Nitrate Radical Chemistry over the Sub-Arctic Pacific

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Motivation

- In mid-latitudes
  - nocturnal chemistry & physics strongly affect NO_x
  - NO_3, N_2O_5 form during the night
  - During daytime photolysis & NO efficiently destruct NO_3

Nighttime:

$NO_2 + O_3 \rightarrow NO_3 + O_2$

$N_2O_5 + M \rightarrow NO_3 + NO_2 + M$

$NO_2 + NO_3 \rightarrow N_2O_5$

Daytime:

$NO_3 + h\nu \rightarrow NO + O_2$

$NO_3 + h\nu \rightarrow NO_2 + O(^3P)$

$NO_3 + NO \rightarrow NO_2 + NO_2$

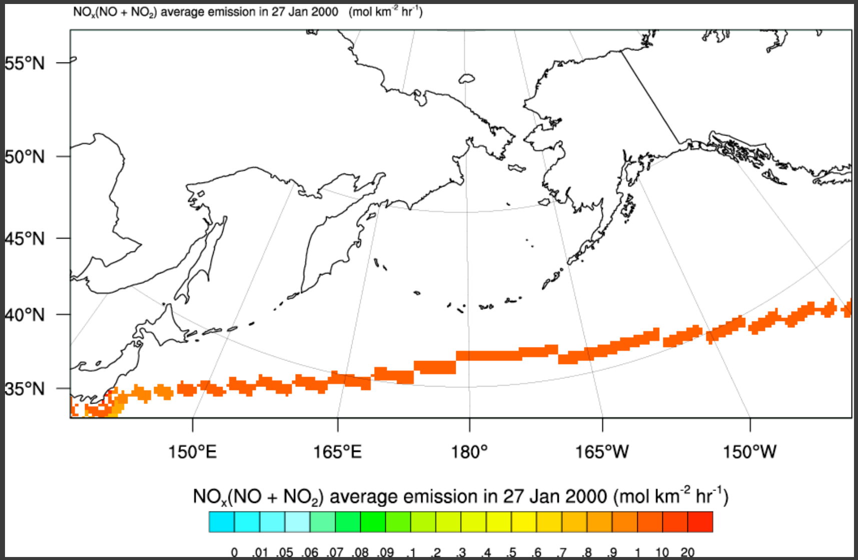
- In high latitudes, Dark Days & White Nights

Q: How does no to low insolation affect nitrate radical chemistry?

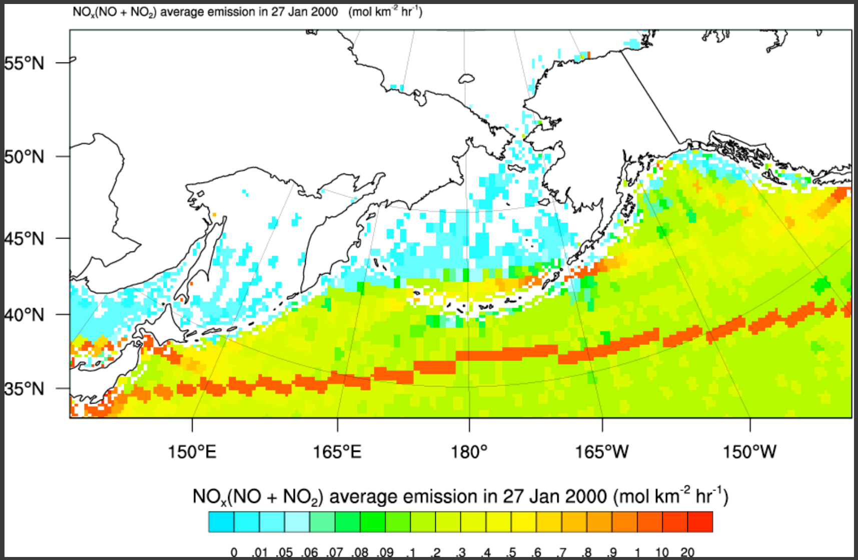
Experimental design

- WRF/Chem simulations over North Pacific for January 2000
- Model setup
  - horizontal grid increment of 30km, 27 vertical layers
  - Lin et al. (1983) cloud microphysical processes
  - Grell-Dévényi cumulus ensemble scheme
  - RRTM longwave, Goddard shortwave scheme
  - Mellor-Yamada-Janjic scheme
  - NOAH land-surface model
  - fractional sea-ice, sea-salt
  - RADM2 chemistry
  - Madronich photolysis rates,
  - MADE/SORGAM
  - Wesley's (1989) dry deposition module modified in accord with Zhang et al. (2003)
  - Modification of stomatal resistance
  - Alaska-typical vertical profiles of background concentrations (Mölders et al. 2010)
  - biogenic emissions calculated inline
- Global emission data

EDGAR and RETRO data have to be merged to include domestic shipping

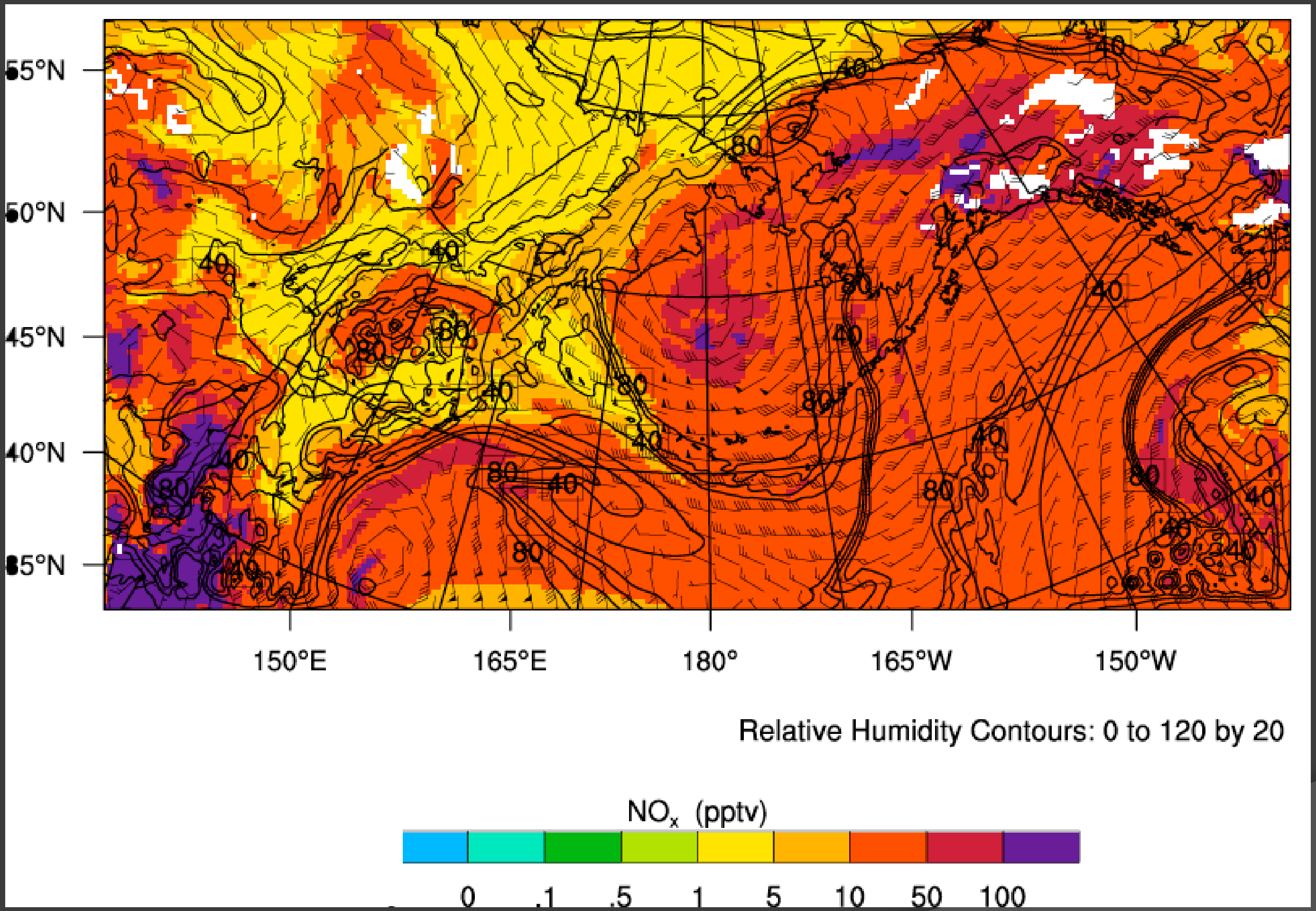


Average ship emission of NO_x for 1-27-2000 from international ship traffic derived from EDGAR

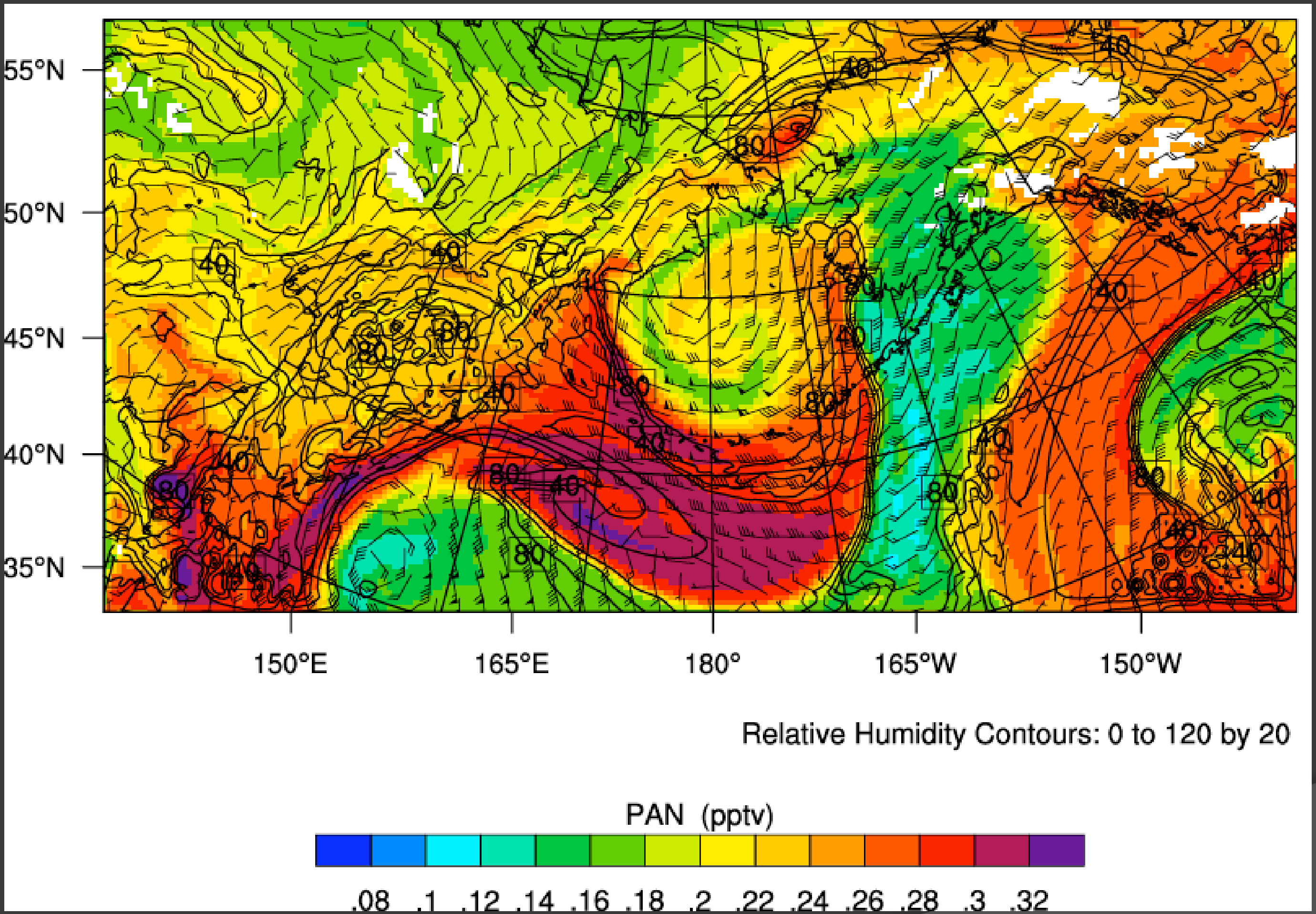


Average ship emission of NO_x for 1-27-2000 from international ship traffic as obtained from the combined EDGAR and RETRO data

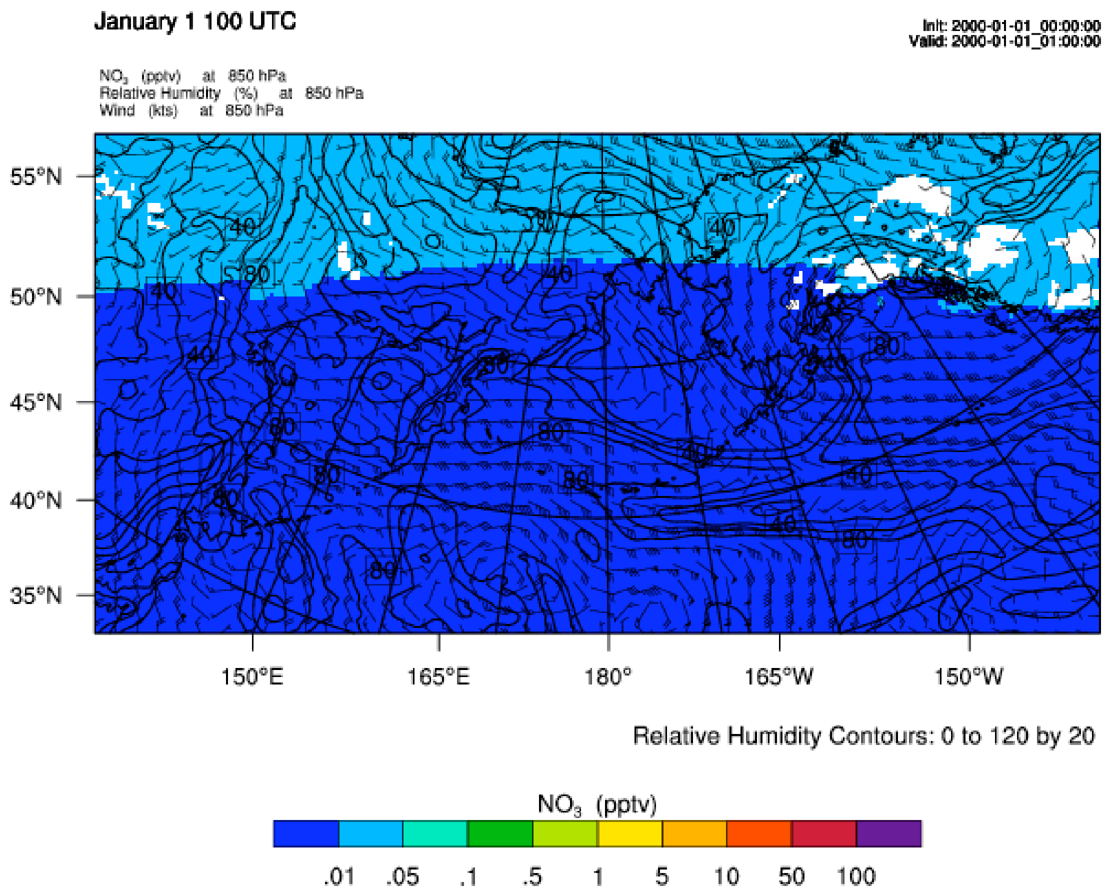
Cyclones transport pollutants from Asia & along sea routes into sub-Arctic Pacific



High PAN in cold air masses



Long nights affect nitrate radical chemistry

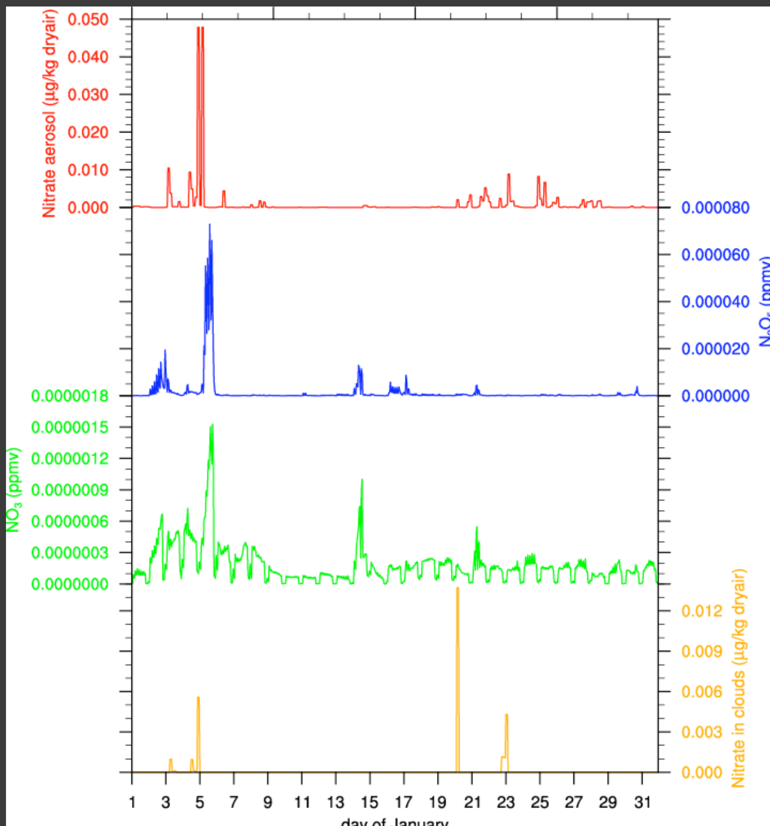


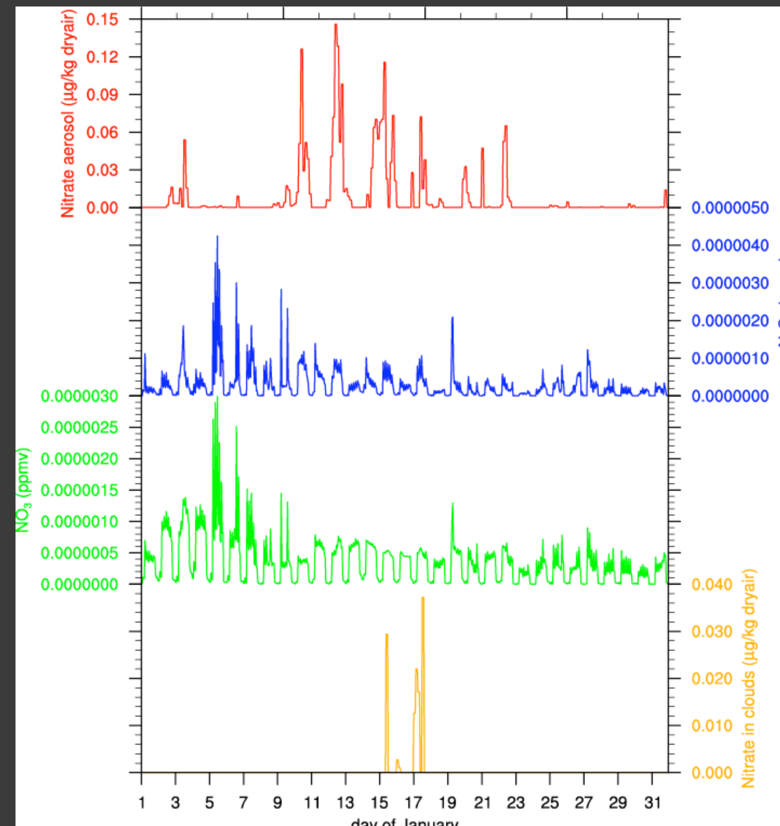
N_2O_5 plot similar, but onset of formation later, destruction earlier

Phase & amplitude of NO_3, N_2O_5 diurnal cycle depend on insolation duration & intensity

"Chemistry" differs from what happens in mid-latitudes

During Dark Days advection of polluted air governs NO_3, N_2O_5

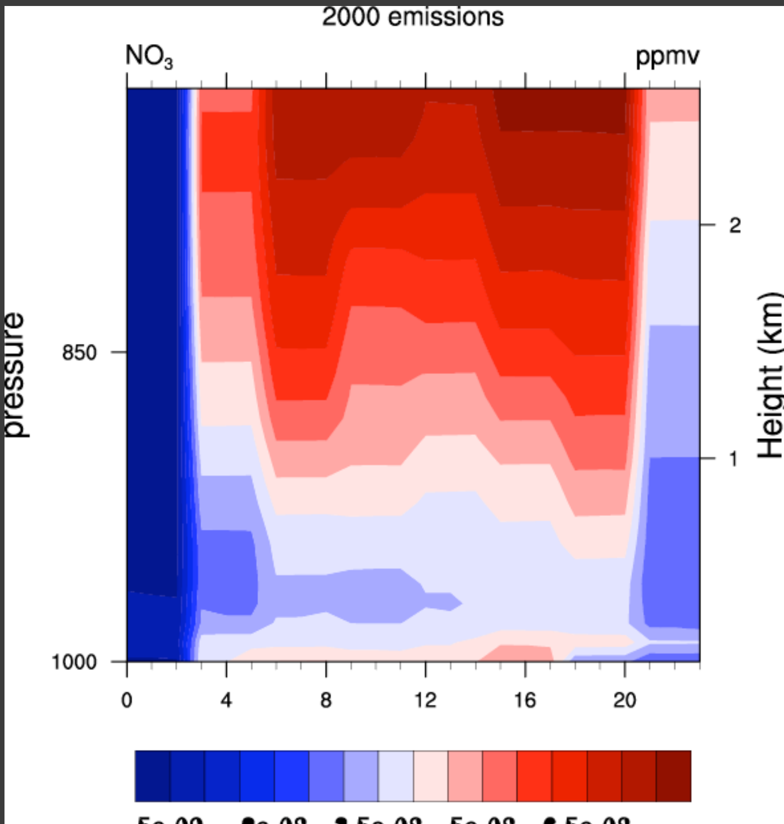




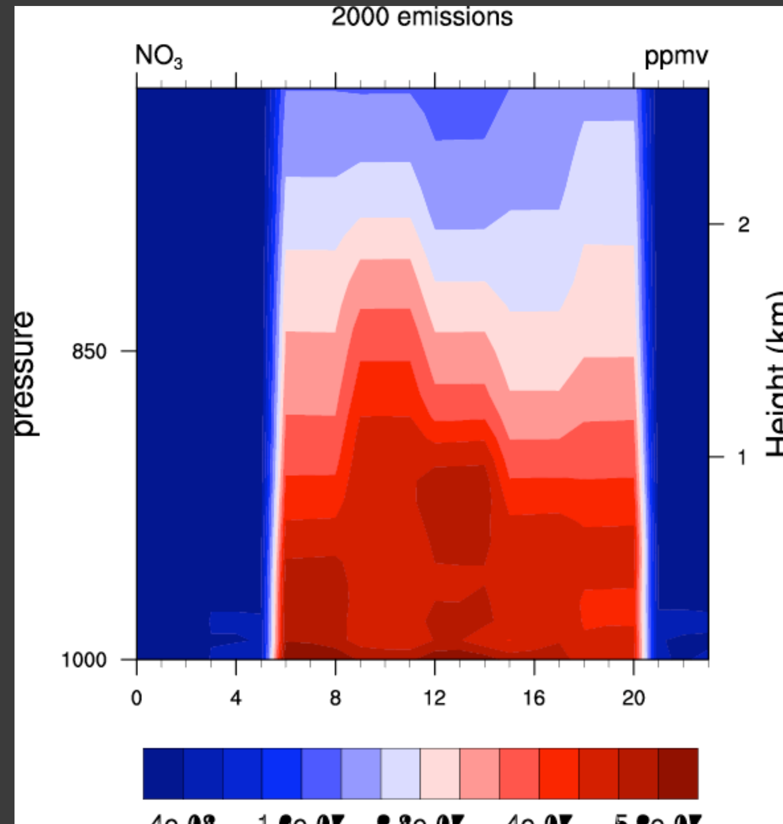
Time series near-surface NO_3, N_2O_5, nitrate aerosol and nitrate in clouds at 65.39N, 177.01E (Anadyer Gulf in Bering Sea).

Time series near-surface NO_3, N_2O_5, nitrate aerosol and nitrate in clouds at 47.96N, 177.32E (middle of North Pacific)

Average time-height NO_3 distribution differs for high, low latitudes

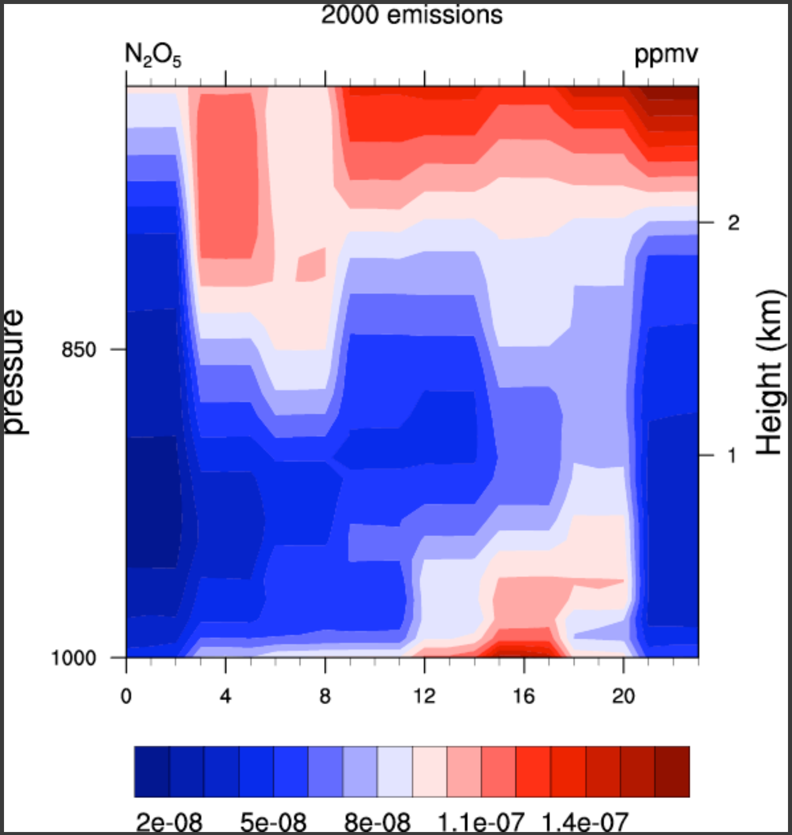


Diurnal cycle of monthly mean NO_3 at 65.39N, 177.01E (Anadyer Gulf in Bering Sea)

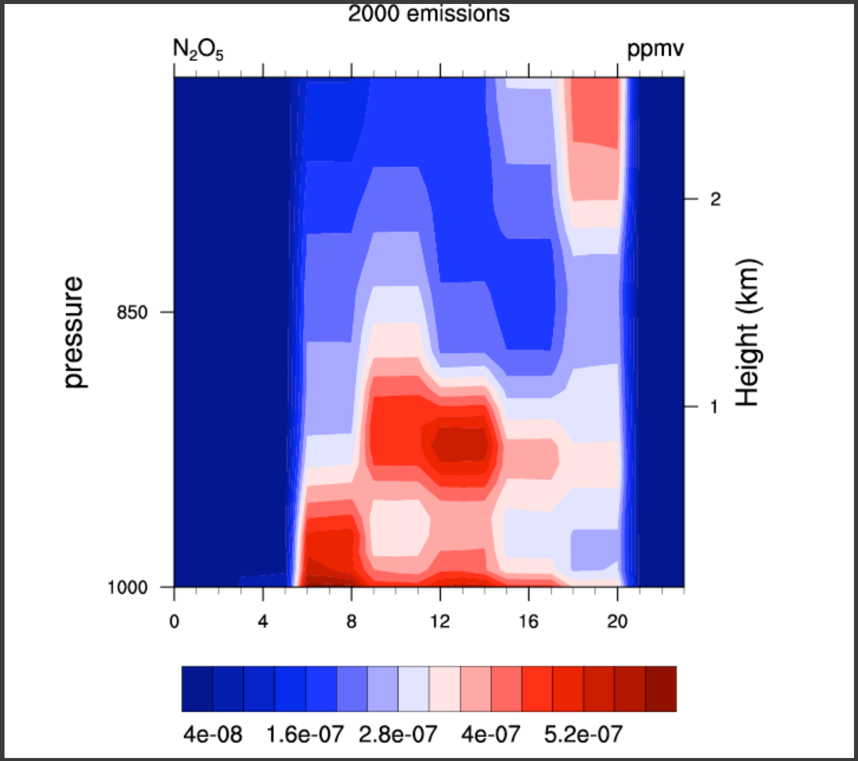


Diurnal cycle of monthly mean NO_3 at 47.96N, 177.32E (middle of North Pacific)

Average time-height N_2O_5 distribution differs for high, low latitudes

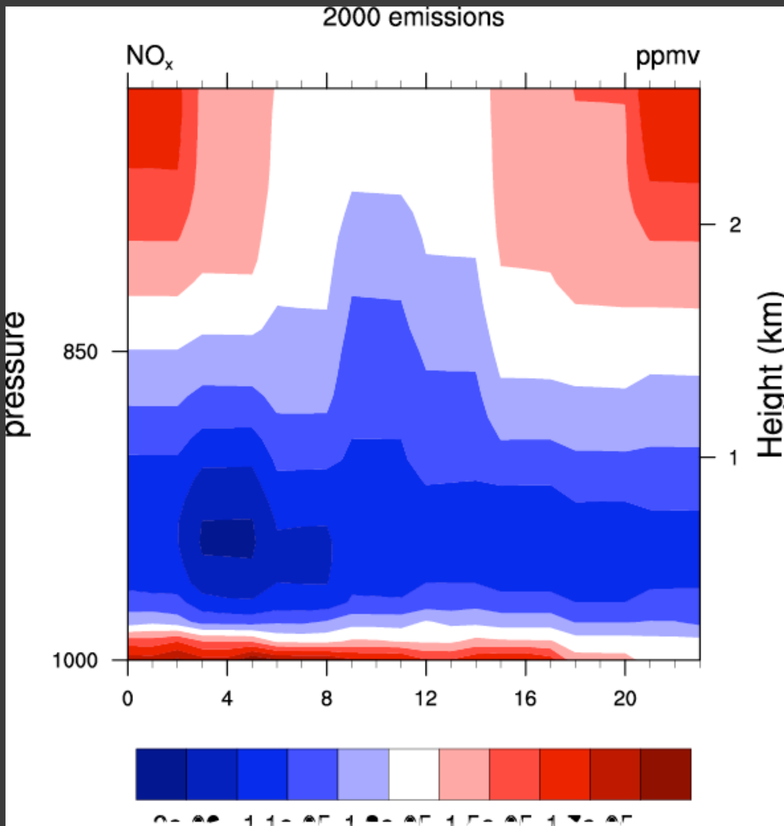


Diurnal cycle of monthly mean N_2O_5 at 65.39N, 177.01E (Anadyer Gulf in Bering Sea)

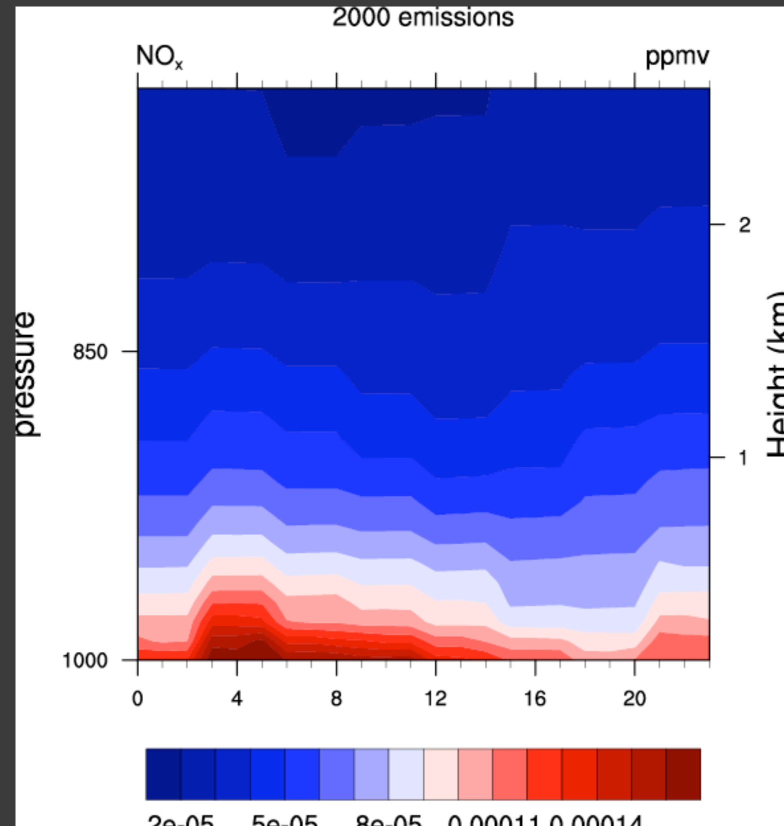


Diurnal cycle of monthly mean N_2O_5 at 47.96N, 177.32E (middle of North Pacific)

High NO_x distribution above top of ABL at high latitudes

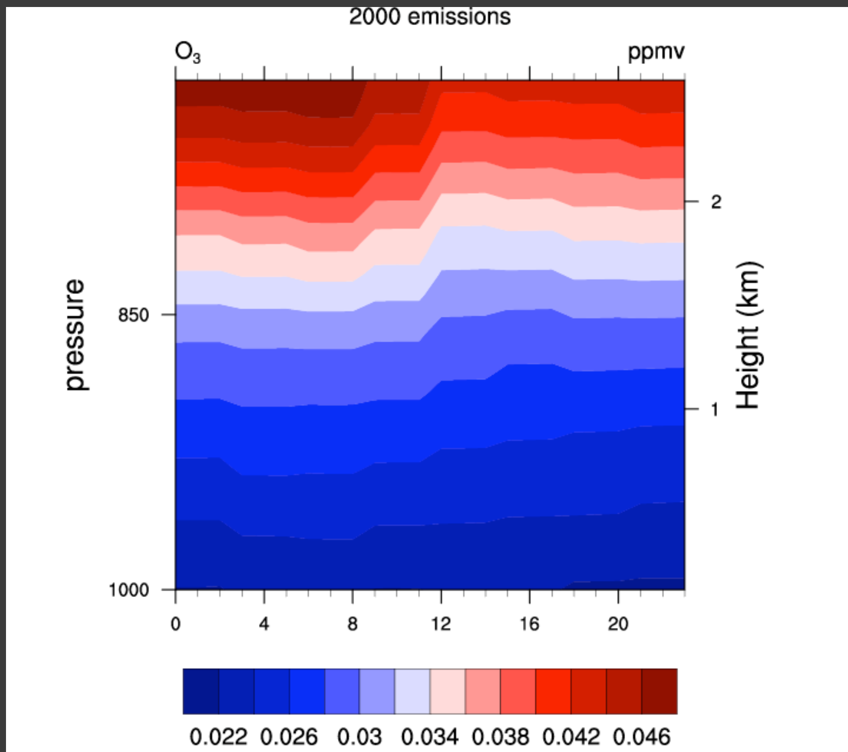


Diurnal cycle of monthly mean N_2O_5 at 65.39N, 177.01E (Anadyer Gulf in Bering Sea)

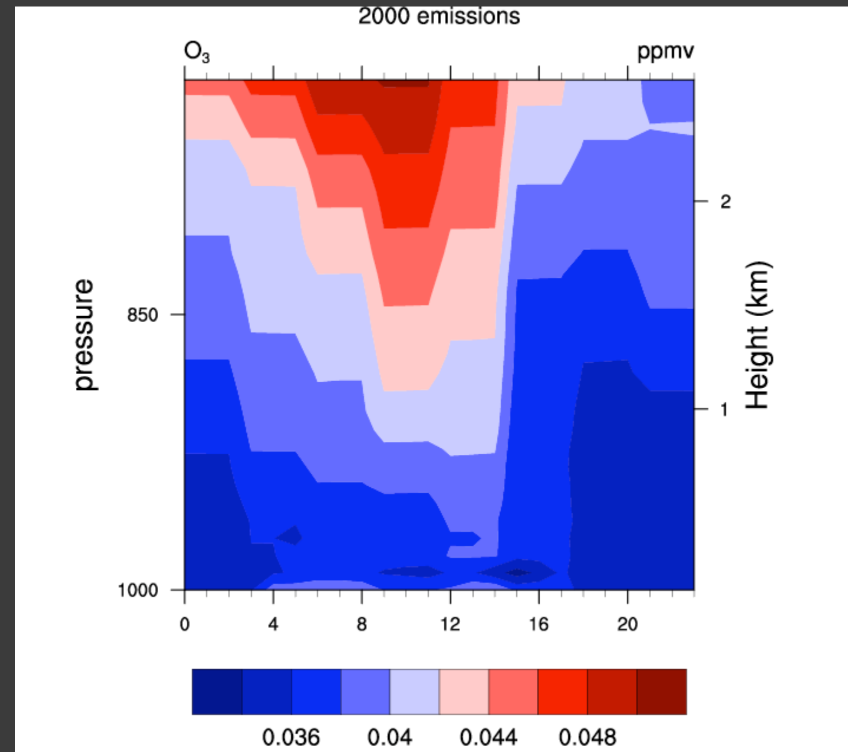


Diurnal cycle of monthly mean N_2O_5 at 47.96N, 177.32E (middle of North Pacific)

Hardly any diurnal cycle in O_3 distribution in ABL at high latitudes



Diurnal cycle of monthly mean N_2O_5 at 65.39N, 177.01E (Anadyer Gulf in Bering Sea)



Diurnal cycle of monthly mean N_2O_5 at 47.96N, 177.32E (middle of North Pacific)

Preliminary conclusions

- Cyclones take up pollutants from emissions in Asia & along international sea routes
- Cyclones transport pollution to the sub-Arctic Pacific & Alaska
- Secondary pollutants form during transport
- Long nights affect nitrate radical chemistry
  - As January progresses amplitude of diurnal NO_3 cycle slightly decreases on average