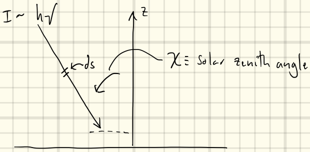
Solar EUV Absorbtion:



$I(\nu) \equiv$ Photon Flux (ν: Frequency; $\lambda \equiv$ wavelength) $\quad I_\infty(\nu) \equiv$ Flux @ infinity (above atmosphere)

$n_N(z) \equiv$ Number density of species N (O, N2 and O2)

$\sigma_N^a(\nu) \equiv$ absorbtion cross section for species N as a function of ν

$s \equiv$ path length

$ds = -dz \sec\chi$ (dz: Altitude; χ: solar zenith angle)

Note: χ, σ_N^a are independent of I or z

this is "a" (sigma - x sect)

$$\partial I(s) = -I(s)\, n(z)\, \sigma^a\, \partial s$$

$$\frac{\partial I}{I} = n(z)\,\sigma^a \sec\chi\, \partial z$$

$$\ln\left(\frac{I_\infty}{I_z}\right) = \sigma^a \sec\chi \int_z^\infty n(z)\,\partial z$$

$$= \sigma^a \sec\chi \underbrace{\int_z^\infty n(z)\, e^{-\frac{z-z_0}{H}}\, \partial z}_{\text{for isothermal atmosphere, This is } n(z)\cdot H}$$

H, scale height

$$H = \frac{kT}{mg}$$

$$\downarrow$$

$$I_z = I_\infty e^{-\sigma^a \sec\chi \underbrace{n(z)H}_{\text{Approximate! Better to use } \int_z^\infty}}$$

A bit more specific:

$$I(z,\lambda,\chi) = I_\infty(\lambda)\, e^{-\int_\infty^z \sum_N n_N(z)\sigma_N^a(\lambda)\,\partial s}$$

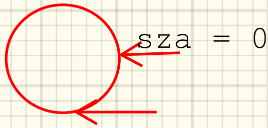
Assumption of $\partial s \approx -\sec\chi\,\partial z$ works to about $\chi = 75°$ $\rightarrow$ Smith & Smith 1972 for better result.

Assumes no horizontal variations of atmosphere! Yikes!

Define $\tau \equiv$ Optical Depth $\Rightarrow \tau(\lambda) = \sigma_N^a(\lambda) \sec\chi \sum_N \int_\infty^z n_N(z)\,\partial z$

remember that $\int_{z_0}^\infty n_N(z)\,\partial z = n_N(z_0) H_N(z_0)$

can use this for above the model domain



Now what?

→ Technically Absorbtion drives ionization
↳ creation of ions + electrons
↳ Exothermic recombination
↳ Heating of atmosphere
↳ ~30% of energy absorbed is turned to heat

Q_EuV = energy added due to EuV

$$Q_{EUV} = \underbrace{\epsilon}_{\text{Heating Efficiency}} \sum_N n_N(z) \int_{0\,(\sim 5\text{Å})}^{\infty\,(\sim 1000\text{Å} \rightarrow \text{ionization Threshold})} E(\lambda)\, I(z,\lambda)\, \sigma_N^a(\lambda)\, \partial\lambda$$

$$= \epsilon \sum_N n_N(z) \sum_\lambda I(z,\lambda)\, \sigma_N^a(\lambda)\, E(\lambda)\, \boxed{\cancel{\partial\lambda}}$$

$$= \epsilon \sum_N \sum_\lambda n_N(z)\, I_\infty(\lambda)\, e^{-\tau}\, \sigma_N^a(\lambda)\, E(\lambda)$$

$\sec\chi \int_z^\infty n_N(z)\,\partial z$ is a chapman integral

$$\tau = \sec\chi \sum_N \underbrace{n_N(z) H_N(z)}_{\text{remember this is } \sim \int_z^\infty n_N(z)\partial z \text{ for exponentially decreasing, isothermal atmosphere (and technically } g = \text{constant)}} \sigma_N^a(\lambda)$$

$\frac{\partial T}{\partial t} \sim \frac{Q_{EUV}}{\rho c_p}$ $\quad \rho \equiv$ mass density $\rho = \sum_N n_N m_N$

$c_p \equiv$ specific heat at constant pressure (or c_v @ constant volume)
- changes with composition
- Can approximate as $1500 \frac{J}{kg\cdot K}$

$\frac{K}{s} \sim \frac{J/s}{kg\cdot ?}$ $\rightarrow \frac{J}{kg\cdot K}$

$$\therefore \frac{\partial T}{\partial t} = \frac{\epsilon \sum_N \sum_\lambda \cancel{n_N(z)}\, I_\infty(\lambda)\, e^{-\tau}\, \sigma_N^a(\lambda)\, E(\lambda)}{c_p \sum \cancel{n_N(z)}\, m_N}$$

$$= \frac{\epsilon \sum_N \sum_\lambda I_\infty(\lambda)\, e^{-\tau}\, \sigma_N^a(\lambda)\, E(\lambda)}{c_p \underbrace{\langle m_N \rangle}_{\text{mean mass, could approximate as } \sim 16 \text{ AMU (O), or could compute}}}$$

$\Rightarrow$ Then $\frac{T^{n+1} - T^n}{\partial t} = R$

$$\boxed{T^{n+1} = \partial t \cdot R + T^n}$$

Where to get $I_\infty(\lambda)$ & $\sigma_N^a(\lambda)$?
- $\sigma_N^a(\lambda)$ → Schunk & Nagy book
- $I_\infty(\lambda)$ ↳ EUVAC
↳ $I_\infty(\lambda) = F74113_\lambda \left[1 + A_\lambda (P - 80)\right]$

- I have uploaded csv file containing:
  - Wavelength Bins (for $E(\lambda)$)
  - $F74113_\lambda$
  - A_λ
  - $\sigma_N^a(\lambda)$ for O, N_2, O_2

$P \equiv (F107 + \underbrace{\langle F107 \rangle}_{\text{81 day ave (3 solar rotations)}})/2$

Local time $= \left[\mathrm{Lon}/15 + \mathrm{UT}(\text{hours})\right] \% \ 24$

@ Equator $\chi = \mathrm{acos}\left(\cos\left[\pi \cdot (\text{local Time} - 12)/12\right]\right)$

(noon $\Rightarrow \chi = 0$; midnight $\Rightarrow \chi = 180 (\pi)$)

Steps:
1. Download csv File
2. Get λ, $F74113_\lambda$, A_λ, $\sigma_O(\lambda)$, $\sigma_{N_2}(\lambda)$, $\sigma_{O_2}(\lambda)$
3. Make an initial function of T; $z \sim 100$-500; $T = 200 + 600 \times \tanh\left(\frac{z-100}{100}\right)$ (compare) - create function initialize_Temp
4. Start with one species: O $\Rightarrow$ Calculate $H(z)$ (compare) - create function that takes T, z, m; return H
5. Calculate $n_O(z)$ from 100-500, given $n_O(100) = 5\times10^{17}/m^3$ [for ref $n_{N_2}(100) = 1.7\times10^{19}/m^3$; $n_{O_2}(100) = 4\times10^{18}/m^3$] (compare) - create function
6. Assume $\chi = 0$; Calculate τ from 100-500 km for $\lambda_{50\text{-}100}$ (compare) - create function that takes χ, $n_N(z)$, $H_N(z)\sigma_N^a(50\text{-}100)$
7. Calculate $I_{\infty(50\text{-}100)}$; Then $I_{(50\text{-}100)}$ from 100-500 km (compare) - create EUVAC Function
8. Calculate $E(50\text{-}100)$; Calculate $\frac{\partial T}{\partial t}$ (for O only; $\lambda = 50$-100; $z = 100$-500 km) (compare) - create function that takes $I_\infty(\lambda)$, τ, σ_N^a, λ returns $\frac{\partial T}{\partial t}$

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9. Rework functions to allow multiple wavelenths (plot τs for all wavelenths on same plot)
10. Rework functions (τ, $\partial T/\partial t$) to allow multi species
11. Allow different χ
12. Update T, Then n_O, n_{N_2}, n_{O_2}
13. choose ∂t; t_0; update T, n_O, n_{N_2}, n_{O_2} over 24 hrs