Atmosphere-based estimates of non-CO_2 greenhouse gas emissions for the U.S. derived from $^{14}CO_2$.

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Conclusions:

* Advances in ***high precision ^{14}C measurements*** from small volume samples *and*
* Development of a ***U.S-wide automated flask sampling network*** are enabling
* ***Nationally-representative emission estimates*** for a range of trace gases affecting climate, stratospheric ozone, & air quality over
* ***Inter-annual periods*** with ***multiple independent methods***

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4. Earth System Science, U of California, Irvine, USA; 5. GNS, Lower Hutt, New Zealand
6. LLNL, Livermore, USA; 7. LBNL, Berkeley, USA

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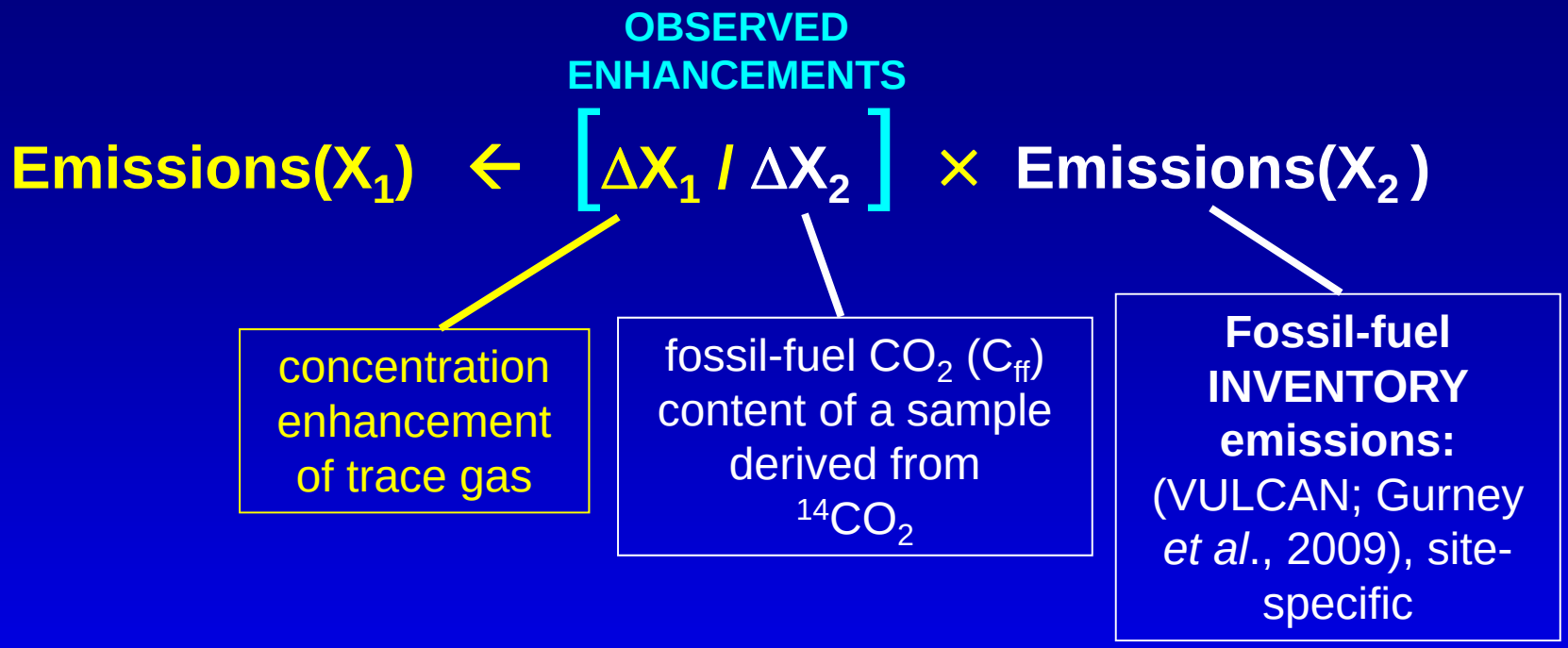
Exploiting measured trace-gas concentration enhancements to derive rates of emissions:



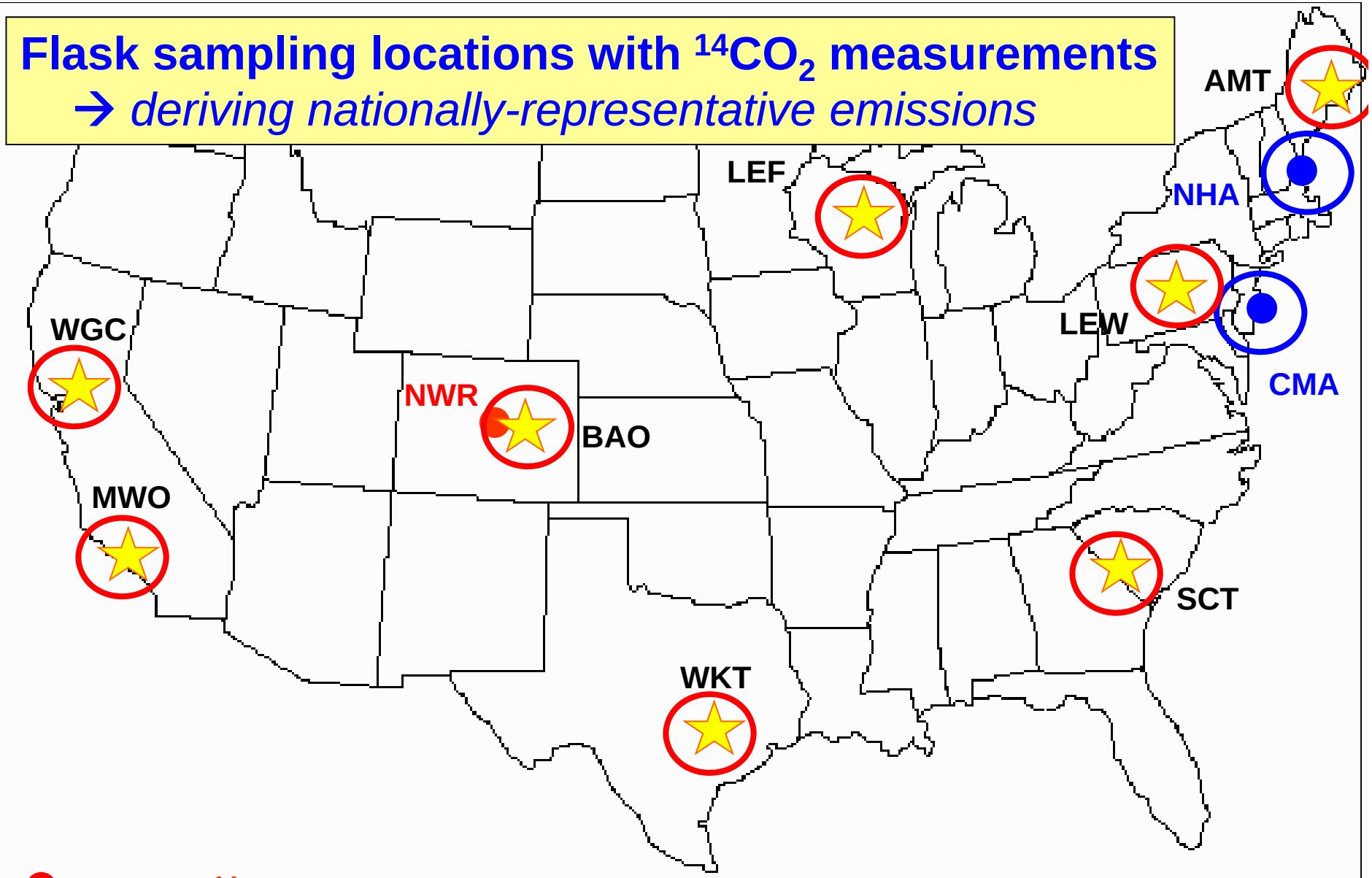
Precise measurements of ^{14}C allow use of an accurate inventory

General considerations:

- *** Co-location and covariation of sources required**
- *** Accurately determined background concentrations**

Flask sampling locations with $^{14}CO_2$ measurements

→ *deriving nationally-representative emissions*



- Weekly $^{14}CO_2$ samples at NWR (since 2003)
- Tall tower flasks; was 120 $^{14}CO_2$ samples/yr/site in 2010; half that in 2012
- Aircraft profile flasks; typically 100-160 $^{14}CO_2$ samples/yr/site

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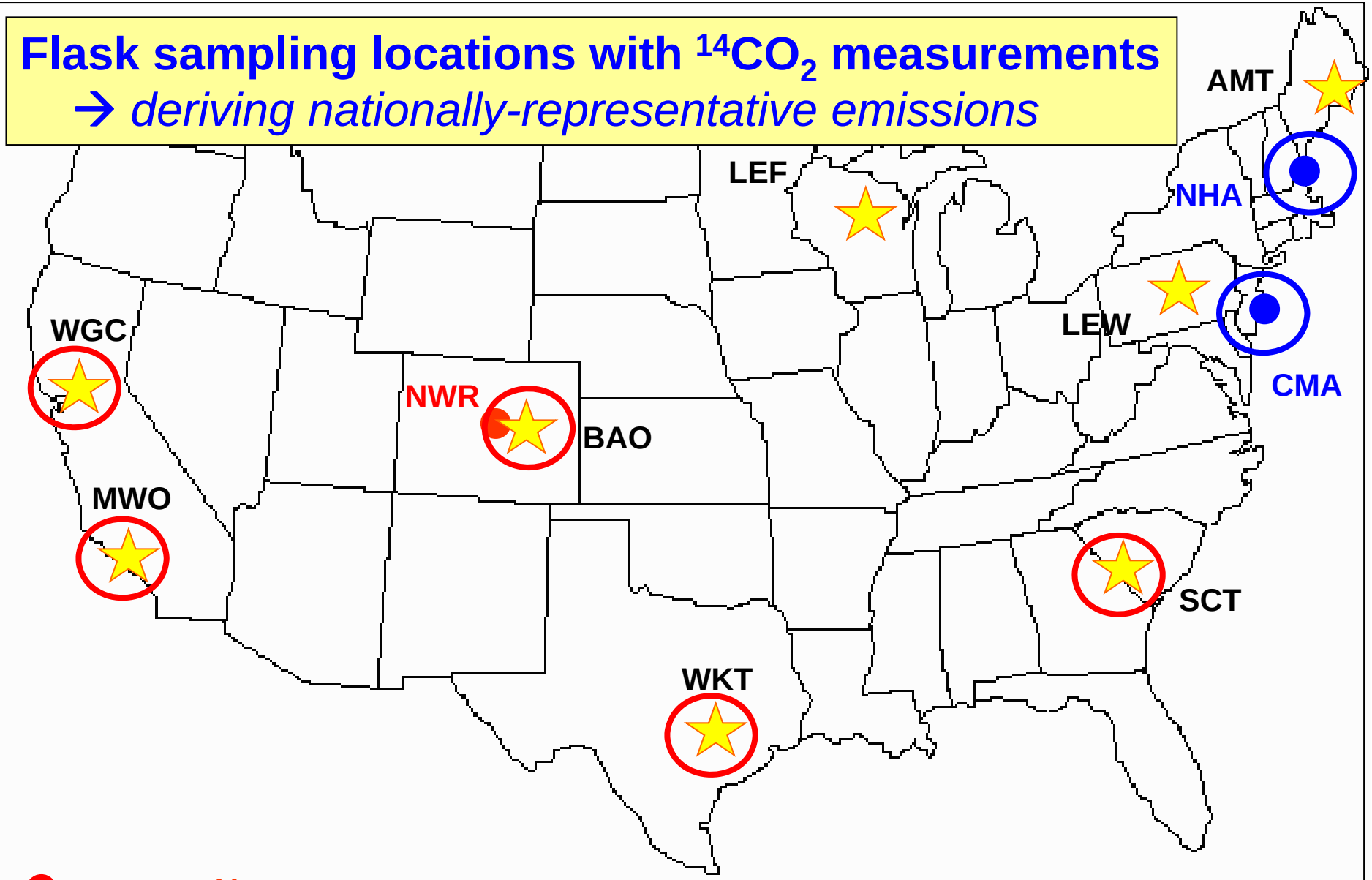

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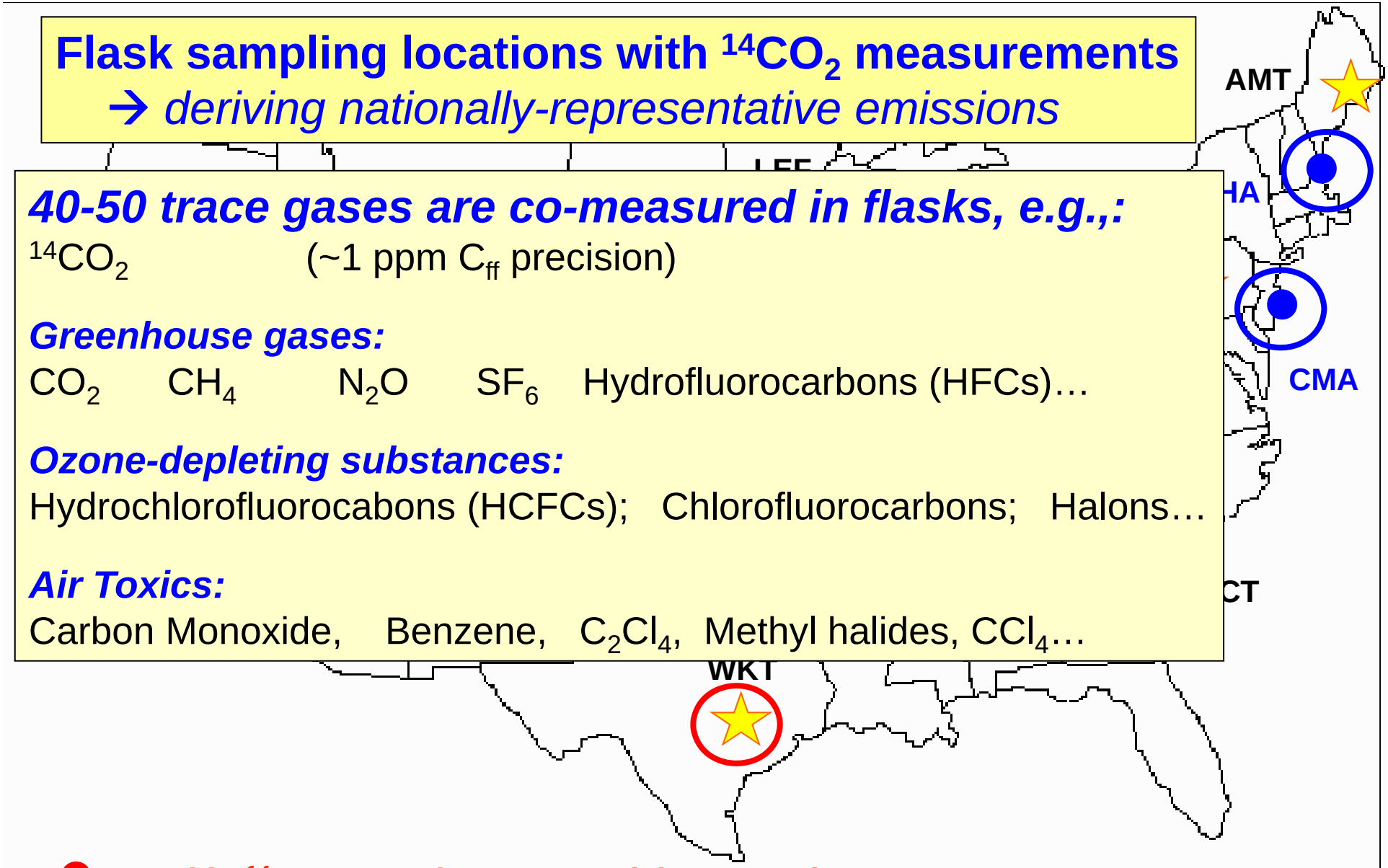

40-50 trace gases are co-measured in flasks, e.g.,:

$^{14}CO_2$ (~1 ppm C_{ff} precision)

Greenhouse gases:

CO_2 CH_4 N_2O SF_6 Hydrofluorocarbons (HFCs)…

Ozone-depleting substances:

Hydrochlorofluorocabons (HCFCs); Chlorofluorocarbons; Halons…

Air Toxics:

Carbon Monoxide, Benzene, C_2Cl_4, Methyl halides, CCl_4…

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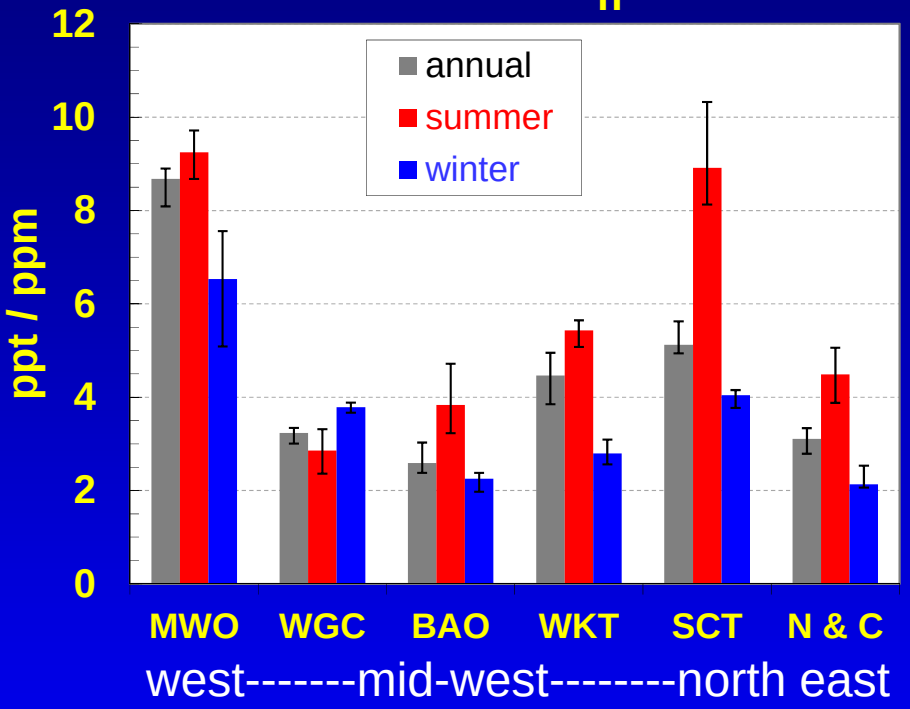
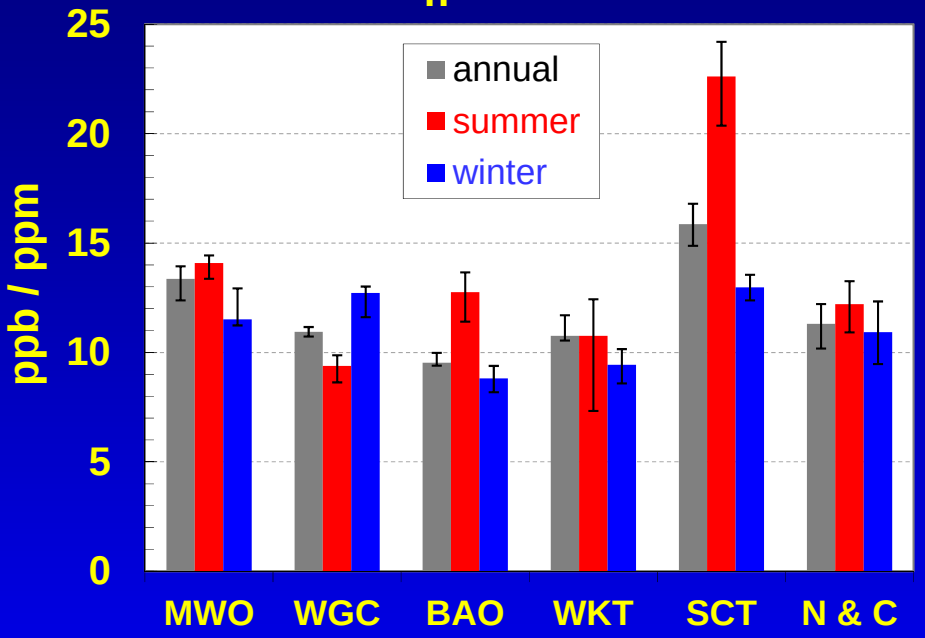
Measured Enhancement Ratios ($\Delta X_1 / C_{ff}$) over regions and season:

ΔHFC-134a / C_{ff}



west-------mid-west--------north east

ΔCO / C_{ff}



* Enhancement ratios vary over region and season
  → Top-down estimates of total U.S. emission from any single region or season can have large biases

* Carbon monoxide enhancement ratios are fairly consistent in winter—but larger differences in summer…
  → Improving our understanding of biogenic vs fossil-derived CO throughout the U.S.

U.S. emissions derived from atmospheric data (^{14}C and inversion)