WRF in the Cloud
Using Amazon Web Services (AWS)

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Today's Agenda

- Presentation:
  - Introduction to cloud computing
  - Creating a cloud environment for setting up and running WRF
- Practice Session
  - Follow steps to create your own instance/environment
  - Follow steps to run WPS and WRF (including visualization)
- Questions and Follow-up Session
- **Gather feedback from you!**

What is cloud computing?

- The utilization of remote servers hosted on the internet to store, manage, and process data
  - Instead of using a local server or personal computer
  - Easy access to, and sharing of data and resources
  - May be only available to a single organization (private), may be public, or a hybrid of private/public

Pros & Cons of Cloud Computing

Pros

- Cuts cost:
  - No capital cost of hardware
  - No ongoing administrative costs
  - No idle assets
- Access to latest compute architectures and tools
- Avoid limitations of shared HPC clusters
- Elastic resource availability
- Easier collaboration/sharing

Cons

- Adds cost:
  - Computing charges
  - Data transfer charges
  - Storage charges
- Large output volumes on remote systems
- Limited or cumbersome visualization
- Steep learning curve
- Charges can accrue when activity not cancelled or suspended

Cloud Service Providers (CSPs):
NCAR Collaborations

- **Amazon Web Services (AWS):** https://aws.amazon.com
  - Own/manage their own cloud server hardware
  - Highly documented
  - Many supported related applications

- **Scala Computing:** https://scalacomputing.com
  - Their server provides access to well-known HPC CSPs and their hardware
  - Manage all processes through their local server
  - Limited documentation
  - Good for repeated and/or regularly-scheduled work

- **Penguin Computing:** https://www.penguincomputing.com
  - Own/manage their own cloud server
  - Limited documentation

- **Rescale Computing:** https://www.rescale.com
  - Provide access to various HPC cloud services
  - Manage processes through their local server
  - Some documentation

AWS Computing Applications

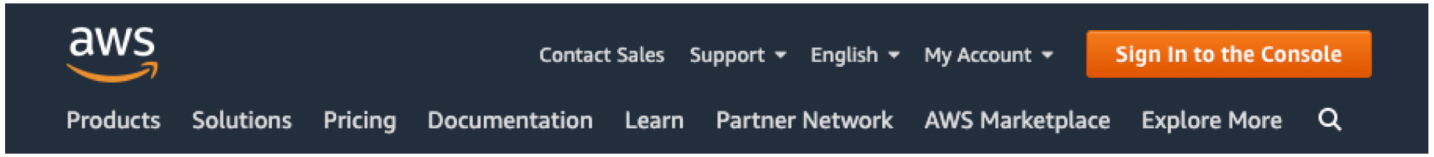
- **AWS Elastic Compute Cloud (EC2) :** https://aws.amazon.com/ec2/
  - Secure and resizable compute cloud platform
- **AWS Command Line Interface (CLI)** : https://aws.amazon.com/cli/
  - Alternative to web interface
  - Usage: Install the tool and then use a terminal window (Unix environment) to navigate and compute
- **AWS S3** : https://aws.amazon.com/s3/
  - Cloud storage facility
- **AWS ParallelCluster** : https://aws.amazon.com/blogs/opensource/aws-parallelcluster/
  - Compute server cluster management tool
  - Enables deployment & management of HPC clusters in the cloud

Steps to Run WRF in the Cloud (using AWS)

- 1. Logging-in to AWS
- 2. Machine image selection
- 3. Instance type selection
- 4. Configure instance
- 5. Key pair preparation
- 6. Launch instance
- 7. Access instance environment
- 8. Configure WRF environment

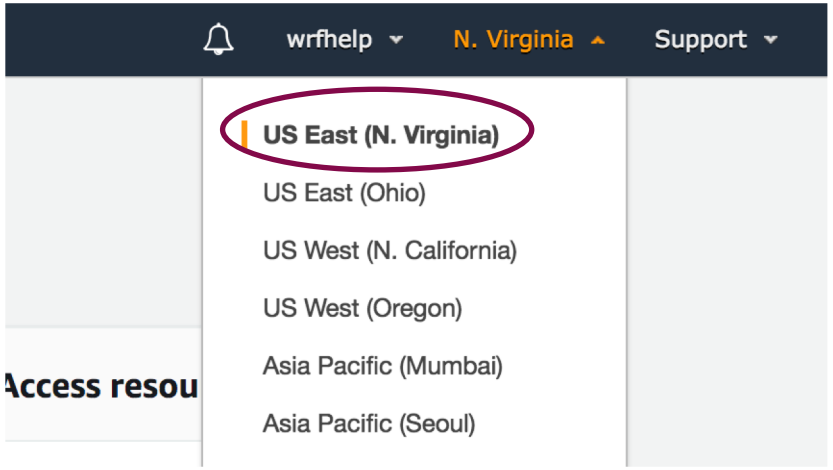
1. Logging-in to AWS: Sign-in and Choosing a Region

- https://aws.amazon.com



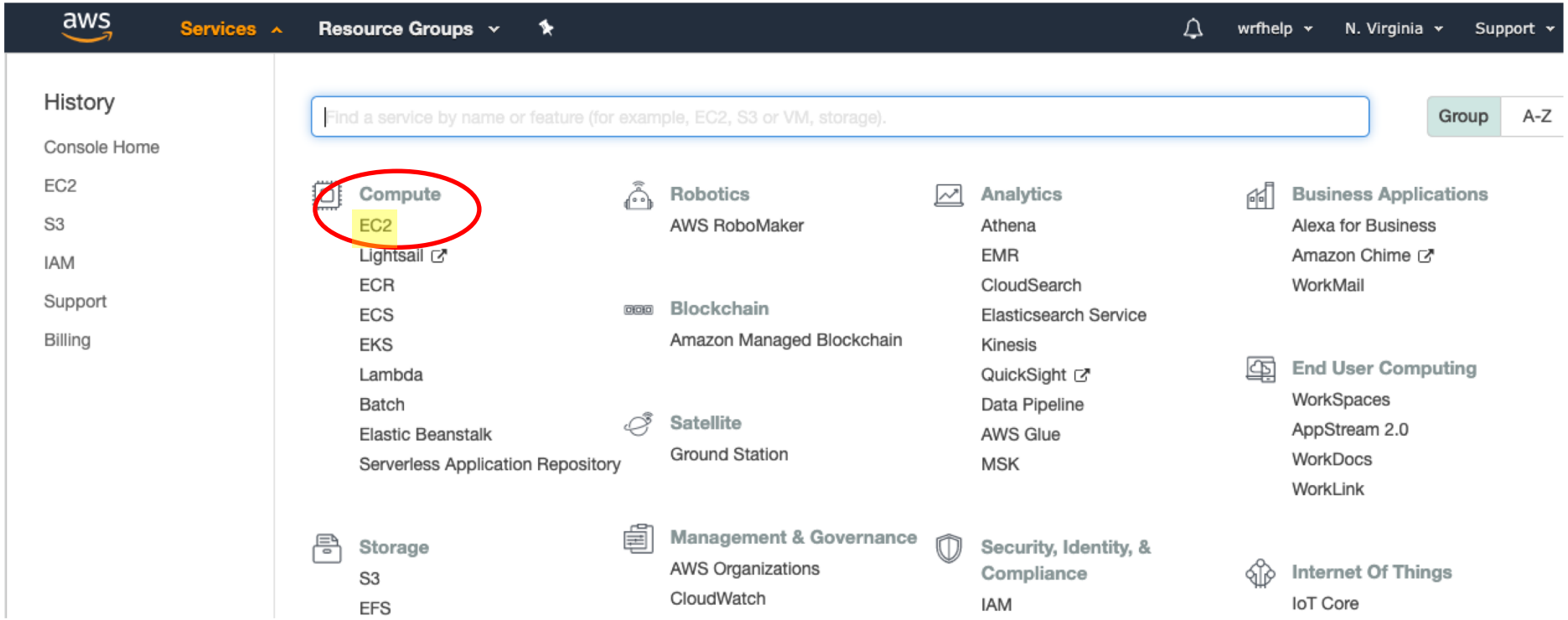
- Follow tutorial instructions and use the IAM (Identity and Access Management) User Name and Password provided.

- Choosing Regions
  - Regional endpoint (URL entry point for a web service)
  - Purpose of reducing data latency
  - US East (N. Virginia)

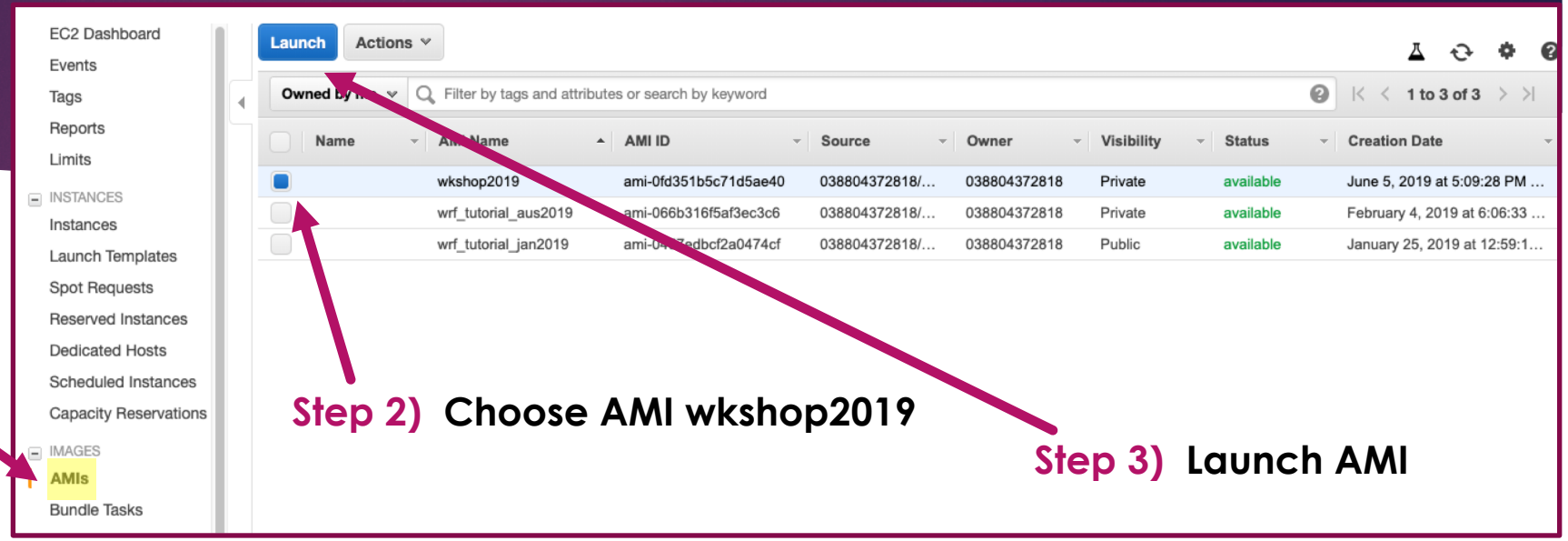


1. Logging-in to AWS: Navigate to EC2

- Navigate to Elastic Compute Cloud (EC2 – under "Compute")



2. Machine image selection



- Amazon Machine Image (AMI)
  - Snapshot of a pre-configured environment
  - Useful for saving work and sharing with others
  - AMI Name: **wkshop2019**
    - Includes OS – Amazon Linux AMI (HVM), SSD Volume Type, 64-bit
    - Includes libraries, compiled WPS/WRF code & NCL

https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/AMIs.html

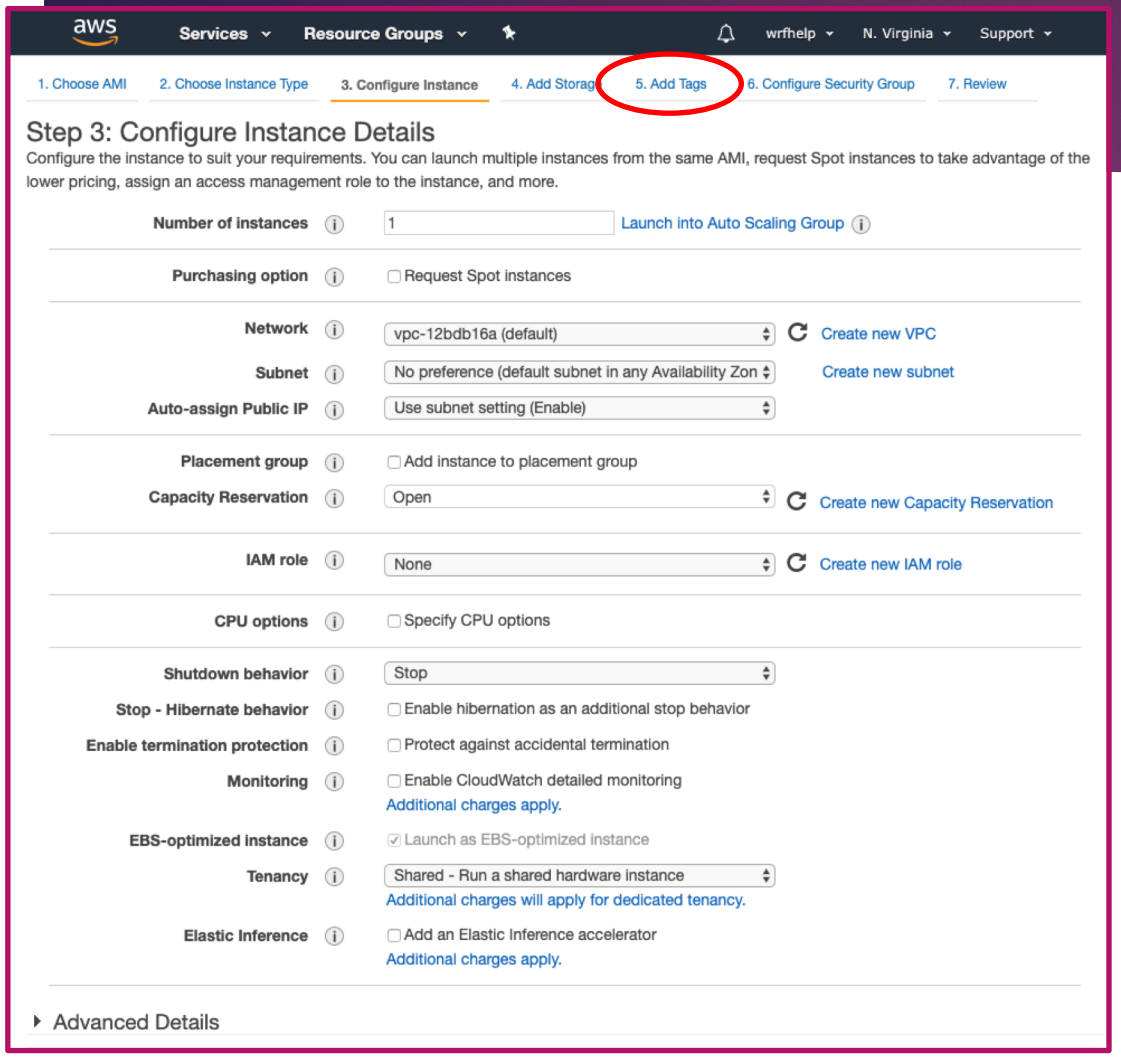
3. Instance Type Selection

	Family	Type	vCPUs	Memory (GiB)	Instance Storage (GB)	EBS-Optimized Available	Network Performance	IPv6 Support
☐	Compute optimized	c5.18xlarge	72	144	EBS only	Yes	25 Gigabit	Yes
☐	Compute optimized	c4.large	2	3.75	EBS only	Yes	Moderate	Yes
☐	Compute optimized	c4.xlarge	4	7.5	EBS only	Yes	High	Yes
☐	Compute optimized	c4.2xlarge	8	15	EBS only	Yes	High	Yes
☑	Compute optimized	c4.4xlarge	16	30	EBS only	Yes	High	Yes
☐	Compute optimized	c4.8xlarge	36	60	EBS only	Yes	10 Gigabit	Yes
☐	FPGA instances	f1.2xlarge	8	122	1 x 470 (SSD)	Yes	Up to 10 Gigabit	Yes

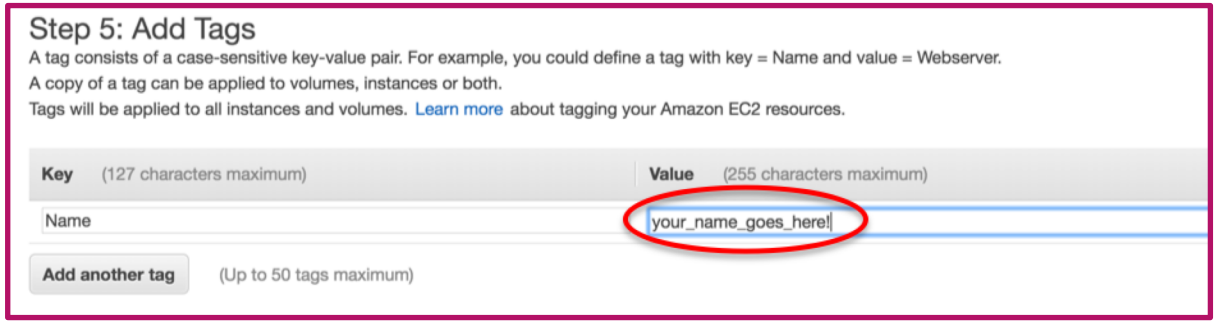
https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/Instances.html

- **Instance:** Virtual Server
- Different instance types determine the hardware
  - Varying compute, memory, & storage capabilities
- Type for this class: **c4.4xlarge**
  - 16 vCPUs (8 CPUs)
  - Reasonable size/speed for basic WRF run

4. Configure Instance Details



- Can launch multiple instances from one AMI
- Configure behavior (e.g., shutdown behavior)
- Add storage
- Add tags (name your instance)
- Configure security options
- For this tutorial, only use "Add Tags"



5. Key Pair Preparation

- AWS uses public-key cryptography to encrypt/decrypt login information
  - AWS uses a *public* key to encrypt data
  - Recipient uses *private* key to decrypt data
- User must download a key pair
  - Change permissions (> chmod 600 *key_pair*.pem)
- Specify key pair when launching an instance (command-line)
  - > ssh -i *key_pair*.pem ec2-user@Public_IP_address

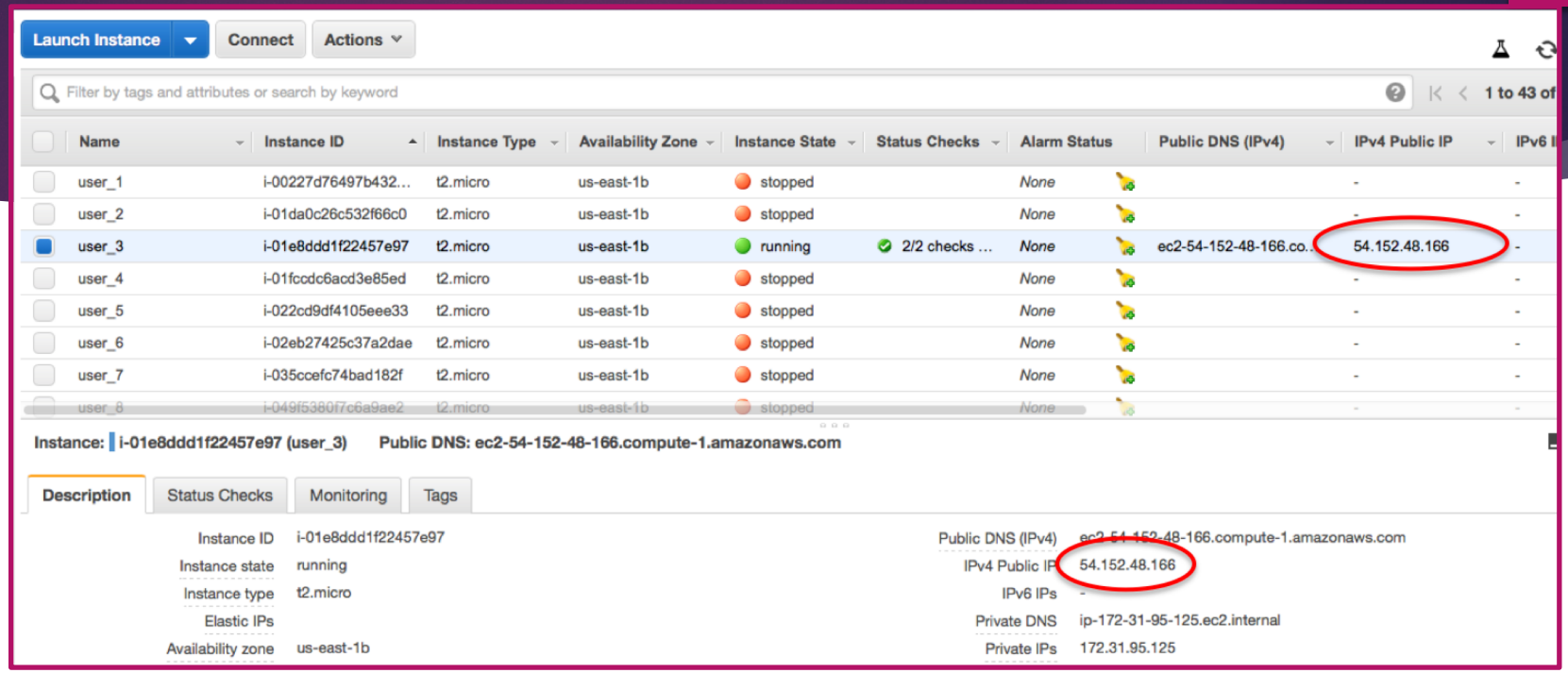
https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/ec2-key-pairs.html

6. Launch Instance

- After downloading a key pair -> Launch Instances -> View Instances



7. Instance environment access



- Create a new directory on your local machine (terminal window) from where you will work
- Place *key_pair*.pem file in that directory (and change permissions)
- Locate the IPv4 Public IP (2 locations)
  - This changes each time you stop and re-start the instance
- SSH into instance environment (e.g., > ssh -X -i *key_pair*.pem ec2-user@54.152.48.166)

8. Configure WRF environment

```
       __|  __|_  )
       _|  (     /   Amazon Linux AMI
      ___|\___|___|

https://aws.amazon.com/amazon-linux-ami/2018.03-release-notes/
22 package(s) needed for security, out of 29 available
Run "sudo yum update" to apply all updates.
/home/ec2-user>ls
graphics  input_data  libraries  tar_files  WPS  WPS_GEOG  WRF
/home/ec2-user>
```

- Configure environment – set up shell preferences, environment scripts (e.g., .cshrc)
- Install compiler/library packages (e.g., gcc, m4, make, perl, which, X11, etc.)
  - > sudo yum install *package*
- Install libraries needed for WRF/WPS (netCDF, mpich, jasper, libpng, zlib)
- Compile WRF/WPS (and any post-processors)
- Import input data (static geographic fields, meteorological first-guess data)

Importing Data or Files

- SCP Option
  - scp –i *key_pair*.pem *file_name* ec2-user@public_IP:/home/ec2-user

- Obtain data from an S3 storage source

  (one file) aws s3 cp <s3 bucket name/path/file> <local path>

  (e.g.): aws s3 cp s3://wpsgeog/albedo_modis/00001-01200.00001-01200 .

  (multiple files or directories) aws s3 cp <s3://bucket_name/path> <local path> --recursive

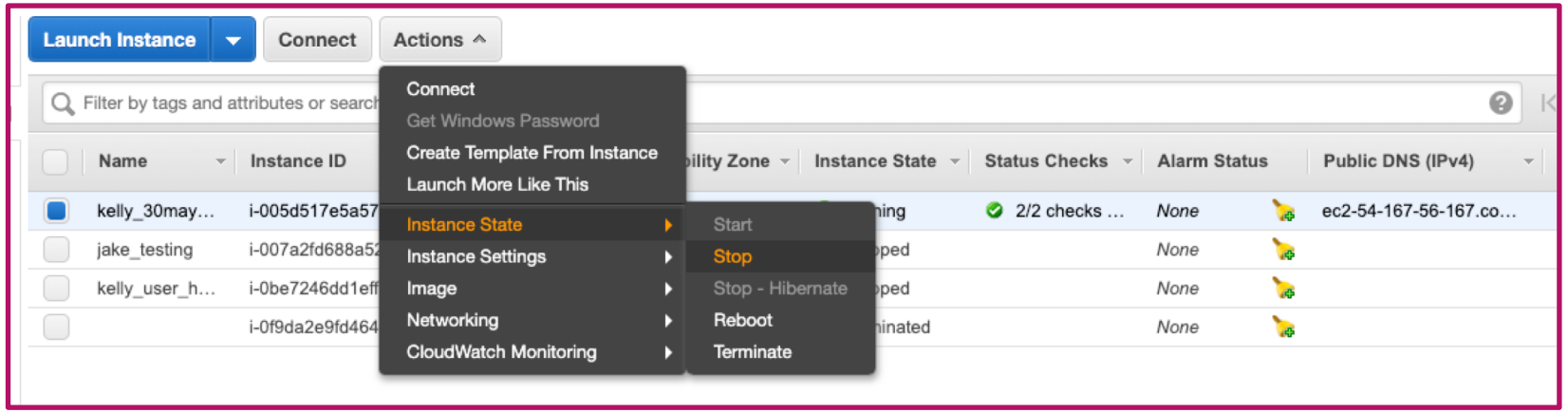
  (e.g.): aws s3 cp s3://wpsgeog/ /home/ec2-user/wps_geog --recursive

- Use ‘git’ to aquire WRF & WPS source code
  - git clone https://github.com/wrf-model/WRF.git

Running WPS/WRF

- Run WPS executables serially
  - (e.g.) ./geogrid.exe
- Run real and wrf with distributed memory (parallel dmpar)
  - (e.g.) mpirun –np 8 ./wrf.exe
- Visualization
  - NCL and ncview available in workshop AMI (uses X11)

- Job ‘stop’ or ‘terminate’
  - **Stop:** like “pausing” the instance, or logging out of a server – will be just as it was when you return (start)
  - **Terminate:** kills the instance forever



Useful Resources

- Using AWS ParallelCluster:

  https://jiaweizhuang.github.io/blog/aws-hpc-guide/

  - WRF examples with ParallelCluster

- AWS Research Cloud Program

  https://aws.amazon.com/government-education/research-and-technical-computing/research-cloud-program/

- Workshop Mini-tutorial Web Page:
  http://www2.mmm.ucar.edu/wrf/OnLineTutorial/wrf_in_cloud_aws_tutorial_2019.php