Centro Euro-Mediterraneo
per i Cambiamenti Climatici

INGV

Seasonal climate prediction activity at CMCC: developments and latest results.

A. Alessandri, A. Borrelli and A. Navarra

Contributions:

Oceanic Initialization and assimilation: S. Masina, P. Di Pietro
Tropical Cyclones Predictability: S. Gualdi and E. Scoccimarro
Monsoon predictability: A. Cherchi
Coupled model development: B. Fogli

APCC Symposium
Busan, 21-24 June 2010

Outline

CMCC-INGV Seasonal prediction System

Retrospective Forecasts Skill

- ***Sensitivity to the improvement of Ocean ICs***
- ***Tropical Cyclone counts predictability***

Contribution to the new European multi-model Seasonal Prediction System: EU ENSEMBLES Framework

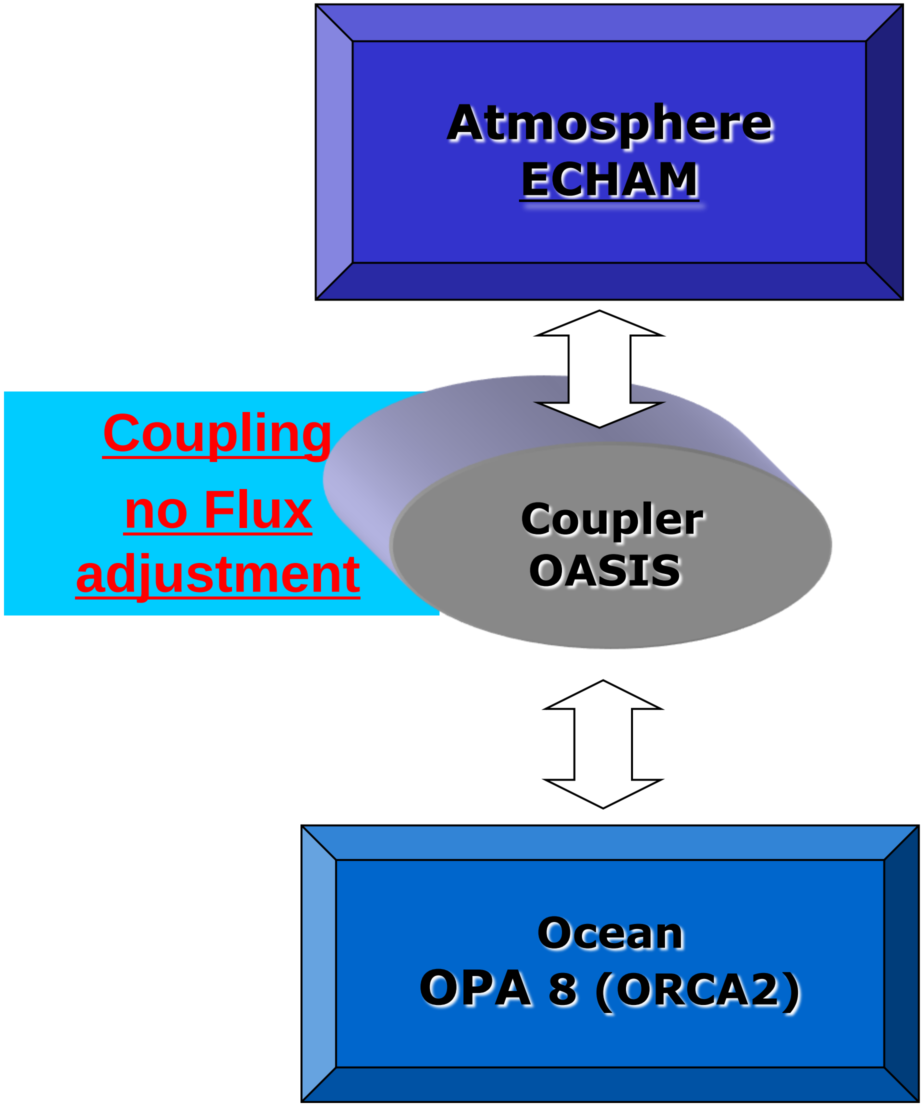
Comparison with previous multi-model system (DEMETER)

Summary & Conclusions

CMCC-INGV Seasonal Prediction System

[DEMETER->MERSEA->ENSEMBLES EU projects]

Coupled Model Components



Atmosphere
ECHAM

Coupling
no Flux
adjustment

Coupler
OASIS

Ocean
OPA 8 (ORCA2)

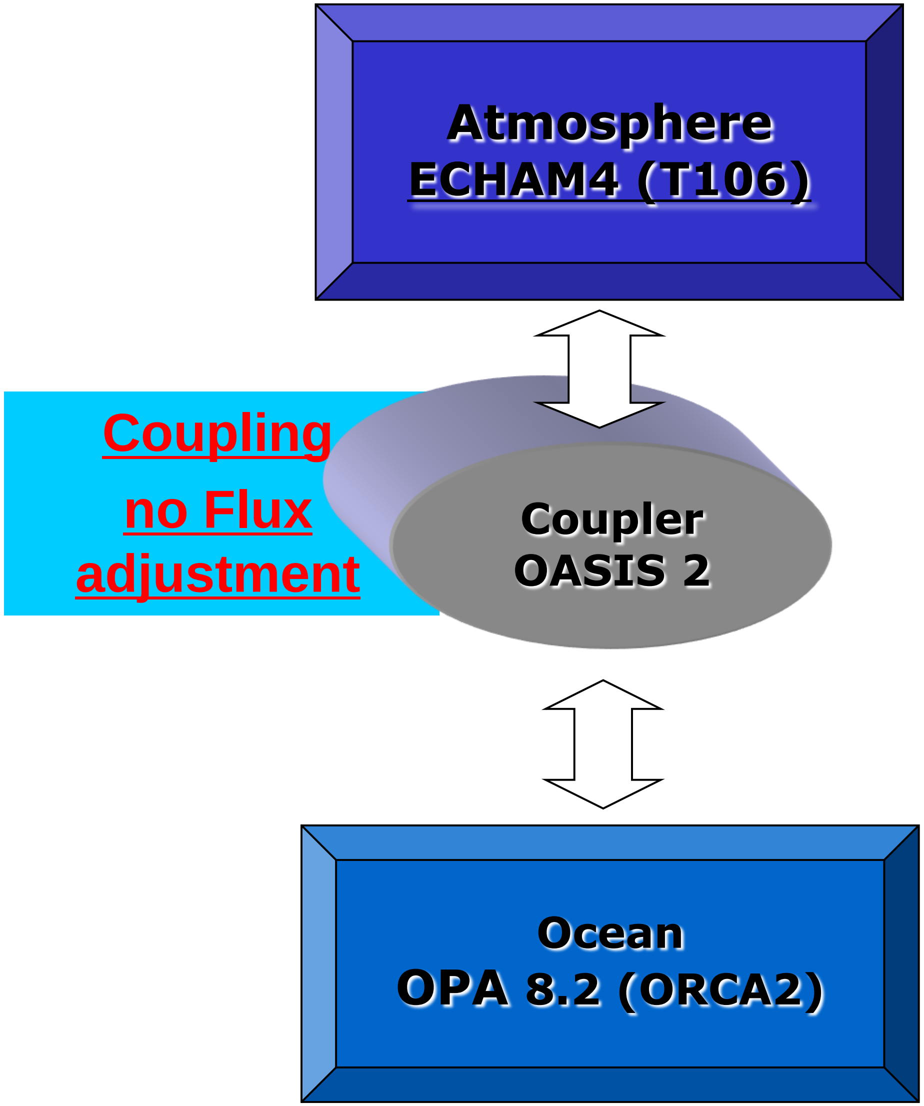
ECHAM:
Max-Planck-Inst., Hamburg
Spectral T42/T63/T106
19 Vertical levels
(Roecker et al 1996, 2003)

OPA 8:
LODYC, Paris,
Global - 2° longitude
0.5° - 2° latitude
31 Vertical Levels
(Madec et al 1998)

CMCC-INGV Seasonal Prediction System

[DEMETER->MERSEA->ENSEMBLES EU projects]

Coupled Model Components



Off line Initialization Tools

CMCC-INGV Global Ocean Data Assimilation System(CIGODAS)

Assimilated Ocean initial condition production:

T & S - OI assimilation
SOFA 3.0
(De Mey and Benkiran 2002)

Bellucci, Masina, Di Pietro & Navarra, 2007

-Di Pietro & Masina, 2009

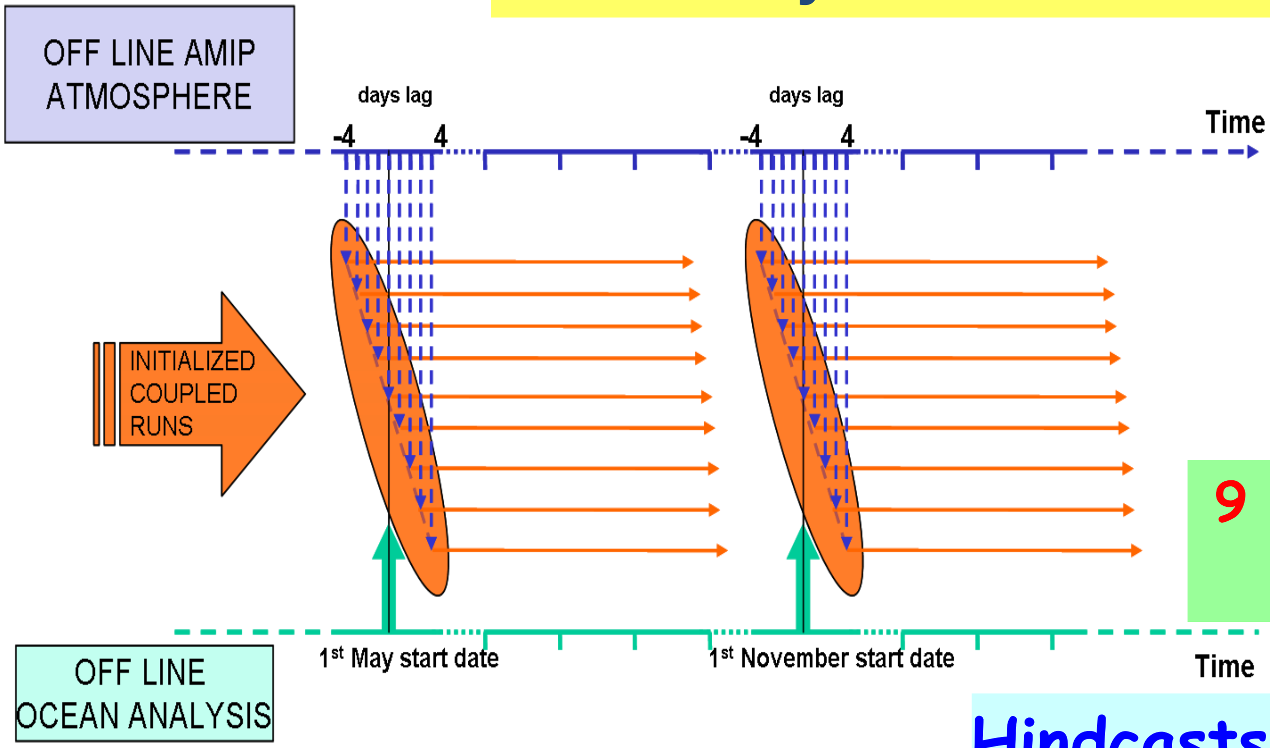
ENSEMBLES

SEASONAL RETROSPECTIVE FORECASTS

Atmospheric forced (HadISST) run

Oceanic run forced with ERA-40
T & S assimilation

For each year, 2 start dates:
1st May and 1st November



Atmospheric IC
from lagged days
(-4:0:+4)

9 perturbed i.c. for each
start date, each year

Hindcasts period 1992-2001

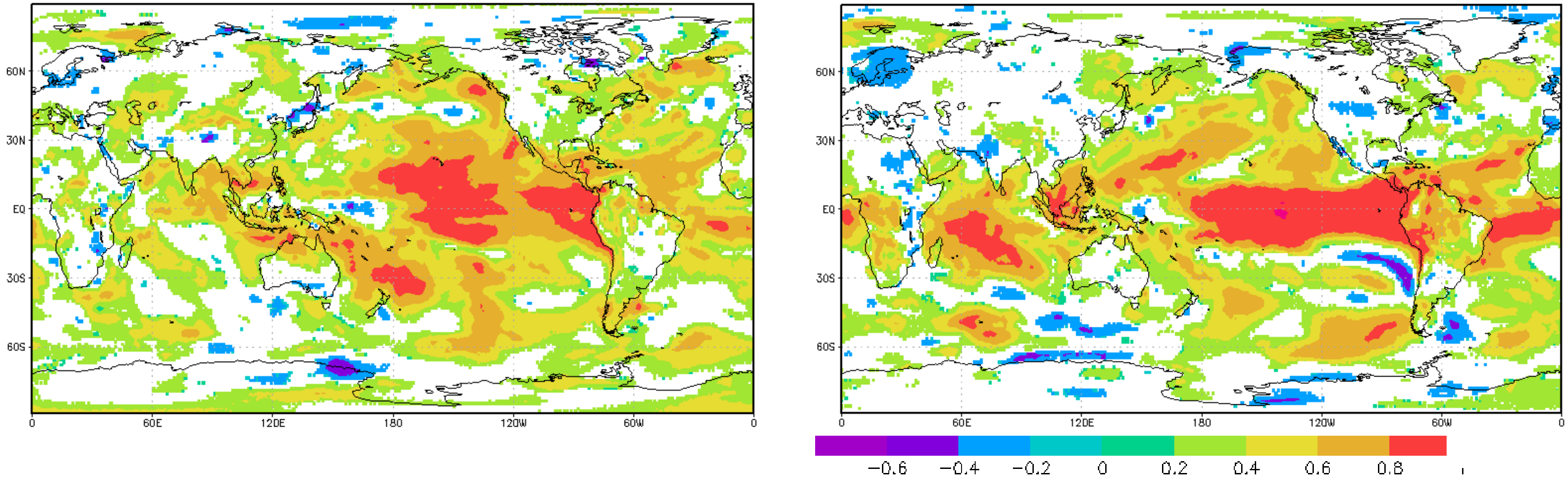
Each hindcast 5 months long

Skill in one month lead surface temperature prediction: Anomaly correlations of seasonal means (months 2-to-4)

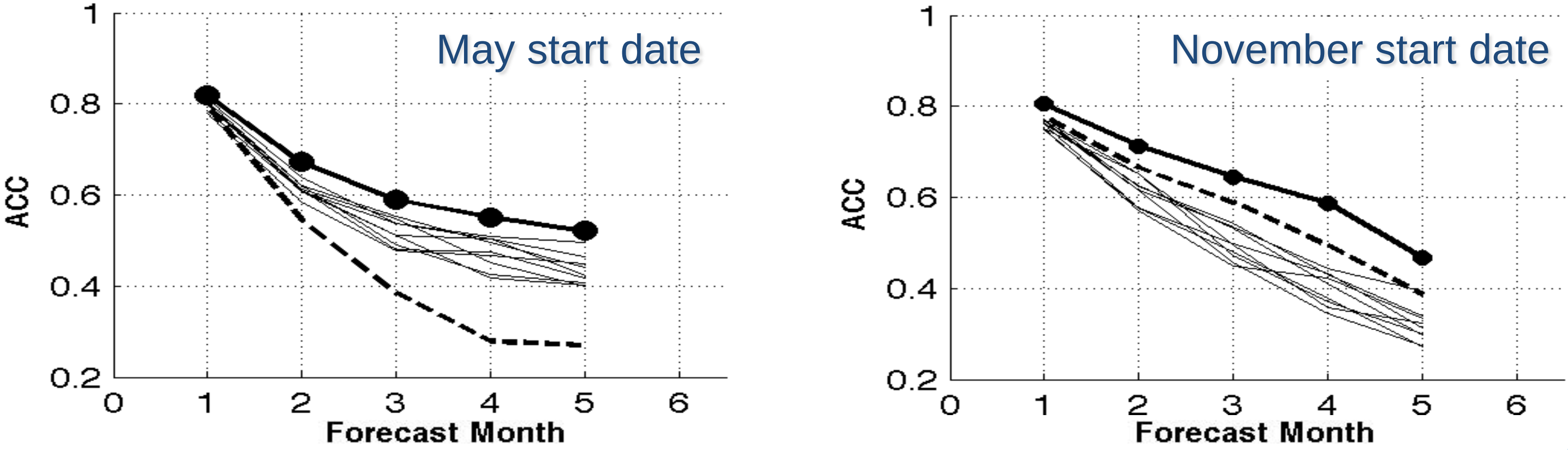
only significant correlations are shaded - bootstrap 10% level

Model vs ERA40   JJA

Model vs ERA40 DJF



Tropical Pacific [25S-25N; 140-280] – Anomaly Correlation Coefficient (ACC)



Solid thick & circles = Ensemble means

Solid thin = Ensemble members

Dashed = persistence

Impact of global assimilation of T & S profiles during Ocean Initialization

➡ Sensitivity experiment with no assimilation of the subsurface (hereinafter NODAS vs DAS)

- Atm **T106** (1.1ºx1.1º)

- Same atmospheric model & atmospheric ICs

- Retrospective forecasts have been performed for the period **1992-2001**

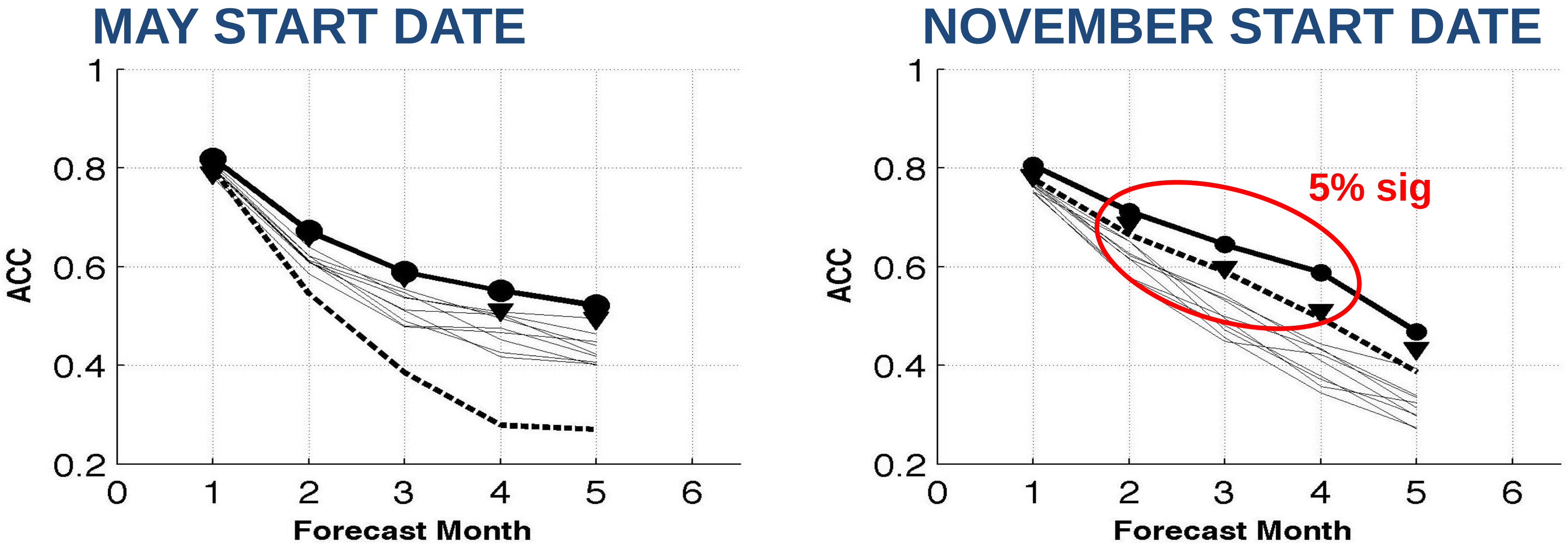
- Start dates **May & November**

Alessandri et al., 2010, MWR.

Impact of improved IC: Tropical Pacific SSTA (140-280E; 25S-25N)

Solid thick & circles = DAS Ensemble means
Solid thin = DAS Ensemble members

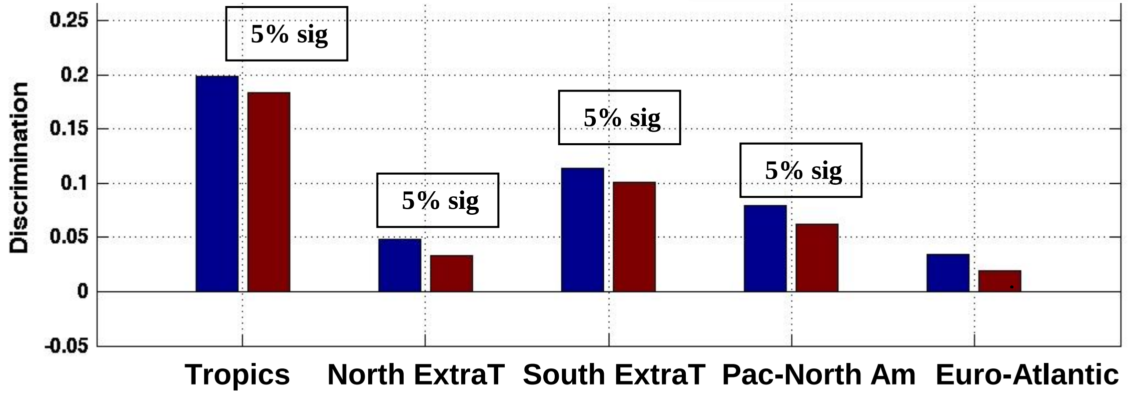
Triangles = NODAS   *Dashed = persistence*



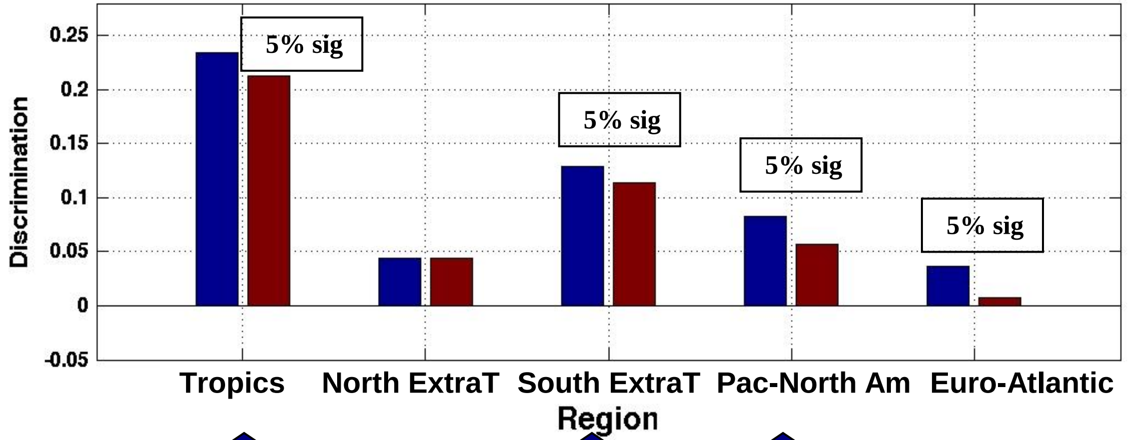
Impact of assimilation on the discrimination of below normal (cold, E^-) and above normal (warm, E^+) surface conditions

1st NOVEMBER START DATE

E^-: Discrimination distance of TAIRA < lower tercile



E^+: Discrimination distance of TAIRA > upper tercile



Blue = DAS

Red = NODAS

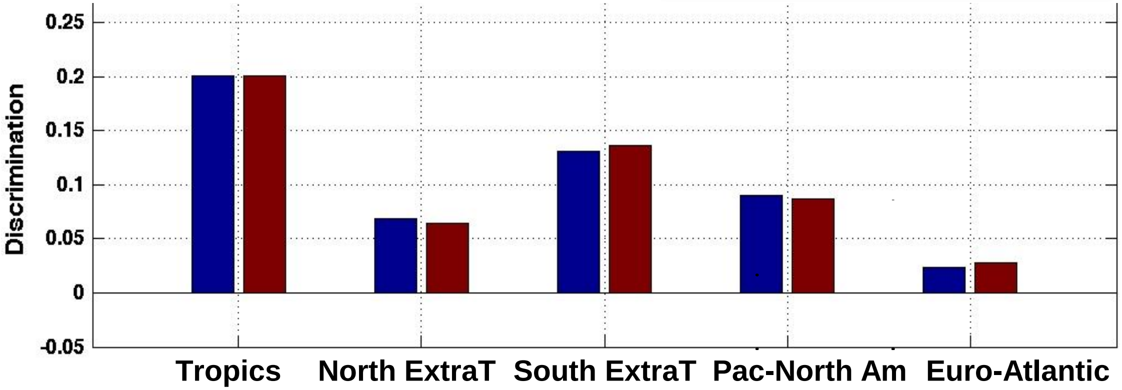
		November IC	
		ICSPSv1	Noassim
Tropics	E^-	**0.198**	0.185
	E^+	**0.233**	0.214
Northern Extra Trop	E^-	**0.047**	0.036
	E^+	0.044	0.044
Southern Extra Trop	E^-	**0.113**	0.102
	E^+	**0.128**	0.115
Pacific North America	E^-	**0.078**	0.063
	E^+	**0.082**	0.057
Euro-Atlantic	E^-	0.034	0.019
	E^+	**0.035**	0.007

Bold underlined indicate significance (5%)

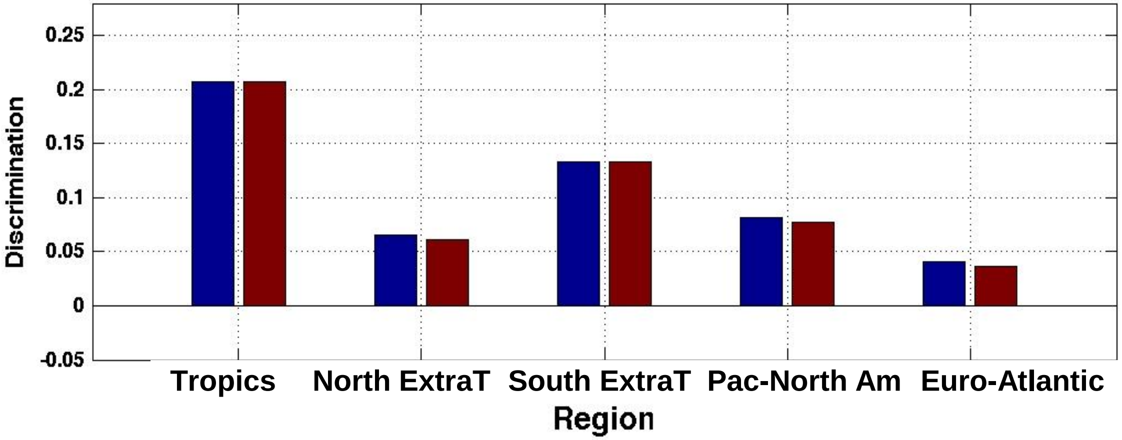
Impact of assimilation on the discrimination of below normal (cold, E$^-$) and above normal (warm, E$^+$) surface conditions

1st MAY START DATE

E$^-$: Discrimination distance of TAIRA < lower tercile



E$^+$: Discrimination distance of TAIRA > upper tercile



Blue = DAS

Red = NODAS

		May IC	
		ICSPSv1	Noassim
Tropics	E$^-$	0.201	0.201
	E$^+$	0.207	0.207
Northern Extra Trop	E$^-$	0.069	0.065
	E$^+$	0.066	0.061
Southern Extra Trop	E$^-$	0.131	0.137
	E$^+$	0.133	0.133
Pacific North America	E$^-$	0.090	0.087
	E$^+$	0.082	0.077
Euro-Atlantic	E$^-$	0.024	0.028
	E$^+$	0.041	0.038

Bold underlined indicate significance (5%)

Predictability of Tropical Cyclone counts

Alessandri et al., 2010, J. Climate. Under revision

A model tropical cyclone is active over a grid point “A” if the following conditions are satisfied (Bengtsson et al. 1995; Walsh 1997):

1. in A $\xi > 3 \cdot 10^{-5}\ s^{-1}$ at 850 hPa
2. relative minimum of SLP, and surface wind velocity > 14 m/s in an area of 2.25° around A
3. sum of T anomaly at 700, 500 and 300 hPa > 2 °K
4. T anomaly (300 hPa) > T anomaly (850 hPa)
5. wind velocity (850 hPa) > wind velocity (300 hPa)
6. above conditions persist for a period longer than 1.5 days

Gualdi et al., 2008

How good is the model in simulating tropical cyclones ?

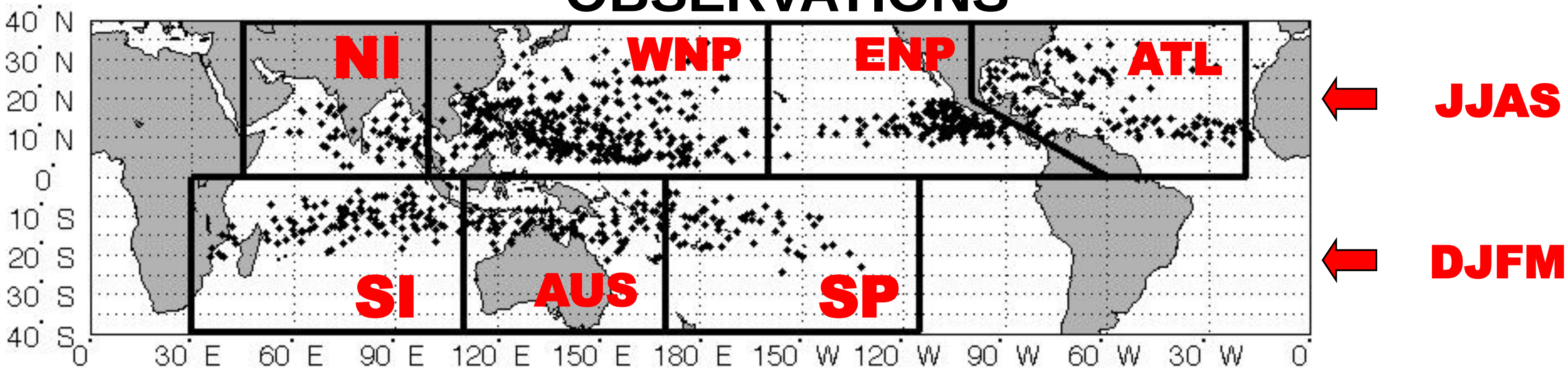
Tropical Cyclone tracks starting points 1992-2001

OBSERVATIONS:

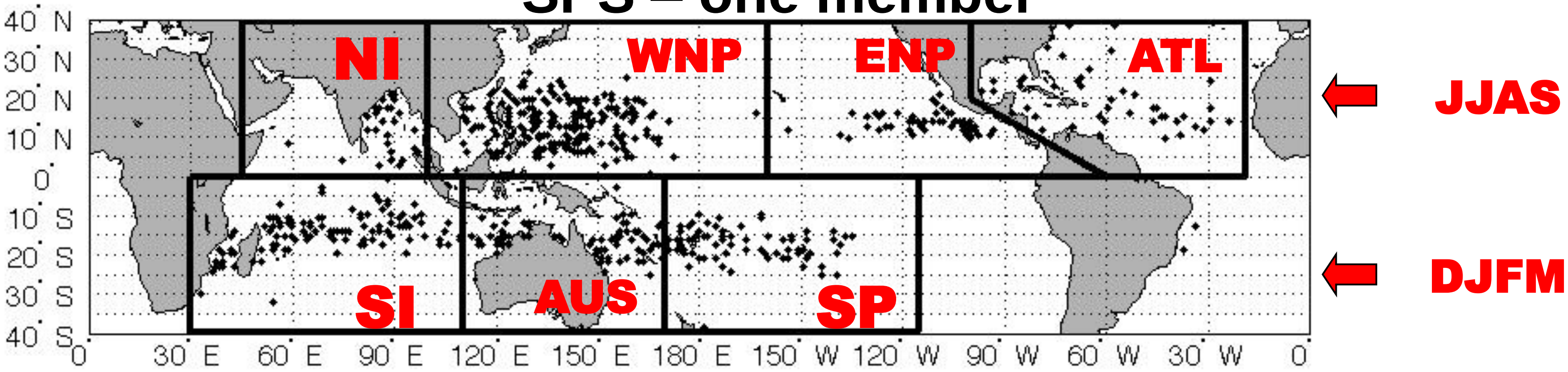
NHC [National Hurricane Center] &

JTWC [U.S. Joint Typhoon Warning Center]

OBSERVATIONS

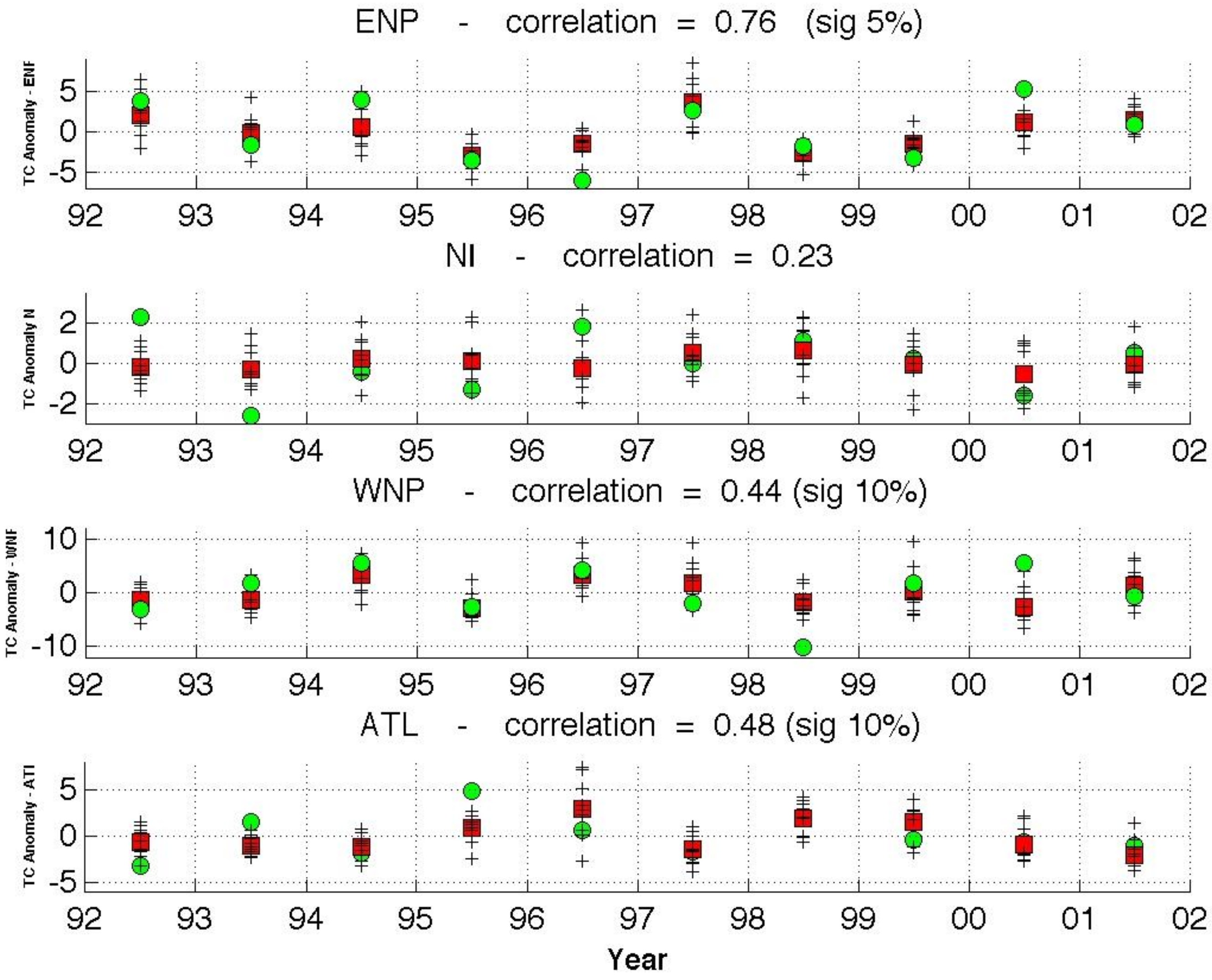


SPS – one member



Regions as in Camargo et al. 2004

Interannual TC Count anomalies Prediction (Boreal Summer)



MAY-to-September (JJAS)

Green=Observations

Red=Ensemble means

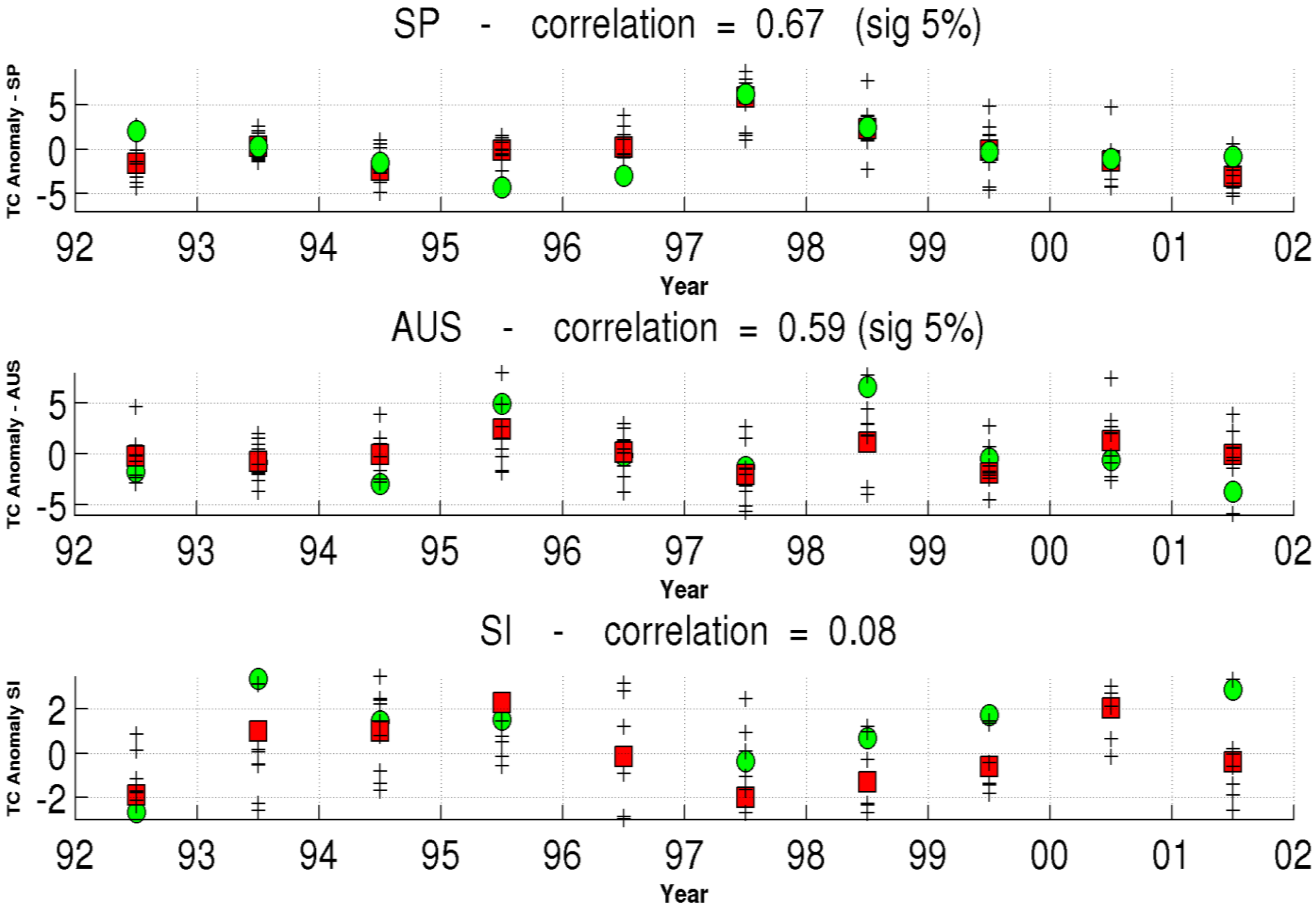
crosses = ensemble members

CORRELATIONS
SPS vs OBS

	May IC
ENP-East North Pacific	<u>0.76</u>
NI-Northern Indian	0.23
WNP-West North Pacific	<u>0.44</u>
ATL-North Atlantic	<u>0.48</u>

<u>Underline indicate significance (10% at least)</u>

Interannual TC Count anomalies Prediction (Austral Summer)



November-to-March (DJFM)

Green=Observations

Red=Ensemble means

crosses = ensemble members

CORRELATIONS

SPS vs OBS

	Nov IC
SP - South Pacific	0.67
AUS – Australian	0.59
SI – Southern Indian	0.08

Underline indicate significance (5%)

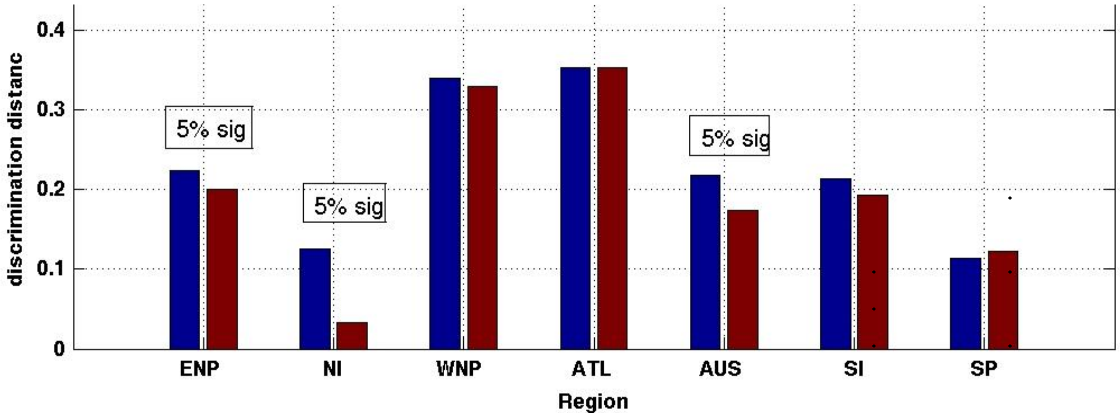
Predictability of Tropical Cyclone counts:

Impact of global assimilation of T & S profiles during Ocean Initialization

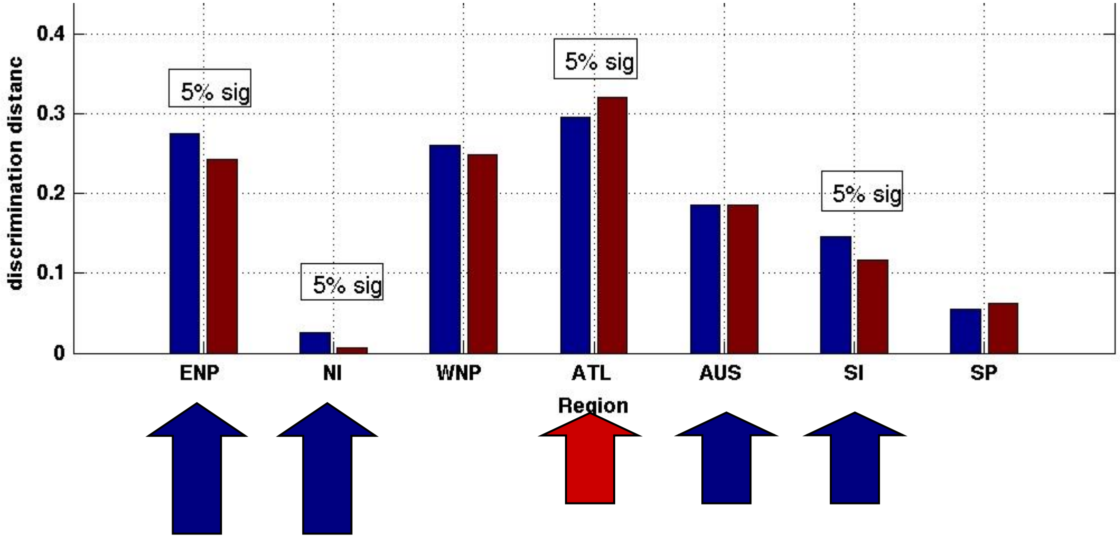
Alessandri et al., 2010, J. Climate. Under revision

Impact of subsurface assimilation on discrimination of anomalous TC Counts: less than normal (E^{-}) & more than normal (E^{+})

E^{-}: Discrimination distance of TC < lower tercile



E^{+}: Discrimination distance of TC > upper tercile



Blue = DAS

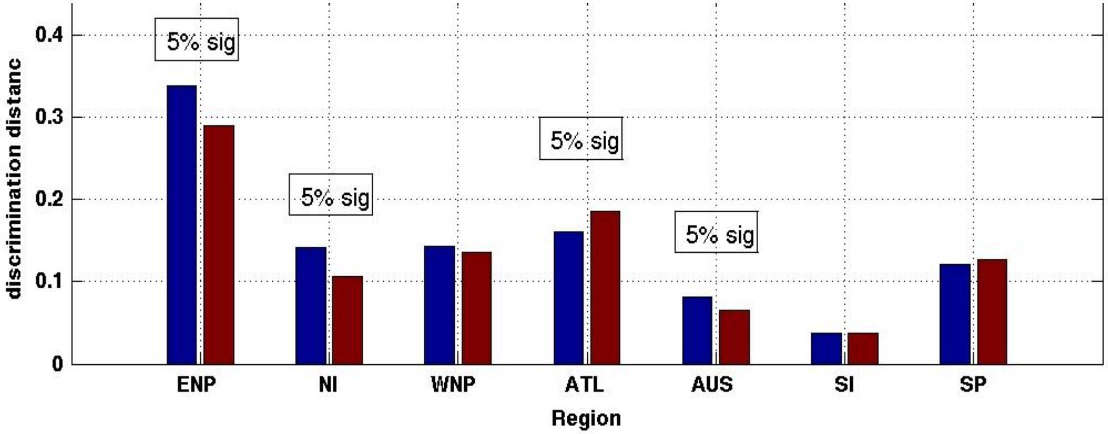
Red = NODAS

		May IC		Nov IC	
		ICSPSv1	Noassim	ICSPSv1	Noassim
ENP	E^{-}	**0.221**	0.201		
	E^{+}	**0.275**	0.246		
NI	E^{-}	**0.125**	0.033		
	E^{+}	**0.022**	0.007		
WNP	E^{-}	0.340	0.327		
	E^{+}	**0.260**	0.246		
ATL	E^{-}	0.352	0.353		
	E^{+}	0.295	**0.320**		
AUS	E^{-}			**0.218**	0.174
	E^{+}			0.185	0.185
SI	E^{-}			0.213	0.191
	E^{+}			**0.146**	0.123
SP	E^{-}			0.122	0.113
	E^{+}			0.055	0.063

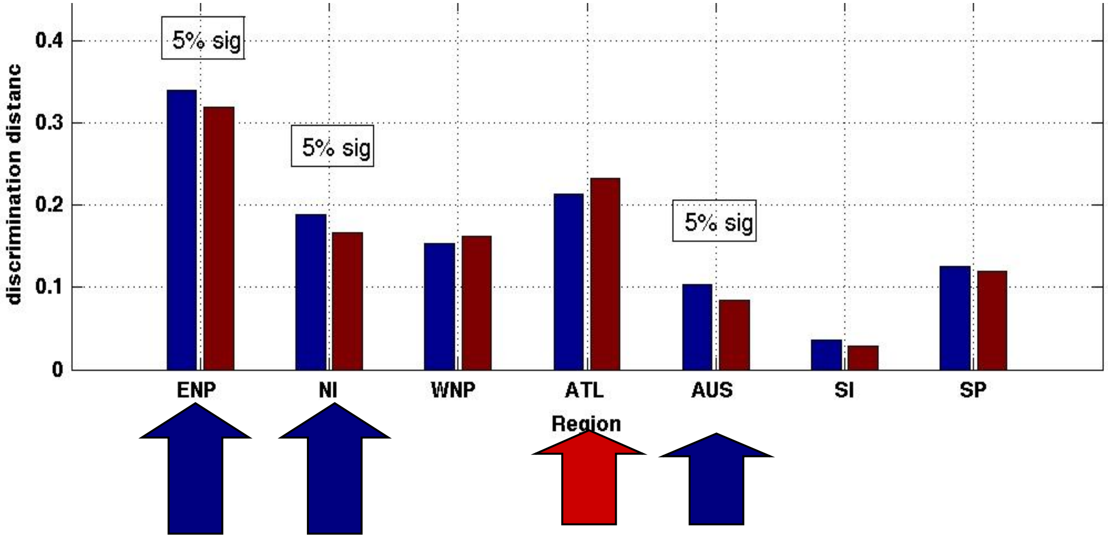
Bold underlined indicate significance (5%)

Discrimination of the daily SSTAs in the study region: cold (E^-) & warm (E^+) conditions

E^-: Discrimination distance of daily SSTA < lower tercile



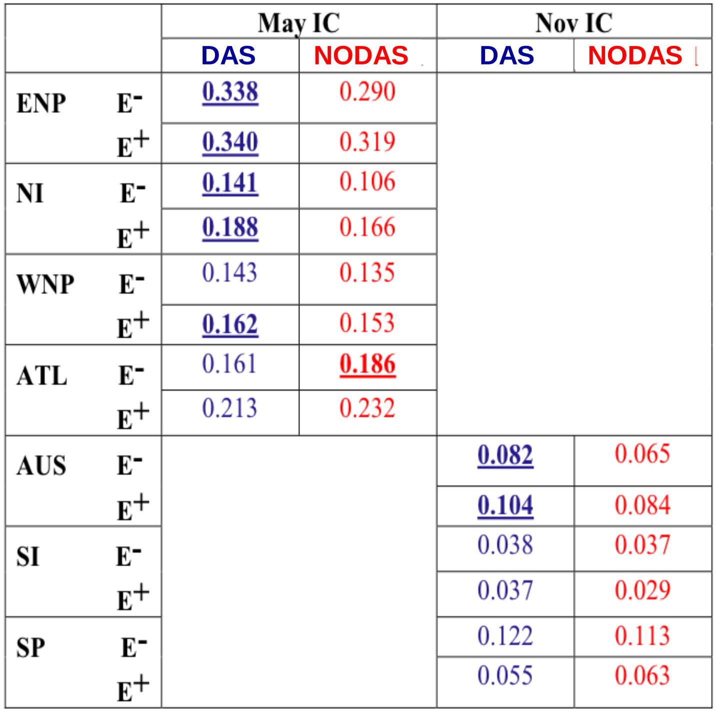
E^+: Discrimination distance of daily SSTA > upper tercile



Impact of subsurface assimilation

Blue = DAS

Red = NODAS



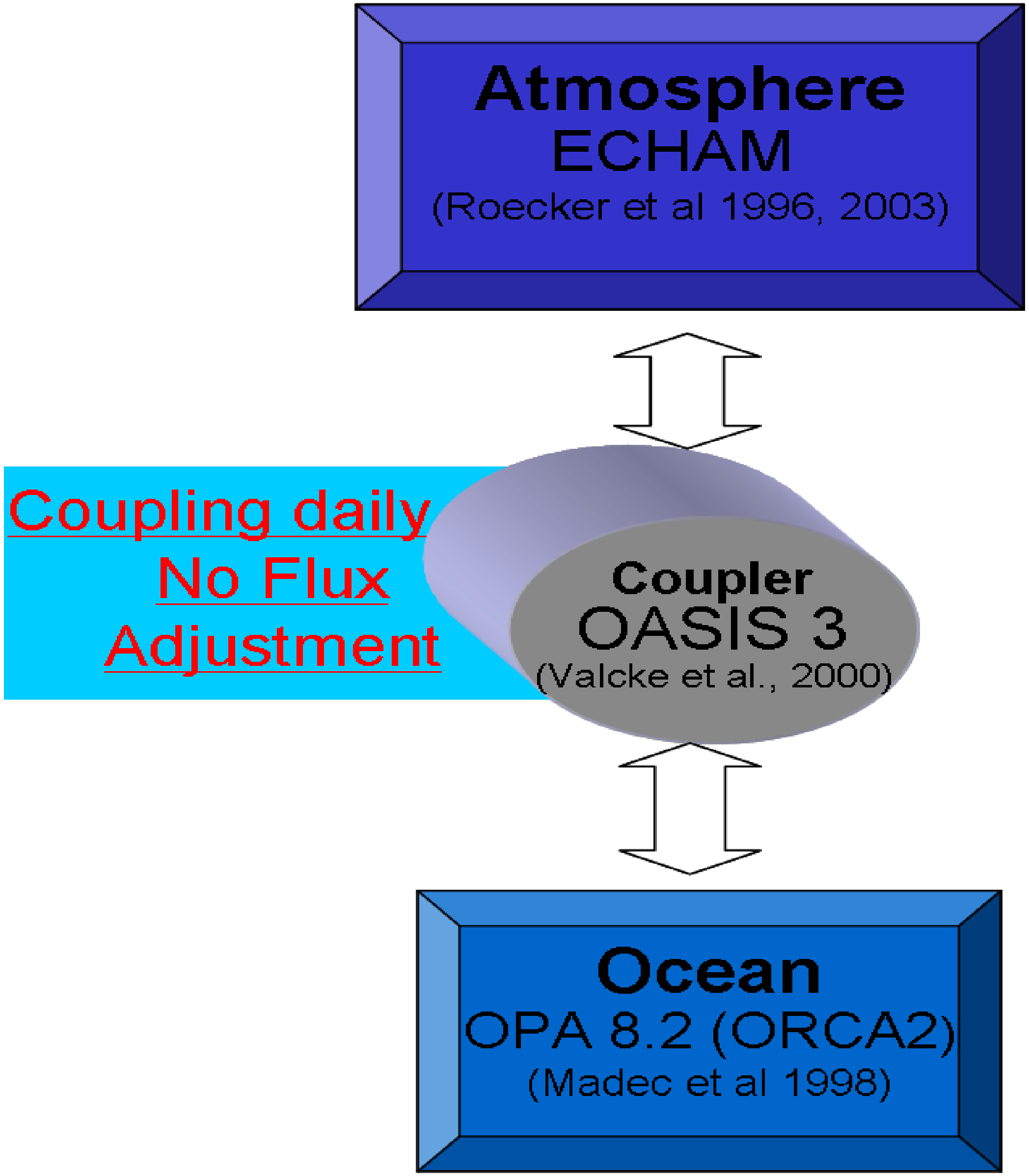
		May IC		Nov IC	
		DAS	NODAS	DAS	NODAS
ENP	E-	**0.338**	0.290		
	E+	**0.340**	0.319		
NI	E-	**0.141**	0.106		
	E+	**0.188**	0.166		
WNP	E-	0.143	0.135		
	E+	**0.162**	0.153		
ATL	E-	0.161	**0.186**		
	E+	0.213	0.232		
AUS	E-			**0.082**	0.065
	E+			**0.104**	0.084
SI	E-			0.038	0.037
	E+			0.037	0.029
SP	E-			0.122	0.113
	E+			0.055	0.063

Bold underlined indicate significance (5%)

Contribution to the new European multi-model Seasonal Prediction System: EU project ENSEMBLES Framework

Alessandri et al., 2010, MWR, Under revision

The coupled Model components



Atmosphere
ECHAM
(Roecker et al 1996, 2003)

Coupling daily
No Flux
Adjustment

Coupler
OASIS 3
(Valcke et al., 2000)

Ocean
OPA 8.2 (ORCA2)
(Madec et al 1998)

Off line Initialization Tools

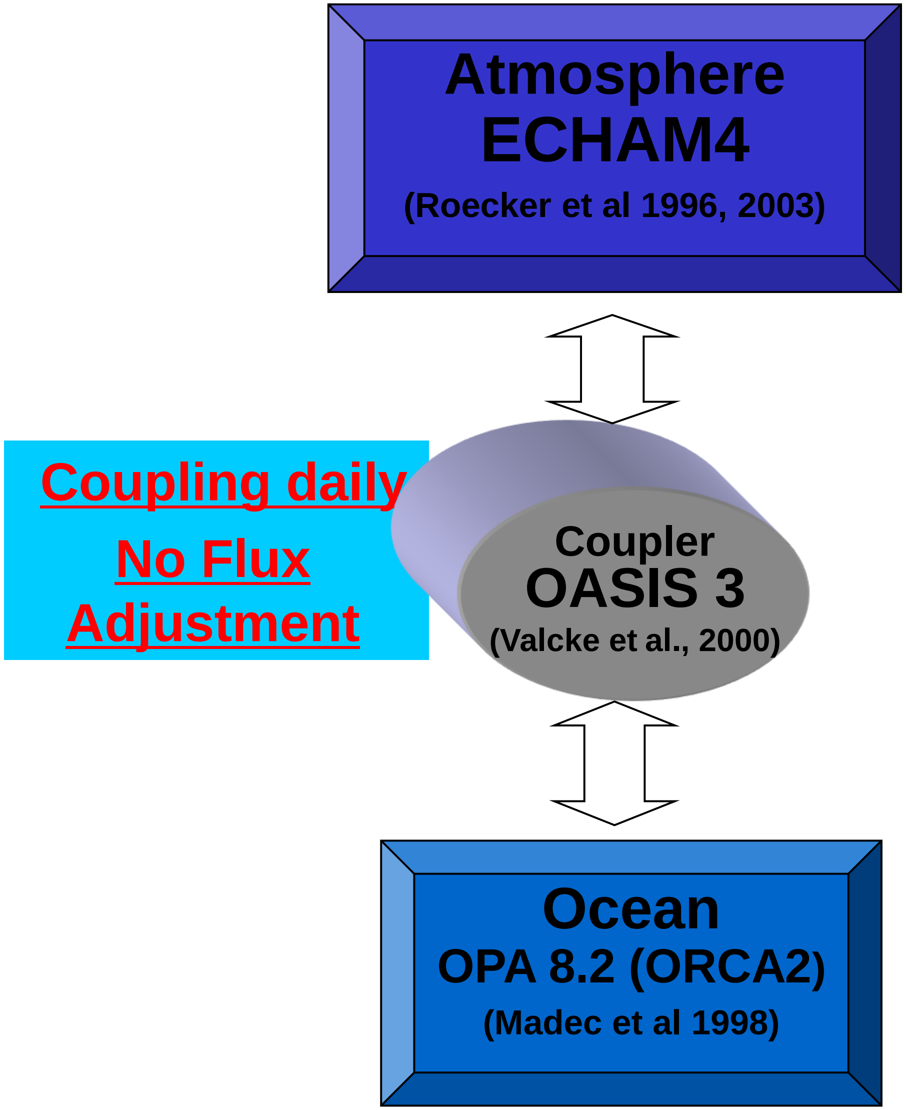
Assimilated Ocean initial condition production:

T & S - OI assimilation
SOFA 3.0
(De Mey and Benkiran 2002)

Bellucci, Masina, Di Pietro & Navarra, 2007

-Di Pietro & Masina, 2009

The coupled Model components



Atmosphere
ECHAM4
(Roecker et al 1996, 2003)

Coupling daily
No Flux
Adjustment

Coupler
OASIS 3
(Valcke et al., 2000)

Ocean
OPA 8.2 (ORCA2)
(Madec et al 1998)

Off line Initialization Tools

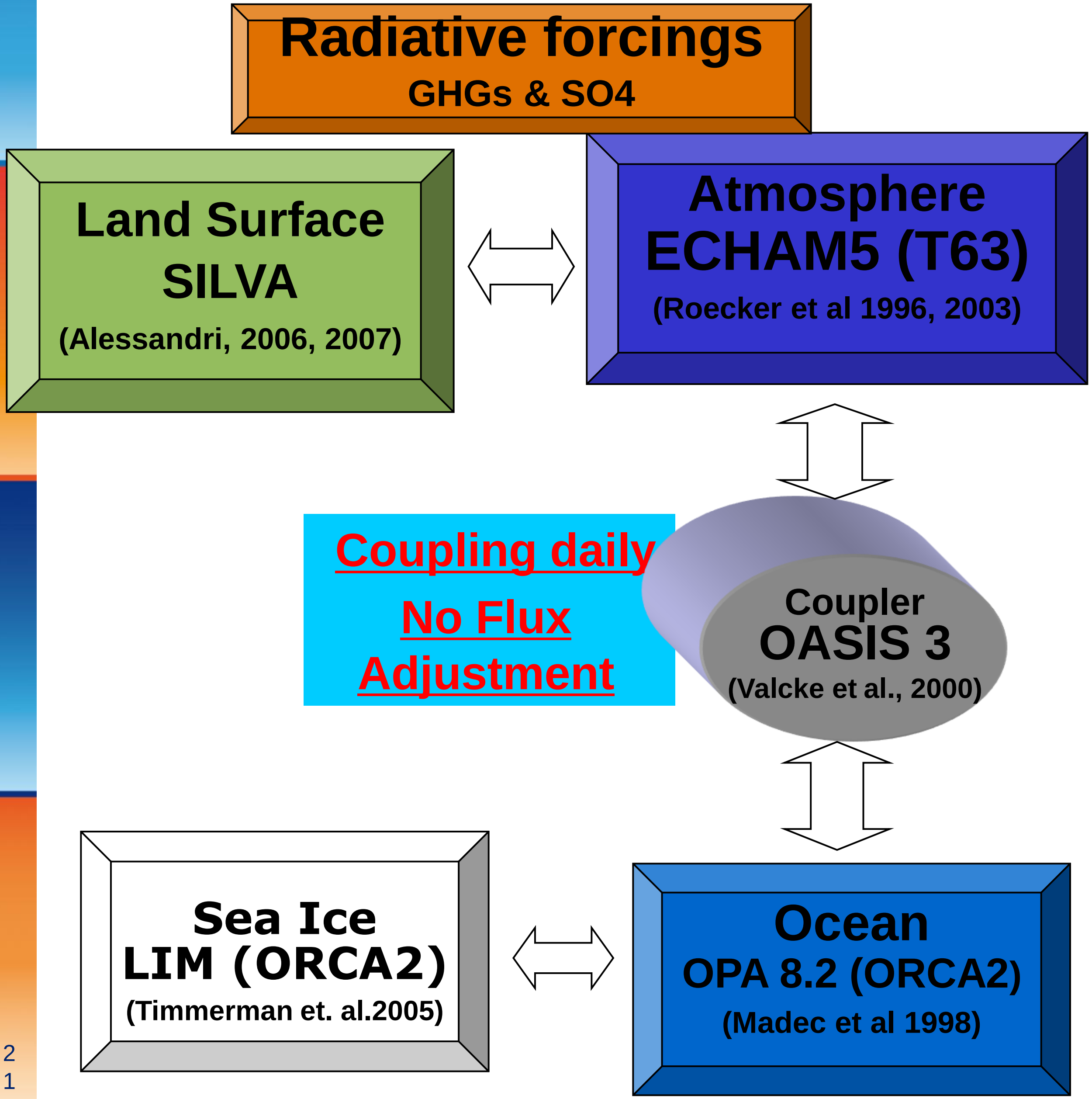
Assimilated Ocean initial condition production:

T & S - OI assimilation
SOFA 3.0
(De Mey and Benkiran 2002)

Bellucci, Masina, Di Pietro & Navarra, 2007

-Di Pietro & Masina, 2009

The coupled Model components



Radiative forcings

GHGs & SO4

Land Surface
SILVA
(Alessandri, 2006, 2007)

Atmosphere
ECHAM5 (T63)
(Roecker et al 1996, 2003)

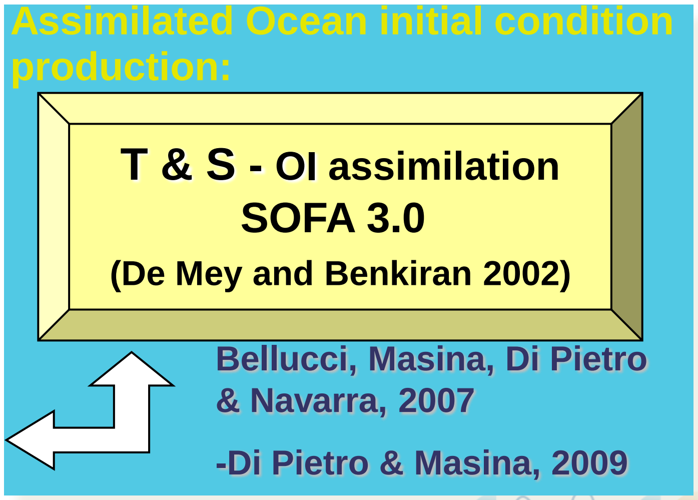
Coupling daily
No Flux
Adjustment

Coupler
OASIS 3
(Valcke et al., 2000)

Sea Ice
LIM (ORCA2)
(Timmerman et. al.2005)

Ocean
OPA 8.2 (ORCA2)
(Madec et al 1998)

Off line Initialization Tools



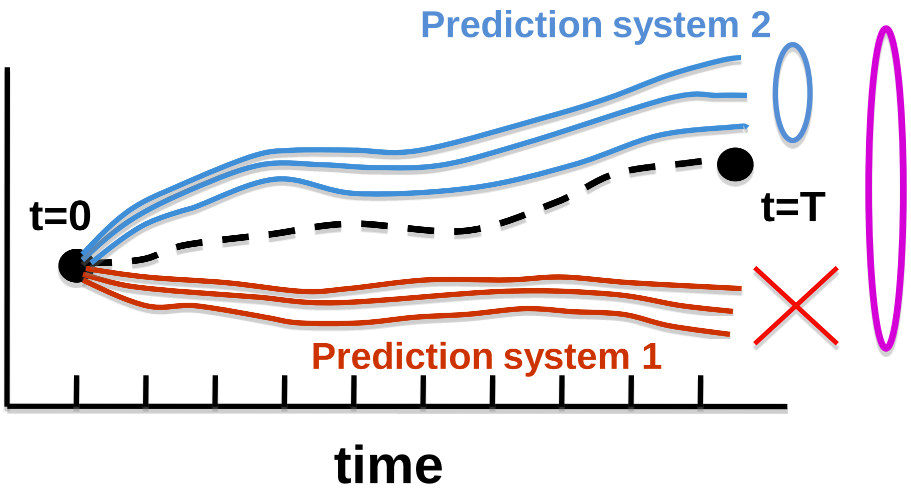
Assimilated Ocean initial condition production:

T & S - OI assimilation
SOFA 3.0
(De Mey and Benkiran 2002)

Bellucci, Masina, Di Pietro & Navarra, 2007

-Di Pietro & Masina, 2009

The rationale behind the use of Multi-Models



- *Single Models performance is limited*
- *Single Models tend to be over-confident*

MME can improve by:

- ***Combining the skill from the single models***
- ***Improve ensembles dispersion and uncertainty consideration***

- ***Independence of the Single models systems***
- ***Degree of over-confidence***

(Hagedorn et al., 2005 ; Weigel et al., 2009; Alessandri et al., 2010)

ENSEMBLES Multi Model Seasonal Prediction System

European Centre for Medium Range Weather Forecasts (ECMWF)

ITALY

Centro Euro Mediterraneo per I Cambiamenti Climatici (CMCC-INGV)

U.K

UK Met Office (UKMO)

FRANCE

Meteo France (MF)

GERMANY

Leibniz Institute of Marine Sciences at Kiel University (IFM-GEOMAR)

For each SPS we performed
9 member ensemble forecasts

Forecasts period 1960-2005

For each year, 4 start dates:
February, May, August and November

Each hindcast 7 months long

The Five European Seasonal Prediction Systems: ENSEMBLES vs DEMETER

The ENSEMBLES MME has improved in all aspects:

-Increase horizontal and vertical resolution

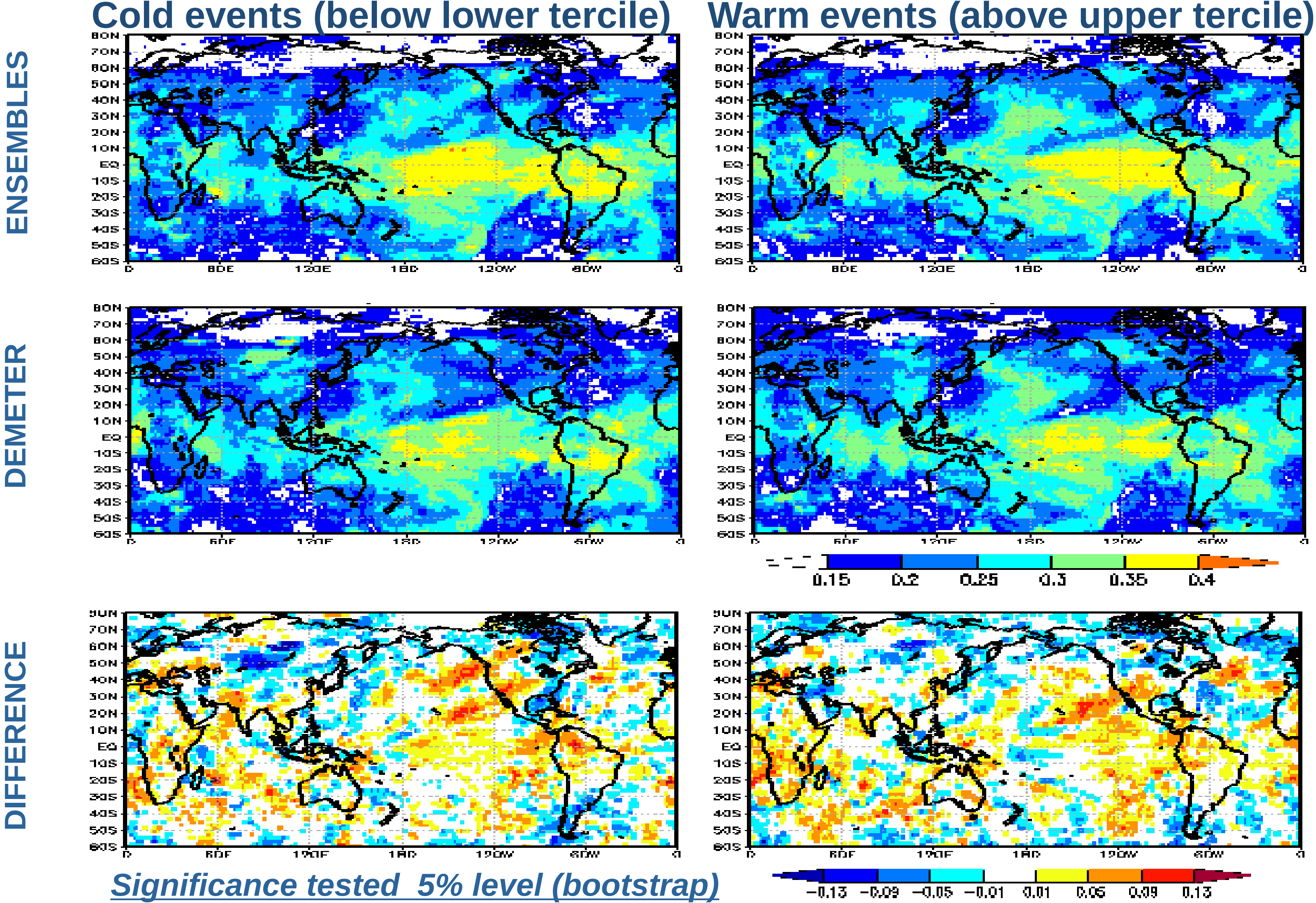
-Better representation of sub-grid physical processes, land and sea-ice

-Inclusion of interannual variability in the greenhouse gas forcing

-More widespread use of subsurface assimilation in the ocean IC (EN3 quality-checked in situ temperature and salinity, Ingleby & Huddleston 2007).

Partner		**Atmosphere model**	**Ocean model**	**Initialization**	
				Atmosphere	Ocean
CMCC-INGV	ENS	Echam5-SILVA; T63/L19	OPA8.2; 2°/L31	AMIP-type	Ocean analysis forced by ERA40/oper; Wind stress and SST perts
	DEM	Echam4; T42/L19	OPA8.2; 2°/L31	AMIP-type	Ocean analysis forced by ERA40; Wind stress and SST perts.
ECMWF	ENS	IFS CY31R1; T159/L62	HOPE; 0.3°-1.4/L29	ERA-40/Oper. analysis; atmospheric SV	Ocean analysis forced by ERA40/oper; Wind stress and SST perts
	DEM	IFS; T95/L40	HOPE-E 1.4°x0.3-1.4°/L29	ERA-40 analysis.	Ocean analysis forced by ERA40/oper; Wind stress and SST perts
UK Met Office	ENS	HadGEM2-A; N96/L38	HadGEM2-O; 0.33°-1°/L20	ERA-40/Oper. analysis, soil moisture assimi	Ocean analysis forced by ERA40/oper; Wind stress and SST perts
	DEM	HadAM3; 2.5°x3.75°/L19	GloSea OGCM	ERA-40	Ocean analyses forced by ERA-40; Wind stress and SST perts.
Meteo France	ENS	ARPEGE4.6; T63	OPA8.2; 2°/L31	ERA-40/Oper. analysis.	Ocean analysis forced by ERA40/oper; Wind stress, SST & fresh water flux perts
	DEM	ARPEGE; T63/L31	OPA8.0; 2°/L31	ERA-40 analysis	Ocean analyses forced by ERA-40; Wind stress and SST perts.
IFM-GEOMAR	ENS	Echam5; T63/L31	MPI-OM1; 1.5°/L40	Permutation of three coupled climate simulations from 1950 to 2005 with SSTs restored to observations.	
	DEM	Echam5; T42/L19	MPI-OM1; 2.5°x0.5-2.5°/L23	Coupled climate simulation with SSTs restored to observations. Nine different atmospheric conditions (lagged method).	

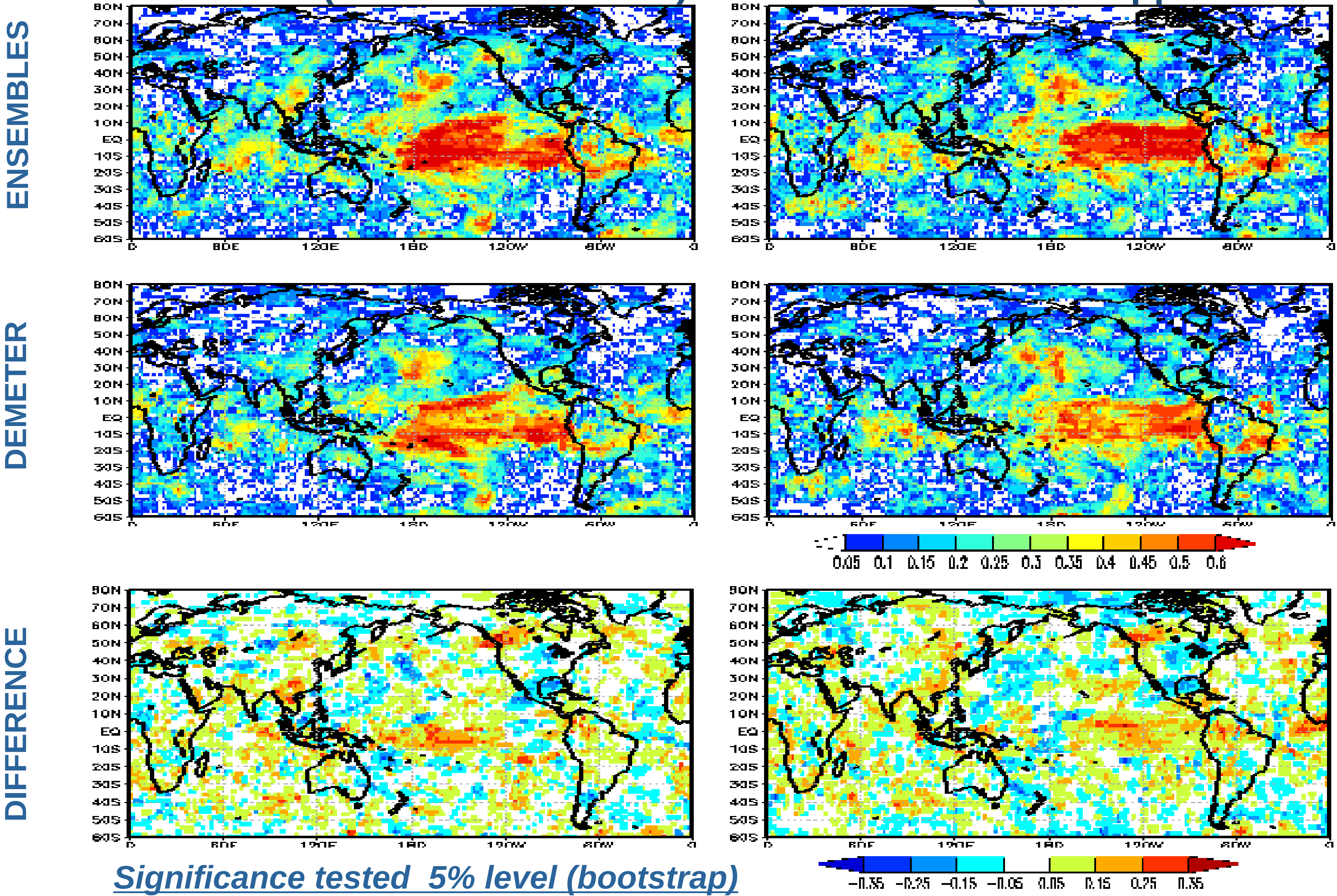
ENSEMBLES vs DEMETER: prediction signal (sharpness) for cold and warm seasonal mean surface air temperature. JJA



Significance tested 5% level (bootstrap)

ENSEMBLES vs DEMETER: prediction skill (discrimination) for cold and warm seasonal mean (JJA) surface air temperature.

Cold events (below lower tercile) **Warm events (above upper tercile)**



Significance tested 5% level (bootstrap)

ENSEMBLES vs DEMETER: Summary of probabilistic forecast quality of cold (E^-) and warm (E^+) multi-model seasonal means

Star marks (*) for significant difference (5% level)

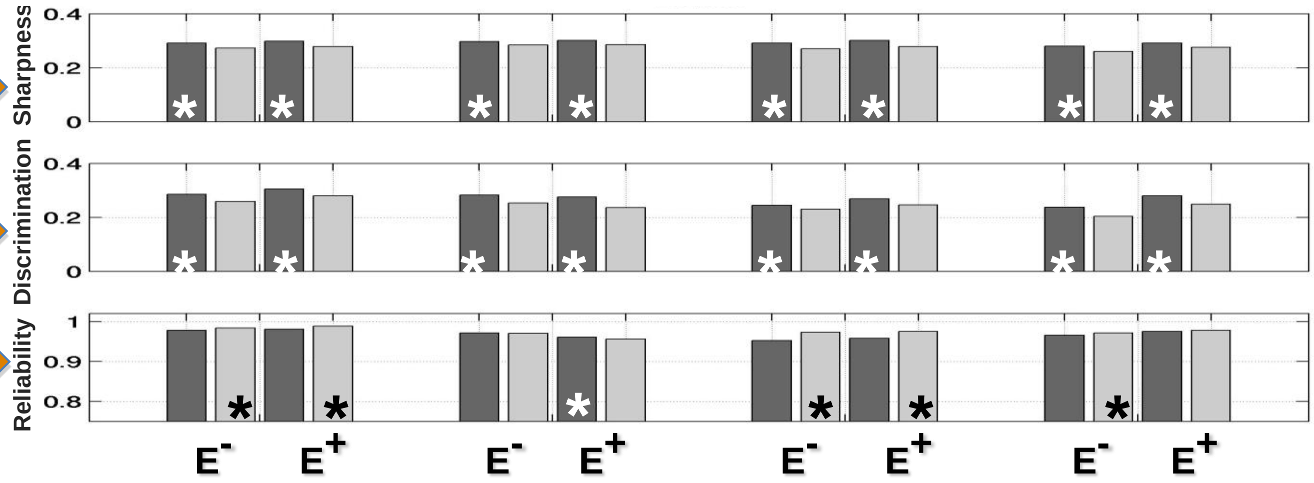
▆ ENSEMBLES ▢ DEMETER

Tropics (25S-25N) **MAM** **JJA** **SON** **NDJ**

Signal →

Skill →

Calibration →

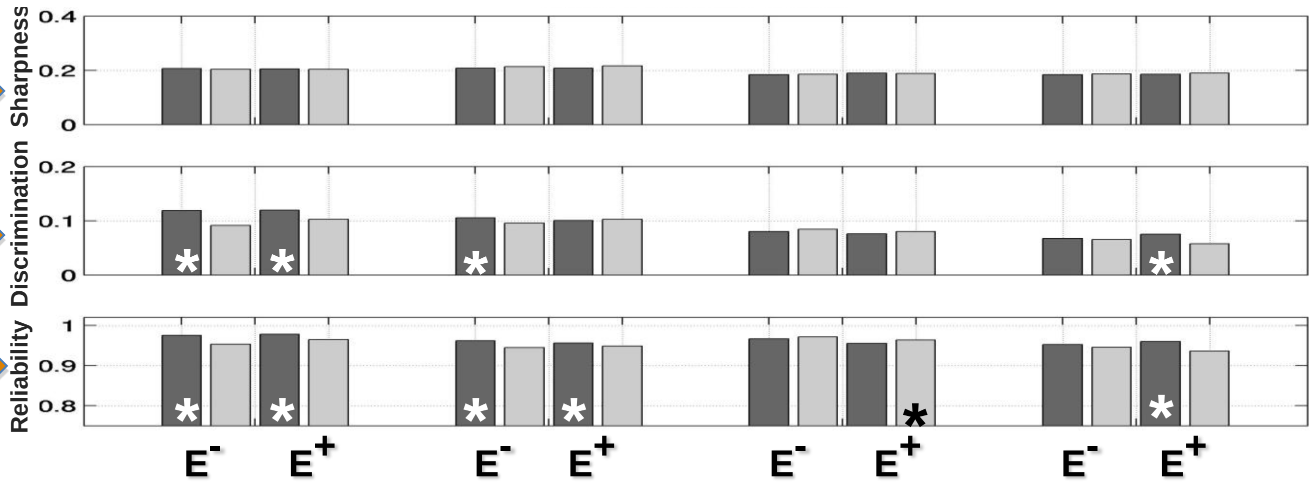


North Middle Lat (30-75N) **MAM** **JJA** **SON** **NDJ**

Signal →

Skill →

Calibration →



Alessandri et al., 2010, MWR, Under revision

Summary and Conclusions

- The seasonal prediction system (SPS) developed at CMCC-INGV is progressing and shows competitive skill in predicting surface climate.

- The present work shows that subsurface T & S assimilation has considerable effects on the skill of the SPS:
    - ENSO forecast and the prediction of seasonal mean TAIRA & PRECA improve. In particular, the forecasts starting in November significantly increase the performance in both Tropics and N. Extratropics

- By applying a TC location and tracking detection method to the forecasts, we demonstrate a realistic simulation of the TC activity in our system. Significant skill in predicting TC count anomalies over ENP, WNP, ATL, AUS and SP is shown.

- Subsurface assimilation in Ocean IC significantly improves the prediction of TC count anomalies over ENP, NI, AUS and SI.
    - This appears to be linked to the modified ability to discriminate above normal and below normal daily SSTA.

Summary and Conclusions

- The latest development of the CMCC-INGV SPS contributed to the new European multi-model SPS in the frame of the EU project ENSEMBLES.

- ENSEMBLES MME improves systematically signal and skill of anomalous surface temperature prediction over tropics and significant improvements are also over Northern latitudes. As a warning for users, we evidence increased needs for calibration over tropics.

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per i Cambiamenti Climatici

Thanks!

Ongoing and future

- ✧A pre-operational version of the system is running next summer prediction
- ✧From Seasonal to intra-Seasonal Predictions (CliPAS ISO hindcast experiment Framework)
- ✧Land surface contribution to predictability: improve initialization (EU FP7 project CLIMAFRICA)
- ✧Heat waves predictability and applications over Europe (e.g: Fire danger forecasting)
- ✧Evaluations and applications of the ENSEMBLES retrospective forecasts under way and strongly encouraged

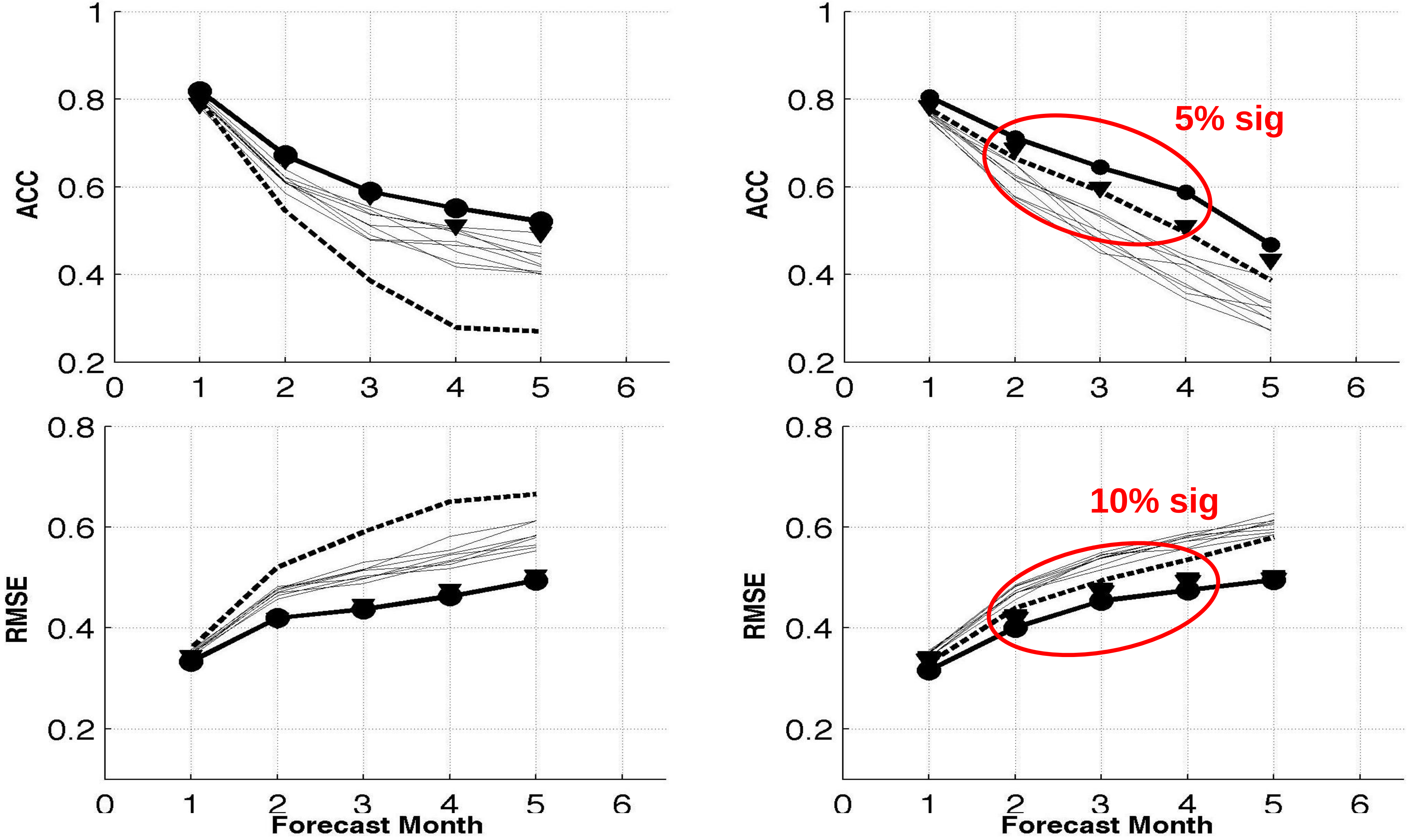
Impact of improved IC: Tropical Pacific SSTA (140-280E; 25S-25N)

Solid thick & circles = DAS Ensemble means
Solid thin = DAS Ensemble members

Triangles = NODAS ***Dashed = persistence***

MAY START DATE

NOVEMBER START DATE

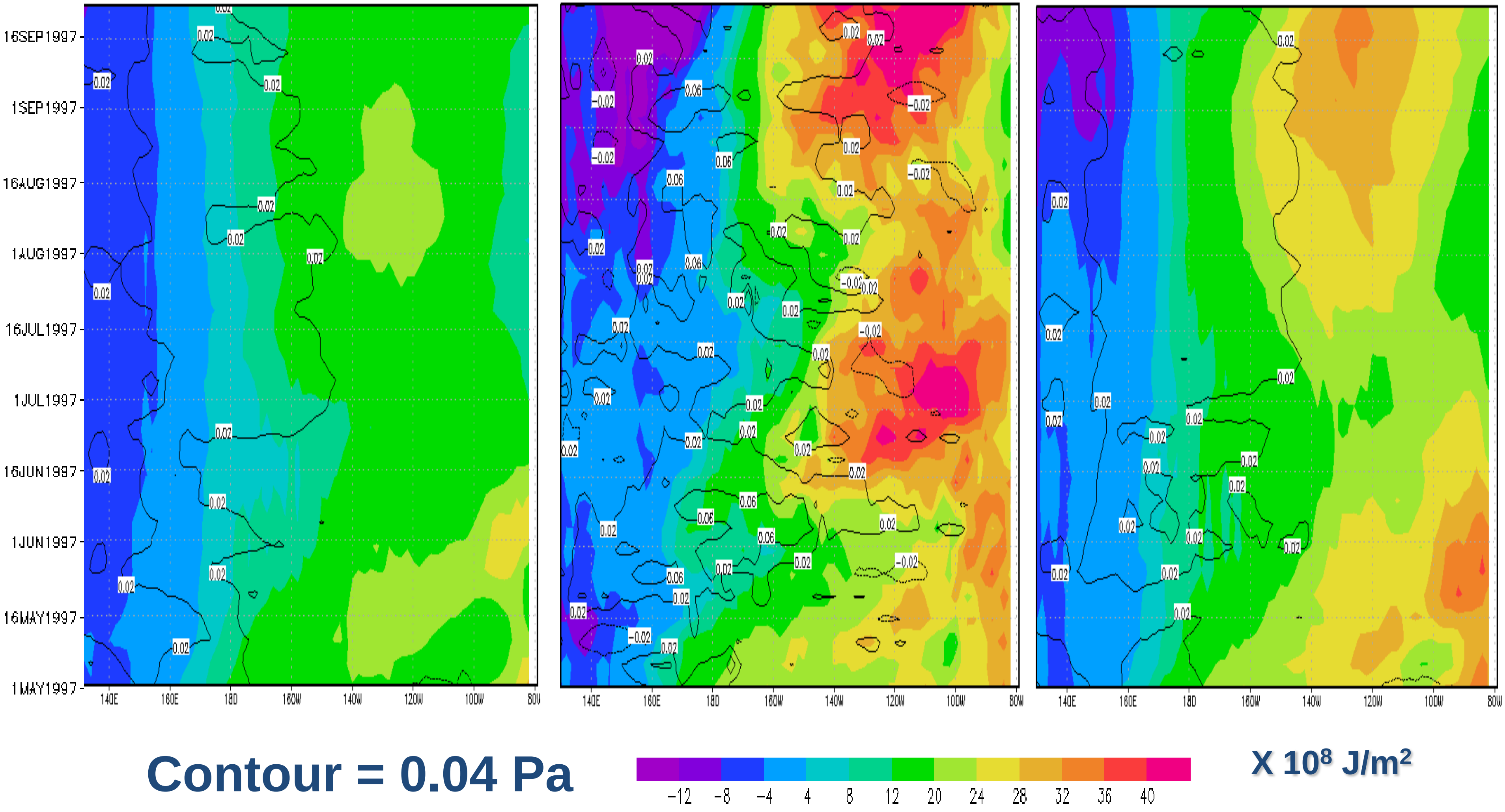


El Nino 97 onset: DAS vs NODAS

Shading heat content anomalies - Countours zonal wind stress anomalies

<u>Reported are ensemble mean predictions</u>

NODAS **Ocean Analysis** **DAS**

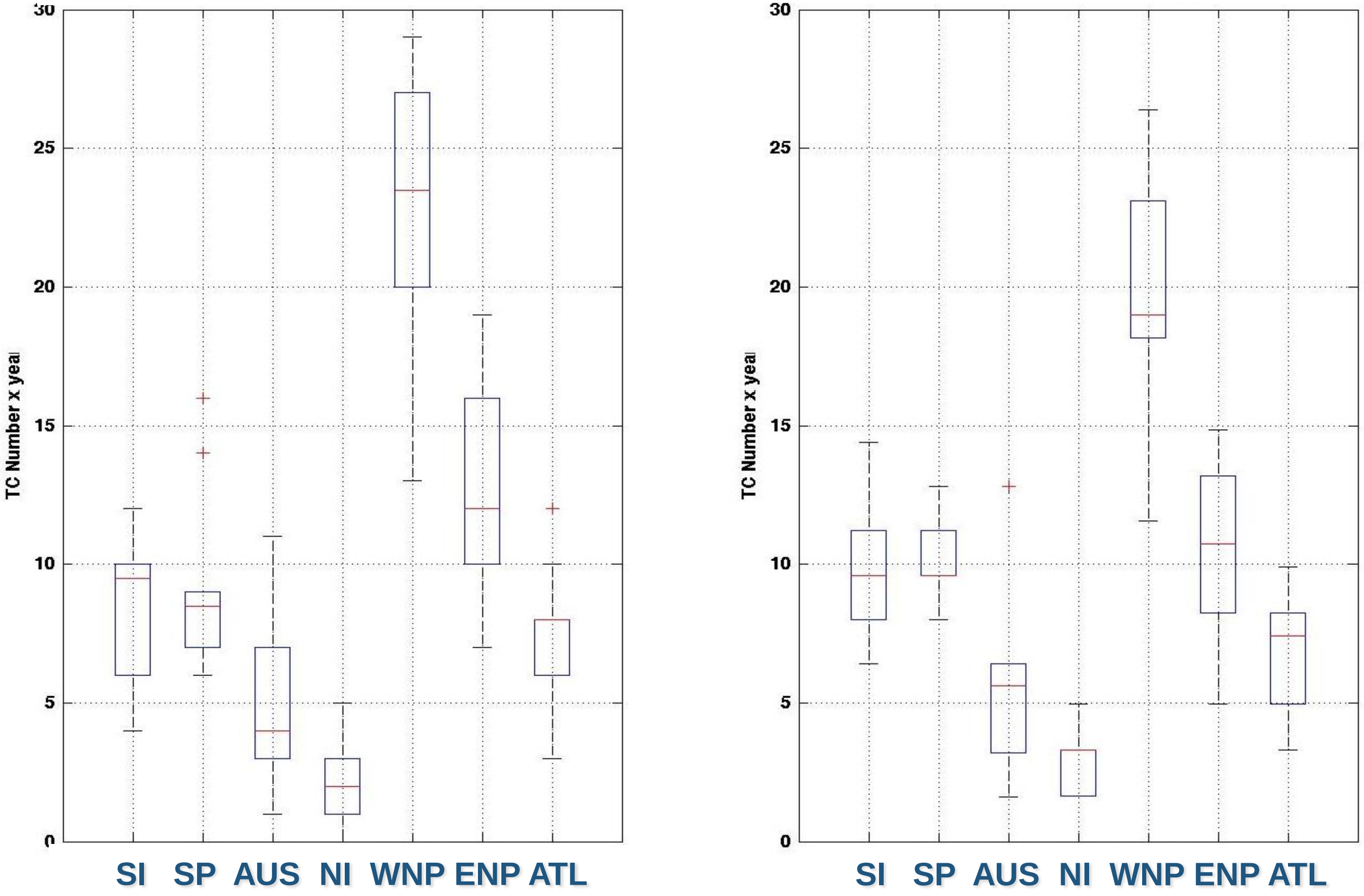


Contour = 0.04 Pa

X 10^8 J/m^2

How good is the model in simulating tropical cyclones ?

Number of Tropical Cyclons per active season



Observations x 1.0

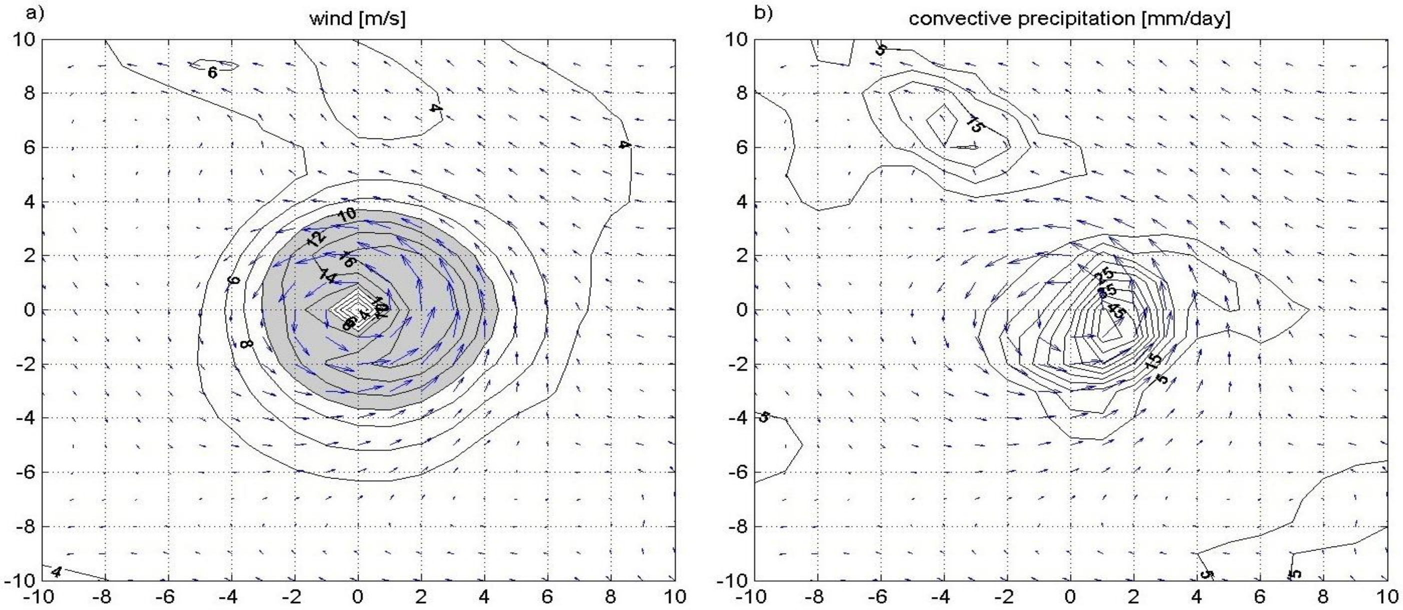
Ensemble Forecast *X 1.5*

How good is the model in simulating tropical cyclones ?

Composite of a simulated Tropical Cyclone (NH 100 most intense)

850-hPa WIND

Precipitation



1000 Km

ENSEMBLES vs DEMETER: Averaged single model probabilistic forecast quality

Star marks (*) for significant difference (5% level)

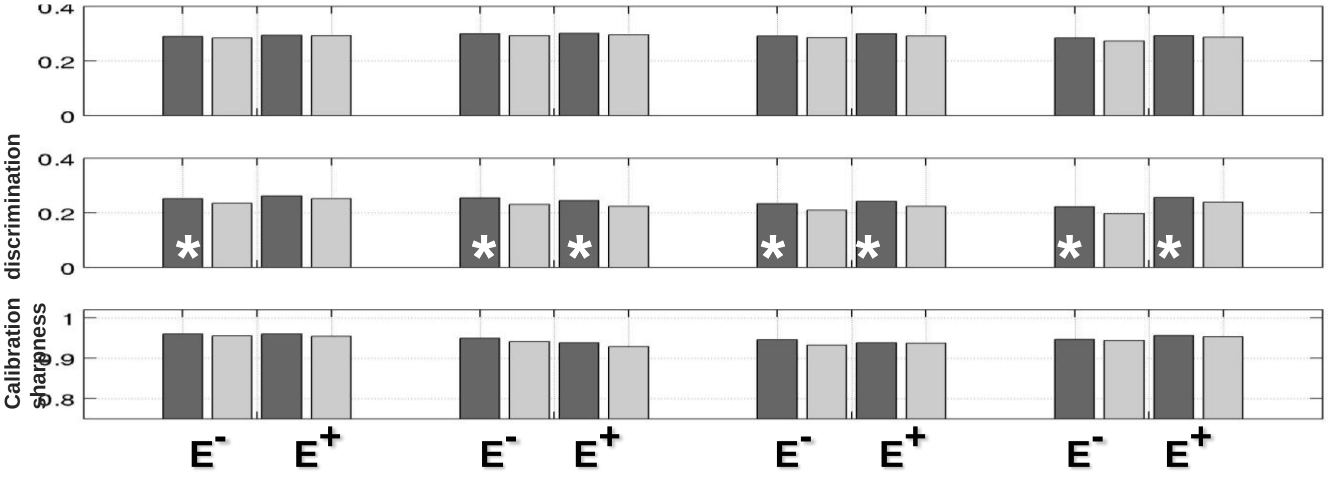
▇ ENSEMBLES ▢ DEMETER

Tropics (25S-25N) **MAM** **JJA** **SON** **NDJ**

Signal

Skill

Calibration



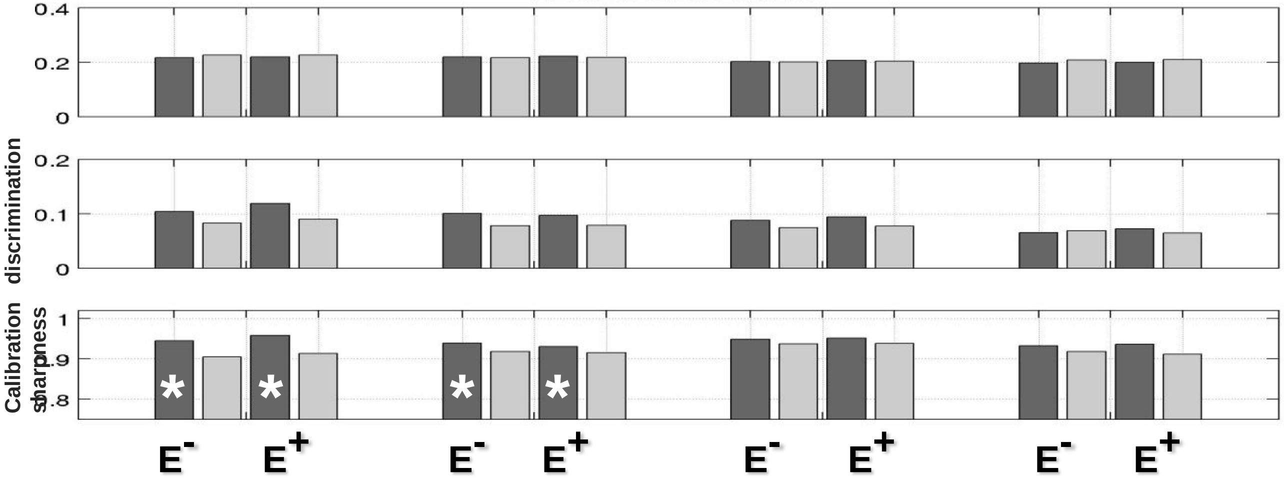
North Middle Lat **MAM** **JJA** **SON** **NDJ**

(30-75N)

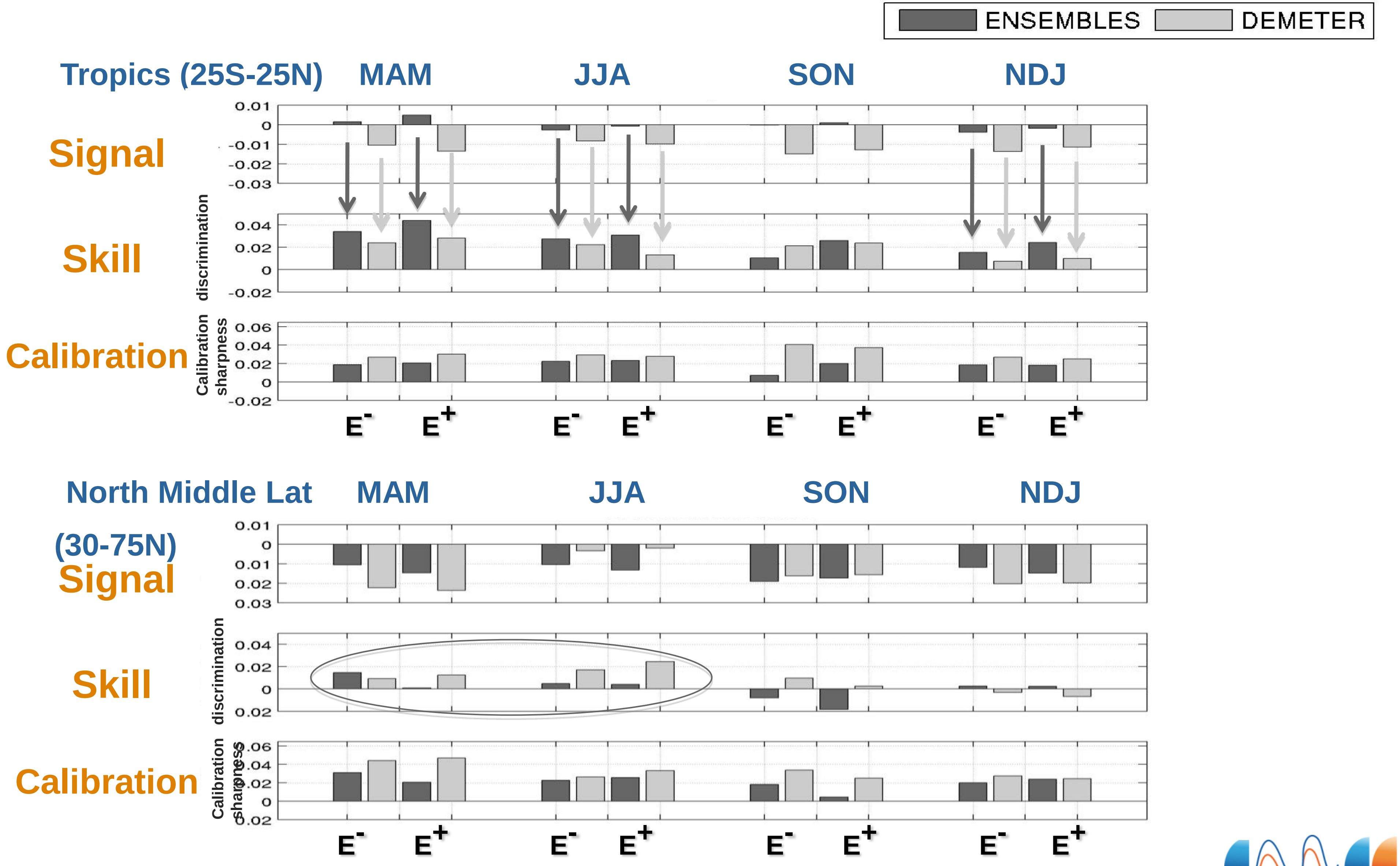
Signal

Skill

Calibration



ENSEMBLES vs DEMETER: difference between multi-models and single-models averaged performance

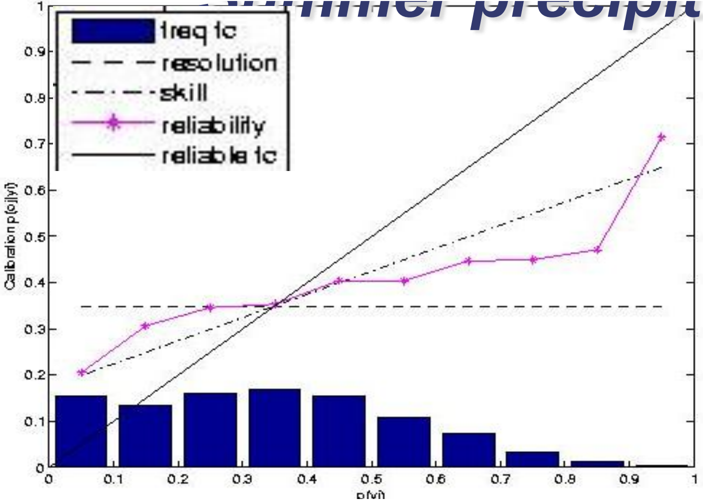


Euro-Mediterranean Region - predictability of dichotomous events: summer precipitation < 1st and > 2nd terciles

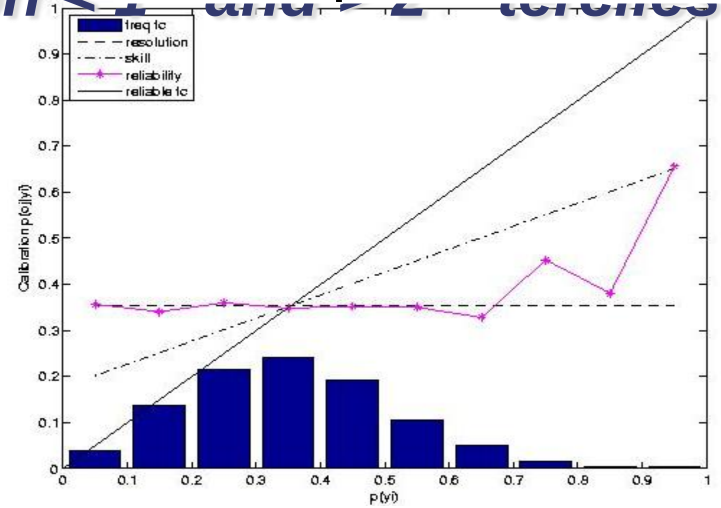
Reliability

$p(o|y_i)$

Prob Precipitation < 1st tercile



Prob Precipitation > 2nd tercile

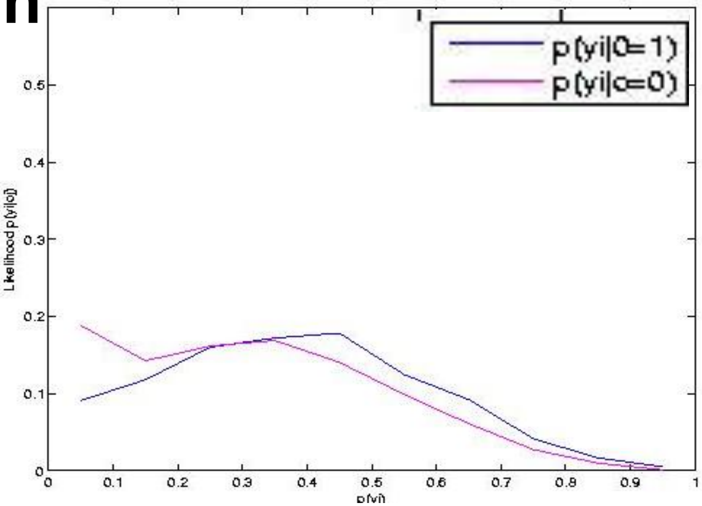


Discrimination

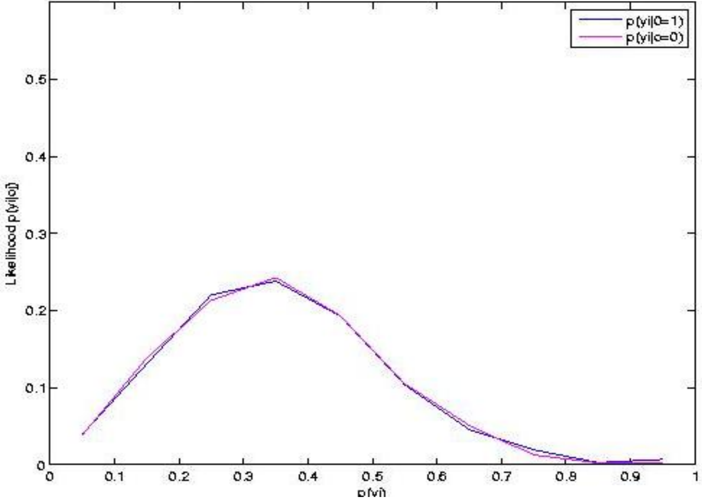
$p(y_i|o=0)$

$p(y_i|o=1)$

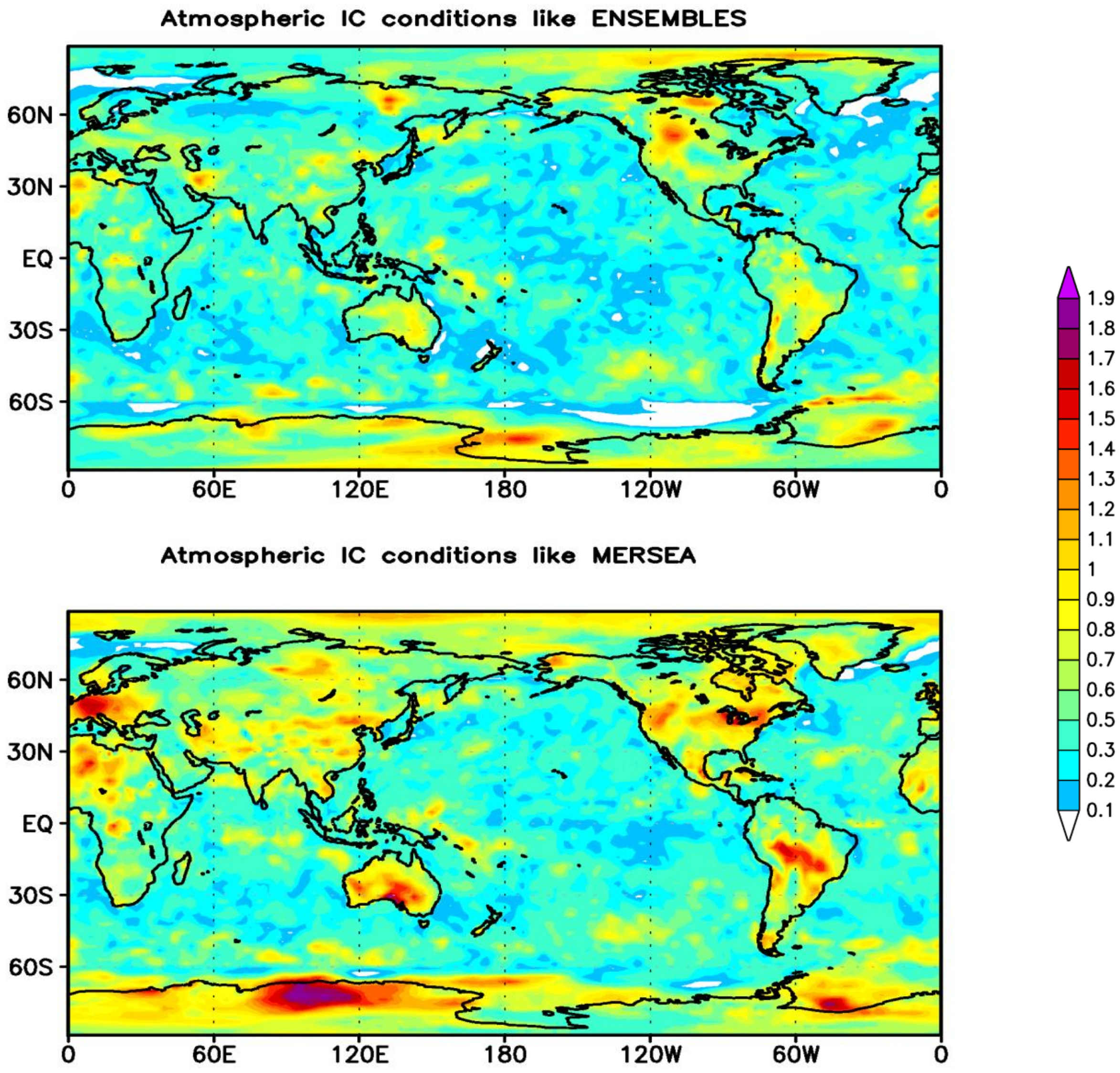
Prob Precipitation < 1st tercile



Prob Precipitation > 2nd tercile



Ensemble spread variance/Interannual signal variance



Atmospheric IC conditions like ENSEMBLES

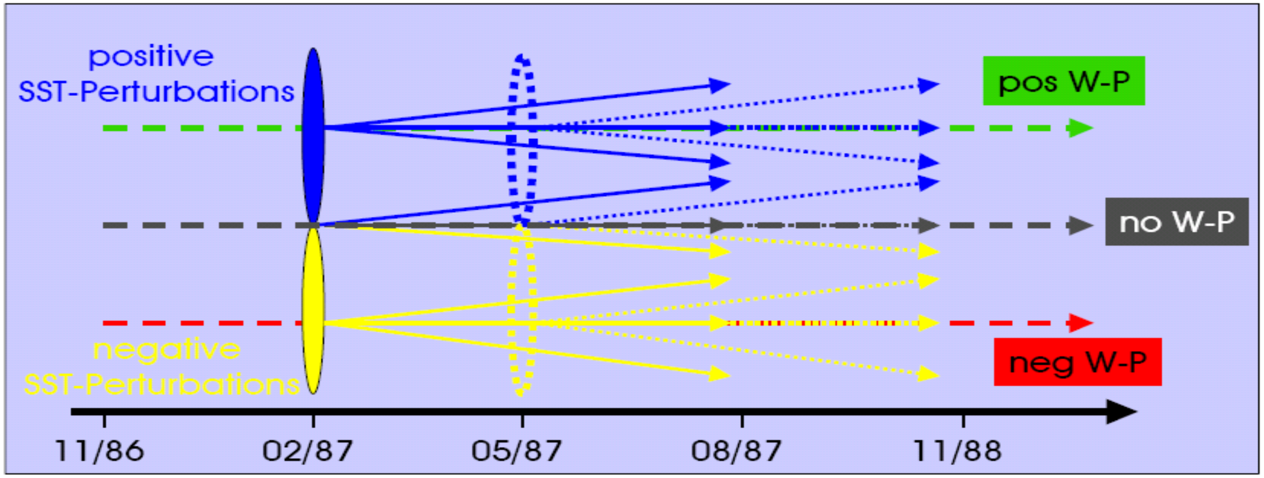
Atmospheric IC conditions like MERSEA

CMCC-INGV SEASONAL FORECASTING (Ensembles framework)

Atmospheric forced (HadiSST) run

Oceanic run forced with ERA-40
T & S assimilation (SOFA)

For each year, 4 initial conditions:
February, May, August and November



SST perturbations

WIND perturbations

9 perturbed i.c. for each start date, each year

Each hindcast 7 months long

Hindcasts period 1960-2005