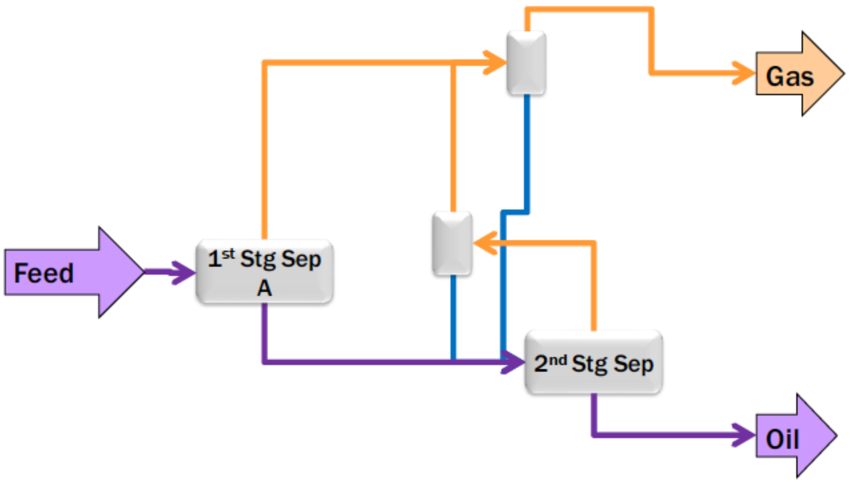
THE CASE FOR INTEGRATED PROCESS SIMULATIONS IN ALLOCATION SYSTEMS



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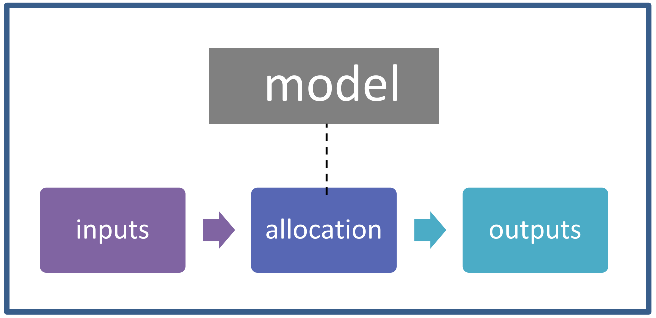
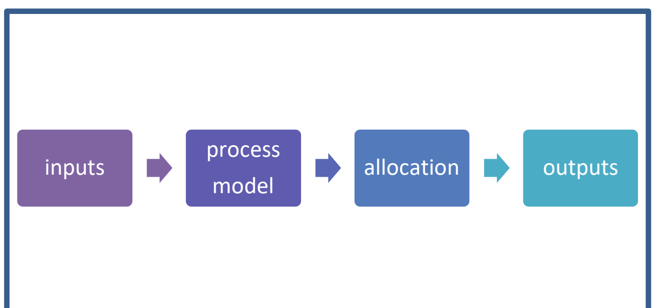
This presentation focuses on how process simulation models are used in allocation systems



Offline & intermittently run

$$f(A,X) = A_n X^n + A_{n-1} X^{n-1} \ldots$$

Correlations & look-up tables



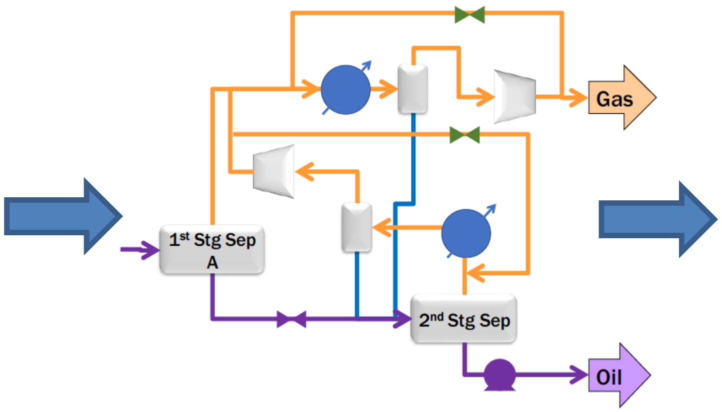
Fully integrated & daily

Simulation models systems provide information on how hydrocarbons behave in a process plant

Operating conditions

Composition

Flow rates



Process factors
Shrinkages

Direct allocation

Calculation of physical properties

Estimation of unmeasured streams

Ideally full process simulation should be run each time the allocation is run but that is seldom done

Historically, integrating the process model into the allocation has not been an attractive prospect

Commercial allocation and process simulation packages have not been designed to integrate with each other so can be costly to set up

Even if successful, vendor software updates can render the interface non-functional

Vendor changes to solution algorithms can result in small changes to the allocation

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Historically, integrating the process model into the allocation has not been an attractive prospect

Typically, only a small subset of proprietary software functionality is required for allocation

Process engineering involvement is needed to solve unstable complex models

For these reasons alternative approaches are used

First, we shall look the impact of using factors from an offline model in the allocation

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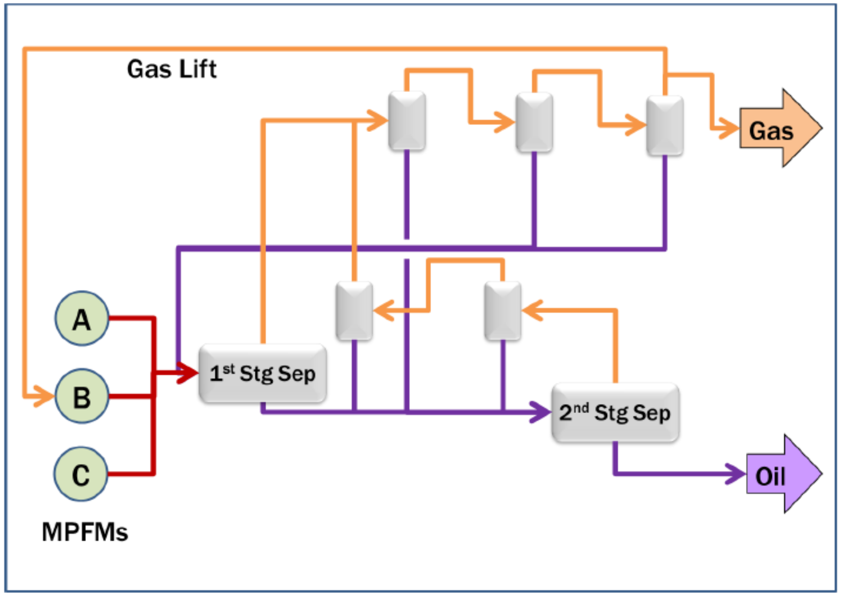
To study the impact of offline modelling and intermittent updating of process factors we used a typical process

This typical offshore process comprises:

- 3 fields A, B & C metered by MPFMs
- commingled fluids processed via 2 stage separation
- gas lift recycle from gas processing
- gas and oil export

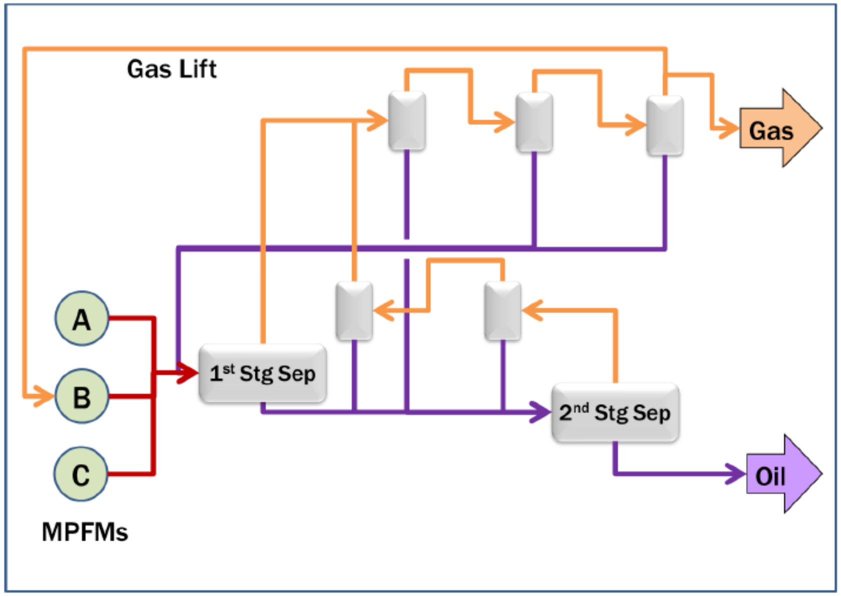


Simulated data sets were generated by introducing variability to the process variables

1000 cases were run with the simulated data and shrinkage factors calculated for use in the allocation

Stable production with 95% uptime for the fields was generated with variability introduced to the process variables:

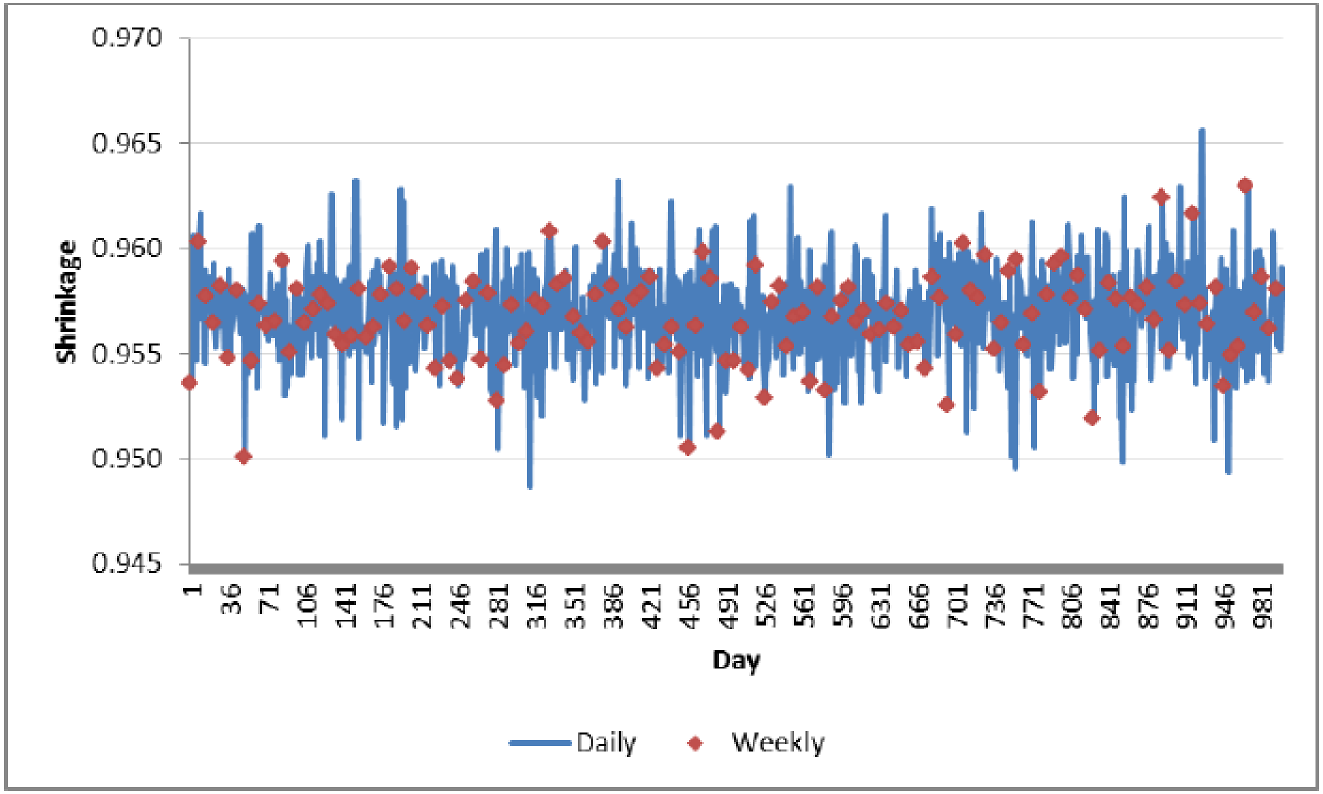
- pressure $\pm$ 0.5 bar
- temperature $\pm$ 3℃
- composition $\pm$ 10%
- field flows $\pm$ 5%



Shrinkage factors for each field were calculated:

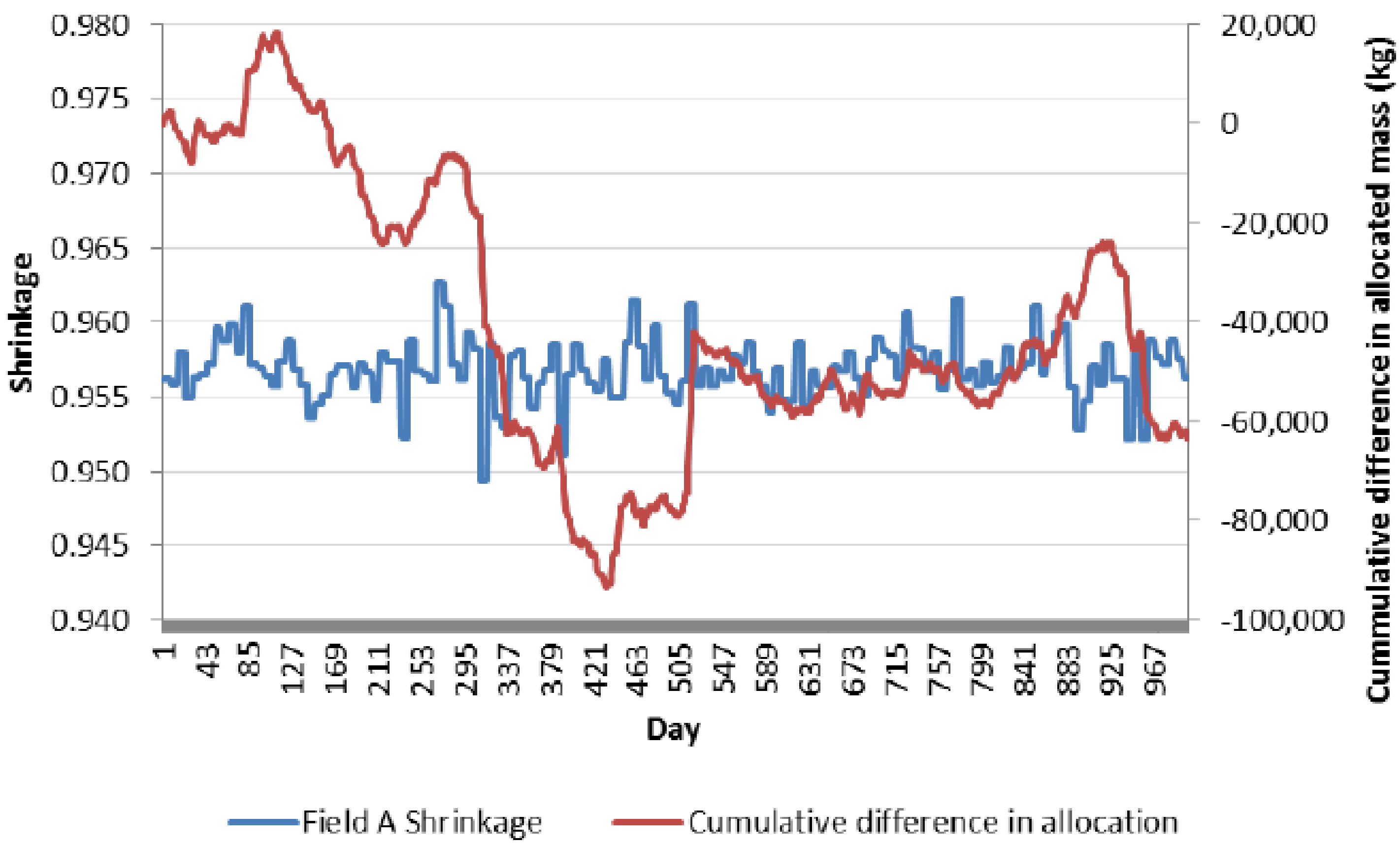
$$\frac{Export\_Oil_{field,c,mass}}{MPFM\_Oil_{field,c,mass}}$$

This plot shows the variability in the shrinkage factors calculated for Field A

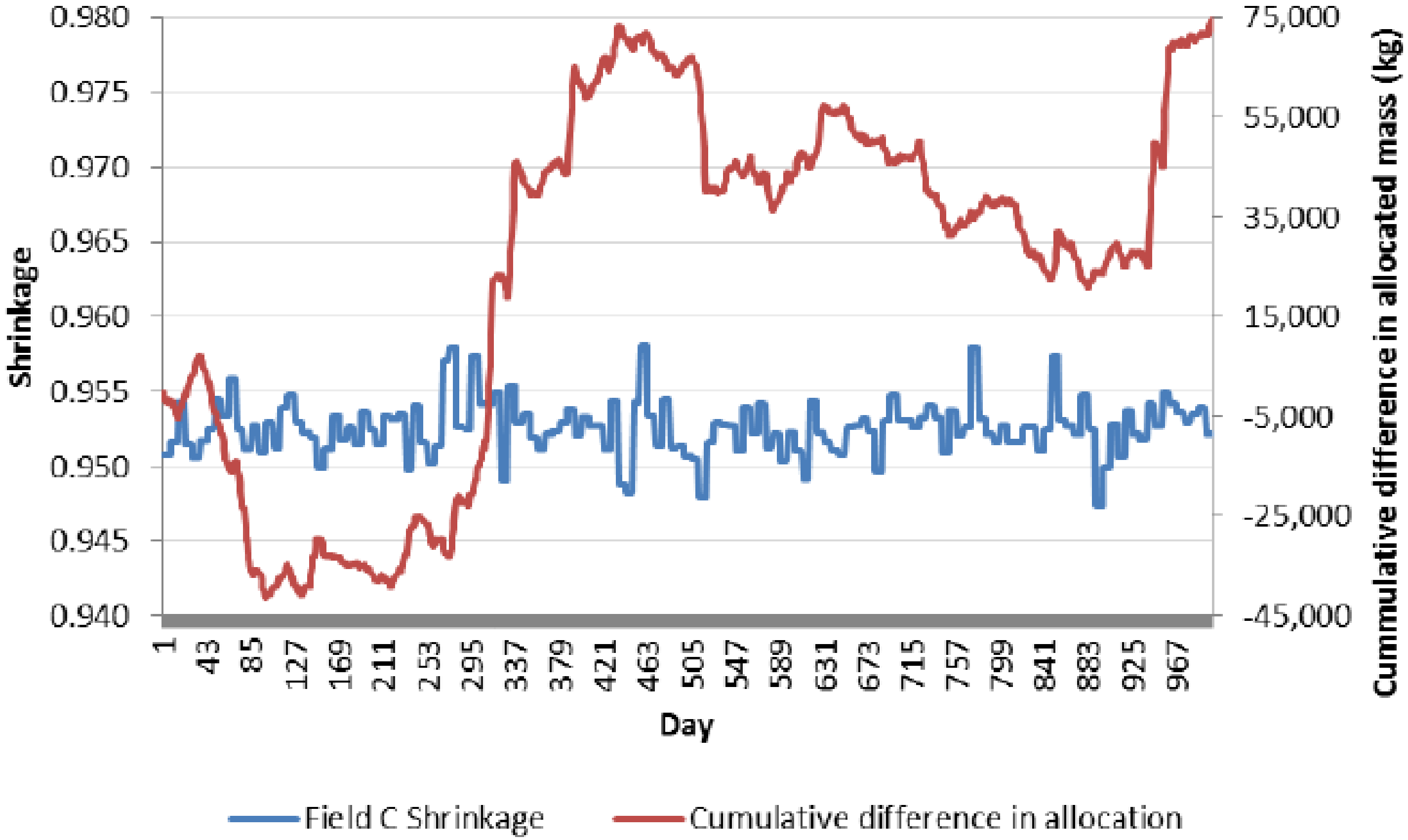


For weekly factors, the shrinkage from every 7th day was used in the allocation for the following 6 days

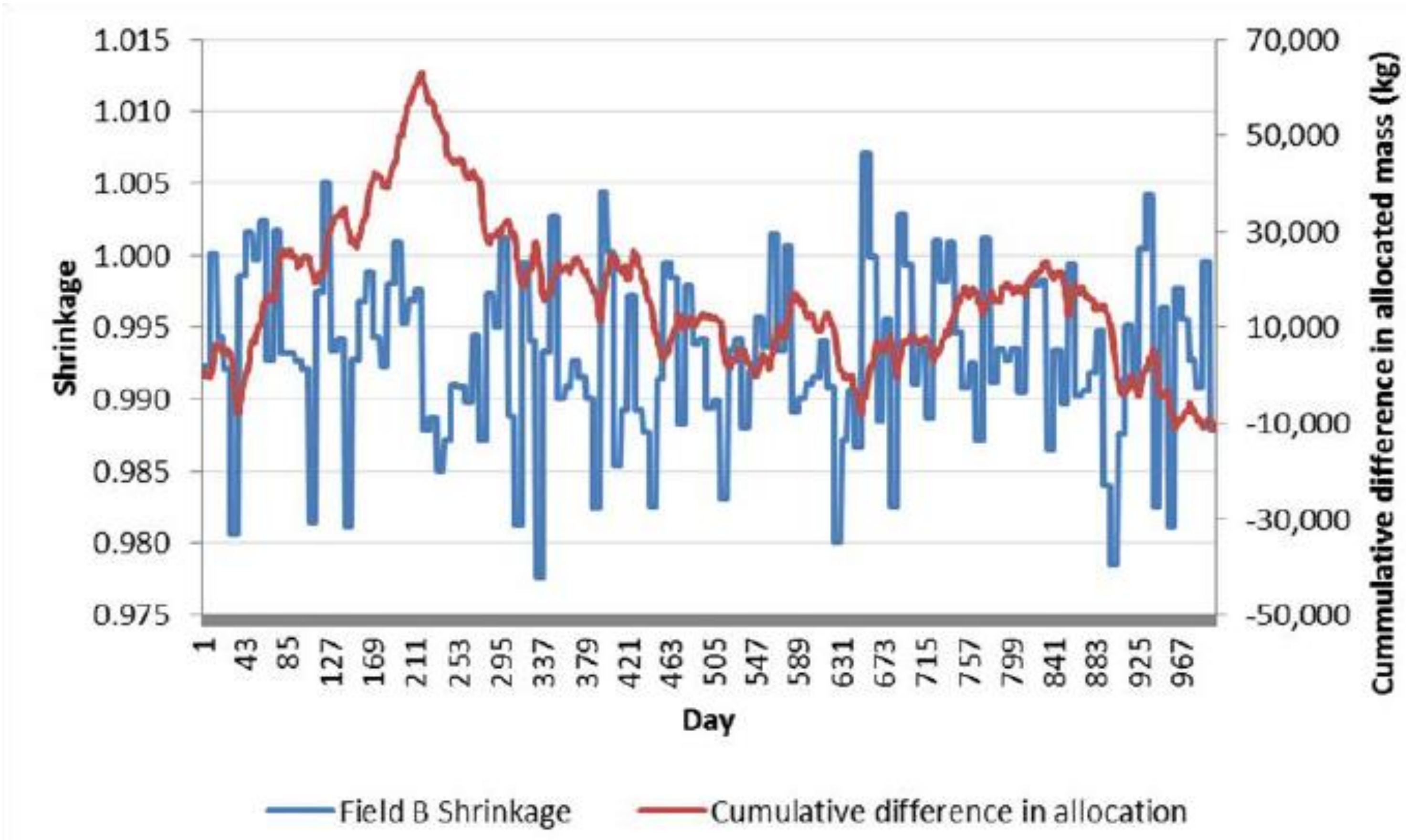
Plots show the cumulative impact of using the weekly shrinkage factors against daily for Field A



The plot for Field C displays a trend that is the opposite of that shown for Field A

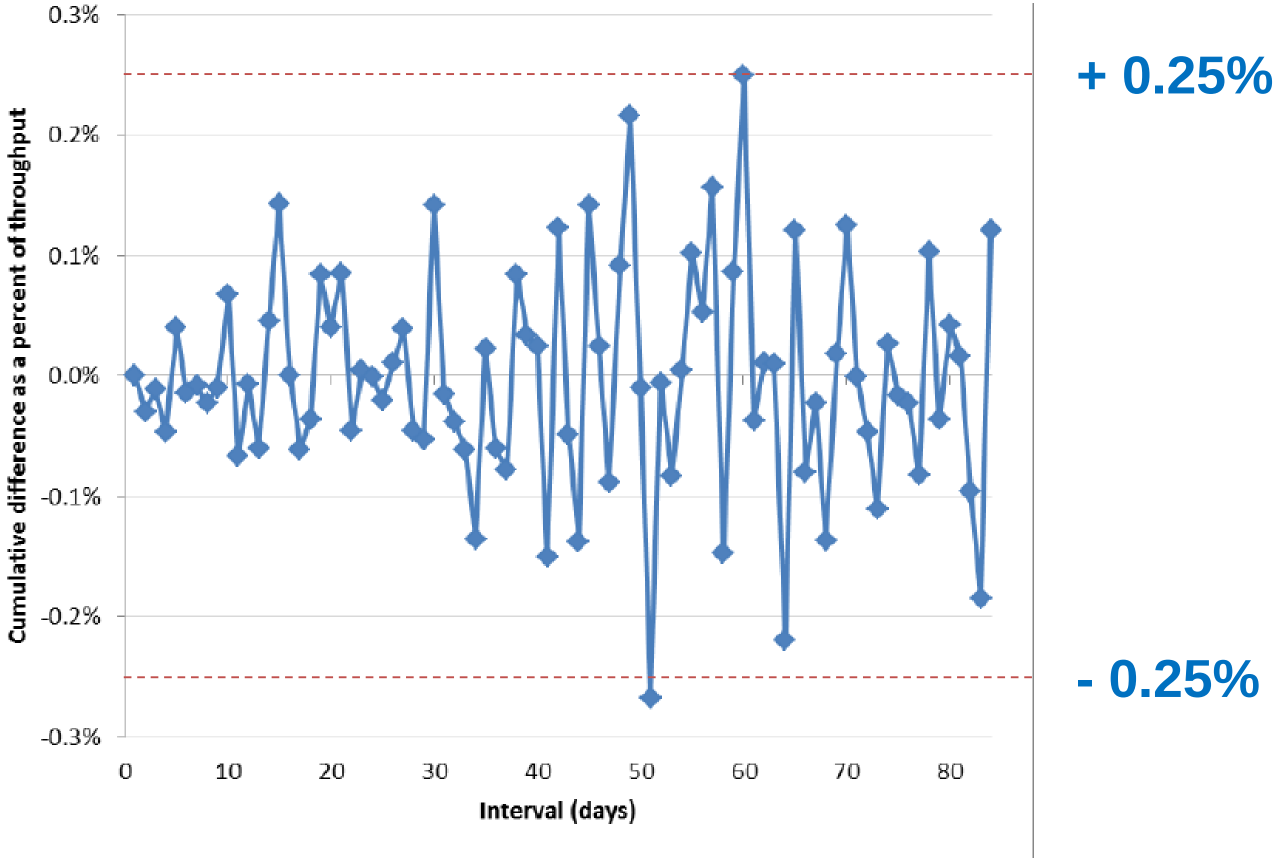


The trend for Field B does not show a significant bias



What happens when the there is a longer interval between updates?

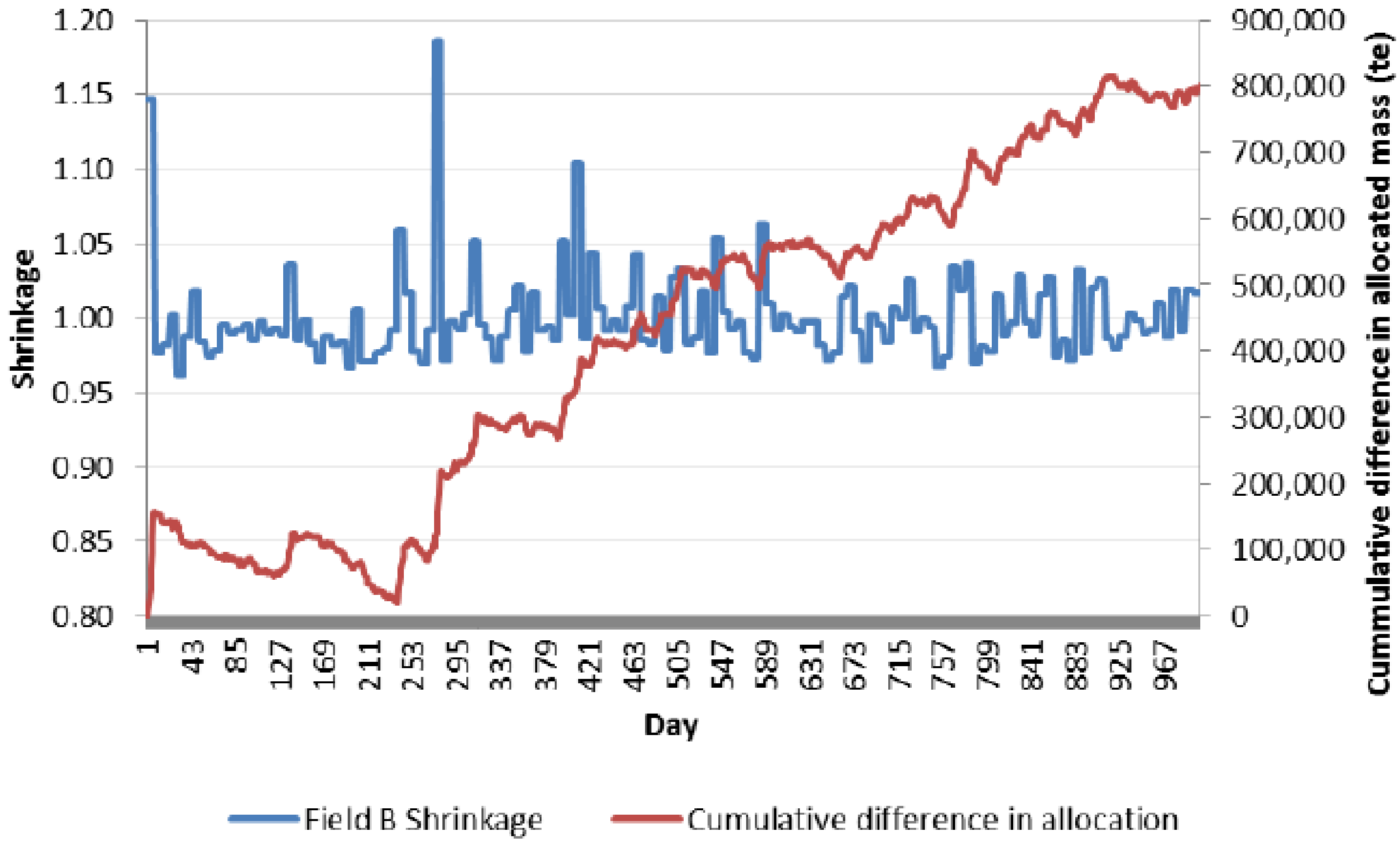
Increasing the time between updating shrinkage factors leads to an increasing impact on the allocation



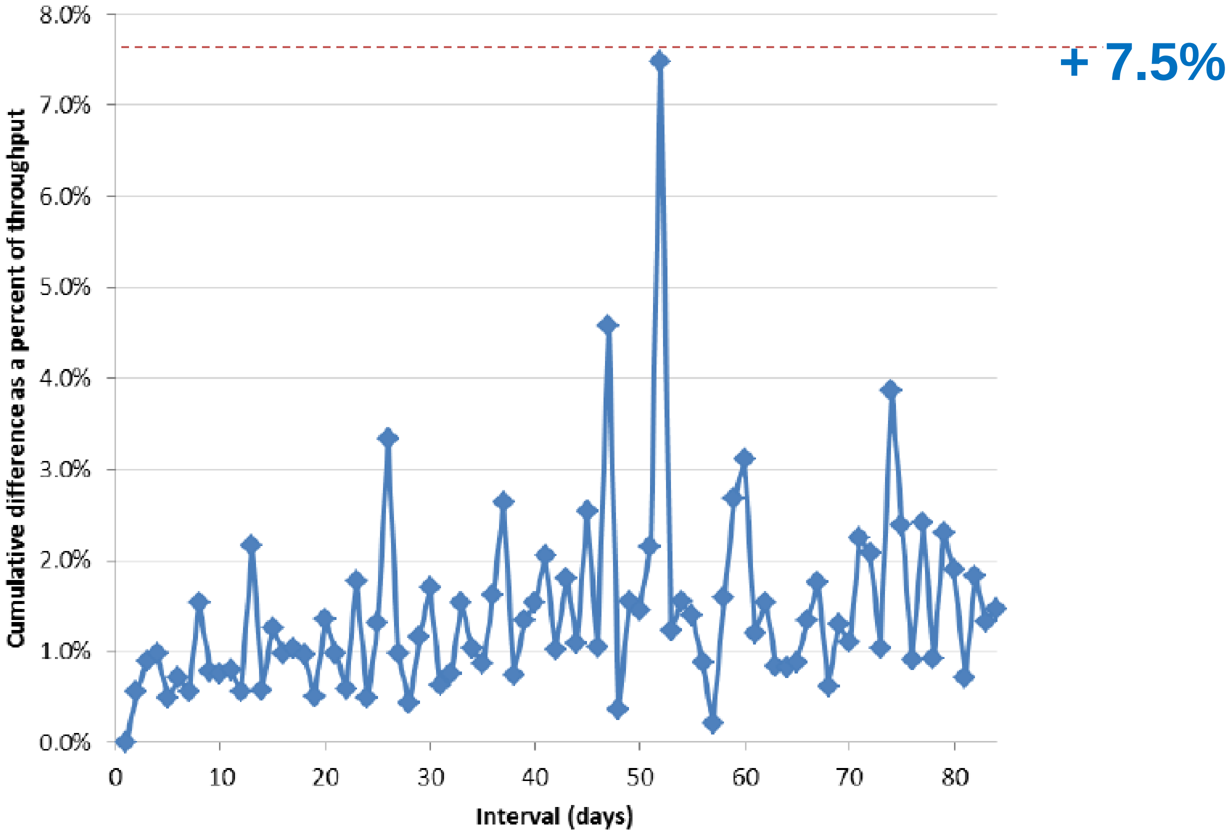
What happens when the variability in the Field B is increased?

Increasing Field B's variability in flow effects a bias in the system

Plot shows the effect of using weekly factors with a flow variability of $\pm 50\%$

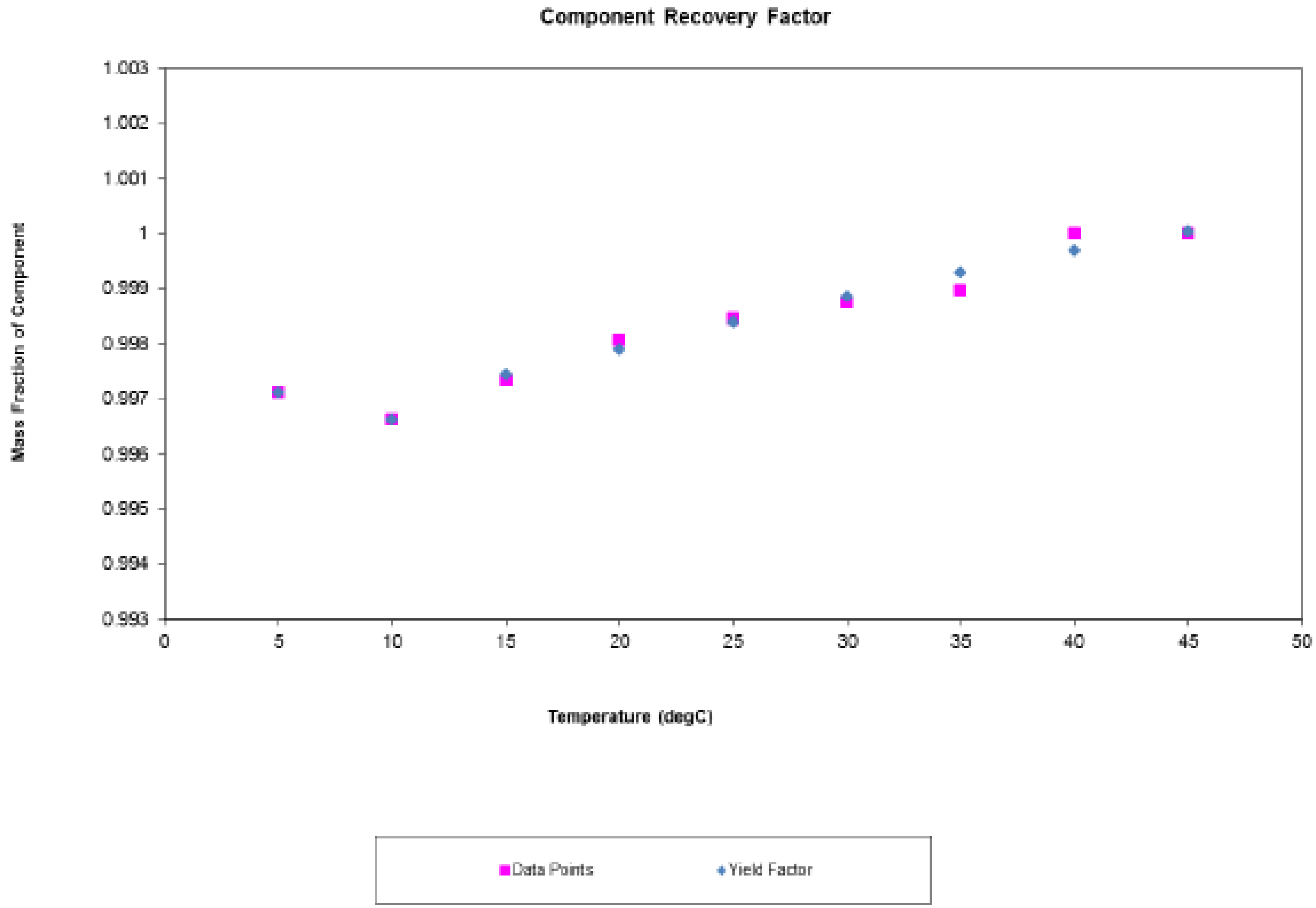


This bias increases as the interval between shrinkage updates increases

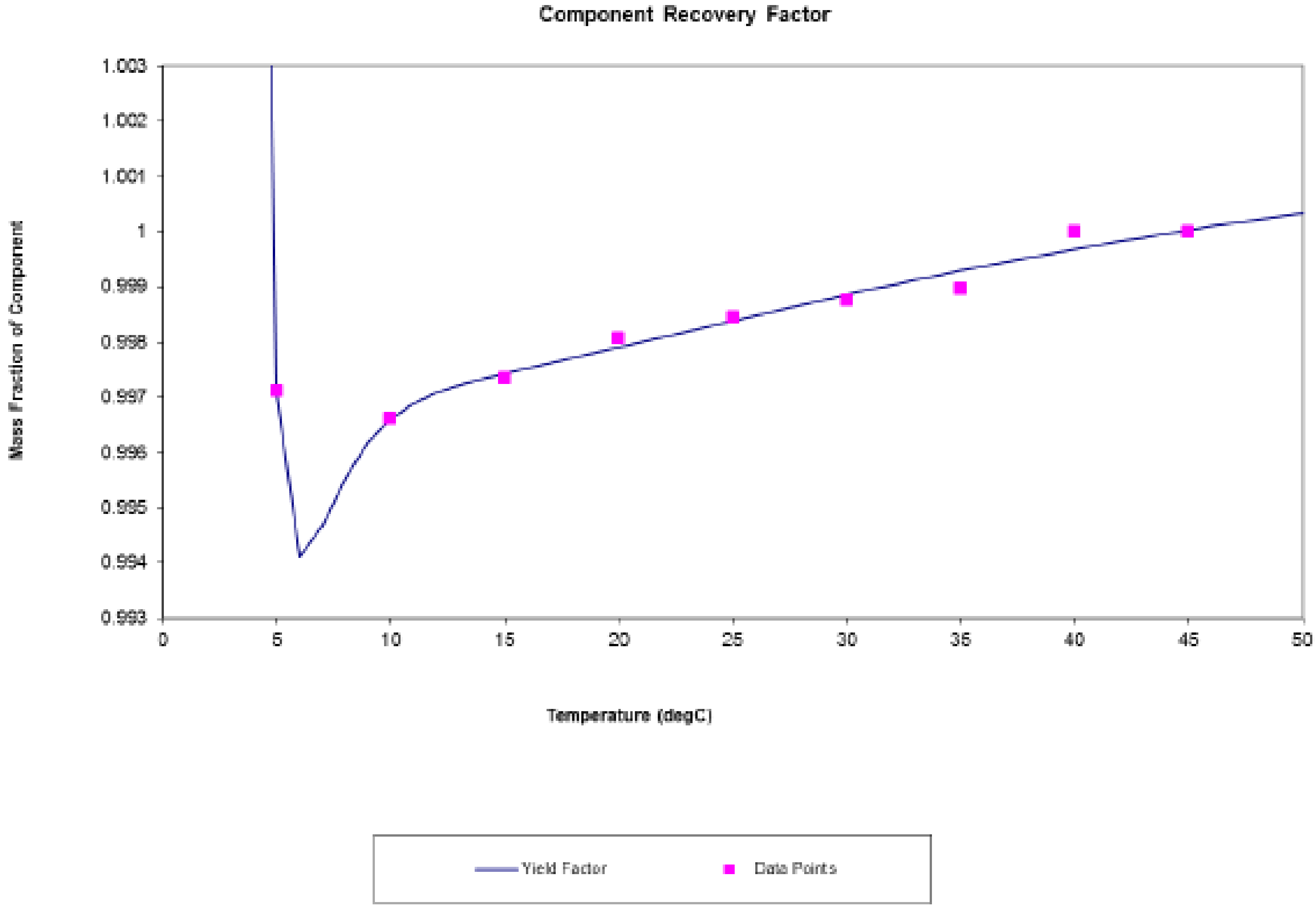


Another option often used is to use models to provide data for correlations or look up tables

For correlations it is important this it fitted over only the points from the data set

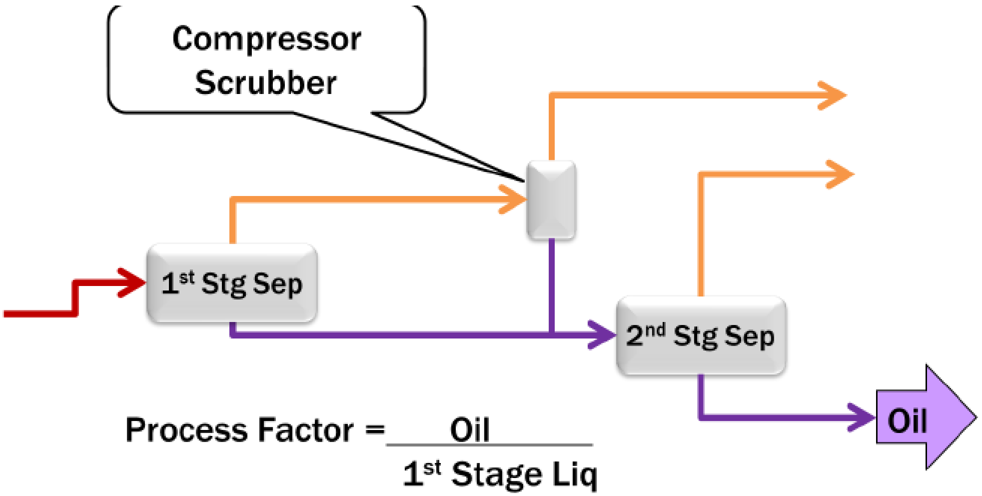


A curve-fit can produce extremely erroneous values from interpolation and extrapolation



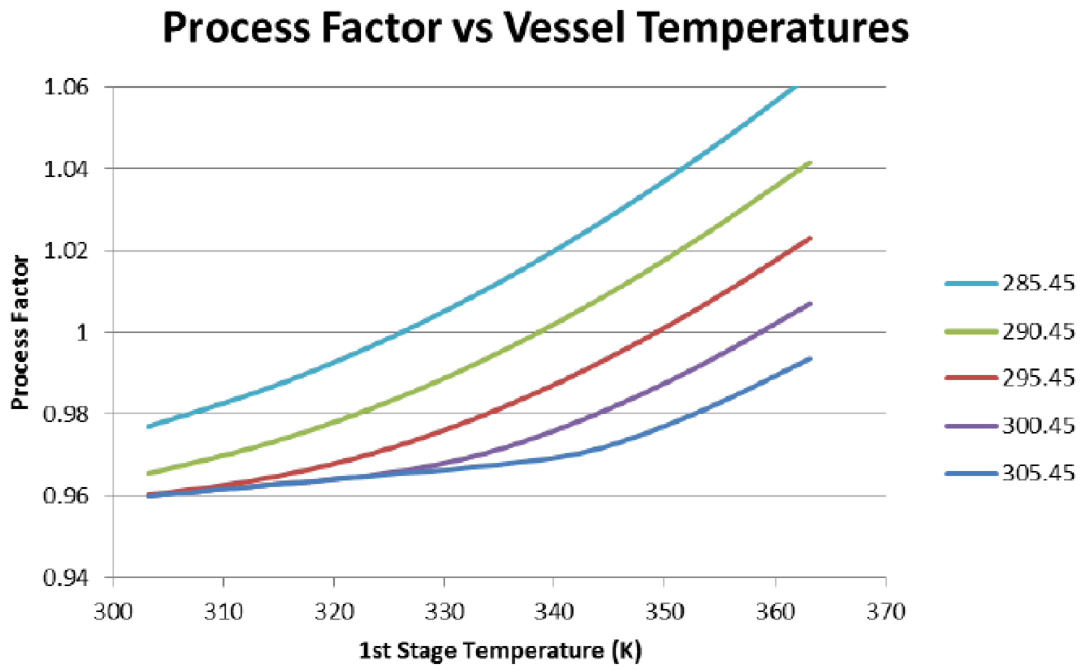
Often factors will be functions of multiple variables even in the case of the very simple process

- single condensate stream
- 2 stage separation
- compressor scrubber
- oil export



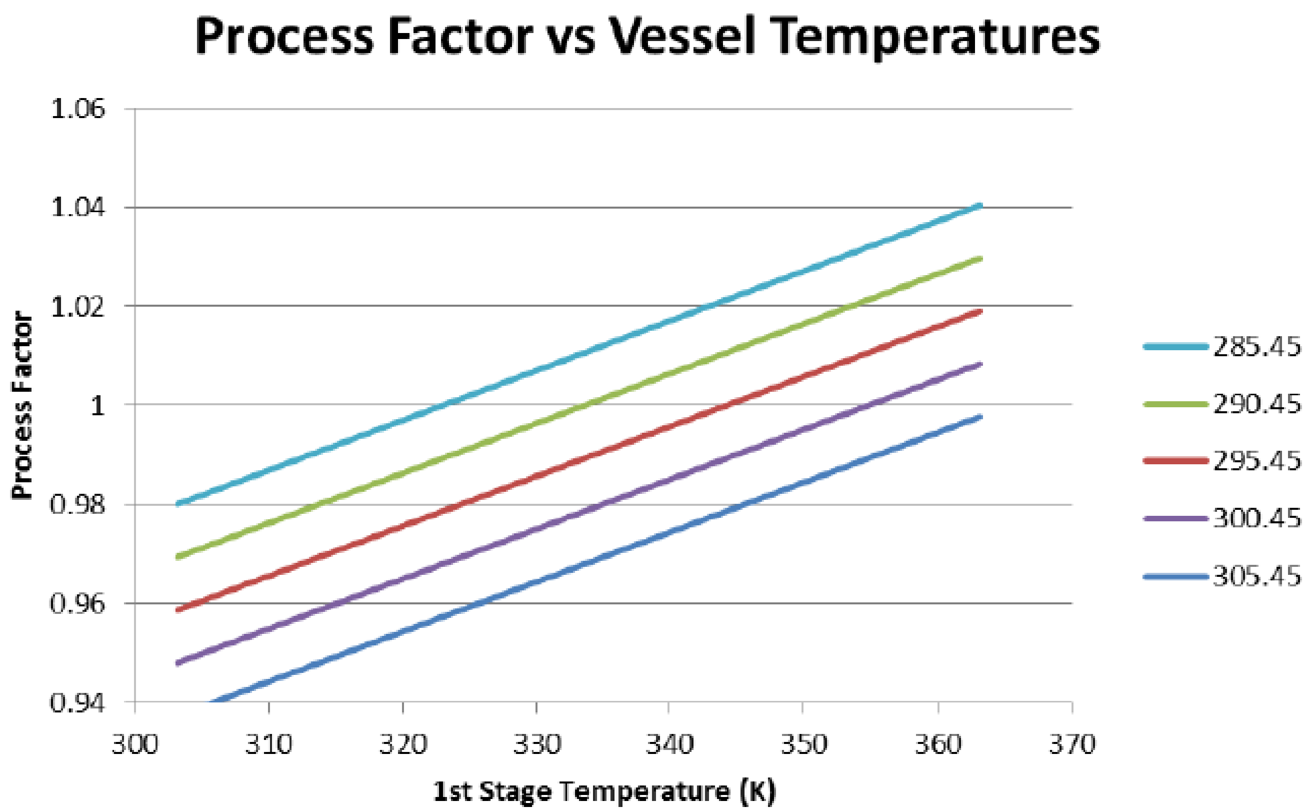
Often factors will be functions of multiple variables even in the case of the very simple process

The process factor was simulated over a range of 1st stage separator and compressor scrubber temperatures and resulted in the plot below

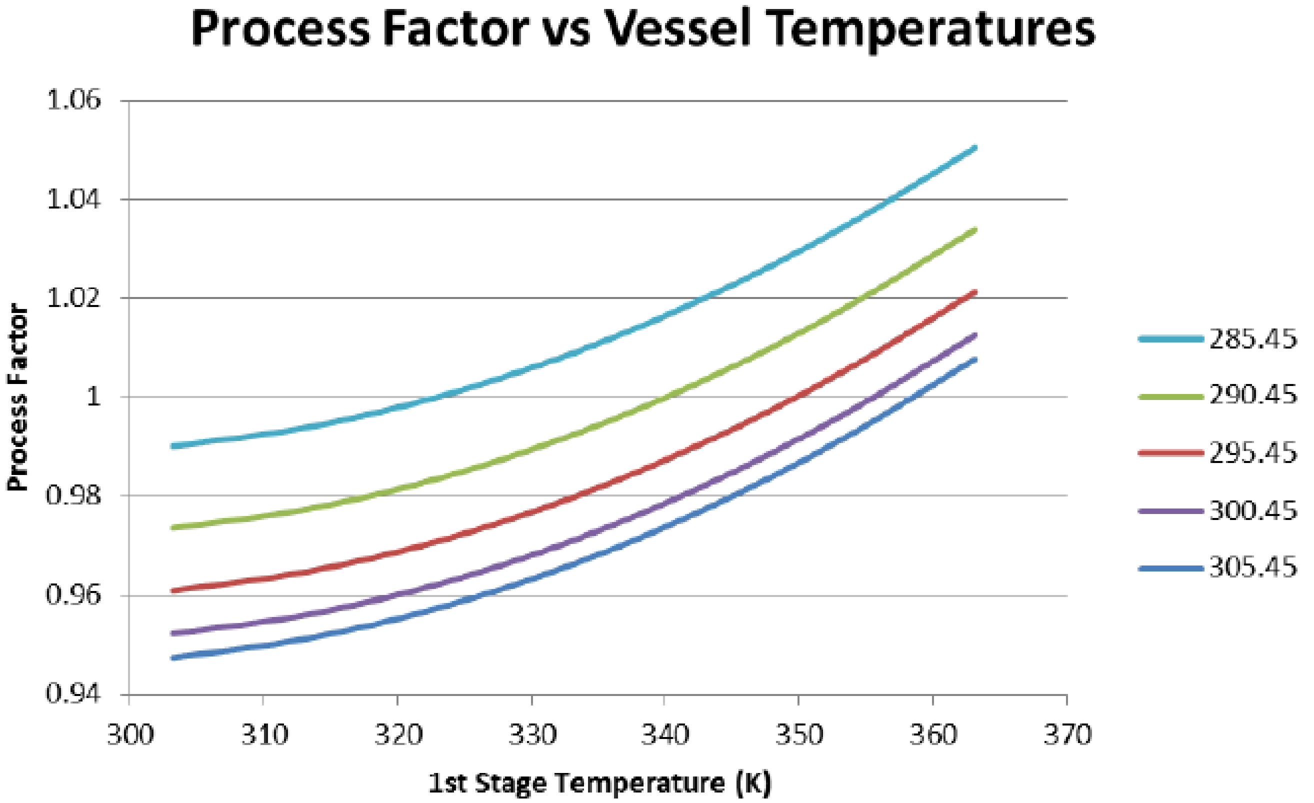


The different lines relate to the process factor at different vessel temperatures

Attempting to model the process factor as a linear function of two variables gives a poor fit to the data



Using a quadratic to correlate improves the fit slightly



Using higher orders can improve the fit but can give rise to the issues seen in the earlier example that used a quartic fit

Lookup tables can be used to overcome the issues with higher order correlations but have limitations

Calculated factors show discontinuities at each stored value

Considerably more data point values have to be stored than with polynomial correlations where only coefficients are needed

This data requirement, x, scales with the number of parameters, n

$$f(n) = x^n$$

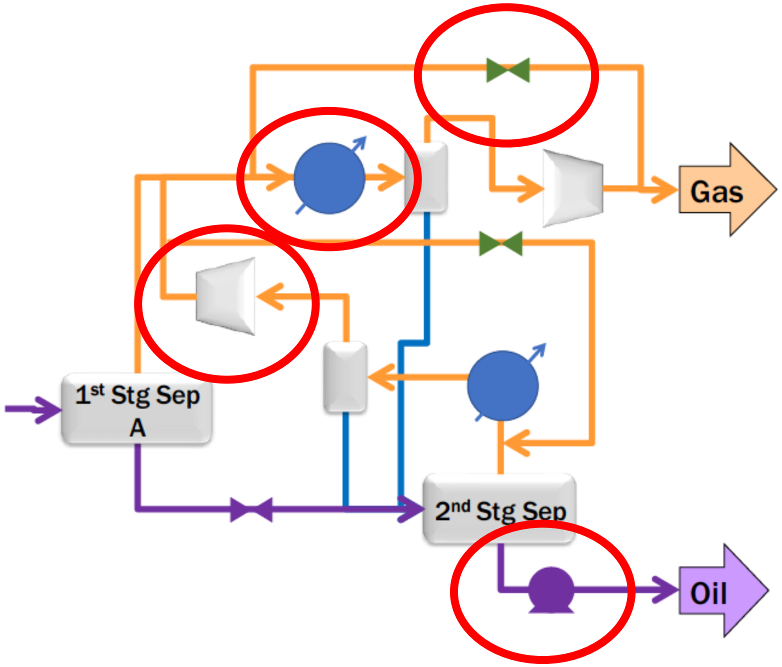
e.g. a process factor of one variable that needs 10 data points, this grows to 1000 data points for 3 variables, 100,000 for 5 variables

So, for all but the simplest of processes it would be more representative to use an integrated model

More representative allocations can be realised when process simulations are used for each allocation run

But, process simulation packages such as HYSYS and PRO/II are aimed primarily for design purposes by process engineers

- heat exchangers
- compressors
- pumps
- control valves



Complex models can be unstable and require the support of process engineers to solve

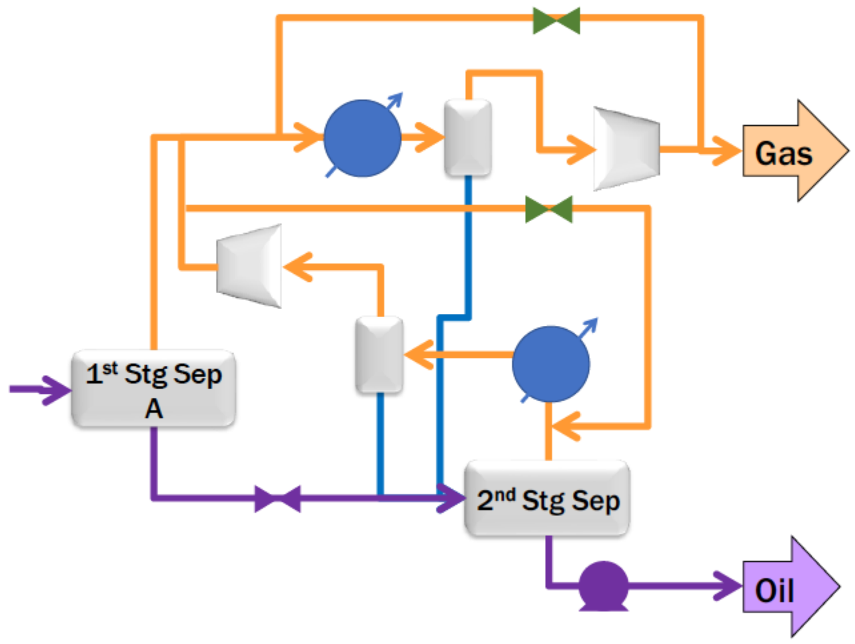
What if the model could be simplified and therefore is easier to configure, integrate and maintain?

For allocation, the model can be simplified by including only the unit operations and equations needed

“For example, if your real-life process shows a heat exchanger, a pump and a splitter, but the only thing that’s really necessary is that the temperature, pressure and separation are achieved properly, consider using a flash drum to accomplish all three functions instead of using a separate unit operation for each. The flash drum can set the temperature, the pressure and perform your separation all at once.” (1)

(1) Most Common Pitfalls in Process Simulation Abstract ID# 302023, Richard Pelletier and Mike Donahue, Invensys Operations Management

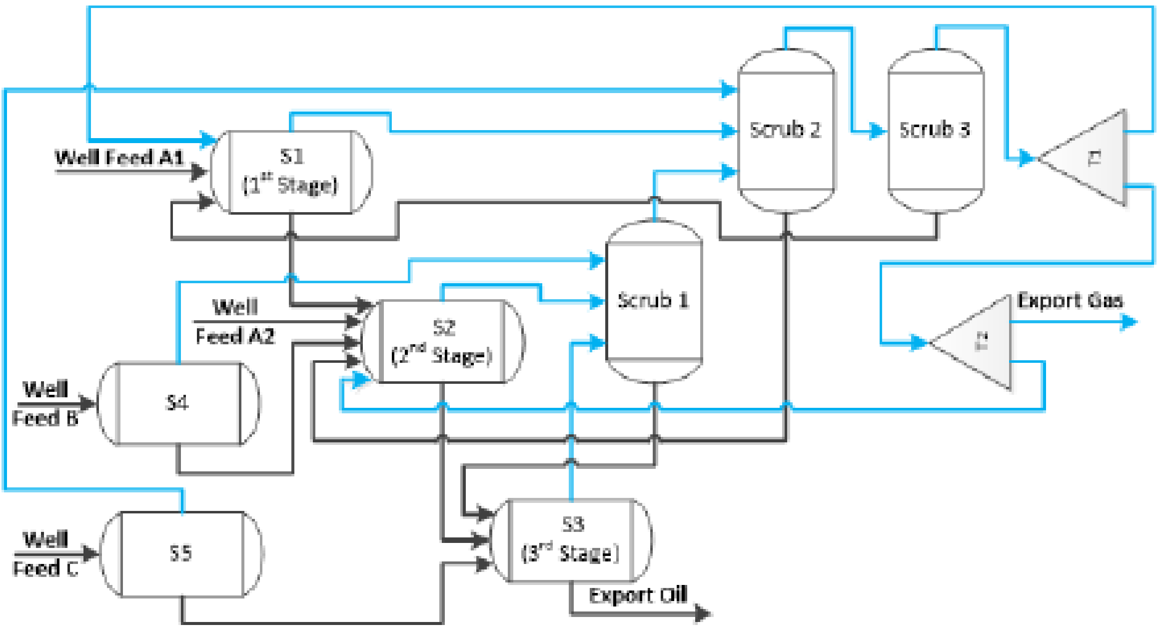
Removing pumps, compressors and control valves does not affect the vapour-liquid equilibria in the vessels



So, how good is this simplified approach?

A simplified model of a 3-stage separation process compared well to results from proprietary software

This simple model uses component mass balances, Peng-Robinson EOS & Rachford Rice equation to predict how the hydrocarbons partition



It is designed to easily integrate with allocation software and solves quickly because no unnecessary calculations are run

The differences between the proprietary software and simplified solution are from tolerances in the calculations

Components	A1 (kg)	A2 (kg)	B (kg)	C (kg)	Proprietary Software		Simplified Simulation		Difference	
					Oil Export (kg)	Gas Export (kg)	Oil Export (kg)	Gas Export (kg)	Oil Export (%)	Gas Export (%)
Nitrogen	0.000	107.050	20.246	116.305	0.167	243.444	0.172	243.427	2.662%	-0.007%
CO2	0.000	403.632	76.639	954.205	24.125	1410.341	24.278	1410.174	0.637%	-0.012%
Methane	331.457	1937.294	1292.636	11688.314	64.080	15184.695	65.182	15184.387	1.721%	-0.002%
Ethane	155.316	1057.172	458.522	3467.905	187.299	4950.668	188.786	4949.967	0.794%	-0.014%
Propane	227.768	1247.000	409.815	3288.704	721.783	4449.373	725.128	4447.728	0.464%	-0.037%
i-Butane	0.000	222.117	112.755	804.400	374.272	764.674	375.526	763.572	0.335%	-0.144%
n-Butane	200.147	932.890	279.003	2243.382	1459.405	2192.427	1462.843	2191.885	0.236%	-0.025%
i-Pentane	124.224	441.152	146.476	1109.472	1251.796	567.647	1253.303	567.696	0.120%	0.009%
n-Pentane	124.224	772.016	230.456	1553.261	2069.322	608.544	2070.566	609.023	0.060%	0.079%
n-Hexane	148.374	1317.291	412.110	2319.038	4058.982	138.530	4058.123	138.629	-0.021%	0.072%
n-Heptane	345.050	2220.972	476.477	2003.119	5027.858	17.486	5028.064	17.524	0.004%	0.219%
n-Octane	393.352	2531.870	530.807	2441.611	5895.734	1.854	5895.761	1.856	0.000%	0.125%
n-Nonane	441.653	2156.583	460.588	2268.087	5326.670	0.201	5326.694	0.201	0.000%	0.048%
Mcyclopentan	0.000	0.000	0.000	465.899	454.529	11.384	454.456	11.438	-0.016%	0.471%
Benzene	0.000	0.000	64.839	264.243	320.793	8.388	320.614	8.465	-0.056%	0.916%
Cyclohexane	0.000	0.000	248.311	634.126	868.117	14.432	867.903	14.528	-0.025%	0.661%
Mcyclohexane	0.000	0.000	0.000	996.508	993.357	3.224	993.264	3.242	-0.009%	0.560%
Toluene	0.000	0.000	96.439	425.057	520.574	0.958	520.527	0.968	-0.009%	1.040%
E-Benzene	0.000	0.000	0.000	163.252	163.213	0.026	163.226	0.027	0.008%	1.258%
m-Xylene	0.000	0.000	0.000	489.757	489.648	0.058	489.698	0.059	0.010%	1.296%
o-Xylene	0.000	0.000	0.000	195.903	195.865	0.020	195.883	0.020	0.009%	1.431%
124-MBenzene	0.000	0.000	0.000	221.788	221.787	0.001	221.787	0.001	0.000%	1.403%
C10+*	6797.534	42012.549	8990.019	55819.599	113619.709	0.000	113619.700	0.000	0.000%	116.679%
Total Molar Rate (kgmole/h)	72.312	448.636	171.748	1344.461	714.688	1322.216	714.991	1322.116	0.042%	-0.008%
Total Mass Rate (kg/h)	9289.100	57359.586	14306.14	93933.933	144309.083	30568.374	144321.483	30564.816	0.009%	-0.012%

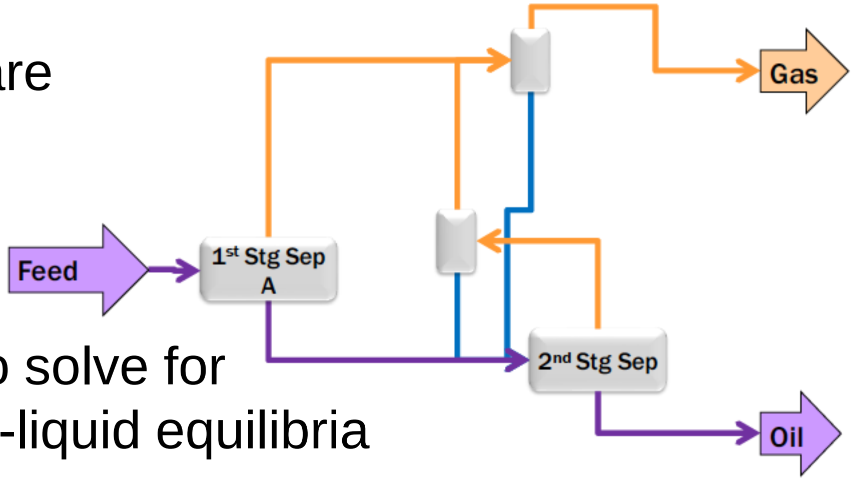
In conclusion, it is now possible to integrate a robust, repeatable process simulation into allocation systems

This approach offers the following:

An accuracy equivalent with existing commercial simulation software

Easy integration with allocation software

Easy configuration and maintenance



Improved speed as it does not need to solve for constraints not pertinent to the vapour-liquid equilibria

Improved robustness as it uses specific solution routines that focus on solving the molar balances rather than expansive of matrix equations

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