A Brief History of TC NWP

is there a forecast role for limited-area models (LAMs) in the era of high-resolution global models?

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A personal history starting in 1976 at Penn State…

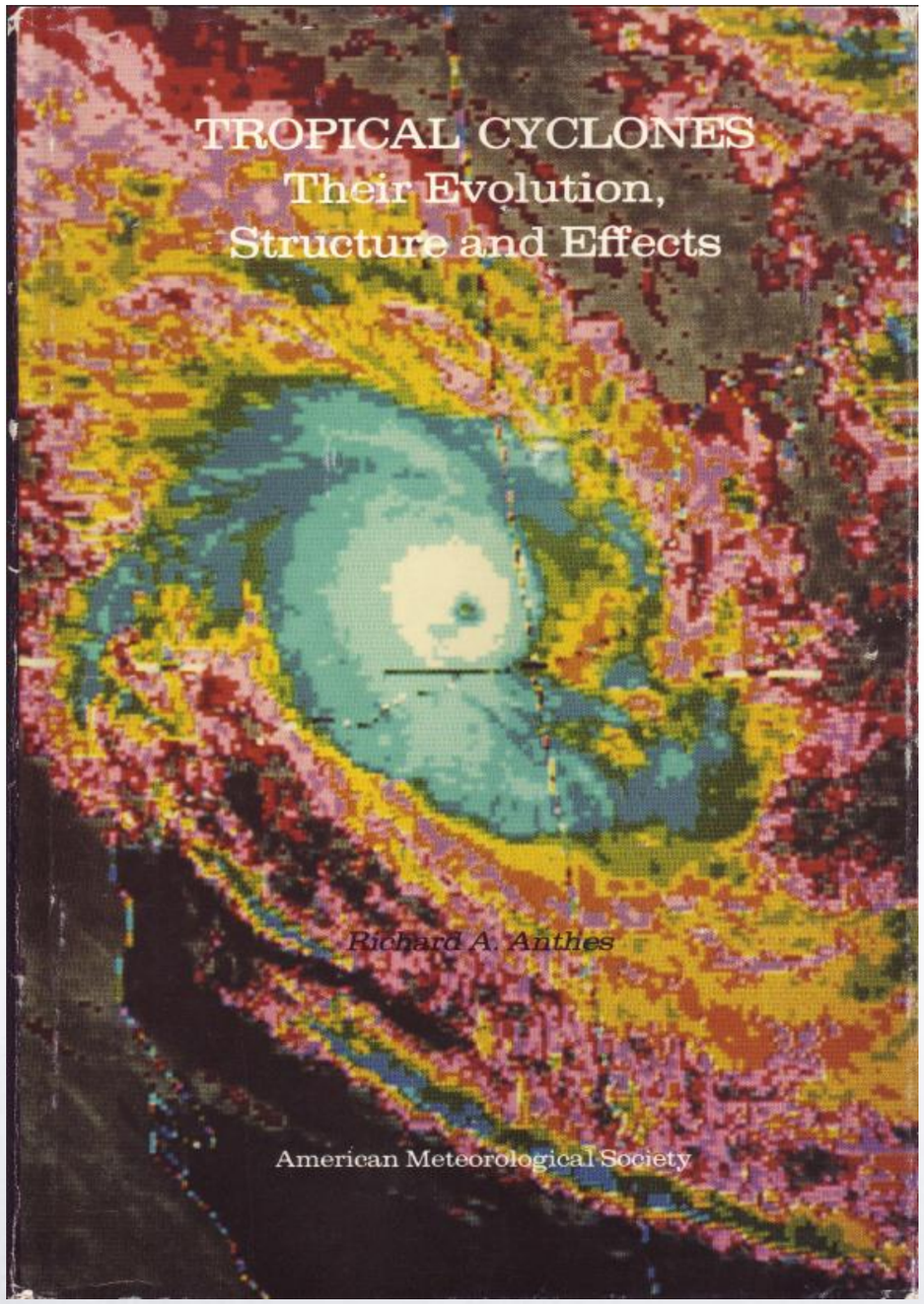
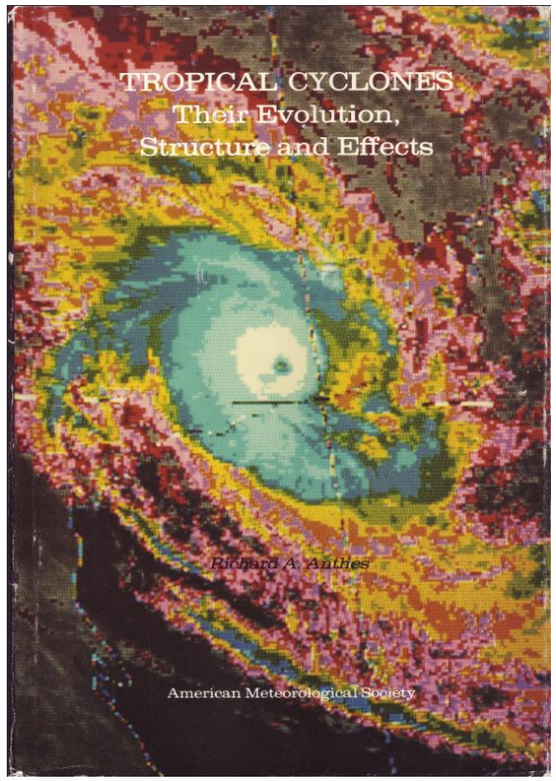


TABLE 4.3. Three-dimensional hurricane model forecasts with observed data.

Investigator	Nested grid	Minimum horizontal dimension (km)	Number of layers	Latent heating	Bases of initialization	Remarks
Miller (1969)	No	140	6	Kuo	Static Initialization (S.I.), wind	24 h forecasts of Alma (1962).
Mathur (1974)	Yes	37	4	Kuo	S.I., wind	Good 96 h forecast of Isbell (1964)
Hovermale and Livezey (1977)	No	60	10	Kuo	2D vortex merged with large-scale analyses	Large number of forecasts made in real time. Track of primary interest.
Ley and Elsberry (1976)	Yes	51	3	Specified	S.I., wind	Nonrecurvature of typhoon Irma correctly predicted.
Hoke and Anthes (1977)	No	60	4	Kuo	Dynamic Initialization (D.I.), wind	12h forecasts of Hurricane Alma (1962); D.I. showed less imbalances than forecast without D.I.
Shewchuk and Elsberry (1978)	Yes	51	3	Specified	S.I., wind	Method of improving initial wind analysis based on recent motion of storm tested on 30 cases. Method improved track forecast during first 18 h by 30%.
Fiorino (1978)	No	30	4	Kuo	D.I., wind, sea-level pressure, rainfall rates	24 h forecasts of Hurricane Eloise made using various types of satellite data in a dynamic initialization
Madala and Hodur (1977)	Yes	60	5	Kuo	S.I., wind	36 h forecast of Typhoon Pamela (1976).
Hodur and Burk (1978)	No	205	3	Specified	S.I., bogus vortex merged with large-scale analysis	Coarse grid version of Ley and Elsberry (1976) model used operationally at Fleet Numerical Weather Facility.
Hacunda (1978)	No	120	5	Modified Anthes (1977a)	S.I., bogus vortex merged with large-scale analysis	Size of bogus storm and initial moisture distribution important in forecasts.

1978 M.S. Thesis – first use of operational analyses in a research-class 3D model with ‘full’ physics: MM0 or pre-MM5 – the “MesoMonster”

HRD 1978-1980 to do NWP…



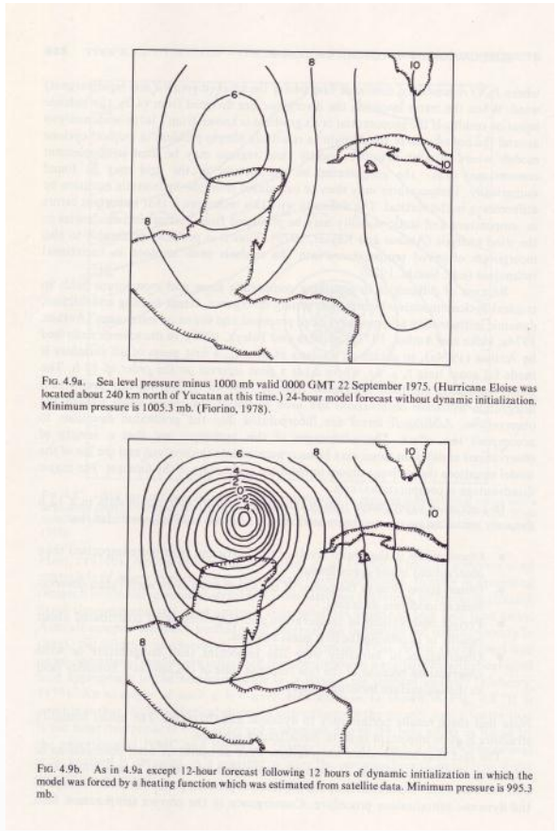


FIG. 4.9a. Sea level pressure minus 1000 mb valid 0000 GMT 22 September 1975. (Hurricane Eloise was located about 240 km north of Yucatan at this time.) 24-hour model forecast without dynamic initialization. Minimum pressure is 1005.3 mb. (Fiorino, 1978).

FIG. 4.9b. As in 4.9a except 12-hour forecast following 12 hours of dynamic initialization in which the model was forced by a heating function which was estimated from satellite data. Minimum pressure is 995.3 mb.

24-h sea-level pressure forecast of hurricane ELOISE 1975 with and without rainfall assimilation

- while at NHEML (now AOML/HRD) ran Bob Jones' big 3-nested grid model both symmetric and asymmetric versions
- had to tell Stan Rosenthal we could not do NWP with 3 runs / year…moved to NEPRF, Monterey in 1980 t(now NRL) to work with USN TC NWP models…

TC NWP in the early years 1975-1985

- JMA – developed a nested-grid model following Harrison and Elsberry 1972
  - two-way interactive v one-way influence
- USN – baroclinic models only
  - emphasized vortex initialization over interactive physics (e.g., Kuo)
  - first operational variational analysis – tropical wind
  - ***first dynamical model to show skill at 72 h – OTCM (One-way influence Tropical Cyclone Model)***
- NCEP – barotropic in operations, “full physics” moving grid in development (MFM, QLM)

Job hunt seminar at NMC 1987 -- NPS PhD work

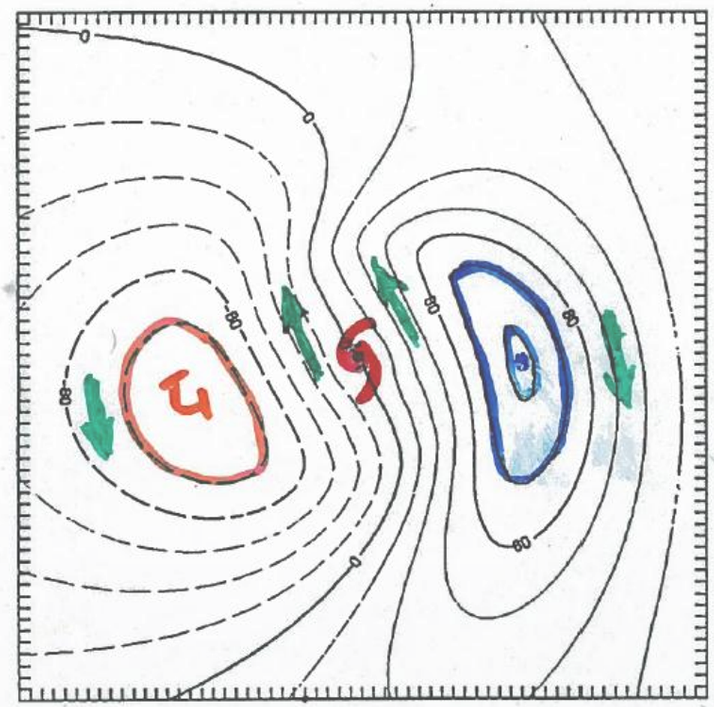
The Role of Vortex Structure in Tropical Cyclone Motion

Michael Fiorino
Fleet Numerical Oceanography Center

1. *Motivation*
2. *Initial Vortex Sensitivity*
3. *Symmetric/Asymmetric Viewpoint*
4. *Nonlinear dynamics*
5. *Key Issues in Future Studies*
6. Recent Results from the NWP global model

ψ_a

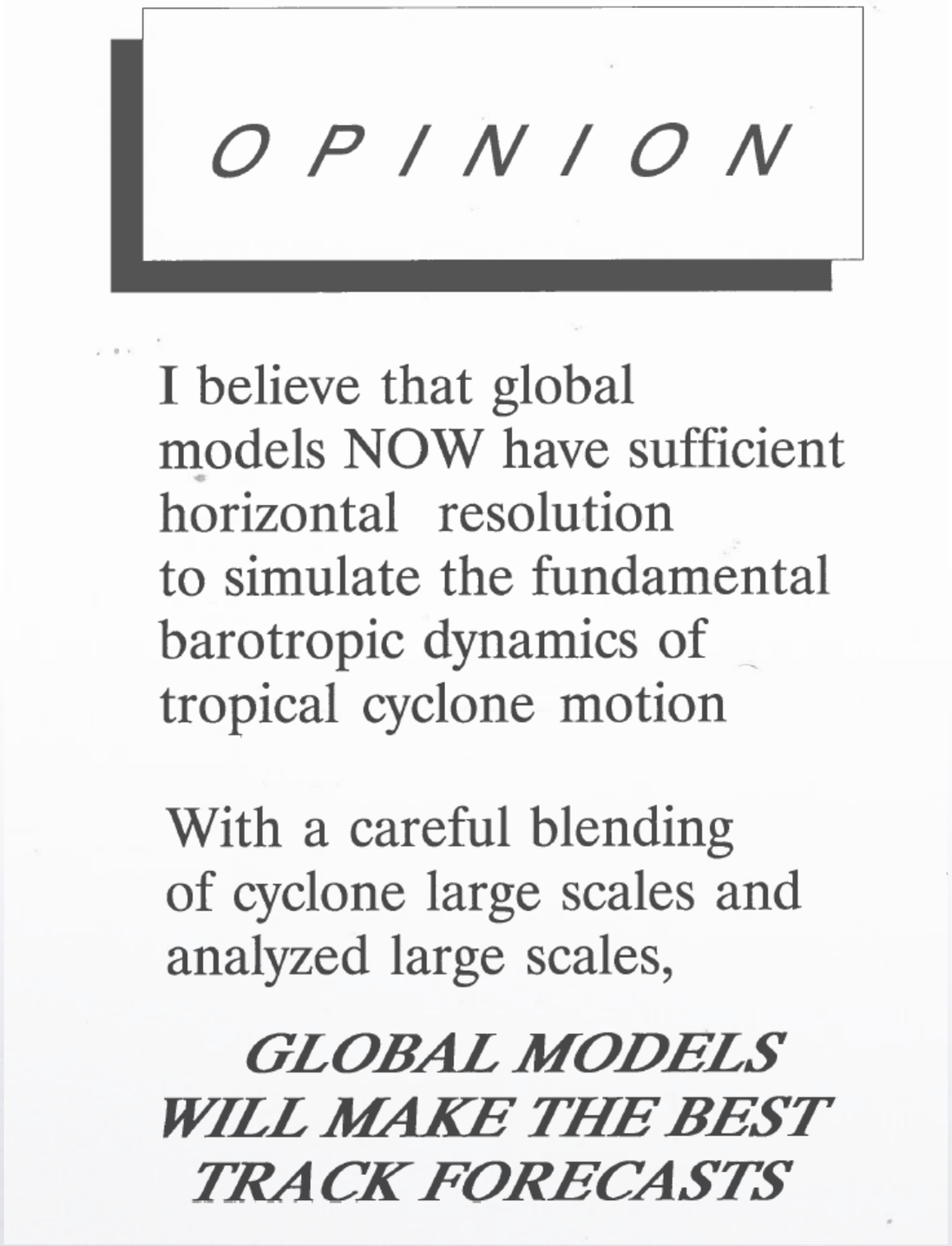
f



"B gyres"

(f) t = 48 h, $|\psi_a|$ ~ 12.0x10^5 m^2/s, contour interval = 200 x 10^3 m^2/s.

my 1987 prediction regarding GCMs and the NMC reaction…



OPINION

I believe that global models NOW have sufficient horizontal resolution to simulate the fundamental barotropic dynamics of tropical cyclone motion

With a careful blending of cyclone large scales and analyzed large scales,

GLOBAL MODELS WILL MAKE THE BEST TRACK FORECASTS

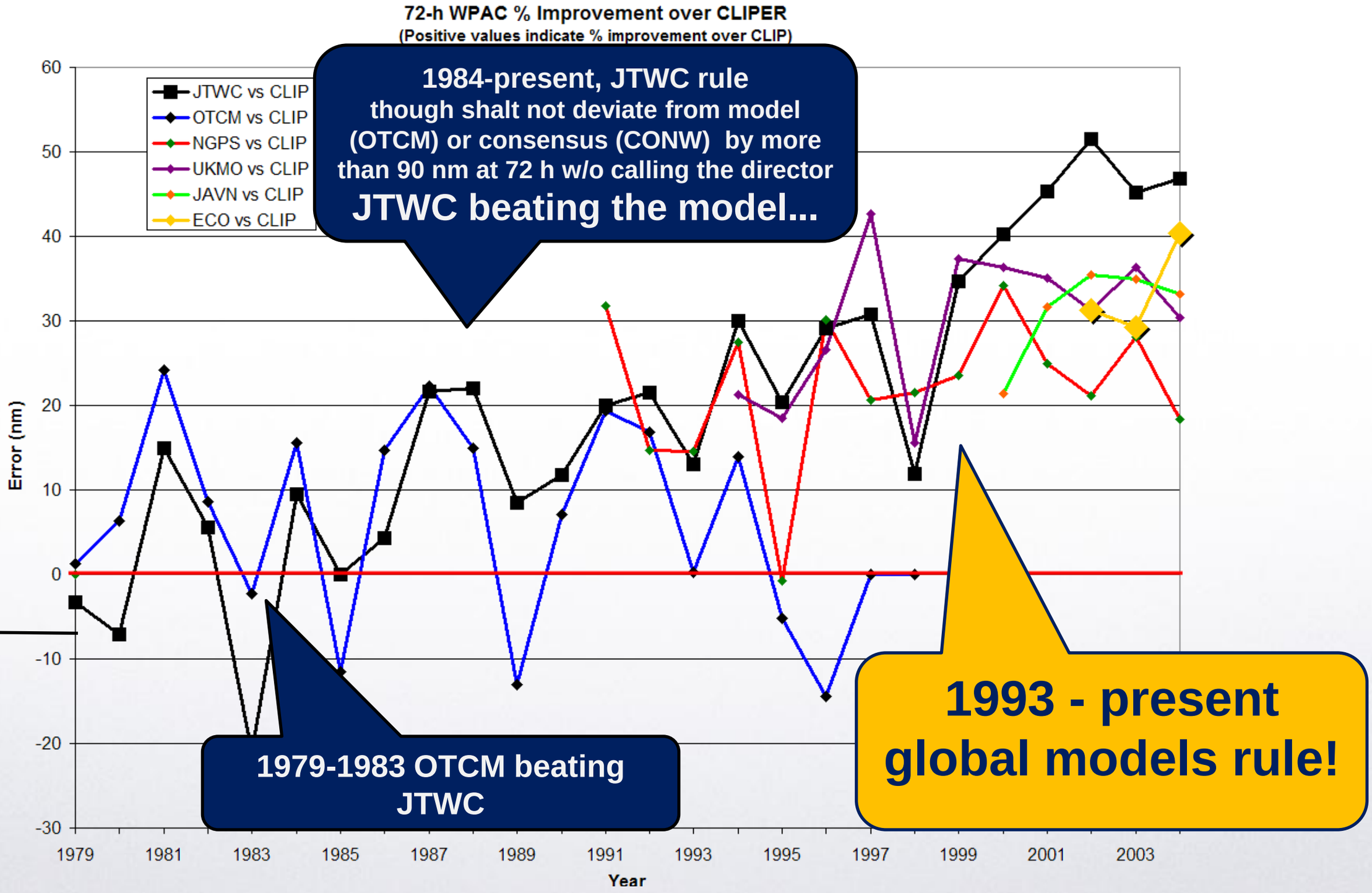
- ***Eugenia Kalnay – smiled and thought – "this guy really gets it"***
- ***Joe Gerrity – scowled and said "that was a very nice seminar until that last slide…"***
- ***Jim Hoke – making distinctions between a global and limited-area model is somewhat artificial – the mesocale model is imbedded in the global model …***

TC NWP 1991-2011 – era of global models

- USN NWP is still tropical oriented – that's where ships sail…
  - ***first operational global model to use Arakawa-Schubert (it's the convection, dummy)***
  - tasked by CO of FNMOC to 'fix the OTCM' in two-weeks…turns out the global model was analyzing and forecasting TCS (1991)…motivated development of 'bogussing' to improve the initial vortex…UKMO followed suit…ECMWF never bogussed even though they invented the technique…
- NCEP – tried bogussing in the GFS…failed…but as the model tropical physics improved, so did the TC forecast skill…

TC NWP Track Forecast Skill Trends

WPAC 72-h FE % improvement over CLIPER, 1979 – 2004 including OTCM



PennState

MM0 using NMC NHEM analyses

1976

why limited-area models (LAM)?

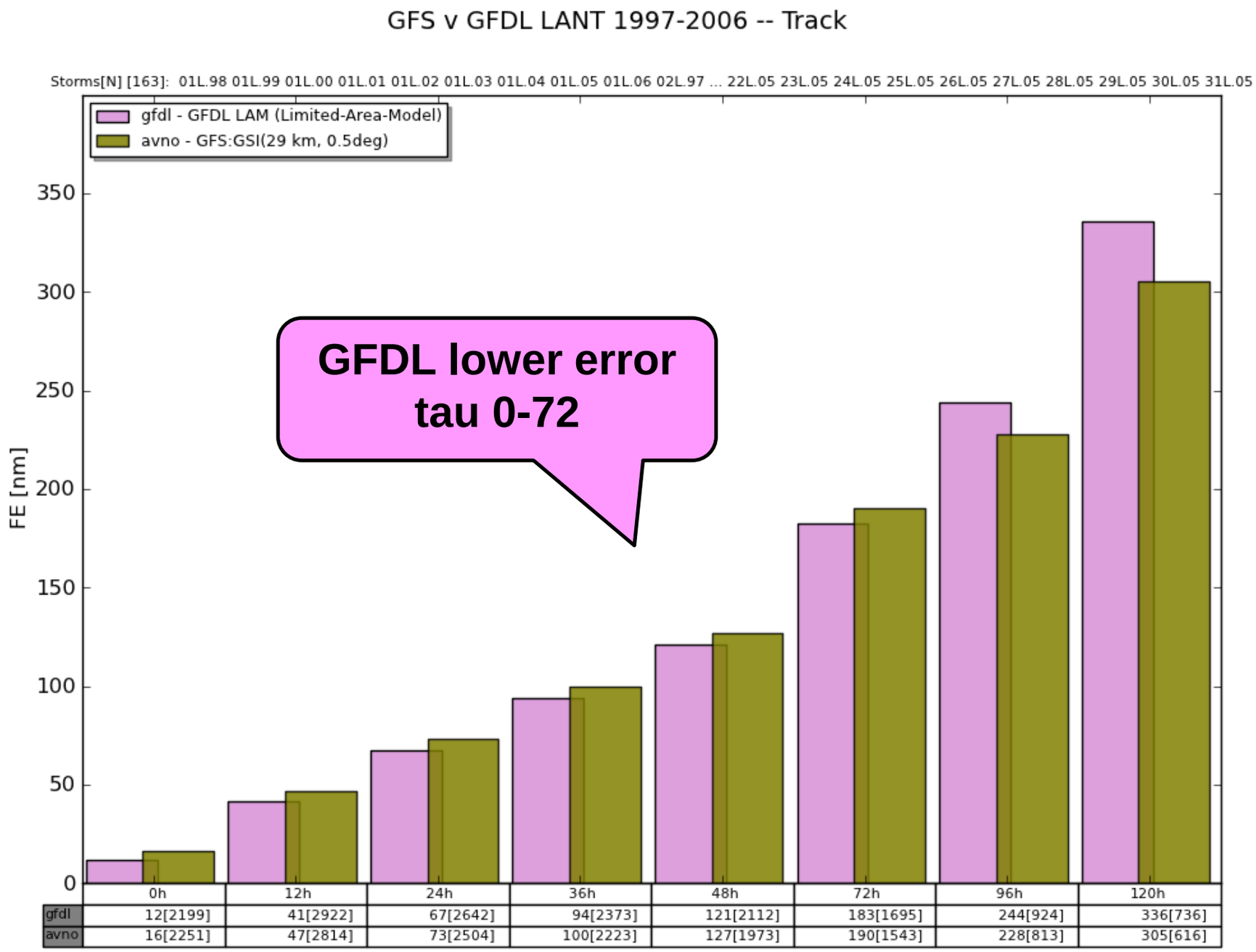
Anthes and Warner 1978 – a rationale for MM0

> However, nonlinear processes are capable of producing smaller scale information in the forecast than is present in the initial conditions, as long waves interact to produce energy in shorter waves. Furthermore, a realistic treatment of local forcing in the model will allow mesoscale perturbations to develop from initial conditions that are representative of larger scales.

- LAMs downscale global models; if the LAM local forcing is correct, will add mesoscale value...
- for TCs the mesoscale value should be intensity
- however, track and intensity are physically related; thus errors in track affect errors in intensity…

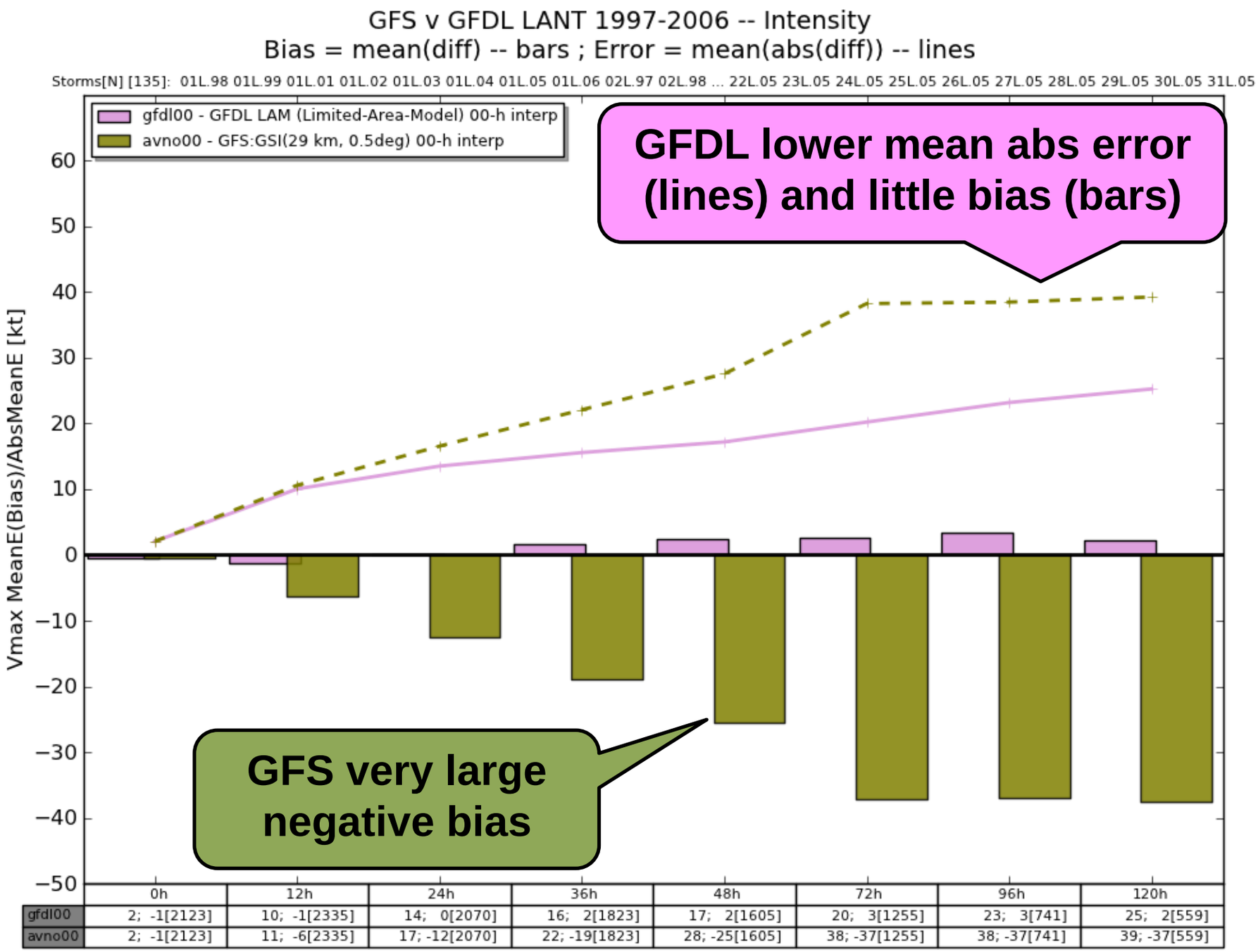
NCEP TC LAM – downscaling the GFS

pre-HWRF period 1997-2006 – Track Error Atlantic



NCEP TC LAM – downscaling the GFS

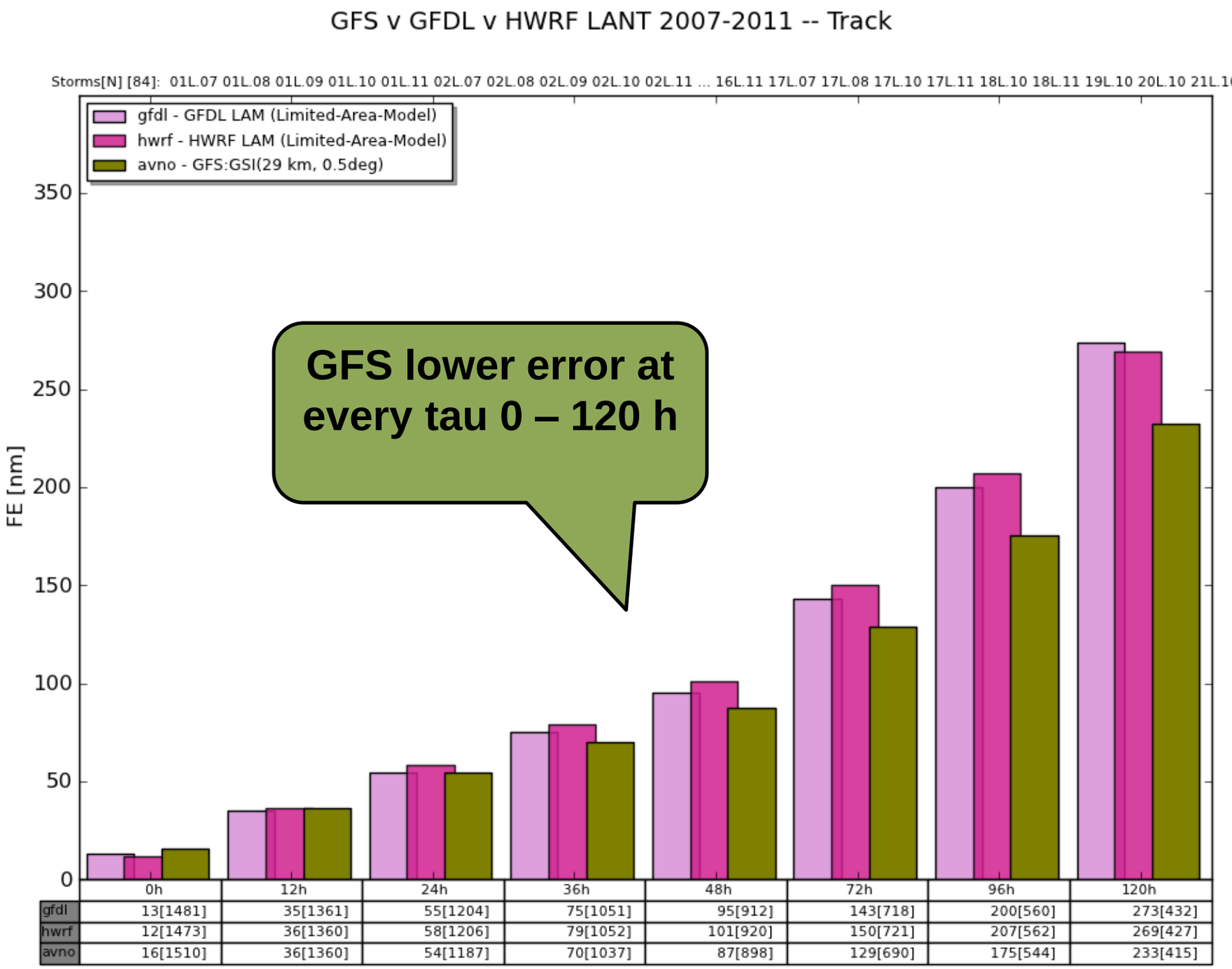
pre-HWRF period 1997-2006 – Intensity Error Atlantic



model intensity forecasts are bias corrected ‘appropriately’ i.e., initial-observed (‘offset’) applied to t=0-24 h for GFDL (GHMI) and t=0-72 for GFS

NCEP TC LAM – downscaling the GFS

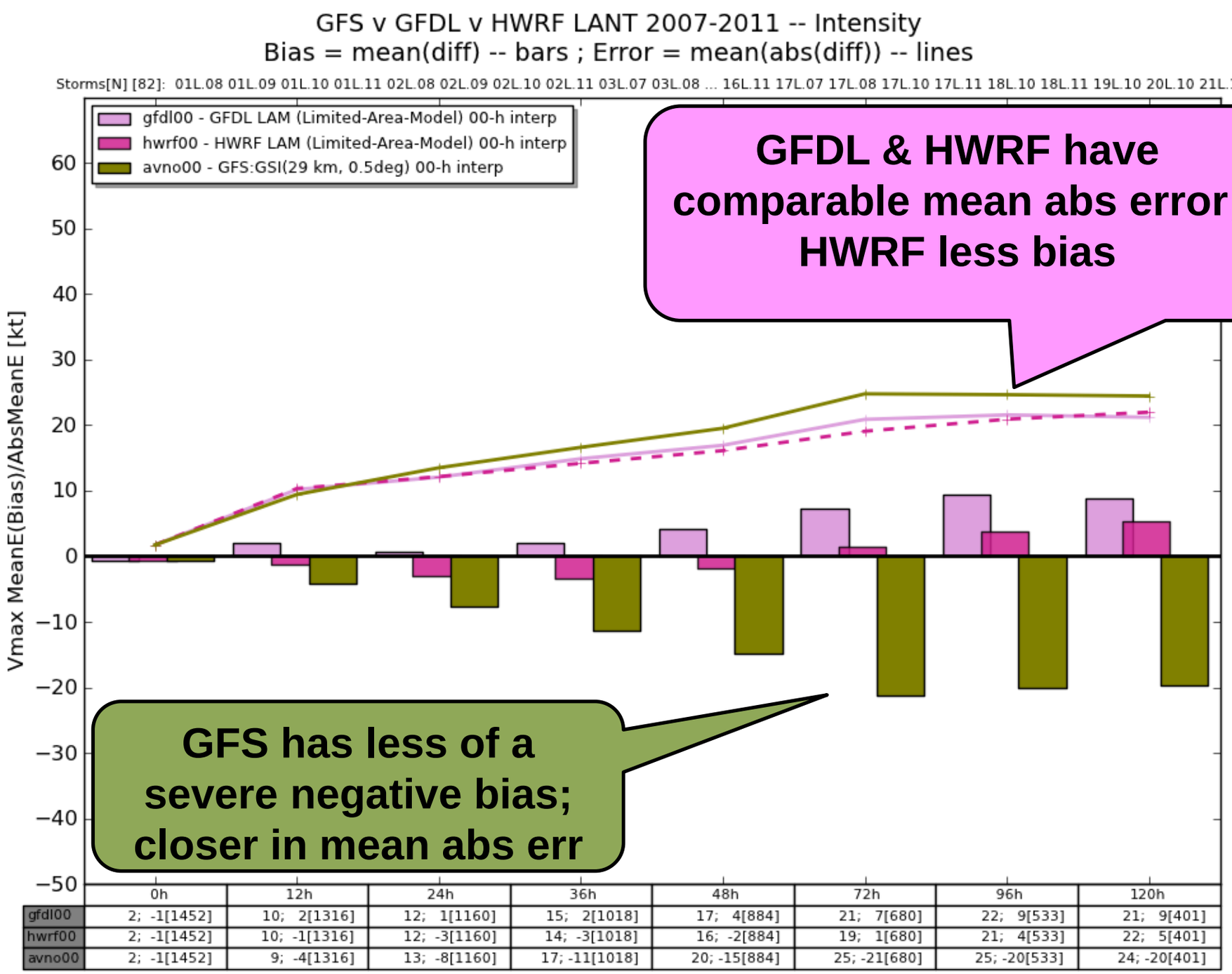
HWRF period 2007-2011 – Track Error Atlantic



	0h	12h	24h	36h	48h	72h	96h	120h
gfdl	13[1481]	35[1361]	55[1204]	75[1051]	95[912]	143[718]	200[560]	273[432]
hwrf	12[1473]	36[1360]	58[1206]	79[1052]	101[920]	150[721]	207[562]	269[427]
avno	16[1510]	36[1360]	54[1187]	70[1037]	87[898]	129[690]	175[544]	233[415]

NCEP TC LAM – downscaling the GFS

HWRF period 2007-2011 – Intensity Error Atlantic



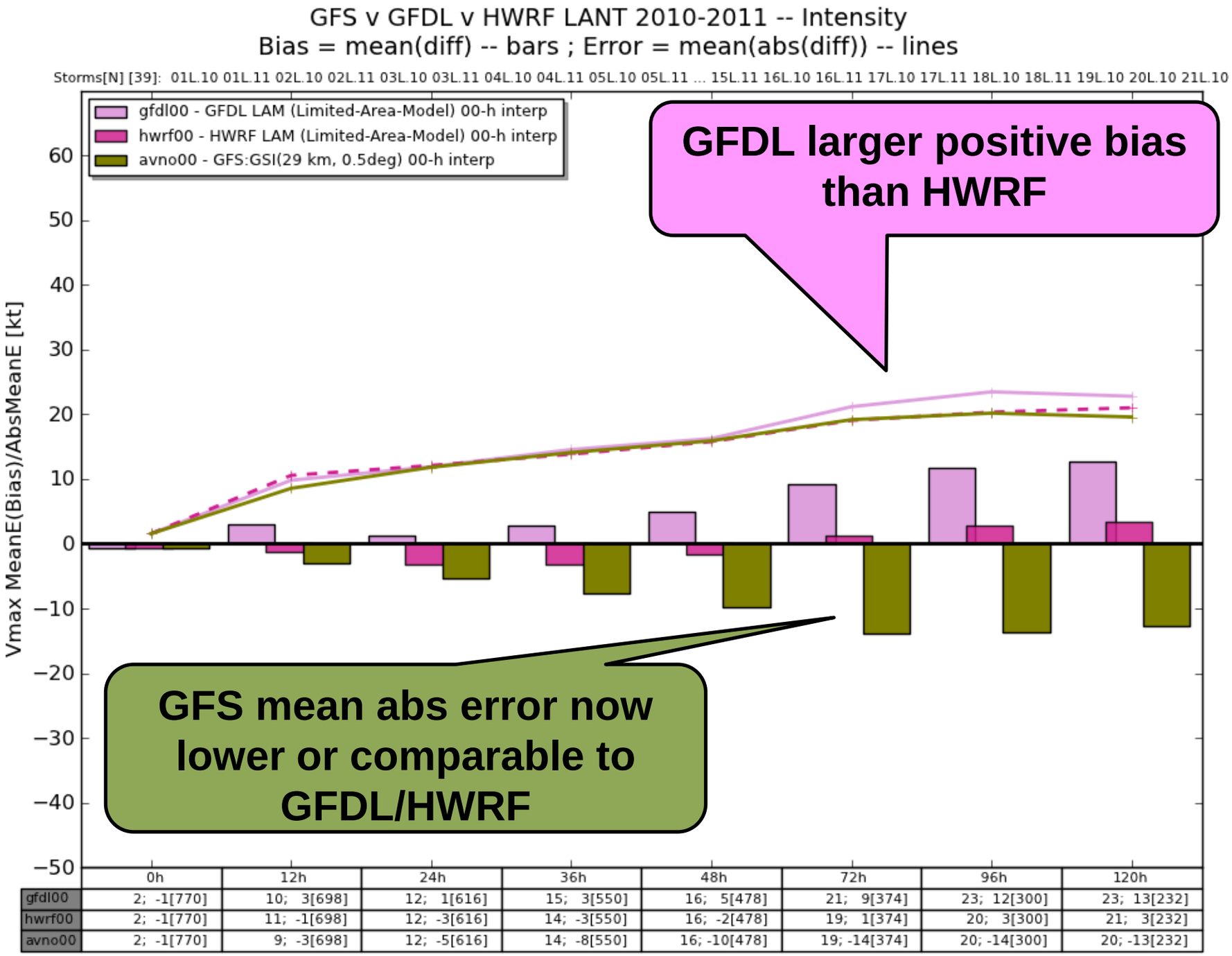
GFDL & HWRF have comparable mean abs error; HWRF less bias

GFS has less of a severe negative bias; closer in mean abs err

model intensity forecasts are bias corrected ‘appropriately’ i.e., initial-observed (‘offset’) applied to t=0-24 h for GFDL (GHMI) and t=0-72 for GFS

NCEP TC LAM – downscaling the GFS

HWRF period 2010-2011 – Intensity Error Atlantic

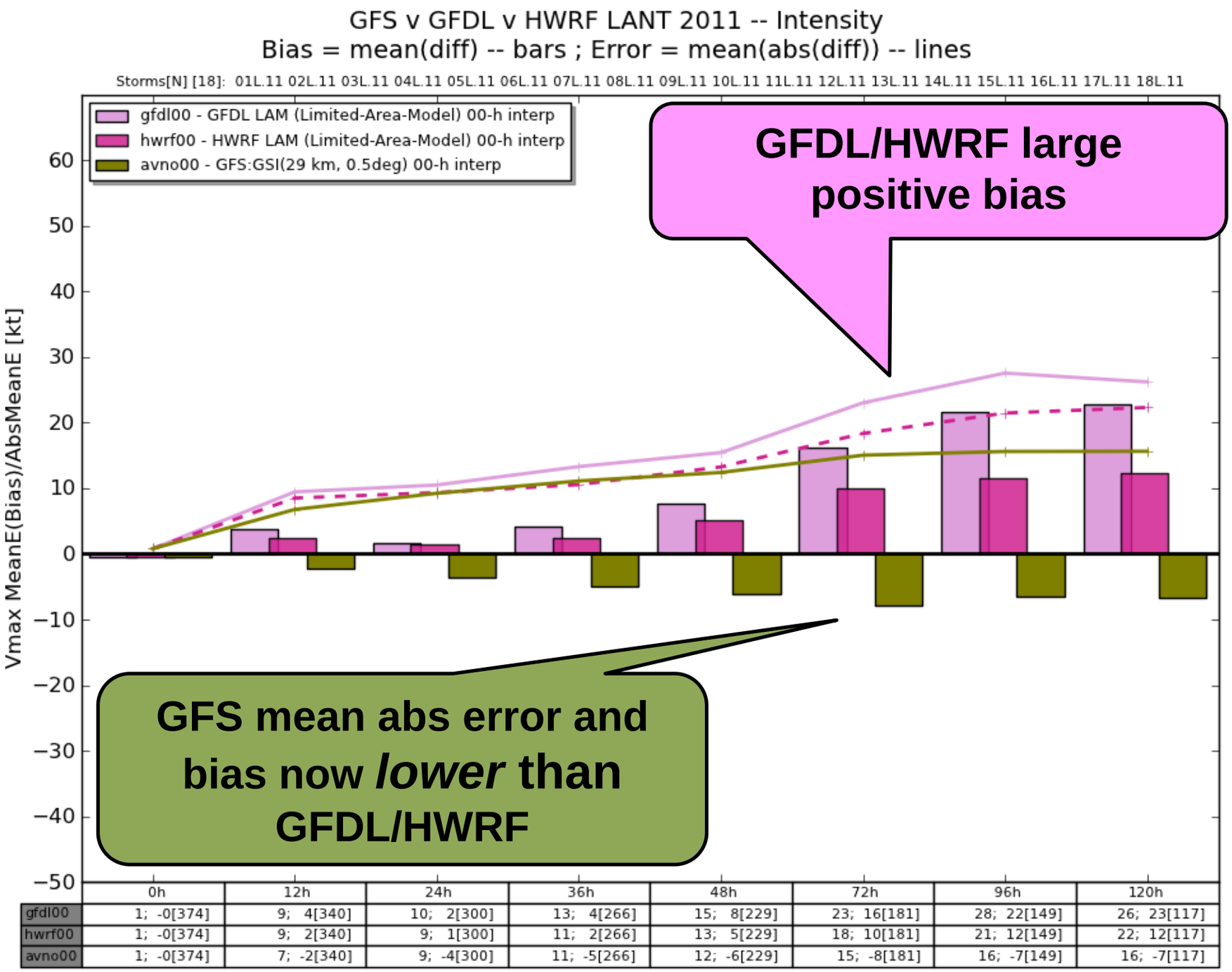


	0h	12h	24h	36h	48h	72h	96h	120h
gfdl00	2; -1[770]	10; 3[698]	12; 1[616]	15; 3[550]	16; 5[478]	21; 9[374]	23; 12[300]	23; 13[232]
hwrf00	2; -1[770]	11; -1[698]	12; -3[616]	14; -3[550]	16; -2[478]	19; 1[374]	20; 3[300]	21; 3[232]
avno00	2; -1[770]	9; -3[698]	12; -5[616]	14; -8[550]	16; -10[478]	19; -14[374]	20; -14[300]	20; -13[232]

model intensity forecasts are bias corrected ‘appropriately’ i.e., initial-observed (‘offset’) applied to t=0-24 h for GFDL (GHMI) and t=0-72 for GFS

NCEP TC LAM – downscaling the GFS

HWRF period 2011 – Intensity Error Atlantic



	0h	12h	24h	36h	48h	72h	96h	120h
gfdl00	1; -0[374]	9; 4[340]	10; 2[300]	13; 4[266]	15; 8[229]	23; 16[181]	28; 22[149]	26; 23[117]
hwrf00	1; -0[374]	9; 2[340]	9; 1[300]	11; 2[266]	13; 5[229]	18; 10[181]	21; 12[149]	22; 12[117]
avno00	1; -0[374]	7; -2[340]	9; -4[300]	11; -5[266]	12; -6[229]	15; -8[181]	16; -7[149]	16; -7[117]

model intensity forecasts are bias corrected ‘appropriately’ i.e., initial-observed (‘offset’) applied to t=0-24 h for GFDL (GHMI) and t=0-72 for GFS

Summary

- the first successful (better than CLIPER at 72 h) TC NWP model was the USN OTCM 1979-1985 in WPAC
- all TC NWP models pre 2000 have been deprecated; with the ascendency of global NWP…
- since 2007 the downscaling of the GFS by the GFDL/HWRF models has ***degraded*** the track at ***all*** forecast taus
- a similar trend is found for intensity and in 2011 the GFDL/HWRF models added no value to the bias-corrected GFS ***intensity*** forecasts

Critical Factors? (NB: IMHO)

- lateral boundary conditions are mathematically ill posed (Harrison and Elsberry, 1972 & Ciment,1971). these 'bad math' errors can be controlled numerically, however, the error is now greater than the error in the forcing global model.
- track and intensity are physically related, errors in track make errors in intensity – can't do one without the other.
- TC NWP != TC modeling; is a subset with different metrics and applications
- Limited area model TC NWP adds no forecast value to the GFS > 36 h…(again IMHO)