The Influence of Stratospheric Intrusions of Ozone on Surface Concentrations

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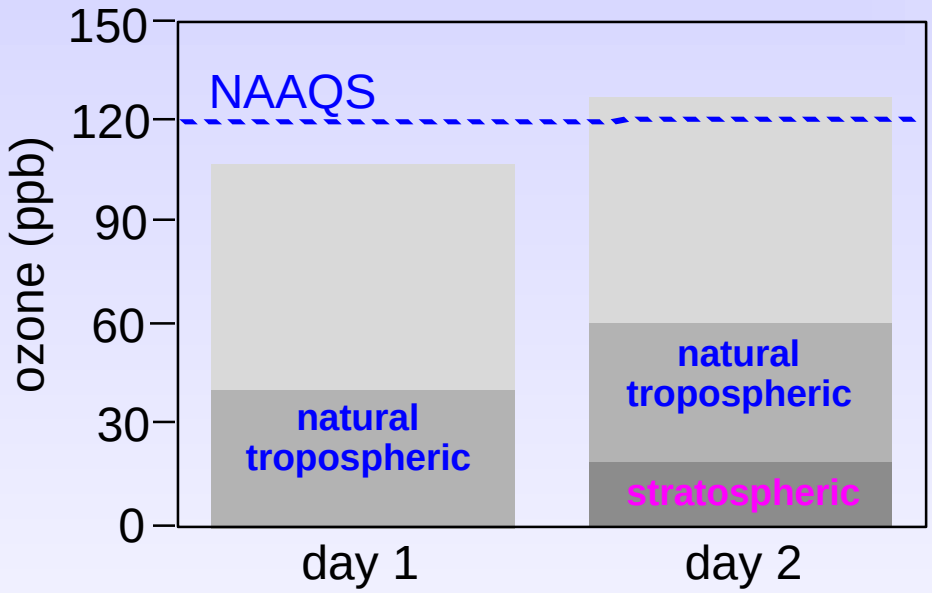
Hypothesis

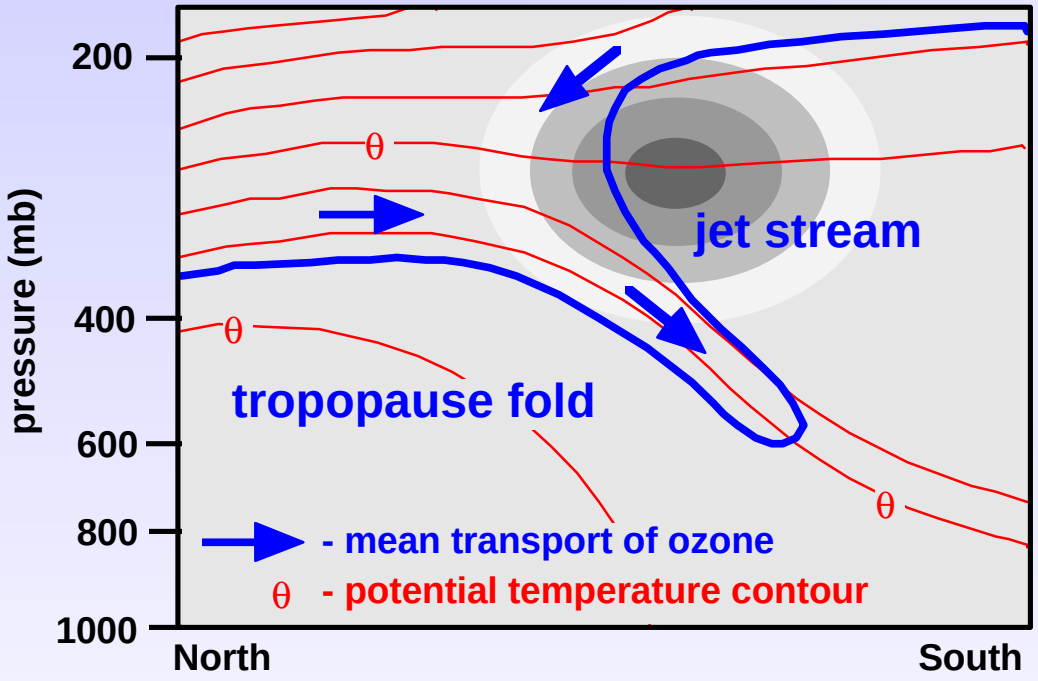
- ***variations of mid-tropospheric ozone resulting from stratospheric intrusions frequently contribute to high surface ozone concentrations that exceed the NAAQS for ozone***



Conceptual diagram depicting the impact of the introduction of **stratospheric** ozone on surface ozone concentrations, assuming that **anthropogenic** and **natural** ozone contributions remain the same from one day to the next.

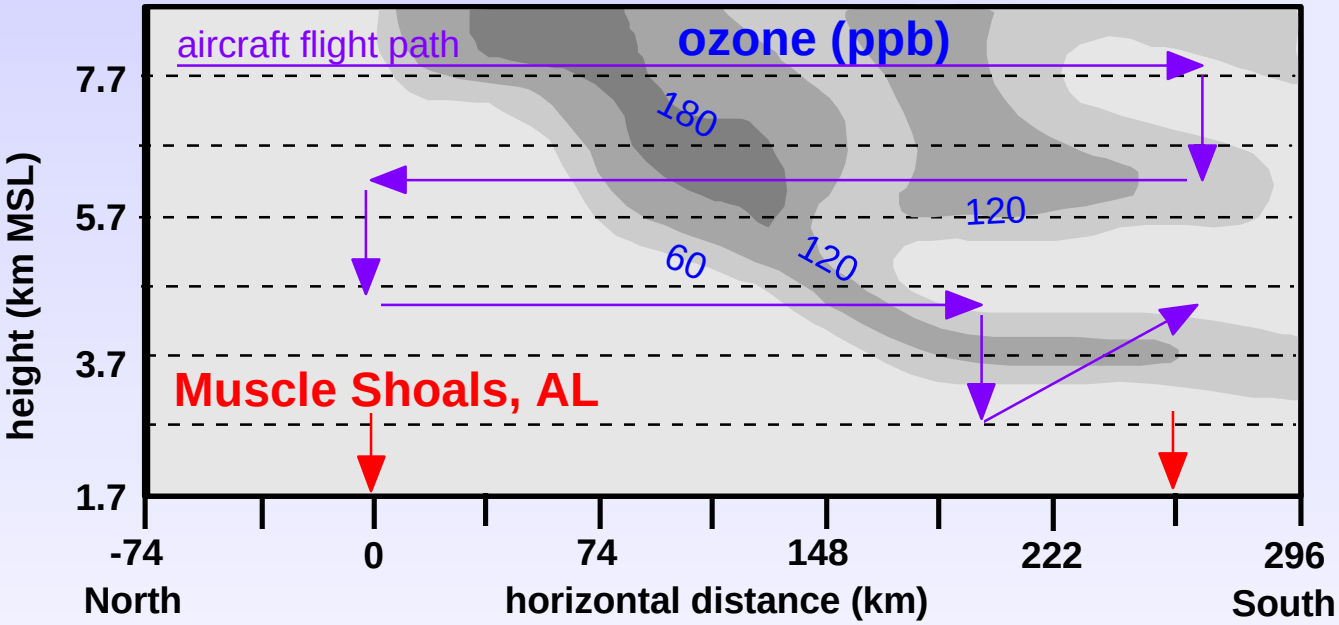
Stratospheric Intrusions of Ozone

- ***conceptual diagram of a tropopause fold and the associated transport of ozone from the stratosphere to the mid troposphere***



Observational Evidence

- ***concentration field based on aircraft measurements over the southern U.S. (Viezee et al. 1983)***
- ***other examples of stratospheric intrusions of ozone can be found in the literature***

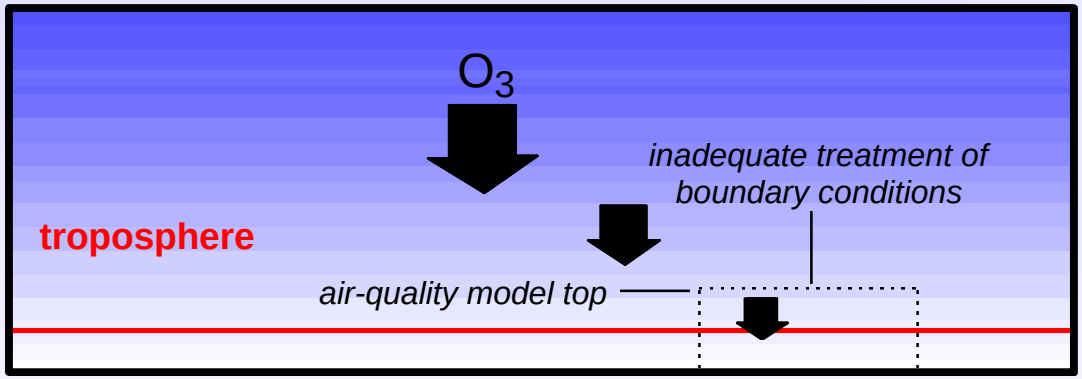


Principal Scientific Questions

- ***what are the combined synoptic, mesoscale, and boundary layer processes responsible for ozone transported and mixed into the lower troposphere?***
- ***what are the relative contributions of stratospheric and tropospheric sources of ozone to the observed surface ozone concentrations?***
- ***how frequently do stratospheric instrusions of ozone significantly increase ozone concentrations in the mid-troposphere and near the surface?***
- ***what regions are more likely to be affected by stratospheric intrusions of ozone?***

Relevance

- ***most air-quality modeling studies simply neglect the influence of stratospheric intrusions that may be responsible for regional variations in ozone concentrations near the surface***
- ***stratospheric intrusions of ozone may complicate emission control strategies***
- ***issue is of interest to NARSTO***



Approach

- ***data analyses*** ***of chemical and meteorological measurements needed to find evidence of the possible influence of stratospheric ozone at the surface***
- ***a series of photochemical*** ***modeling studies*** ***designed to simulate intrusions of stratospheric ozone and determine the relative contribution of ozone sources in the lower troposphere***

Approach: Data

- ***meteorological fields*** ***from the NCEP/NCAR reanalysis archives***
- ***total column ozone*** ***from satellite measurements***
- ***ozone profiles from ozonesonde measurements***
- ***surface ozone*** ***and ozone precursors from air-quality monitoring stations***

Existing observations will be used primarily, but we plan to take advantage of data collected by ACP field experiments in 1998 and 1999.

Approach: Data Analyses

- ***analyze potential vorticity (PV) fields from the NCEP/NCAR meteorological archives***
- ***correlate meteorological variables, including PV, with available ozone data***
- ***because stratospheric intrusions of ozone are episodic, obtain climatological information about their occurance***
- ***estimate average downward fluxes of ozone***
- ***identify stratospheric intrusions events for regional-scale model case studies***

Approach: Models

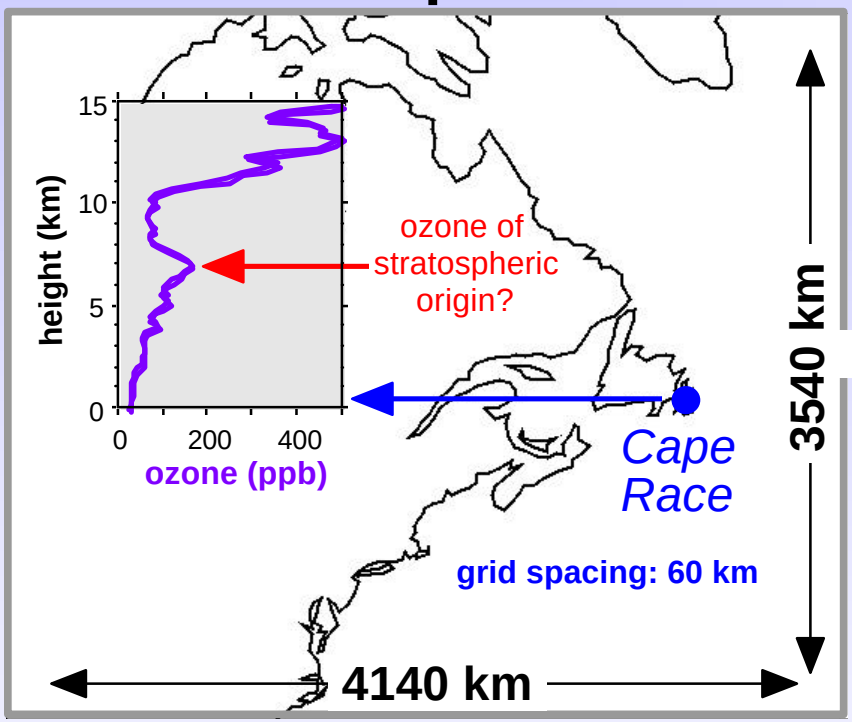
- ***Chemistry Model*** ***- a limited-area version of PNNL's Global Chemistry Model (GChM) is used to simulate stratospheric intrusions of ozone as well as the natural and anthropogenic production of ozone***
- ***Meteorological Model*** ***- a nested mesoscale model (RAMS) with four-dimensional data assimilation will be used to provide high spatial and temporal resolution meteorological fields***
- ***Lagrangian Particle Dispersion Model*** ***- a particle model will be used to compute the trajectories of air parcels originating in the stratosphere***

Approach: Modeling Studies

- ***modify GChM to include stratospheric chemistry***
- ***several cases will be examined, based on previous data reported in the literature or evidence of instrusions obtained from the data analyses***
- ***control simulations that include all processes***
- ***sensitivity simulations that either systematically eliminate air chemistry processes or modify initial and lateral boundary conditions***

Preliminary Case Study

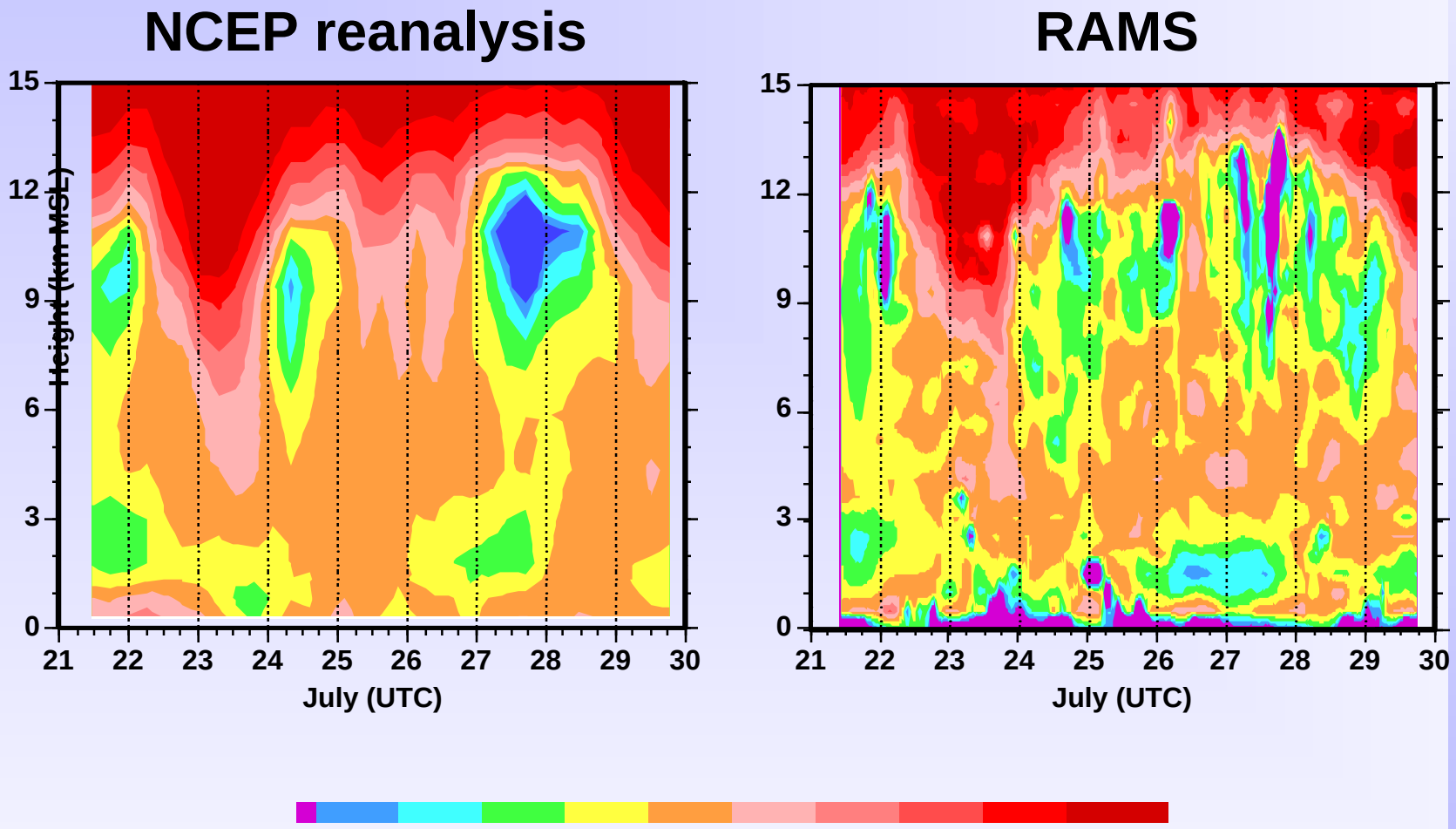
GChM / RAMS domain and model parameters



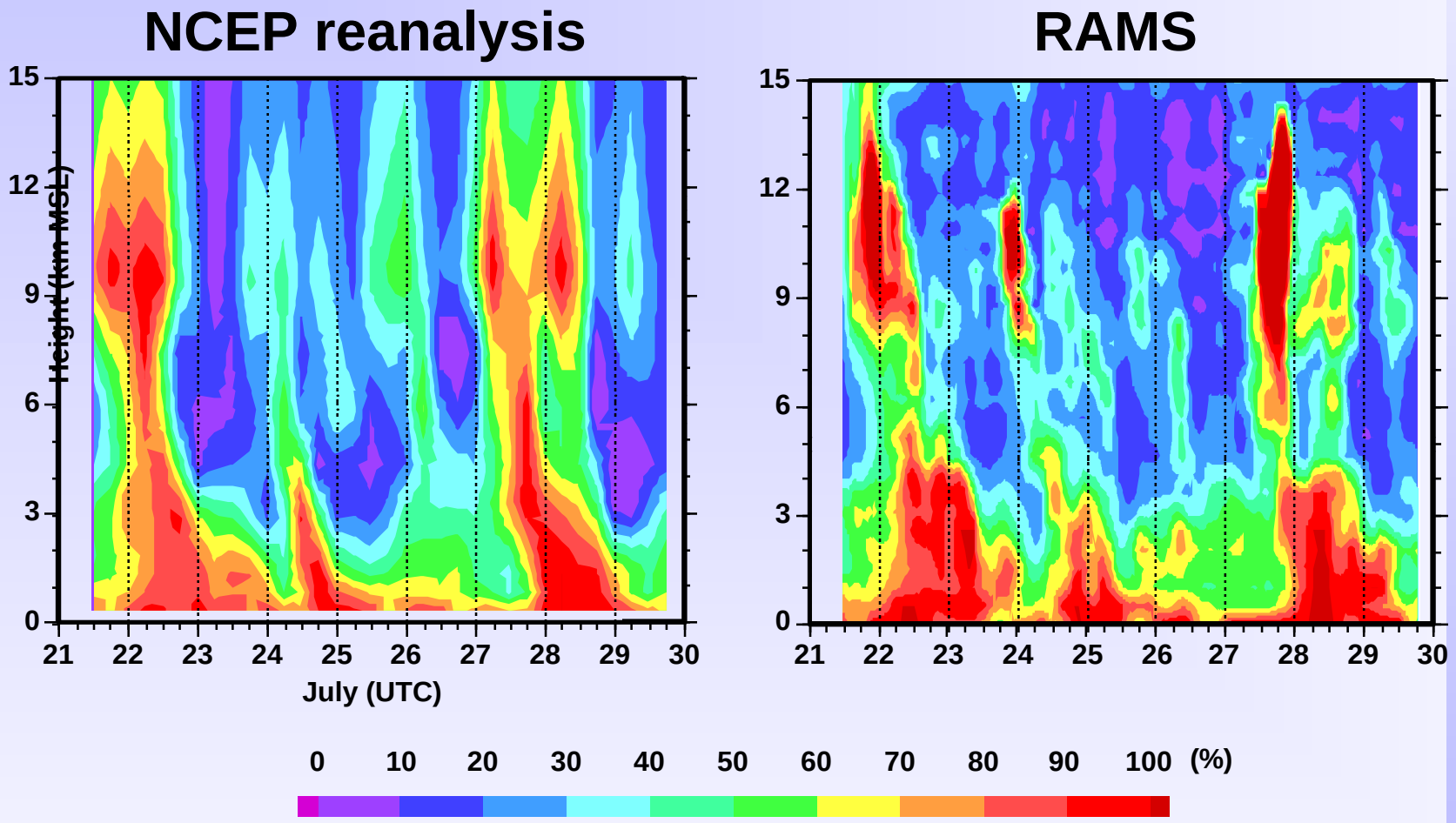
simulation period: 12 UTC July 21 - 18 UTC July 30

- ***ozonesonde data between 22 July and 4 August, 1991 over Cape Race, Newfoundland suggest that stratospheric intrusions of ozone occurred***
- ***GChM currently run with chemical production and emissions turned off to examine transport only***
- ***predicted ozone compared with observations***
- ***model results used to examine meteorological mechanisms associated with the intrusions***

Potential Vorticity over Cape Race



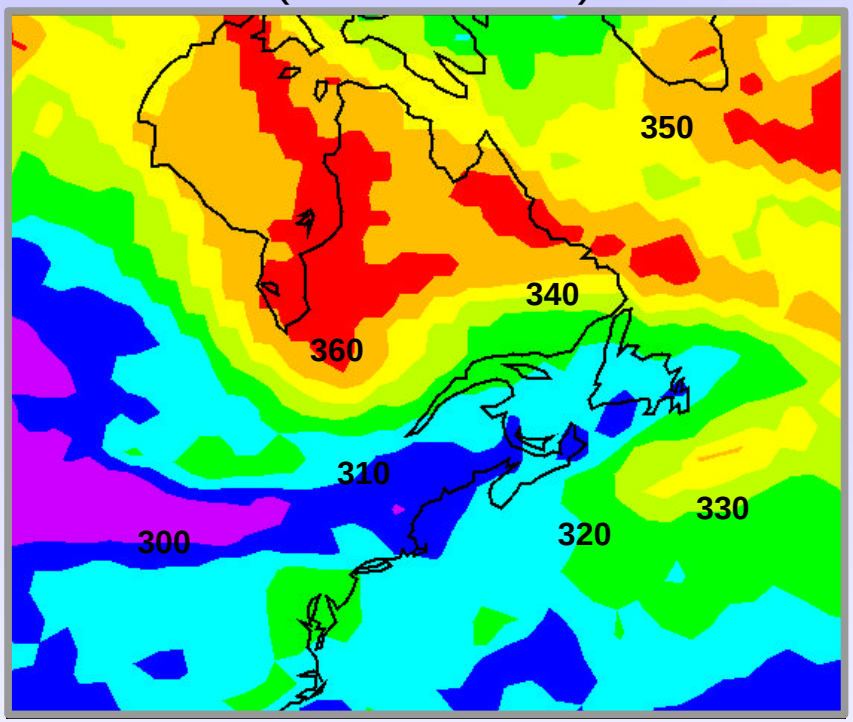
Relative Humidity over Cape Race



Total Ozone on 21 July 1991

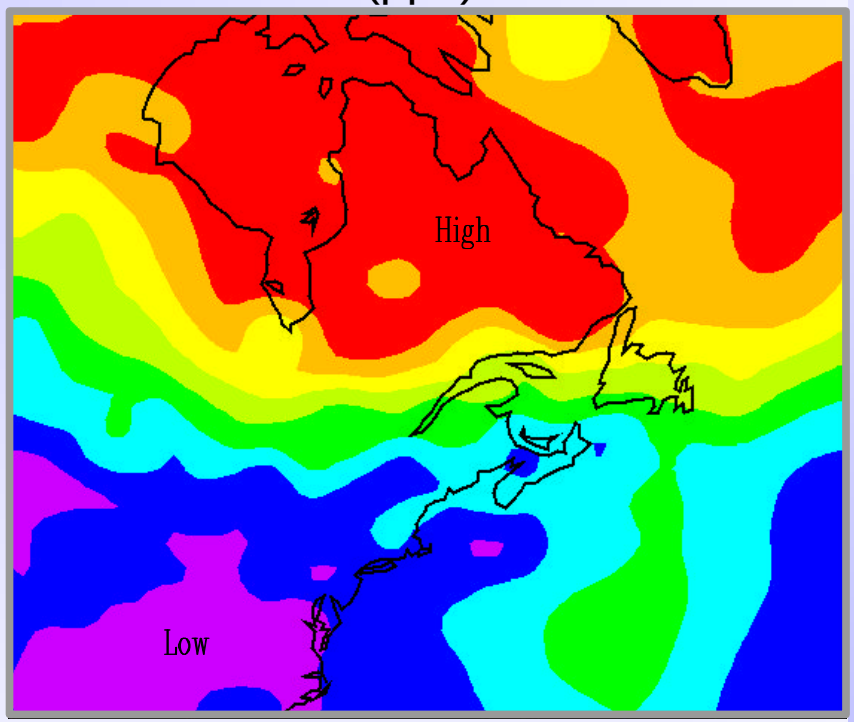
Observed TOMS Ozone

(Dobson Units)



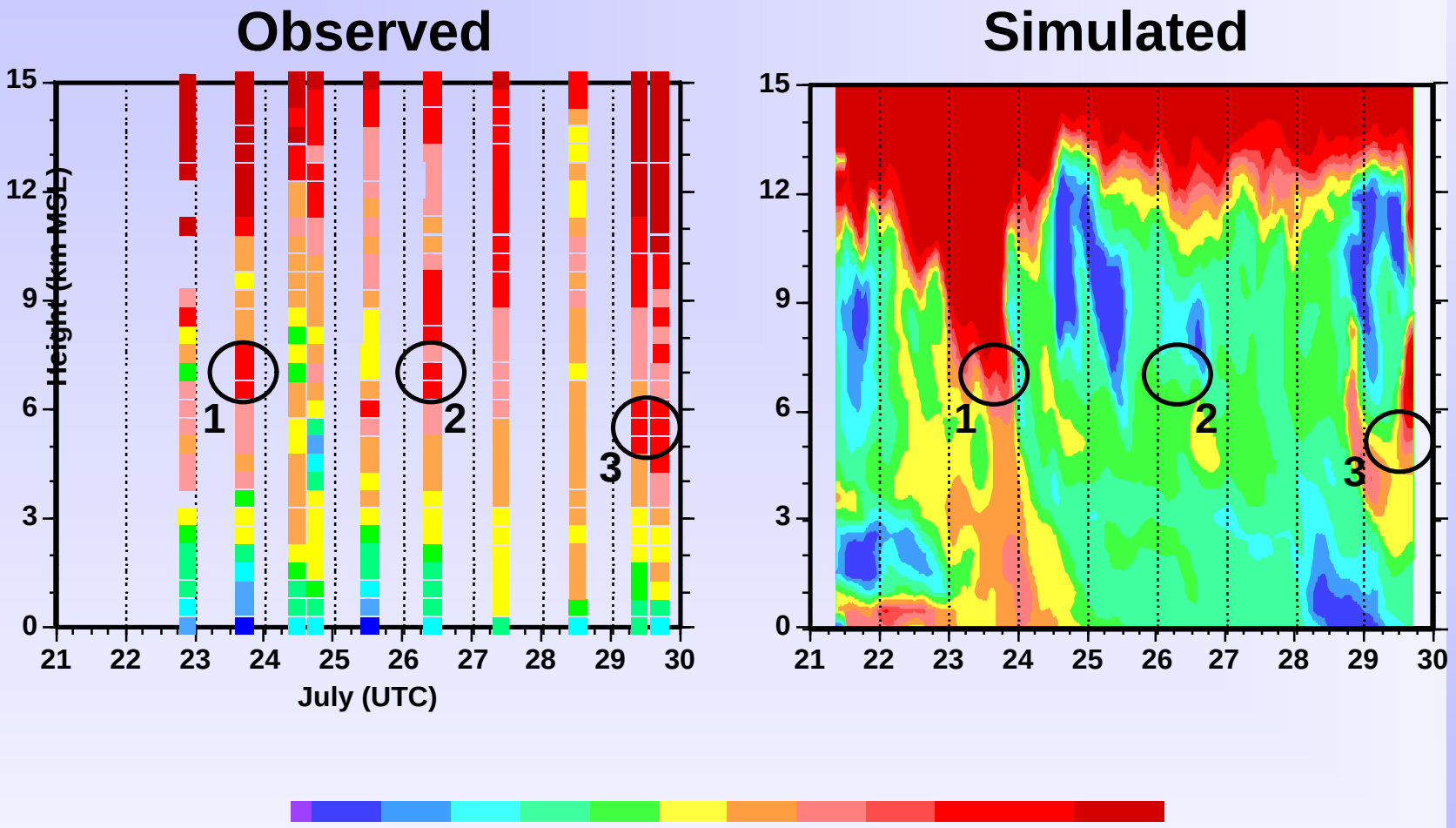
Derived Ozone

(ppb)



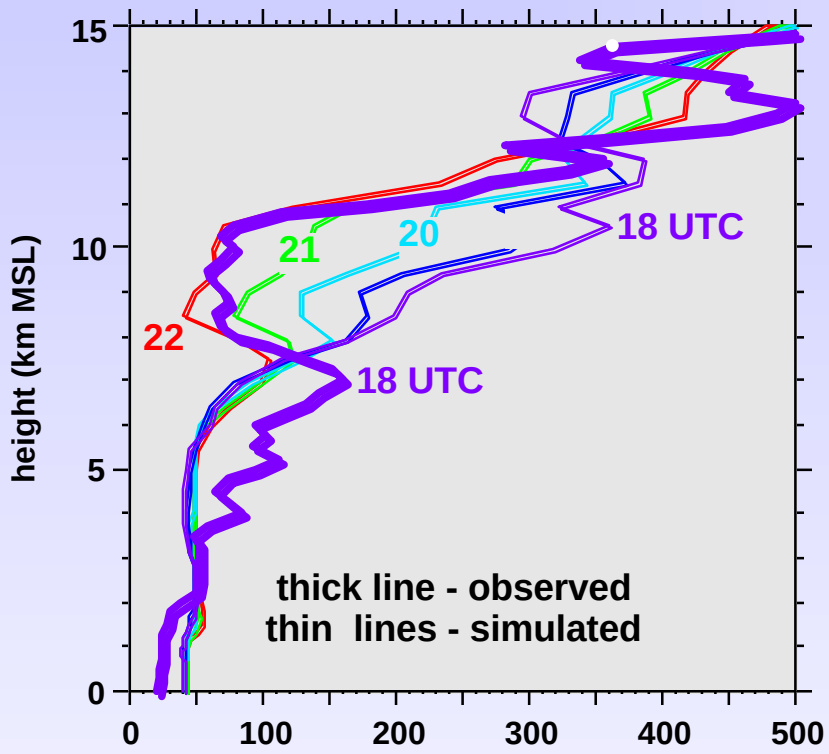
- based on NCEP PV fields at 12 UTC
- initial conditions employed by GChM

Ozone Profiles over Cape Race



Ozone Profiles on 23 July 1991

Observed and Simulated

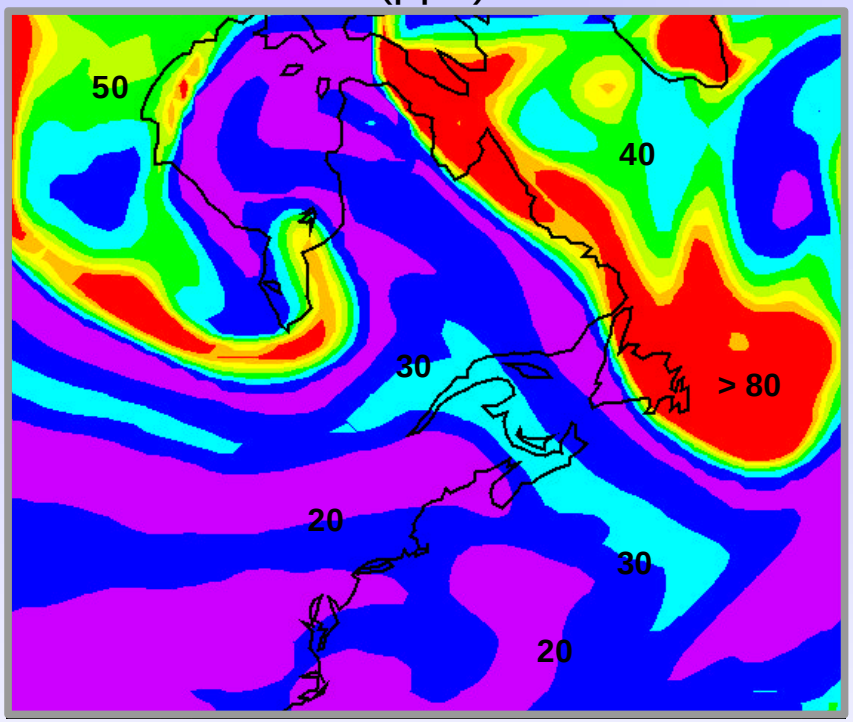


- *simulated ozone profiles are **instantaneous values** obtained at the grid point closest to Cape Race, Newfoundland*
- *simulated ozone profiles at **21 and 22 UTC** in better agrement with the observed profile*
- *simulated peak ozone mixing ratio at **7.5 km** at about the same height as observed peak*
- ***large temporal variation** in ozone due to the passage of the stratospheric intrusion*

Ozone and PV on 23 July 1991

Ozone Mixing Ratio

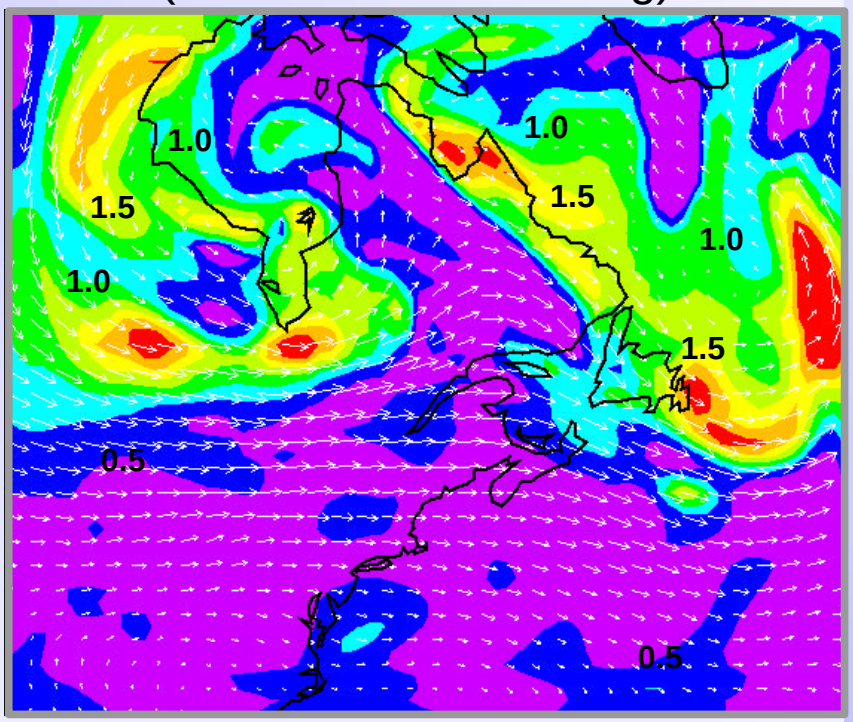
(ppb)



at 18 UTC and ~ 8 km MSL

Potential Vorticity

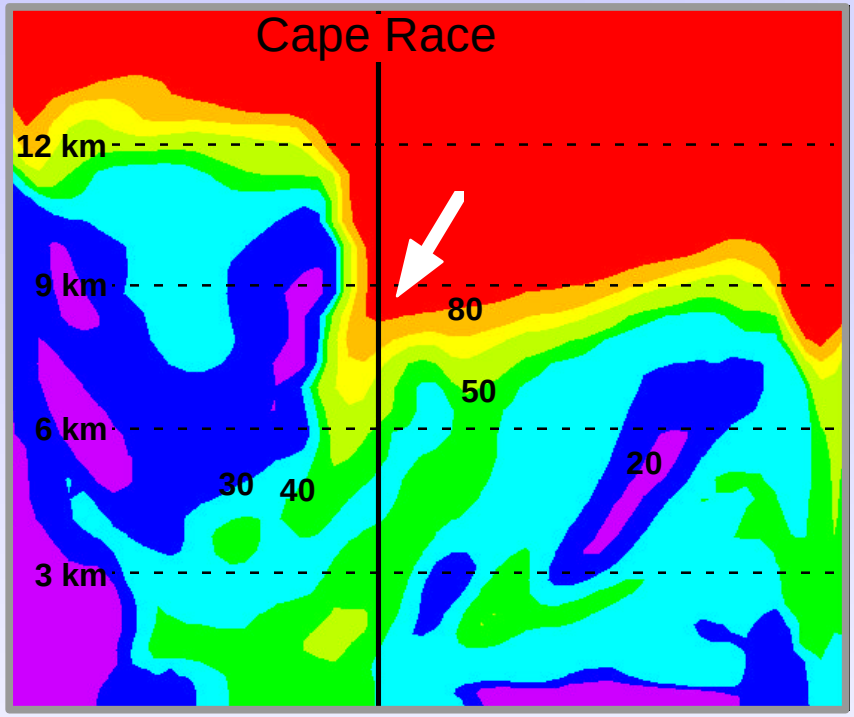
(PVU = 10^{-6} m^2 s^{-1} K kg)



at 18 UTC and ~ 8 km MSL

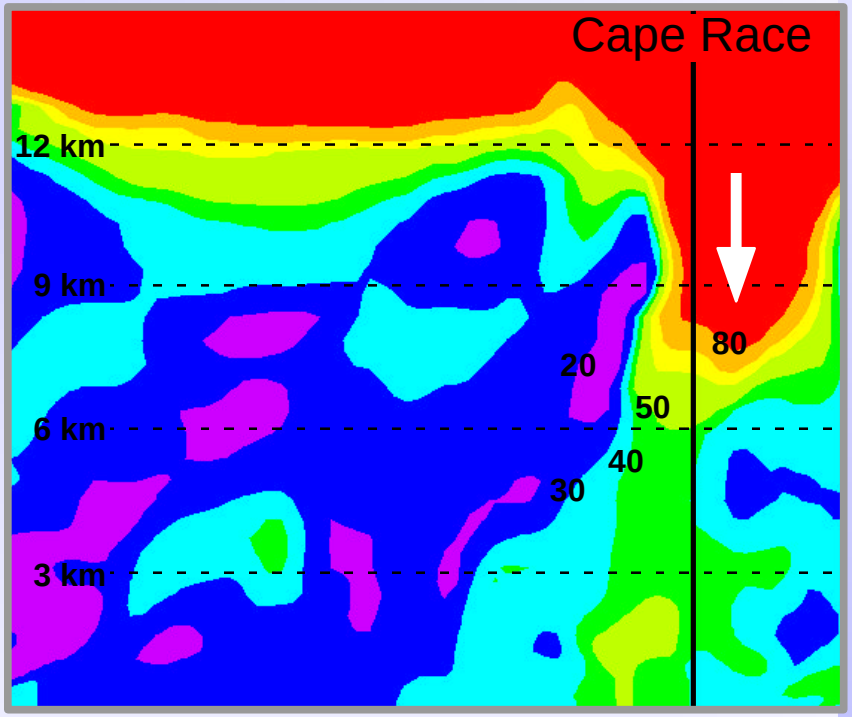
Intrusion Event 1 - 18 UTC 23 July

Ozone Mixing Ratio
(ppb)



South North

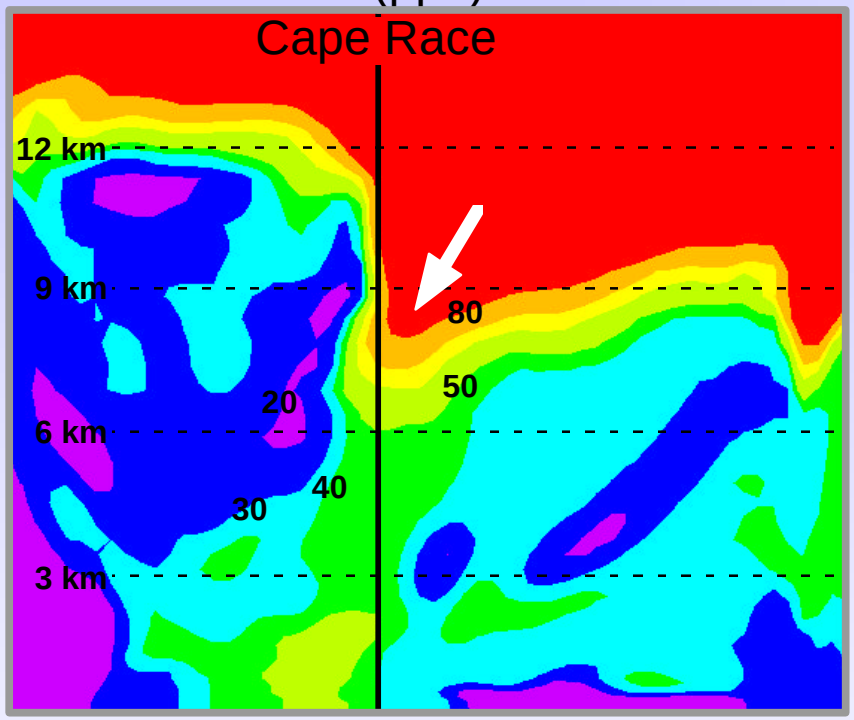
Ozone Mixing Ratio
(ppb)



West East

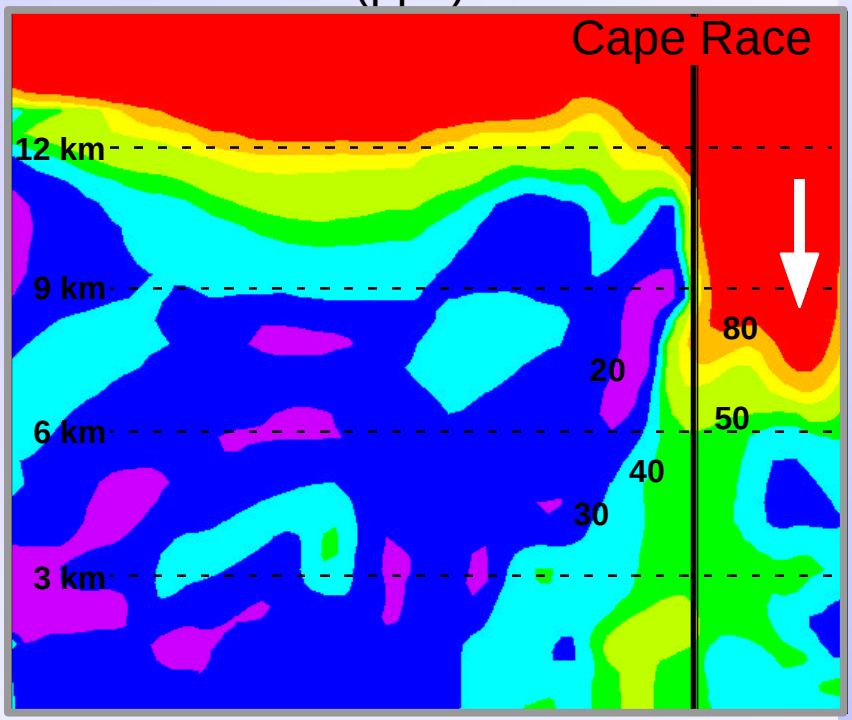
Intrusion Event 1 - 21 UTC 23 July

Ozone Mixing Ratio
(ppb)



South North

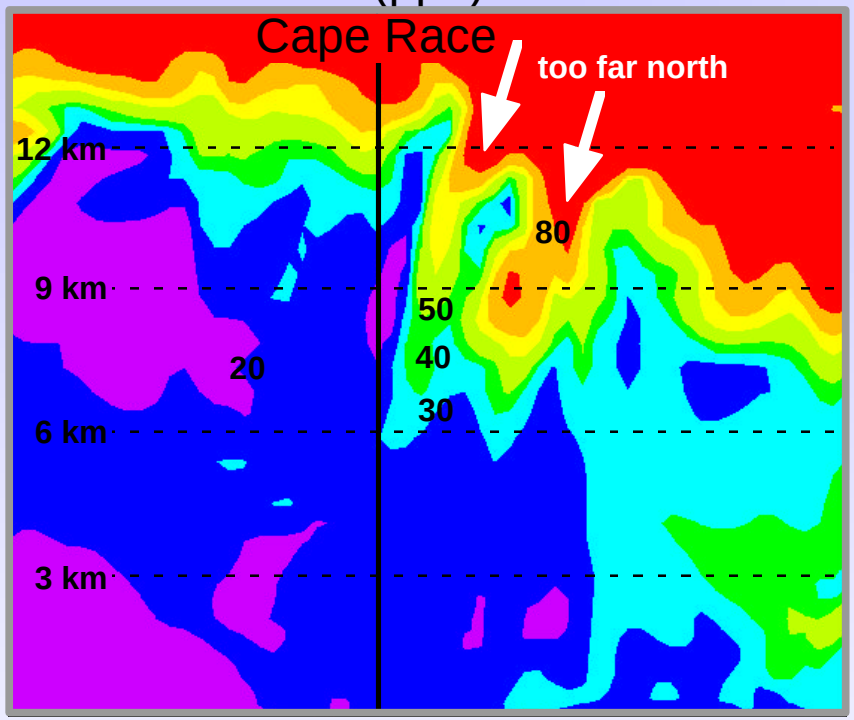
Ozone Mixing Ratio
(ppb)



West East

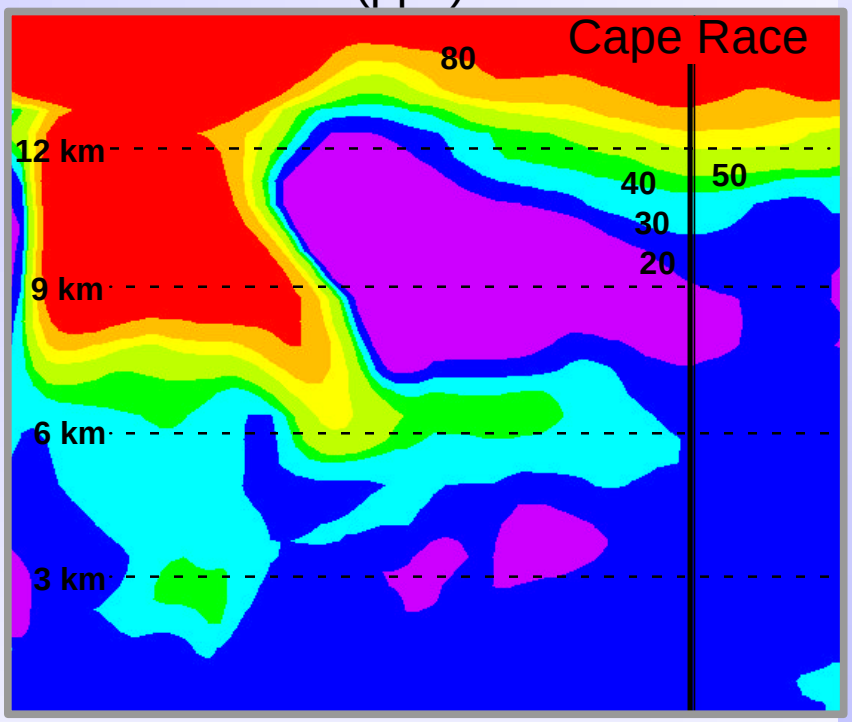
Intrusion Event 2 - 12 UTC 26 July

Ozone Mixing Ratio
(ppb)



South North

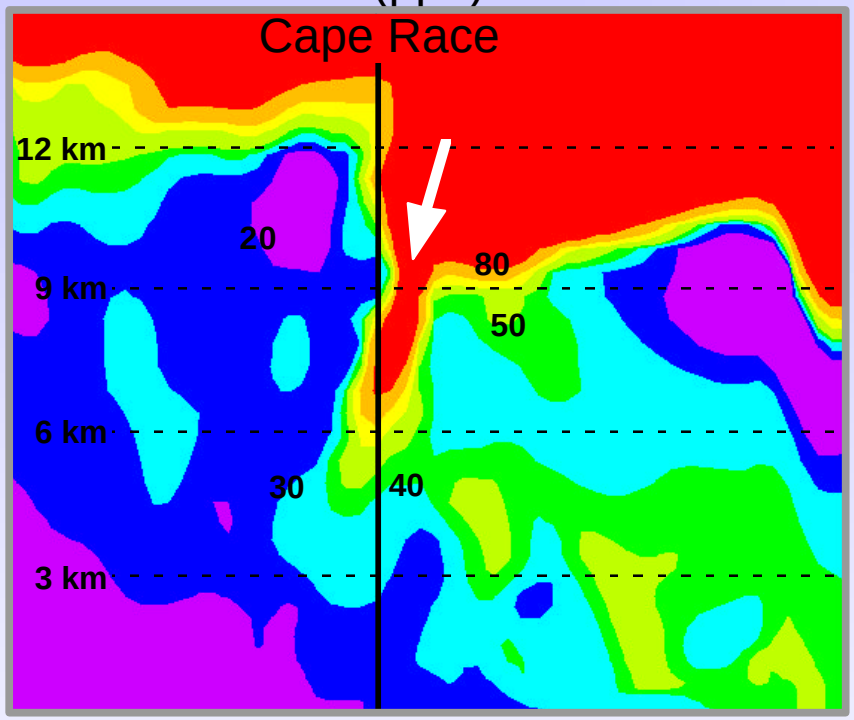
Ozone Mixing Ratio
(ppb)



West East

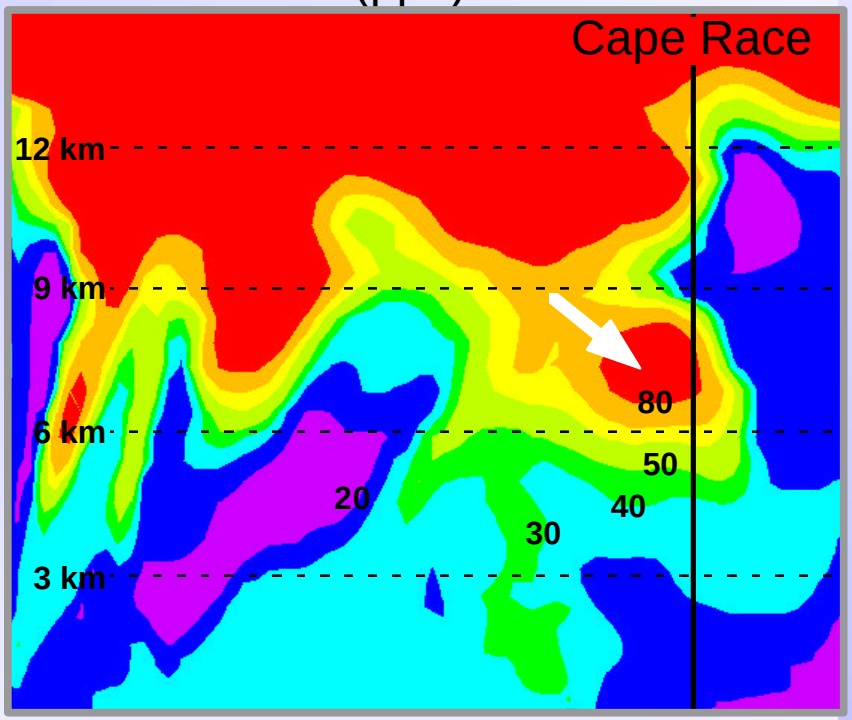
Intrusion Event 3 - 18 UTC 29 July

Ozone Mixing Ratio
(ppb)



South North

Ozone Mixing Ratio
(ppb)

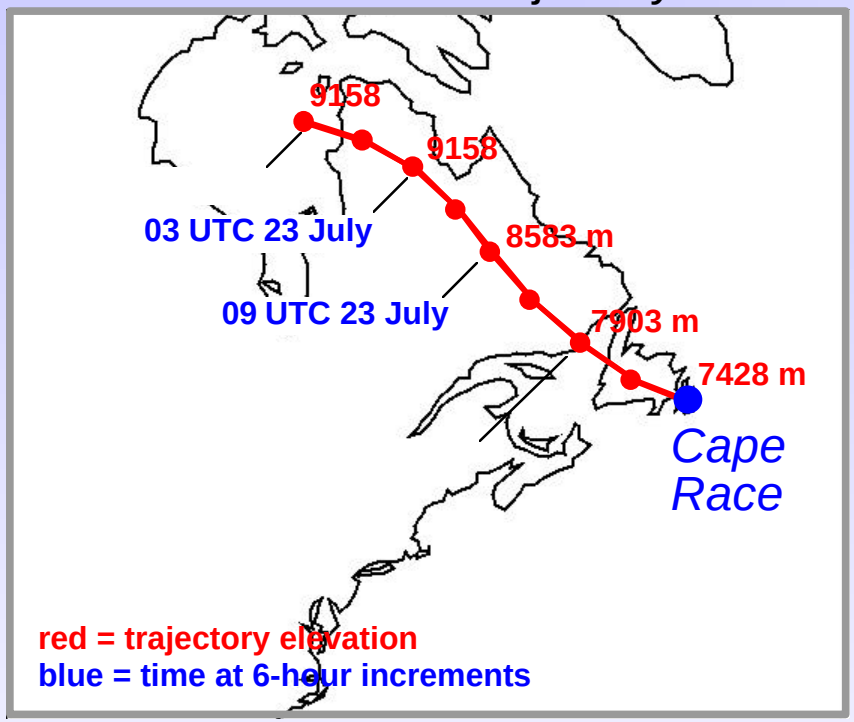


West East

Trajectories

Intrusion Event 1

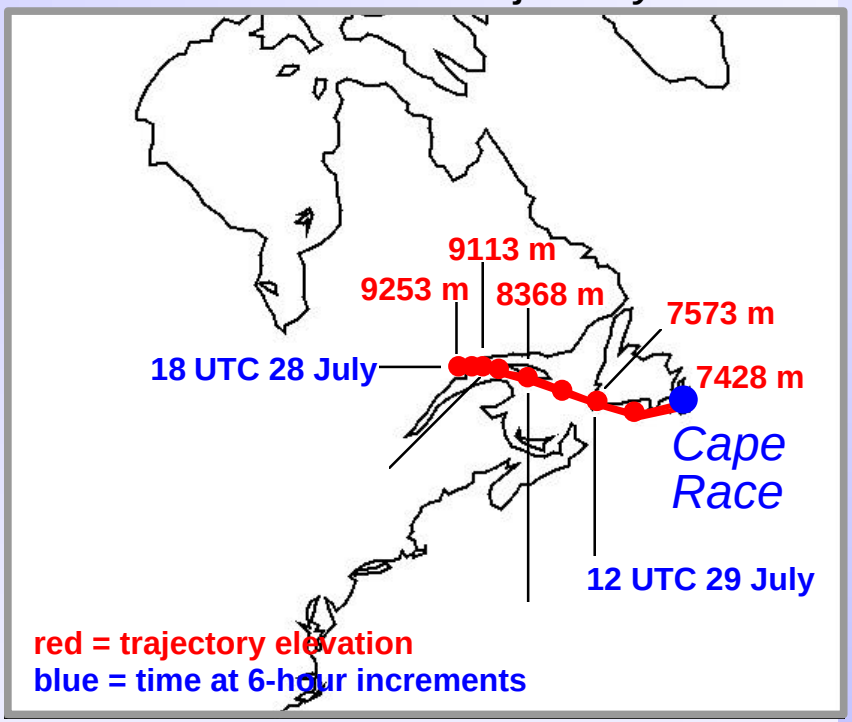
24-hour back trajectory



21 UTC 23 July

Intrusion Event 3

24-hour back trajectory



18 UTC 29 July

Summary of Preliminary Case Study

- ***encouraging results obtained - the GChM / RAMS modeling system results suggest that peak ozone concentrations in the mid-troposphere over Cape Race are due to stratospheric intrusions of ozone***
- ***differences between observed and simulated ozone profiles suggest some improvements are necessary before applying the model to other cases***
- ***differences may be due to horizontal resolution, initial conditions, and lateral boundary conditions***
- ***four-dimensional data assimilation will be employed to reduce errors associated with transport***