Trends in Remote Sensing of Ocean Biogeochemistry

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NASA GSFC
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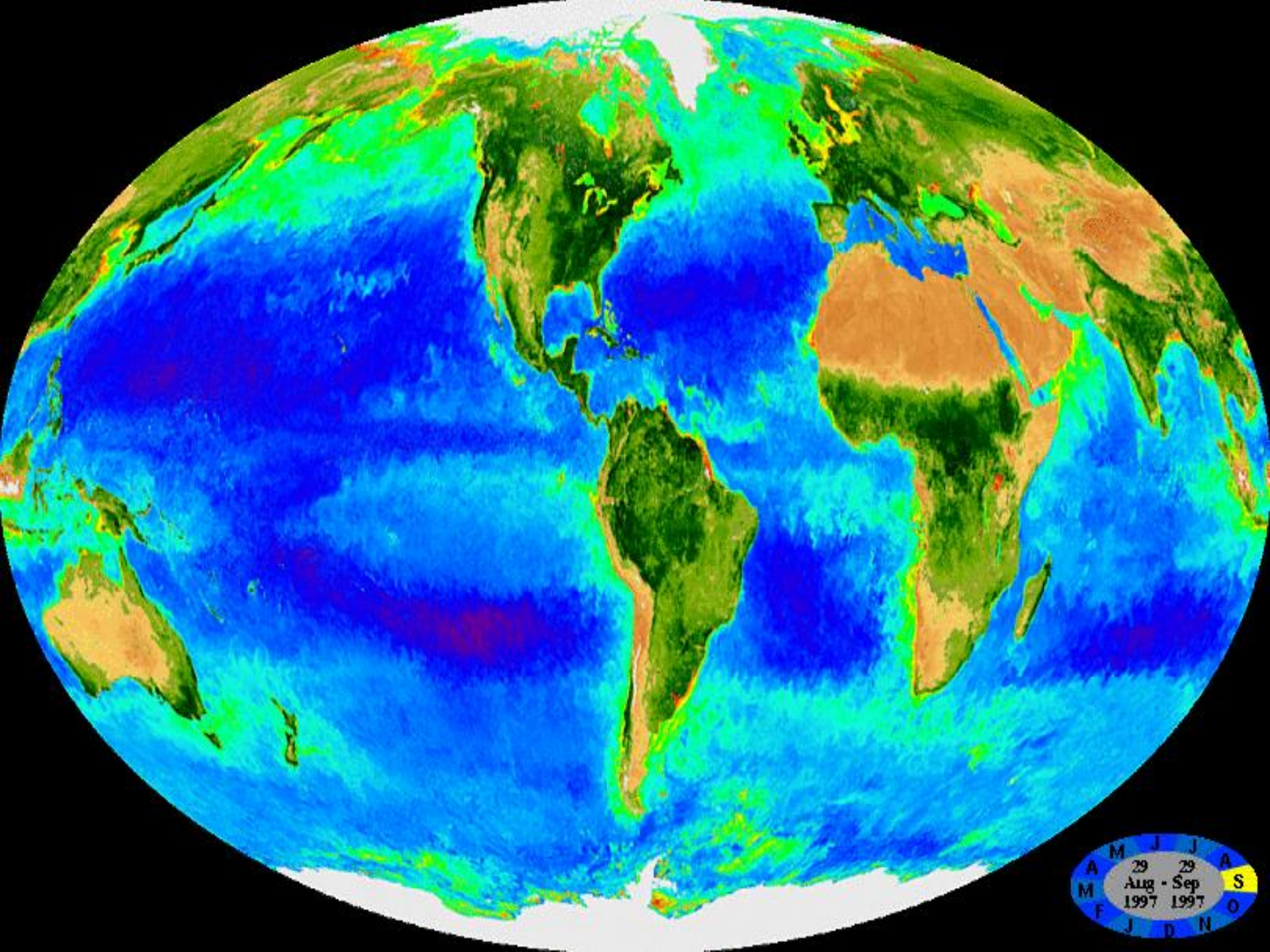
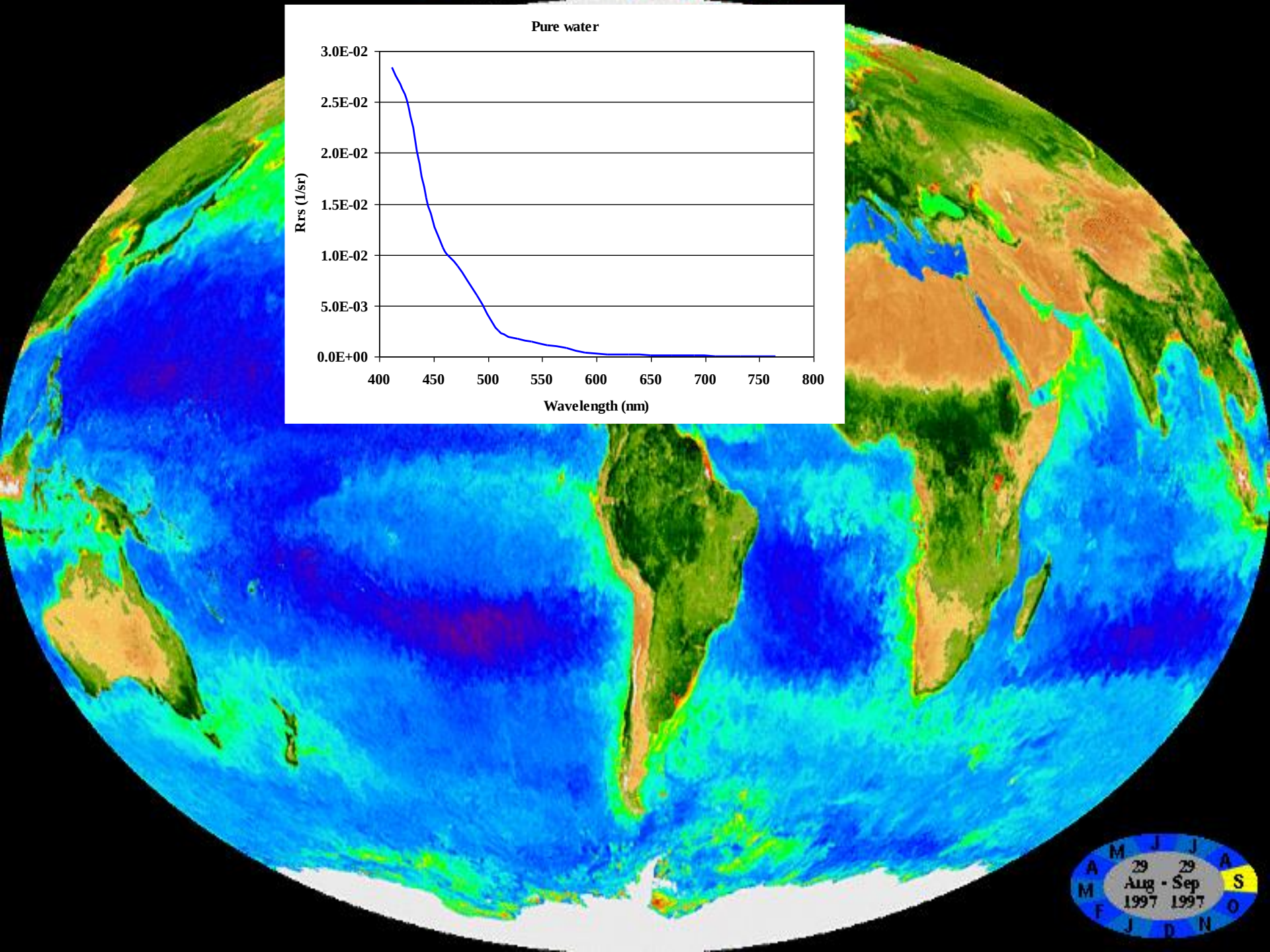
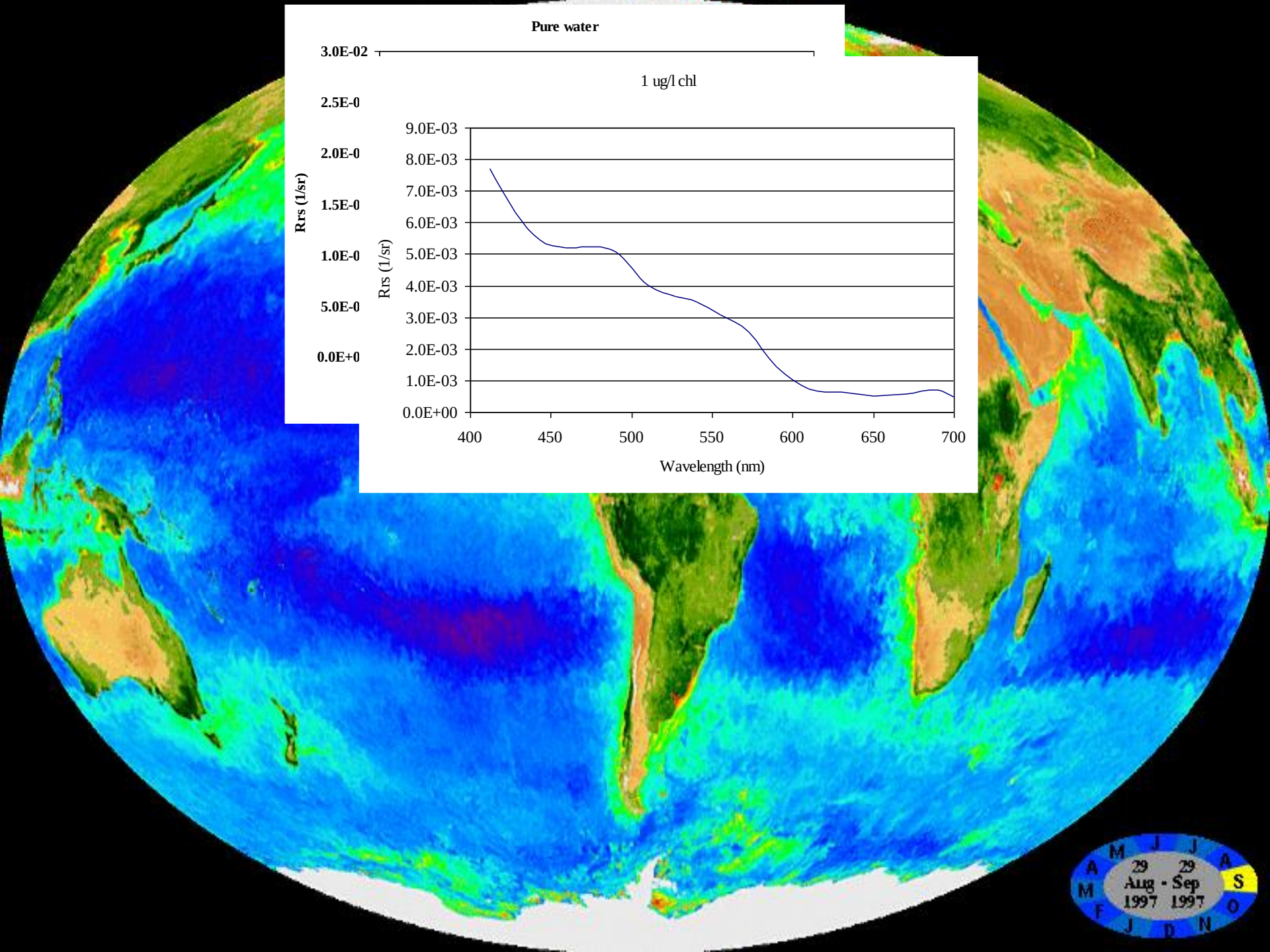
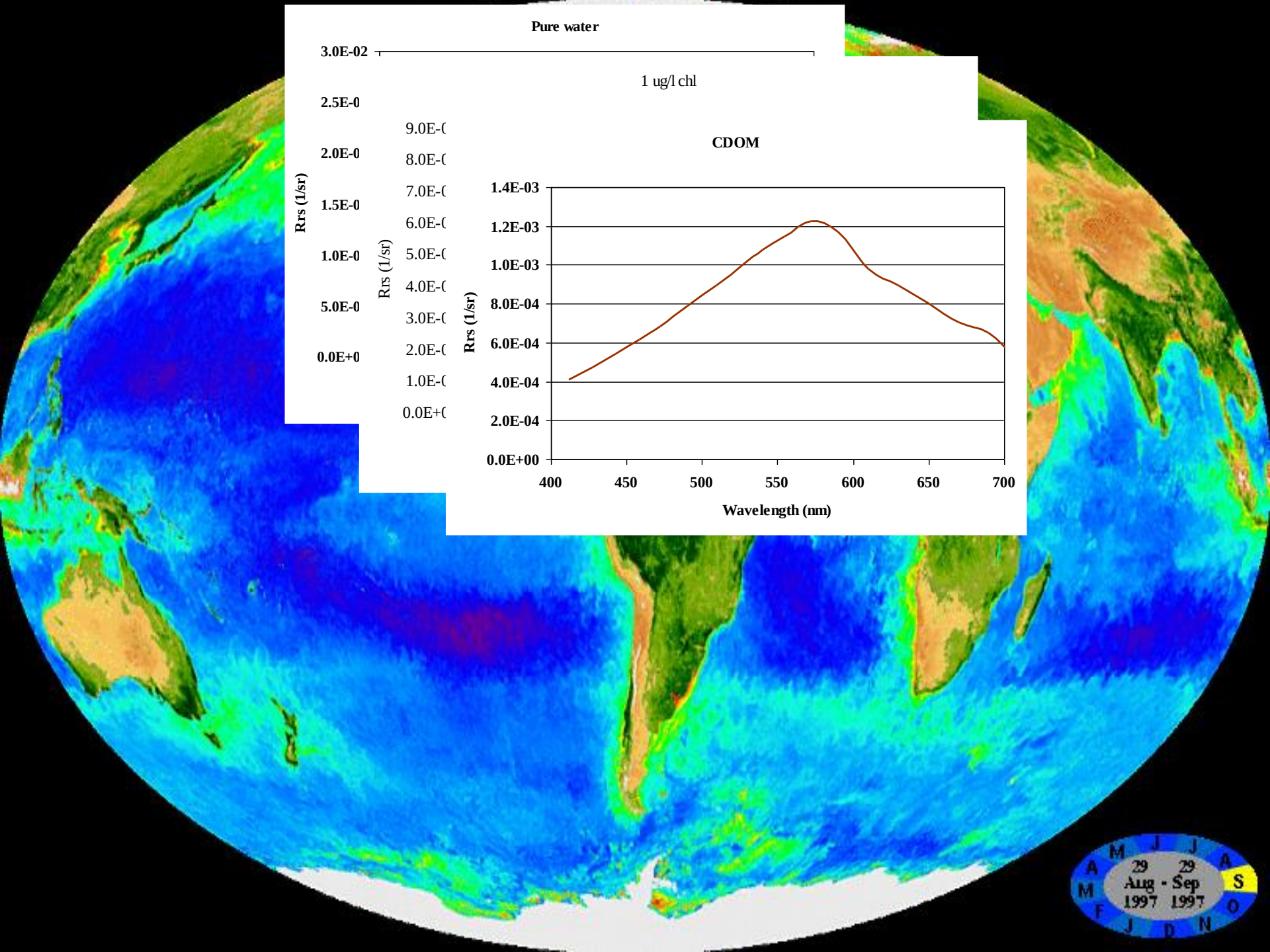
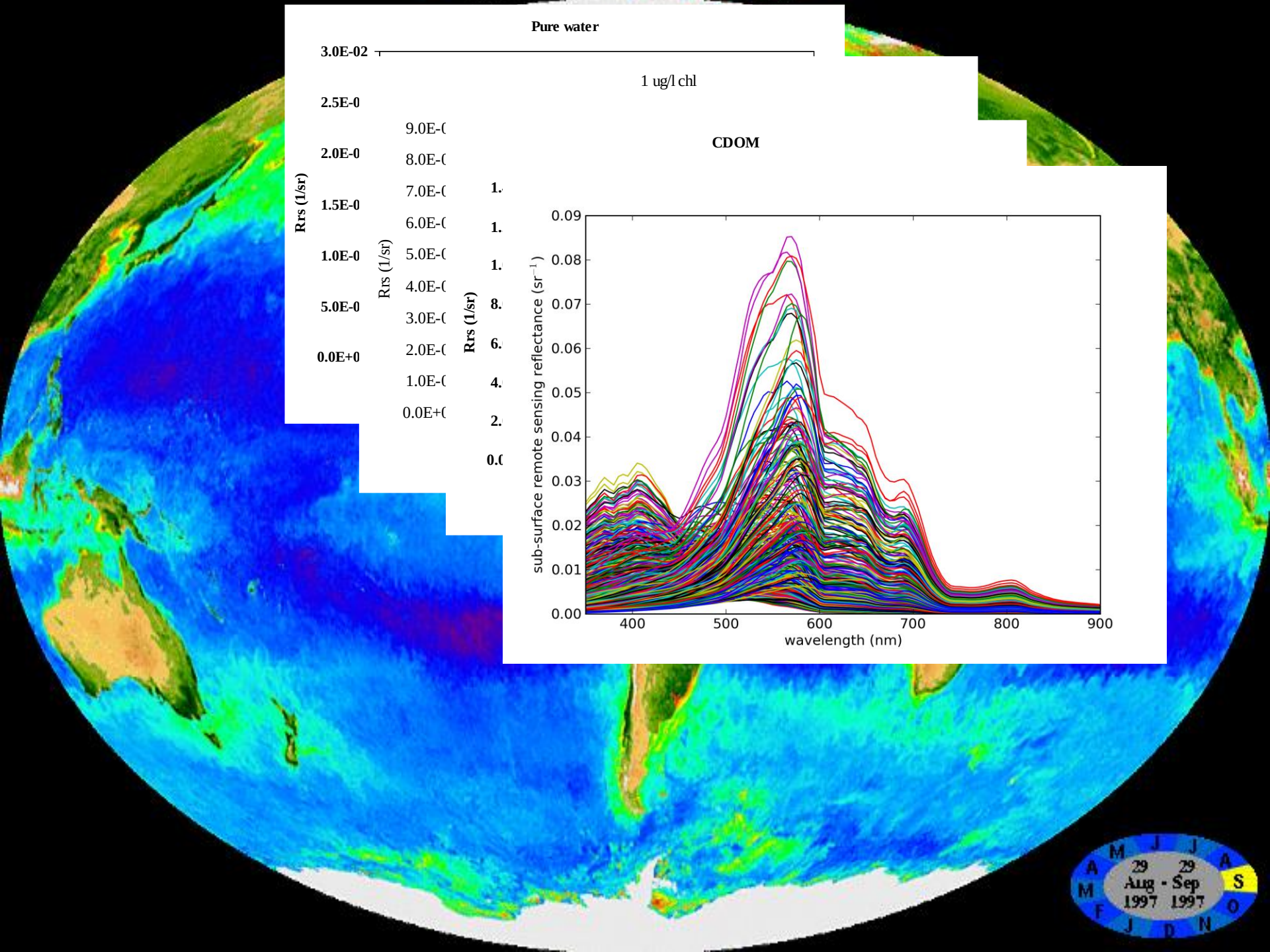
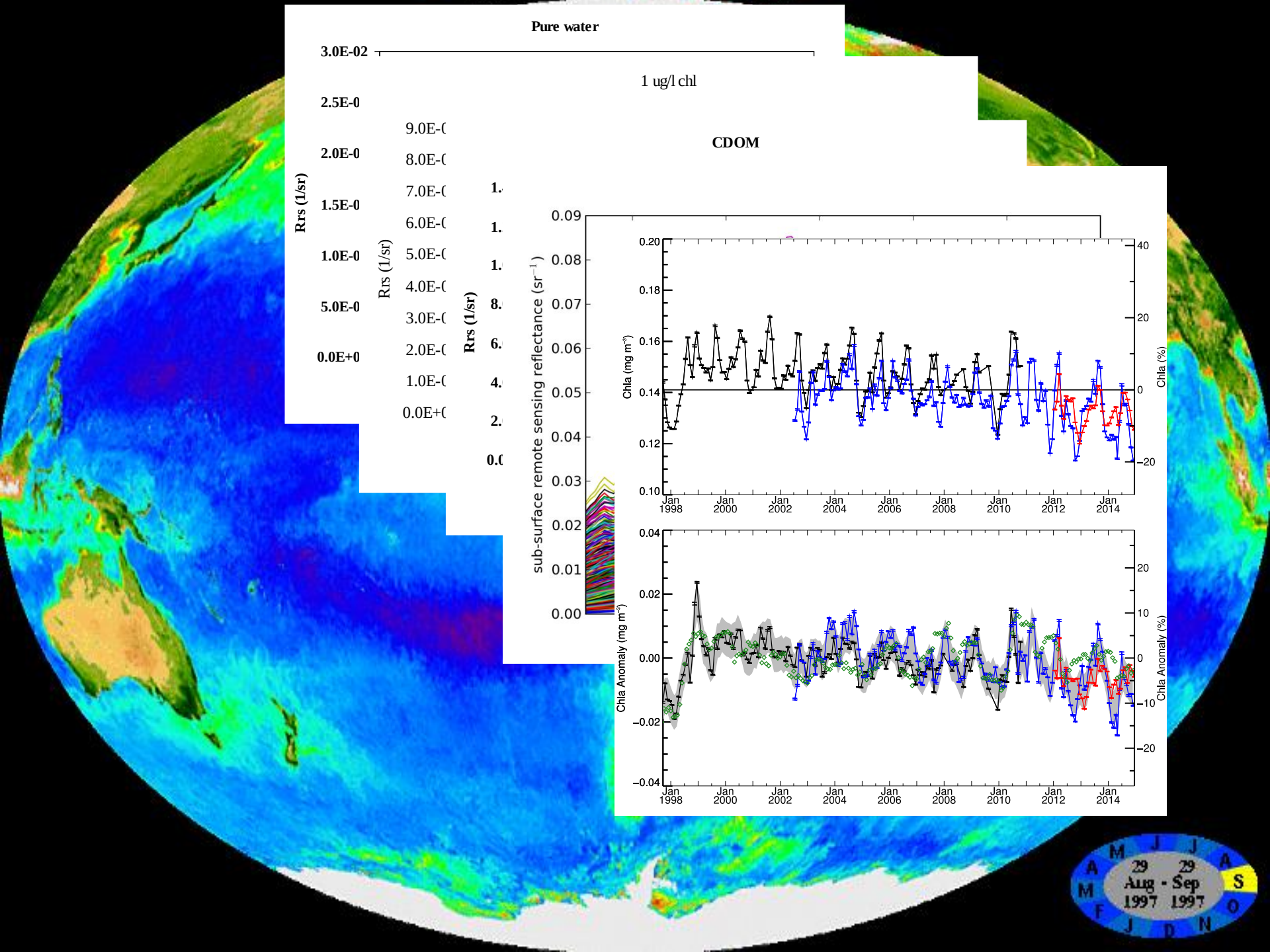

M J J A
A 29 29 A
M Aug - Sep S
1997 1997
F O
J D N

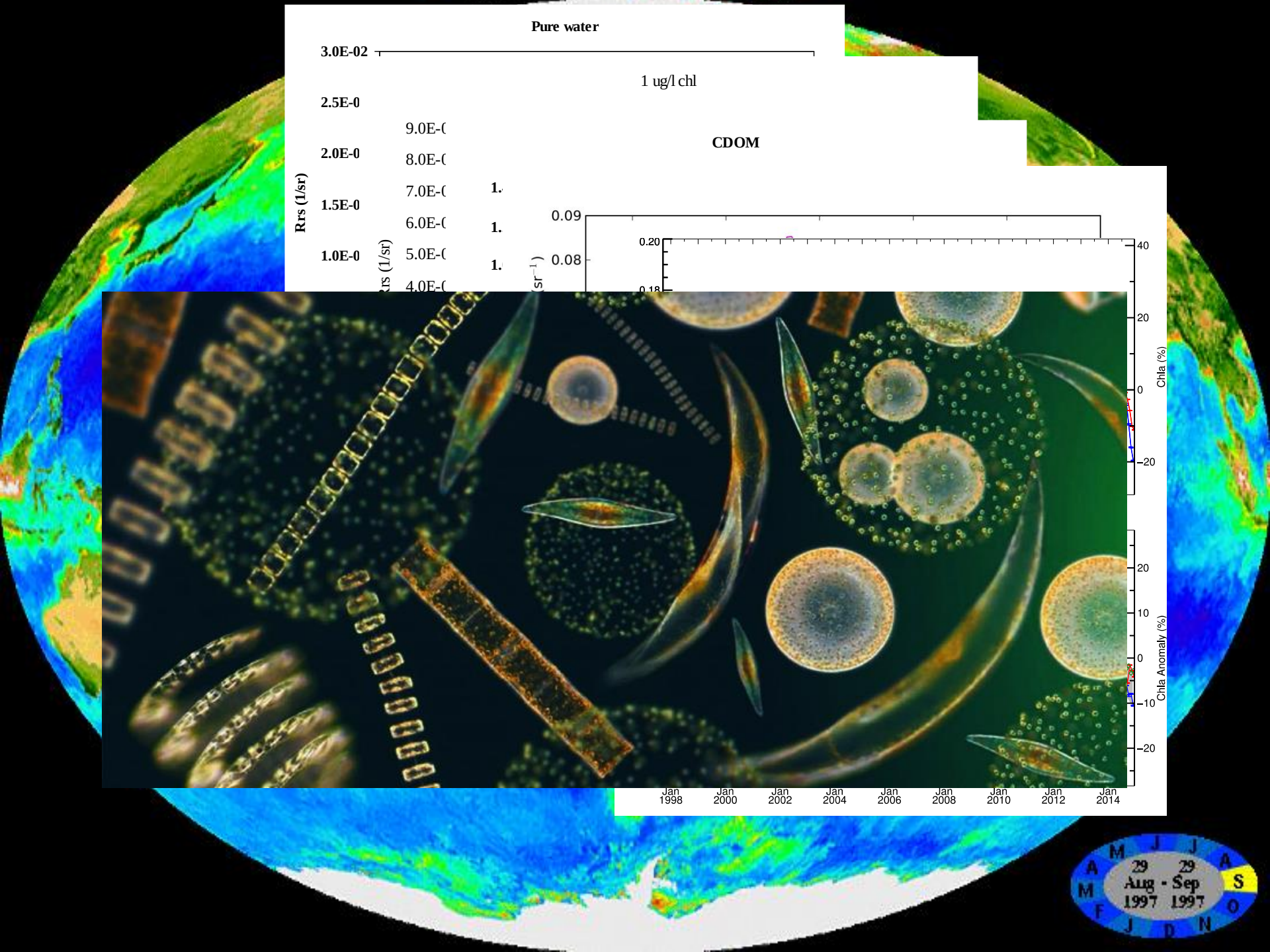

Pure water
3.0E-02
2.5E-02
2.0E-02
1.5E-02
1.0E-02
5.0E-03
0.0E+00
Rrs (1/sr)
400
450
500
550
600
650
700
750
800
Wavelength (nm)
M J J A
A 29 29 S
M Aug - Sep O
1997 1997
F J D N


Pure water
3.0E-02
2.5E-0
2.0E-0
1.5E-0
1.0E-0
5.0E-0
0.0E+0
Rrs (1/sr)
1 ug/l chl
9.0E-03
8.0E-03
7.0E-03
6.0E-03
5.0E-03
4.0E-03
3.0E-03
2.0E-03
1.0E-03
0.0E+00
Rrs (1/sr)
400
450
500
550
600
650
700
Wavelength (nm)
M J J A
A 29 29 S
M Aug - Sep O
1997 1997
F J D N

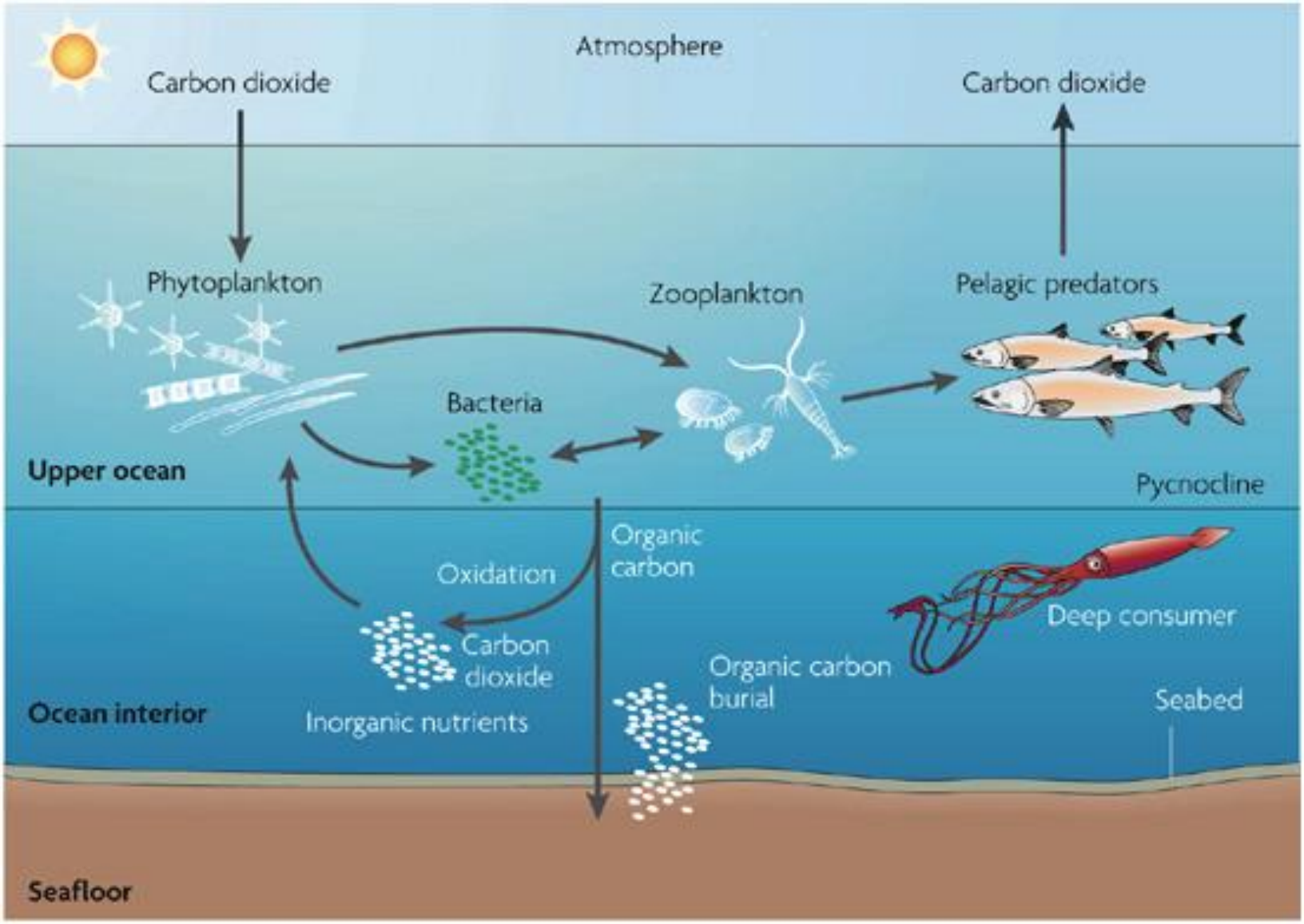

Pure water
3.0E-02
2.5E-0
2.0E-0
1.5E-0
1.0E-0
5.0E-0
0.0E+0
Rrs (1/sr)
1 ug/l chl
9.0E-(
8.0E-(
7.0E-(
6.0E-(
5.0E-(
4.0E-(
3.0E-(
2.0E-(
1.0E-(
0.0E+(
Rrs (1/sr)
CDOM
1.4E-03
1.2E-03
1.0E-03
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
Rrs (1/sr)
400
450
500
550
600
650
700
Wavelength (nm)
M J J A S O N D J F M A
29 Aug - 29 Sep
1997 1997


Pure water
3.0E-02
2.5E-0
2.0E-0
1.5E-0
1.0E-0
5.0E-0
0.0E+0
Rrs (1/sr)
1 ug/l chl
9.0E-(
8.0E-(
7.0E-(
6.0E-(
5.0E-(
4.0E-(
3.0E-(
2.0E-(
1.0E-(
0.0E+(
Rrs (1/sr)
1.
1.
1.
8.
6.
4.
2.
0.(
CDOM
sub-surface remote sensing reflectance (sr^{-1})
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
400
500
600
700
800
900
wavelength (nm)
M J J A
A 29 29 A
M Aug - Sep S
1997 1997
F O
J D N


Pure water
3.0E-02
2.5E-0
2.0E-0
1.5E-0
1.0E-0
5.0E-0
0.0E+0
Rrs (1/sr)
1 ug/l chl
CDOM
9.0E-(
8.0E-(
7.0E-(
6.0E-(
5.0E-(
4.0E-(
3.0E-(
2.0E-(
1.0E-(
0.0E+(
Rrs (1/sr)
sub-surface remote sensing reflectance (sr^{-1})
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Chla (mg m^{-3})
Chla (%)
0.20
0.18
0.16
0.14
0.12
0.10
40
20
0
−20
Jan 1998
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Chla Anomaly (mg m^{-3})
Chla Anomaly (%)
0.04
0.02
0.00
−0.02
−0.04
20
10
0
−10
−20
J
J
A
S
O
N
D
J
F
M
A
M
29 Aug - 29 Sep
1997 1997


Pure water
3.0E-02
2.5E-0
2.0E-0
1.5E-0
1.0E-0
Rrs (1/sr)
1 ug/l chl
CDOM
9.0E-(
8.0E-(
7.0E-(
6.0E-(
5.0E-(
4.0E-(
0.09
0.08
0.20
0.18
40
20
0
−20
Chla (%)
20
10
0
−10
−20
Chla Anomaly (%)
Jan 1998
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
29 Aug - 1997
29 Sep 1997

Biological Pump and Food Web



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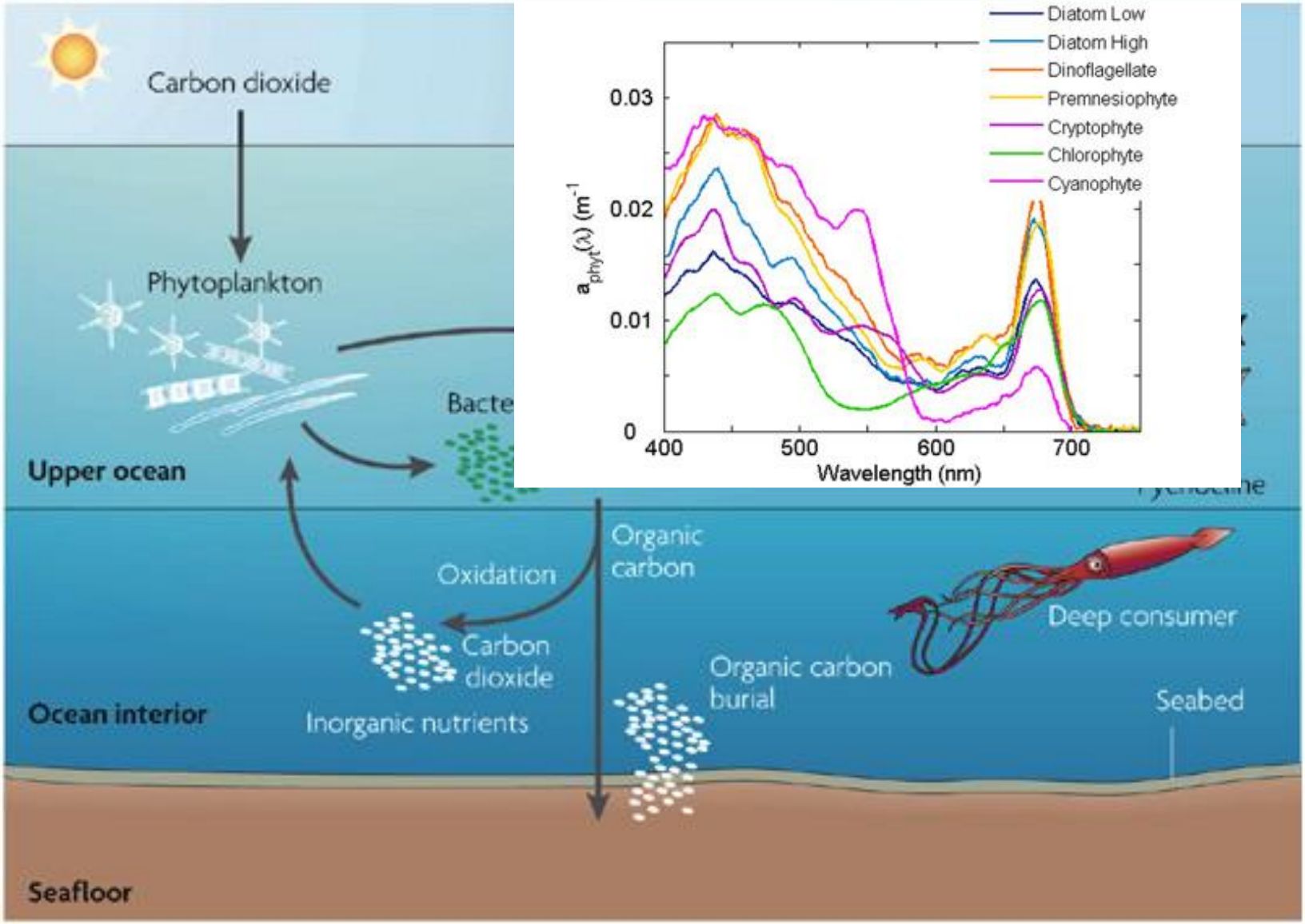
Biological Pump and Food Web



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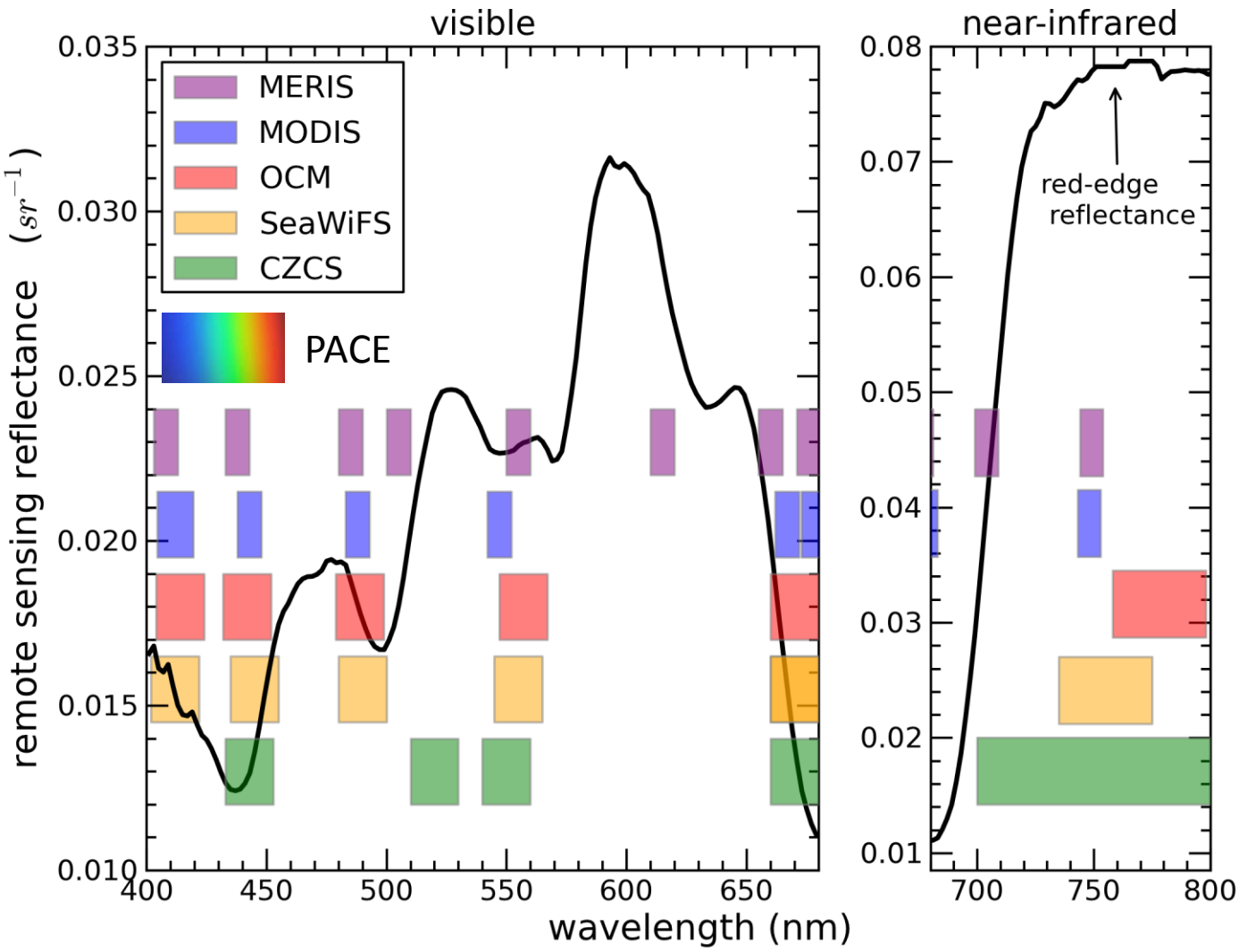

visible
near-infrared
MERIS
MODIS
OCM
SeaWiFS
CZCS
PACE
red-edge
reflectance
remote sensing reflectance (sr^{-1})
wavelength (nm)
0.035
0.030
0.025
0.020
0.015
0.010
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
400
450
500
550
600
650
700
750
800

Ocean Color remote sensing has very stringent measurement and mission requirements:

- >90% of radiance reaching the satellite comes from the atmosphere
- High contrast between clouds, land, and ocean
- The ocean is dynamic and deep.
- We are trying to measure biology…bugs are messy.
- Low tolerance for striping and other image artifacts.
- We are trying to maintain a climate data record for Chlorophyll.

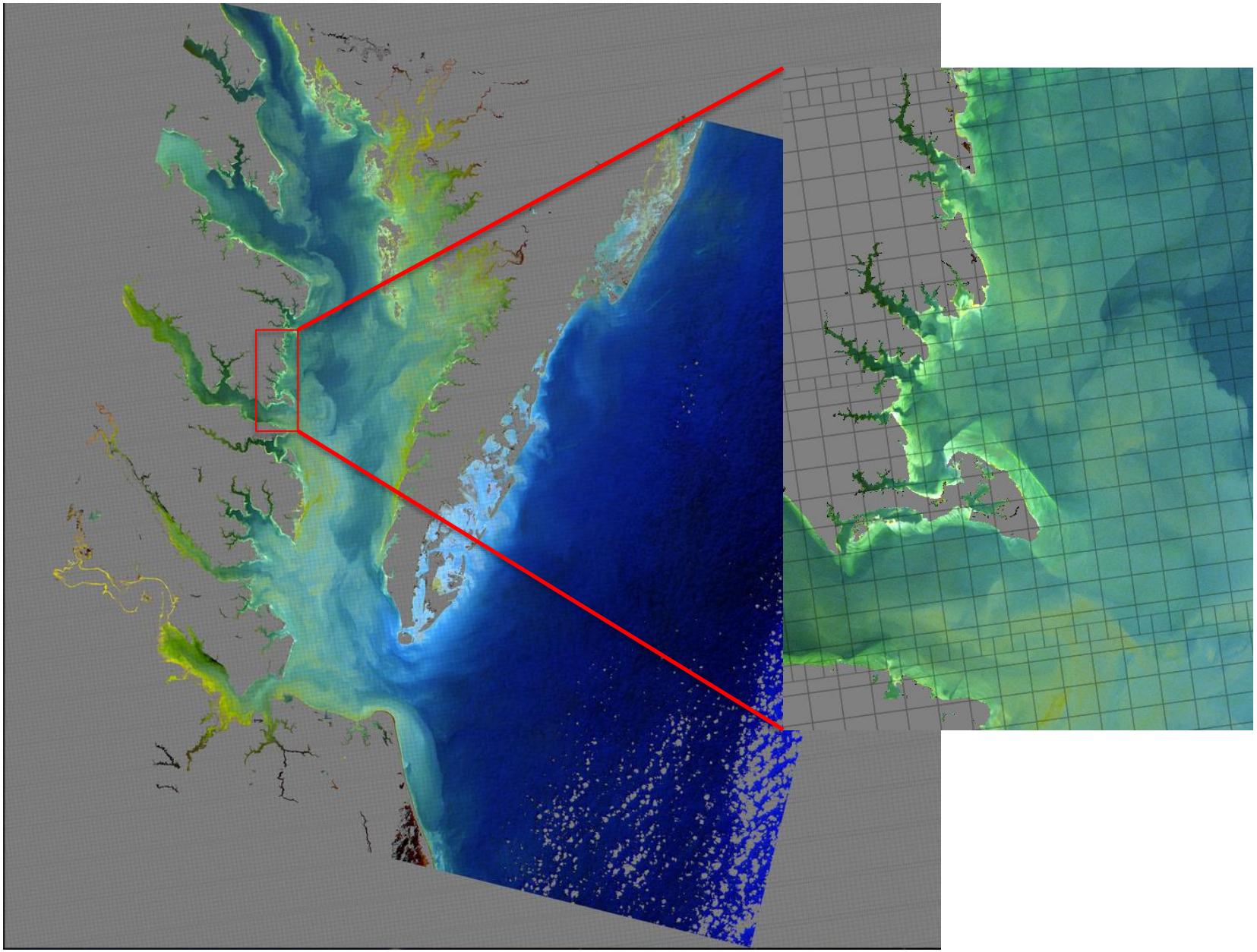
Summary of the PACE SDT Recommendations

1-To address **threshold** PACE science questions dealing with global Ocean Biogeochemistry and Ecology the PACE mission must include:

- A well-characterized ocean color instrument covering the spectral range between 350 and 900 nm at ~5 nm resolution, plus three SWIR bands at a spatial resolution of 1 km^2 (nadir). This instrument option is called **OCI**.
- A mission architecture that includes continual post launch calibration (including lunar and vicarious calibration), algorithms development and maintenance, field validation and process studies.

λ	Band Width (nm)	Spatial Resolution (km^2)	L_{typ}	L_{max}	SNR-Spec
350	15	1	7.46	35.6	300
360	15	1	7.22	37.6	1000
385	15	1	6.11	38.1	1000
412	15	1	7.86	60.2	1000
425	15	1	6.95	58.5	1000
443	15	1	7.02	66.4	1000
460	15	1	6.83	72.4	1000
475	15	1	6.19	72.2	1000
490	15	1	5.31	68.6	1000
510	15	1	4.58	66.3	1000
532	15	1	3.92	65.1	1000
555	15	1	3.39	64.3	1000
583	15	1	2.81	62.4	1000
617	15	1	2.19	58.2	1000
640	10	1	1.9	56.4	1000
655	15	1	1.67	53.5	1000
665	10	1	1.6	53.6	1000
678	10	4	1.45	51.9	2000
710	15	1	1.19	48.9	1000
748	10	1	0.93	44.7	600
820	15	1	0.59	39.3	600
865	40	1	0.45	33.3	600
1240	20	1	0.088	15.8	250
1640	40	1	0.029	8.2	180
2130	50	1	0.008	2.2	50

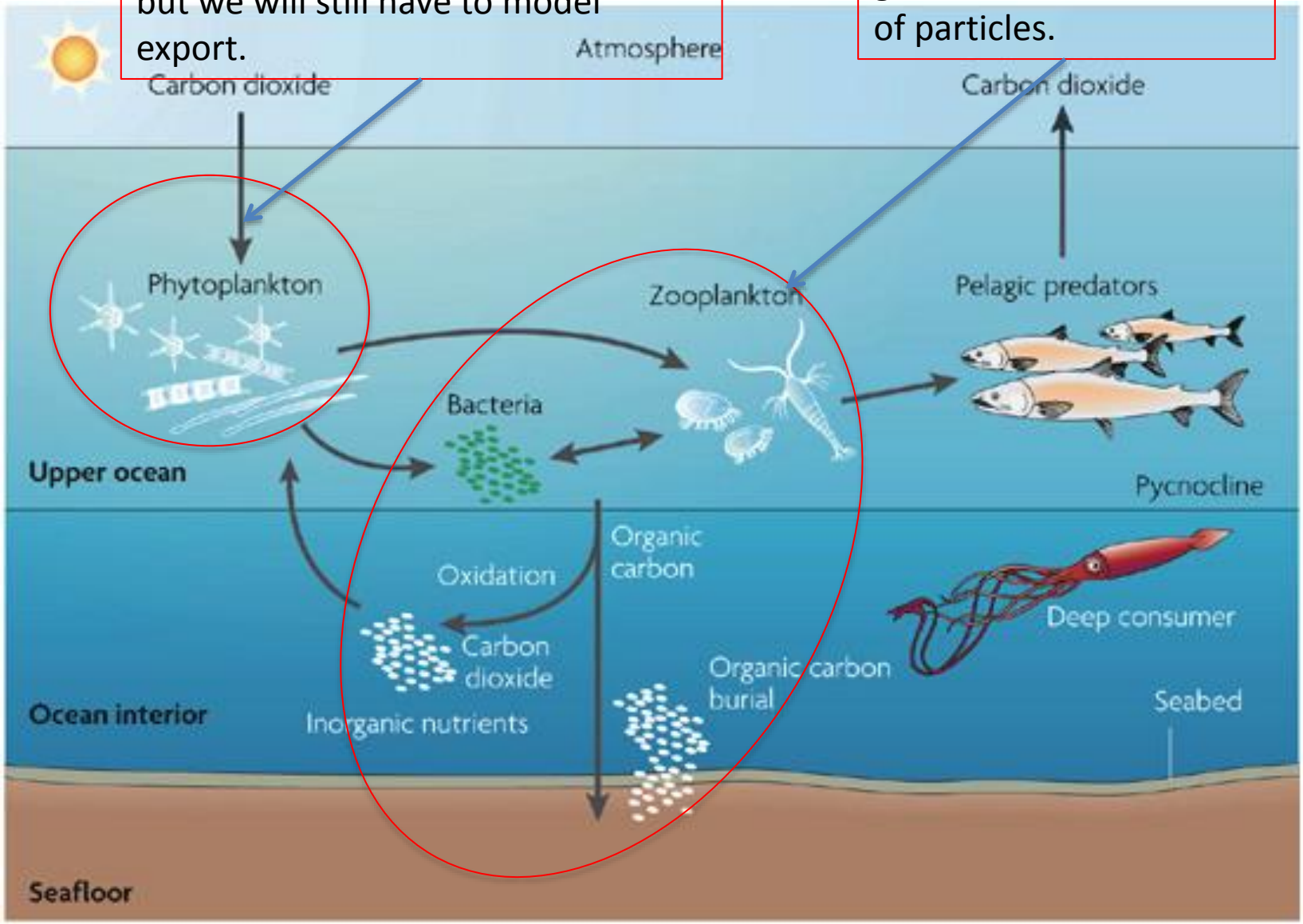
The Spatial resolution problem in coastal research



The export question

We hope to get these with PACE, but we will still have to model export.

Need active sensors to get vertical distribution of particles.



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Other topics of interest

- Increase the use of ocean color products in global and regional coupled biogeochemical models.
  - Include realistic satellite based IOP
  - Improve phytoplankton functional types and include stoichiometry
- Sensitivity analyses to drive improvements in ocean color products
- Improve accuracy, precision, and spectral range of IOP measurements.
- Improve field measurement protocols and develop mechanisms to ensure compliance.
- Extend the use of airborne (manned, unmanned) sensors for validation and process studies.
- Extend the use of autonomous vehicles for in-water measurements.