Air-Sea-Ice Feedbacks in DMS production in the Arctic Ocean

(A 1-D model work in progress)

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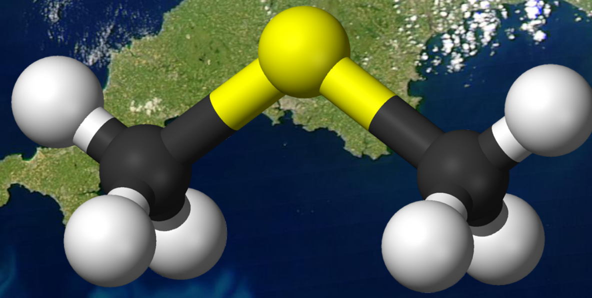
What is DMS?



-a very smelly gas

-a biogenic compound produced by certain phytoplankton

-an important part of the marine sulphur cycle

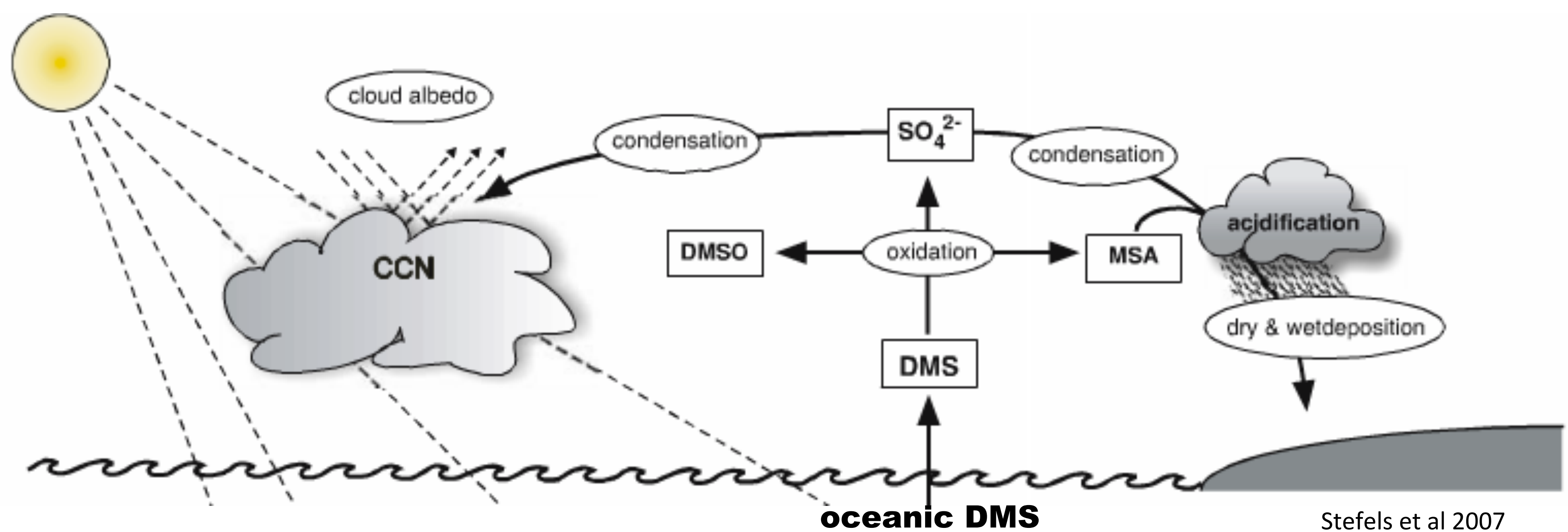
Why do we study it?

-up to 80% of global biogenic sulphur budget

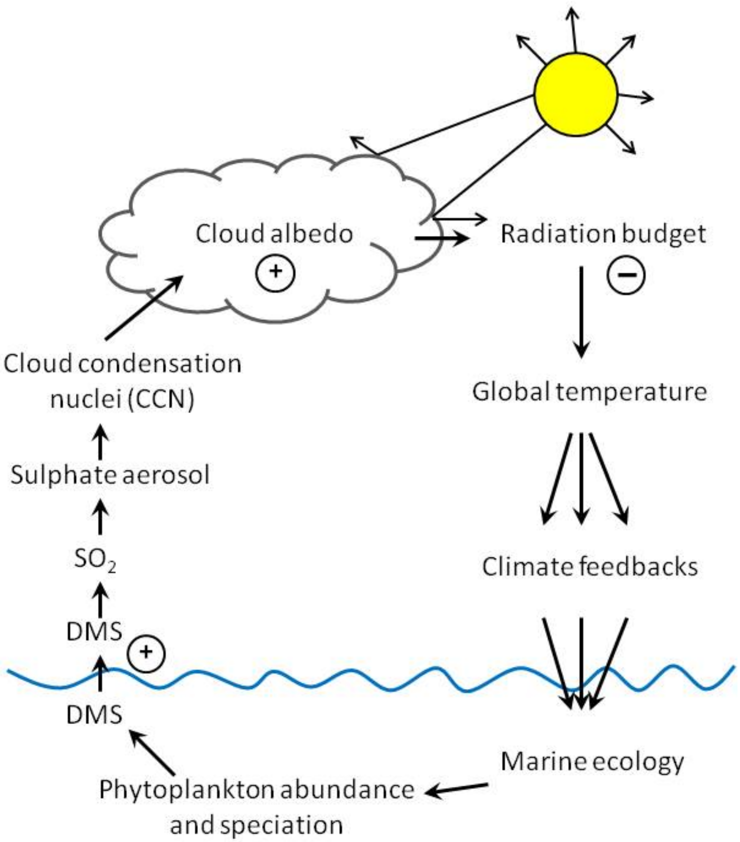
-Oceans: 95% of DMS emissions to atmosphere

-component of some global climate models

-global cooling/ potential climate feedbacks

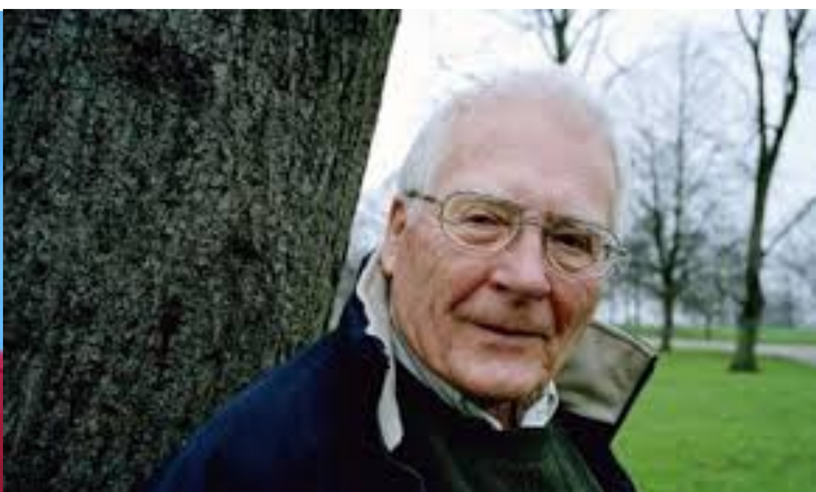


Stefels et al 2007



C.L.A.W.
HYPOTHESIS

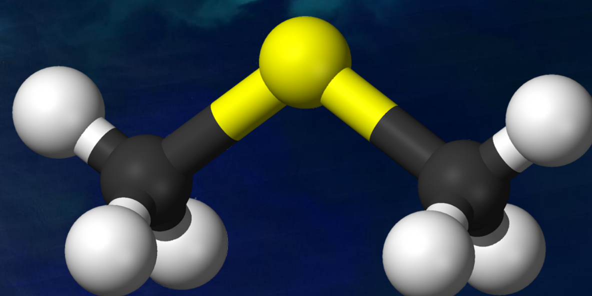


My goal in this project:

To create a simple model that asks:

In the Arctic,
do DMS emissions actually affect subsequent DMS production?
If so, how much?



2 main questions in the model:

-How much DMS is produced?

-How much does it change the radiative forcing?

General Approach:

-ODE describing primary productivity

-ODE describing radiative forcing

- **(seasonally dependent) links between the two**
- **3 ‘domains’: SEA, ICE, SKY**

The Arctic Environment

-permanent presence of frozen water (ice)

-large watershed (freshwater flux)

-low sea surface temperature

-large seasonal variation in radiation

-seasonal nutrient limitation

-salinity stratification

-polar bears

Environmental Variables in Model

(monthly resolution)

-ice cover

-windspeed

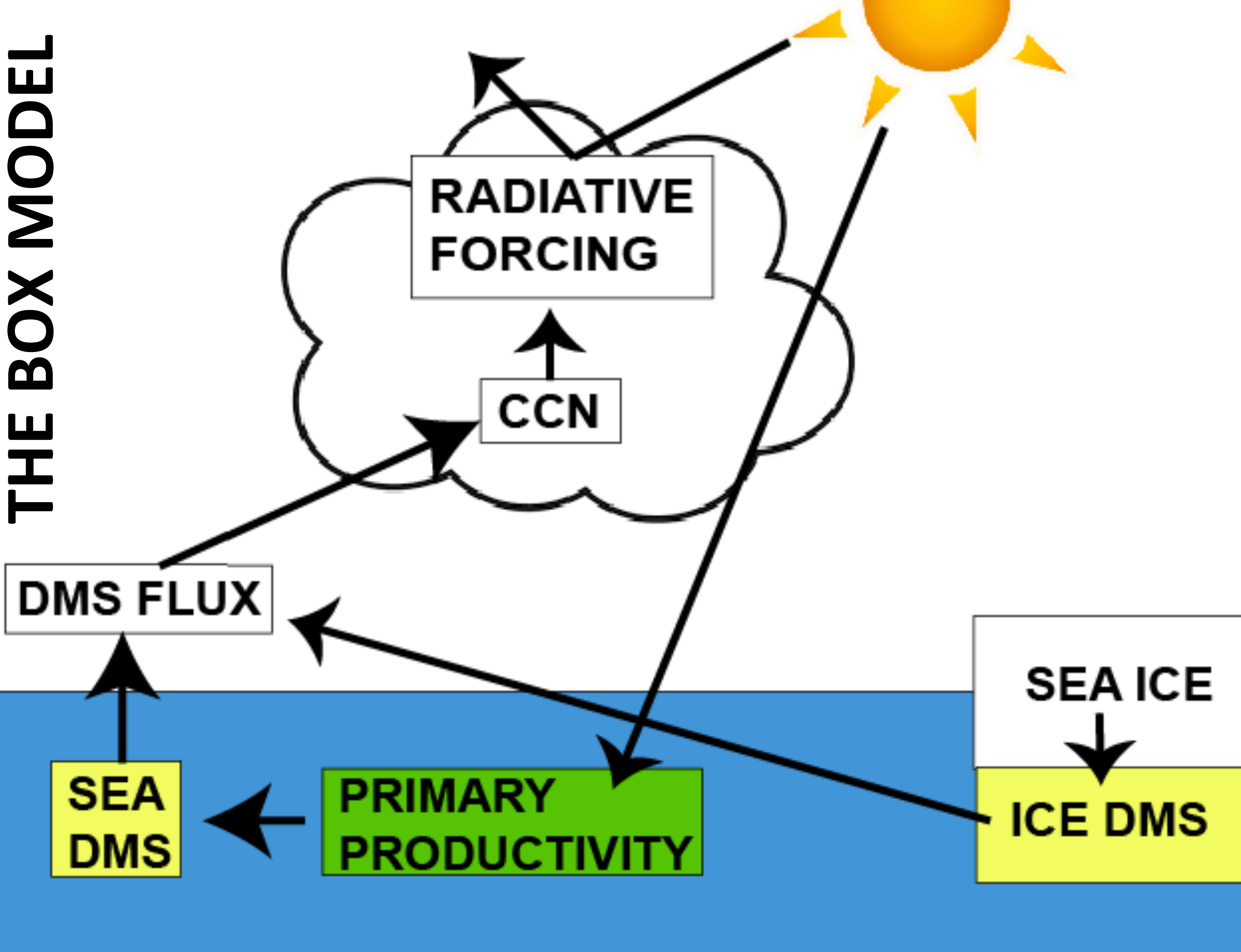
-PAR (ie. sunlight)

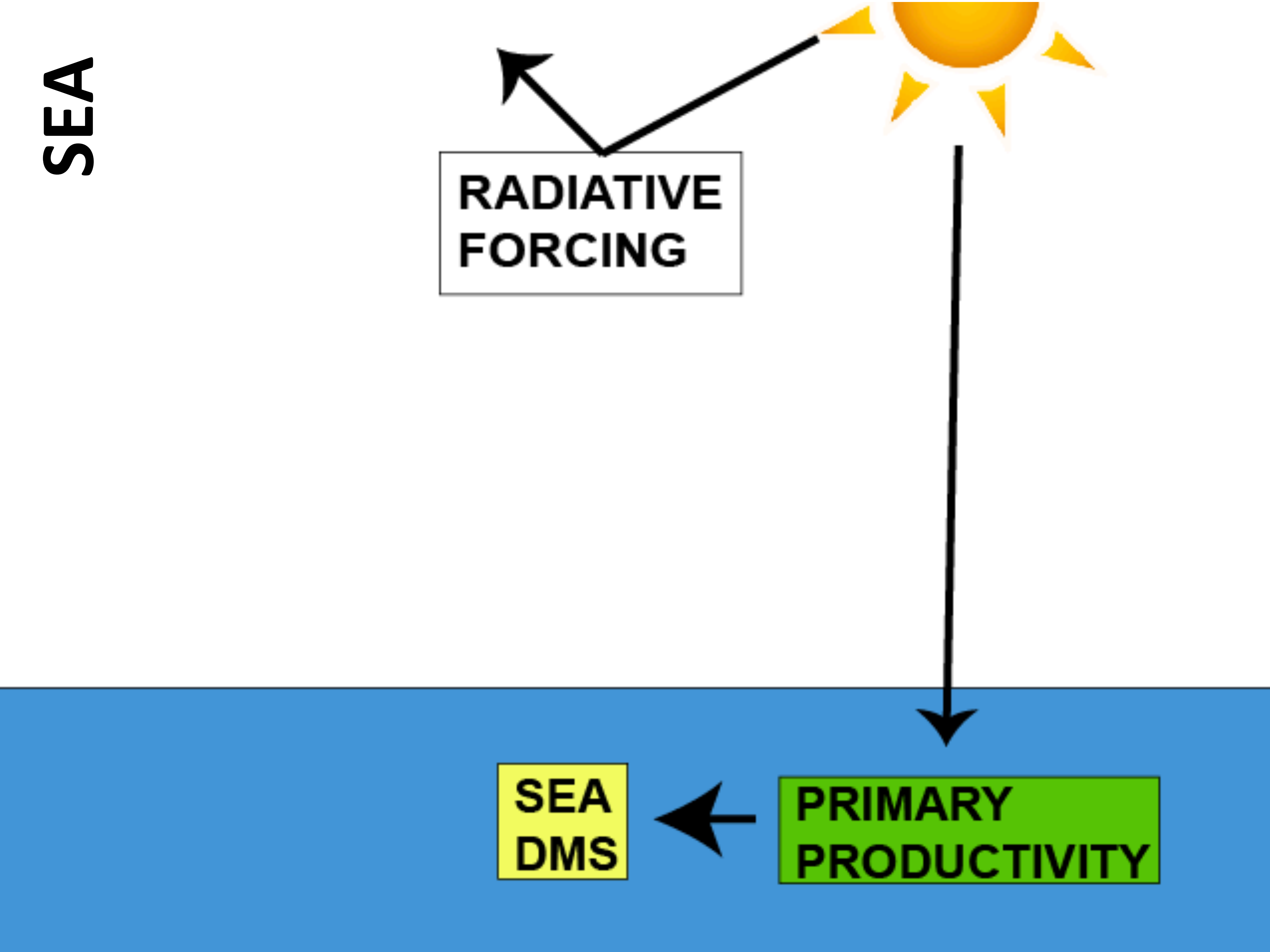
-sea surface temperature

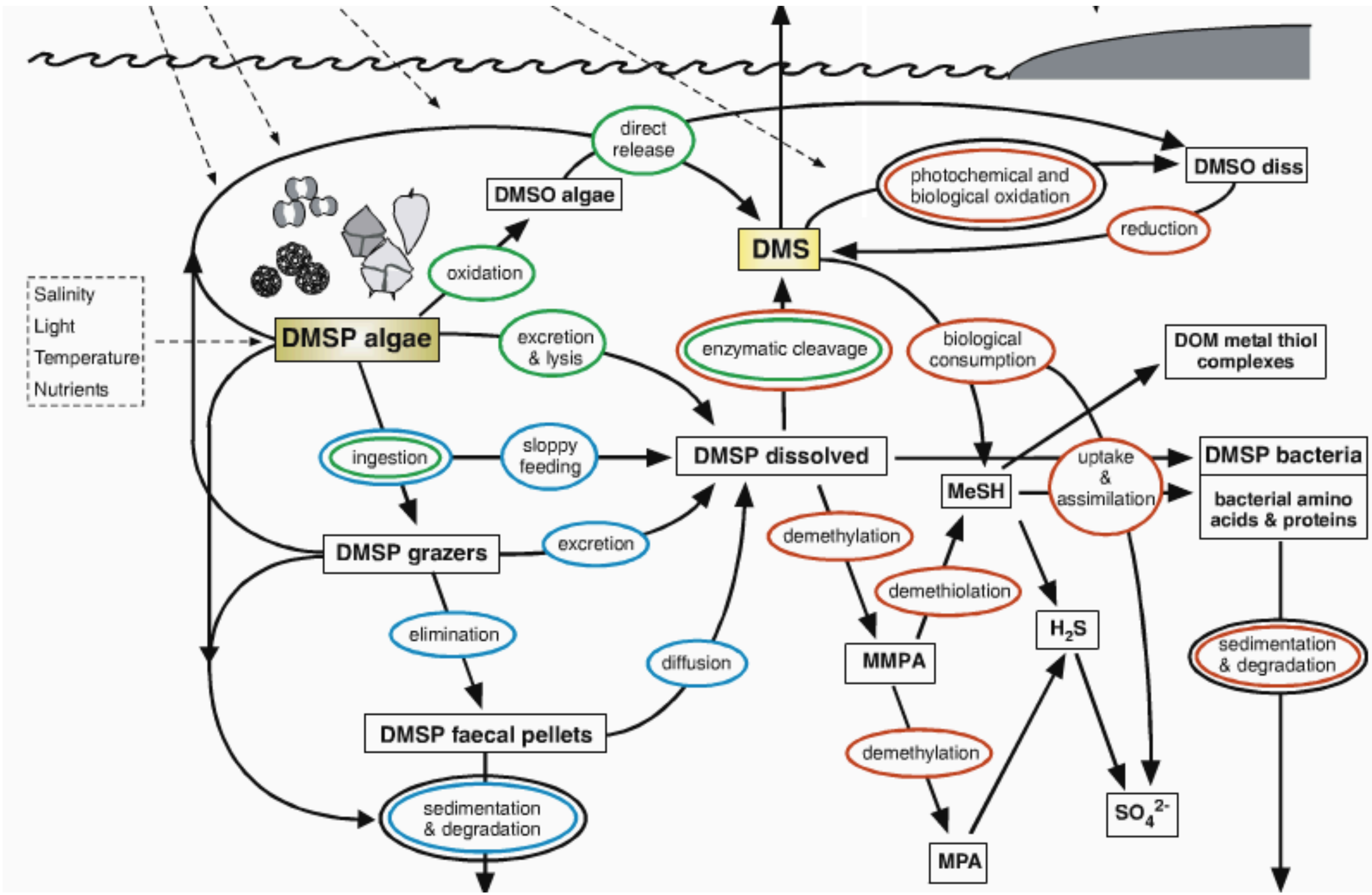
-albedo

-cloud cover

THE BOX MODEL




SEA
RADIATIVE FORCING
SEA DMS
PRIMARY PRODUCTIVITY



Stefels et al 2007

SEA EQUATIONS

Primary productivity (Gabric et al 2004)

$\frac{dP}{dt} = P(\mu - \chi)(1 - P_{ice})$ where P_{ice} = proportional ice cover

μ = growth rate = $\mu_0 R_L R_T$

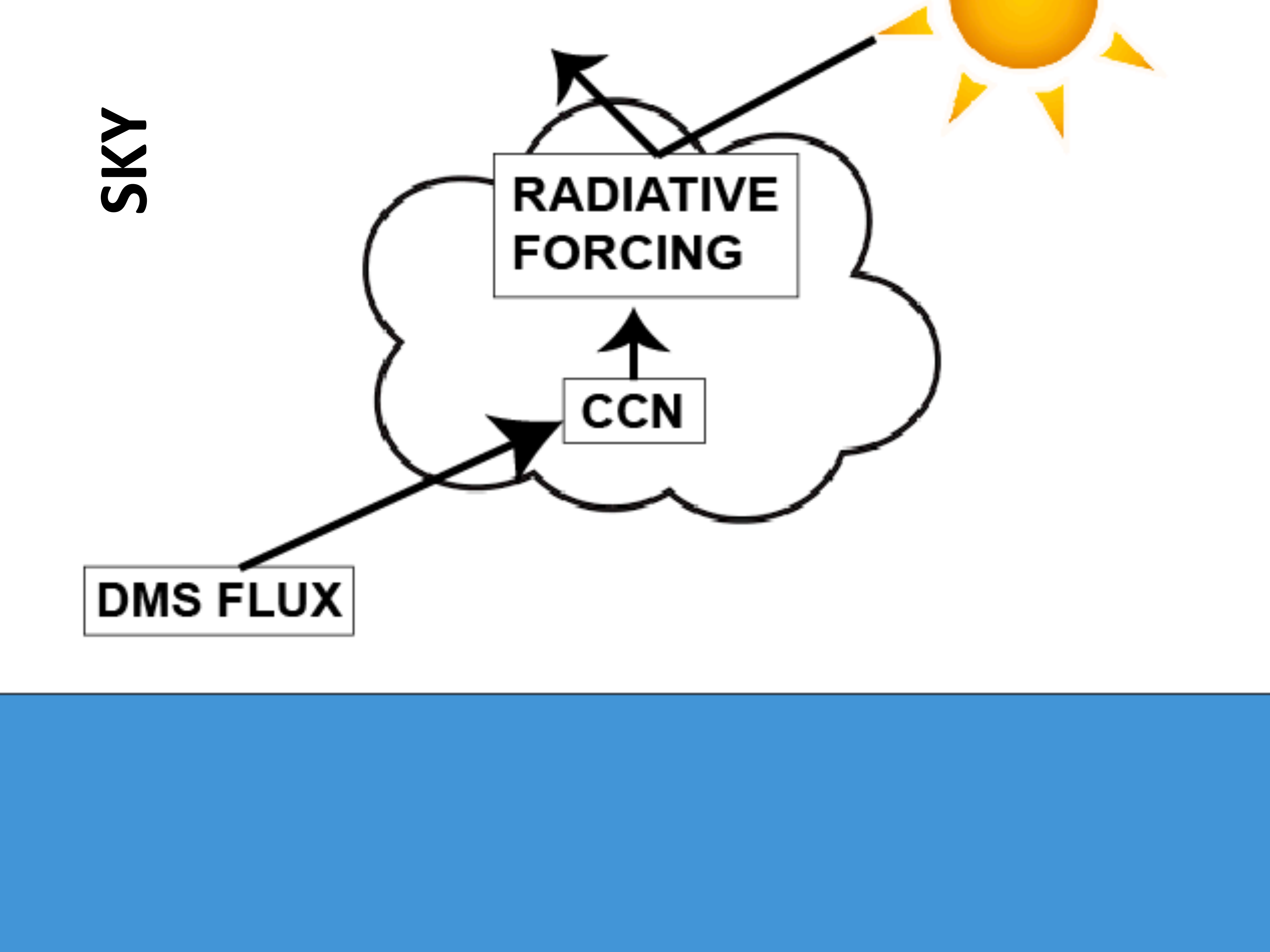
μ_0 = base growth rate = 0.79

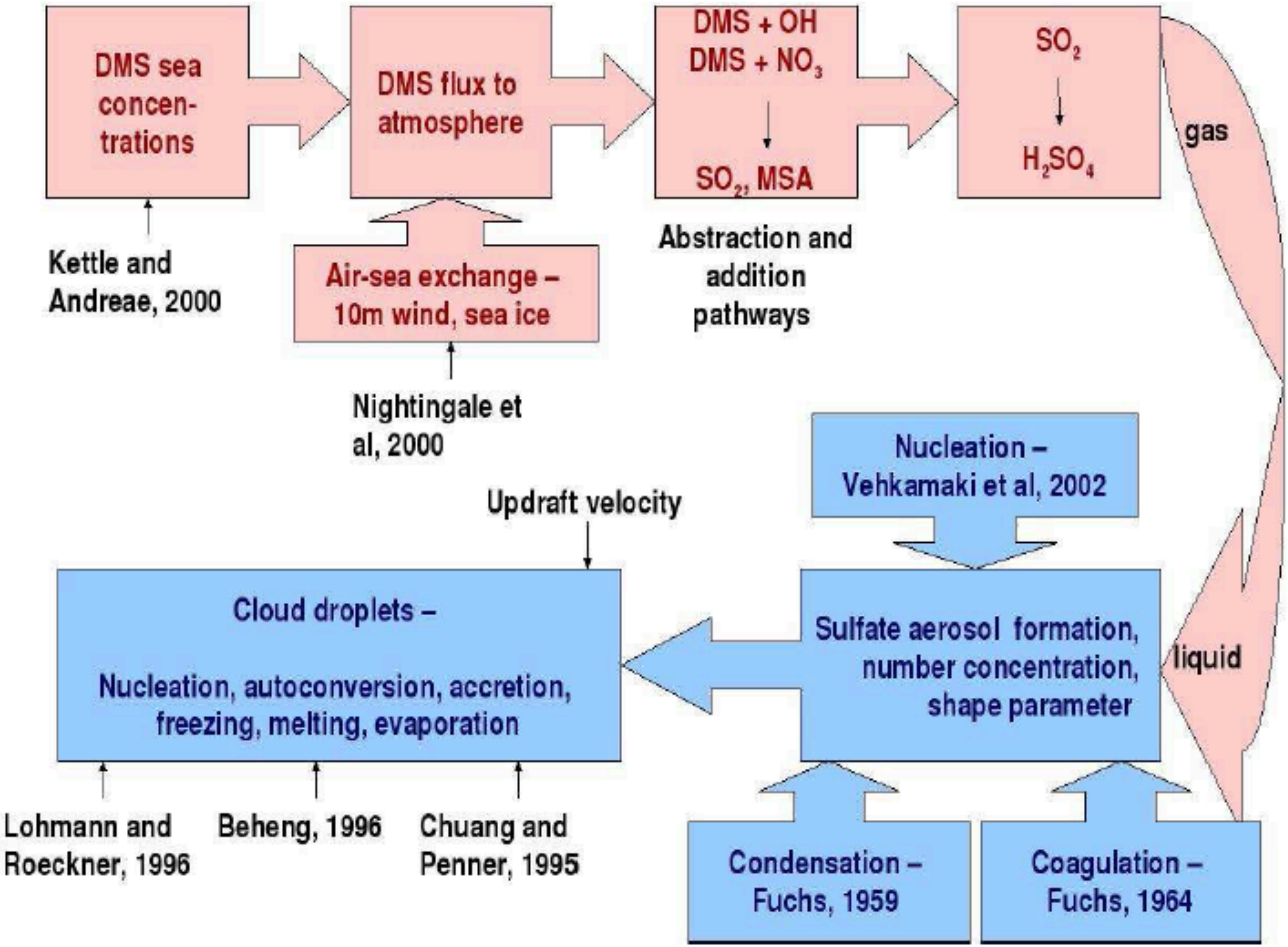
R_L = light correction factor = $\dfrac{\frac{I}{I_k}}{\sqrt{1+\frac{I}{I_k}^2}}$

I_k = saturating light intensity

I = current percieved light intensity (PAR) = $I + \Delta F$

$$\frac{dDMS}{dt} = \gamma \frac{dP}{dt}\ , \gamma = 1.5$$


SKY
RADIATIVE FORCING
CCN
DMS FLUX


DMS sea concen-trations
DMS flux to atmosphere
DMS + OH
DMS + NO_3
SO_2, MSA
SO_2
H_2SO_4
gas
Kettle and Andreae, 2000
Air-sea exchange – 10m wind, sea ice
Abstraction and addition pathways
Nightingale et al, 2000
Nucleation – Vehkamaki et al, 2002
Updraft velocity
Cloud droplets –
Nucleation, autoconversion, accretion, freezing, melting, evaporation
Sulfate aerosol formation, number concentration, shape parameter
liquid
Lohmann and Roeckner, 1996
Beheng, 1996
Chuang and Penner, 1995
Condensation – Fuchs, 1959
Coagulation – Fuchs, 1964

SKY EQUATIONS pt 1

transfer velocity (k_w) calculations (Liss and Merlivat (1986)):

$$Flux_{DMS} = k_w[DMS]$$

where:

w = windspeed (m/s)

$$k_w = \alpha 0.17w \text{ for } w \leq 3.6$$

$$k_w = \beta(2.85w - 10.3) + 0.61\alpha \text{ for } 3.6 < w \leq 13$$

$$k_w = \beta(5.9w - 49.9) + 0.61\alpha \text{ for } w > 13$$

$$\alpha = (600/Sc)^{2/3}$$

$$\beta = (600/Sc)^{1/2}$$

Where Sc is the Schmidt number, which depends on sea surface temperature as follows:

$$Sc = 2674.0 - 147.12(SST) + 3.726(SST)^2 - 0.038(SST)^3$$

SKY EQUATIONS pt 2

$$\frac{\frac{dCCN}{dt}}{CCN} = 0.02\,\frac{\frac{dFlux_{DMS}}{dt}}{Flux_{DMS}}$$

Radiative Forcing

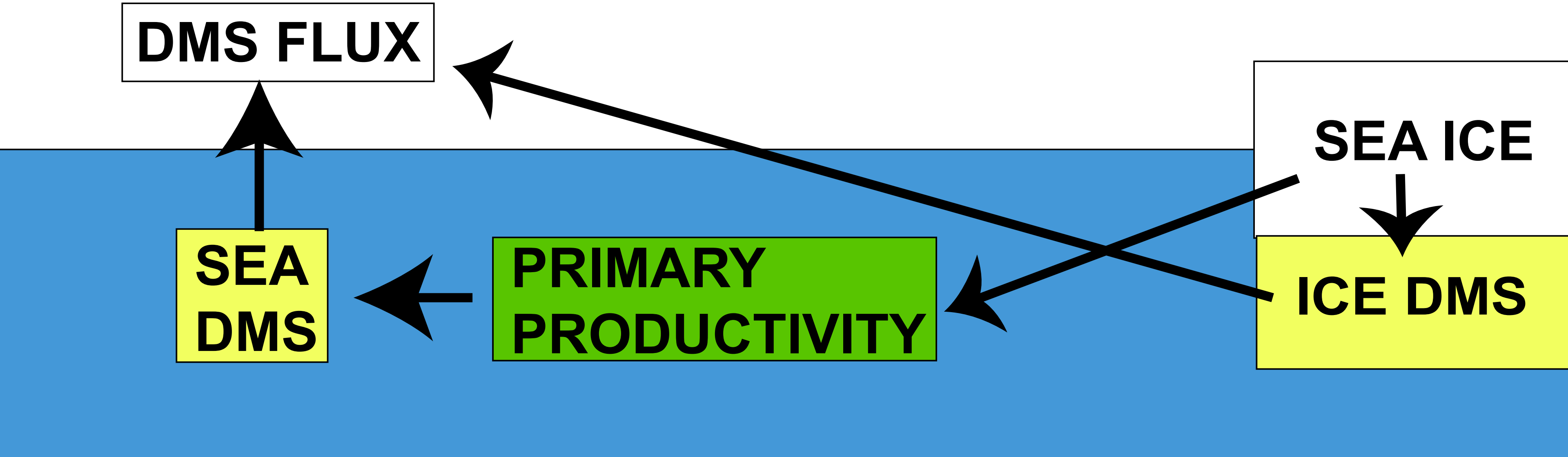
(Meskhidze 2006)

$$\frac{dF}{dt} = \frac{-1}{3} F A_c R_c (1 - R_c) \Delta N_{db}$$

where F = perceived light intensity

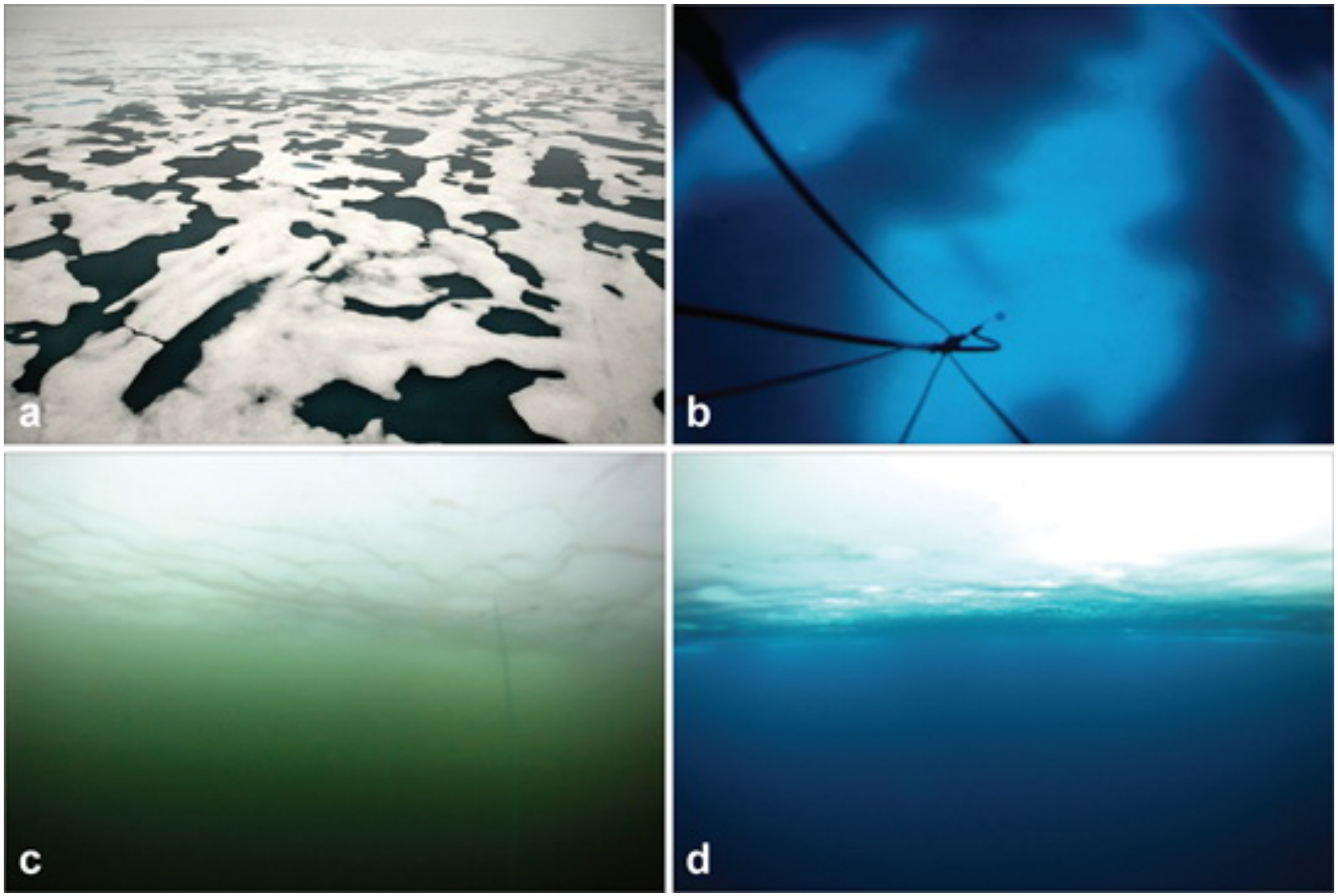
A_c = cloud cover fraction, R_c = cloud albedo, $\Delta N_{db} = \frac{\frac{dCCN}{dt}}{CCN}$

My model:
SEA ICE



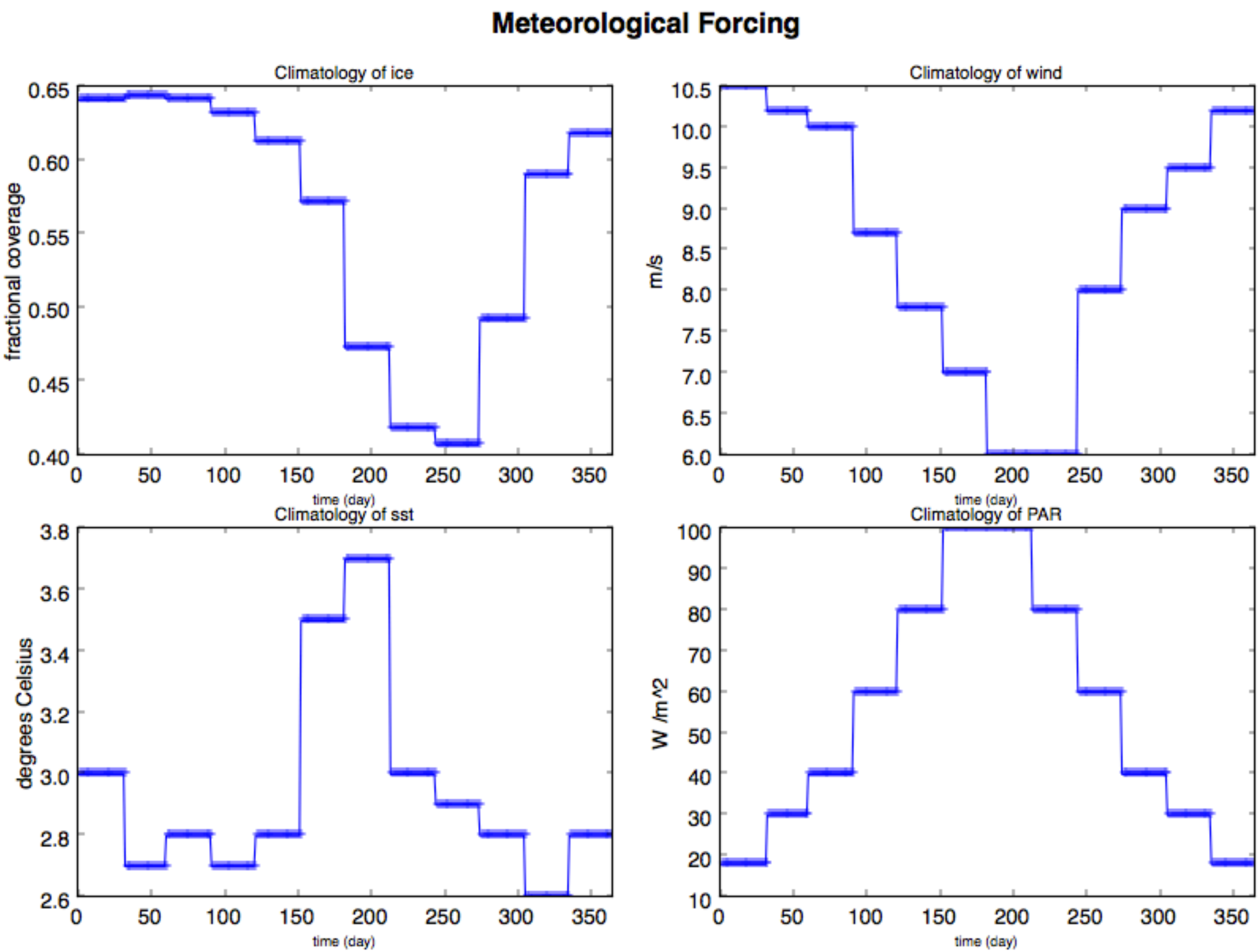
ICE EQUATIONS

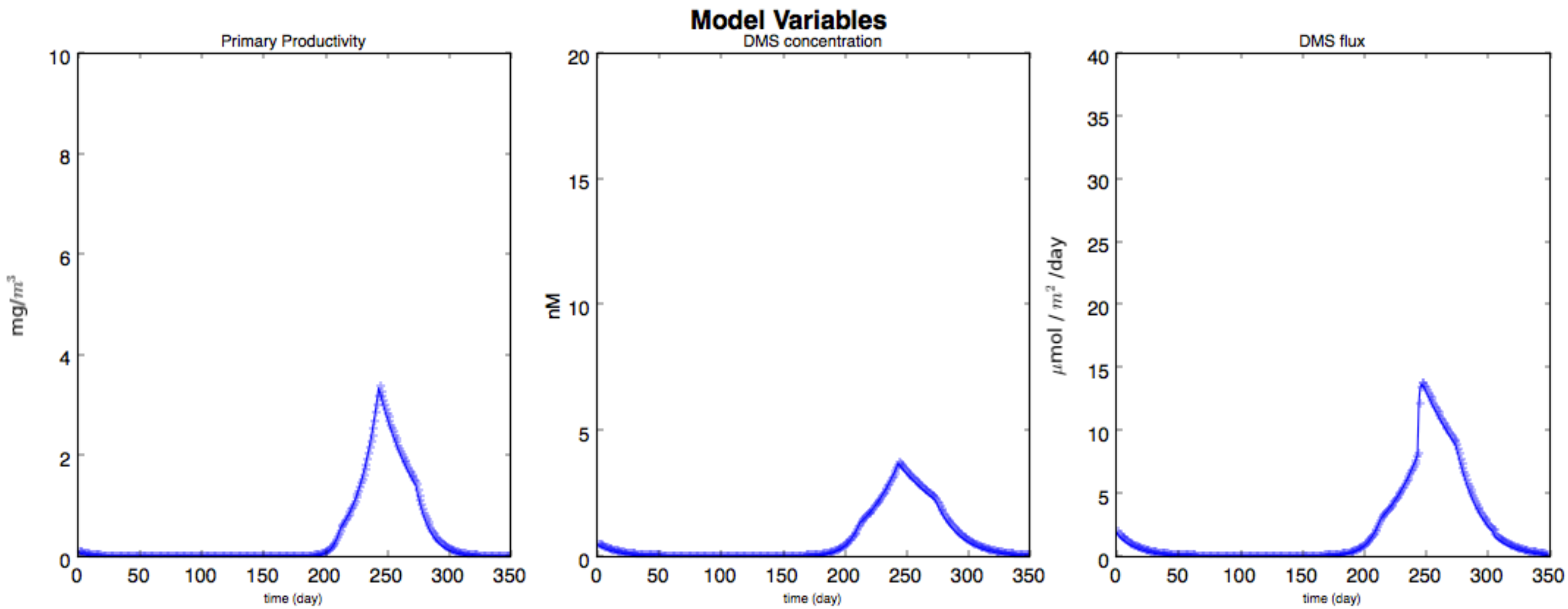
…to be determined



Model construction

-fixed step-size Runge-Kutta
-model length: 1 year, model step size: 1 day
-adaptation of Integrator class
-environmental forcing at monthly resolution
    (stored in nested dictionaries)
-spline interpolation of critical variables (eg. ice!)


Meteorological Forcing
Climatology of ice
fractional coverage
0.65
0.60
0.55
0.50
0.45
0.40
0
50
100
150
200
250
300
350
time (day)
Climatology of wind
m/s
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
time (day)
Climatology of sst
degrees Celsius
3.8
3.6
3.4
3.2
3.0
2.8
2.6
time (day)
Climatology of PAR
W /m^2
100
90
80
70
60
50
40
30
20
10
time (day)


Model Variables
Primary Productivity
mg/m^3
time (day)
DMS concentration
nM
time (day)
DMS flux
μmol / m^2 /day
time (day)

THANK YOU FOR YOUR TIME!

COMMENTS?
SUGGESTIONS?