Ensemble Research and Tropical Cyclones at NRL

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OUTLINE

NOGAPS Experiments

COAMPS Coupled Ensemble

Future Plans

NOGAPS ET Ensemble System Experiments

26 June to 15 October 2008

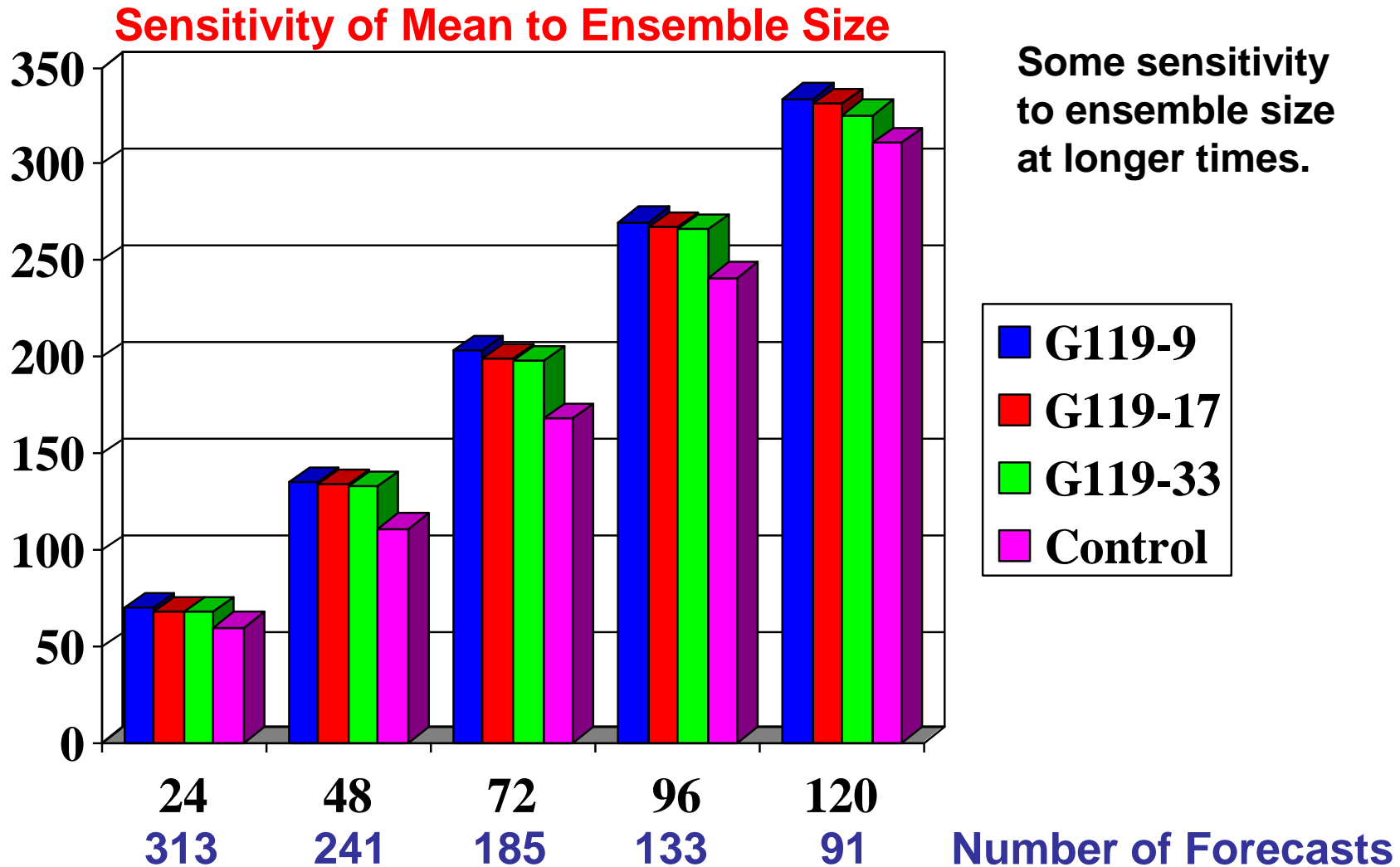Resolution tests: global ET initial perturbations
1. T119 (110-km, 33 members)
2. T159 (82-km, 17 members); 20% more expensive than 1
3. T239 (55-km, 9 members); twice as expensive as 1

Ensemble design tests at T159 17 members
1. Global ET
2. Banded ET
3. Banded ET with SKEB

Control run, the operational T239 NOGAPS forecasts.

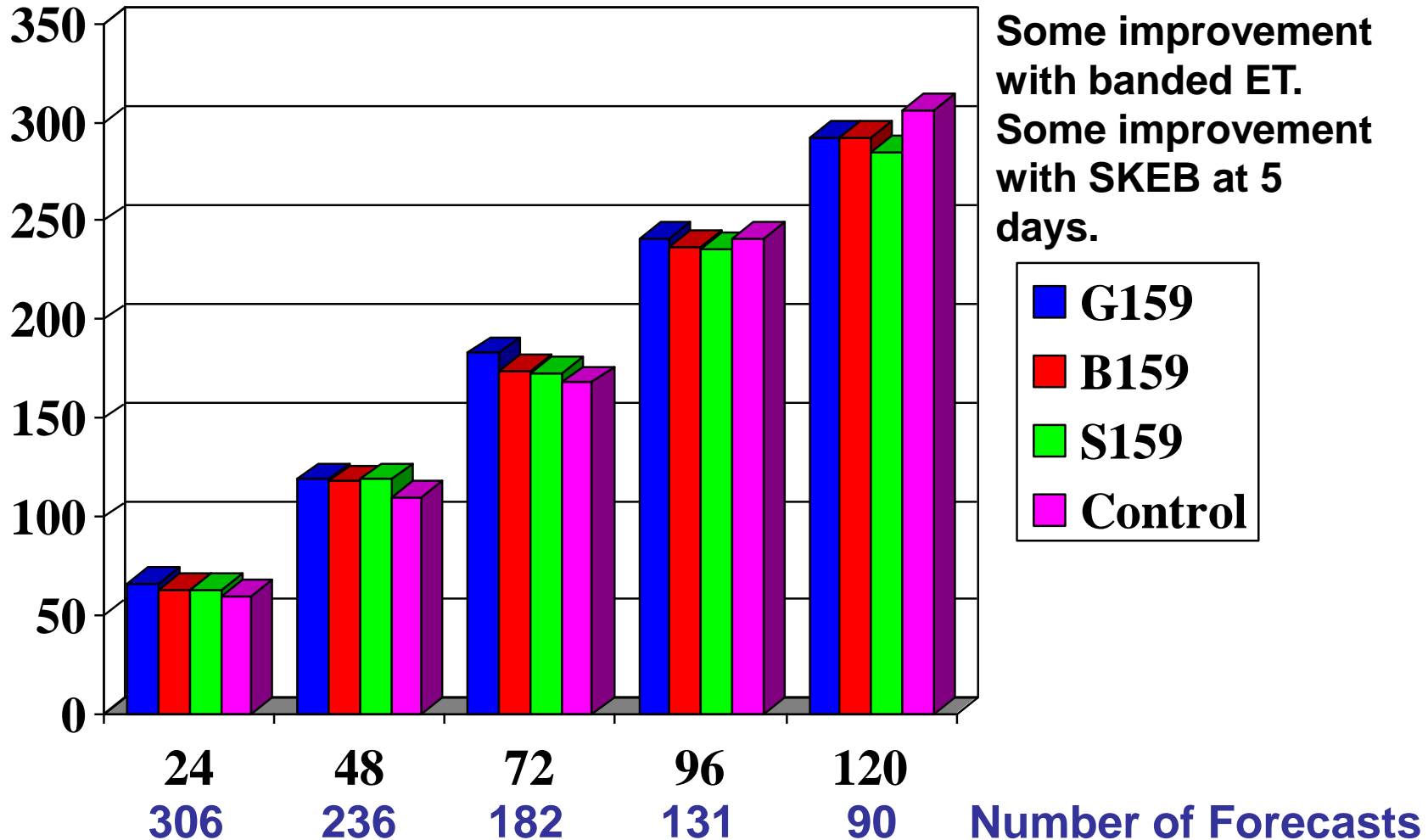# 2008 Northern Hemisphere Homogeneous TC Forecast Error (nm)

Sensitivity of Mean to Ensemble Size

Some sensitivity to ensemble size at longer times.

Legend:
- G119-9
- G119-17
- G119-33
- Control

Number of Forecasts

2008 Northern Hemisphere Homogeneous TC Forecast Error (nm)
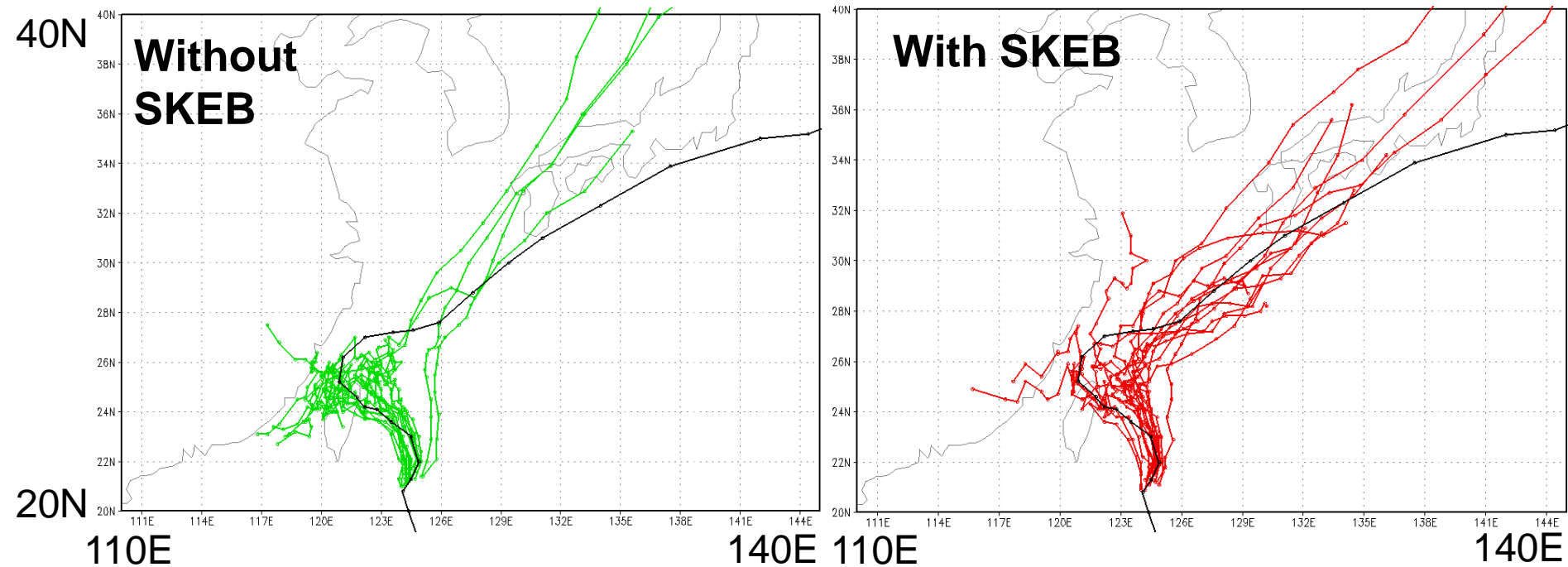

Sensitivity of Mean to Ensemble Model Resolution

Biggest improvement from T119 to T159
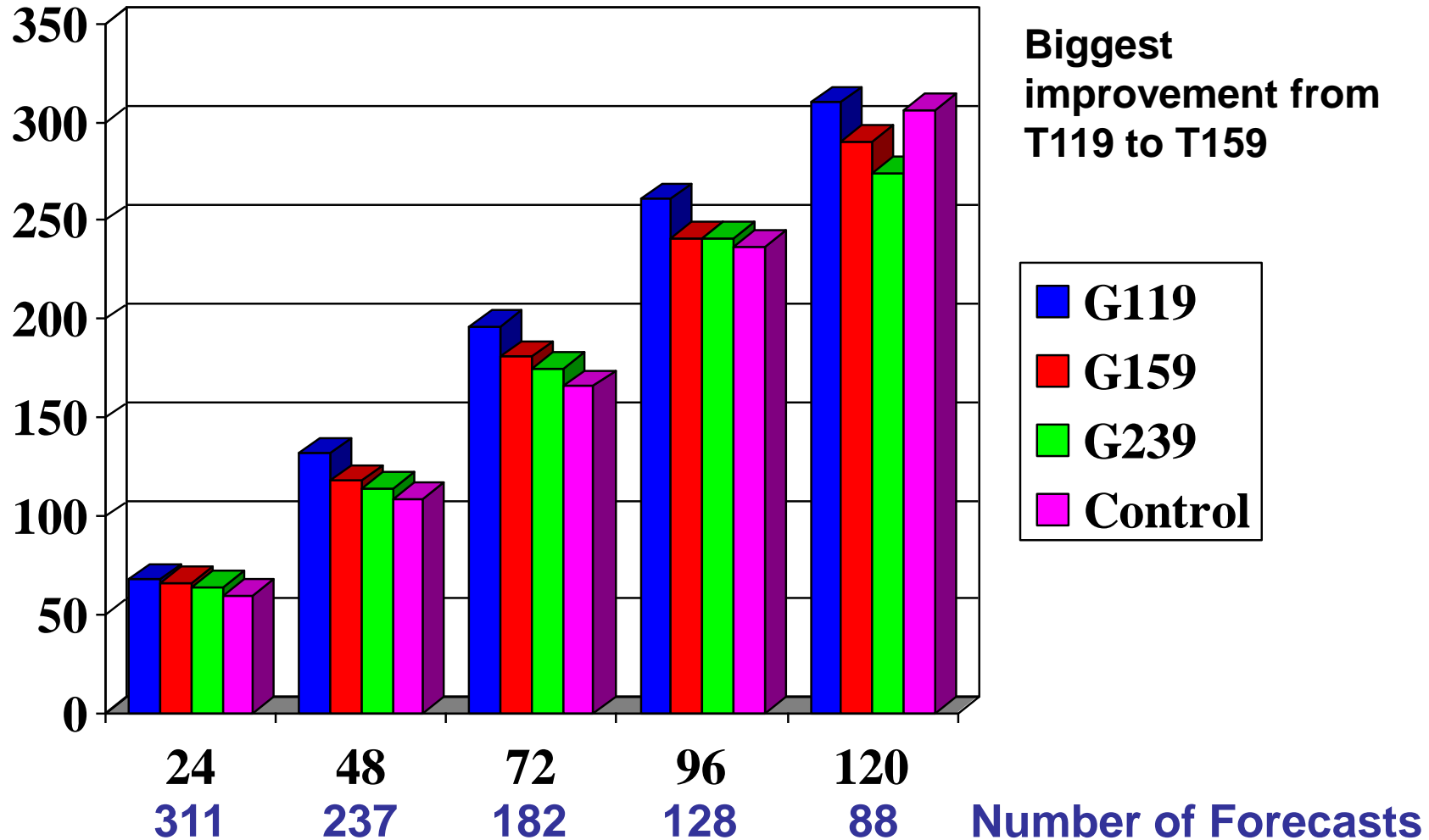
2008 Northern Hemisphere
Homogeneous TC Forecast Error (nm)

Sensitivity of Mean to Initial Ensemble Perturbations

Some improvement with banded ET. Some improvement with SKEB at 5 days.

Legend:
- G159
- B159
- S159
- Control

24	48	72	96	120
306	236	182	131	90

Number of Forecasts

Forecasts for Typhoon Sinlaku (2008091100)
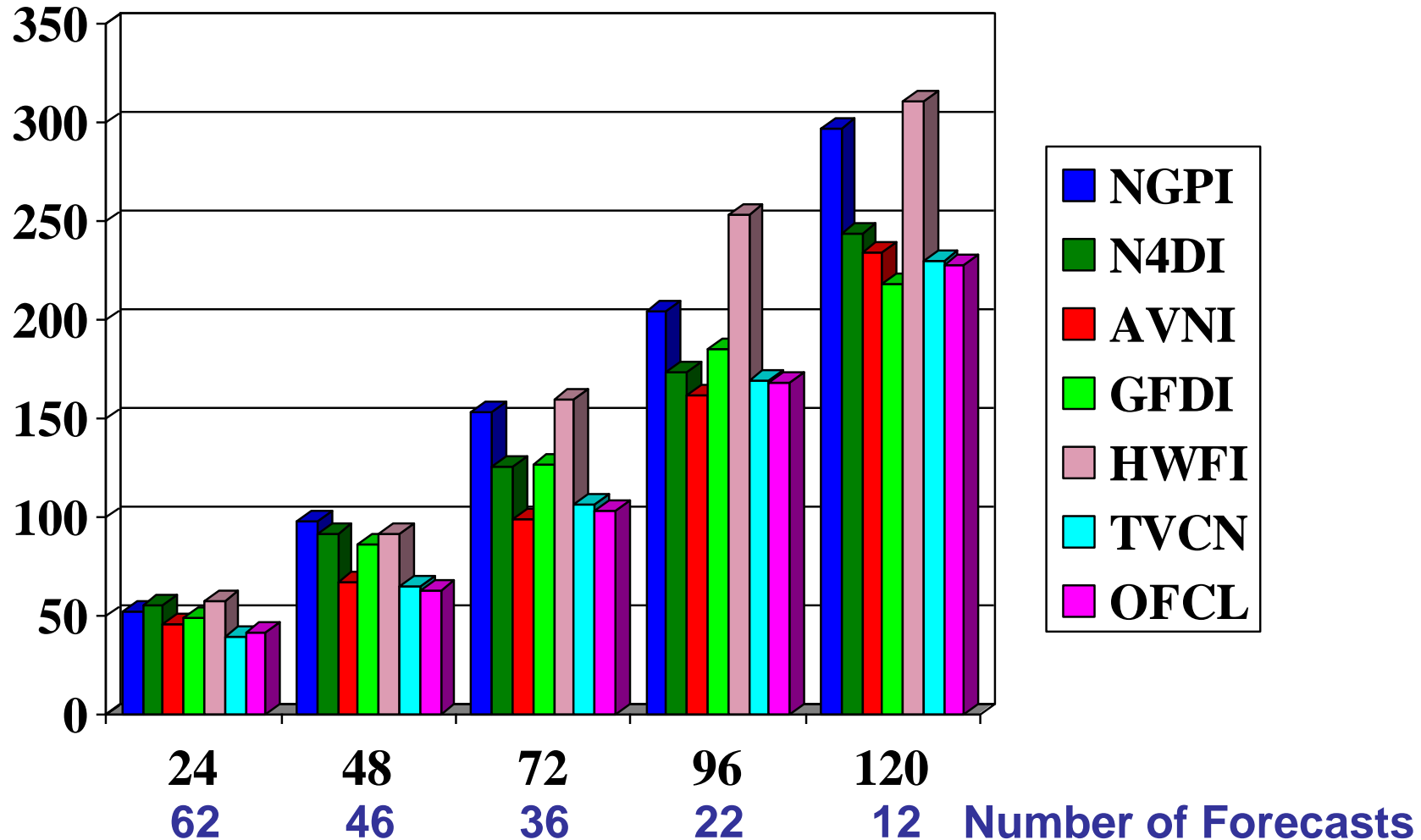## Impact of SKEB

SKEB appears to increase ensemble spread in case studies.

Will quantify this in the near future.

3DVAR-4DVAR Comparison
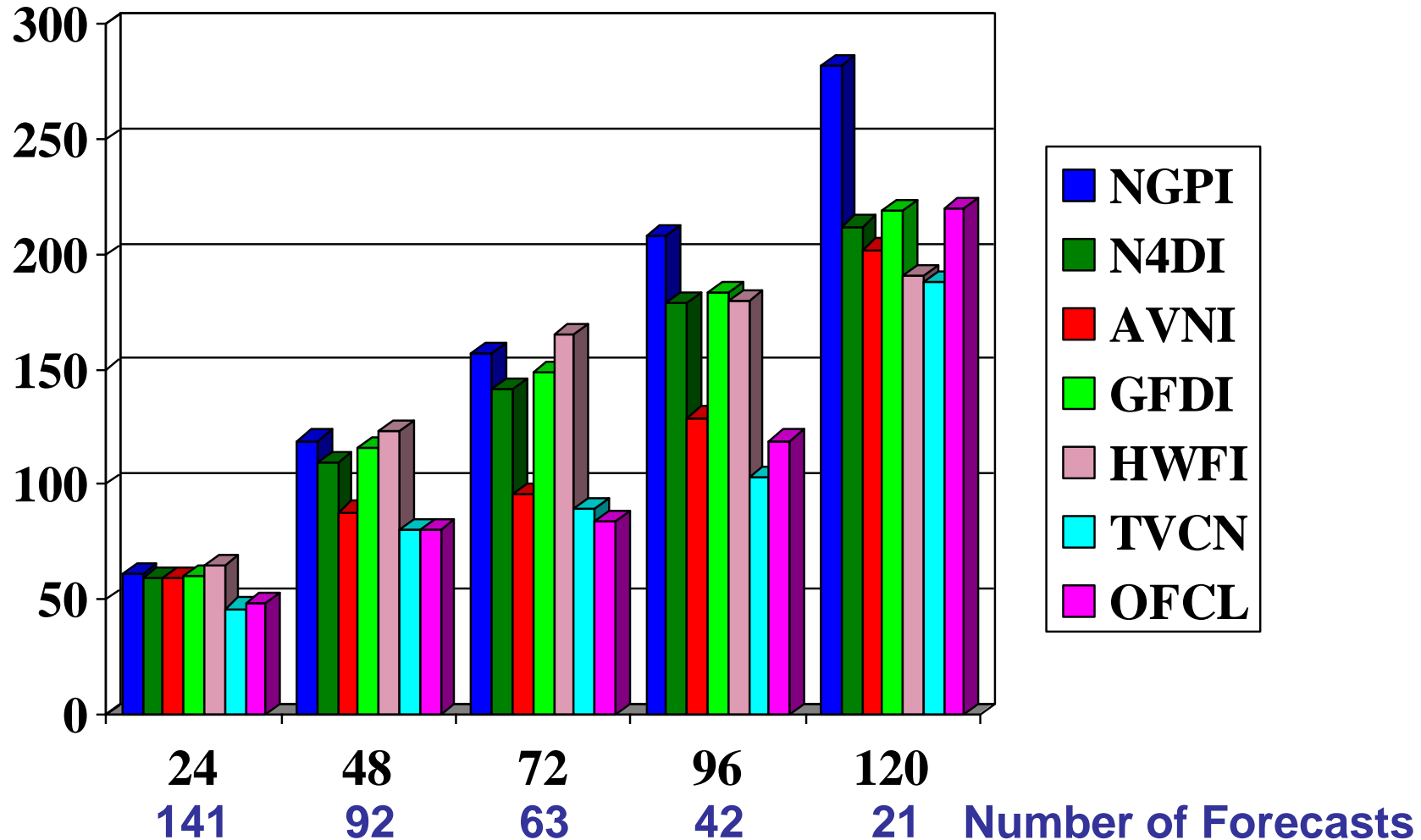## Atlantic 2009 (02L-07L)
Homogeneous TC Forecast Error (nm)

3DVAR-4DVAR Comparison
Eastern North Pacific 2009 (06E-17E)
Homogeneous TC Forecast Error (nm)

Improvement with 4DVAR

2009080900. FNMOC operational tracker (upper left) shows smoother tracks than research tracker (lower right). Some tracks in the research version look unrealistic. Both trackers show erroneous recurvature of Goni. Operational tracker captures Korean landfall of Morakot while research tracker does not.
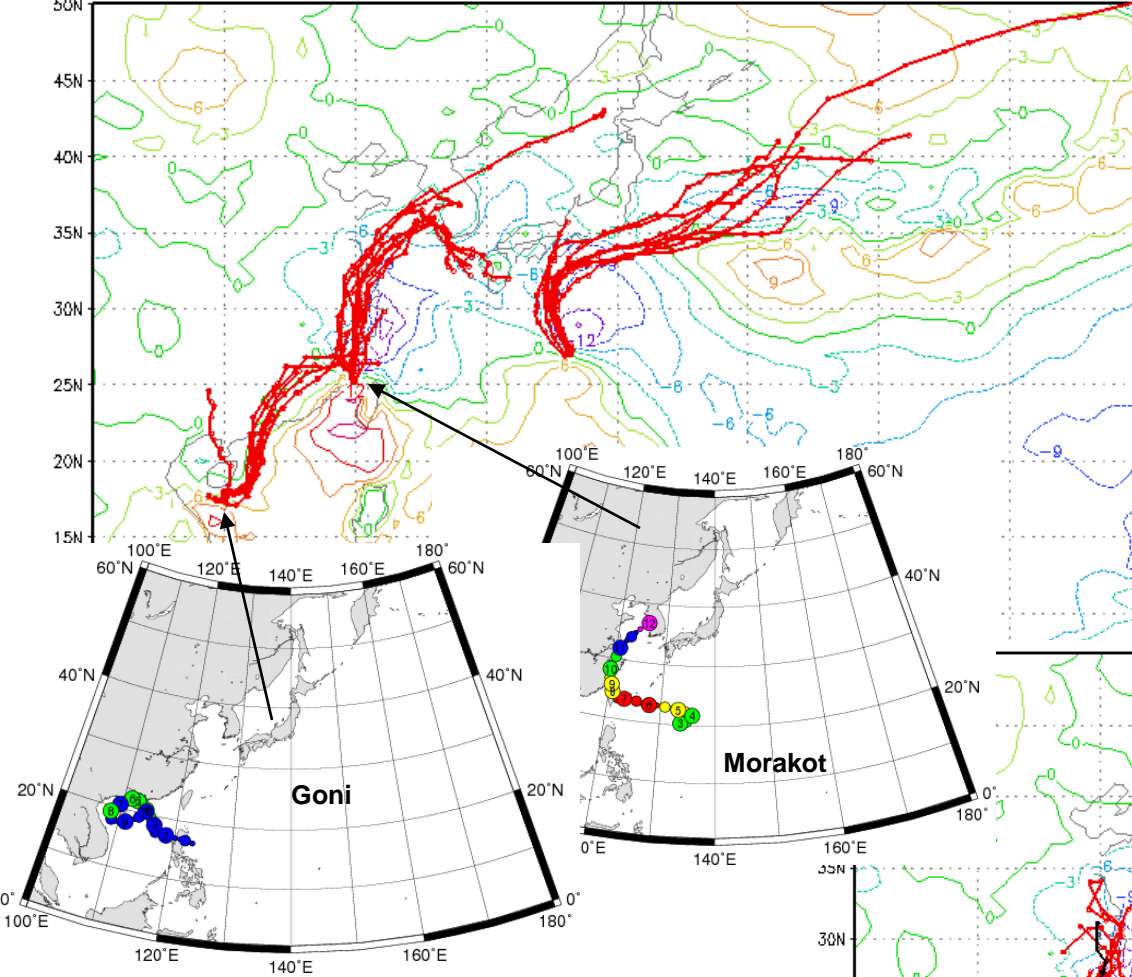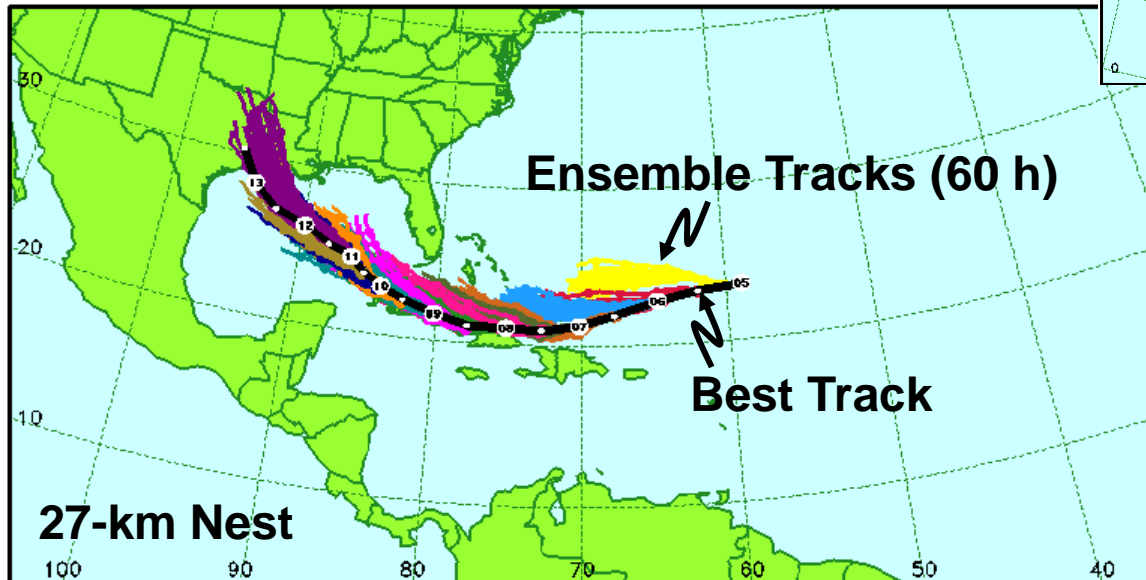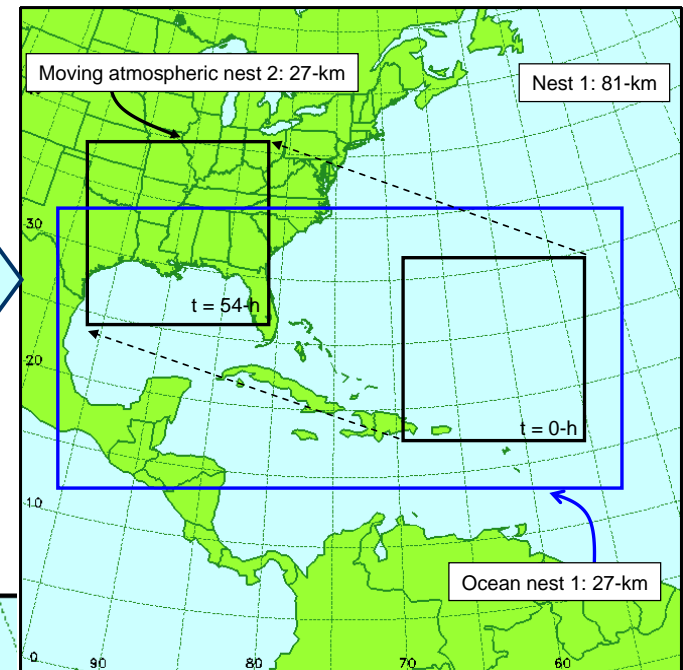
Both track plots are based on the same 9-member ensemble forecasts at a T239L30 resolution, but the trackers themselves use different fields and different techniques.

GrADS: COLA/IGES
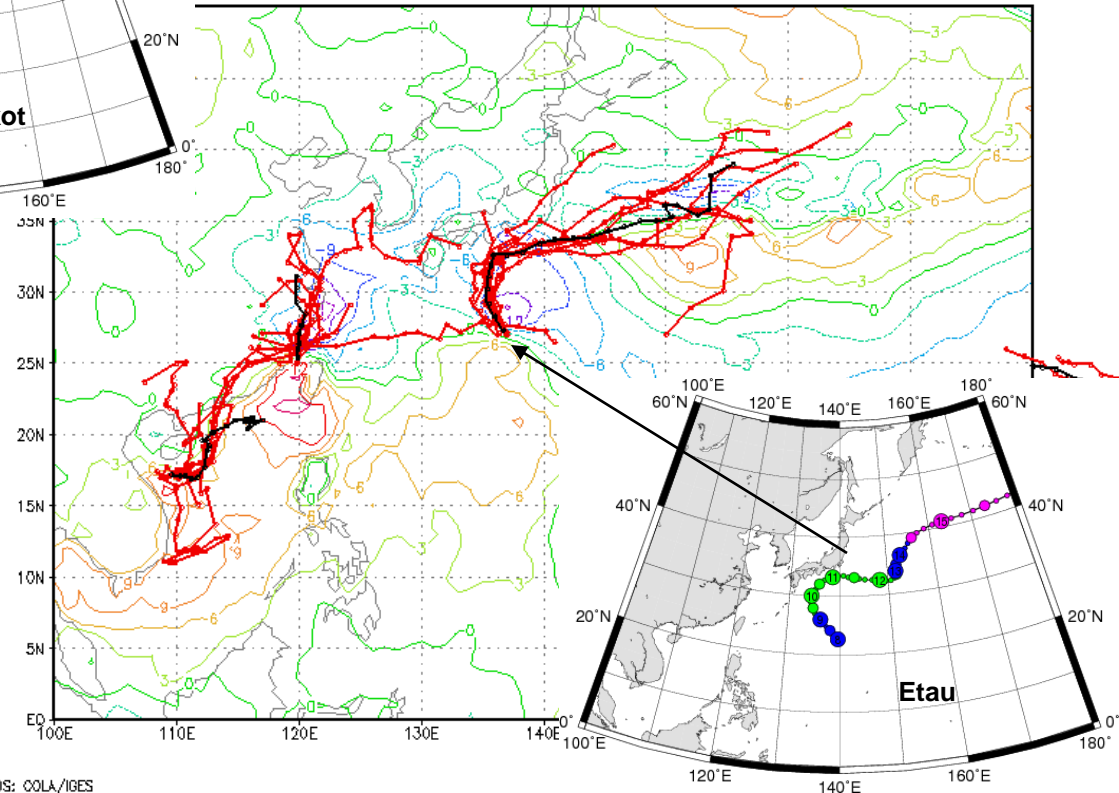
COAMPS-TC Ensembles
2-Way Coupled Air-Sea Ensembles of Ike (2008)

- **29 member COAMPS-TC coupled ensemble forecasts of Hurricane IKE.**
- **Atmosphere: 81 km, 27 km**
- **Ocean: 27 km (NCOM)**
- **Perturbations: ET initial conditions, LBCs, ocean, model physics perturbations (cumulus, microphys., PBL, surface fluxes).**

Moving atmospheric nest 2: 27-km

Nest 1: 81-km

t = 54-h

t = 0-h

Ocean nest 1: 27-km

Ensemble Tracks (60 h)

Best Track

27-km Nest

Coupled air-ocean ensembles provide probabilistic prediction of TC track, intensity, ocean response

FUTURE PLANS

GLOBAL:

•Complete examination of current ensemble tests (ensemble spread, other metrics?)

•Test higher-resolution NOGAPS ensembles with NOGAPS SL

•Consider other types of model uncertainty in ensemble design (surface parameterizations, improved stochastic parameterizations)

•4DVAR Ensembles, Hybrid, wave models

MESOSCALE:

•Continue testing and development of coupled ET system

•Research with uncoupled EnKF in DART

•Future work will include wave model

Track Forecast Guidance

Interpolated Model Guidance

AVNI – Global Forecast System (GFS) run at NCEP

GFDI – GFDL model run at NCEP

HWFI – Hurricane WRF run at NCEP

NGPI – Navy global model (NOGAPS) run at FNMOC

GFNI – GFDL model run at FNMOC

EGRI – UK Met Office global model

EMXI – ECMWF global model

TVCN – Consensus of above models (at least two)

CMCI – Canadian global model

Ensemble Prediction with NOGAPS

Current Navy operational global ensemble system

Navy Operational Global Atmospheric Prediction System (NOGAPS) T119L30 (110-km)

Initial perturbation methodology: Ensemble Transform (ET, McLay et al 2008)

Operational version recently upgraded from global ET to banded ET (McLay et al 2010)

- ET produces initial perturbations by transforming 6-h ensemble forecast perturbations to be consistent with analysis error estimates

- The global ET, where transform was computed over the entire globe, produced initial perturbations that were too small in the tropics and too large in the extratropics

- The local "banded" ET performs this transformation in latitude bands, resulting in a better match to the analysis error estimate, and much improved performance in the mid-latitudes. Initial perturbations are still too small in the tropics.

- Stochastic kinetic energy backscatter (SKEB; Shutts and Palmer 2004, Shutts 2005, Berner et al 2009) adopted to account for model uncertainty and increase size of tropical perturbations.

Impact of New Global Models and Ensemble Prediction Systems on Consensus TC Track Forecasts

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March 3, 2010

Track Forecast Guidance

Interpolated Model Guidance

AVNI – Global Forecast System (GFS) run at NCEP

GFDI – GFDL model run at NCEP

HWFI – Hurricane WRF run at NCEP

NGPI – Navy global model (NOGAPS) run at FNMOC

GFNI – GFDL model run at FNMOC

EGRI – UK Met Office global model

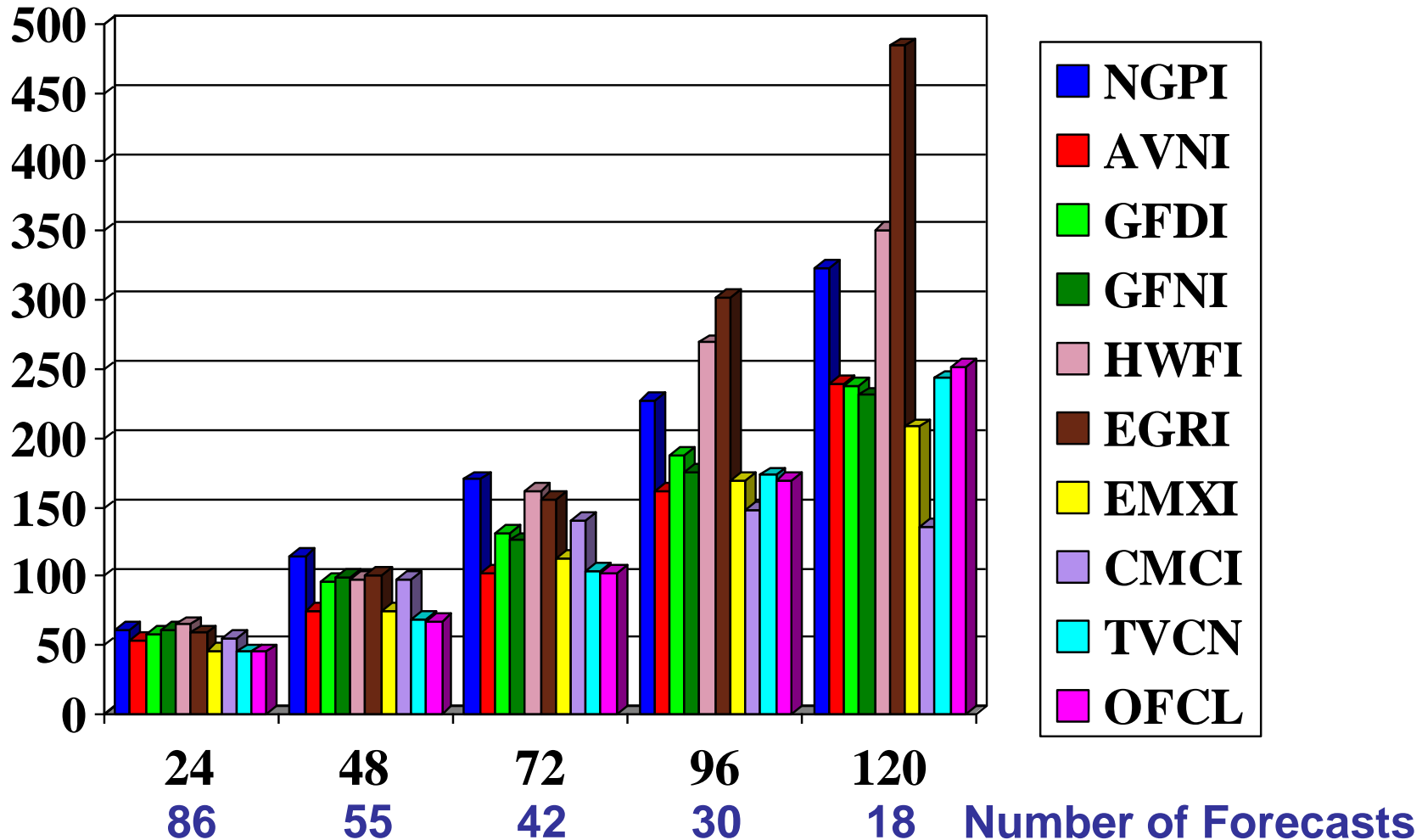**EMXI – ECMWF global model**

TVCN – Consensus of above models (at least two)

CMCI – Canadian global model

Atlantic 2009
Non-Homogeneous TC Forecast Error (nm)

The Canadian Global Model performed very well.

HFIP Demonstration

As part of the Hurricane Forecast Improvement Project Demonstration, a number of forecasts were made using different configurations of the NOAA/ESRL FIM (a global model using a flow-following vertical coordinate, finite-volume numerics, and an icosahedral global grid). Interpolated guidance was created from these model forecasts.

Interpolated Model Guidance

F8MI – FIM (30 km resolution, GFS initial conditions)
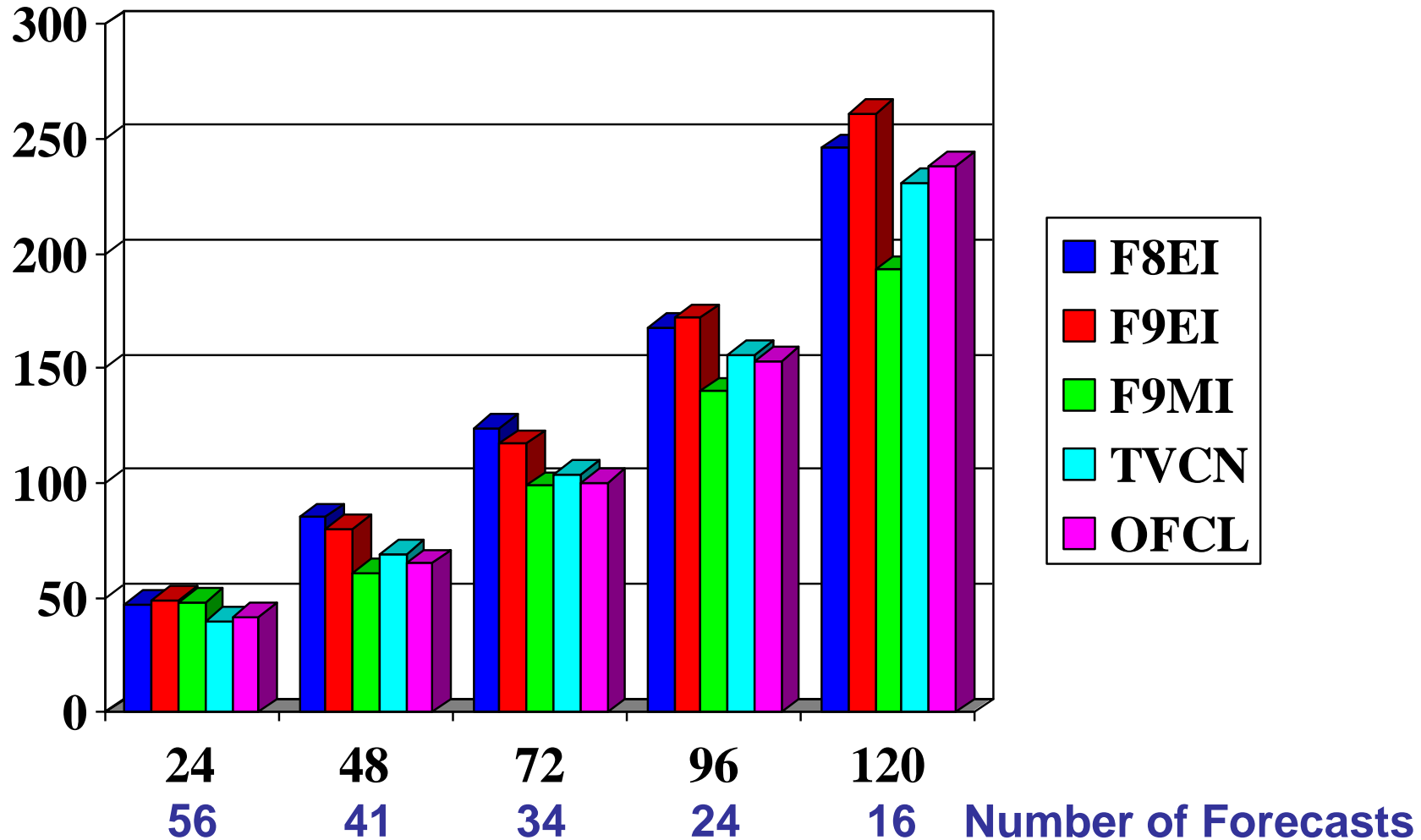
F8EI – FIM (30 km resolution, EnKF initial conditions)

F9MI – FIM (15 km resolution, GFS initial conditions)

F9EI – FIM (15 km resolution, EnKF initial conditions)

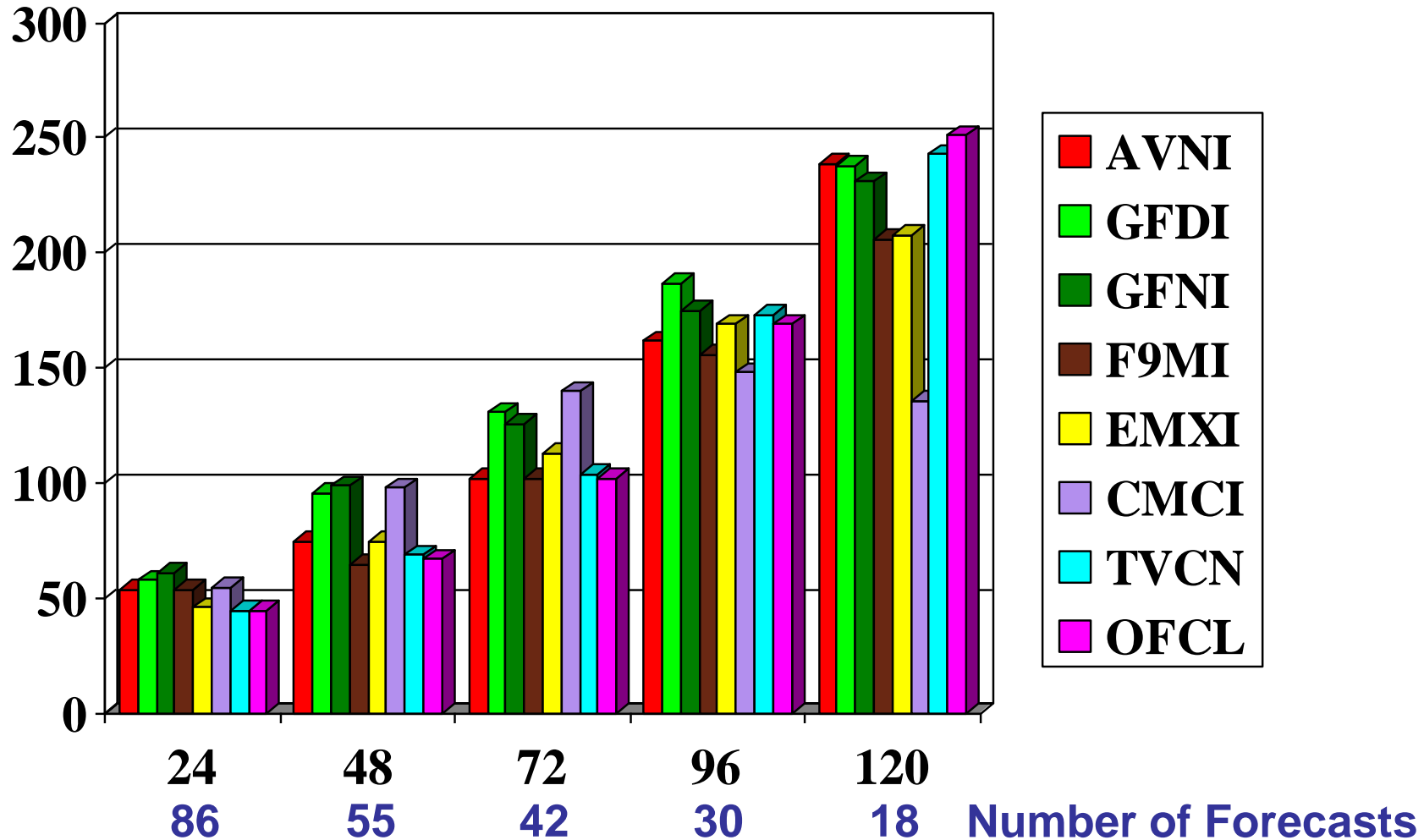F0EI – FIM (10 km resolution, EnKF initial conditions)

Atlantic 2009
Homogeneous TC Forecast Error (nm)
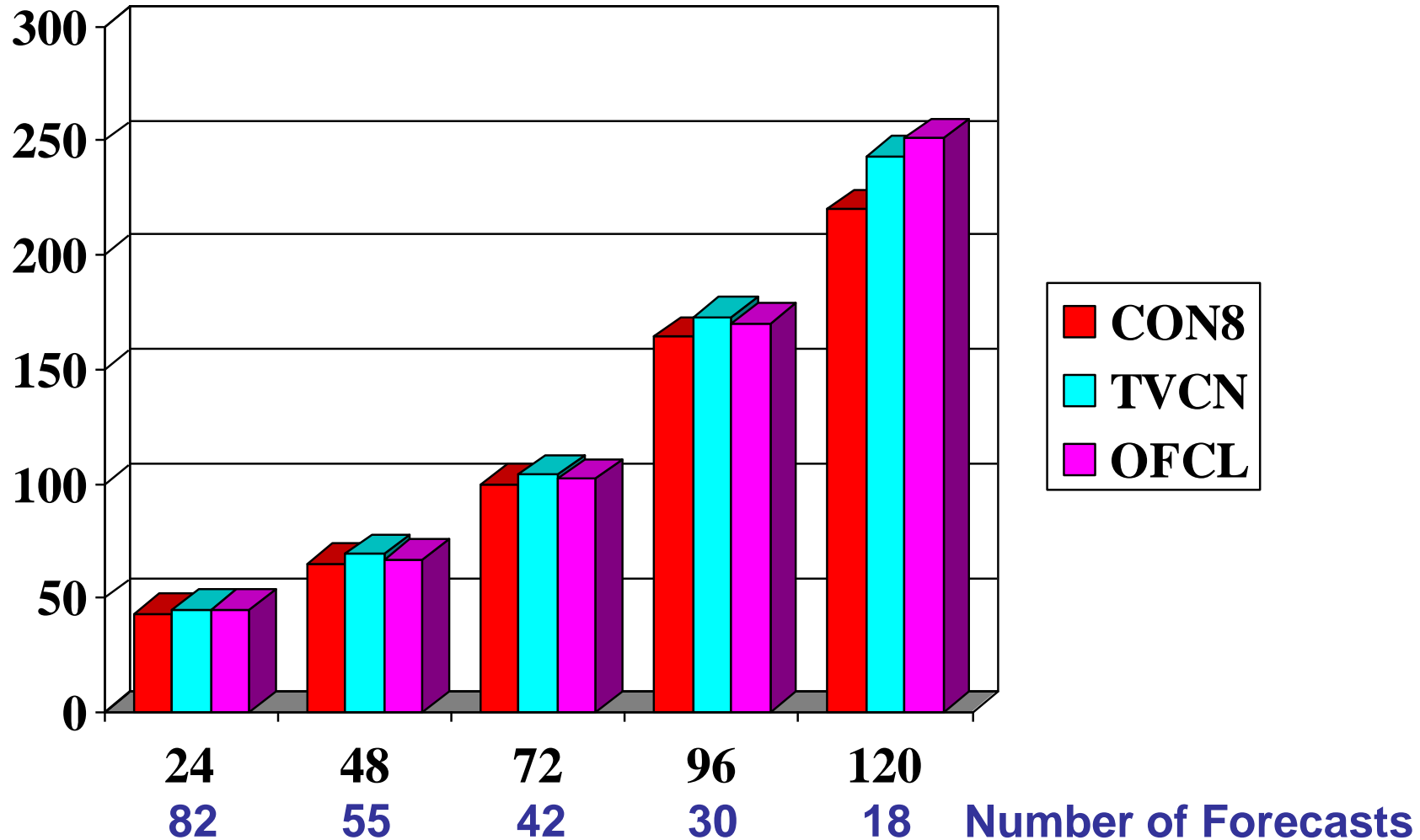
Atlantic 2009
Non-Homogeneous TC Forecast Error (nm)

The 15-km FIM with GFS IC's performed very well.

Legend:
- AVNI
- GFDI
- GFNI
- F9MI
- EMXI
- CMCI
- TVCN
- OFCL

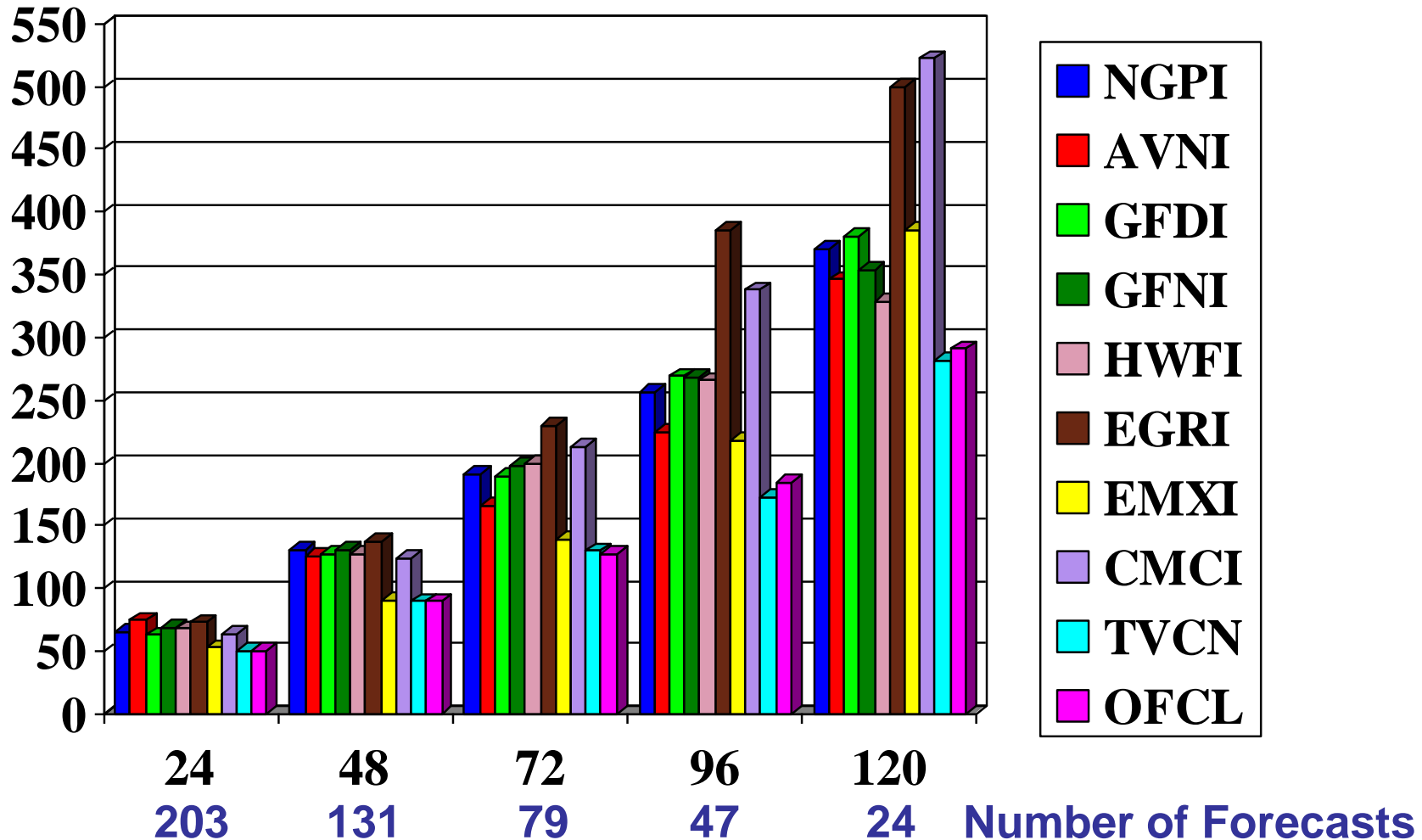| Forecast Period	24	48	72	96	120
Number of Forecasts	86	55	42	30	18

Number of Forecasts

Atlantic 2009
Homogeneous TC Forecast Error (nm)

CON8 – consensus including CMCI and F9MI

Eastern North Pacific 2009
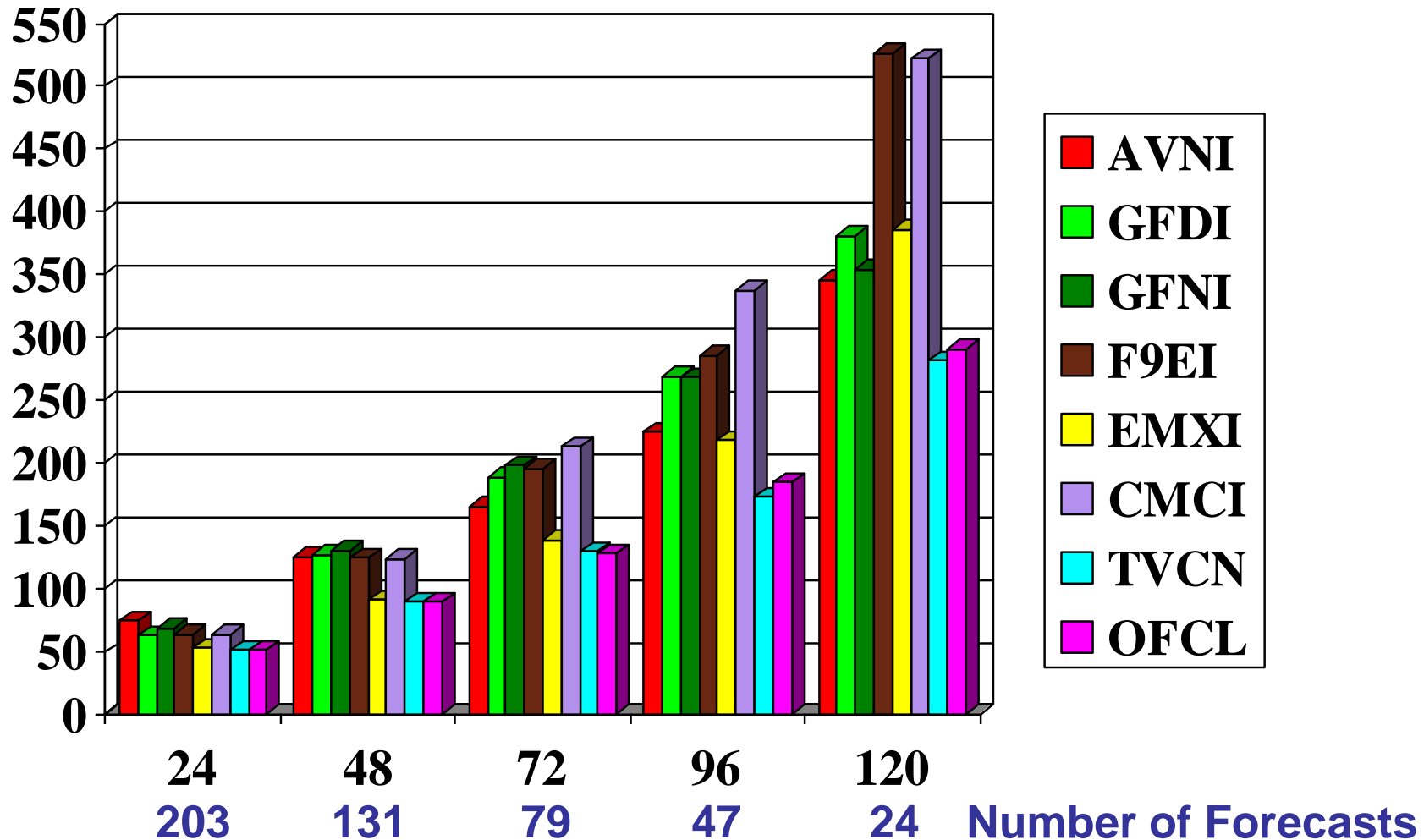# Non-Homogeneous TC Forecast Error (nm)

The Canadian Global Model was not a top performer.
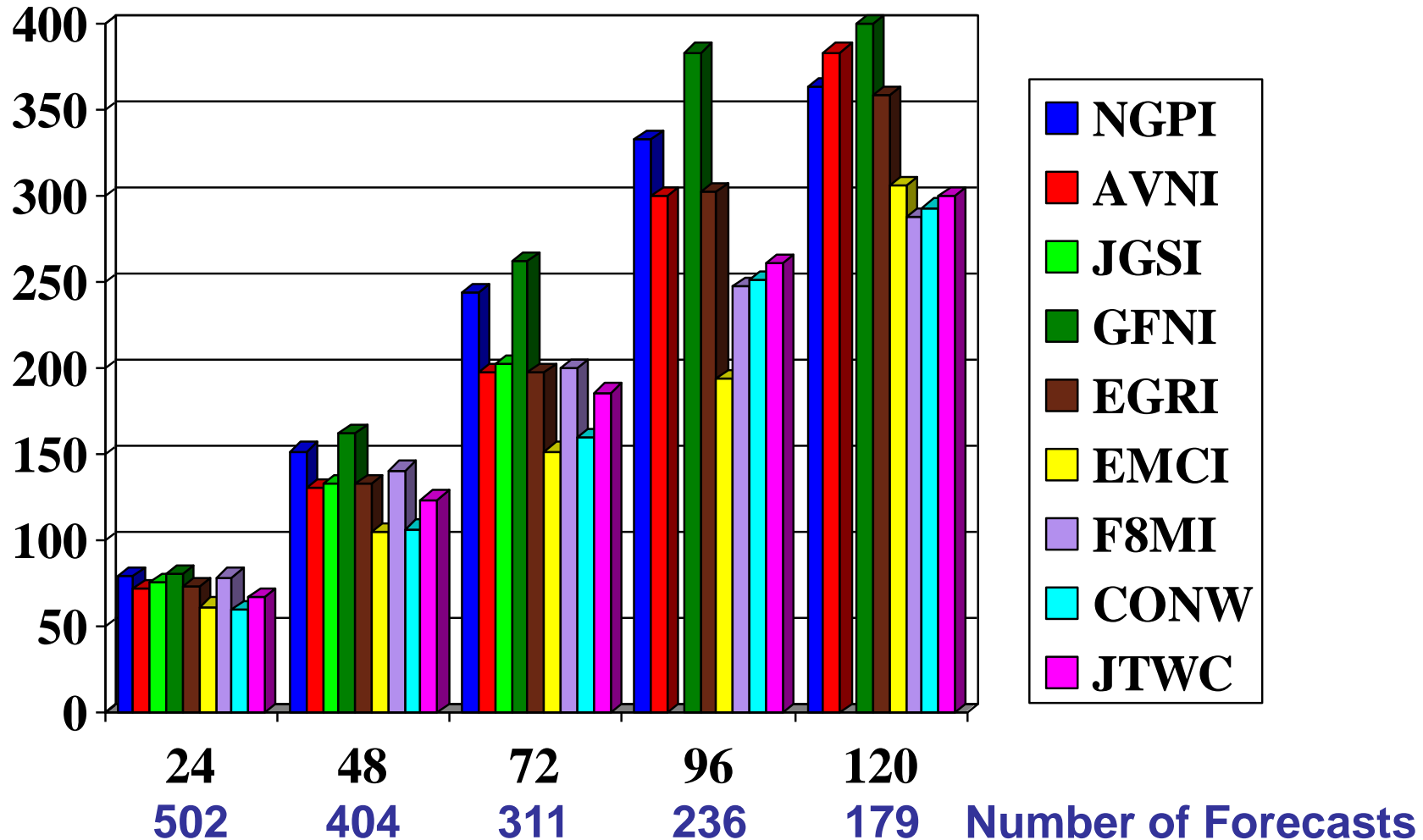
Eastern North Pacific 2009
Non-Homogeneous TC Forecast Error (nm)

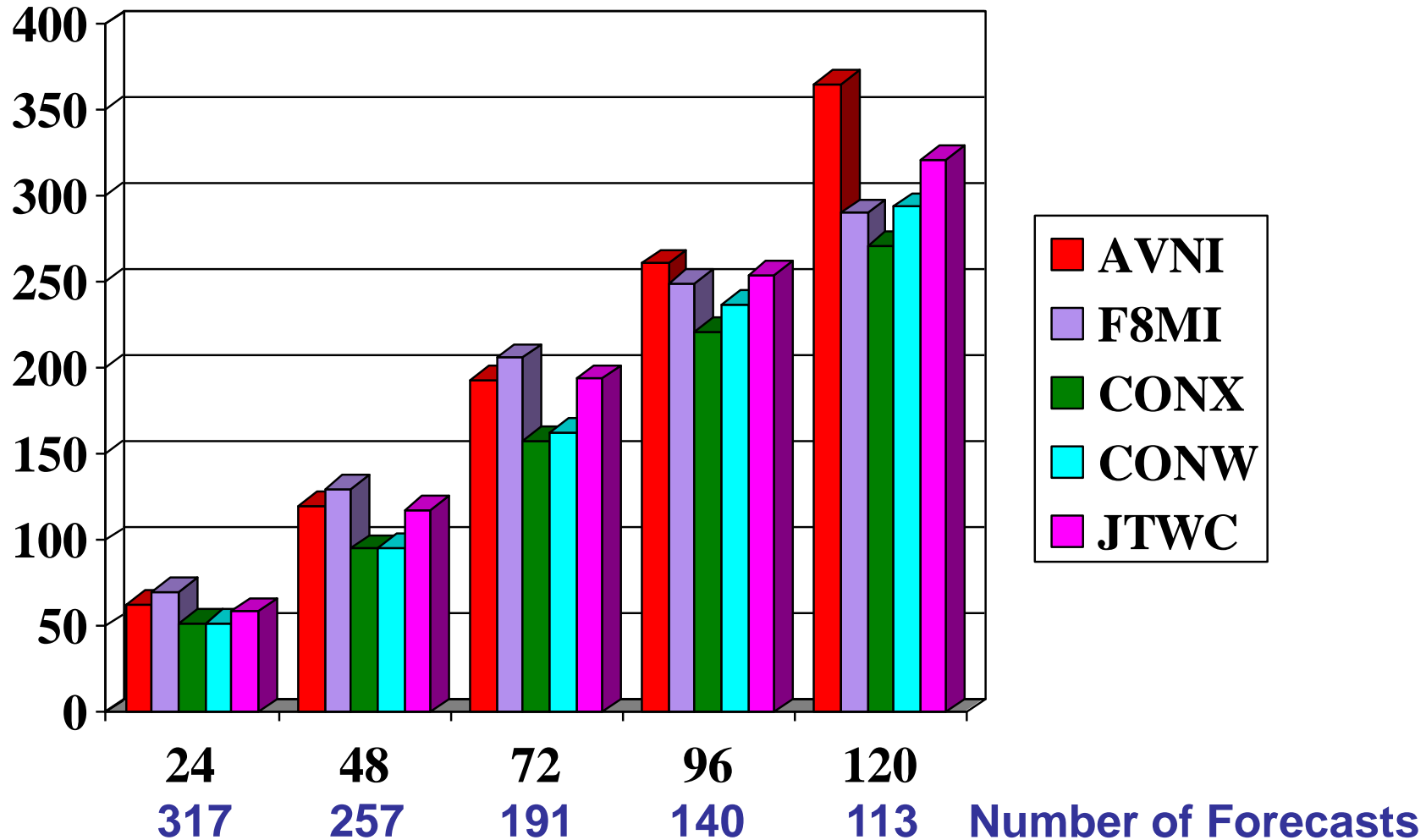The 15-km FIM with EnKF IC's was not a top performer.

Western North Pacific 2009
Non-Homogeneous TC Forecast Error (nm)

The 30-km FIM with GFS IC's performed well.

Number of Forecasts

Western North Pacific 2009
Homogeneous TC Forecast Error (nm)

CONX – consensus including F8MI

Legend:
- AVNI
- F8MI
- CONX
- CONW
- JTWC

|	24	48	72	96	120
Number of Forecasts	317	257	191	140	113

HFIP Demonstration

As part of the Hurricane Forecast Improvement Project Demonstration, a 20-member ensemble was run using the 30-km FIM (EnKF IC's) for a limited number of cases. Interpolated guidance was created from the ensemble mean of the member forecasts.

Interpolated Model Guidance

F8NI – Ensemble mean for 20-member FIM (30 km resolution, EnKF initial conditions) ensemble

Northern Hemisphere
Homogeneous TC Forecast Error (nm)
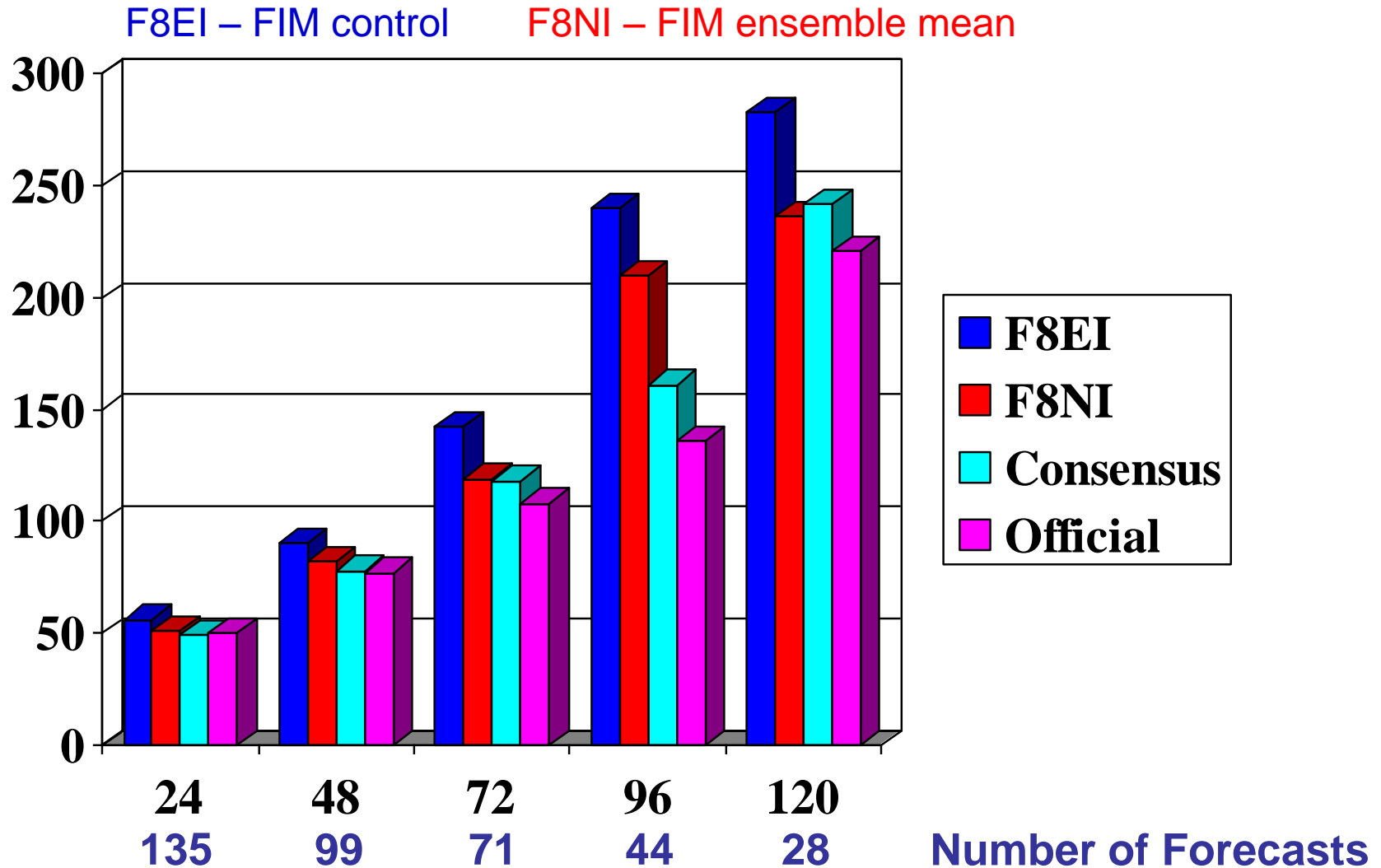
Summary

- Prior to the start of the 2009 Atlantic season, upgrades were made to the Canadian global model (CMCI) resulting in greatly improved TC track forecasts.

- As part of the HFIP Demonstration a number of configurations of the FIM were run for the 2009 Atlantic season. It was found that the 15-km FIM using GFS initial conditions (F9MI) had the best TC track forecast performance.

- A new consensus aid was formed by adding CMCI and F9MI to the TVCN models. For the Atlantic, the TC track forecast improvement for this new aid ranged from about 5 percent at 24 h to almost 10 percent at 120 h.
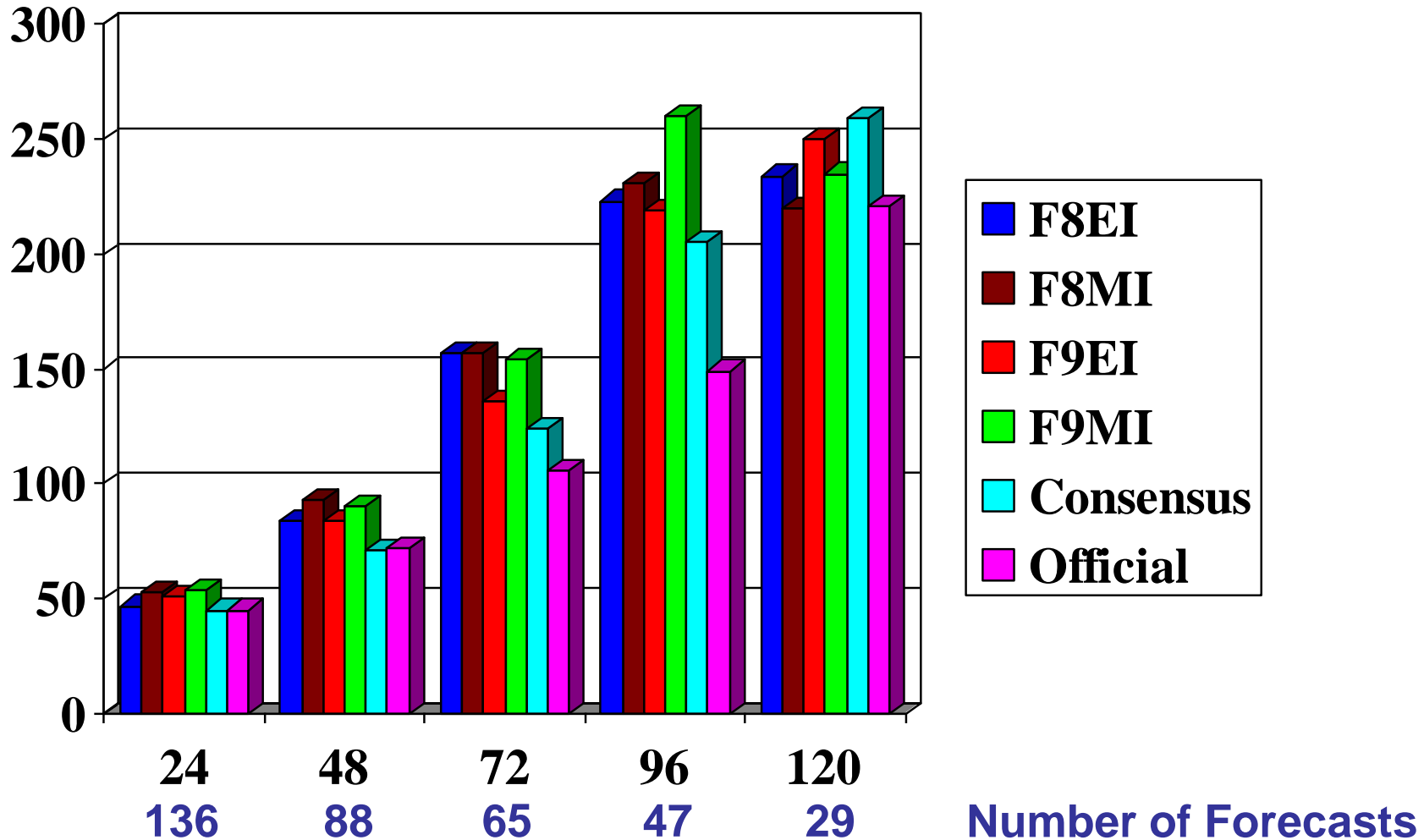
Summary

- **Neither the Canadian global model nor the FIM were among the top performers for the eastern North Pacific. Their addition to consensus did not result in significant impact.**

- **The 30-km FIM using GFS initial conditions (F8MI) was run regularly for the western North Pacific and performed quite well. Its addition to the CONW consensus resulted in 5-10 percent track forecast improvement at 96 h and 120 h.**

- **The track forecast improvement for the ensemble mean of the 30-km FIM using EnKF initial conditions EPS ranged from 10 percent at 24 h to over 15 percent at 120 h with respect to the control run. For a very limited sample, these ensemble mean forecasts were competitive with those from the multi-model consensus (TVCN/CONW).**

Questions?

Northern Hemisphere
Homogeneous TC Forecast Error (nm)

Atlantic 2009
Homogeneous TC Forecast Error (nm)