Update of Radiance DA in WRF-Var

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General features of Radiance DA in WRF-Var

- Adopt RTMs used in operation centers
  - RTTOV and **CRTM** (only clear-sky condition)
- NCEP radiance BUFR data interface
- Air-mass dependent **bias correction** algorithm
- Quality Control for some instruments
  - AMSU, **AIRS**
- Observation error tuning tool
- FGAT mode
- Parallel with **load balancing and thinning**
- Flexible design to facilitate adding new instruments

CRTM implementation

- CRTM: Community Radiative Transfer Model developed by JCSDA at NOAA
  - Contributions from research community
  - More structured design and user friendly interface
- Currently Beta Release
- Share the same user interface as RTTOV in WRF-Var

CRTM Sensors

Microwave Sensors

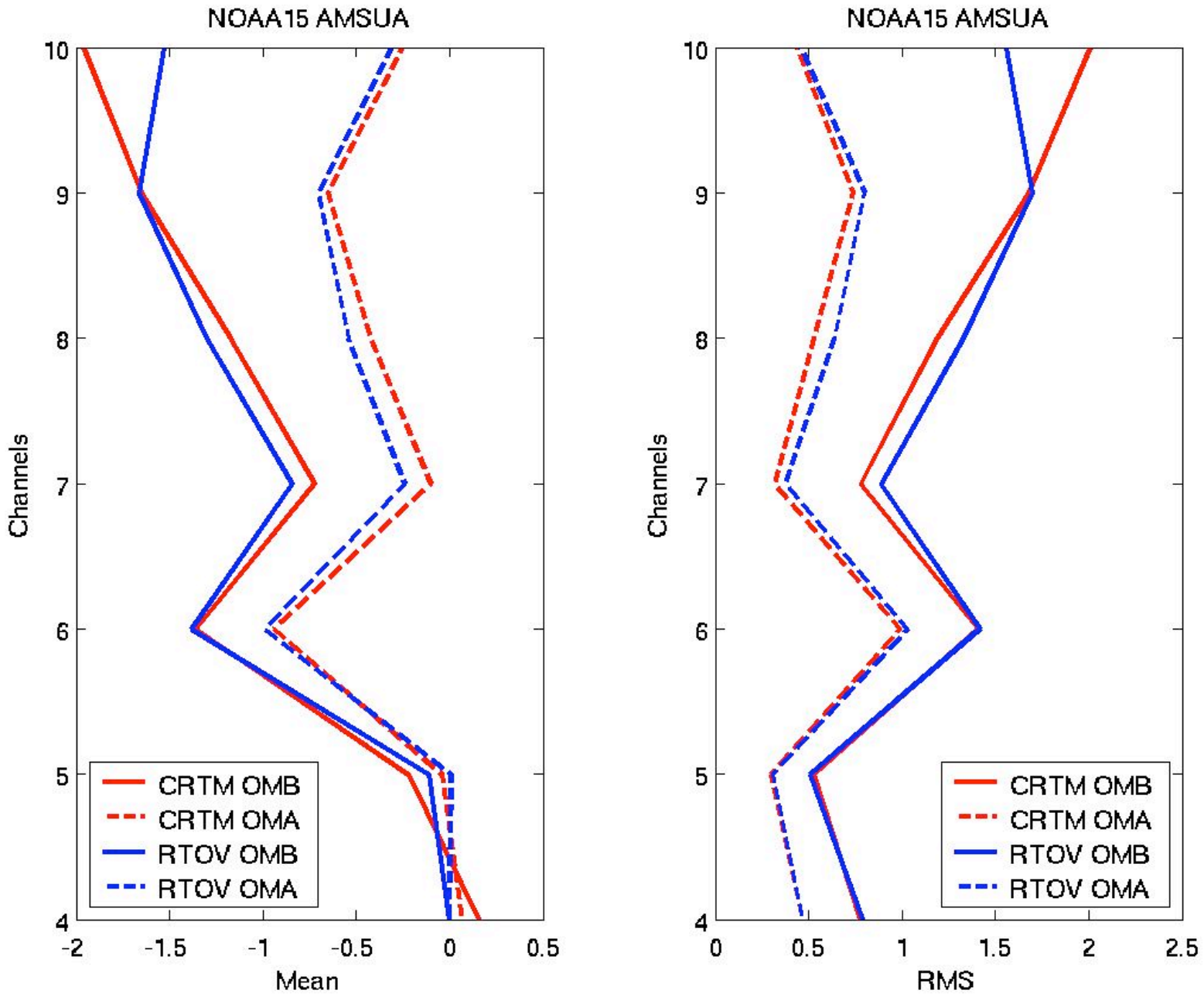
Sensor name	Satellite name	Sensor descriptor	# channels
AMSR-E	AQUA	amsre_aqua	12
AMSU-A	AQUA	amsua_aqua	15
AMSU-A	NOAA-15	amsua_n15	15
AMSU-A	NOAA-16	amsua_n16	15
AMSU-A	NOAA-17	amsua_n17	15
AMSU-A	NOAA-18	amsua_n18	15
AMSU-B	NOAA-15	amsub_n15	5
AMSU-B	NOAA-16	amsub_n16	5
AMSU-B	NOAA-17	amsub_n17	5
ATMS	NPOESS-C1	atms_c1	22
HSB	AQUA	hsb_aqua	4
MHS	NOAA-18	mhs_n18	5
MSU	TIROS-N	msu_n05	4
MSU	NOAA-06	msu_n06	4
MSU	NOAA-07	msu_n07	4
MSU	NOAA-08	msu_n08	4
MSU	NOAA-09	msu_n09	4
MSU	NOAA-10	msu_n10	4
MSU	NOAA-11	msu_n11	4
MSU	NOAA-12	msu_n12	4
MSU	NOAA-14	msu_n14	4
SSM/I	DMSP-13	ssmi_f13	7
SSM/I	DMSP-14	ssmi_f14	7
SSM/I	DMSP-15	ssmi_f15	7
SSMIS	DMSP-16	ssmis_f16	24
SSM/T-1	DMSP-13	ssmt1_f13	7
SSM/T-1	DMSP-15	ssmt1_f15	7
SSM/T-2	DMSP-14	ssmt2_f14	5
SSM/T-2	DMSP-15	ssmt2_f15	5
WindSat	Coriolis	windsat_coriolis	16

Infrared sensors

Sensor name	Satellite name	Sensor descriptor	# of channels
AIRS	AQUA	airs_aqua	2378
AIRS	AQUA	airsSUBSET_aqua	281
AVHRR/2	TIROS-N	avhrr2_n05	2
AVHRR/2	NOAA-06	avhrr2_n06	2
AVHRR/2	NOAA-07	avhrr2_n07	3
AVHRR/2	NOAA-08	avhrr2_n08	2
AVHRR/2	NOAA-09	avhrr2_n09	3
AVHRR/2	NOAA-10	avhrr2_n10	2
AVHRR/2	NOAA-11	avhrr2_n11	3
AVHRR/2	NOAA-12	avhrr2_n12	3
AVHRR/2	NOAA-14	avhrr2_n14	3
AVHRR/3	NOAA-15	avhrr3_n15	3
AVHRR/3	NOAA-16	avhrr3_n16	3
AVHRR/3	NOAA-17	avhrr3_n17	3
AVHRR/3	NOAA-18	avhrr3_n18	3
HIRS/2	TIROS-N	hirs2_n05	19
HIRS/2	NOAA-06	hirs2_n06	19
HIRS/2	NOAA-07	hirs2_n07	19
HIRS/2	NOAA-08	hirs2_n08	19
HIRS/2	NOAA-09	hirs2_n09	19
HIRS/2	NOAA-10	hirs2_n10	19
HIRS/2	NOAA-11	hirs2_n11	19
HIRS/2	NOAA-12	hirs2_n12	19
HIRS/2	NOAA-14	hirs2_n14	19
HIRS/3	NOAA-15	hirs3_n15	19
HIRS/3	NOAA-16	hirs3_n16	19
HIRS/3	NOAA-17	hirs3_n17	19
HIRS/3	NOAA-18	hirs3_n18	19
IMAGER	GOES-08	imgr_g08	4
IMAGER	GOES-09	imgr_g09	4
IMAGER	GOES-10	imgr_g10	4
IMAGER	GOES-11	imgr_g11	4
IMAGER	GOES-12	imgr_g12	4
MODIS	AQUA	modis_aqua	16
MODIS	TERRA	modis_terra	16
SOUNDER	GOES-08	sndr_g08	18
SOUNDER	GOES-09	sndr_g09	18
SOUNDER	GOES-10	sndr_g10	18
SOUNDER	GOES-11	sndr_g11	18
SOUNDER	GOES-12	sndr_g12	18

Mesos

CRTM vs. RTTOV



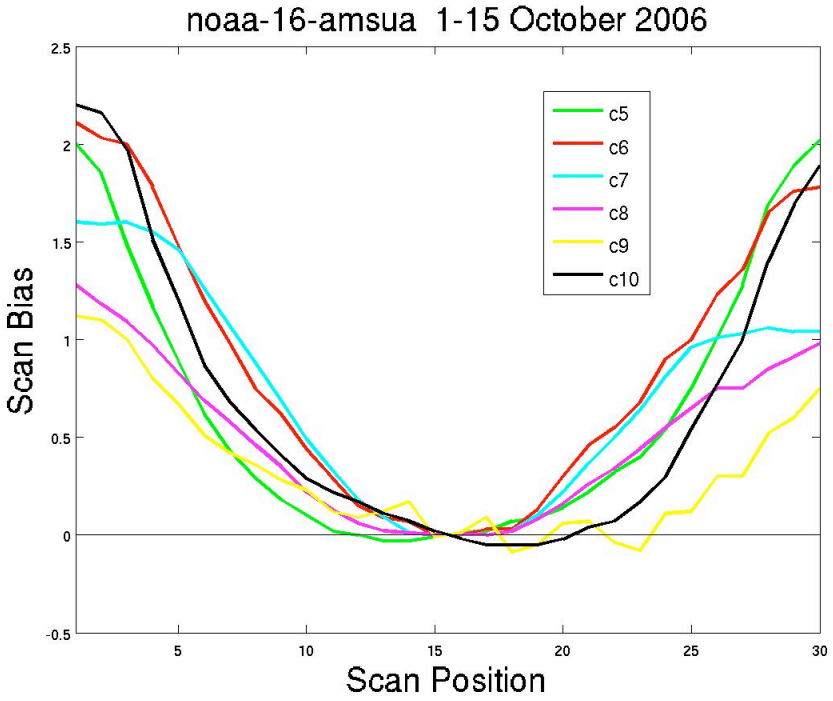
Air-Mass dependent Bias Correction

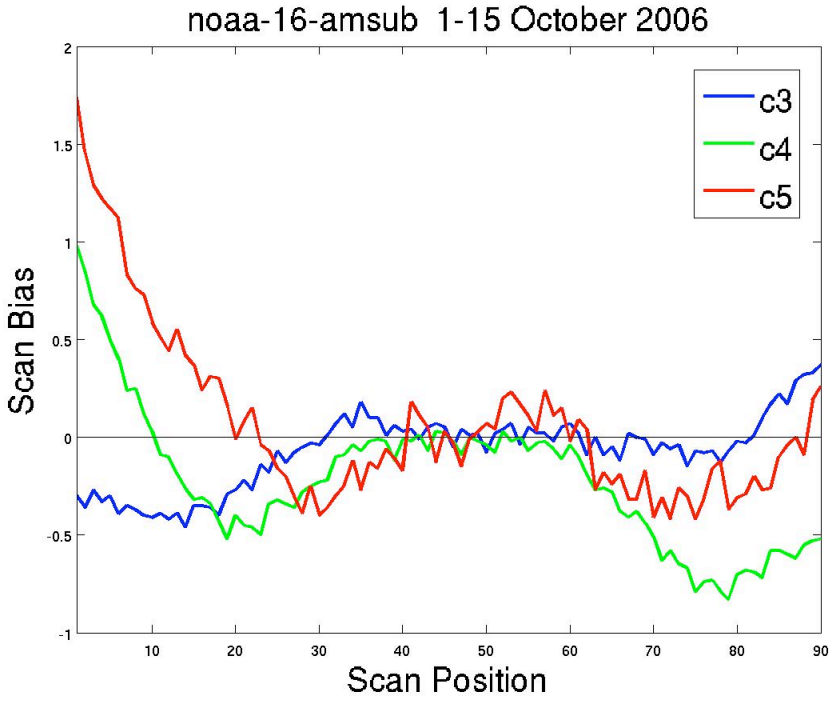
- Harris and Kelly (2001) bias correlation scheme (originally used by ECMWF)
  - Separate total bias into scan bias and air-mass dependent bias
  - Air-mass bias is predicted by some 'predictors'
    - 1000-300mb thickness
    - 200-50mb thickness
    - surface skin temperature
    - Total column precipitable water

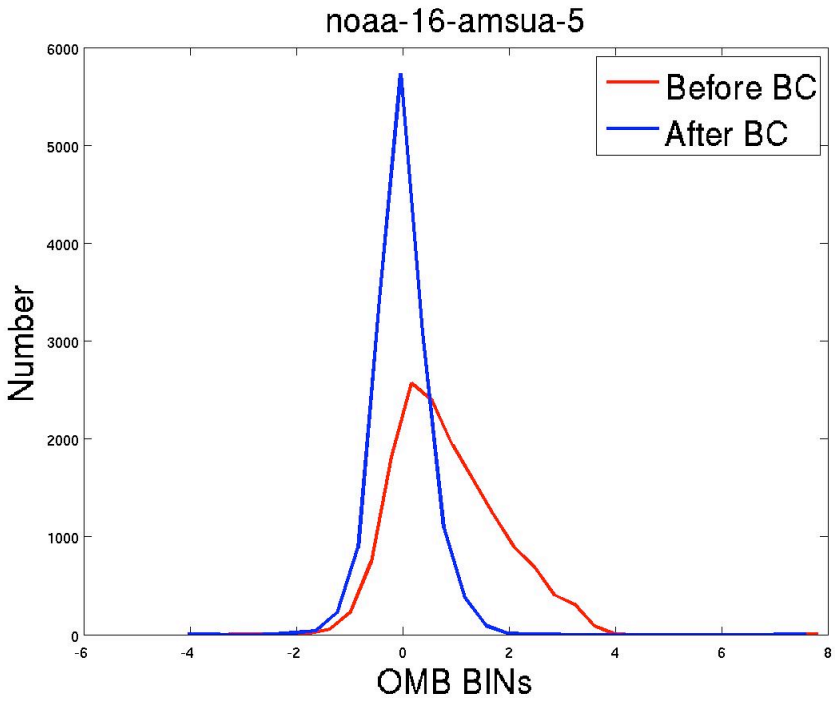
Scan Bias

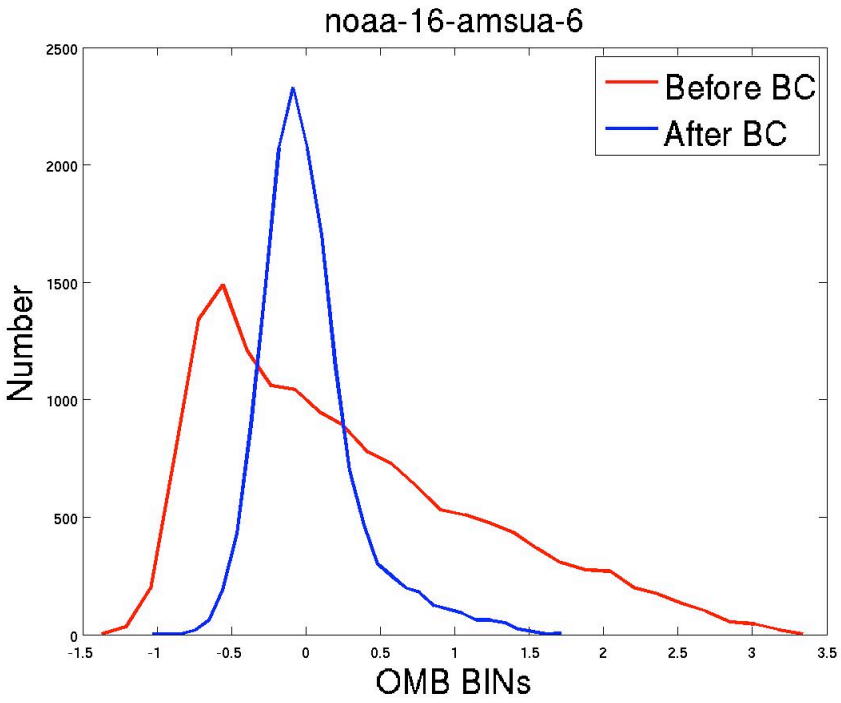
- Scan Bias = d(limb) - d(nadir)
  - d(.) is departure (omb or oma)
  - This is relative bias between limb and nadir

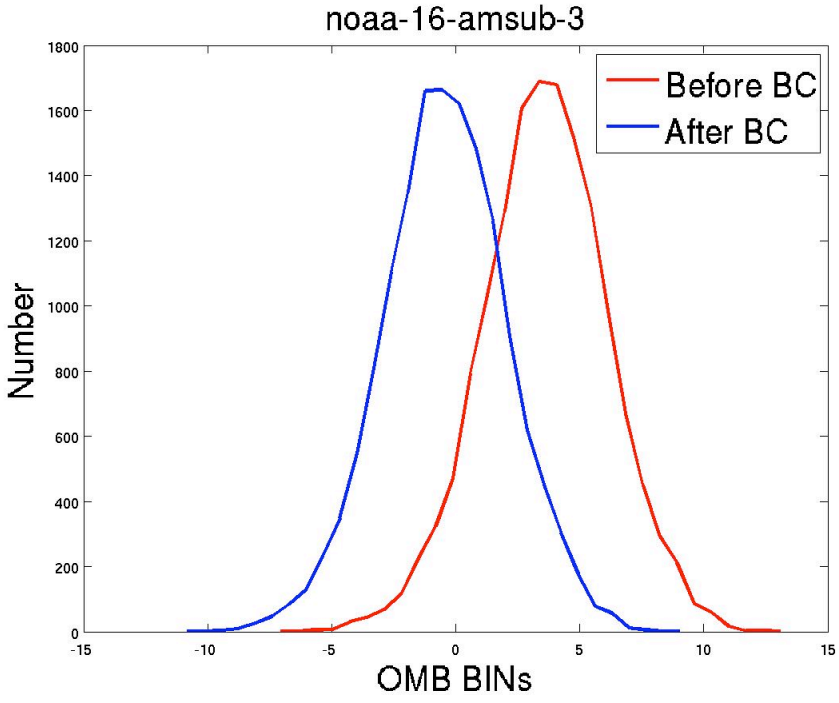
Scan bias statistics for SWA domain with 15 days data

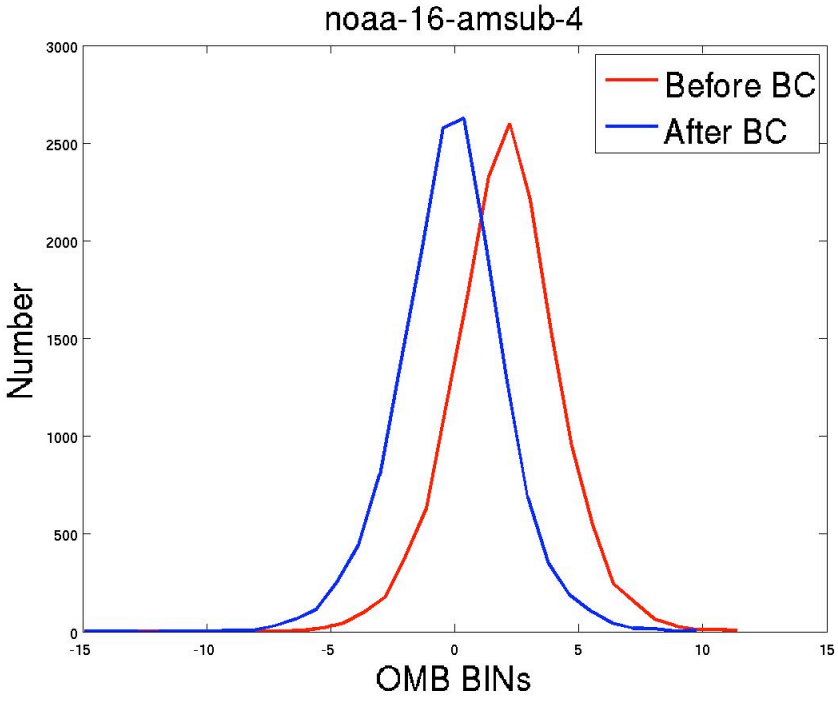




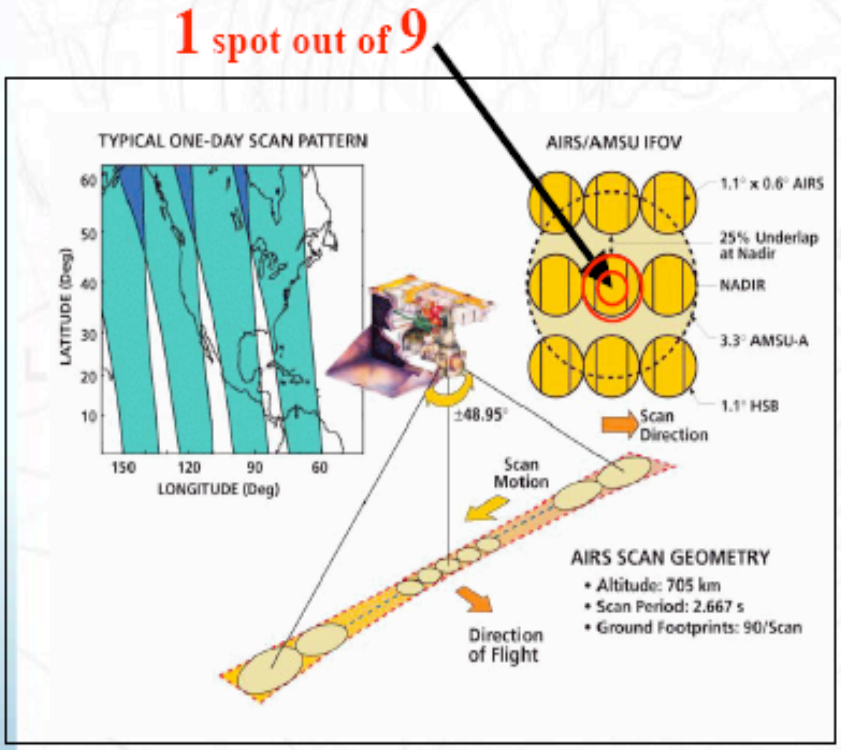

noaa-16-amsua-5
Before BC
After BC
Number
OMB BINs
0
1000
2000
3000
4000
5000
6000
-6
-4
-2
0
2
4
6
8

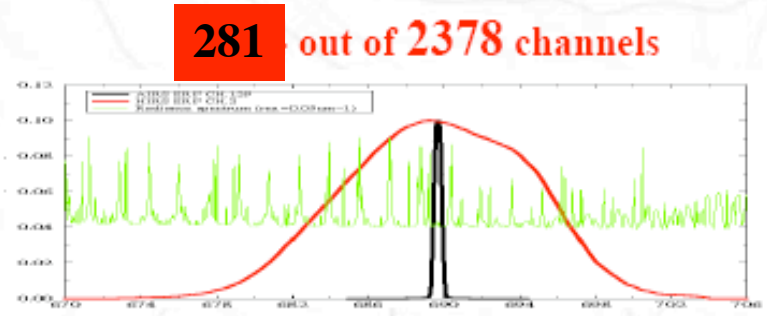

noaa-16-amsua-6
Before BC
After BC
Number
OMB BINs
0
500
1000
1500
2000
2500
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5


noaa-16-amsub-3
Before BC
After BC
Number
OMB BINs
0
200
400
600
800
1000
1200
1400
1600
1800
-15
-10
-5
0
5
10
15


noaa-16-amsub-4
Before BC
After BC
Number
OMB BINs
0
500
1000
1500
2000
2500
3000
-15
-10
-5
0
5
10
15

AIRS Data (NCEP subset)



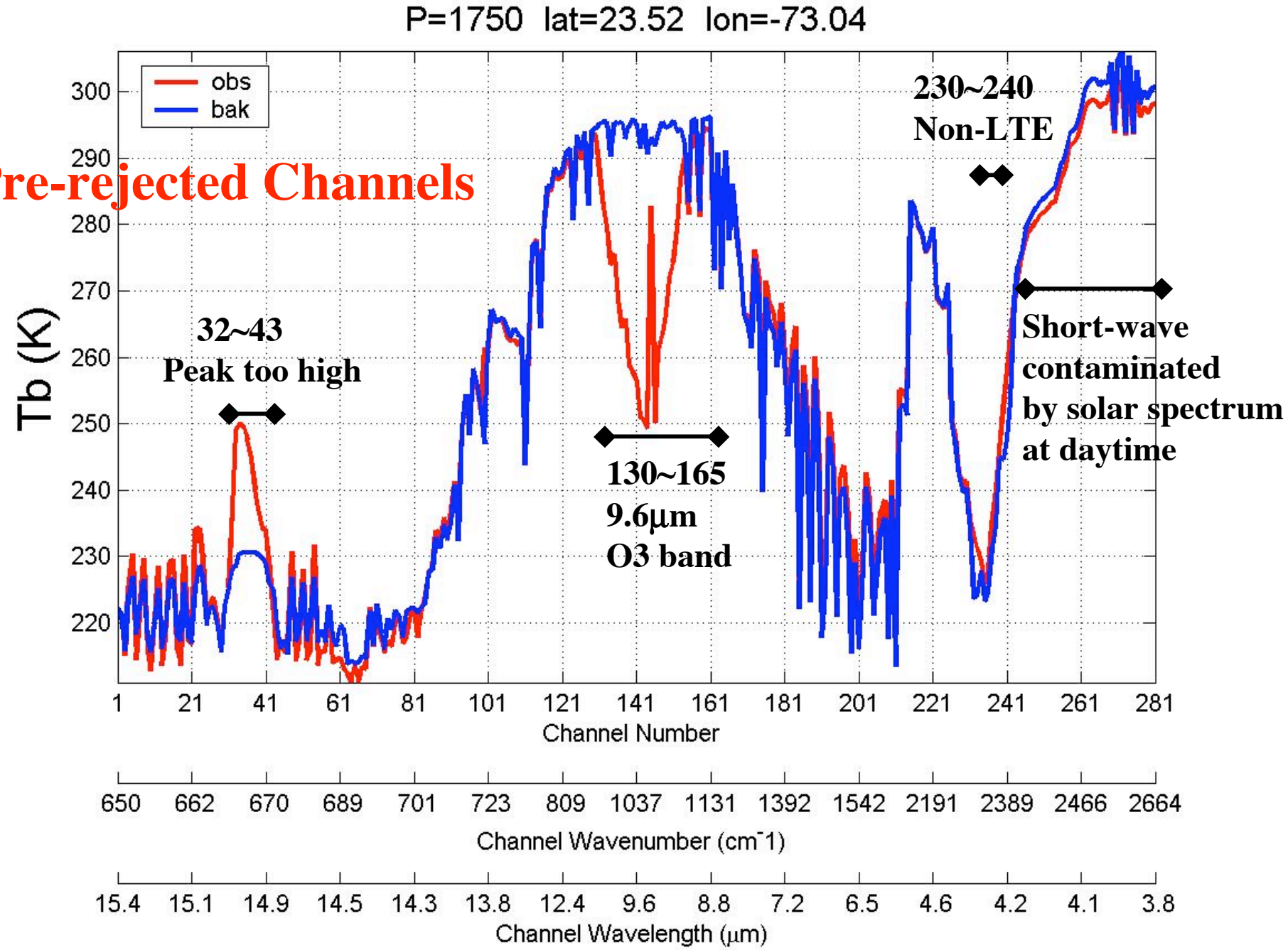


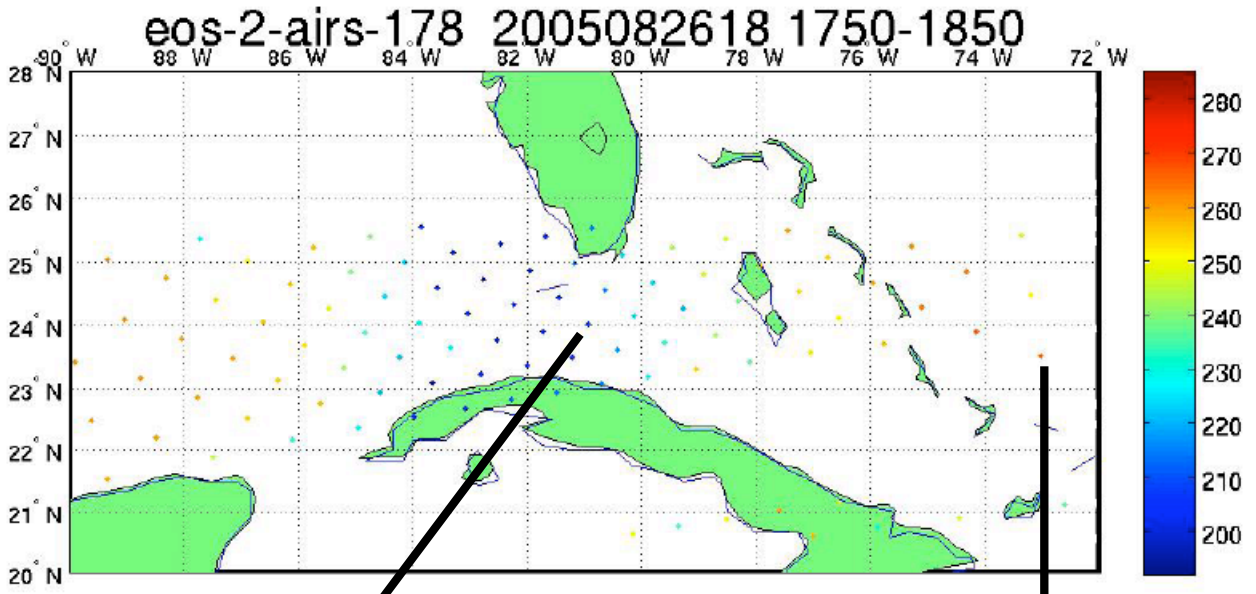
Specifications

Infrared Spectral Coverage	3.74 - 4.61 μm 6.20 - 8.22 μm 8.80 - 15.4 μm
Spectral Response	
Spectral Resolution	λ/Δλ>1200 nominal
Spectral Sampling	Δλ/2
Integrated Response (95%)	±1 Δλ
Wavelength Stability	0.05 Δλ/24 hours
Wavelength Knowledge	0.01 Δλ
Spatial Coverage	
Scan Angle	±49.5° around nadir
IFOV	1.1°
Measurement Simultaneity	>99%
Sensitivity (NEDT)	0.14 K at 4.2 μm 0.20 K from 3.7 - 13.6 μm 0.35 K from 13.6 - 15.4 μm
Radiometric Calibration	± 3% absolute error
Power / Mass	256 W / 166 kg
Lifetime	5 years

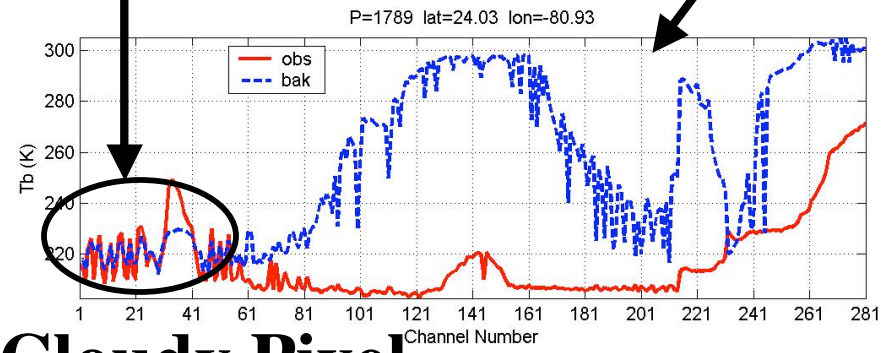
Visible Spectral Coverage	0.41 - 0.44 μm 0.58 - 0.68 μm 0.71 - 0.92 μm 0.49 - 0.94 μm
Spatial Coverage	
Scan Angle	±49.5° around nadir
IFOV	0.185°
SNR @ Albedo = 0.4	>100
Polarization	<5%

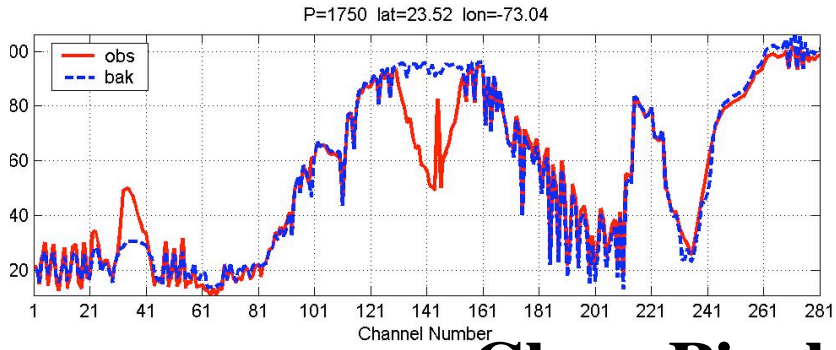
Pre-rejected Channels



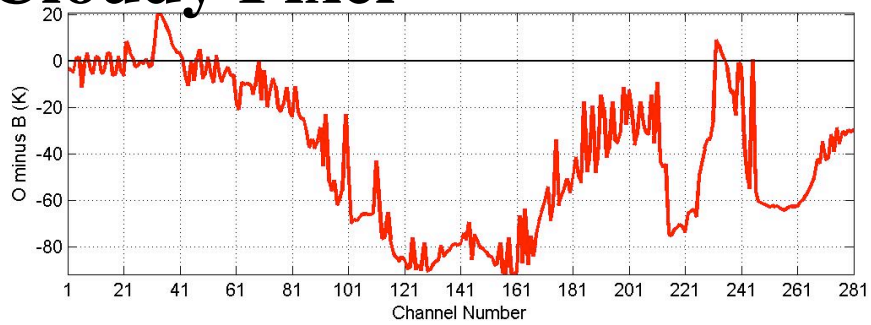


Can be used
Above cloud

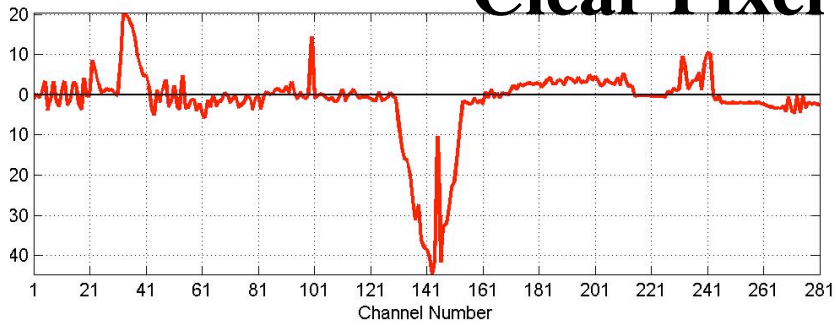


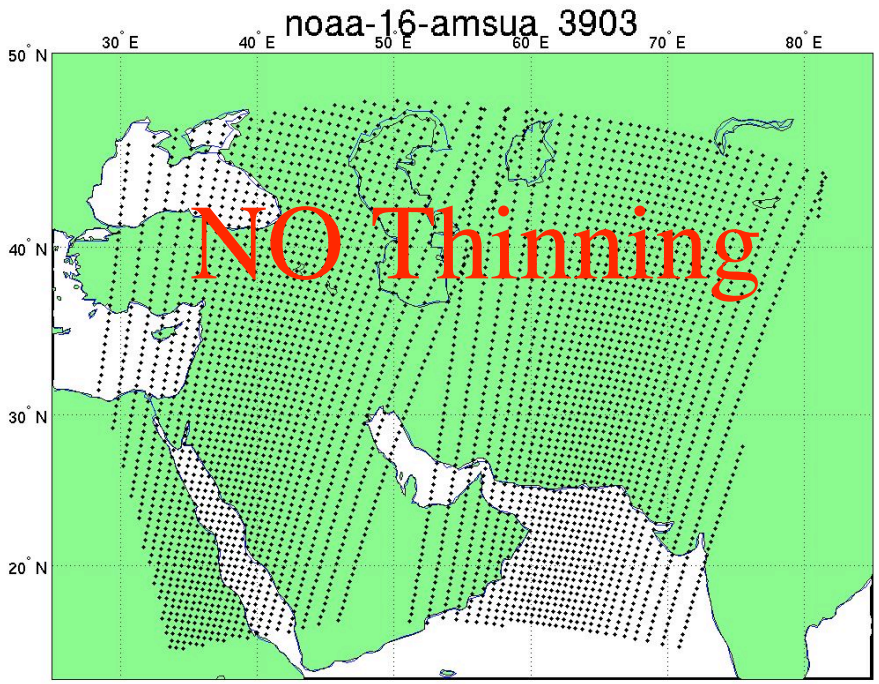


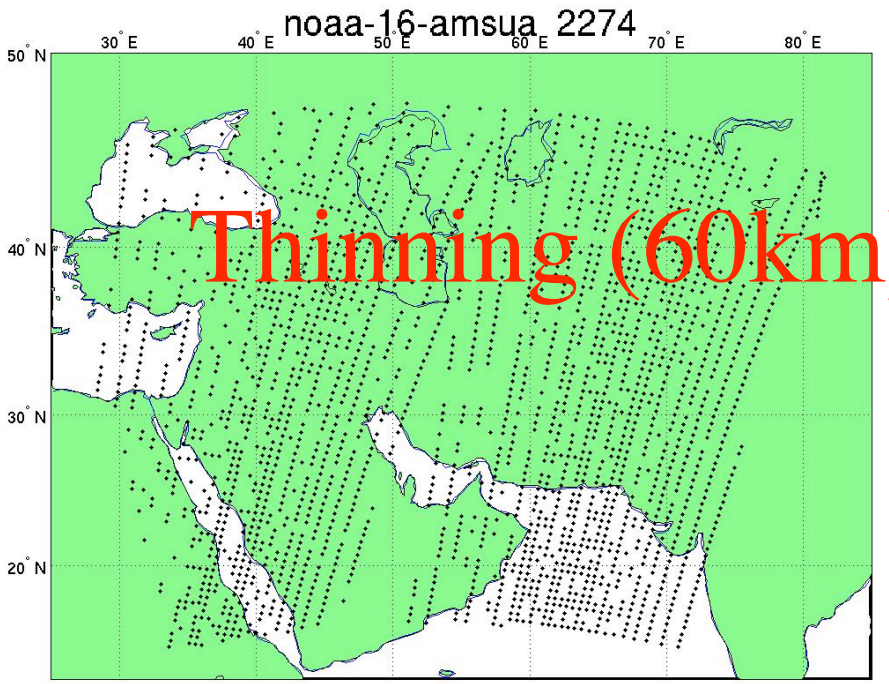
Cloudy Pixel

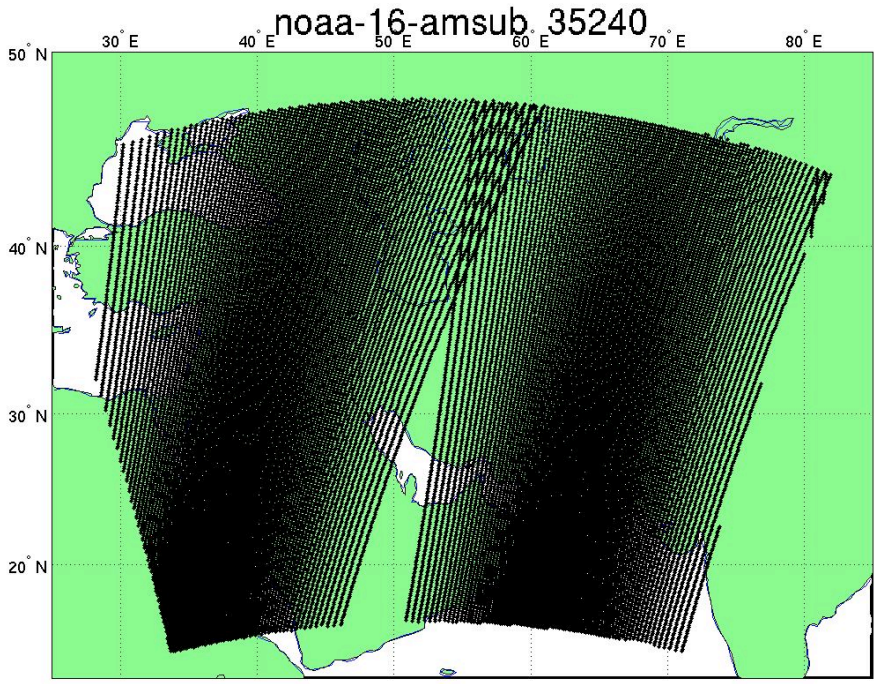


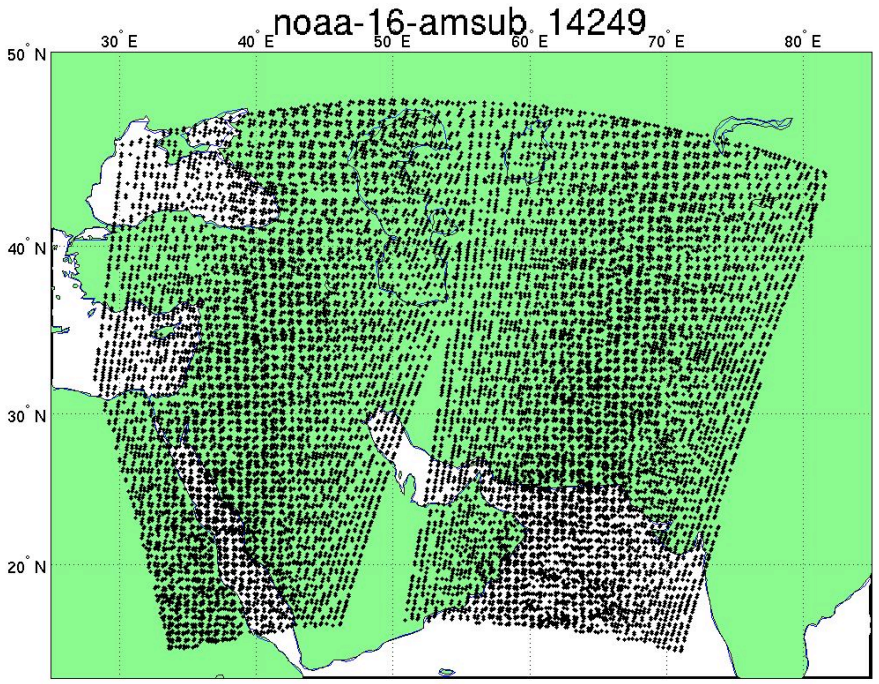
Clear Pixel




noaa-16-amsua_3903
NO Thinning
30° E
40° E
50° E
60° E
70° E
80° E
50° N
40° N
30° N
20° N


noaa-16-amsua_2274
Thinning (60km)
30° E
40° E
50° E
60° E
70° E
80° E
50° N
40° N
30° N
20° N

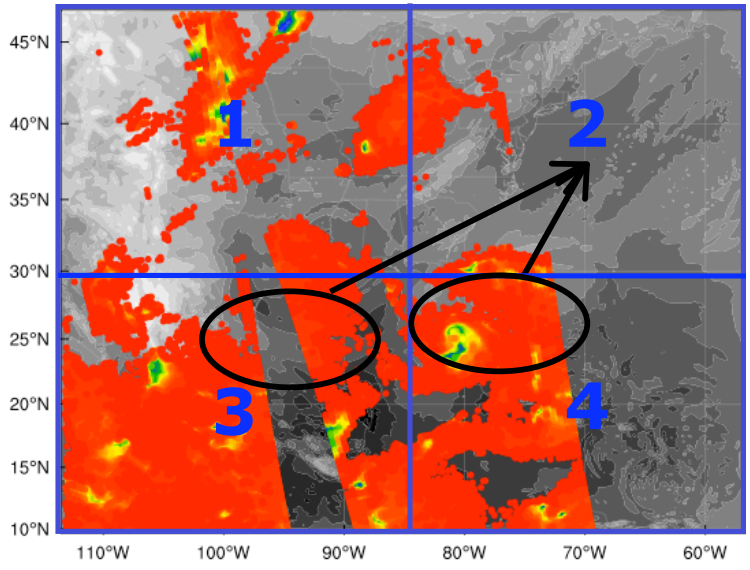

noaa-16-amsub_35240
30° E
40° E
50° E
60° E
70° E
80° E
50° N
40° N
30° N
20° N


noaa-16-amsub_14249
30° E
40° E
50° E
60° E
70° E
80° E
50° N
40° N
30° N
20° N

Load Balancing of Radiance Obs.

- Inhomogeneous observation distributions considered:

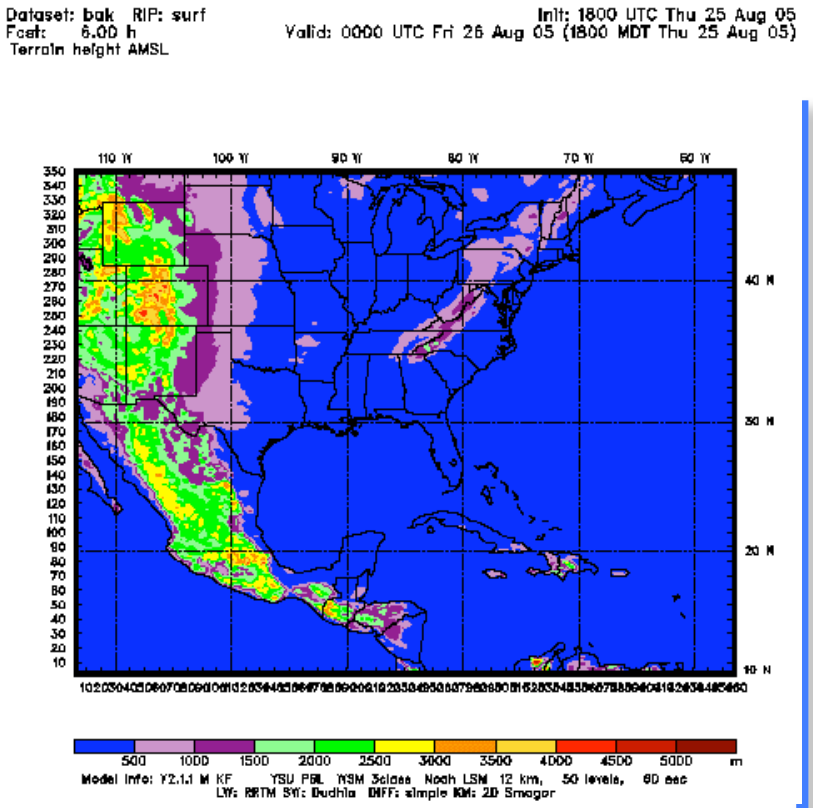
Regular Domain Decomposition, redistribute ob. space calculations



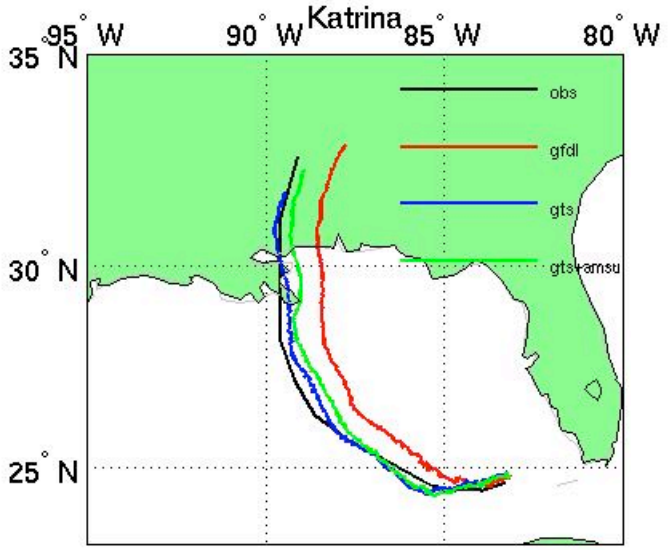
Currently implemented only for RTTOV option.

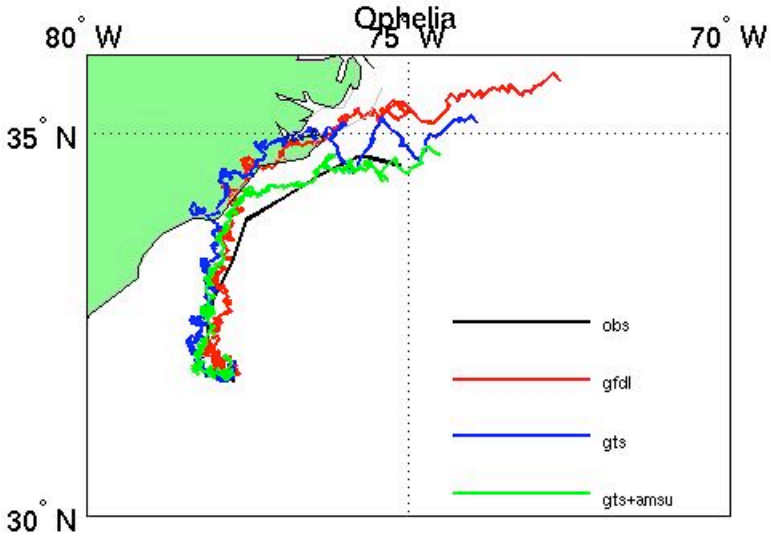
2005 Hurricane Experiments

- 4 cases (Initial time is at 00Z):
  - Katrina (0827), Ophelia (0913), Rita (0921), Wilma (1021)
- 72h forecasts (WRF-ARW 2.2)
  - Movable nests (12km/4km/1.33km), Setup by Wei Wang
- 3 experiments:
  - GFDL initialization with bogus (provided by Wei Wang)
  - GTS (only conventional data assimilation)
  - GTS+AMSU (conventional + amsu assimilation)

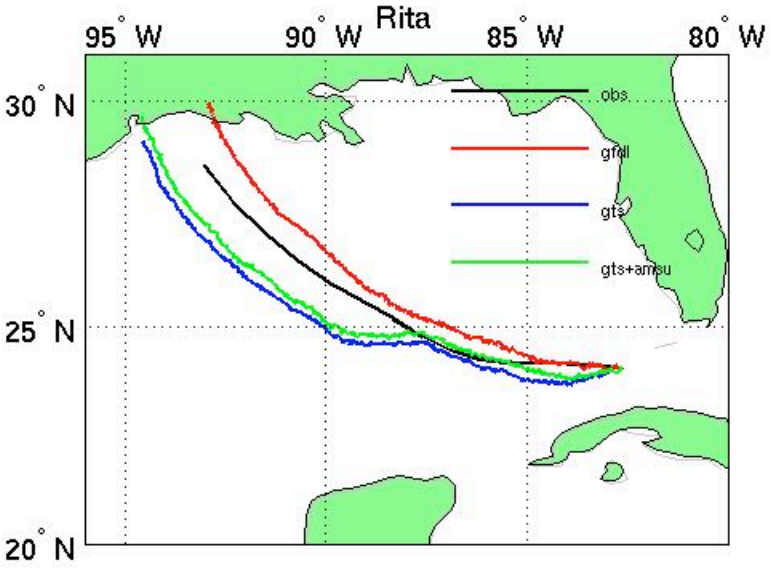


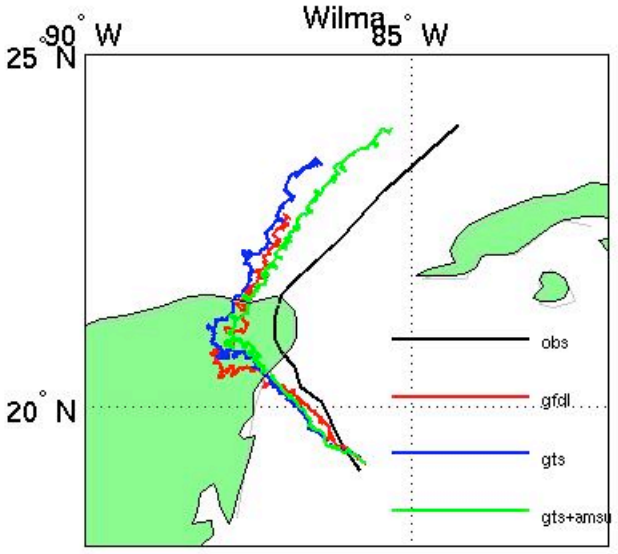
12km domain Terrain Height

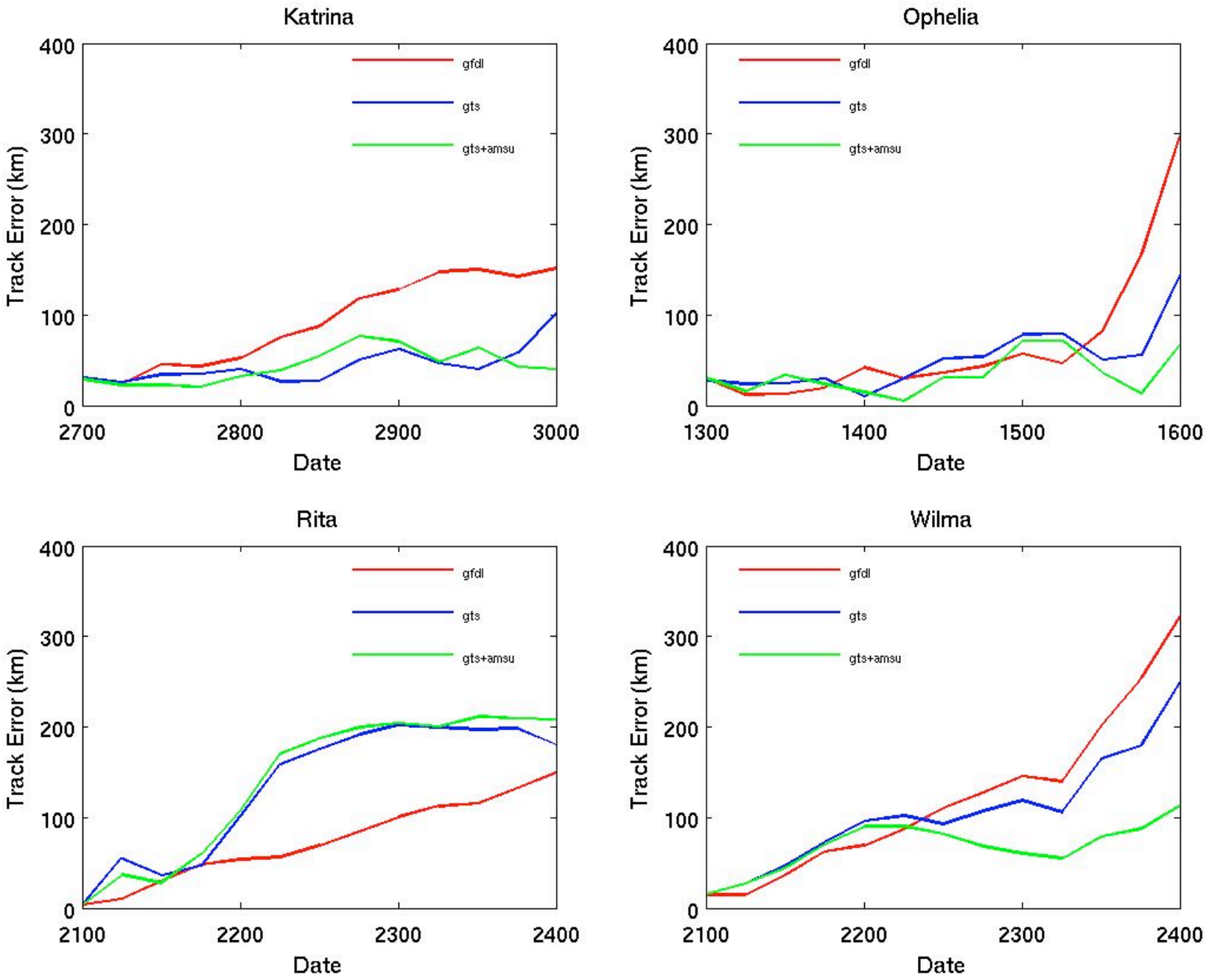

Katrina
95° W
90° W
85° W
80° W
35° N
30° N
25° N
obs
gfdl
gts
gts+amsu

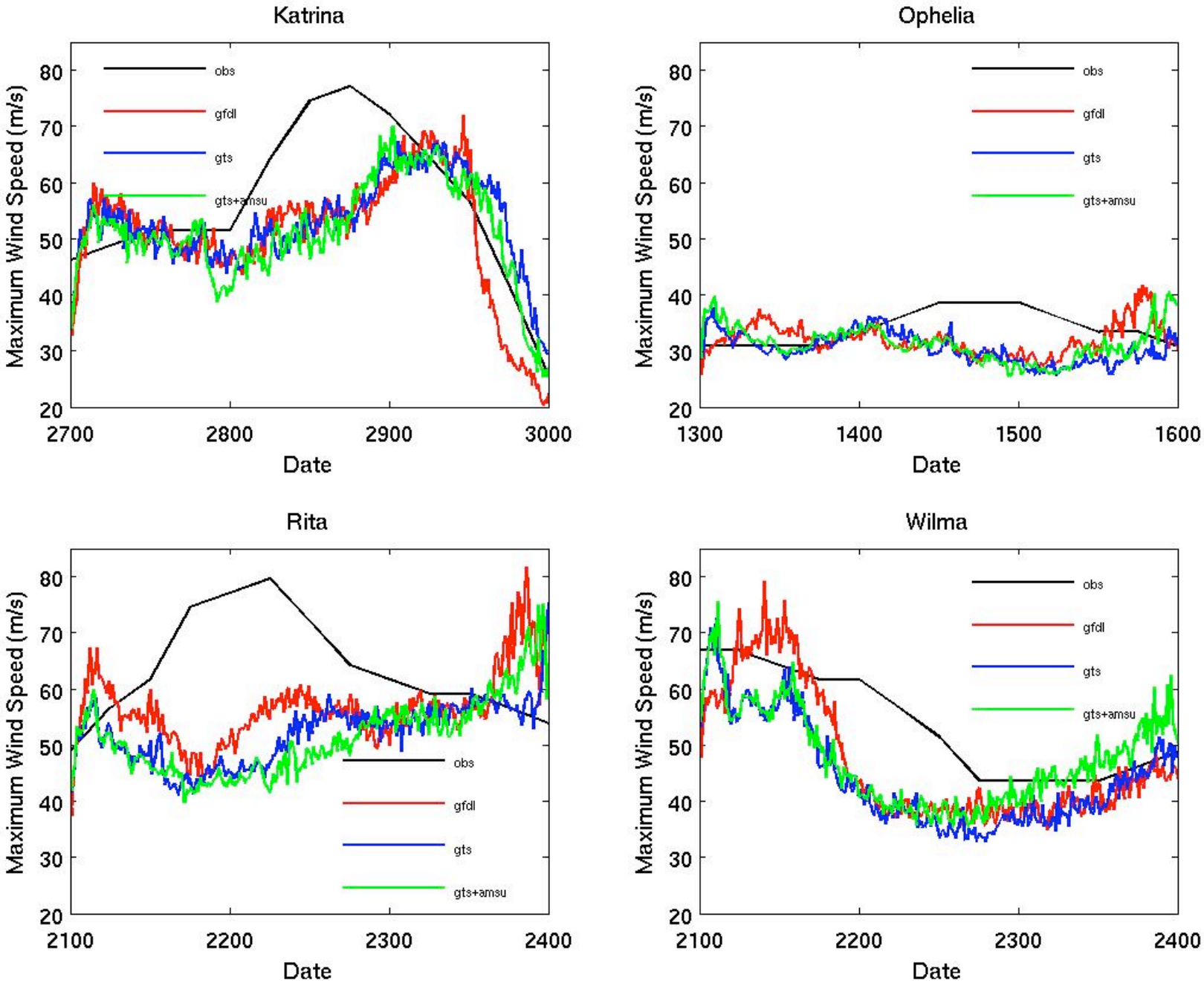

Ophelia
80° W
75° W
70° W
35° N
30° N
obs
gfdl
gts
gts+amsu

Track


Rita
95° W
90° W
85° W
80° W
30° N
25° N
20° N
obs
gfdl
gts
gts+amsu


Wilma
90° W
85° W
25° N
20° N
obs
gfdl
gts
gts+amsu


Katrina
Track Error (km)
Date
gfdl
gts
gts+amsu
0
100
200
300
400
2700
2800
2900
3000
Ophelia
Track Error (km)
Date
gfdl
gts
gts+amsu
0
100
200
300
400
1300
1400
1500
1600
Rita
Track Error (km)
Date
gfdl
gts
gts+amsu
0
100
200
300
400
2100
2200
2300
2400
Wilma
Track Error (km)
Date
gfdl
gts
gts+amsu
0
100
200
300
400
2100
2200
2300
2400


Katrina
Ophelia
Rita
Wilma
Maximum Wind Speed (m/s)
Date
obs
gfdl
gts
gts+amsu
20
30
40
50
60
70
80
2700
2800
2900
3000
1300
1400
1500
1600
2100
2200
2300
2400

Future Plans

- Radiance assimilation capability is planned to be released with WRF/WRF-Var 3.0 in 2008
- Developing Monitoring Tools
  - Crucial to understand observation error characteristics and operational implementation
- Cloudy radiance assimilation
- More sensors
  - SSMIS, METOP, GEOS, future NPOESS etc.
- DATC tests and Applications
  - South East Asia, AMPS, Hurricane, India …