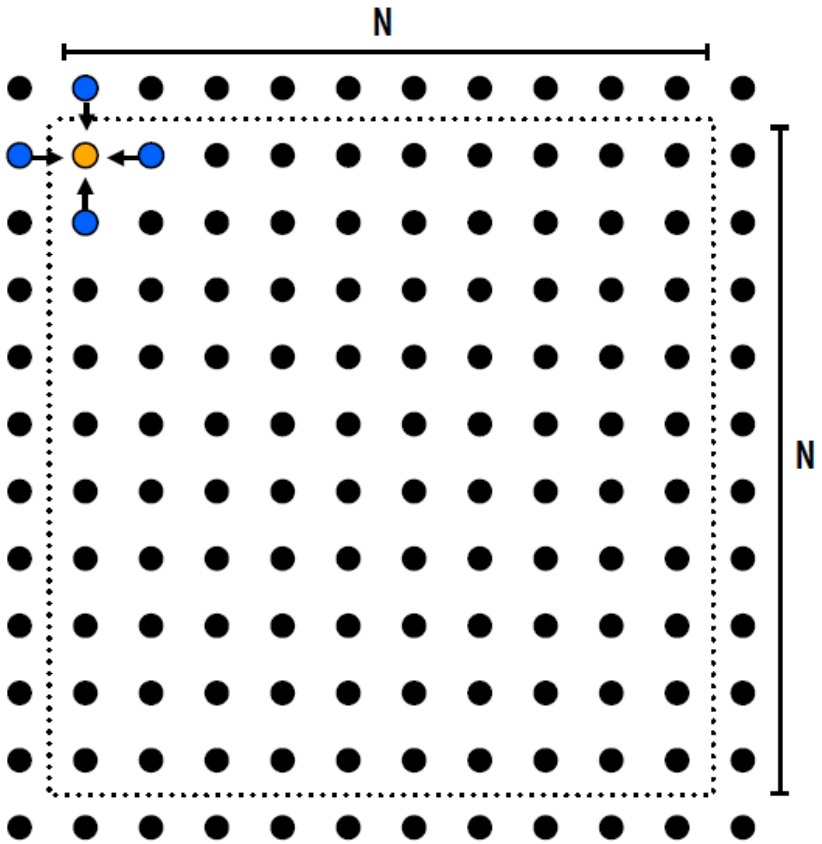
Ocean Kernel

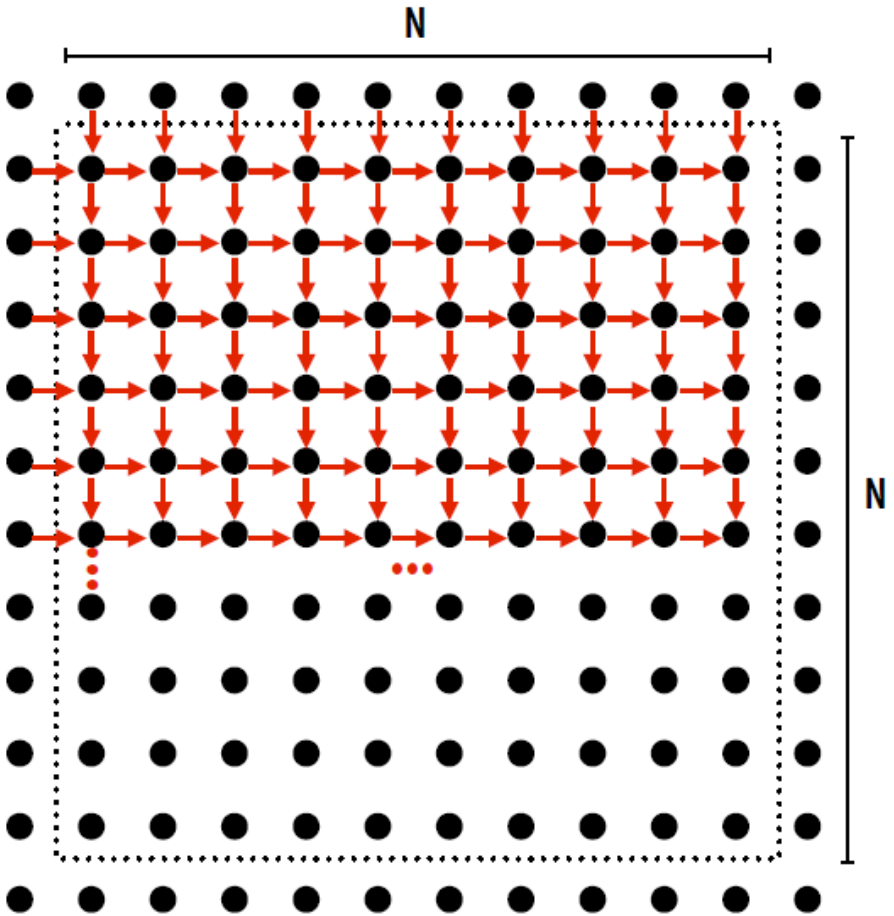



```
A[i,j] = 0.2 * (A[i,j] + A[i,j-1] + A[i-1,j]
                       + A[i,j+1] + A[i+1,j]);
```

Ocean Kernel

```
Procedure Solve(A)
begin
  diff = done = 0;
  while (!done) do
      diff = 0;
      for i ← 1 to n do
        for j ← 1 to n do
          temp = A[i,j];
          A[i,j] ← 0.2 * (A[i,j] + neighbors);
          diff += abs(A[i,j] – temp);
        end for
      end for
      if (diff < TOL) then done = 1;
  end while
end procedure
```

identify dependencies



Each row element depends on element to left.

Each column depends on previous column.

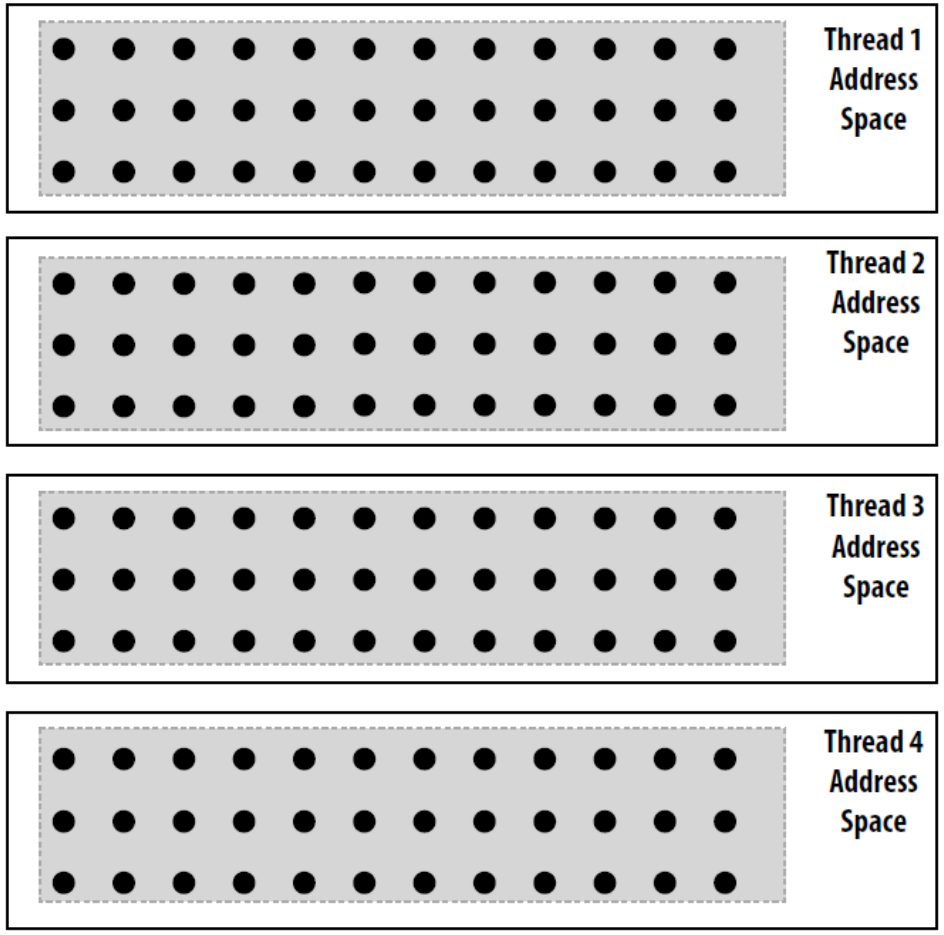
Shared Address Space Model

```
int  n, nprocs;
float  **A, diff;
LOCKDEC(diff_lock);
BARDEC(bar1);


main()
begin
   read(n); read(nprocs);
   A ← G_MALLOC();
   initialize (A);
   CREATE (nprocs,Solve,A);
   WAIT_FOR_END (nprocs);
end main
```

```
procedure Solve(A)
    int i, j, pid, done=0;
    float temp, mydiff=0;
    int mymin = 1 + (pid * n/nprocs);
    int mymax = mymin + (n/nprocs);
    while (!done) do
      mydiff = diff = 0;
      BARRIER(bar1,nprocs);
      for i ← mymin to mymax
        for j ← 1 to n do
          …// mydiff
        endfor
      endfor
      LOCK(diff_lock);
      diff += mydiff;
      UNLOCK(diff_lock);
      BARRIER (bar1, nprocs);
      if (diff < TOL) then done = 1;
      BARRIER (bar1, nprocs);
    endwhile
```

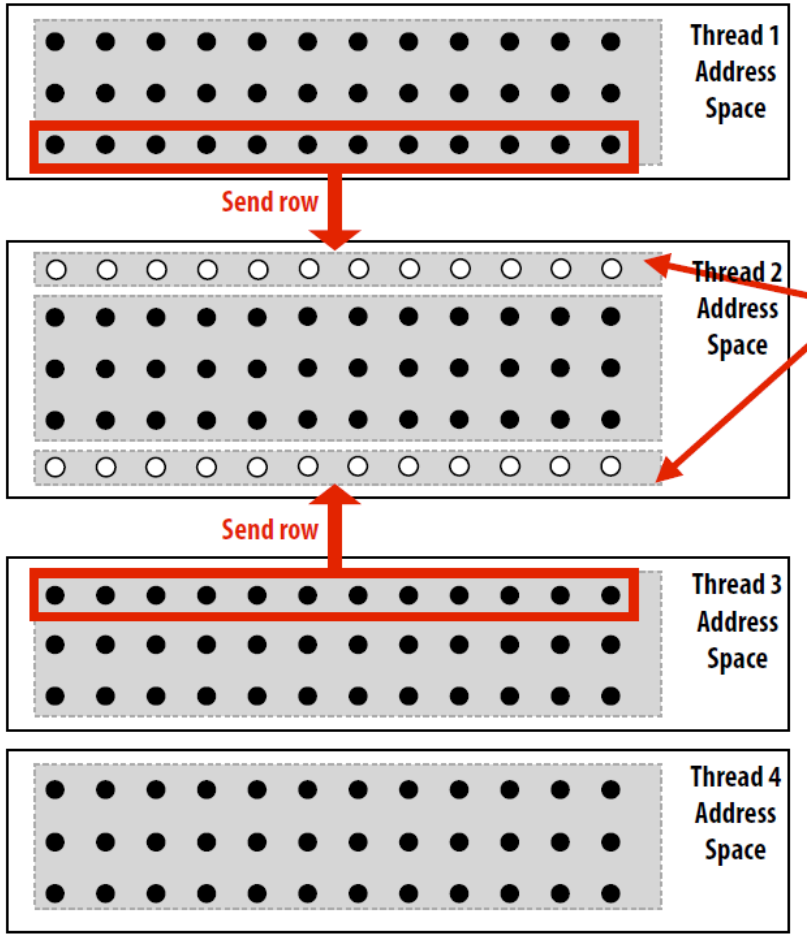
Message passing model: each thread operates in its own address space



This figure: four threads

So the grid data is partitioned into allocations residing in each of the four unique address spaces (four per-thread private arrays)

Data replication is now required to correctly execute the program



Message Passing Model

```
main()
  read(n); read(nprocs);
  CREATE (nprocs-1, Solve);
  Solve();
  WAIT_FOR_END (nprocs-1);

procedure Solve()
  int i, j, pid, nn = n/nprocs, done=0;
  float temp, tempdiff, mydiff = 0;
  myA ← malloc(…)
  initialize(myA);
  while (!done) do
    mydiff = 0;
    if (pid != 0)
      SEND(&myA[1,0], n, pid-1, ROW);
    if (pid != nprocs-1)
      SEND(&myA[nn,0], n, pid+1, ROW);
    if (pid != 0)
      RECEIVE(&myA[0,0], n, pid-1, ROW);
    if (pid != nprocs-1)
      RECEIVE(&myA[nn+1,0], n, pid+1, ROW);
    for i ← 1 to nn do
      for j ← 1 to n do
        … //mydiff
      endfor
    endfor
    if (pid != 0)
      SEND(mydiff, 1, 0, DIFF);
      RECEIVE(done, 1, 0, DONE);
    else
      for i ← 1 to nprocs-1 do
        RECEIVE(tempdiff, 1, *, DIFF);
        mydiff += tempdiff;
      endfor
      if  (mydiff < TOL)  done = 1;
      for i ← 1 to nprocs-1  do
        SEND(done, 1, I, DONE);
      endfor
    endif
  endwhile
```

Similar structure to shared address space solver, but now communication is explicit in message sends and receives

Send and receive ghost rows to "neighbor threads"

Perform computation

All threads send local my_diff to thread 0

Thread 0 computes global diff, evaluates termination predicate and sends result back to all other threads

```
int n;
int tid = get_thread_id();
int rows_per_thread = n / get_num_threads();

float* localA = allocate(sizeof(float) * (rows_per_thread+2) * (n+2));

// assume localA is initialized with starting values
// assume MSG_ID_ROW, MSG_ID_DONE, MSG_ID_DIFF are all constants

////////////////////////////////////

void solve() {
  bool done = false;
  while (!done) {

    float my_diff = 0.0f;

    if (tid != 0)
       send(&localA[1,0], sizeof(float)*(N+2), tid-1, MSG_ID_ROW);   // send row 0
    if (tid != get_num_threads()-1)
       send(&localA[rows_per_thread-2,0], sizeof(float)*(N+2), tid+1, MSG_ID_ROW);

    if (tid != 0)
       recv(&localA[0,0], sizeof(float)*(N+2), tid-1, MSG_ID_ROW);
    if (tid != get_num_threads()-1)
       recv(&localA[rows_per_thread-1,0], sizeof(float)*(N+2), tid+1, MSG_ID_ROW);

    for (int i=1; i<rows_per_thread-1; i++) {
       for (int j=1; j<n+1; j++) {
         float prev = localA[i,j];
         localA[i,j] = 0.2 * (localA[i-1,j] + localA[i,j] + localA[i+1,j] +
                              localA[i,j-1] + localA[i,j+1]);
         my_diff += fabs(localA[i,j] - prev);
       }
    }

    if (pid != 0) {
       send(&mydiff, sizeof(float), 0, MSG_ID_DIFF);
       recv(&done, sizeof(bool), 0, MSG_ID_DONE);
    } else {
       float remote_diff;
       for (int i=1; i<get_num_threads()-1; i++) {
          recv(&remote_diff, sizeof(float), i, MSG_ID_DIFF);
          my_diff += remote_diff;
       }
       if (my_diff/(n*n) < TOLERANCE)
         done = true;
       if (int i=1; i<gen_num_threads()-1; i++)
         send(&done, sizeof(bool), i, MSD_ID_DONE);
    }
  }
}
```