Modelling Solar Potential For Energy Generation in Cold Regions

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OUTLINE OF TALK

- Solar Energy Applications at A.N.A.R.E (Australian National Antarctic Research Expedition) stations
- Modelling Solar Potential with S.E.M.A.S (Solar Energy Modelling for Antarctic Stations)
- Potential Solar Energy Estimates for A.N.A.R.E. stations

Solar Energy Applications at A.N.A.R.E Stations

- High Cost of Fossil Fuel Transportation and Increased Environmental Risk
  - Applications for Stand-Alone Summer Installations (Photovoltaic and Solar Hot Water power)
- Limitations of Latitude and Meteorology
  - Elevation of Sun, Winter Darkness beyond Polar Circle (~66° 33´)
  - High Average Cloud Cover

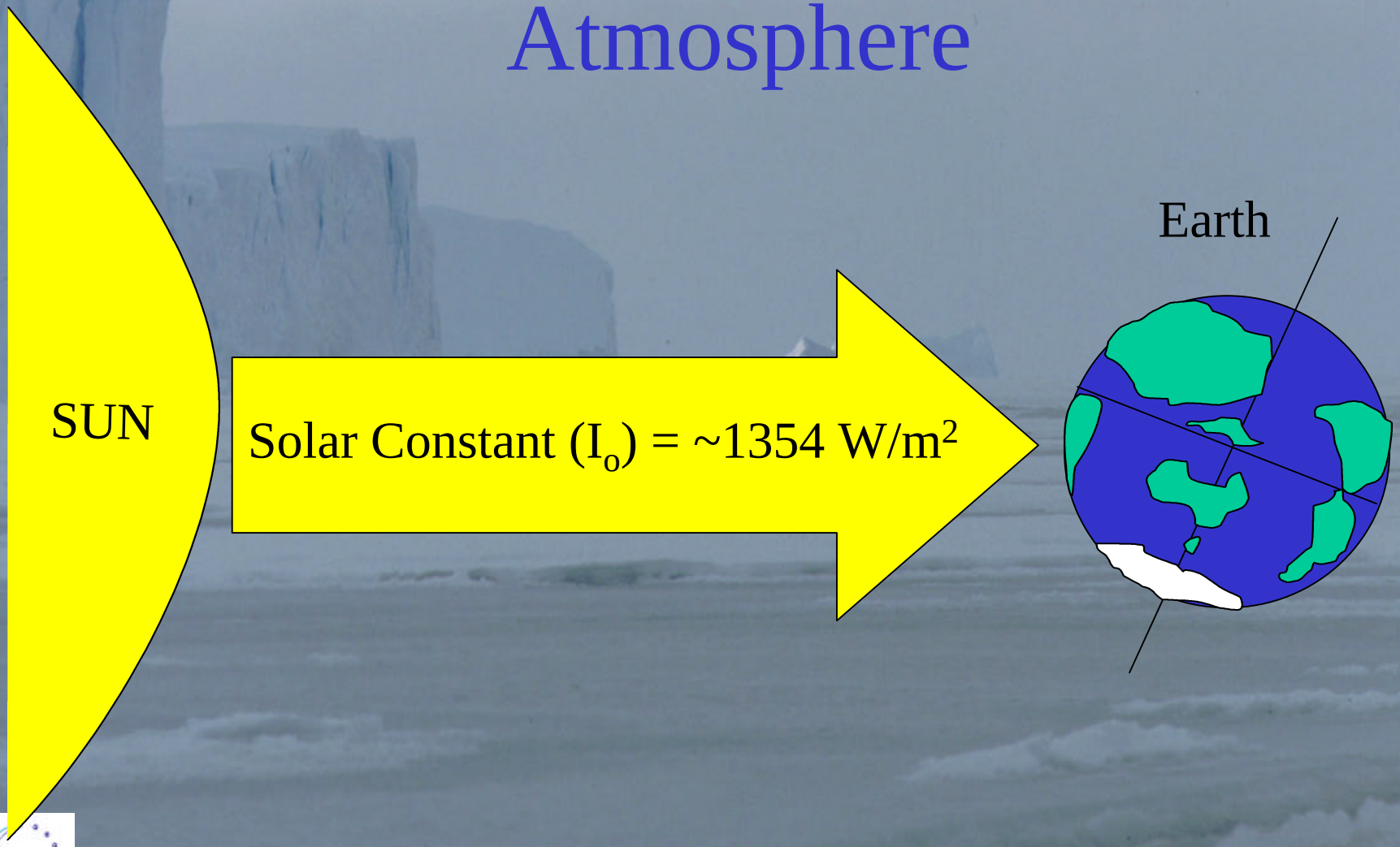
Limitations of Latitude and Meteorology

STATION	LAT	LONG	AVG CLOUD COVER
MACQUARIE	54° 29′	158° 57′	84 %
CASEY	66° 17′	110° 32′	70 %
DAVIS	68° 34′	77° 58′	65 %
MAWSON	67° 36′	62° 52′	58 %

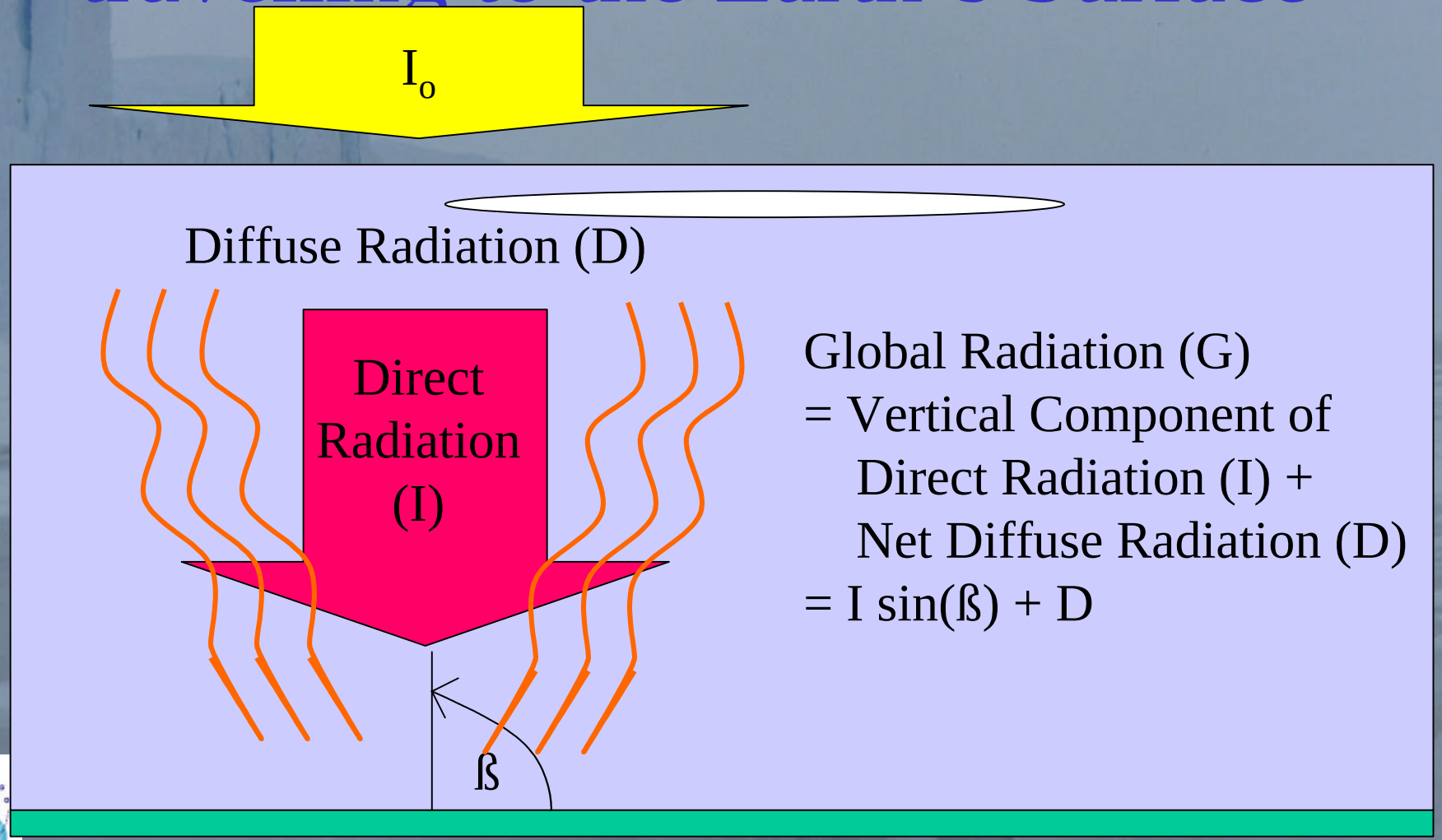
Solar Energy Modelling for Antarctic Stations (SEMAS)

- Extraterrestrial radiation reaching the Earth's atmosphere
- Interaction with the atmosphere en route to the Earth's surface
- Interaction with collecting surfaces and
- Efficiency of conversion from energy into usable power

Radiation reaching the Earth's Atmosphere

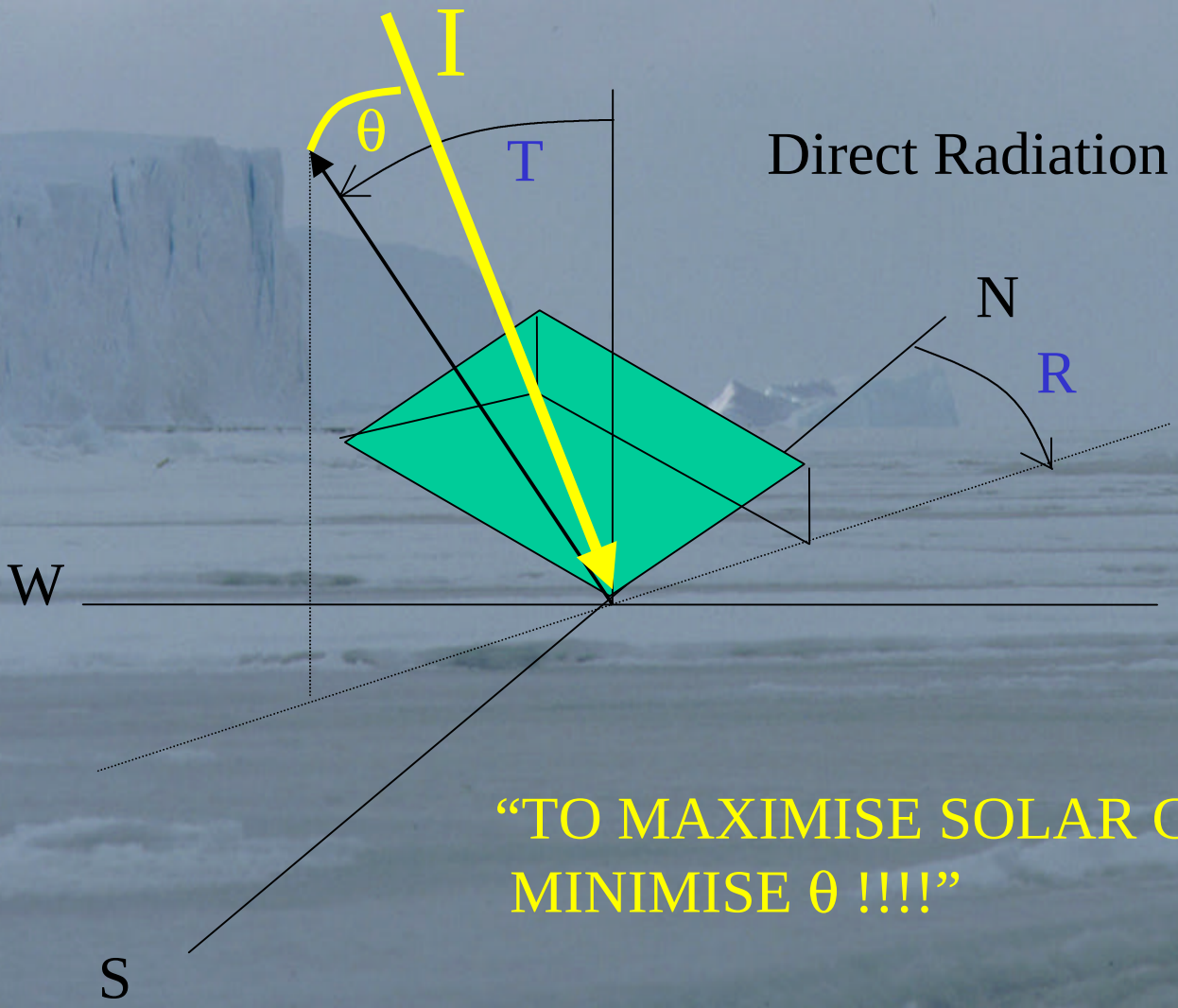


Interaction with Atmosphere travelling to the Earth's Surface



Global Radiation (G)
= Vertical Component of
Direct Radiation (I) +
Net Diffuse Radiation (D)
= I sin(ß) + D

Interaction of Direct Radiation with non-horizontal solar collecting surface



Direct Radiation = I cos(θ)

"TO MAXIMISE SOLAR COLLECTION, MINIMISE θ !!!!"

SOLAR RADIATION COLLECTION STRATEGIES

- Fixed Panel
  - Horizontal
  - Fixed tilt and rotation angle
- Tracking Systems
  - Altitude (varying tilt angle, T)
  - Azimuth (varying rotation angle, R)
  - Full Tracking (varying tilt and rotation angle)

AVAILABLE DATA

- Meteorological Data from the Bureau of Meteorology
  - Total Cloud Cover (3 hourly), Operational Temperatures
- Operational Data collected from Pilot Solar Hot Water Installation at Davis Station (1998 - 1999)
  - Global Radiation, Power Output

SEMAS - A Simple Model

- Determines the timing and position of the sun with respect to a given location on the Earth's surface
- Determines Annual Global Radiation levels
- Factors in 3 hourly cloud observations
- Calibrated to observed radiation observations
- Filtered across varying collecting strategies

RESULTS

- Annual Global Solar Radiation estimates incident upon the ground at A.N.A.R.E Stations
- Annual Global Solar Radiation estimates for non-horizontal, fixed and tracking collection strategies

Annual Global Solar Radiation (horizontal surface)

STATION	GLOBAL RADIATION	
	DAILY AVERAGE (kWh/m^2)	ANNUAL TOTAL (kWh/m^2)
MACQUARIE ISLAND	2.8	1003
CASEY	2.3	836
DAVIS	2.4	834
MAWSON	2.4	878

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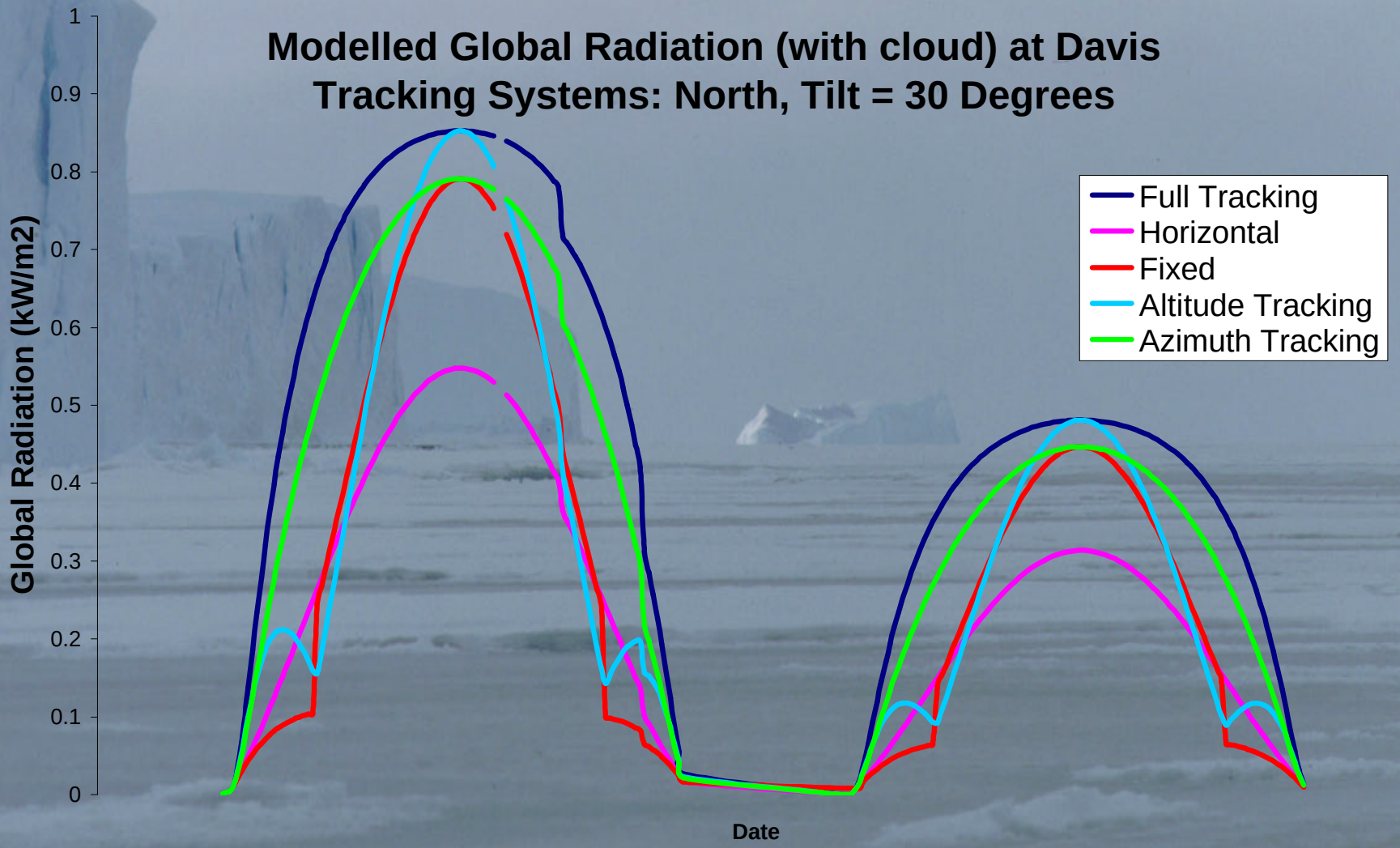

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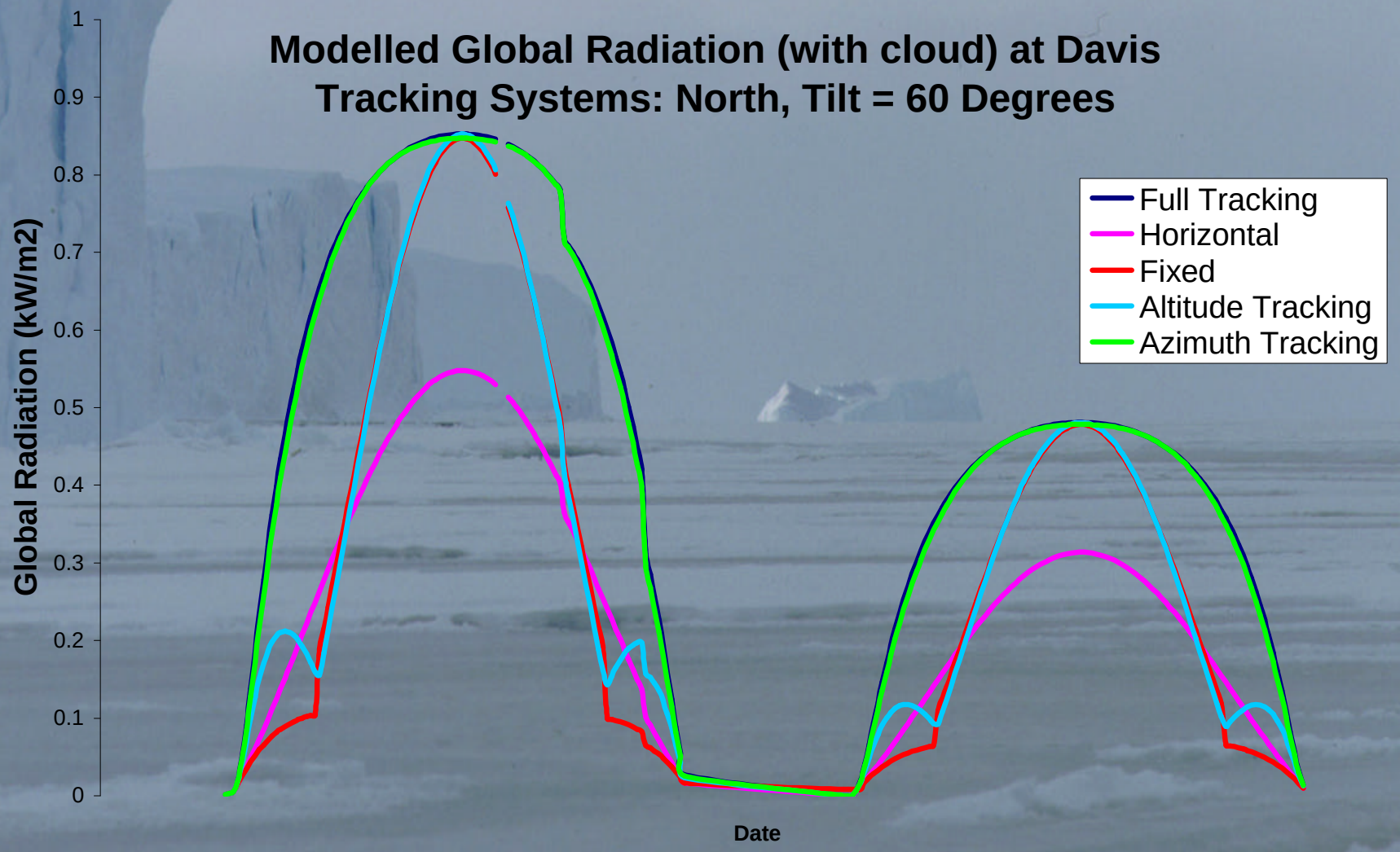

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Annual Global Solar Radiation (non-horizontal surfaces)

Station	Best Angle (degrees)	Fixed (kWh/m^2)	Altitude Tracking (kWh/m^2)	Azimuth Tracking (kWh/m^2)	Full Tracking (kWh/m^2)
MACQUARIE	40	1209	1276	1621	1689
CASEY	60	1098	1208	1617	1651
DAVIS	60	1079	1201	1630	1662
MAWSON	60	1148	1273	1711	1745

DISCUSSION

- Fixed Vs Tracking Systems
- Evaluating the success of Solar Power Generation
- Future Work
  - further development of SEMAS model

FIXED VS TRACKING SYSTEMS

- Tracking Systems more expensive to purchase per m^2
- Tracking Systems more expensive to maintain per m^2
- Fixed Systems greater collection area per $ outweighs greater collection efficiency of Tracking Systems
- Design Solution: Adjustable Fixed System

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Pilot Solar Collection Installation at Davis Station

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Best Collection Strategy at Davis

DATE	BEST ANGLE (DEGREES)
WINTER – 10th SEPTEMBER	80
10th SEPTEMBER – 1ST OCTOBER	70
1ST OCTOBER – 5th NOVEMBER	60
5th NOVEMBER – 25th NOVEMBER	40
25th NOVEMBER – 10th JANUARY	10
10th JANUARY – 1st FEBRUARY	40
1st FEBRUARY – 5th MARCH	60
5th MARCH – 5th APRIL	70
5th APRIL – WINTER	80

Solar Power Output

- Photovoltaics
  - assuming 12% conversion efficiency
  - existing solar panel configuration (12m^2)
  - 1500-1700 kWh
- Solar Hot Water Power
  - 500-1000 kWh

Further SEMAS Development

- Cloud Integration
  - resolution of cloud data into finer scale time grid, differentiating between cloud types
- Calibration with increased data set from current season (1999-2000)
- Application to sites around the world

CONCLUSION

- Solar power at A.N.A.R.E. stations can supplement traditional power generation, in particular in stand-alone summer installations
- Fixed systems more cost effective.
- SEMAS: Efficient and inexpensive method of assessing solar potential

THANK YOU

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