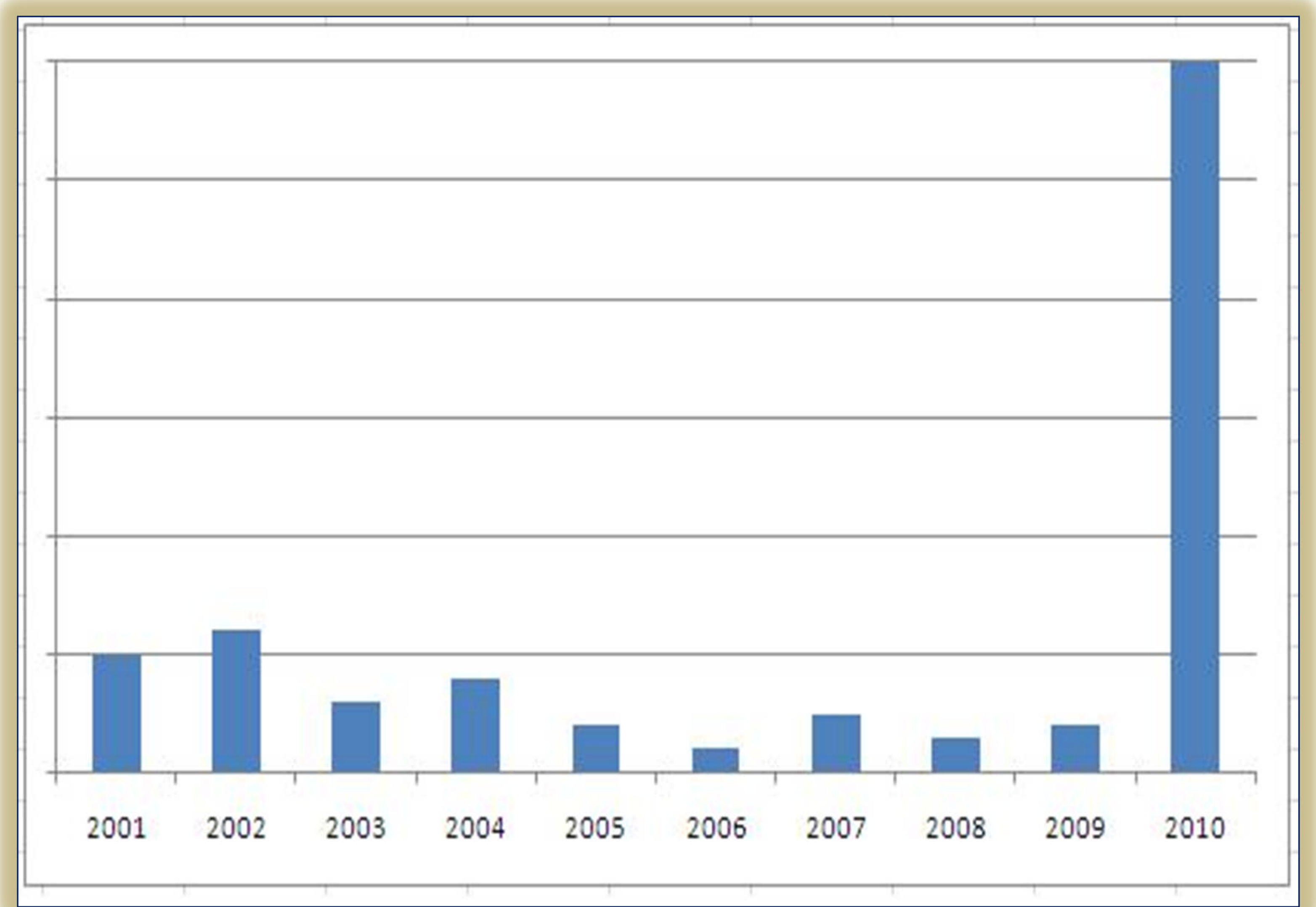
Daylight Dispersion Garden Pathway Carbon-14 Dose Sensitivity Study

Catawba Nuclear Station

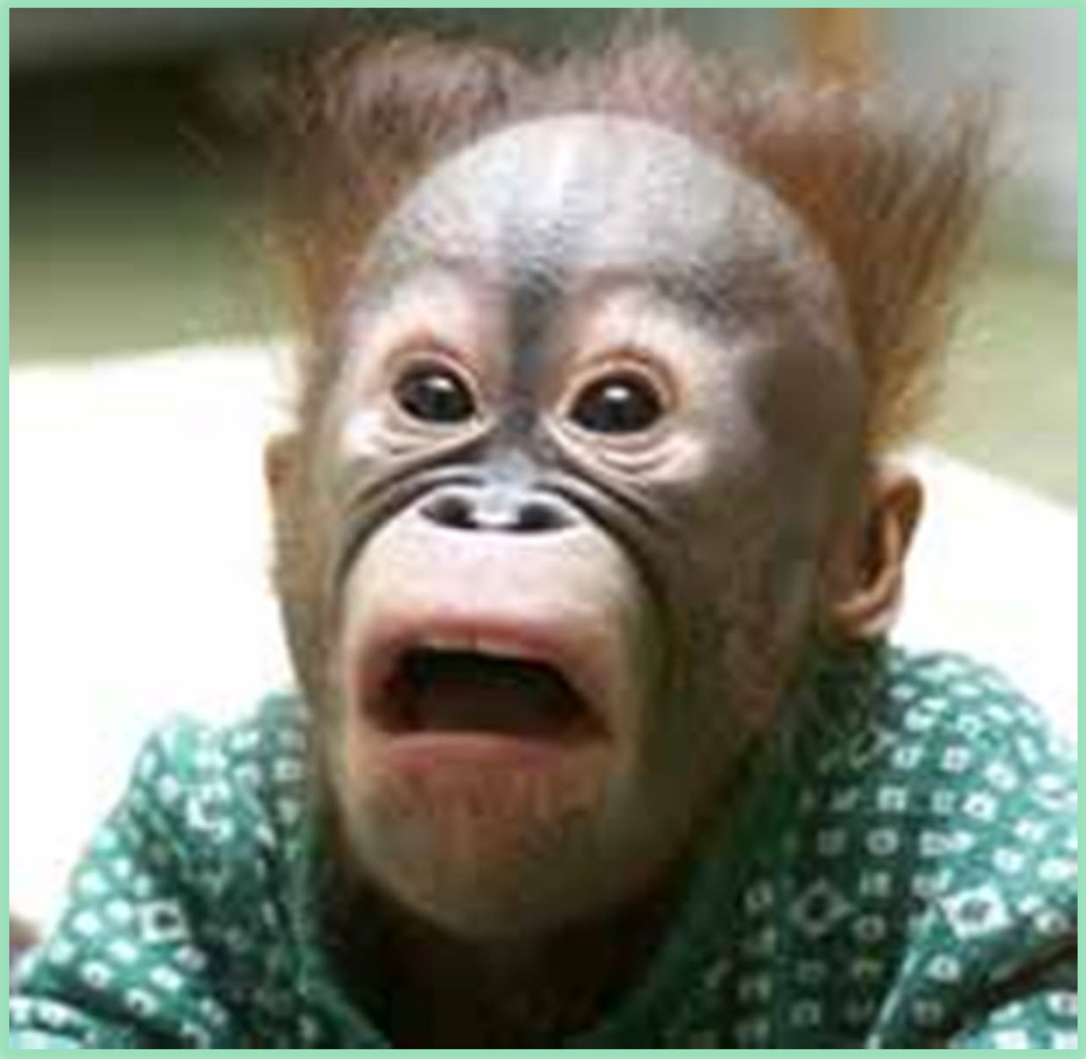
Stanton Lanham, Meteorologist
Caryl Ingram, PE, Senior Engineer

2011 RETS/REMP Workshop
Oak Brook, IL

Effect of Carbon-14 on Gaseous Effluents Maximum Organ Dose



Oh Noooooo!!!!



Parameters to reduce C-14 Garden Pathway Dose in the RG 1.109 Dose Model (PWRs)

1. C-14 Chemical Form (Organic/Inorganic Fractions)

Various studies documenting measured C-14 releases from PWRs suggest a range of 70% to 95% organic with an average of 80% organic with the remainder being CO_2 (Ref. EPRI TR-105715, Table 5-1).

Table 5-1

Measured Releases of Gaseous C-14 from Two U.S. and Six German Commercial PWRs

PWR Station	Rated Power MW(e)	Measure ment Period	Plant Availability	Gaseous C-14 Releases: Inorganic Release Fraction	Organic Release Fraction	Total Curies/ GW(e)-yr
E*	965	1980-82	41%	25%	75%	9.6
F*	490	1980-81	75%	10%	90%	11.6
H**	1204	1978	71%	29%	71%	2.5
I**	1300	1978	54%	9%	91%	6.3
J**	345	1978-9	80%	35%	65%	3.6
K**	662	1979-80	76%	40%	60%	6.6
L**	855	1978-81	71%	10%	90%	7.0
M**	1300	1979	75%	7%	93%	7.3
* U.S.**German			Average	20%	80%	6.4

Onsite C-14 Studies (Containment, Unit Vent, WGDTs) (Outage/Innage)

For example, GEL Engineering

2. The infamous Regulatory Guide 1.109 "p" factor.

The "p" factor in the Regulatory Guide 1.109 C-14 vegetation concentration equation is the ratio of the total annual C-14 release time to the total annual time during which photosynthesis occurs (taken to be 4400 hours).

Without actual measurements what should you assume for percent batch and percent continuous releases?

*Reg. Guide 1.21, Rev. 2, states that for PWRs C-14 is released **primarily** through the waste gas system.*

*IAEA Technical Reports Series no. 421, which is referenced in Reg. Guide 1.21, Rev. 2, is more specific, and states that **70%** of C-14 gaseous effluent from PWRs can be assumed to be from batch releases (WGDTs) and **30%** from continuous releases (unit vents).*

*For the Catawba "p" factor it was assumed that WGDTs release approximately **20 hours** per year. (Conservative estimate based on 2007-2010 data)*

Using the assumptions from the previous slide, "p" can be estimated for Catawba as follows:

$$p = 0.7 * \text{WGDT Release Hours per year}/4400 + 0.3 * \text{Continuous Release Hours}/4400$$

$$p = 0.7 * 20/4400 + 0.3 * 4400/4400 = 0.303$$

$p \approx 0.31$

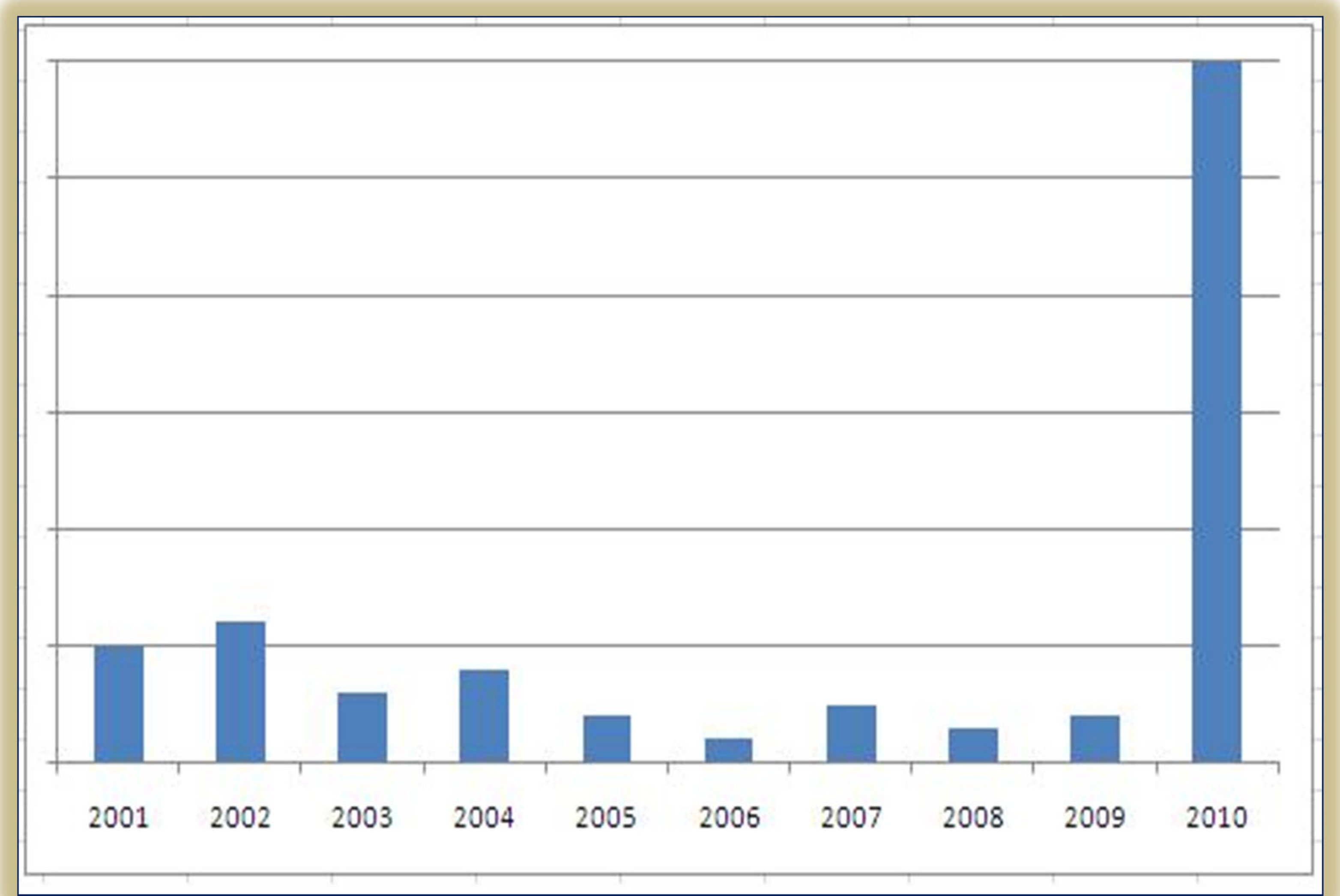
3. Use of Daylight Dispersion Factors

Can possibly lower C-14 garden pathway dose, but it depends on the location.

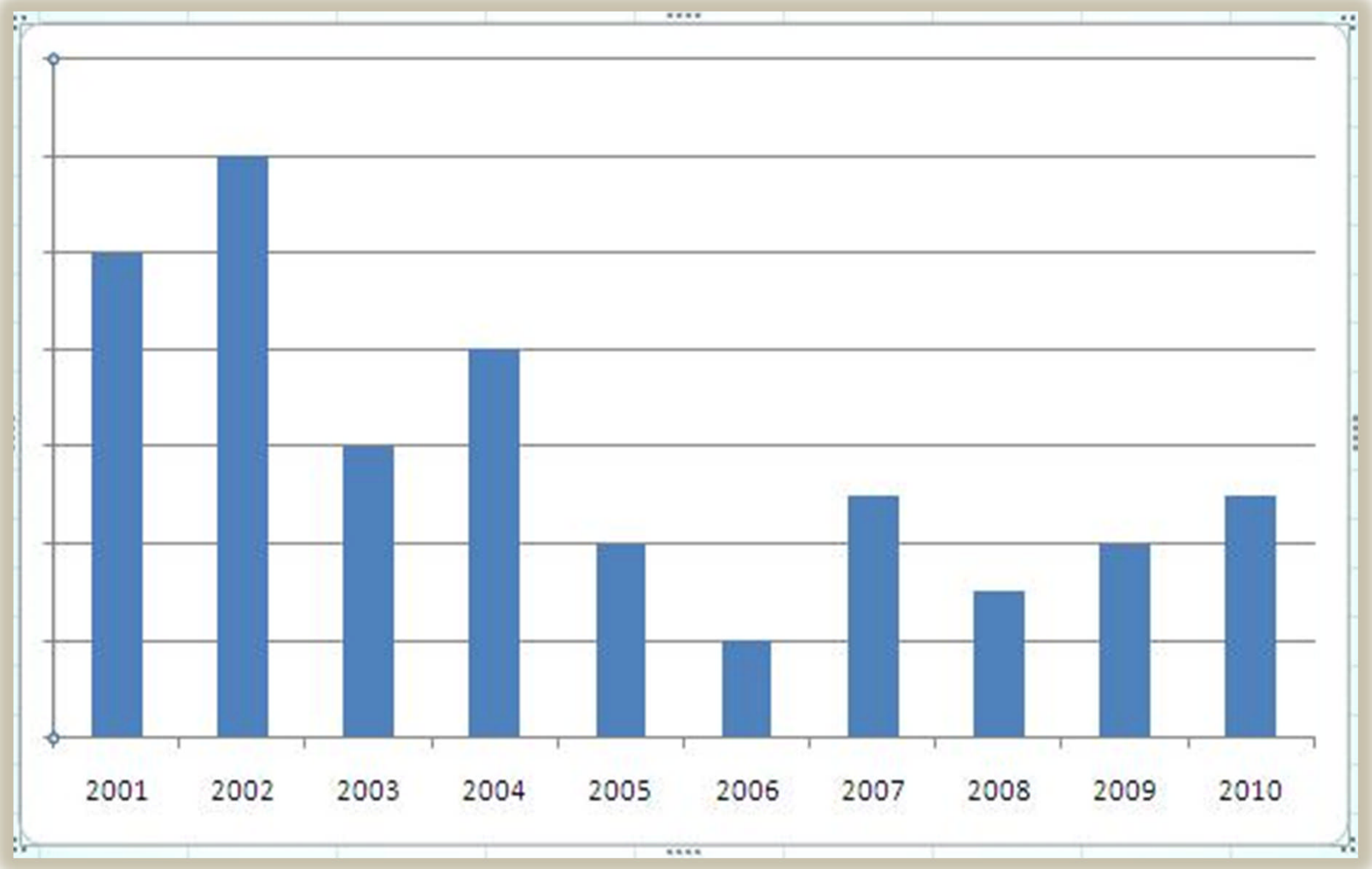
Duke performed a sensitivity study that showed how much use of daytime χ/Qs helps reduce the dose very much depends on the location of your maximum garden location.

For Catawba's max garden location the daytime χ/Q was **~43% smaller** than the 24-hour χ/Q.

So there are parameters available to you that may allow you to go from a gaseous effluent maximum organ dose graph of this:



To one that looks like this:



Oh Yeah!!!!

Sensitivity Study: Calculation of the Daylight dispersion factor with ***XOQDOQ*** (NUREG /CR-2919, 1982)

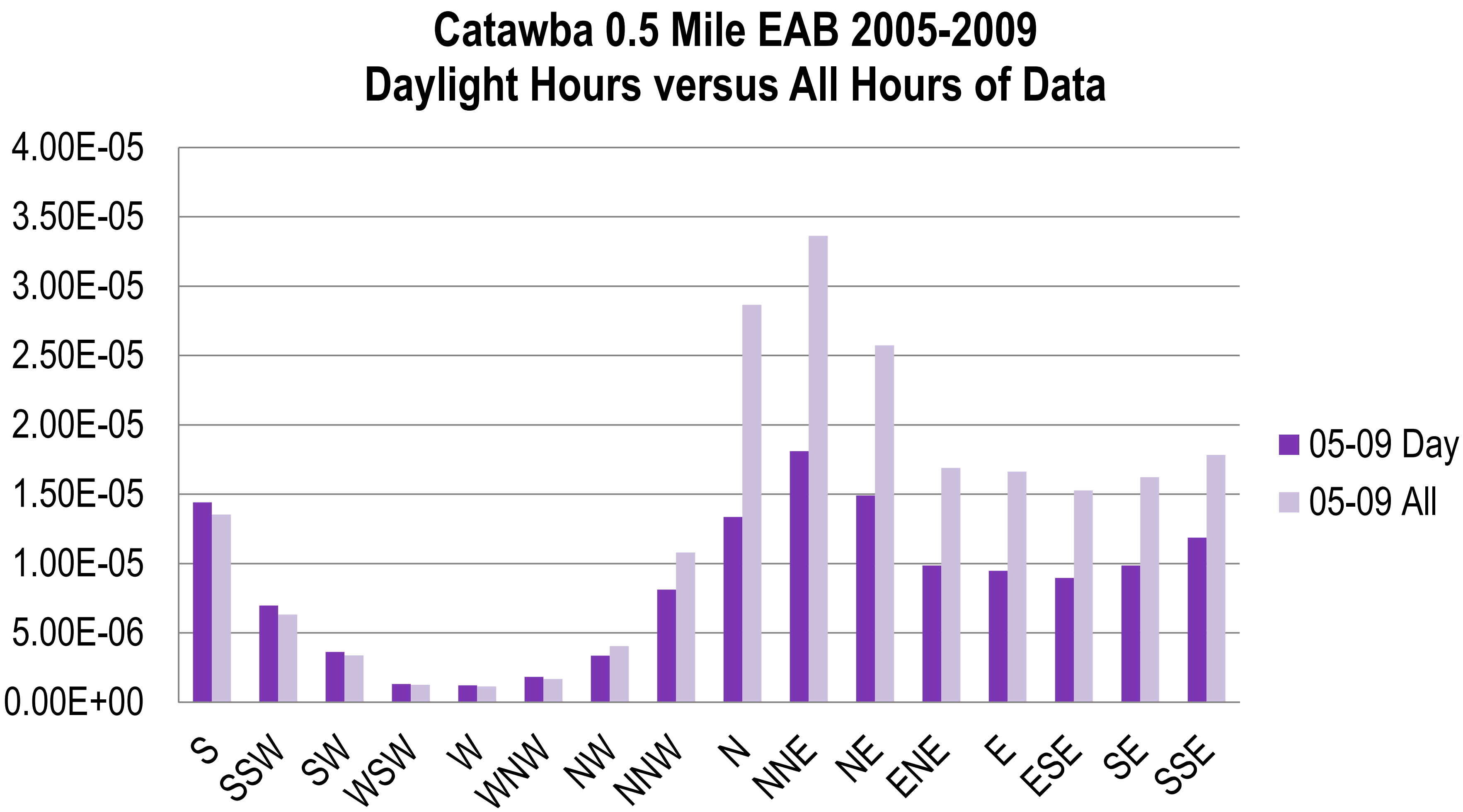
Model Inputs

- 5 years of meteorological data (2005-2009)
- "Daylight" run of the model limited the input hours to the seasonally defined daylight hours in NUREG-0917.
- Locations of Gardens in each downwind sector
- A few Catawba-specific building inputs, release heights, and exit velocities
- No terrain inputs due to no significant terrain in the area

Month	Daylight Hours
January – March	8-17
April-June	7-18
July-September	6-19
October-December	7-18

Some liberties were taken with the exact dates of the seasonal changeover for programming ease – overall this has very little effect on results.

Results of the XOQDOQ Daylight Sensitivity:



One caveat (out of a few) of XOQDOQ:

Catawba 0.5 mile EAB Results:

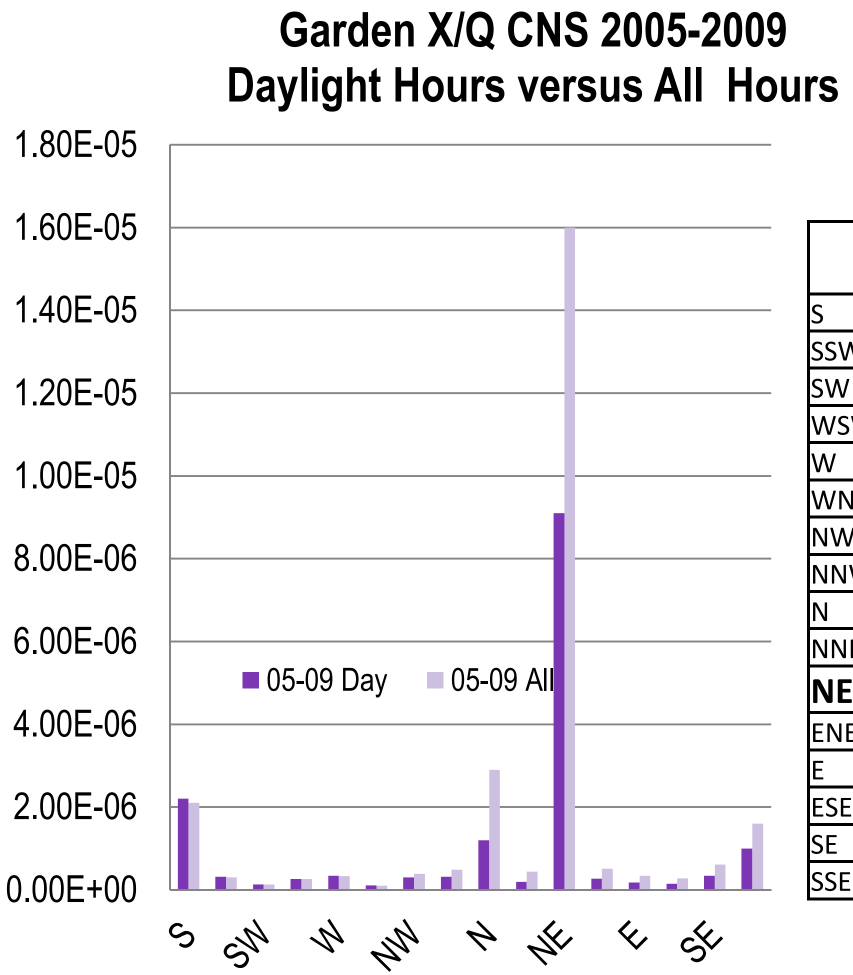
2005-2009	% Change
S	7%
SSW	10%
SW	8%
WSW	5%
W	7%
WNW	9%
NW	-17%
NNW	-25%
N	-53%
NNE	**-46%**
NE	-42%
ENE	-42%
E	-43%
ESE	-41%
SE	-39%
SSE	-33%

Question:

Why would we see increases when using less hours?

XOQDOQ only calculates **relative annual averages** – so even though we limited the input data to the "Daylight" hours, the model will distribute those conditions across a year's worth of 24 hour days.

Garden Results from Daylight Sensitivity:



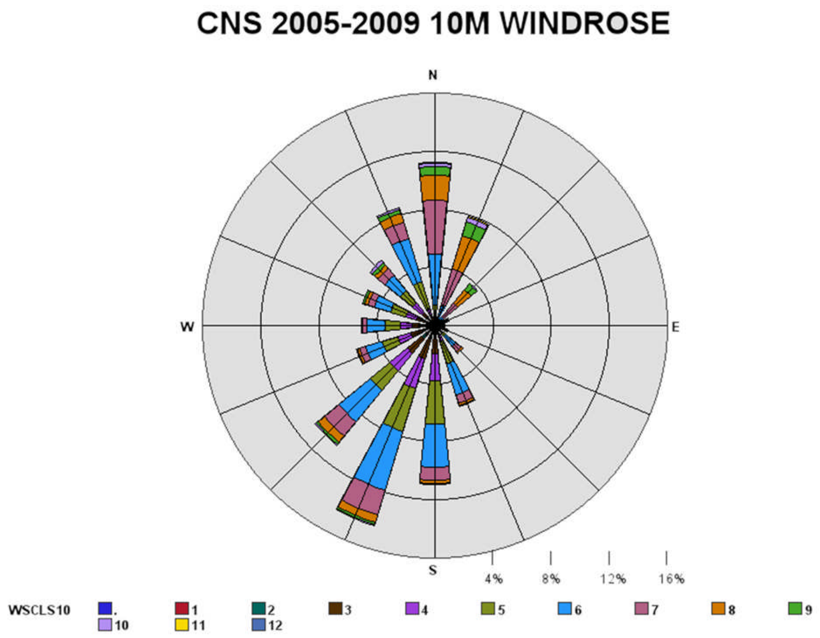
	% Change
S	5%
SSW	7%
SW	0%
WSW	0%
W	3%
WNW	10%
NW	-23%
NNW	-35%
N	-59%
NNE	-57%
NE	**-43%**
ENE	-47%
E	-47%
ESE	-46%
SE	-44%
SSE	-38%

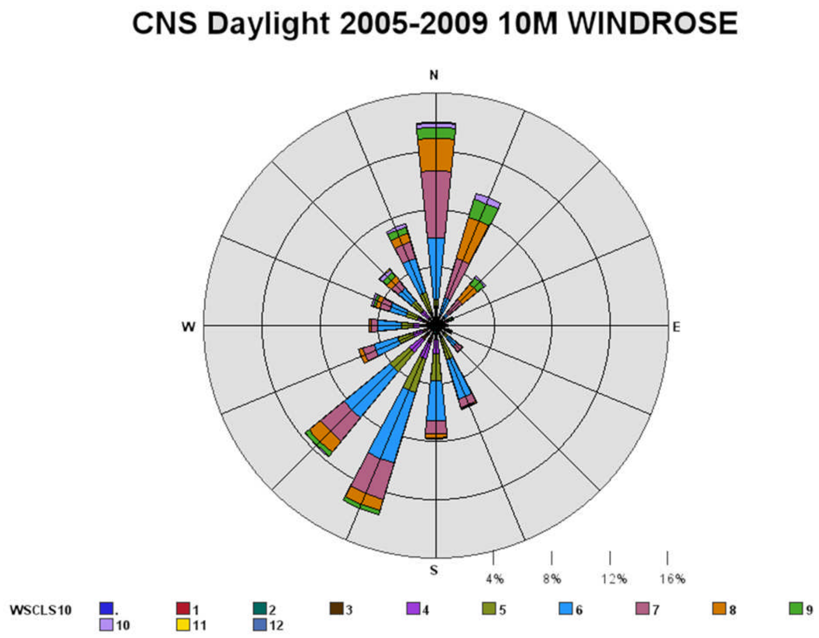
Garden results are similar to the EAB results, though the Garden X/Q is also sensitive to how close each garden is to the release point within each downwind sector.

Meteorological Reasoning:

- At Catawba, the most adversely affected sectors experienced X/Q reductions when only using Daylight hours. Why?
- Concentration is predominantly dependent on two factors:
    1. Frequency that the wind blows in the direction of a receptor
    2. The atmospheric stability at that time
        - Surface wind speed is generally a function of stability
- Catawba experiences a flow regime that has little effect from localized terrain – so nightime flow is pretty similar to the daytime flow.
    - Based on this – we know that the X/Q reductions at CNS are mostly due to instances of decreased stability during the day. This allows for higher wind speeds and greater plume dispersion – i.e. lower concentrations.
    - Where we do see the slight increases, it is due to the ***relative increase*** in frequency that the wind is blowing in that direction during the day versus all hours of the day.

Wind Roses: All hours vs. Daytime





Overall wind direction distribution is quite similar.

Wind speed magnitude varies between the two.

Back to that XOQDOQ caveat:

Problem:

- It wouldn't make physical sense that you're getting larger average concentrations at some locations when using ***less*** hours than the full dataset.
  - Especially when the daylight data is just a subset of the full dataset!

But Remember!

- XOQDOQ uses a joint frequency distribution applied to a full year's worth of hours, no matter what you give it, to calculate a relative ***annual average concentration***.

- The higher values are valid in the sense that you're comparing those values only to the other results in that single model run.

Conclusions from XOQDOQ Sensitivity Study

- Catawba's maximum EAB and garden relative concentrations are greatly reduced (~50%) by only analyzing daytime meteorology conditions.
  - This is primarily due to elevated instability allowing for greater dispersion, despite a similar wind rose.
- Some sectors at Catawba see increases in relative concentrations, due to the slight changes in the wind rose
  - In a scenario where topography dominates flow, sectors could see more dramatic increases/decreases.
- The use of an hour by hour Gaussian model (AERMOD, CALPUFF) would yield better actual concentration results.

Options for accounting for XOQDOQ's shortcomings

1. Multiply the XOQDOQ results by the fraction of daytime versus all hours.
   - » Factor = 4320/8760 = .493

OR…

2. Try another model!
   - **AERMOD** (EPA model) will allow you to have no emissions during non-daylight hours, allowing the full benefit of using daylight only hours. (daytime dispersion and no emissions at night)

Quick look at new results for Gardens in each sector at Catawba

Applying the factor directly to the XOQDOQ results:

% Change vs. All Hours

S	-48.33%
SSW	-47.39%
SW	-50.68%
WSW	-50.68%
W	-49.19%
WNW	-45.75%
NW	-62.06%
NNW	-67.79%
N	-79.59%
NNE	-78.70%
NE	-71.95%
ENE	-73.89%
E	-73.89%
ESE	-73.58%
SE	-72.51%
SSE	-69.18%

AERMOD results

% Change vs. All Hours

S	-84.29%
SSW	-74.96%
SW	-88.74%
WSW	-87.74%
W	-90.14%
WNW	-82.84%
NW	-80.66%
NNW	-82.08%
N	-80.91%
NNE	-88.72%
NE	-87.81%
ENE	-79.43%
E	-82.66%
ESE	-84.71%
SE	-81.42%
SSE	-81.53%

* AERMOD run based on 2002 NWS data, not onsite data as with XOQDOQ