LCALS: Livermore Compiler Analysis Loop Suite

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LCALS: Outline

- LCALS Overview
- LCALS Serial Performance Comparison
- LCALS Parallel Performance Comparison
- Future work

LCALS: Background

- **LCALS: Livermore Compiler Analysis Loop Suite**
  - Loop kernels designed to measure compiler performance
  - Developed by LLNL
  - https://codesign.llnl.gov/LCALS.php

LCALS Code
Richard D. Hornung
LCALS version 1.0
LLNL-CODE-638939
2013

- **Three loop subsets (30 kernels total)**
  - Subset A: Loops representative of application codes
  - Subset B: Simple, basic loops
  - Subset C: Loops extracted from "Livermore Loops coded in C"

- **Each kernel is run for three sizes (Short, Medium, Long)**

- **Each kernel is implemented in a number of "variants"**
  - RAW (traditional C usage), OpenMP, C++ template-based, etc.

LCALS: Chapel Port

- **Chapel LCALS port consists of**
  - ~2400 lines of framework Chapel code
  - ~2200 lines of kernel Chapel code
- **Implements two kernel variants**
  - RAW+Serial: 30 kernels
  - RAW+Parallel: 11 kernels
    - RAW+Parallel kernels are a modified subset of the RAW serial kernels
    - The OpenMP variant in the reference
- **Performance compared vs. reference versions**
  - Executed on one Cray XC40 compute node
  - 24 Intel Xeon cores per node
  - Compiled with: gcc 5.3.0
  - The following charts show results for the “Long” size

LCALS: Serial Kernel Format

- **Each serial kernel follows the pattern:**

C reference

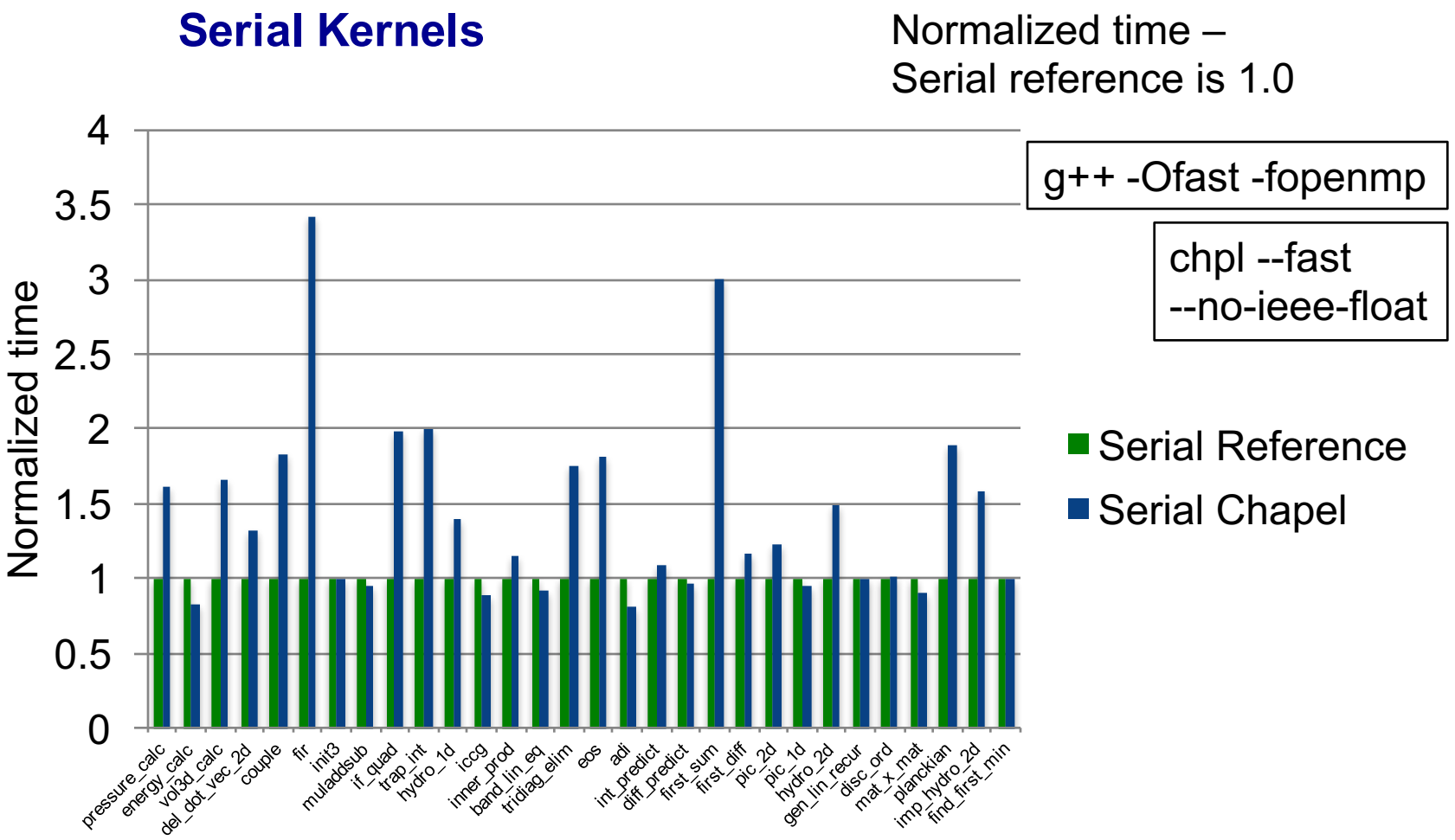
```
initArrays();
startTimer();
for (isamp=0; isamp<num_samples; isamp++) {
  for (i=0; i<len; i++) {
    <main kernel body>
  }
}
stopTimer();
```

Chapel

```
initArrays();
startTimer();
for isamp in 0..#num_samples {
  for i in 0..#len {
    <main kernel body>
  }
}
stopTimer();
```

- **A few kernels have additional inner loops**

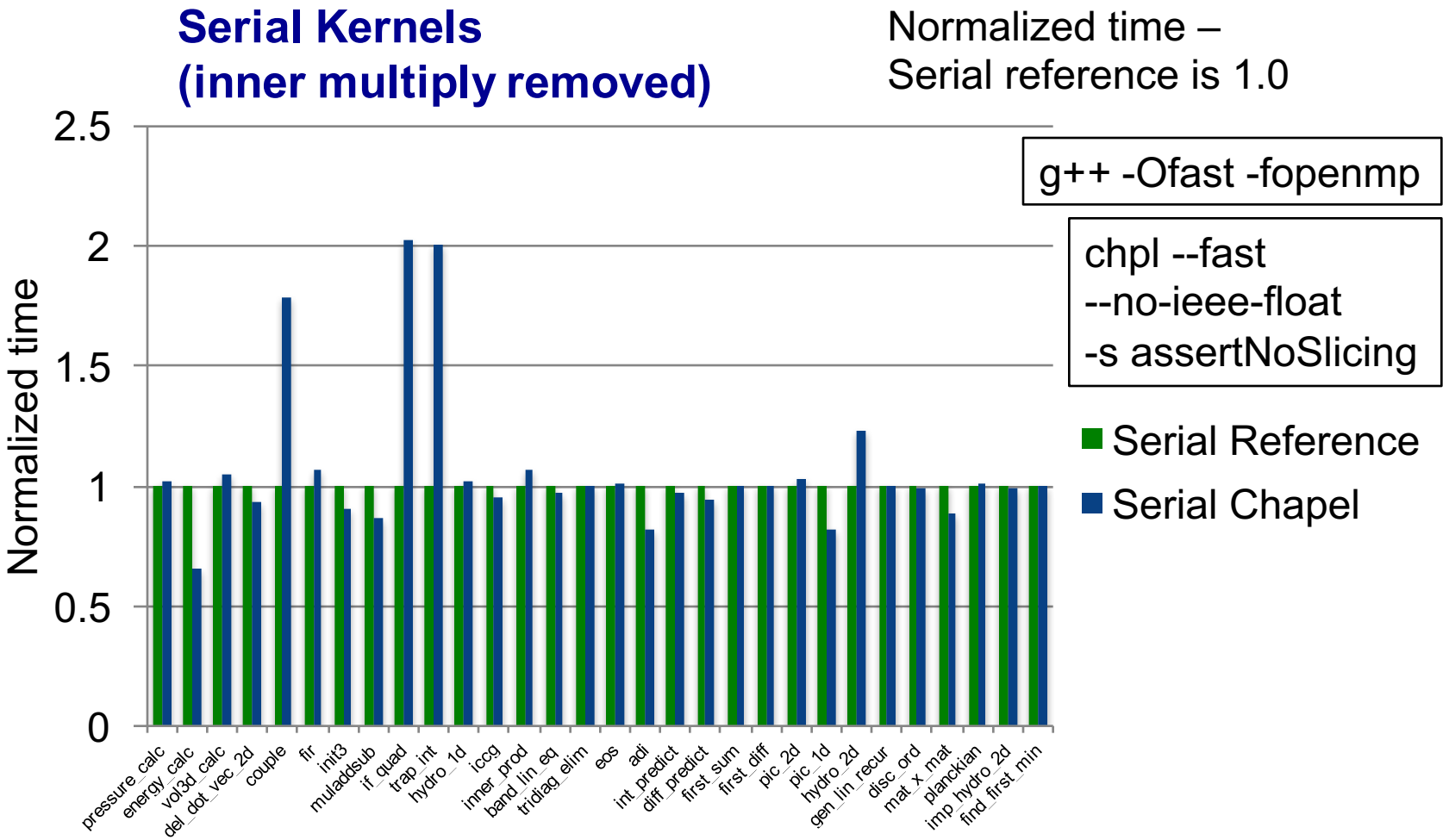
LCALS: Performance Comparison



LCALS: Array Inner Multiplications

- **LCALS serial performance lags C for many kernels**
  - Chapel uses an integer multiply for an array's innermost dimension
    - Unnecessary for typical arrays, only for more advanced ones
    - e.g., rank-change, reindexing of strided slices, …
  - For typical cases, adds overhead relative to C
    - Ongoing work is striving to eliminate multiplies in these cases
  - Meanwhile, can be squashed manually using a config param
    - Results in dramatic serial performance improvements for most loops…
    - …bringing them in line with C except for a few outliers

LCALS: Performance Comparison



LCALS: Parallel Kernel Format

- Parallel kernels are derived from serial kernels
- Usually one parallel loop inside the 'num_samples' loop

C reference

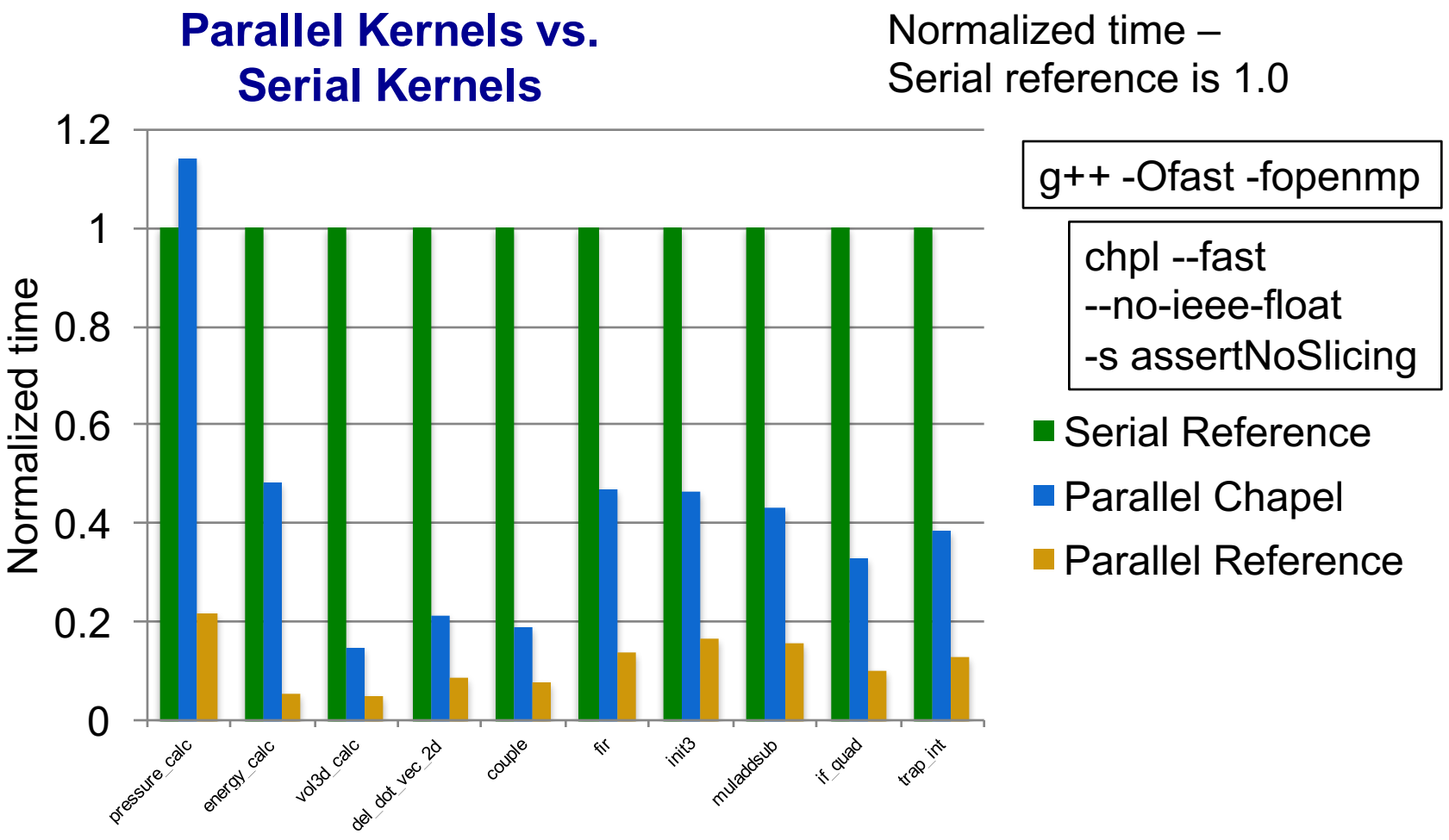
```
initArrays();
startTimer();
for (isamp=0; isamp<num_samples; isamp++) {
  #pragma omp parallel for
  for (i=0; i<len; i++) {
    <main kernel body>
  }
}
stopTimer();
```

Chapel

```
initArrays();
startTimer();
for isamp in 0..#num_samples {
  forall i in 0..#len {
    <main kernel body>
  }
}
stopTimer();
```

- A few kernels have additional inner loops

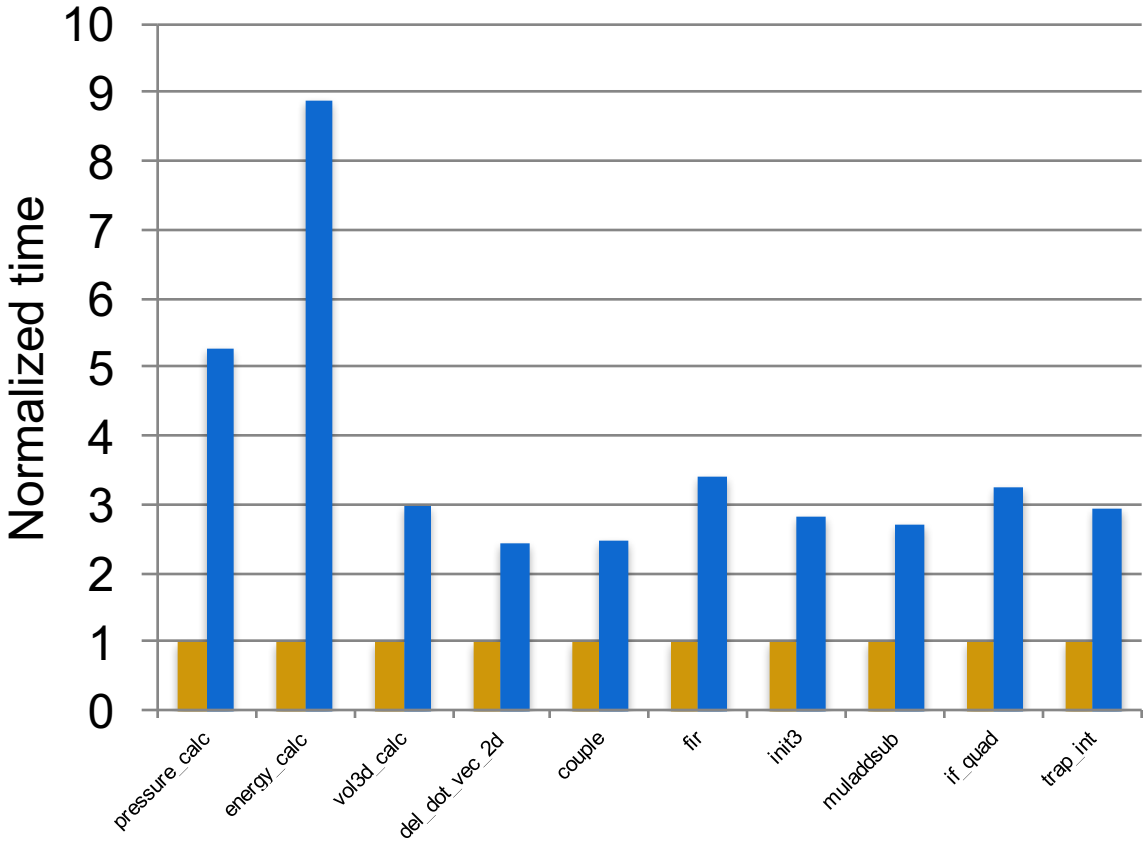
LCALS: Performance Comparison



LCALS: Performance Comparison

Parallel Kernels

Normalized time –
Parallel reference is 1.0



g++ -Ofast -fopenmp

chpl --fast
--no-ieee-float
-s assertNoSlicing

Parallel Reference

Parallel Chapel

LCALS: Array Inner Multiplications

- **Most kernels are ~3x slower than OpenMP reference**
  - …except for pressure_calc (5x) and energy_calc (9x)
  - …the two parallel kernels with multiple inner loops

These used an obvious translation:

OpenMP Reference

```
#pragma omp parallel
{
  #pragma omp for nowait
  for (i=0; i<len; i++) {
    …work1()...
  }
  #pragma omp for nowait
  for (i=0; i<len; i++) {
    ...work2()...
  }
}
```

Parallel Chapel

```
forall i in 0..len {
  …work1()...
}
forall i in 0..len {
  ...work2()...
}
```

Combined foralls

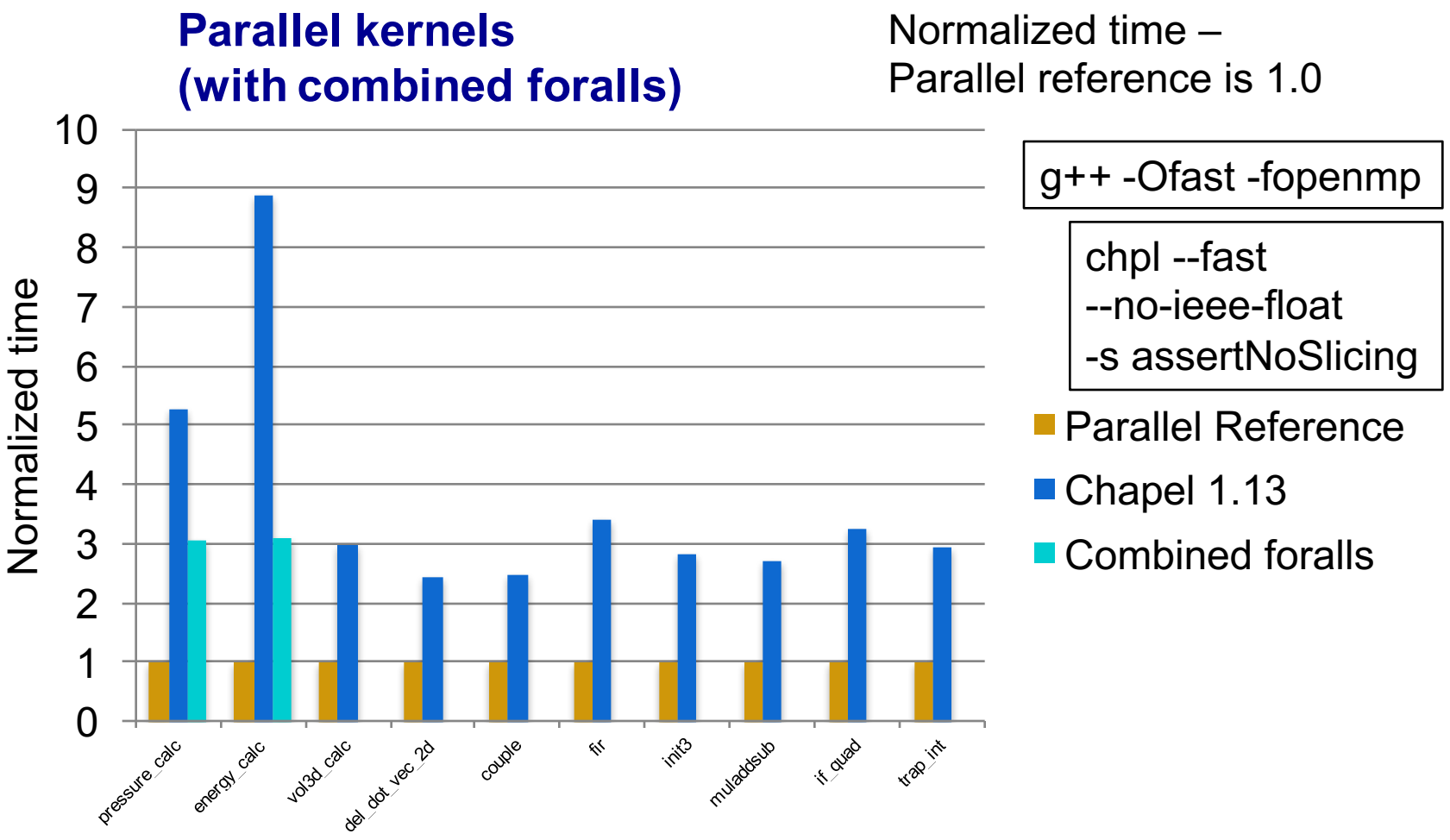
```
forall i in 0..len {
  …work1()...
  ...work2()...
}
```

So instead, combined consecutive forall loops.

nowait clause doesn't have an obvious Chapel equivalent

Not always possible, but works for these kernels.

LCALS: Performance Comparison



LCALS: Parallel loop startup cost

- **'forall' startup is more costly than OpenMP 'parallel for'**
  - Allocates and initializes an argument bundle per task
  - Should be able to eliminate most of this overhead
- **The parallel loops are short, even in the 'long' size**
  - Around 45,000 iterations in each parallel loop
  - … split between 24 tasks
  - … and repeated 15,000 times
  - Magnifies startup cost difference
- **Increasing the iteration count would mask the difference**
  - But need task startup improvements to match OpenMP at small sizes

LCALS: Next Steps

- **Eliminate array inner multiplies when unnecessary**
  - The -sassertNoSlicing hammer is too big
  - A new feature is planned to do this in a more principled way
- **Optimize the last few uncompetitive serial kernels**
- **Improve task startup overhead**
  - If the problem size is increased this overhead is masked
  - But should be able to match OpenMP performance for small loops too
- **Explore more elegant Chapel loop expressions**
  - Use whole-array operations, array slicing, etc.
  - Make sure the elegant versions perform well too

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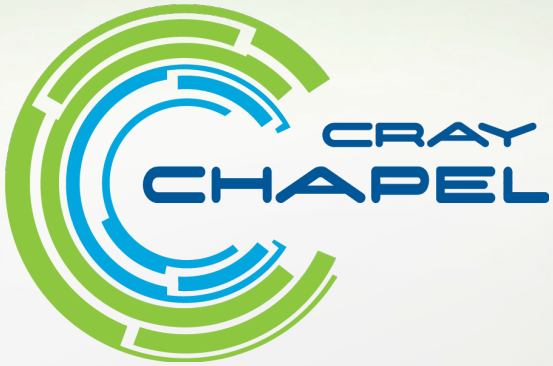

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