Climate data records from microwave satellite data: a new high quality data source for reanalysis

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Outlines

- Overview of the CDR project
- AMSU/MHS products
- **Geolocation correction** (the focus of the talk)
- Scan Asymmetry Correction

The Development of AMSU FCDR's and TCDR's for Hydrological Applications

Definition for CDR (Wiki): According to NRC [*National Research Council 2004. Climate Data Records from Environmental Satellites. Washington D.C.: National Academy Press.I SBN-10: 0-309-09168-3, ISBN 978-0-309-09168-8*]

"a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change."

Goals

– Develop Advance Microwave Sounding Unit-A and -B (AMSU-A/-B), and Microwave Humidity Sounder (MHS) FCDR's for AMSU-A window (23.8, 31.4, 50.3, 89.0 GHz) and all AMSU-B/MHS channels (89, 150/157; 183.3±1, 183.3±3, 183.3±7/190.3 GHz)

– Develop TCDR's for hydrological products: Rain Rate, TPW, CLW, IWP, Snow Cover, SWE

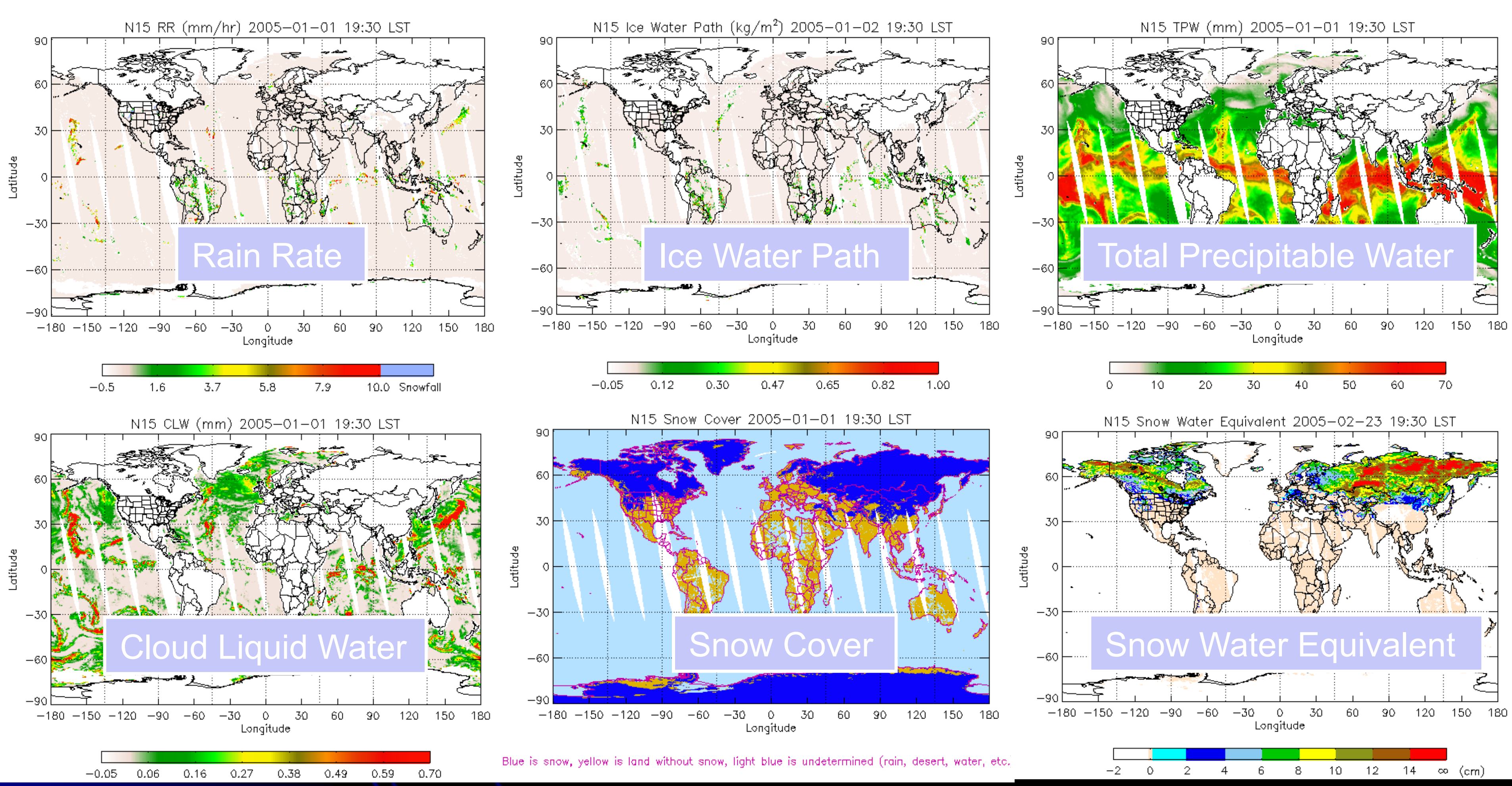
Products

- AMSU (MSPPS) hydrological products

Products	Main Channels Used in MSPPS*
Rain Rate	AMSU-A 23.8 and 31.4 GHz; AMSU-B/MHS 89, 150/157, 183.3±1, ±3, ±7/190.3 GHz
Ice Water Path	AMSU-A 23.8 and 31.4 GHz; AMSU-B/MHS 89 and 150/157 GHz
Total Precipitable Water	AMSU-A 23.8 and 31.4 GHz
Cloud Liquid Water	AMSU-A 23.8 and 31.4 GHz
Snow Cover	AMSU-A 23.8, 31.4 GHz and 89 GHz; AMSU-B/MHS 89 GHz
Snow Water Equivalent	AMSU-A 23.8 and 31.4 GHz; AMSU-B/MHS 89 GHz
Sea Ice	AMSU-A 23.8, 31.4, and 50.3 GHz

* In MIRS, all AMSU-A, -B/MHS channels are used in product retrievals

Sample Products



Data, Products, Users

- **Source Data**
  - NOAA-15,16,17,18,19 L1B data
  - MetOp-A L1B data
- **Deliverables**
  - FCDR’s from 2000 – 2010 for all satellites (perhaps to 1998 for NOAA-15)
  - TCDR’s; same time periods
- **Current/Expected Users**
  - National: government (NASA, NOAA, NRL); science community
  - International: IPCC; GEWEX (GPCP); CEOS; GCOS; IPWG
  - Other – General climate community

AMSU/MHS Bias Sources

Bias Source	Effect
Satellite and sensor attitude errors Satellite clock drift	**Geolocation error**, scan bias, LZA bias
Antenna pattern correction bias (asymmetry, sidelobe spacecraft interference etc.)	Scan bias
Polarization twist	Scan bias
Reflector misalignment	Geolocation, Scan bias
Orbital decay	LZA bias
Sensor RFI	Scan bias, measurement bias
Warm target contamination + sensor nonlinear calibration error	Measurement bias
Pre-launch calibration offset	Measurement bias
Sensor and satellite degradations	Measurement bias

Geolocation Correction

Sources of geolocation errors

1. Human errors
2. Satellite clock offset
3. Satellite attitude offset and sensor pointing errors

   Satellite attitudes are known as Pitch, Roll and Yaw (in mathematics: Euler Angles) and are included in the geolocation algorithm by a rotation matrix

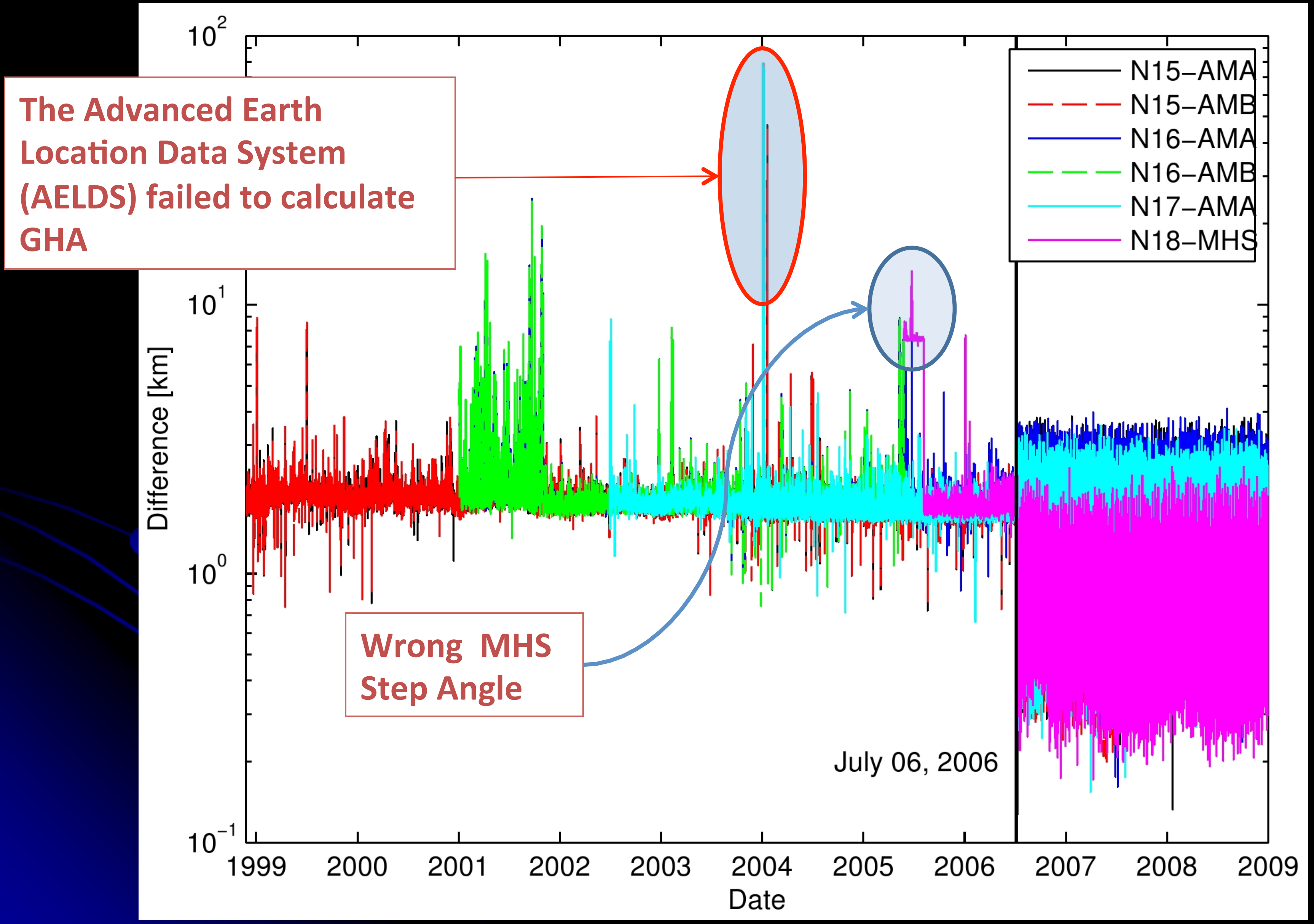
4. Poor spacecraft ephemeris data

Channel No.	Frequency (GHz)	Polarization at nadir	Atmospheric transmission (tropical)	Atmospheric transmission (winter subarctic)
1	23.8	V	0.78	0.99
2	31.4	V	0.89	0.96
3	50.3	V	0.63	0.68
4	52.8	V	0.29	0.32
5	53.596 ± 0.115	H	0.11	0.13
6	54.40	H	0.02	0.02
7	54.94	V	0.00	0.00
8	55.50	H	0.00	0.00
9	57.290 = ν	H	0.00	0.00
10	$\nu \pm 0.217$	H	0.00	0.00
11	$\nu \pm 0.322 \pm 0.048$	H	0.00	0.00
12	$\nu \pm 0.322 \pm 0.022$	H	0.00	0.00
13	$\nu \pm 0.322 \pm 0.010$	H	0.00	0.00
14	$\nu \pm 0.322 \pm 0.0045$	H	0.00	0.00
15	89.0	V	0.61	0.91

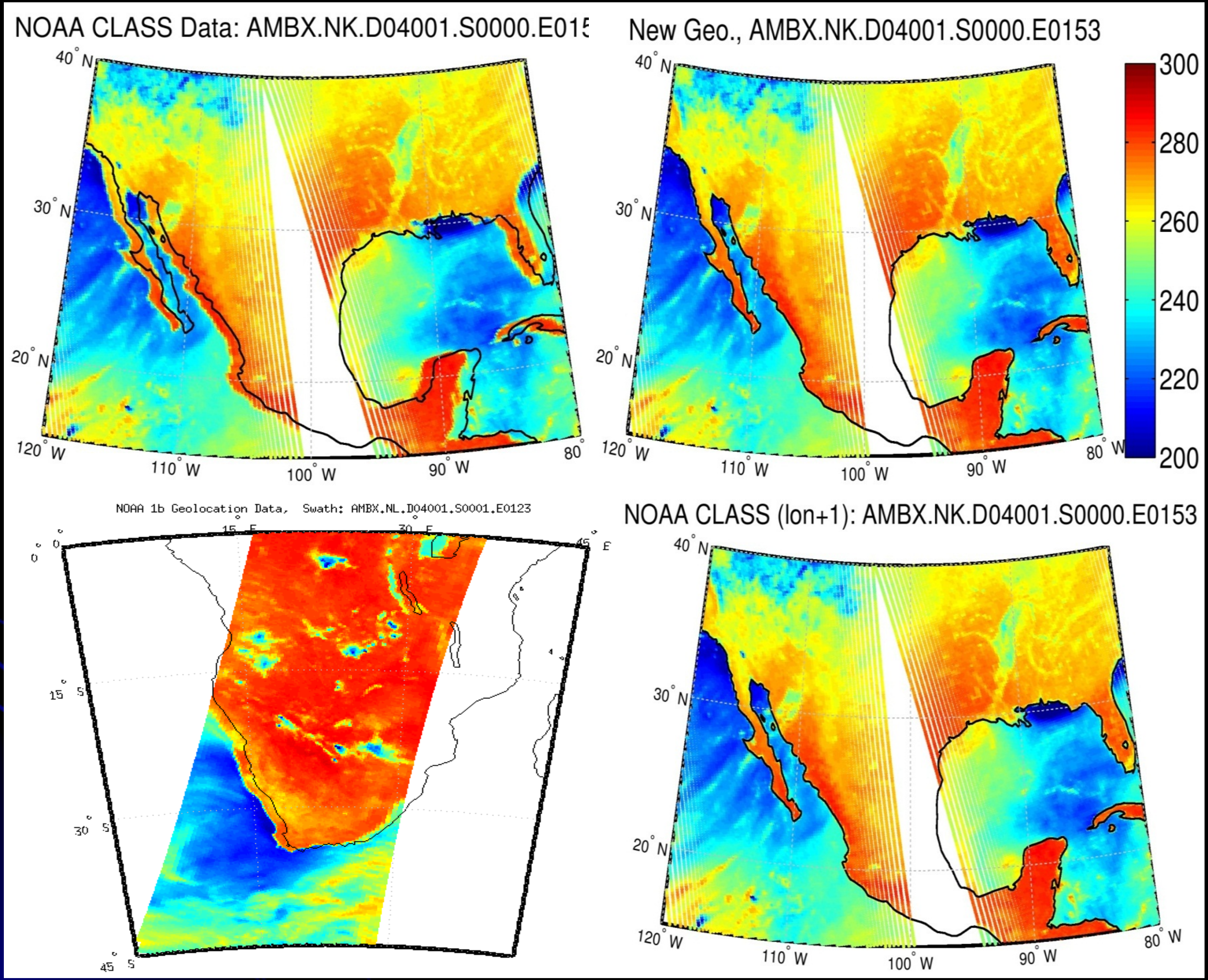
The implemented correction method will take care of all sources of errors.

The method is just applicable to the microwave window channels

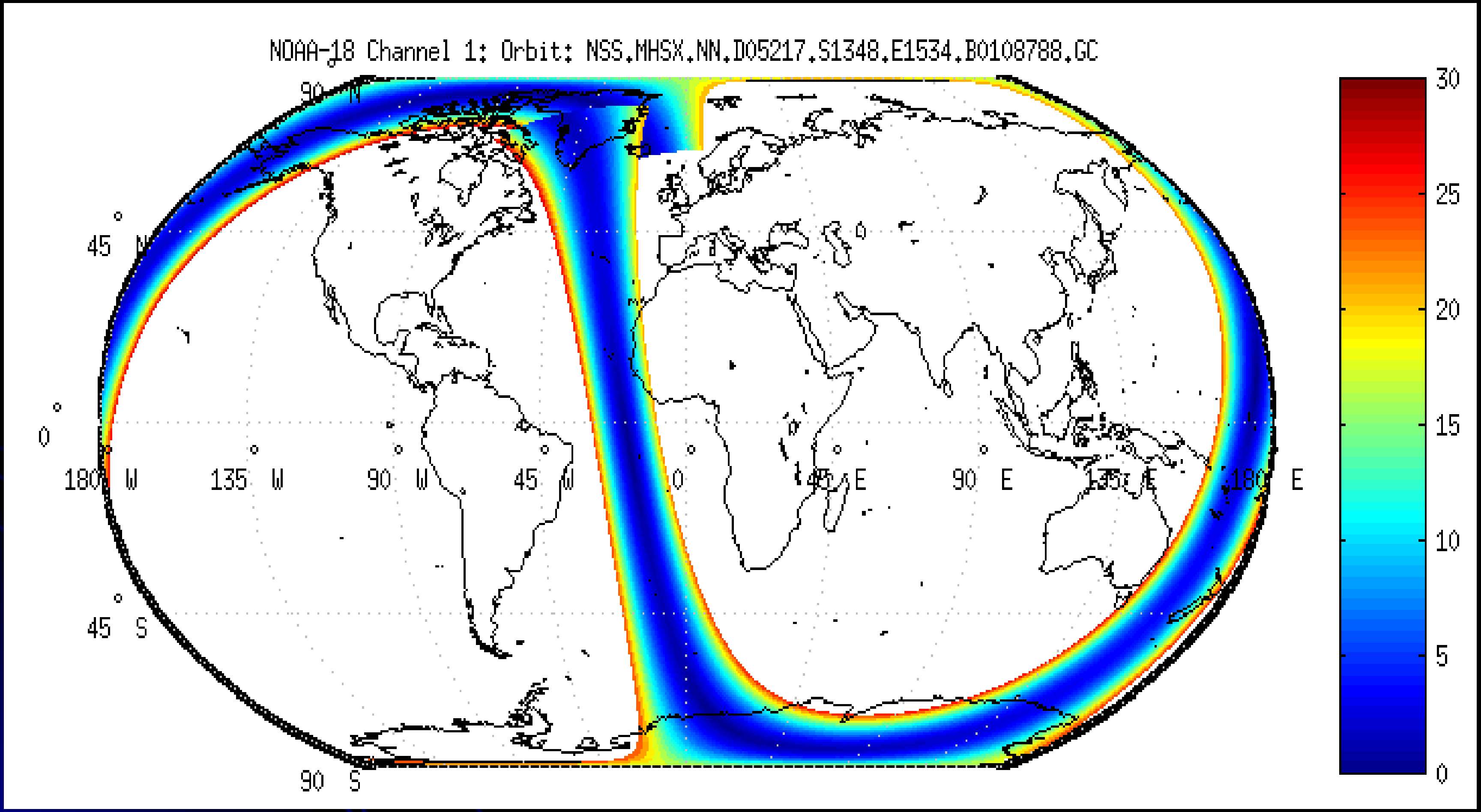
Difference between NOAA-L1b and new geolocation



NOAA Level 1b geolocation problems

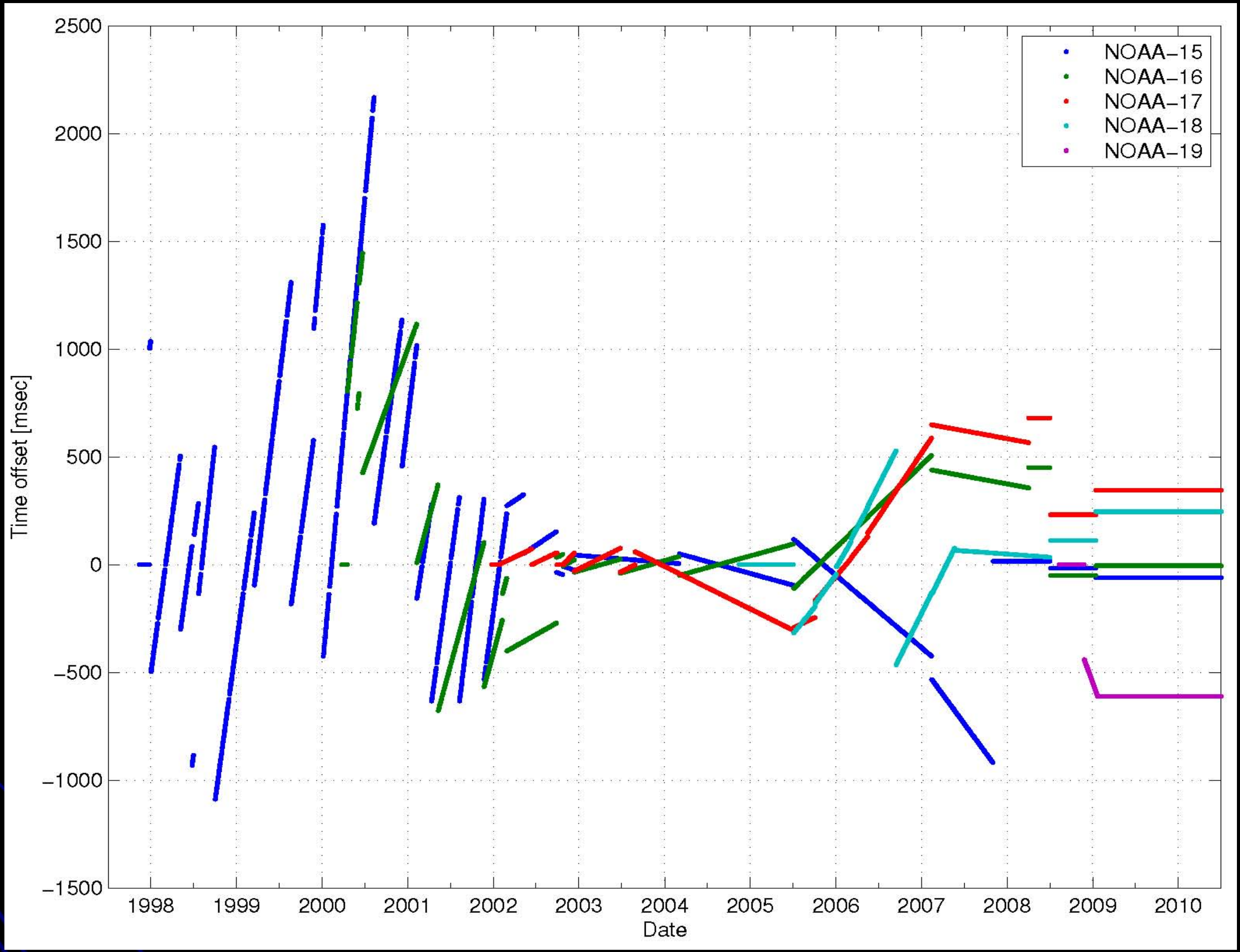


Error in MHS Step Angle

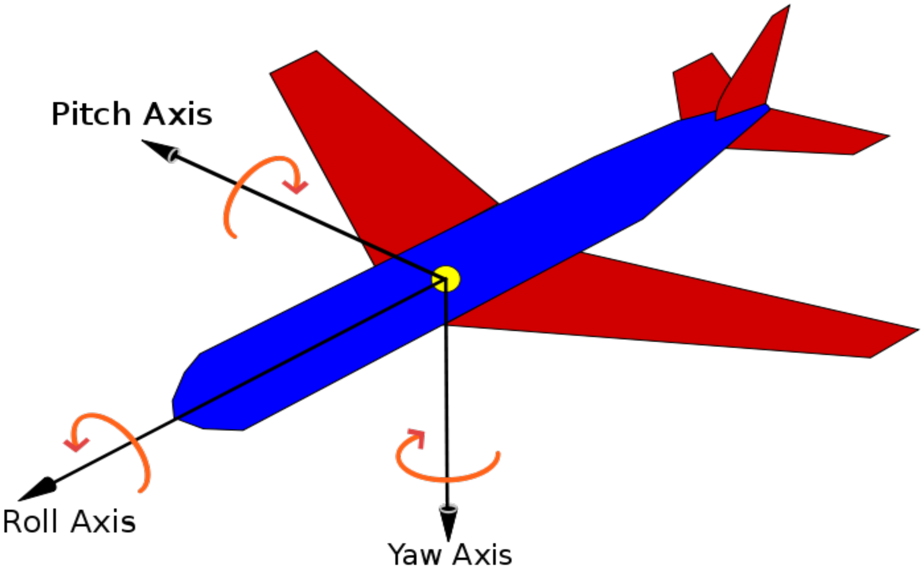


Clock offset for NOAA POES satellites

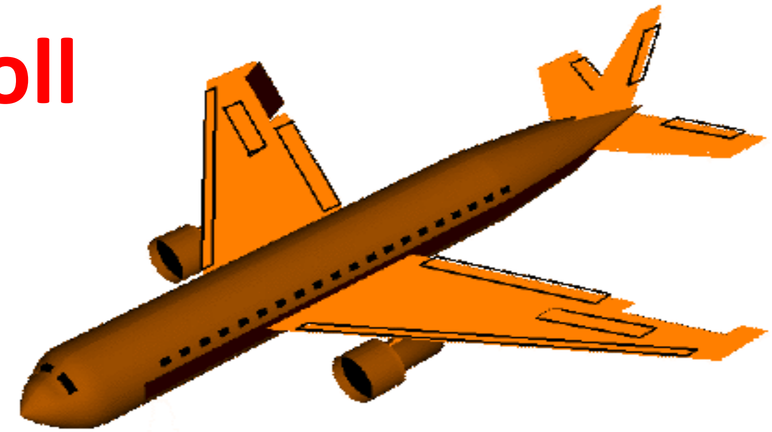
In the original NOAA-L1b data, the clock offset is not taken into account for geolocating NOAA-17 data



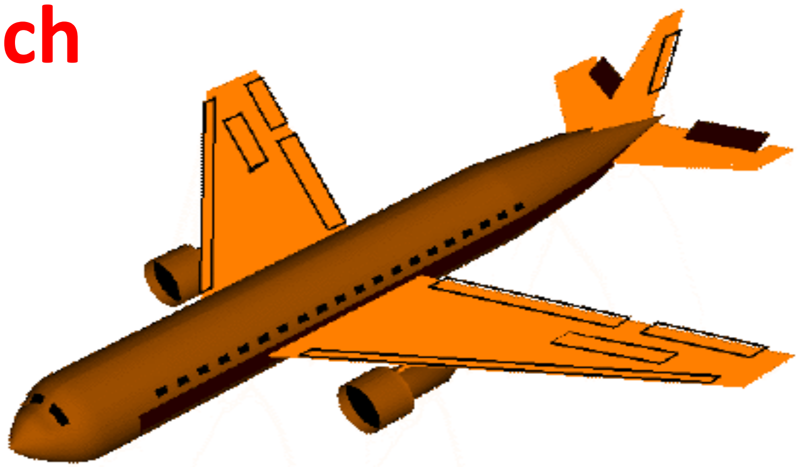
Satellite attitudes



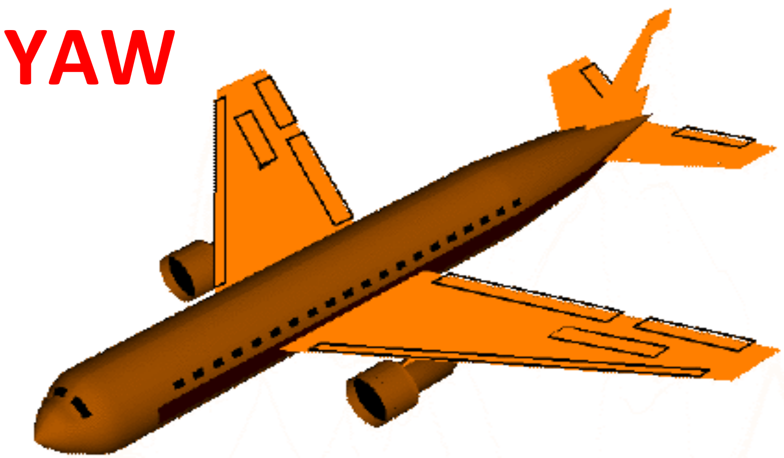
Roll



Pitch



YAW



Source: Wikipedia

Quantifying the geolocation error

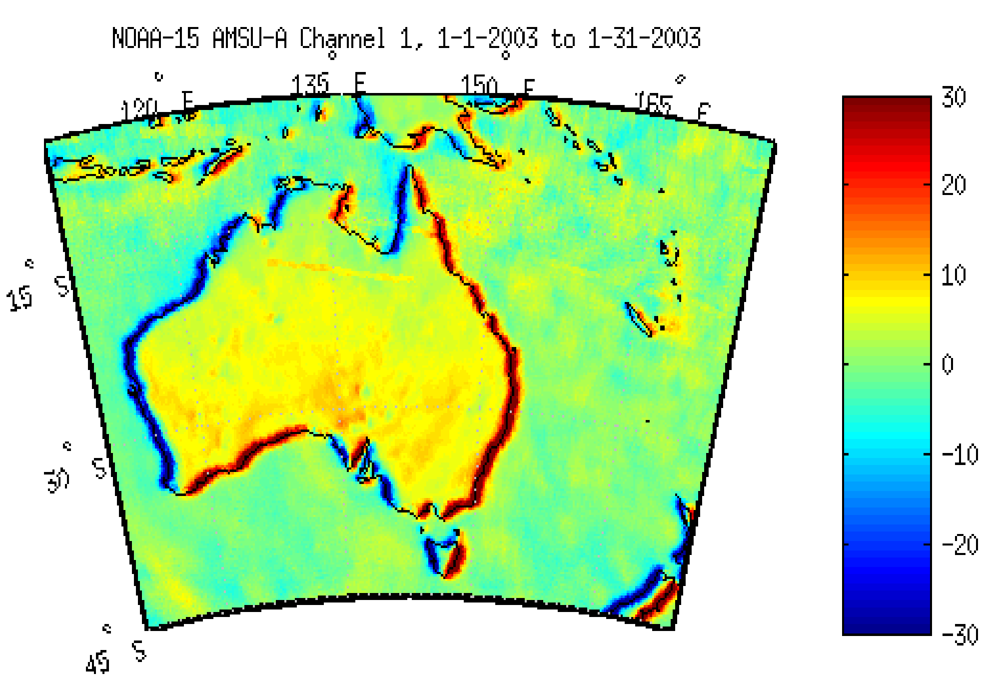
- No geolocation error => ΔTB, ascending – descending, is very small (diurnal variation, environmental conditions, limb effect).

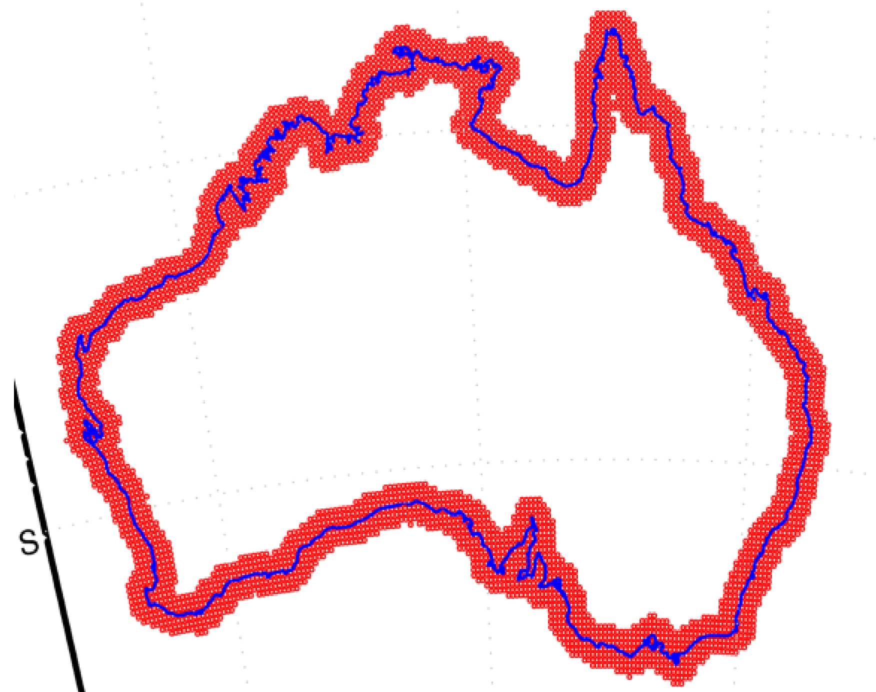
- Geolocation error => ΔTb is very large along the coast lines because the land TB is much higher than ocean TB

- ***negative alongtrack** offset => **northern** coastlines will have a **cold** edge, and **southern** coastlines will have a **warm** edge*.

- ***negative crosstrack** offset => **western** coastlines will have a **cold** edge and the **eastern** coastlines will have a **warm** edge*

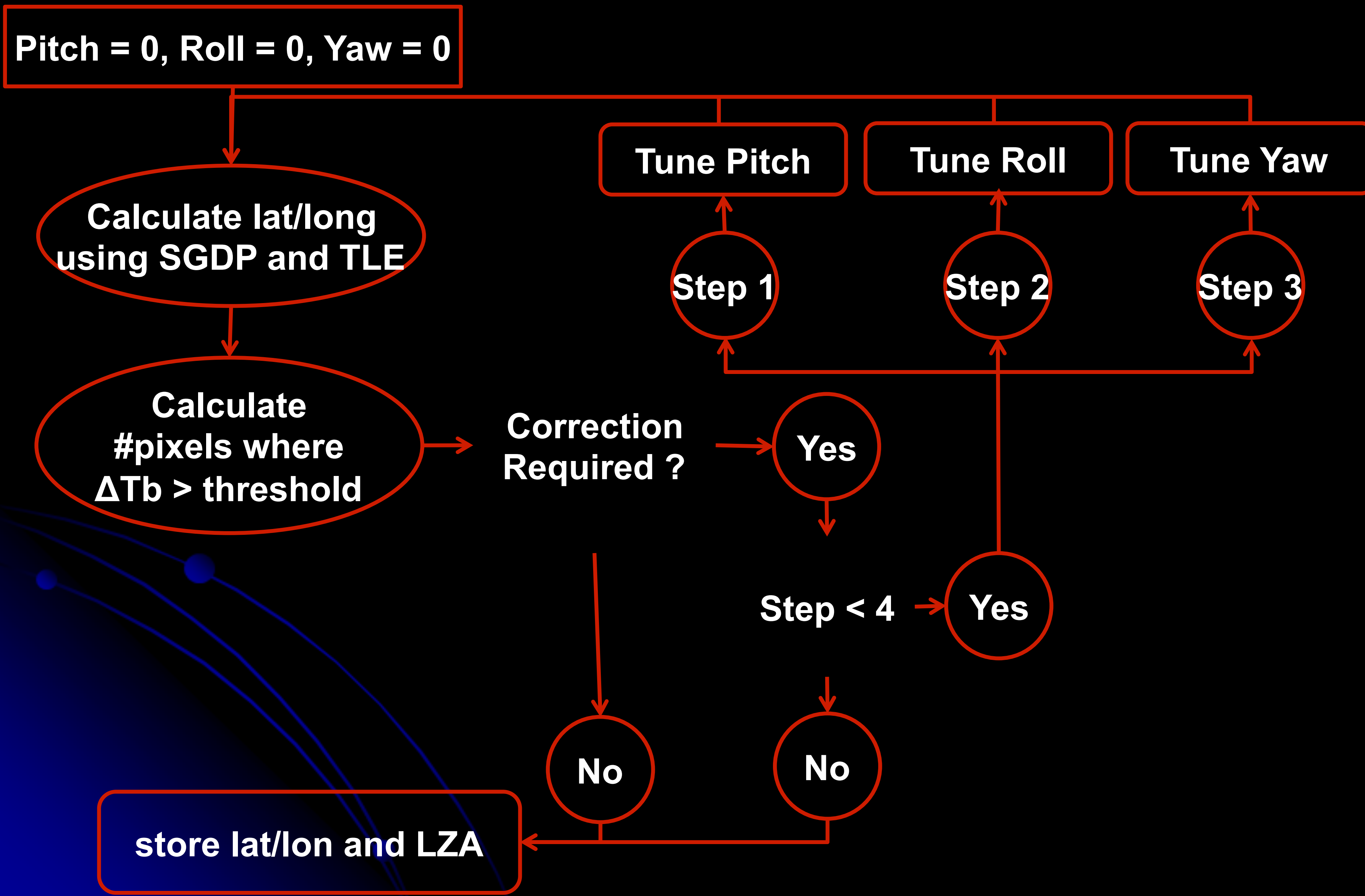
Sample difference map



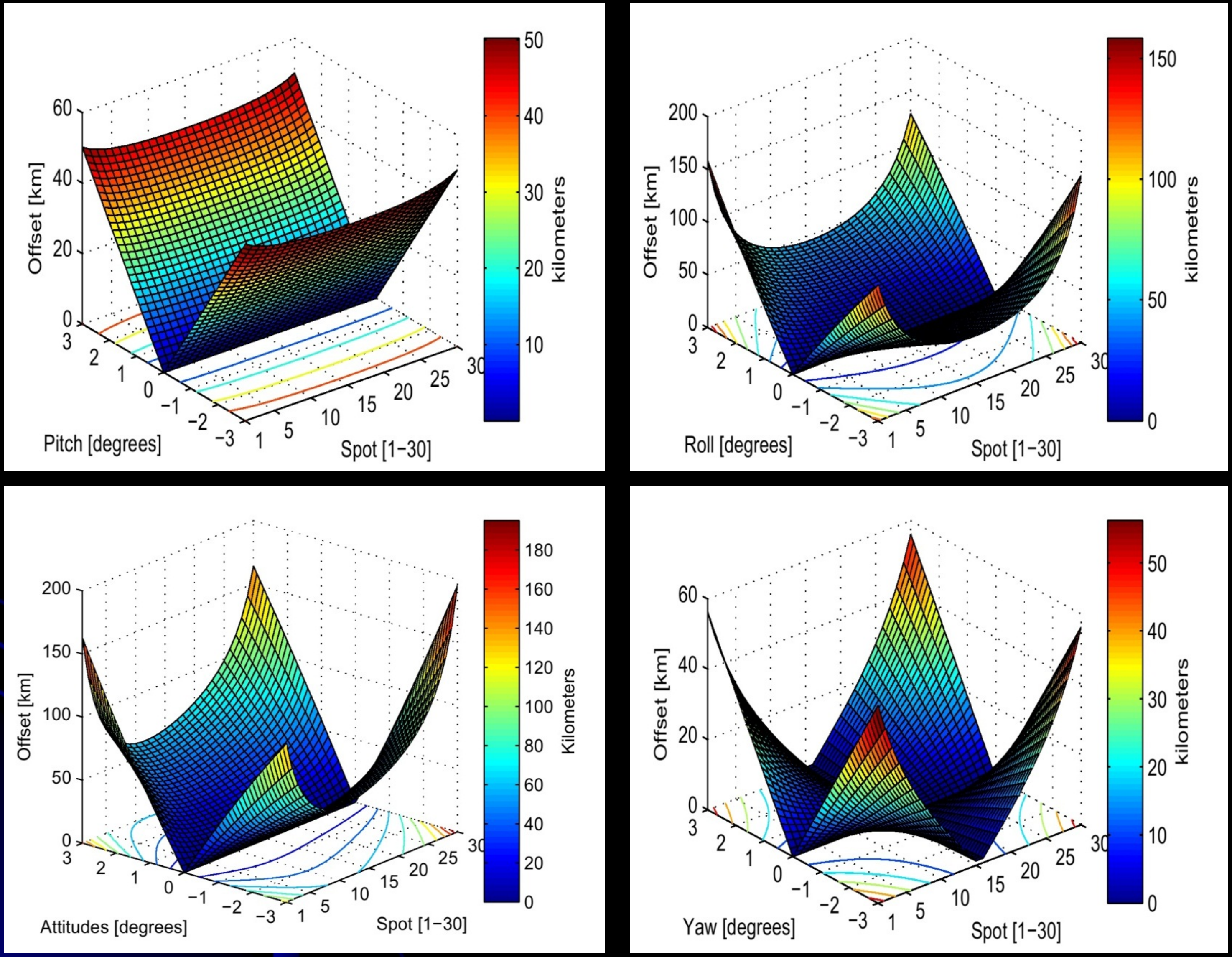


Index = number of pixels along the coastlines where ΔTb > threshold

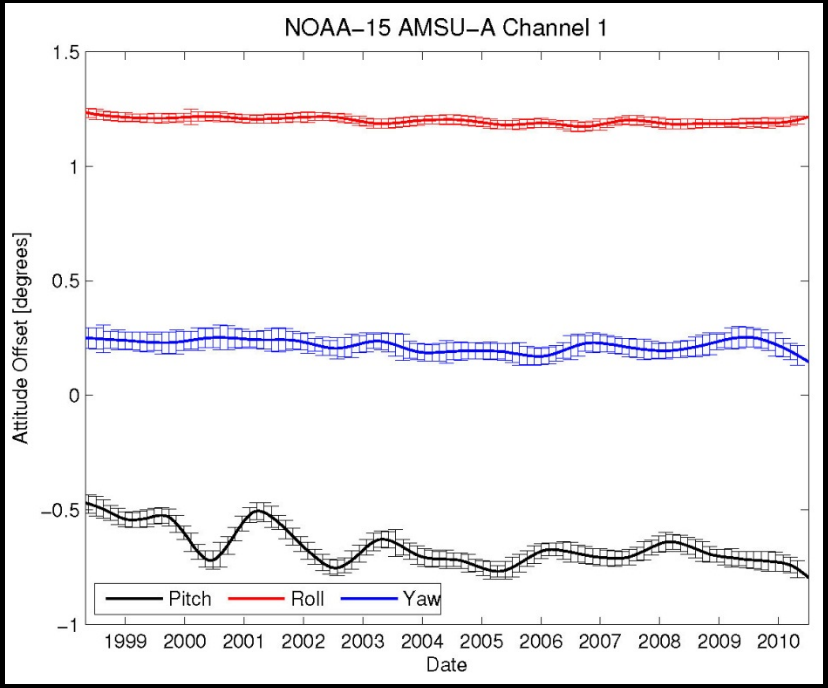
How to tune pitch, roll, and yaw?

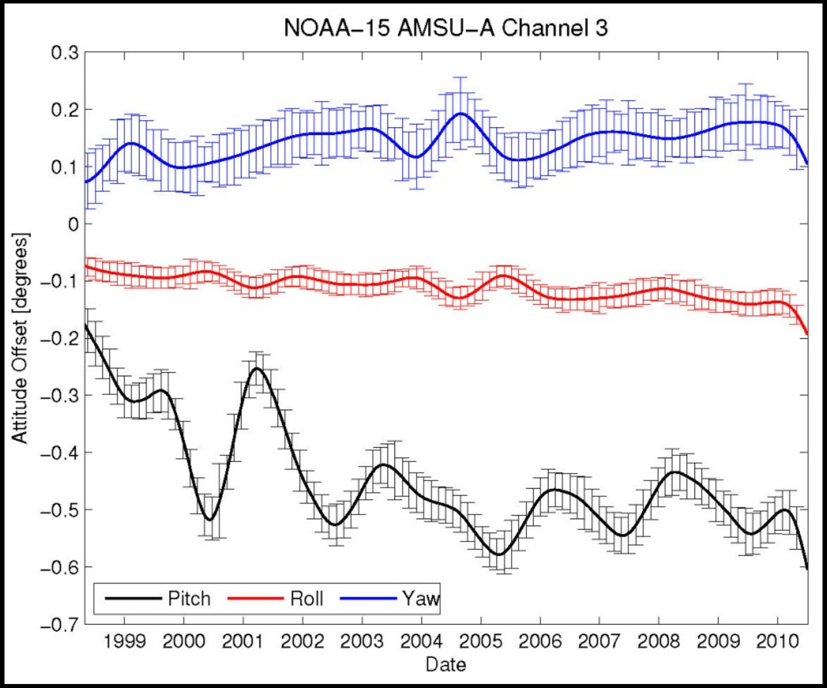


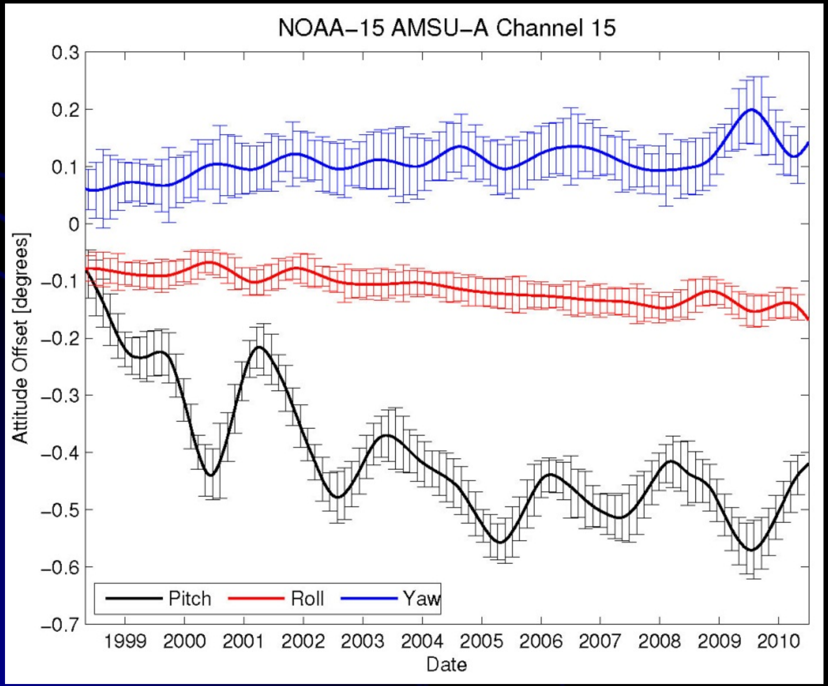
Sensitivity analysis

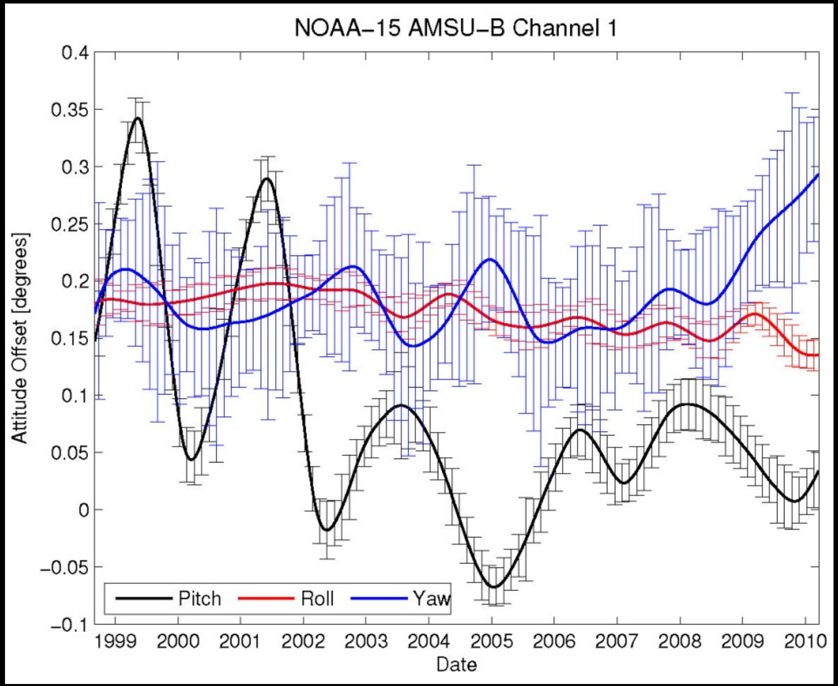


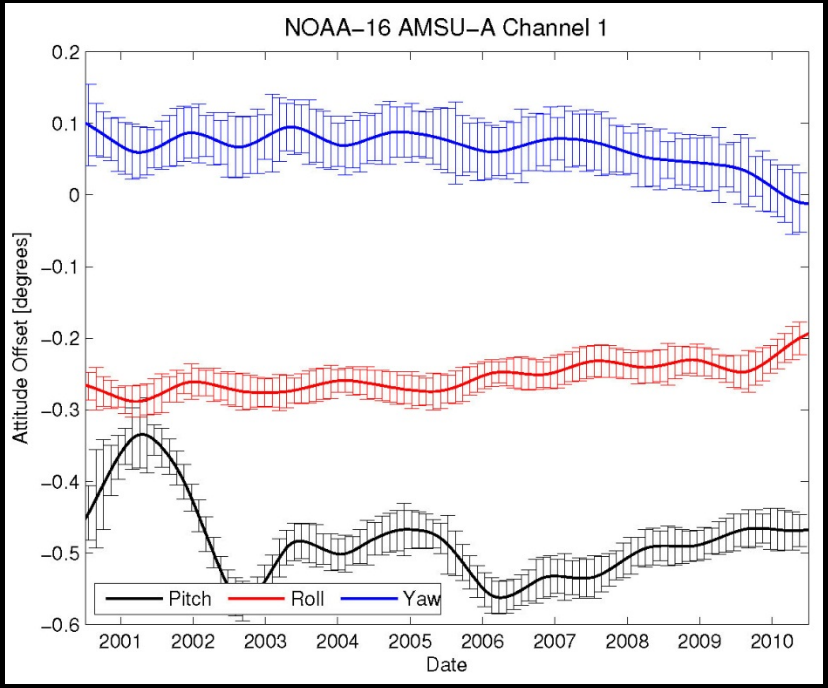
Results

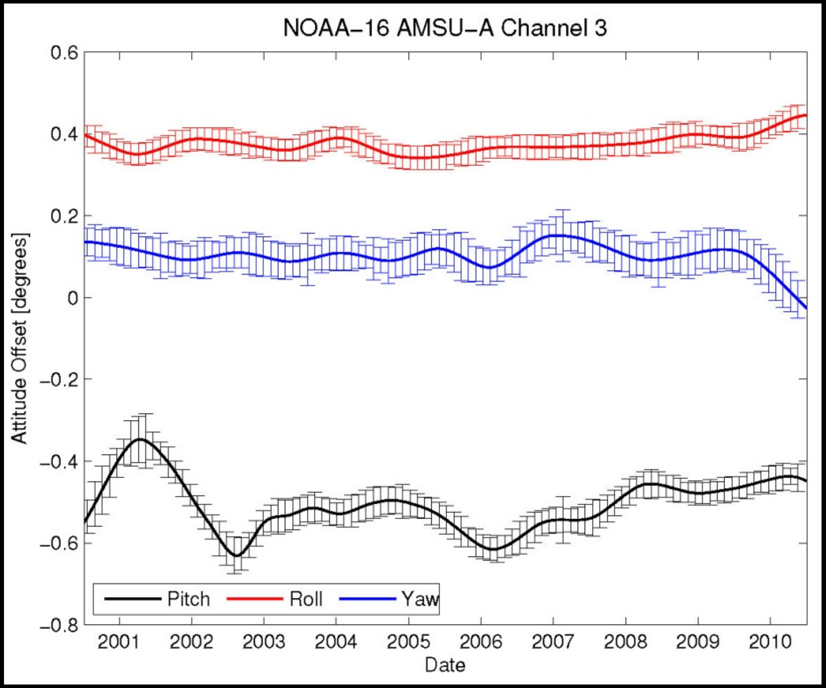

NOAA−15 AMSU−A Channel 1
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw


NOAA−15 AMSU−A Channel 3
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw


NOAA−15 AMSU−A Channel 15
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw


NOAA−15 AMSU−B Channel 1
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw


NOAA−16 AMSU−A Channel 1
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


NOAA−16 AMSU−A Channel 3
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw
0.6
0.4
0.2
0
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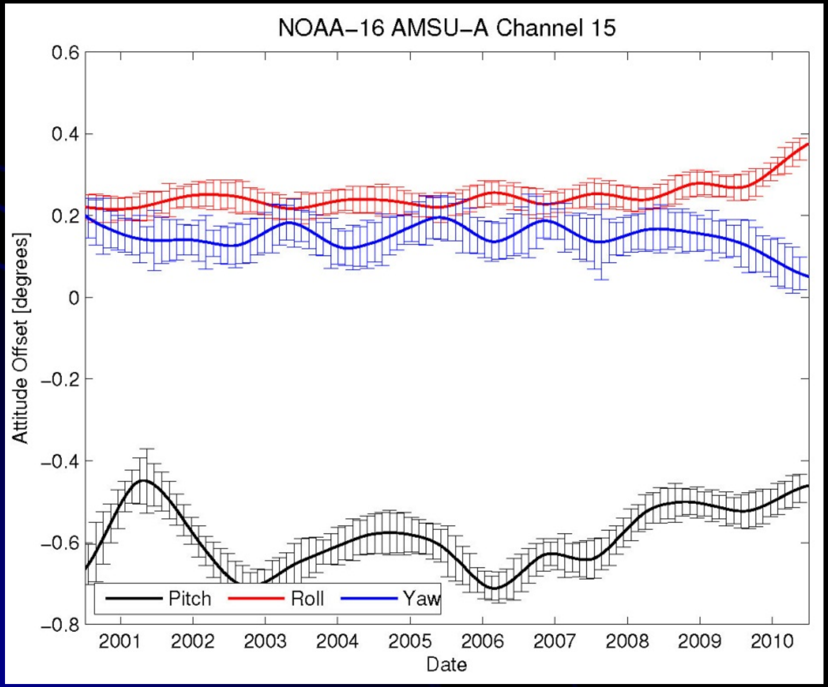
−0.4
−0.6
−0.8
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


NOAA−16 AMSU−A Channel 15
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw
0.6
0.4
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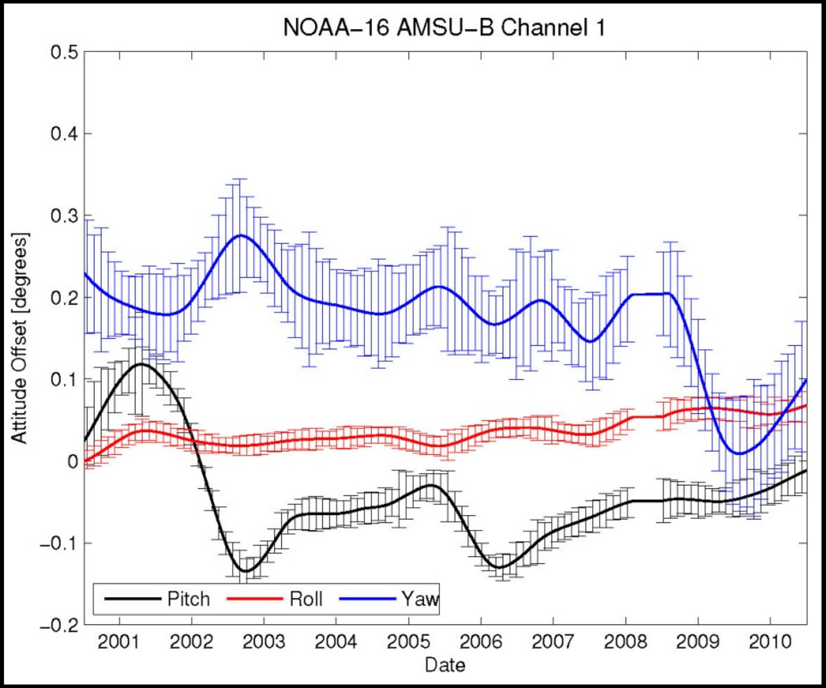
−0.4
−0.6
−0.8
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


NOAA−16 AMSU−B Channel 1
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw
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0.4
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0
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−0.2
2001
2002
2003
2004
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2006
2007
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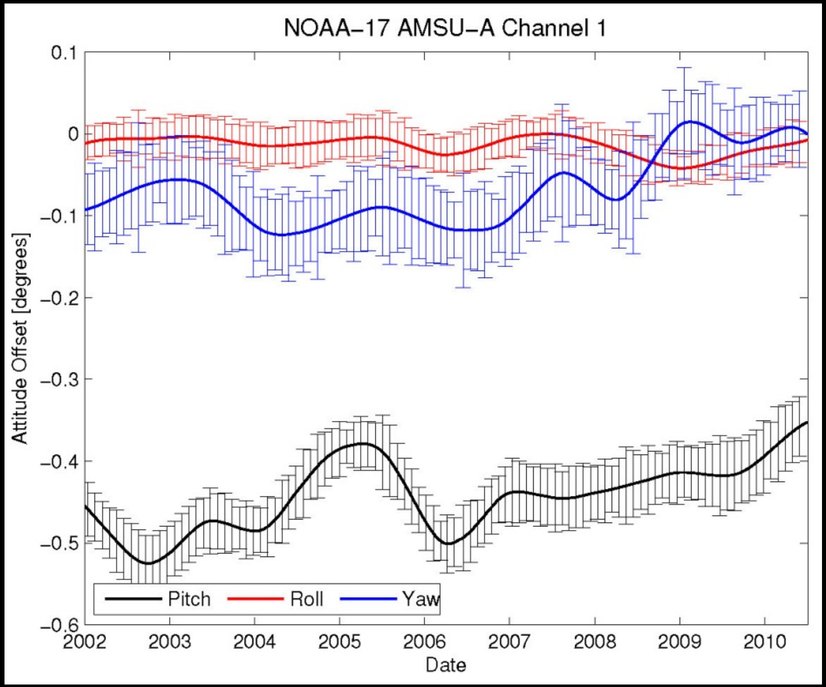
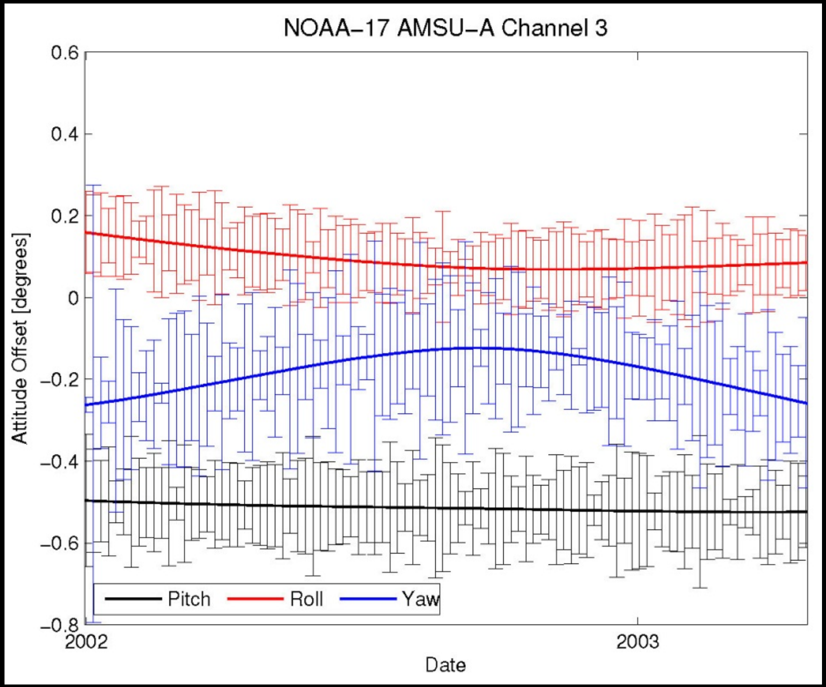
2009
2010


NOAA−17 AMSU−A Channel 1
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
2002
2003
2004
2005
2006
2007
2008
2009
2010


NOAA−17 AMSU−A Channel 3
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw
0.6
0.4
0.2
0
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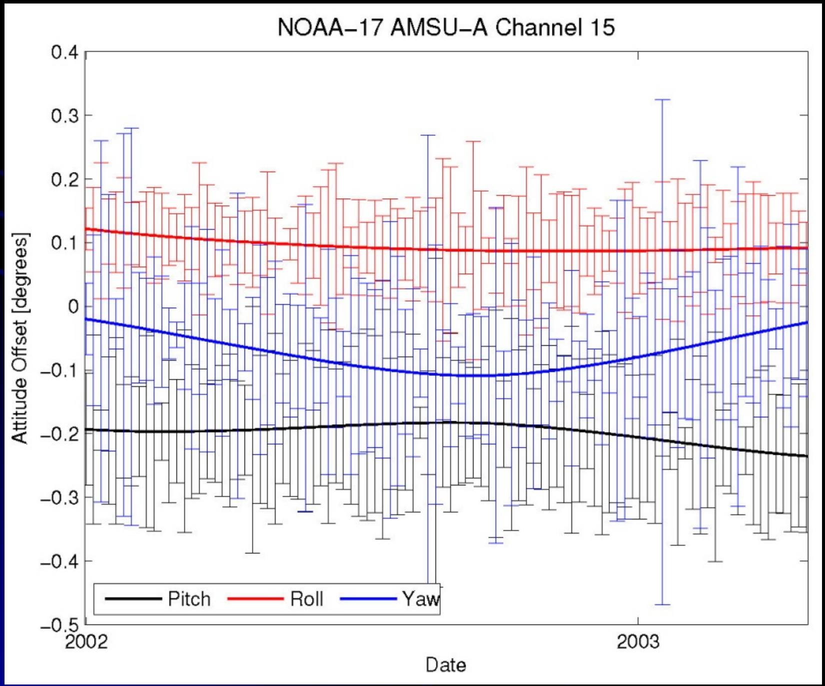
−0.4
−0.6
−0.8
2002
2003


NOAA−17 AMSU−A Channel 15
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw
0.4
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0.2
0.1
0
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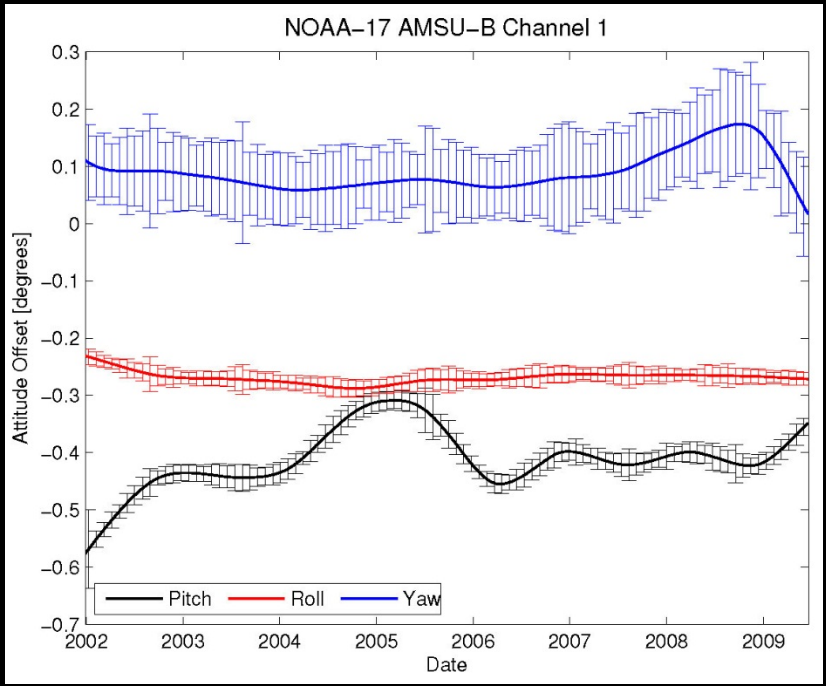
−0.2
−0.3
−0.4
−0.5
2002
2003


NOAA−17 AMSU−B Channel 1
Attitude Offset [degrees]
Date
Pitch
Roll
Yaw
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0.1
0
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−0.4
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−0.6
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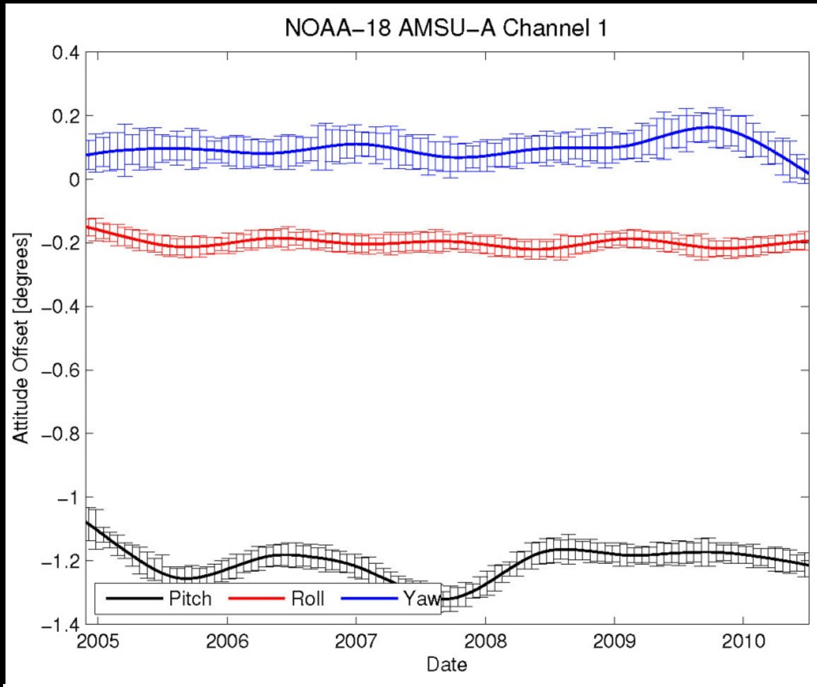
2002
2003
2004
2005
2006
2007
2008
2009


NOAA−18 AMSU−A Channel 1
Attitude Offset [degrees]
Date
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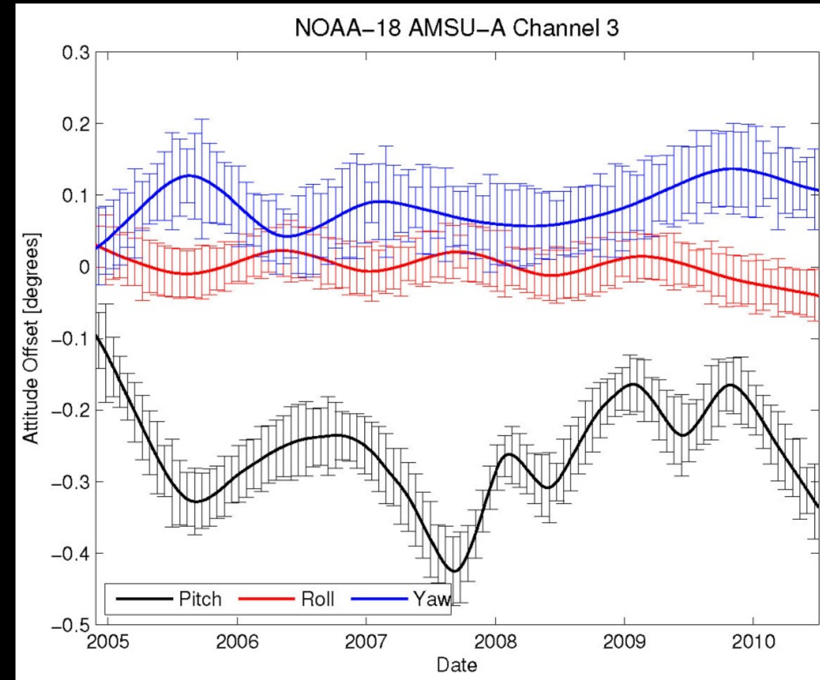
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
2005
2006
2007
2008
2009
2010
Pitch
Roll
Yaw


NOAA−18 AMSU−A Channel 3
Attitude Offset [degrees]
Date
0.3
0.2
0.1
0
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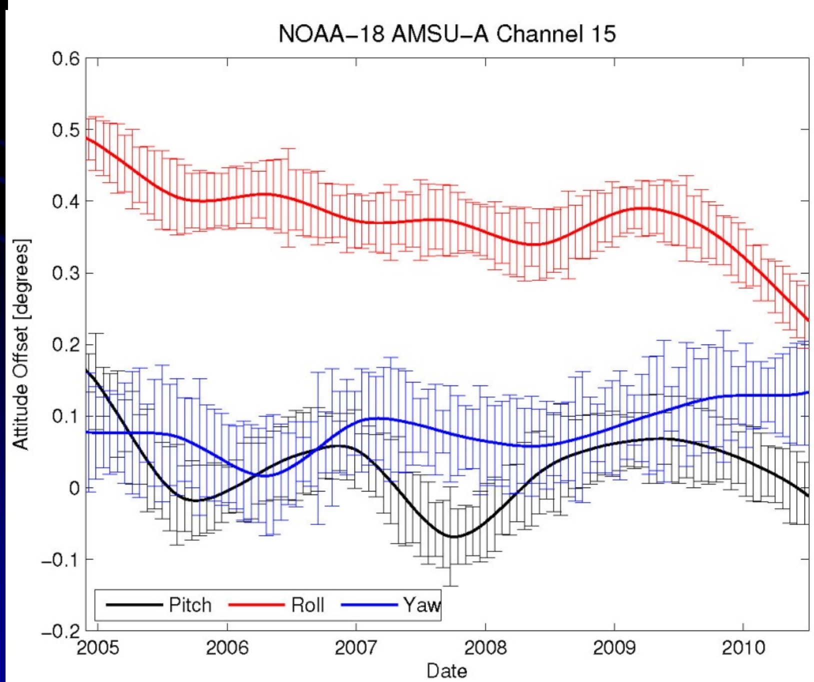
−0.3
−0.4
−0.5
2005
2006
2007
2008
2009
2010
Pitch
Roll
Yaw


NOAA−18 AMSU−A Channel 15
Attitude Offset [degrees]
Date
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0.4
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0
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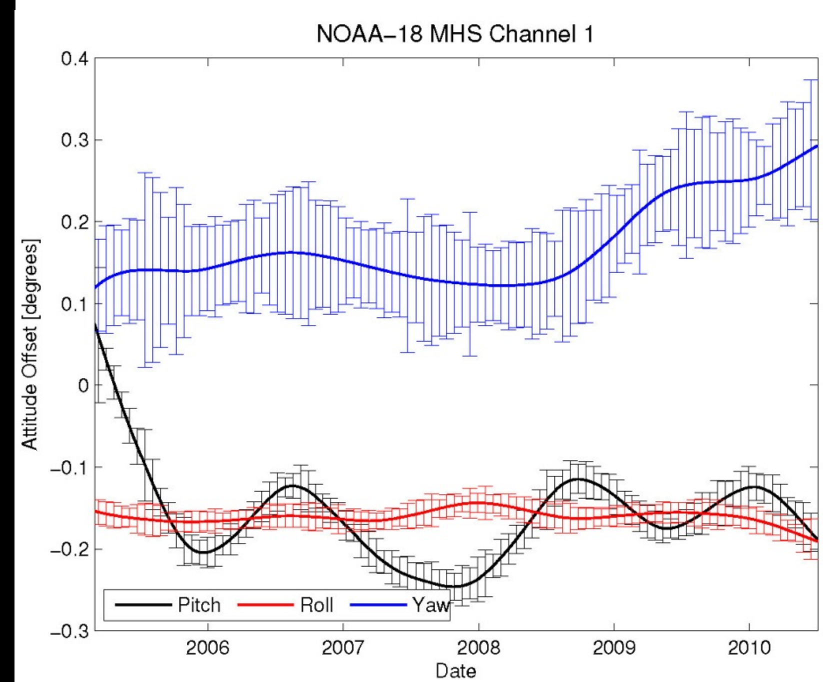
−0.2
2005
2006
2007
2008
2009
2010
Pitch
Roll
Yaw


NOAA−18 MHS Channel 1
Attitude Offset [degrees]
Date
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0
−0.1
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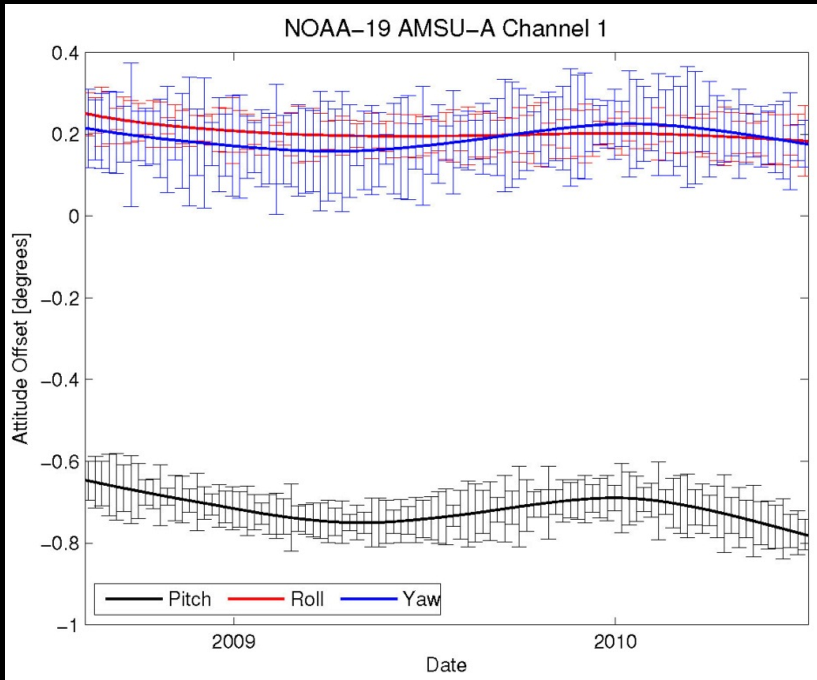
−0.3
2006
2007
2008
2009
2010
Pitch
Roll
Yaw


NOAA−19 AMSU−A Channel 1
0.4
0.2
0
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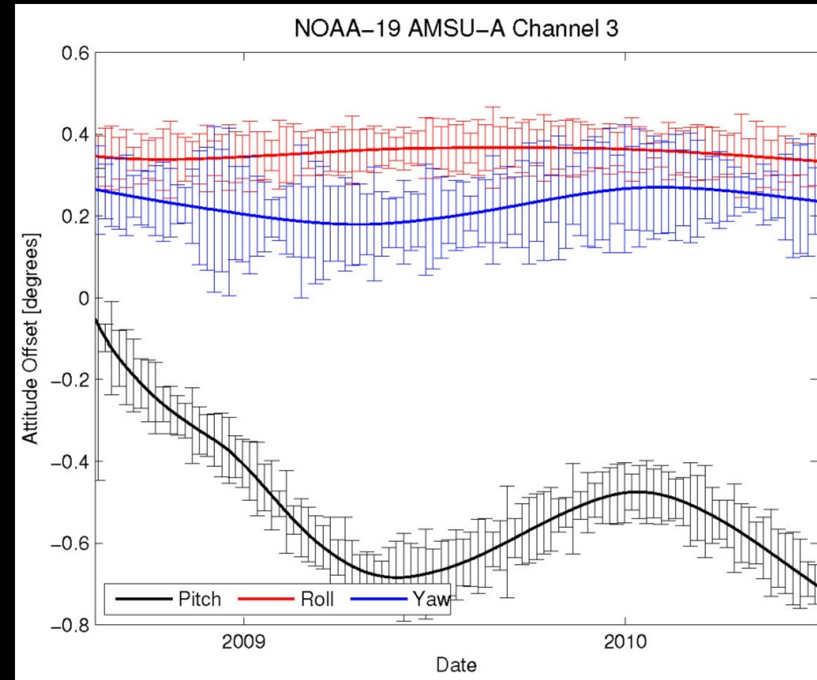
−0.4
−0.6
−0.8
−1
Attitude Offset [degrees]
2009
2010
Date
Pitch
Roll
Yaw

NOAA−19 AMSU−A Channel 3
0.6
0.4
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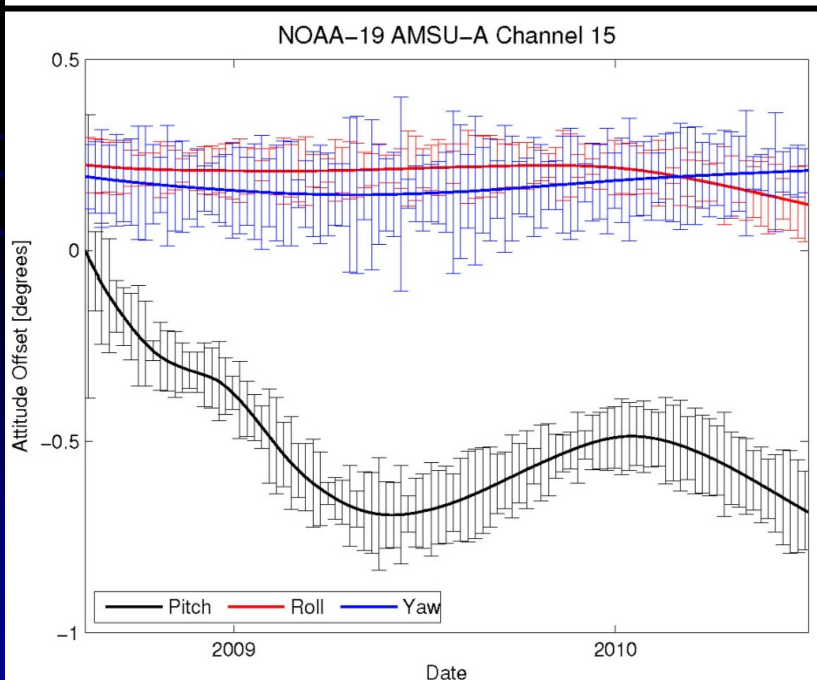
−0.4
−0.6
−0.8
Attitude Offset [degrees]
2009
2010
Date
Pitch
Roll
Yaw

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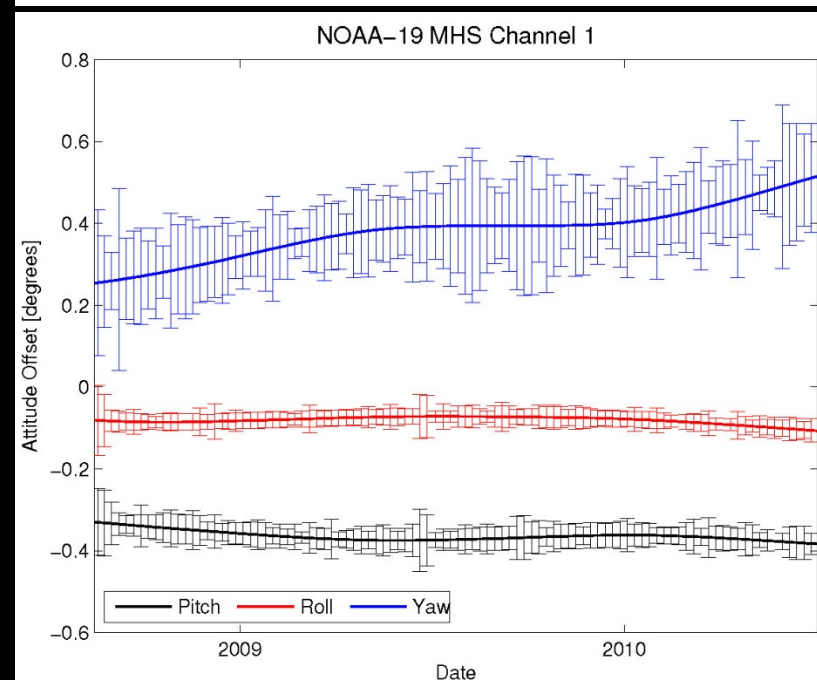
Attitude Offset [degrees]
2009
2010
Date
Pitch
Roll
Yaw

NOAA−19 MHS Channel 1
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0.6
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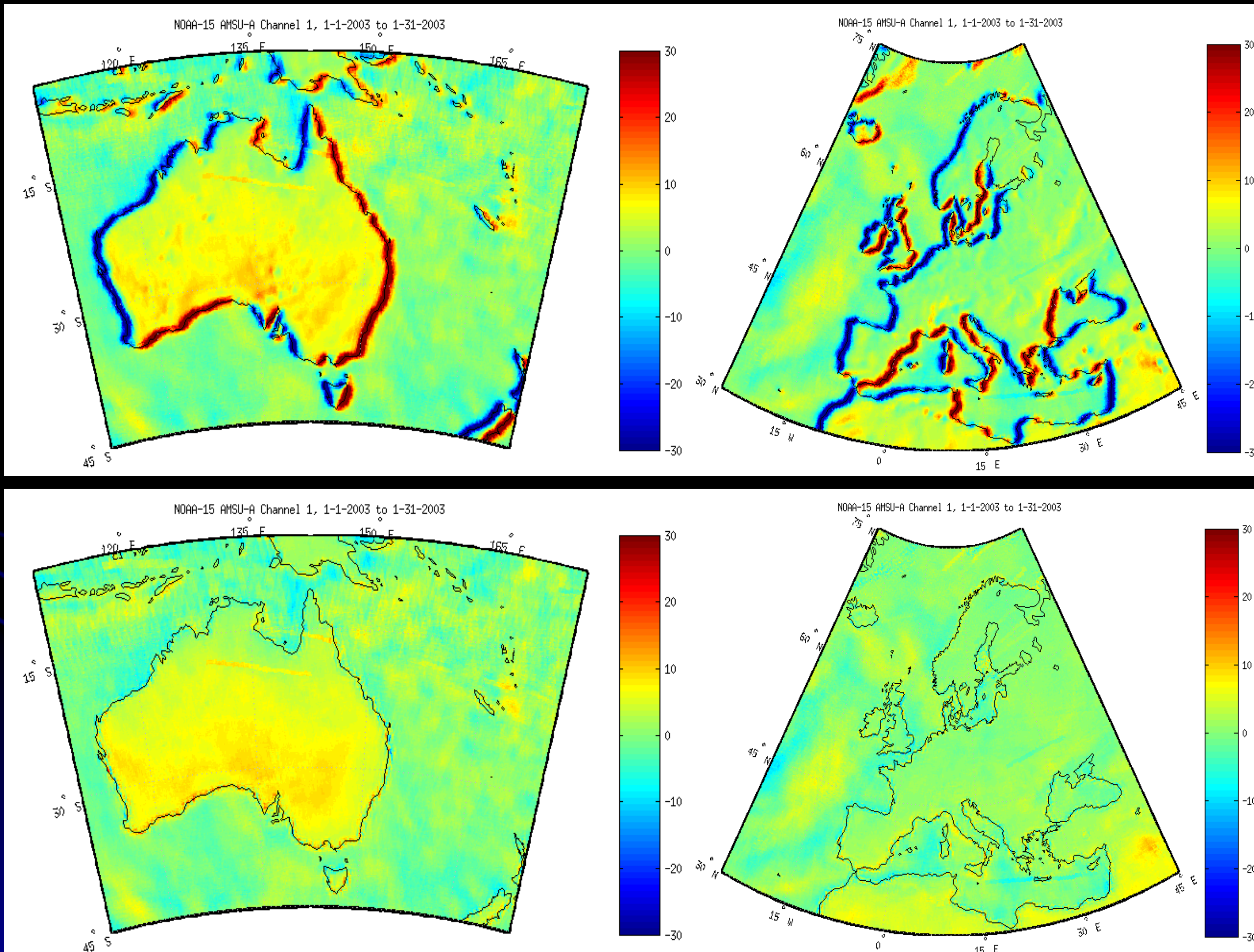
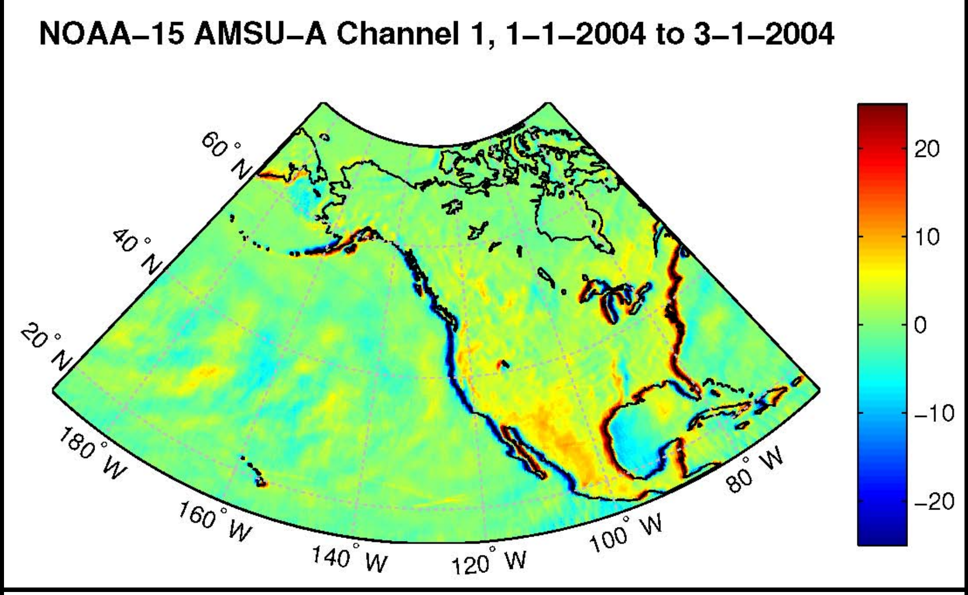
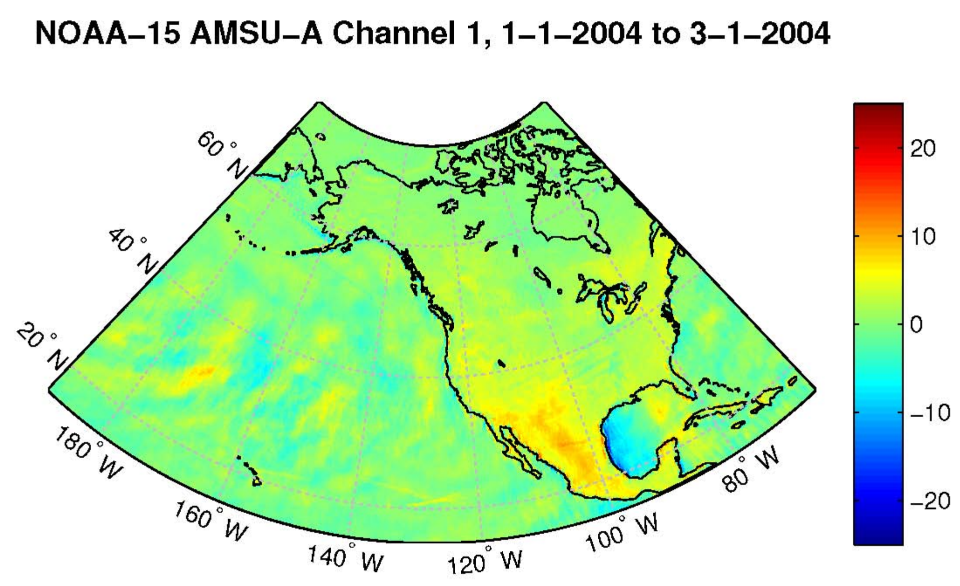
0
−0.2
−0.4
−0.6
Attitude Offset [degrees]
2009
2010
Date
Pitch
Roll
Yaw

Before and After Correction



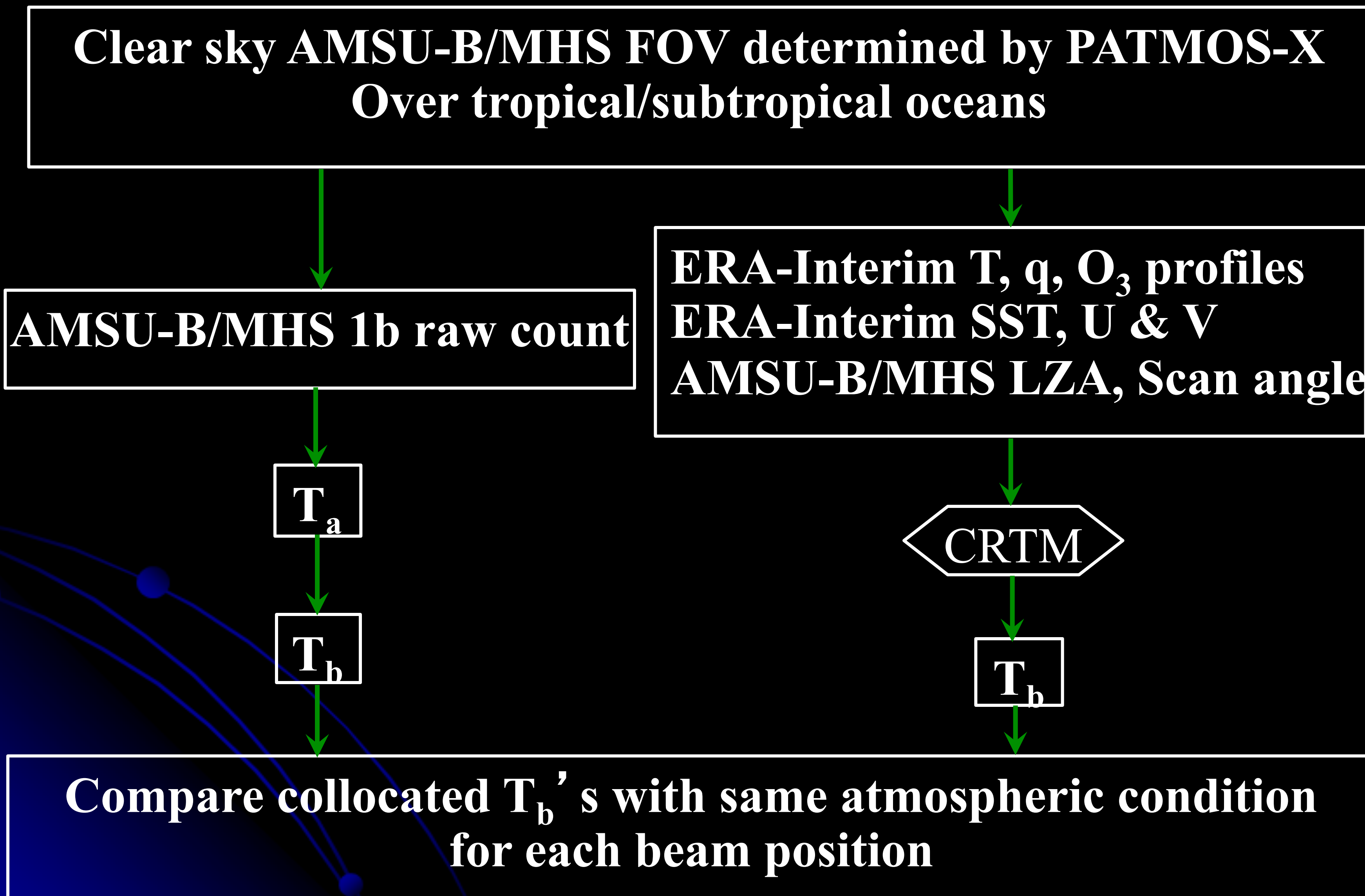
Before and After Correction

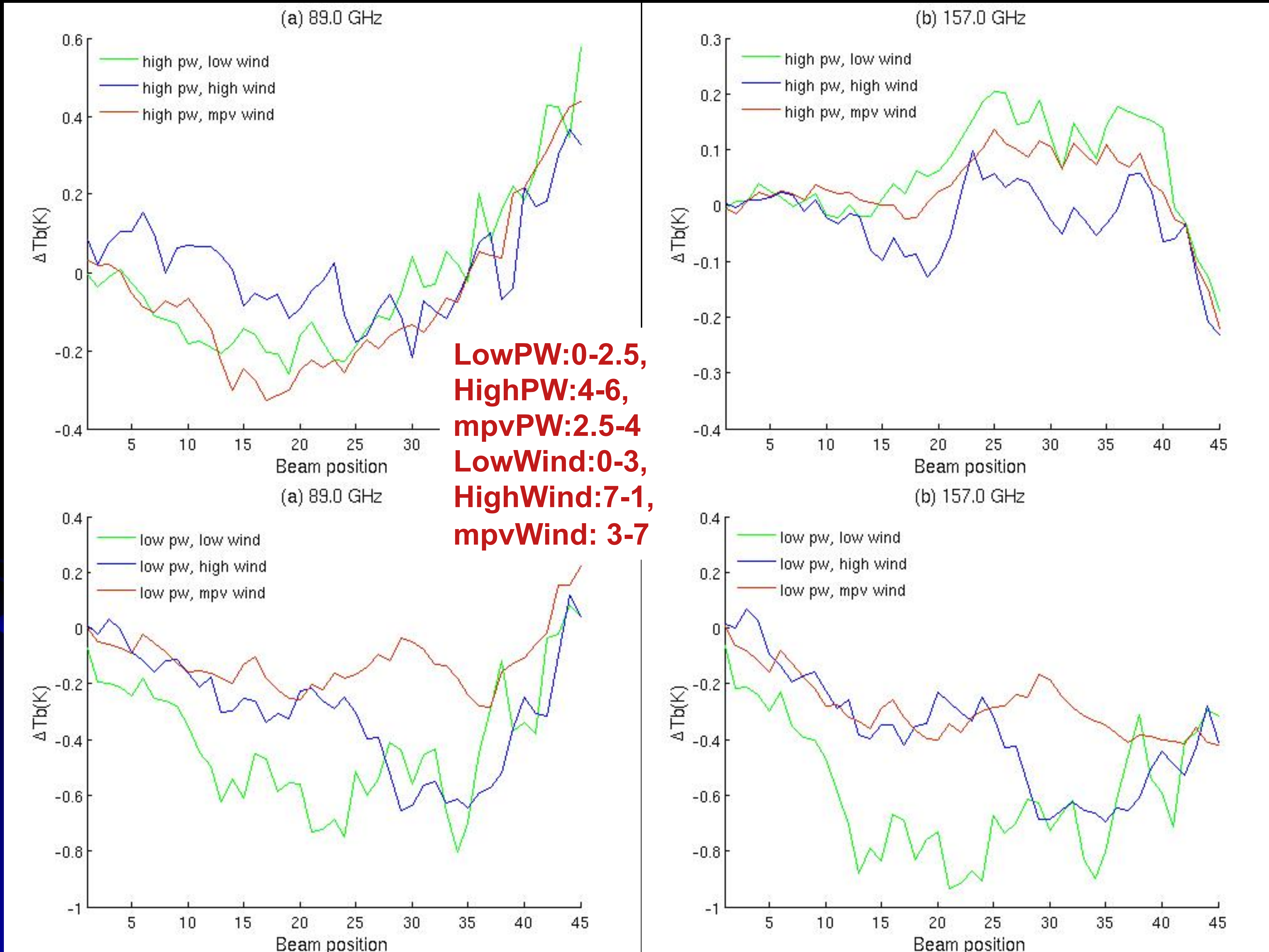


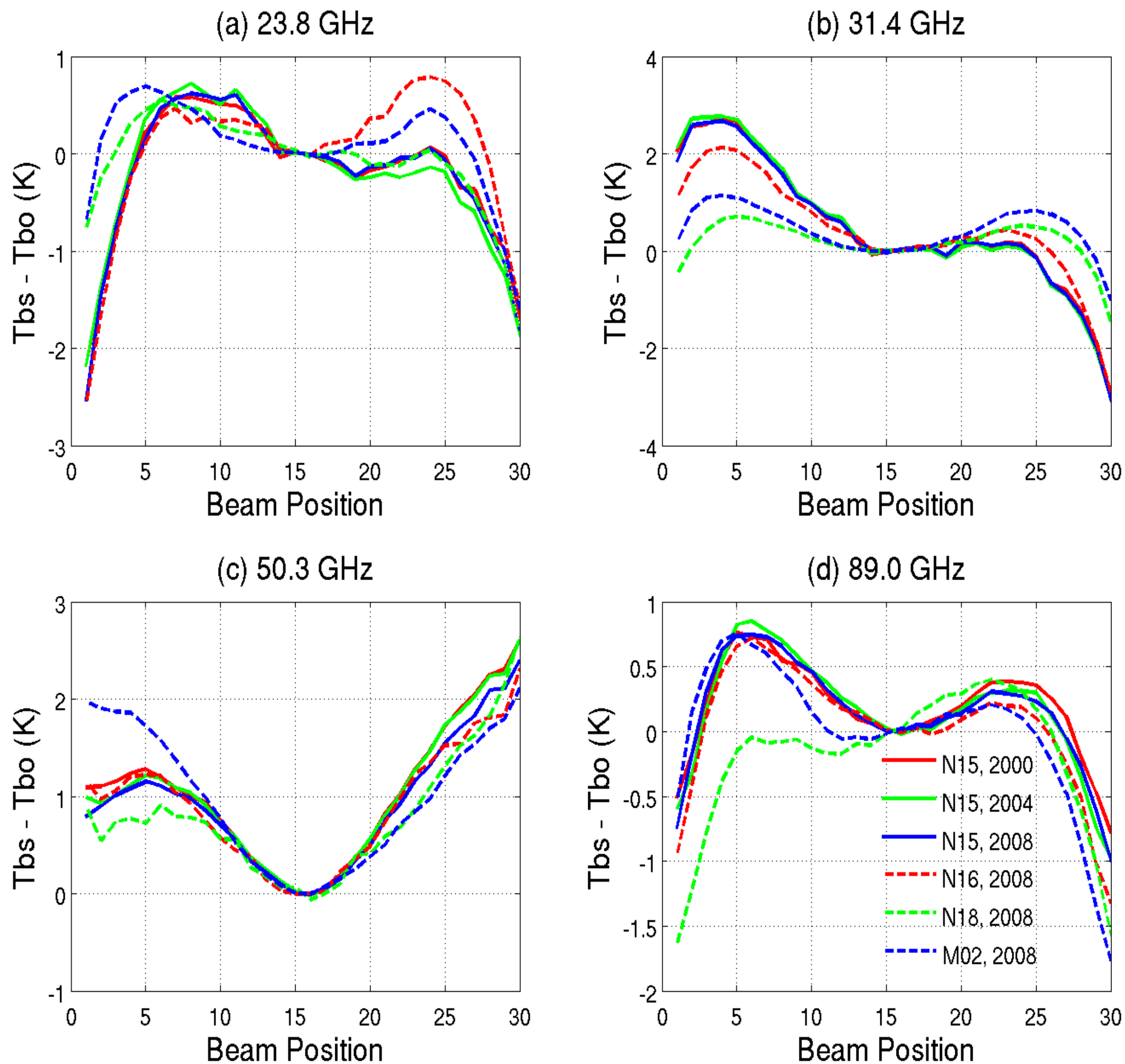


Scan Asymmetry

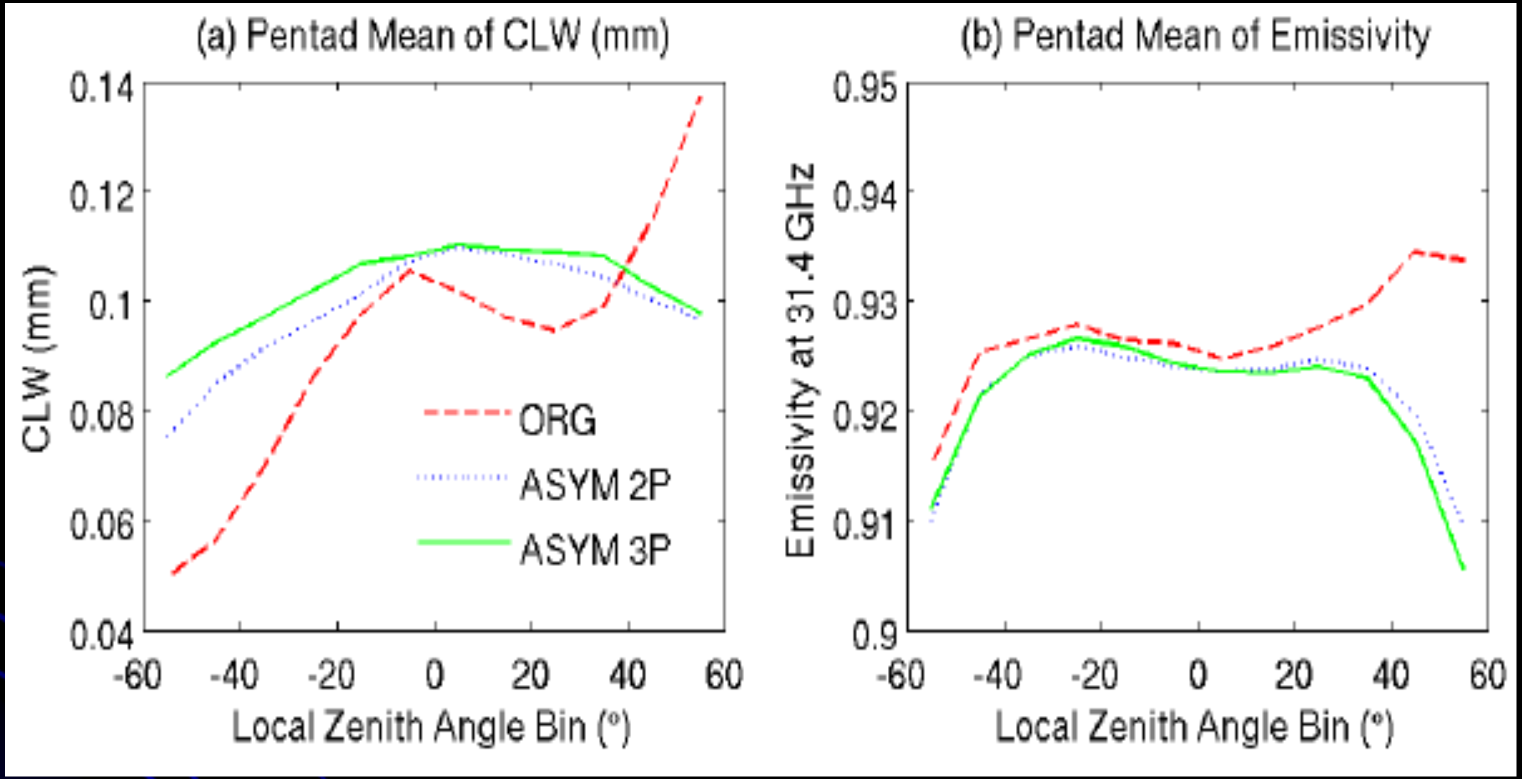
Scan bias characterization method




(a) 89.0 GHz
high pw, low wind
high pw, high wind
high pw, mpv wind
ΔTb(K)
Beam position
(b) 157.0 GHz
high pw, low wind
high pw, high wind
high pw, mpv wind
ΔTb(K)
Beam position
(a) 89.0 GHz
low pw, low wind
low pw, high wind
low pw, mpv wind
ΔTb(K)
Beam position
(b) 157.0 GHz
low pw, low wind
low pw, high wind
low pw, mpv wind
ΔTb(K)
Beam position
LowPW:0-2.5,
HighPW:4-6,
mpvPW:2.5-4
LowWind:0-3,
HighWind:7-1,
mpvWind: 3-7


(a) 23.8 GHz
(b) 31.4 GHz
(c) 50.3 GHz
(d) 89.0 GHz
Tbs - Tbo (K)
Beam Position
N15, 2000
N15, 2004
N15, 2008
N16, 2008
N18, 2008
M02, 2008

CLW and Land Emissivity at 31.4 GHz: Before vs. After Correction



Questions?

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Reference:

Moradi, I, Meng, H., Ferraro, R, Bilanow, S., 2012. Correcting geolocation errors for microwave instruments aboard NOAA satellites. IEEE Trans. Geoscience and Remote Sensing (under review)