Environment Canada Environnement Canada

Canada

"Strato-2b": Upgrade to the global deterministic data assimilation systems (GDPS 2.2.0)

Seminar at CMC

October 15, 2010

Presented by Mark Buehner, Louis Garand and Bruce Brasnett

Contents

- Description of what is included in “Strato 2b” (additions to “Strato 2a”)
- Results from final cycles of 65 days, 130 forecasts, scores compared with operational configuration
  - Winter: 2008121500 → 2009021712
  - Summer: 2008061800 → 2008082112
- Next steps

Contributors to project:

- ARMA: Louis Garand, Sylvain Heilliette, Bin He, Stephen MacPherson, Jeff Blezius, Godelieve Deblonde
- CMDA: Alain Beaulne, Chantal Côté, Ervig Lapalme, Nicolas Wagneur, Bruce Brasnett, Réal Sarrazin, Iriola Mati, José Garcia
- CMDN: Anne-Marie Leduc

Strato 2b: additions to Strato 2a

- All additions and modifications first tested independently
- New observations - large increase in volume of assimilated obs:
  - IASI: 62 channels, sensitive to temperature below 150hPa
  - SSMIS: 7 SSMI-like channels sensitive to humidity and surface wind speed (over the ocean)
  - GEORAD: 5 geostationary satellites (previously only 2 GOES satellites), 1 water vapour channel assimilated using RTTOV
  - AIRS: assimilate upper level channels previously rejected within 30° of both poles
  - Reduced horizontal thinning for all satellite radiance observations (250km → 150km, except SSMI: 200km → 150km)
  - Humidity from aircraft

Strato 2b: additions to Strato 2a

Number of radiance observations assimilated February 1st, 2009 (4 analyses):

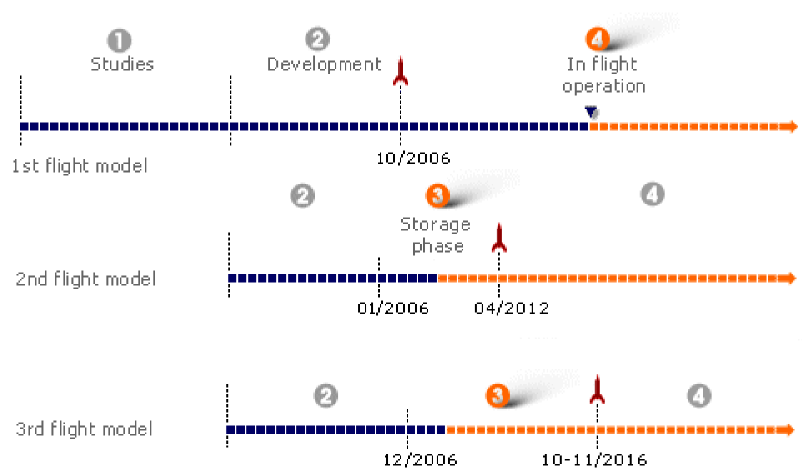
Instrument	Platform	Strato 2a	Strato 2b	% Change
AIRS	AQUA	392 554	659 751	+ 68%
IASI	Metop-2	0	500 783	New
AMSU-A	NOAA-15	121 875	338 194	+ 178%
	NOAA-18	170 773	472 474	+ 177%
	AQUA	119 805	331 557	+ 177%
AMSUB	NOAA-15	14 762	41 350	+ 180%
	NOAA-16	30 082	84 341	+ 180%
	NOAA-17	32 965	92 609	+ 181%
MHS	NOAA-18	34 671	96 025	+ 177%
SSMI	DMSP-13	37 965	60 761	+ 60%
SSMIS	DMSP-16	0	39 330	New
GOES Imager	GOES-11	11 813	34 967	+ 196%
	GOES-12	10 024	41 919	+ 318%
SEVERI	MSG-2	0	69 183	New
MVIRI	Meteosat-7	0	41 882	New
GMS MTSAT	MTSAT-1	0	20 612	New
All Radiances:		**977 289**	**2 925 788**	**+ 199%**

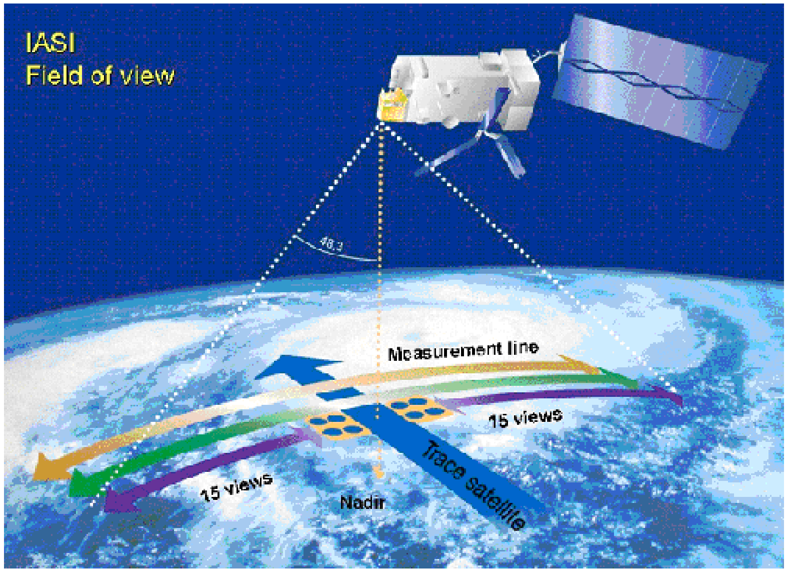
Strato 2b: additions to Strato 2a

- Improved treatment of satellite observations:
  - new unified obs error bias correction system for satellite radiances
  - FASTEM bug fix in RTTOV
  - RTTOV coefficients for AMSU-A with no zeeman effect
  - reduced time window for bias correction 15 days → 7 days
  - several minor improvements and bug fixes related to AIRS
- Other improvements
  - new sea-surface temperature analysis (B. Brasnett)
  - first MPI version of variational assimilation code (all steps related to observations are now parallelized)
  - new, parallelized post-processing of analysis increment (separate program: addanalinc)

The IASI Instrument (1/2)

- **I**nfrared **A**tmospheric **S**ounding **I**nterferometer
- Flying onboard the METOP-A European **operational** satellite



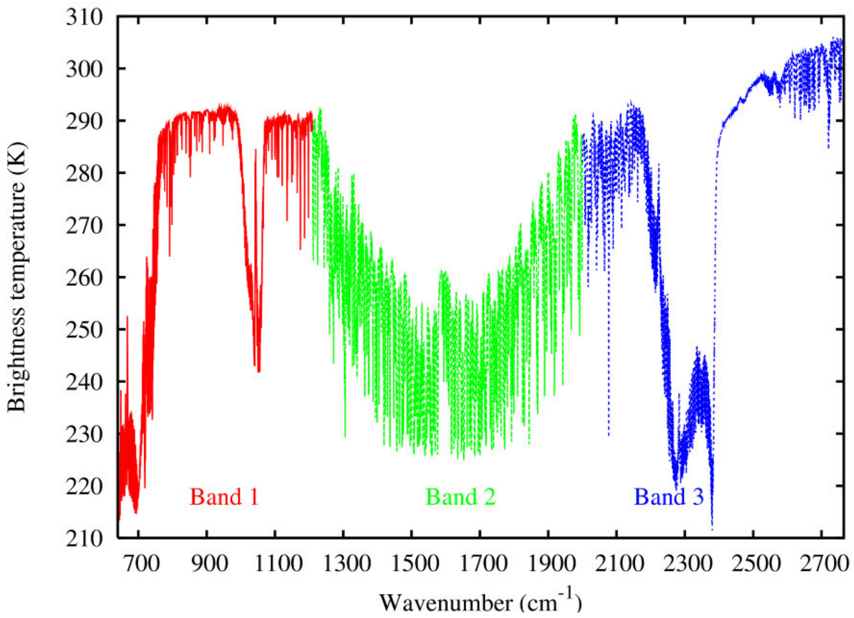


(Courtesy from CNES)

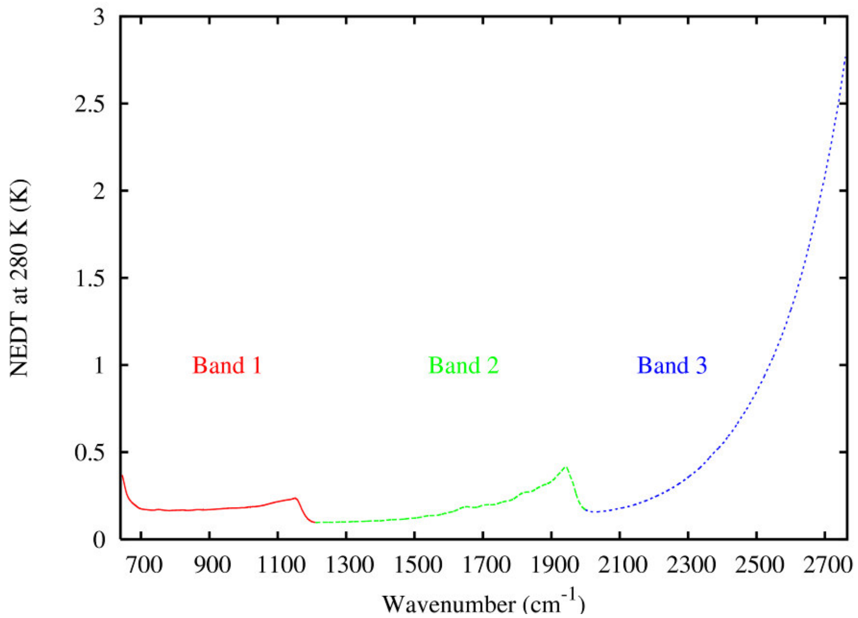
The IASI Instrument (2/2)

- Provides high resolution spectra (resolution of 0.5 cm^{-1}) of the infrared radiation emitted by earth/atmosphere between 645 cm^{-1} and 2760 cm^{-1} in 8461 spectral bands (channels)

Typical full resolution spectrum



Radiometric noise characteristics

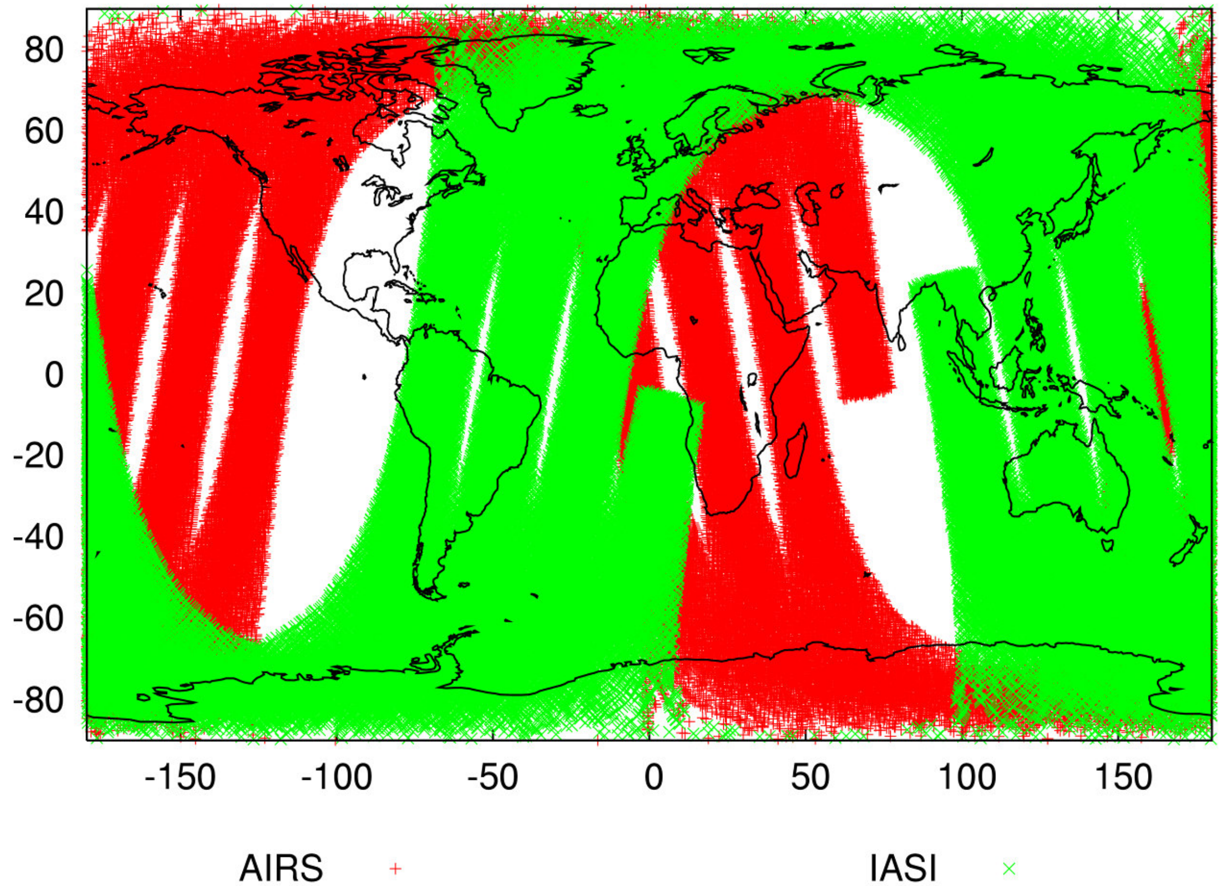


IASI versus AIRS

instrument	AIRS	IASI
# of channels	2378	8461
# of channels received at CMC	281 (324)	616 (314)
Spectral resolution	Resolving power λ/Δ λ =1300	0.5 cm^{-1} apodised
Spectral coverage	3 spectral bands: [650 cm^{-1};1137 cm^{-1}] [1217 cm^{-1};1614 cm^{-1}] [2181 cm^{-1};2665 cm^{-1}]	3 spectral bands: [645 cm^{-1};1210 cm^{-1}] [1210.25 cm^{-1};2000 cm^{-1}] [2000.25 cm^{-1};2760 cm^{-1}]
Technology	Grating Spectrometer	Michelson like interferometer
Platform	Research satellite AQUA	Operational satellite METOP-x
Orbit	sun-synchronous polar orbit, mean equator crossing time 09.30 am, descending node	sun-synchronous polar orbit, mean equator crossing time 1.30 pm, descending node

Spatial coverage (6-h, before thinning)

81,000 locations per 6-h, warmest among 9/4 FOV for AIRS/IASI



IASI quality control (QC) 1/3

1. Gross check: BT > 150 K, BT < 350 K
2. EUMETSAT flags GQisFlagQual and GQisQualIndexLoc
3. Cloudy or clear ? Based on window channel+ trial T profile

* Garand-Nadon 1998 algorithm

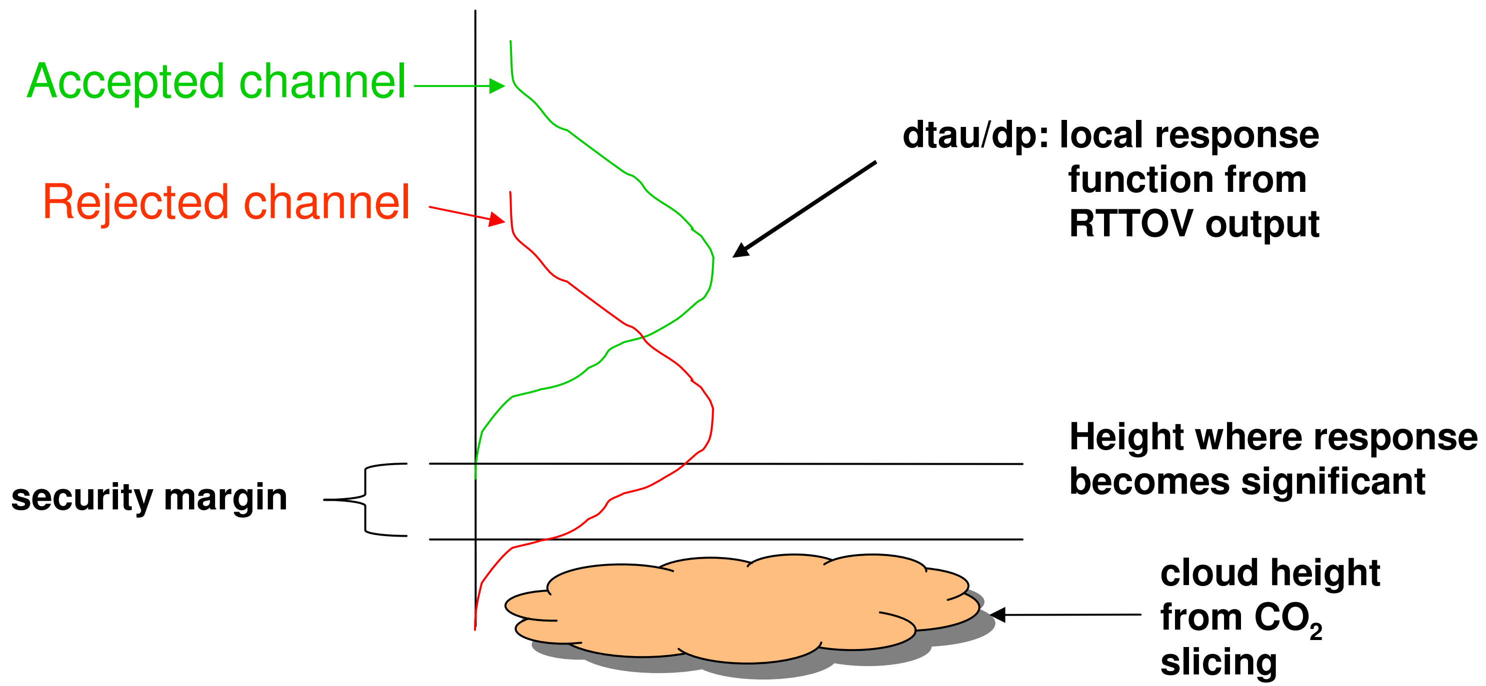
* Invert RTE for TS using BT(window) assuming trial T,q profile perfect

- if |TS(window) – TS(guess)| > 2K(ocean) or 4K(not ocean), cloudy

* Use of AVHRR sub pixel information

IASI quality control 2/3

- IASI assimilation setup inspired from AIRS assimilation setup (assimilated operationally at CMC since June 2008)
- Assimilation of cloud unaffected radiances:

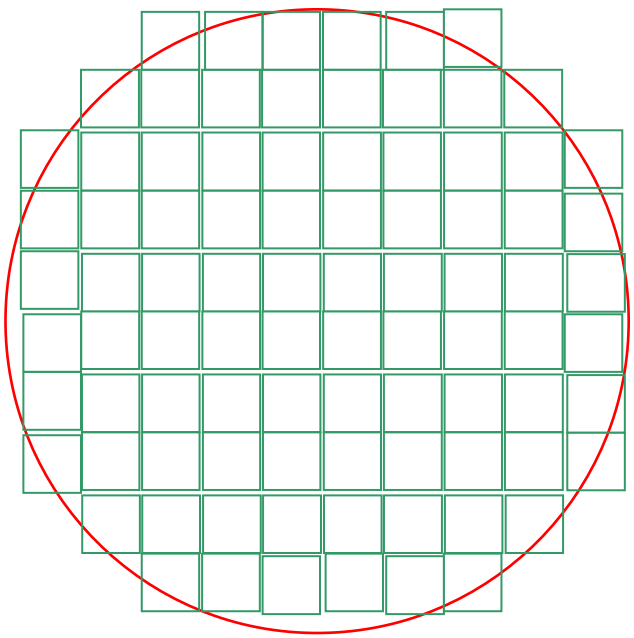


IASI quality control 3/3

- The main difference between AIRS and IASI assimilation setup is related to cloud detection
- For IASI use is made of the cluster radiance analysis which gives AVHRR sub-pixel information

AVHRR/3: 5 channels :
1, 2, 3a (day only) : visible and near IR
3b (night only), 4 and 5 thermal IR;

Red disk: IASI field of view approximately 11.7 km in diameter at nadir
Green squares: AVHRR field of views Approximately 1.08 km at nadir

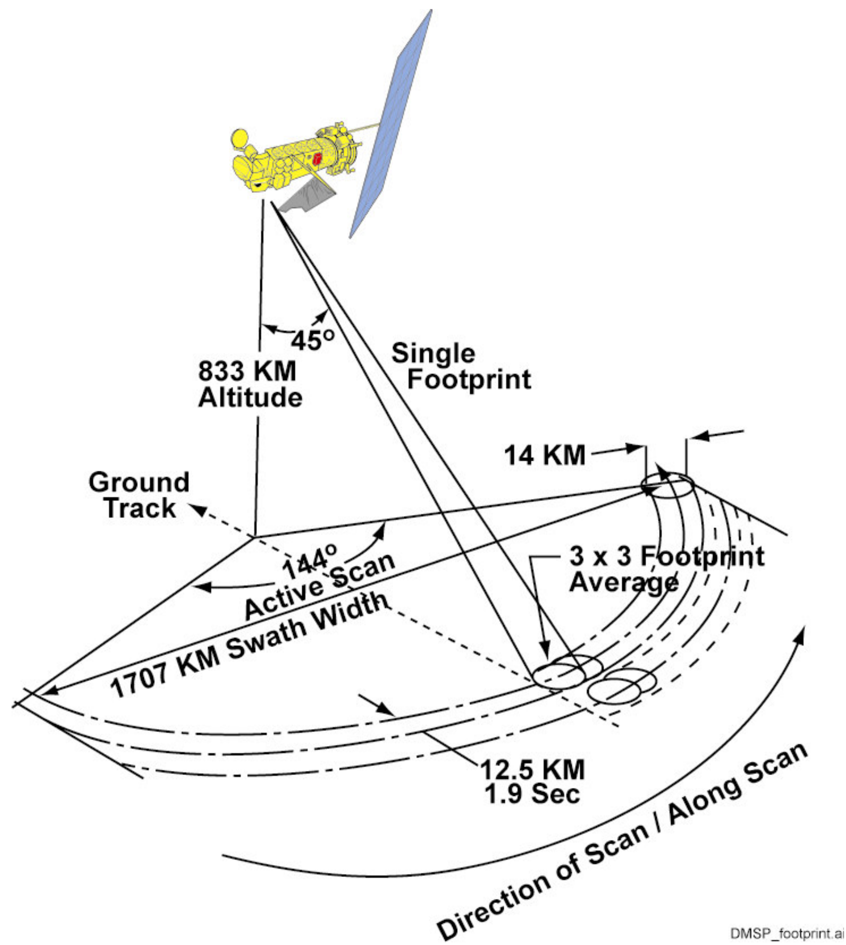


Channel selection for assimilation

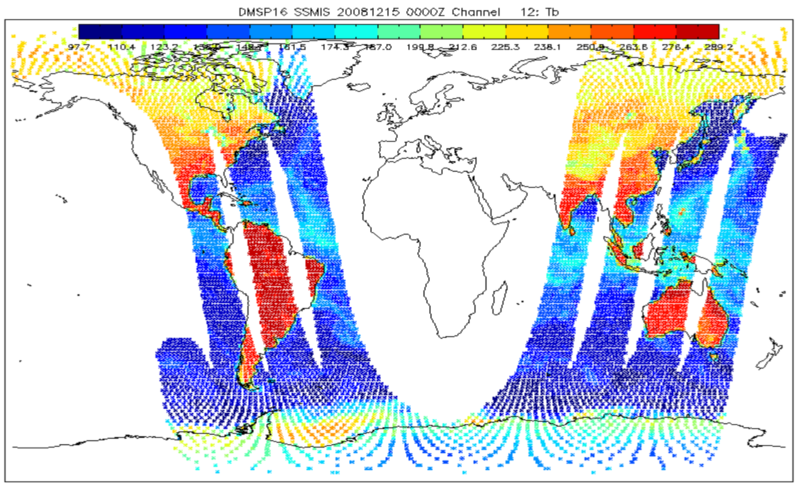
cm-1	Spectral bands	Ops and Strato2a		Strato2b		Currently tested	
		AIRS	IASI	AIRS	IASI	AIRS	IASI
650-770	T sounding (peak higher than 80mb)	0	0	0	0	0	0
	T sounding (80mb < peak < 150mb)	0	0	0	0	35	13
	T sounding (peak lower than 150mb)	20	0	20	43	20	40
770-980	Surface and cloud properties	6	0	6	19	6	19
1000-1070	Ozone sounding	0	0	0	0	0	0
1070-1150	Surface and cloud properties	4	0	4	0	4	0
1210-2100	Water vapor temperature sounding	33	0	33	0	33	10
2100-2150	CO column amount	0	0	0	0	0	0
2150-2250	Temperature sounding	9	0	9	0	9	0
2350-2420	Temperature sounding (CO2 Band)	15	0	15	0	15	0
2420-2700	Surface and cloud properties	0	0	0	0	0	0
	Total	**87**	**0**	**87**	**62**	**122**	**82**

SSMIS (Special Sensor Microwave Imager/ Sounder)

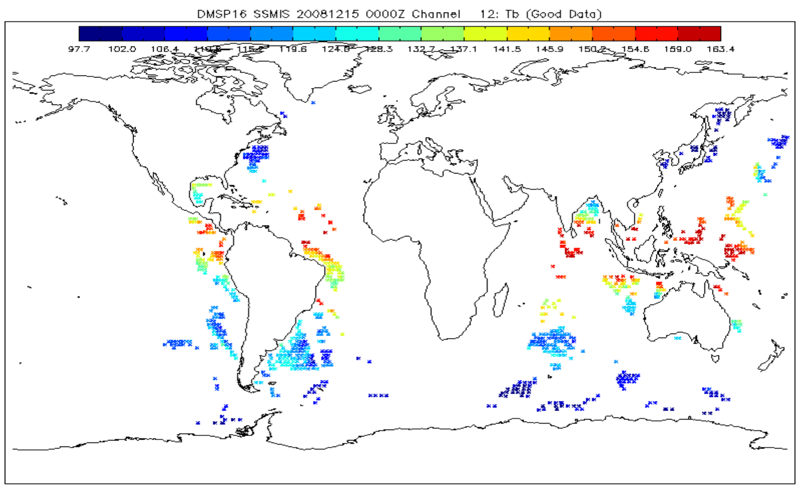
- Conical scanning microwave imager and sounder
- 24 channels (19-183 GHz)
  - **7 like SSM/I imager ch.1-7**
  - 10 like AMSU-A sounder ch.3-14
  - 4 like AMSU-B/MHS sounder ch. 2-5
  - 3 stratospheric sounder channels
- 3 satellites: DMSP16-17-18
- For Strato 2b, only DMSP16 7 SSM/I-like imager channel data are assimilated



SSMIS (Special Sensor Microwave Imager/ Sounder)



DMSP16 Ch. 12 All Tb data - thinned (150 km)



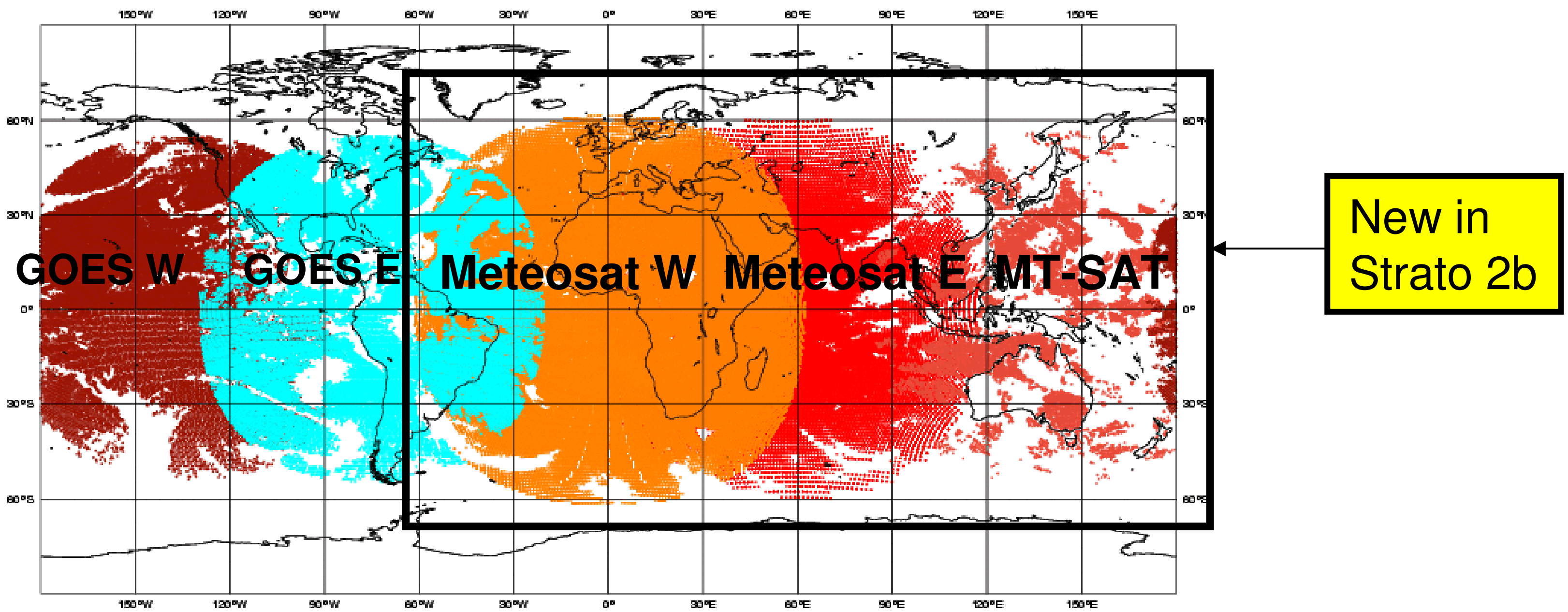
DMSP16 Ch. 12 Tb data selected for assimilation

- Radiance (Tb) data from 7 SSM/I-like imager channels on DMSP16-18 will effectively replace lost SSM/I data on DMSP13-15.
- Like SSM/I, only “clear-sky” radiances over open water are assimilated.
- Data mainly impact analysis of integrated humidity (TPW) and surface wind speed
- Assimilation of data from sounder channels will be tested in future (Strato 2b+)

Environment Canada Environnement Canada

Canada

GeoRad (Radiances from Geostationary Satellites)



- Radiances assimilated from 5 geostationary satellites, 3-h
- One (water-vapour) channel from each satellite
- RTTOV used for all vs MSCFAST for GOES up to now

Unified Dynamic Satellite Radiance Bias Correction System

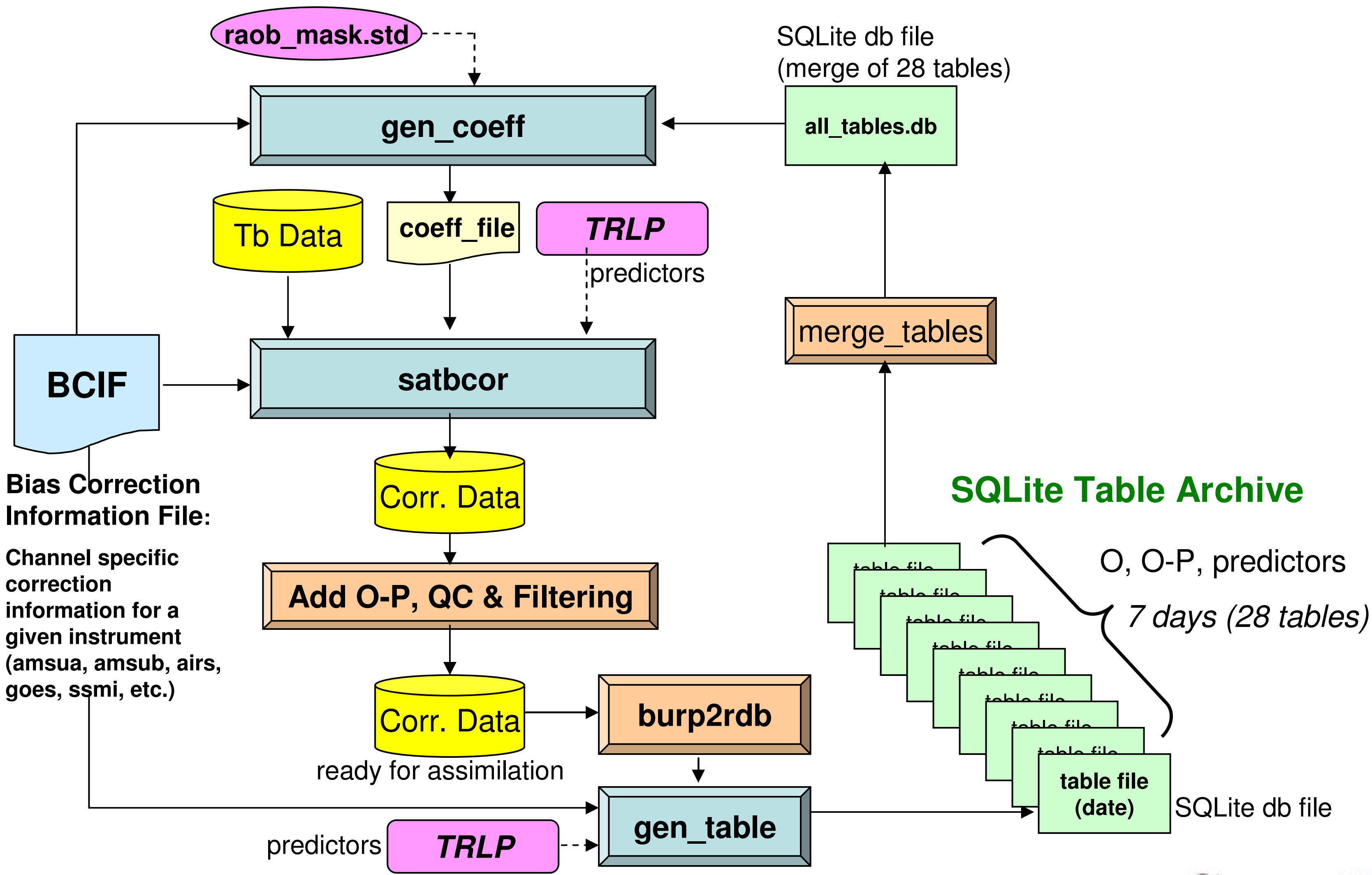
OLD SYSTEM (in 2a)

- Different systems/code used for data from microwave and IR instruments
- Different formats for system files (e.g. standard file, binary, SQLite tables, ASCII)
- Not robust. Data gaps can lead to problems including bad corrections due to low sample size
- Predictors limited to 2 or 4 thicknesses and Tb hard-coded in system and applied uniformly to all channels

UNIFIED SYSTEM (in 2b)

- Common code set for all instrument types
- Common format for bias correction coeff files (ASCII)
- SQLite database tables used to store data for dynamic correction (coeff file) generation
- More robust. System handles data gaps intelligently
- Choice of 11 predictors (more can be added easily); up to 6 can be specified uniquely for each channel
- Mode (static or dynamic) can also be specified uniquely for each channel

Unified Dynamic Satellite Radiance Bias Correction System



Satellite Radiance Bias Correction in Strato 2 cycles

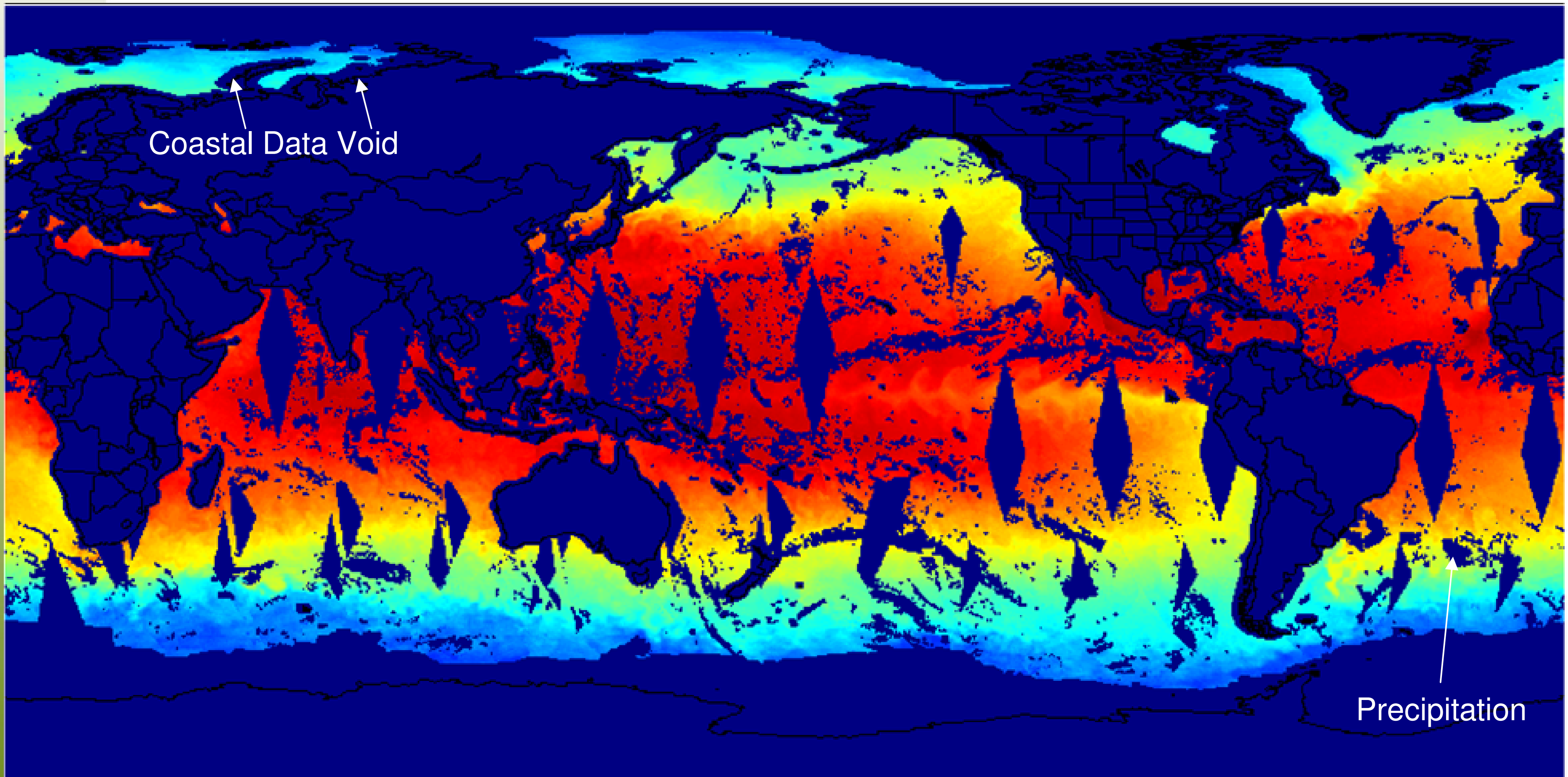
- Dynamic bias correction applied (bias correction coeff updated each analysis)
  - last 15 day averaging period in old system (Strato 2a)
  - last 7 day averaging period in new system (Strato 2b)
  - static correction applied for AMSU-A channels 11-14
- Thickness (ΔGZ) predictors and scan position dependent corrections applied for microwave radiances (AMSU-A, AMSU-B/MHS, SSM/I, SSMIS)
- For IR radiances (AIRS, GeoRad, IASI), sole predictor is radiance observation (Tb); scan position biases are not considered

Improved SST Analysis

- Description of the observations used
- Description of the analysis method
- Assessment of analysis quality
  1. Verification against independent data for several analyses (zonal average)
  2. Verification against independent data (time series)

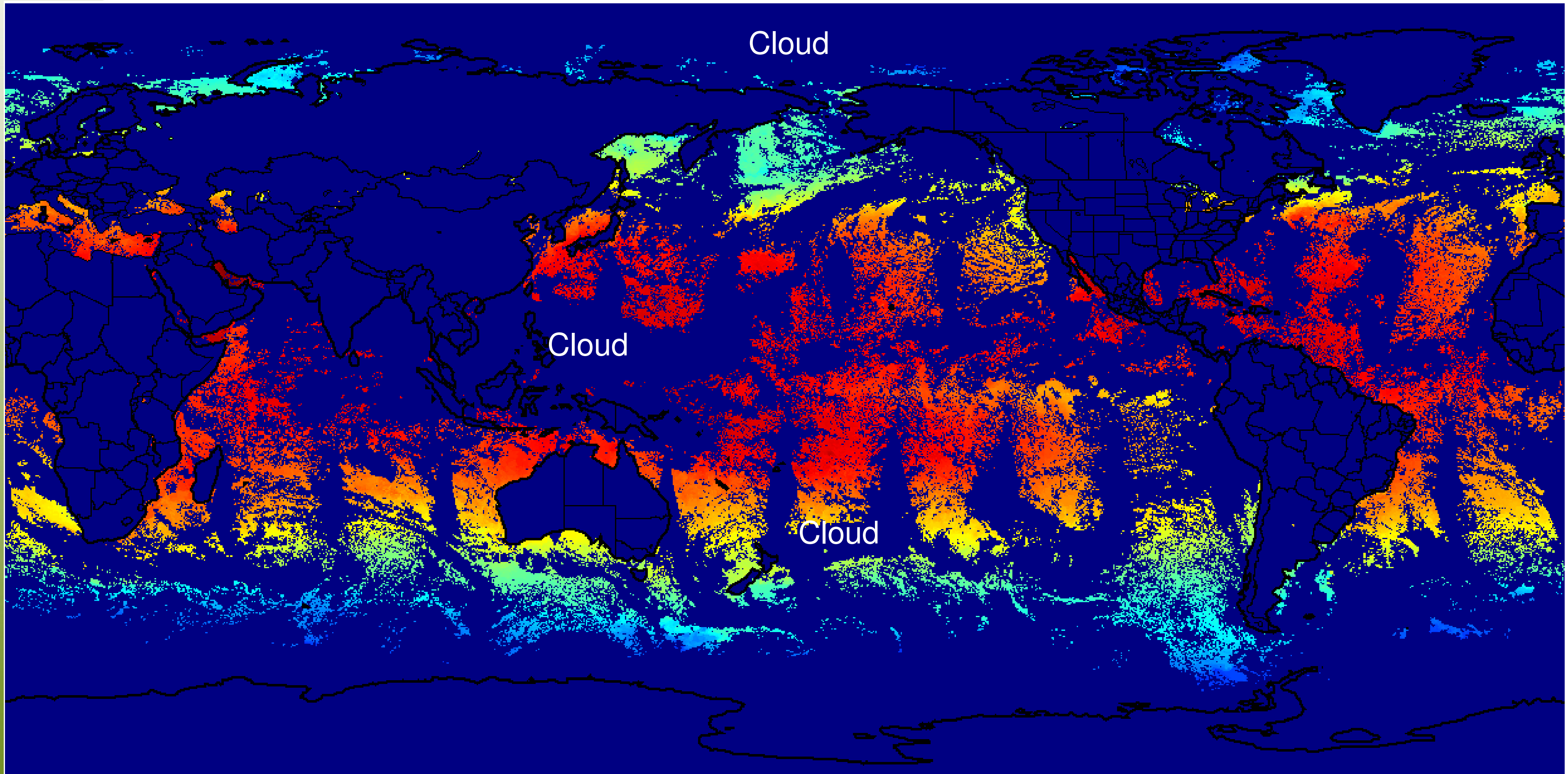
24-hour coverage from AMSR-E (passive microwave sensor aboard AQUA)

Data from September 21 2007



24-hour coverage from AVHRR (infrared sensor aboard NOAA-18)

Data from September 21, 2007



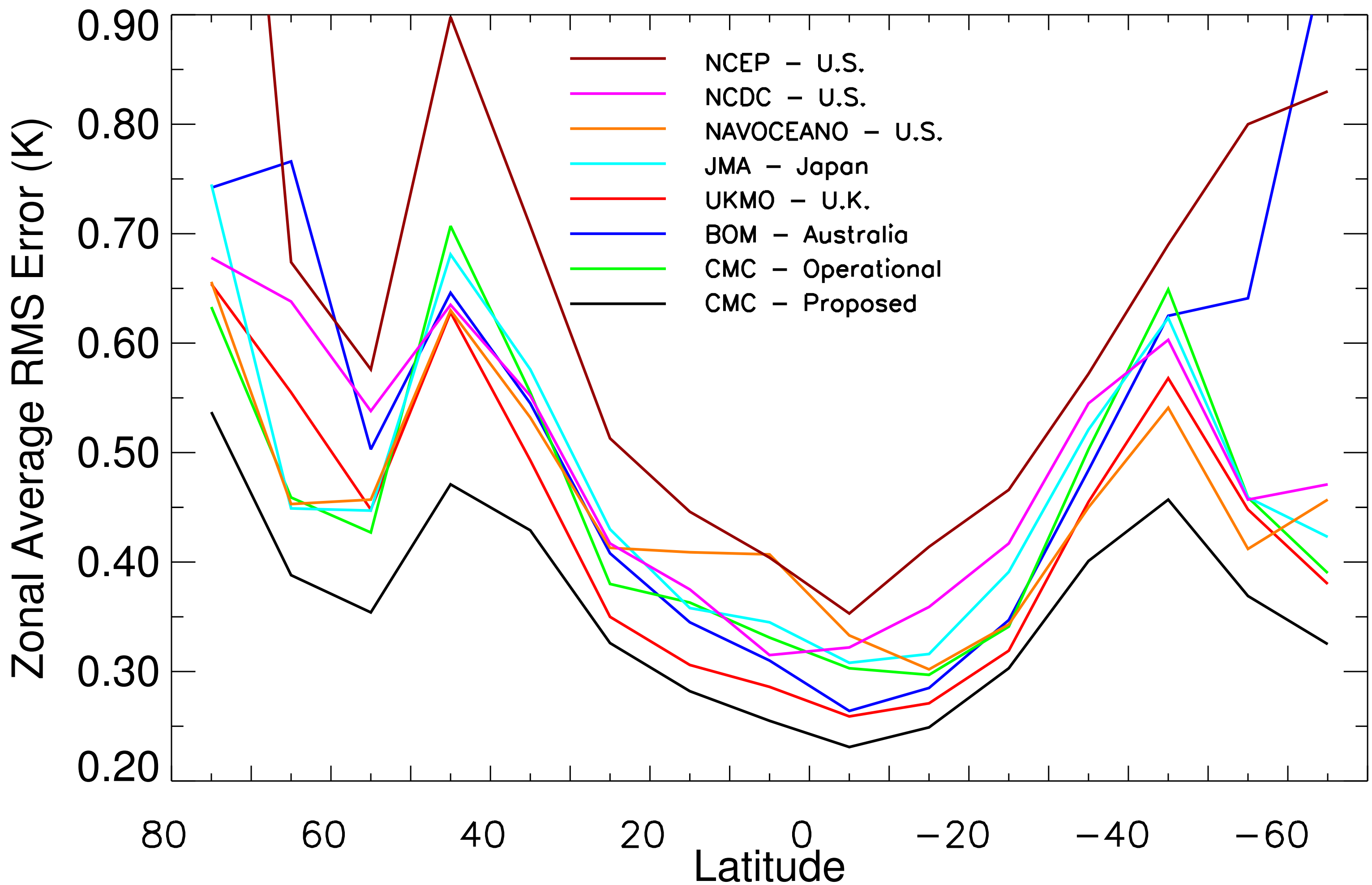
Description of data assimilated

- AMSR-E (passive microwave) retrievals from RSS gridded on a 0.25° grid (65,000 /day)
- NAVO (infrared) retrievals for NOAA-18, NOAA-19 and METOP-A (45,000 /day from each source)
- A/ATSR (infrared) retrievals from ESA (16,000 /day)
- Proxy SSTs based on the CMC ice analysis (9,000/ day)
- Ships (1500 /day)
- Drifters (1200 /day)
- Moored buoys (200 /day)

Analysis Description

- Analysis variable is anomaly from climatology
- Updated once per day on a global, 0.2° grid
- Uses previous analysis as background (persistence)
- Method is statistical (optimal) interpolation
- Extensive quality control of observations
- Goal is to produce an analysis of the foundation SST (SST at a depth where there is no diurnal variation)
- Uses data from a variety of sources, in situ and satellite
- Biases of satellite retrievals are estimated and removed

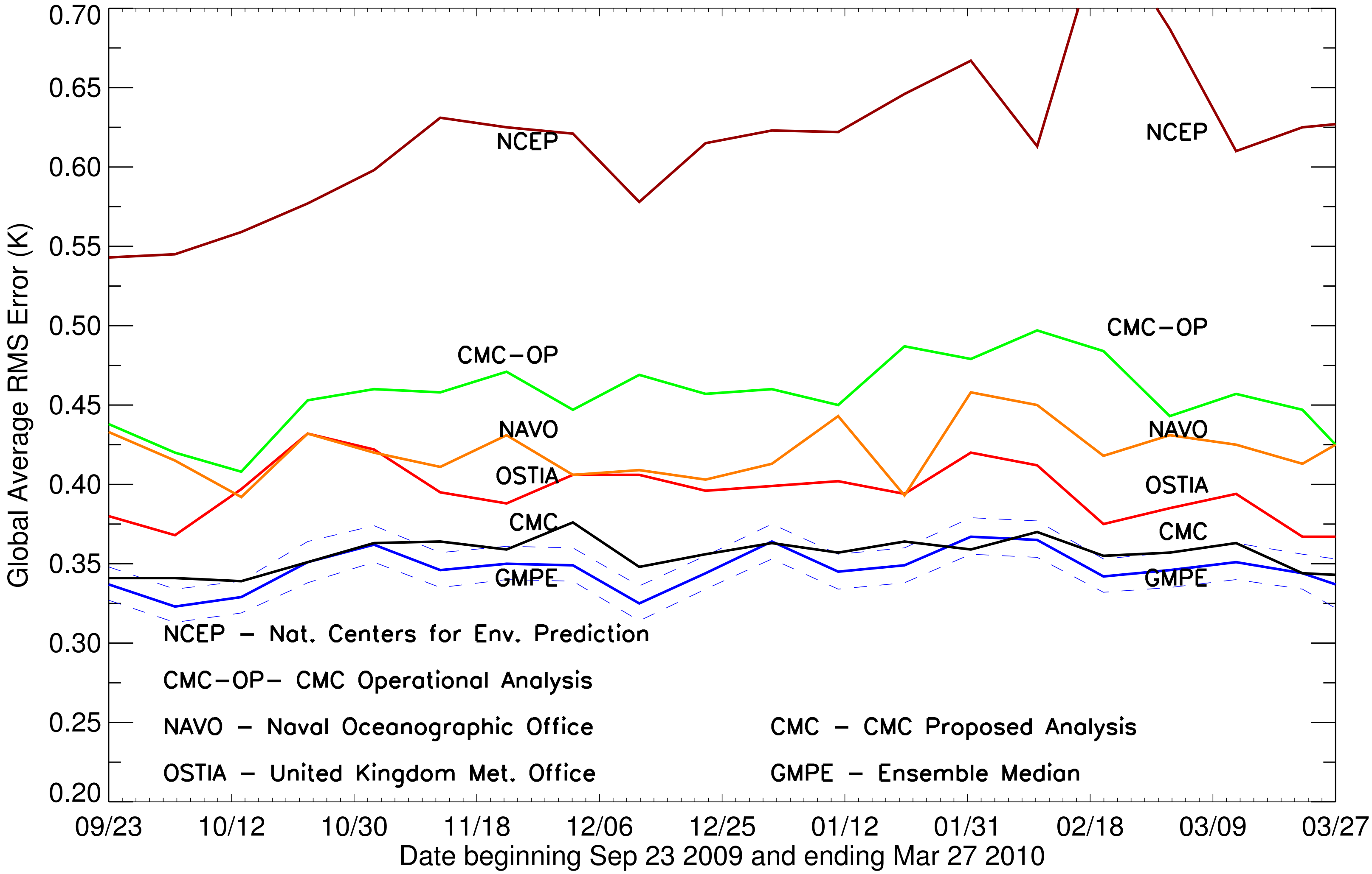
Comparison of zonally averaged analysis error for 8 products based on independent Argo floats



Analysis Comparison Project

- Global Multi-Product Ensemble (GMPE) Project is a real-time assessment of analysis quality using ensemble methodology, and performed by the UK Met Office
- Currently 11 SST analyses participate (6 from the U.S., one each from Australia, Canada, France, Japan and the U.K.)
- At each grid point, the median and standard deviation of the 11-member ensemble are calculated
- The median and standard deviation in grid point form can be obtained by contacting the MyOcean service desk

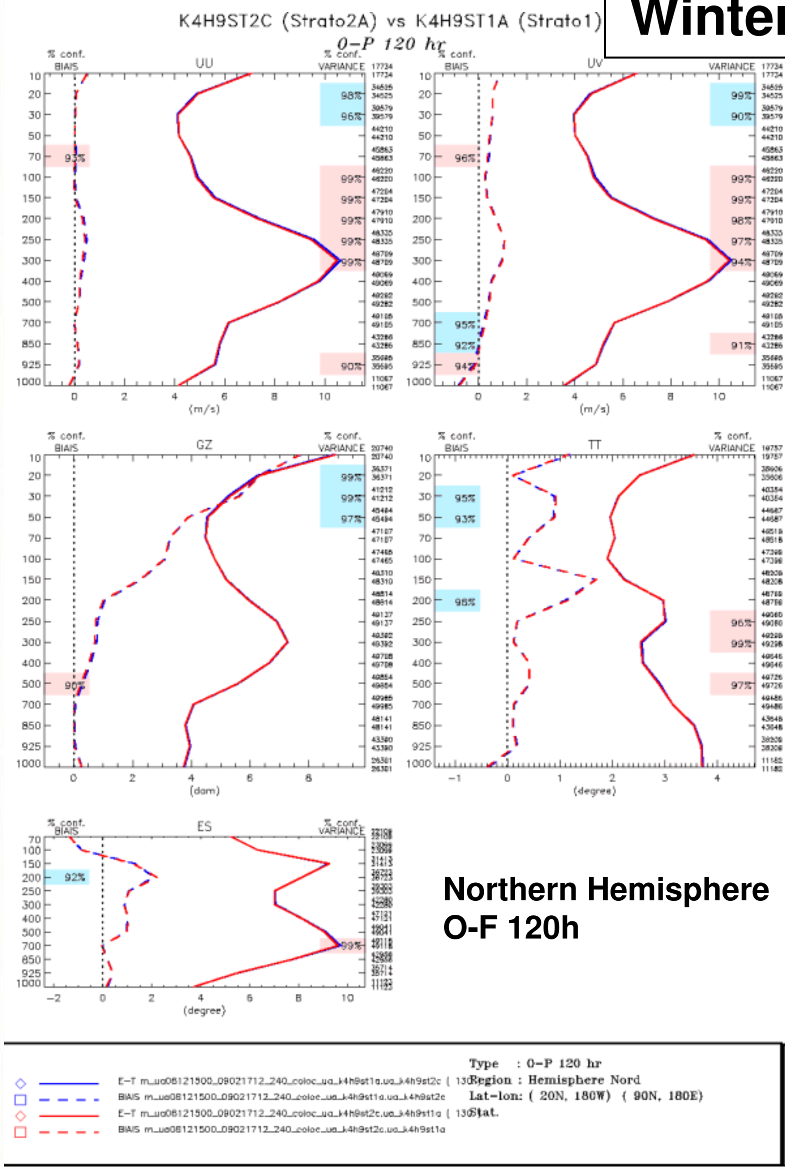
Time series of global average error based on independent data from Argo floats

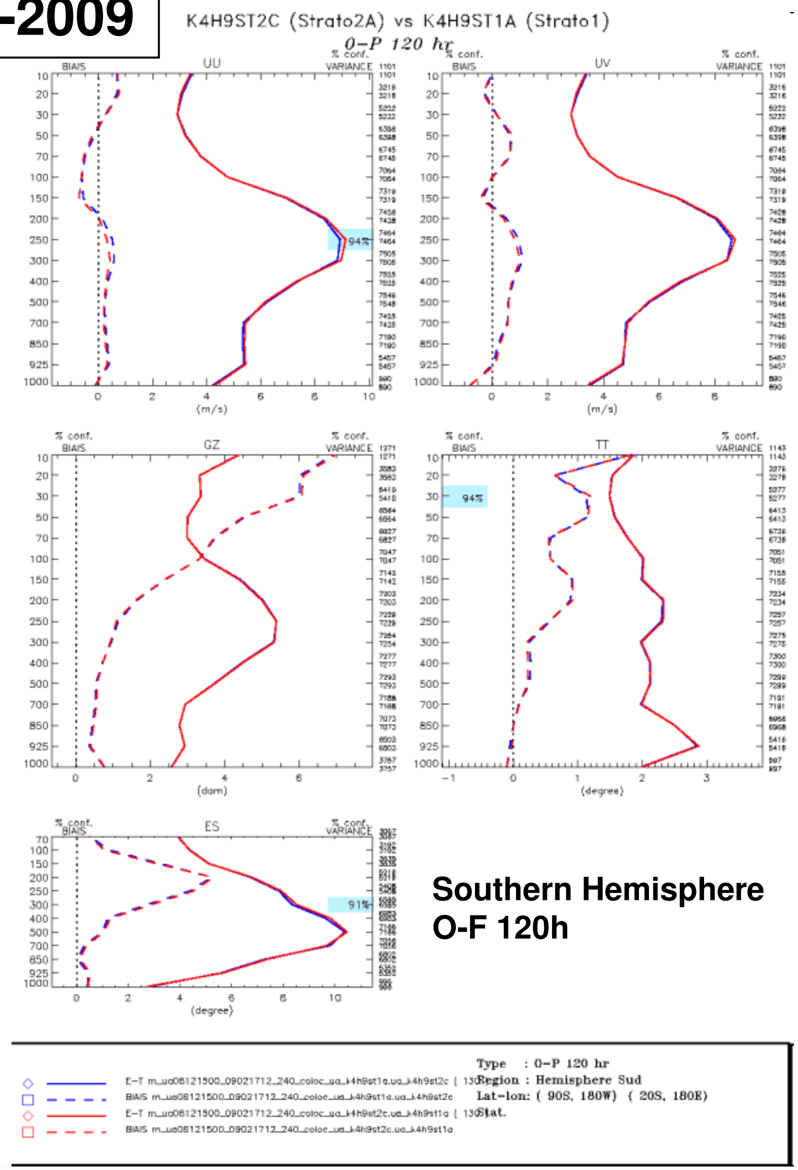


Reminder:

Results from final cycles - Strato 2a

Winter 2008-2009

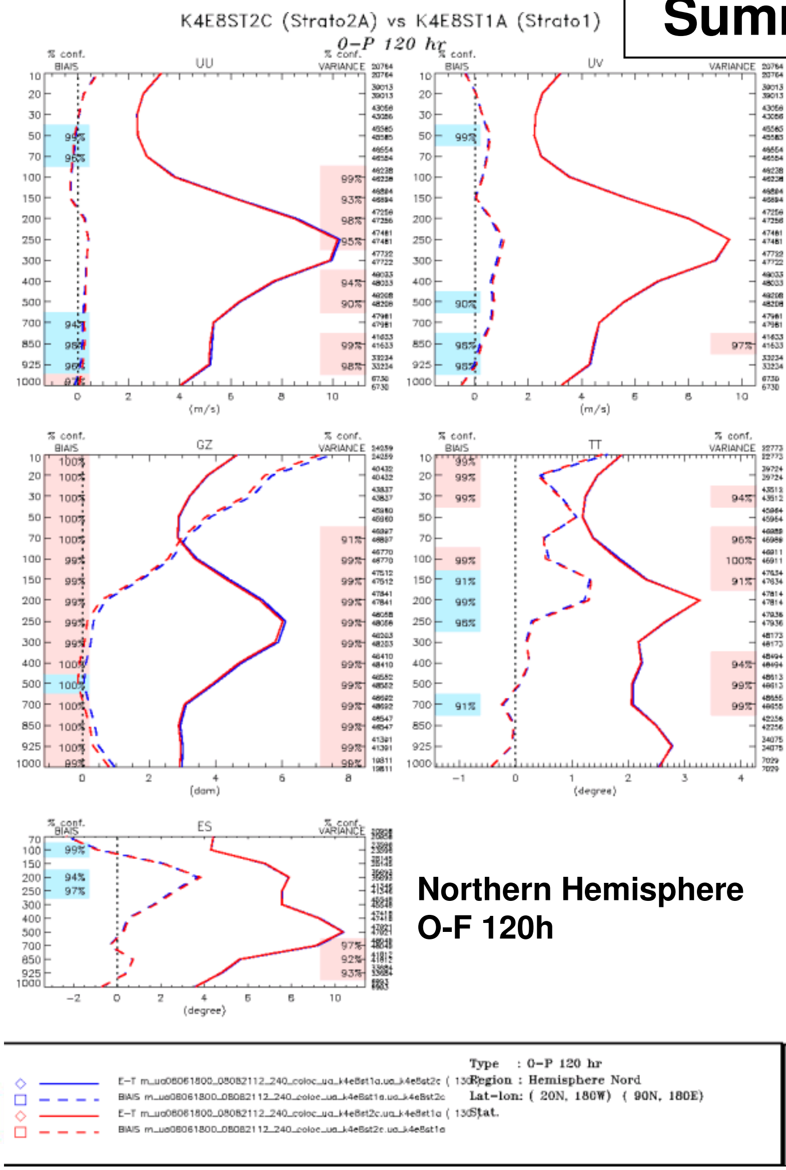




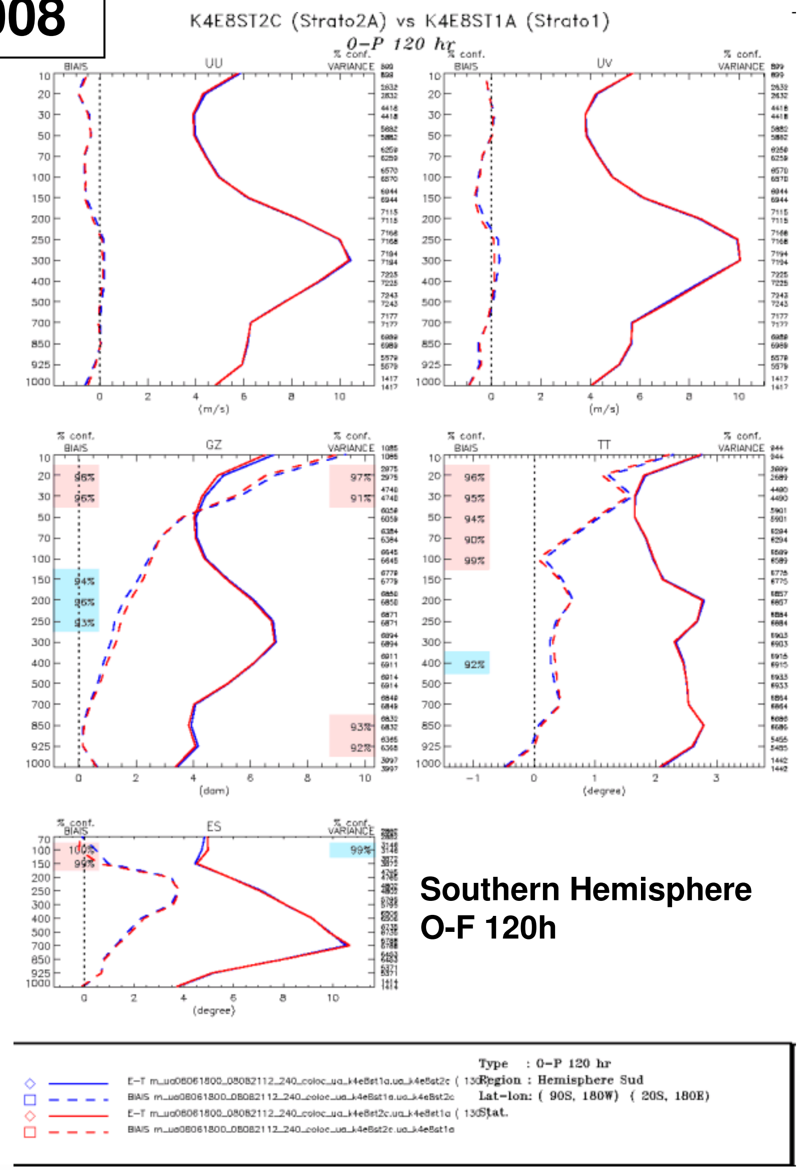
Reminder:

Results from final cycles - Strato 2a

Summer 2008



Northern Hemisphere
O-F 120h

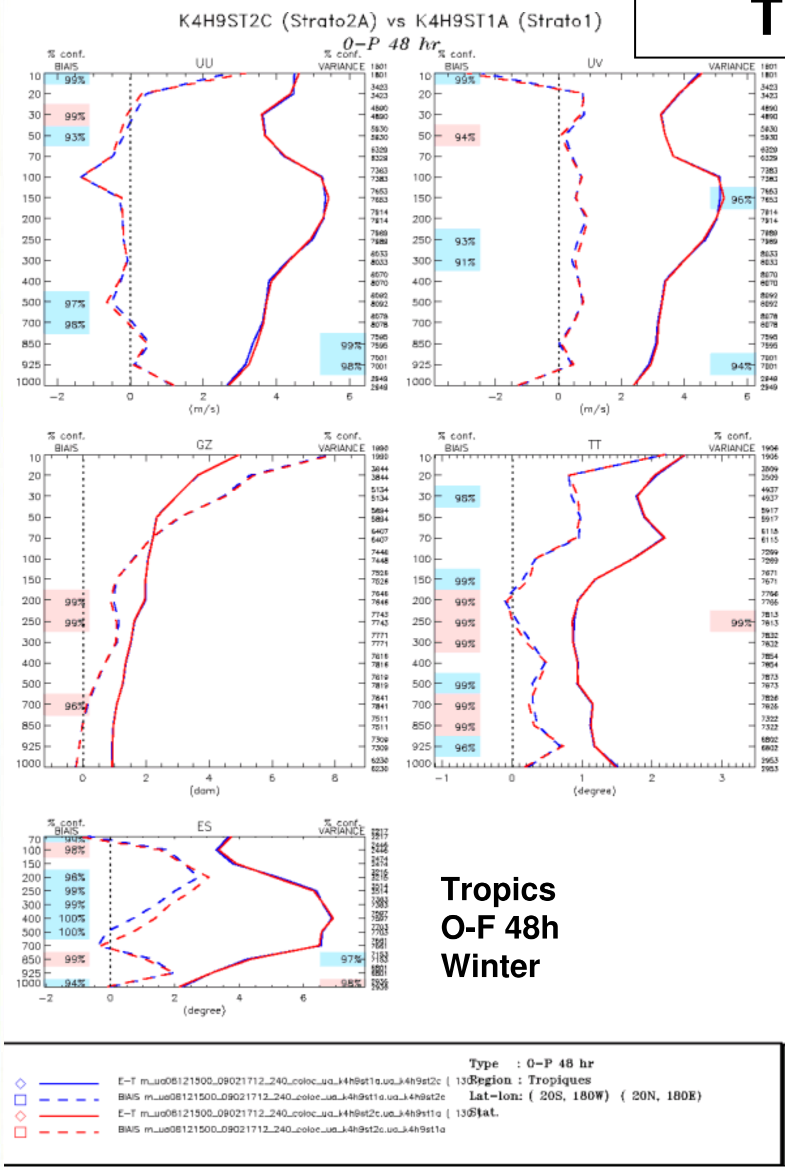


Southern Hemisphere
O-F 120h

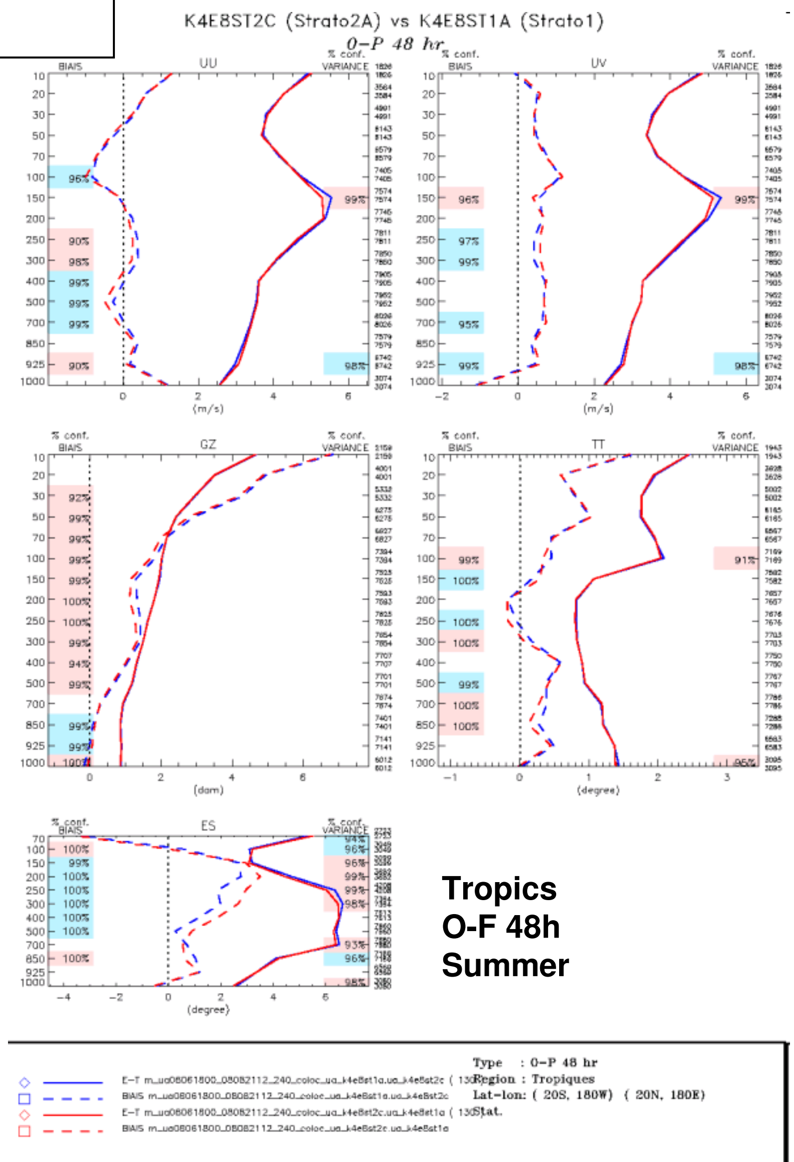
Reminder:

Results from final cycles - Strato 2a

Tropics



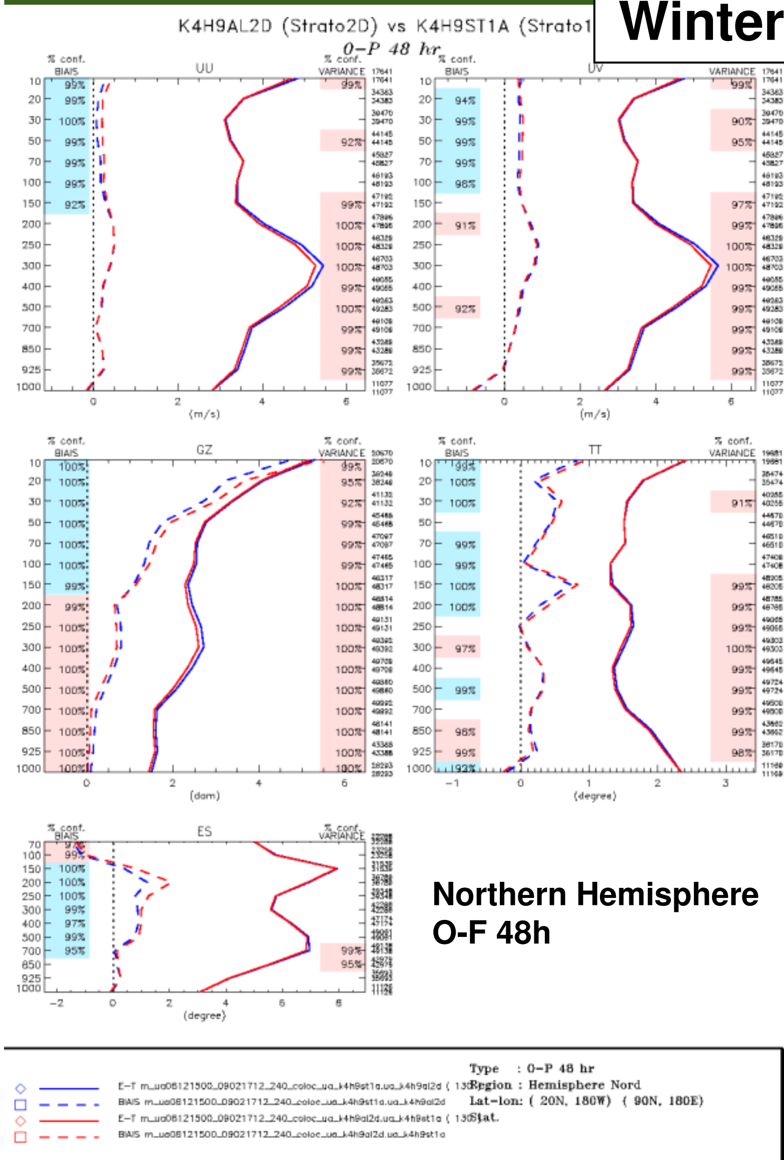
Tropics
O-F 48h
Winter



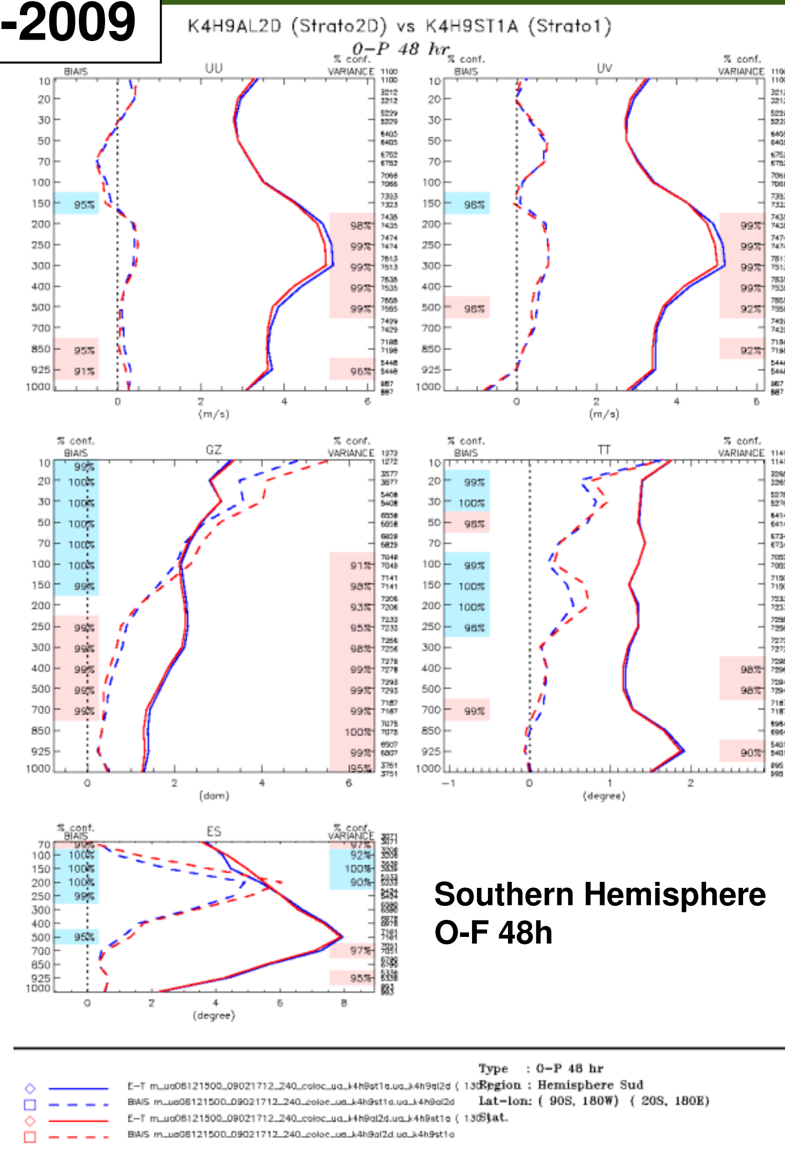
Tropics
O-F 48h
Summer

Results from final cycles:
Strato 2b vs operational

Winter 2008-2009



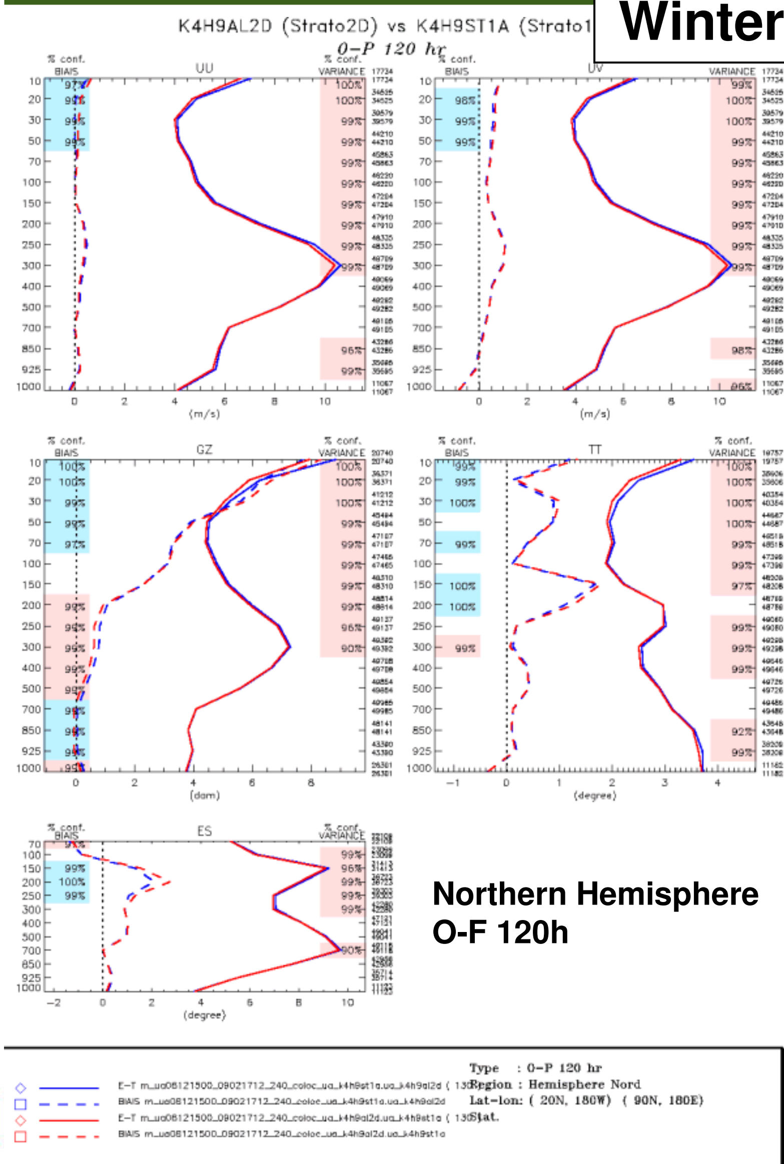
Northern Hemisphere
O-F 48h



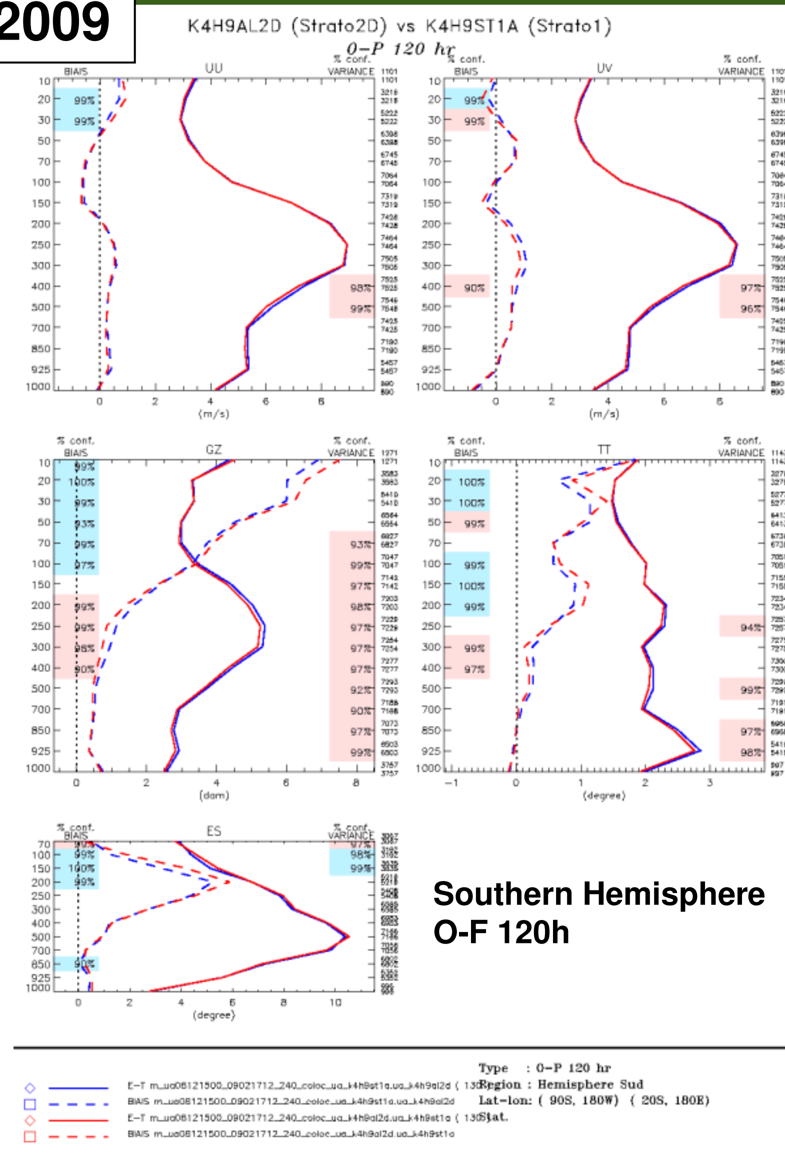
Southern Hemisphere
O-F 48h

Results from final cycles:
Strato 2b vs operational

Winter 2008-2009



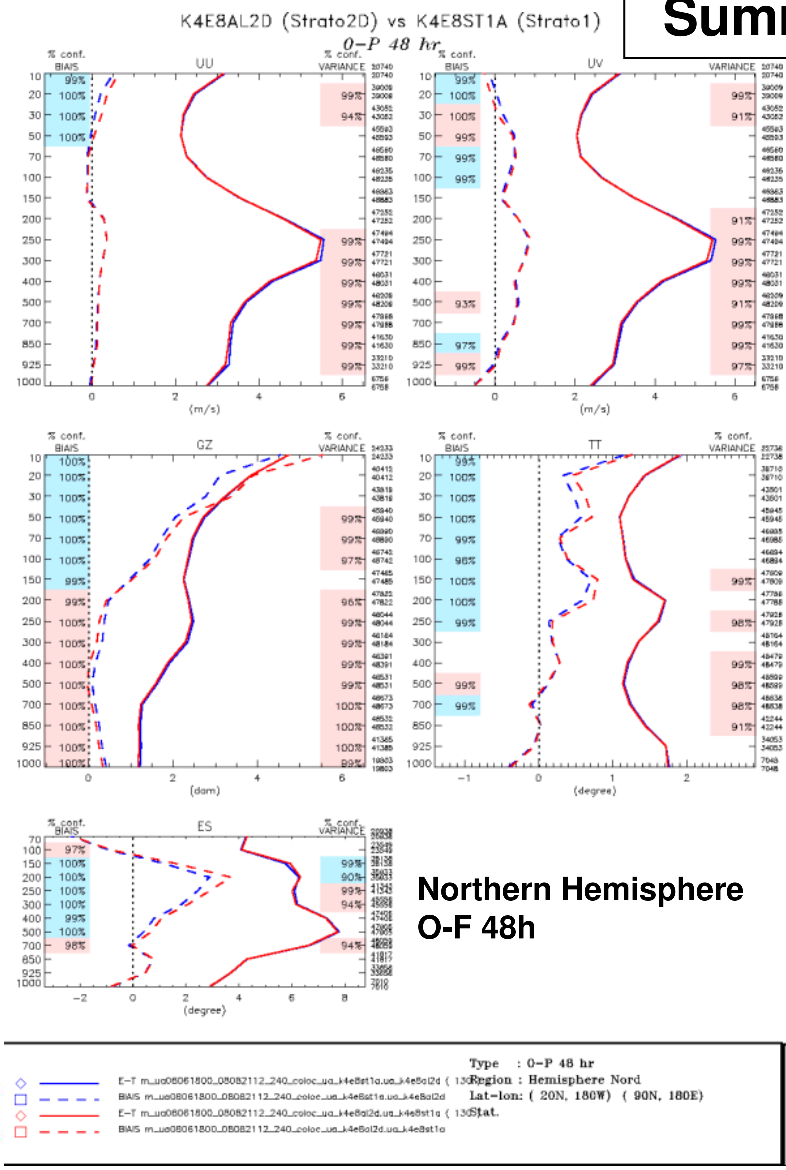
Northern Hemisphere
O-F 120h



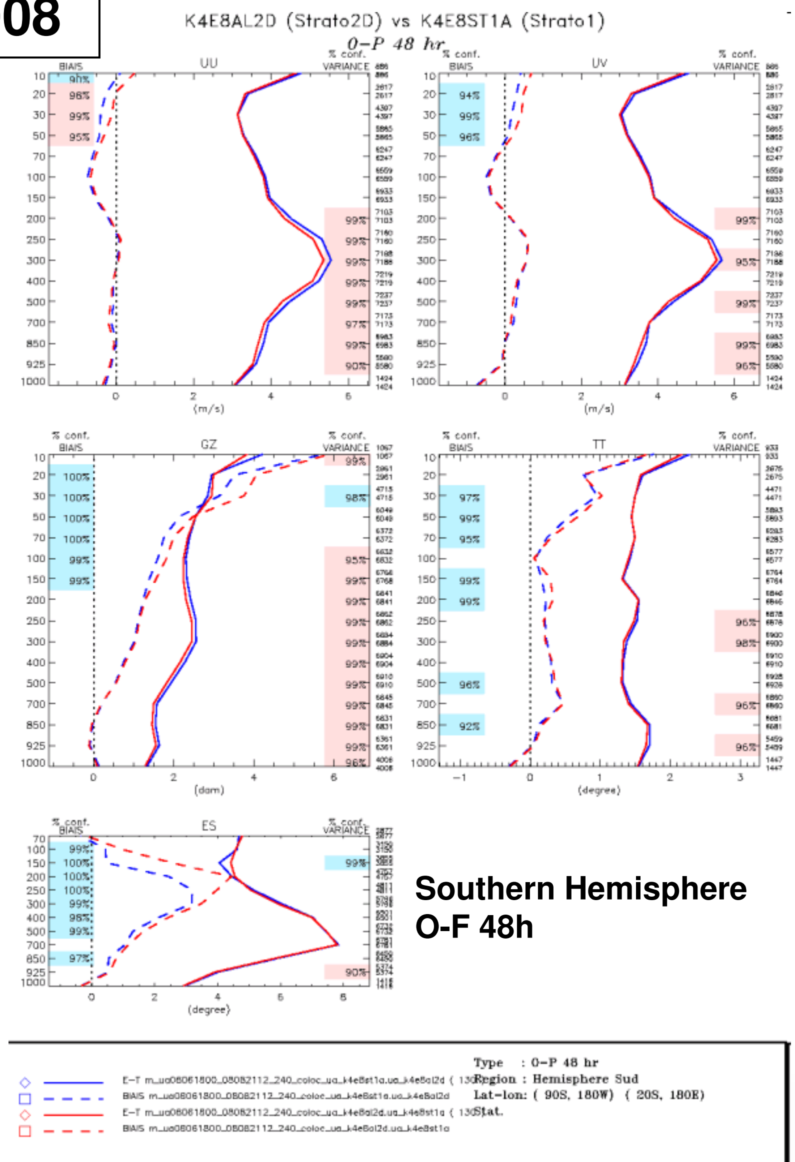
Southern Hemisphere
O-F 120h

Results from final cycles:
Strato 2b vs operational

Summer 2008



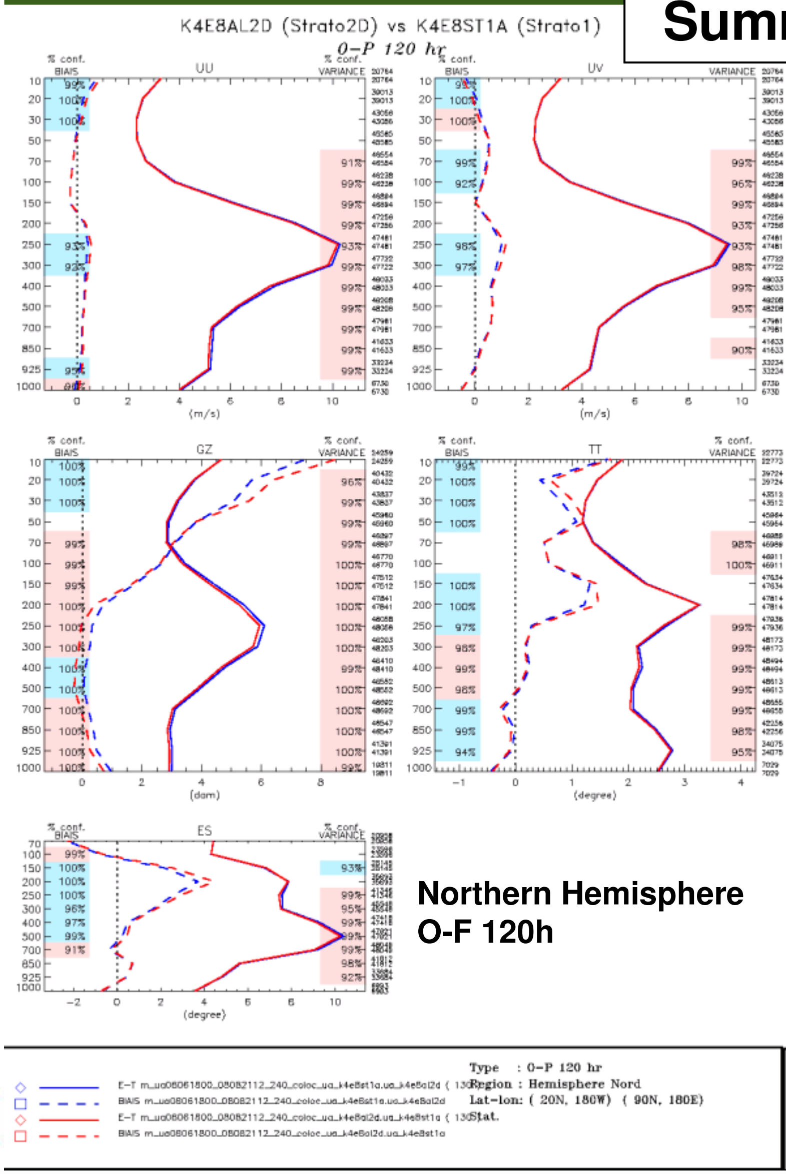
Northern Hemisphere O-F 48h

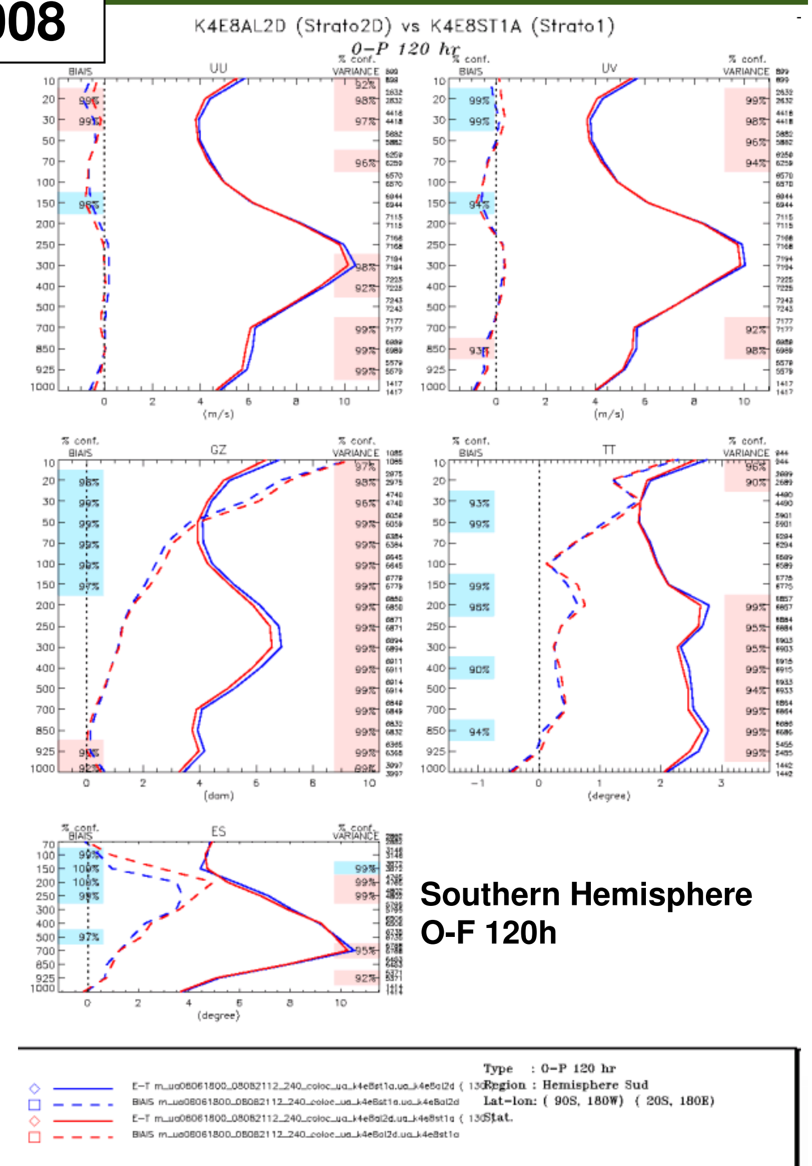


Southern Hemisphere O-F 48h

Results from final cycles:
Strato 2b vs operational

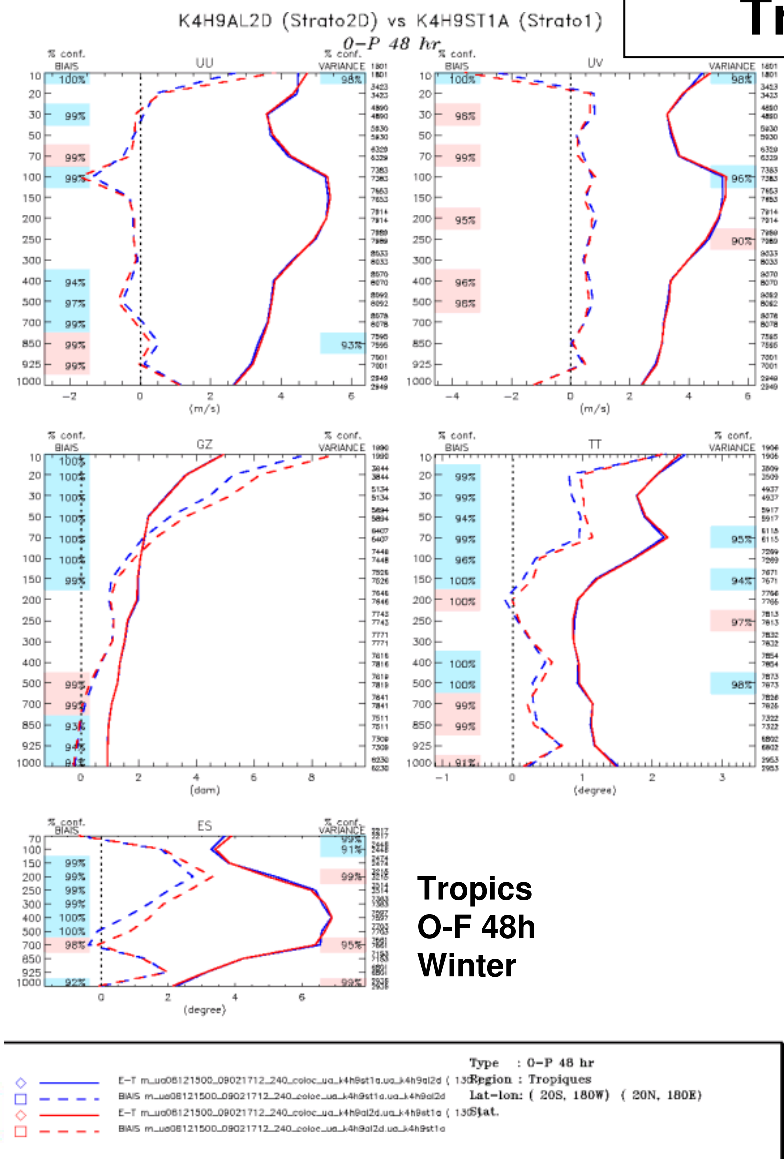
Summer 2008

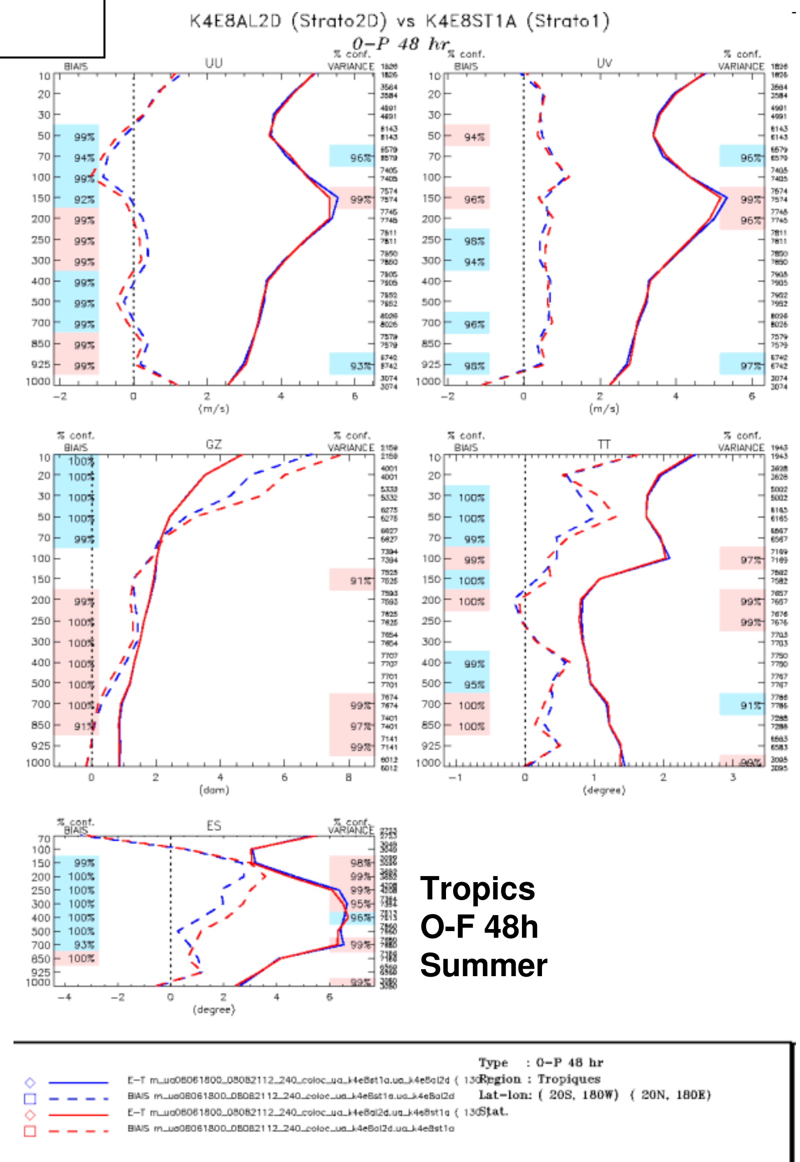




Results from final cycles:
Strato 2b vs operational

Tropics



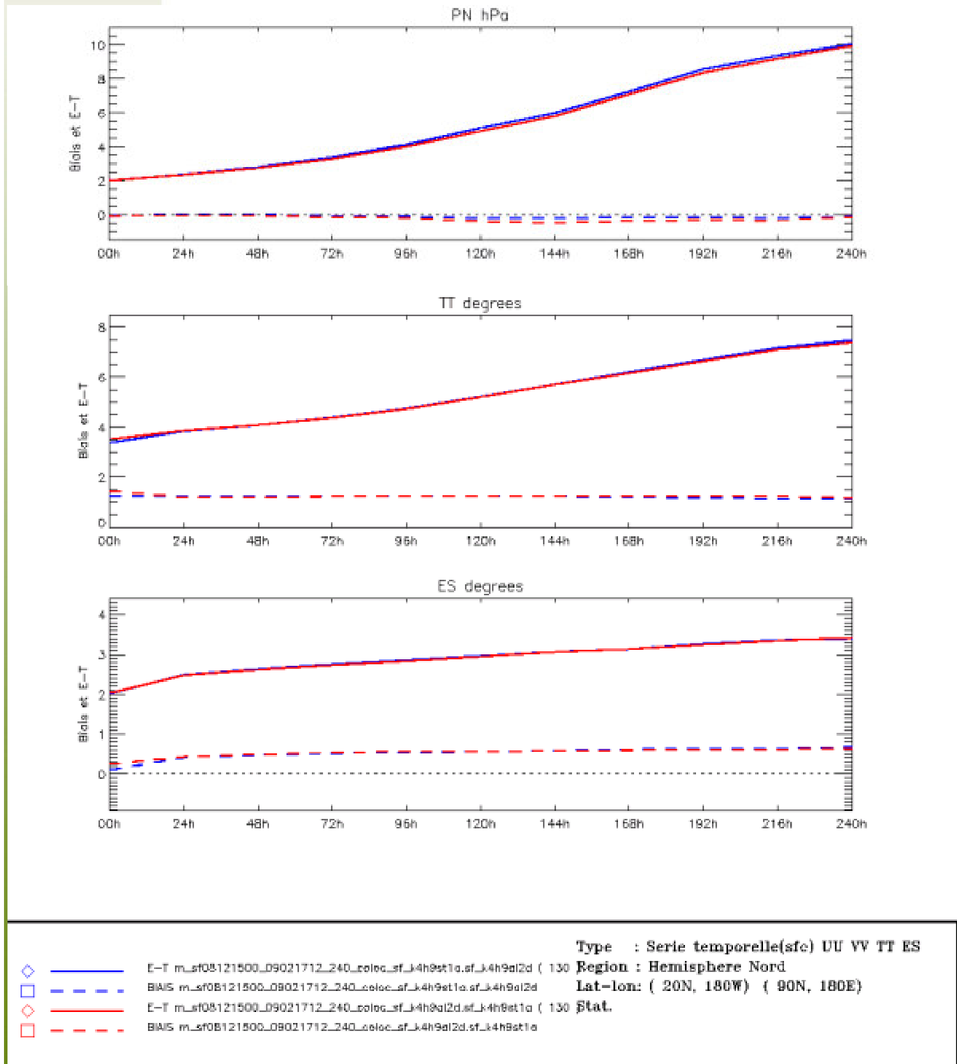


Results from final cycles - Strato 2b

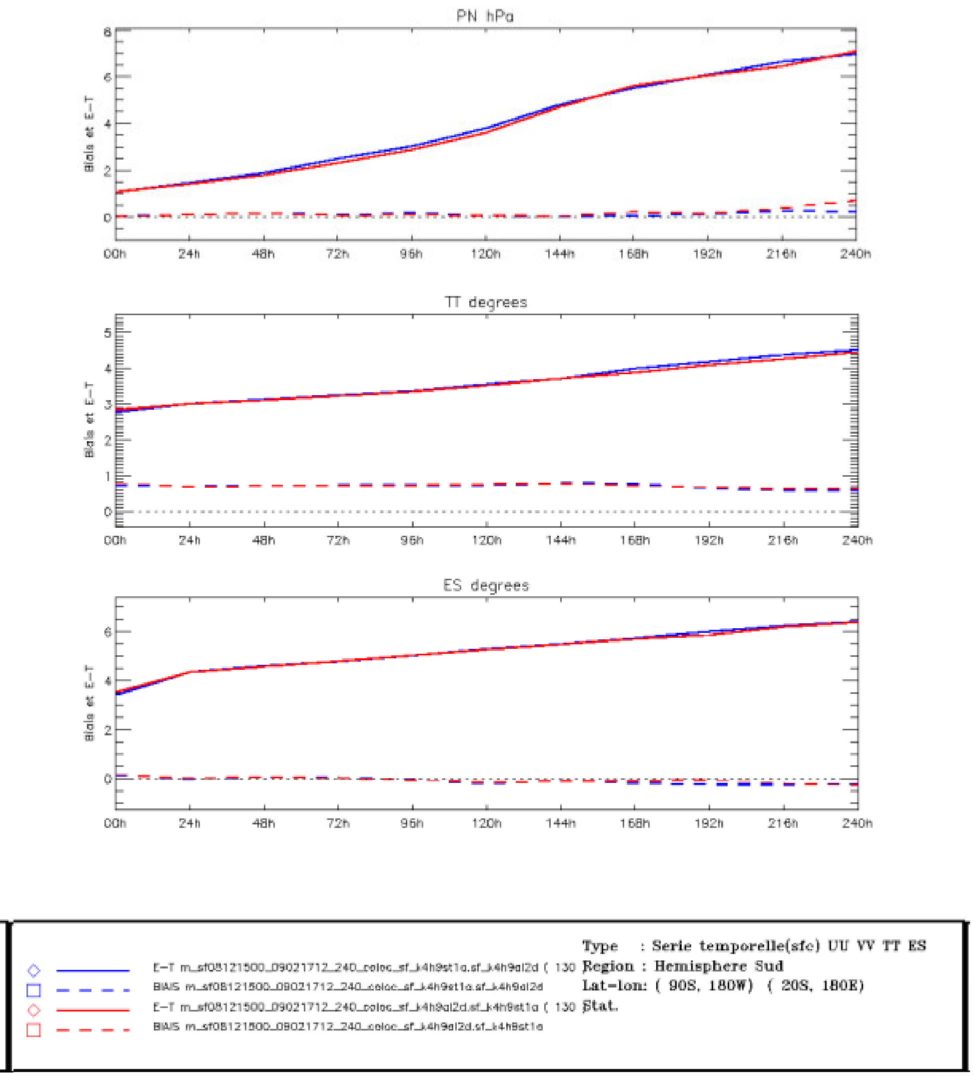
Surface verification

Winter 2008-2009

Northern Hemisphere



Southern Hemisphere

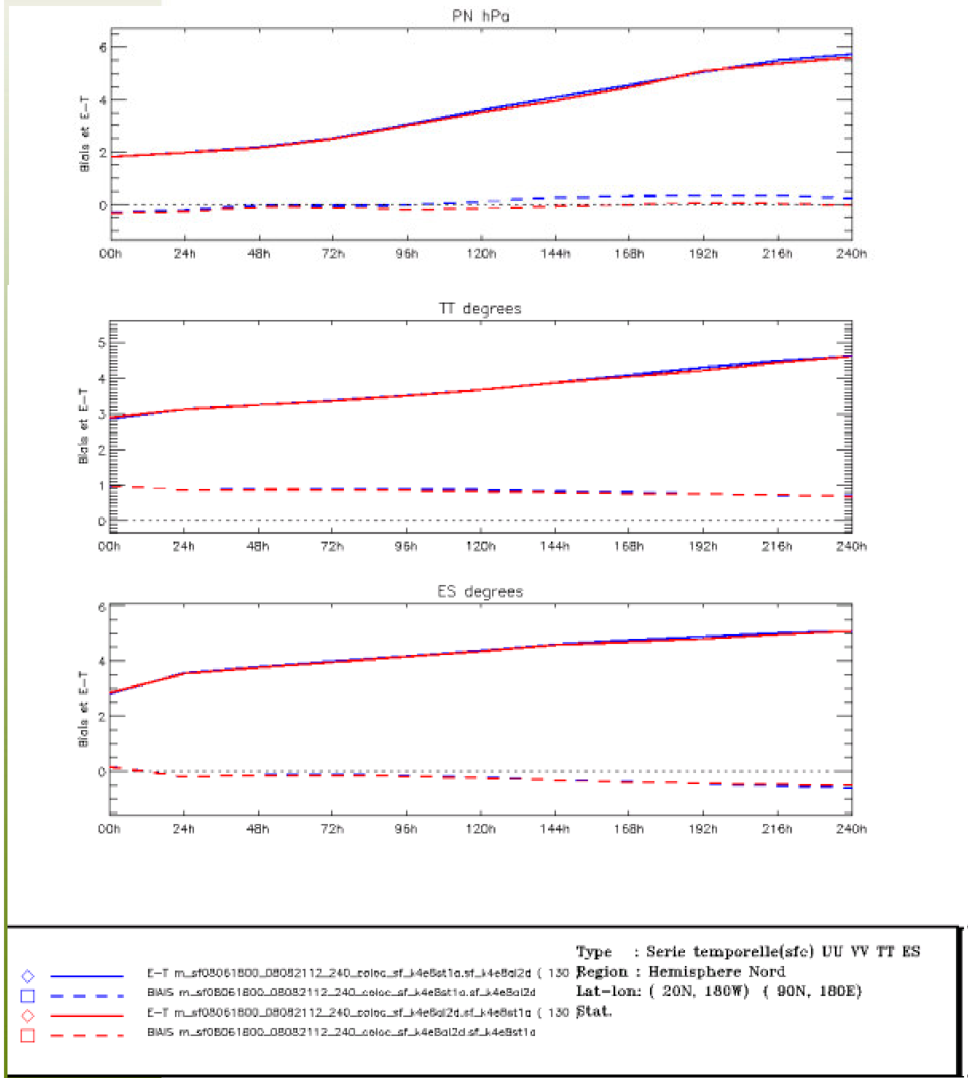


Results from final cycles - Strato 2b

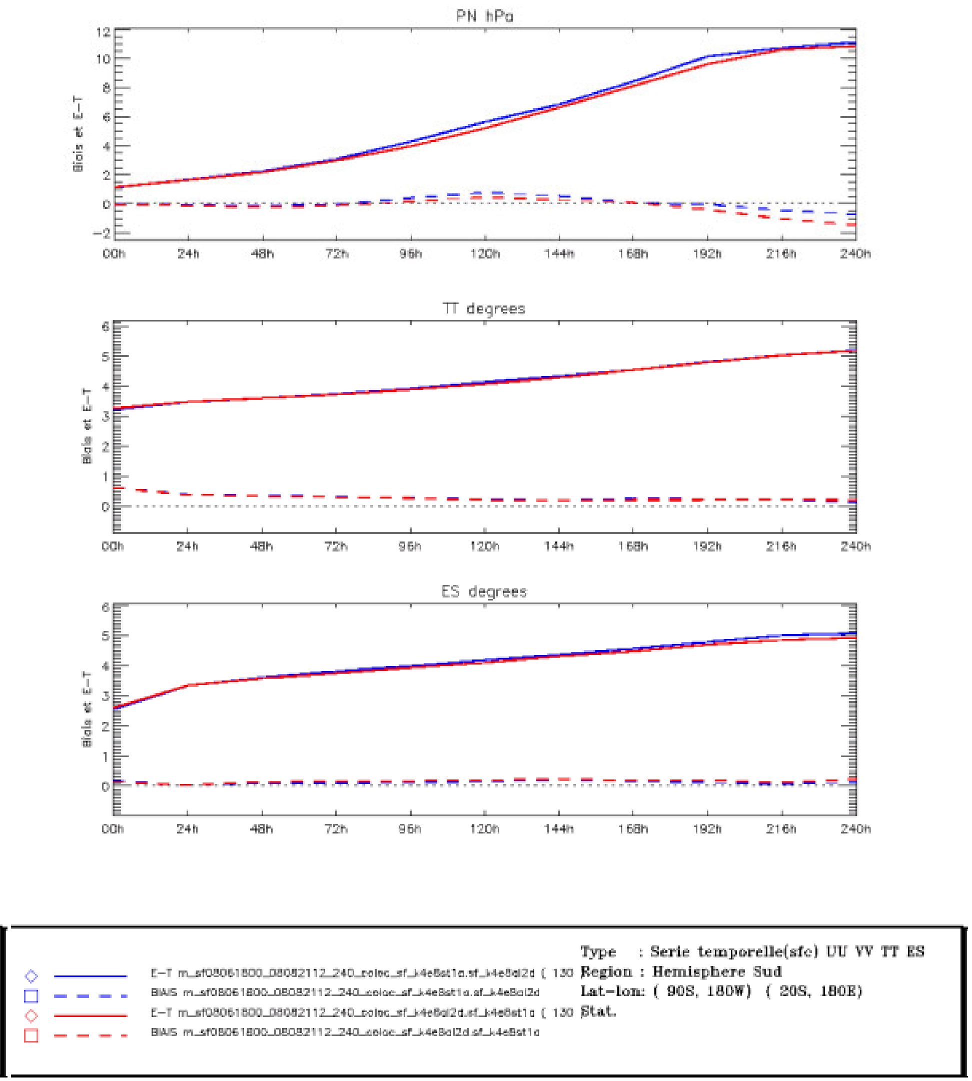
Surface verification

Summer 2008

Northern Hemisphere



Southern Hemisphere

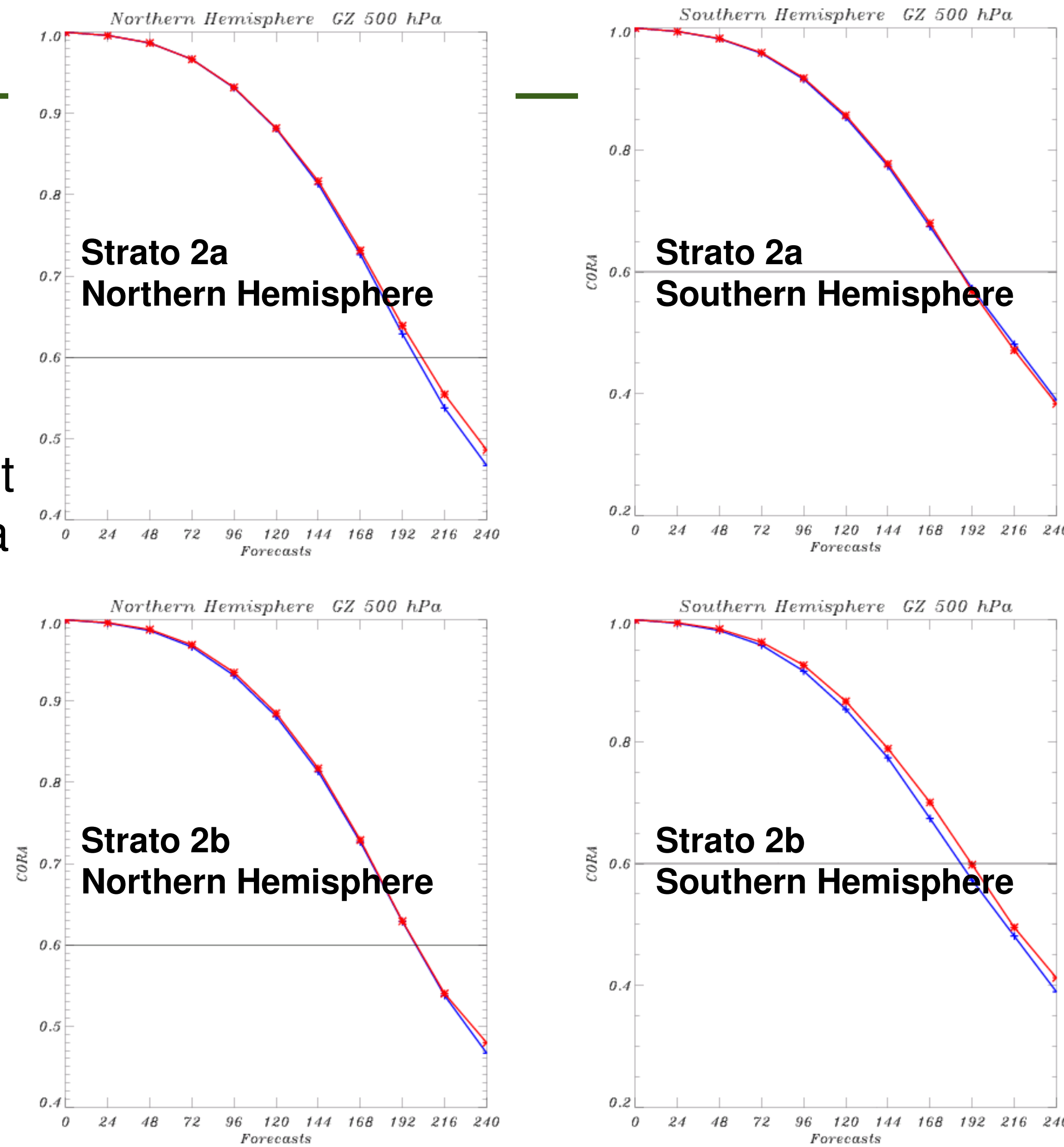


Results from final cycles

Anomaly Correlation
for GZ 500 hPa

Winter 2008-2009

Consistent gain of 2-6 h at
day 5, 100 hPa – 850 hPa

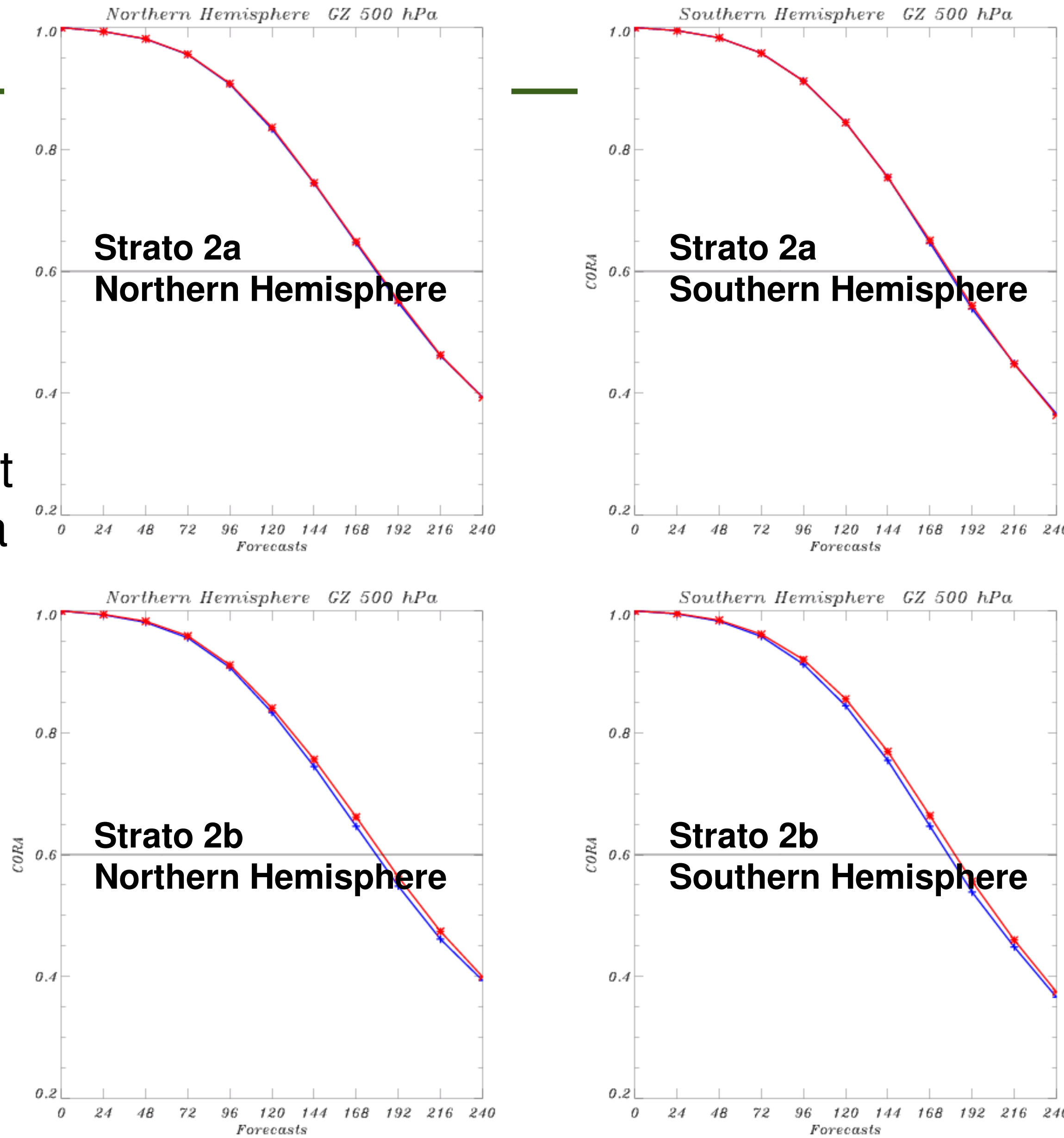


Results from final cycles

Anomaly Correlation
for GZ 500 hPa

Summer 2008

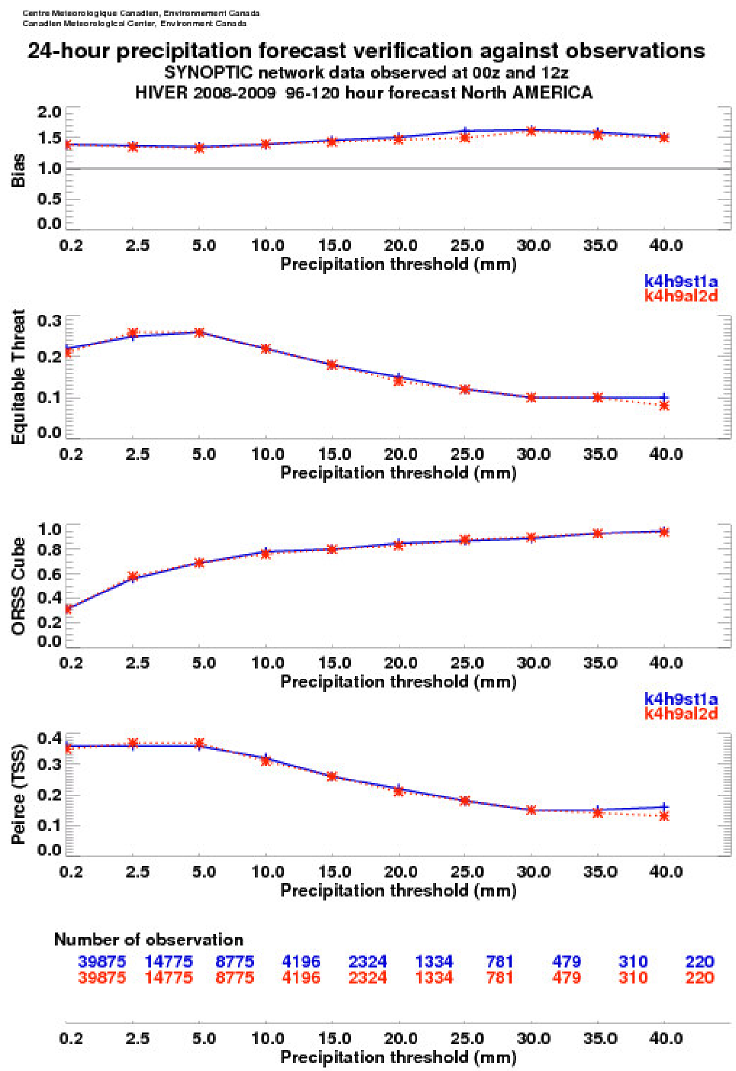
Consistent gain of 4-6 h at
day 5, 100 hPa – 850 hPa



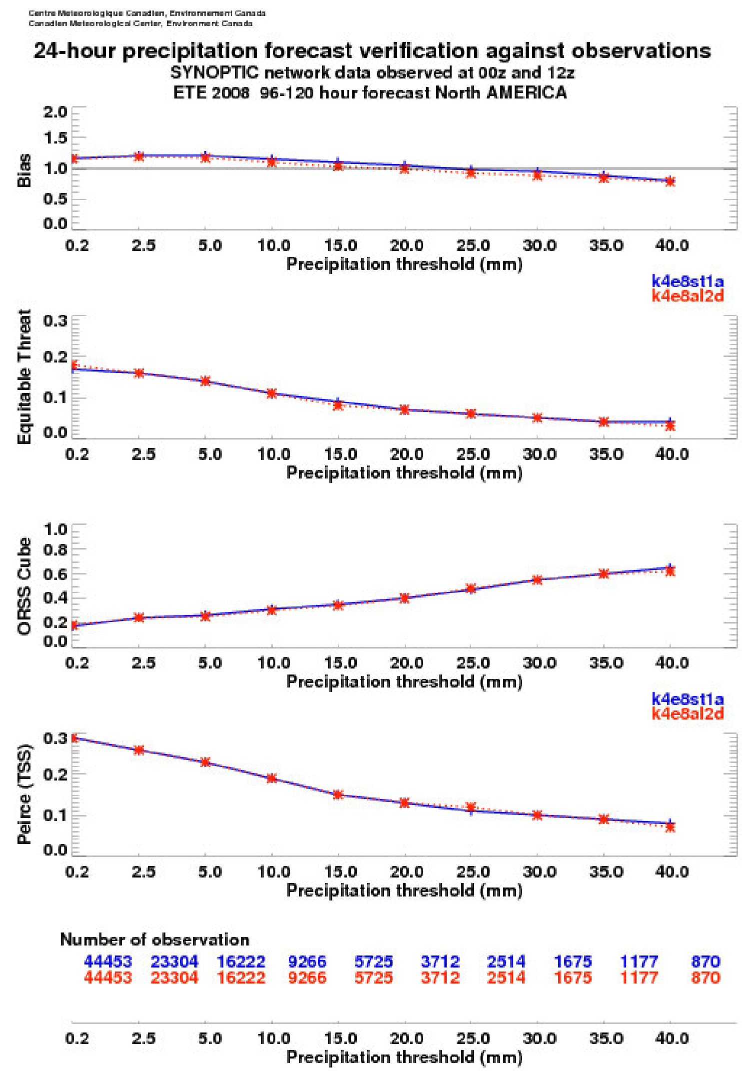
Results from final cycles

96h- 120h accumulated precipitation

Winter – N. America (Synop)



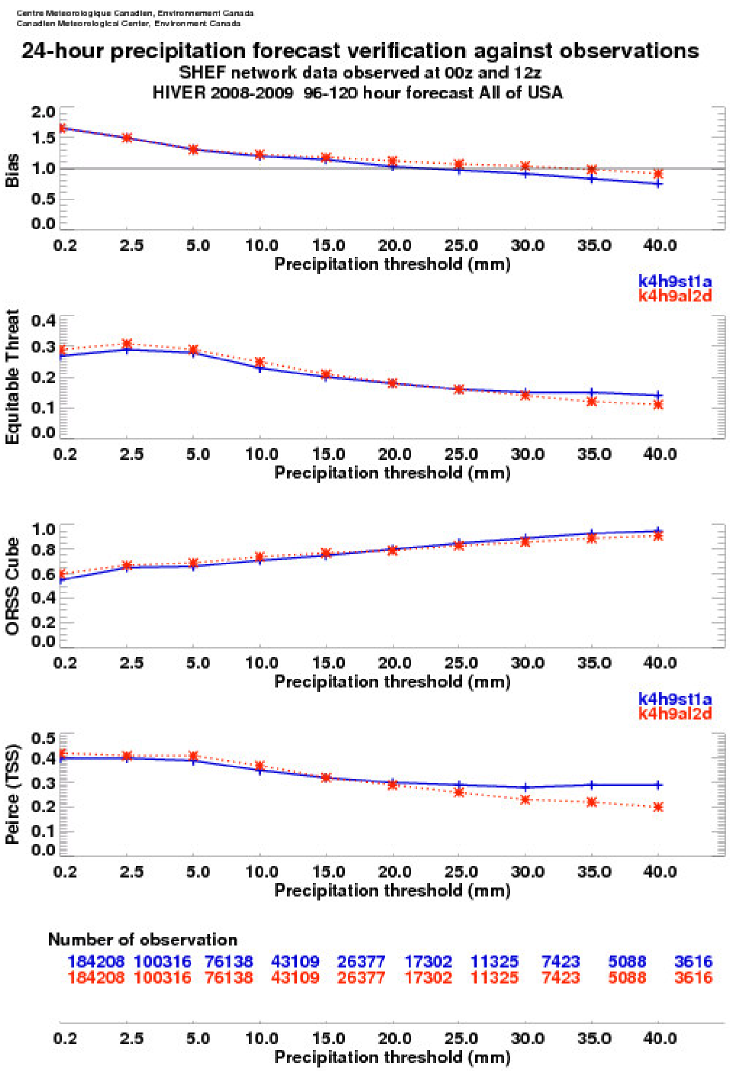
Summer – N. America (Synop)



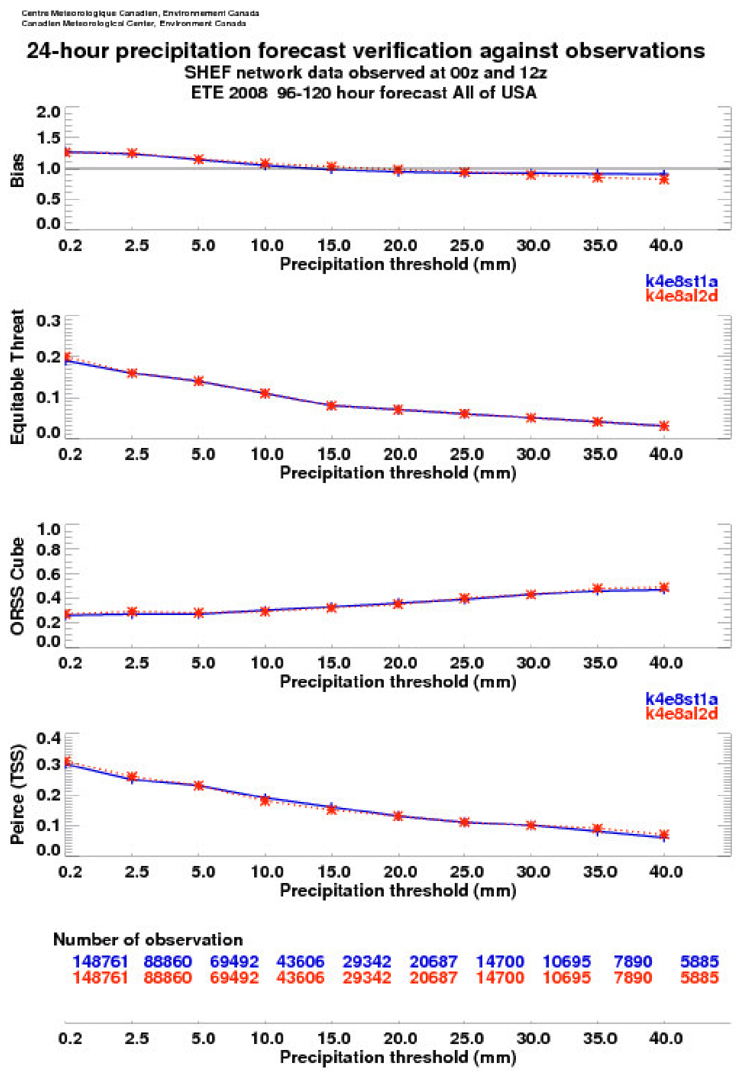
Results from final cycles

96h- 120h accumulated precipitation

Winter – USA (SHEF)



Summer – USA (SHEF)

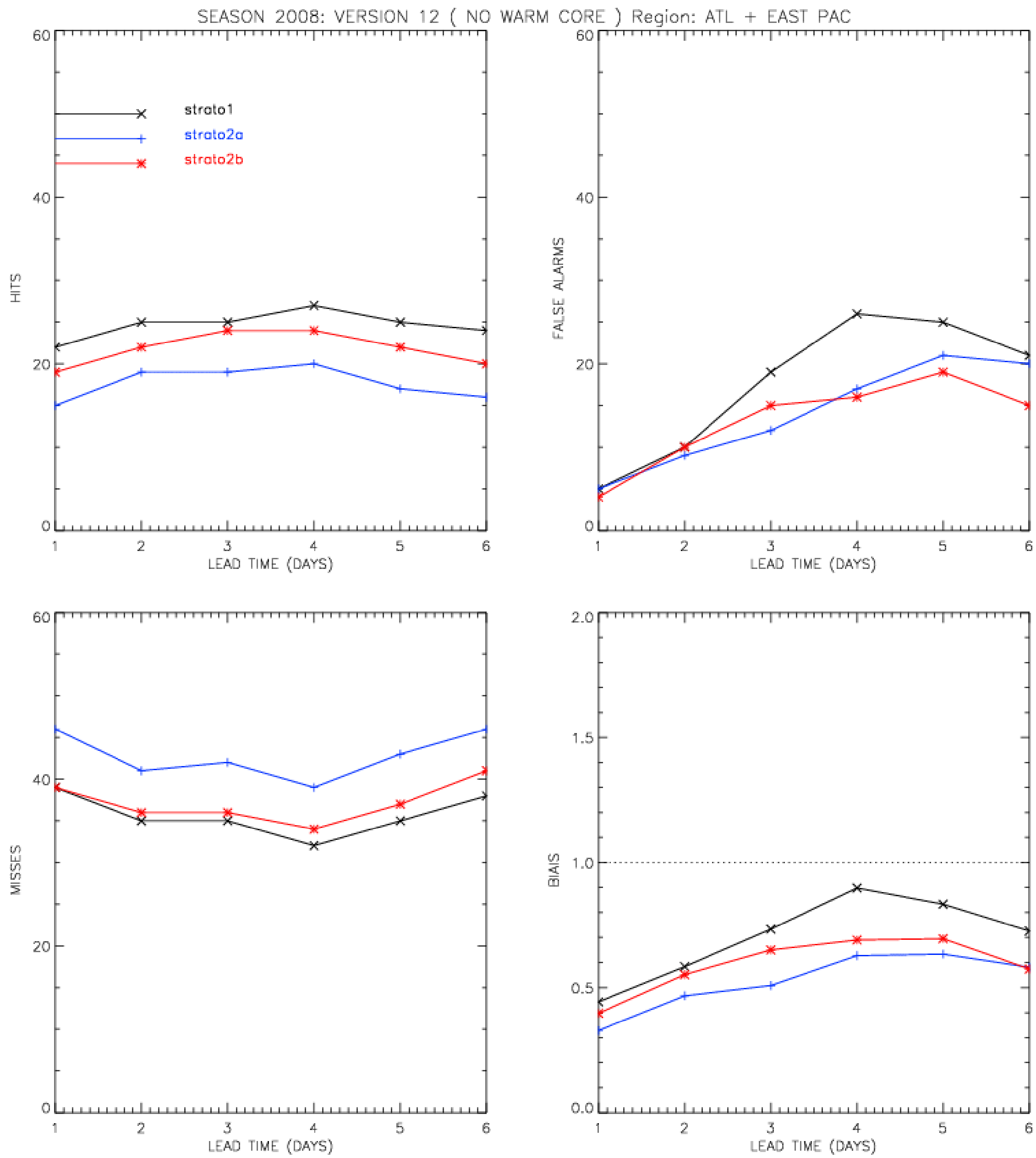


Impact on tropical cyclone forecasts

Atlantic and Eastern Pacific
Summer 2008

Operational
“Strato 2a”
“Strato 2b”

More “Hits” and fewer “Misses” than Strato-2a



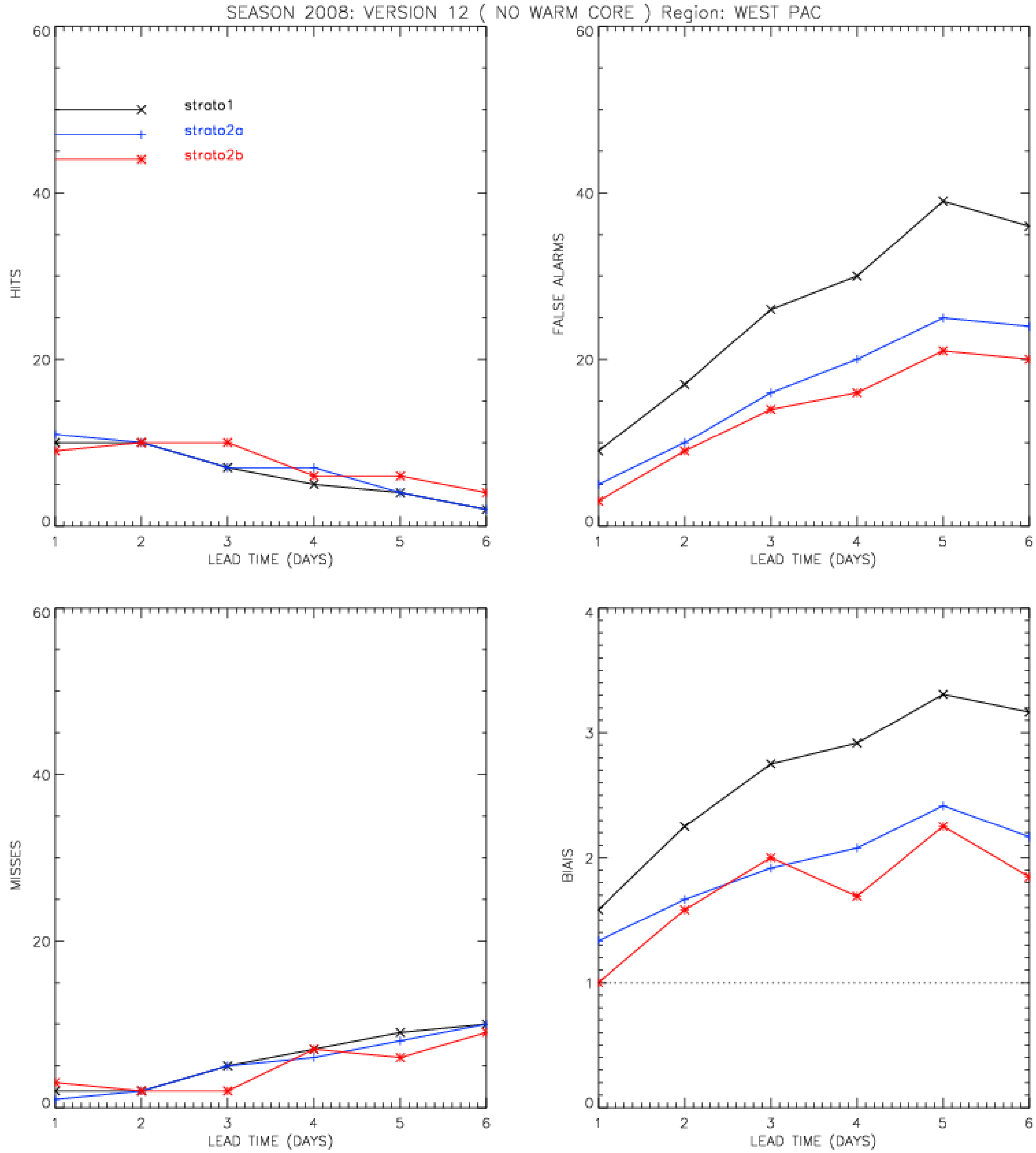
Environment Canada Environnement Canada

Impact on tropical cyclone forecasts

Western Pacific
Summer 2008

Operational
"Strato 2a"
"Strato 2b"

Slightly fewer "False alarms" than Strato-2a



Environment Canada Environnement Canada

Modifications to the regional deterministic prediction system

- All “Strato 2b” modifications adopted in regional configuration (new observations, reduced thinning, new SST, etc.)
- Modifications will be made directly to operational version of OCM configuration to ease transfer
- Experiments completed in ~2 weeks

Strato 2b – highlights of results

- Consistent improvement in extra-tropical troposphere: against raobs and analyses relative to operational configuration (up to ~6h gain at day 5)
- Slight degradation of extra-tropical tropopause temperature bias and stratospheric temperature bias
- Neutral or slight improvement in surface fields
- Neutral impact on precipitation scores
- Improved tropical cyclone forecasts:
  - improved “hits” and “misses” relative to Strato 2a in Atlantic & eastern Pacific
  - improved “false alarm rate” relative to Strato 1 & 2a in western Pacific
- Complete verification scores at: https://wiki.cmc.ec.gc.ca/wiki/Strato_2b/Evaluation_des_cycles_finaux

Next Steps

- Planning of transfer to operations already begun
- Nearly complete: incorporation of new components in kuklos config (no impact on results):
  - MPI version of variational code (analysis only)
  - External post-processing of analysis increment: addanalinc
- Verification of impact on regional system
- Co-ordination with delivery of EnKF/EPS upgrade
- Official CPOP proposal, October 19, 2010
- Presentation at A&P meeting in November