Climate Change Projections for SEDSIM Modelling over North-East Australia

Report prepared for CSIRO Petroleum

by

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Climate Change Impacts and Risk Stream,
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September 2005

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Important Disclaimer

This report relates to climate change scenarios based on computer modelling. Models involve simplifications of the real physical processes that are not fully understood. Accordingly, no responsibility will be accepted by CSIRO for the accuracy of projections in this report or actions on reliance of this report.

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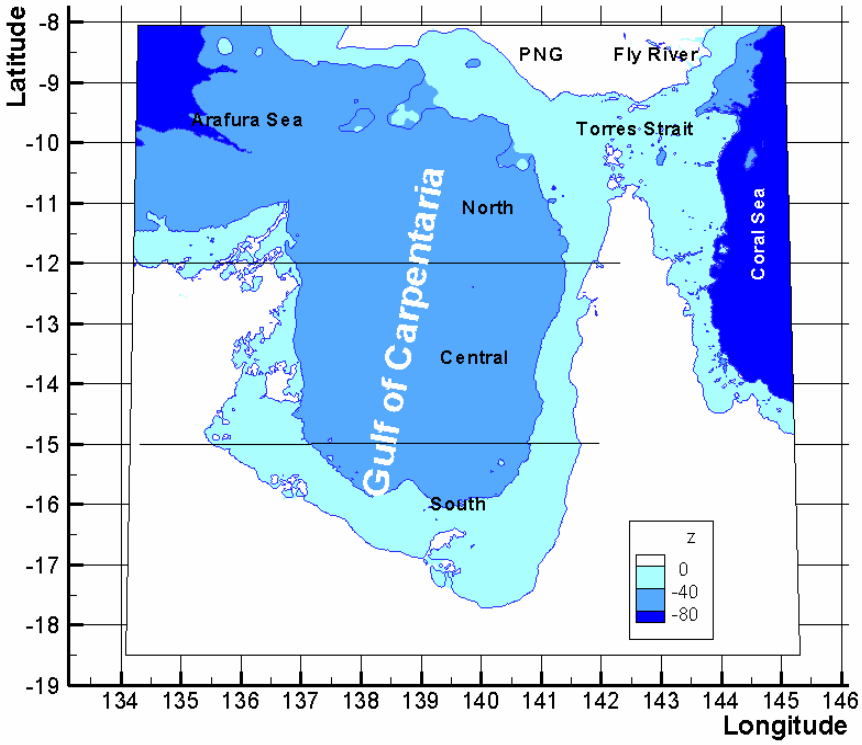
Background

The purpose of this document is to provide relevant, up-to-date projections of various ocean and coastal conditions required as input into an Australian seabed modelling initiative that is being undertaken as a component of the Wealth from Oceans Flagship Program. The seabed modelling is being carried out by Dr Fanjun Li in the Predictive Geoscience Group at CSIRO Petroleum.

Recent work undertaken within the Climate Change Impacts and Risk Stream has yielded new information about future rainfall and wind changes and their associated range of uncertainty over north-east Australia (e.g. Hennessy et al., 2004a). A range of recent climate projections has been re-examined to extract information in a relevant format for incorporation into SEDSIM model simulations for the domain shown in Figure 1. A set of proposed climate changes for this region provided by CSIRO Petroleum formed the basis for the format of the climate change information provided in this report.

Figure 1 The domain for the north-east Australia SEDSIM model simulations



Rainfall

Projections of rainfall for the drainage basins of rivers flowing into the seas off north-east Australia were developed using the OzClim software package (see Page and Jones, 2001). OzClim is a PC-based climate scenario generator developed by CSIRO Marine and Atmospheric Research in collaboration with the International Global Change Institute in New Zealand. Ranges of possible change in rainfall were developed from the output of eight climate models from CSIRO and international institutions that were found to accurately simulate the current climate of Australia. The ranges incorporate uncertainty due to greenhouse gas emissions, the sensitivity of the climate system to the greenhouse gas forcing and the regional variation from model to model.

Projections of rainfall have been prepared for 2055 (50 years from the present) and are summarised in Table 1. The changes given are percentage changes relative to 1961 to 1990 rainfall averages. Since rainfall changes in north-east Australia are expected to be

seasonably variable, changes in seasonal (DJF, MAM, JJA and SON) rainfall, rather than changes in annual rainfall, have been provided.

Table 1 Projected changes in rainfall for 2055 relative to 1961 to 1990 averages (%)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	-8 to +22	-5 to +24	-4 to +26	-8 to +17	-7 to +11	-11 to +13
MAM	-29 to +11	-23 to +10	-27 to +7	-25 to +20	-27 to +46	-25 to +20
JJA	-24 to +7	-15 to +16	-23 to +14	-52 to +12	-52 to +13	-52 to +52
SON	-21 to +23	-30 to +34	-32 to +30	-30 to +15	-33 to +22	-52 to +32

The projections for the DJF season show a tendency towards an increase in rainfall for the region of interest. This tendency is most marked for the north-east of the region, comprising the North-West Coral Sea, Torres Strait and North Gulf of Carpentaria, for which changes in rainfall lie within the range -8 to +26%. The tendency towards an increase in rainfall is less marked outside the north-east, with changes lying in the range -11 to +17%.

The projections for the MAM season show a tendency towards a decrease in rainfall for the areas outside the South Gulf of Carpentaria, with changes lying in the range -29 to +20%. This tendency is most marked for the North-West Coral Sea and North Gulf of Carpentaria. The projection for the South Gulf of Carpentaria shows a bias towards an increase in rainfall and is more uncertain, with a range of change of -27 to +46%.

The projections for the JJA season show a tendency towards a decrease in rainfall except for those for the Torres Strait and East Arafura Sea which show no marked tendency towards an increase or decrease. The tendency towards a decrease in rainfall is more marked for the Central and South Gulf of Carpentaria and more slight for the North-West Coral Sea and the North Gulf of Carpentaria. The projections for the north-east of the region of interest, with changes lying in the range -24 to +16%, are somewhat less uncertain than those for the areas outside the north-east, with changes spanning the range ±52%.

The projections for the SON season show no marked tendency towards an increase or decrease in rainfall for the north-east of the region of interest. The projections for the areas outside the north-east show a tendency towards a decrease in rainfall. This tendency is most marked for the East Arafura Sea, with a range of change of -52 to +32%. The projections for the areas outside the East Arafura Sea are less uncertain, with changes lying in the range -33 to +34%.

Sediment Load

Sediment loads are related to the health of the catchment rather than climate change and so no changes are suggested for the ranges of change of ±10% that have been already proposed.

Outflow

Jones and Durack (2004) estimated the impact of climate change on outflow from Victorian rivers from projections of rainfall and areal potential evaporation using a relationship that addresses hydrological sensitivity to climate change. Their approach was applied to the rivers flowing into the seas off north-east Australia using annual rainfall and areal potential evaporation changes weighted to represent the strong regional seasonality in streamflow. OzClim was used to develop catchment average rainfall and areal potential evaporation projections from the output of the same eight climate models from which the rainfall projections in Table 1 were developed.

The projections of outflow are summarised in Table 2. The changes given are percentage changes relative to 1961 to 1990 outflow averages. The methodology only provides a general

estimate of the plausible range of change in outflow on an annual basis, so changes in annual outflow, rather than changes in seasonal outflow, have been provided.

Table 2 Projected changes in outflow for 2055 relative to 1961 to 1990 averages (%)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
Annual	-30 to +30	-20 to +20	-20 to +20	-40 to +10	-50 to +20	-50 to +30

The projections show no consistent tendency towards an increase or decrease in outflow for the north-east of the region of interest, comprising the North Gulf of Carpentaria, Torres Strait and North-West Coral Sea, for which changes in outflow lie within the range -30 to +30%. The projections for the areas outside the north-east show a bias towards a decrease in outflow, with changes spanning the range -50 to +30%.

Cyclone Intensity and Frequency

The IPCC (2001) concluded that by the late 21st century (e.g. 2070) peak winds in tropical cyclones may increase by 5 to 10%. A scenario for 2055 would be an approximate increase in peak winds of 4 to 8%.

The IPCC (2001) concluded that during the 21st century tropical cyclone frequency may change in some regions. In the Australian region cyclone frequency is strongly correlated with indices of the El Nino Southern Oscillation (ENSO), with increased cyclone frequency during the La Nina phase and decreased frequency during the El Nino phase. Changes to ENSO as a result of climate change are largely uncertain at this time. Therefore no changes are suggested for the range of change in cyclone frequency of ±10% that has been already proposed.

Wind Speed

Projections of average and extreme wind speed 10m above the surface for seas off north-east Australia were developed from recent projections carried out for New South Wales (see Hennessy et al., 2004b). Ranges of possible change in wind speed were developed from the output of eleven climate models from CSIRO and international institutions that were found to accurately simulate the current climate of Australia. The ranges incorporate uncertainty due to greenhouse gas emissions, the sensitivity of the climate system to the greenhouse gas forcing and the regional variation from model to model (For more information on the methodology used see McInnes et al., 2003 or Whetton et al., 2005).

Projections of median and 95th percentile wind speed have been prepared for the DJF, MAM, SON and JJA seasons for 2055 and are summarised in Tables 3 and 4 respectively. The changes given are percentage changes relative to 1961 to 1990 wind speed averages.

Table 3 Projected changes in average (median) 10m wind speed for 2055 relative to 1961 to 1990 averages (%)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	-10 to +4	-7 to +8	-7 to +8	-6 to +9	-3 to +6	-10 to +9
MAM	-5 to +2	-5 to +3	-5 to +4	-7 to +3	-10 to 0	-5 to +3
JJA	-2 to +4	-2 to +3	-2 to +2	-4 to +3	-3 to +3	-3 to +4
SON	-4 to +3	-4 to +5	-5 to +3	-5 to +4	-2 to +5	-5 to +2

Changes in average wind speed for the DJF season lie within the range -10 to +9% for the region of interest. The projections for the Torres Strait, North Gulf of Carpentaria and East Arafura Sea show little tendency towards an increase or decrease in wind speed. A marked bias towards a decrease is indicated for the North-West Coral Sea and a slight bias towards

an increase is suggested for the Central and South Gulf of Carpentaria. The projection for the South Gulf of Carpentaria is somewhat less uncertain than the other projections.

Changes in average wind speed for the MAM season lie within the range -10 to +4% for the region of interest. All the projections show a tendency towards a decrease in wind speed. This tendency is most marked for the South Gulf of Carpentaria for which any magnitude of increase in wind speed is considered to be unlikely.

Changes in average wind speed for the JJA season lie within the range ±4%. The projections show little tendency towards an increase or decrease in wind speed except for the North-West Coral Sea for which a slight bias towards an increase is suggested.

Changes in average wind speed for the SON season lie within the range ±5%. The projections show little tendency towards an increase or decrease in wind speed except for the South Gulf of Carpentaria for which a slight bias towards an increase is suggested and the East Arafura Sea for which a slight bias towards a decrease is suggested.

Table 4 Projected changes in extreme (95th percentile) 10m wind speed for 2055 relative to 1961 to 1990 averages (%)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	-13 to +10	-11 to +13	-9 to +14	-5 to +10	-6 to +8	-6 to +13
MAM	-4 to +4	-5 to +3	-5 to +3	-6 to +2	-6 to +4	-5 to +2
JJA	-1 to +3	0 to +4	-1 to +3	-3 to +2	-3 to +4	-2 to +4
SON	-2 to +4	-3 to +6	-4 to +3	-6 to +2	-7 to +4	-5 to +2

Changes in extreme wind speed for the DJF season lie within the range ±13% for the region of interest. All of the projections show a tendency towards an increase in wind speed except for the North-West Coral Sea for which a bias towards a decrease is indicated. The projections for the north-east of the region, comprising the North-West Coral Sea, Torres Strait and North Gulf of Carpentaria, are somewhat more uncertain than the other projections.

Changes in extreme wind speed for the MAM season lie within the range -6 to +4% for the region of interest. All of the projections show a tendency towards a decrease in wind speed except for the North-West Coral Sea for which no tendency towards an increase or decrease is indicated.

Changes in extreme wind speed for the JJA season lie within the range ±4%. All of the projections show a tendency towards an increase in wind speed except for the Central Gulf of Carpentaria for which a slight bias towards a decrease is suggested. The tendency towards an increase in wind speed is most marked for the Torres Strait Carpentaria for which any magnitude of decrease in wind speed is considered to be unlikely.

Changes in extreme wind speed for the SON season lie within the range -7 to +6%. All of the projections show a tendency towards a decrease in wind speed except for the North-West Coral Sea and Torres Strait for which a bias towards an increase is indicated.

Wave Height

The Beaufort Wind Scale has been used to calculate changes in average wave height from average 10m wind speeds for 2055. These wind speeds have been generated by applying the projected changes in average 10m wind speed (Table 3) to average wind speeds derived from mean wind speed data from the NCEP reanalyses for the 40 year period 1961 to 2000 (Table 5). A similar method has been used to obtain changes in extreme wave height from the projected changes in extreme 10m wind speed (Table 4) and extreme wind speeds derived from 99th percentile wind speed data from the same set of NCEP reanalyses (Table 6).

Table 5 Average (mean) 10m wind speeds for the period 1961 to 2000 (ms^{-1})

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	4	3	5	4	3	5
MAM	6	4	5	6	4	5
JJA	8	6	7	7	4	7
SON	7	5	5	5	4	5

Table 6 Extreme (99^{th} percentile) 10m wind speeds for the period 1961 to 2000 (ms^{-1})

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	14	13	16	14	10	14
MAM	16	13	15	14	10	14
JJA	13	11	13	13	10	13
SON	13	10	12	13	10	12

Projections of average and extreme wave height for 2055 are summarised in Tables 7 and 8 respectively.

Table 7 Projected changes in average wave height for 2055 relative to 1961 to 1990 averages (%)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	-10 to +4	-7 to +8	-7 to +8	-6 to +9	-3 to +6	-10 to +9
MAM	-5 to +2	-5 to +3	-5 to +4	-7 to +3	-10 to 0	-5 to +3
JJA	-2 to +15	-2 to +3	-2 to +2	-4 to +3	-3 to +3	-3 to +4
SON	-4 to +3	-4 to +5	-5 to +3	-5 to +4	-2 to +5	-5 to +2

Table 8 Projected changes in extreme wave height for 2055 relative to 1961 to 1990 averages (%)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	-23 to +17	-20 to +24	-14 to +22	-9 to +18	-15 to +20	-10 to +22
MAM	-6 to +6	-9 to +6	-8 to +5	-11 to +4	-16 to +11	-9 to +4
JJA	-2 to +6	0 to +9	-2 to +6	-6 to +4	-8 to +11	-4 to +8
SON	-4 to +8	-7 to +15	-8 to +6	-11 to +4	-17 to +10	-10 to +4

Wave Power

Wave power or deep water energy flux per unit length of wave crest is related to wave height by the following formula;

$$P = 1/8\ \rho\ g\ C\ n\ H^2$$

where P is the power, ρ is the water density, g is the gravity, C is the wave celerity, n varies in value from 0.5 in deep water and 1 in shallow water and H is the deep water wave height. Therefore percentage changes for wave power, summarised in Tables 9 and 10, are twice those for wave height (Tables 7 and 8).

Table 9 Projected changes in average wave power for 2055 relative to 1961 to 1990 averages (%)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	-20 to +8	-14 to +16	-14 to +16	-12 to +18	-6 to +12	-20 to +18
MAM	-10 to +4	-10 to +6	-10 to +8	-14 to +6	-20 to 0	-10 to +6
JJA	-4 to +30	-4 to +6	-4 to +4	-8 to +6	-6 to +6	-6 to +8
SON	-8 to +6	-8 to +10	-10 to +6	-10 to +8	-4 to +10	-10 to +4

Table 10 Projected changes in extreme wave power for 2055 relative to 1961 to 1990 averages (%)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
DJF	-46 to +34	-40 to +48	-28 to +44	-18 to +36	-30 to +40	-20 to +44
MAM	-12 to +12	-18 to +12	-16 to +10	-22 to +8	-32 to +22	-18 to +8
JJA	-4 to +12	0 to +18	-4 to +12	-12 to +8	-16 to +22	-8 to +16
SON	-8 to +16	-14 to +30	-16 to +12	-22 to +8	-34 to +20	-20 to +8

Local Mean Sea Level

A rise in global mean sea level of between 0.05 and 0.32m for 2050 can be estimated from information summarised by the IPCC (2001). It is expected that, to a good approximation, mean sea level rise will be spatially homogeneous so this estimate is also appropriate for the rise in local mean sea level around north-east Australia by 2050.

Atmospheric Carbon Dioxide Concentration

Measurements summarised by the IPCC (2001) show that the atmospheric carbon dioxide concentration increased from approximately 310 to approximately 370ppm over the period 1960 to 2000. According to an ensemble of future carbon dioxide emissions scenarios considered to be plausible by the IPCC (see IPCC, 2000), it is likely that the atmospheric carbon dioxide concentration will lie between approximately 470 and 570ppm in 2050.

Summary

The revised changes to the input parameters for the SEDSIM model are shown in Table 11. Rows shaded in blue have been modified from those supplied to CSIRO Marine and Atmospheric Research on the basis of this report. Note that it has not been possible to provide projections for the Fly River region of south Papua New Guinea and projections of wind and wave direction.

Table 11 Projected changes in input parameters for the SEDSIM model for the mid 21st century (% unless otherwise indicated)

	North-West Coral Sea	Torres Strait	North Gulf of Carpentaria	Central Gulf of Carpentaria	South Gulf of Carpentaria	East Arafura Sea
Rainfall						
DJF	-8 to +22	-5 to +24	-4 to +26	-8 to +17	-7 to +11	-11 to +13
MAM	-29 to +11	-23 to +10	-27 to +7	-25 to +20	-27 to +46	-25 to +20
JJA	-24 to +7	-15 to +16	-23 to +14	-52 to +12	-52 to +13	-52 to +52
SON	-21 to +23	-30 to +34	-32 to +30	-30 to +15	-33 to +22	-52 to +32
Sediment Load						
	-10 to +10	-10 to +10	-10 to +10	-10 to +10	-10 to +10	-10 to +10
Outflow						
Annual	-30 to +30	-20 to +20	-20 to +20	-40 to +10	-50 to +20	-50 to +30
Cyclone Intensity						
	+4 to +8	+4 to +8	+4 to +8	+4 to +8	+4 to +8	+4 to +8
Cyclone Frequency						
	-10 to +10	-10 to +10	-10 to +10	-10 to +10	-10 to +10	-10 to +10
Average Wind Speed						
DJF	-10 to +4	-7 to +8	-7 to +8	-6 to +9	-3 to +6	-10 to +9
MAM	-5 to +2	-5 to +3	-5 to +4	-7 to +3	-10 to 0	-5 to +3
JJA	-2 to +4	-2 to +3	-2 to +2	-4 to +3	-3 to +3	-3 to +4
SON	-4 to +3	-4 to +5	-5 to +3	-5 to +4	-2 to +5	-5 to +2
Extreme Wind Speed						
DJF	-13 to +10	-11 to +13	-9 to +14	-5 to +10	-6 to +8	-6 to +13
MAM	-4 to +4	-5 to +3	-5 to +3	-6 to +2	-6 to +4	-5 to +2
JJA	-1 to +3	0 to +4	-1 to +3	-3 to +2	-3 to +4	-2 to +4
SON	-2 to +4	-3 to +6	-4 to +3	-6 to +2	-7 to +4	-5 to +2
Average Wave Power						
DJF	-20 to +8	-14 to +16	-14 to +16	-12 to +18	-6 to +12	-20 to +18
MAM	-10 to +4	-10 to +6	-10 to +8	-14 to +6	-20 to 0	-10 to +6
JJA	-4 to +30	-4 to +6	-4 to +4	-8 to +6	-6 to +6	-6 to +8
SON	-8 to +6	-8 to +10	-10 to +6	-10 to +8	-4 to +10	-10 to +4
Extreme Wave Power						
DJF	-46 to +34	-40 to +48	-28 to +44	-18 to +36	-30 to +40	-20 to +44
MAM	-12 to +12	-18 to +12	-16 to +10	-22 to +8	-32 to +22	-18 to +8
JJA	-4 to +12	0 to +18	-4 to +12	-12 to +8	-16 to +22	-8 to +16
SON	-8 to +16	-14 to +30	-16 to +12	-22 to +8	-34 to +20	-20 to +8
Local Mean Sea Level						
	+0.05 to +0.32m					
Atmospheric Carbon Dioxide Concentration						
	Increase to 470 to 570ppm					

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