Environment Canada Environnement Canada

Canada

An analysis of tropical storm forecasts of the global GEM model

Ayrton Zadra

on behalf of the “strato-2 modelling team”:
B. Dugas, A.-M. Leduc, M. Roch
& P. Vaillancourt

CMC – 29 Jan 2010

Acknowledgments

- RPN: Stephane Belair, Martin Charron, Lubos Spacek, Michel Desgagne, Ron McTaggart-Cowan, Marcel Valle
- CHC: Chris Fogarty
- CMD: Manon Lajoie, Alain Patoine
- CMC: Laura Lam, Andre Giguere, Allan Rahill
- UQAM: Louis-Philippe Caron, Katja Winger
- ARMA: “strato-2 data assimilation team”

Outline

- TC tracking and verification
- mesoglobal *versus* mesostrato (strato-1)
- strato-2 project
  - description of model changes
  - TC statistics
  - other scores
- Potential Intensity diagnostics
- Final remarks and conclusions

TC statistics:
Step 1 - Tracking

> Tracking program originally developed by **K. Winger** and **L.-P. Caron** (UQAM) to study TC climatology in GEMCLIM; adapted by **A.-M. Leduc** for strato-2 project

> **MAIN CONDITIONS** used to identify and track tropical storms in the latest version of the tracking program.

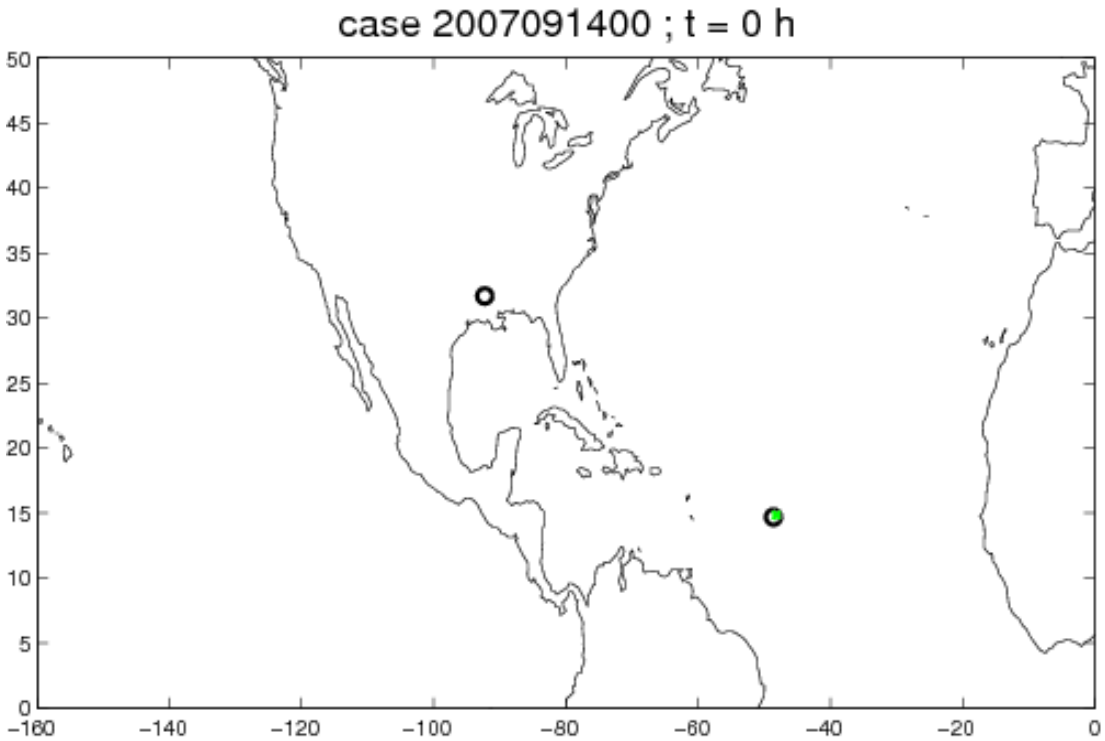
1) Find minimum pressure and must be < 1012 mb
2) The relative vorticity at the center must be > 1E-5 s-1
3) 850 mb wind > 250 mb wind within radius of 170km
4) sfc wind > w_max (22 kts) within a 170km radius
5) distance between 2 storms > distcc (400km)
6) optional warm core condition: Temperature within 170 km must be > T field for 3 levels: 700,500,250 mb

Example of tracking output

Storm#	Point#	i	j	date	time	lat	lon	vort	pres	wind
1	1	424	415	2008100800	84	34.35	-169.65	0.00024	1006.39172	36.31882
1	2	427	416	2008100806	90	34.65	-168.30	0.00031	1003.41284	40.96595
1	3	431	416	2008100812	96	34.65	-166.50	0.00028	1001.40710	37.94922
1	4	435	421	2008100818	102	36.15	-164.70	0.00026	1000.51678	38.36294
1	5	439	423	2008100900	108	36.75	-162.90	0.00022	998.91016	37.01458
1	6	445	426	2008100906	114	37.65	-160.20	0.00026	999.48328	39.13258
1	7	450	431	2008100912	120	39.15	-157.95	0.00023	999.67926	37.87506
2	1	606	332	2008100612	48	9.45	-87.75	0.00036	1007.53851	22.39978
2	2	606	331	2008100618	54	9.15	-87.75	0.00037	1007.77246	28.02093
2	3	608	330	2008100700	60	8.85	-86.85	0.00042	1006.43024	29.09504
2	4	608	331	2008100706	66	9.15	-86.85	0.00035	1007.10114	26.94382

NOTE: Similar data are available from TC best-track data (e.g. NHC) for observed storms.

Example: observed and forecast tracks



black: best track data

color: tracks from different versions of the model

* animations available in
http:/iweb.cmc.ec.gc.ca/~armnaza/tracking_anims_strato.html

TC statistics:
Step 2 – Full period (6-day) assessment

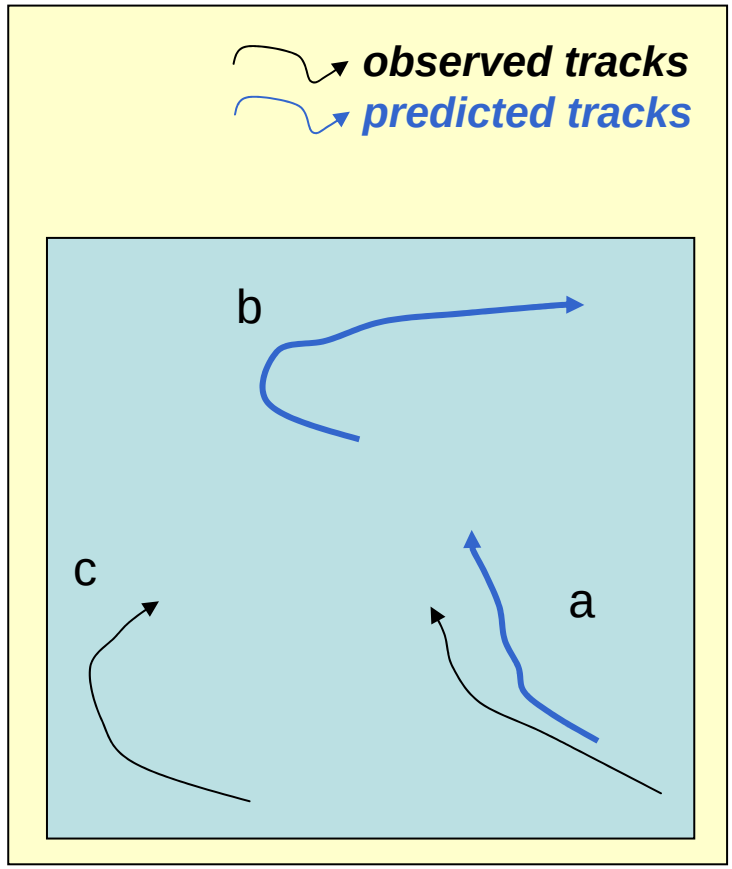
> each predicted TC is compared to each observed TC using information from the entire 6-day period, in an attempt to **identify TC pairs**.

> (a) **TC pair**: predicted TC is found within **600 km** of an observed TC (a temporary hit), at least once during the 6-day period.

> (b) if a predicted TC is never paired: **unequivocal false alarm**

> (c) If an observed TC is never paired: **unequivocal miss**

> for each pair of predicted-observed TCs -- i.e. a temporary hit -- proceed to step 3 (instantaneous classification)

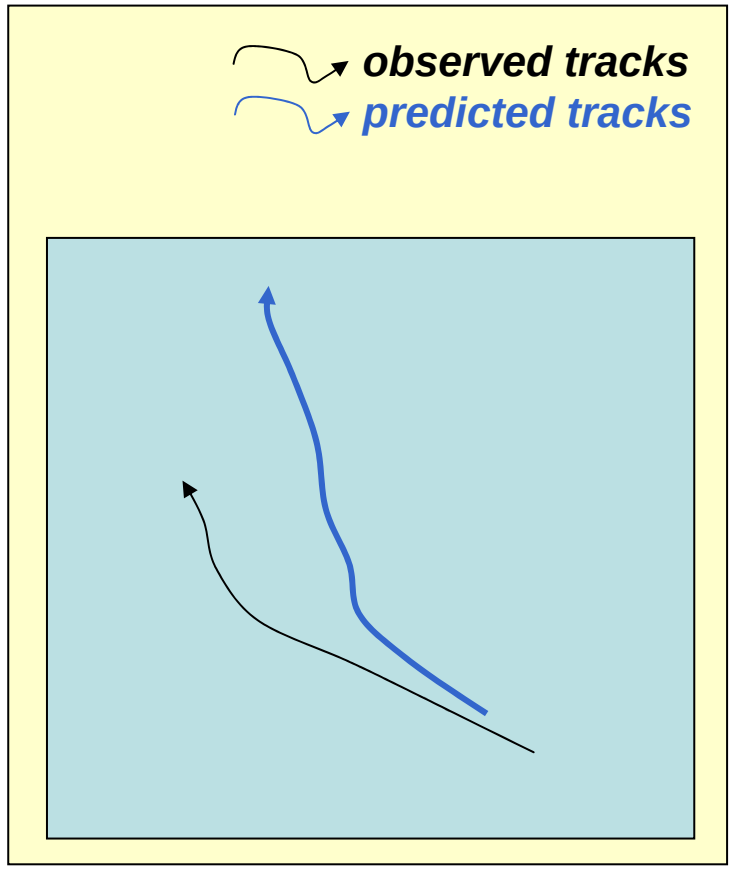


TC statistics:
Step 3 – Instantaneous assessment

> suppose data available every 6h

> at each timestep, count # of unequivocal false alarms and misses (step 2)

> for each pair of predicted-observed TCs:
- **hit**: predicted and observed TCs co-exist and are close enough (distance <= 600 km)
- **temporary track-error**: predicted and observed TCs co-exist but are too far apart (distance > 600 km)
- **temporary false alarm**: predicted TC exists but the the observed TC does not
- **temporary miss**: observed TC exists but the predicted TC does not
- **temporary correct-no**: neither predicted nor observed TC exist



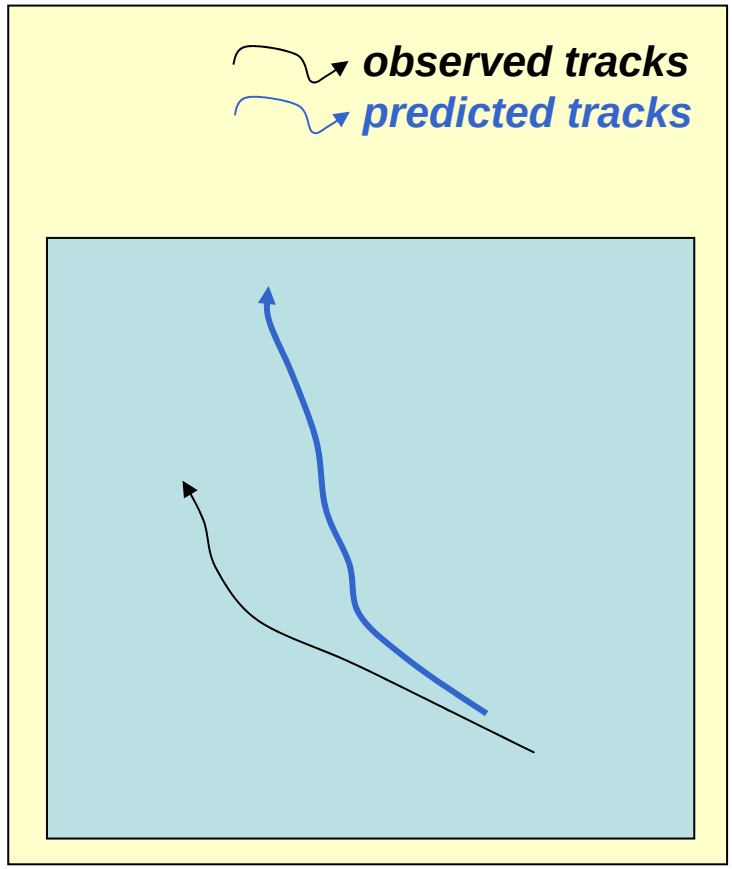
TC statistics:
Step 3 – Instantaneous assessment (cont.)

> temporary errors (temporary track error, temporary false alarm, or temporary miss): possibly errors in the initialization / intensification / propagation of predicted storm -- but not a "complete bust"

> instantaneous "total" # of false alarms and misses:

[# false alarms] =
[# unequivocal false alarms] +
[# temporary false alarms] +
[# temporary track errors]

[# misses] =
[# unequivocal misses] +
[# temporary misses] +
[# temporary track errors]



TC statistics:
Step 4 – 24-h averages

> example:

[average # hits at day 1] =

{ [# hits at 6h] + [# hits at 12h] + [# hits at 18h] + [# hits at 24h] } / 4

TC statistics:
Step 5 – Ensemble average & bootstrapping

> averaging over **ensemble of N cases/forecasts** available

> 2000 random re-samples of the N cases are generated, to estimate the uncertainty

TC statistics: UNEQUIVOCAL FALSE ALARMS

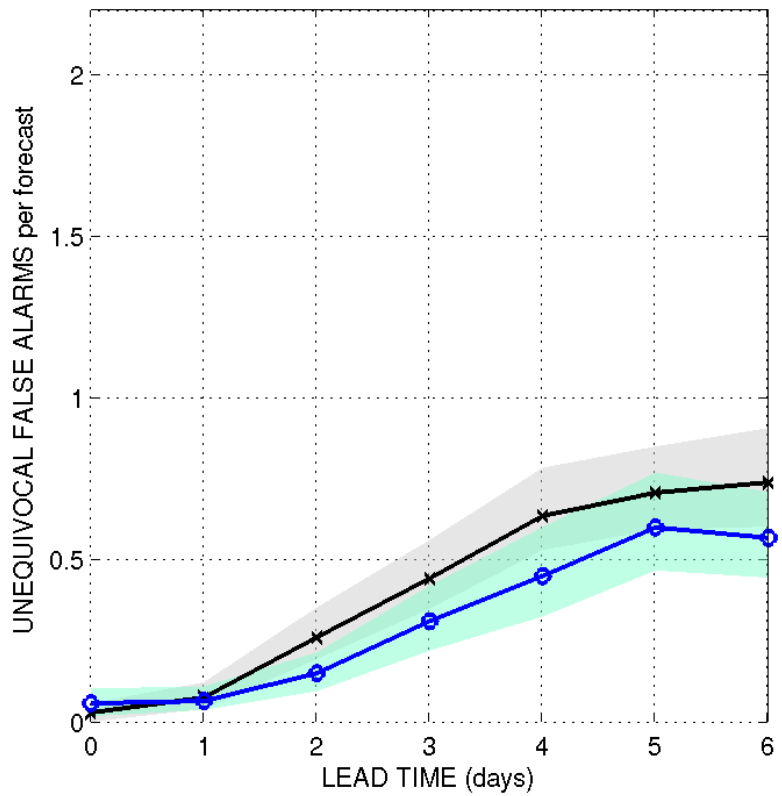
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-1

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: FALSE ALARMS

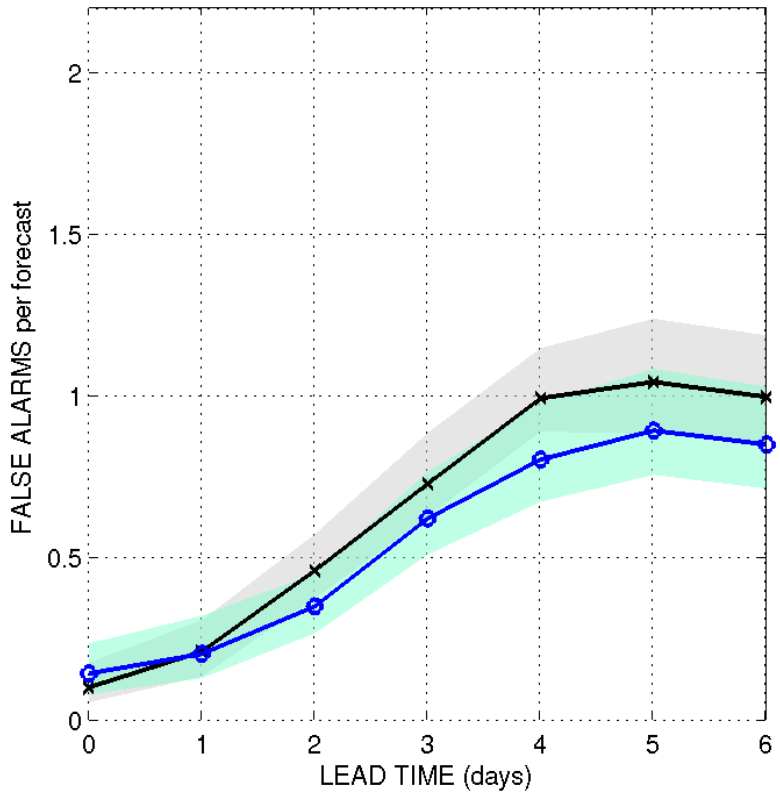
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-1

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: HITS

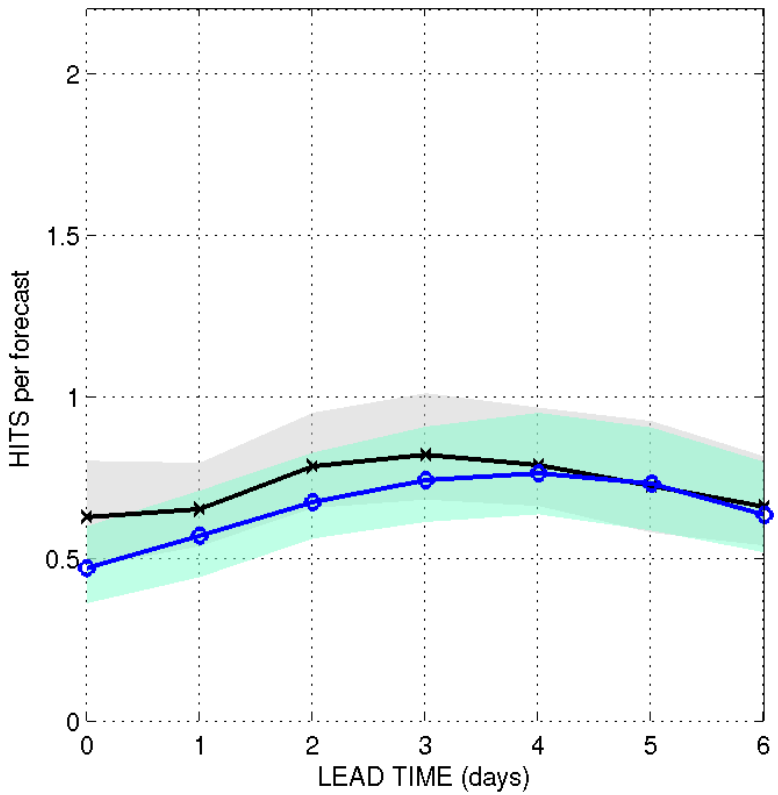
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-1

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: MISSES

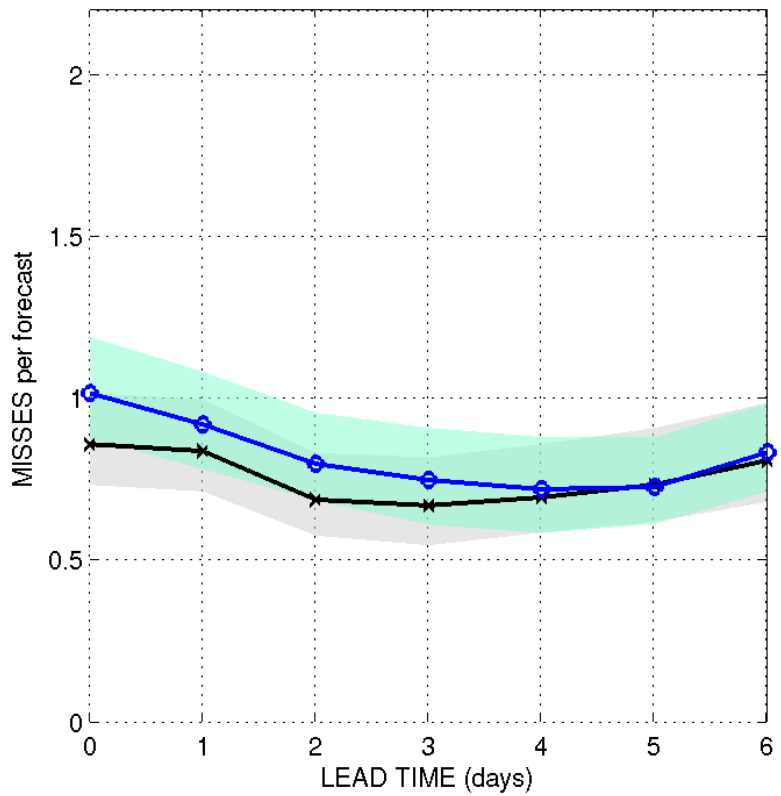
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-1

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: BIAS

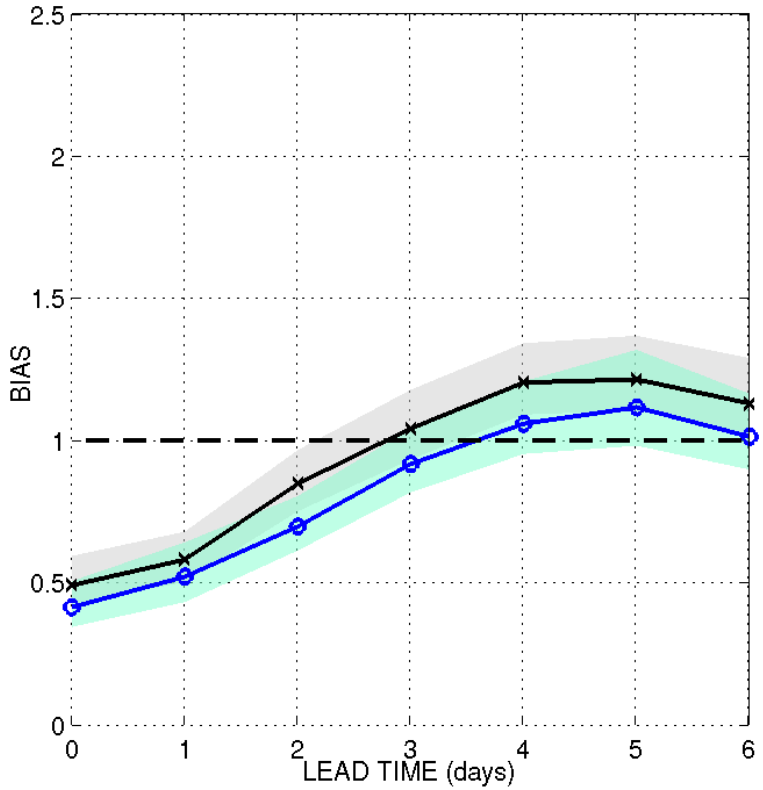
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-1

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: FALSE ALARMS

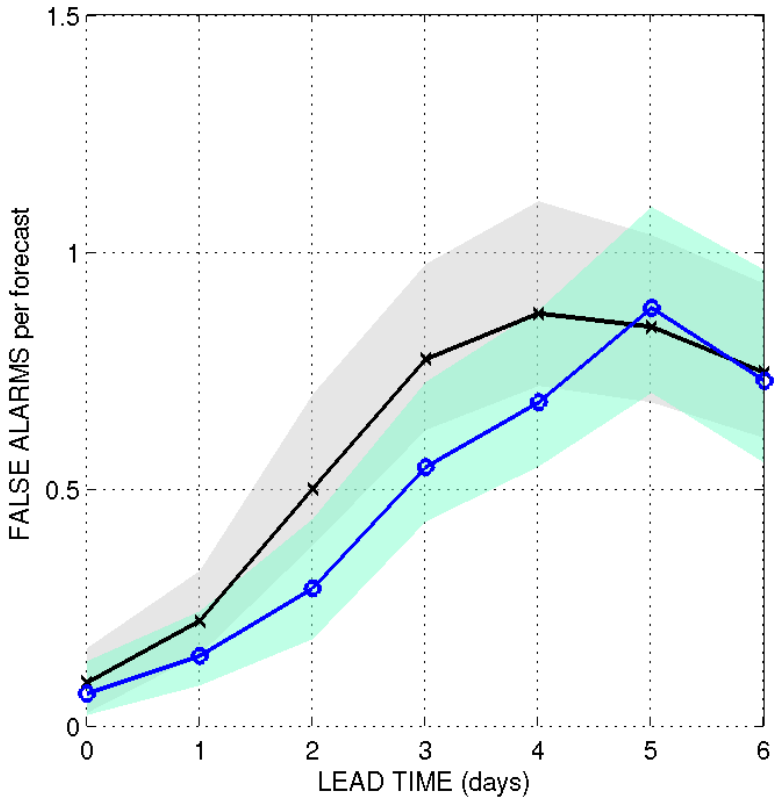
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

West Pac

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-1

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



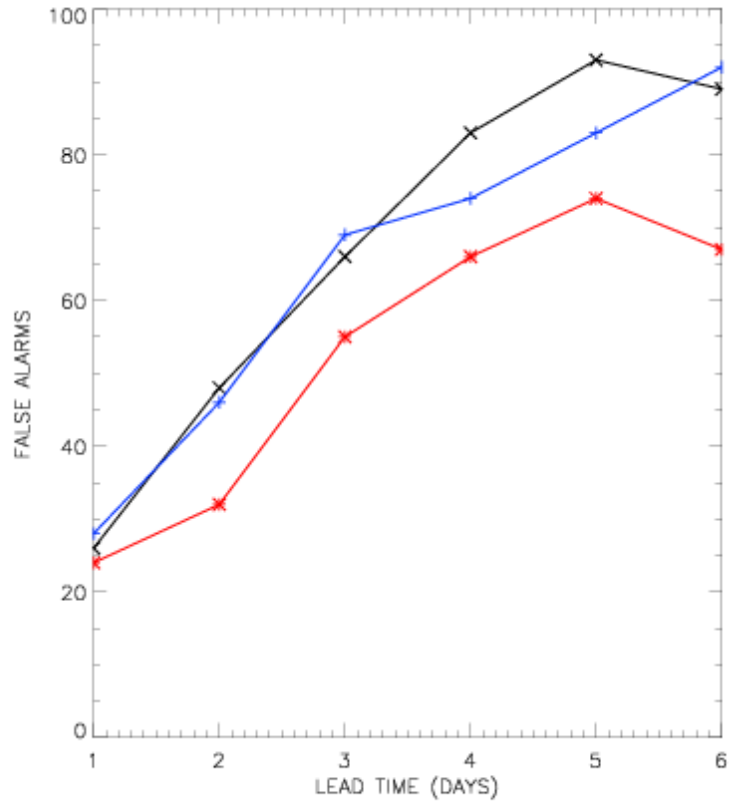
From mesoglobal to mesostrato: what led to the reduction of TC false alarms?

season: 2008

region: Atlantic + East Pacific

color code:

- **meso with newrad**
- **strato with newrad**
- **strato with cccmarad**



The Strato-2 project

- **Main goal**: further **reduce the TC false alarm rate** in the global model forecasts

- **Time frame**:
  - start of project: summer 2008
  - expected final cycles: summer 2009

- **Work plan**:
  - identify and document false alarm cases
  - develop diagnostic tools (tracking, verification, etc.)
  - investigate possible solutions (e.g. changes in model physics)

The Strato-2 project

Physical parameters & parameterizations identified as candidates for changes/adjustments:

- **radiative transfer** scheme

- **deep convection** (Kain & Fritsch) scheme
  - convective momentum transfer (CMT)
  - triggering parameters (e.g. critical vertical velocity)

- **thermal roughness length over water** in the tropics (Z0T)

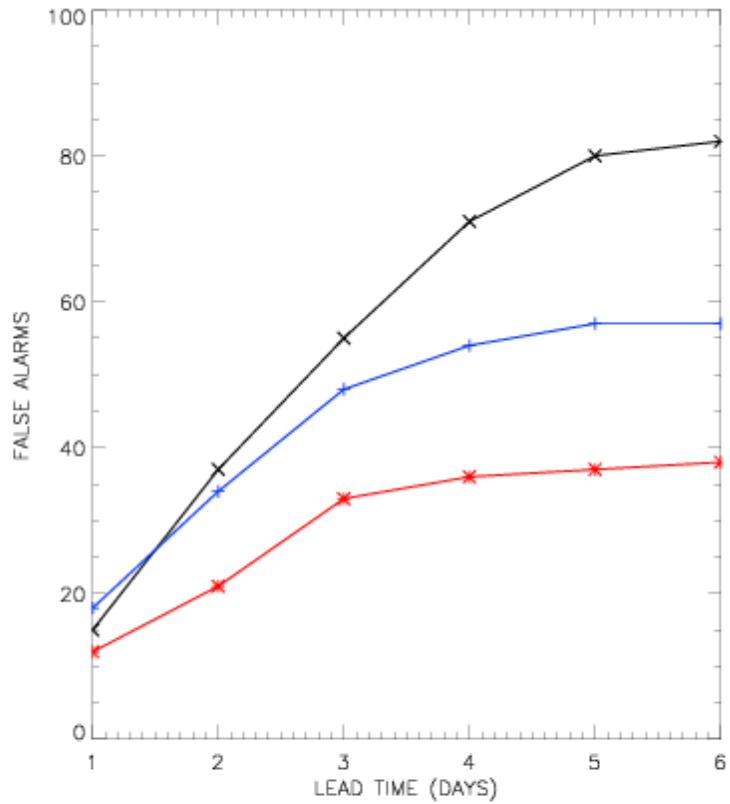
Convective momentum transport (CMT): impact on TC false alarms

season: 2007

region: Atlantic + East Pacific

color code:

- **meso NO CMT**
- **strato NO CMT**
- **strato WITH CMT**



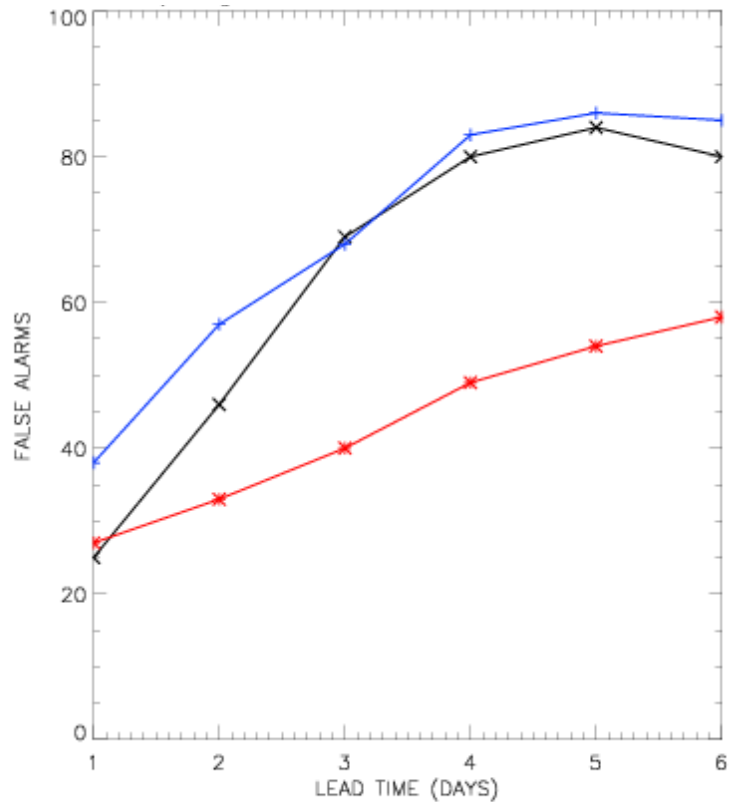
Convective momentum transport (CMT): impact on TC false alarms

season: 2007

region: West Pacific

color code:

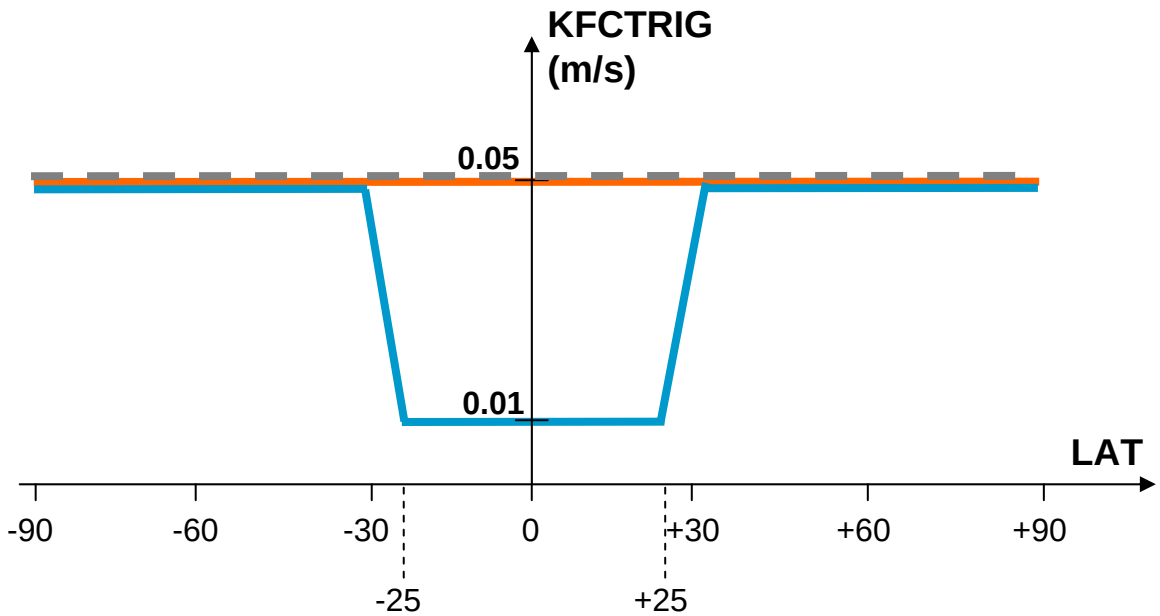
- **meso NO CMT**
- **strato NO CMT**
- **strato WITH CMT**



Changes in the Kain-Fritsch scheme: *la rampe masquee*

- Following a suggestion by S. Belair

La rampe masquee:



KFCTRIG = threshold vertical velocity used in the trigger function of Kain-Fritsch

over oceans

over land or fresh water

currently operational over land & water

Changes in the Kain-Fritsch scheme: *la rampe masquee* (cont.)

- Other examples of “modulation” of the triggering vertical velocity parameter:
  - “temporal” dependence used in the regional model
  - resolution dependence used in GEMCLIM
  - moisture dependence also found in the literature (e.g. dependence on height of the lifting condensation level)

- Extent of the constant Z0T value over water (parameter z0tlat) adjusted according to the *rampe masquee* range

TC statistics: UNEQUIVOCAL FALSE ALARMS

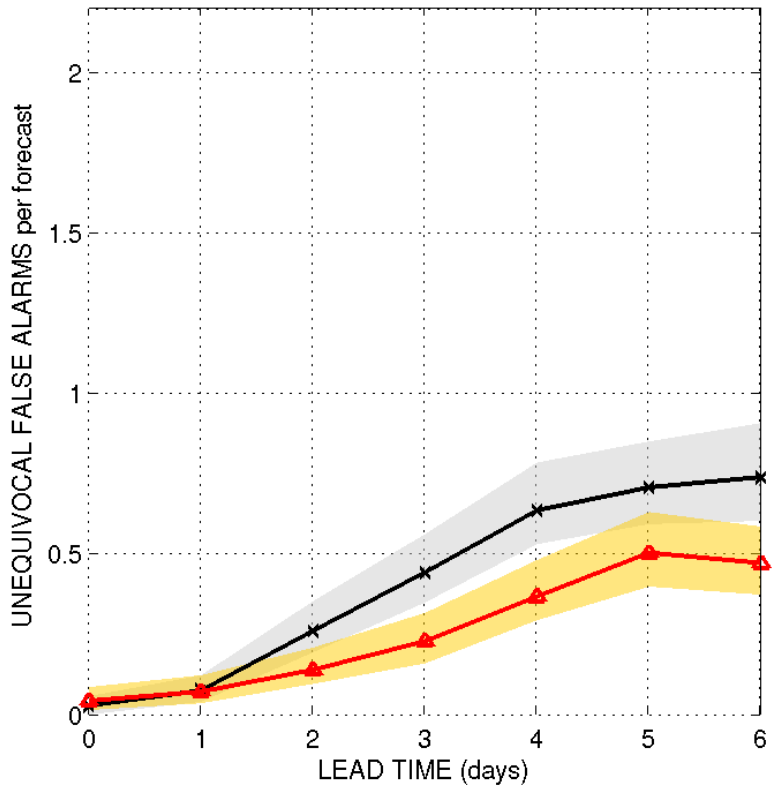
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-2

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: FALSE ALARMS

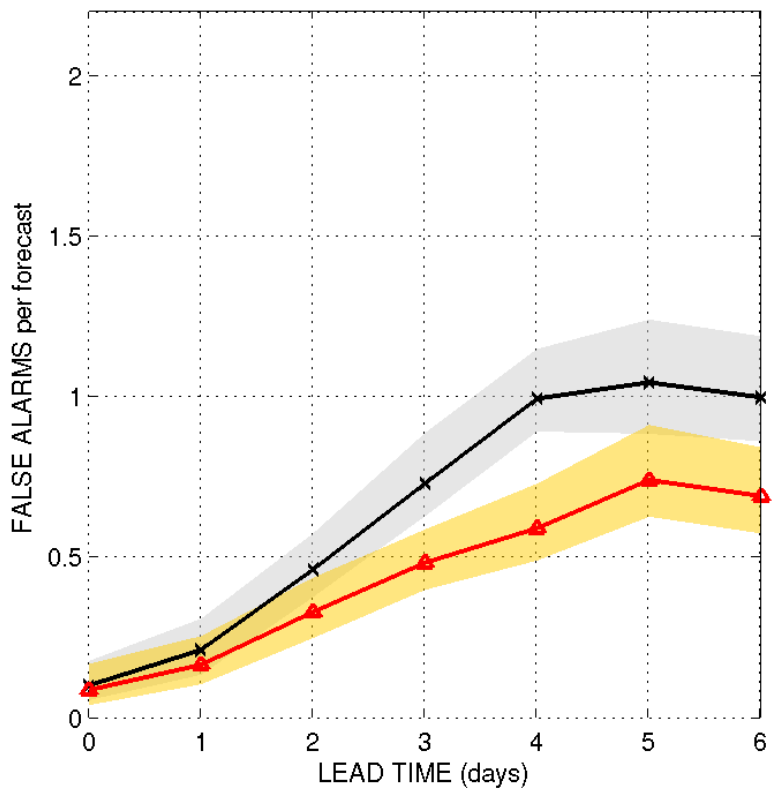
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-2

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: HITS

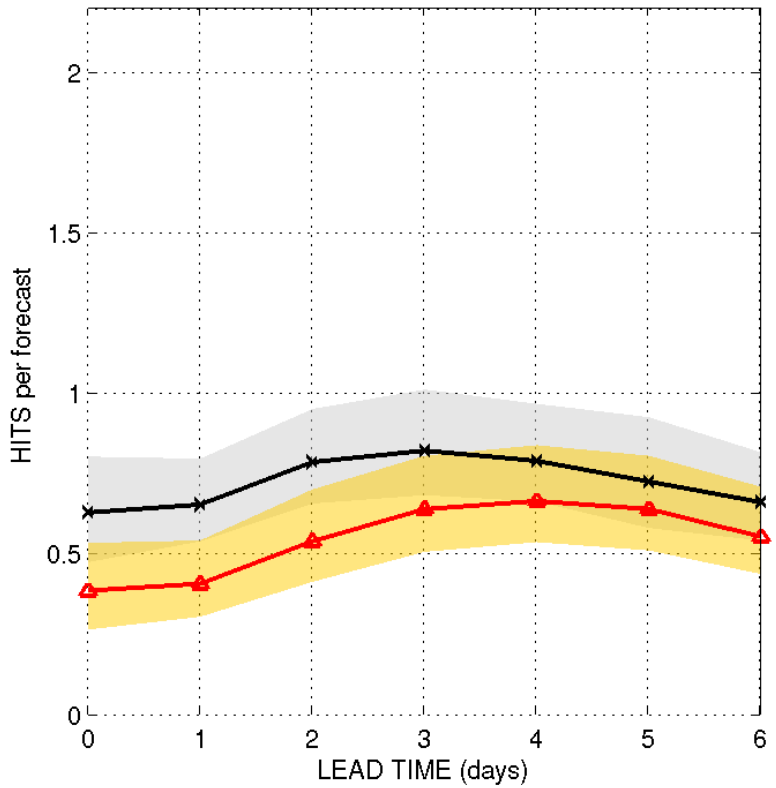
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-2

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: MISSES

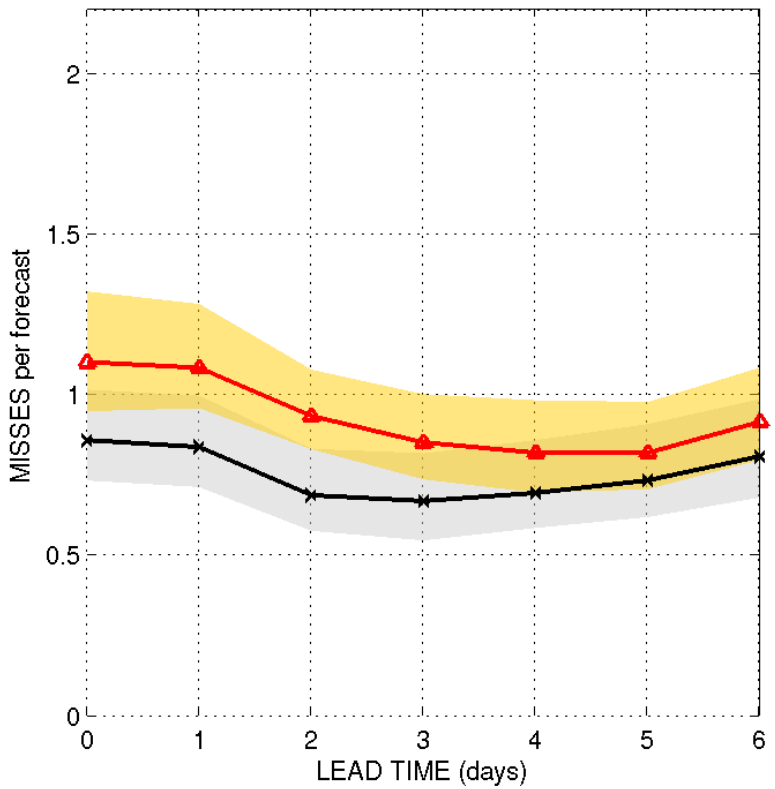
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-2

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: BIAS

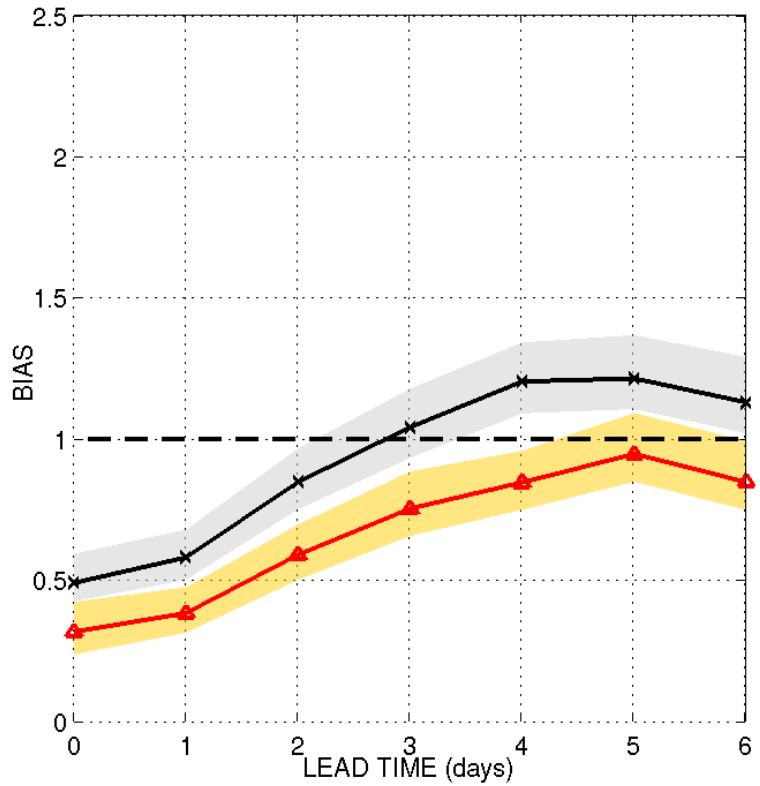
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

ATL + EPAC

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-2

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



TC statistics: FALSE ALARMS

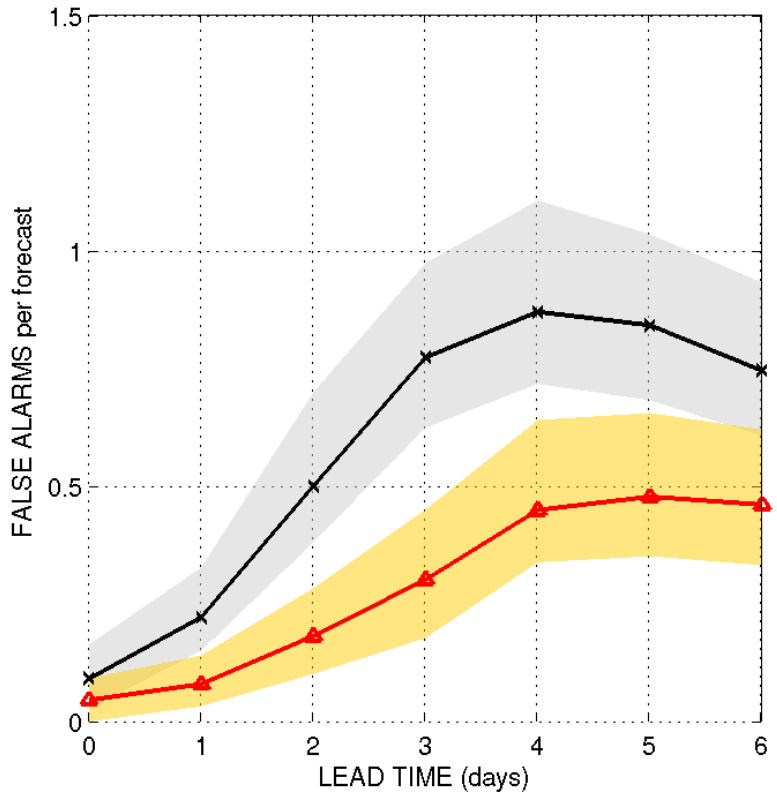
2008 season
(70 progs:
03-Jul to 15-Oct, every 36h)

West Pac

Verification against
NHC best track data

Color code:
- Mesoglobal
- Strato-2

Shaded areas indicate
estimates of uncertainty
at the 90% significance level



Impact of strato-2 changes on other verification scores

> For the **standard verification scores**, i.e.

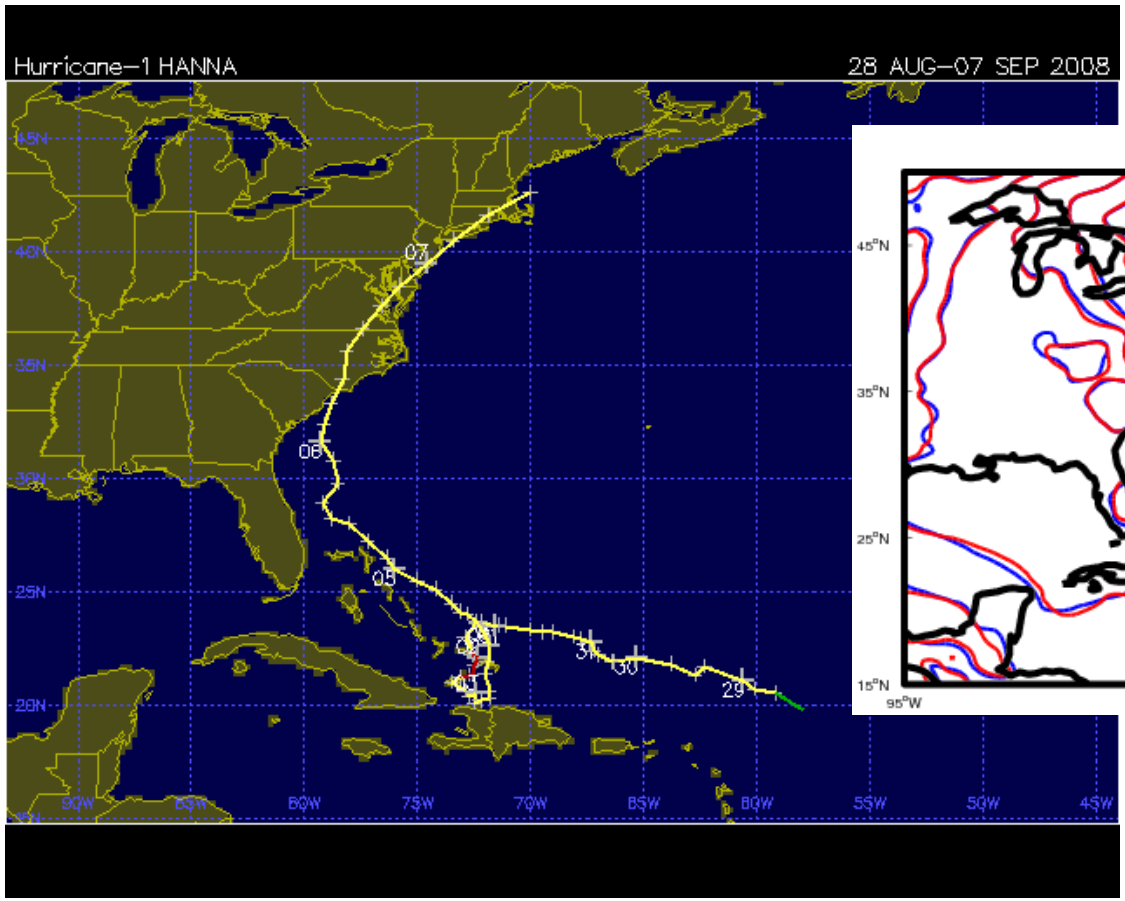
- *upper-air and surface arcad scores*
- *anomaly correlation*
- *precipitation over N. America*

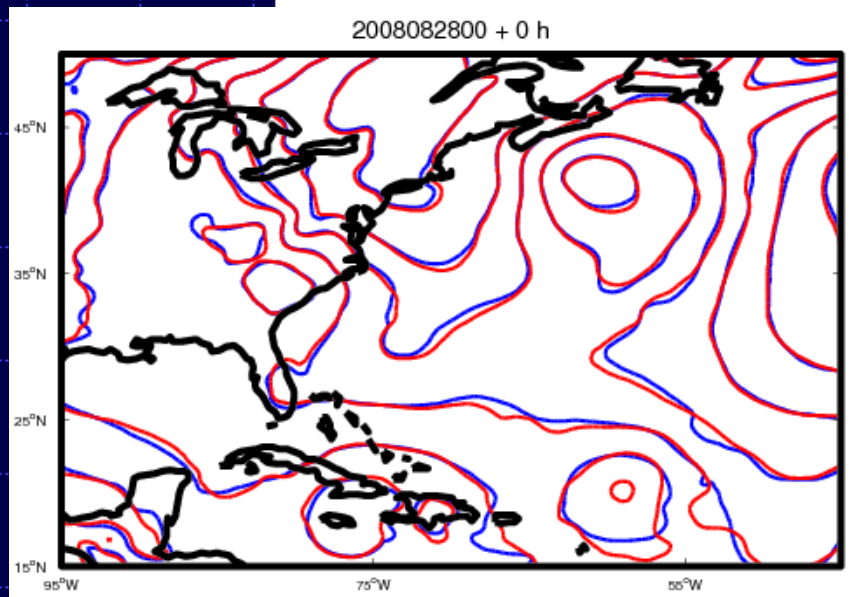
the impact is **mostly neutral in the summer and winter**, and **positive in the fall**.

> Precipitation **verification against GPCP data**: slight improvement at mid- and long-range (depends on the season)

> For **actual TCs**: based on results for 2007, 2008 and 2009 season, the impact if **mostly neutral**.

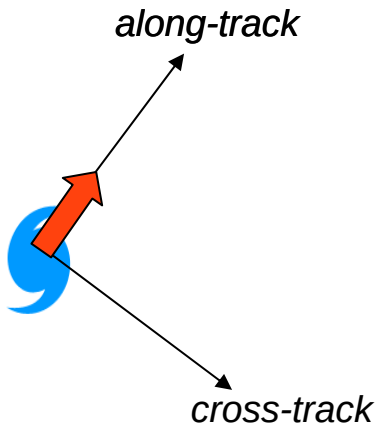
Example: Forecast trajectory of observed tropical cyclones



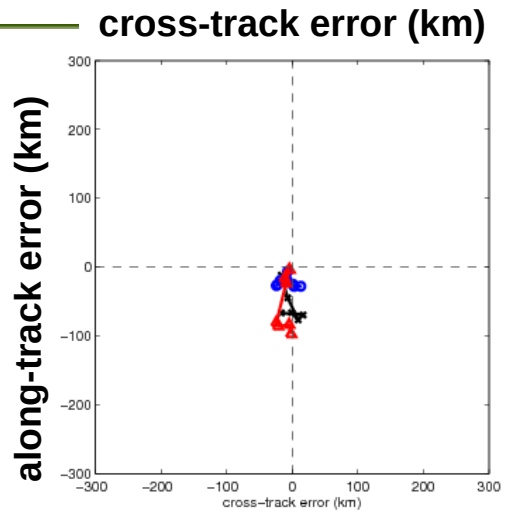


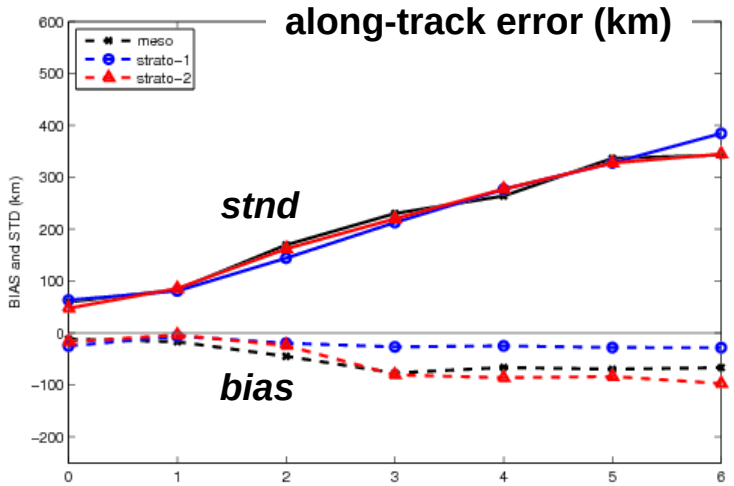
* animations available in
http:/iweb.cmc.ec.gc.ca/~armnaza/anims_hanna_cycle.html

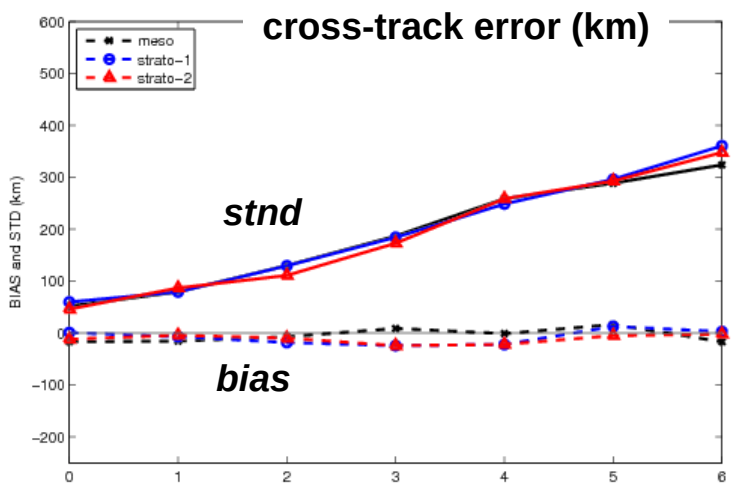
Track-position error statistics



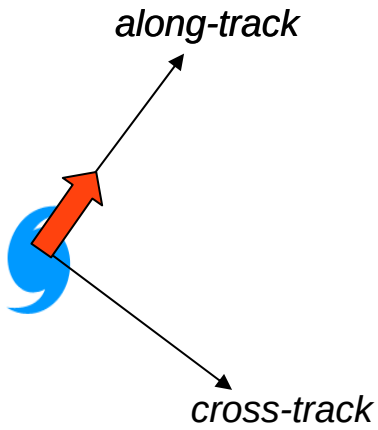
Atlantic
+
East Pacific



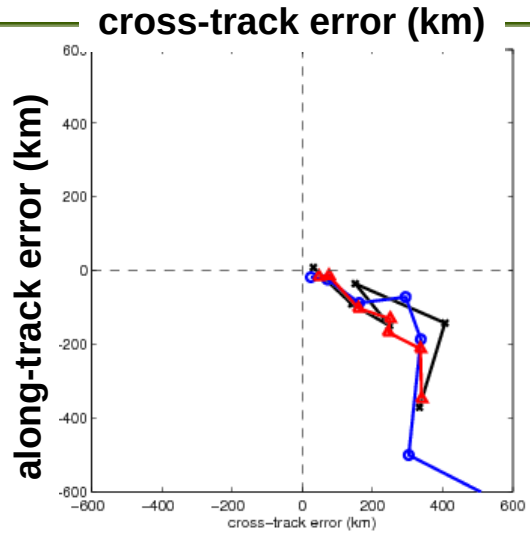


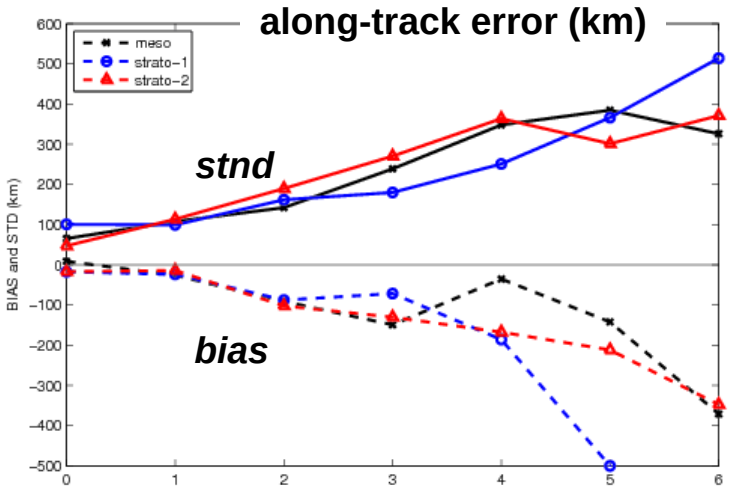


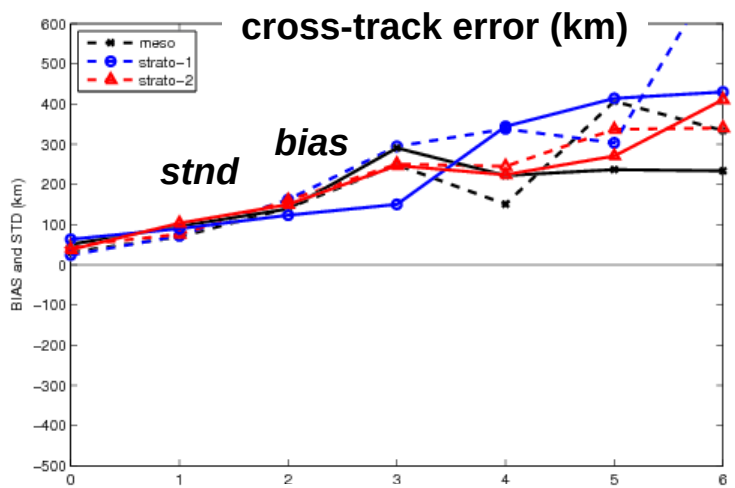
Track-position error statistics



West Pacific

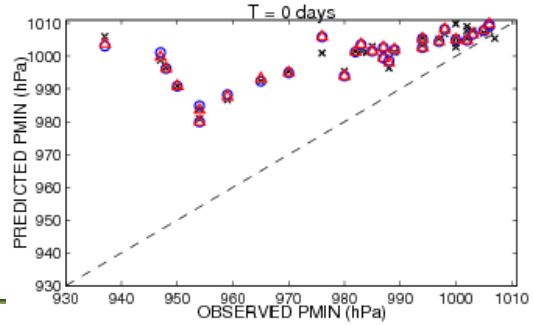


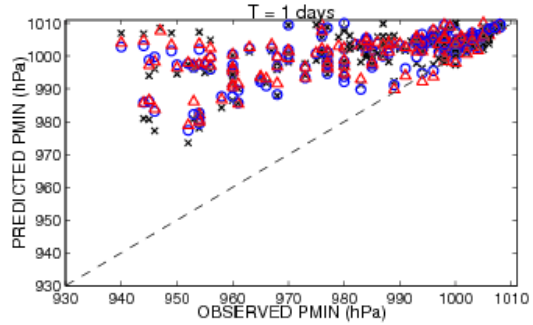


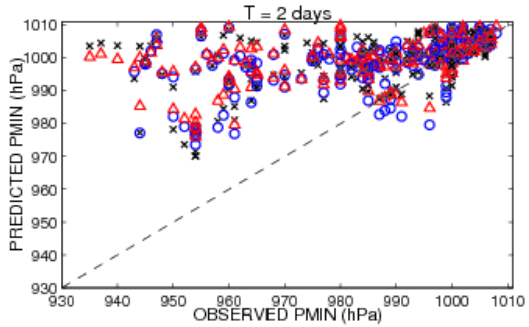


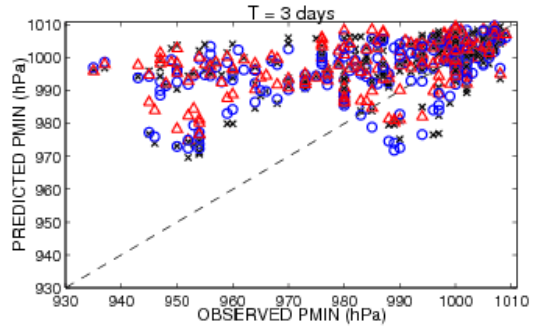
Central pressure error statistics

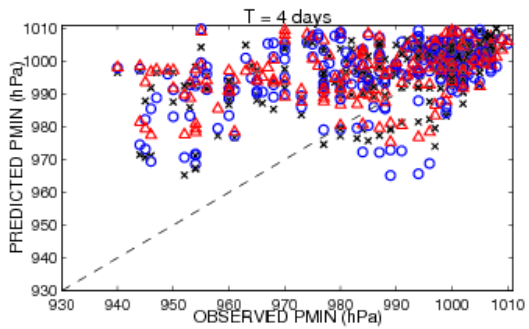
Atlantic
+
East Pacific

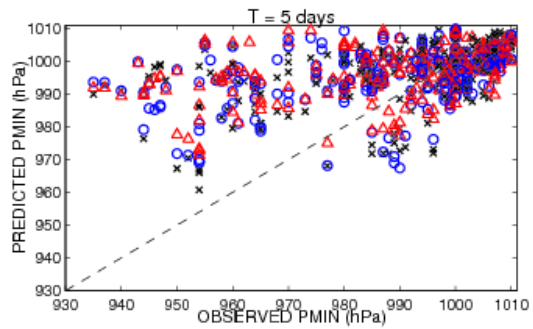


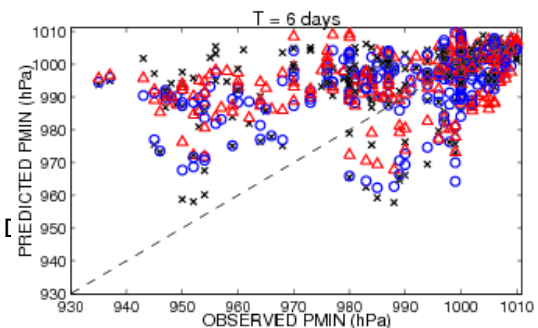


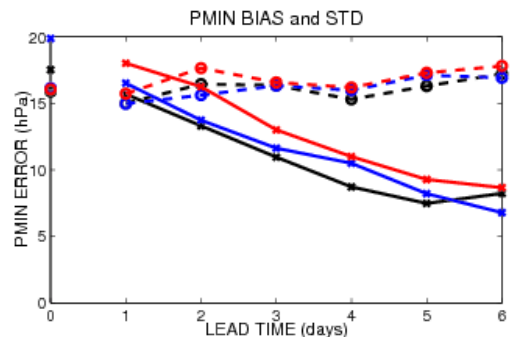








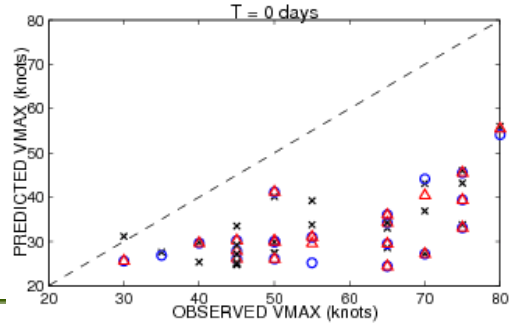


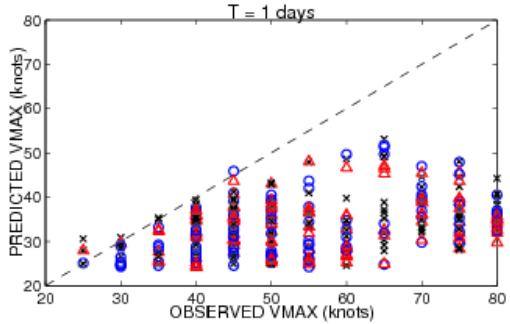


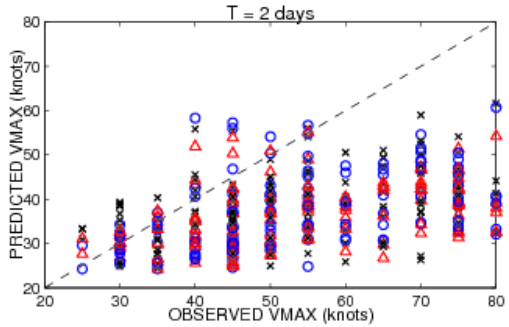
Environment Canada Environnement Canada

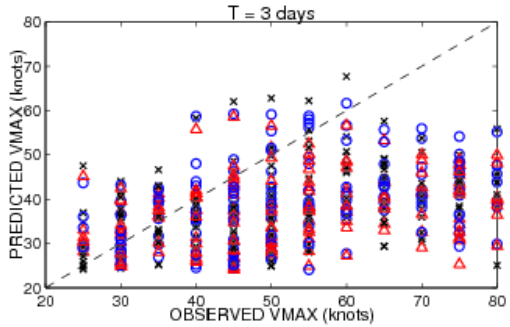
Max wind speed error statistics

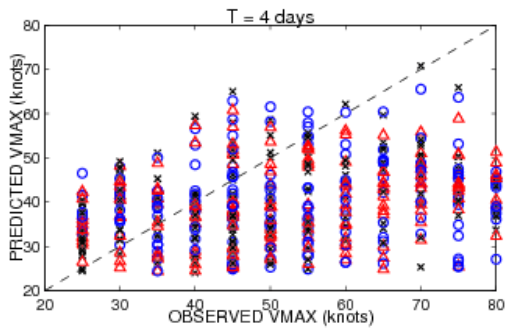
Atlantic
+
East Pacific

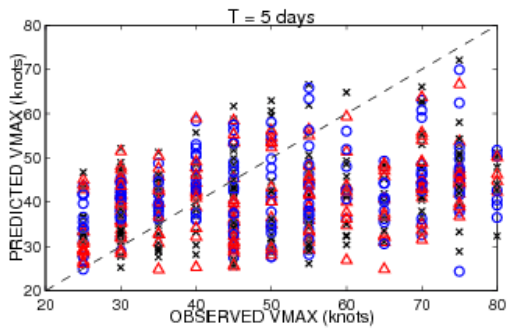


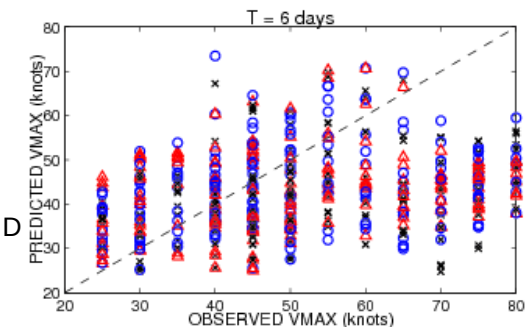


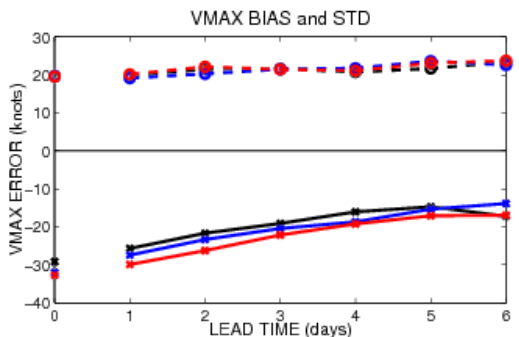








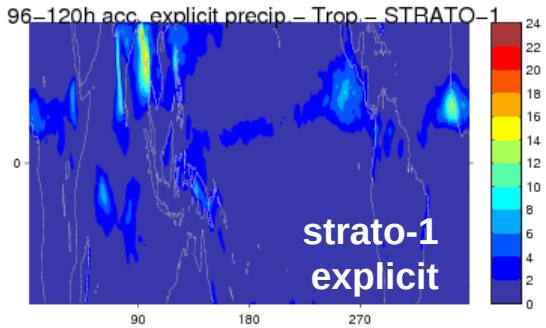


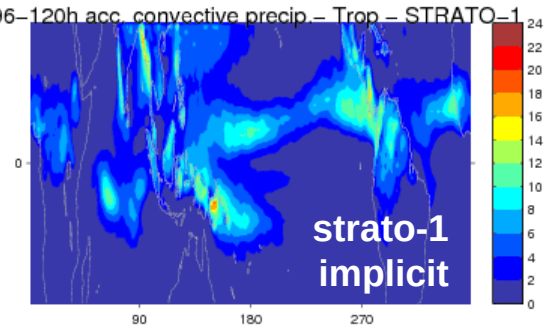


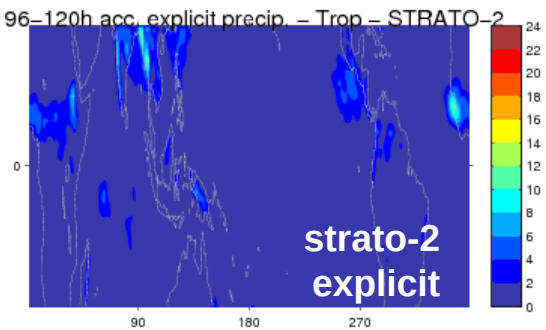
D

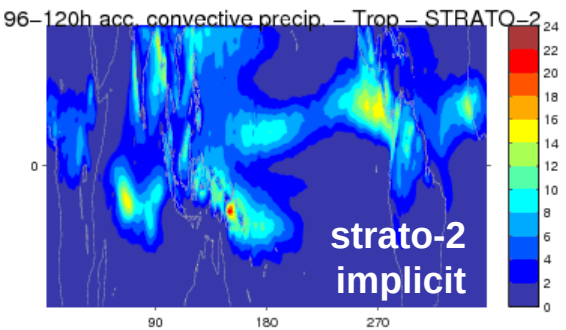
Environment Canada Environnement Canada

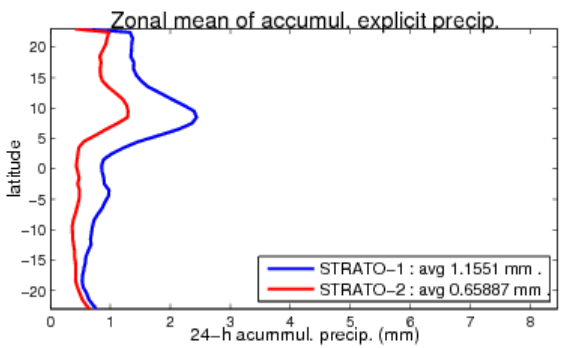
Precipitation partition in the tropics: explicit versus implicit contributions

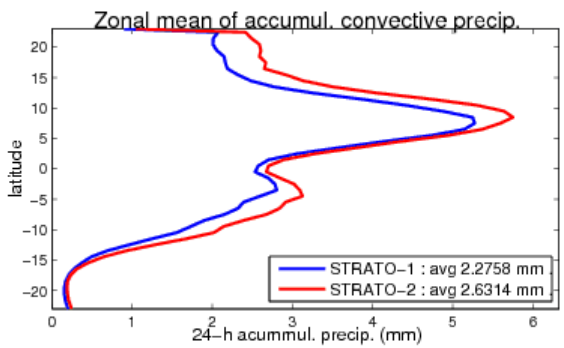












Enviro Canada

Canada

Example of upper-air scores

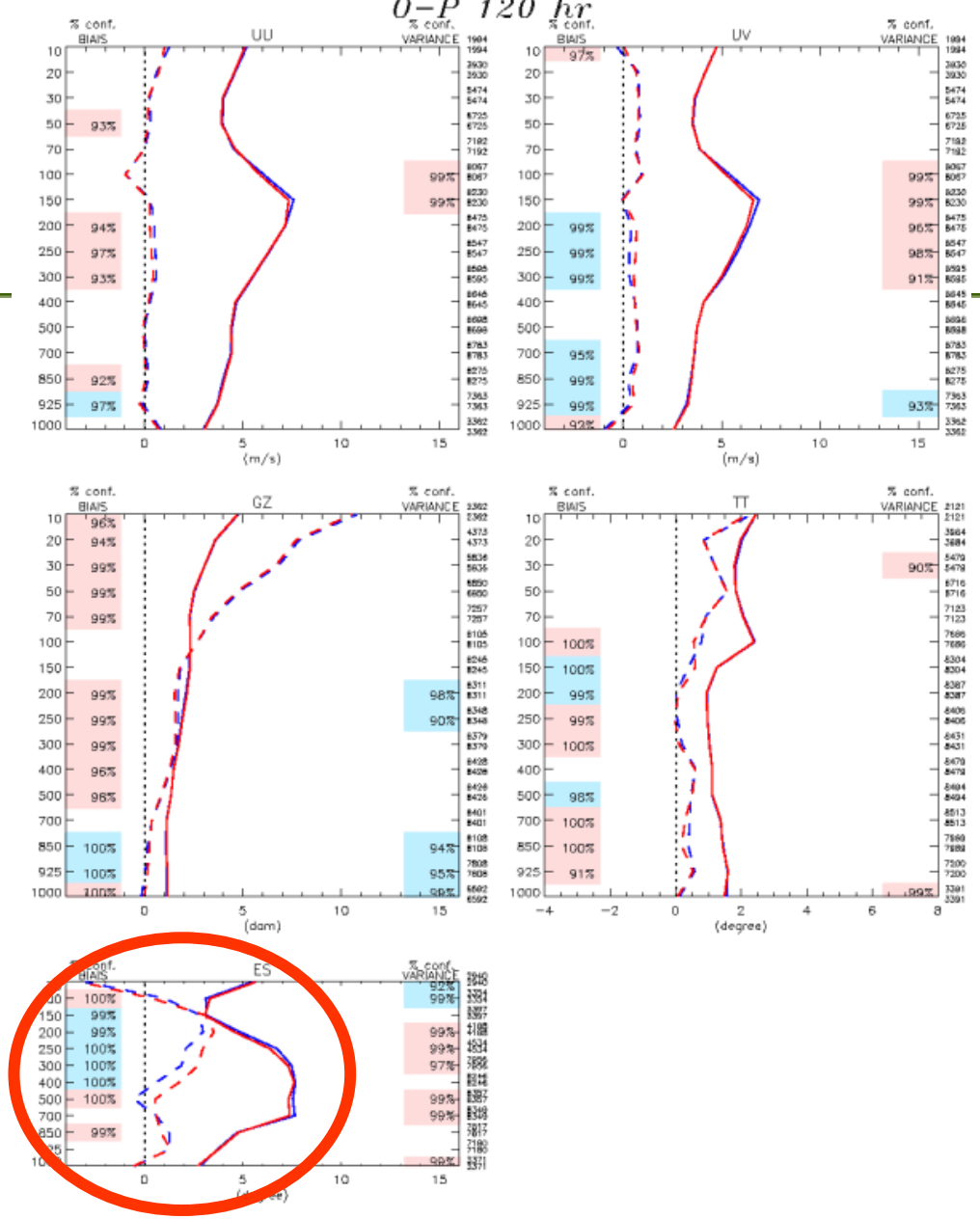
Tropics

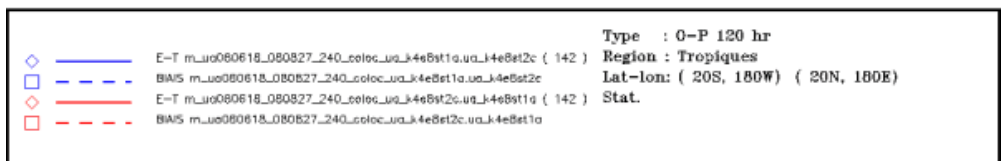
120 h

Summer 2008

142 cases

4D-Var cycle





DRAFT –

Environment Canada

Environnement Canada

Hurricane potential intensity

[in collaboration with R. McTaggart-Cowan]

- theory developed by Emanuel, K.A., 1995, JAS
- estimates of potential maximum winds V_m and potential minimum central pressure p_c :

$$V_m^2 = \frac{c_k}{c_D}\frac{T_s}{T_D}[CAPE^* - CAPE]_m$$

$$c_p T_s \ln\frac{p_0}{p_m} = \frac{1}{2}V_m^2 + CAPE\Big]_m$$

$$c_p T_s \ln\frac{p_m}{p_c} = \frac{1}{2}V_m^2$$

CAPE* = convective available potential energy of air lifted from saturation at sea level in reference to the environmental sounding
CAPE = same, for boundary layer air [both quantities are evaluated near the radius of maximum wind]
Ts = ocean temperature
Td = mean outflow temperature,
Ck = exchange coefficient for enthalpy
Cd = drag coefficient (for momentum)
Pm = surface pressure at radius of maximum winds
P0 = ambient surface pressure

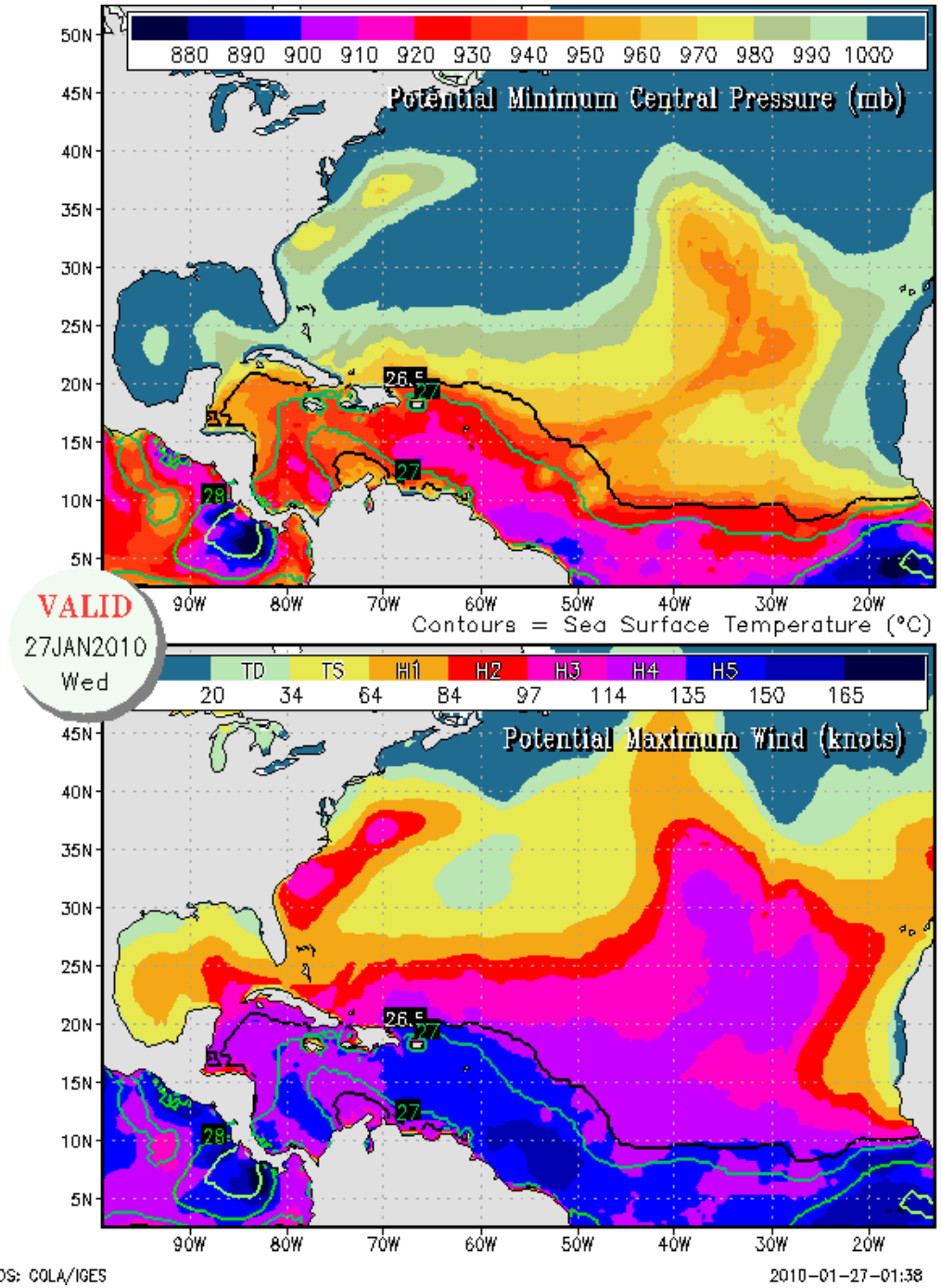
Example

> The maps are based on data from the **00Z global operational analysis from NCEP** for the date shown on the plot.

> Also shown are the sea surface temperatures (°C).

> The bottom panel shows the potential maximum wind speed expressed in terms of the type and severity of storm they would represent (TD = Tropical Depression, TS = Tropical Storm, H1-H5 = Hurricanes of category 1-5 on the Saffir-Simpson scale).

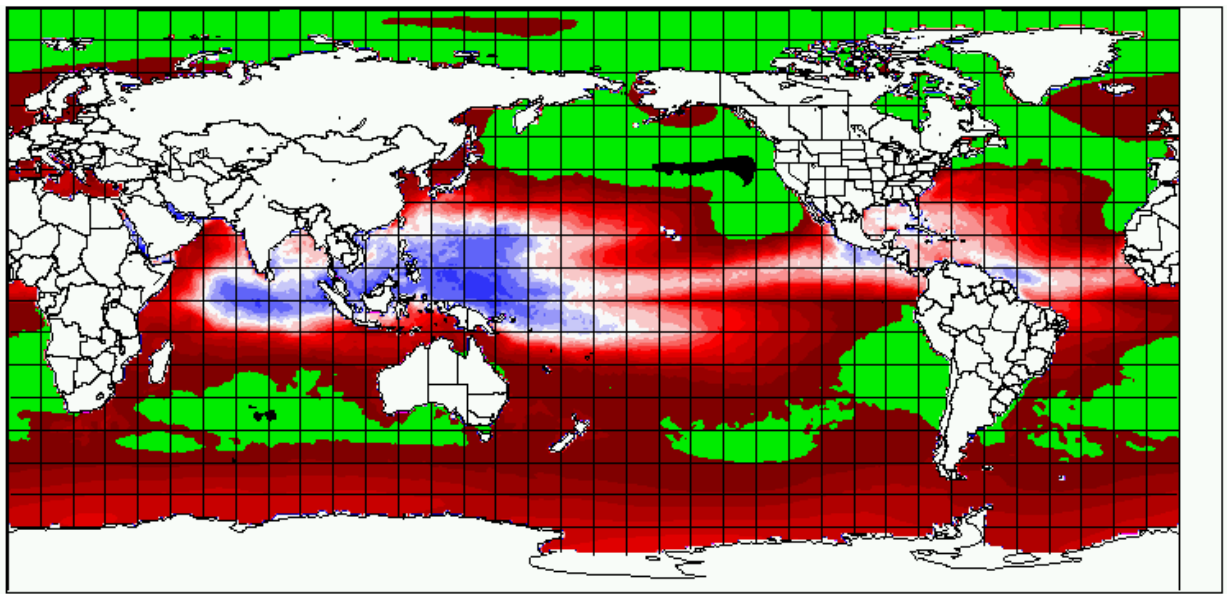
From http://wxmaps.org/pix/hurpot.html#ATL



DR

Example: PI climatology for strato-1 model

Potential minimum central pressure



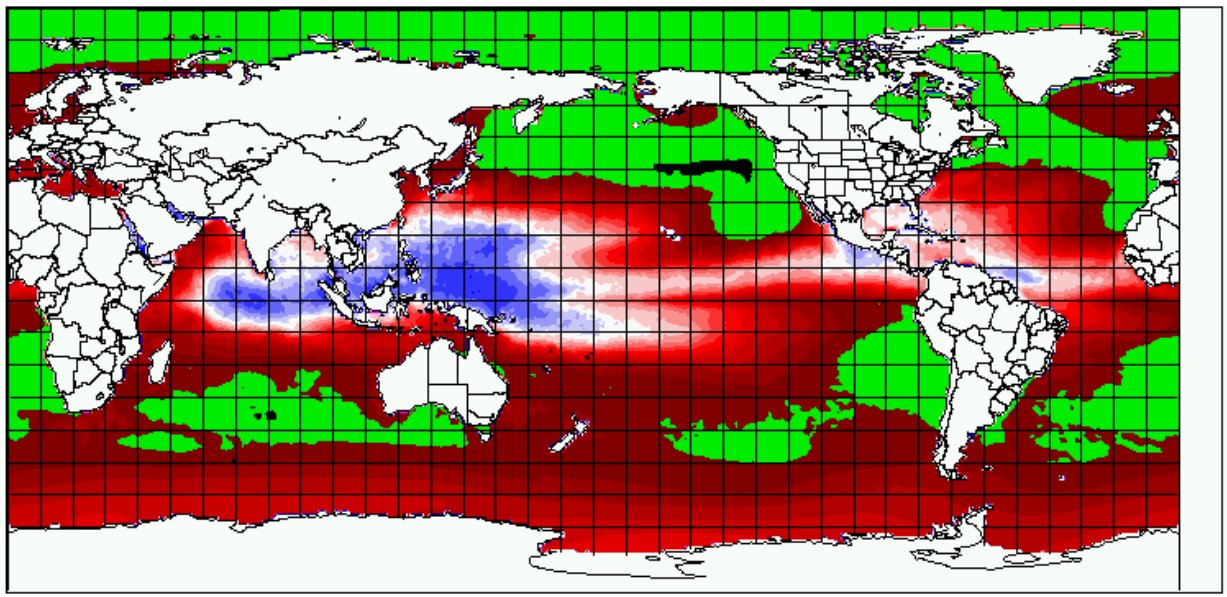
x 1000 hPa

1.00
0.95
0.90
0.85
0.80

average (18-Jun to 06-Sep 2008) for 120-h forecasts

Example: PI climatology for strato-2 model

Potential minimum central pressure



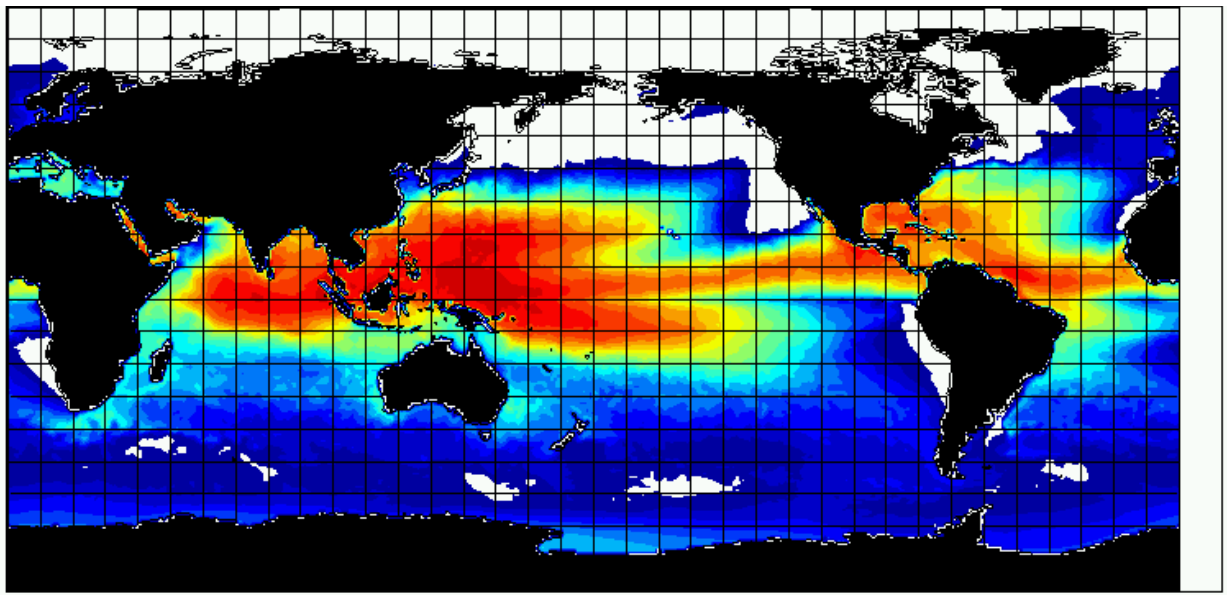
x 1000 hPa

1.00
0.95
0.90
0.85
0.80

average (18-Jun to 06-Sep 2008) for 120-h forecasts

Example: PI climatology for strato-1 model

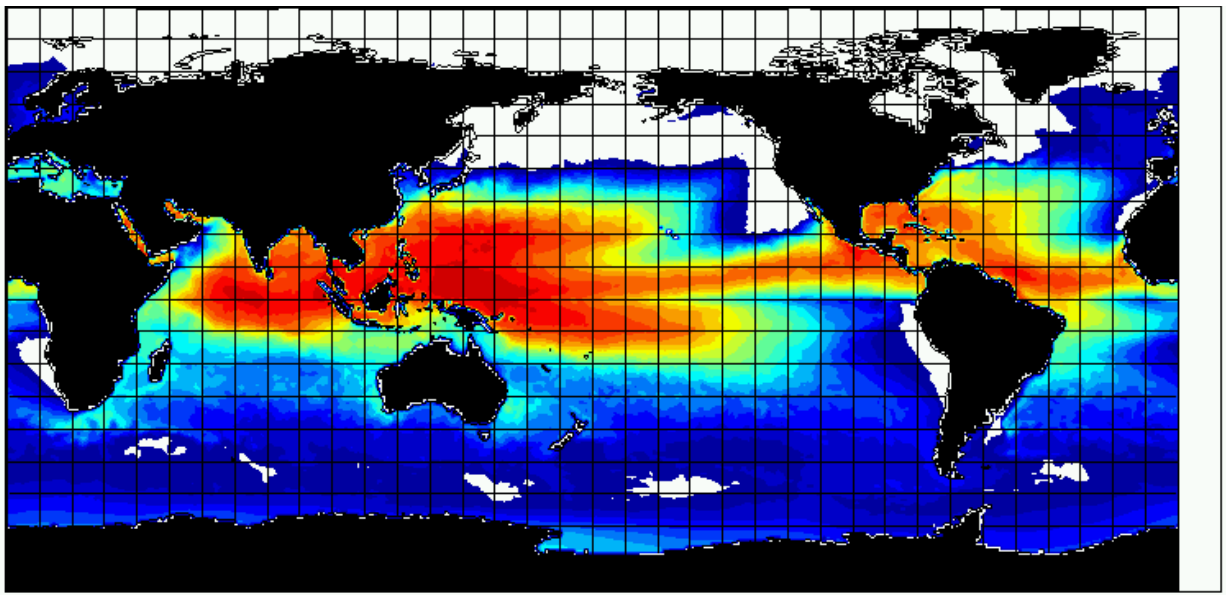
Potential maximum wind speed



average (18-Jun to 06-Sep 2008) for 120-h forecasts

Example: PI climatology for strato-2 model

Potential maximum wind speed



average (18-Jun to 06-Sep 2008) for 120-h forecasts

Genesis Potential Index (GPI)

- see e.g. Camargo et al. 2007, J. Climate

$$GPI = \left|10^5 \eta\right|^{3/2} \left(\frac{H}{50}\right)^5 \left(\frac{V_{pot}}{70}\right)^3 \frac{1}{(1+V_{shear}/10)^2}$$

absolute vorticity (s^-1) at 850 hPa

relative humidity (%) at 700 hPa

potential maximum winds (m/s)

magnitude of vertical wind shear (m/s) between 850 hPa and 200 hPa

Genesis potential index (GPI) *versus* climatological number of cyclones

NTC = average number of tropical cyclones

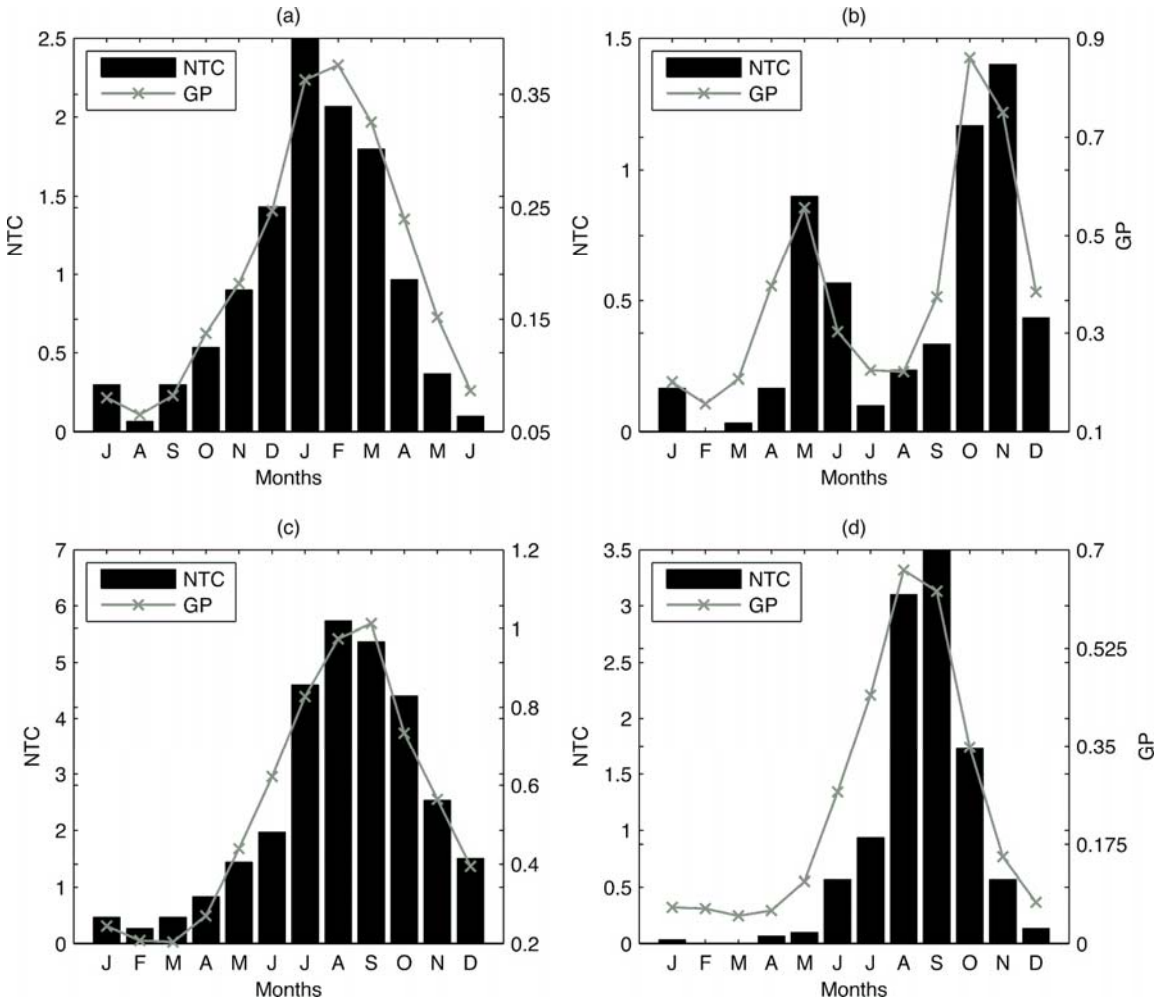
- **South Pacific**

(b) North Indian

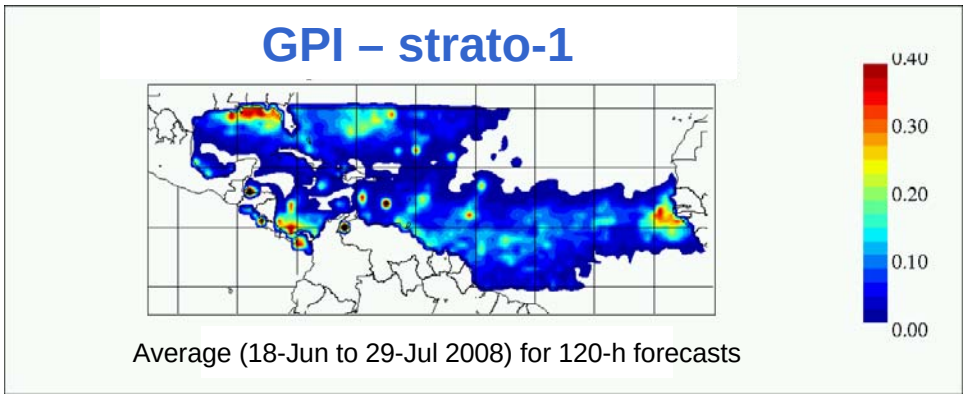
(c) western North Pacific

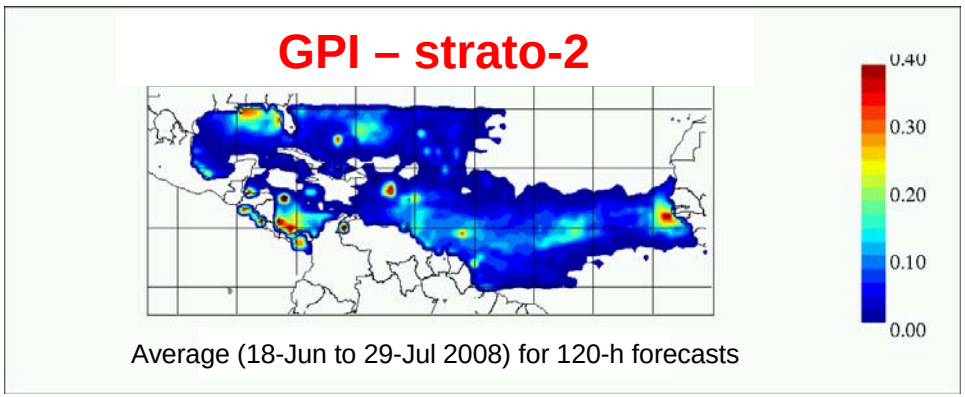
(d) North Atlantic

From Camargo et al. 2007, J. Climate

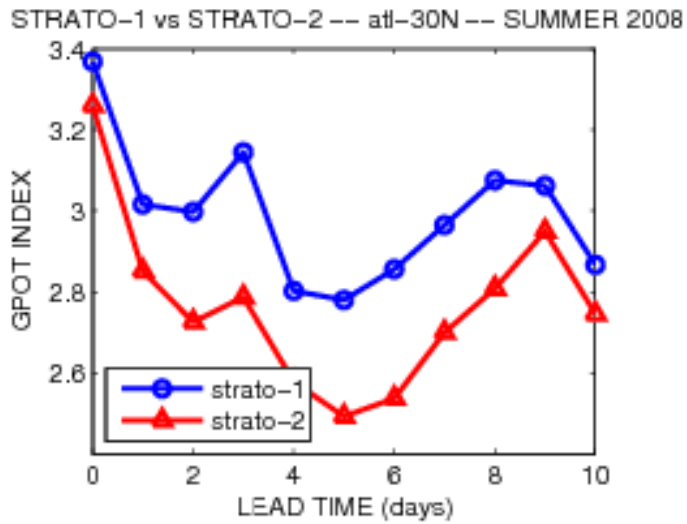


GPI climatology: strato-1 *versus* strato-2

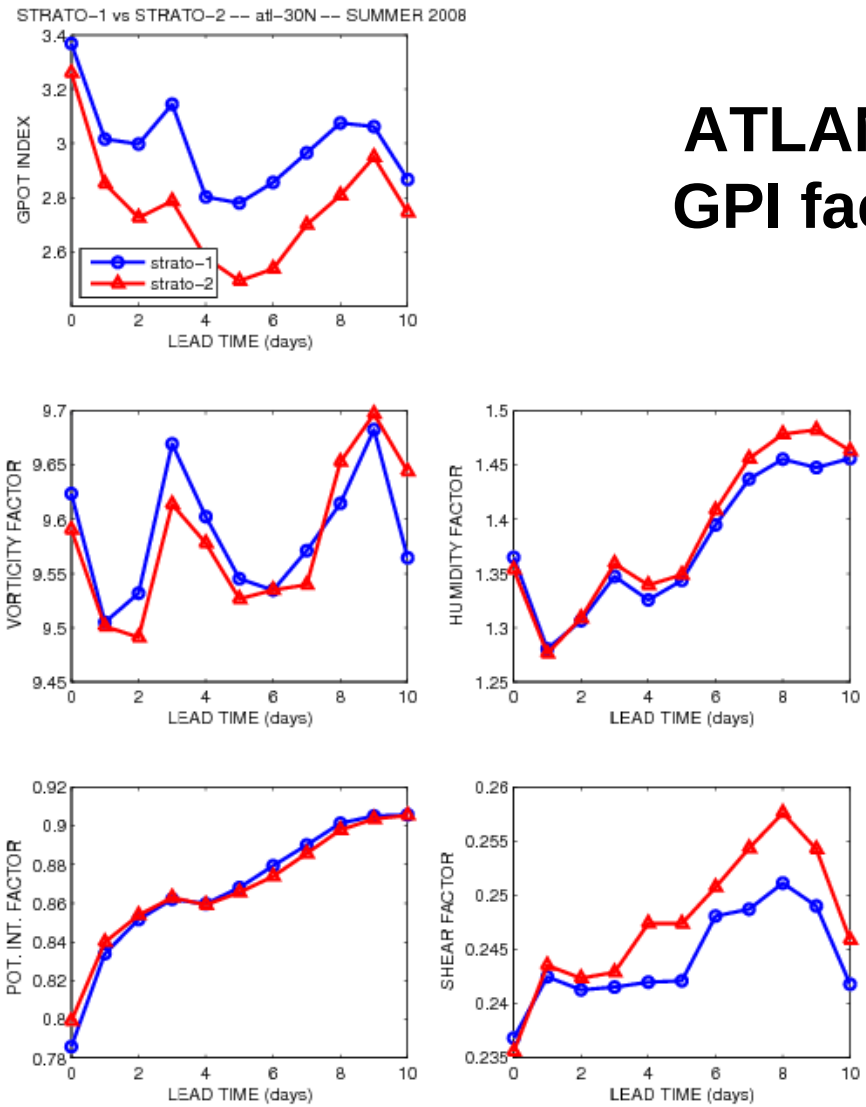




ATLANTIC

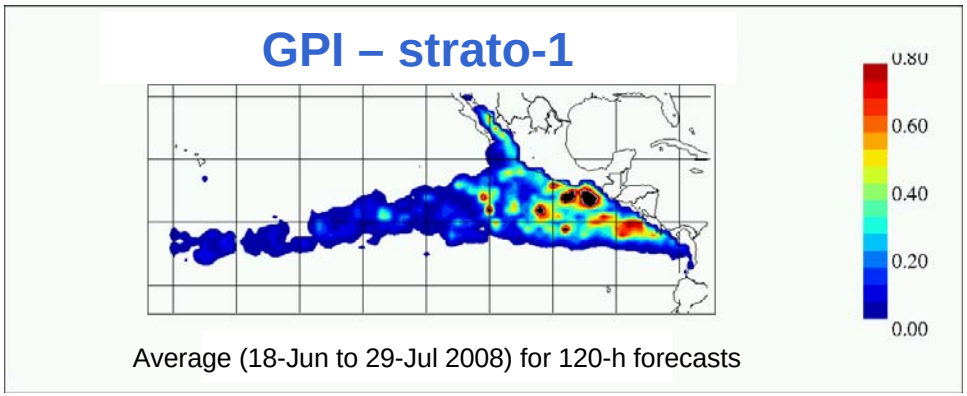


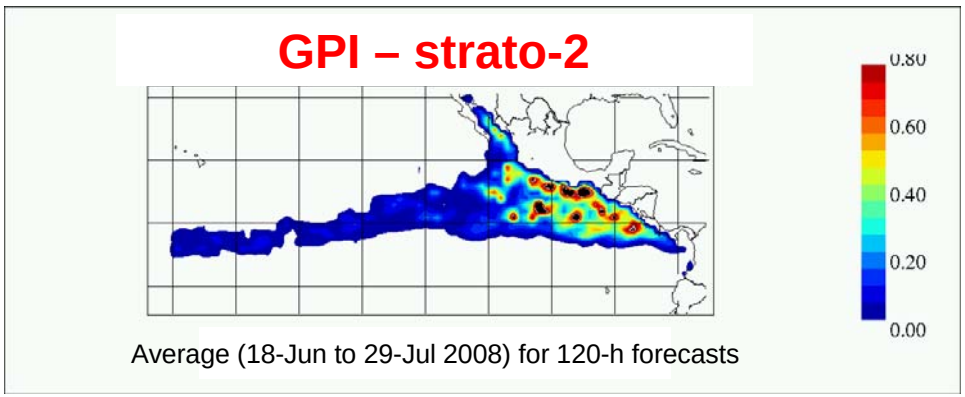
GPI climatology: strato-1 *versus* strato-2 (cont.)



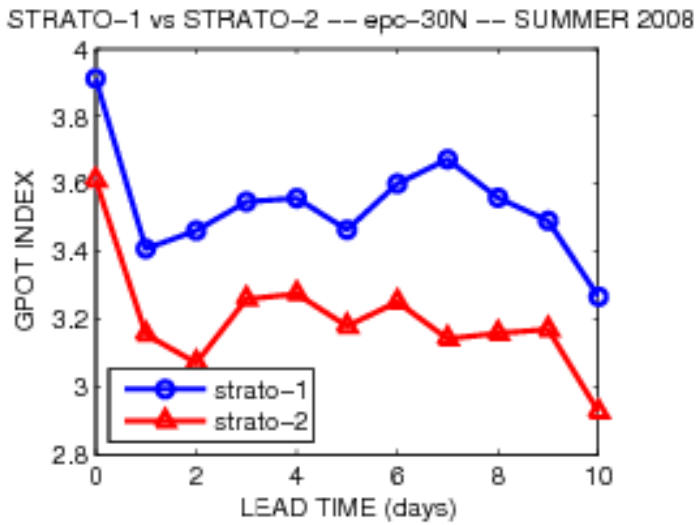
ATLANTIC
GPI factors

GPI climatology: strato-1 *versus* strato-2 (cont.)

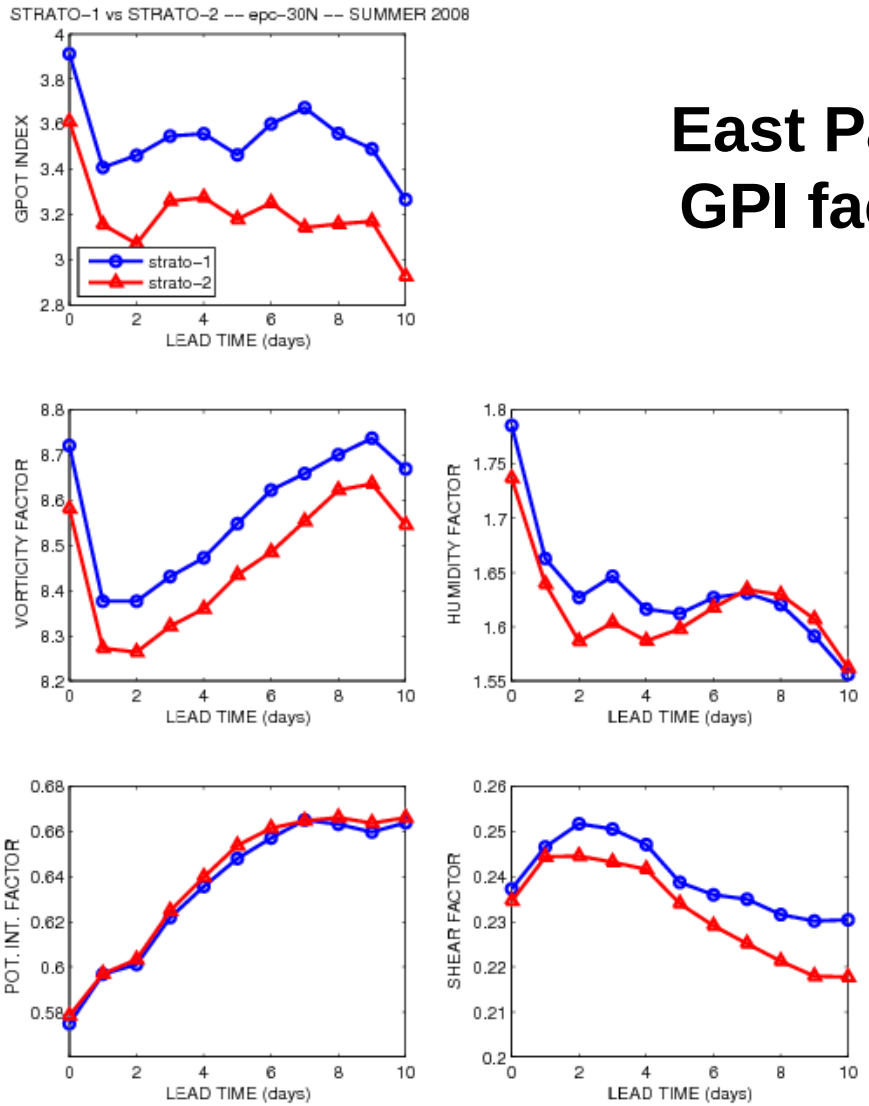




EAST PACIFIC

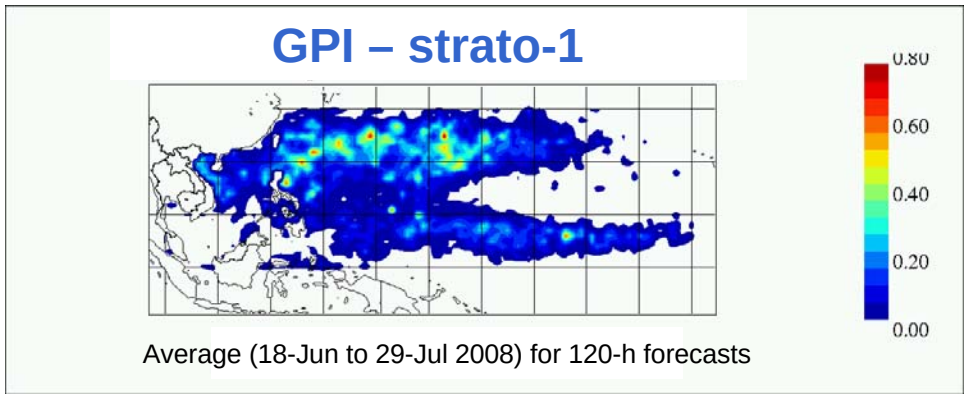


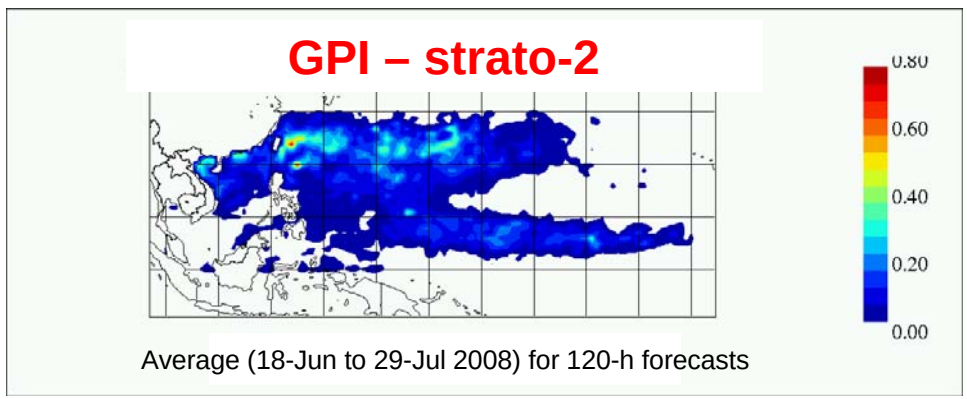
GPI climatology: strato-1 *versus* strato-2 (cont.)



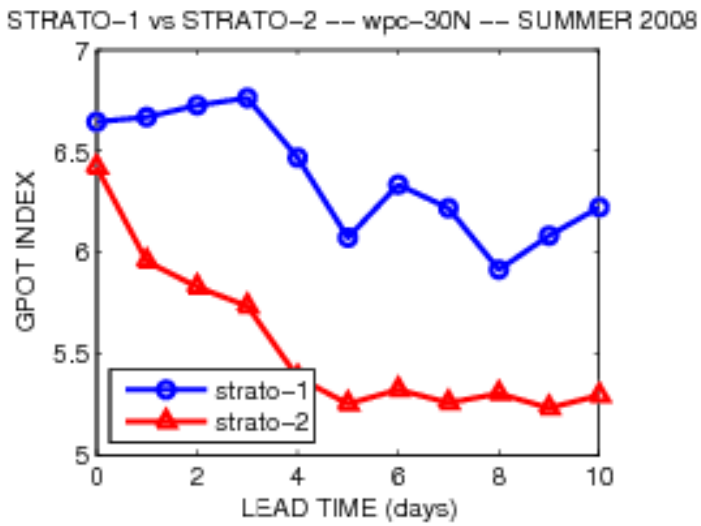
East Pacific GPI factors

GPI climatology: strato-1 *versus* strato-2 (cont.)

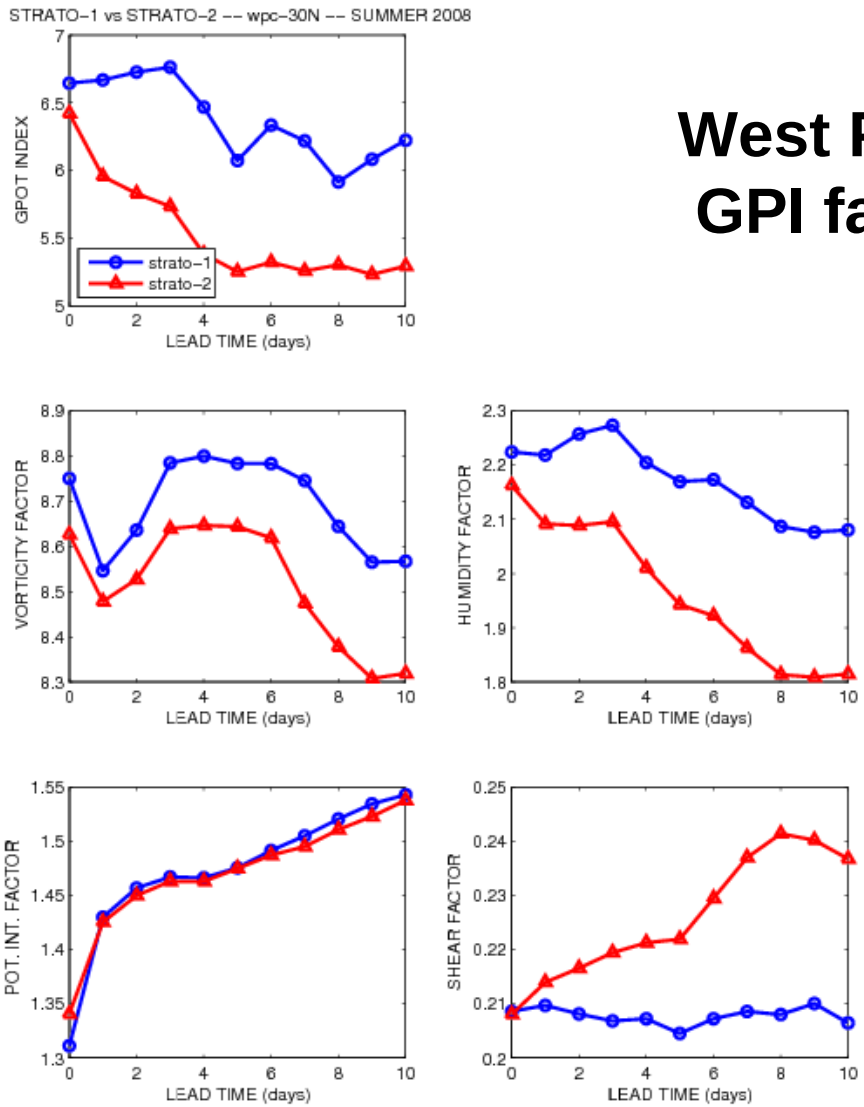




WEST PACIFIC



GPI climatology: strato-1 *versus* strato-2 (cont.)



West Pacific GPI factors

Final remarks & conclusions

- Performed detailed study of TC forecast properties of various configurations of the global model (3DVar and 4Dvar), covering 3 seasons (2007, 2008 and 2009) and 3 basins (Atlantic, East and West Pacific).

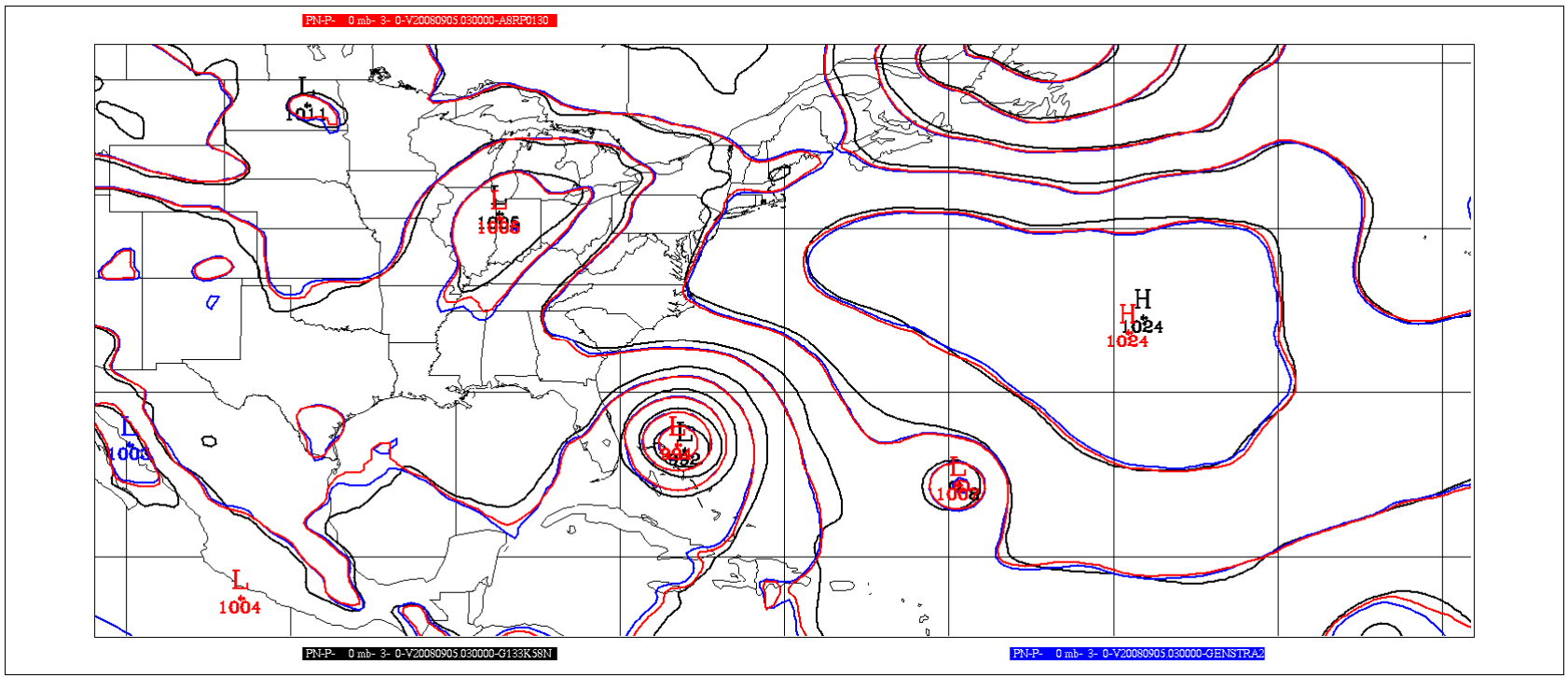
- Model changes proposed (strato-2 configuration), leading to statistically significant reduction in TC false alarm ratio -- while other verification scores remain mostly neutral.

Final remarks & conclusions (cont.)

- Note: Results suggest that the **TC detection rate** (already at initial time) is relatively low.
- Project Strato-2: Changes in model have been combined with changes in data assimilation system, and final cycles (summer 2008 and winter 2009) are currently being run. Implementation (or parallel run) expected in the summer of 2010.
- Detailed scores and documentation available at

  http://iweb.cmc.ec.gc.ca/~armnaza/proj_MESOSTR.html

Merci



* animation available in
http:/iweb.cmc.ec.gc.ca/~armnaza/proj_MESOSTR.html