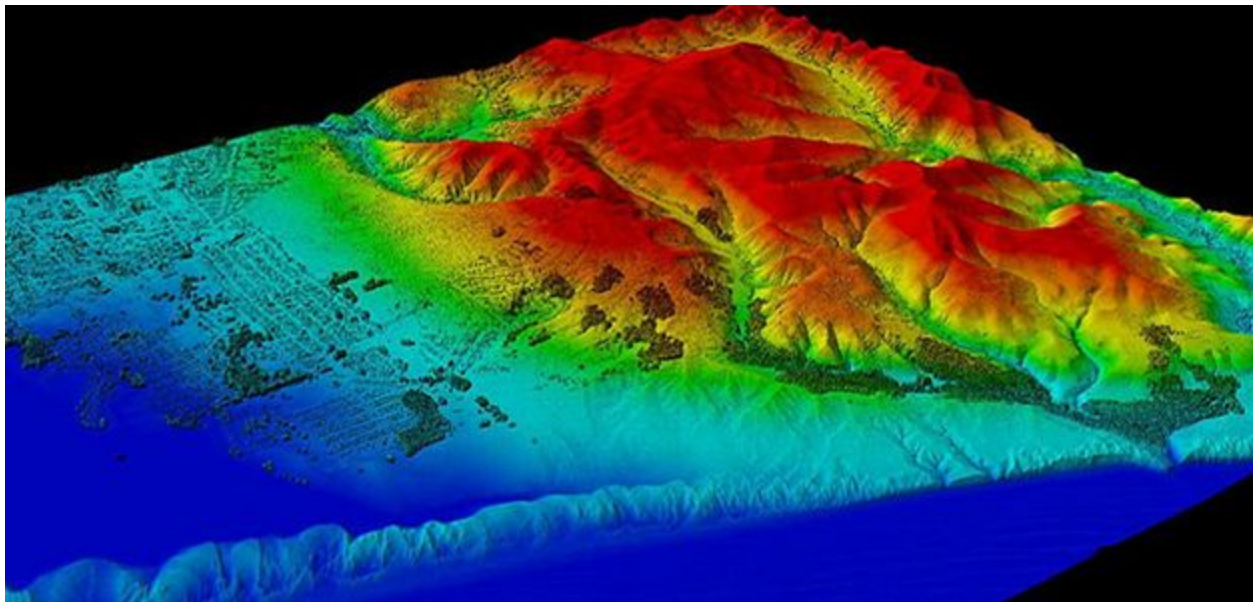




Science Olympiad
at
Princeton University

**Princeton Science Olympiad Invitational
Remote Sensing Exam**



Team Name: _____

Team Number: _____

Raw Score: _____

Tiebreaker: 1 / 2 / 3

Place: _____

Directions: [qw'j cxg'72'o kpwgu'v'eqo r ngv'y ku'gzco 0[qw'o c{ 'j cxg'y kj '{ qw'c'uelkpw'kle"
 ecrewvqt.'c'ukpi ng'pqvguj ggv.'cpf 'r gpeku0Rqkp'xcnngu'hqt'gcej 's wgu'kqp'y kn'dg'kpf kecvgf 0[qw'
 o c{ 'ur rk'vj g'vgu'dw'dg'uwg'v'wtp'kp'cml'rt v'kpu'v'j g'vgu'r tqvqt'chgt'vj g'gzco 'ku'hkpij gf 0'

Part 1: Multiple Choice (One Point Each)

- 30 Tcplnj gug'o cvgtkcn'htqo 'uo cnngu'v'j ki j guv'cdgf q0'
 J0.....Upqy "
 K0.....Cur j cn'
~~K0~~.....Dctg'Uqkn'
 KX0.....I tggp'I tcuu"
 "
 c0 K'K'K'K'K'K'X'0'
 d0 K'K'K'K'X'0'K'0'
 e0 K'K'X'0'K'K'K'0'
f0 K'K'K'K'X'0'0'
 g0 K'K'X'0'K'K'0'0'
- 40 Ngvu'u'c{ '{ qw'g'v'cnkpi 'cp'ko ci g'qh'cp'ctgc'v'f'ij gt'f'c'v'qp'vj g'vgo r gtcwtg'qh'c'htgv'
 htg'kp'vj cv'tgc0Y j cv'tgu'w'kqp'f'q' '{ qw'necessarily'pggf 'kp' '{ qw'uecppgtA'
 c0 Ur ge'tcn'
 d0 Ur cv'kcn'
e0 Tcf kqo gvtle"
 f0 Vgo r qtcn'
 g0 Vy q'qh'vj g'cdq'xg"
- 50 Y j cv'ku'Ur ge'tcn'Tcf kcpv'Go kw'pegA'
 c0 Co qwpv'qh'k'pekf gpv'gp'gti { 'qp'c'lw'hc'eg'r gt'w'pk'ctgc'cpf 'r gt'w'pk'v'ko g"
d0 Rqy gt'go kw'gf 'r gt'ctgc'r gt'y cxg'rg'pi vj "
 e0 Co qwpv'qh'gp'gti { 'd'g'kpi 'go kw'gf 'qt't'gh'ge'vgf 'qp'c'r ct'v'ew'ct'ctgc'r gt'w'pk'u'q'rkf "
 cpi ng'r gt'w'pk'v'ko g"
 f0 Rqy gt'go kw'gf 'r gt'ctgc"
 g0 P qpg'qh'vj g'cdq'xg"
- 60 Y j cv'ku'vj g't'gr'v'kpuj kr 'dgy ggp'cn'pi 't'cenl'cpf 'cetquu't'cenl'uecppgtuA'
 c0 Cn'pi 't'cenl'j cu'o qtg'o qxl'pi 'r ctv'u'cpf 'ku'o qtg'gzr gpuk'xg'vj cp'cetquu't'cenl'
d0 Cn'pi 't'cenl'j cu'rguu'o qxl'pi 'r ctv'u'cpf 'ku'o qtg'gzr gpuk'xg'vj cp'cetquu't'cenl'
e0 Cn'pi 't'cenl'j cu'rguu'o qxl'pi 'r ctv'u'cpf 'ku'rguu'gzr gpuk'xg'vj cp'cetquu't'cenl'
 f0 Cn'pi 't'cenl'j cu'o qtg'o qxl'pi 'r ctv'u'cpf 'ku'rguu'gzr gpuk'xg'vj cp'cetquu't'cenl'
 g0 P qpg'qh'vj g'cdq'xg"
- 70 Y j cv'ku'vj g'N'cpf U'cv'9'd'cpf 'eqo dk'p'v'kqp'*5.'4.'3+'v' r k'ecm' { 'wug'f'htA'
 c0 Vtcf k'k'q'p'cn'h'cn'g'eqm't'ko ci gu"
 d0 F luegt'p'kpi 'dgy ggp'up'qy 'cpf 'leg'eq'x'gt'ci g"
 e0 F g'ge'v'kpi 'j g'cn'j { 'x'gi g'cv'k'qp"
 f0 Tgo q'vg'ug'p'ukpi 'wt'c'p'ug'w'kpi u"
g0 P qpg'qh'vj g'cdq'xg"
 "
 "

80 J qy 'f q'uo qqj 'uwtcegu'cr r gct 'kp'c'tgo qvg'ugpukpi 'ko ci g'eqo r ctgf 'vq'tqwi j 'uwtceguA'
c0 Uo qqj 'uwtcegu'j cxg'dgwgt 'ur cvknt'guqnwkqp "
d0 Uo qqj 'uwtcegu'ctg'f ctngt 'kp'eqm't'f wg'vq'f khwug'tghgevkqp "
e0 Uo qqj 'uwtcegu'ctg'f ctngt 'kp'eqm't'f wg'vq'ur gewrct'tghgevkqp "
f0 Uo qqj 'uwtcegu'j cxg'rguu'pqlug "
g0 Vy q'qh'vj g'Cdqxg "
90 Cp'kpuwwo gpv'qp'CWTC'ku'vj g'O letqy cxg'Nko d'Uqwpf gtO'Y j cv'cpf 'j qy 'f qgu'kv'
hwpvkqpA'

c0 K'ku'c'r cuukxg'ugpuqt'cpf 'vcngu'q| qpg.'y cvgt'xcr qt.'cpf 'i tggpj qwug'i cu'tgcf kpi u'
cv'vj g'wr r gt'vqr qur j gtg "
d0 K'ku'cp'cev'xg'ugpuqt'cpf 'vcngu'ectdqp'f kqz'kf g.'cpf 'cgtquqnt'gcf kpi u'cv'vj g'wr r gt'
vqr qur j gtg "
e0 K'ku'c'r cuukxg'ugpuqt'cpf 'vcngu'q| qpg.'y cvgt'xcr qt.'cpf 'i tggpj qwug'i cu'tgcf kpi u'
cv'vj g'vqr 'qh'vj g'cvo qur j gtg "
f0 K'ku'cp'r cuukxg'ugpuqt'cpf 'vcngu'ectdqp'f kqz'kf g.'cpf 'cgtquqnt'gcf kpi u'cv'vj g'wr r gt'
vqr qur j gtg "
g0 Vy q'qh'vj g'Cdqxg "

: 0 Y j cv'cee'qpwu'ht' hmwew'v'kqp'u'ku'Mggrkpi 'Ewt'xgA'

c0 W'vcng'qh'E Q₄'d { 'cwq'vqr j 'r j qvqu { pyj guku "
d0 Guecr g'qh'E Q₄'htqo 'ectdqp'cv'ugf ko gpw "
e0 Tgrgcug'qh'E Q₄'htqo 'vj g'f geqo r qukkqp'qh'hc'xgu "
f0 Vy q'qh'vj g'Cdqxg "
g0 Cm'qh'vj g'Cdqxg "

; 0 Y j kej 'uvc'go gpv'ku'kpe'qpu'v'gpv'y kj 'r cuukxg'ugpukpi 'uecp'kpi 'u { u'vgo uA'

c0 Rcuukxg'ugpukpi 'u { u'vgo u'tgs'vkt'g'cp'gz'vgt'pcnt'cf k'v'kqp'u'vte'g "
d0 Rcuukxg'ugpukpi 'kpx'q'v'gu'r wuj dtqo 'uecp'kpi "
e0 UCT'ku'p'qv'c'v { r g'qh'r cuukxg'ugpukpi "
f0 Cm'qh'vj g'Cdqxg "
g0 P qpg'qh'vj g'Cdqxg "

320 Y j cv'ctg'vj g'cf xcp'vci gu'qh'h'kf ct'qxgt'tcf ctA'

c0 Nkf ct'r tqx'kf g'ko ci gu'y kj 'rguu'pqlug "
d0 Nkf ct'ctg'r cuukxgn' 'ugpugf "
e0 Nkf ct'ctg'rguu'g'zr gpukxg'kpuwwo gpw "
f0 Cm'qh'vj g'Cdqxg "
g0 P qpg'qh'vj g'Cdqxg "

330 Y j kej 'qh'vj gug'uvc'go gpw'cd'q'w'q| qpg'ku'h'cnugA'

c0 Ut'cv'v'ur j g'tke'q| qpg'ku'c'i tggpj qwug'i cu "
d0 Vj g'q| qpg'r { gt'ku'p'gegu'ct { 'hqt'uj k'grf kpi 'vj g'Gct'vj 'htqo 'j cto hwi'WX'tc { u "
e0 EHEu'ctg'h'qwpf 'vq'tg'cev'y kj 'q| qpg'cpf 'ctg'cwt'kdw'gf 'vq'vj g'j qrg'kp'vj g'q| qpg "
r { gt "
f0 Q| qpg'j cu'c't'gm'v'x'gn' 'h'pi 'h'g'v'ko g'kp'vj g'vqr qur j gtg "
g0 Cm'qh'vj g'Cdqxg'ctg'v'v'wg "
"
"

340Y j cv'qtdkcn'r cvj 'f q'ucvgnksgu'qp'vj g'C'Vtclp'hqmqy A'

- c0 K'ku'i gqu{pej tqpqwu'cpf "etquugu'vj g'gs wcvqt 'cv'33-52'r o 'uqmt'vko g"
- d0 K'ku'uwv'u{pej tqpqwu'cpf "etquugu'vj g'gs wcvqt 'cv'3-52'r o 'uqmt'vko g"
- e0 K'ku'i gqu{pej tqpqwu'cpf "etquugu'vj g'gs wcvqt 'cv'3-52'uqmt'vko g"
- f0 K'ku'uwv'u{pej tqpqwu'cpf "etquugu'vj g'gs wcvqt 'cv'33-52'r o 'uqmt'vko g"
- g0 P qpg'qh'vj g'Cdqxg"

350Y j cv'ku'vj g'r wtr qug'qh'c'iqy 'gctvj 'qtdkA'

- c0 I RU'ucvgnksgu"
- d0 Eqo o wplecvkqp'ucvgnksgu"
- e0 J wo cp'Ur ceghki j v'
- f0 Vy q'qh'vj g'Cdqxg"
- g0 Cm'qh'vj g'Cdqxg"

360Y j kej 'qh'vj gug'ku'c'f kucf xcpvci g'qh'tgo qvg'ugpukpi 'cu'c'vqqrA'

- c0 F khlwvku'g'y kj 'ko ci g'lpvgr tgcwvqp"
- d0 Eqctug'T guqnvkqp"
- e0 Wpegtvkv'v'cpf 'f kvqtvkqp'y kj 'o gcuwtgo gpw"
- f0 Vy q'qh'vj g'Cdqxg"
- g0 Cm'qh'vj g'Cdqxg"

370Y j kej 'qh'vj gug'ucvgnksgu'y qwf 'o quv'rkng' 'dg'lp'c'i gqucvkqpct { 'qtdkA'

- c0 J wddrg'Ur ceg'Vrgueqr g"
- d0 I QGU"
- e0 QEQ/4"
- f0 Ncpf Ucv'
- g0 P qpg'qh'vj g'Cdqxg"

380Y j cv'f q'lpvwo gpw'f q'Vgttc'cpf 'Cs wc'j cxg'lp'eqo o qpA'

- c0 CO UT/G"
- d0 EGTGU"
- e0 O QF KU"
- f0 O KUT"
- g0 GVO - "
- h0 Vy q'qh'vj g'Cdqxg"

390Y j { 'ku'QEQ'pqv'c'r ctv'qh'C/VtclpA'

- c0 Vj g'r tqlgv'y cu'uetcr r gf 'f wg'vq'rcem'qh'hwvf lpi "
- d0 Vj g'ucvgnksg'y cu'f kucdrf 'lp'qtdk'f wg'vq'gs wkr o gpv'o crhwpevqp"
- e0 Vj g'ucvgnksg'y cu'f gvtq { gf 'f wg'vq'rcwpej 'xgj keng'rcvwtg"
- f0 Vj g'r tqlgv'y cu'tgpco gf 'QEQ/4.'j gpeg'vj g { 'ctg'vj g'uco g"
- g0 P qpg'qh'vj g'cdqxs"

3: 0Y j cv'r j gpqo gpqp'ecp'dg'cwtkdwgf 'vq'Tc { rgi j 'uecvgtkpi A'

- c0 Vj g'qegcpu'ctg'dnwg"
- d0 Vj g'um' 'ku'dnwg"
- e0 Rrcpw'ctg'i tggp"
- f0 Vy q'qh'vj g'cdqxs"
- g0 Cm'qh'vj g'cdqxs"
- "

3; 0Y j lej "qh'vj g'hqmjy lpi 'y qwf "o qu'rkngn{ "ecwug'pqpugrgevxg'uecwgtlpi 'y kj 'xkukdng'hi j vA"

c0 Emwf "eqxgt"

d0 XQEu"

e0 Ectdqp'f kqz kf g"

f0 EHEu"

g0 P qpg'qh'vj g'Cdqxg"

420Y j lej "qh'vj g'hqmjy lpi 'ku'pqv'c'i tggpj qwug'i cuA"

c0 Y cvgt "Xcr qt"

d0 Vtqr qur j gtle'Ql qpg"

e0 Ectdqp'f kqz kf g"

f0 Vy q'qh'vj g'Cdqxg"

g0 P qpg'qh'vj g'Cdqxg"

430Y j cv'ctg'vj g'f khtgpegu'dgwj ggp'c'ur gevto gvg't'cpf "c'tcf kqo gvg'tA"

c0 C'ur gevto gvg't'ctg'ucpf cmppg'u{ uvgo u'vj cv'ctg'j ki j n{ "ceewtcvg'lp'cpcn{| lpi " o wnr ng'ur gevto'ncpi gu"

d0 C'tcf kqo gvg't'ctg'bo wej "o qtg'uko r ng'cpf "qpn{ "o gcuwtgu'c'ur gekle'y cxgrppi vj " tpci g"

e0 C'ur gevto gvg't'ctg'pqv'ucpf cmppg'cpf "tgs vkt'g'c'ugv'qh'qr vku'vq'eqttgevn{ 'y qtm'

f0 Vy q'qh'vj g'Cdqxg"

g0 P qpg'qh'vj g'Cdqxg"

440Y j lej "qh'vj g'hqmjy lpi 'ku'c'uj qtv'rkxgf 'i tggpj qwug'i cu'>'7"{ gctu+'tgnv'kxg'vq'vj g'qvj gt'vj tggA"

c0 EQ"

d0 UH₈"

e0 P₄Q"

f0 EJ₆"

g0 P qpg'qh'vj g'Cdqxg"

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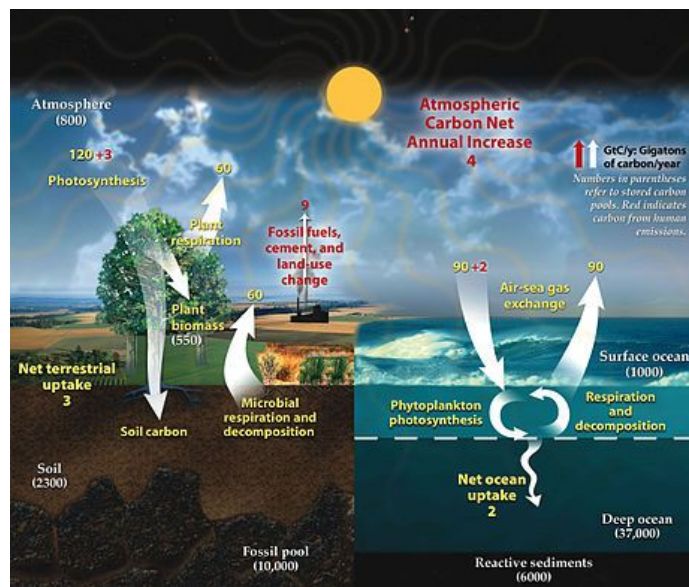
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Part 2: Short Answer and Calculations (Point values will be specified) Please show all work to earn full credit!

30Vj g'ectdqp'e{erg'ku'ng{ 'vq'erko cvg'ej cpi g'r tqeguugu0(Tiebreaker 1)

c0Ungvej 'vj g'ectdqp'e{erg0Vj g'hqmy kpi 'ctg'ng{ 'y qtf u' {qw'o wv'kpenmf g<' Rj qvqu{ pyj guku.'F gec{ .'T gur ktcvkp.'Ugf ko gpvcvkp.'Hquuk k cvkp.'Eqo dwukqp." Y gcvj g'kpi 0P qvg'pqv'cm'qh'vj g'r tqeguugu'kp'vj g'ectdqp'e{erg'ctg'eqxgtgf 'd{ 'vj g' ng{y qtf u'cdqyg.'o cmg'uw'g' {qw'kpenmf g'cm'tgrxcpv'r ct u'qh'vj g'e{erg#*8'Rqkpw+

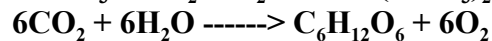
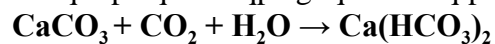
A diagram that encompasses the seven keywords above (0.5 points each) with arrows in the correct direction. Also includes ocean and bicarbonate/carbonate cycling (2.5 points)



d0Gzr rckp'j qy 'tkug'kp"cv qur j gtle"ectdqp"f kqz kf g'i cugu'kphwgegu'vj g'dcncpeg'qh" dlectdqpvcg'cpf "ectdqp"f kqz kf g'kp'vj g'qegcp0Gzr rckp'y j cv'vj ku'o gcpu'hqt'vj g'r J " qh'vj g'qegcp0Y j cv'y qwf 'vj gqtg'ecm{ 'vq'vj g'r J "cpf "dcncpeg'qh"dlectdqpvcg'cpf " ectdqp"f kqz kf g'f wg'vq'tkupi 'vgo r gtcwtguA*5'Rqkpw+

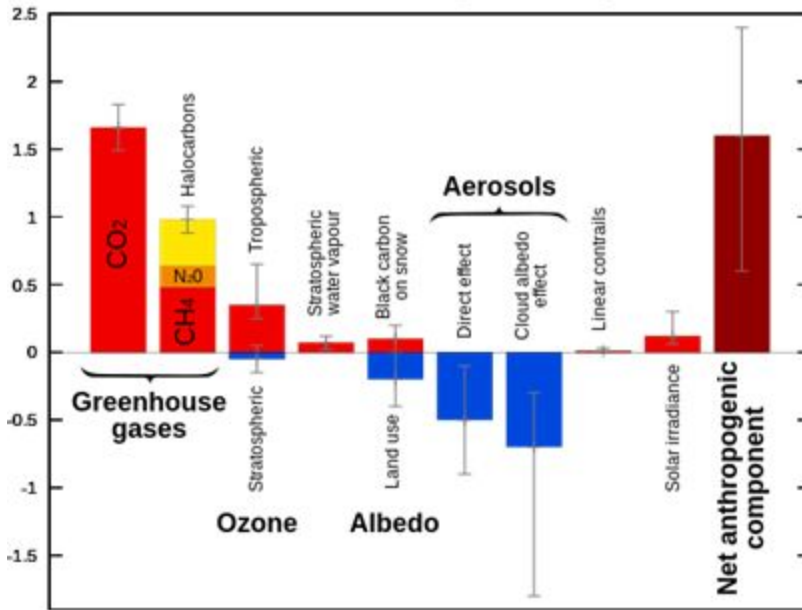
Rise in atmospheric carbon dioxide gases increases the amount of dissolved carbon dioxide in the ocean (1 Point). This decreases the pH/makes the ocean more acidic (1 Point). Theoretically, less carbon dioxide would be soluble due to rising temperatures. This would result in a higher pH/more basic ocean (1 Point)

e0Y tkw'qw'vj g'ej go kecn'gs wcvkqpu'hqt'vj g'tgcev'kqpu'hqt'r j qvqu{ pyj guku'cpf 'vj g' f kuqrxkpi 'qh'ectdqpvcg'tqen0*4'Rqkpw+



(0.5 Points for correct chemicals in each equation, 0.5 Points for correct balancing)

40Cpen| g'v'j g'hqmy kpi 'f'kci tco "



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c0Vj g'hqmy kpi 'o gcuwtgu'c'xcnw'ecmgf ":-TH0Y j cv'f qgu'TH'ucpf 'hqtA*3'r qlpv+
Radiative Forcing

d0I kxgp'v'j g'pco g'qh'-TH0'y j cv'ctg'uqo g'r r'wukdrg'wpku'hqt 'v'j ku'xcnwA*3'r qlpv+
W/(m²) - if it's power over an area in any units (1 Point)

50Vj g'ur ggf "qh'iki j v'kp'cp'wmpqy p'o gf kw0 'ku'o gcuwtgf "v'q'dg'408'z'32' "o lu0"

c0Y j cv'ku'v'j g'kpf gz "qh't'ghtcevkqp'qh'v'j g'o gf kw0 A*4'Rqkpv+ "

Statement of formula $n = c/v$ (0.5 Points)

Correct values placed into the equation $n = (3.00 \times 10^8 \text{ m/s}) / (2.76 \times 10^8 \text{ m/s})$

Correct answer $n = 1.087$

d0C "dgco "qh'iki j v'tcxgrkpi 'v'j tqwi j 'v'j g'o gf kw0 "o cmgu'eqpcev'y kj 'v'j g'ckt0Y j cv' ku'v'j g'cpi rg'k'p'ggf u'v'q'j k'v'j g'ckt'hqt 'v'j gtg'v'q'dg'v'q'v'cn'lpvgtpcnt'ghtcevkqpA*4'Rqkpv+ "

Statement of Snell's Law $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (0.5 Points)

Rearrangement and substitution of $n_1 = 1$ for air and $\theta_1 = 90$ (0.5 Points)

Substitution of $n_2 = 1.087$ (0.5 Points) (If this is incorrect from the previous question, do not give them the points)

Solving for $\theta_2 = 66.92$ degrees (0.5 Points)

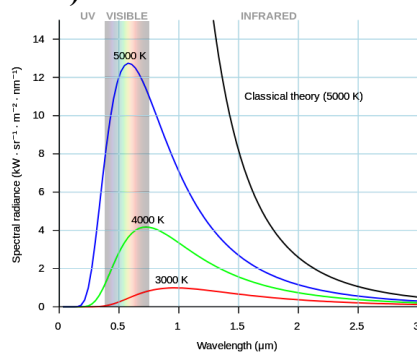
60 Wikipi "emuekci'o gej cpleu."uekpvkuu'kp"vj g"rcvg"3; y"cpf "gctn{"42"j "egpwt {"y gtg"wpcdrg" vq"gzr mlp"vj g"drcndqf {"rj gpqo gpqp0'

c0Y j cv's wcpwo "o gej cpleu'r tlpkr ng"fk "O cz "Rrcpen'go r m{" "vq"hpcm{"uqrg"vj g" Drcndqf {"Rj gpqo gpqp"y kj "Rrcpen'u"Ncy A"3"Rqlpv+"

The quantization of light waves into discrete ‘quanta’ (photons).

d0Y j cv'j cr r gpu"vq"vj g'y cxgrpi vj "qh'o czko wo "kpvpuk{"qh"vj g"drcndqf {"cu" vgo r gtcwtg"lpetgcugu0Y j cv'j cr r gpu"vq"vj g'o czko wo "kpvpuk{"kugrhAF tcy "c" i tcr j "vq"uj qy {"qwt"cpuy gt"6"Rqlpv+"

As the temperature increases, the wavelength of maximum intensity of the blackbody decreases. Show this with the fact that Wein’s Displacement Law has maximum wavelength inversely proportional to temperature (1 Point) Maximum intensity itself increases, as shown by Stefan-Boltzmann’s Law (1 Point)



The test taker needs to show the progression from a lower temperature (ex. 3000 K) to a higher temperature (4000 K), shifts the curve to the left and increases the maximum of the curve (1 Point) The graph needs to have wavelength on the x axis, and intensity on the y axis while disregarding units (1 Point)

e0C"r ctvwrt"drcndqf {"j cu"vgo r gtcwtg"qh"7982"MOY j cv'ku"vj g'y cxgrpi vj "cv" y j kej "vj g"drcndqf {"go ku"cv'o czko wo "kpvpuk{"A"4"Rqlpv+"

State Wien’s Displacement Law $\lambda_{max} = (\text{constant})/\text{Temperature}$ (0.5 Points)

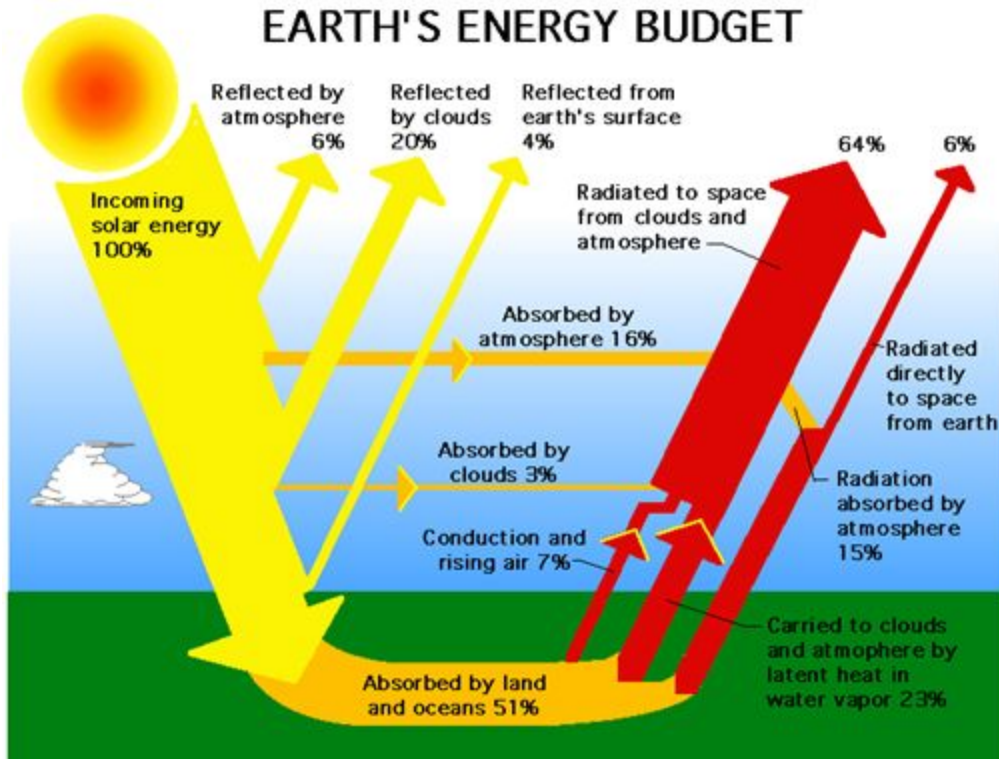
Substitute Constant and temperature $\lambda_{max} = (2.90 \times 10^{-3} \text{ m} \cdot \text{K})/(5760 \text{ K})$ (0.5 Points)

Correct Answer $\lambda_{max} = 503.47 \text{ nm}$ (1 Point)

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70Cpcn{ | g'yj g'hqmry kpi 'f'kci tco '(Tiebreaker 3)



cOI kxgp'yj g'hqmry kpi 'f'kci tco "cpf 'yj g'vgo r gtcwtg'cpf 'tcf kwu'qh'yj g'Uwp"*7999" M'8; 7922'no +'cpf 'yj g'f kxpeg'htqo 'yj g'Gctyj 'vq'yj g'Uwp'ku'36; .822.222'no ."cpf " yj g'tcf kwu'qh'yj g'Gctyj 'ku'8.593'no ."ecrewe'v'g'g'co qwpv'qh'gpsti { "cduqtdgf "d{ " yj g'rcpf "cpf "qegcpu'kp'y cwuOCuwo g'cndgf q'c'ku' gtq0*6'Rqkpu+ "

Statement of Stefan-Boltzmann's Law $L = 4\pi R^2 \sigma T^4$ (1 Point)

Substitution of $\sigma = 5.67 \times 10^{-8} \text{ Wm}^2/\text{K}^4$, $R = 696700000 \text{ m}$, and $T = 5777 \text{ K}$ into the above equation and solving to get $3.84 \times 10^{26} \text{ W}$. (1 Point).

Assuming the albedo is a , the incident energy from the Sun to the Earth is $P_{in} = (L_o(1 - A)(\pi R_E^2))/(4\pi d^2)$. Plugging in the values we get $P_{in} = 8.88 \times 10^{22} \text{ W}$. (1 Point).

Multiplying by 0.51, we get $4.53 \times 10^{22} \text{ W}$.

"

d0P co g'vy q'v'r gu'qh'GO 'tcf k'v'kp'yj cv'ctg'o quv'kngn{ 'tghge'v'g'cpf 'pq'cduqtdgf " d{ 'yj g'Gctyj 0*4'Rqkpu+ "

Any two of the following - UV, X-ray, Infrared, or Microwave (2 Points for two of the above).

e0F gtxg'c'htqo we'ht' yj g'ghge'v'xg'vgo r gtcwtg'qh'yj g'Gctyj 0Dg'uwg'vq'rku'cm' uvr u'cpf "gzr r'kp'yj g'o q'v'x'v'kp'ht'gcej 'uvg' OCuwo g'yj g'Gctyj 'j cu'cp'cndgf q'c." tcf kwu'T_G' yj cv'yj g'Uwp'j cu'c'no k'p'qu'v' "N_q'cpf "c'f kxpeg'htqo 'yj g'Gctyj 'qh'f 08" Rqkpu+ "

$P_{out} = 4\pi R_E^2 \sigma T^4$ (1 point) (The 'luminosity' of the Earth give by Stefan Boltzmann Law)

$P_{in} = (L_o(1 - A)(\pi R_E^2)/(4\pi d^2)$ (2 Points) (The amount of energy absorbed from the Sun by the Earth) (Note the use of albedo to show the amount of energy absorbed by the the fraction of the Earth facing the Sun with area/volume fraction)

Set $P_{out} = P_{in}$ and solve for the temperature and solve. (1 Point)

$T = ((L_o(1 - A))/(16\sigma\pi d^2))^{1/4}$ (2 Points for correct arithmetic to get into this page.)"

f0Y j cv'ku'yj g'f hgtgpeg'dgy ggp'yj g'ghgevkxg'vgo r gtcwtg'hqto wr'ecrwrvgf " cdqxcg'cpf 'yj g'lwthceg'vgo r gtcwtg'A'Vj cv'ku.'y j cv'cuwo r vkpu'f kf "{qw'o cng'hqt " yj g'ghgevkxg'vgo r gtcwtg'hqto wr'cpf 'j qy 'f qgu'yj ku'chgevj g'vgo r gtcwtg' ecrwrvgf 'eqo r ctgf 'vq' yj g'lwthceg'vgo r gtcwtg'A*5'Rqkvu+"

With effective temperature, we assume Greenhouse effect is negligible (1 Point). The Earth's net emissivity is the same as that it absorbs from the Sun (1 Point). Not all the incident energy on the Earth is absorbed by surface - some of it is reflected. (1 Point)."

g0Wkpi 'yj g'hqto wr'qdvkpgf 'lp'e0ecrwrvg'yj g'ghgevkxg'vgo r gtcwtg'qh'yj g' Cctvj 0Cuuwo g'crldg'q'c'"? "2"*3'Rqkvu+"

$T = ((L_o(1 - A))/(16\sigma\pi d^2))^{1/4}$ (Statement of the equation (0.5 Points), if the equation is incorrect, not points for the subsequent calculations).

Substitution of values into the equation $T = (L_o/(16\sigma\pi d^2))^{1/4}$ we get $T = 255$ K (0.5 Point).

"

80K'yj g'htgs wgpel "qh'c'riki j v'y cxg'ku'847'O J | "

c0Y j cv'ku'yj g'gpsti { "qh'yj g'r j qvqp'lp'LA*4'Rqkvu+"

State equation $E = hv$ (0.5 Points)

Substitute values $E = (6.626 \times 10^{-34} \text{ Js})(625 \times 10^6 \text{ Hz})$ (0.5 Points)

Solve for $E = 4.141 \times 10^{-25} \text{ J}$ (1 Point)

d0Y j cv'ku'yj g'y cxgrpi yj "qh'yj g'riki j v'y cxg'lp'o A*4'Rqkvu+"

Dimensional analysis - multiply 625 MHz by 10^6 Hz to get 625×10^6 Hz (1 Point)

$= c/v = (3.00 \times 10^8 \text{ m/s})/(625 \times 10^6 \text{ Hz}) = 0.48 \text{ m}$ (1 Point)

e0Y j cv'eqmt 'ku'yj g'riki j v'y cxg'A*3'r qkvu+"

Not visible light, no color

"

9c0Y j cv'v{r g'qh'lphtctgf 'y cxgrpi yj u'f q'r rcpv'rgcxgu'tghgevf khwugn{ A*3'Rqkvu+"

Near Infrared and Shortwave Infrared Wavelengths (0.5 Points Each)

d0Y j cv'ku'"tgur qpukdr'ht' yj ku'tghgevkqpA*3'Rqkvu+"

Mesophyll or Chloroplasts (Cell Structure) (0.5 Points)

Free Water (0.5 Points)

: 0Nku'vj g'hqwt'ucvgnkxgu'vj cv'ctg'r ctv'qh'vj g'Gct y 'Qdugt xkpi 'U{ ugo 'dw'pqv'c'r ctv'qh'
C/Vtclp'vj cv'ctg'ukm'cevxg'*6'Rqlpw+0Chgty ctf u."g zr nkp'vj g'r wtr qug'qh'gcej "qh'vj g"
ucvgnkxgu'q w'hkugf "cpf "pco g"qpg'lpwtwo gpv'qpdqctf '*6'Rqlpw+0(Tiebreaker 2)

Any four of the following (SMAP, LandSat 8, SORCE, Terra, GRACE, LandSat 7, NMP/EO-1) (1 Point Each)

(2 Points Each)

SMAP - Measure surface soil moisture and freeze-thaw state

LandSat 8 - Supply the world with global land surface images

SORCE - Improve our understanding of the Sun

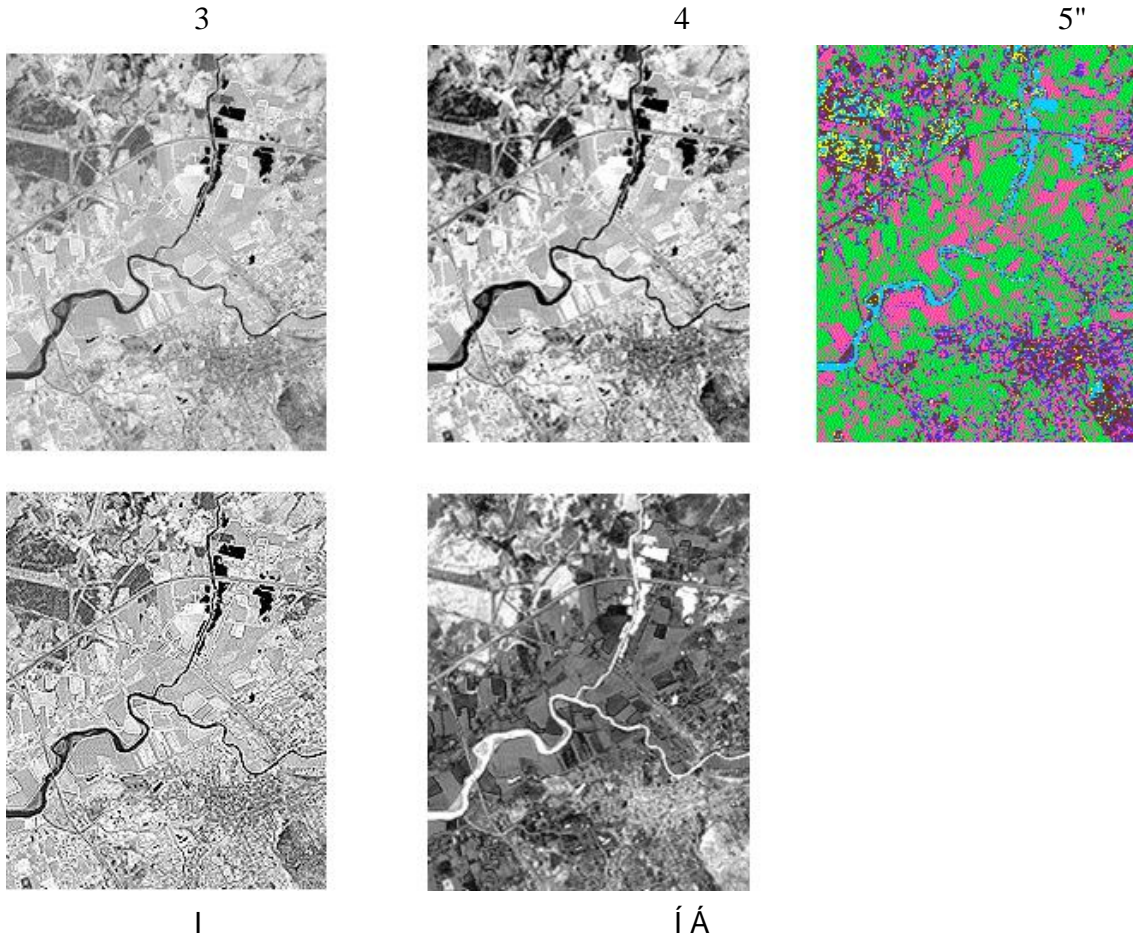
Terra - Provide global data on the state of the atmosphere, land, and oceans

GRACE - Measure Earth's mean and time-variable gravity field

LandSat7 - Supply the world with global land surface images

NMP/EO-1 - Demonstrate new technologies and strategies for improved Earth observations

; 0Vj g'lo ci gu'dgmy "uj qy "ko ci g'gpj cpego gpw'f qpg'vq"cp"qtki kpcilko ci g"*3-0F guetkdg'y j cv'
 j cu'dggp'f qpg'y kj "gcej "o qf kkecvkp"cpf "y j cv'vj g'r tqr gt'pco g"qh'gcej "o qf kkecvkp"ctg0*8"
 Rqkpu+ "



Á
 Image 2 is a contrast stretch enhancement (0.5 points). It involves expanding the range of brightness values so that dark areas are darker and bright areas are brighter (1 point).

Image 3 is an intensity slicing enhancement (0.5 points). This reduces the number of discrete levels of grey (brightness so to say). The resulting levels are then displayed as discrete colors (1 point).

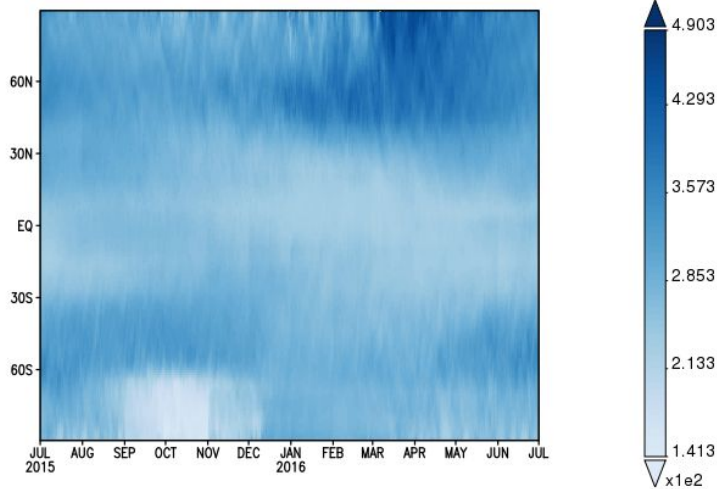
Image 4 is a high pass filter enhancement (0.5 points). This filter produces an image that emphasizes areas of spatial detail. The enhanced image would look sharper and crisper (1 point).

Image 5 is merely an inverted color scheme (0.5 points). This displays the grey areas as lighter shades and light areas as darker, greyer shades (1 point).

Part 3: Giovanni Data (Point values will be specified) Please show all work to earn full credit!

320Vj g'hqmty kpi 'J qxo qmgt'f kci tco 'o gcwtgu'eqno p'q| qpg'hgxgn'qxtg'qpg'gct0'

Hovmoller, Longitude-Averaged of Ozone Total Column (Nighttime/Descending) daily 1 deg. [AIRS AIRX3STD v006] DU over 2015-07-01 - 2016-07-01



"

c0 Y j cv'f qgu'CKU'ucpf 'hqtA*3+

Atmospheric Infrared Sounder

d0 Y j cv'ucvgnkg'ku'yj ku'kputwo gpv'hqwpf "qpA*3+

Aqua

e0 Y j cv'r j gpqo gpqp'ku'kpf kecvgf "d{ 'yj g'y j kg'ctgc'kp'yj g'dqwqo 'rgh'qh'yj g'f kci tco A*3+

Ozone hole

f0 Eqo r ctgf "q'r t gxlqwu" { gctu.'j qy "f qgu'yj ku" { gctau'kpuvpeg'qh'yj ku'r j gpqo gpqp'eqo r ctg. " kp'vgtu u'qh'vko g'cpf "mdecvqpA*4+

It occurred later and is larger

g0 Y j cv'yj tgg"eqpf kkp'u'ctg'pggf gf 'hqt'yj ku'r j gpqo gpqp"v"qeewtADg'uxtg'v'vkg'yj gug" eqpf kkp'u'v'yj g'vko g'cpf "mdecvqp'qh'yj g'r j gpqo gpqp0*8+

Low temperatures (July/August in the Antarctic) needed to form polar stratospheric clouds (which increase relative abundances of reactive chlorine gases).

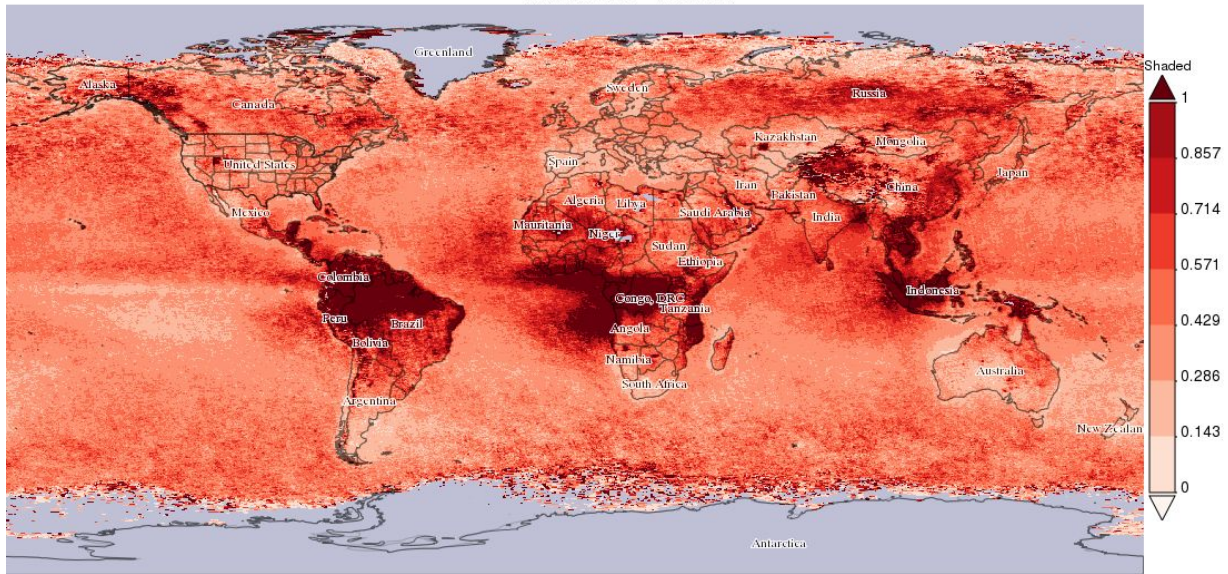
Isolation from air in other stratospheric regions (strong winds over the Southern ocean encircle Antarctica).

Sunlight (until ~November in the Antarctic) opens up ClO and BrO reactions with ozone.

"
"
"
"

330Vj g'hqmqy kpi 'ku'c'o cr "qh'cgtquqnlhgxgnu'lp'yj g'ncvg'lwao o gt0'

Time Averaged Map of Aerosol Optical Depth 483.5 nm daily 0.25 deg. [OMI OMAEROe v003] over 2015-07-01 - 2016-09-01



c0 Y j cv'f qgu'QO Kuxcpf 'hqtA*3+"

Ozone Monitoring Instrument"

d0 Y j cv'ucvgnkg'ku'yj ku'kpwtwo gpv'hqwpf "qpA*3+"

Aura "

e0 F qgu'f ctmntgf 'lpf kecvg'c'hqy "qt'j ki j 'hgxgn'qh'cgtquqnuA*3+"

High "

f0 Y j cv'ecwugu'yj g'f ctmntgf "ctgc'qxgt'yj g'Co c| qpA*3+"

Land clearing/agricultural fires"

g0 Y j cv'ecwugu'yj g'tgf 'kp'yj g'Ctdkcp'RgpkpuwrcA*3+"

Dust storms"

h0 Y j cv'ecwugu'yj g'tgf 'kp'gcuvgtp'Ej kpcA*3+"

Pollution"

i 0 Y j cv'ku'yj g'f kgev'cgtquqn'ghhgevA*3+"

It can reflect or absorb sunlight "

j 0 Y j cv'ku'yj g'lpf kgev'cgtquqn'ghhgevA*3+"

It stimulates the formation of clouds by acting as cloud nuclei"

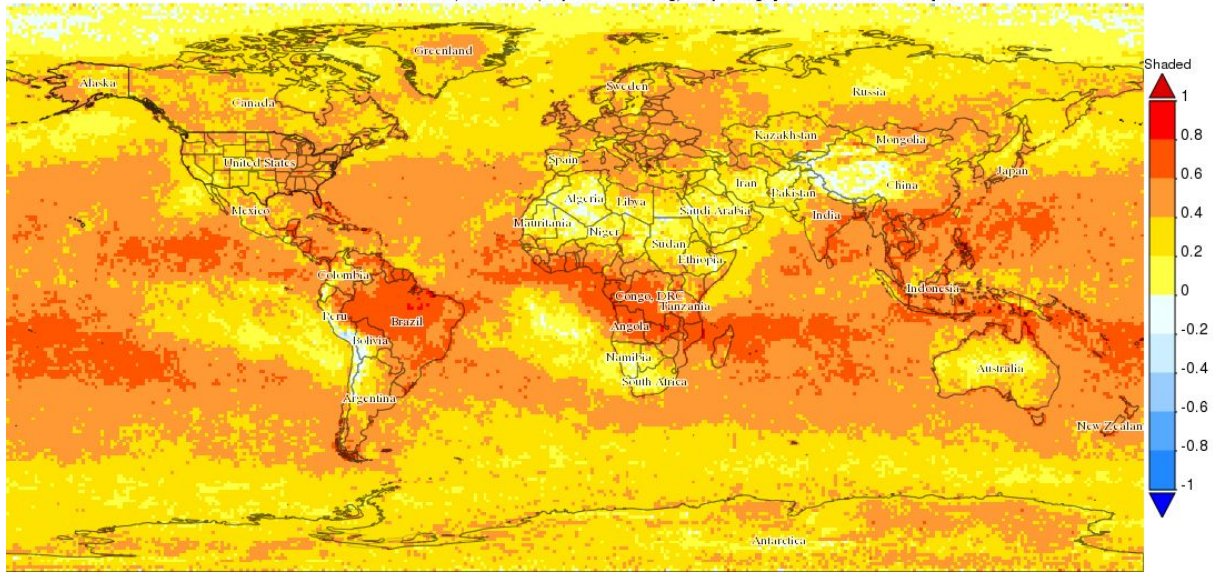
k0 Kp'yj cv'vy q'y c {u'ku'wtecur j gtle"cgtquqn'hqto gf A*4+"

Oxidation of carbonyl sulfide (OCS) or oxidation of ejected sulfur dioxide (SO2)"

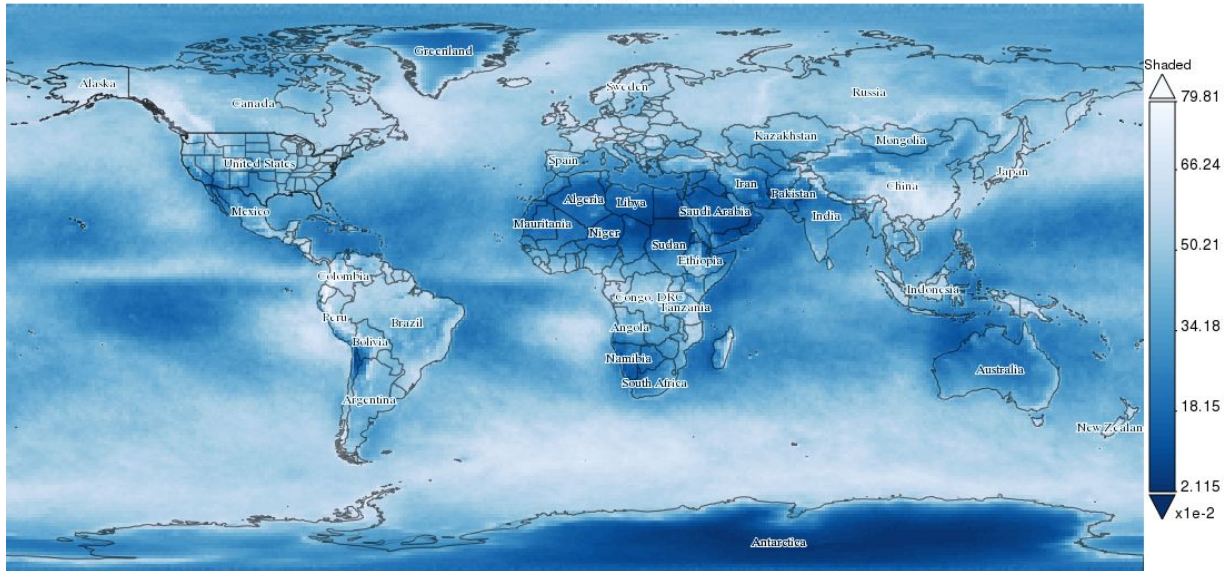
"
"
"
"
"

340Vj g'hqmqy kpi 'ctg'vy q'bo cr u<vj g'htuv'o gcuwtgu'vj g'eqttgrvklp'dgwy ggp'eqno p'bo gj cpq'cpf " eqwv 'vqr 'r tguwtg.'cpf 'vj g'ugeqpf 'eqwv 'eqxgt 'htcevkpOÁ

Correlation for 2015-07-01 - 2016-07-01
 1st Variable: Methane Total Column (Daytime/Ascending) daily 1 deg. [AIRS AIRX3STD v006] mol/cm2
 2nd Variable: Cloud Top Pressure (Daytime/Ascending) daily 1 deg. [AIRS AIRX3STD v006] hPa



Time Averaged Map of Cloud Fraction (Daytime/Ascending) daily 1 deg. [AIRS AIRX3STD v006] over 2015-07-01 - 2016-07-01



c0 Y j cv'ku'eqwv 'vqr 'r tguwtg'wugf 'vq'bo gcuwtgA*3+"

Cloud top height"

d0 Cr r tqzko cvgn 'y j cv'r gtegpvc i g'qh'tcf kvkxg'hqtelkpi 'ku'f wg'vq'bo gj cpqA*3+"

20%"

e0 Y j cv'dkqo g'ku'vj g'ixti guv'o gj cpq'go kvgtA*3+"

Wetlands"

f0 Y j cv'ku'vj g'ixti guv'o gj cpq'ukpmA*3+"

Tropospheric OH"

g0 Vj g'htuw'o cr 'tapi gu'ltqo 'y j kg']t?2_'q'tgf "]t?3_="j gtg'ku'pq"dnwg"]t>2_0Y j cv'gZR m'ku'vj g"
r qukkxg"eqttgrv'kp"dgvy ggp"vj g'vy q'xctkcdguA*4+"

Clouds reduce the concentration of tropospheric OH, so with a lack of sink methane concentrations increase."

h0 J qy "f q'vj gug'vy q'o cr u'eqttgrv'q'xgt'rcpf A'Y j { "o ki j v'vj ku'dgA*5+"

The correlation between column methane and cloud height is highest when cloud cover is high, and lowest when cloud cover is low. [accept reasonable hypotheses for 'why might this be?']"

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