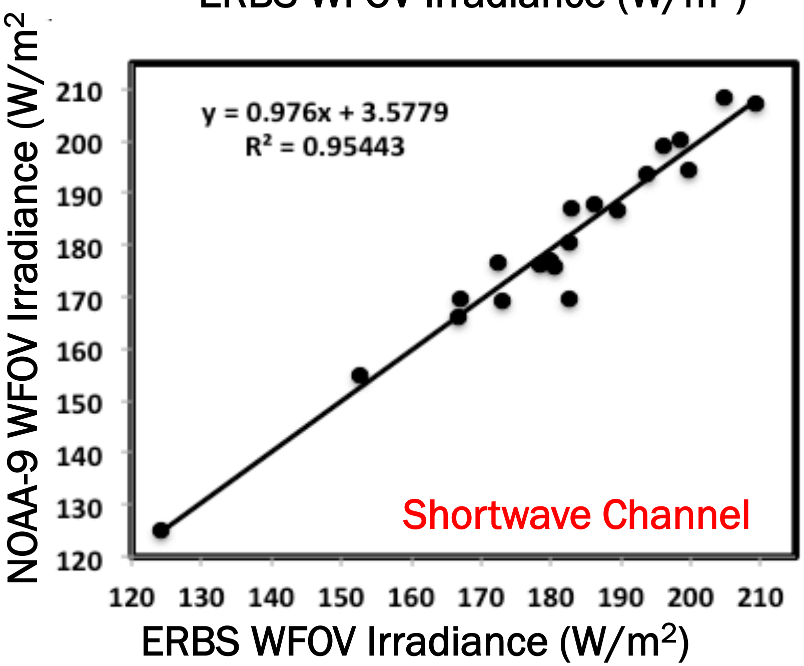


Table: NOAA-9 and ERBS Monthly Irradiance Difference Averaged Over Two Years

(NOAA-9 – ERBS)/ERBS		
Channel	Relative Difference	Relative RMS
Night Longwave	-0.6%	0.7%
Day Longwave	0.4%	0.9%
Shortwave	0.3%	3.0%

Scanner and WFOV Nonscanner Footprint Colocation

α : Nadir Angle

β : Azimuth Angle

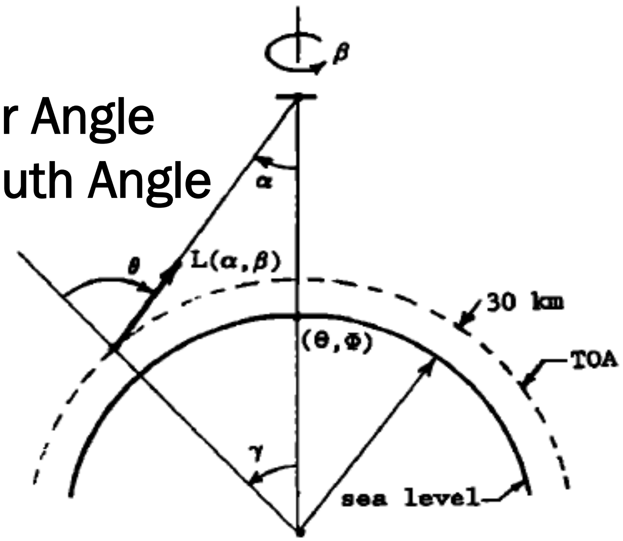


Fig 1: Geometry Nonscanner Measurements

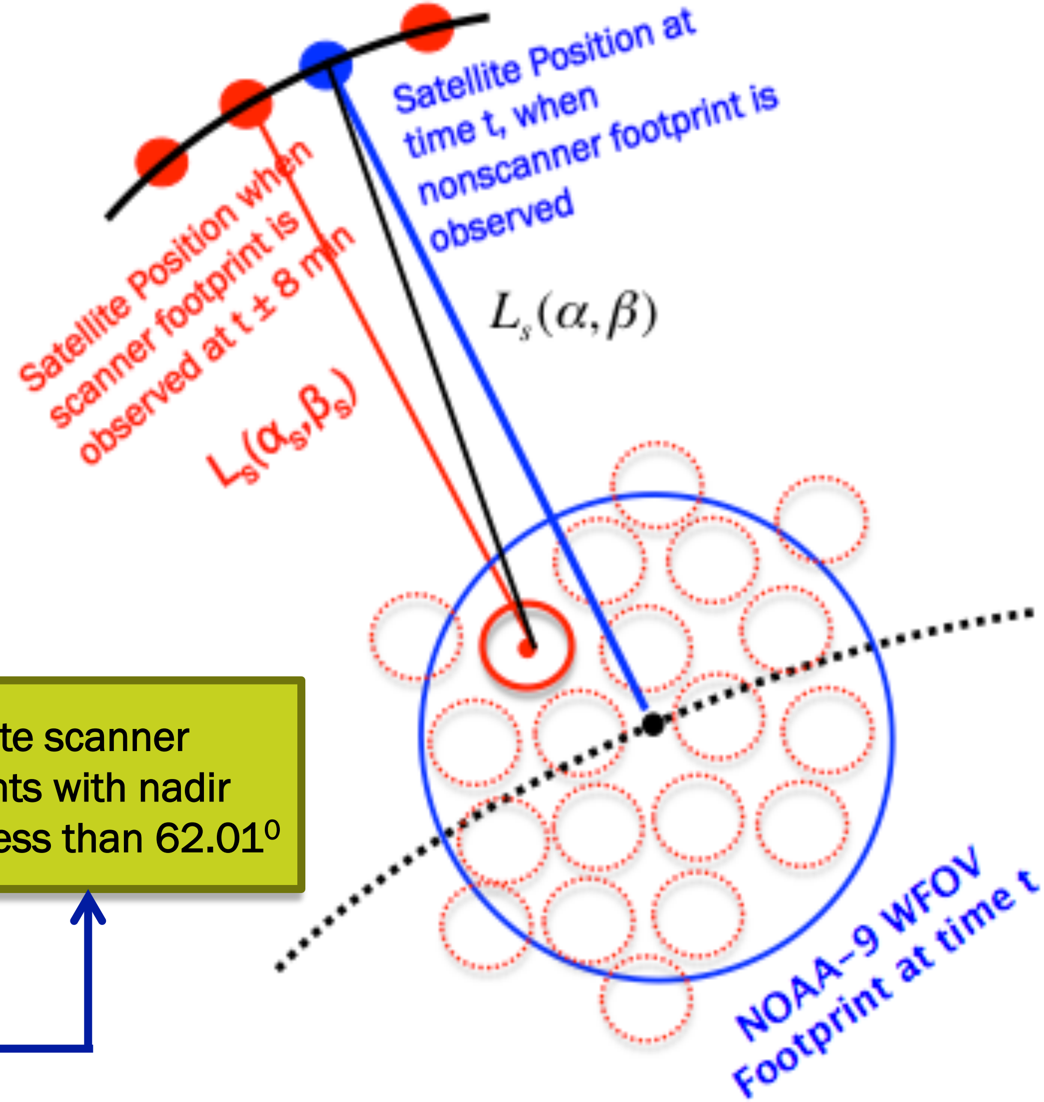


Fig 2: Geometry of Scanner and Nonscanner Comparisons (NOT IN SCALE)

Identify NOAA-9 scanner footprints which are within ± 8 min of NOAA-9 nonscanner footprint.

↓

Compute nadir, and azimuth angle of all scanner footprints from nonscanner position.

→

Separate scanner footprints with nadir angle less than 62.01^0

α_c : 62.01^0

Nadir Angle Limit or Cutoff For NOAA-9 WFOV nonscanner

Estimation of scanner Irradiance

By Integrating Scanner Radiance

$$L_s(\alpha,\beta) = f(\alpha,\beta \mid \alpha_s,\beta_s) L_s(\alpha_s,\beta_s) ......(1)$$

$L_s(\alpha, \beta)$ is the scanner radiance derived by turning $L_s(\alpha_s, \beta_s)$ from scanner position to nonscanner position.

Here, $f(\alpha,\beta \mid \alpha_s,\beta_s)$ Is the turning function

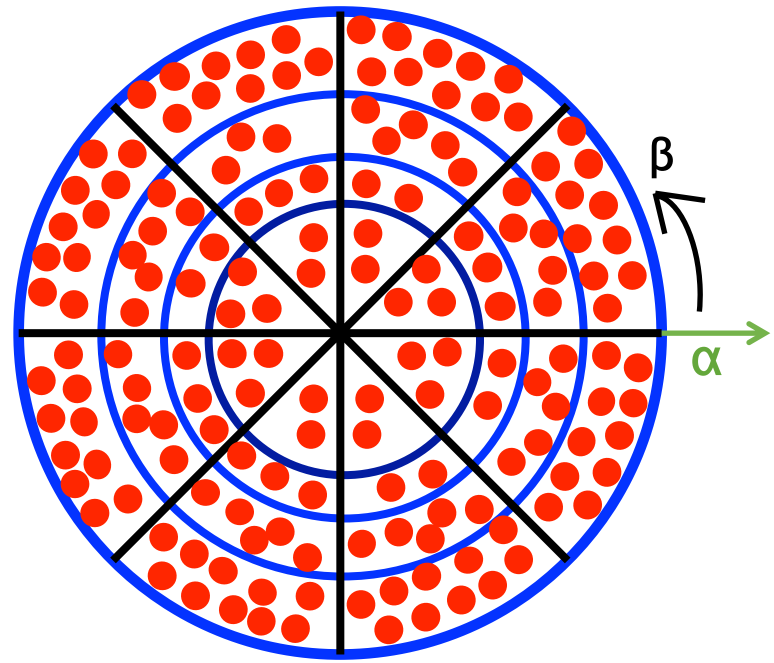
$$f(\alpha,\beta \mid \alpha_s,\beta_s) = \frac{R_s(\alpha,\beta)}{R_s(\alpha_s,\beta_s)}$$

R : Anisotropic Factor

- Scanner radiance is integrated using Eq. 2

$$\hat{m} = \sum_{i=1}^{i=10} \sum_{j=1}^{j=10} \hat{L}_{s,ij} \cos\alpha_i \Delta\Omega_{ij} ....(2)$$

$\hat{L}_{s,ij}$ Is the average of all $L_s(\alpha,\beta)$ In the ijth angular bin and $\Delta\Omega_{ij}$ Is solid angle of this bin.



Discretizing measurement into nadir and azimuth angle (α , β) angular bins to get the flux

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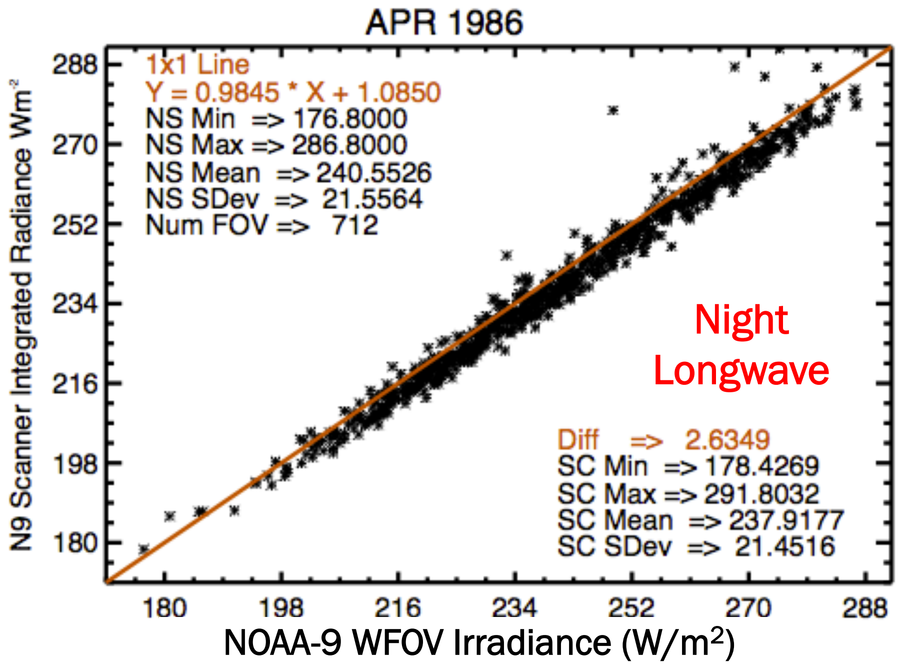
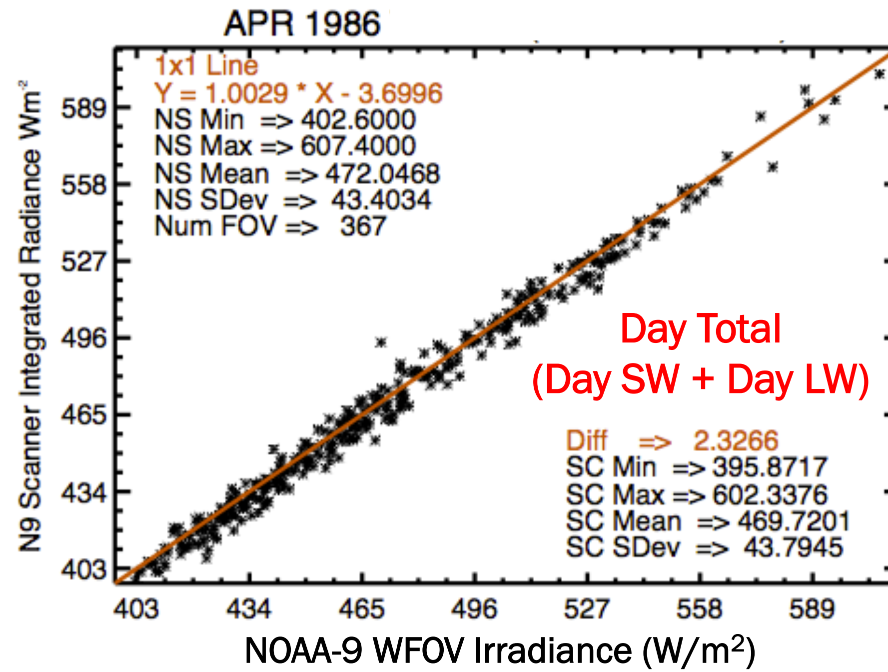
Instantaneous Irradiance of Nonscanner & Scanner





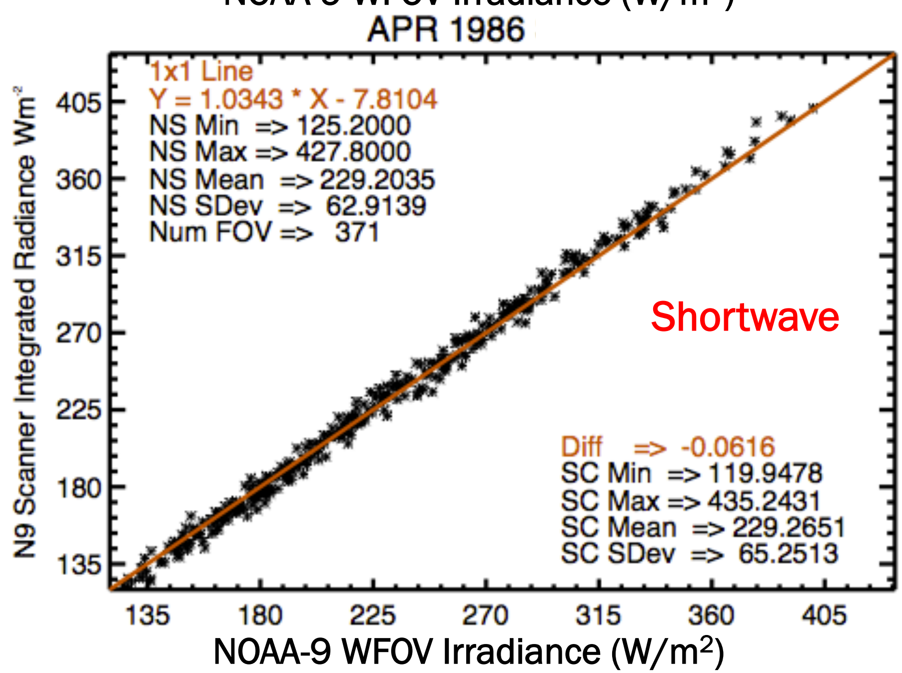
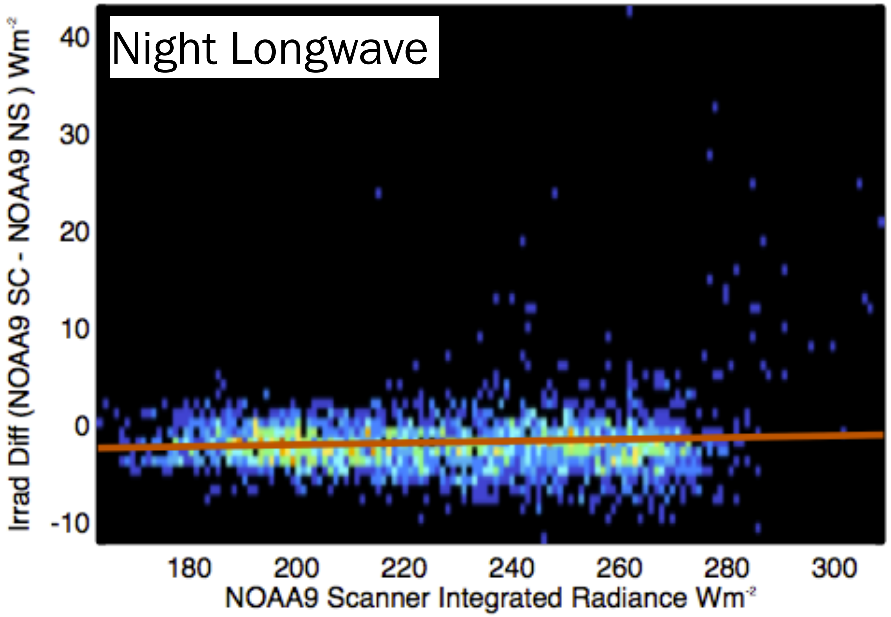
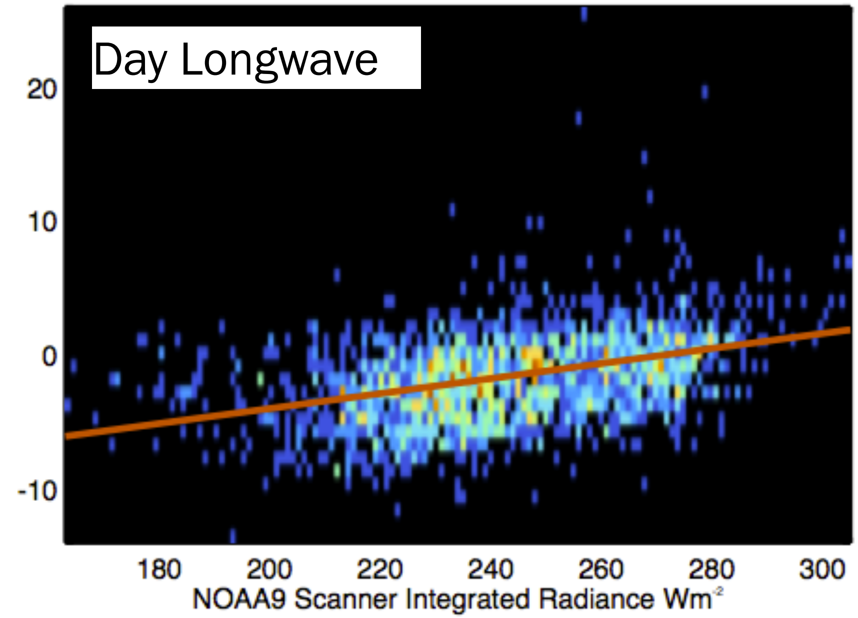


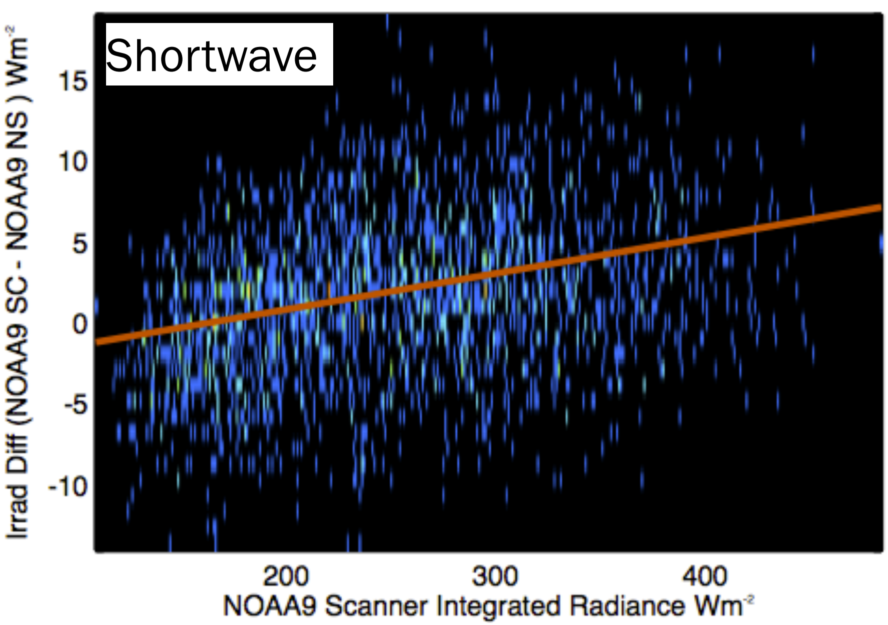
Table: Scanner Integrated Radiance and Nonscanner Irradiance **averaged over 4 Months** (Apr, Jul, Nov, Dec, 1986)

Channel	NOAA-9 Scanner (W/m^2)	NOAA-9 WFOV (W/m^2)	REL DIFF
Night LW	227.7	229.4	-0.7%
Day LW	243.9	245.6	-0.7%
SW	247.5	245.2	0.9%

2-D Histogram of Number of Matched Footprints



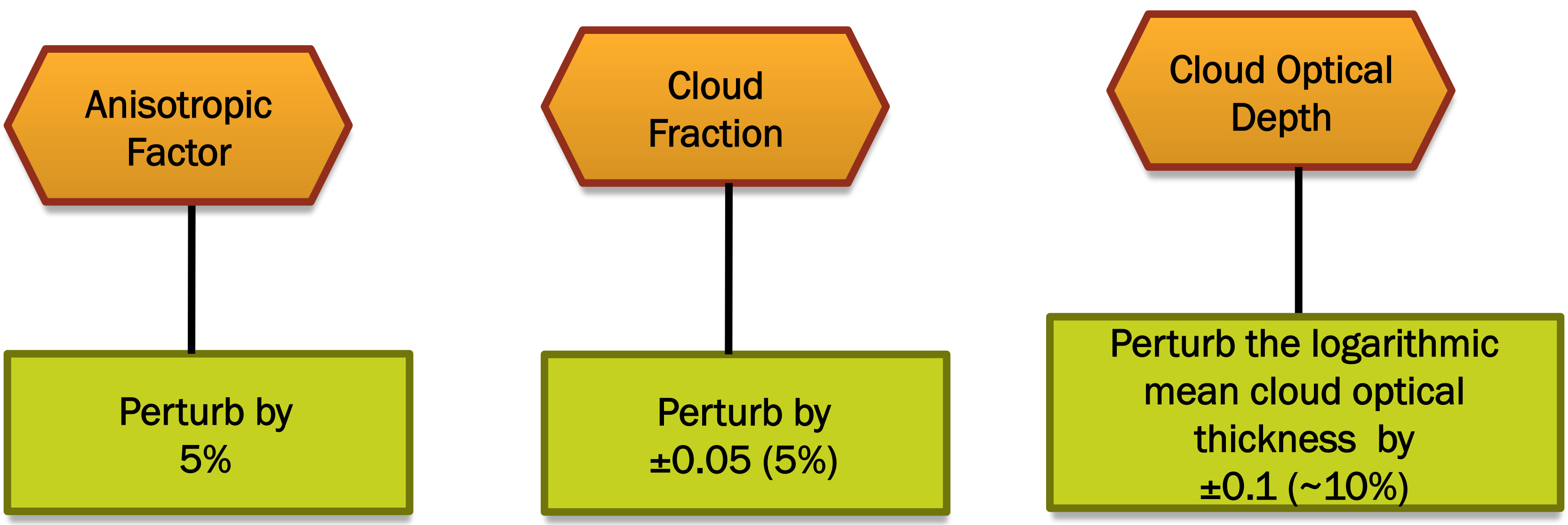




Channel	Number of Footprints	Standard error (W/m^2)	Rel. Standard error
Night LW	2255	3.3	1.4%
Day LW	1825	3.0	1.2%
SW	1842	4.9	2.0%

Sensitivity Study to Irradiance Comparisons (Scanner and WFOV)

- How sensitive is the calibration to Turning Function ?
- Turning function depends on
  - Anisotropic Factor
  - Scene Identification
    - Cloud Fraction
    - Cloud Optical Depth



Irradiance Comparison Sensitivity to Anisotropic Fraction and Scene Identification (Scanner and WFOV)

Table: Sensitivity of longwave and shortwave irradiance differences' to anisotropic factor, cloud fraction and optical depth changes

	Irradiance Difference When anisotropic factor perturbed by 5%	Irradiance Difference when cloud fraction perturbed by 5% Increase (Decrease)	Irradiance Difference when cloud optical depth perturbed by ~10% Increase (Decrease)
Night Longwave	1.8%	0.1(0.01)%	0.01(0.1)%
Day Longwave	1.8%	0.2(0.01)%	0.01(0.01)%
Shortwave	5.8%	0.5(0.1)%	0.2(0.3)%

- Uncertainty during comparison of NOAA-9 scanner and nonscanner observations is dominated by anisotropic factor.

Total Uncertainty in Scanner, WFOV Nonscanner, and its Comparison Process

Relative Difference of Average Irradiance	Instrument Uncertainty	NOAA-9 WFOV & ERBS-WFOV Comparison	Anisotropic Uncertainty	Total Uncertainty
Night Longwave	1%	-0.6%	0.3%(1)	1.2%
Day Longwave	1%	0.4%	0.3%(2)	1.1%
Shortwave	2%	0.3%	1.5%(3)	2.5%

- CERES-ADM has uncertainty of
    - 5% in Shortwave channel
    - 3% in Longwave channel

(1) 1.8%/3/2 [3 is for longwave uncertainty, and 2 is for the ± direction]

(2) 1.8%/3/2 [3 is for longwave uncertainty, and 2 is for the ± direction]

(3) 5.8%/2/2 [2 is for shortwave uncertainty, and other 2 is for the ± direction]

Summary and Conclusions

- Comparison of 2 years of ERBS and NOAA-9 WFOV nonscanner suggests NOAA-9 WFOV irradiance is:
    - Lower by 0.6% for night longwave channel
    - Higher by 0.4% for day longwave channel
    - Higher by 0.3% for shortwave channel

- Comparison of 4 months of NOAA-9 scanner and WFOV nonscanner suggests NOAA-9 scanner integrated radiance is:
    - Lower by 0.7 % for both night and day longwave channel
    - Higher by 0.9% for shortwave channel

- Total uncertainties (Uncertainty in scanner, nonscanner, and calibration process) are
    - 1.2% for night longwave channel
    - 1.1% for day longwave channel
    - 2.5% for shortwave channel

Summary and Conclusions

- Scanner and nonscanner comparison is relatively sensitive to anisotropic factor than to scene identification (cloud fraction, cloud optical depth).

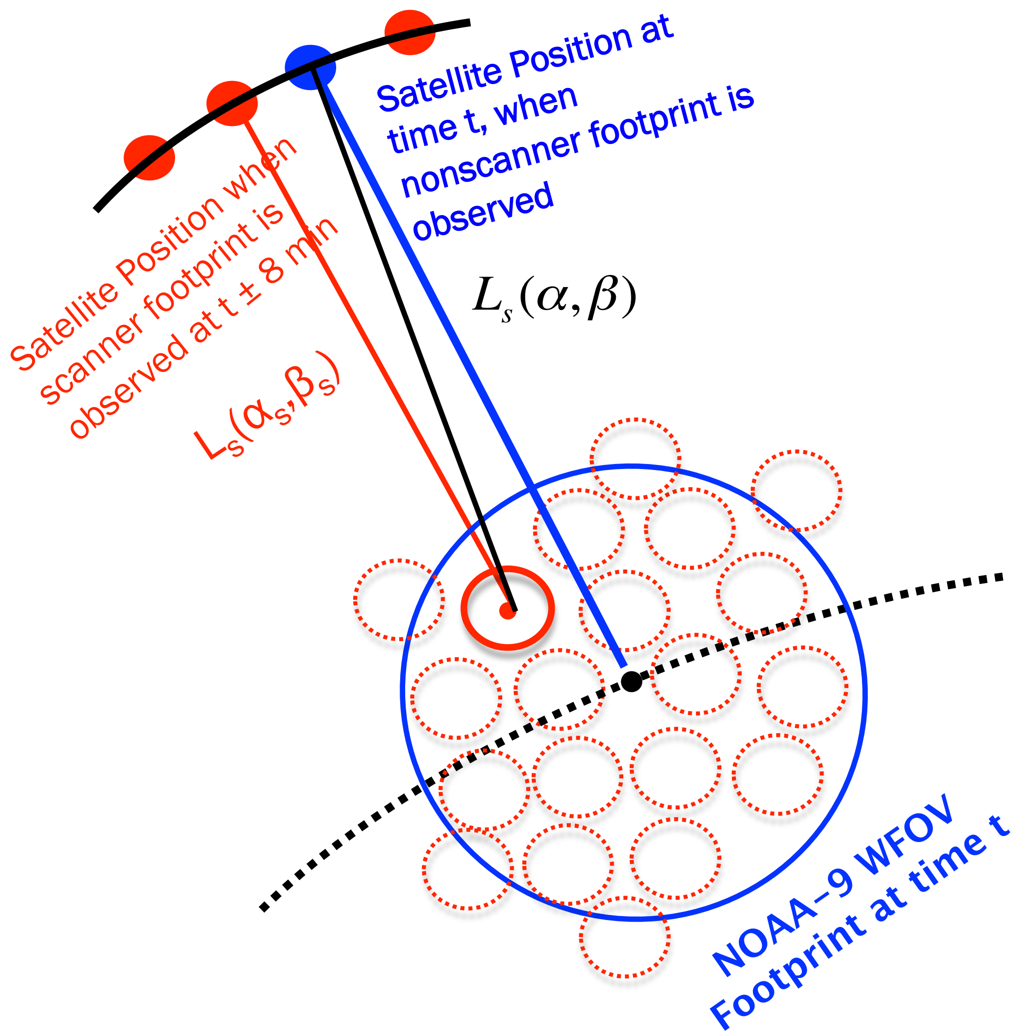
Future Work

- Use full (Two Years) of NOAA-9 scanner data to compare with NOAA-9 WFOV nonscanner observations.
- Reprocess NOAA-10 data and perform similar analysis.

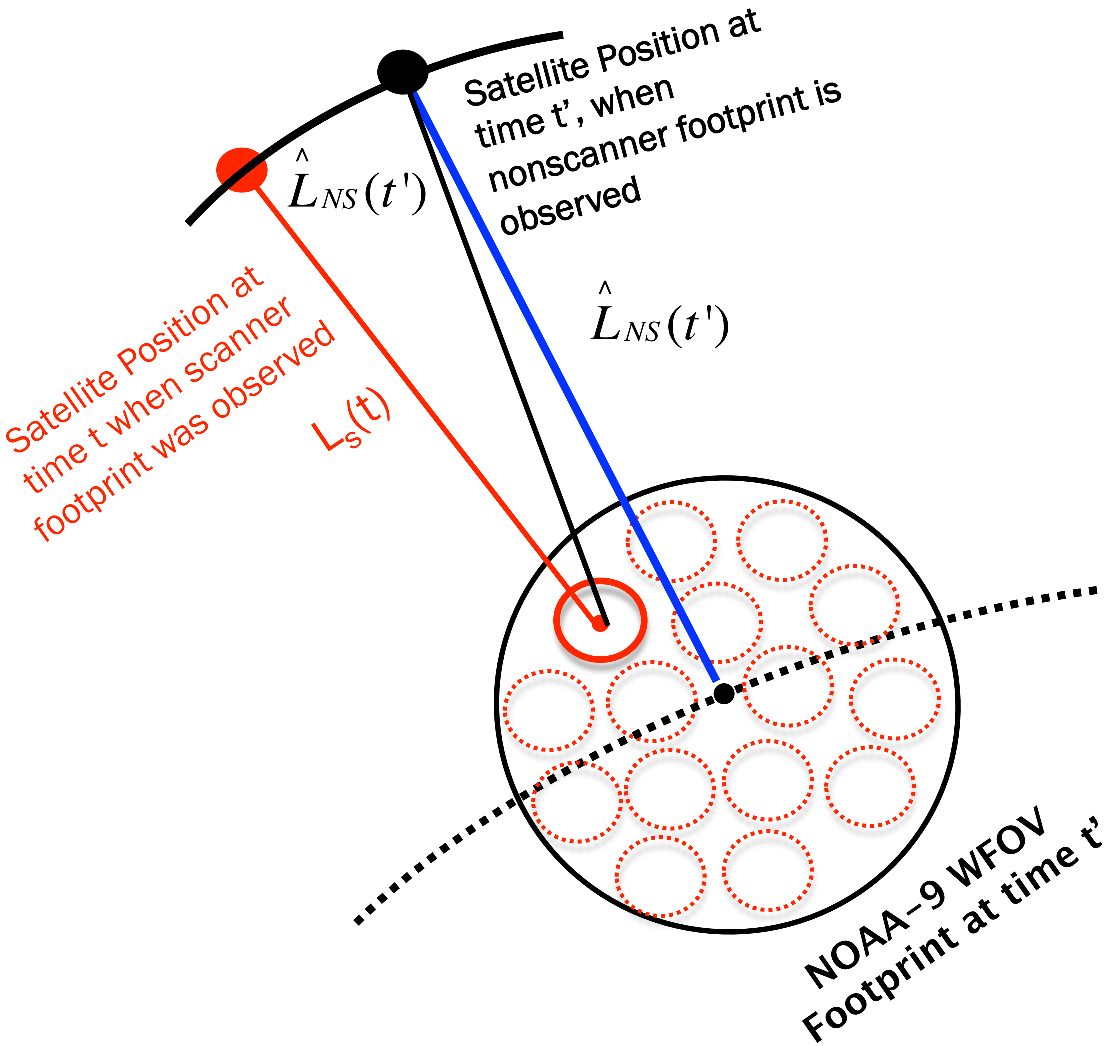
Thanks

Backup Slides

Scanner and WFOV Nonscanner Comparison Process

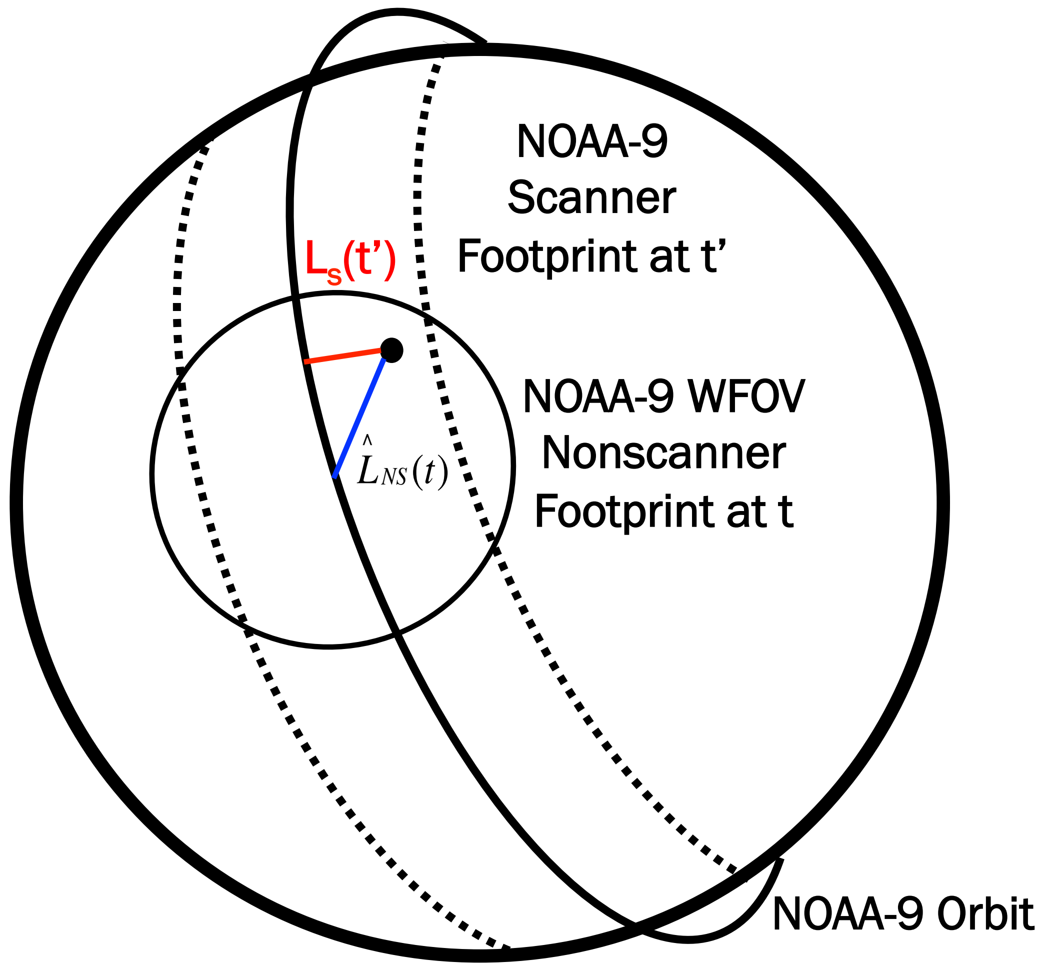


Scanner and WFOV Nonscanner Comparison Process



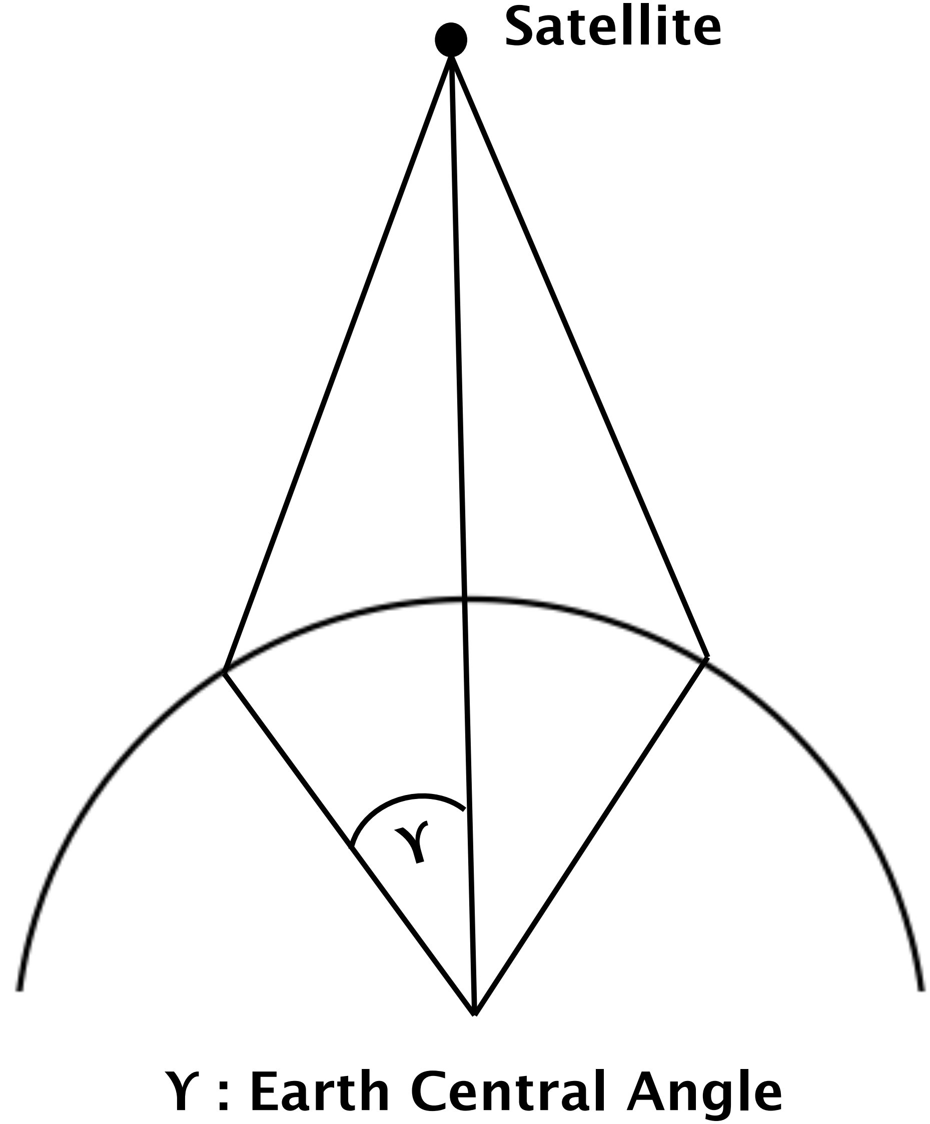
Methodologies : Colocation of Footprints

Scanner and WFOV nonscanner



Methodologies : Colocation of Footprints

WFOV and WFOV nonscanner



Monthly Irradiance of NOAA-9 Vs ERBS WFOV

Table: NOAA-9 and ERBS Monthly Irradiance Averaged Over Two Years

	Average Irradiance		(NOAA-9) - ERBS		(NOAA-9 – ERBS)/ ERBS	
	ERBS WFOV (W/m^2)	NOAA-9 WFOV (W/m^2)	Difference (W/m^2)	RMS (W/m^2)	Relative Difference	Relative RMS
Nighttime LW	215.3	214.0	-1.4	1.6	-0.6%	0.7%
Daytime LW	220.0	220.8	1.0	2.0	0.4%	0.9%
SW	158.0	158.3	0.4	4.7	0.3%	3.0%

Sensitivity Study

Table 1: Anisotropic Sensitivity Study

Average Flux	W/O Change REL-DIFF	5% Change	DIFF
LWDT	-0.7	-2.5%	1.8%
SWDT	0.9	6.7%	5.8%
LWNT	-0.7	-2.5%	1.8%

Table 2: Cloud Fraction Sensitivity Study

Average Flux	W/O Change REL-DIFF	5% Increase (Decrease)	DIFF
LWDT	-0.7	-0.9(-0.7)%	0.2(0.01)%
SWDT	0.9	1.4(1.0)%	0.5(0.1)%
LWNT	-0.7	-0.8(-0.7)%	0.1(0.01)%

Table 3: Cloud Optical Depth Sensitivity Study

Average Flux	W/O Change REL-DIFF	~10% Increase (Decrease)	DIFF
LWDT	-0.7	-0.7(-0.7)%	0.01(0.01)%
SWDT	0.9	0.7(1.2)%	0.2(0.3)%
LWNT	-0.7	-0.7(-0.8)%	0.01(0.1)%

- Uncertainty during comparison of NOAA-9 scanner and nonscanner observations is dominated by anisotropic factor.