

# PREDICTING TROPICAL CYCLONE ACTIVITY

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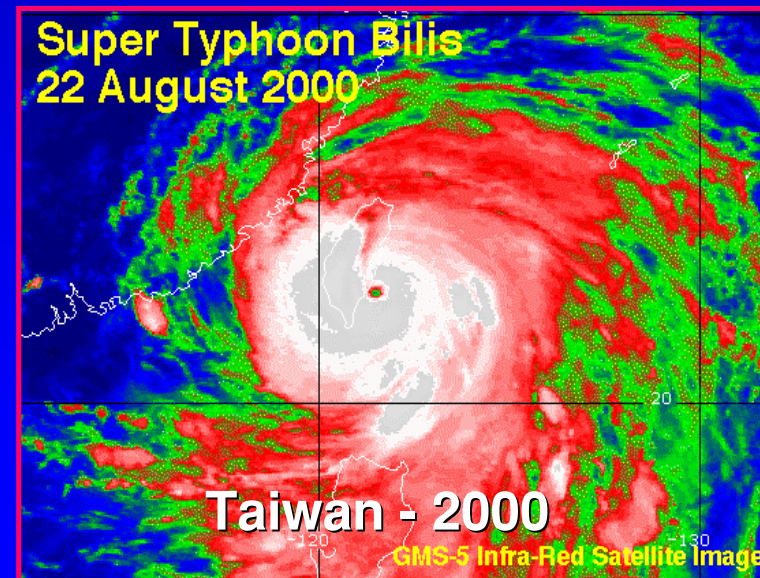
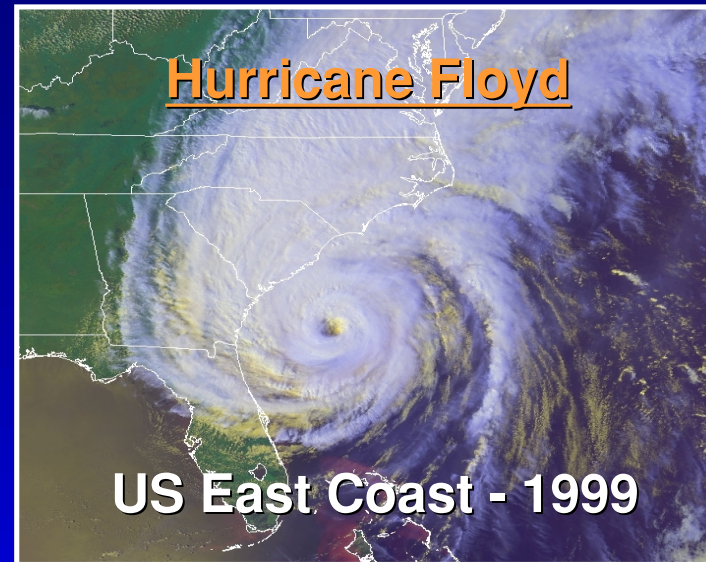
EGS-AGU-EUG Joint Assembly  
Nice, France, 6-11 April 2003





# Tropical Cyclone Impacts

- **USA.** Hurricane annual damage bill 1925-2002 is estimated as US \$ 5.3Bn (at 2002 \$).
- **Asia.** Typhoon annual damage bill (1990-2001) is US \$3.3Bn. (at 2002 \$).
- **Asia.** Typhoon annual fatality rate is 700 deaths (1990-2001).





# Seasonal Forecast Relevance

- **Substantial interannual variability exists in regional tropical cyclone losses.** For example, in the US in 1999 and 1997, the losses were US \$ 8.2 bn and just US \$ 0.16 bn respectively.
- **Skillful seasonal forecasts of tropical cyclone landfalling activity will benefit society, business and government by reducing risk, uncertainty and financial volatility.**



# History

- Seasonal forecasts of Atlantic basin hurricane activity were pioneered by **William Gray at Colorado State University in 1984**. Indeed Gray's forecasts are arguably the first seasonal forecast of any climate phenomenon.
- Today seasonal forecasts of tropical cyclone activity are available for a **number of ocean basins and different landfalling areas**. These forecasts are issued by a range of agencies and university groups.



# Forecast Regions



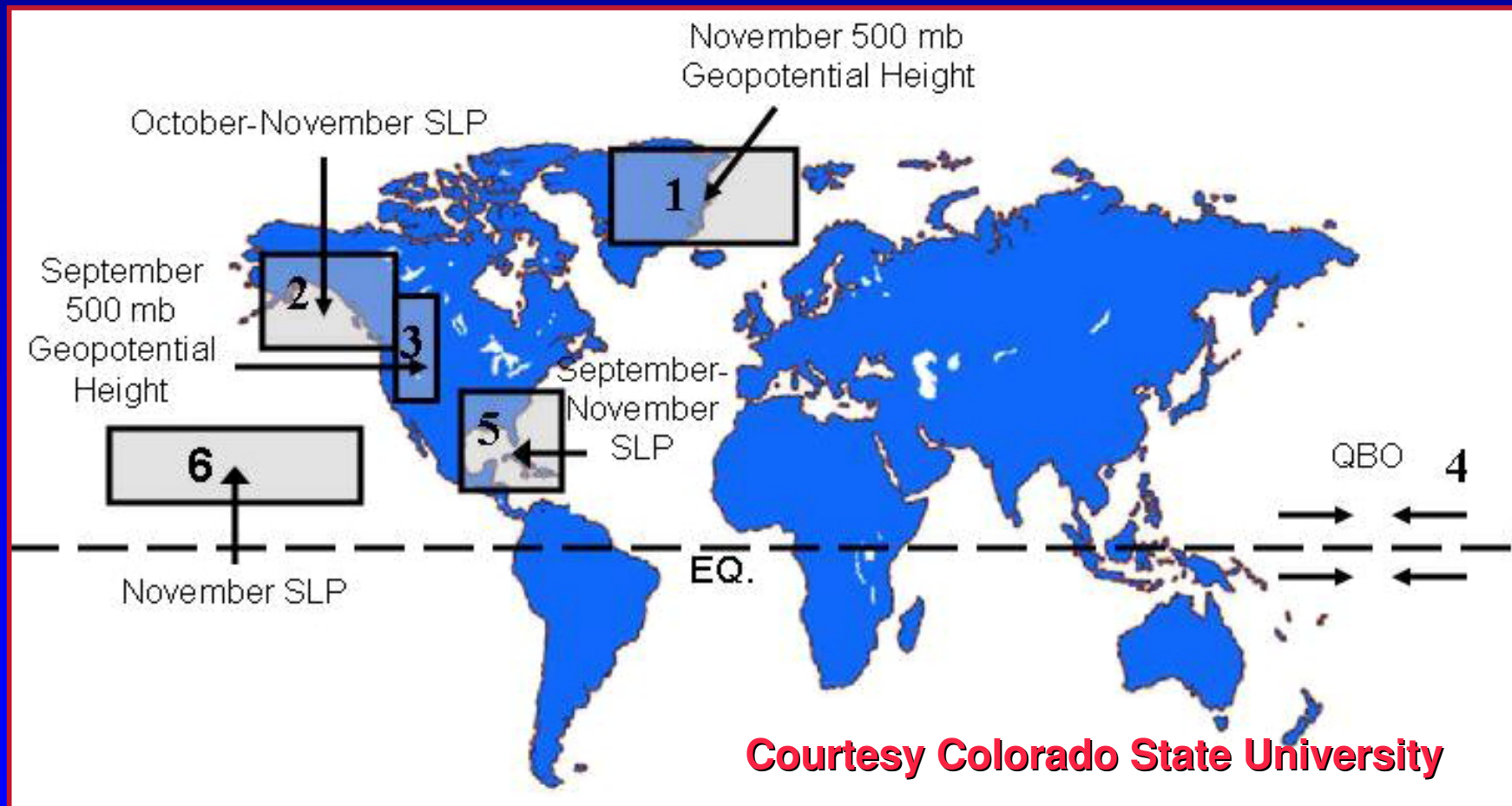
**Colorado State University  
Tropical Storm Risk (TSR)  
NOAA  
Meteorol. Institute, Cuba**

**University of Hong Kong  
Tropical Storm Risk (TSR)**



# Gray Forecast Methodology

New extended range predictors for 2003



Courtesy Colorado State University



# TSR Forecast Methodology

## Statistical Model and Strategy

- Interannual variability in hurricane numbers modelled using a Gaussian model.
- Divide Atlantic basin into three sub-regions:
  - Main development region (10°N-20°N, 20°W-60°W)
  - Caribbean Sea and Gulf of Mexico
  - Extra-tropical north Atlantic.

## Predictors Used

1. JUL-AUG-SEP (JAS) forecast 925mb U-wind for 7.5°N-17.5°N, 30°W-100°W.
2. AUG-SEP (AS) forecast SST for Atlantic hurricane main development region 10°N-20°N, 20°W-60°W.



# Atlantic Forecast Performance 2002

Atlantic Total Numbers 2002				
		Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number ( $\pm$ SD) (1992-2001)		11.5 ( $\pm$ 4.1)	6.9 ( $\pm$ 2.9)	2.9 ( $\pm$ 2.0)
Average Number ( $\pm$ SD) (1972-2001)		9.5 ( $\pm$ 3.6)	5.7 ( $\pm$ 2.4)	2.1 ( $\pm$ 1.5)
Actual Number 2002		12	4	2
TSR Forecasts( $\pm$ SD)	07 Aug 2002	8.1 ( $\pm$ 2.2)	3.9 ( $\pm$ 1.3)	1.3 ( $\pm$ 1.4)
	08 July 2002	6.8 ( $\pm$ 2.3)	3.1 ( $\pm$ 1.5)	0.9 ( $\pm$ 1.6)
	07 June 2002	7.5 ( $\pm$ 2.1)	3.6 ( $\pm$ 1.6)	1.1 ( $\pm$ 1.4)
	07 May 2002	8.9 ( $\pm$ 2.7)	4.6 ( $\pm$ 1.9)	1.6 ( $\pm$ 1.5)
	05 Apr 2002	11.2 ( $\pm$ 3.1)	6.3 ( $\pm$ 2.3)	2.4 ( $\pm$ 1.9)
	06 Mar 2002	12.5 ( $\pm$ 3.6)	7.2 ( $\pm$ 2.5)	2.8 ( $\pm$ 1.9)
	06 Feb 2002	13.6 ( $\pm$ 3.5)	8.0 ( $\pm$ 2.5)	3.2 ( $\pm$ 1.8)
	10 Jan 2002	13.1 ( $\pm$ 3.6)	7.7 ( $\pm$ 2.6)	3.0 ( $\pm$ 1.8)
	03 Dec 2001	13.0 ( $\pm$ 3.6)	7.5 ( $\pm$ 2.5)	3.0 ( $\pm$ 1.6)
Gray/Colorado State-University Forecasts	02 Sep 2002	8	3	1
	07 Aug 2002	9	4	1
	31 May 2002	11	6	2
	05 Apr 2002	12	7	3
	07 Dec 2001	13	8	4
NOAA Forecasts	08 Aug 2002	7-10	4-6	1-3
	20 May 2002	9-13	6-8	2-3
Meteorological Institute, Cuba Forecasts	01 Aug 2002	12	9	-
	02 May 2002	12	9	-





# TSR/Gray Skill Comparison

Strength	Lead	Start Year	End Year	PVE		RMSE <sub>CL</sub> (%)		MAE <sub>CL</sub> (%)	
				TSR	Gray	TSR	Gray	TSR	Gray
H	0	1987	2001	67	45	43	25	43	22
H	2	1987	2001	44	22	21	13	17	14
H	4	1995	2001	30	0	20	10	19	12
H	8	1992	2001	23	0	17	0	15	0

- **TSR outperforms Gray at all leads.**
- **However, one can not conclude the TSR model is better than the Gray model since the latter has changed with time.**

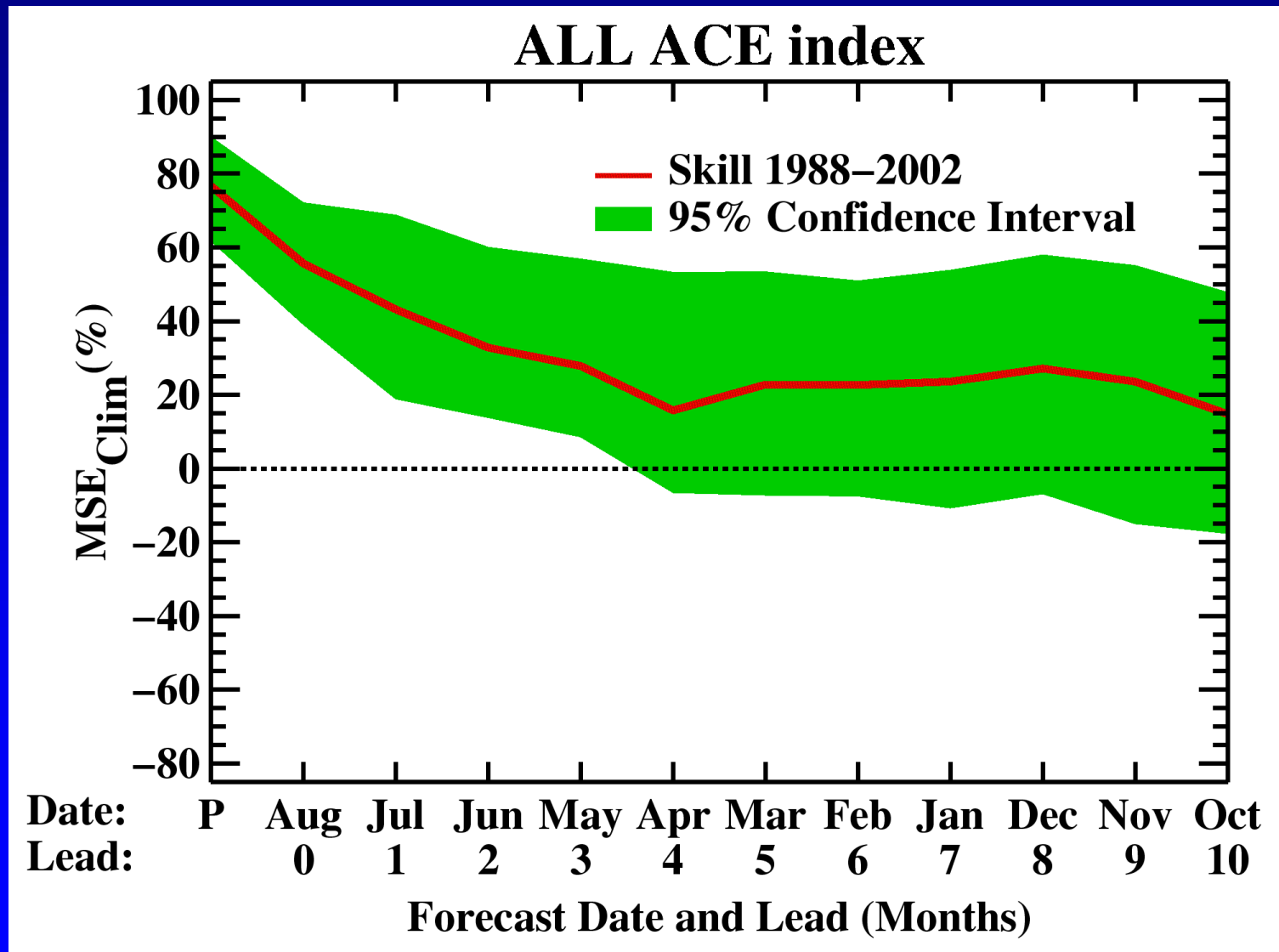


# NOAA ACE Index Forecasts

- The NOAA Accumulated Cyclone Energy (ACE) Index is the sum of the squares of maximum 1-min sustained winds every 6 hours for all systems while they are at least tropical storm strength.
- Since this index reflects a combination of intensity and duration it should be a **better measure of likely damage** than the number of tropical storms or hurricanes alone.

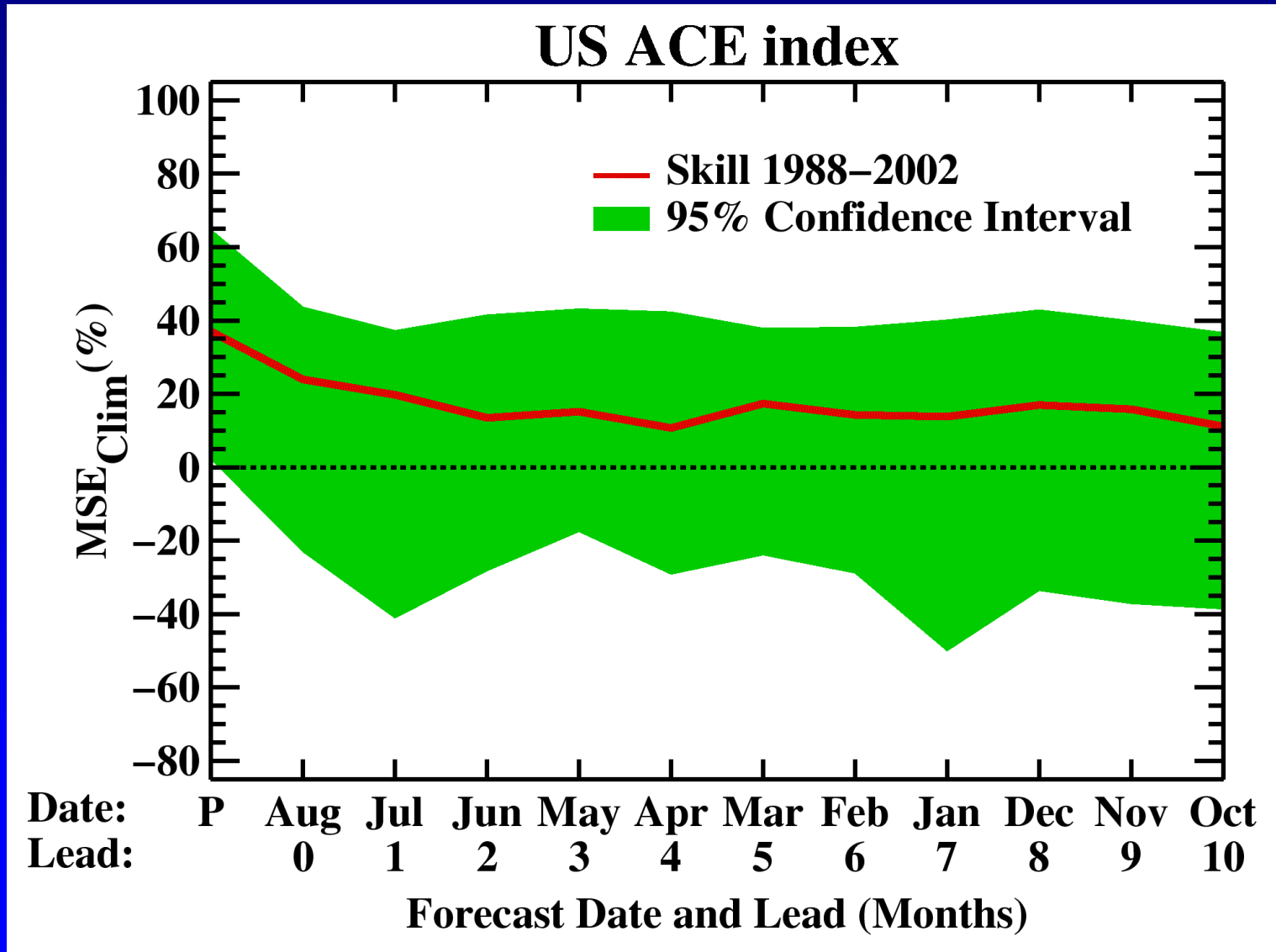


# TSR Hindcast Skill for Atlantic Seasonal ACE Index





# TSR Hindcast Skill for Seasonal US ACE Index





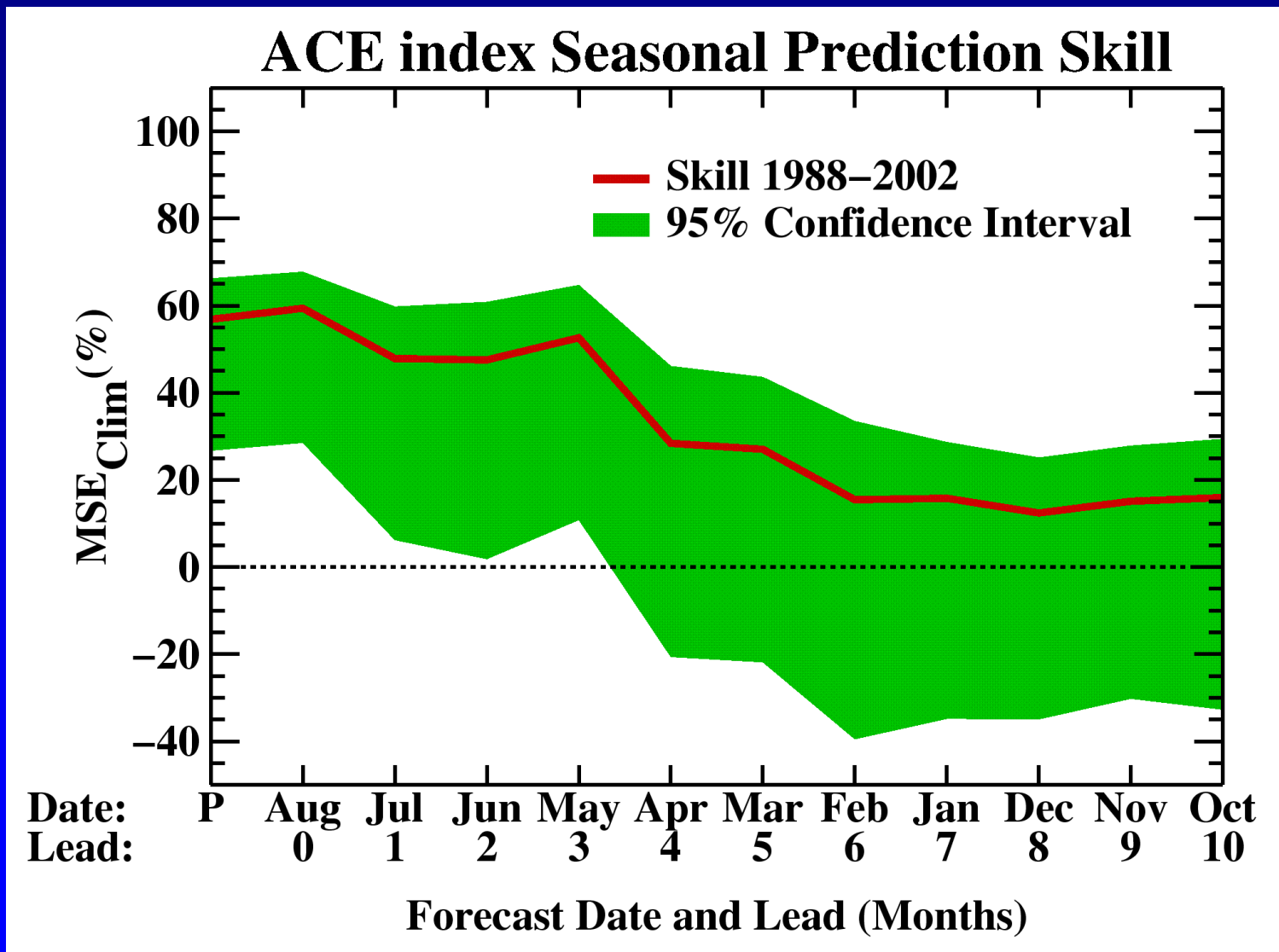
# NW Pacific Forecast Performance 2002

## NW Pacific Total Numbers and ACE Index in 2002

		ACE Index ( $\times 10^4$ knots <sup>2</sup> )	Tropical Storms	Typhoons	Intense Typhoons
Average Number ( $\pm$ SD) (1992-2001)		319 ( $\pm$ 140)	27.4 ( $\pm$ 4.6)	16.9 ( $\pm$ 4.3)	9.0 ( $\pm$ 3.1)
Average Number ( $\pm$ SD) (1972-2001)		289 ( $\pm$ 106)	26.3 ( $\pm$ 4.0)	16.4 ( $\pm$ 3.6)	8.2 ( $\pm$ 3.3)
Actual Number 2002		388	26	17	12
TSR Forecast ( $\pm$ FE)	6 August 2002	-	28.4 ( $\pm$ 4.2)	19.0 ( $\pm$ 3.4)	11.5 ( $\pm$ 1.7)
	11 July 2002	-	28.6 ( $\pm$ 4.4)	19.2 ( $\pm$ 3.7)	11.8 ( $\pm$ 2.2)
	7 June 2002	-	30.8 ( $\pm$ 4.5)	21.1 ( $\pm$ 3.5)	10.5 ( $\pm$ 2.2)
	7 May 2002	-	30.5 ( $\pm$ 4.6)	20.9 ( $\pm$ 3.4)	10.3 ( $\pm$ 2.2)
	5 Apr 2002	-	29.6 ( $\pm$ 5.0)	19.8 ( $\pm$ 4.1)	9.8 ( $\pm$ 2.6)
	6 Mar 2002	-	28.6 ( $\pm$ 4.8)	18.7 ( $\pm$ 4.1)	9.3 ( $\pm$ 2.5)
Chan Forecast ( $\pm$ SD)	28 June 2002	-	27 ( $\pm$ 3)	18 ( $\pm$ 2)	-
	7 May 2002	-	27 ( $\pm$ 3)	17 ( $\pm$ 2)	-



# TSR Hindcast Skill for NW Pacific Seasonal ACE Index





# Atlantic Outlook 2003

## Atlantic Total Wind Energy and System Numbers 2003

		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number ( $\pm$ SD) (1993-2002)		153 ( $\pm$ 94)	12.1 ( $\pm$ 3.6)	6.9 ( $\pm$ 2.9)	3.0 ( $\pm$ 1.9)
Average Number ( $\pm$ SD) (1973-2002)		100 ( $\pm$ 72)	9.8 ( $\pm$ 3.4)	5.7 ( $\pm$ 2.4)	2.1 ( $\pm$ 1.4)
TSR Forecasts ( $\pm$ FE)	4 April 2003	128 ( $\pm$ 85)	11.1 ( $\pm$ 2.9)	6.1 ( $\pm$ 2.4)	2.4 ( $\pm$ 1.8)
	5 Mar 2003	166 ( $\pm$ 87)	12.7 ( $\pm$ 3.5)	7.1 ( $\pm$ 2.7)	2.9 ( $\pm$ 1.9)
	5 Feb 2003	180 ( $\pm$ 90)	13.3 ( $\pm$ 3.3)	7.6 ( $\pm$ 2.7)	3.1 ( $\pm$ 1.8)
	7 Jan 2003	126 ( $\pm$ 65)	12.3 ( $\pm$ 3.4)	6.9 ( $\pm$ 2.8)	2.7 ( $\pm$ 1.8)
	16 Dec 2002	-	12.4 ( $\pm$ 3.5)	7.0 ( $\pm$ 2.8)	2.8 ( $\pm$ 1.8)
Gray Forecasts	4 April 2003		12	8	3
	6 Dec 2002		12	8	3



# NW Pacific Outlook 2003

## Northwest Pacific Total Wind Energy and System Numbers 2003

		ACE Index	Named Tropical Storms	Typhoons	Intense Typhoons
Average Number ( $\pm$ SD) (1993-2002)		300 ( $\pm$ 113)	27.8 ( $\pm$ 5.0)	17.2 ( $\pm$ 4.7)	9.1 ( $\pm$ 3.2)
Average Number ( $\pm$ SD) (1973-2002)		285 ( $\pm$ 97)	26.7 ( $\pm$ 4.3)	16.6 ( $\pm$ 3.7)	8.0 ( $\pm$ 3.0)
TSR Forecasts ( $\pm$ FE)	4 Apr 2003	318 ( $\pm$ 102)	26.7 ( $\pm$ 5.1)	17.1 ( $\pm$ 4.5)	9.2 ( $\pm$ 2.9)
	5 Mar 2003	296 ( $\pm$ 100)	26.2 ( $\pm$ 5.1)	16.6 ( $\pm$ 4.5)	8.5 ( $\pm$ 2.9)





# Future Developments

## **1. Incorporation of Dynamical Forecast Information into Seasonal Forecasts.**

Potential exists to benefit from multi-model (eg DEMETER) seasonal forecasts of ENSO, Trade Wind speed and SST at lead.

## **2. Seasonal Forecasting of Landfalling Activity.**

$r$  (US ACE Index, Atlantic ACE Index) 1952-2002 = 0.65  
Thus potential exists if eg Atlantic seasonal activity could be predicted better.

## **3. Intraseasonal Tropical Cyclone Forecasting.**

Potential exists through eg sound links to the MJO.



# Conclusions

- Seasonal forecasts of basin tropical cyclone activity are skillful enough to be used for **improved risk awareness.**
- Skill to 95% confidence exists from:
  - Early May for the Atlantic ACE Index*
  - Early May for the NW Pacific ACE Index.*
- Outlook for 2003 activity:
  - Atlantic** - above the 30-year average but below the 10-year average.
  - NW Pacific** - close to average.